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APEC Energy Demand and Supply Outlook

8th Edition 2022

Volume 2

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Asia Pacific Energy Research Centre

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Foreword

The first *APEC Energy Demand and Supply Outlook* was published in 1998, when the Asia Pacific Energy Research Centre (APERC) was just two years old. Since then, the *Outlook* has evolved to present data and analysis through periods of unprecedented growth and rapid change in the energy sector of the Asia-Pacific Economic Cooperation (APEC) region.

Today, the global energy sector is undergoing a rapid transformation while trying to balance security, affordability, and sustainability. The *APEC Energy Demand and Supply Outlook 8th Edition* highlights the reality that energy choices made in the APEC region will have impacts on energy security and the environment on the global level.

The primary aim of this *Outlook* is to support APEC economies in achieving individual and collective energy objectives. It explores potential impacts of energy policies, technologies, and economics on future energy systems. The *Outlook* is also intended to serve as a point of reference for those wishing to become more informed about recent and potential future energy trends in the APEC region.

The report includes two volumes: **Volume 1** presents key trends and insights for the APEC region. **Volume 2** presents an outlook for each of the 21 APEC economies. We undertook extensive analysis of two scenarios to understand the challenges and opportunities ahead for the diverse energy systems of APEC economies. **The Reference scenario (REF)** illustrates the pathway that APEC is currently on, which includes the aspirational APEC energy goals of reducing energy intensity and doubling the share of renewables in the energy system.

There is growing momentum both globally and within APEC to further decarbonise energy systems towards net zero carbon emissions or carbon neutrality. To assist stakeholders, APERC developed a hypothetical pathway, **the Carbon Neutrality scenario (CN)**, that illustrates ways for APEC economies to simultaneously meet their development and decarbonisation goals, while identifying challenges along the way.

Our modelling analysis was completed before March 2022. The current disruptions in international energy markets, including the impact of the Ukraine Crisis, are not considered in this edition of the *Outlook*. Analysis on those issues will be our future task in the next edition of the *Outlook*.

Like the APEC energy systems, the *Outlook* is constantly evolving. The *8th Edition* relies more heavily on visuals and emphasizes key messages, recognizing the need for dense and actionable insights. The *Outlook 8th Edition* returns to using data submitted by APEC economies to the Expert Group on Energy Data and Analysis to form the basis of modelling and statistical analysis.

This edition is the product of over three years of planning, intensive work, and collaboration by the APERC research team, under the leadership of Dr. David Wogan and Mr. Glen Sweetnam, and with contributions from experts across the 21 APEC economies and globally. It is my pleasure to present this edition of the *Outlook*.

Dr. Kazutomo IRIE

President, APERC

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We are grateful to The Ministry of Economy, Trade and Industry, Japan, who sponsored our work and provided the primary funding for this project.

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Introduction

APEC Energy Demand and Supply Outlook 8th Edition

- Published since 1998, the *APEC Energy Demand and Supply Outlook* provides objective and rigorous analysis of potential future energy demand and supply for the 21 APEC member economies. The *Outlook* presents progress on two APEC EWG energy-related goals and key opportunities and barriers for policymakers.
- The *Outlook 8th Edition* contains two volumes. **Volume 1** covers APEC-wide trends beginning with a look at aggregate energy demand in **Chapter 2**.
- Electricity generation and power capacity are reported in **Chapter 3**.
- New in this edition, energy supply is presented by fuel (**Chapter 4**), enabling a convenient resource of major energy carriers.
- The APEC energy intensity and modern renewables share doubling goals are assessed in **Chapter 5**. Progress on the energy intensity goal is reported for final energy and energy supply.
- **Chapter 6** reports projected CO_2 emissions, including a breakdown by components. Three technologies (CCS, electric vehicles, and nuclear) are highlighted to showcase their potential, risks, and uncertainties in future energy mixes.
- Finally, several conventional and nascent energy security themes are presented for oil, natural gas, and electricity (**Chapter 7**).
- **Volume 2** provides demand and supply projections for all 21 APEC economies.
- Important updates have been made for the *Outlook 8th Edition*. First, historical data is now provided by the Expert Group on Energy Data and Analysis (EGEDA), a workstream of the APEC Energy Working Group.
- This historical data provides the foundation for the projections and analysis. Historical energy balance data is shown for the years 2000 through 2018.
- The base year is 2018 with projections continuing until 2050.
- The energy units have been changed from million tonnes of oil equivalent (MTOE) to petajoules (PJ). Electricity generation is still reported in terawatt-hours (TWh), and power capacity is provided in gigawatts (GW).
- Detailed tables are provided along with this report.

Scenarios in the 8th Edition

- The *APEC Energy Demand and Supply Outlook 8th Edition* contains two scenarios. The hypothetical pathways presented in the *Outlook* are intended to provide reference material to support APEC member economies in navigating the uncertain energy system landscape.
- Given the large uncertainty about the future, the two scenarios are intended to illustrate how assumptions and trends shape energy supply and demand.
- **The Reference scenario (REF)** is a pathway where existing trends in technology development and deployment, and policy frameworks continue in a similar manner.
- On the demand side, energy efficiency and fuel economy standards continue to improve gradually. Electric vehicles become increasingly prominent in the transport sector. Gradual improvements in energy efficiency and fuel switching occur in industry, and in the power sector, fuel switching from coal to gas and towards renewables accelerates. Global demand for oil, gas, and coal remains robust, offering an export market for APEC energy producers.
- **The Carbon Neutrality scenario (CN)** outlines a potential pathway where energy efficiency, fuel switching, and technological advancement leads to a significant reduction in CO_2 emissions from fossil fuel combustion out to 2050.
- Technology maturity and commercial availability are key assumptions in CN. Hydrogen supply chains—blue and green—are assumed to be available at scale from 2030 to serve end-use applications in buildings, industry, and transport. While technically possible, hydrogen consumption by the power sector is not considered.
- There is a small uptake of CCS use in industry and hydrogen production in REF. CCS becomes far more commercially viable in CN and is utilised in greater quantities by industry, power, hydrogen production, and own use sectors from the 2030s.
- CN is intended to illustrate the magnitude of CO_2 emissions reductions possible in the context of the assumptions made about technology diffusion, costs, and global trends.
- CN can be used to quantify the magnitude of remaining CO_2 emissions that would require further action from policymakers, industry participants, and researchers.

Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Components of the APEC energy system

Supply

Production
Domestic production of coal, natural gas, oil, and NGLs.

Energy Trade
Imports and exports of coal, natural gas, oil, refined products, and hydrogen.

Transformation

Power and heat
Production of electricity and heat using fossil fuel, renewable, and nuclear technologies.

Hydrogen
Production using fossil fuels and renewables

Refining
Production of refined products

Demand

Buildings
Activities in the residential and services sub-sectors: lighting, heating, cooling, and cooking.

Industry
Activities in the iron & steel, chemicals, aluminium, non-metallics, mining, pulp & paper, and non-specified sub-sectors.

Transport
Passenger and freight activities in the road, rail, marine, and air modes.

Agriculture and others
Agricultural, own use, non-specified, and other activities.

Non-energy
Use of feedstocks to produce non-energy goods such as fertilizers and plastics.

1. Australia

Highlights

Demand

- Australia's population growth and output/activity growth is mostly offset by improvements in energy efficiency in REF, with energy consumption only marginally higher in 2050 relative to its pre-COVID peak. Energy demand falls by one-quarter in CN due to widespread electrification and greater levels of energy efficiency.
- Electricity accounts for almost half of all end-use energy demand in 2050 in CN. Refined products see a very large decline, displaced mostly by electricity, particularly in the transport sector.
- The development of unconventional gas fields in Queensland to supply markets in Asia has coincided with significant domestic natural gas price increases in the 2010s. Electricity is now the most economic fuel choice for many end-use applications in most regions in Australia, which limits domestic gas consumption growth in both scenarios.
- Transport is the largest energy consuming sector in Australia, accounting for over 40% of all end-use energy demand before the pandemic. In CN, greater fuel efficiency, electrification, and hybridisation leads to gasoline falling 80%, and diesel falling two-thirds, out to 2050.

Supply

- Australia is a large energy exporter, producing more than three times the level of energy that it consumes.
- Almost 90% of Australia's current coal production is exported. Metallurgical coal will become relatively more important for Australia in both scenarios due to diminishing global prospects for thermal coal.
- Renewables almost triple in Australia's energy supply over the projection period in REF. This growth is exceeded in CN, with renewables growing almost five-fold and accounting for over half of Australia's energy supply in 2050.
- Development of unconventional gas resources in the Surat and Bowen basins has been the basis for LNG export terminals in Gladstone, Queensland. Additional export-driven production in Western Australia and the Northern Territory has seen natural gas production increase from below 2 000 PJ in 2010 to almost 5 000 PJ before the pandemic. Natural gas production and exports are expected to maintain current levels in REF, while declining by a quarter in CN.

Power

- Electricity generation is projected to increase by almost a third in REF and by almost three-quarters in CN, owing to widespread electrification in almost all areas of the economy.
- The installed capacity of Australia's power sector undergoes transformational change in both scenarios. The growth of solar, wind, and storage continues at a rapid pace, with total capacity increasing by two-and-a-half times in REF and by almost three-and-a-half times in CN.
- Domestic natural gas supply is likely to remain difficult to secure at competitive prices, meaning that natural gas generation does not increase in either scenario. However, natural gas remains an important fuel to meet the challenge of variable renewable generation. CCS technology is incorporated in CN to maintain this role while meeting emissions reductions goals.
- Australian residential rooftop solar has posted world-beating growth over the last decade and will continue to grow strongly in both scenarios.
- There is a slightly faster phase-out of coal in CN, with the last remaining coal-fired power plant closing in the 2040s.

CO_2 emissions

- In REF, the continued phase-out of domestic coal-fired power plants and rise of renewable generation capacity will see power sector CO_2 emissions decline by two-thirds to 2050. Power sector emissions reductions are 90% in CN, with transport, industry, and own use sectors contributing to significant additional reductions.
- Energy sector CO_2 emissions in 2050 of just under 80 million tonnes will need to be offset by the non-energy sectors to achieve carbon neutrality.

Hydrogen

- The market for hydrogen advances rapidly in CN, with multiple industry and transport use cases fueling robust global trade. Australian hydrogen production from natural gas with CCS and from electrolysis grows to over 300 PJ by 2050, supporting exports of 200 PJ.

About Australia

- Australia has abundant natural resources, a highly-skilled populace, and one of the highest standards of living in APEC.
- Australia's GDP and emissions per capita are double the per capita values for the APEC region.
- Australia's energy exports were only exceeded by Russia and the US in 2018. The rapid growth in east coast LNG exports in recent years has seen Australia surpass Qatar to become the largest global LNG exporter. However, Russia and the US still export far greater volumes of natural gas from pipelines and LNG capacity of their own.
- Coal is extremely abundant in Australia, with most production of thermal coal and metallurgical coal exported to Asia. There will continue to be a role for coal to feed Australian coal-fired power plants, though that role is diminishing with a fleet that is nearing the end of its lifecycle.
- Oil deposits are relatively scarce in Australia and the small amount of annual production is largely exported. Domestic refineries are typically configured to process light-sweet blends of crude rather than the heavy-sour extracted locally. Closure of two of the remaining four refineries in Australia in 2021 means that Australia's fuel security will be more reliant on securing refined products imports rather than crude oil imports.
- Australia is home to the largest reserves of recoverable uranium in the world. Domestic use cases do not currently exist, though the industry has potential to establish itself should nuclear power see a resurgence to assist with meeting emissions reduction goals.
- Australia has a very large land mass combined with a relatively small population. Yet Australia has one of the highest urbanisation rates in the world. Most people live in the south-east corner and on the east coast. Large portions of the rest of the continent are classified as desert with scarce water resources that are effectively uninhabitable.

Table 1-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	25	0.9%	14
GDP	1 262	1.8%	11
TPES	5 360	1.6%	10
Production	17 231	5.1%	6
Imports	2 229	1.8%	11
Exports	13 929	13%	3
Electricity generation	261	1.5%	10
Heat production	0.0	0.0%	-
CO_2 emissions	376	1.8%	9

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 1-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	2 650 000	315	14.0%	3
Natural gas	86 000	17	1.3%	4
Oil	14 600	14	0.1%	9
Uranium	1 692 700	255	27.5%	1

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- **Australia's updated NDC:** Australia announced a commitment to achieving net-zero emissions by 2050 in October 2021 as part of the lead-up to the UN Climate Change Conference of the Parties in Glasgow (COP26). The commitment relies primarily on technological innovation supported by a technology investment roadmap rather than direct emissions policies.
- **Coal and natural gas exports:** Coal and natural gas are the second and third largest exports for Australia (behind iron ore). While there is no direct government involvement in the extraction of these commodities, both state and federal governments derive royalties and tax receipts from these activities. Despite building momentum for global decarbonisation, demand for Australia's coal and gas resources is almost certain to persist for multiple decades. There are no policies constraining Australian supply of these commodities on the basis that a forced reduction in Australian production will be offset by production from other global suppliers.
- **Net-zero emissions:** The technology investment roadmap that underpins Australia's updated NDC and net-zero commitment prioritises clean hydrogen, electricity storage, low emissions steel and aluminium, carbon capture and storage, soil carbon sequestration, and ultra low-cost solar. These priorities will be reviewed and updated annually with advice from an expert group of science, business, technology, and government leaders.
- **Domestic emissions projections have Australia meeting its 2030 NDC:** The Australian government has consistently overestimated its projected emissions trajectory for over a decade. These overestimates have meant that Australia was projected to fall short of its NDC of a 26% to 28% emissions reduction by 2030 relative to 2005. By updating economic activity forecasts, technology assumptions, and including new government policies, Australia's 2021 projections show that there will be a 30% to 35% reduction by 2030. This new calculation does not rely on overachievement from the first commitment of the Kyoto Protocol (2008–2012), which had been previously cited as a way for Australia to meet its NDC.
- **National Energy Productivity Plan and relationship with emissions trajectory trends:** The consistently lower-than-projected emissions trajectory of the last decade has been largely due to the decline in coal-fired power generation. This decline is mostly due to the rapid rise in rooftop solar, as well as the increasing pace in rollout of both utility-scale solar and wind. The suite of energy demand side policies, such as those under the umbrella of the National Energy Productivity Plan 2015–2030, have played a relatively small role in reducing energy consumption and emissions. Implementation of such policies will become more important in reducing emissions as the gains from the coal-fired power phase-out slow.
- **Increased reliance on refined products imports:** Large distances between Australia's population centres is one of the reasons why transport is the largest energy-consuming sector. Gasoline and diesel remain the most important fuel sources for this sector, with much of this supply reliant on imports. This reliance increased in 2021 following the decommissioning of two of Australia's four remaining refineries. The Australian government has made commitments to support the remaining two refineries, Lytton in Queensland and Geelong in Victoria, to operate until at least 2027. The refinery closures mean additional imports of refined products have supplanted imports of crude oil for refining in fuel security considerations.
- **Energy security:** Australia has been non-compliant with the IEA 90 days of oil stock requirement since 2012. The federal government signed an agreement with the US in 2020 to lease a portion of the US Strategic Petroleum Reserve as part of a commitment to return Australia to compliance by 2026.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- In the lead-up to finalising the modelling for this version of the *Outlook*, many economies in APEC (and throughout the world) have made commitments to achieving carbon neutrality.
- Australia's whole-of-economy plan to achieve net-zero emissions by 2050 was made on the eve of COP26 Glasgow. The commitment is reliant on technological innovation rather than emissions policies.
- For the modelling in this report, **the Reference scenario (REF)** and **the Carbon Neutrality scenario (CN)** were developed prior to Australia's net-zero commitment.
- The REF and CN are reliant on the same GDP and population projections. However, CN incorporates some adjustments, such as increased material efficiency in industry (less production required to deliver the same output).
- In REF, developments in energy efficiency and fuel switching mostly follow the historical trends of recent decades. For CN, more optimistic assumptions are imposed, driven by either explicit or implicit policy intervention.
- On the supply side, production of energy commodities accounts for the evolving domestic and APEC energy demand. Assumptions for the rest of the world, are simplified and top-down (rather than more bottom-up assumptions for APEC economies).
- The CN involves assumptions that lead to positive CO_2 emissions in 2050 for the Australian energy sector. It is beyond the scope of this report to model the non-energy sectors, such as land use, land-use change, and forestry. However, the implicit assumption is that the other sectors will deliver negative emissions, and thus deliver a 'carbon-neutral' outcome.
- The CN makes explicit assumptions that trace a trajectory for energy and CO_2 emissions out to 2050. The assumptions deliver one credible path for Australia to meet decarbonisation ambitions while maintaining economic prosperity. The ultimate path Australia takes is almost certain to differ from the one that is laid out by the modelling, and there are many possible paths for Australia to take.

Table 1-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Australia

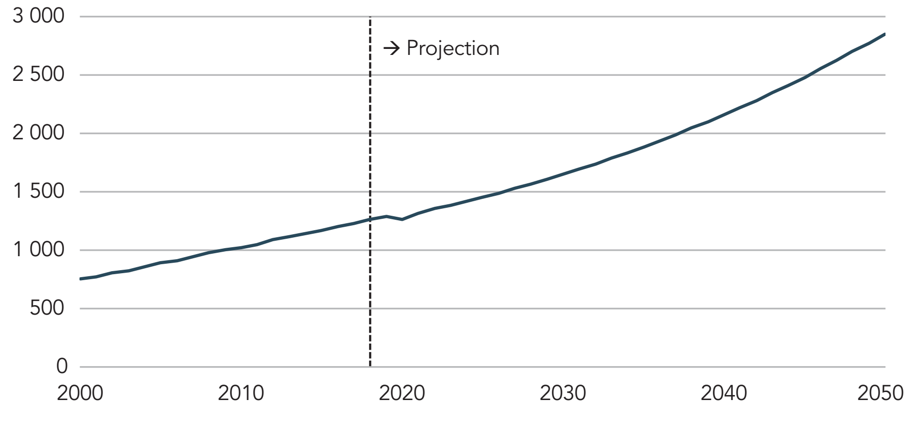
Table 1-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• REF incorporates recent trends and in-place policies and does not assume that aggressive action will be taken to meet global emissions reduction goals.	• CN incorporates bottom-up changes from all sectors to deliver lower levels of energy intensity and carbon intensity.
Buildings	• Improvements in appliance energy efficiency through labelling and other measures. • Commercial Building Disclosure Program promotes energy efficiency in commercial buildings.	• More stringent energy efficiency standards for new buildings and improved retrofits lead to higher energy savings in buildings. • Much higher levels of electrification than in REF, particularly for heating. • Very large increase of solar energy in water heating.
Industry	• Small uptake of CCS and hydrogen in heavy industries closer to the end of the modelling period. • Some fuel switching to biomass, natural gas and electricity. • Historic level of improvements in energy efficiency and electrification continues.	• Greater uptake of hydrogen and CCS than in REF for heavy industries. • Higher levels of electrification, energy efficiency, and fuel switching away from fossil fuels. • Technological change sees less production of steel, cement, and chemicals to achieve the same level of final products (material efficiency). • Increase in critical minerals mining.
Transport	• Strong population growth fuels demand growth but this is offset by continued improvements in fuel efficiency.	• EV sales grow rapidly; 60% share of passenger vehicle sales by 2035. • Heavy truck battery EVs and fuel cell EVs sales grow to 30% and 10% of sales. • Improved fuel efficiency and hybridisation.
Power	• Thermal coal/lignite capacity is slowly retired out to 2050 and there are no new coal-fired power plants. • Snowy Hydro 2.0 begins operating with two GW of capacity in 2025. • Offshore wind development is relatively conservative	• Sun Cable electricity exports begin in 2028, though development is driven by Singapore's climate ambitions, rather than Australia's. • Natural gas with CCS technology is adopted so that natural gas still plays a transition role while Australia meets ambitious emissions reductions goals. • Slightly faster coal phase-out in the latter half of the projection than in REF.
Supply	• Gas production is constrained by the high costs of coal-seam gas. • LNG import terminals come online in 2027. • LNG exports are constrained near current levels due to cost and competition from lower-cost producers. • Coal export markets are determined by APERC demand trends.	• Domestic demand for natural gas is partially met by falling natural gas exports. • Green hydrogen projects are promoted, with demand for Australia's hydrogen exports predominantly from Japan and Korea (global hydrogen demand calculations are based on the IEA global development scenario for 2019 to 2070). • As in REF, the two remaining refineries are assumed to continue operating through the projection period for fuel security reasons.
Climate	• CO_2 emissions trajectory is not consistent with Australia's NDC of a 26% to 28% reduction in greenhouse gas emissions by 2030 relative to 2005.	• Achieves CO_2 emissions reductions that are close to what will be required for Australia's NDC in 2030 and 2050. • Positive emissions in 2050 are assumed to be offset by non-energy sectors.

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

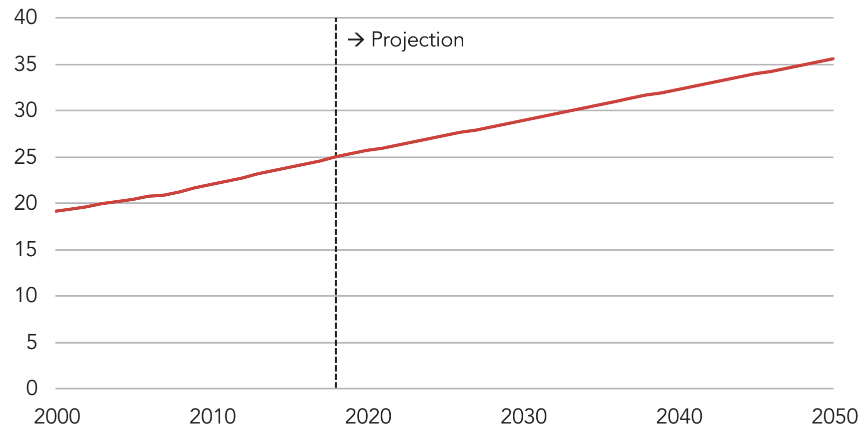
Macroeconomic backdrop

Figure 1-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 1-2. Population in millions, 2000-2050

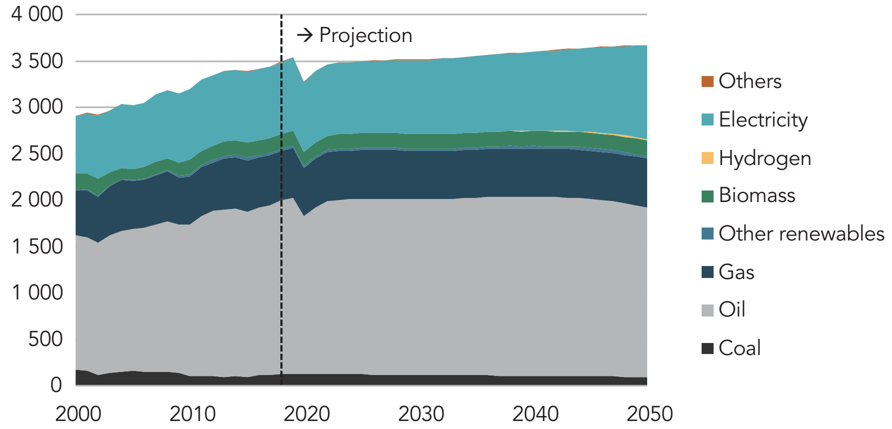


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- Australia's population has grown from 19 million at the turn of the century to almost 26 million in 2021.
- This population growth is higher than most other developed economies and is driven primarily by a large migration program, rather than a high natural birth rate.
- COVID-19 has seen population growth slow, though federal and state level governments are planning to increase migration significantly once borders begin to open in a post-pandemic world.
- Population growth to 2050 is assumed to be at the upper bound of the UN DESA 2019 estimates, reaching over 35 million people. This projection lands on the lower end of domestic projections from the Australian Bureau of Statistics, that estimate population to be between 34 and 41 million people in 2050, depending largely on the size of Australia's migrant intake.
- Relatively high population growth provides significant support to GDP growth, which is assumed to more than double from the 2020 COVID-19 trough to over USD 2.8 trillion on a purchase power parity (PPP) basis in 2050.
- Australia has per capita GDP of over USD 50 000 on a PPP basis in 2018, placing it sixth in APEC. Before COVID, median real household income had plateaued since the Global Financial Crisis, with the significant rise in real GDP matched by a similarly large growth in population.
- Australia's sovereign debt levels have increased markedly in response to the COVID pandemic to now be at 93% of GDP. A relatively small portion of the COVID-19 stimulus is flowing directly into the energy sector with the federal government providing subsidies to oil refineries and providing grants to assist with building additional diesel storage.

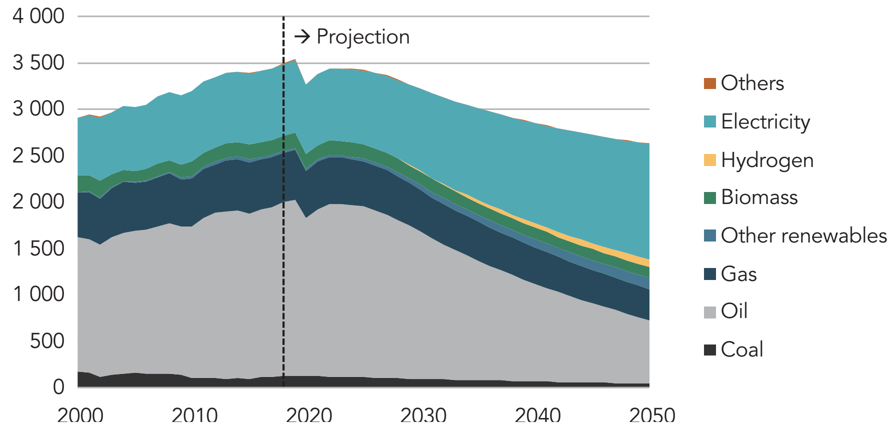
End-use energy demand

Figure 1-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 1-4. Energy demand in CN, 2000-2050 (PJ)

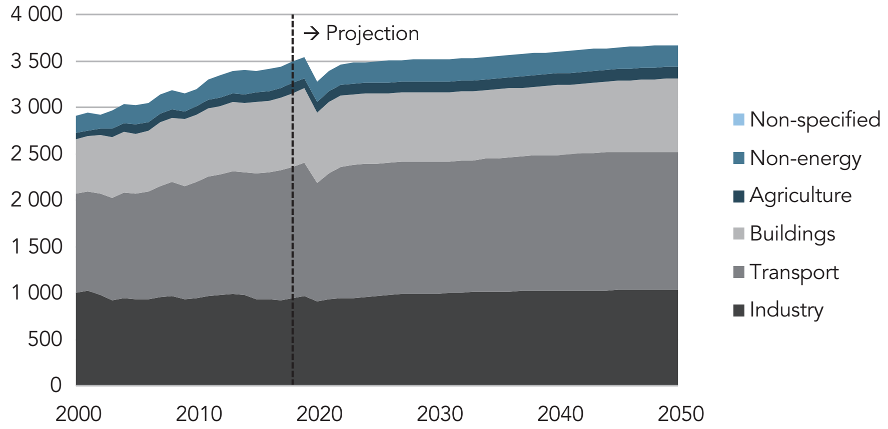


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Refined products (oil) dominate end-use energy demand in Australia largely due to the prominence of the transport sector.
- While most people live in urban areas, the distance between cities requires a large consumption of energy to move people, goods, and resources between the different population centres.
- Population and GDP growth does not lead to significant additional energy consumption in REF out to 2050, as energy efficiency and electrification temper energy demand from most fuel sources.
- The CN sees a significant reduction in energy demand, falling by 26% to 2050 from the pre-COVID peak.
- Electricity grows substantially in CN, accounting for almost half of all end-use energy demand in 2050. Oil and gas see a very large decline, displaced by electricity, particularly in the transport sector. Energy efficiency improvements also contribute to the decline.
- Small amounts of hydrogen adoption takes place in REF. End-use hydrogen adoption occurs earlier and at a faster rate in CN, reaching almost 85 PJ in 2050. The transport sector accounts for most of this consumption. There is less capacity for industry to incorporate hydrogen given that many heavy industry pursuits have been offshored in recent decades. It is unlikely that these industrial pursuits can be resurrected.
- The CN sees a large increase in demand for liquid biofuels by aviation applications in the transport sector. Biomass consumption by the industry sector remains robust, albeit at a lower level than in REF. In contrast, biomass consumption by the buildings sector falls away, mostly displaced by electricity.
- Oil was the fuel most impacted by the COVID-19 pandemic, with demand falling by 10% in 2020, due to the large decrease in transport activity. The fall in consumption of all other fuels was typically less than 5%.

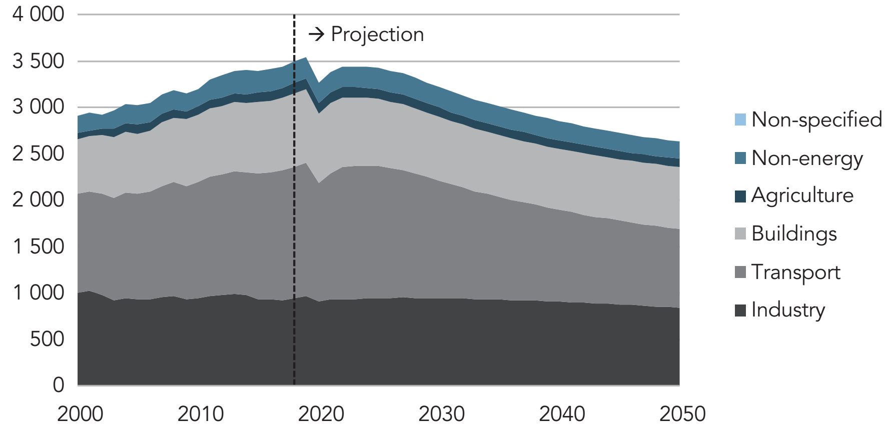
End-use energy demand by sector

Figure 1-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 1-6. Energy demand by sector in CN, 2000-2050 (PJ)

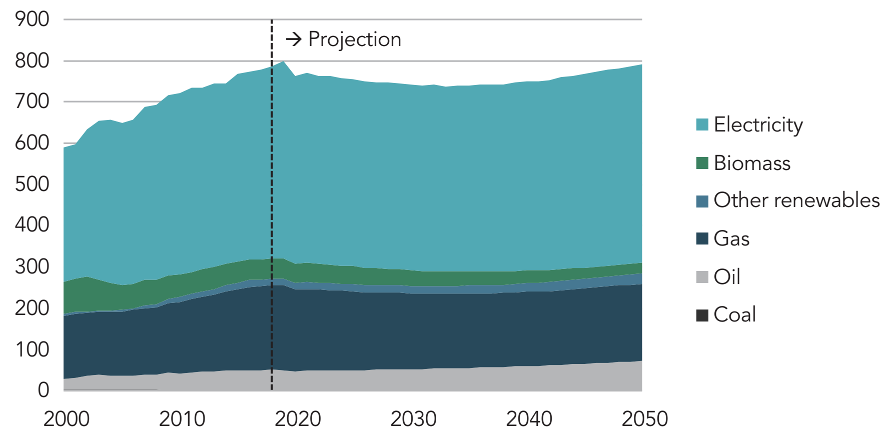


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Australia's population growth and output/activity growth is mostly offset by improvements in energy efficiency in REF, with energy consumption only marginally higher in 2050 relative to the pre-COVID peak.
- Relative consumption by the energy sectors remains consistent through the outlook to 2050 in REF. In contrast, the large decrease in transport demand in CN means that industry becomes just as prominent in energy consumption as the transport sector in 2050. Both sectors account for almost two-thirds of end-use energy consumption at the end of the projection period.
- In CN, transport sector energy consumption falls by more than 40% out to 2050. Greater efficiency, driven primarily by electrification of the light vehicle fleet, accounts for much of this decline. Energy consumption falls by between 10% and 20% in the buildings, industry, agriculture, and non-energy sectors.
- For buildings, the persistence of the existing stock, and an already high share of electricity, limits energy use reductions in CN.
- Industry sector energy consumption in CN is four-fifths of REF levels in 2050. There is a large increase in critical minerals mining activity in CN, but much of this increase in activity is offset by energy efficiency gains. All other industry subsectors consume less energy due to material efficiency (in heavy industry) and energy efficiency improvements.
- Agricultural energy consumption has grown by almost two-thirds in the last two decades due to significant growth in agricultural output that supplies both domestic and international markets. Growth slows in the REF projection period due to greater levels of energy efficiency that partially offsets growth in output. Agriculture energy consumption increases by 15% out to 2050 in REF.
- In CN, greater levels of energy efficiency see agricultural energy consumption fall by 20% out to 2050. Diesel and other oil product consumption falls by 40% due to significant electrification. Electricity consumption by agricultural activities almost quadruples over the projection period.

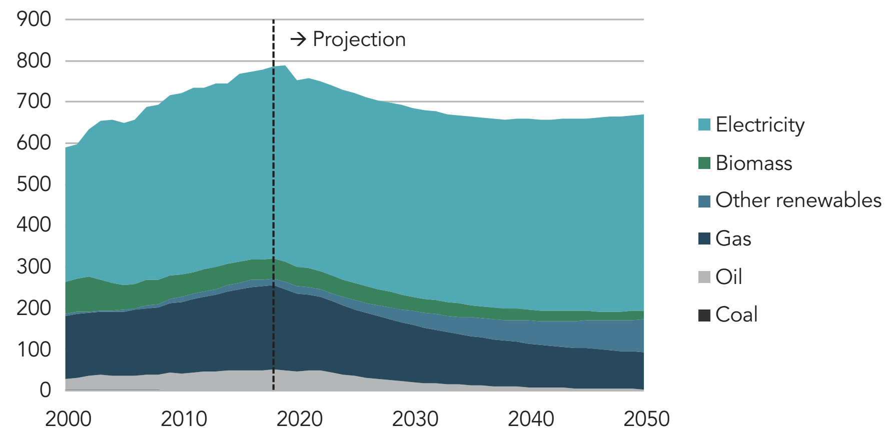
Buildings energy demand

Figure 1-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-8. Buildings energy demand in CN, 2000-2050 (PJ)

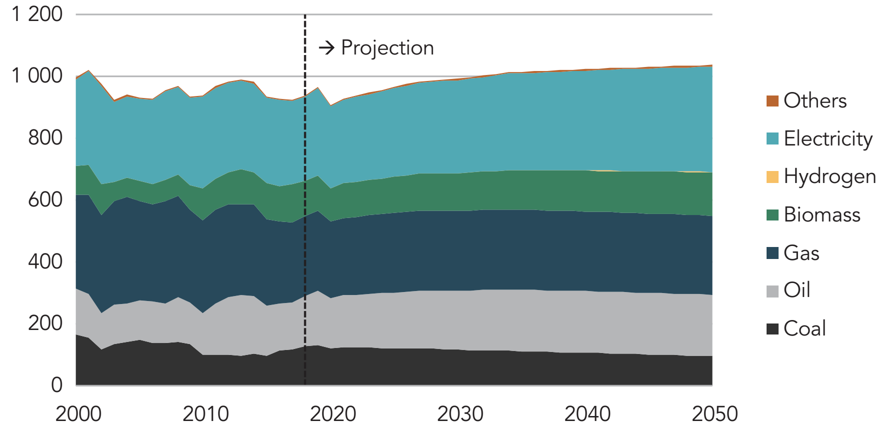


Sources: EGEDA, APERC analysis.

- Australia is not subject to the cold weather climatic extremes that are characteristic of APEC economies such as Canada, China, Japan, Korea, Russia, and the US. However, there is still significant climatic variability in the places that Australians live that necessitates both heating and cooling, depending on the location.
- Southern regions in Australia have historically relied on cheap conventional gas from the Gippsland and Ottaway Basin to meet domestic heating demand in winter. Declining gas production from these legacy basins has led to greater reliance on unconventional gas fields in Queensland at higher prices. Electricity is now the most economic fuel choice for heating in most regions in Australia, which places a ceiling on the growth in gas demand in both scenarios.
- Electricity is projected to account for over 70% of buildings energy consumption in CN in 2050. Whereas the share of gas falls by almost half over the projection period, with electricity taking most of its share.
- Solar water heaters comprise most other renewables and grow by almost 60% in REF. This level of growth is dwarfed in CN, with other renewables growing five-fold over the course of the projection period. Solar water heaters complement rooftop solar PV due to their assumed continuing advantage at delivering lowest-cost water heating.
- COVID-19 saw a decline in energy consumption in 2020 due to lockdowns that forced many commercial businesses to close or reduce operating hours. Reduced commercial buildings energy consumption was partly counteracted by an increase in residential energy consumption, due to increased time spent at home for many Australians.
- In CN, buildings energy consumption is 15% lower than REF by the end of the projection period. LPG and diesel fall to very low levels, with batteries (electricity) increasingly providing back-up energy, supported by higher levels of grid connectivity and off-grid solutions.

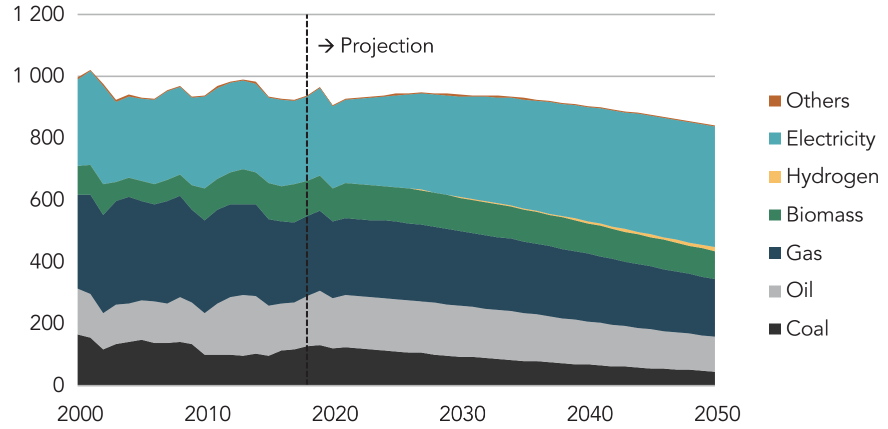
Industry energy demand

Figure 1-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 1-10. Industry energy demand in CN, 2000-2050 (PJ)



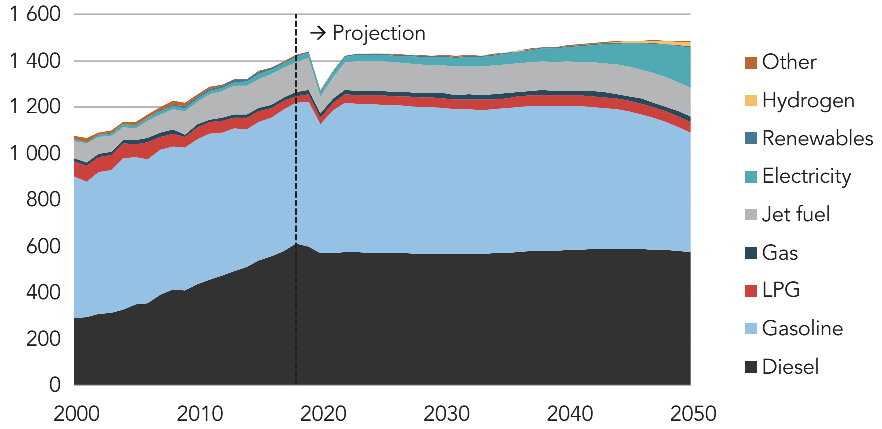
Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Australian manufacturing is in a multi-decade decline in terms of contribution to GDP and level of employment. Mining is the most prominent counterpoint to this trend, with demand from China fueling a commodities boom in Australia through the 2000s and most of the 2010s. Mining and resource extraction of energy and non-energy commodities is likely to remain elevated, though there is limited capacity for continued growth. Even with the boom, minerals mining only accounted for one-fifth of industrial energy consumption in 2018.
- Despite the fall in manufacturing, industrial energy consumption has remained relatively stable in the two decades prior to the COVID pandemic.
- LNG exports have linked Australia's east coast gas market with international markets for gas. Price increases have contributed to difficulties for some industrial natural gas users being able to secure long-term gas supply contracts. Continued tight natural gas markets are assumed to place a ceiling on industrial gas consumption for the projection period.
- While there is likely to be a reduction in natural gas intensive industries, there is an assumed pivot to higher value-add manufacturing industries that are more reliant on electricity rather than primary energy fuels. This trend is assumed to be more prominent in CN, with electricity accounting for almost half of the total industrial energy demand in 2050. Electricity consumption is slightly less than a third in REF.
- Electrification occurs in most of the non-heavy industry subsectors. Mining is particularly influential in reducing diesel consumption, with refined products falling by 36%, mostly in favour of electricity in CN. Coal mining is expected to fall significantly in CN (as shown in the supply section and captured by own use). However, these falls are likely to be offset by increased mining of critical minerals (captured in industry).
- Coal consumption is prominent in heavy industry subsectors such as steel and cement production. Material and energy efficiency improvements, electrification, and switching to hydrogen and biomass for certain processes sees coal consumption fall by almost two-thirds in CN.

Note: Energy commodity (coal, oil, and gas) mining energy consumption is captured within own use.

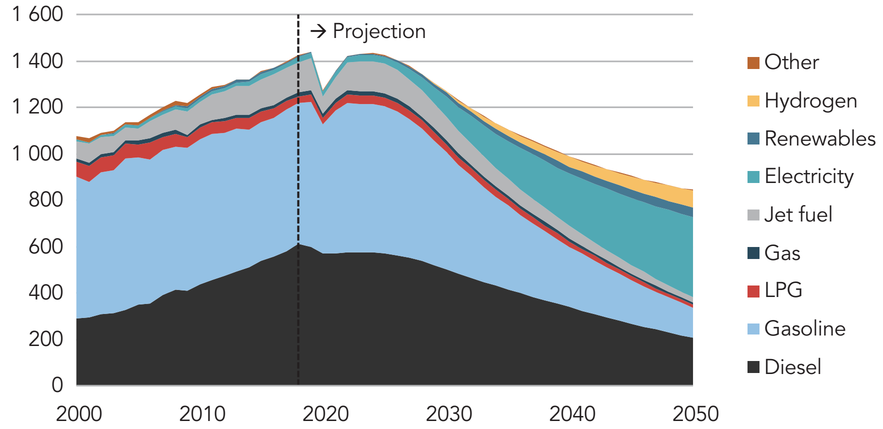
Transport energy demand

Figure 1-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 1-12. Transport energy demand in CN, 2000-2050 (PJ)

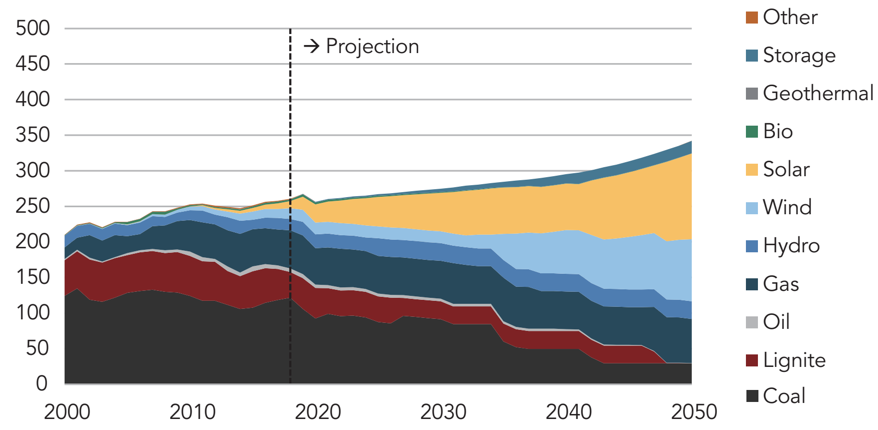


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport is the largest energy consuming sector in Australia, accounting for over 40% of all end-use energy demand before the COVID pandemic.
- Diesel consumption has increased significantly since 2000 and is now at similar levels to gasoline. This growth has been tied to growing consumer preference for diesel vehicles, increasing road freight transport, and increasing rail freight that has accompanied the resources boom of the 2000s and 2010s.
- The impact of COVID was most pronounced for the aviation sector, with jet fuel consumption almost halving in 2020. In contrast, diesel demand remained robust in 2020 due to its importance in maintaining freight and mining operations. A decrease in passenger trips resulting from lockdowns had the largest impact on gasoline consumption and meant that diesel became the most prominent transport fuel for the first time.
- Australia has typically relied on vehicle efficiency standards from international jurisdictions rather than instituting standards of its own. This has meant that the Australian market exhibits fuel efficiency that is below the frontier of advanced APEC economies such as Japan and Korea.
- Electric vehicle sales grow rapidly in CN, reaching a 60% share of passenger vehicle sales, and 40% share of heavy truck sales (battery electric and fuel-cell electric), by 2035. By 2050, all vehicle sales are battery electric or fuel cell electric.
- In CN, greater fuel efficiency and electrification combine to lead to gasoline consumption falling by almost 80%, and diesel falling by almost two-thirds out to 2050.
- Jet fuel falls by over 80% in CN, supplanted by biojet fuel, and hydrogen applications for aviation.

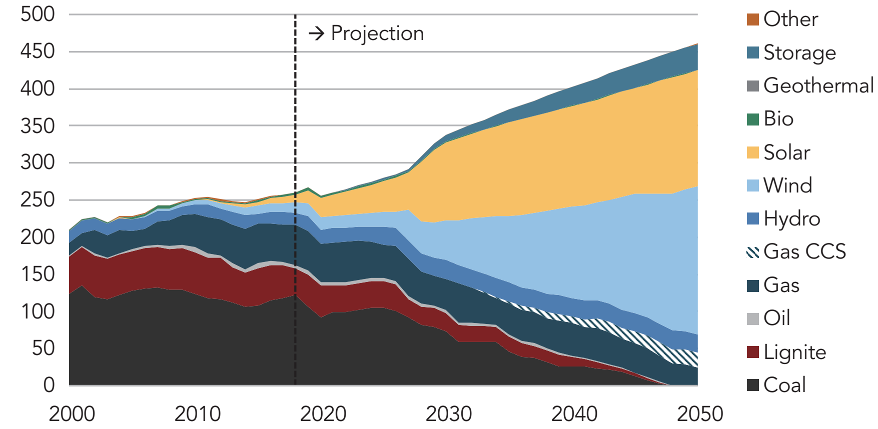
Electricity generation

Figure 1-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 1-14. Electricity generation in CN, 2000-2050 (TWh)

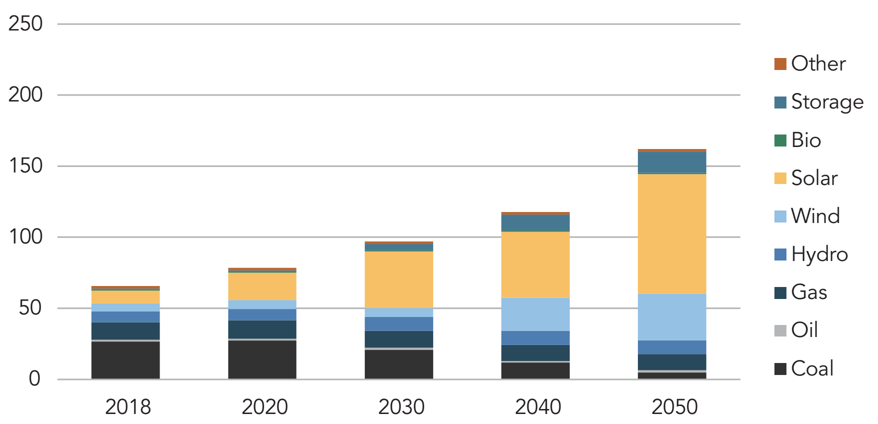


Sources: EGEDA, APERC analysis.

- Electricity generation is projected to increase by almost a third in REF and by almost three-quarters in CN, owing to widespread electrification reaching almost all areas of the economy.
- Coal (including lignite) has historically been the most important source of electricity generation for Australia. Its relative prominence diminishes steadily throughout REF, with only a small amount of coal generation remaining in the 2040s.
- Both coal and lignite still provide important baseload generation in the first two decades of CN, though their use tails off faster, reaching zero generation with the closure of the last remaining coal-fired power plants in the 2040s.
- Australian residential rooftop solar has posted world-leading growth over the last decade and will continue to grow strongly in both scenarios, even without the policy support it received in the 2000s and 2010s.
- Utility scale solar surpasses rooftop generation in the 2030s in REF. In CN, the inclusion of the Sun Cable project, which will export electricity to Singapore, drives utility solar past rooftop solar in 2028.
- Domestic natural gas supply is likely to remain difficult to secure at a sufficiently low price, meaning that natural gas-fired power plants do not increase their current levels of generation in either scenario. However, natural gas remains an important fuel to meet the challenge of variable renewable generation. CCS technology is incorporated in CN for this role to be maintained while meeting emissions reductions goals.
- Australia's electricity markets remain disparate, with most generation occurring in the North Electricity Market (NEM), which covers the south-east and east coast of the continent. There are smaller electricity grids that service the western and northern parts of the continent. The Sun Cable project is assumed to be an isolated infrastructure project that will not be able to serve any part of the domestic market.
- Renewable sources, storage and gas with CCS account for 95% of the generation in CN in 2050, showcasing the extent to which the power sector can decarbonise in Australia.

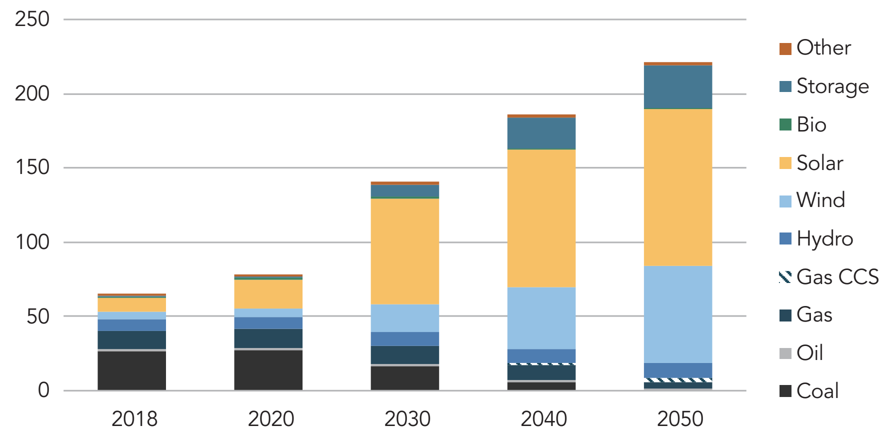
Generation capacity

Figure 1-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 1-16. Generation capacity in CN, 2018-2050 (GW)

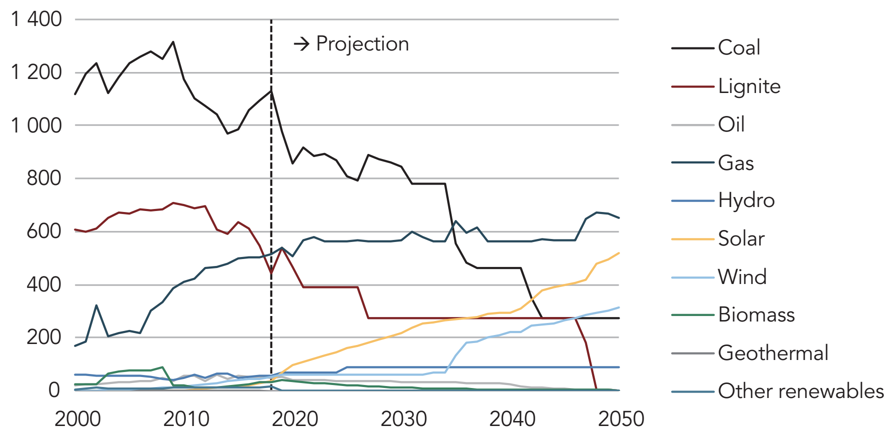


Sources: EGEDA, APERC analysis.

- The installed capacity of Australia's power sector undergoes transformational change in both scenarios. The growth of solar, wind, and storage continues at an incredible pace, with total capacity increasing by two-and-a-half times in REF and by almost three-and-a-half times in CN.
- Both solar and wind capacity increase by a factor of more than 11 in CN, while storage capacity increases more than 50-fold.
- The Australian Energy Market Operator (AEMO) has identified four significant offshore wind zones off the coast of NSW, Victoria, and Tasmania, with all being close to ports that could serve as major hydrogen export hubs. Renewable capacity for hydrogen production (via electrolysis) is additional to the capacity shown here and discussed in the hydrogen slide later in the chapter.
- Both scenarios consider a relatively conservative trajectory for the development of AEMO-identified wind zones. Actual wind capacity to 2030 is already shaping up to be closer to CN results than REF due to the rapid pace of approval of Australian wind projects.
- The Sun Cable project increases Australia's solar capacity by 20 GW in 2028 in CN, with this capacity accounting for over one-quarter of Australia's solar capacity in 2030, and almost one-fifth by 2050. The large contribution of the Sun Cable project means that the solar capacity delivering power for domestic consumption is lower than what is indicated on the chart. This is because the Sun Cable project only delivers power to Singapore.
- The challenge of variable renewable energy is partly met by the 2025 expansion of the Snowy Hydro scheme, legacy coal-fired power plants in REF, and a very large build out of battery storage capacity at both the utility and household level, particularly in CN. Natural gas capacity, including with CCS technology in CN, also remains to ensure generation at times of highest need.

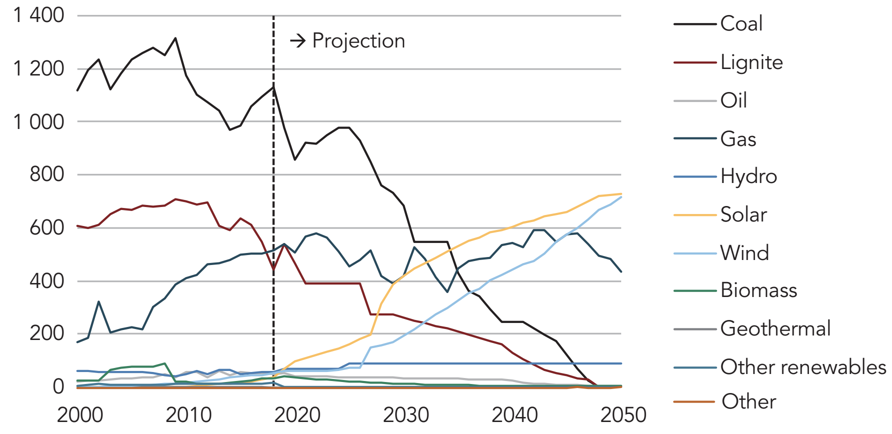
Fuel consumption by the power sector

Figure 1-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 1-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

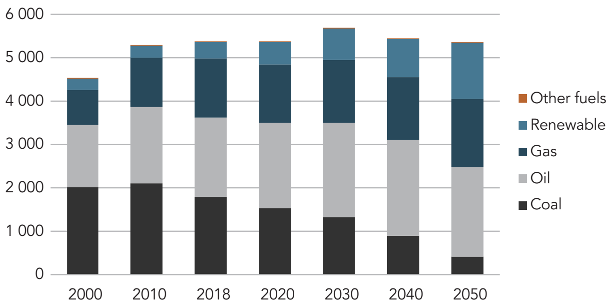


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- Despite announcements of early closures of the Eraring, Bayswater, and Loy Yang plants, coal (including lignite) remains the most prominent fuel consumed by the Australian power sector through to the 2040s in REF, and the 2030s, in CN.
- Natural gas is truly a transition fuel for the Australian power sector in both scenarios. Strong growth in renewables and retirements of aging coal plants result in gas maintaining a similar level of consumption through the entire projection period for both scenarios. In CN, natural gas consumption is only marginally lower, though decarbonisation is achieved with the building and deployment of natural gas generation with CCS technology.
- The large increase in solar radiation consumption in CN occurs in 2028, when the Sun Cable is assumed to begin operating.
- Hydrogen production is not modelled as part of the power sector. Electrolysis from renewable sources will contribute to even more renewable electricity generation, but it is assumed to be from standalone systems, separate from the main grids.
- Only four coal-fired power plants incorporate supercritical technology in Australia. These plants were completed in the 2000s in Queensland and consume almost 10% less coal per MWh than the many subcritical coal-fired power plants that were constructed in the 1960s through to the 1990s. There are currently no ultra-supercritical or advanced ultra-supercritical coal-fired power plants in Australia. The much higher costs of these plants negatively impacts their economic viability.
- Most gas-fired power plants in Australia are open cycle gas turbines. These units will be important in providing peaking and ancillary services, as coal phase-outs and renewable deployments accelerate in both scenarios.

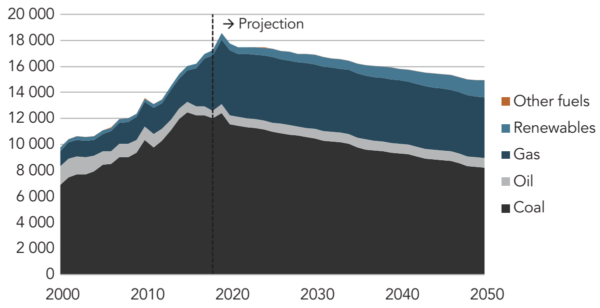
Energy supply in the Reference scenario

Figure 1-19. Total energy supply in REF, 2000-2050 (PJ)



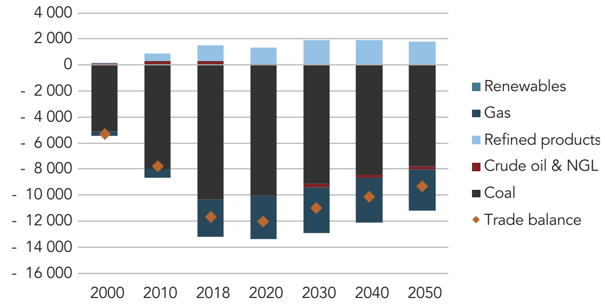
Sources: EGEDA, APERC analysis.

Figure 1-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-21. Net energy trade in REF, 2000-2050 (PJ)

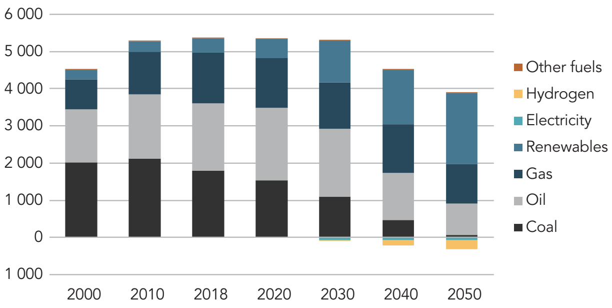


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Australia is one of the largest energy exporters in the world, and currently produces more than three times the level of energy that it consumes.
- On an energy content basis, coal accounted for 70% of Australia's energy production in 2018. Thermal coal (and lignite), used primarily in coal-fired power plants, accounted for just over half this production, while metallurgical coal, used as a key input for steel production, accounts for the remainder.
- Almost 90% of Australia's current coal production is exported, with near equal quantities of thermal coal and metallurgical coal on an energy content basis. Given that metallurgical coal trades at a price premium, it currently provides more of an economic contribution to Australia's GDP.
- With diminishing prospects for thermal coal in REF, metallurgical coal will become relatively more important for Australia, accounting for 60% of Australia's total coal exports in 2050. Most of the decline in coal production and exports is due to declines in demand for thermal coal use in export markets.
- Natural gas production has increased markedly in the 2010s due to the development of conventional and unconventional gas resources in the east, north, and west of the continent. Development of unconventional resources in the Surat and Bowen basins are noteworthy, with these basins supplying LNG export terminals in Gladstone, Queensland. When combined with additional export destined production in Western Australia and the Northern Territory, natural gas production has increased from below 2 000 PJ in 2010 to almost 5 000 PJ before the pandemic.
- Natural gas production and exports are expected to maintain current levels for the rest of the projection period. Current levels of production are reliant on exploration, appraisal, and commercialisation of additional basins out to 2050.
- Imports of refined products will displace imports of crude oil following the closure of two of the four remaining oil refineries in Australia in 2021. The remaining two refineries are expected to continue operating to apportion energy security risks between crude oil and refined products.

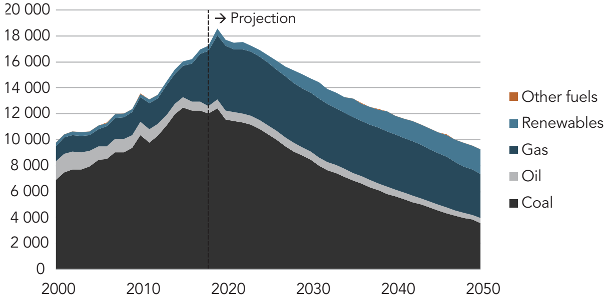
Energy supply in the Carbon Neutrality scenario

Figure 1-22. Total energy supply in CN, 2000-2050 (PJ)



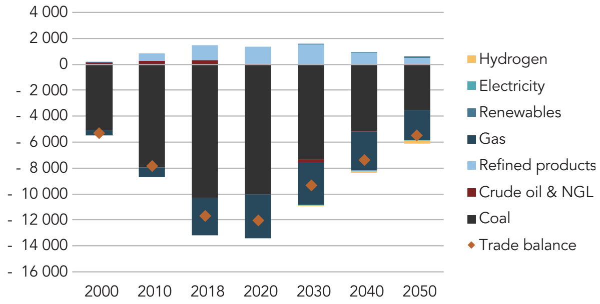
Sources: EGEDA, APERC analysis.

Figure 1-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-24. Net energy trade in CN, 2000-2050 (PJ)

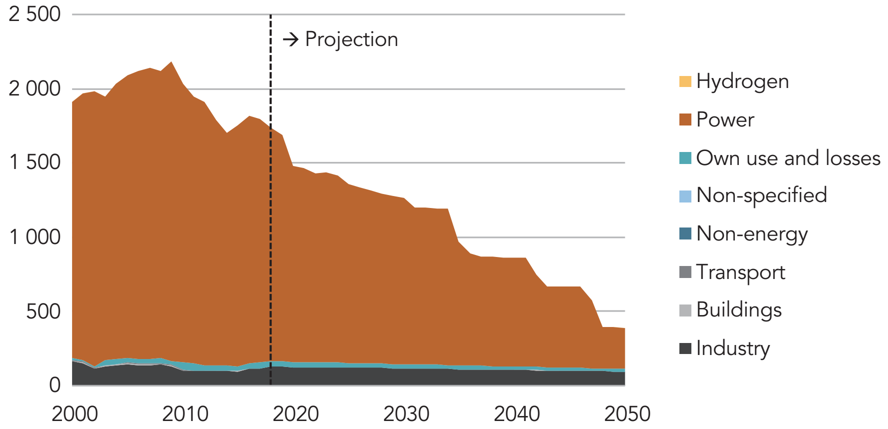


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Renewables almost triple in Australia's energy supply over the projection period in REF. This growth is exceeded significantly in CN, with renewables growing almost five-fold and accounting for over half of Australia's energy supply in 2050. Most of this growth is via solar and wind electricity generation.
- The trend of declining thermal coal production and exports in REF is even more pronounced in CN, with falls of almost 90%. Although metallurgical coal demand is robust in REF, the rise of alternative steel production techniques in CN begin to see a decline in Australia's metallurgical coal production in response to diminishing global demand. However, Australia's metallurgical coal production in 2050 is still more than half of the peak production output before the pandemic.
- Electricity and hydrogen are energy carriers and do not show in primary energy supply unless there is some form of trade component. Australia is assumed to become a large exporter of both electricity and hydrogen in CN. Electricity exports are via the Sun Cable project, assumed to begin operating in the late 2020s. Hydrogen exports begin to ramp up from the late 2020s as well, produced by natural gas with CCS technology and electrolysis. These exports are expected to reach over 200 PJ in 2050.
- Natural gas production and LNG exports remain more robust than coal in CN, though there is a reduction, with production and exports equal to three-quarters of REF values in 2050.
- Refined products imports decline more rapidly in CN due to declining domestic demand, most notably from the transport sector.
- Although electricity and hydrogen exports begin in CN, their impact is relatively small and unable to offset the much larger decline of coal and gas exports. Australia's CN trade balance is only 60% of the balance in REF in 2050.

Coal in the Reference scenario

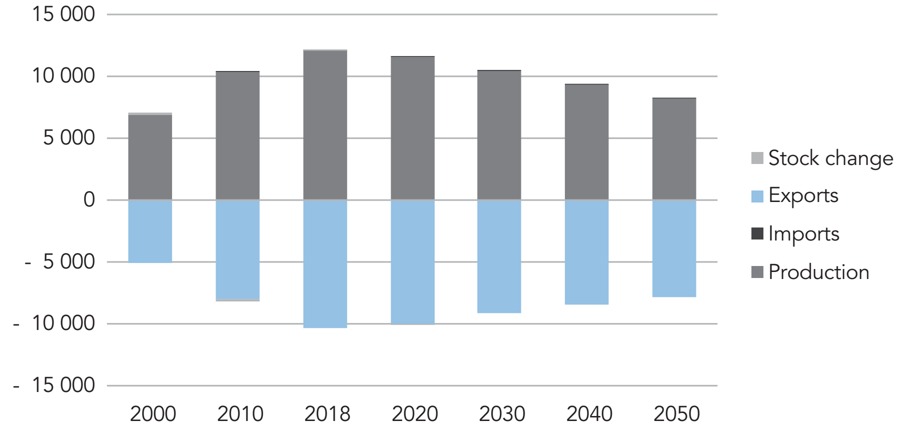
Figure 1-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

- The power sector consumes an overwhelming majority of coal in Australia. Peak consumption by the power sector was over 2 000 PJ in 2009, with this having fallen to 1 500 PJ just before the pandemic. The decade-long decline is set to continue in REF as the remaining coal-fired power plants in NSW, Victoria, Queensland, and Western Australia reach the end of their operational lifetimes.
- There is assumed to be no new coal-fired power plants built in either scenario, due to the rapidly increasing capacity of alternative generation technologies such as solar and wind. Increased pumped hydro capacity in the mid-2020s will also facilitate the coal power phase out.
- Coal-fired power plant utilisation rates have been falling with the rise of variable renewable generation. This fall in utilisation is contributing to deteriorating economics for coal-fired power, which is likely to accelerate the inevitable phase-out.
- Multiple Australian industrial subsectors continue to rely on thermal coal for processes that require consistent heating properties. The demand by these subsectors remains relatively small, though is more robust than demand from the power sector given that there are fewer viable substitutes.

Figure 1-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

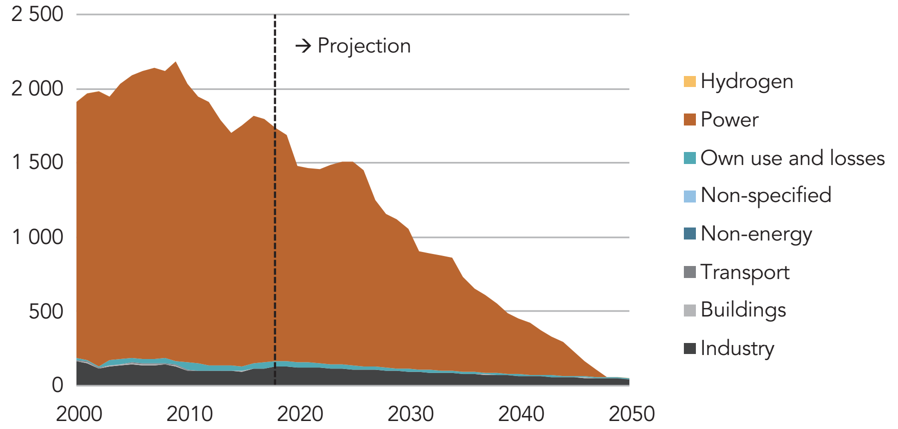


Sources: EGEDA, APERC analysis.

- Production of coal is assumed to have peaked prior to the COVID pandemic, and gradually tapers to 2050, falling by one-third. Almost 95% of coal production is exported in 2050, reflecting the rapid decline in coal consumption by domestic applications.
- The markets for Australian coal exports will almost exclusively be in Asia, with metallurgical coal accounting for 60% of all coal exports in 2050, which is up from less than 50% currently. Thermal coal production declines will be in response to reducing global demand for thermal coal by the global power sector.

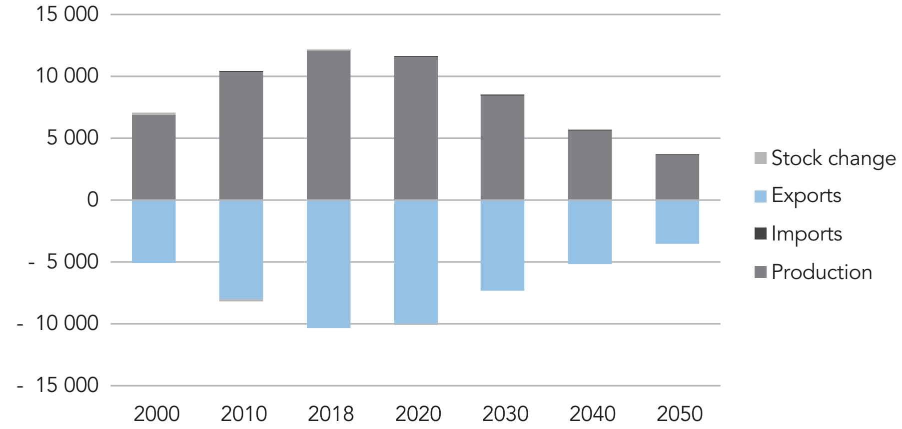
Coal in the Carbon Neutrality scenario

Figure 1-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

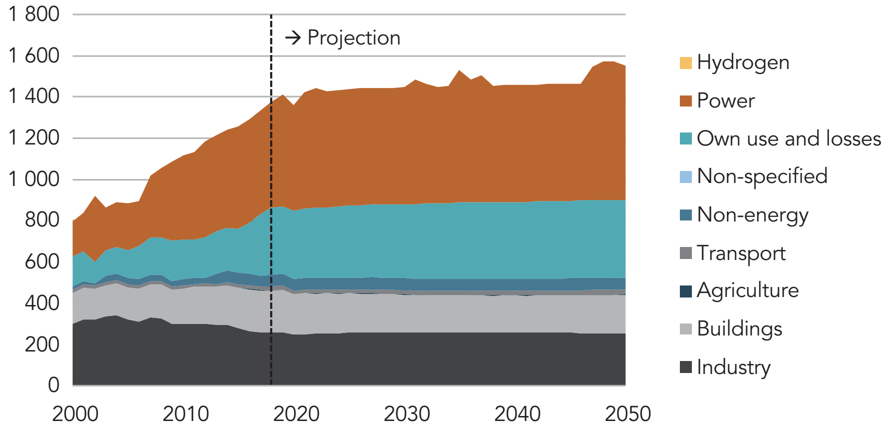


Sources: EGEDA, APERC analysis.

- Power sector consumption of coal in CN follows a similar trajectory to REF in the 2020s. However, there is an accelerated timeline of coal-fired power plant closures from the 2030s onward due to assumed policy intervention combined with a more rapid rise in renewables and storage capacity additions. The last coal-fired power plant is expected to cease operating in the late 2040s.
- Industrial consumption of coal is less robust in CN. Electrification, other fuel switching, and changes in industry subsector composition means that industrial consumption falls by two-thirds to 2050.
- The decline in global markets for thermal coal is assumed to be even more pronounced in CN, with Australia's thermal coal production and exports falling by almost 90% to 2050.
- Global metallurgical coal demand begins to be displaced by alternative virgin steel production technologies incorporating hydrogen. Metal scrap recycling rates also increase to allow electric arc furnaces to displace even more metallurgical coal. Even so, metallurgical coal demand remains, with Australia continuing to supply global markets. Australia's exports of metallurgical coal in 2050 are projected to be slightly more than half of what they were at their peak.
- CCS technologies are assumed to contribute to bolstering global demand for metallurgical coal-based steel production in the face of aggressive emissions abatement. The rise of this technology will provide support for Australian production of metallurgical coal.
- Over 98% of Australia's coal production in CN is exported in 2050.

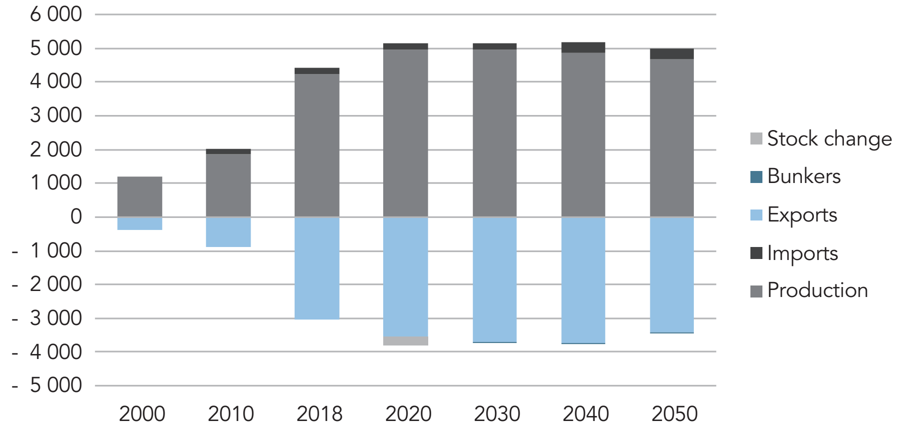
Natural gas in the Reference scenario

Figure 1-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

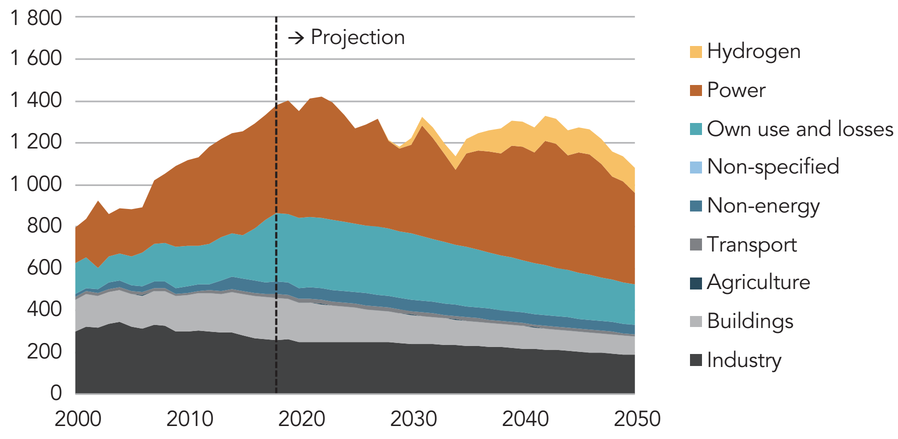


Sources: EGEDA, APERC analysis.

- Natural gas is consumed by almost all energy sectors in the Australian economy, with total consumption increasing by 80% since the turn of the century. Much of this growth is due to significant gas-fired power capacity additions, and the large volumes of own use required to liquefy natural gas for Australia's LNG export industry.
- Unconventional production from the Surat and Bowen basins that underpinned the investment in east coast LNG export capacity has been lower than was originally forecast. In response, LNG exporters have been compelled to source substantial volumes of gas from other domestic producers.
- Declining southern production and gas demand by Australia's LNG exporters has placed upward pressure on wholesale gas prices in recent years, making it more difficult for domestic consumers to secure long-term supply. Uncertainty of supply at a competitive price places a ceiling on growth of domestic gas consumption out to 2050.
- The Australian Domestics Gas Security Mechanism (ADGSM) was instituted to ease supply issues by empowering the federal resources minister to limit LNG exports in the face of a domestic supply shortfall. The ADGSM has yet to be exercised and medium- to long-term supply uncertainty remains.
- To ease supply tensions, there are plans for multiple east coast LNG import terminals. Both scenarios assume that some of these projects begin to alleviate supply pressure by the late 2020s. However, these projects are unlikely to deliver low prices.
- While unconventional natural gas production out of Queensland has been lower than forecast, Australian production has still managed to increase by a factor of 2.5 since 2010. Production and exports are assumed to maintain current levels for most of the projection period. This will be reliant on exploration, appraisal, and commercialisation of new basins. Multiple LNG export facilities will also require refurbishment during the mid-2030s.

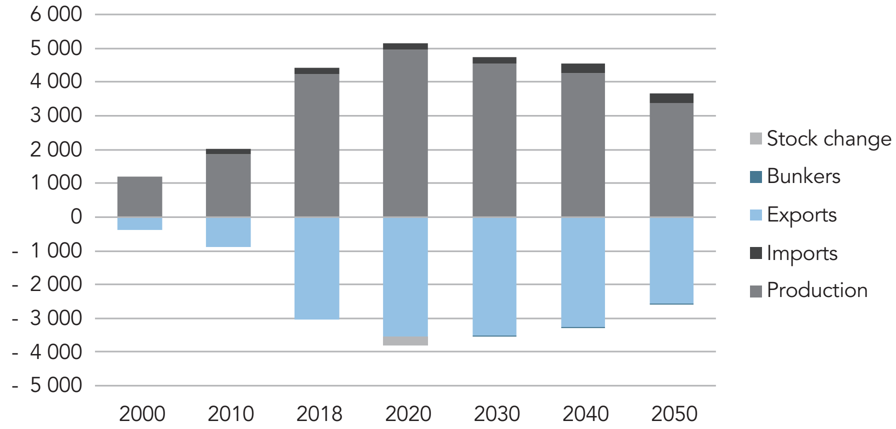
Natural gas in the Carbon Neutrality scenario

Figure 1-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

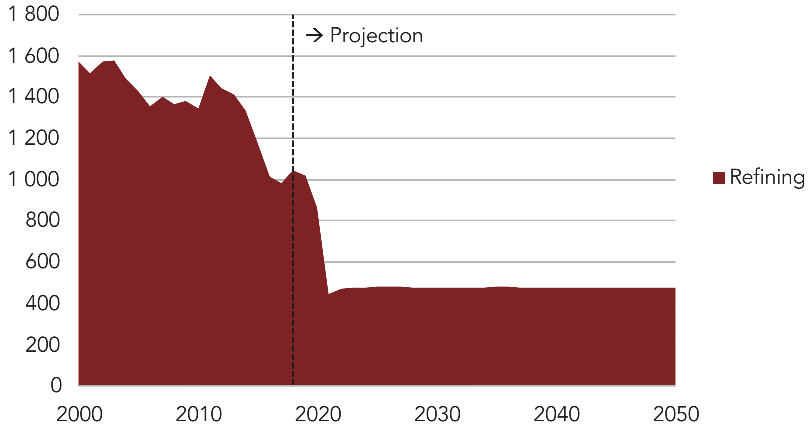


Sources: EGEDA, APERC analysis.

- Natural gas consumption is typically lower in CN for almost all energy sectors. Power sector consumption is more volatile due to an increased role in meeting the challenge of greater variable renewable generation. That role is heightened due to a faster phase out of coal-fired generation.
- Reduced natural gas consumption in many of the other consuming sectors is due to improved energy efficiency and fuel switching, particularly to electricity. Such switching has already started to occur with the higher domestic prices filtering through to most parts of the economy since the mid-2010s.
- The hydrogen sector begins to become a large natural gas consumer from the late 2020s. Steam methane reforming with CCS hydrogen production grows rapidly. However, by the mid-2040s, electrolysis accounts for almost all additional hydrogen production, and so natural gas consumption for hydrogen does not continue to grow.
- Australia's natural gas production in CN declines slowly from current levels in response to lower global demand for natural gas. Natural gas production in 2050 is 30% lower than the current peak, with a similar forecast decline for exports.
- Natural gas pipeline imports from the East Timor Joint Petroleum Development Area have been liquefied in Darwin before being exported to Asia since 2005. These imports are expected to cease in 2022, following exhaustion of the Bayu Undan offshore gas field. There is likely to be development of additional gas resources in the Northern Territory to make-up for this forecast shortfall.
- In both scenarios, the west and east natural gas markets remain separated with only a small pipeline linking the Northern Territory to the east coast. Easing the current supply issues is less of a priority in CN due to lower consumption. However, east coast import terminals are still assumed to play a role, becoming operational in the 2020s.

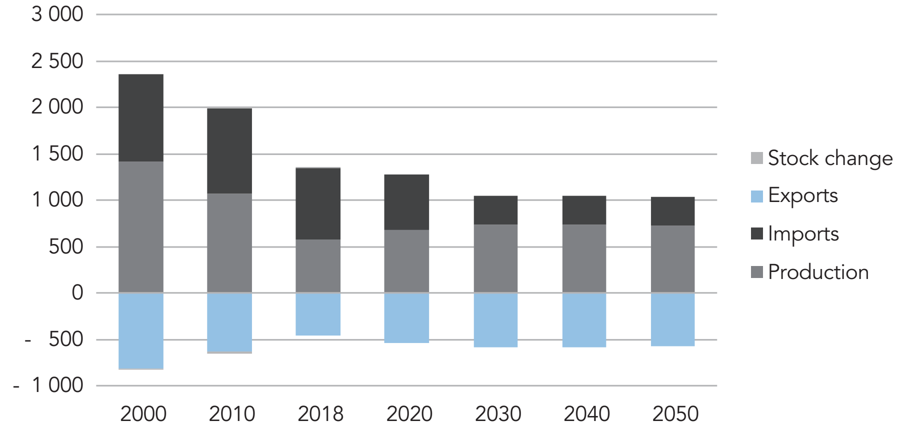
Crude oil and NGLs in the Reference scenario

Figure 1-33. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-34. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

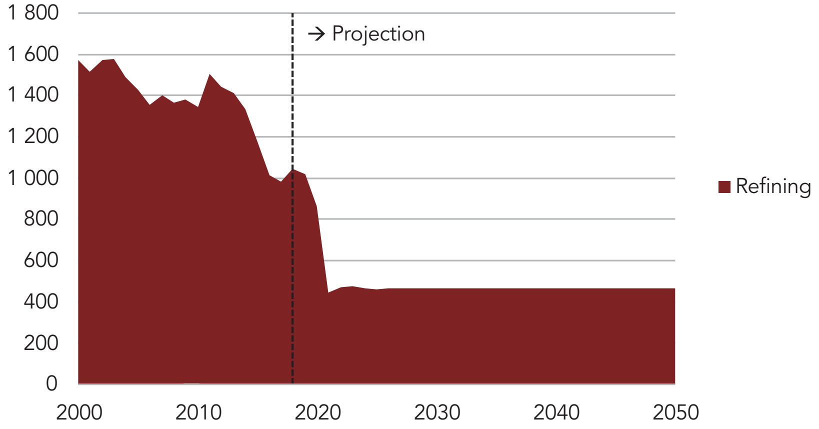


Sources: EGEDA, APERC analysis.

- Australian crude oil production is modest in comparison to Australia's coal and natural gas production, due to far smaller reserves. Bass Strait production (southern Australia) is mostly refined by Victorian refineries due to proximity and ease of transport via pipeline. The bulk of other production, such as from the Northern Carnarvon and Roebuck basins in Western Australia, is closer to Asian markets and of a quality that is not suitable for Australian refineries.
- In 2021, two of the four remaining Australian refineries, Altona in Victoria and Kwinana in Western Australia, announced that they would be ceasing operations. This has roughly halved demand for crude oil for Australian refineries, accelerating the decline of the previous two decades.
- The Australian government has announced support measures to ensure that the Lytton refinery in Queensland and Geelong refinery in Victoria continue to operate until at least 2027.
- Energy security is a consideration for the two remaining Australian refineries to continue operating. However, both refineries rely on a large quantity of imported crude oil to meet their required processing capabilities. This means that Australia is still vulnerable from an energy security standpoint with challenges of supply of crude oil supplanted by challenges of supply of petroleum products.
- In both scenarios, the two remaining refineries are assumed to continue operating until 2050. Production and exports are also assumed to maintain levels in place following the refinery closure announcements of 2021. Imports are assumed to maintain levels that are sufficient to supply the two remaining refineries.
- Part of the fall in crude oil production from established fields has been offset by an increase in NGL production that is tied to the exploitation of liquids-rich offshore reserves.

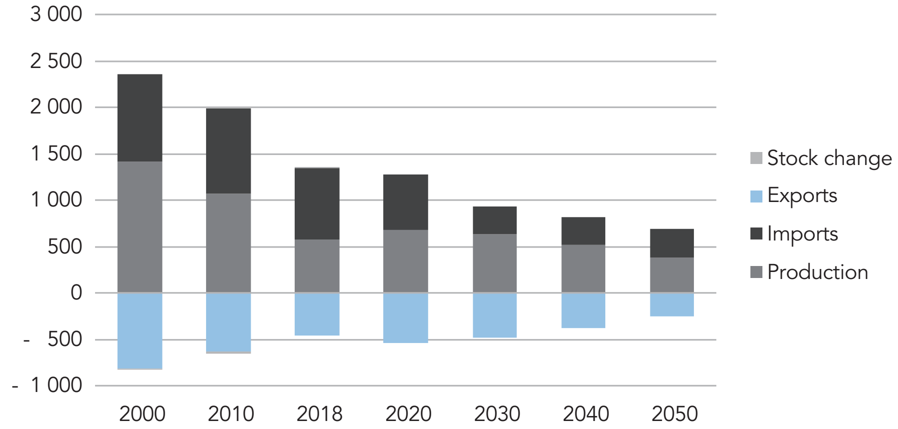
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 1-35. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-36. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

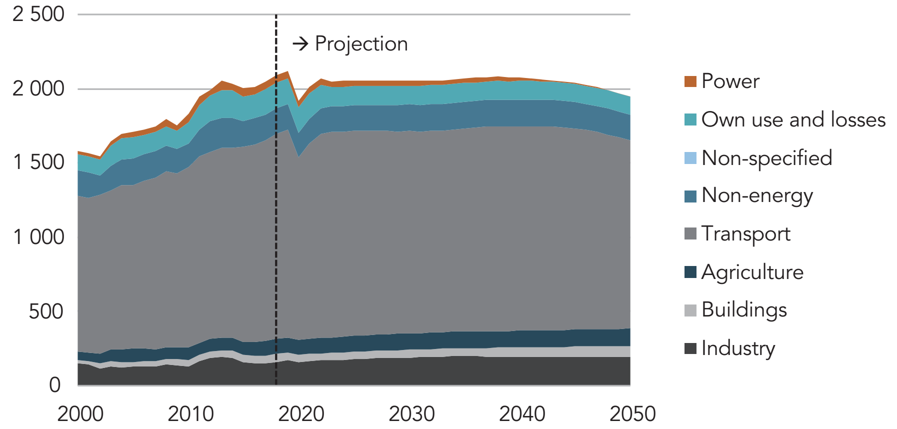


Sources: EGEDA, APERC analysis.

- In CN, demand for crude oil by the two remaining Australian oil refineries is assumed to be almost the same as in REF.
- While demand for refined products decreases rapidly in CN, domestic refinery output remains significantly below this demand for the entire projection period. This means that there is an economic case for two operational domestic refineries in Australia out to 2050, even in a scenario with rapid decarbonisation of the energy sectors.
- Importing higher-cost, premium light-sweet blends, places Australia's refineries at an economic disadvantage relative to international competition. However, this additional cost may be justifiable in the context of fuel security.
- Constant domestic refinery output means that Australia's import dependence for transport fuels declines throughout the outlook period; domestic refining satisfies more and more of domestic demand out to 2050.
- In CN, production of crude oil and NGLs in 2050 falls to slightly more than half of the production that occurs in REF. Imports remain about the same between the two scenarios, owing to the almost identical refinery consumption.
- Exports of crude oil in CN are only 40% of what they are in REF due to the rapid move away from refined products that takes place in order to meet emission abatement goals.

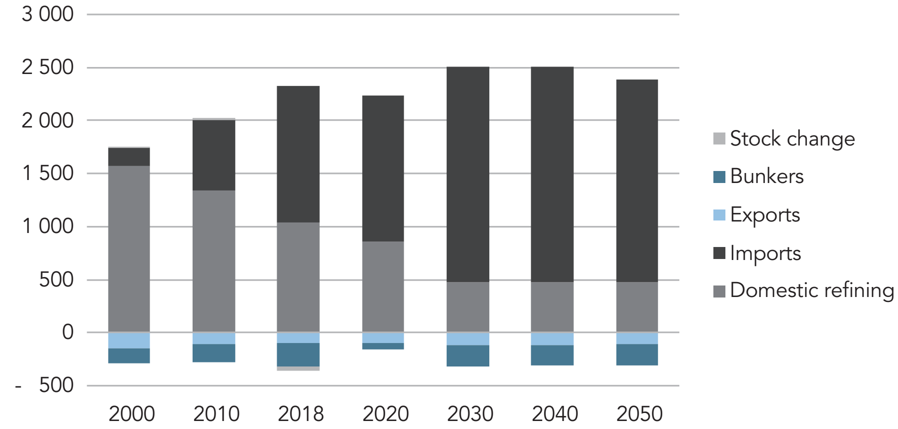
Refined products in the Reference scenario

Figure 1-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

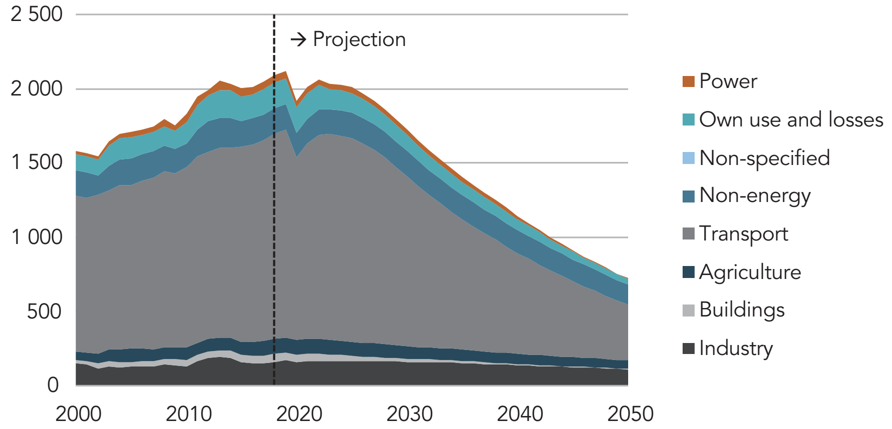


Sources: EGEDA, APERC analysis.

- Outside the transport sector, minerals mining (a subsector of industry) consumes the largest amount of diesel, with this consumption having tracked the commodities boom of the 2000s and early 2010s. Agriculture is also a large user of diesel, and the non-energy sector consumes a significant portion of refined products as a feedstock.
- In REF, growth in population and output/activity is tempered by improvements in energy efficiency and some fuel switching. This translates to similar levels of refined products consumption out to 2050.
- Demand for refined products is assumed to have peaked in Australia prior to the COVID pandemic. The most visible impact on refined products consumption is in the transport sector, with consumption falling by 12% in 2020. Bunkers supply, which captures demand from international aviation and maritime applications, also shows a very large decrease. Other consumption sectors were less impacted due to activities largely continuing under lockdown conditions.
- Imports of refined products have grown significantly since 2000 due to steady growth in consumption and a diminishing domestic refining fleet. There were eight Australian refineries at the turn of the millennium, though with the most recent closure announcements from Kwinana (Western Australia) and Altona (Victoria) in 2021, only two remain. Imports of refined products as a proportion of supply have increased from 10% in 2000 to over 70% in 2021.
- The two remaining domestic refineries (Geelong and Lytton) are assumed to continue operating for the remainder of the projection period. However, import dependency will be close to 100% given that exports and bunkers (international aviation and maritime) will offset the domestic refining output.
- Australia has been non-compliant with the IEA 90 days of oil stock requirement since 2012. The federal government signed an agreement with the US in 2020 to lease a portion of the US Strategic Petroleum Reserve as part of a commitment to return Australia to compliance by 2026.

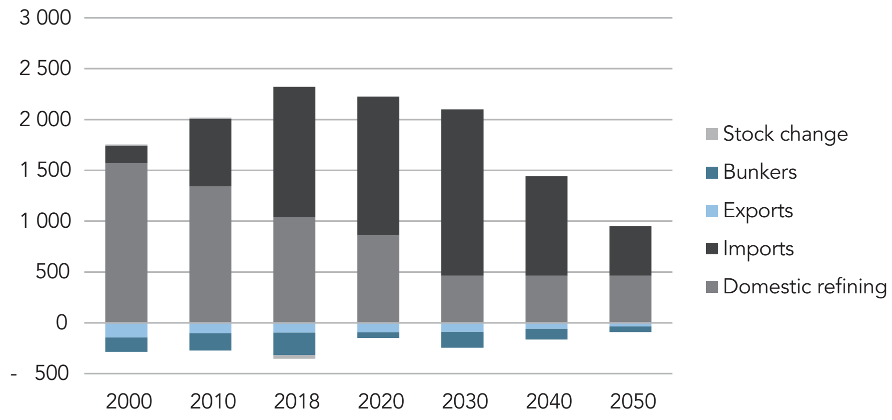
Refined products in the Carbon Neutrality scenario

Figure 1-39. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 1-40. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

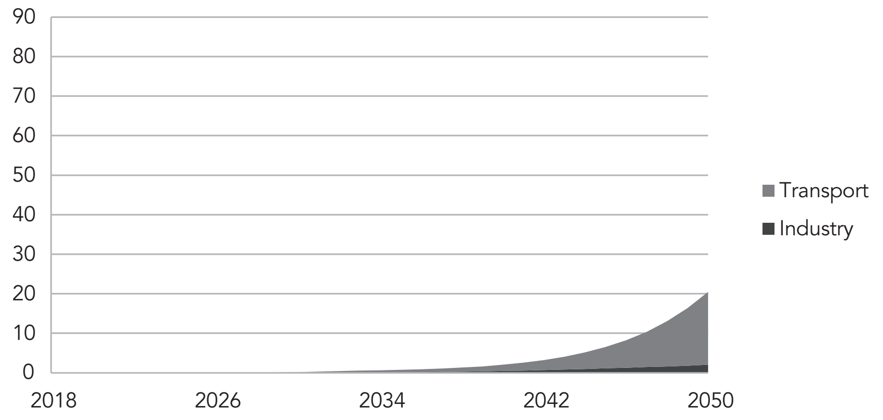


Sources: EGEDA, APERC analysis.

- Consumption of refined products falls by two-thirds to 2050 in CN. The transport sector contributes most of the heavy lifting via electrification and fuel efficiency improvements, with consumption falling by almost three-quarters. For buildings, refined products consumption falls by 90%, albeit from a lower base, with significant switching away from LPG and diesel generators. Agriculture and the industry sector achieve more modest reductions of 40%, with electrification of mining activities playing a leading role for industry.
- The initial post-COVID rebound is similar in both scenarios, though improved energy efficiency performance in CN, including accelerated electrification in road transport applications, means that refined products consumption begins to fall dramatically away from the REF trajectory.
- The two remaining oil refineries are expected to continue to operate for the entire projection period as part of a diverse fuel security strategy. With rapidly falling consumption patterns in CN, the Australian refineries meet a much larger proportion of demand; refinery output is equal to almost two-thirds of domestic consumption in 2050. A similar quantity of imports are required due to continued small export quantities and to supply bunkers for international aviation and marine demand.
- Compliance with meeting the IEA's requirement to hold 90 days of daily net imports will remain a similar challenge for Australia in CN in the short-term. However, sustained lower consumption levels will mean that it will be easier for Australia to comply in the medium- to long-term, without needing to resort to leasing offshore storages or implementing ticketing arrangements.

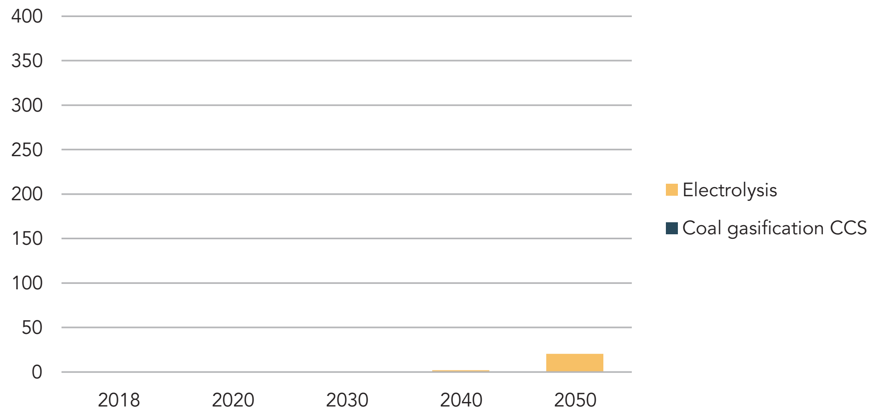
Hydrogen in the Reference scenario

Figure 1-41. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 1-42. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

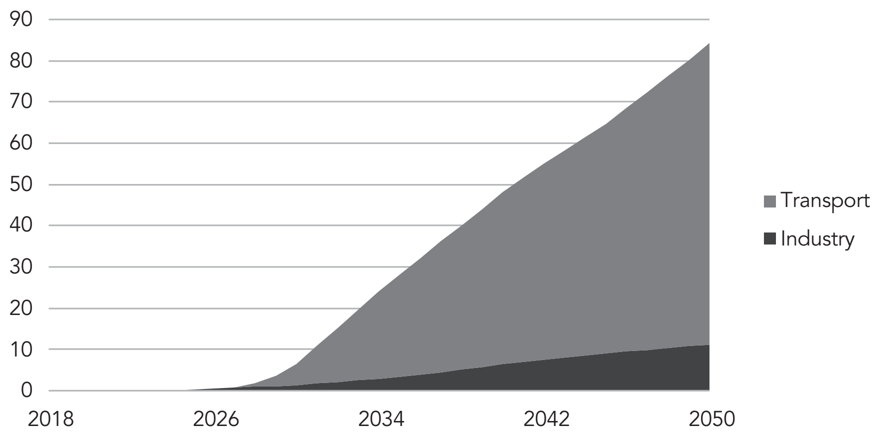


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- Hydrogen is currently produced by refineries for use as a feedstock in hydrocracking and hydroprocessing of oil and refinery products in both the refining and upgrading process. However, this *Outlook* only models the production and consumption of hydrogen as an energy carrier in the end-use sectors.
- Hydrogen is an emerging energy carrier with an uncertain future in the global and Australian energy system. Like most emerging energy carriers, its integration depends on the successful development of multiple hydrogen applications on the demand side in concert with an economic development of hydrogen supply. Parallel development of export markets could also help achieve scale and reduce costs on the supply side.
- In REF, there is a small take-up of hydrogen by heavy trucking. There is also a very small amount of use cases that begin to incorporate hydrogen as an energy source and fuel in the chemicals industry subsector. This small amount of demand is met by a domestic hydrogen industry, that is almost exclusively produced by electrolysis.
- The purpose of the inclusion of hydrogen in REF is to reflect the reality that hydrogen use cases are likely to eventuate, but the limited developments fail to gain meaningful traction. In REF, there is not a large global market for hydrogen that would support large-scale hydrogen export activities out of Australia.

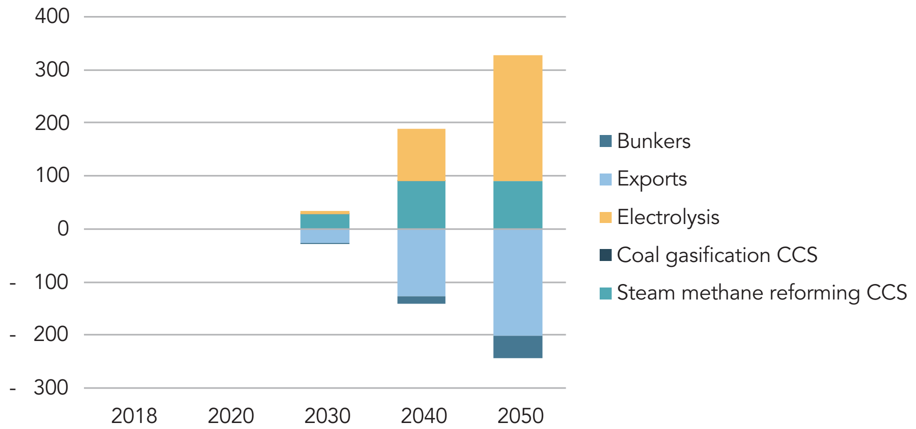
Hydrogen in the Carbon Neutrality scenario

Figure 1-43. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 1-44. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

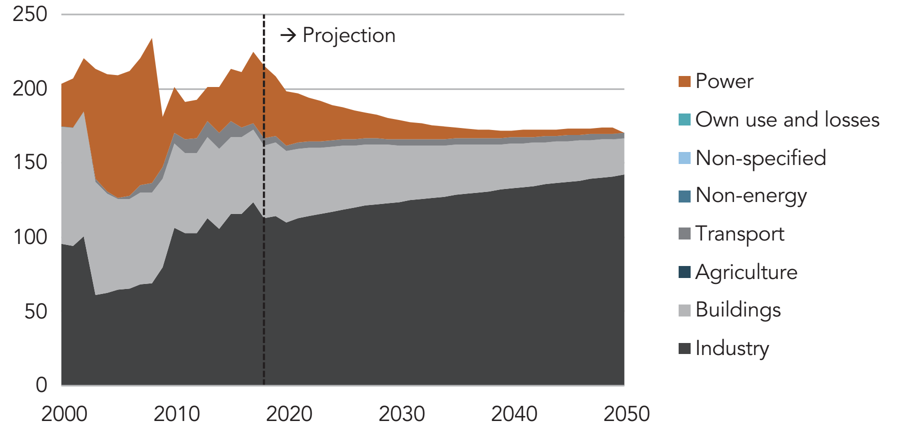


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- In contrast to REF, the market for hydrogen advances rapidly in CN, with multiple global industry and transport use cases fueling robust global trade. Japan also incorporates hydrogen consumption in buildings applications.
- For Australia, hydrogen transport demand grows to almost 80 PJ, with applications in heavy trucking, aviation, and maritime activities. Industrial hydrogen applications are less available for Australia due to the significant offshoring of heavy industry activities through the latter half of the twentieth century and through the 2000s. Nevertheless, hydrogen begins to be incorporated in Australia's chemicals and steel industry subsectors from the late 2020s.
- While domestic consumption use cases remain modest, Australian hydrogen production grows to over 300 PJ by 2050, supporting an export market of 200 PJ. The production also supports additional demand from international aviation and shipping (captured by bunkers) of 40 PJ.
- Hydrogen production from steam methane reforming with CCS initially grows at a faster rate than electrolysis from the mid-2020s. But growth in electrolysis production accelerates, so that it accounts for over 70% of Australia's hydrogen production in 2050.
- The Australian Government has recently announced over AUD 1.5 billion of support for a clean hydrogen industry. Investments are for clean hydrogen industrial hubs, electrolyser projects, and multiple knowledge sharing and collaboration initiatives with other economies. This level of support will be pivotal in facilitating an outcome such as the one that occurs in CN.

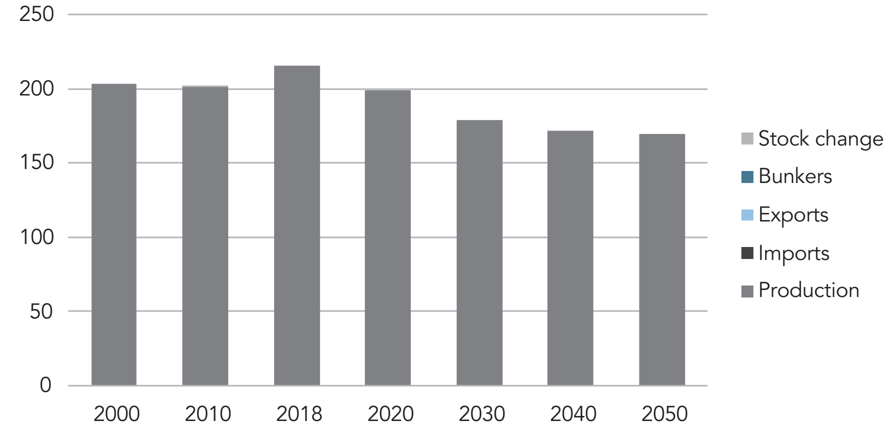
Bioenergy in the Reference scenario

Figure 1-45. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 1-46. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

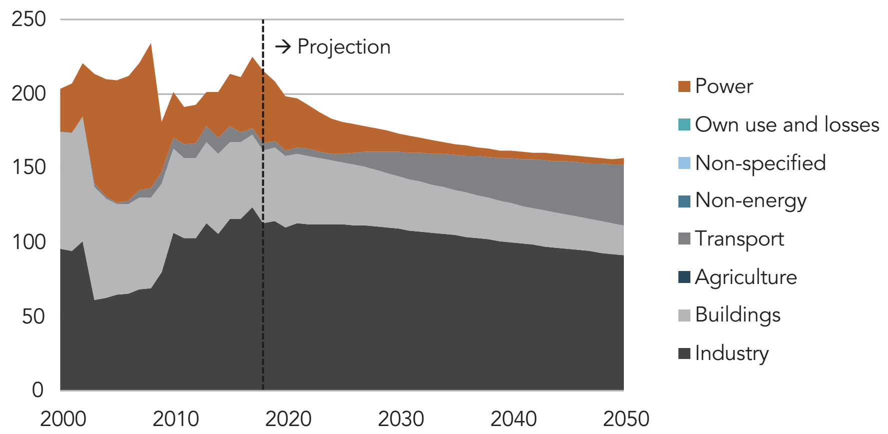


Sources: EGEDA, APERC analysis.

- Consumption of solid and liquid renewables maintains a similar level in Australia through the projection period, though the sectoral composition of that consumption shifts significantly. Biomass used by the power sector falls close to zero by 2050. Biomass used in the buildings sector falls as well, but only by half, due to certain remote regions being unable to switch to other fuel sources. The buildings biomass switching that does occur is mostly to electricity.
- In contrast to declining use of biomass in the power sector and buildings, the industrial sector uses an increasing amount of biomass, displacing a small amount of fossil fuels in certain subsectors such as food and beverages and non-metallic minerals production. Industry accounts for over 80% of the consumption of these renewables by 2050.
- Supply of these solid and liquid renewables used in the different energy consuming sectors is exclusively from domestic production sources.

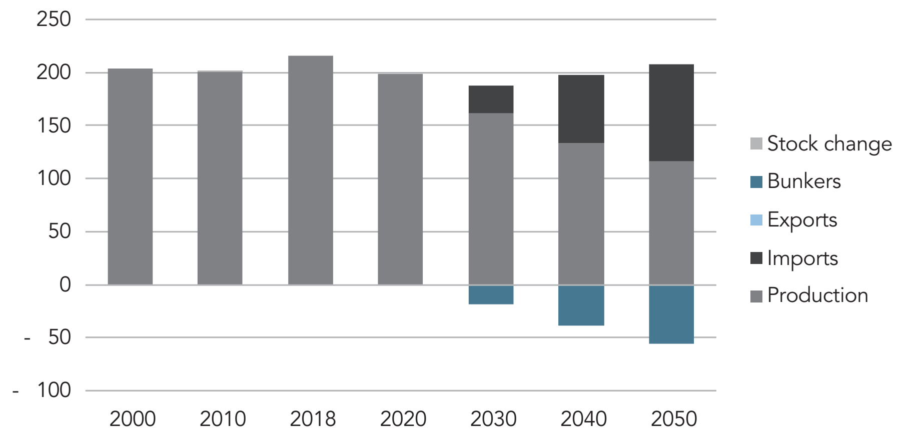
Bioenergy in the Carbon Neutrality scenario

Figure 1-47. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 1-48. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

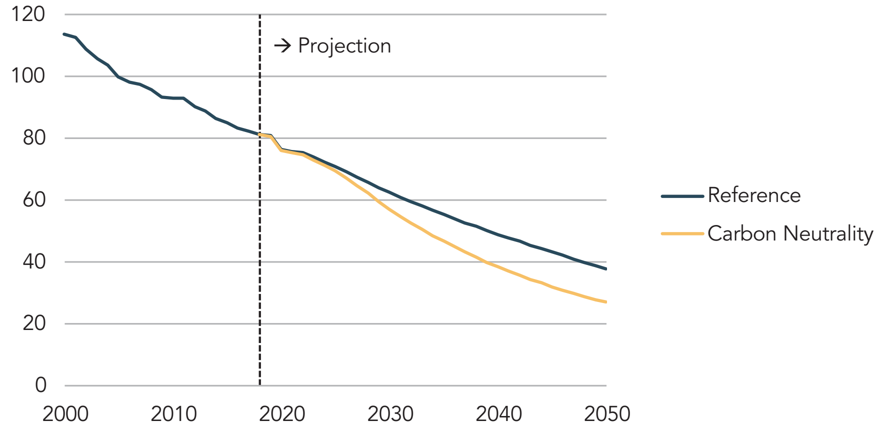


Sources: EGEDA, APERC analysis.

- Total consumption of solid and liquid renewables is slightly lower in CN. Biomass consumption by the power sector similarly falls close to zero. There is also a large decline in buildings sector consumption, which falls by 60%.
- Unlike in REF, biomass consumption in the industry sector declines by a small amount out to 2050. This is due to the increased role for electricity and hydrogen in CN that out-compete many of the applications for biomass.
- The big change in consumption patterns in this scenario is from the rise of biojet and biogasoline fuels used by the aviation sector. Consumption of these fuels increases from zero in the mid-2020s to almost 40 PJ in 2050. By 2050, the transport sector accounts for a quarter of the total consumption.
- To complement the rise in domestic aviation demand for biofuels, over 55 PJ of biojet fuel is consumed by international aviation demand, as captured by bunkers.
- Imports meet the entirety of demand for these aviation biofuels given that the two remaining Australian refineries do not have capacity to produce these fuels.

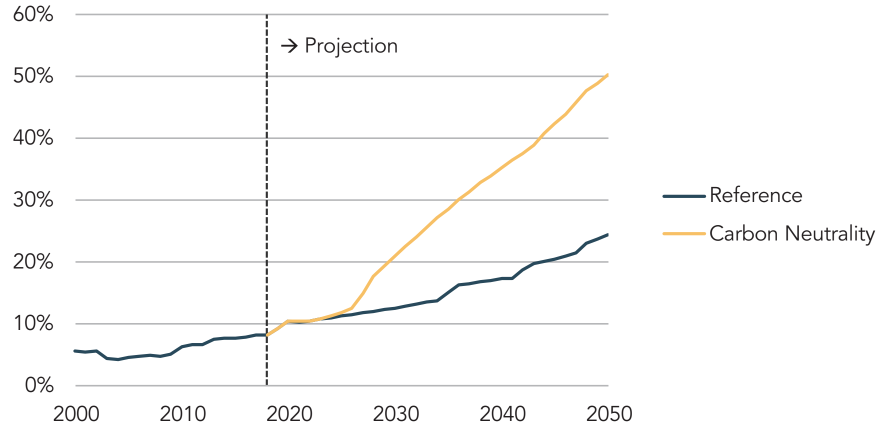
Energy intensity and modern renewables share

Figure 1-49. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 1-50. Modern renewables share in REF and CN, 2000-2050



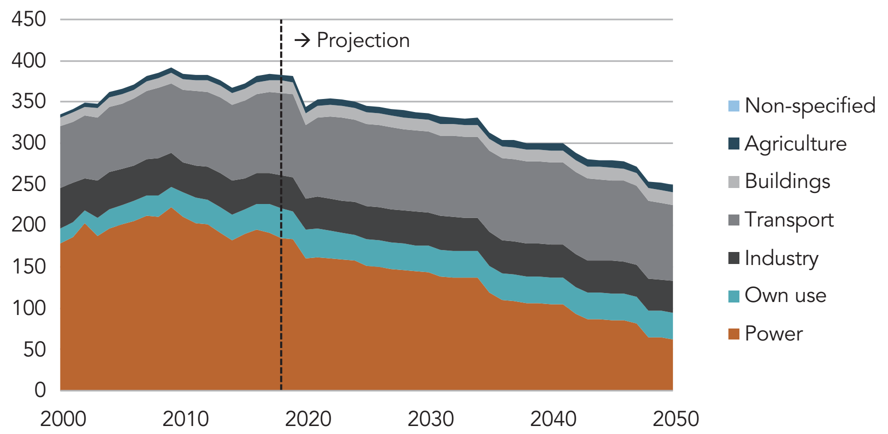
Sources: EGEDA, APERC analysis. Note: Modern renewables includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- Australia's final energy intensity has improved by 30% over the previous two decades, supported by strong GDP growth, a continued move to a more service-intensive economy, and improvement in physical energy efficiency in all sectors.
- Final energy intensity is expected to improve by over 60% for the period of 2005 to 2050 in REF, and by over 70% in CN.
- Australia's share of modern renewables in its energy mix has recently increased to more than 10% following a rapid rise in household rooftop solar, and increasing utility scale renewable generation, over the last decade.
- Modern renewables growth is expected to continue recent historical trends and reach almost a quarter of Australia's energy mix by 2050 in REF. This growth is supported by the continued build-out of wind and solar capacity, which is rapidly displacing fossil fuel generation.
- In CN, modern renewables trace a meteoric rise, accounting for over 50% of Australia's energy mix in 2050. This rapid rise is mostly facilitated by rapid electrification of the transport sector, with electrification in all other sectors playing a role as well.
- To emphasise the importance of electrification, renewable generation accounts for two-thirds of all generation in REF, and over 80% of the generation in CN.
- The rise of liquid biofuels and hydrogen also play a role in displacing fossil fuels in multiple sectors, which improves the share of modern renewables in the energy mix.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

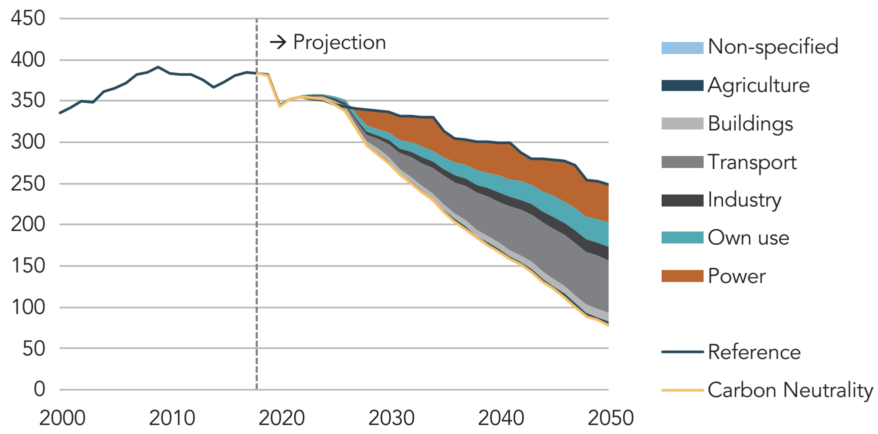
Gross CO_2 emissions

Figure 1-51. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 1-52. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

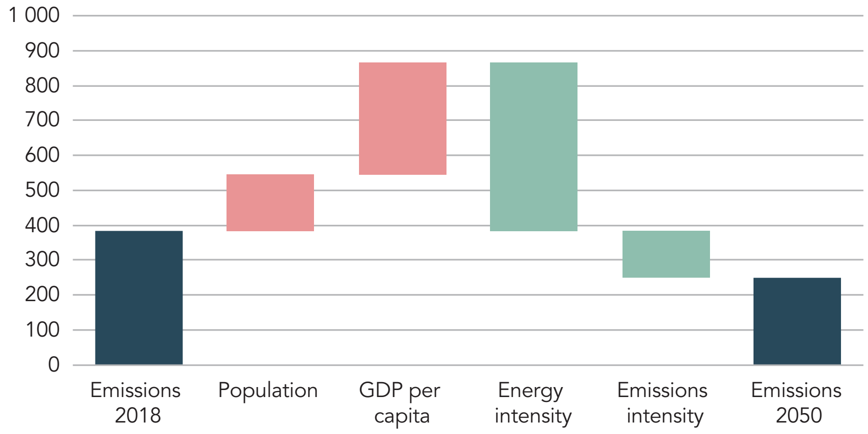


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Australia's CO_2 emissions have maintained a high plateau for most of the last decade. A slight decline in the mid-2010s coincided with a price on carbon from 2012 to 2014.
- Australia's power sector has been decarbonising over the most recent decade, with CO_2 emissions declining 13% in the face of 6% higher generation. All other sectors have posted an increase in CO_2 emissions of between 10% to 20% for the same decade.
- In REF, the continued phase-out of domestic coal-fired power plants and rise of renewable generation will see power sector CO_2 emissions decline by two-thirds. This large reduction in CO_2 emissions is eclipsed in CN, with a decline of over 90%.
- Transport sector CO_2 emissions decline by just under 10% in REF and by almost three quarters in CN, due to wide-scale electrification, greater fuel efficiency, behavioural change (less transport activity), and the rise of biofuels and hydrogen.
- There is a significant amount of own use CO_2 emissions attached to LNG. This is projected to decline by over 90% in CN due to CCS, efficiency improvements, and lower levels of liquefaction. The buildings sector is projected to see emissions reductions of almost two-thirds to 2050 due to electrification and energy efficiency. Industry sector CO_2 emissions decline by almost half, assisted by material and energy efficiency, CCS, and electrification.
- Australia's current NDC is to reduce greenhouse gas emissions by 26% to 28% from the 2005 level by 2030 and to achieve carbon neutrality by 2050. CO_2 emissions decline by 25% between 2005 and 2030 in CN. While these reductions are close to Australia's 2030 target, the two emissions frameworks are not directly comparable.
- Australia's recently released whole-of-economy plan to achieve net-zero emissions relies on negative emissions from non-energy sectors. This is consistent with the CN, which shows energy sector CO_2 emissions in 2050 of almost 80 million tonnes. Other sectors are assumed to deliver negative emissions to balance out this remainder.

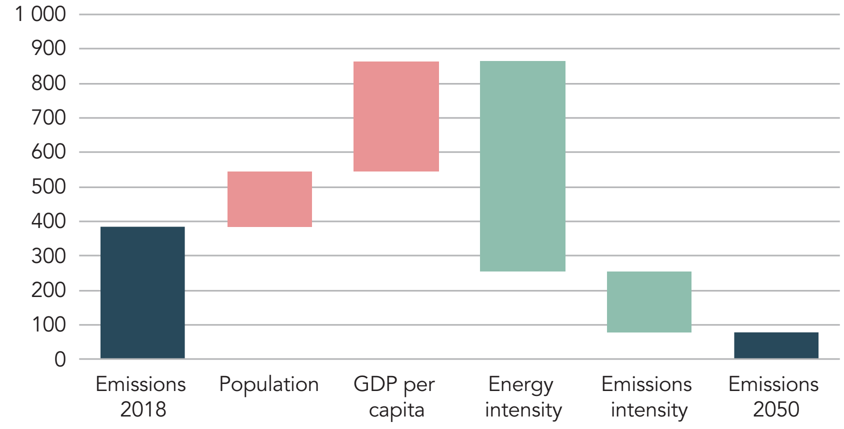
Components of CO_2 emissions

Figure 1-53. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 1-54. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Australia emitted 383 million tonnes of CO_2 in 2018, which amounted to less than 2% of total APEC emissions. While these CO_2 emissions were relatively small, Australia has high emissions per capita, placing at number three out of the 21 APEC economies.
- Given the assumptions about Australia's population and GDP growth, emissions would more than double to over 850 million tonnes of CO_2 in 2050, holding all else equal.
- In REF, all else does not remain equal, and improvements in energy intensity and emissions intensity instead reduce projected emissions to 250 million tonnes of CO_2 in 2050. Energy intensity accounts for 78% of this reduction while CO_2 emissions intensity accounts for the remaining 22%.
- In CN, energy intensity emissions reductions are 26% greater than in REF and emissions intensity reductions in CN are 33% greater. These additional improvements mean that 2050 energy sector CO_2 emissions are only one-fifth of what they were in 2018.
- Positive energy sector CO_2 emissions in CN will need to be countered by negative emissions in other sectors for Australia to achieve net-zero ambitions. The challenge will be even greater when including process emissions and all other greenhouse gases in the calculation. However, these challenges are not insurmountable. The CN is only one of many plausible paths for Australia to prosper while also meeting the goal of reducing emissions in line with its international commitments.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2 \text{ emissions}}{\text{Energy supply}}$.

Additional information

Australian Bureau of Statistics. https://www.abs.gov.au/

Australian Competition and Consumer Commission. https://www.accc.gov.au/

Australian Energy Market Commission. https://www.aemc.gov.au/

Australian Energy Market Operator. https://aemo.com.au/

Australian Energy Regulator. https://www.aer.gov.au/

Australia's National Energy Analytics Research Program. https://near.csiro.au/

Australia's Nationally Determined Contribution. https://www.industry.gov.au/news/affirming-australias-net-zero-emissions-by-2050-target

Australian Renewable Energy Agency. https://arena.gov.au/

Commonwealth Scientific and Industrial Research Organisation. https://www.csiro.au/

Clean Energy Finance Corporation. https://www.cefc.com.au/

Clean Energy Regulator. http://www.cleanenergyregulator.gov.au/

Department of Industry, Science, Energy and Resources. https://www.industry.gov.au/

Energy.gov.au. https://www.energy.gov.au/

OSeMOSYS. http://www.osemosys.org/

ReserveCable. Bank of Australia. https://www.rba.gov.au/

Sun. https://suncable.sg/

The Treasury. https://treasury.gov.au/

2. Brunei Darussalam

Highlights

Demand

- Natural gas is set to account for the largest share of energy demand in the Reference (REF) and Carbon Neutrality (CN) scenarios (2018-2050). Growth in gas demand is largely driven by the non-energy sector, where significant volume of gas is used as a feedstock for domestic production of methanol in Brunei Methanol Company (BMC) and of fertilisers in Brunei Fertilizer Industries (BFI).
- Electricity demand in the industry sector is expected to be dominant in both scenarios, driven by developments in the chemicals subsector, particularly Hengyi Industries and BFI. In CN, fuel switching within the sector leads to a small amount of hydrogen consumption.
- Electric vehicles are expected to penetrate the domestic market in both scenarios in Brunei's transport sector. REF sees a contribution of 11% of the total demand share in the transport sector in 2050, while CN sees a significant 41% share of EVs in 2050. A small number of fuel-cell vehicles (FCVs) is expected to be on the market as well in REF and CN.

Supply

- Oil and gas continue to fuel Brunei's energy supply in both REF and CN.
- The production target of 350 000 BOE per day of oil and gas by 2025 is achievable. However, production and trade trends decline due to maturing fields and regional decline in demand for oil and gas in both REF and CN.
- Coal is a part of Brunei's energy supply mix in both scenarios through imports, providing electricity for the operation of the Hengyi Industries refinery and petrochemical complexes (first phase and second phase). The substantial refining capacity of these complexes requires imports of crude oil as feedstock in addition to local crude sources.

Power

- Solar PV is set to eclipse gas-fired power plants by 2050 in both scenarios, accounting for over 50% of the total share of installed capacity.
- However, natural gas continues to be integral in providing baseload on-grid electricity generation.
- Coal is expected to be utilised to provide off-grid electricity for Hengyi Industries.

CO_2 emissions

- CO_2 emissions increase 50% in REF (2018-2050).
- Gas remains the largest source of CO_2 emissions but declines from 74% to 51% (2018-2050) in REF.
- The introduction of coal increases the overall carbon content in Brunei's energy supply in 2050 above 2018 levels, thus increasing the emissions intensity in REF.
- Coal becomes the second largest share of CO_2 emissions in 2050 (31%) in REF.
- In CN, CO_2 emissions peak by 2030. By 2050, CO_2 emissions are 37% lower than 2018.
- The CO_2 emissions reduction between CN and REF (54%) is largely due to the gradual phase-out of coal.
- In the transport sector, electrification of vehicles and infrastructure reforms contribute to emissions reductions in both scenarios.
- Carbon capture and storage (CCS) technology in CN plays a notable role in reducing CO_2 emissions from the power sector.

Energy security

- Brunei maintains its energy self-sufficiency status, given its abundance of oil and gas. However, possessing limited resources, the government is diversifying away from over-reliance on oil and gas through the expansion of renewable energy deployment.

About Brunei Darussalam

- Situated on the northwest coast of the third largest island in the world, Borneo Island, Brunei Darussalam (Brunei) is a tiny economy that spans 5 765 km^2. The Malaysian state of Sarawak surrounds Brunei on three sides. The remaining border has a coastline with a length of about 168 km along the South China Sea, and that the coastal areas are generally low-lying of up to 12 meters below sea level. The elevation progressively increases towards the south, reaching a peak height of 300 meters. Climate-wise, Brunei is blessed with constant tropical weather the whole year round, with daily temperatures ranging between 23°C and 32°C. Humidity has been consistently on the high side throughout the year, averaging above 85%.
- With a capital city of Bandar Seri Begawan, or fondly known as 'Bandar' by the local people, Brunei comprises four districts: Belait, Tutong, Brunei-Muara, and Temburong. Despite being the smallest district, Brunei-Muara houses the capital, effectively making the district the most densely populated.
- Based on EGEDA, the population in 2018 was 0.43 million people, an increase of about 4 479 people from 2017. According to the Department of Economic Planning and Statistics, Ministry of Finance and Economy, Malays comprise about 66% of the total population, followed by Ethnic Chinese and other groups at 11% and 25%, respectively.

Table 2-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	0.4	0.01%	21
GDP	26.5	0.04%	21
TPES	191.4	0.1%	21
Production	692.2	0.2%	15
Imports	15	0.01%	21
Exports	506.9	0.5%	14
Electricity generation	4.3	0.03%	21
Heat production	–	–	9
CO_2 emissions	7.6	0.04%	20

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 2-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	NA	NA	NA	NA
Natural gas	8 003	18	0.1%	10
Oil	6 730	27	0.1%	10
Uranium	NA	NA	NA	NA

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- The oil and gas sector has been the backbone of Brunei's economy for over 85 years. The risk of fluctuations in global oil prices remains and has affected Brunei's economy in recent years. Large fiscal deficits were recorded between 2015 and 2017 due to 2014-2016 global oil price crash, and Brunei moved towards fiscal austerity measures.
- In January 2021, the Ministry of Finance and Economy (MOFE) released its Economic Blueprint for Brunei, in which the goal is to achieve economic diversification. Five key areas are being targeted, namely downstream oil and gas, food, tourism, info-communications and technology (ICT).
- Significant investments have been made to further expand downstream activities. Apart from Brunei Methanol Company (BMC), Hengyi Industries Sdn Bhd (Hengyi), a joint venture between China's Zhejiang Hengyi Petrochemicals Co. Ltd and Damai Holdings Limited, a wholly-owned subsidiary under Brunei's Strategic Development Capital Fund, started operations in 2019. Under this, the refinery and integrated petrochemical complex with a total capacity of 175 000 barrels per day was successfully commissioned and started operations in November 2019. The second phase of the complex will see a capacity increase of 280 000 barrels per day.
- The Brunei Fertilizer Industries (BFI) is another major downstream project that started production in early 2022. The plant has a production capacity of 1 365 million tonnes of urea per year, making it one of the largest fertiliser plants in southeast Asia. The urea will be exported to markets such as Australia, India, Latin America, and the United States.
- Brunei has also completed a demonstration project on hydrogen supply, where a Japanese consortium consisting of the Chiyoda Corporation, Mitsui & Co Ltd, and Nippon Yusen Kabukishi Kaisha established the Advanced Hydrogen Energy Chain Association (AHEAD). Spearheading the world's first global hydrogen chain between Brunei and Japan, AHEAD built a demonstration hydrogenation plant in SPARK which is capable of transporting 210 tonnes (t) of hydrogen per year to Japan in the form of methyl-cyclohexane (MCH).
- Brunei has also launched its first Brunei Darussalam National Climate Change Policy (BNCCP) in July 2020, paving the way for a low-carbon and climate-resilient economy. This eventually resulted in the update of Brunei's Nationally Determined Contribution (NDC), which was submitted in December 2020, with the goal of achieving a 20% emissions reduction by 2030, relative to business-as-usual (BAU) levels. The economy has also recently pledged to move towards net-zero emissions by 2050, which was announced during the 26th United Nations Climate Change Conference of the Parties (COP26) in Glasgow, Scotland, United Kingdom in November 2021.
- In supporting the Ministry of Energy's vision for a sustainable energy future, as well as the BNCCP's fourth strategy in renewable energy transition, Brunei Shell Petroleum (BSP) inaugurated a 3.3 MW solar PV plant in April 2021, which will generate renewable electricity for the company's headquarter office. In addition, Berakas Power Company Sdn Bhd (BPC) has installed their first rooftop solar PV with a total capacity of 135 kW. A 100 kW solar PV system at the Temburong District Office was also installed recently. The Brunei LNG Sdn Bhd (BLNG) also recently announced in 2021 that it aims to shift 10% of its power generation source from gas to renewable energy by 2025.
- In terms of large-scale installations, the government's plan to develop a 30 MW solar PV plant in Belimbing Subok is also in the pipeline.
- On transportation, the two-year Electric Vehicle Pilot Project was launched in March 2021. The project aims at exposing various aspects of EVs, particularly on its usage, benefits, and charging equipment, apart from studying and identifying the public's perception and acceptance of EVs.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- **The Reference scenario (REF)** is built around Brunei's recent and updated policies and measures that have been established since the *Outlook 7th edition*. Alongside recent infrastructure developments, Brunei's trends differ from those presented in the *Outlook 7th edition*.
- **The Carbon Neutrality scenario (CN)** explores various ways that could assist Brunei in moving towards its carbon neutrality goal by 2050. Recently, the economy has announced its commitment to move towards net-zero emissions by 2050 at COP26 in Glasgow, Scotland, UK by pledging to phase out coal, as well as accelerate renewables utilisation and reforestation.
- On a macroeconomic level, both REF and CN use the same GDP and population trajectories through to 2050.
- On the supply side, the dominance of fossil fuels is expected to continue trending in both scenarios, although renewables are gradually on the rise following the government's diversification plans.
- For the transport sector, the historical trend is expected to continue. As the global automotive market focuses towards increasing efficiency as well as electrification, this is assumed to be included in Brunei's REF and CN trends, with the latter driven further by increased policy intervention.
- For the industry sector, both REF and CN consider the latest major industrial developments. Energy efficiency and fuel switching practices are expected to be more prominent in CN than in REF.
- The historical trend of the power sector is assumed to continue in REF, with gradual renewable power deployment. CN is expected to see significant decarbonisation in the power sector as well as the significant role of CCS.
- CN is intended as a guide to show the magnitude of CO_2 reductions possible in the context of the assumptions made about technology diffusion, costs, and global trends.
- CN can be used to quantify the magnitude of remaining CO_2 emissions that would require further action from policymakers, industry participants, and researchers.

Table 2-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Brunei Darussalam

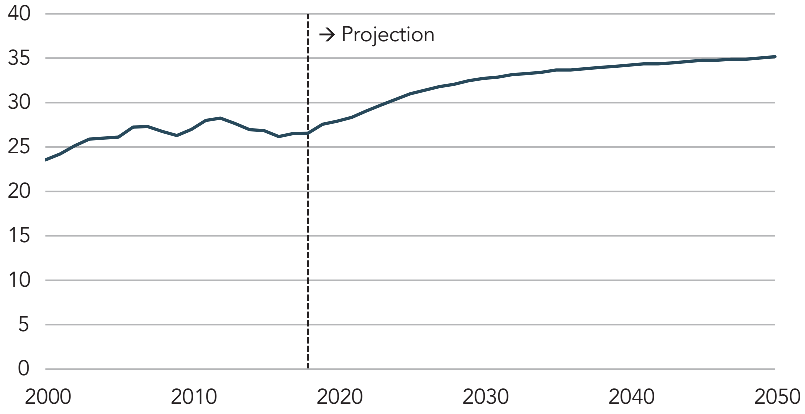
Table 2-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population growth is based on United Nations projection (medium-variant projection). • GDP is forecasted using APERC Solow-Swan model.	• Population growth is based on the United Nations projection (medium-variant projection). • GDP is forecasted using the APERC Solow-Swan model.
Buildings	• Appliances in households and commercial and public buildings are regulated under Standards and Labelling Order 2021.	• Appliances in households and commercial and public buildings are regulated under Standards and Labelling Order 2021. • Enhanced energy efficiency measures.
Industry	• Chemicals subsector to dominate electricity consumption.	• Hydrogen enters the mix beginning in 2025 in the chemicals subsector. • CCS adoption for chemicals subsector beginning in 2030.
Transport	• Electric vehicle fleet grows at a modest rate with policy intervention. • Fuel economy of conventional vehicle fleet improves in line with technological growth.	• Significant growth in electric vehicle fleet, following stronger policy interventions.
Power and heat	• Gas power plants to be maintained throughout. • Diesel power plant ceases its operation from 2023 onwards. • Coal power plant to enter the electricity generation mix beginning in 2020. • Cumulative renewable energy installed capacity reaches 1 100 MW (41% of the total installed capacity) in 2050.	• Existing gas power plants to be fitted with CCS units. • Diesel power plant ceases its operation from 2023 onwards. • Cumulative renewable energy installed capacity reaches 1 500 MW (59% of the total installed capacity) in 2050.
Supply	• Coal enters the energy supply mix via imports. • Oil and gas production reaches 350 kBOE per day in 2025; declines gradually after. • Oil and gas exports decline in response to declining external demands. • Significant crude oil imports from 2020 onwards to meet domestic refining requirements.	• Oil and gas production reaches 350 kBOE per day in 2025. • Rapid decline in production and exports in line with anticipated fall in external demand in a carbon-neutral world. • Crude oil imports decline substantially as domestic refining requirements decrease.
Climate	• A 20% reduction in total emissions by 2030 from its Business-as-Usual (BAU) levels.	• Move towards carbon neutral by 2050.

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

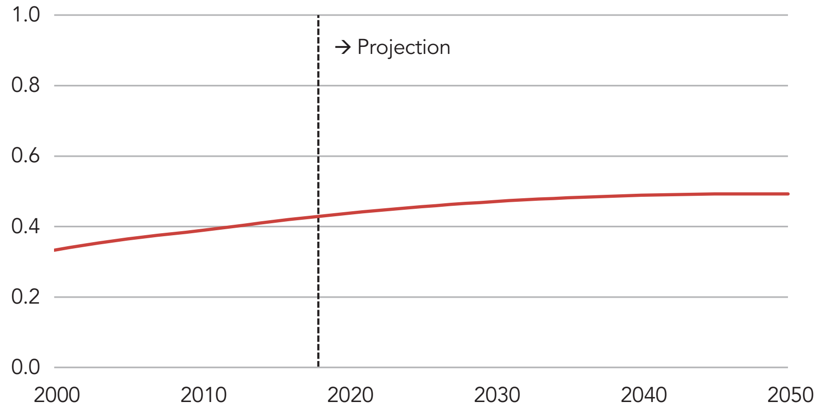
Macroeconomic backdrop

Figure 2-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 2-2. Population in millions, 2000-2050

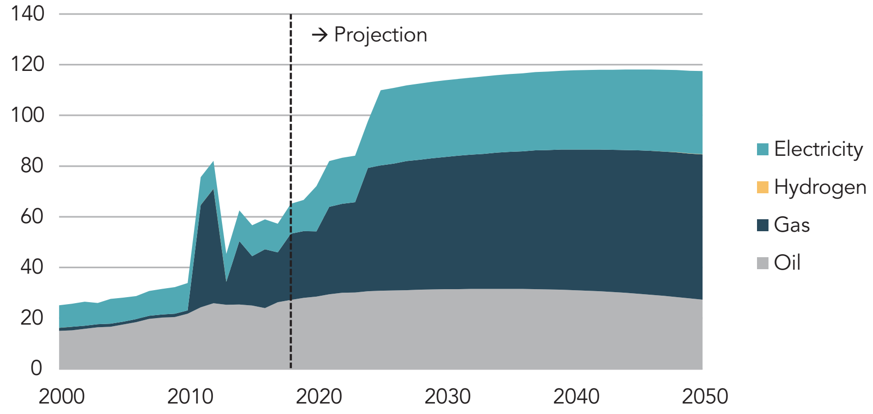


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- The economy of Brunei has been largely built around its industry, especially production of oil and gas since its series of commercial discoveries that led to its first crude oil export in 1932.
- In 2018, the oil and gas industry accounted for 57%, 91%, and 81% of Brunei's overall GDP, export, and revenues, respectively. Non-oil and gas sectors, such as services, agriculture, forestry, and fisheries sectors make up the remaining small shares.
- Following the outbreak of COVID-19 in Brunei in March 2020, the government introduced an economic stimulus package worth BND 0.45 billion (approximately USD 0.34 billion). The aim is to reduce the burden of targeted business sectors including micro, small and medium enterprises (MSMEs) and affected individuals.
- Such stimulus package has a little impact on Brunei's economy as the economy is expected to grow at a modest pace amidst the global COVID-19 pandemic beyond 2020. This is driven by outputs from downstream industries, particularly the first phase of Hengyi Industries' refinery and petrochemical complex. Further expansion of the complex, as well as the newly-established Brunei Fertilizer Industries (BFI) will continue to strengthen the economy in the long run.
- The population is expected to grow at a medium pace, in accordance with projections by the United Nations. It is forecasted to remain just below half a million people in 2050.

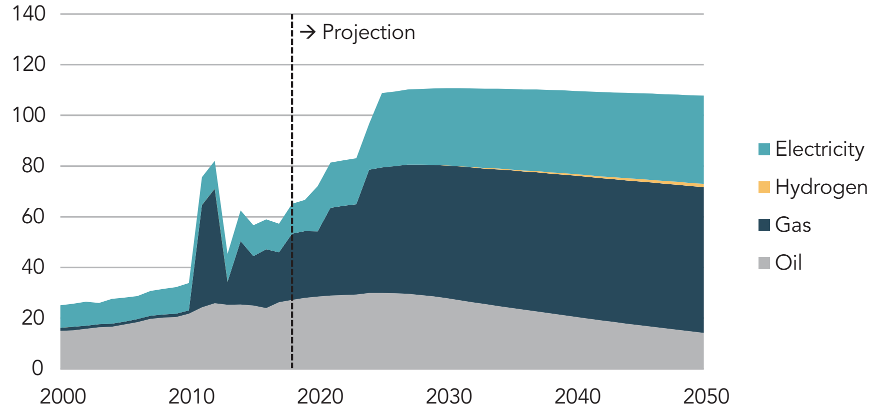
End-use energy demand

Figure 2-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 2-4. Energy demand in CN, 2000-2050 (PJ)

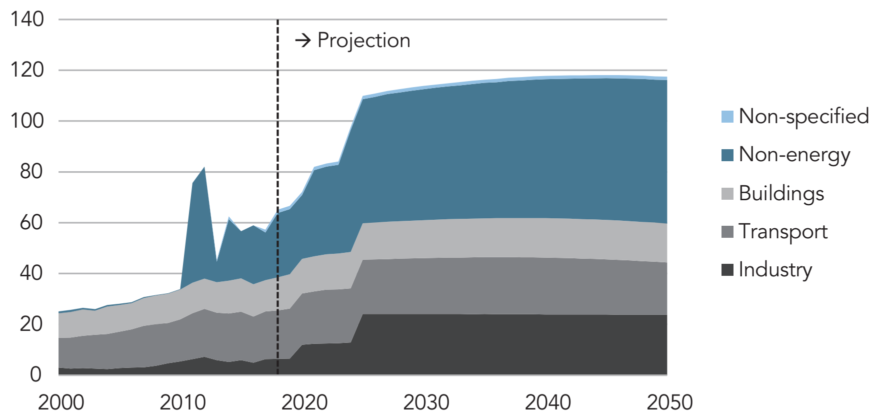


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Throughout the historical period, oil (refined products) especially gasoline and diesel, have been consistently dominant in Brunei, driven mainly by the growth in demand in its transport sector.
- The demand for gas remained marginal until about 2010, when Brunei Methanol Company (BMC) - a downstream facility that began operation - drove gas demand up by about 20 times on average (2018-2050).
- In REF, demand for oil (refined products) is expected to remain strong.
- Gas and electricity demand is projected to register the most significant growth in both scenarios.
- The surge in gas demand is expected as Brunei continues to expand downstream facilities within the industry sector, in which gas is crucial as feedstock. In addition, electricity usage continues to play an important role for proper and efficient functioning of the industry sector, particularly within the chemicals subsector.
- Oil (refined products) demand in CN is expected to decrease by 48% (2018-2050), given the changing landscape within the transport sector, particularly the electrification of vehicles.
- CN also sees small penetration of hydrogen in the mid-2020s to be used by the industry sector as well as by the transport sector.

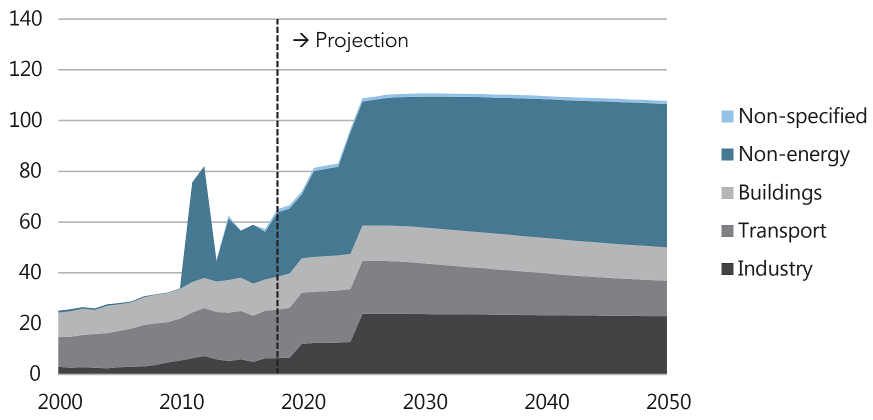
End-use energy demand by sector

Figure 2-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy. Agriculture is negligible and not shown.

Figure 2-6. Energy demand by sector in CN, 2000-2050 (PJ)

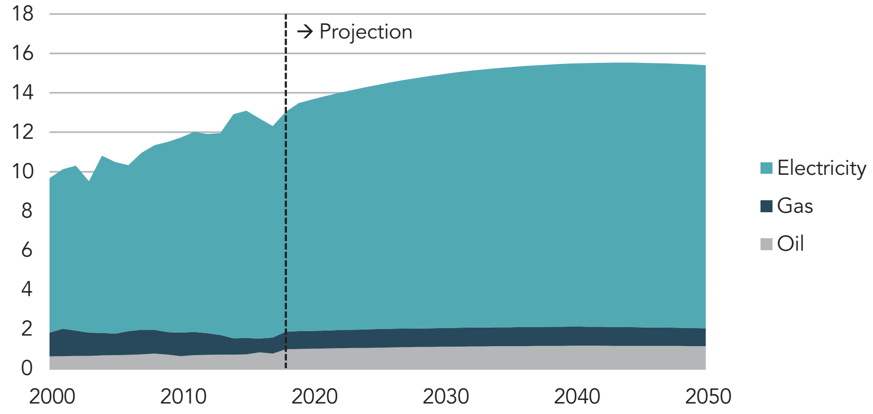


Sources: EGEDA, APERC analysis. Note: Includes non-energy. Agriculture is negligible and not shown.

- The commercial operation of BMC in 2010 until present signalled the initial step towards further downstream development in Brunei. The sectoral demand landscape has since changed, with a significant share of non-energy consumption as a result of a substantial volume of gas required as feedstock.
- In line with further downstream expansion, particularly the establishment of the new BFI, the non-energy sector is projected to account for more than half of the overall energy demand in REF and CN.
- Transport sector energy demand is expected to grow, and it remains the second largest slice in REF and CN, accounting for shares of 21% and 18%, respectively.
- The agriculture sector (not shown) is a small share of Brunei's GDP. Brunei imports most of its food requirements. This effectively makes it the least energy-consuming sector, and it is expected to continue.

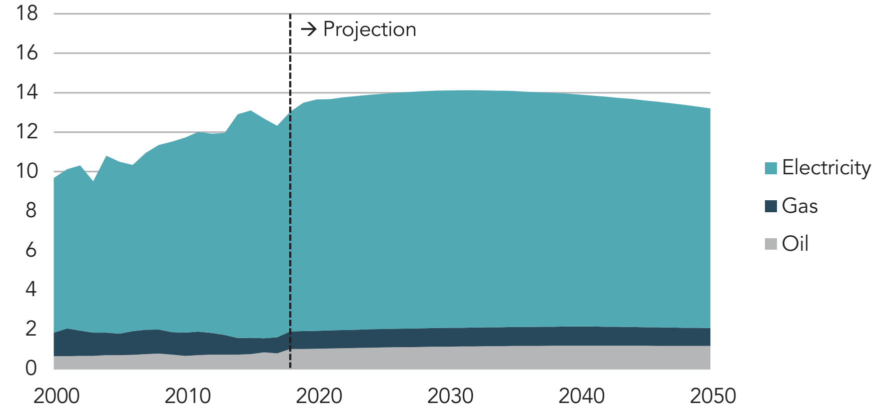
Buildings energy demand

Figure 2-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-8. Buildings energy demand in CN, 2000-2050 (PJ)

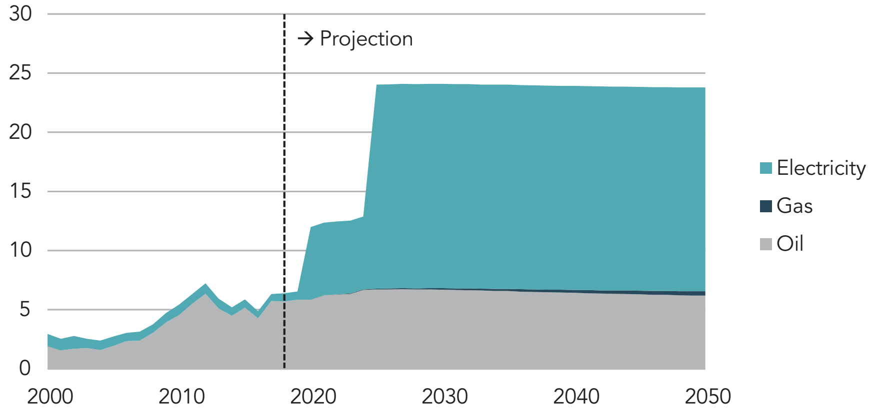


Sources: EGEDA, APERC analysis.

- The electrification rate in Brunei has been consistently high at 99% on average.
- Due to Brunei's tropical climate, space cooling accounts for about 60% of the overall electricity consumption in buildings, based on the recent energy consumption survey conducted across residential, government, and commercial buildings by a study group led by the Economic Research Institute for ASEAN and East Asia (ERIA).
- The prevalence in air conditioner usage in Brunei highlights the importance of energy-efficient air-conditioning appliances, as space cooling continues to be dominant. The government has recently announced new energy efficiency standards for air conditioners. Under the Energy Efficiency (Standards and Labelling) Order 2021, this regulation ensures that only air conditioners sold in the domestic market meet the minimum energy performance standards beginning June 2022.
- On the other hand, the shares of town gas and liquefied petroleum gas (LPG) are low, as they are mainly utilised for cooking. Between these two, LPG is dominant over the other, as town gas is only being supplied to a small number of households within the Belait district towns of Seria and Kuala Belait that have direct connection to gas pipelines.
- In REF, buildings energy demand increases by 16% in 2050 relative to 2018 levels. Demand from government and commercial buildings (services buildings) registers the largest increase of 21%, whereas residential energy demand only rises by 11%.
- In CN, the overall energy demand in 2050 is assumed to be 14% lower than REF's overall in the same year, with services buildings demand registering the highest reduction. Such reduction is driven by the assumption that government and commercial buildings are obliged to achieve energy efficiency savings in appliances at a more significant level, following enforcement of the Standards and Labelling Order 2021.
- In both scenarios, town gas supply to residents is expected to decline over the projection period as new residential houses are moving towards LPG cylinders for cooking purposes.

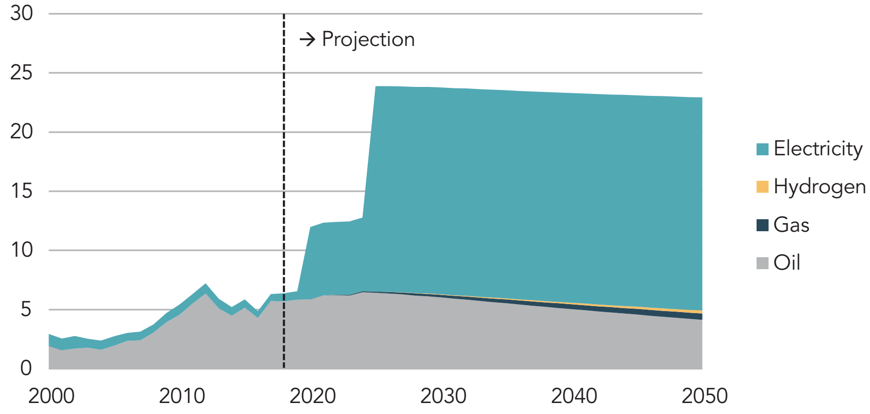
Industry energy demand

Figure 2-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 2-10. Industry energy demand in CN, 2000-2050 (PJ)

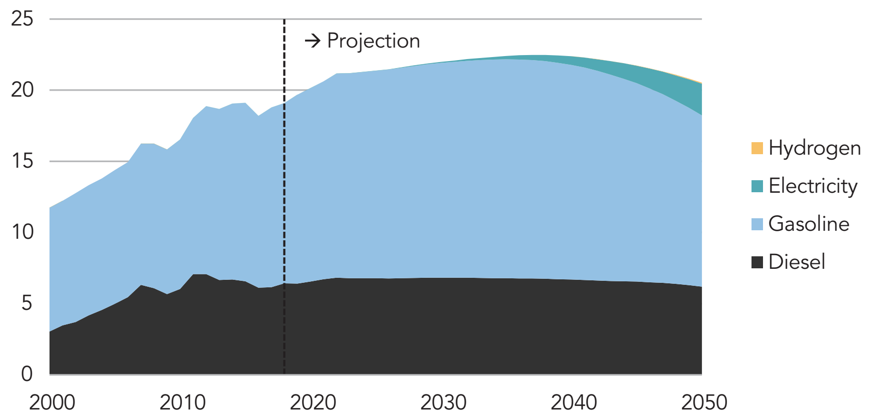


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- In REF, electricity demand increases by over 2 400% (2018-2050). This increase in electricity demand is attributed to developments in the chemicals subsector, particularly from Hengyi Industries' refinery and petrochemical complex (first and second phase) and BFI complex to which electricity is crucial in their operations.
- In CN, the share of electricity is expected to be slightly higher than in REF in 2050. Concurrently, the oil demand also decreases in 2050 which is a result of fuel switching.
- Hydrogen also enters the fuel mix in the beginning of 2025 in CN. This is prominent in the chemicals subsector.

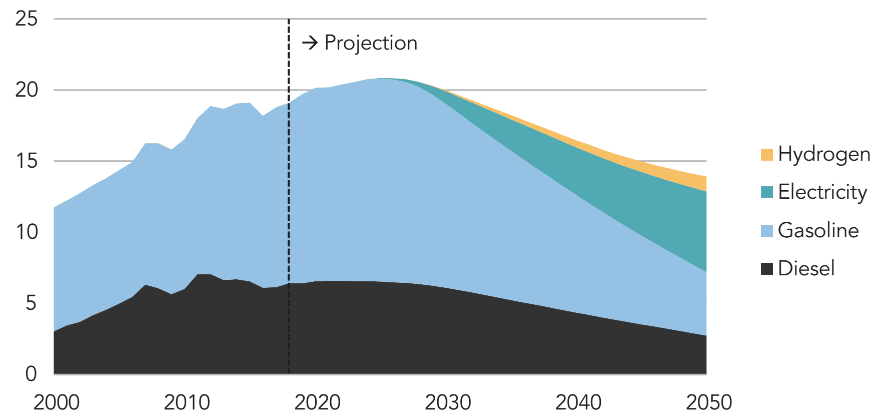
Transport energy demand

Figure 2-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 2-12. Transport energy demand in CN, 2000-2050 (PJ)

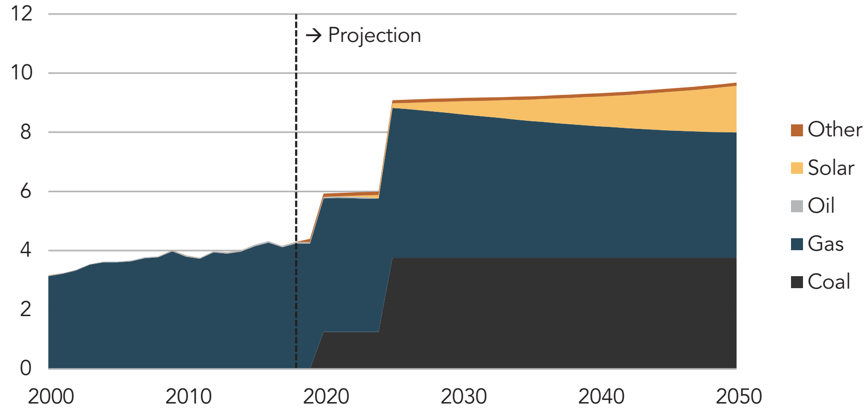


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Gasoline and diesel have accounted for most of the domestic transport energy demand, with gasoline constituting more than 50%.
- While these trends are set to continue beyond 2020, electricity and hydrogen are set to enter the demand mix in both scenarios.
- In REF, gasoline and diesel vehicles continue to be dominant in 2050, with EVs only contributing to 11% of the total demand share. Only a small number of fuel-cell vehicles (FCVs) enter the domestic market.
- In CN, electric vehicles overtake gasoline and diesel vehicles to reach a 41% share of the transport energy demand in 2050. As in REF, FCVs domestic market remains small, although its share improves significantly.
- These measures, coupled with improvements in vehicle fuel economy standards, yield 32% energy demand savings by 2050 in CN relative to REF.
- Road transport has been the sole domestic transport mode in the past, and this trend will continue to be.
- Unsurprisingly, the lack of public transportation, as well as low domestic fuel prices, led to Brunei having the highest private vehicles ownership in the APEC region.
- While REF expects an unchanged situation throughout, CN sees an increased adoption of public transportation. As a result, it is anticipated that significant improvements in public buses and taxis are required to achieve a projected 25% increase in the public transportation share.
- In addition to public transportation improvement, deployment of electric and fuel cell buses would contribute to 32% demand reduction in CN.

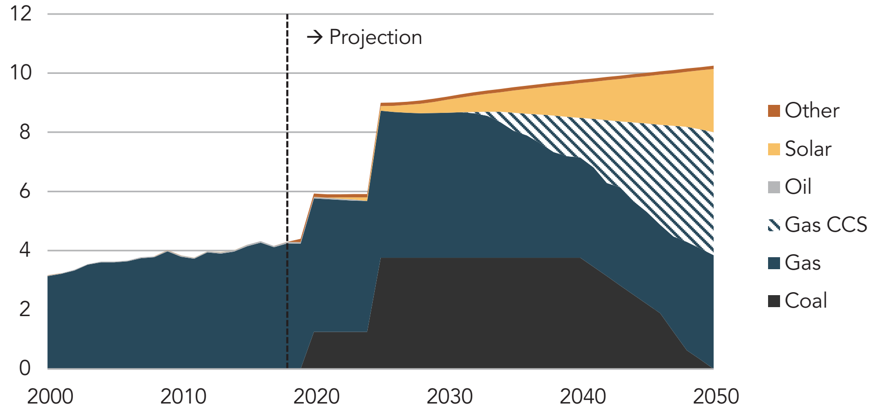
Electricity generation

Figure 2-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 2-14. Electricity generation in CN, 2000-2050 (TWh)

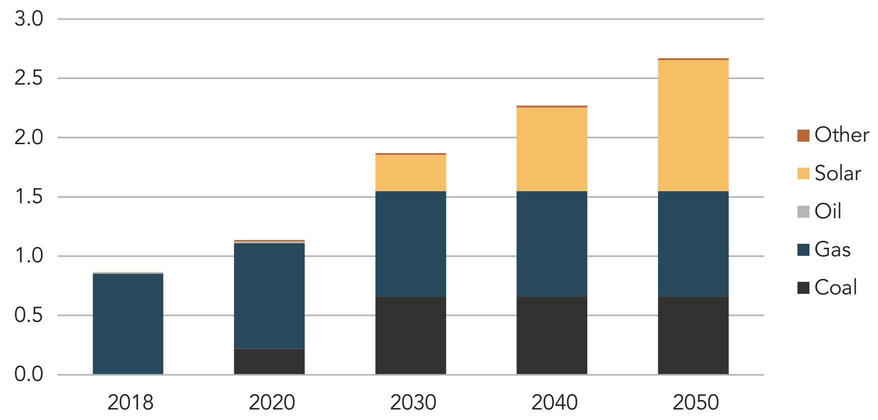


Sources: EGEDA, APERC analysis.

- Brunei has two major utilities providers: the Department of Electrical Services (DES), and Berakas Power Company (BPC). Four gas-fired power plants (Gadong 1A, Gadong 2, Bukit Panggal, and Lumut stations) are under the authority of DES, while BPC owns three plants (Berakas, Gadong 3, and Jerudong stations).
- Virtually all these plants burn natural gas and are expected to remain an important source of baseload electricity in both REF and CN. Particularly in CN, the utilisation of CCS units in existing gas-fired power plants is expected to be substantial in order to mitigate CO_2 emissions.
- Coal enters the generation mix from 2020 onwards in both scenarios. Initially, about 1.0 TWh of electricity is generated to cater for the first phase of Hengyi Industries' refinery and petrochemical complex. Once the second phase comes into operation from 2025 onwards, electricity from coal increases to almost 4.0 TWh.
- It is also important to note that electricity generated from coal is independent from the public grid.
- In CN, electricity from coal is gradually decreasing from 2040 onwards, eventually phased out in 2050.
- DES also currently has Tenaga Suria Brunei (TSB), which is a 1.2 MW solar PV plant which has been operational since 2011. The expansion of large-scale solar PV capacity is set to increase its electricity generation to 1.6 TWh by 2050 in REF. In CN, electricity from solar PV increases to 2.1 TWh by 2050.

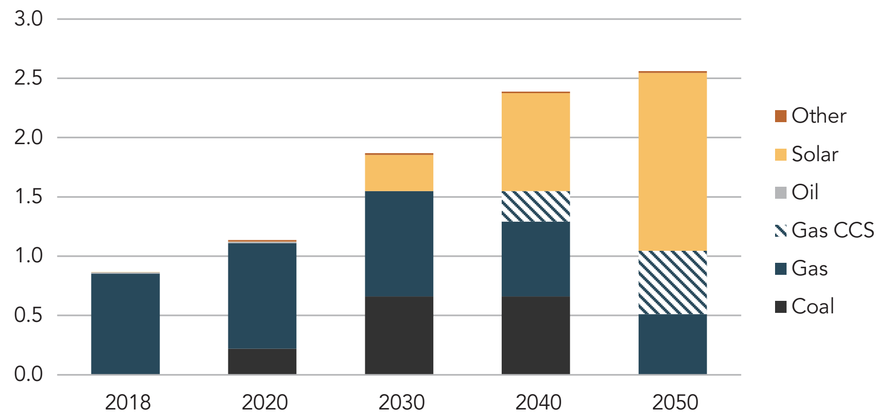
Generation capacity

Figure 2-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 2-16. Generation capacity in CN, 2018-2050 (GW)

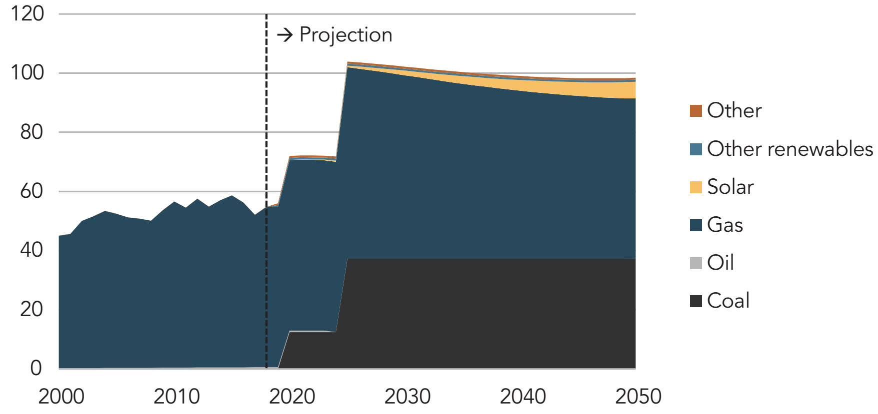


Sources: EGEDA, APERC analysis.

- Gas-fired power plants total installed capacity is assumed to be maintained in REF, as the government sets sights on renewables expansion.
- Similar capacity size is expected in both scenarios for gas-fired plants, but in CN, CCS units are to be installed and fitted alongside existing gas-fired plants to reduce CO_2 emissions.
- In addition to the existing TSB solar PV plant, the government plans to add a large-scale 30 MW plant on a 37.4-hectare remediated landfill site in Belimbing Subok. The cumulative capacity is expected to reach past 100 MW in 2025, assuming addition of other technologies such as floating solar panels. The intermittent electricity generation from solar PVs can still be covered by the existing baseload electricity from gas, hence the absence of energy storage capacity.
- Early feasibility studies by the government identified nine potential water bodies across the economy for floating solar panels deployment. Successful deployment of these projects are expected to help Brunei achieve about 300 MW of cumulative solar PV capacity in 2035 in REF, exceeding the 30% aspirational target. By 2050, about 1 100 MW of solar PV capacity is expected to be reached in REF, while a more rapid growth in deployment sees the capacity reaching 1 500 MW in 2050 in CN.
- Over 200 MW of coal-fired power capacity has been installed to supply electricity to the first phase of Hengyi Industries' refinery and petrochemical complex for its operation. Once the second phase of the complex comes in, altogether an estimated total capacity of about 700 MW of coal power station is expected to be in operation in REF. In CN, the gradual phase out of coal towards 2050 implies that the installation of CCS units alongside coal power stations are not considered.
- DES has also been owning and operating a small 15 MW Belingus diesel power plant, independent from the main grid, since 1966 in the Temburong exclave district. The development of a major bridge linking the Temburong district and the rest of mainland Brunei would allow grid interconnection which is expected to see the district receive reliable and sufficient electricity in the long run. In line with this, the Belingus plant is envisaged to decommission in 2023, therefore phasing out the use of diesel for power. This is also reflected in CN.

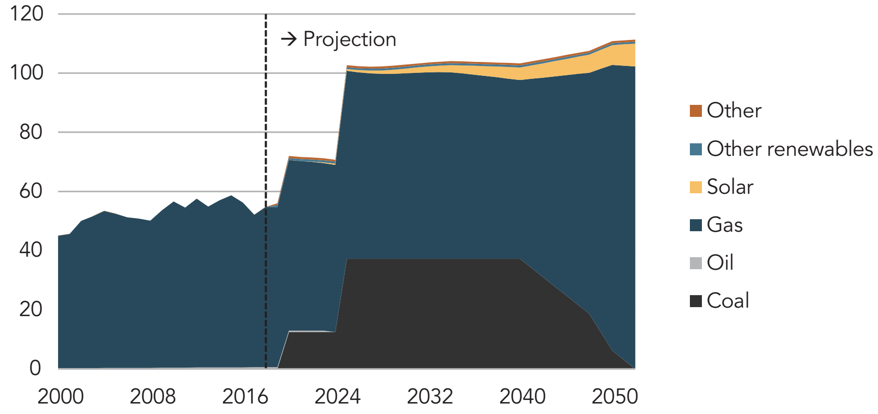
Fuel consumption by power sector

Figure 2-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 2-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

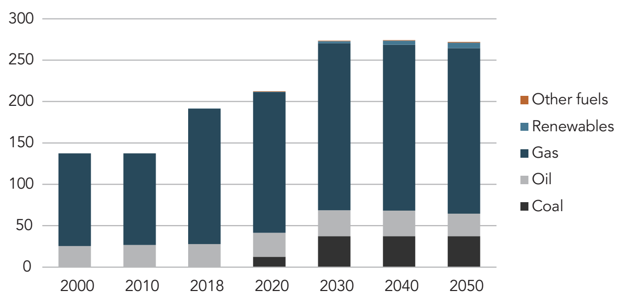


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- The majority of the gas-fired power plants owned by DES and BPC have single-cycle gas turbines, apart from Bukit Panggal station which utilises combined-cycle systems. The current average efficiency Brunei's utility system is, therefore, on the lower side which is assumed to be consistent throughout the projection.
- The increasing penetration of solar in the electricity generation mix in both REF and CN helps decrease the input of natural gas for its existing power plants, yielding gas savings.
- Coal consumption is expected as the Hengyi Industries complex (first and second phases) comes into operation. The second phase of the complex requires about three times the amount of coal in 2025 compared to that for the first phase, assuming a similar average efficiency of the coal-fired power plant.
- In CN, as coal is gradually phased out, the Hengyi Industries complex is expected to be supported by gas-fired power plants from 2050 onwards.

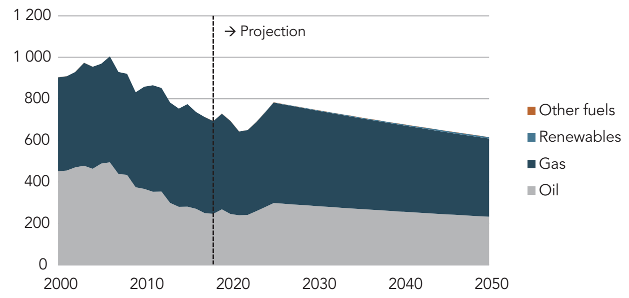
Energy supply in the Reference scenario

Figure 2-19. Total energy supply in REF, 2000-2050 (PJ)



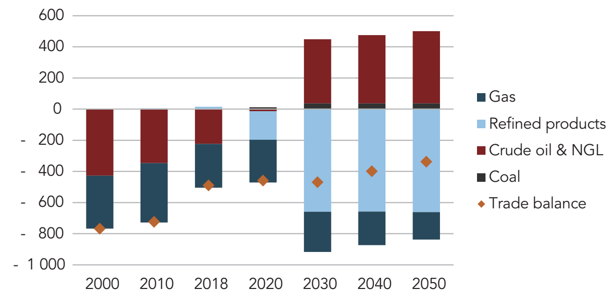
Sources: EGEDA, APERC analysis.

Figure 2-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-21. Net energy trade in REF, 2000-2050 (PJ)

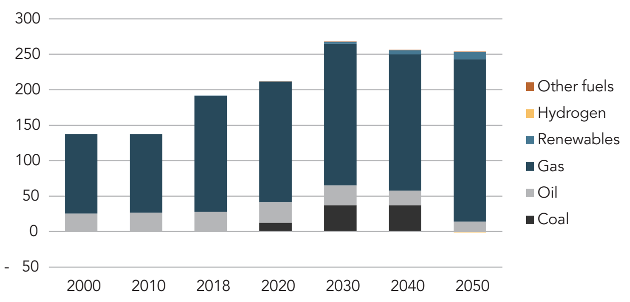


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Oil and gas remain dominant shares of Brunei's energy supply.
- The deployment of large-scale PV capacity is reflected by an expansion of renewables in the energy supply. While the growth rate is high, the absolute proportion of supply is small.
- The establishment of Hengyi Industries' refinery and petrochemical complex (first and second phase) is expected to alter Brunei's energy supply landscape.
- First, it leads to the presence of coal in the economy's energy supply mix for the first time. Second, the immensity of the complex leads to the complex requiring at least 15 times as much volume of crude oil input as the existing Brunei Shell Petroleum (BSP)'s refining complex does. Therefore, significant importation of crude oil is necessary to supplement the limited domestic supply of crude by BSP.
- Production decreased throughout between 2000-2018 due to maturing major oil and gas fields. In mitigating further decline in production, the government is committed to developing marginal fields and venturing into deepwater exploration. These are expected to help the government reach the target of 350 000 barrels of oil equivalent (BOE) per day in 2025. Between 2025-2050, production is expected to decline steadily in line with the decreasing lifespan of fields.
- Brunei remains a net energy exporter despite the net import status of crude oil. This is mainly driven by the offset of significant crude oil import by a much larger export volume of refined products by Hengyi Industries.

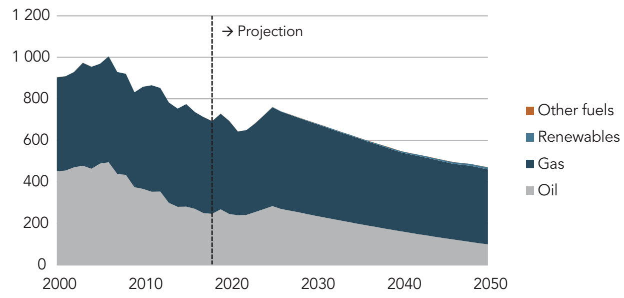
Energy supply in the Carbon Neutrality scenario

Figure 2-22. Total energy supply in CN, 2000-2050 (PJ)



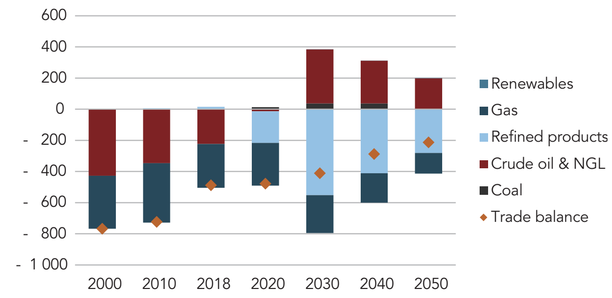
Sources: EGEDA, APERC analysis.

Figure 2-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-24. Net energy trade in CN, 2000-2050 (PJ)

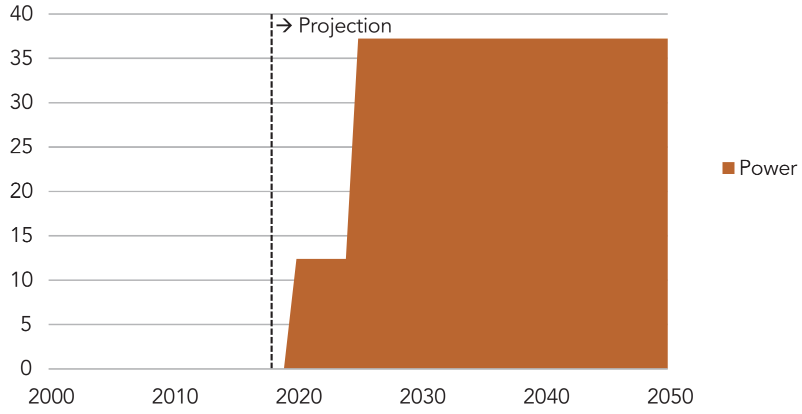


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- The domestic supply of both oil and gas in CN is generally comparable with that in REF, apart from coal and renewables which have significant changes.
- CN sees a gradual declining of coal supply from 2040 onwards until it is completely phased out in 2050. This implies that Hengyi Industries will undergo fuel switching from coal and gas.
- The increase of renewables is 50% higher in CN than REF, driven significantly by acceleration in solar power deployment. However, the absolute proportion of renewables in energy supply is still small.
- A more rapid pace of decline in oil and gas production is noticed beyond 2025 during which the target of 350 kBOE per day is reached. This decline is expected in the carbon neutrality world where economies are expected to transition away from fossil fuels towards renewables.
- Although Hengyi Industries' refinery and petrochemical complex remains operational in CN, its activities are expected to decline towards 2050 due to declining domestic demand for refined products. This is also driven by decreasing demand for such products from importing economies, eventually leading to a decrease in exports. This, in turn, allows Hengyi to import less volume of crude oil in CN than it does in REF.

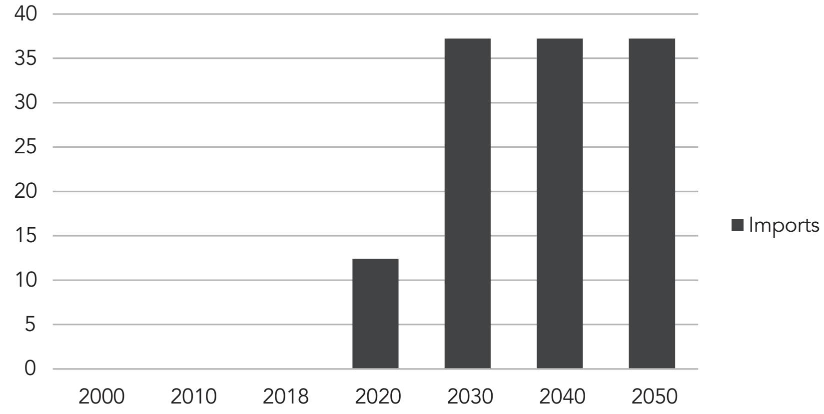
Coal in the Reference scenario

Figure 2-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

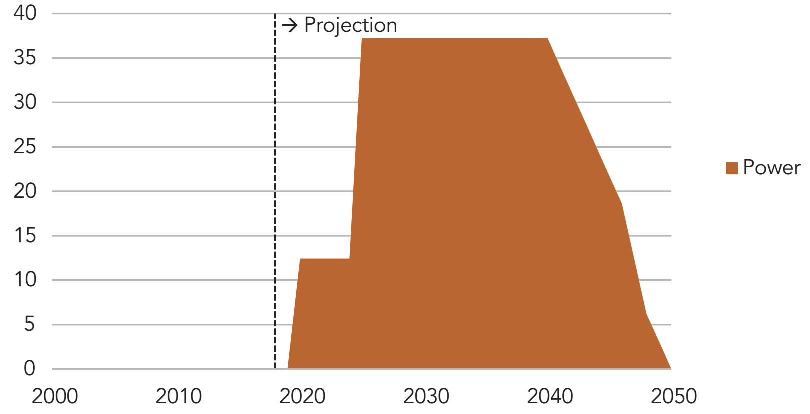


Sources: EGEDA, APERC analysis.

- Coal is expected to be utilised for power generation solely for Hengyi Industries' complex, and not connected to the public grid.
- The second phase of the complex requires about three times the amount of coal in 2025 compared to that for the first phase. In total, Brunei's coal consumption amounts to about 37 PJ (2025-2050).
- Brunei does not produce coal domestically. Therefore, all coal requirements are met through imports from neighbouring economies, particularly Indonesia.

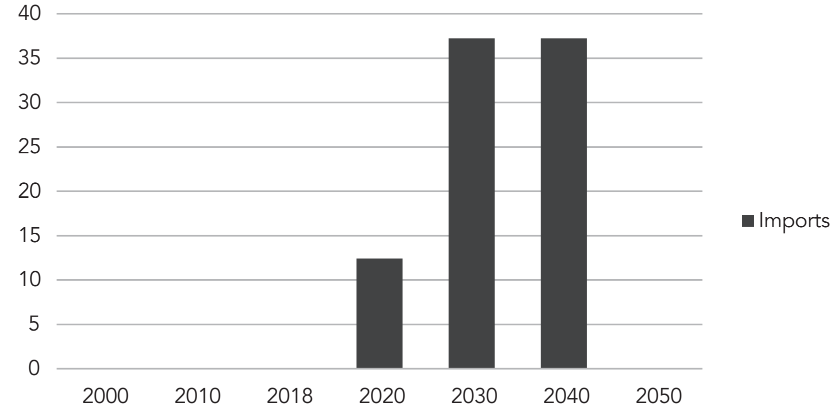
Coal in the Carbon Neutrality scenario

Figure 2-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

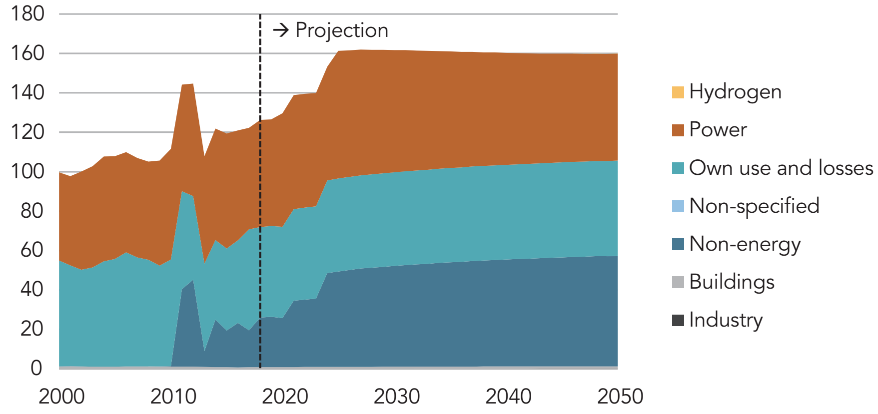


Sources: EGEDA, APERC analysis.

- Consumption of coal in CN within Hengyi Industries is the same as it is in REF until 2040. From 2040 onwards, coal consumption gradually decreases until it is phased out in 2050. This subsequently reduces the import activity of coal.
- The gradual phasing out of coal is driven by Brunei's recent commitments in transitioning from coal, pledged during the recent COP26 in Glasgow, Scotland, United Kingdom.

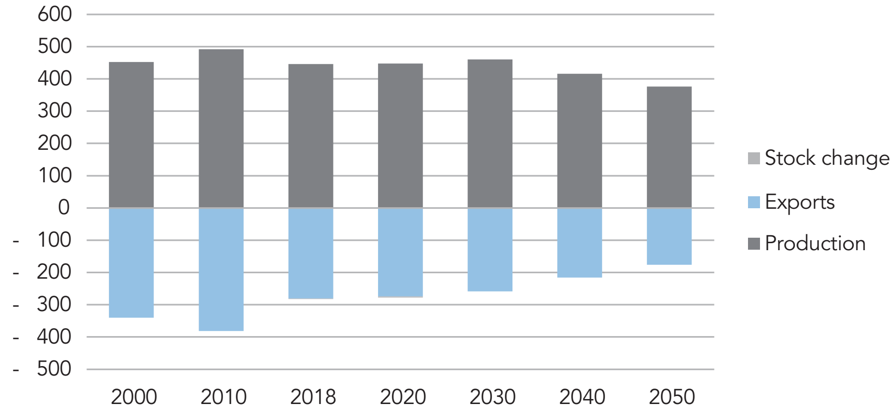
Natural gas in the Reference scenario

Figure 2-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

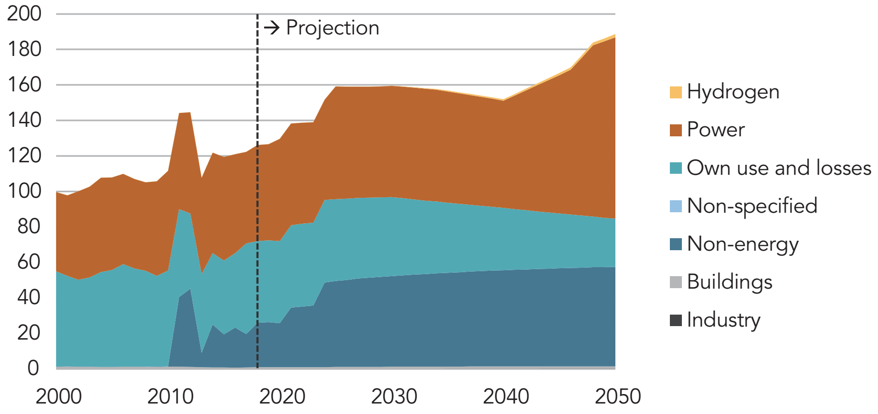


Sources: EGEDA, APERC analysis.

- Natural gas has been dominant in Brunei's power sector. Between 2000 and 2018, on average, 88% of the sector's gas consumption was for public electricity generation. The remaining 12% was utilised within major industries such as Brunei Shell Petroleum (BSP) and BLNG to provide electricity in supporting their operations.
- Some natural gas is also being used during the natural gas liquefaction process at BLNG as well as during the production of oil and gas at BSP (own use).
- Since 2010, natural gas has been utilised as non-energy feedstock for producing methanol at BMC, which has an annual production capacity of 850 kt per year. The product has been exported to various markets in northeast Asia, southeast Asia, India, and the United States.
- The operation of BFI is expected to increase the share of natural gas consumption within the non-energy sector portfolio by more than two-fold in REF (2018-2050).
- A significant volume of gas is required to annually produce 1 365 Mt of fertilisers per year. On the other hand, demand from power and own use are expected to remain uniform throughout.
- As a result, non-energy surpasses power as the most dominant sector in terms of natural gas consumption at a 35% share in 2050. This is followed by power and own use at 34% and 30% shares, respectively.
- Despite the net increase of gas demand in 2050 from 2018 levels, domestic production is expected to decrease by 16% due to a natural decline of fields. Export volume decreases by 37% in line with anticipated fall in demand from importing economies.

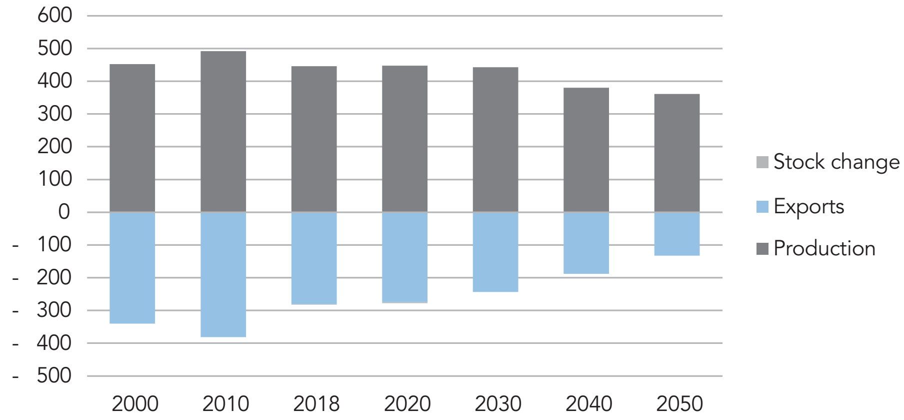
Natural gas in the Carbon Neutrality scenario

Figure 2-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

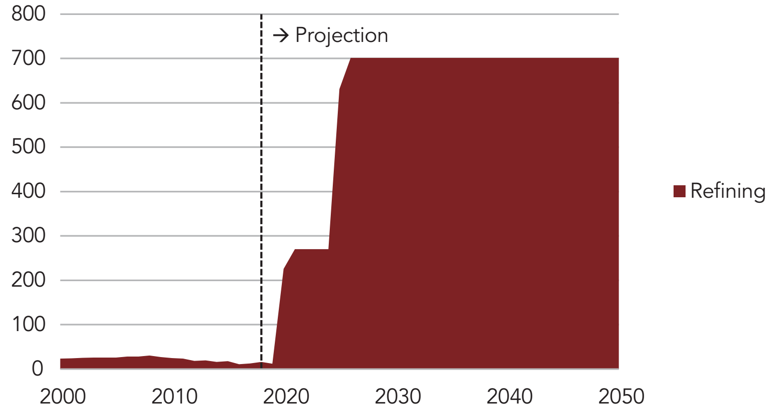


Sources: EGEDA, APERC analysis.

- It is assumed that the operation of BFI is not affected in CN, and that its output volume remains the same as in REF. Therefore, the growth of natural gas demand for non-energy is similar through 2050.
- Own use consumption of natural gas during the liquefaction process and extraction of oil and gas is expected to decrease by 41%, in line with the decline in oil and gas production and LNG production.
- As Hengyi Industries transitions gradually towards gas-fired power generation technologies from coal, gas consumption in the power sector increases 89%.
- Production of natural gas decreases by 19% (2018-2050). Due to this, LNG production is expected to decline and, therefore, a 53% reduction in its exports is envisaged in 2050 from 2018 levels.
- In line with a significant fall in global demand for natural gas, CN highlights the potential impact of Brunei as a net exporter of fossil fuels, given that they may no longer be options for the economy's current importers.

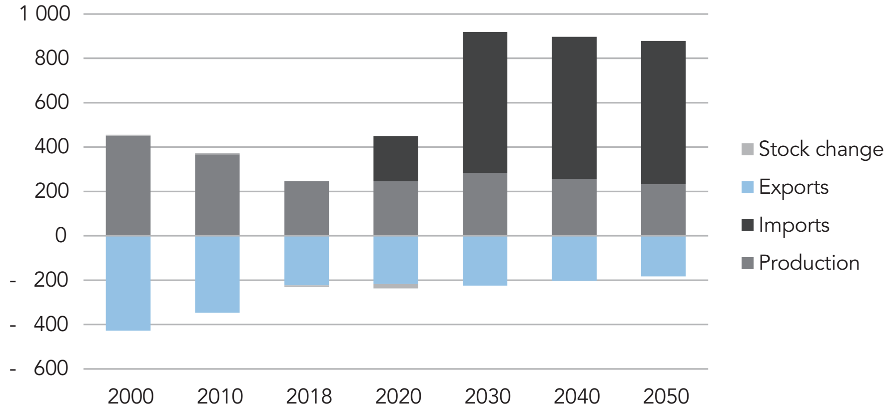
Crude oil and NGLs in the Reference scenario

Figure 2-33. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-34. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)



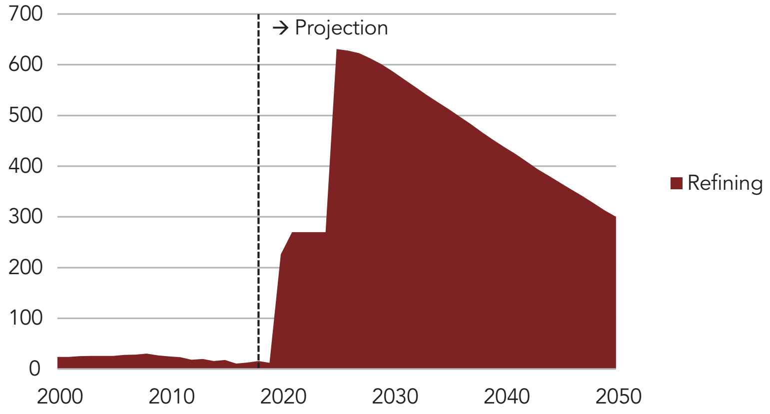
Sources: EGEDA, APERC analysis.

- Between 2000 and 2018, crude oil refining activities have revolved around the small 12 000 bbl per day BSP refinery complex. This has been integral in providing the domestic population with essential fuels for end-use sectors.
- After operating for more than 30 years, the ageing refinery ceased operations in 2020. This makes way for the development of larger Hengyi Industries' petrochemical and refinery complex, which has become a main supplier of refined products domestically from 2020 onwards.
- The first phase of the complex that runs from 2020 to 2024 requires about 15 times as large crude oil volume as BSP did throughout the historical period. The second phase requires an additional three times as much crude oil volume as does the first phase by 2025.
- The superiority in the size of the Hengyi Industries' complex necessitates the importing of crude oil to supplement the domestic supply of crude by BSP from 2020 onwards. The first and second phase of Hengyi Industries' complex is expected to run with a mixed blend of import and domestic crude oil (average ratio of 70:30).
- Projected production and export trends are expected to generally decrease towards 2050, driven by a natural decline of oil and gas fields. Maximising the yield from these fields is, therefore, subject to further economic and technological assessment and evaluation.

Notes: Most of the imported crude is expected to be sourced from the Middle East and Africa, based on the information from Argus Media.

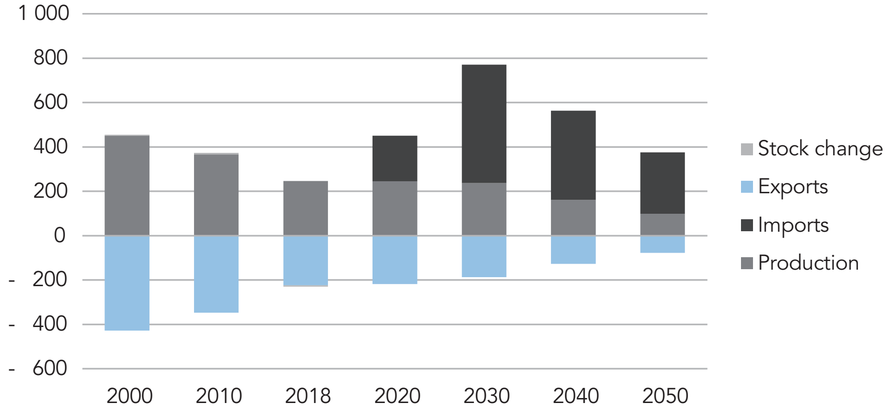
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 2-35. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-36. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

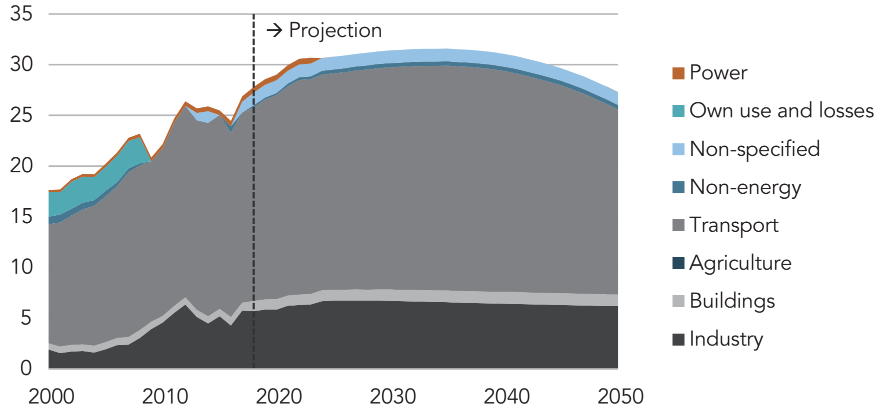


Sources: EGEDA, APERC analysis.

- From 2025 onwards, there is a steep decline of 2.9% per annum in the crude oil requirement by Hengyi Industries. The level of the crude oil requirement is expected to almost reach the first phase's crude oil requirement by 2050, therefore, significantly reducing the operation of Hengyi Industries' second phase complex.
- The decline in the crude oil requirement follows the dwindling of imported crude from the Middle East and Africa, and domestic production by 60% in 2050. This is driven by a declining demand for refined products that is expected in the carbon neutral world.
- The declining operation of Hengyi Industries' refinery yields a positive step towards reducing Brunei's environmental impact. However, the low utilisation rate may necessitate further economic assessment and evaluation on maintaining the operation of the second phase complex.

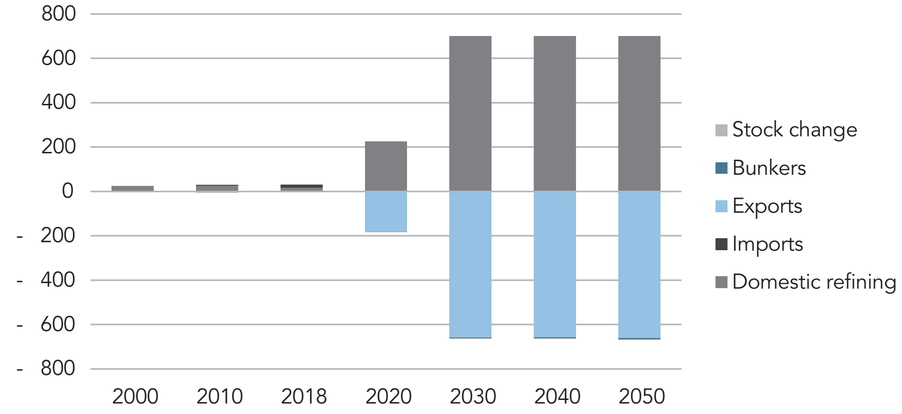
Refined products in the Reference scenario

Figure 2-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

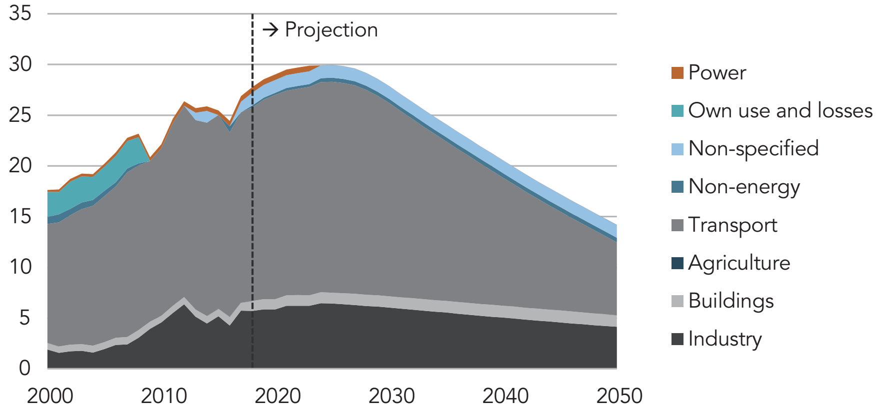


Sources: EGEDA, APERC analysis.

- The transport sector has been the major consumer of refined products, with an over 70% share on average, throughout the historical period. Its dominance is expected to continue.
- One notable difference from the historical period is that all conventional vehicles are fuelled by gasoline and diesel fuels sourced from Hengyi Industries, as the existing BSP refinery complex has ceased operations.
- Diesel fuel continues to support the industry sector in the long run, with its consumption stabilising through 2050. The expected decommissioning of the Belingus diesel power plant in 2023 phases out the consumption of diesel in the power sector.
- The significant increase in the refining capacity enables Hengyi Industries to export its surplus. To date, the government has revealed that the products have been exported to a few APEC economies: Australia; China; Hong Kong, China; Indonesia; Malaysia; the Philippines; Singapore; the United States; and Viet Nam.

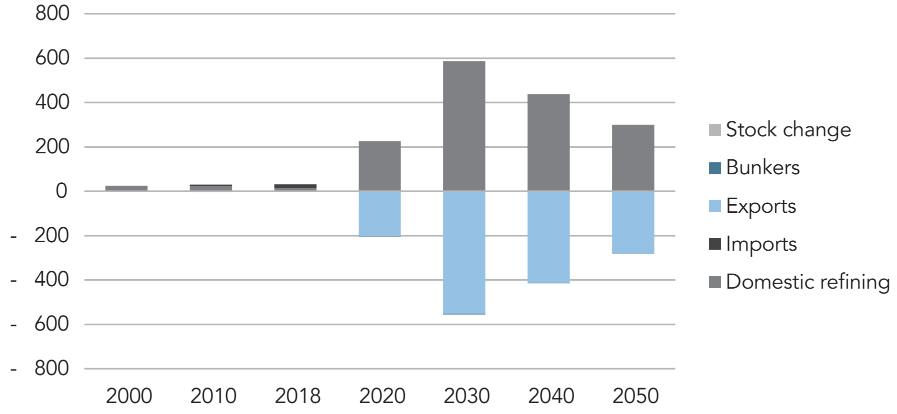
Refined products in the Carbon Neutrality scenario

Figure 2-39. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 2-40. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

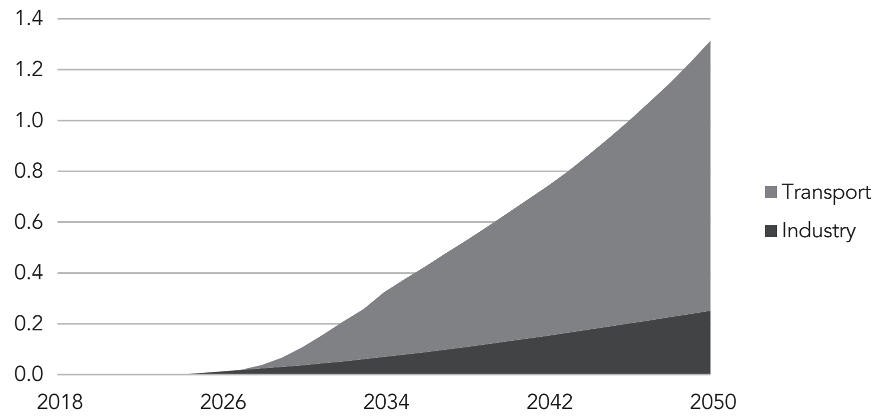


Sources: EGEDA, APERC analysis.

- The consumption of refined products is projected to decline by 49% (2018-2050). Transport diversification, by means of higher EVs and FCVs shares, contributes significantly to this decrease.
- A gradual decline in diesel consumption is expected within the industry sector through 2050, driven by a transition to electricity and hydrogen.
- Diesel no longer appears in CN within the power sector, due to ceasing the Belingus diesel power plant in 2023. This is also reflected in REF.
- The significant decline in the refined products requirement leads to a decrease in refining activities within the Hengyi Industries' complex, particularly from 2025 to 2050. In a carbon neutral world, this presents an opportunity for Hengyi refinery to shift towards low-carbon refinery technologies that are capable to yield advanced biofuels and hydrogen.

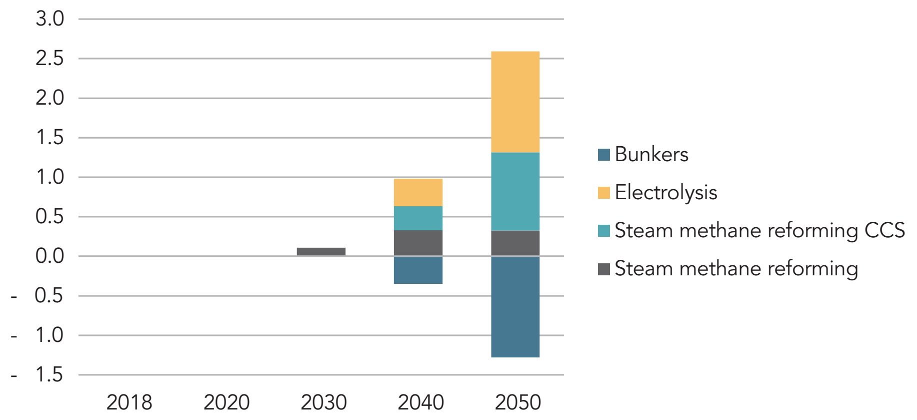
Hydrogen in the Reference and Carbon Neutrality scenarios

Figure 2-41. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 2-42. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)



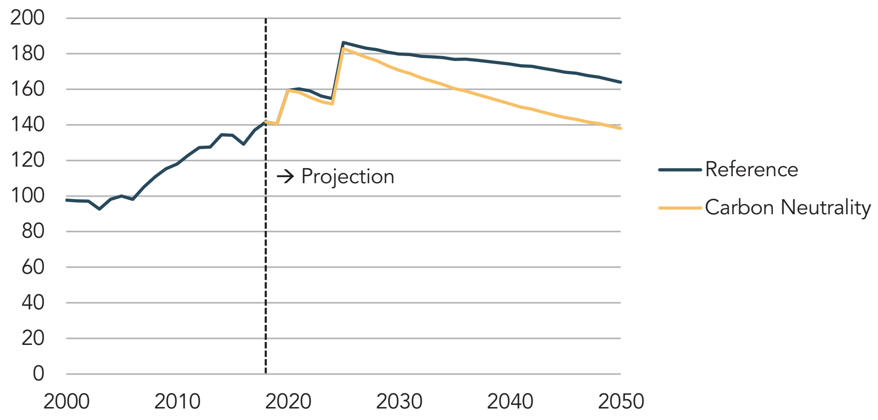
Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- REF (not shown) sees a small number of FCVs beginning to enter the domestic market after 2027, possibly through a small-scale demonstration project. Once its feasibility is proven, hydrogen may see a sharp uptake towards 2050 albeit a small amount as government's hydrogen policies start to take shape.
- The existing demonstration hydrogenation plant in Brunei could become a full-fledged system that produces hydrogen domestically. The plant, which uses natural gas as a feedstock fuel, continues to adopt the steam methane reforming method but is equipped further with CCS as hydrogen production through this method becomes cost-competitive towards 2050.
- Stronger and favourable hydrogen policies in CN would see a much higher uptake of hydrogen in the transport sector, including in the public transportation (fuel cell buses). The industry sector starts to see a small hydrogen penetration, possibly through the expansion of hydrogen policies to include the industry sector as an off-taker.
- The hydrogenation plant would be able to cater for higher demand through a combination of steam reforming methods with and without a CCS unit. In addition, hydrogen is also being produced through electrolysis, benefitting from significant solar PV capacities that are operational in this scenario.

Note: The hydrogen values in REF are negligible and not shown.

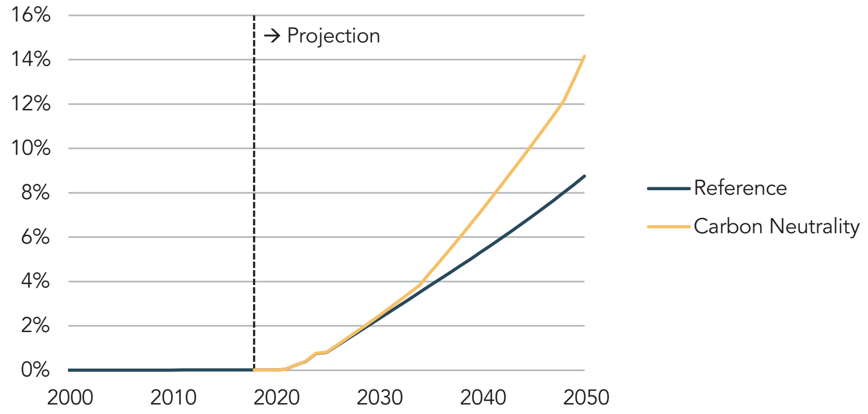
Energy intensity and modern renewables share

Figure 2-43. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 2-44. Modern renewables share in REF and CN, 2000-2050



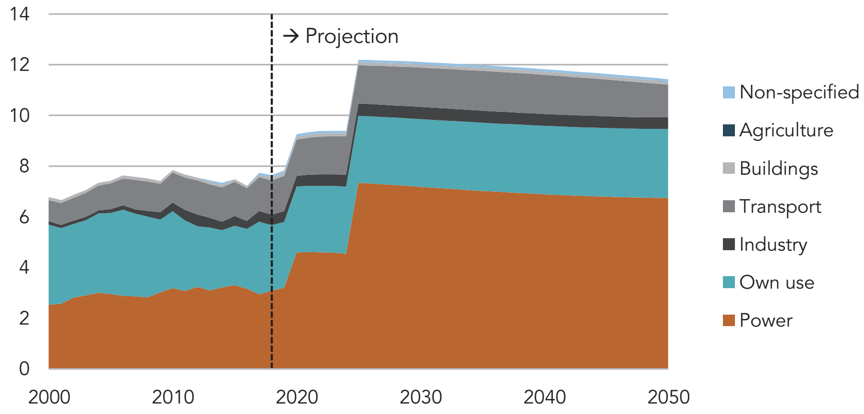
Sources: EGEDA, APERC analysis. Note: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- In general, the energy intensity in REF and CN continues to increase between 2018 and 2025. The intensity is expected to peak in 2025 before showing a downward trend.
- Relative to 2018 levels, REF energy intensity shows a 16% increase in 2050, while a 3% decrease is seen in CN. This is primarily driven by the transport sector, in which enhancing the share of EVs drives down the shares of conventional vehicles, thus decreasing the sector's demand.
- A significant increase in the share of renewables is attributable to the government's push for at least 100 MW of total installed solar PV capacity by 2025, and eventually surpassing the target of 30% renewable energy capacity by 2035. Capacities continue to grow at a modest pace in REF but exponentially in CN.

Note: Additional calculations for final energy intensity and the modern renewables share are available in the supporting dataset.

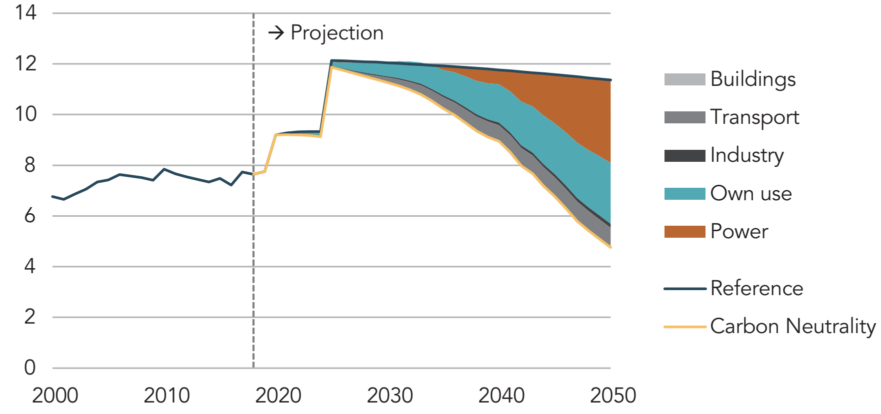
Gross CO_2 emissions

Figure 2-45. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 2-46. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

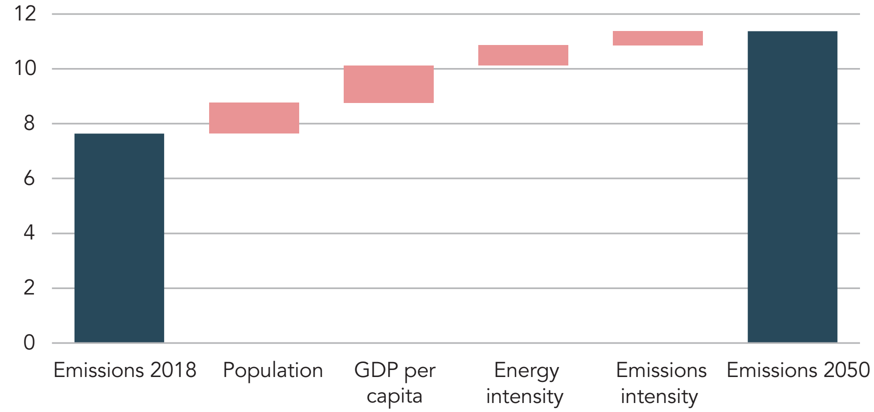


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Brunei's domestic CO_2 emissions have been largely attributed to gas for electricity generation. Between 2000 and 2018, natural gas combustion accounted for 79%, on average, of overall CO_2 emissions, while 21% of the share was attributable to the utilisation of refined products in the form of gasoline and diesel in the transport sector.
- The power sector generated the most CO_2 emissions (2000-2018), followed by the own use and transport sectors.
- In REF, CO_2 emissions grow by 50% (2018-2050), in contrast to the slight growth recorded between 2000-2018. The significant growth is attributed to the utilisation of coal by Hengyi Industries in generating electricity for their day-to-day refinery and petrochemical operations. Coal is expected to account for 31% of the overall CO_2 emissions in 2050.
- Gas remains the major source of CO_2 emissions at a 51% share in 2050 in REF.
- In CN, CO_2 emissions are expected to grow and peak by 2030. Between 2018-2050, CN emissions decline 37%. The largest reduction comes from coal, accounting for 54% of the overall decline, driven by the gradual phase out.
- The utilisation of CCS units in existing gas-fired power plants contributes to 32% of the reduction from gas. Transport electrification, on the other hand, accounts for 14% of the reduction from oil (refined products).

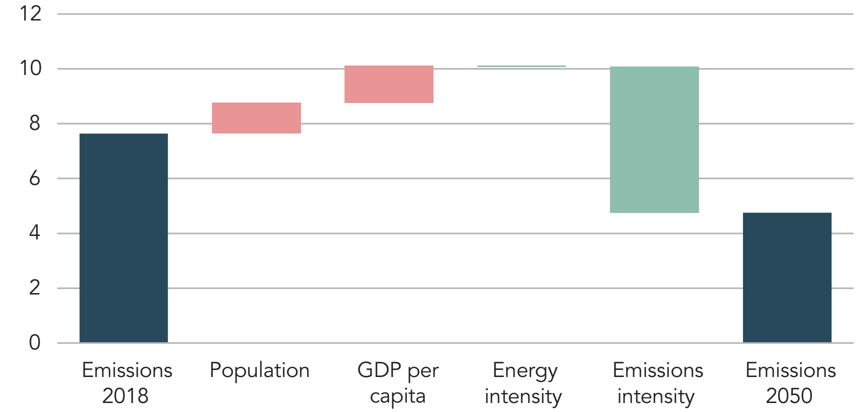
Components of CO_2 emissions

Figure 2-47. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 2-48. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Brunei's CO_2 emissions amounted to 7.7 million tonnes in 2018, accounting for only 0.036% of APEC-wide CO_2 emissions.
- Assuming the same growth trajectories of Brunei's population and GDP per capita in both REF and CN, Brunei's CO_2 emissions trends are determined by changes in energy and carbon intensities.
- In REF, both energy and emissions intensities increase CO_2 emissions. Energy intensity of the energy supply contributes to more of the emissions increase.
- The increase in emissions intensity in REF is attributed to coal utilisation in the domestic energy supply, illustrating that the overall carbon content in Brunei's energy supply is noticeably higher in 2050 than it was in 2018 during the pre-coal era.
- In CN, the gradual phase out of coal, coupled with the use of CCS units in existing gas-fired power plants, significantly improve the emissions intensity. Emissions intensity improvement constitutes 96% of the emissions reduction, while energy intensity only accounts for the remaining 4.2%.
- CN results highlight one of many ways that Brunei can move towards its net-zero target by 2050, at least for the economy's energy sector.
- In order to reach zero CO_2 emissions in 2050, removal through CO_2 sinks through natural or technological means might be necessary. This could be an opportunity for collaboration with APEC member economies.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2 \text{ emissions}}{\text{Energy supply}}$.

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3. Canada

Highlights

Demand

- Energy demand continues to decouple from GDP in both scenarios due to energy intensity improvements. Energy demand increases marginally (2.7%) through to 2050 in REF and falls three-tenths in CN.
- Electrification reduces the role of fossil fuels in both scenarios and increases electricity to nearly three-tenths of the fuel mix in REF and a dominant 50% in CN. Fossil fuels remain relevant but diminish, falling from three-quarters of the mix to three-fifths in REF, and less than two-fifths in CN.
- Transport demand drops a sixth in REF and nearly a half in CN, as policy reduces Canada's reliance on fossil fuels. The Clean Fuel Standard, zero-emission vehicle (ZEV) policy, emissions pricing, and emissions standards result in lower fossil fuel use, more biofuel blending, and higher EV adoption in transport.
- REF buildings demand rises a sixth and CN demand falls a quarter, showing how retrofit standards, net-zero-ready building codes, and heat pumps reduce energy intensity. While gas use is steady in REF, it falls three-quarters in CN due to the electrification of heating, improvements in building envelopes, and the addition of hydrogen to the city gas stream.
- Industrial energy demand is resilient, growing 3.5% in REF and falling an eighth in CN. An acceleration of fuel switching reduces the role of fossil fuels significantly in CN, and energy and material efficiency reduces energy demand.
- Hydrogen demand grows significantly but remains a niche fuel.

Supply

- The completion of export infrastructure increases Canada's role as a global supplier of oil and gas in REF, but global demand destruction in CN risks stranding these same assets.
- In REF, LNG exports reach 3.7 Bcf/d in 2032, while production increases 21 Bcf/d by 2050 on higher exports and rising domestic supply requirements. In CN, lower domestic demand and a declining global export market reduces LNG exports by a quarter and production falls to 13 Bcf/d by 2050.
- In REF, oil production increases to 6.6 Mb/d in the 2040s. Exports increase by half as almost all incremental production is exported. In CN, declining global oil demand reduces exports a third and oil production falls to 3.8 Mb/d.
- Coal supply continues to decline in both Canada and abroad, lowering production by almost half in REF and two-thirds in CN.

Power

- Non-emitting generation continues to dominate Canada's power mix, maintaining current levels of 80% in REF and rising to over 86% in CN.
- Low-cost supply enables gas generation to double in REF to 17% of the power mix. CCS adoption in CN allows gas to deliver 11% of the generation by 2050, with unabated gas capacity almost completely phased out.
- High costs limit large-scale hydroelectric and nuclear capacity additions. In both scenarios, hydro capacity grows to nearly 90 GW, and Ontario's refurbishment schedule keeps nuclear at 11 GW.
- Wind generation triples in REF to 13% of the power mix and grows six-fold in CN to a quarter of it. Solar grows five-fold in REF to 2.8% of the power mix and eight-fold in CN to 4.1% of it.
- Policy and lower-priced alternatives phase out coal in both scenarios. Oil capacity falls significantly in both scenarios, but some remains as a back-up and to power remote communities.

CO_2 emissions

- Canada fails to meet its NDC in either scenario but comes close to achieving it in CN. A higher penetration, and a front-loaded schedule, of low-emitting solutions is required to fulfill Paris Agreement commitments than presented in either scenario.
- Emissions fall 7.2% in REF and by over three quarters in CN. In CN, Canada will require offsets and sequestration to mitigate its remaining 126 Mt of annual emissions in 2050.
- Own use demand increases are mitigated by energy efficiency in both scenarios and lower fossil fuel production in CN. CCS adoption in CN limits emissions.

About Canada

- Canada is a large economy with abundant natural resources, and a high standard of living which stems from its institutional ties to the British Monarchy and its geographic proximity, and close ties, to the US.
- Energy is a key driver of the Canadian economy, contributing 11% of GDP and supplying inputs to the energy-intensive manufacturing, mining, and construction sectors, which make up a further 3%.
- Canada's production exceeds its domestic supply requirements, freeing up much of its energy production for export markets. Canada is one of the world's top-five exporters of crude oil, natural gas, uranium, and electricity.
- On a per capita basis, Canada is one of the highest energy users (2nd) and GHG emitters (4th) in the APEC region. While this is partly due to its vast area, relatively cold climate, and the sparse dispersion of its inhabitants, the abundance of cheap energy also contributes.
- Canada is a top-four producer of crude oil in the world and is largely dependent on the US market to process its excess supplies. Canada is striving to diversify its export market and increase its pipeline export capacity to support growing oil sands production, which drove two-thirds of oil production growth in Canada over the last decade.
- Canada is a top-five natural gas producer. Gas makes up almost two-fifths of its TPES, with the surplus exported into the US market. Canada is looking to diversify its export markets via LNG terminals.
- The role of coal in Canada's economy is fading as it pursues a phase-out of coal-fired electricity. Carbon pricing, and competition from lower-cost natural gas are also lowering demand. Exports, too, are falling in response to a competitive global market. Production has fallen over 40% since 2014.
- Over 80% of Canada's power mix comes from non-emitting sources. Hydroelectric capacity and generation is third in the world and plays a role in powering the US via electricity exports. Variable renewables are playing an increasing role in Canada's electricity system, providing 10% of the generation in 2021.

Table 3-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	37	1.3%	11
GDP	1 852	2.6%	8
TPES	12 459	3.6%	5
Production	22 160	6.5%	4
Imports	3 533	2.8%	9
Exports	13 062	12%	4
Electricity generation	654	3.8%	5
Heat production	20	0.2%	7
CO_2 emissions	527	2.5%	7

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 3-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	132 187	166	0.6%	6
Natural gas	84 742	14	1.3%	5
Oil	1 028 336	89	9.7%	1
Uranium	564 900	–	9.2%	2

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- **Emissions pricing:** Central to Canada's climate change plan is an economy-wide price on GHG pollution. The price is currently CAD 50 per tCO_2e and will rise gradually to 170 CAD per tCO_2e in 2030. An output-based pricing system applies to large-scale industrial emitters, providing lumpsum benchmark payments to prevent carbon leakage while maintaining the marginal incentive to reduce emissions.
- **Canada's NDC and 2050 net-zero emissions target:** Canada strengthened its NDC to a 40 to 45% emissions reduction below 2005 levels by 2030. Canada is committing to becoming a net-zero economy by 2050 and is in the process of legislating short-term emission reduction targets to guide reductions.
- **Clean Fuel Standard:** Canada is in the process of establishing a fuel standard to reduce the lifecycle carbon intensity of liquid fuels by 13% below 2016 levels by 2030. This policy will target fuel distributors, setting a benchmark GHG intensity for fuel streams. Compliance with the benchmark can be achieved via increases in refining efficiency, ZEV investment, and increases in biofuel content.
- **Zero-emissions vehicles (ZEV)s:** ZEV adoption is central to Canada's drive to decarbonise the transport sector. Canada is incentivising adoption with retail ZEV rebates, trade-in incentives, home recharging rebates and investment in the buildout of recharging infrastructure across the economy. Recent mandate letters to NRCan and ECCC should deliver additional stronger policy formation to kickstart ZEV adoption enroute to achieving its 100% ZEV light-duty vehicles sales by 2035.
- **Buildings efficiency:** Recent amendments to the Energy Efficiency Act are improving energy efficiency in cooling, heating, and appliances. The inclusion of tiered coding in the 2020 building model codes will lead to the development of net-zero-ready building codes for all newly constructed buildings by 2030. Canada is developing a retrofit code for the existing building stock.
- **Transport efficiency:** Current emissions standards will improve the emissions intensity of light-duty model years 2022 to 2025 by 5% per year for LDVs and 3.5% for LDTs. A review of the light-duty policy is currently in place. Canada also has standards to reduce the GHG emissions of HDVs from 2022 to 2027.
- **Diversifying energy exports:** Canada's first large-scale LNG export project will commission in 2024; a second phase is planned for the 2030s. This project will provide diversity from its sole current export market in the US, buoying production for several decades. The TMX pipeline expansion, expected to be completed in 2022, will serve the dual-purpose of increasing oil export capacity and opening Canadian crude oil up to growing Asian markets.
- **New technology deployment:** Canada supports technological development to reduce emissions, particularly those that will decarbonise heavy industry. This includes the production and use of hydrogen, the adoption of CCS, and the electrification of process heating. It is also pursuing the potential for SMRs to further decarbonise its power fleet.
- **Power developments:** Canada is phasing out unabated coal-fired electricity generation by 2030. Emissions pricing is accelerating this trend in some provinces, like Alberta. The declining costs of wind and solar technologies are allowing capacities to continue to compete with existing thermal technologies without the aid of provincial subsidies. Recent mandate letters to senior government officials indicate that additional electricity policy will be crafted to drive a net-zero electricity sector in Canada by 2035.
- **Era of smaller projects, shorter payback periods:** Cost escalation, low public acceptance, and shifting investor sentiment is driving investment away from large-scale capital projections throughout the Canadian energy system. Most large-scale projects currently under construction are continuing due to significant support from the government.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- Energy policy in Canada is dynamic and exists at the nexus of public and private sector objectives. The two scenarios are intended to illustrate potential long-term pathways for energy demand, transformation, and supply in Canada with respect to uncertainty about the future.
- **The Reference scenario (REF)** is a pathway where existing trends in technology development and deployment, and policy frameworks continue in a similar manner. REF represents one generally higher energy demand and generally limited decarbonisation pathway.
- Energy efficiency and fuel economy standards continue to improve gradually. Electrification of the transport sector accelerates, driven by policy incentives, such as rebates and investments in recharging infrastructure, and biofuel blending increases out to 2030 due to the Clean Fuel Standard. The industry sector is assumed to gradually make improvements in energy efficiency and fuel switching. In the power sector, the coal phase-out and emissions pricing leads to lower coal-fired generation. Global demand for oil and gas continues, providing an export market for surplus production. A ban on thermal coal exports in 2030, the power coal phase-out, and declines in thermal coal usage in China and southeast Asia reduce coal exports and production.
- **The Carbon Neutrality scenario (CN)** illustrates a potential pathway where energy efficiency, fuel switching, and technology advance substantially to reduce CO_2 emissions from fossil fuel combustion by 2050.
- While CN is more conservative than Canada's existing NDC and net-zero ambitions, it does pave a way to carbon neutrality in the presence of sufficient carbon offsets. CN is one generally lower energy demand and generally more ambitious decarbonisation pathway.
- Technology maturity and commercial availability are key assumptions in CN. Hydrogen supply chains — blue and green — are assumed to be available at scale starting in 2030 to serve end-use applications in the buildings, industry, and transport sectors. While technically possible, hydrogen consumption by the power sector is not considered.
- Global export markets for fossil fuels in CN are assumed to decline at similar rates to those of APEC's TPES relative to the REF, leading to lower exports and production of fossil fuels.

Table 3-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Canada

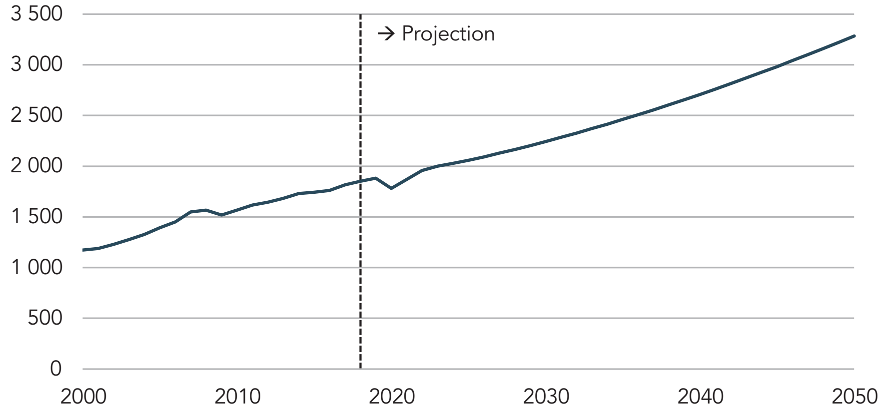
Table 3-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium), GDP: World Bank (historical), OECD (projections), IMF (COVID-19 impacts). • REF incorporates recent trends and in-place policies and does not assume that aggressive action will be taken to meet global emissions reduction goals.	• Population and GDP assumptions are the same as REF.
Buildings	• Gradual improvements to efficiency	• More aggressive improvement in energy efficiency due to revised tiered building codes, the establishment of retrofit standards in 2025, and net-zero-ready building codes applying to all newbuilds in 2030. • Reduction of gas diesel oil, motor gasoline, and kerosene in the residential sector. • Electrification of water and space heating and cooking
Industry	• Small uptake of CCS for steel, cement, and chemicals starting in 2040. • Small amount of hydrogen for the steel and chemicals sectors starting in 2025. • Energy efficiency and electrification improvements follow historic trends to 2050. • Small amount of fuel switching in multiple industry subsectors, primarily to electricity, biomass, and gas.	• Material efficiency improvements for steel, cement, and chemicals subsectors. • Hydrogen for steel production and chemicals introduced in 2030. • Higher fuel switching rates to natural gas, electricity, hydrogen, and biomass in multiple industry subsectors. Energy efficiency more rapid than REF. • Uptake of CCS for steel, cement, and chemicals starting in 2030.
Transport	• Liquid Clean Fuel Standard pushes biofuel blending to 25% in the 2030s. • Fuel efficiency follows current standards and recent trends. • Electric vehicles sales grow slowly, reaching 60% by 2050 for LDV and 30% HDVs. • Over three fifths of the stock remains ICE by 2050.	• Higher biofuel blending due to carbon price, more stringent blending standards. • Improved fuel efficiency and hybridisation • EV sales share is 90% in 2035 and approaches 100% in 2050; stocks hit 80%. • Hydrogen fuel cell vehicles utilised for freight transport.
Power and heat	• Unbated coal phase-out drives coal out of the fuel mix by 2050. • Low costs of wind, solar lead to a two-third share of capacity additions; gas nearly a third of capacity additions. • Nuclear fleet remains after refurbishment.	• Do not hit net-zero by 2035 but approach a carbon-neutral power sector by 2050. • Retain existing nuclear fleet, with no utilisation of SMRs. • Utility storage adoption from 2025; CCUS-equipped gas adoption from 2030.
Supply	• LNG export capacity reaches 14 Mtpa by 2026; peaks at 28 Mtpa in the 2030s. • Oil production matches CER EF 2021; surplus exported to market. • Natural gas production and exports increase to meet export markets demand. • Coal exports/production falls in response to declining domestic/overseas demand.	• Production declines to match lower global oil, gas, and coal demand. • Export market for oil is 58% below REF levels in 2050; gas 75%; coal 82%. • LNG capacity remains the same as REF, with lower utilisation rates due to a declining global market.
Climate	• NDC targets not explicitly considered.	• Carbon neutral energy sector by 2050

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

Macroeconomic backdrop

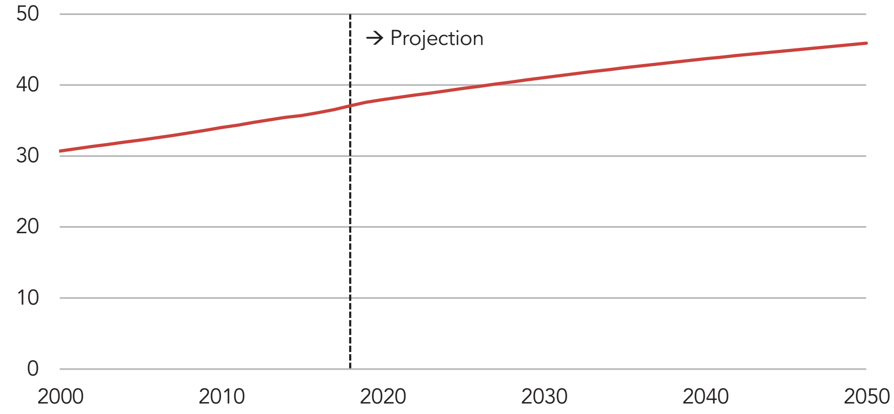
Figure 3-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

- The economic impact of COVID-19 on the Canadian economy is significant. The 5.4% drop in real GDP in 2020 is the fifth-largest in APEC and surpasses the drop seen during the 2009 financial crisis. The duration and evolution of the pandemic is uncertain, and its persistence adds downside pressure to these GDP projections.
- Canada's GDP grows more rapidly in the early 2020s following the lows of the COVID-19 recession, and real output surpasses 2019 levels in 2022. Economic growth continues at a slower pace than the first two decades of the millennium, at a growth rate of 2.0% from 2020 to 2050.
- Canada's population continues to grow, but at a slower rate than the last twenty years, hitting almost 46 million by 2050. GDP per capita grows by over 40% through the projection period.

Figure 3-2. Population in millions, 2000-2050



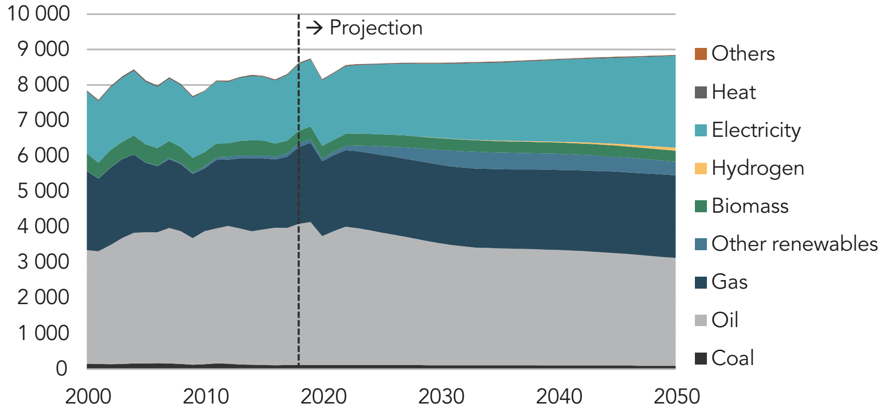
Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- As a simplifying assumption, the macroeconomic projections are the same in both scenarios. However, as a producer-exporter of energy, a contraction of fossil fuel markets observed in CN could impact Canada's growth trajectory. Nevertheless, the evolution of the Canadian and global economy in a carbon-neutral future is uncertain, and Canada could make up for declining fossil fuel revenues with other sectoral developments, including those from evolving energy carriers, like hydrogen, and carbon abatement technology, like CCUS.
- The structural evolution of Canada's economy follows historic trends out to 2050. Both industry and manufacturing are supplanted by more services, with the latter accounting for about two-thirds of Canada's GDP in 2050.

Note: For a detailed analysis of projections with a macroeconomic analysis that is endogenous to oil and gas development, please consults CER's EF 2021.

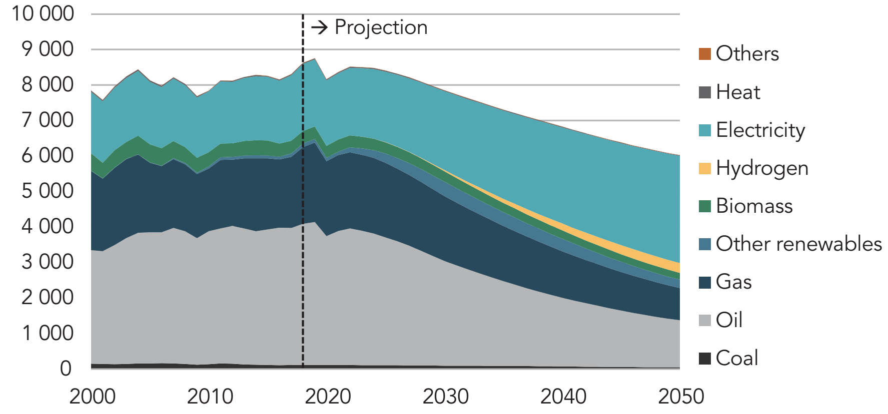
End-use energy demand

Figure 3-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 3-4. Energy demand in CN, 2000-2050 (PJ)

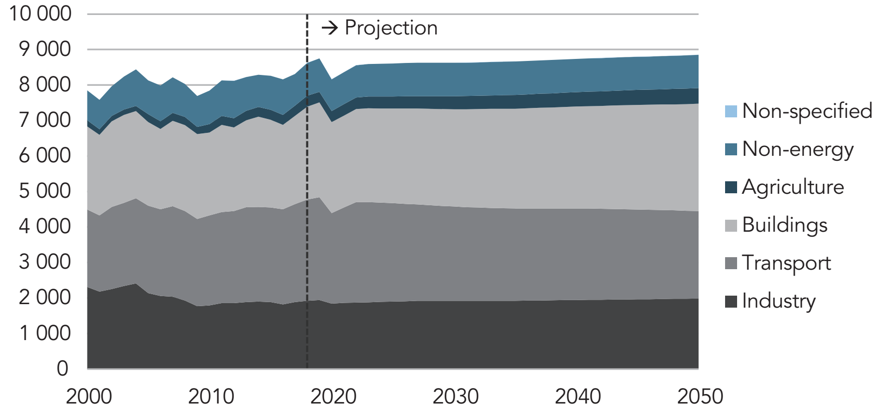


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Energy demand increases slightly in REF, following the slow growth of economic drivers, like GDP and population, and a continuation of the historical decoupling of energy use from economic growth due to advances in energy efficiency.
- Electrification of end-uses throughout all sectors increases in both scenarios, reducing the role of fossil fuels in the fuel mix. The rise of EVs, and their efficiency relative to ICE vehicles, means that transport plays a significant role in the declining share of fossil fuels in end-use energy demand. While electricity increases to almost three-tenths of the fuel mix in REF, it surges to half in CN. Meanwhile, oil falls to just over a third of the fuel mix in REF and a fifth in CN.
- Gas plays a steady role throughout REF, hovering around a quarter of the fuel mix. Fuel-switching to electricity and hydrogen means that gas falls more than half in CN, accounting for 15% of the fuel mix in 2050.
- Hydrogen makes up 1.0% of demand by 2050 in REF and rises to 4.7% in CN on the back of transport fuel cells, industrial applications, and blending in the buildings sector.
- Fossil fuels continue to provide a meaningful but diminished role, falling from three-quarters of the fuel mix to 62% in REF and 38% in CN.
- Energy demand fell 6.7% in 2020 due to the COVID-19 recession, eclipsing the 4.2% fall observed during the Global Financial Crisis in 2009. Energy efficiency prevents demand from surpassing its 2019 peak until 2042, and the peak is never reached in CN, where demand falls over a quarter below its pre-pandemic peak.
- Uncertainties in the development of data centres, cryptocurrency mining, and an accelerated adoption of space cooling, plus higher utilisation to cope with rising temperatures, could increase electricity demand above these levels. Additional electrification of end-uses in Canada is possible, allowing for tremendous upside potential for electricity demand in excess of the growth captured in either scenario.

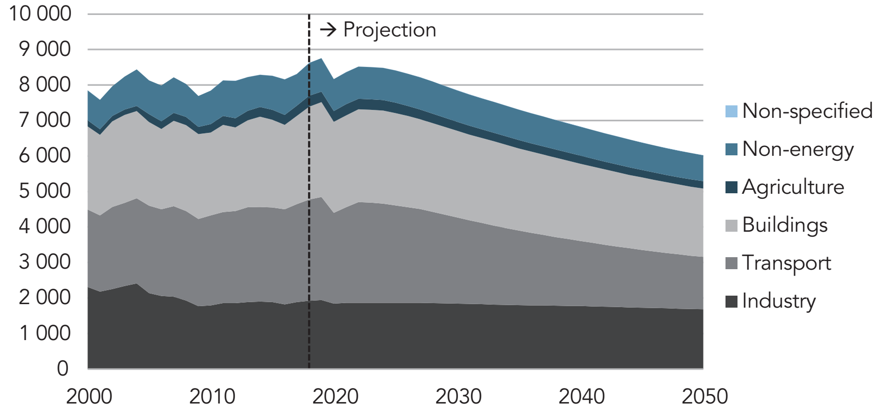
End-use energy demand by sector

Figure 3-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 3-6. Energy demand by sector in CN, 2000-2050 (PJ)

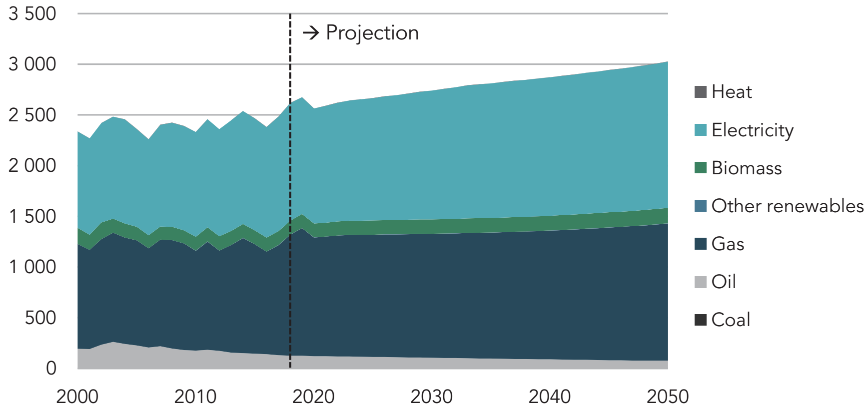


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Emissions standards and the electrification of road transport is instrumental in reducing transport energy demand by 14% in REF and, with the aid of some behavioural changes, by nearly a half in CN. While transport is the highest energy-using sector today, efficiencies reduce it to second in REF and third in CN. CN transport demand is 40% lower than REF in 2050.
- Industrial and non-energy demand remains stable in REF, while reductions are limited to 15% in CN. The difficult-to-decarbonise nature of several end-uses in heavy industry and higher mining activities, attributable to higher critical minerals mining, both limit demand reductions. CN energy demand is a sixth lower than REF in 2050.
- Buildings becomes the largest demand sector in both scenarios. Moderate efficiency improvements constrain buildings energy growth in REF. In CN, retrofit building standards reduce the energy intensity of the existing housing stock, and a net-zero-ready code ensures that all new buildings after 2030 are eligible to be net-zero if linked with a non-emitting electricity source. However, the persistence of the existing stock limits energy use reductions, with demand falling by slightly more than a third below REF levels by 2050.
- Agriculture is the largest growing sector in REF, but efficiency improvements in CN reduce demand by a third; CN demand is half of REF by 2050.
- Energy demand in CN is a third below REF in 2050.
- Energy efficiency improvements slightly prolong the extent to which energy demand bounces back in the years after the pandemic. In REF, buildings demand does not surpass pre-pandemic levels until 2026, and industry does not surpass 2019 levels of demand until 2040. Transport demand never surpasses 2019 levels.

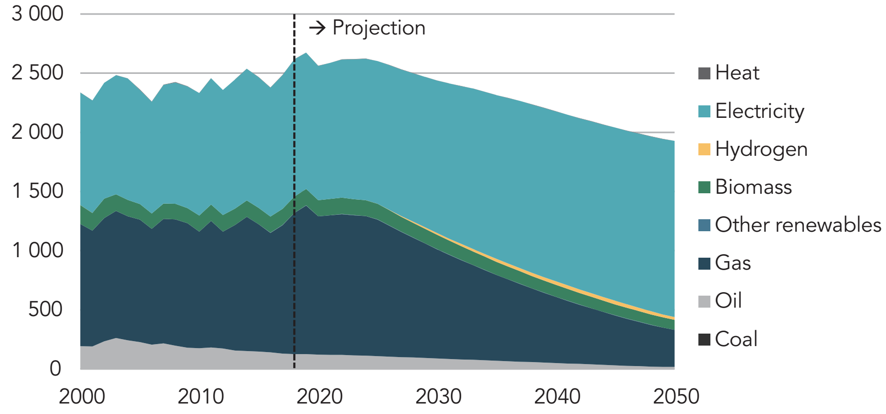
Buildings energy demand

Figure 3-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-8. Buildings energy demand in CN, 2000-2050 (PJ)

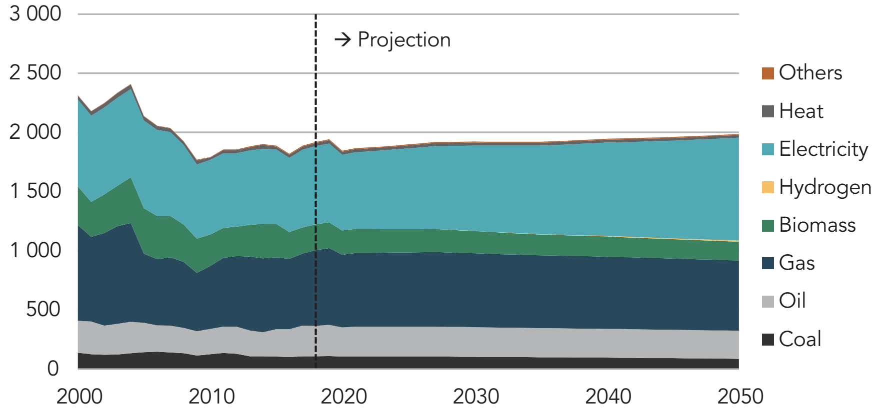


Sources: EGEDA, APERC analysis.

- Buildings demand growth in REF is steady but limited by gradual efficiency improvements in heating, cooling, appliances, and building envelopes.
- Electrification in buildings pushes electricity up by almost a quarter in REF, to become the dominant energy source ahead of gas. Increased electrification in CN, particularly of heating, increases electricity demand by more than a quarter, though higher efficiency, particularly of heat pumps over baseboard heating, limits the absolute increase.
- The efficiency of the building stock increases in CN, as retrofit building standards reduce the energy intensity of the existing housing stock, and a net-zero-ready code ensures that all new buildings after 2030 are zero-emission buildings. However, the persistence of the existing stock limits energy use reductions, with demand falling by slightly more than a third below REF by 2050.
- While gas continues to play a significant role in cooking and heating end-uses in REF (rising 13% over the outlook period), the electrification of these end-uses increases significantly in CN. Gas use falls by about three-quarters in CN, and heat pump efficiency is integral to this significant drop.
- Hydrogen blending of the natural gas stream also reduces natural gas use in CN. The blending of hydrogen increases gradually starting in 2026, rising to just over 20% of the gas stream by volume (or just over 6% by energy content). Blending beyond this level will likely require significant investment in new distribution networks and appliances.
- Oil and coal see their roles in fueling buildings decline in both scenarios. Use of oil in heating and cooking falls over a third in REF and 86% in CN. Coal is fully phased out in both scenarios, due to the high costs of continuing to use coal in the face of increasing carbon prices.
- Biomass, mainly as wood-pellets for heating purposes in remote areas, grows 11% in REF. However, the electrification of heating reduces its use by almost two-fifths in CN.
- A key uncertainty in these projections is the pace of electrification over the projection period. Higher electrification and a rise of electric-intensive commercial uses, like data centers and cryptocurrency mining, could increase electricity demand well above the levels in either scenario.

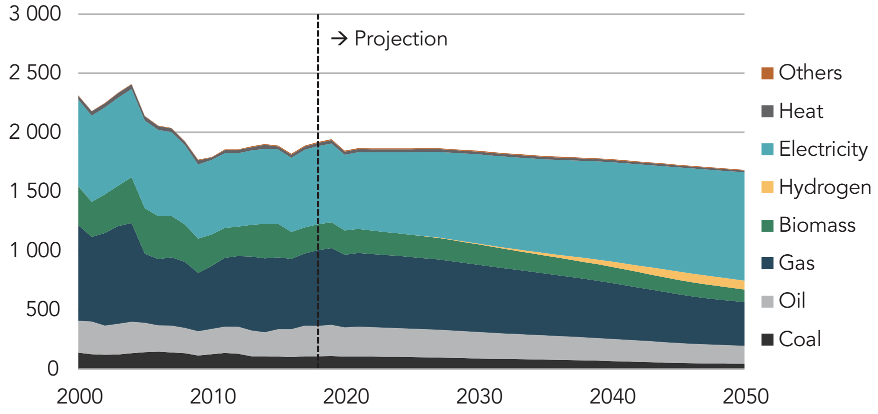
Industry energy demand

Figure 3-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 3-10. Industry energy demand in CN, 2000-2050 (PJ)

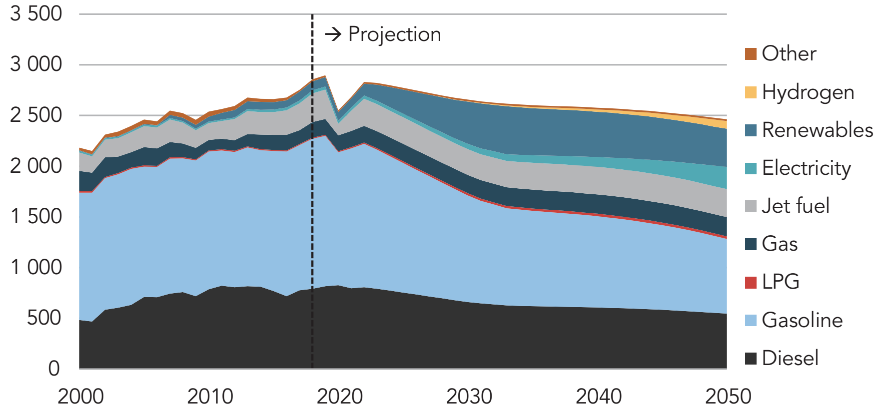


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industrial demand increases at a similar pace of the previous decade in REF, growing 3.5%, while material and energy efficiency improvements reduce demand by an eighth in CN.
- Fuel switching to electricity, natural gas, and biomass continues moderately in REF. An acceleration of fuel switching, particularly from fossil fuels to electricity, biomass, and hydrogen, sees electricity increase by 6% over REF levels in CN, even with declining overall energy consumption. Electricity makes up two-fifths of the industrial fuel mix in REF and over half in CN.
- Fossil fuels remain dominant in REF, comprising 44% of the 2050 fuel mix. Fossil fuels see significant reductions in CN: coal falls by three-fifths, while oil and gas fall by two-fifths. Fossil fuels account for a third of the fuel mix in 2050.
- Biomass falls over a quarter, due partly to declining output from the pulp and paper sector. However, rising demand for packaging limits the decline. Biomass shares fall to 7.9% by 2050 in REF and 6.4% in CN, with many biomass applications supplanted by electricity and hydrogen.
- Hydrogen is introduced in 2025 in select sub-sectors of both scenarios, but adoption accelerates more rapidly in CN, with demand hitting six-times REF levels by 2050. Despite significant growth, hydrogen remains a niche fuel. In 2050, it makes up only 4.4% of the industrial fuel mix in CN and 0.6% in REF.
- REF demand grows in all sub-sectors, except for pulp and paper, which declines but remains the highest energy-consuming sector by 2050. Manufacturing grows the most, followed by mining. Mining is the one sector that grows in CN, as a growing critical minerals market for assembling low-carbon technologies increases activity.
- Industrial sectors remain somewhat resilient throughout the onset of the pandemic, with energy demand falling 5.0% below 2019 levels in 2020.
- An acceleration of energy efficiency improvements in all sectors, plus material efficiency improvements in the cement, steel, and chemicals sub-sectors are contributors to demand reductions in CN.
- CCS adoption starts in 2035 in the cement, steel and chemicals sub-sectors in REF and to a much larger degree from 2030 in CN.

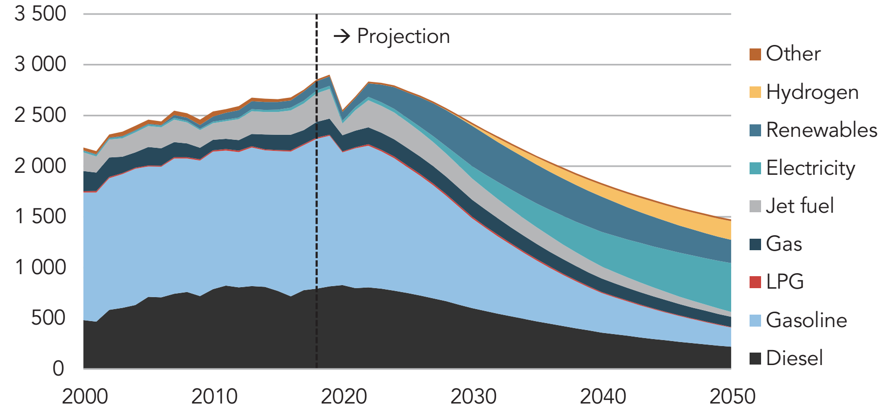
Transport energy demand

Figure 3-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 3-12. Transport energy demand in CN, 2000-2050 (PJ)

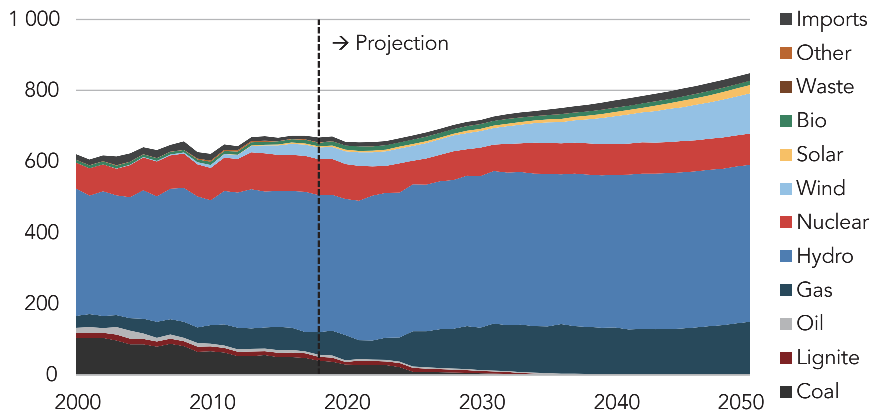


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Energy efficiency improvements in road transport are instrumental in driving energy consumption down from the transport sector in both scenarios. In REF, fuel efficiency programs for both LDVs and HDVs are continued past their current horizons of 2025 and 2027, respectively. Higher ZEV adoption, particularly EVs, is largely responsible, as new EV models are currently three-to-five times more efficient than their ICE counterparts. REF demand falls 14% over the projection period.
- In CN, higher penetration of ZEVs, moderate modal switching from personal vehicles to public transport, along with more aggressive fuel economy standards reduce energy demand further. Demand falls almost in half in CN, 40% below REF.
- Canada's ZEV mandate is achieved in REF, and ZEVs grow in REF to make up 60% of vehicle sales and a third of the vehicle stock by 2050. However, Canada does not achieve the 2035 phase-out of ICE vehicle sales in either scenario. In CN, EV sales surpass 90% in 2035 and approach close to 100% in 2050, and ICE vehicles remain in the vehicle stock, holding a 20% share in CN.
- COVID-19 had a significant impact on transport, reducing demand by 12% in 2020, which is well below the Global Financial Crisis fall of 2.5%. While demand rebounds, already slowing demand and efficiency improvements prevent it from growing beyond the 2019 peak in REF.
- Modal changes are instrumental in achieving energy reductions in CN. Compared to REF, passengers use 3.7 times more rail and 2.4 times more bus, which displaces half the air activity and a quarter of personal vehicle travel. In freight, air activity falls 29%, while heavy duty vehicles decline 45%.
- Canada's Clean Fuel Standard leads to a significant growth in biofuels in both scenarios, hitting 25% in 2030 in REF and over 30% in CN. The role of biofuels peaks in the 2030s in both scenarios, as energy efficiency and fuel-switching in road transport reduces demand for the fossil streams.
- The evolution of US automobile standards is a key uncertainty for Canada's transport demand due to the interconnected vehicle manufacturing market between the two economies. US policy will influence the manufacturing and deployment of both ZEV and ICE vehicles.

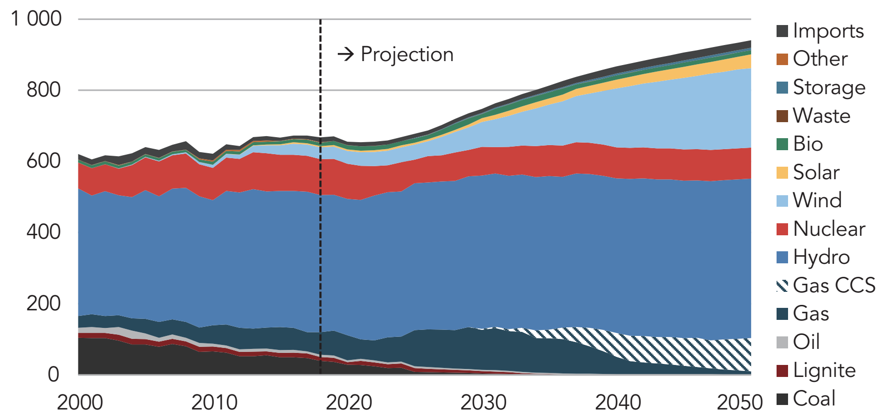
Electricity generation

Figure 3-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 3-14. Electricity generation in CN, 2000-2050 (TWh)



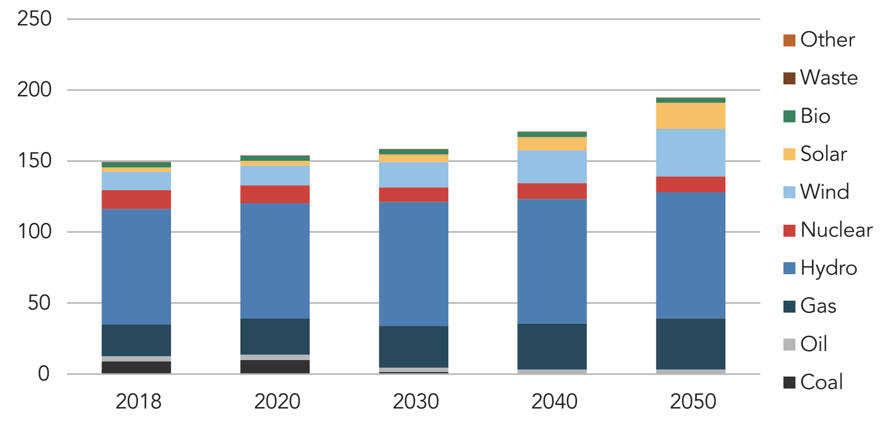
Sources: EGEDA, APERC analysis.

- Electricity demand fell 2.3% in 2020 and remains depressed for the first few years of the projection. However, the economic recovery lifts demand above pre-pandemic levels in 2025 in both scenarios. In the longer term, macroeconomic drivers and the electrification of end-uses supports a load growth of a third in REF and three-fifths in CN.
- Non-emitting power sources retain their dominant grip on supplying Canadian power demand in both scenarios. Generation from these sources remains around 80% in REF and grows to 86% in CN.
- The role of hydro increases over the projection, on the back of existing expansions and some additional facilities in the 2040s. Generation grows 14% in REF and 16% in CN. Acceptance of newbuild interconnects in the US is a significant uncertainty, as opposition to large-scale transmission projects could limit Canada's electricity exports, and in turn its hydroelectric generation potential.
- Low feedstock prices help natural gas generation to double in REF, growing to 17% of the power mix. Competition from lower-emitting alternatives and higher emissions prices limit growth to 62% in CN. Gas makes up 11% of the 2050 CN fuel mix, but the generation is almost entirely from CCS-equipped facilities.
- Nuclear generation is the same in both scenarios, as Ontario follows its current refurbishment schedule. SMRs are not adopted in this projection.
- REF wind generation triples, reaching 13% of the electricity mix, on the back of Canada's significant wind resources and the competitive cost of wind capacity. Further wind cost reductions and more stringent carbon pricing prompt a six-fold increase in CN, with wind reaching a quarter of the power mix.
- Solar generation grows five-fold in REF, but only comprises 2.8% of generation. Declining costs and stringent emissions pricing pushes CN generation to grow nine-fold. However, solar only comprises 4.1% of generation.
- Policy and lower-cost alternatives phase out coal-fired generation by 2040 in both scenarios.

Note: Long-duration storage is defined as battery systems that can provide energy for more than 10 hours at a time.

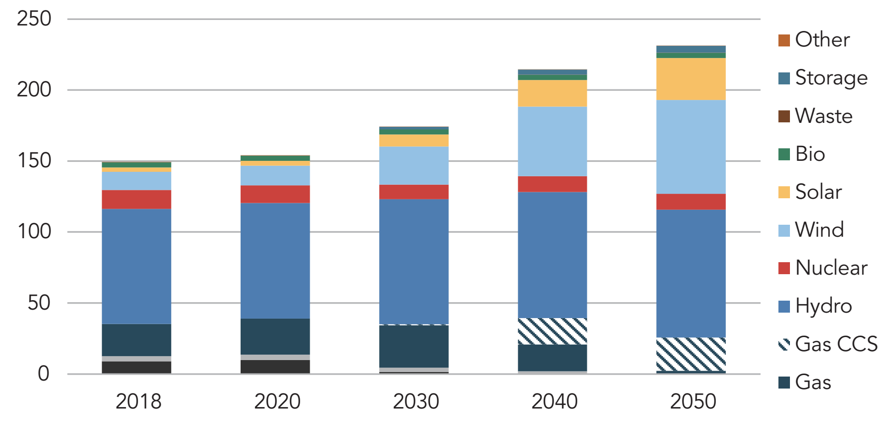
Generation capacity

Figure 3-15. Generation capacity in REF, 2017-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 3-16. Generation capacity in CN, 2017-2050 (GW)



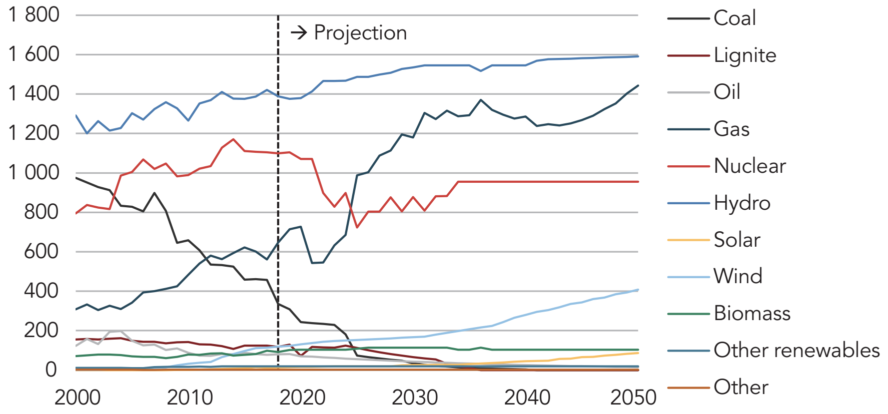
Sources: EGEDA, APERC analysis.

- Cost escalation and shifting investor sentiment dampen investment in large-scale hydro facilities. Still, significant facilities currently under construction, like Site C and Muskrat Falls, push capacity near 90 GW in both scenarios.
- Low feedstock costs and rising demand enable gas capacity to grow three-fifths in REF to 36 GW. While unabated gas capacity peaks at 30 GW in 2030 in CN, more stringent carbon pricing puts the technology on an unequal footing with the declining costs of CCS and renewable technologies. Only 1.9 GW of unabated gas remains in 2050, but over 23 GW of CCS-equipped projects continue to operate.
- Canada's significant onshore wind potential, declining costs, and supportive climate policy supports growth in wind capacity in both scenarios. Capacity grows 2.6-fold in REF and almost five-fold in CN. Offshore wind is not deployed in either scenario.
- Solar capacity grows six-fold in REF and almost nine-fold in CN, on the back of declining costs and supportive climate policy.
- Nuclear capacity remains the same in both scenarios and is driven by Ontario's refurbishment plans over the next decade. SMRs are not considered in either scenario.
- In 2025 of CN, utility-scale long-duration battery storage arrives, growing to almost 5 GW by 2050.
- Policy and costs lead to a complete phase-out of coal capacity in both scenarios. Oil capacity falls significantly in both scenarios due to emissions standards, carbon policy, and the declining costs of alternative technologies. Oil capacity does remain as a back-up and to power remote communities in both scenarios.
- Opposition to large-scale energy projects within Canada, particularly large-scale hydro, wind and utility solar, and transmission lines in both Canada and the US, could hinder non-emitting power capacity growth. Such opposition would hinder decarbonisation in both Canada and the US electricity sector.
- Offshore wind capacity is not considered here. Canada is currently examining its potential, and over 3.6 GW of projects are being proposed.

Note: Long-duration storage is defined as battery systems that can provide energy for more than 10 hours at a time.

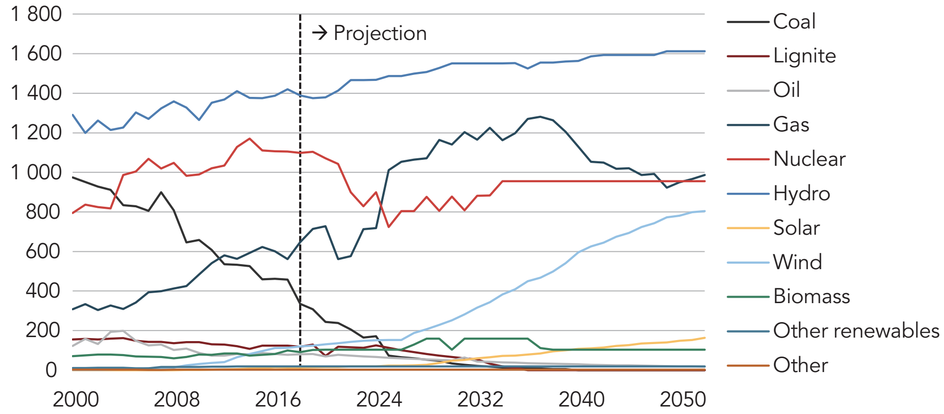
Fuel consumption by power sector

Figure 3-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 3-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

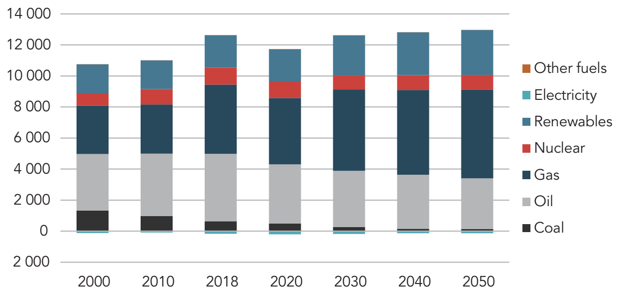


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- In both scenarios, overall fuel consumption by the power sector decouples moderately from generation trends due to the retirement of more inefficient thermal assets. The coal phase-out and increasing power generation standards drive this. In both scenarios, fuel consumption rises a fifth, despite generation growing a quarter in REF and by two-fifths in CN.
- Gas use in the power sector doubles over the projection in REF and shows no sign of slowing in the 2040s. In CN, climate policies and the competitiveness of alternative power sources cause gas use to peak in 2037. However, the deployment of CCS-fired units buoys the usage of gas.
- A key uncertainty of the fuel consumption outlook is the successful deployment of CCS-equipped technology to capture emissions from gas-fired generation. Without demonstrative success, it will be unlikely that natural gas remains in the fuel mix if the world is to approach carbon neutrality.
- Another key uncertainty for natural gas consumption is the success in mitigating methane leakages in the natural gas supply chain. With a global warming potential nearly thirty-times that of carbon dioxide, methane venting and fugitive emissions contribute significantly to global warming. Failing to contain these emissions would likely divert many economies away from using natural gas in a world progressing towards carbon neutrality. Canada is committing to reducing upstream methane emissions by 40 – 45% below 2012 levels by 2025 and 75% by 2030 and is supporting the Global Methane pledge to reduce methane emissions by 30% below 2020 levels by 2030.

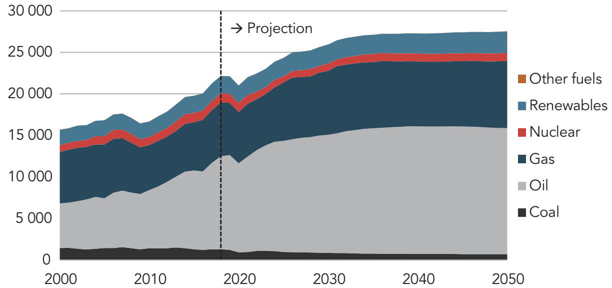
Energy supply in the Reference scenario

Figure 3-19. Total energy supply in REF, 2000-2050 (PJ)



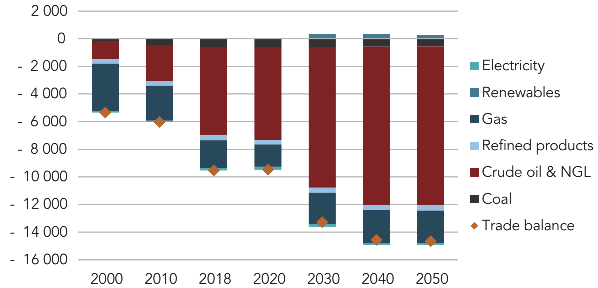
Sources: EGEDA, APERC analysis.

Figure 3-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-21. Net energy trade in REF, 2000-2050 (PJ)

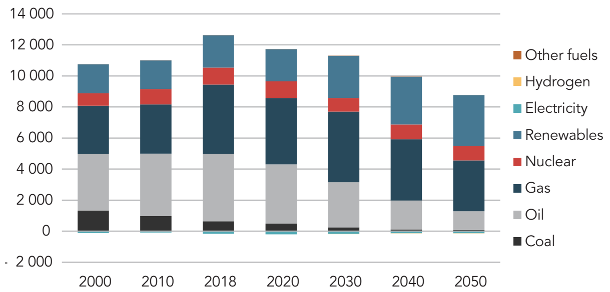


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Canada's energy supply grows slightly in REF, and fossil fuels hold onto a three-quarter share of the fuel mix. However, components undergo some moderate changes. Electrification, particularly of a significant portion of the transport sector, pushes oil down from a third of the supply to a quarter. Natural gas becomes the dominant source of the supply, rising to 45% in 2050, due to rising demand from own use and power sectors. Renewables supply grows two-fifths to comprise 23% of the fuel mix.
- Canadian production of oil and gas remained resilient during the first year of the COVID-19 pandemic. Despite supply requirements falling 8%, oil and NGL production only fell 6.1%, and gas production 1.6%.
- Canada's role as a global supplier of energy increases following the completion of significant large-scale export projects, increasing net energy trade by 50%. Various pipeline expansions allow oil production, mainly from the oil sands, to grow by a third to 6.6 Mb/d. LNG export terminals and rising domestic demand supports the increase of natural gas production by 25% to almost 21 Bcf/d.
- Declining demand for coal by domestic power producers and an oversupplied global coal market has driven coal production down 40% over the past five years. After a brief reprieve following the pandemic, this trend continues as the 2030 coal phase-out and thermal coal export ban drives production lower. However, resilient global demand for metallurgical coal limits overall declines to 46%.
- These production trends are contingent on a robust global export market for fossil fuels. Declining demand for oil, gas and metallurgical coal pose significant risks for Canadian fossil fuel producers. The CN case (next slide) illustrates this.
- The *Outlook* assumes that there are no capacity constraints for Canadian export markets. However, existing opposition to infrastructure projects targeting the development of electricity transmission lines, LNG feeder pipelines, and oil export pipelines could challenge this assumption and Canada's export and production outlook.

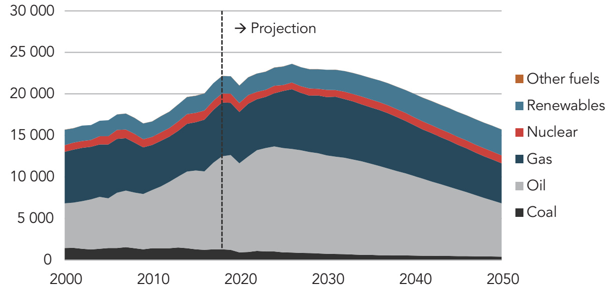
Energy supply in the Carbon Neutrality scenario

Figure 3-22. Total energy supply in CN, 2000-2050 (PJ)



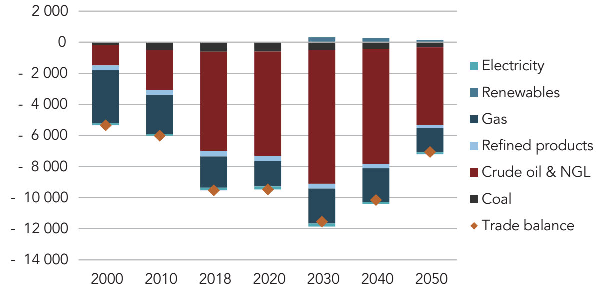
Sources: EGEDA, APERC analysis.

Figure 3-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-24. Net energy trade in CN, 2000-2050 (PJ)

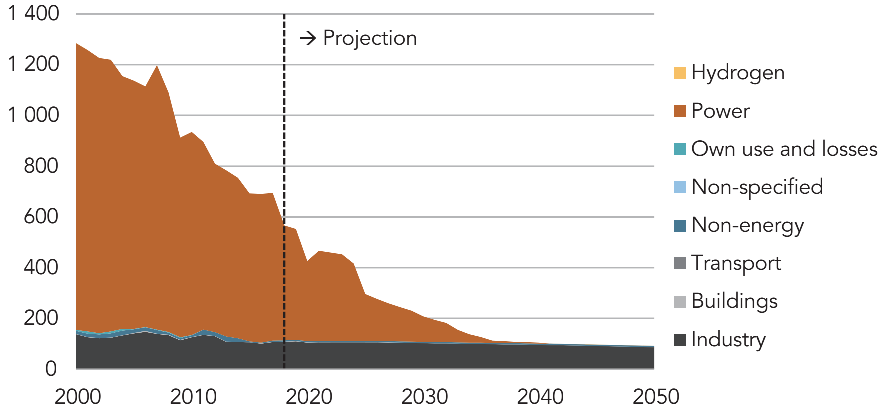


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Supply declines 31% below 2018 levels by 2050. Electrification and modal changes in transport are integral to reducing oil supply requirements by two-thirds. Gas is more resilient, falling a quarter, but remaining the most-supplied fuel in a virtual tie with renewables at 39%. Renewables supply grows 56% on the back of declining costs and support from climate policy. The role of coal falls 89% as industrial users embrace other fuel sources over metallurgical coal.
- Net trade falls a quarter as the global embrace of carbon neutrality limits Canada's role as a global energy supplier. Fossil fuel production declines are a function of both this and lower domestic demand. Oil production declines by two-fifths to under 4 Mb/d. Natural gas production falls a quarter to 13 Bcf/d, which is in line with both domestic supply reductions. Coal production falls over two-thirds, buoyed by the continued use of metallurgical coal in some economies.
- Canada is at risk of stranding several large-scale infrastructure projects in this scenario. A reduction in oil exports by a third highlights risks to both the Trans Mountain Pipeline expansion and the replacement and debottlenecking of other major crude oil export pipelines. A 25% drop in LNG exports under REF levels could also strand the second phase of the LNG Canada project.
- This scenario illustrates how declining global demand for fossil fuels will affect Canadian fossil fuel production. An action-backed embrace of carbon-neutral strategies across the globe would surely result in more reductions than presented here. The resilience of fossil fuel exports and production shown here could prove fleeting if Canada does not embrace reducing emission intensity across the fossil fuel supply chain and keep pace with global competitors on successfully reducing methane emissions.
- Hydrogen production in CN rises to 292 PJ to meet demand and bunkers withdrawals. This scenario assumes no export of hydrogen. Should Canada prove to be a reliable exporter of low-emitting hydrogen, this value could increase, as could the natural gas supply to feed the production of it.

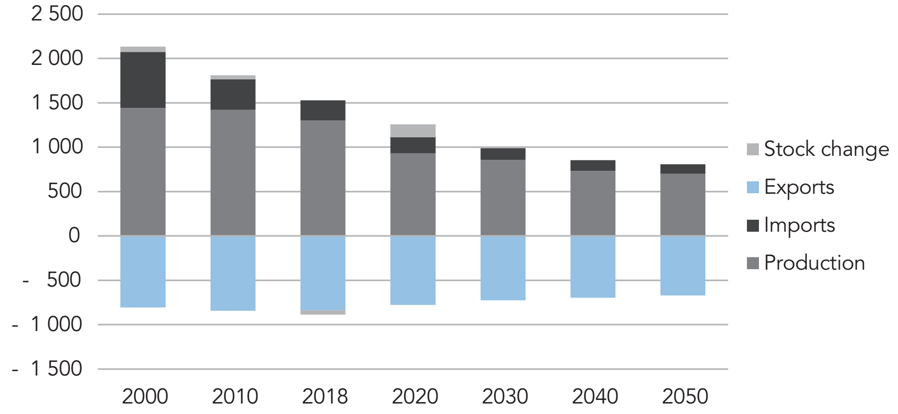
Coal in the Reference scenario

Figure 3-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

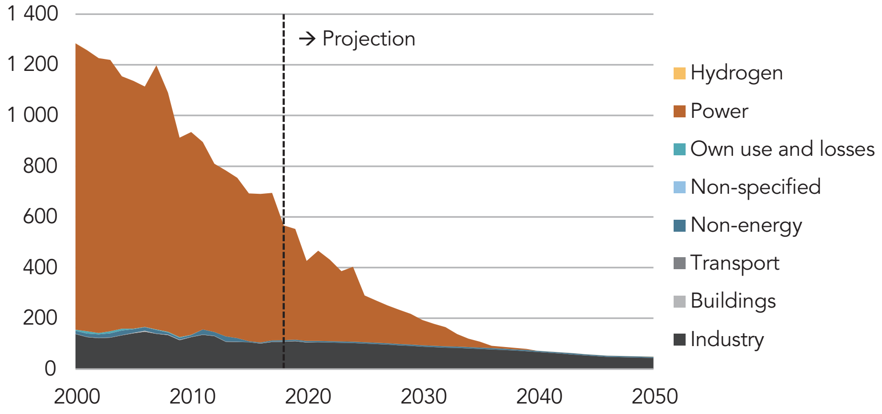


Sources: EGEDA, APERC analysis.

- Despite a moderate resurgence in coal usage in the early 2020s, the phasing out of coal in the power sector continues in both scenarios. Buildings cease coal use by 2030.
- The coal phase-out ends unabated coal-fired power generation by 2030, but some abated generation remains in the 2030s. A complete phase-out of coal in the power sectors occurs in 2041.
- The industrial and non-energy sectors remain coal consumers to 2050, with coal supply falling to just over three-quarters of its 2018 levels.
- Ongoing, but falling, demand for coal products by the industrial and non-energy sectors buoy imports, which are halved by 2050.
- The thermal coal export ban reduces coal exports, but a resilient demand for both metallurgical coal and coal products sustains exports at 80% of their 2018 levels by 2050.

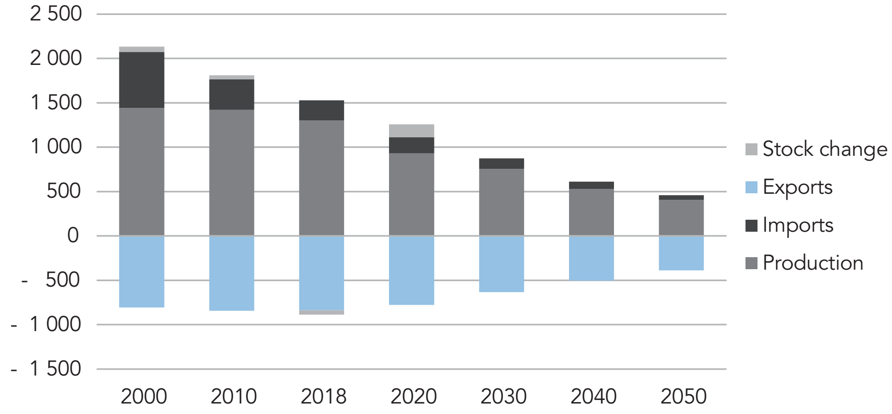
Coal in the Carbon Neutrality scenario

Figure 3-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

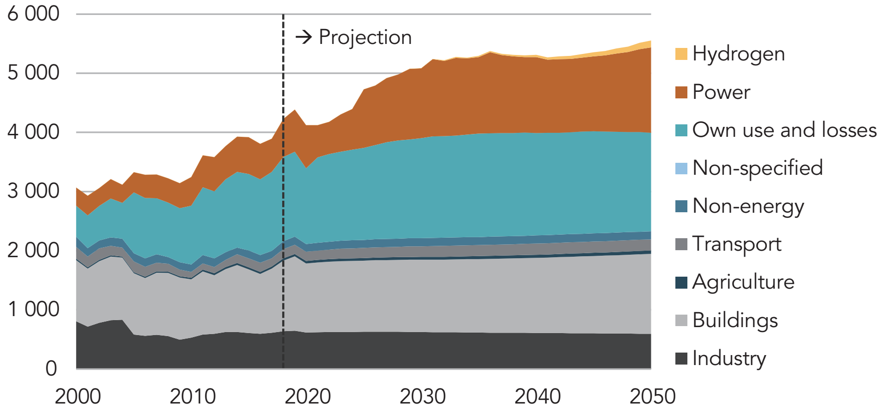


Sources: EGEDA, APERC analysis.

- Coal use in CN follows a similar trajectory to REF due to the phase-out in the power sector in both scenarios. However, buildings cease to consume coal sooner, in 2027, and industrial and non-energy reduce their usage, increasingly opting for other forms of process heat. Some coal uses persists at about 11% of 2018 levels in 2050.
- Resilient, but declining, demand for coal products by the industrial and non-energy sectors buoy imports, which falls by three quarters to 2050.
- The thermal coal export ban reduces coal exports, but a resilient demand for both metallurgical coal and coal products sustains exports at half their 2018 levels.
- Additional technological advancements in the industrial and non-energy sectors are required to eliminate the remaining coal and coal product usages in the Canadian economy.

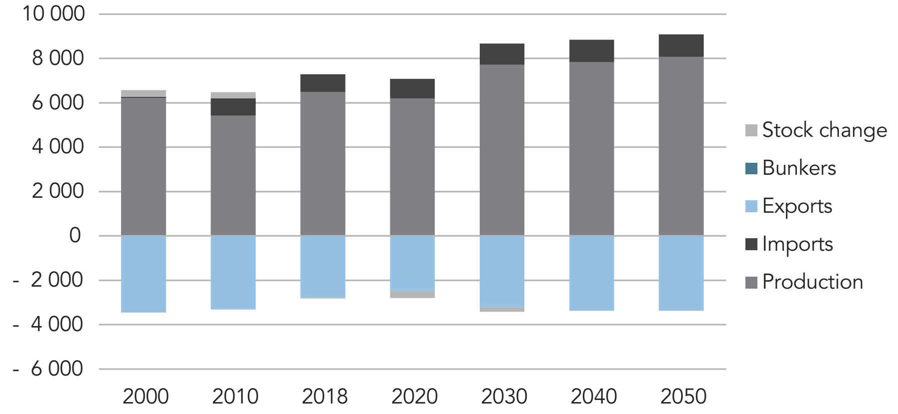
Natural gas in the Reference scenario

Figure 3-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)



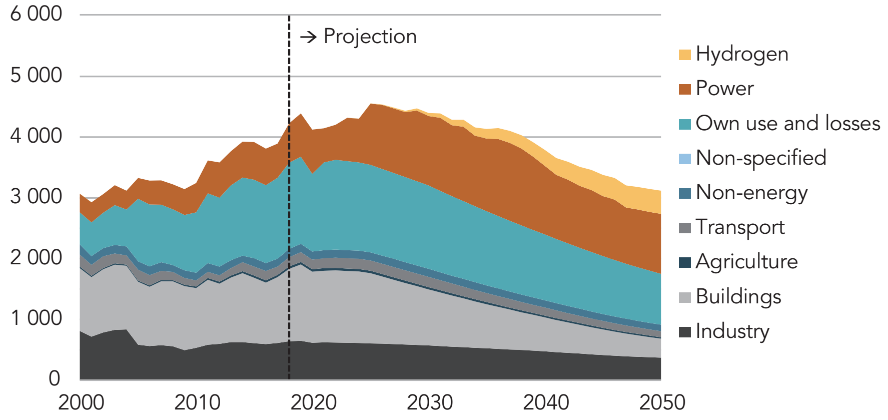
Sources: EGEDA, APERC analysis.

- Natural gas consumption grows 28% to fuel rising electricity demand and aligns with rising production of both oil and natural gas. Power burn of natural gas doubles as low-cost gas feedstocks meet rising electricity demand and partially make up for the phase-out of coal-fired generation.
- Own use demand peaks in 2035 as oil sands producers embrace efficiency to lower the costs of operations and carbon compliance. Emerging emissions reduction technologies, such as steam-solvents and methane co-injection, are instrumental in improving the natural gas intensity of in-situ oil sands production. A structural shift towards dilbit production, at the expense of synthetic crude oil[1], also plays a role in reducing gas demand at oil sands mining projects.
- In the face of a moderate adoption of heat pumps, natural gas continues to play an important role in heating buildings.
- Industrial gas demand falls nearly a tenth due to falling pulp and paper activity and electrification of iron and steel. Demand to generate hydrogen from natural gas starts in 2025 and rises to 117 PJ by 2050.
- Competition with low-cost production results in net pipeline trade continuing its historical decline until 2040, with net trade settling at around 2.6 Bcf/d.
- LNG exports rise on the back of two LNG Canada phases to reach 3.7 Bcf/d in 2032. Competition from significant incumbents, like the US and Qatar, prevents additional LNG export markets gains in the long-term. However, successful execution of a large-scale LNG export supply chain could manifest more project development, lifting export and production past the levels illustrated in this report.
- Growing supply requirements domestically and LNG export requirements together lift gas production to almost 21 Bcf/d by 2050.

[1]Note: Shipping oil sands bitumen production requires reducing its viscosity. Facilities do this by creating diluted bitumen (dilbit) or upgrading bitumen into synthetic crude oil. Because upgrading is an energy and emission-intensive process, and a structural shift towards dilbit production reduces the energy use and emissions of the oil sands.

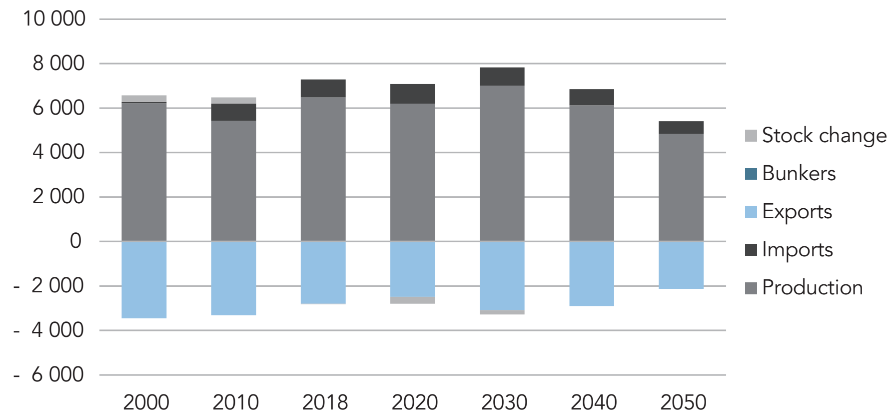
Natural gas in the Carbon Neutrality scenario

Figure 3-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

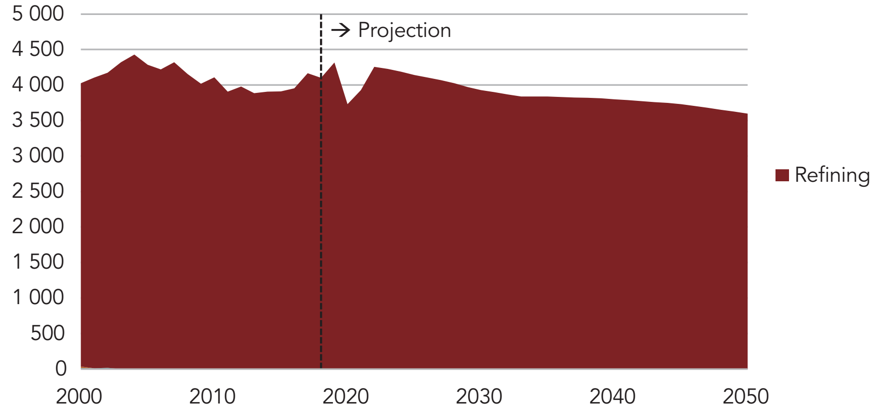


Sources: EGEDA, APERC analysis.

- After peaking in 2025, natural gas consumption falls a quarter from 2018 levels, as a tripling of the emissions price encourages investments in efficiency and fuel-switching and declining gas production lowers demand in the own use sector.
- Gas use in power increases a third overall but peaks in 2037, falling almost a quarter from this height. The start of CCS in 2030 insulates gas demand from higher carbon pricing, while unabated gas is almost phased out of generation.
- Higher demand for hydrogen results in higher transformation of natural gas, via CCS-equipped steam-methane reforming, to 380 PJ in 2050, which is three-times REF levels.
- Buildings gas demand falls three-quarters as retrofit standards, net-zero-ready codes and higher emission price signals encourage higher heat pumps adoption, which electrifies most heating requirements. However, Canada's cold climate and legacy buildings require some use of natural gas in 2050.
- Lower fossil fuel production and efficiency improvements brought on by higher emissions compliance costs reduce own use gas by two-fifths from 2018 levels and half of the REF levels by 2050.
- By 2050, lower US demand for natural gas drags net pipe exports down to 1.5 Bcf/d, and a smaller global gas market reduces LNG to 2.8 Bcf/d in 2050, a quarter below REF levels. Declining exports and domestic demand lower production to 13 Bcf/d, two-fifths below REF.
- The role of natural gas in a carbon-neutral global economy is contingent on the successful mitigation of methane leakages in the natural gas supply chain. Failing to contain these emissions would prompt global consumers to move away from natural gas in a carbon-neutral pathway. Canada is committing to reducing upstream methane emissions by 40 to 45% below 2012 levels by 2025 and 75% by 2030.

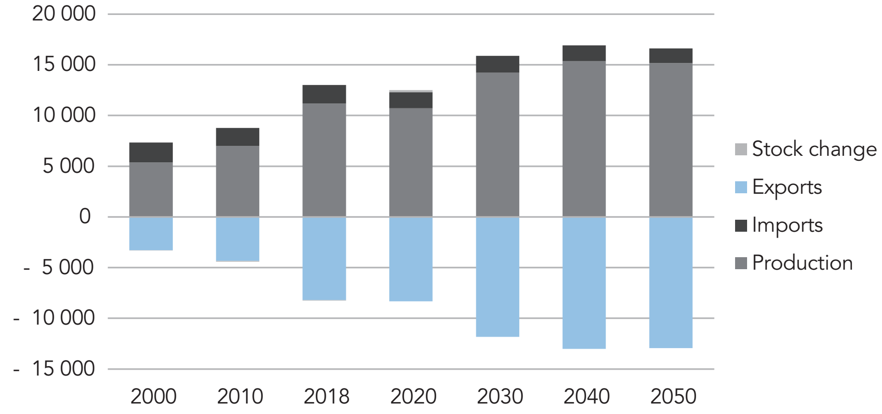
Crude oil and NGLs in the Reference scenario

Figure 3-33. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-34. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

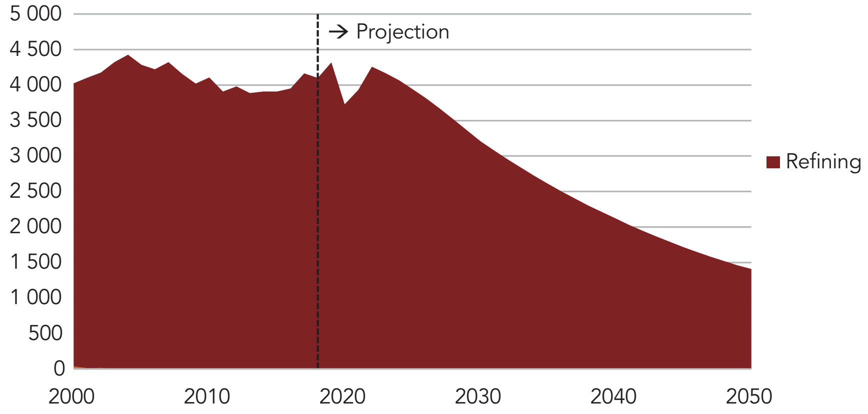


Sources: EGEDA, APERC analysis.

- Crude oil use in Canada is predominantly by refineries to make refined products for both domestic use and export. After falling 14% due to lower demand during the onset of the coronavirus, refinery runs briefly recover close to pre-pandemic levels. However, efficiency gains, emanating from manufacturing fuel standards and higher EV adoption, reduce domestic refined product demand, which pushes refinery runs down by an eighth relative to 2018 levels.
- Canadian refineries are built to run on a myriad of crude types, including some that are not produced domestically. Thus, despite having a large surplus of production beyond its demand needs, Canada imports over a third of its crude requirements. This share remains stable over the outlook period, but declining runs reduce imports by a fifth. A reconfiguration of Canadian refineries to process heavier domestically-produced oil could reduce crude imports, but the different product yield could require some offsetting refined product imports.
- Low utilisation rates by refineries could facilitate a reduction in refinery capacity in this scenario.
- Production quickly rebounds from the pandemic and increases to 6.6 Mb/d in the 2040s on the back of significant increases in oil sands production. Exports increase by over 50% as almost all incremental production increases are exported.
- Production will begin to exceed the current schedule of pipeline capacity in the late 2020s. However, the debottlenecking of existing pipelines could likely circumvent the significant opposition that Canada faces in commissioning newbuild pipelines and expanding the oil sands resource.

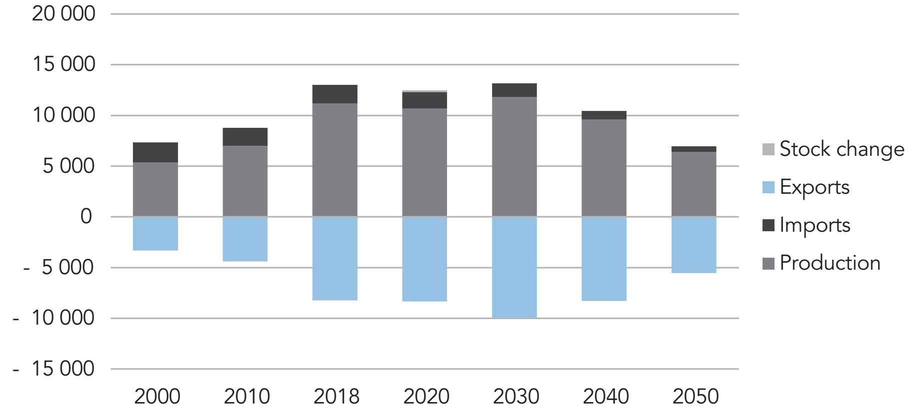
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 3-35. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-36. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

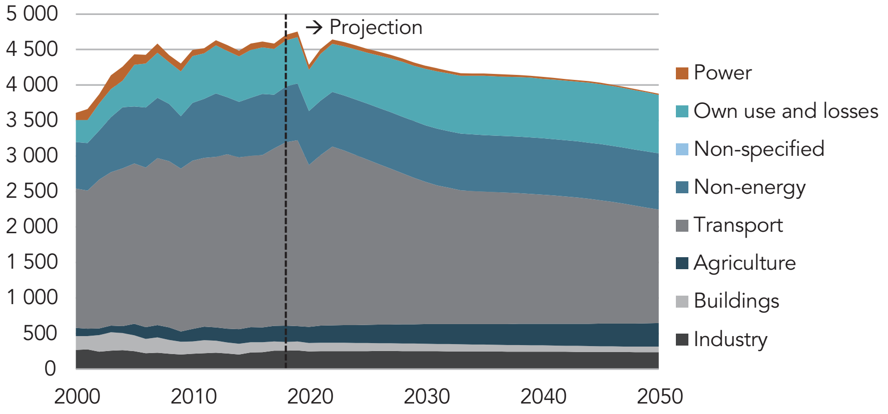


Sources: EGEDA, APERC analysis.

- Efficiency gains and higher electrification of transport results in declining refined product use both at home and abroad, which reduces refinery runs of crude oil and NGLs by two-thirds in CN.
- Imports continue to make up two-fifths of the Canadian crude oil supply, but declining refinery runs lower import levels by 70%.
- The embrace of carbon neutrality across the globe causes Canadian oil production to peak in 2024 and fall over two-fifths to 3.8 Mb/d. Exports fall a third, highlighting the significant risk that carbon neutrality poses to investments in incremental crude oil export capacity.
- The climate impact of lifecycle emissions from oil sands production poses a significant downside risk to this *Outlook*. While the oil sands sector is committing to net-zero targets covering its operational emissions, this only covers around a quarter of lifecycle emissions. A push to include lifecycle product emissions into accounting frameworks when announcing climate targets could pose an existential threat to oil sands producers and other oil producers, resulting in both more expensive and lower oil production.

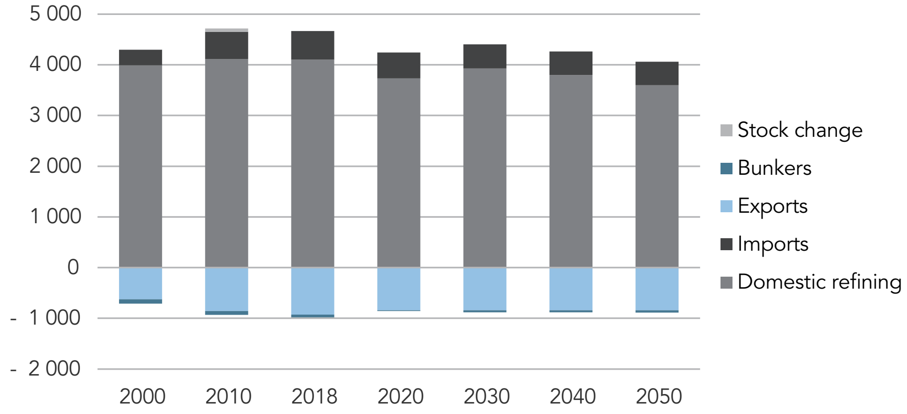
Refined products in the Reference scenario

Figure 3-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

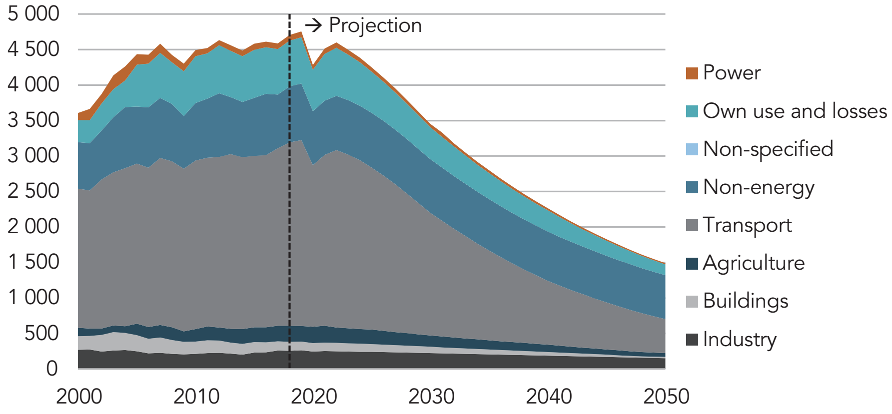


Sources: EGEDA, APERC analysis.

- Oil product demand falls a sixth on efficiency and fuel-switching, mostly in the transport sector, but consumption rises a third in the agriculture and own use sectors due to higher activity.
- The Clean Fuel Standard forces some of this fuel switching to occur at the distributor level, as refineries use biofuel blending to partly meet their emission intensity reduction requirements. Blending reduces the gasoline and diesel content in their product streams and leads to declines in the production of refined products by refineries. Blending rates begin to hit around 25% by 2030 in REF and refined product production falls 4% below 2018 levels in the same year.
- Oil product imports fall in line with domestic demand decreases, while exports are flat around 2020 levels, following lower crude runs than before the pandemic.
- About a fifth of domestic refining production is exported, while the rest meets the needs of the Canadian domestic market. However, Canada still needs to supplement around an eighth of its oil product demand with imports due to a mismatch in the types of fuels produced and consumed by refineries in the economy.
- Domestic refining production falls slightly over the projection on the back of lower oil demand. Falling demand will lead to lower utilisation rates of some refineries over the projection period, which could challenge the economics of some projects.

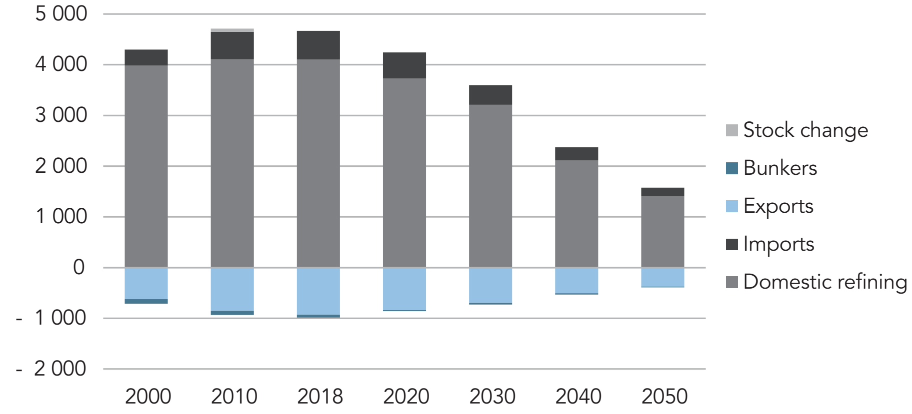
Refined products in the Carbon Neutrality scenario

Figure 3-39. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 3-40. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

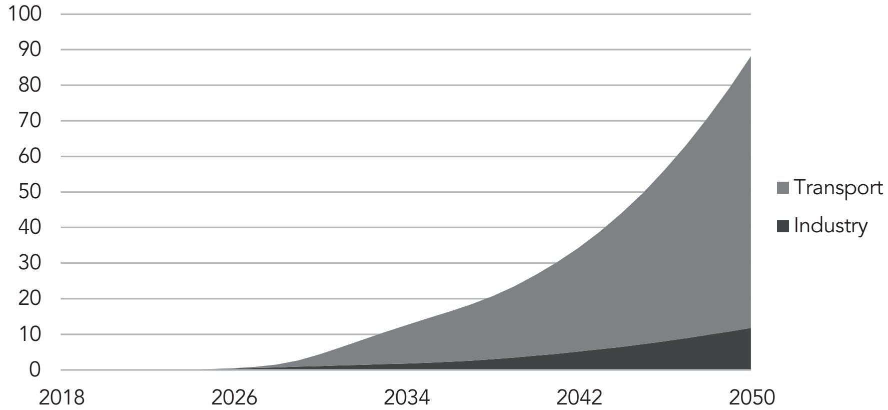


Sources: EGEDA, APERC analysis.

- Refined products demand falls two-thirds due to efficiency and fuel-switching throughout the economy, particularly within the transport sector. Transport declines make up two-thirds of the decline in refined product demand in CN.
- The significant uptake in ZEVs in the transport sector is instrumental in improving transport efficiency and lowering Canadian refined product demand in CN.
- A more stringent Clean Fuel Standard in CN results in more fuel switching at the distributor level, resulting in higher biofuel blending rates, upwards of 30%, starting in the 2030s. This reduces the content of gasoline and diesel in their fuel streams, resulting in lower consumption, and lowers refinery production of oil products. The aviation sector also looks to biojet fuel to supply more of its activity, which further reduces oil product use.
- Refinery output falls in line with domestic demand for refined products, about two-thirds over the CN. This is three-fifths below REF levels. Refined products imports also fall in line with domestic demand decreases.
- A global embrace of carbon neutrality reduces global refined product demand, which leads to a three-fifths reduction in exports over the projection period.
- The low utilisation of refineries in CN would likely necessitate the decommissioning of two-thirds of Canadian refinery capacity. The uptake of biofuels in CN would support the recommissioning of some refinery capacity into biorefineries.

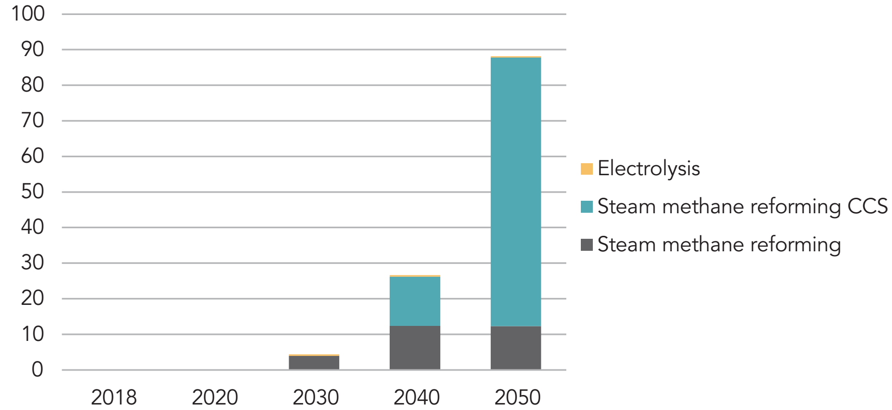
Hydrogen in the Reference scenario

Figure 3-41. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 3-42. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

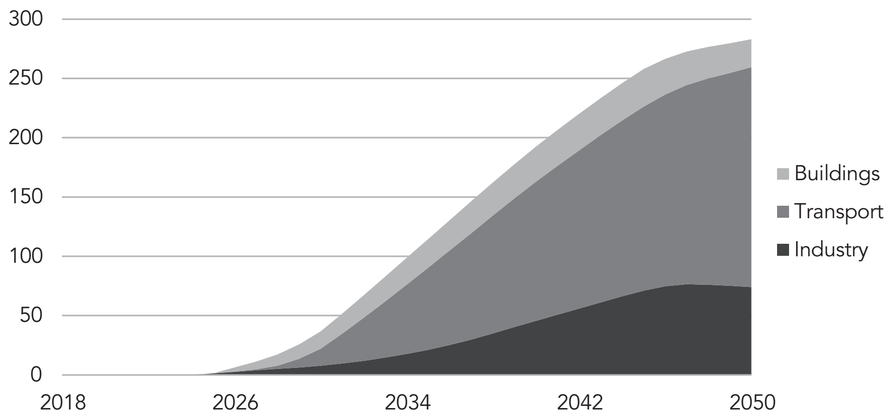


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- Hydrogen is currently produced by refineries for use as a feedstock in hydrocracking and hydroprocessing of oil and refinery products in both the refining and upgrading process. However, this *Outlook* only models the production and consumption of hydrogen as an energy carrier in the end-use sectors.
- Canadian end-use demand for hydrogen emerges slowly in the 2020s and grows to around three quarters of a million tonnes, or almost 90 PJ, by 2050.
- Almost all Canadian (non-refinery) production over the projection occurs via steam methane reformation. Equipping steam methane reformation with CCS begins in the 2030s and makes up most of Canada's hydrogen production by 2050. Electrolysis remains a marginal provider of hydrogen over the projection.
- The *Outlook* assumes that Canada only produces hydrogen for domestic consumption over the projection period. Canada does possess low-cost fossil fuel feedstocks and well-developed rail-driven liquids supply chains that could move hydrogen for export to multiple ports if global hydrogen demand takes off. While pipelines could also play a role in gaseous transportation, overcoming the opposition to newbuild, large-scale infrastructure projects would be challenging.

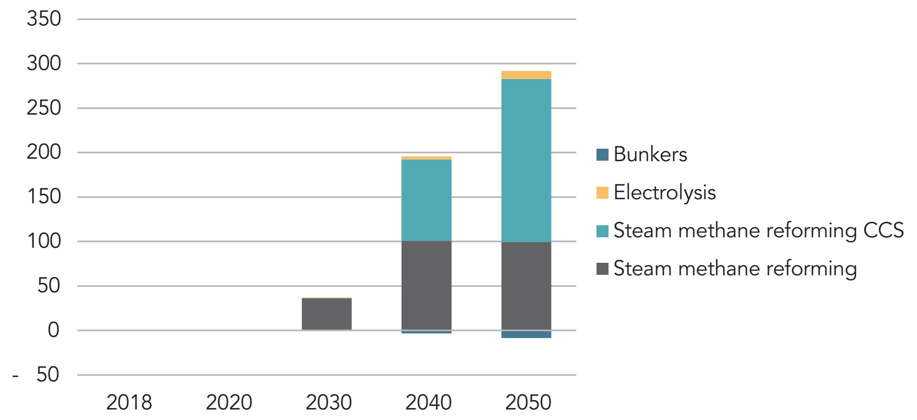
Hydrogen in the Carbon Neutrality scenario

Figure 3-43. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 3-44. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

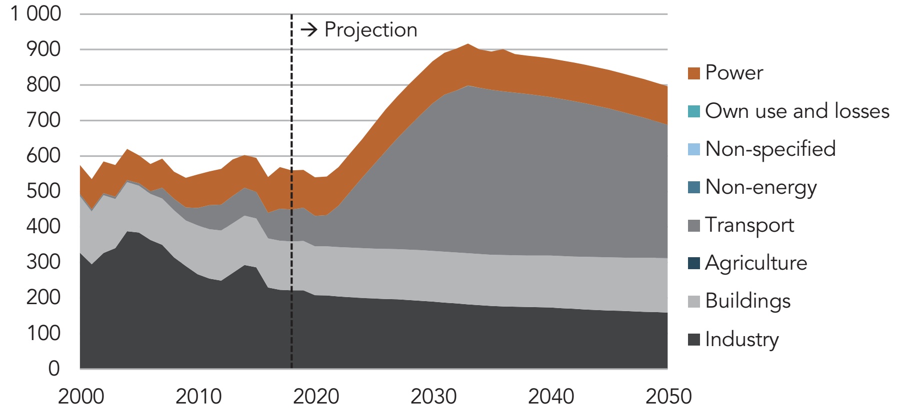


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- Hydrogen emerges more rapidly in the 2020s than in REF, growing to over 2.5 Mt, or more than 280 PJ, by 2050.
- The blending of hydrogen into gas distribution networks starts in 2026, rising to 20% in volume (7% by energy content). Higher values will require significant investments in infrastructure and appliances due to hydrogen-specific challenges. Transport and industrial applications grow more quickly in CN due to the lower costs of hydrogen fuels.
- This *Outlook* does not model hydrogen use in the own use sector. However, hydrogen could play a key role in reducing operational emissions in the oil and gas sector, particularly the oil sands, by replacing natural gas in process heat applications. Use in the oil sands alone has potential to increase hydrogen use to multiples of the levels shown here.
- Electrolysis accounts for more supply than in REF, though it is still relatively low at 3.1% of hydrogen production in 2050. Steam methane reformation remains dominant.
- Canada has significant potential for hydrogen demand and supply beyond the values shown here. In its Hydrogen Strategy, Natural Resources Canada estimates that hydrogen could meet 30% of Canada's end-use demand by 2050, and that Canada could become a top global supplier. Policy support through collaboration, innovation, and the establishment of regulatory frameworks, and the development of large-scale projects in regional hubs are required to illustrate the viability of the energy carrier.
- It is assumed that Canada only produces hydrogen for domestic consumption. Canada does possess low-cost fossil fuel feedstocks and well-developed rail-driven liquid supply chains to move hydrogen for export to multiple ports. Pipeline networks also exist, but opposition to transmission projects will challenge a pipeline-built supply chain for hydrogen. Competition in this emerging space will be fierce, as other APEC players, particularly Chile, have an incumbent advantage in producing and exporting green ammonia and hydrogen. Connecting Canadian hydrogen to export markets would lift production closer to its full potential.

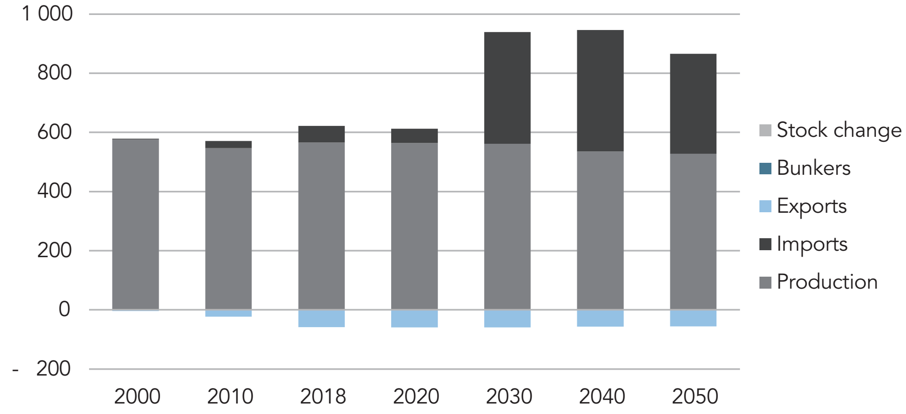
Bioenergy in the Reference scenario

Figure 3-45. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 3-46. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)



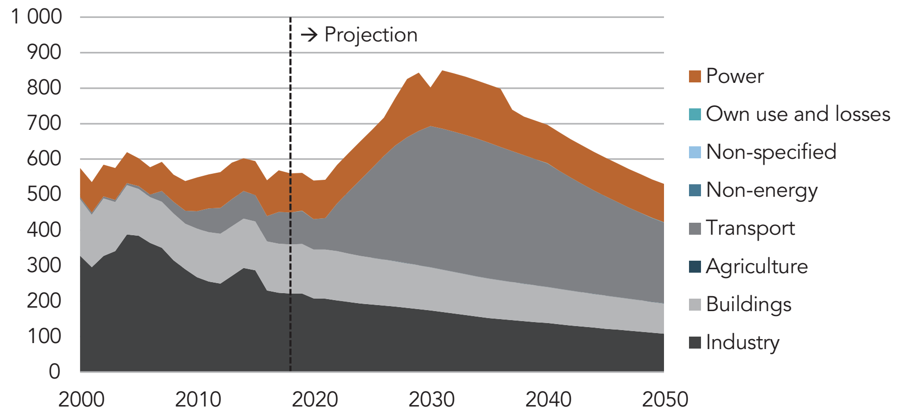
Sources: EGEDA, APERC analysis.

- Canada's liquid Clean Fuel Standard drives renewable fuel demand up significantly in the transport sector, as refineries predominantly turn to biofuel blending to comply with the standard. Blending rates rise over 25% by 2030.
- Blends of ethanol and biodiesel in the gasoline and biodiesel fuel streams take off in the 2020s, peaking total renewable fuel demand at two-thirds its 2018 levels in 2033. Demand declines thereafter as demand for the gasoline and diesel streams decline on the back of higher vehicle efficiency. Declining pulp and paper activity also plays a factor in this decline.
- Canada relies heavily on biofuel imports to meet its domestic fuel standard requirements and, according to the US-based Renewable Fuels Association, was the largest ethanol market in the world in 2020. Almost half of the Canadian ethanol is imported (from the US), and according to EGEDA, more than 80% of its biodiesel supply is also imported.
- REF renewable fuel imports peak in 2033 at nearly eight-times current levels, on the back of growing demand for biofuels for blending. Imports decrease a fifth from this peak as efficiency reduces the demand for liquid oil products and their associated biofuels. Production remains relatively stable throughout, decreasing 6.9%.
- Sourcing supply to comply with these mandates could be difficult, particularly if other, larger economies began to embrace biofuels in a similar fashion to Canada. To mitigate the risks of renewable fuel disruptions and rising costs to the gasoline and diesel fuel streams, Canada could expand its domestic renewable fuel production capacity or convert older refineries into biorefineries, a process that is currently ongoing for the decommissioned Come By Chance refinery.
- In the power sector, renewable fuel use increases slightly due to higher usages of solid biomass. Other sectors use of renewables declines. In buildings, wood and wood pellet use declines due to the emergence of alternatives, like heat pumps. Industry biomass use declines mostly track pulp and paper activity, which declines over the projection.

Note: Biofuel production will likely be higher than shown here. For example, the Come By Chance refinery sale and plan to convert into a biorefinery occurred after the analysis portion of this report.

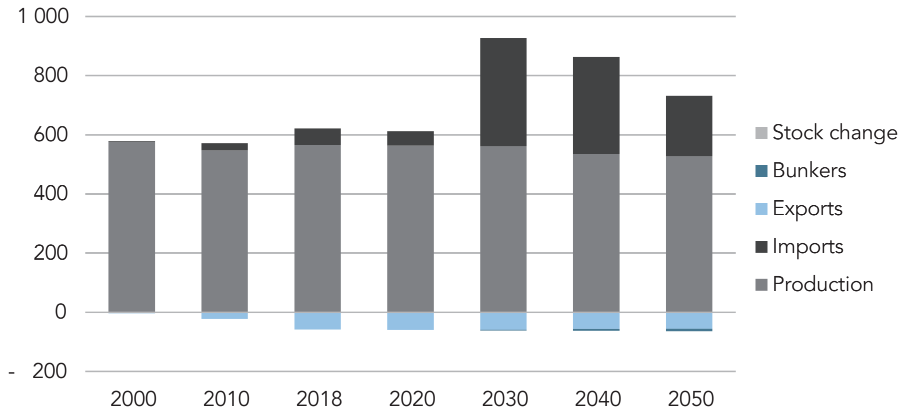
Bioenergy in the Carbon Neutrality scenario

Figure 3-47. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 3-48. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

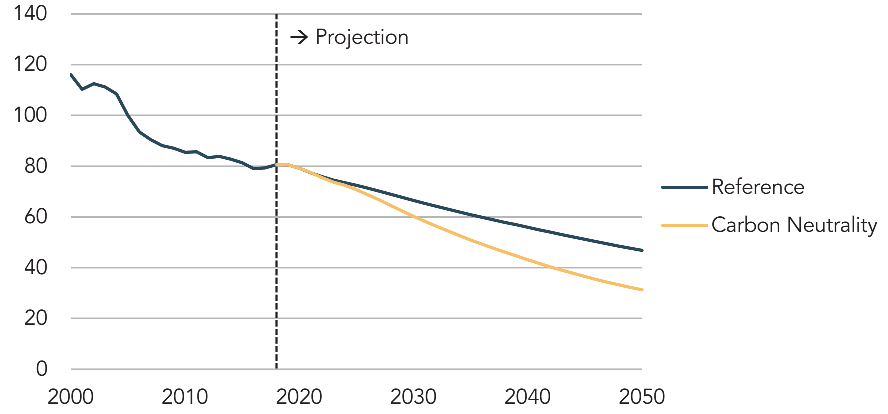


Sources: EGEDA, APERC analysis.

- Blending rates inch higher in CN, reaching around 30% of the fuel stream by 2030. However, higher ZEV penetration, more stringent efficiency standards and modal switching reduces demand for liquid fuel blends, which in turn reduces renewable fuel demand in CN, even in the face of higher blending rates.
- CN renewable fuel imports peak earlier than REF, in 2030, at close to seven-times higher than current levels. Imports nearly halve from this peak as falling demand for liquid refined products reduces biofuel demand requirements. Like REF, production remains relatively stable throughout, decreasing 6.9%.
- In the power sector, renewable fuel use increases slightly due to higher usages of solid biomass. Other sectors use of renewables declines on the back of lower biomass. In buildings, wood and wood pellet use declines due to the emergence of alternatives, like heat pumps, and higher efficiency in appliances and building envelopes brought on by the net-zero-ready newbuild and retrofit standards. Industry biomass use declines still track pulp and paper activity but fall lower due to higher efficiency than REF, and electricity and hydrogen out-competing biomass in some applications.

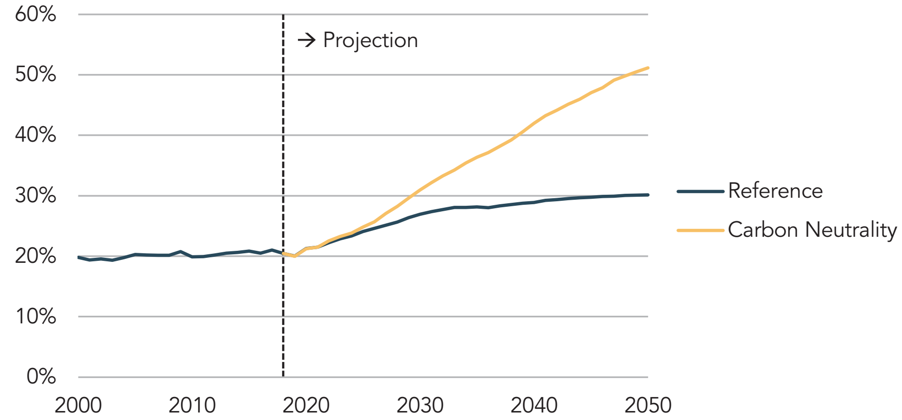
Energy intensity and modern share renewables share

Figure 3-49. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 3-50. Modern renewables share in REF and CN, 2000-2050



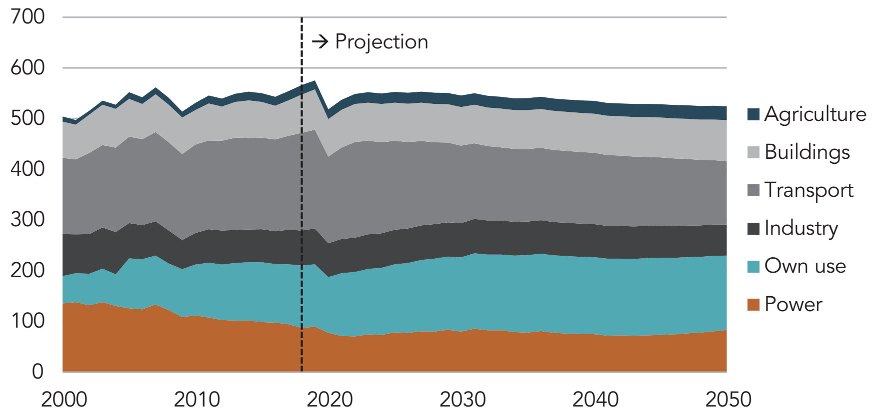
Sources: EGEDA, APERC analysis. Note: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- Canada's energy intensity improved almost a third in the last two decades, supported by strong GDP growth, energy efficiency improvements in the buildings and transport sectors, and a structural shift in the economy towards less energy-intensive service activities. However, lower economic growth, the surge in emission-intensive oil and gas activities, and stagnating efficiency in transport, resulting from an affinity for larger passenger vehicles, has plateaued energy intensity in recent years.
- Canada continues to decouple energy use from economic activity in both scenarios. In REF, energy intensity declines at the historical rate, falling to less than half (47%) of 2005 levels by 2050, or three-fifths of 2018 levels. These improvements are partially driven by rising efficiency standards in both passenger and heavy-duty vehicles, rising EV adoption at the expense of ICE vehicles, and rising efficiency in the building sector.
- In CN, energy intensity declines to 31% of the 2005 level in 2050. Energy intensity in 2050 is only two-fifths of the 2018 level. This is supported by a diminution of ICE vehicles, a net-zero-ready building standard, building retrofits, and efficiency improvements throughout the industry and own use sectors.
- Canada's energy efficiency efforts help APEC achieve its goal of reducing energy intensity by 45% below 2005 levels in 2035 in both scenarios.
- Canada's share of modern renewables has remained high, but stable, due in part to the inherent role that hydroelectricity has historically played in fueling its economy.
- The adoption of the Clean Fuel Standard and further penetration of both wind and solar help Canada increase its share of modern renewables from 20% to over 30% in REF and over half in CN.
- In both scenarios, Canada's higher use of modern renewables helps APEC achieve its goal of doubling APEC's share of modern renewables over 2010 levels, from 6% to 12%, by 2030.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

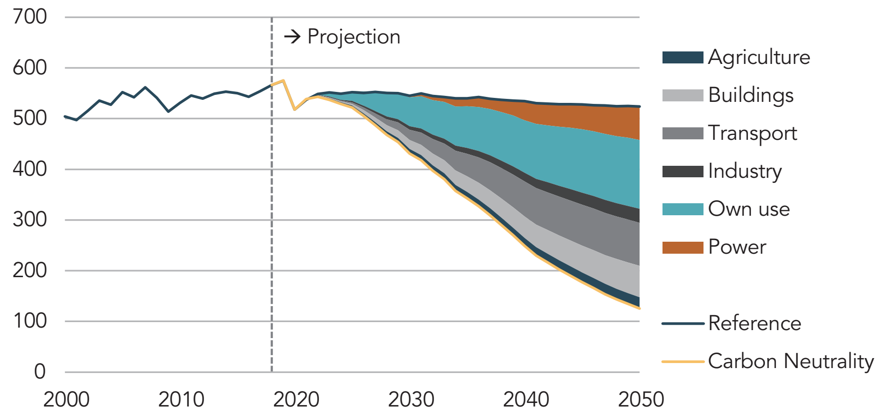
Gross CO_2 emissions

Figure 3-51. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 3-52. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

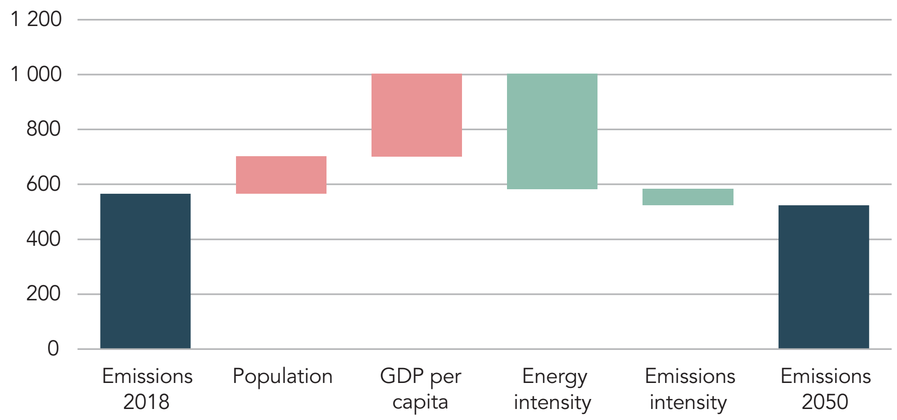


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Canada's emissions fall 10% in 2020 as lower domestic mobility reduces transport activity and lower global mobility causes a drop in energy prices significant enough to curtail fossil fuel production.
- Efficiency improvements and electrification, particularly in industry, buildings, and transport, limit emissions recovery to 3.9% below the 2019 peak. Emissions decline 7.2% over the projection period.
- Emission declines from the coal phase-out are limited by the doubling of gas use in the power sector over the projection period.
- Canada's combustible emissions trajectory is not consistent with achieving its NDC of reducing emissions by 40 to 45% below 2005 levels in either scenario. In 2030, combustible emissions are equal to 2005 levels in REF and 22% below in CN. Canada reduces emissions within its NDC target range by 2036 in CN. While reducing non-combustible emissions could help achieve the target, more ambitious or front-loaded policy is required for combustible emissions to fall in line with the NDC. The rapid deployment of hydrogen in the own use sector, for example, could be sufficient to help Canada hit its 2030 target.
- Canada's emissions are 125 Mt by 2050 in CN. Complying with carbon neutrality would require offsetting these emissions or achieving an equivalent sequestration using other capturing methods.
- Canada has significant carbon sequestration potential, ranging from 206 Gt to 1 445 Gt onshore, and over 2 000 Gt, including offshore. If CCS technology can manifest commercial viability at a large scale, Canada could sequester the *Outlook*'s worth of emissions in either scenario and aid in the sequestration of emissions from other economies.
- Own use makes up a quarter of emissions reductions in CN. This is partly due to lower fossil fuel production and improved efficiency, but also a significant deployment of CCS to capture emissions from fossil fuel production in Western Canada.

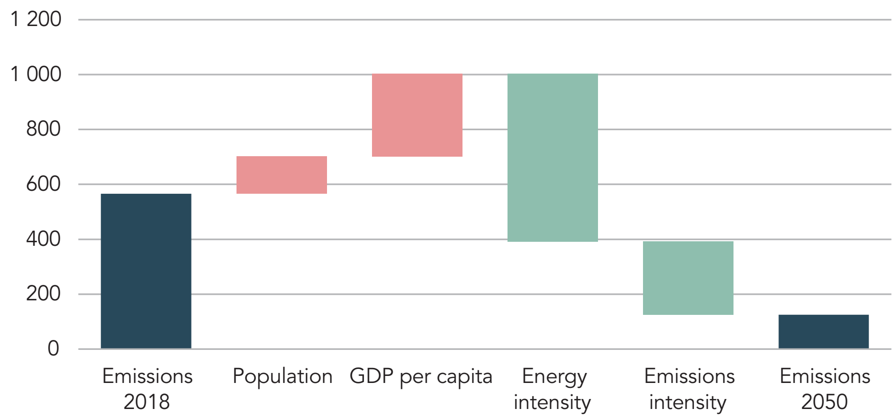
Components of CO_2 emissions

Figure 3-53. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 3-54. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Population and GDP per capita growth contribute to significant upward pressure on CO_2 emissions. Canada's assumed growing population would increase CO_2 emissions by 134 Mt, while increases in incomes would lead to CO_2 emissions increasing by an additional 302 Mt out to 2050.
- Energy intensity and emissions intensity improve in both scenarios which leads to a reduction in CO_2 emissions through the projection period. The differing policy assumptions and market trends leads to different levels of energy efficiency, technology diffusion, and fuel choices.
- In REF, energy efficiency improvements reduce CO_2 emissions by 412 Mt. While CO_2 emissions are relatively flat in this scenario, energy efficiency plays a key role in limiting further increases. Emissions intensity of energy consumed contributes a 64 Mt reduction, as end-users switch away from carbon-intensive fossil fuels and towards lower-emitting alternatives.
- More stringent climate policy in CN increases energy intensity declines by 50% to 609 Mt and emissions intensity reductions fall by almost 3.8 times more than in REF. The latter reflects a further decarbonisation of Canada's fuel mix through fuel switching to lower-emitting energy alternatives, and the rising coverage of CCS to capture combustible emissions from fossil fuels.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

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4. Chile

Highlights

Demand

- In the Reference scenario (REF), energy demand grows 30% from 2018 to 2050, which is lower than the period 2000-2018 (38%).
- In the Carbon Neutrality scenario (CN), energy demand grows only 6.3% (2018-2050). Energy efficiency, fuel switching, and technological innovations curb demand growth in CN.
- The share of fossil fuels is important in both scenarios, demonstrating how challenging it is to displace these fuels in Chile.
- The industry sector is the largest energy consumer. The share of industry energy demand grows in both scenarios from 38% in 2018 to 47% in REF and 55% in CN. Increased mining activities, particular for rare minerals, contribute to growing industry energy demand.
- On the other hand, the transport sector share of energy demand declines from 34% in 2018 to 25% in REF and 19% in CN.
- The buildings sector maintains its share of energy demand around 23%.

Supply

- Total energy supply increases by more than 13% in REF (2018-2050). This increase is explained mainly by the growth of renewables, almost doubling from 2018 levels. The share of fossil fuels declines from 71% in 2018 to 50% in 2050.
- Chile remains an energy importer in both scenarios. However, imports decline in REF.
- In CN, energy supply peaks in the mid-2020s, following declining energy demand.
- Exports of green hydrogen, a goal of the national hydrogen strategy, start in 2030.

Power

- Electricity generation grows from 82 TWh to 157 TWh in REF (2018-2050).
- The share of electricity generated from solar and wind grows from 11% in 2018 to 40% in 2030, then to 67% in 2050 in REF.
- In CN, generation reaches 198 TWh in 2050. The share of solar and wind generation increases to 77% in 2050.
- Coal is completely phased out by 2037 in REF, and by 2031 in CN.
- Although the capacity of oil-based electricity generation is retained, the share of oil in electricity fuel mix is reduced by 2040 in both scenarios.

CO_2 emissions

- In REF, energy related CO_2 emissions fall from 86 million tonnes to 60 million tonnes by 2050.
- Power sector CO_2 emissions fall from 33 to 7.6 million tonnes CO_2 due to fuel switching and renewables.
- Industry sector CO_2 emissions rise from 14 to 20 million tonnes, as it becomes the second largest emitting sector by 2050.
- In CN, CO_2 emissions fall to 31 million tonnes in 2050.
- To reach "full" carbon neutrality in 2050, removal by CO_2 sinks through natural or technological means could offset gross emissions. This could be an opportunity for collaboration with APEC member economies.

About Chile

- Chile is one of two APEC economies that is in South America. It extends from the Antarctic in the extreme south to the Atacama Desert in the north. Chile spans three continents, with its sovereign territory mainly on the South American continent, its westernmost border on Easter Island in Oceania, and its southernmost region in Antarctica. Peru is to the north, Bolivia and Argentina to the east, Antarctica to the south, and the Pacific Ocean to the west. Chile has a land area of 756 102 km^2, with an average width of 175 km and a coastline of 6 435 km.
- Chile has 16 regions headed by elected regional governors. Additionally, the president of Chile is represented in the region by a president-appointed regional delegate. In 2018, the population reached 18.7 million, with 40% residing in the Santiago metropolitan region.
- Chile has been a member of OECD since 2010 and has been considered as a high-income economy by the World Bank since 2011.
- The Chilean economy model is free-market based and is considered one of the most robust in South America. Chile is the fifth-largest energy consumer of the Americas, but unlike most other large economies in the region, it is only a small fossil fuel producer. Despite the availability of vast solar and wind energy resources and the rapid shift towards cleaner energy over the past decade, Chile is dependent on energy imports. Recent exploratory drilling in the Magallanes Basin, a shale formation, may increase Chile's domestic oil supply. There are an estimated 2.4 billion barrels of shale oil in the Magallanes Basin.
- The mining sector is a key part of Chile's economy and contributes to almost 10% of the GDP and over half of the total exports. The mining sector relies heavily on fossil fuels.
- Chile is a large producer of lithium, and other critical materials, which are increasingly in demand.
- Chile has the largest known uranium reserves. Chile's conventional uranium resources are estimated at 1.40 kilotonnes. These resources are recoverable at a price of USD 260 per kilogram at a recovery factor of 75%. However, no new uranium resources have been identified since 2011.

Table 4-1. Chile statistics, 2018

	2018	APEC share	APEC ranking
Population	18.7	0.6%	16
GDP	482.8	0.7%	16
TPES	1 635.5	0.5%	15
Production	570.6	0.2%	17
Imports	1 151.5	0.9%	16
Exports	44.9	0.0%	20
Electricity generation	82.3	0.5%	15
Heat production	–	–	–
CO_2 emissions	86.0	0.4%	15

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 4-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	–	–	–	–
Natural gas	–	–	–	–
Oil	–	–	–	–
Uranium	1 400	–	–	–

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Scenarios in the 8th Edition

- The *Outlook* considers two hypothetical scenarios that are intended to provide material to support APEC member economies in decision-making.
- The COVID-19 pandemic has added uncertainty, particularly in the short-term, to decision-making and planning. The long-term effects of COVID-19 on human behavior such as the increase of teleworking and reduction of commuting have not been included as they are still highly uncertain.
- **The Reference scenario (REF)** for Chile reflects recent trends and current policies in place or planned to capture the evolving nature of the energy system. REF tries to identify potential risks and problems that might arise if the energy sector develops according to that trend, especially if some goals and domestic strategies such as the NDCs and the National Adaptation Plan against Climate Change are considered. REF serves as the baseline against which the alternative scenario can be compared.
- **The Carbon Neutrality scenario (CN)** investigates a potential pathway for the development of the Chilean energy system to reach carbon neutrality by 2050 that can help to achieve the goals of the Chilean commitments. This scenario is guided by the objectives of the National Energy Policy 2015-2040 and the National Adaptation Plan against Climate Change. Several mitigation measures were considered to reach carbon neutrality.
- CN illustrates the additional transformation required to supply energy under the aspirations of reaching a carbon neutral energy system. CN does not represent APERC's recommendation or advocacy for a pathway or set of policies.
- Remaining gross CO_2 emissions represent the scale of emissions that would need to be offset with negative emissions from natural sources (e.g., forests) or technologies (e.g., direct air capture) in order to reach zero CO_2 emissions in 2050.
- CN is performed as a bottom-up analysis by making assumptions about behavioral changes, efficiency improvements, fuel switching, technology, commercialization, and deployment, and potential policy guidelines with more emphasis on decarbonisation than REF.

Table 4-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Energy policy context and recent developments

- **Carbon neutrality pledge.** The Chilean government announced in June 2019 its aim to reach carbon neutrality by 2050. Since 2022, this goal is mandatory, according to the new Climate Change Framework Law.
- **Coal-fired power plant shutdown.** 3.63 GW of coal-fired power plants will shut down before 2025, which is equivalent to 65% of the total coal electricity capacity. Operation of coal power plants will cease by 2040 at the latest according to official commitment. Nonetheless, the recently published update of the long-term Energy Policy of Chile, commits efforts to work towards a total coal-fired power plant shutdown by 2030. This effort is supported by the new government administration in place since March 11, 2022.
- **National electromobility strategy.** Outlines actions to be taken in the short- and medium-term to meet the government's goal of having 100% sales of light and medium vehicles and 100% of new incorporations of urban public transport being zero emission vehicles by 2035. By the end of 2050, 58% of privately-owned vehicles will be powered by electricity.
- **NDC update, and emission budget.** A new absolute emission target: a maximum emission level in 2030 of 95 million tonnes CO_2 (excluding LULUCF). A GHG emission budget of 1 110 million tonnes CO_2 between 2020 and 2030, and GHG emissions peaking in 2025. The new target is 26% lower than the 2016 NDC agreement.
- **Energy efficiency bill.** The law outlines a long-term energy efficiency plan, to be updated every five years. The new law promotes management of energy by large consumers and delivers information to home buyers regarding housing energy requirements and establishes vehicles energy standards.
- **Hydrogen strategy for Chile.** The design and implementation of a development policy for hydrogen would allow the displacement of fossil fuels on a large scale in the power generation, transport, and industry sectors.

Note: Policy context and notable developments are current as of October 2021.

Key assumptions for Chile

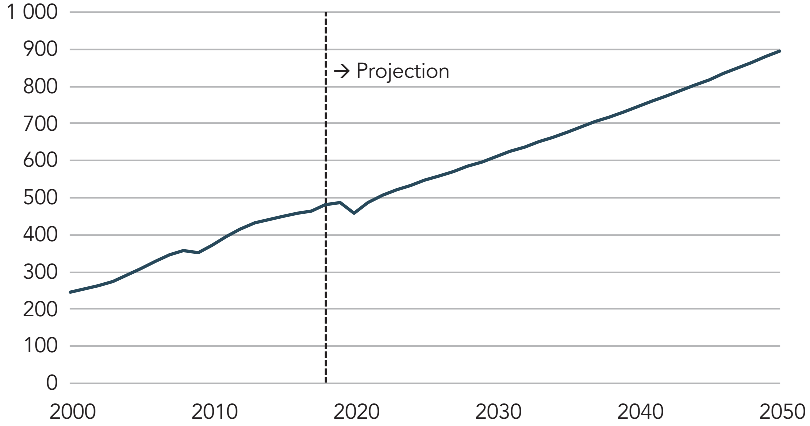
Table 4-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: World Population Prospective 2019 (UN medium). • GDP: World Bank (historical), MEF (Pre-electoral Projection 2016-2021), APERC Solow-Swan model.	• Same as REF
Buildings	• No structural changes. • Energy Efficiency improvements in appliances (10% by 2050). • Fuel switching from biomass to LPG.	• Sustainable buildings, heating electrification, improvements in insulation of buildings (20% of energy savings by 2050). • Solar water heating. • Cooking electrification in the residential sector. • Insulation improvement of vulnerable homes: 20 000 homes per year.
Industry	• Energy management systems: annual savings of 0.6%. • Small amount of hydrogen for steel sector beginning in 2035. • 0.5% p.a. improvement in energy efficiency for GVA data subsectors and aluminium, and pulp and paper, and 0.5% p.a. movement from fossil fuels to biomass in the pulp and paper sector. • Electrification is 0.5% per annum in other sectors. • Additional effort to shift from diesel to electricity in the mining sector (0.25% p.a). • Fuel switching in the chemical sector to electricity, biomass, and hydrogen starting in 2025.	• Electrification machine drives in copper mining reach 65% of the total energy consumption for motor uses in 2050. Other industries reach 54% by 2050. • Hydrogen for steel and chemical sectors begins in 2030. • Material efficiency in steel, cement, and chemicals. • Mining is assumed to have 1% p.a. additional growth than the reference scenario due to ramping up of rare earths production. • 1.0% p.a. improvement in energy efficiency for most subsectors. Steel only 0.5% p.a. and cement 0.5% p.a. (BAT to existing).
Transport	• 20% electric public transportation and 21% of taxis by 2050. • 21% private vehicles become electric by 2050. • 21% commercial vehicles become electric by 2050.	• 100% of urban public transport vehicles will be electric by 2050. • 40% of private vehicles become electric by 2050.
Power and heat	• Close all coal power plants by 2040.	• Close all coal power plants by 2030.
Supply		• Chilean green hydrogen cost follows the trend shown in the National Green Hydrogen Strategy. • Chilean green hydrogen exports reaches almost 3 000 PJ by 2050. • H_2 production of the HIF and HyEX projects were considered.
Climate		• Carbon neutral by 2050

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

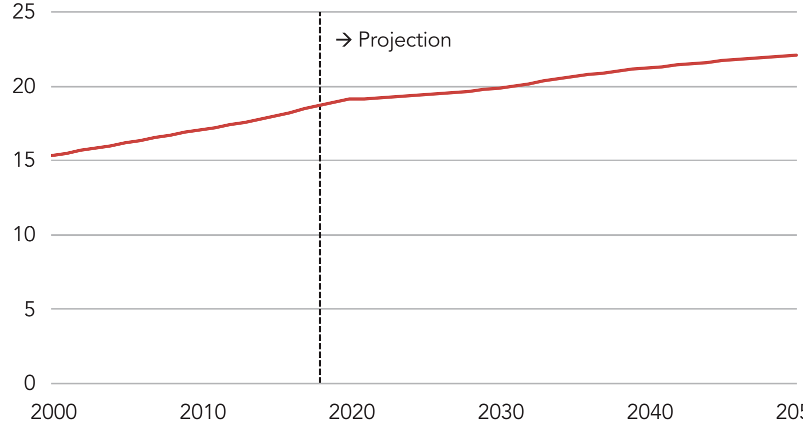
Macroeconomic backdrop

Figure 4-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 4-2. Population in millions, 2000-2050

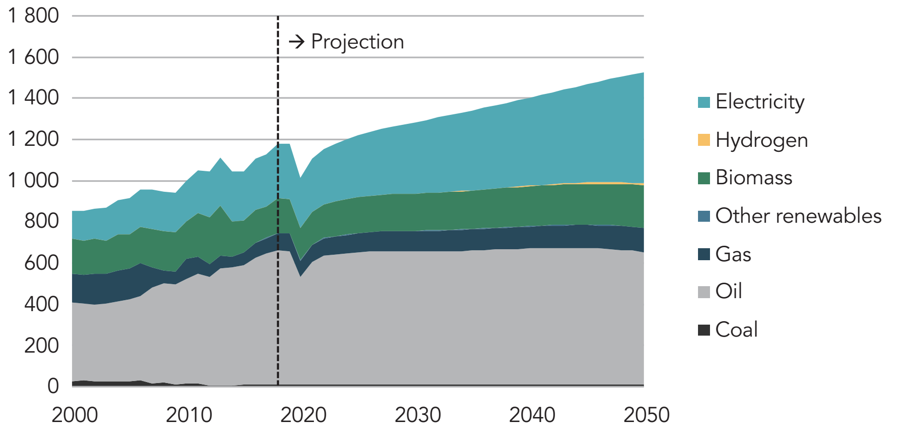


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- From 2000 to 2018, Chile's population grew by 20%. This rate was higher than the growth rate for the APEC region. From 2018 to 2050, it is estimated that population will grow 17%. In terms of the number of inhabitants, Chile grows from 18.7 million people in Chile in 2018 to 19.9 million by 2030, and 22.1 million by 2050.
- In 2020, Chile's GDP dropped due to COVID-19.
- Long-term GDP estimations follow OECD projections. The Chilean economy has been one the fastest growing economies in APEC. From 2000 to 2018, Chile's economy almost doubled in size. Economic growth is expected to decelerate during the projection period 2018 to 2050. Chile's economy will be 77% larger than the 2018 level in 2050. GDP and population are the main drivers of the energy demand projection in the scenarios that have been constructed.
- Even though the macroeconomic projections are the same in both scenarios as a simplifying assumption, global efforts to reach carbon neutrality might highly increase demand of critical minerals for electrification and impact the assumed economic growth in CN. Chile is the largest producer of copper and the second largest producer of lithium in the world. Nevertheless, the evolution of the global economy in a path toward carbon neutrality is uncertain.
- The evolution of Chile's GDP continues historical trends and major structural changes to the economy have not been assumed. However, the shifting of GDP from both industry and manufacturing to services continues, with the latter converging to two-thirds of GDP by 2050.

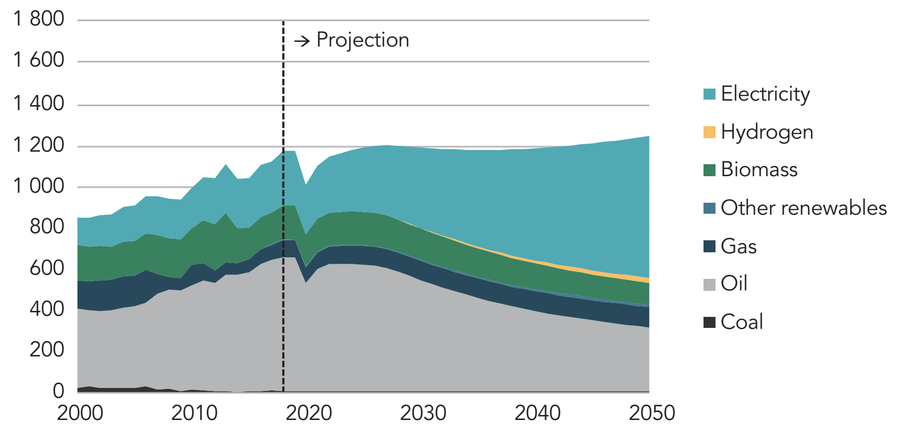
End-use energy demand

Figure 4-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 4-4. Energy demand in CN, 2000-2050 (PJ)

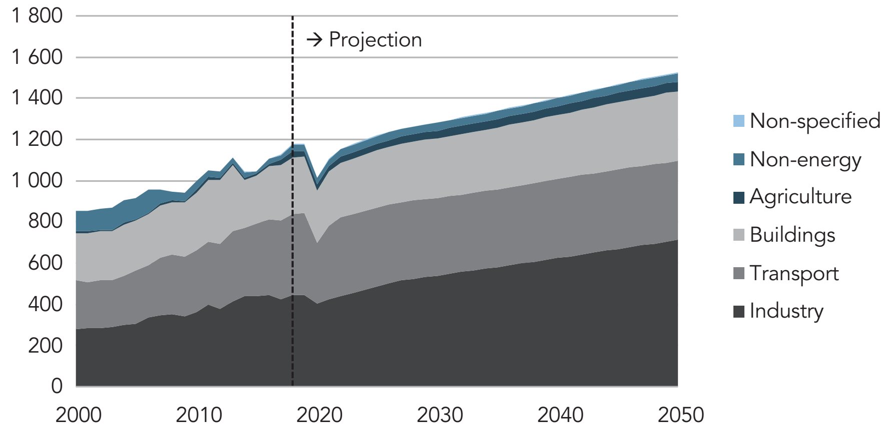


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- End-use energy demand trends are driven by macroeconomic trends, policies, and technological innovations.
- Prior to the projections, energy demand in Chile grew 38% (2000-2018).
- In REF, energy demand grows 30% (2018-2050). In CN, efficiency, fuel switching, and technological innovations curb the demand growth leading to only a 6.3% increase.
- Both projected growth rates are lower than the historical growth rate. The expected economic growth that drives energy demand offsets energy savings after 2040 in CN.
- The share of fossil fuels are important in both scenarios, demonstrating how challenging it is to displace these fuels in Chile. In REF, around 50% of the energy demand remains fossil fuels even as electrification increases. In CN, the share of fossil fuels approaches 33%.
- Hydrogen emerges as an energy carrier in both scenarios because of the implementation of the Green Hydrogen National Strategy. The share of hydrogen remains small with only 0.7% share in REF and 1.9% in CN (2050).
- Traditional biomass, mainly fuelwood, plays an important role in the historical energy mix, especially in the southern region of Chile. Demand is reduced in CN because of the replacement of fuelwood stoves with more efficient stoves and switching from biomass to LPG and electricity.

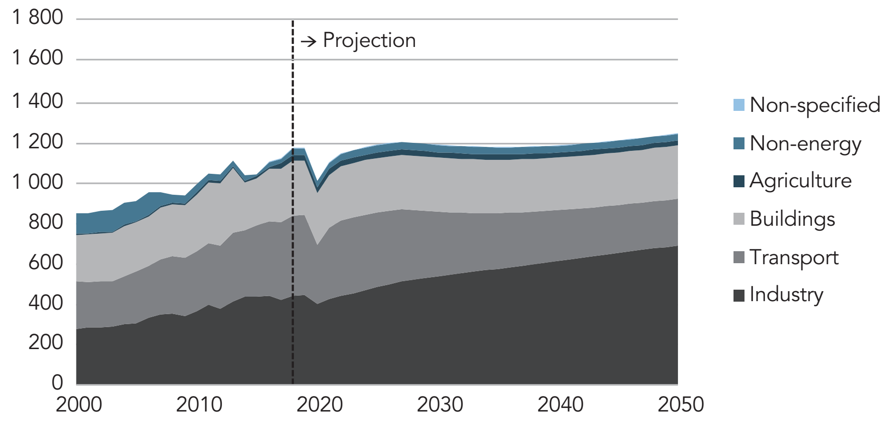
End-use energy demand by sector

Figure 4-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 4-6. Energy demand by sector in CN, 2000-2050 (PJ)

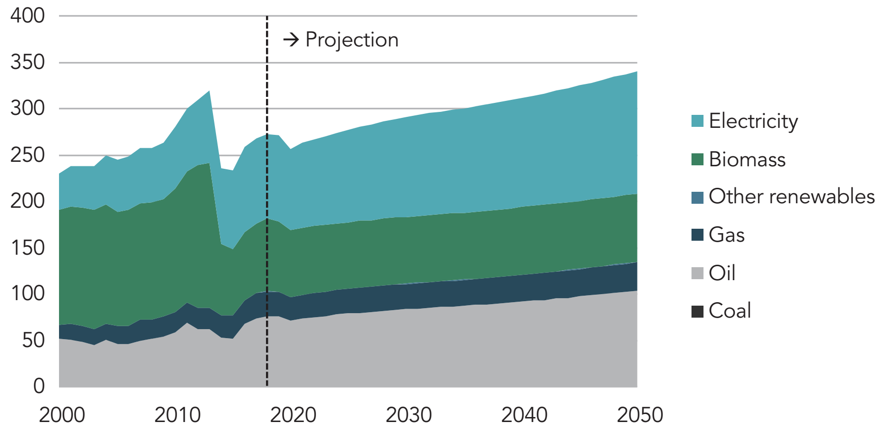


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Energy demand drops drastically in 2020 due to the COVID-19 pandemic, particularly in the transport sector.
- All sectors begin to recover in the years following COVID-19.
- In REF, energy demand in transport recovers but does not reach pre-pandemic growth rates. Demand is slower through 2050 as a result of the improvement of vehicle energy efficiency in accordance with the guidelines established by the National Energy 2050 Policy and the promotion of electric vehicles with the increase of efficiency.
- Industry is the biggest energy consuming sector in Chile. Industry energy demand grows 61% in REF and 56% in CN (2018-2050). The increasing energy demand in CN is driven by the growth of demand for critical minerals, such as lithium and copper, that are expected to be in higher demand as deployment of batteries and other clean technologies increases in a carbon neutral world.
- On the other hand, buildings energy demand increases 25% in REF (2018-2050) while it slightly falls, around 1.6%, in CN, indicating that, in the last scenario, the improvement of energy efficiency offset the increase of demand due to economical and population growths
- In CN, transport energy demand falls 40% (2018-2050) due to efficiency measures and electrification.
- In general, CN energy demand growth is lower because of more ambitious energy efficiency increments due to new technologies, stronger energy efficiency standards, and the replacement of fuels with more efficient alternatives.

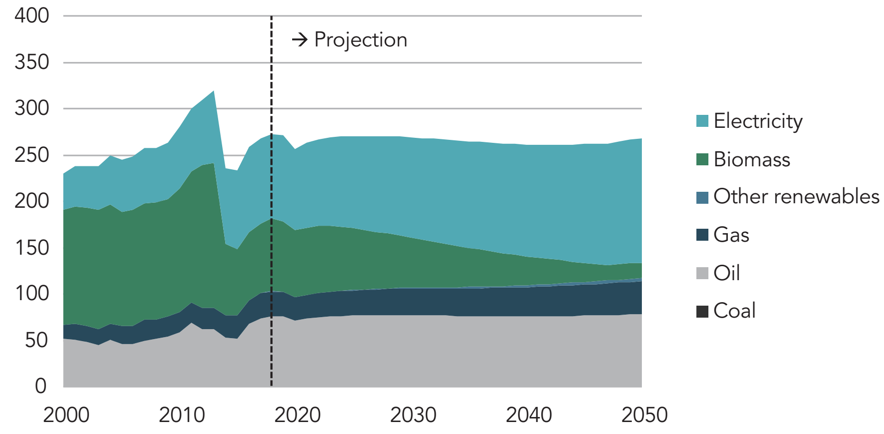
Buildings energy demand

Figure 4-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-8. Buildings energy demand in CN, 2000-2050 (PJ)

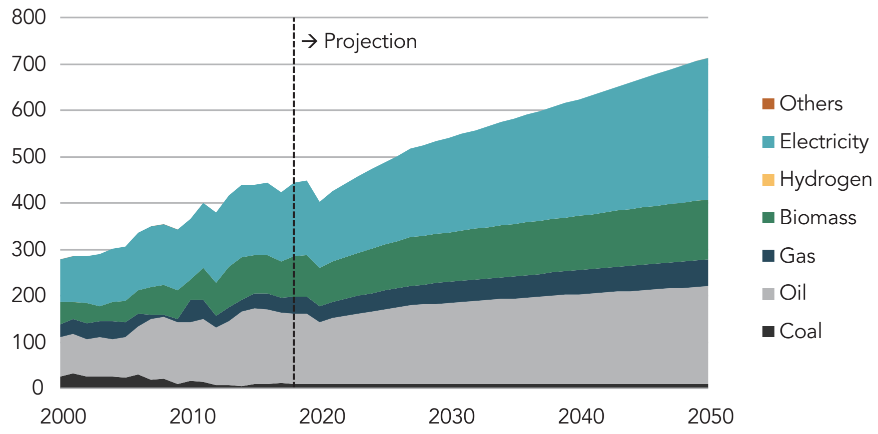


Sources: EGEDA, APERC analysis.

- Chile has set goals and developed plans to reduce imported fossil fuel consumption; however, there are not specific goals for the building sector.
- Energy demand in buildings increases by 25% in REF and decreases by 1.6% in CN (2018-2050). The increase in REF is due to energy efficiency measures being outweighed by population and economic growth during that period. On the other hand, the effect of electrification helps curb demand in CN.
- In both scenarios, electricity is the largest single energy carrier consumed by 2050. The share of electricity rises from 33% in 2020 to 39% in 2050 in REF and to 50% in 2050 in CN.
- In CN, programs that replace traditional fuelwood stoves with more efficient and less contaminant technologies, such as the ones promoted by the Ministry of the Environment, are more ambitious; consequently, consumption of biomass is reduced by 80% from 2018 to 2050.
- Energy efficiency labelling, and public awareness has improved the energy efficiency in the use of appliances in buildings in both scenarios. However, a more ambitious inclusion of highly efficient appliances in buildings support savings of 33 PJ by 2050 in CN.
- In CN, more stringent building codes were assumed, improving the thermal performance of buildings. Around one-third of existing buildings in 2050 will save 50% of the thermal energy, accounting for 14 PJ of savings in residential buildings.

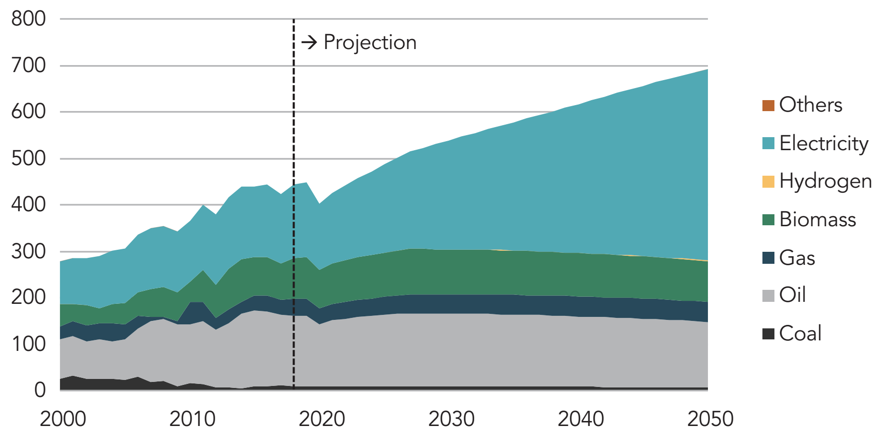
Industry energy demand

Figure 4-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 4-10. Industry energy demand in CN, 2000-2050 (PJ)

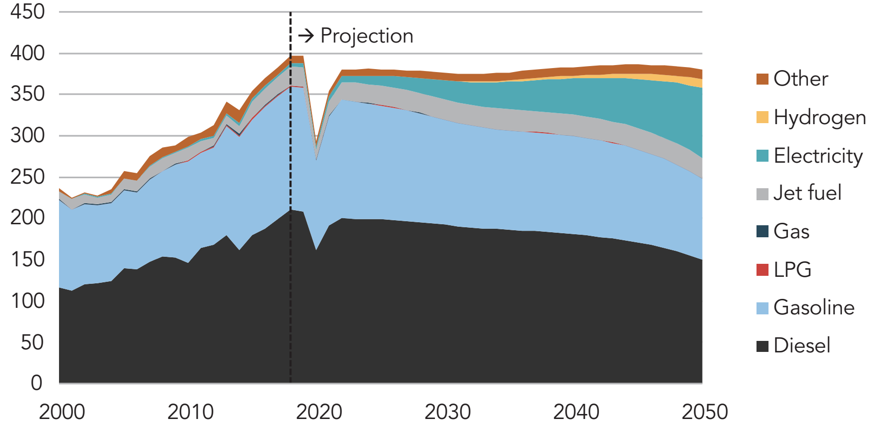


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- One of objectives of *Energy Policy Chile 2050* is to achieve an industrial sector that uses energy resources efficiently, with active energy management systems and implementing active energy efficiency improvements. Energy demand in the industry sector depends mainly on GDP growth, which leads to an increase in sub-sector activity.
- Of note, critical materials are considered as global demand for renewable technologies and batteries are anticipated to increase in a carbon neutral world.
- Industry demand rises 61% from 2018 to 2050 in REF. In CN, industry demand rises to 56%, slightly lower than REF. Unlike other sectors, industry demand does not peak during the projection period. This continuous growth is related to the expected increase of energy demand in the mining subsector.
- In CN, an increase of international demand of critical minerals such as cooper or lithium drives an increase of energy demand. Mining demand is expected to grow 80% from 2018.
- Electricity accounts for nearly 36% of the energy demand in industry in 2018. The share of electricity increases to 43% in REF and to 60% in CN in 2050, due to the electrification in production processes.
- Fossil fuels account for 44% of the energy demand in 2018 (197 PJ). In REF, the promotion of energy efficiency in industry and moderate electrification lessens fossil fuel demand.
- By 2050, fossil fuel demand is 39% of the total energy demand (279 PJ). In contrast, fossil fuel demand falls to 191 PJ, 28% of the total energy in 2050 in CN.
- Hydrogen appears as a fuel in 2040 in REF representing 0.04% of the total energy demand in 2050. On the other hand, hydrogen appears in 2025 and is 0.19% of the energy demand in 2050 in CN.

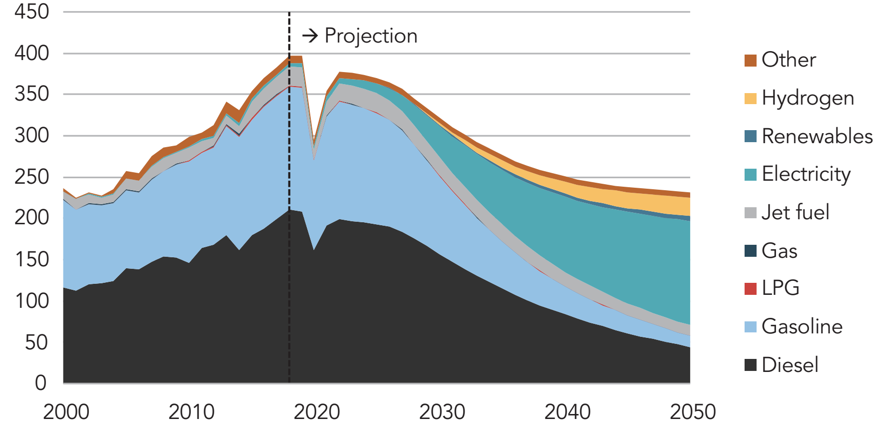
Transport energy demand

Figure 4-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 4-12. Transport energy demand in CN, 2000-2050 (PJ)

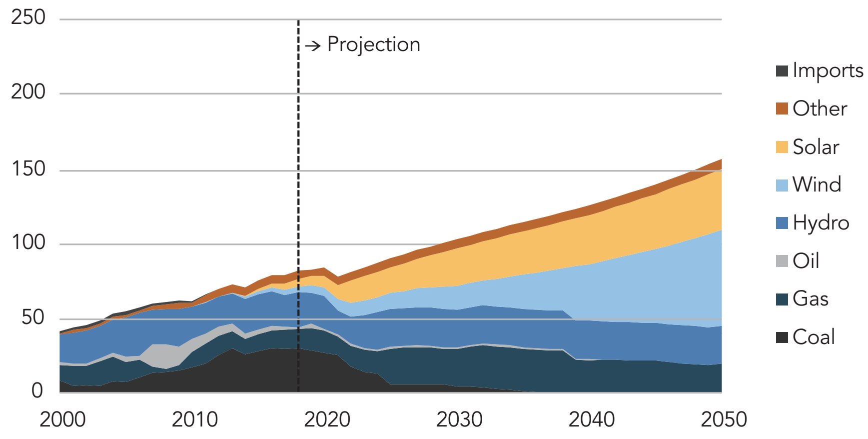


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport is the second largest energy consuming sector in Chile. Given its challenging geography with a long and narrow territory, road transport plays a major role of supporting economic development, as products and people need to move within the economy and to exporting hubs. An increase of economic activity will require an increase of activities in the transport sector.
- From 2000 to 2018 transport energy demand grew by 67%. There is an estimated decline in energy demand in 2020 because of COVID-19. Despite the increase of transport activity in terms of person-kilometer and tonne-kilometer, energy demand from 2018 to 2050 is expected to stay relatively stable due to increase of electricity in REF and the subsequent increase in energy efficiency.
- Transport energy demand decreases by 42% in CN. The main difference between both scenarios is the increase of more efficient electric vehicles (hybrid, battery, and fuel cell) in transportation of passengers and freight, reducing the demand for diesel and gasoline.
- Diesel and gasoline represented almost 91% of the total energy consumption in transport in 2018. This share decreases by 2050 in REF, reaching 65%. In contrast, the share of diesel and gasoline is reduced to 25% of 2018 in CN.
- The share of electricity rises from 1% in 2018 to 22% in REF, and to 55% in CN. Battery electric vehicles represents 18% of the vehicle stocks in REF, and 88% in CN.
- Hydrogen appears in 2026 but grows noticeably starting 2030. The share of hydrogen reaches 3% in REF, a consumption of around 90 ktH_2, and 10% in CN, a consumption of 200 ktH_2. Transport sector is the biggest hydrogen consumer in Chile.
- This result is around one tenth of the potential domestic demand presented in the National Green Hydrogen because it the assumed available stock of fuel cell vehicles assumed is more conservative. Fuel cell electric vehicles represents 2% of the vehicle stocks in REF, and 6% in CN.

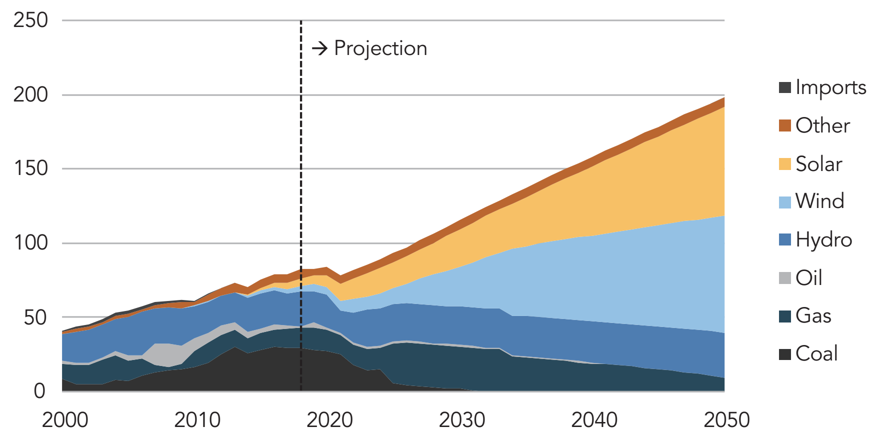
Electricity generation

Figure 4-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 4-14. Electricity generation in CN, 2000-2050 (TWh)

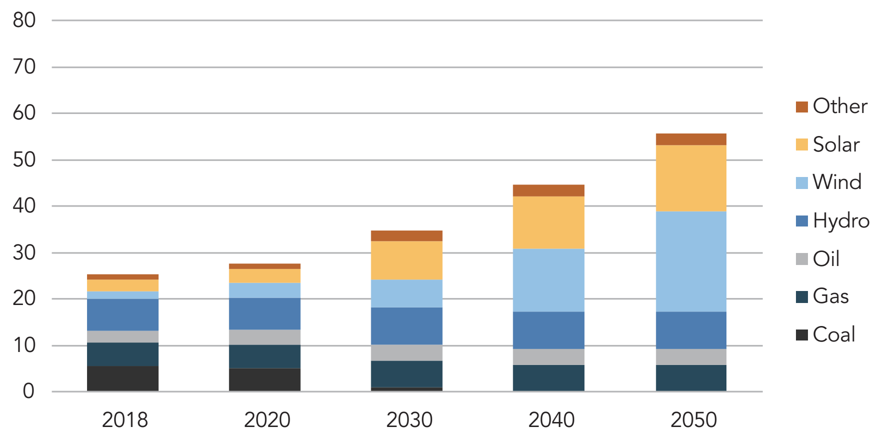


Sources: EGEDA, APERC analysis.

- Chile's electricity sector has been dominated by coal, hydro and natural gas during the last several decades.
- From 2018-2050, electricity generation grows from 82 TWh to 157 TWh in REF. CN requires an additional 41 TWh in 2050, more than doubling the levels of generation in 2018.
- The share of solar and wind grows from 11% in 2018 to 40% in 2030, and finally to 67% in 2050 in REF.
- In CN, electricity generated by solar, and wind reaches 45% in 2030 and 77% in 2050 in CN as the technologies become more cost competitive. At the same time, additional renewable generation will require improvements in the power system flexibility and reinforcement of the transmission system.
- The abundance of low-carbon resources for electricity generation makes the use of thermal generation with carbon capture and storage technologies (CCS) a less attractive alternative in Chile. For that reason, CCS has not been incorporated in the power system.
- Coal is phased out in accordance with the commitment to Powering Past Coal Alliance (PPCA) to stop coal-fueled electricity generation by 2040. Coal is phased out by 2031 in CN due to the extra efforts announced by Chile to phase out coal by 2030. Oil-based power plants do not generate after 2040.
- Natural gas generation grows more than 50% in 2050 from the 2018 level in REF. In CN, natural gas generation peaks in 2030 (29 TWh) but then declines to 9 TWh in 2050, a decrease of 28% from 2018. Still, natural gas generation continues to be an important source of electricity generation.
- Electric vehicles in the transport sector consume around 23 TWh of electricity in 2050 in REF, which corresponds to 15% of electricity generation. In CN, transport consumes 36 TWh of electric in 2050 (18% of electricity generation).

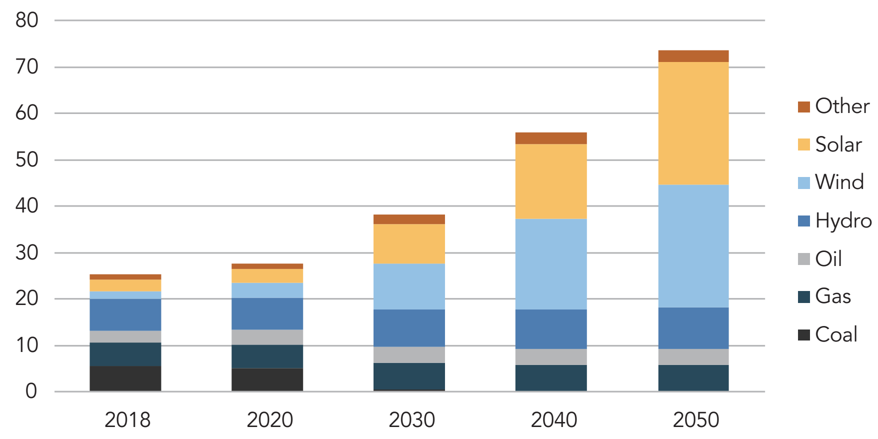
Generation capacity

Figure 4-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 4-16. Generation capacity in CN, 2018-2050 (GW)

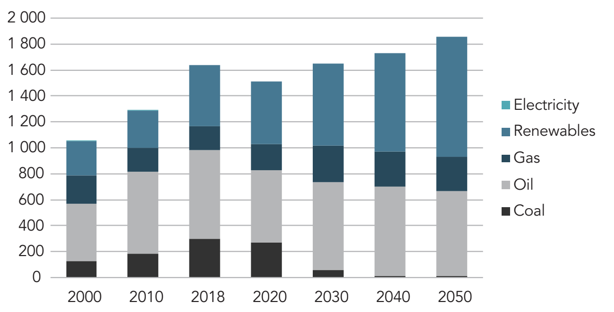


Sources: EGEDA, APERC analysis.

- Solar and wind technologies play an important role in the decarbonisation of the power sector. In REF, wind capacity reaches 21.6 GW in 2050, up from 1.7 GW in 2018. Additionally, solar capacity reaches 14.3 GW in 2050, up from 2.4 GW in 2018. Of this, 940 MW of the capacity is from concentrated solar plants (CSP). CN requires an additional 4.9 GW of wind capacity and 11.9 GW of solar capacity in 2050.
- A scenario with high penetration of variable renewable energy, mainly solar and wind, requires a responsive grid that, in the case of Chile, will be supplied by hydropower and natural gas-based power plants. Additionally, it is necessary to reinforce the transmission system to allow the electricity flow from different geographical zones and balance the system.
- In both scenarios, natural gas-based power plant capacity does not increase after 2025 when it reaches 5.8 GW.
- On the other hand, hydropower capacity increases by 1.2 GW from 2018 to 2050 in REF and by 2.3 GW in CN.
- The reserve margin increases from 8% in 2018 to 15% in 2050. Fossil fuels-based power plants, mainly gas and oil, provide capacity to maintain the reserve margin. Particularly, oil-based power plants are not expected to run as baseload. On the other hand, the addition of energy storage systems starting in 2025 contributes to providing system reliability.
- Storage capacity is added to the grid starting in 2025 and increases to 500 MW by 2045. Natural gas and hydro are assumed to complement solar and wind by providing flexibility. Higher levels of storage than in these scenarios could be considered to increase duration (e.g., seasonal) and would likely replace gas and possibly oil capacity. Transmission and operational restrictions can also affect the results of optimal storage capacity; for example, restricting renewable energy curtailment will increase storage capacity requirements.

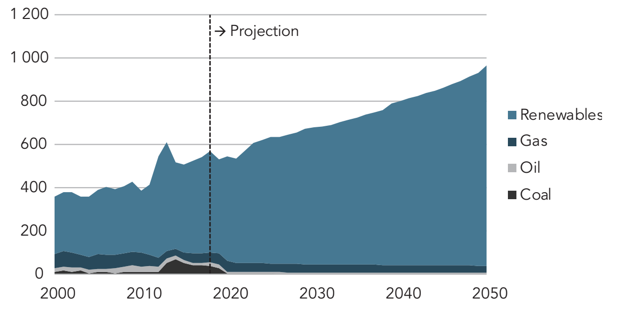
Energy supply in the Reference scenario

Figure 4-17. Total energy supply in REF, 2000-2050 (PJ)



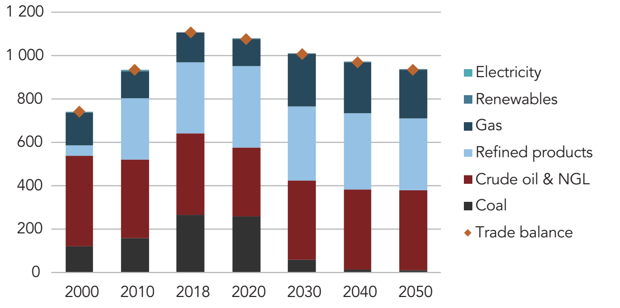
Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

Figure 4-18. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-19. Net energy trade in REF, 2000-2050 (PJ)

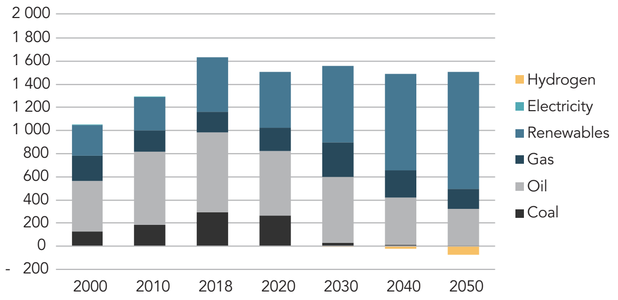


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Total energy supply increases by 13% between 2018 and 2050 in REF. This increase is explained mainly by the growth of renewables, almost doubling over 2018 levels.
- In REF, the share of fossil fuels declines from 71% in 2018 to 50% in 2050.
- Coal supply is reduced drastically from 304 PJ in 2018 to 11 PJ in 2050 because of the reduction of coal consumption in the power sector.
- There is also an increase of 36% of the natural gas supply (69 PJ) by 2050. The supply of natural gas peaks in the late 2030s.
- Energy production is dominated by renewables and a small portion of natural gas that comes from Magallanes region. Renewable energy production grows 96% from 2018 to 2050. Coal and oil production decreases by 100% and 65%, respectively.
- Chile remains an energy importer in REF. However, imports are reduced by 16% in 2050 from 2018 levels. Coal imports are reduced by 96%. In contrast, gas imports increase 64% in 2050 from 2018.

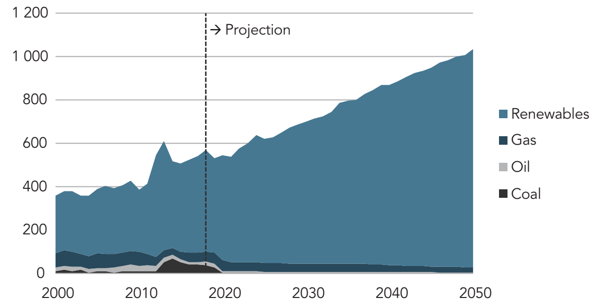
Energy supply in the Carbon Neutrality scenario

Figure 4-20. Total energy supply in CN, 2000-2050 (PJ)



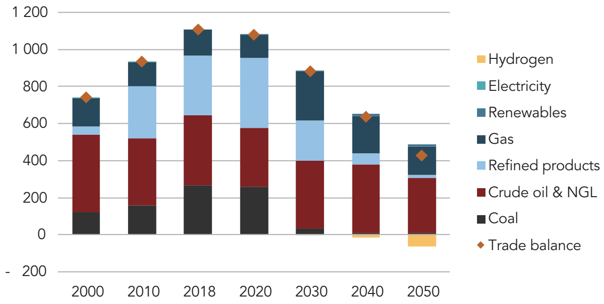
Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

Figure 4-21. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-22. Net energy trade in CN, 2000-2050 (PJ)

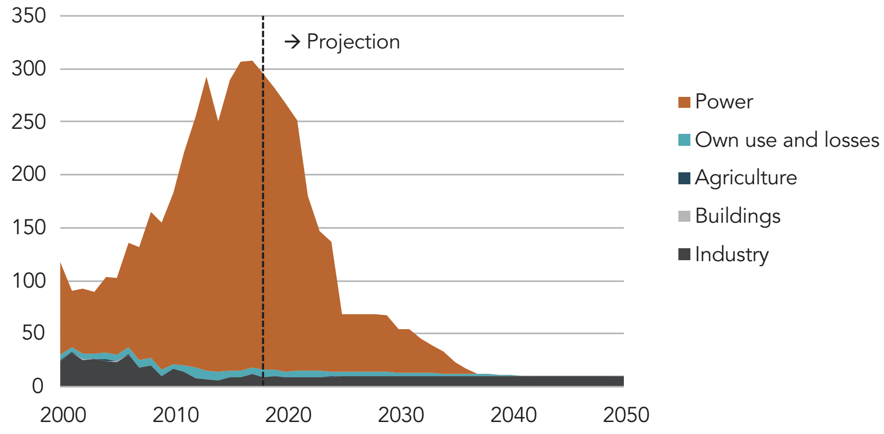


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, energy supply peaks above 1 600 PJ at the start of the projection then oscillates around 1 500 PJ through 2050.
- Production of fossil fuels declines through 2050, reflecting the increasing role of renewables in Chile's energy supply.
- Renewable energy production increases around 114%.
- Net energy trade is reduced by 54% in 2050 in CN, leading to a reduced dependency of imported fossil fuels.
- Hydrogen exports begin in 2030. The global addressable market for hydrogen exports is highly uncertain. In CN, demand for hydrogen exports and bunkers is 72 PJ (600 kilotonnes H_2) by 2050.
- This result is lower than the estimated market in the national hydrogen strategy because of lower export demand assumptions and potential infrastructure limitations. Still, Chilean hydrogen exports are around 5% of the import requirements within APEC member economies.

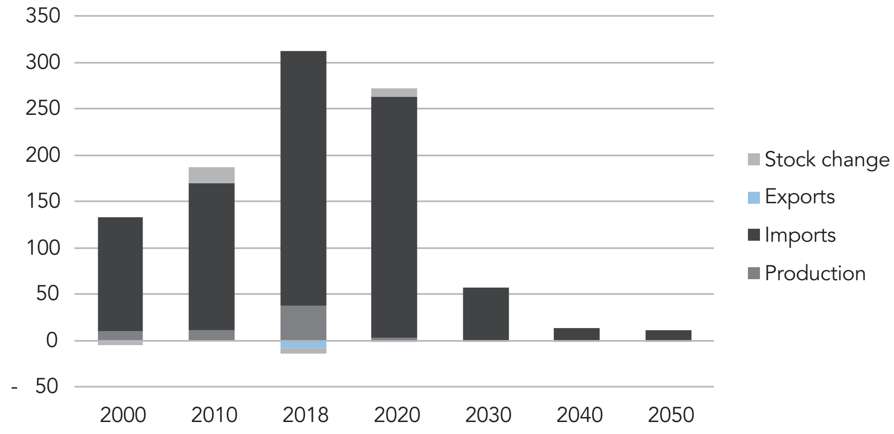
Coal in the Reference scenario

Figure 4-23. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-24. Coal production, imports, and exports in REF, 2000-2050 (PJ)

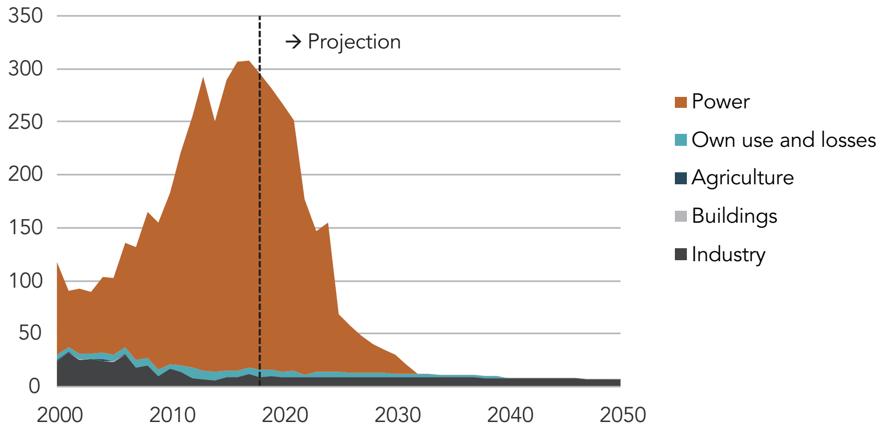


Sources: EGEDA, APERC analysis.

- The power sector is the largest consumer of coal in Chile. The growth in coal demand from 2005 to 2018 corresponds to the natural gas supply crisis originated by the restrictions on imports from neighboring Argentina. Consequently, coal fired power plants were operated at maximum capacity.
- Coal consumption falls in the 2020s because of the decommissioning of the coal plants announced by Chile. A second phase of decommissioning starts in 2030. Coal power plants are phased out by 2036. This date is the average estimated phase out reported in the *Update report of background information 2020 for long-term energy planning*.
- Consequently, coal imports fall drastically to around 40 PJ by 2050. Currently, most of the imported coal comes from Colombia and Australia.
- The last Chilean coal mine, Mina Invierno, was closed in 2020. Therefore, there is not domestic coal production in the projection.

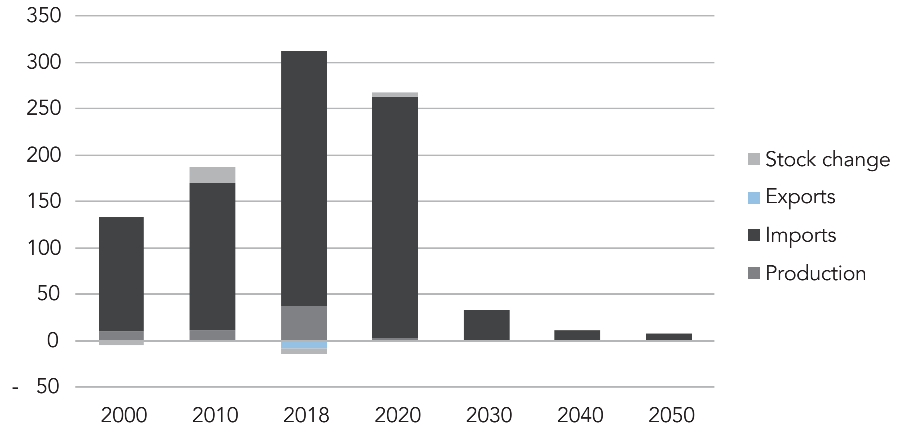
Coal in the Carbon Neutrality scenario

Figure 4-25. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-26. Coal production, imports, and exports in CN, 2000-2050 (PJ)

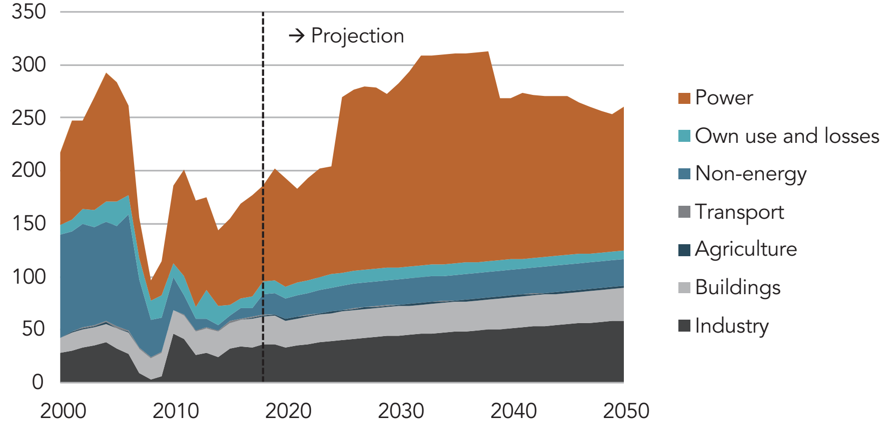


Sources: EGEDA, APERC analysis.

- CN includes a more ambitious decarbonisation path and decommissioning of coal-fired plants happens earlier than in REF. Coal-fired plants are completely phased out by 2031. Afterwards, coal demand is sustained by industry. Industry sector coal demand falls from 10 PJ in 2018 to 7PJ in 2050.
- Consequently, coal imports fall to 33 PJ in 2030 and 8 PJ in 2050.

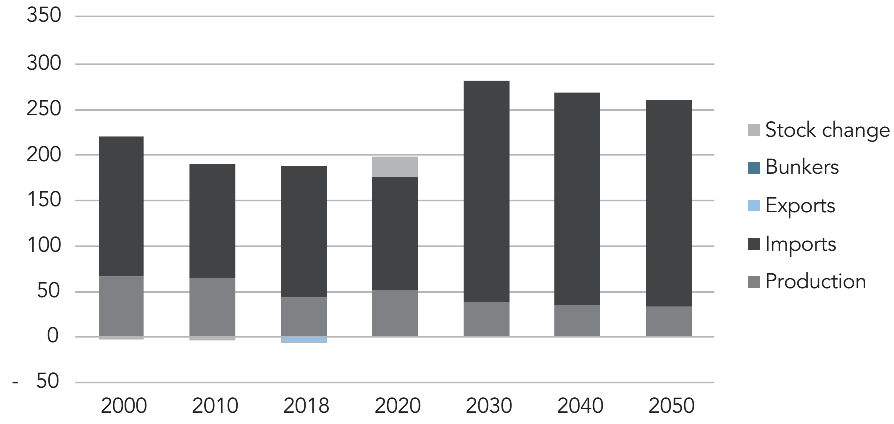
Natural gas in the Reference scenario

Figure 4-27. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-28. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

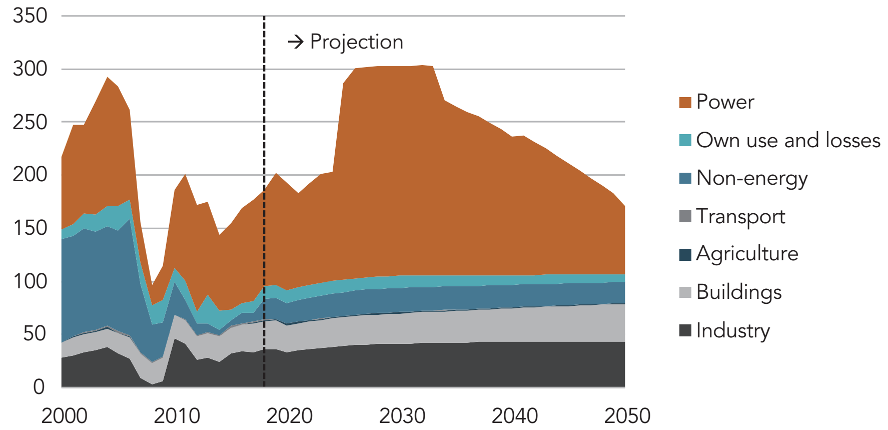


Sources: EGEDA, APERC analysis.

- Natural gas consumption, including end-use and transformation sectors, increases 40% (2018-2050). Consumption peaks around 300 PJ in the late 2030s.
- Natural gas consumption is largely driven by the power sector and, in a lesser extent, the growth of the other sector. Natural gas consumption in the power sector rises from around 90 PJ in 2018 until almost 200 PJ in 2038. After that, consumption falls to 30% in 2050 due to the increase of renewable energy in electricity generation.
- While the power sector consumes the most natural gas, the industry sector's consumption grows the fastest. Industry remains the second largest natural gas consuming sector.
- Between 75% to 90% of the natural gas demand is satisfied by imports. Local production of natural gas, mainly from the southern region of Magallanes, decays around 15% from 2018 to 2050 emphasising Chilean dependence of imports.
- An increase of imports after 2030, almost doubling the 2018 level, relies on increased natural gas import capacity through either LNG or pipelines.

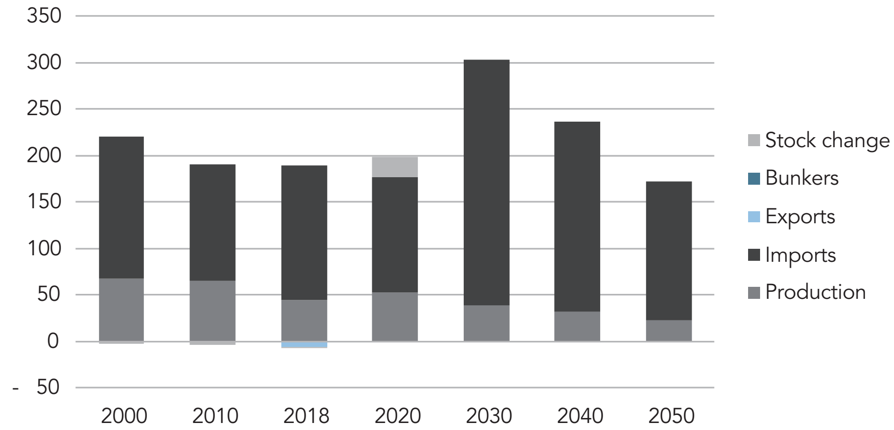
Natural gas in the Carbon Neutrality scenario

Figure 4-29. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-30. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

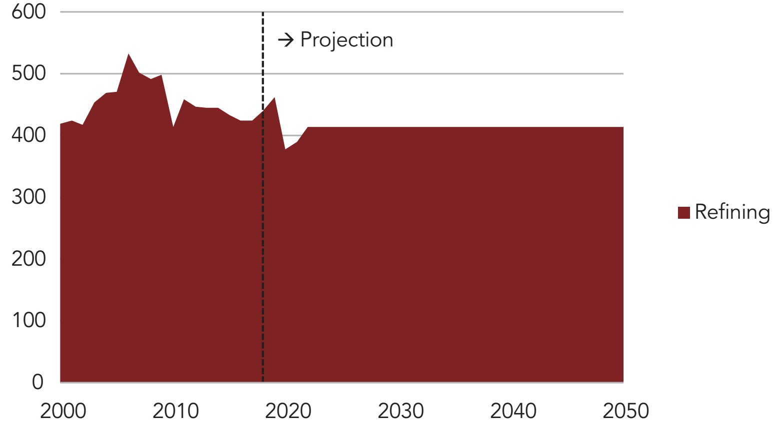


Sources: EGEDA, APERC analysis.

- In CN, natural gas consumption peaks earlier than REF (around 300 PJ in 2032). By 2050, consumption returns to levels last seen in the latter half of the 2000s.
- The power sector is responsible for both the large increase and decrease in gas consumption. The decline occurs as solar and wind displace natural gas-fired electricity generation.
- The estimated imports of natural gas fall after 2030 in CN, reaching 150 PJ in 2050. This is a reduction of 34% with respect to REF.
- Domestic natural gas production falls 50% from 2018 to 2050 because of declining internal consumption.

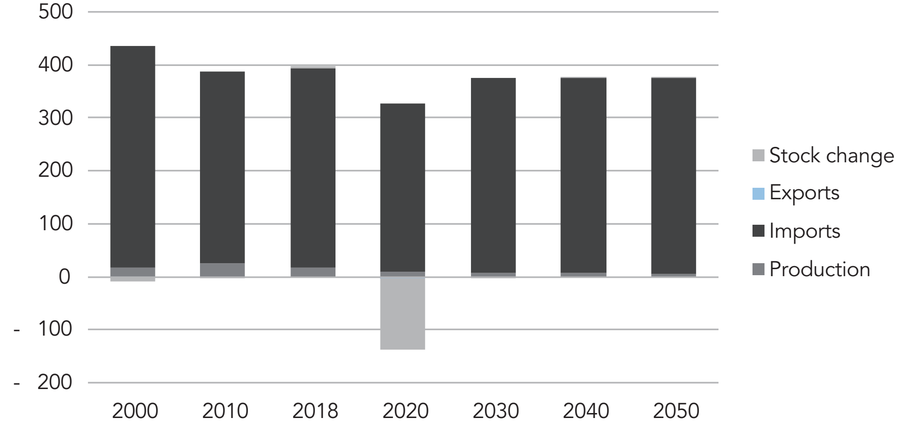
Crude oil and NGLs in the Reference scenario

Figure 4-31. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-32. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

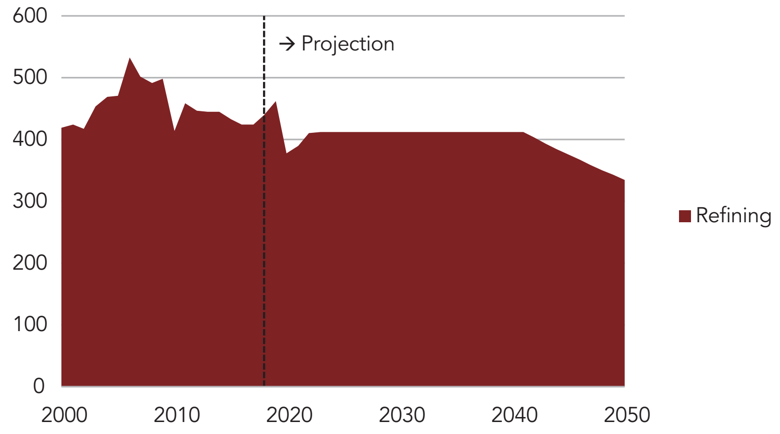


Sources: EGEDA, APERC analysis.

- Chile has three refineries with a total capacity of 220 000 barrels per day. The main two refineries are Biobio and Aconcagua Concon.
- In accordance with the Chilean efforts to switch away from fossil fuels, there is no additional refining capacity during the projection. Consequently, the refineries operate at a constant capacity factor.
- Between 98%-99% of the available oil is imported. Brazil is the main origin of crude oil imports.
- Domestic production of oil declines from current levels of 9.0 PJ in 2020 to 6.0 PJ in 2050 in REF. There is not an increase of production capacity in REF.
- There is an estimated increase in stock changes in 2020 because oil products demand, the main driver of the refining process, decreased due to the measures implemented during the COVID-19 pandemic and subsequent decline in economic activity.

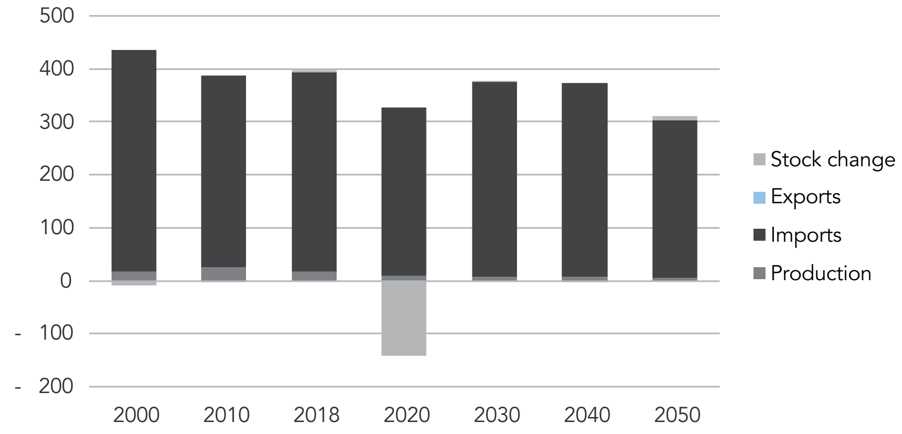
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 4-33. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-34. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

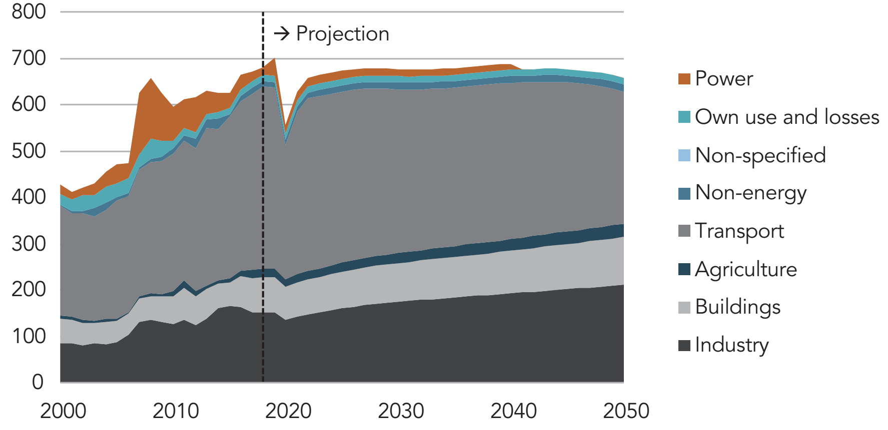


Sources: EGEDA, APERC analysis.

- In CN, there is a decrease of crude oil consumption starting in 2041. Refinery capacity factors are adjusted to this declining consumption. Crude oil intake by refineries falls 9.0% from 2040 to 2050.
- Crude oil imports decline starting in 2040. Imports fall to 299 PJ in 2050, 19% less than REF.
- Oil production also decreases reaching 5.0 PJ in 2050, 17% less than in REF.

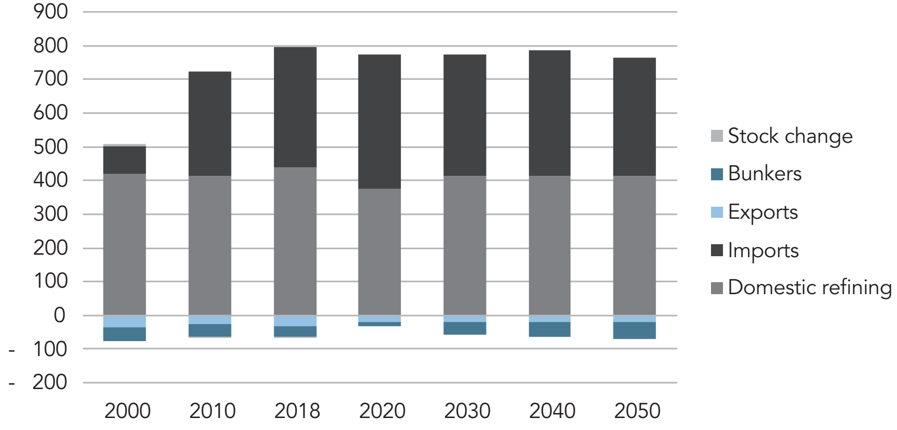
Refined products in the Reference scenario

Figure 4-35. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-36. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

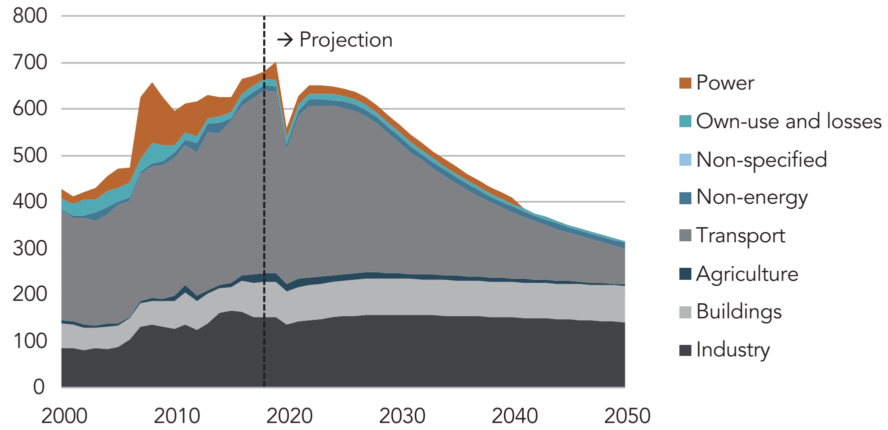


Sources: EGEDA, APERC analysis.

- Gasoline and diesel are the main petroleum products consumed in Chile, largely in the transport sector.
- Refined products consumption peaks at 688 PJ in 2040 then declines to 658 PJ in 2050. This trend is explained by the slowdown of refined products consumption in all sectors, the drop in transport energy demand, and the phase-out of oil-based electricity generation in 2040.
- Imports satisfy between 57% to 60% of the domestic refined products demand. Imports peak at 398 PJ in 2020, and later fall to 350 PJ in 2050. On the other hand, bunkers increases 42% from 2018 to 2050.

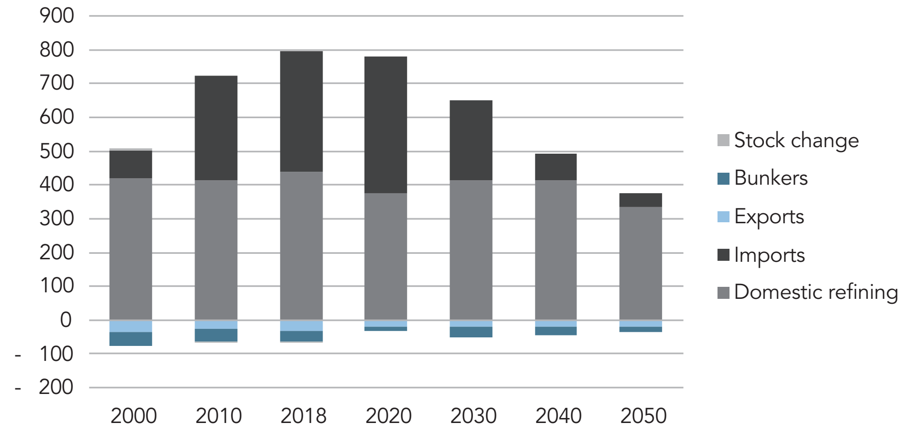
Refined products in the Carbon Neutrality scenario

Figure 4-37. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-38. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

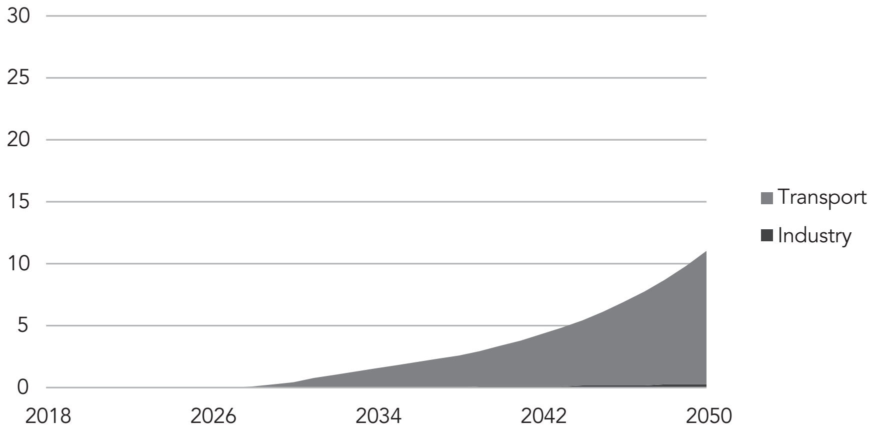


Sources: EGEDA, APERC analysis.

- Refined products demand declines following the behavior of the transport sector.
- Domestic refining is maintained at a stable level of 412 PJ until 2040 as no additional refining capacity is added in Chile.
- Later, refinery output falls 19% by 2050; however, participation of domestic processing increases as imports are reduced drastically. Imports drops from 356 PJ in 2018 to 39 PJ in 2050.

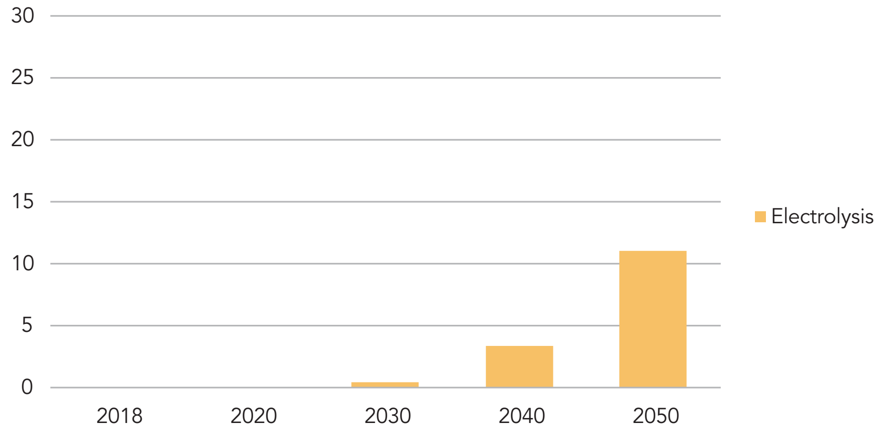
Hydrogen in the Reference scenario

Figure 4-39. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 4-40. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

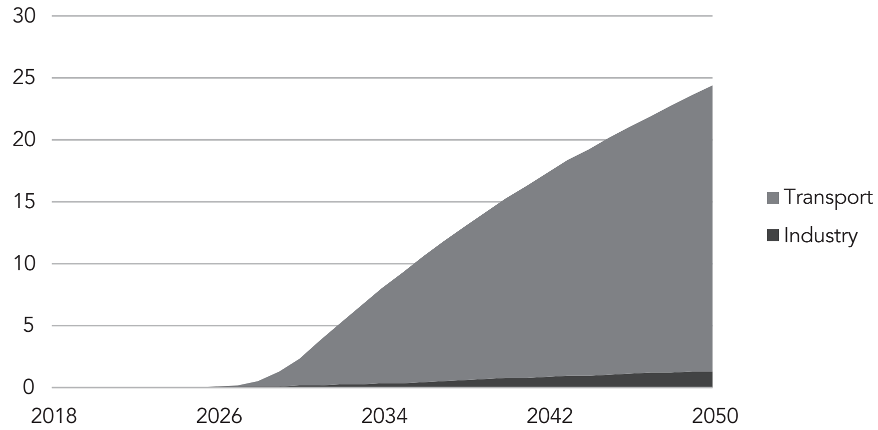


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- In 2020, Chile published its "National Green Hydrogen Strategy" for developing a green hydrogen industry taking advantage of the high renewable energy potential in Chile. The "National Green Hydrogen Strategy" aims to make Chile an important player in the future global hydrogen market by producing the cheapest green hydrogen in the world.
- Hydrogen consumption begins in 2026 with small pilot projects. Commercial use of hydrogen starts around 2030.
- The transport sector is the main consumer of hydrogen in larger road vehicles for public and freight transportation. Hydrogen demand in transport is 10.7 PJ or 89 ktH_2 in 2050. Additionally, there is an initial use of hydrogen in industry reaching 0.3 PJ or 2.0 ktH_2 in 2050.
- Hydrogen exports are not considered for any APEC economy in REF.

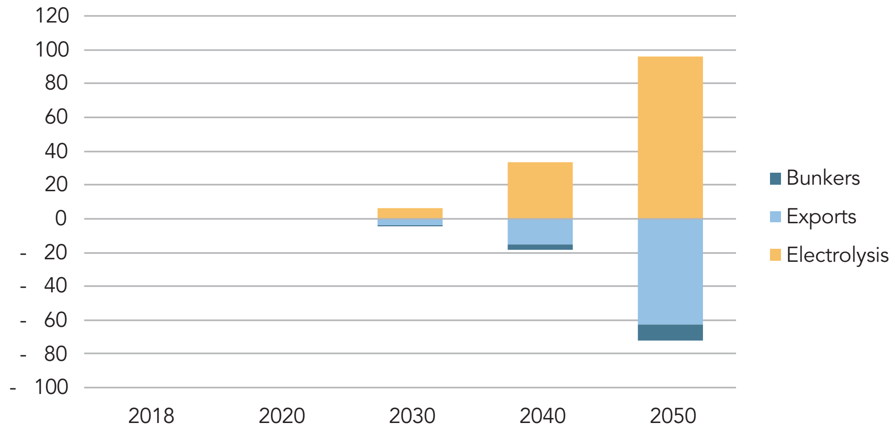
Hydrogen in the Carbon Neutrality scenario

Figure 4-41. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 4-42. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

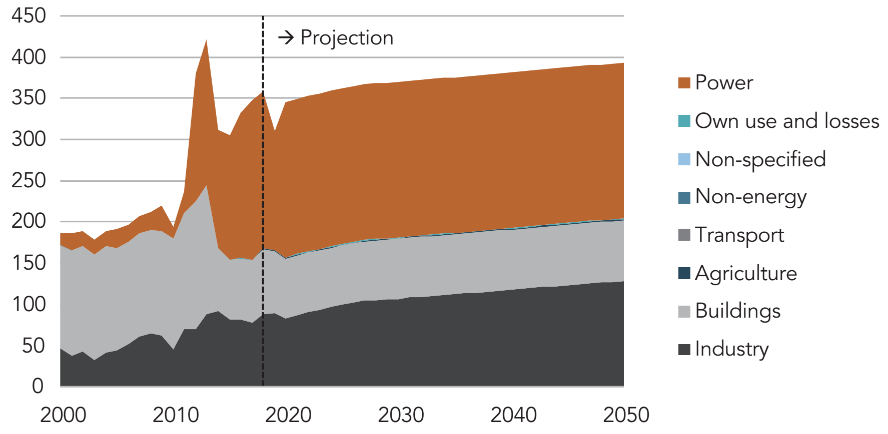


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- In CN, local hydrogen demand increases. Transport demands 23 PJ (192 kt of H_2) and industry 1.3 PJ (11 kt of H_2) by 2050. These results are an increase of four- and two-fold of the results in REF.
- Following the objectives of the "National Green Hydrogen Strategy", exports are an important source of demand for locally produced green hydrogen. Between exports and bunkers, international hydrogen demand consumes 75% of the produced green hydrogen.

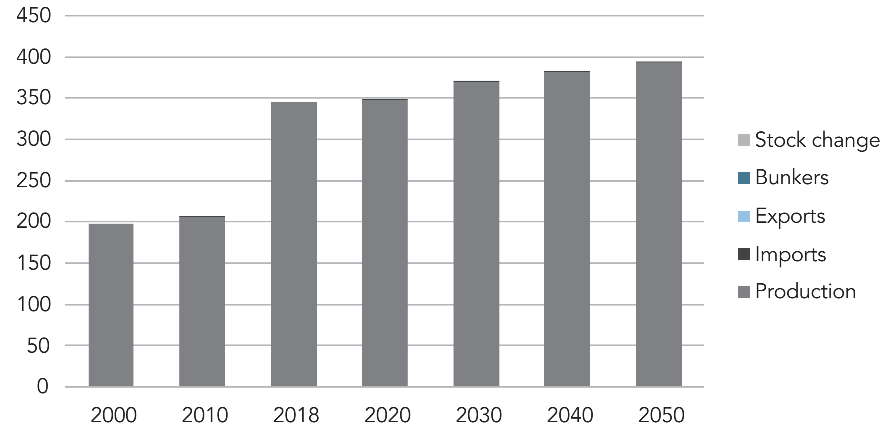
Bioenergy in the Reference scenario

Figure 4-43. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 4-44. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

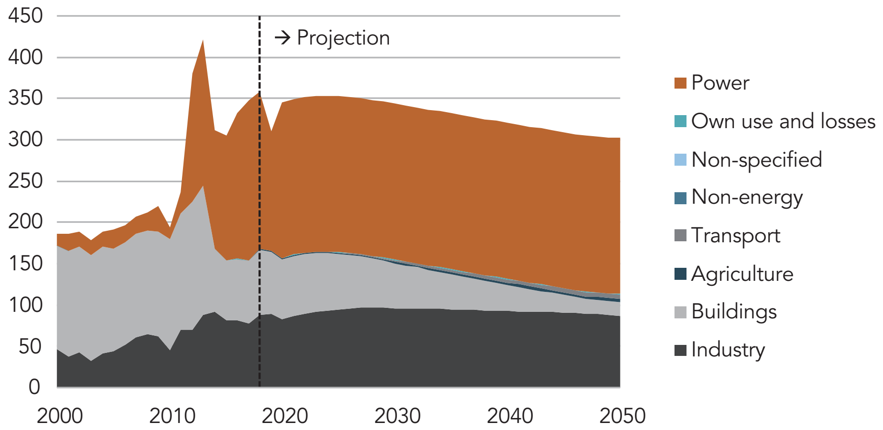


Sources: EGEDA, APERC analysis.

- Around 53% of the biomass was consumed for electricity generation in 2018. Most of this capacity is installed in the central part of Chile. Around 25% was consumed by industry, mainly in the pulp & paper subsector, the remainder is consumed in the buildings sector. Biomass consumed in buildings corresponds to fuelwood and pellets.
- In REF, industrial biomass consumption in pulp & paper and mining subsectors grows 46% from 2018 to 2050. This biomass includes charcoal.
- Additionally, fuelwood is an important energy source in buildings, mainly in the residential sector, especially in the southern regions of Chile. Biomass consumption in buildings and power sectors does not change drastically from 2018 to 2050. On the other hand, there is also a marginal use of charcoal in agriculture.
- Almost all renewable energy demand is satisfied by indigenous production.

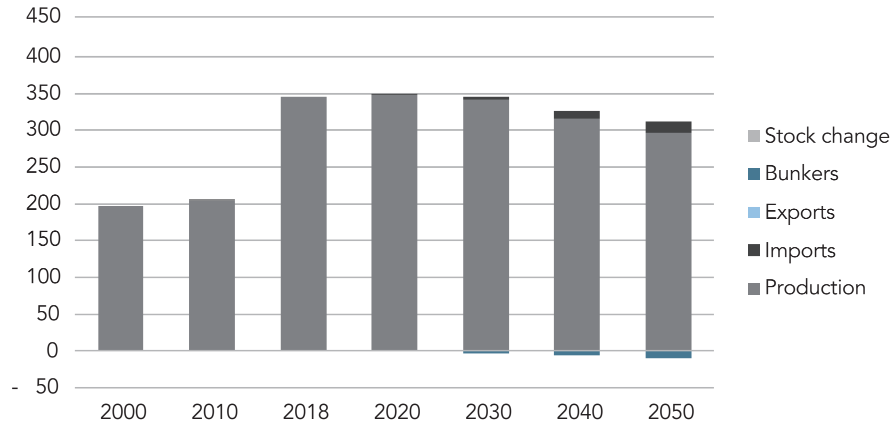
Bioenergy in the Carbon Neutrality scenario

Figure 4-45. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 4-46. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

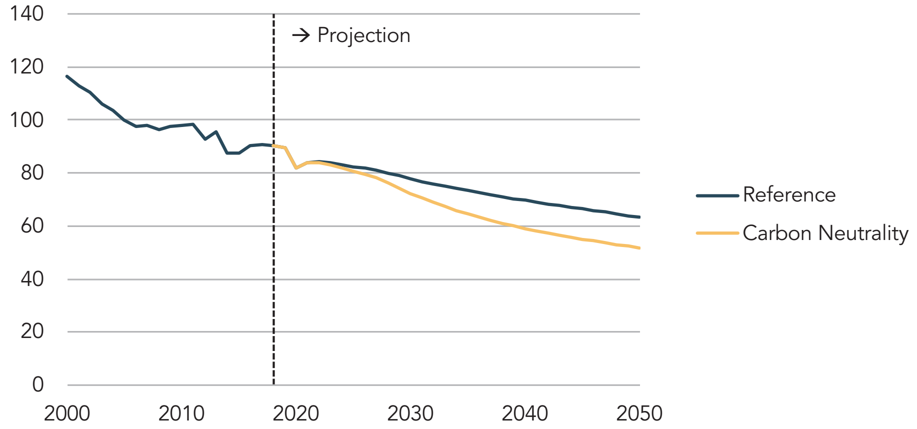


Sources: EGEDA, APERC analysis.

- Biomass consumption in the power sector is maintained at the same level as in REF. There is a decline in solid and liquid renewables consumption due to improvements of energy efficiency in buildings and industry.
- Replacement of fuelwood with more efficient fuels such as LPG and electricity is higher in CN. Despite efforts, traditional fuelwood is not eliminated by 2050 because of the difficulties to reach very isolated populations with effective alternative fuel. Fuelwood consumption in 2050 is 20% of 2018 levels.
- Transport consumes biofuels starting in 2025. By 2050, biofuels will supply around 2.0% of the transport energy demand in CN.
- Because of the use of biofuels in transport, there are also some exports of them into bunkers, and they represent approximately 3.0% of the domestic renewable production.
- The increase of domestic demand of solid and liquid renewables drives an increase of imports with respect to REF. Imports represent 5.0% of the total primary solid and liquid renewables energy demand by 2050.

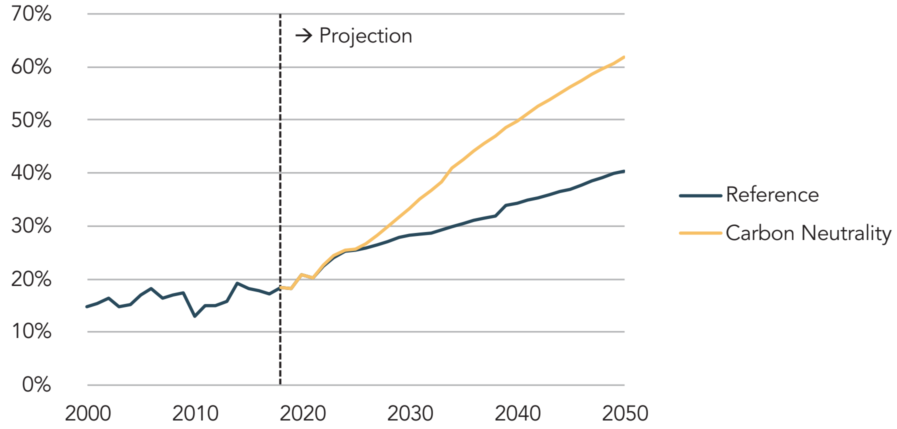
Energy intensity and modern renewables share

Figure 4-47. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 4-48. Modern renewables share in REF and CN, 2000-2050



Sources: EGEDA, APERC analysis. Note: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

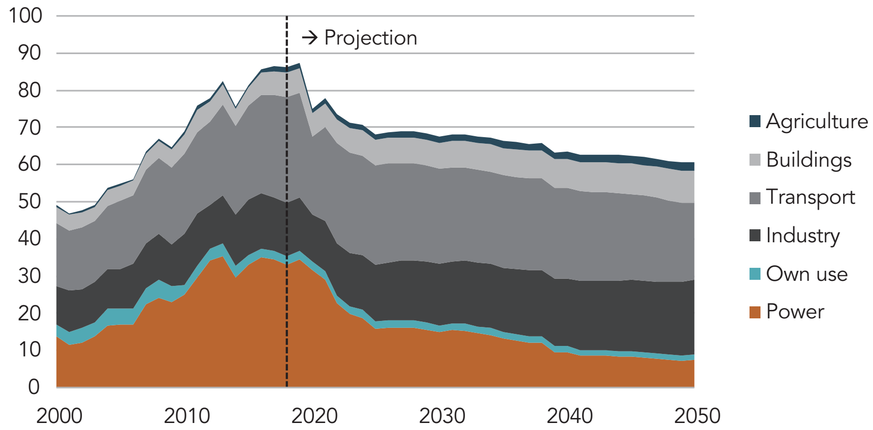
- APEC has an aspirational goal to reduce aggregate energy intensity by 45% by 2035, relative to 2005. This goal does not apply to individual economies.
- Chile's final energy intensity has declined by 22% (2000-2018). Relative to 2005, final energy intensity declined 10% by 2018.
- In REF, intensity continues to decline as final energy demand grows at a slower rate than economic activity.
- In CN, final energy intensity declines more than in REF. Energy efficiency improvements support the intensity improvements (economic growth is assumed to the same as REF).
- The second energy-related APEC aspirational goal is doubling the share of modern renewable energy by 2030 (relative to 2010 levels). Modern renewable energy does not include traditional biomass such as fuelwood because its use is often inefficient and harmful to human health. Renewables used in electricity production are considered modern renewables.

- Chile doubles the share of modern renewables by 2027 and more than triples the share by 2050 in REF.
- In CN, the share of modern renewables doubles one year earlier (2026) and increases five-fold by 2050. Inclusion of very ambitious goals for renewable energy in electricity generation contributes to this growth.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

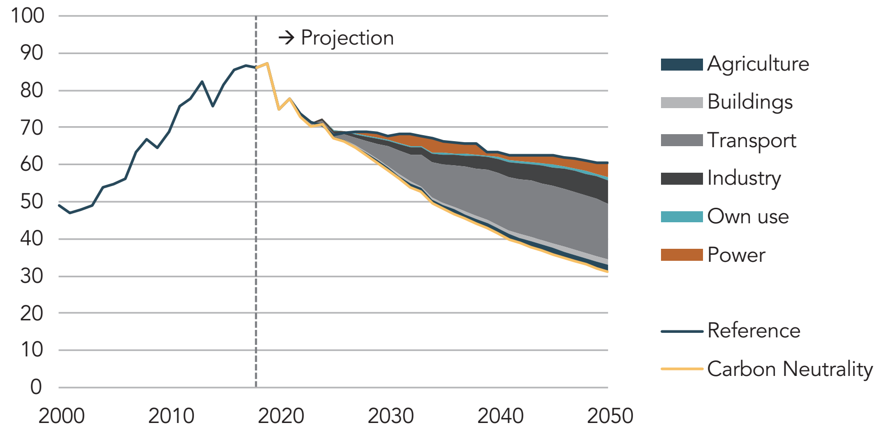
Gross CO_2 emissions

Figure 4-49. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 4-50. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

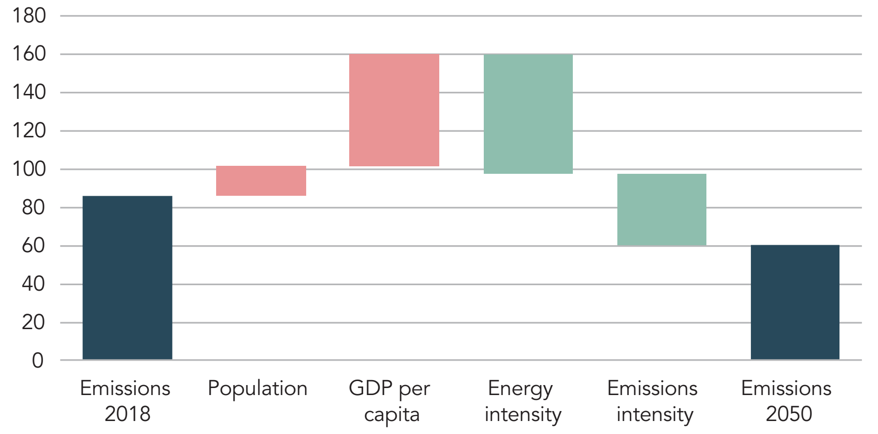


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- CO_2 emissions are calculated from direct combustion. In 2018, energy related CO_2 emissions accounted for 86 million tonnes.
- In REF, emissions fall from the beginning of the projection. In 2030, emissions decline to 67.6 million tonnes (71% of the 95 million tonnes CO_2-e goal set in the updated NDC). Declines continue down to 60.5 million tonnes in 2050.
- Chile has ambitious goals regarding the participation of renewable energy in the power sector. In REF, power emissions fall from 33 million tonnes to 8 million tonnes. Transport emissions fall from 28 million tonnes (2018) to 21 million tonnes (2050), mainly due to EVs. In contrast, industry emissions increase from 14 million tonnes to 20 million tonnes. Industry and transport have roughly the same amount of emissions in 2050.
- In CN, emissions fall to 31 million tonnes CO_2 in 2050. Under this scenario, emissions reach 58.5 million tonnes CO_2.
- Given that the power sector has already shown great emission reduction in REF, the transport and industry sectors become the key sectors where additional remission reductions can be obtained.
- Transport emissions fall to 6 million tonnes while industry emissions fall to 14 million tonnes by 2050.
- In order to reach zero CO_2 emissions in 2050, removal through CO_2 sinks through natural or technological means would be necessary. This could be an opportunity for collaboration with APEC member economies.

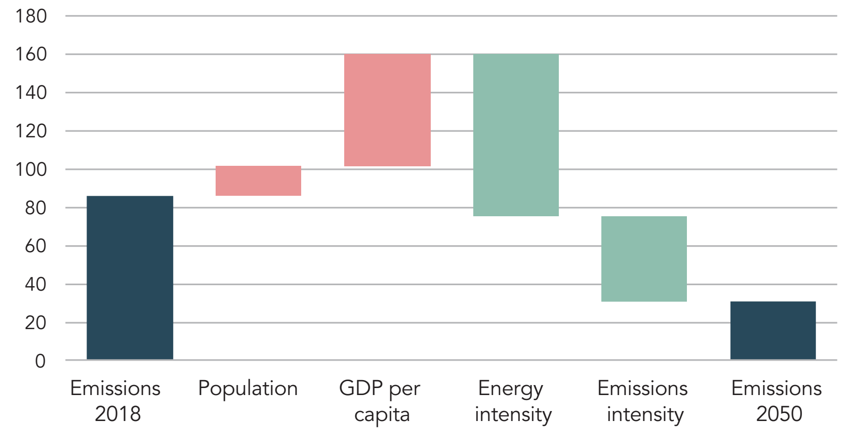
Components of CO_2 emissions

Figure 4-51. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 4-52. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Economic and population growth drive CO_2 emissions increases of around 73 million tonnes. Around 58 million tonnes of the increase is due to economic growth.
- In REF, energy intensity improvements reduce emissions by 63 million tonnes. These improvements are due to energy efficiency and fuel switching from oil products.
- An improvement to emissions intensity offsets 36 million tonnes, mainly due to an increase of renewable energy in electricity generation.
- The combined improvements of energy and emissions intensities results in lower emissions in 2050 than 2018, fully offsetting increases from macroeconomic factors.

- In CN, emissions increases from macroeconomic factors are the same as REF. Energy and emissions intensities both improve to offset 128 million tonnes by 2050.

Note: The Kaya identity is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

Ministry of Energy. https://energia.gob.cl/

International Energy Agency. https://www.iea.org/data-and-statistics/data-tables

Energy Balance. http://energiaabierta.cl/visualizaciones/balance-de-energia/e.

BP Statistical Review of World Energy. https://www.bp.com/

Uranium 2020, Resources, Production and Demand. https://www.oecd-nea.org/

Long-Term Energy Planning. https://energia.gob.cl/planificacion-energetica-de-largo-plazo-proceso

OECD Data. https://data.oecd.org/gdp/gdp-long-term-forecast.htm

5. China

Highlights

Demand

- In REF, end-use energy demand slowly peaks in the early 2030s. By 2050, energy demand falls from the peak to be 10% greater than in 2018. Only coal demand decreases during this period, with the reduction led by the industry sector. The share of coal in the end-use energy mix falls to 20% in 2050, while electricity reaches 30%. The share of oil and gas is relatively stable.
- In CN, energy demand peaks in the early 2020s and ends the projection period 10% lower than in 2018. The energy demand decrease in CN is mainly driven by reduction in use of coal and oil. The industry sector is the main driver of reduced coal demand as fuel switching from coal to electricity and hydrogen accelerates. Oil demand decreases in transport and industry, mainly via electrification. The share of coal and oil falls to 16% and 19% respectively.
- Electricity demand increases in both REF and CN. In CN, although overall energy demand falls, electricity demand is slightly higher than in REF in 2050. From 2018 to 2050, electricity demand increases from 6 000 TWh to approximately 8 000 TWh in both scenarios. Additional demand is from EVs in transport, and cooking, cooling, heating, and home appliance applications in buildings.

Supply

- In REF, China's energy supply increases 14% from 2018 to 2050. Coal's share in energy supply peaked in 2005 and has since declined, though its relative prominence is still clear, accounting for 62% of China's energy supply in 2018. The share of coal and oil declines through to 2050, whereas the share of nuclear, renewables, and gas increases.
- In CN, China's energy supply peaks in the early 2020s. From there, energy supply declines to be 14% lower in 2050 relative to 2018. Coal's supply declines from a share of 62% in 2018 to only 16% in 2050. Oil also declines from 20% to 13% for the same period. Natural gas almost triples to over 28 000 PJ to become the largest source of supply.
- Compared with REF, in CN, net energy imports are a third smaller in 2050, and much of this reduction is due to lower oil supply requirements. This result illustrates that reducing oil demand, via increased energy efficiency and EV deployment, can reduce import dependency and improve energy security.

Power

- Electricity generation increases in both scenarios in response to increased electricity demand, particularly from the buildings and transport sectors. In the buildings sector, the switch away from coal is influential in increasing electricity demand. In the transport sector, fuel switching primarily from gasoline and diesel to electricity leads to increased electricity demand through to 2050, particularly in CN.
- In CN, power generation from fossil fuels declines to 18% in 2050, and a third of this is from gas with CCS. These gas-fired CCS units will be deployed from the early 2030s and gradually increase through 2050 to complement variable renewable generation while keeping emissions low.
- Renewables (hydro, solar and wind) and nuclear are dominant in power generation in 2050 in CN. The share of electricity generated by these four technologies reaches 80% in 2050.

CO_2 emissions

- In REF, CO_2 emissions decrease 20% between 2018 and 2050, with most significant declines from power, industry, and buildings.
- In CN, a large decline in coal demand leads to significant emissions reductions. From 2018 to 2050, CO_2 emissions decline by almost 70%. Although emissions decline in all sectors in CN, decarbonisation in the power sector and by industry lead to the greatest level of reductions.
- In the power sector, a transformational transition leads to 90% electricity generation from low-CO_2 sources (renewables, nuclear, and gas with CCS). In the transport sector, fuel switching from fossil fuels to electricity and hydrogen contribute to most of the reductions. Lower transport activity also contributes.

About China

- China is in northeast Asia and is bordered by the East China Sea, Yellow Sea, and South China Sea. Its population of 1.4 billion is approximately one-fifth of the world's population. China has a land area of approximately 9.6 million square kilometres (km^2) with diverse landscapes consisting of mountains, plateaus, plains, deserts, and river basins.
- After a long period of development, China has become the world's largest energy producer and consumer, forming an energy supply system through the comprehensive development of coal, electricity, oil, natural gas, and renewable energy.
- In 2018, total primary energy supply (TPES) increased by 4.4%, reaching 129 092 PJ. The supply of natural gas increased by 13.3% and that of renewable energy by 9.2%. Energy production increased by 5.6%; coal was the dominant source, accounting for 62%, followed by oil (20.3%), gas (8.0%), renewables (6.7%), and others (3.0%). Coal production began to decline in 2014; it reached its lowest level in 2016 and resumed growth in 2017. The production in 2018 was roughly the same as in 2015. Driven by internal demand, net imports rose to 28 271 PJ in 2018, an 11.1% annual increase.
- Total final consumption is a representation of end-use energy, including non-energy consumption. The proportion of industry is relatively large. It was above 50% in 2018, though this share represents a 9% decrease from 2011. The transport sector is the next largest, accounting for 16% of all end-use sectors.
- Power generation has continued to grow since 2000. China's power sector is reliant on coal. Almost 67% of China's electricity was generated by coal in 2018, although this represents a significant decline from 75% in 2000. From 2011, the proportion of non-fossil energy in electricity generation has increased.

Table 5-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	1 393	48%	1
GDP	21 747	31%	1
TPES	129 092	37%	1
Production	102 673	30%	1
Imports	31 670	25%	1
Exports	3 398	3%	7
Electricity generation	7 166	42%	1
Heat production	5 244	45%	2
CO_2 emissions	9 611	45%	1

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 5-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	3 462 283	37	13.3%	2
Natural gas	302 348	43.3	4.5%	3
Oil	158 836	18.2	1.5%	4
Uranium	119	–	3.1%	4

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- **Carbon Neutrality:** In September 2020, President Xi Jinping declared China's aim to achieve carbon neutrality by 2060.
- **Coal:** In April 2021, President Xi mentioned that China will strictly limit the increase in coal consumption over the 14th FYP (2021-2025) and phase it down in the 15th FYP period (2026-2030).
- In China, a **Five-Year Plan (FYP)** is issued every five years and is the foundation of all government policies including energy policy.
- **14th FYP:** In this latest FYP, which determines policies from 2021 to 2025, energy consumption per unit of GDP and carbon emissions per unit of GDP are targeted to decline by 13.5% and 18%, respectively. As a nonbinding indicator, the proportion of non-fossil fuels in primary energy consumption is raised to 20% from 15% in the 13th FYP. The 14th FYP promotes low-carbon development and the circular economy with new approaches to transport, energy production, and waste management policies. In this plan, the government aims to peak CO_2 emissions before 2030.
- **Emissions:** The action plan for carbon dioxide peaking before 2030 was released in 2021. According to the action plan, by 2030, the share of non-fossil fuel energy will reach around 25% and CO_2 emissions per unit of GDP will drop by more than 65% compared with the 2005 level, successfully achieving carbon dioxide peaking before 2030.
- **Oil and gas:** China will keep oil consumption within a reasonable range and will speed up the large-scale exploitation of unconventional oil and gas resources.
- **Renewable generation:** The construction of solar and wind power will be accelerated. By 2030, total installed capacity will reach more than 1 200 GW. Also, construction of hydro power bases will be actively advanced. Approximately 40 GW of additional hydro power capacity will be deployed during both the 14th and 15th FYP periods.
- **Nuclear:** A reasonable layout and timetable for the construction of nuclear power stations will be set, and steady pace of construction will be maintained.
- **Industry:** As the industry sector is one of the primary sources of CO_2 emissions, the industry sector is influential on China's efforts to peak overall carbon dioxide emissions. China will spur industrial energy consumption to go low-carbon, promote efficient use of fossil fuels, increase the proportion of renewable energy utilisation, strengthen electricity demand-side management, and raise the level of industrial electrification.
- **Steel-making:** China will strictly prohibit additional production capacity, push for the optimisation of existing capacity, and retire outdated capacity.
- **Non-ferrous metals:** Capacity replacement of electrolytic aluminium production will be enacted, and additional production capacity will be strictly controlled.
- **Buildings:** China will increase R&D and promote energy-saving and low-carbon technologies that can be incorporated by different buildings in multiple climates. These initiatives will lead to ultra-low-energy consumption and low-carbon buildings throughout the economy. Renewable energy use by buildings will also be promoted, and the integration of photovoltaics into buildings will be expanded.
- **Transport:** Utilisation of electricity, hydrogen, natural gas, and advanced liquid biofuels will be expanded, while reducing the proportion of new car sales that run on traditional refined product fuels.
- **Hydrogen:** The 14th FYP labels hydrogen a 'frontier' area that the economy pledges to advance. Although an economywide strategy has yet to be developed, some provinces and cities launched their own plans to specifically feature hydrogen. China is initiating a four-year program to support local governments in researching hydrogen technology and developing an industry chain.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- **The Reference scenario (REF)** illustrates a pathway where recent trends in energy efficiency, technology deployment and policy frameworks continue throughout the projection period. This scenario provides a baseline for comparison.
- **The Carbon Neutrality scenario (CN)** illustrates a hypothetical pathway where energy efficiency, fuel switching, and technology advance significantly to reduce CO_2 emissions from fossil fuel combustion by 2060. Results are shown through 2050.
- For a better comparison between REF and CN, the macroeconomic backdrop (GDP and population) is held constant between the two scenarios.
- The CN does not intend for the energy sector to reach carbon neutrality on its own. Instead, the magnitude of remaining energy sector CO_2 emissions is highlighted for policymakers, industry, and researchers to assess pathways to 'full' carbon neutrality that includes CO_2 emissions sinks from outside of the energy sector.
- The REF incorporates the expectation that China strictly limits the increase in coal consumption over the 14th FYP (2021-2025) and begins to phase it down in the 15th five-year plan period (2026-2030).
- The CN incorporates an evolving transportation structure with reduced road transportation and increased rail transportation (in alignment with China's NDC).

Table 5-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support low carbon objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Low carbon measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant low carbon measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for China

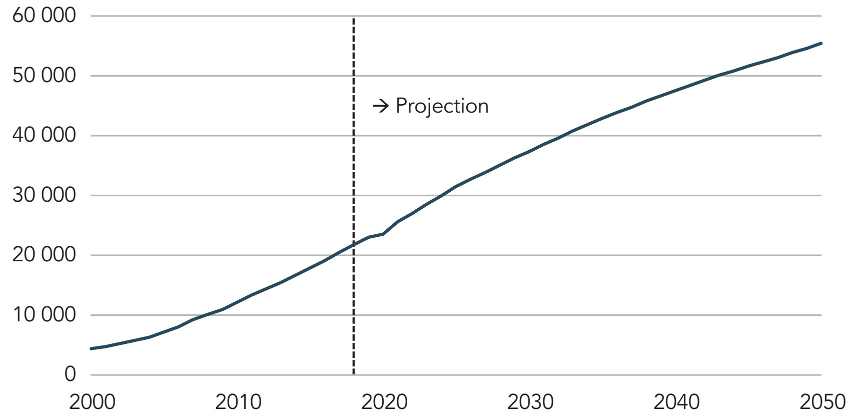
Table 5-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN low), GDP: World Bank, IMF.	• Population: (UN low), GDP: World Bank, IMF.
Buildings	• Clean heating accounts for 70% of all heating in northern China by 2025. • Effect of energy efficiency labeling in household equipment.	• Increased energy efficiency, energy saving, electrification and the use of renewable energy.
Industry	• CCS uptake for heavy industry begins 2040. • Hydrogen for steel and chemical industries begins in 2035. • Steel and non-metallic minerals production output projections decouple from economic growth, with production significantly lower than current levels in 2050.	• CCS uptake for heavy industry begins 2030 and hydrogen for steel and chemical industries begins in 2030. • Greater energy efficiency improvements and electrification in all industries. • More of a move from coal to gas in certain industries. • Material efficiency means there is roughly 10% less production in steel, non-metallic minerals, and chemicals industries. • Increased critical minerals mining.
Transport	• Low-carbon transportation	• Transition to low-carbon energy, including electricity, sustainable biofuels, and hydrogen.
Power and heat	• China will strictly control coal-fired power generation projects, and strictly limit the increase in coal consumption over the 14th FYP period and phase it down in the 15th FYP period. • At least 1 200 GW of renewables (solar and wind) • Traditional hydro and conventional storage technologies are adopted. • Increasing role of natural gas.	• Coal phasing out by 2050. • CCUS-equipped gas adoption from 2030. • Large scale adoption of renewables including offshore wind projects. • Large scale deployment of nuclear reactors. • No hydrogen consumption to produce electricity as other technologies expected to be more cost-competitive.
Supply	• Gas pipeline imports: POS1 reaches 38 bcm capacity by 2024; POS2 starts 2031, reaching 40 bcm in 2035. • Gas production reaches 260 bcm in 2025; 333 bcm in 2035; 390 bcm in 2050. • LNG import capacity requirements rise to 195 Mtpa by 2050.	• LNG import capacity requirements rise to 212 Mtpa by 2045.
Climate	• CO_2 emissions peak before 2030.	• CO_2 emissions peak before 2030. • Carbon neutrality by 2060

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

Macroeconomic backdrop

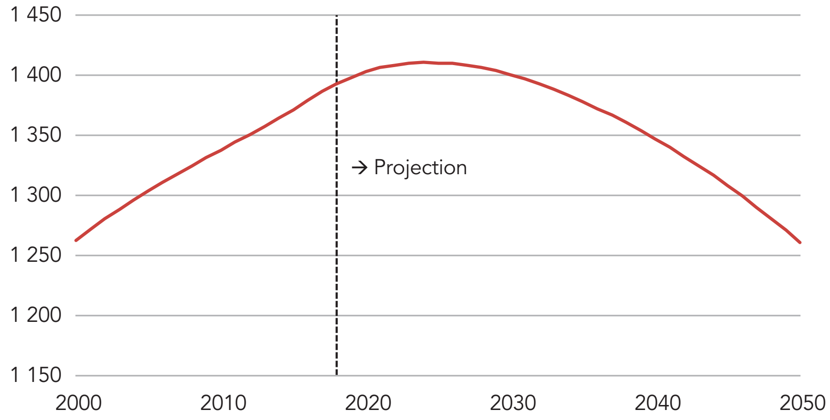
Figure 5-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

- China has experienced rapid economic growth, with GDP expanding more than four-fold from 2000 to 2018. The economy is heavily weighted to industry, though there has been a gradual transition to a more service-oriented economy. China's economy is the largest in the world, as measured by purchase power parity (PPP), though it falls to second (behind the US), in nominal GDP terms.
- The COVID-19 pandemic led China to post its lowest economic growth of the past two decades in 2020. However, in contrast to most other global economies, China posted positive economic growth and has since recovered strongly in 2021. GDP growth will moderate through the projection period given that the high growth that China has experienced in recent decades is unsustainable for the long-term.
- Although the one-child policy ended in 2015 (it began in 1979), China's birthrate has not recovered. The population is projected to peak in the mid-2020s and then is expected to continue to decline through the projection period due to the low birthrate. The average age is also expected to continue to increase.
- The combination of moderate GDP growth and a declining population will lead to GDP per capita growing at a faster rate than GDP through to 2050.

Figure 5-2. Population in millions, 2000-2050

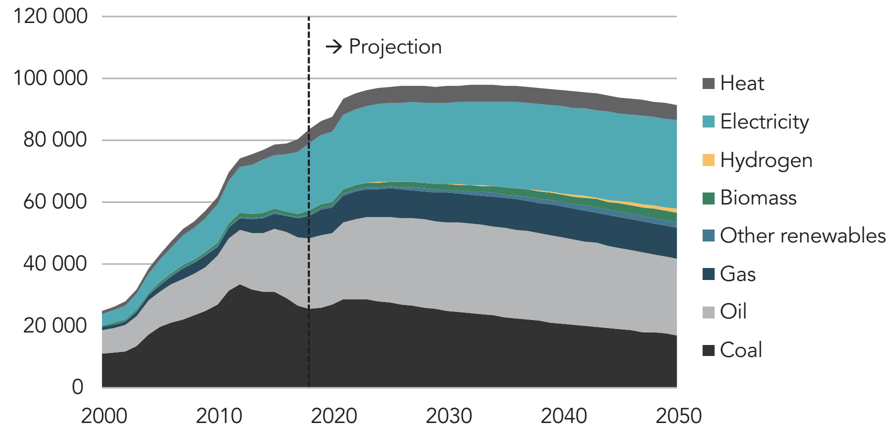


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- GDP per capita is projected to almost triple from approximately USD 16 000 (PPP) in 2018 to USD 44 000 (PPP) in 2050.

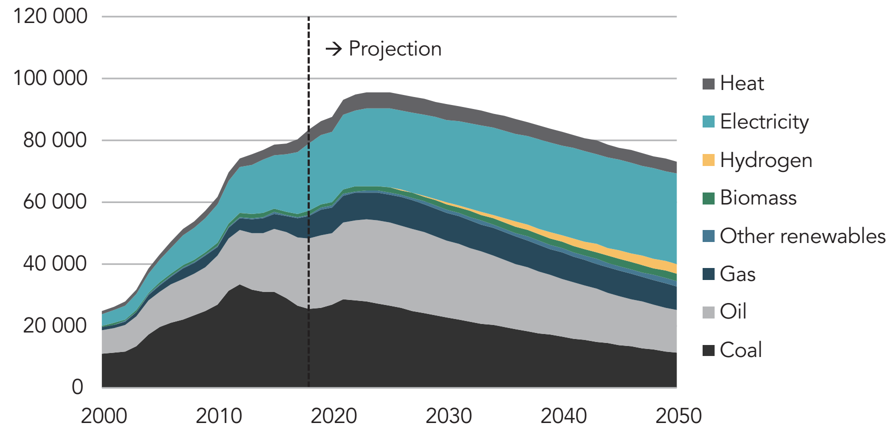
End-use energy demand

Figure 5-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 5-4. Energy demand in CN, 2000-2050 (PJ)

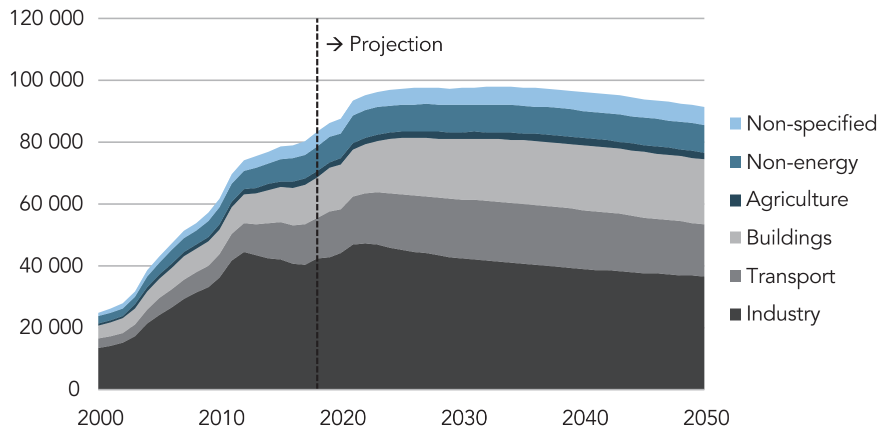


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- From 2000 to 2018, China's rapid economic expansion saw energy demand more than triple (230% increase). GDP increased by almost 390%, or an annual rate of 9%. Population also contributed to growing energy demand, increasing from 1.3 billion to 1.4 billion for the same period.
- The share of coal in end-use energy demand has declined to 31% in 2018. This decline has been offset by gas and electricity increasing to 9% and 26% respectively. The industry sector accounts for almost 70% of end-use coal demand, and with a continued decline in the share of industrial energy demand, the decline in coal is expected to continue in both scenarios. However, even in CN scenario, coal demand remains important for certain difficult to decarbonise industrial subsectors.
- In REF, energy demand peaks in the early 2030s, and is 10% higher in 2050 relative to 2018. Coal declines through the projection, led by reduced consumption from the industry sector. Coal's share in the end-use energy mix falls to 20% in 2050, while electricity increases to 30%. Oil and gas maintain similar shares from 2018 to 2050.
- In CN, energy demand is 10% lower in 2050 relative to 2018, and peaks in the early 2020s. Energy demand is 20% lower in CN than in REF in 2050. The reduction in CN is mainly due to a fall in coal and oil. The industry sector is the main driver of reduced coal demand due to fuel switching from to gas and electricity. Fuel switching also leads to reduced oil demand in transport and in industry. In CN, the share of coal and oil drops to 16% and 19% respectively.
- Electricity demand increases in both REF and CN. In CN, although overall energy demand falls, electricity demand is slightly higher than in REF in 2050. From 2018 to 2050, electricity demand increases from 6 000 TWh to approximately 8 000 TWh in both scenarios. Additional demand is from EVs in transport, and cooking, cooling, heating, and home appliance applications in buildings.
- In 2050, CN hydrogen consumption is nearly triple that in REF and is mainly consumed in the steel and chemicals sub-sectors of industry and by fuel cell EVs in transport.

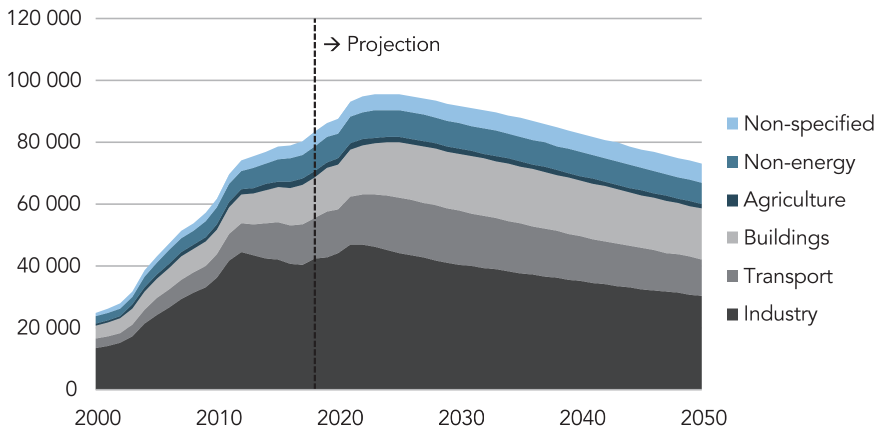
End-use energy demand by sector

Figure 5-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 5-6. Energy demand by sector in CN, 2000-2050 (PJ)

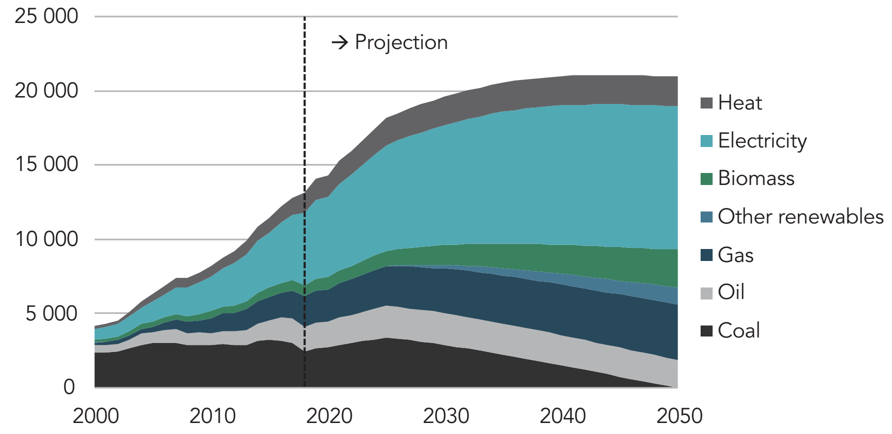


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- China's industrial sector is the largest in the world and currently provides more than half the world's steel production, very large volumes of cement (that have facilitated China's property and infrastructure led growth), and all manner of manufactured products. Energy demand from industry almost quadrupled from 2000 to 2012, though has since stabilised.
- In 2018, industry accounted for more than half of total final consumption, which includes the non-energy sector. The next most prominent sectors of transport and buildings account for less than one-third of industry energy demand.
- The industry sector peaked at three-fifths of China's energy product demand in 2011, with the decline since then reflecting that China is beginning to shift to a more services intensive economy. With continued structural change, the share of the industry sector in overall energy demand is expected to decline to two-fifths in 2050 for both scenarios.
- In REF, all sectors except industry will consume more energy by 2050. Notably, the buildings sector will increase nearly 60% which occurs against the backdrop of a significantly expanding services sector, supported by continued robust growth in per capita income.
- In CN, industry is the largest contributor to overall energy demand decline, though this contribution is mostly due to the sheer size of the sector. The transport sector accounts for the next largest portion, though contributes a far greater relative decline. Only the buildings sector will see energy demand grow (excluding the non-specified sector from this discussion). This is driven by the growing trend of urbanisation and higher per capita incomes, that brings with it greater energy consumption per person, even with assumed improvements in appliance and other end-use energy efficiency.

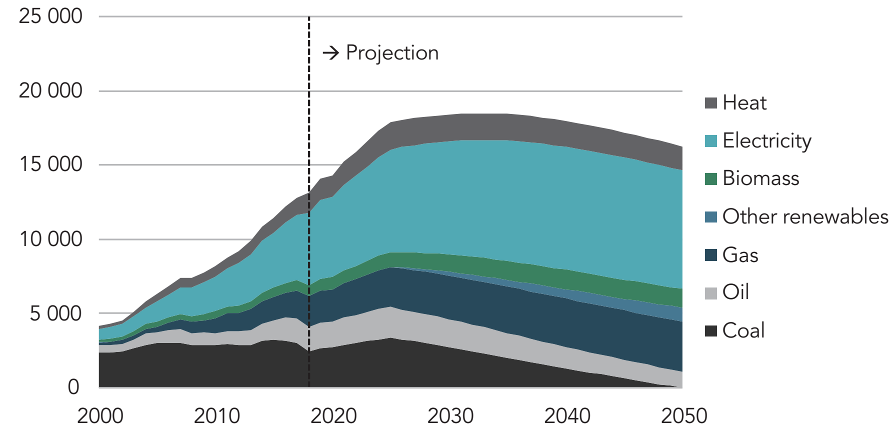
Buildings energy demand

Figure 5-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-8. Buildings energy demand in CN, 2000-2050 (PJ)

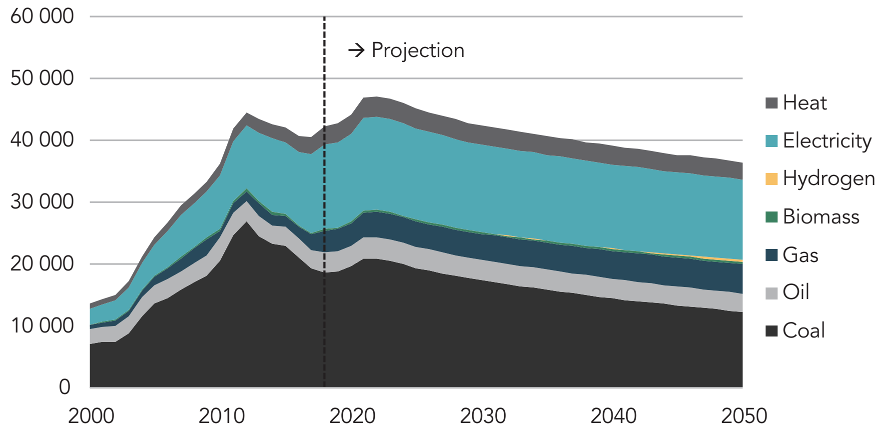


Sources: EGEDA, APERC analysis.

- From 2018 to 2050, China's GDP is projected to increase almost 150% at an annual average of 3%, whereas population is expected to fall nearly 10%. In both scenarios, these trends of greater prosperity spread amongst a declining population are anticipated to be the driving force for buildings energy consumption.
- Another important trend for buildings consumption is the movement of people from China's rural regions to its cities. From 2000 to 2020, the urban population in China increased from 36% to 61%. A continuation of this trend implies an increase in access to modern fuels.
- The number of durable goods owned by households has increased in parallel with incomes. For example, the ownership of washing machines, refrigerators, air conditioners, microwave ovens, and mobile phones increased significantly. As incomes continue to increase, durable goods ownership, and associated energy use will increase.
- New building construction will comply with more stringent building codes that increase the energy efficiency of the sector. The buildings sector in CN is 20% more efficient than in REF, with this efficiency driving energy use falls from the late 2030s.
- The Residential Coal Switch Policy is leading to a gradual phasing out of coal fired boilers. Coal consumption peaks in 2025 in both scenarios on the back of this policy, with a complete phase out achieved in both scenarios by 2050.
- Significant fuel switching occurs in CN, including coal-to-gas and coal-to-electricity for space heating. There is also a large-scale switch away from traditional biomass, though it persists due to the difficulty in switching to alternatives in isolated regions. Nevertheless, biomass demand in CN is half that of REF in 2050. The switch away from traditional biomass is anticipated to lead to more gas for cooking and heating. Electricity demand also increases for the use of cooking and home appliances.

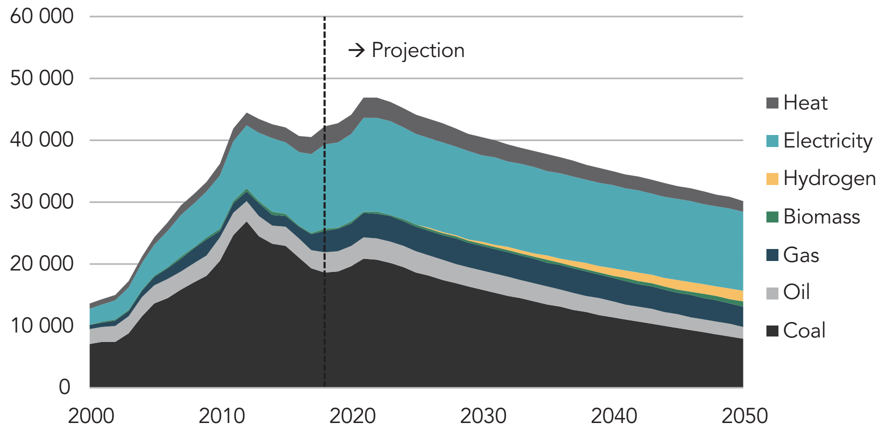
Industry energy demand

Figure 5-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 5-10. Industry energy demand in CN, 2000-2050 (PJ)

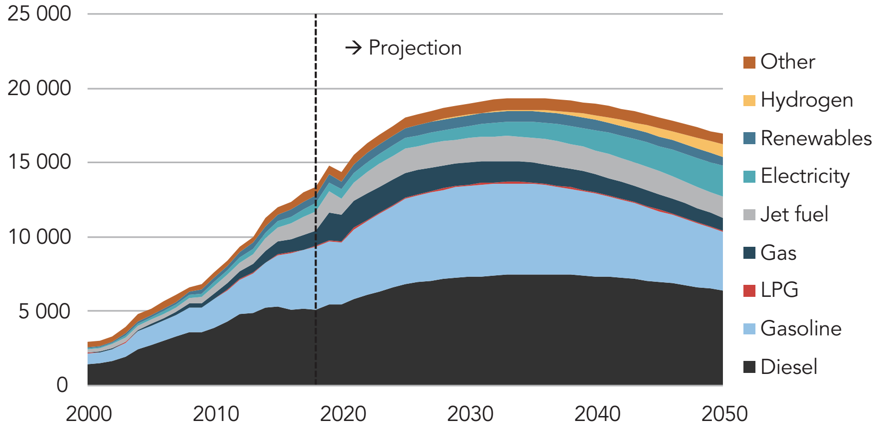


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- In response to significant overcapacity in cement production, China enacted policies to downsize and consolidate the industry in 2013, which contributed to declining industrial energy consumption through the mid-2010s. The impact of global stimulus and outsized demand for goods brought on by the COVID-19 pandemic has led to a surge in China's industrial output and associated energy demand. This is expected to moderate and decline in both scenarios out to 2050, with an assumed peak in the early 2020s.
- China recognises the importance of industry in its action plan for emissions peaking before 2030. Even with assumed moderation in output, China is committed to enhancing energy efficiency across all industry sub-sectors. The move towards greater energy efficiency is assumed to occur at a greater rate in the CN scenario.
- While industrial coal demand has fallen from its peak in 2012, it is still almost 160% higher than at the beginning of the century. For 2000 to 2018, electricity demand growth has been even greater, increasing 4.4 times.
- In CN, the additional reduction in energy demand is due to energy efficiency improvements in all subsectors and less production due to material efficiency improvements in heavy industries (steel, cement and chemicals). Part of the energy efficiency story is an assumed fuel switching away from coal and oil to electricity, hydrogen and gas. The share of fossil fuel demand will decrease to less than half of all industrial demand.
- Hydrogen will be utilised mainly in steel making and the chemicals subsector in both scenarios. Hydrogen take-up will be five times larger in CN by 2050 due to assumed policy support and a more rapid improvement in the economics of hydrogen-based industrial processes.
- CCS is incorporated by heavy industries from 2030 in CN, with almost one-third of fossil fuels used by heavy industry subject to some form of CCS process by 2050.
- While there is an assumed lower level of coal mining in CN (captured in own use consumption), part of this reduction is offset by an increased amount of critical minerals mining, which are important for low-carbon technologies.
- There is fuel switching to natural gas in REF. However, electricity, hydrogen and biomass tend to out-compete natural gas in CN.

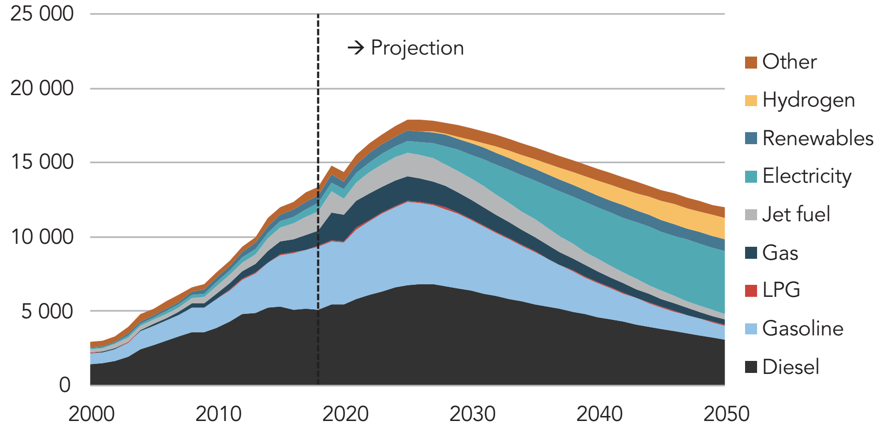
Transport energy demand

Figure 5-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 5-12. Transport energy demand in CN, 2000-2050 (PJ)

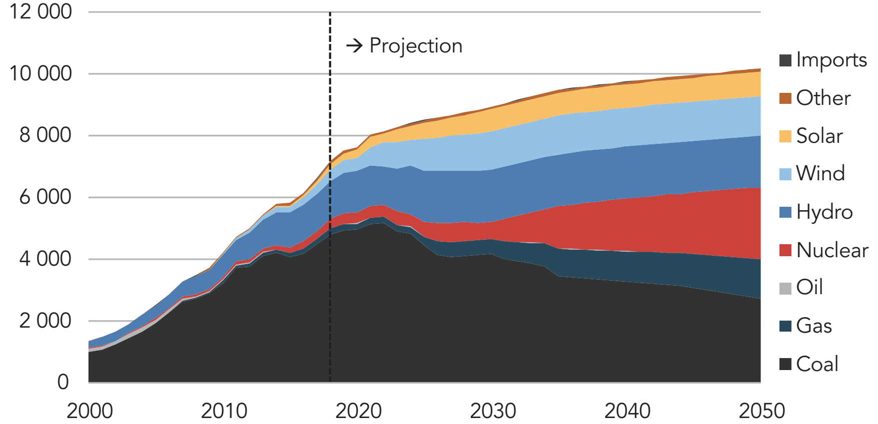


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Energy demand in transport increased almost 370% from 2000 to 2018, which is an annual growth rate of 9%. The increase is driven by road transport and the demand for gasoline and diesel. From 2013 to 2020, the number of automobiles owned per 100 households increased from 17 to 37, reflecting significant increases in incomes.
- In REF, demand peaks in the early 2030s, as transport activity for passenger vehicles is expected to start to slow and to shift to public railways. Passenger battery EVs increased significantly in the past 10 years, yet the share of battery EVs in the passenger vehicle fleet was still only 3% in 2018. Gasoline cars had almost a 90% share. The share of EVs is expected to continue to increase in REF, reaching 40% in 2050. In 2050, electricity demand in the transport sector will reach 580 TWh, up from 140 TWh in 2018.
- Energy demand is expected to peak in the mid-2020s in CN, with a much larger shift from private to public transportation. In addition to this shift, the sales share of battery electric passenger vehicles (motorbikes, buses, light trucks, and light vehicles) increases to more than 50% by 2028. This means that the battery EV share of the stock of passenger light vehicles increases to more than 80% in 2050.
- In 2050, electricity demand by transport will reach 1 180 TWh in CN, which is twice as high as REF. Electricity's share of transport energy demand reaches 35% in CN (versus 12% in REF).
- In CN, hydrogen up-take, especially for heavy trucks, is significantly higher than in REF. The share of hydrogen in transport energy demand is expected to reach 12% in CN (5% in REF).
- China's NDC states that reducing road transportation and increasing rail and water transportation is an important measure for China to achieve low-carbon development of transportation. The CN trends align with the NDC statement.

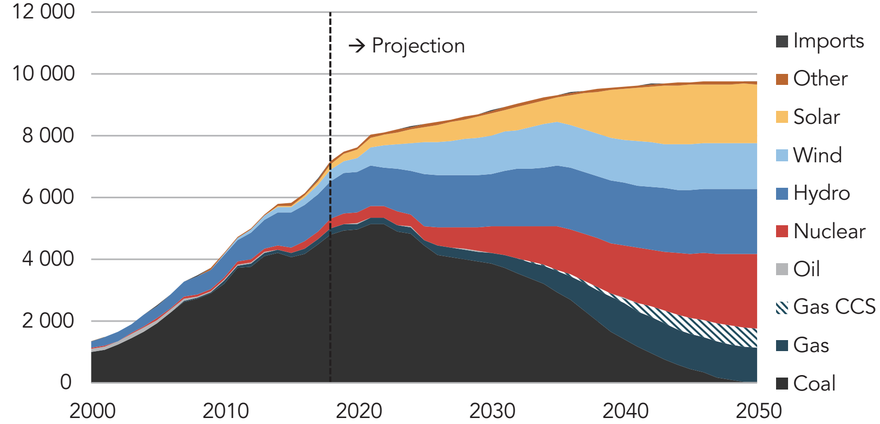
Electricity generation

Figure 5-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 5-14. Electricity generation in CN, 2000-2050 (TWh)

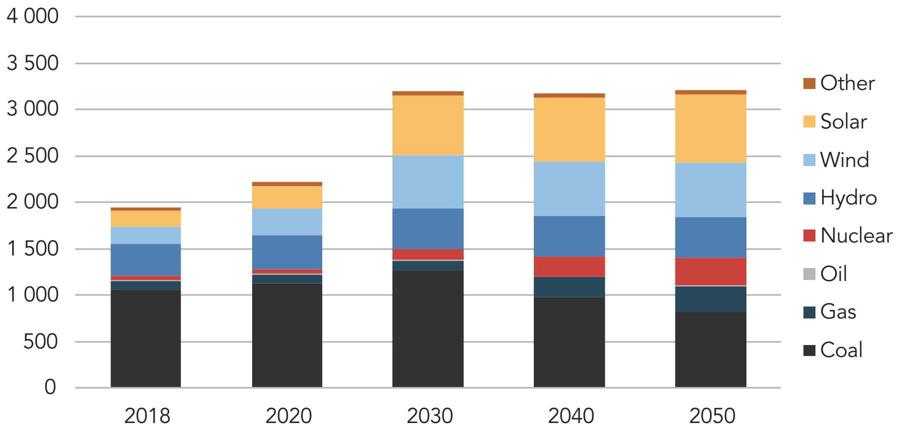


Sources: EGEDA, APERC analysis.

- Electricity generation has almost quadrupled with the rapid economic expansion that occurred from 2000 to 2018.
- China is limiting coal-fired generation projects over the 14th FYP period (2021-2025) and the 15th FYP period (2026-2030).
- Electricity generation increases in both scenarios in response to increased electricity demand, particularly from the buildings and transport sectors. In the buildings sector, the switch away from coal is influential in increasing electricity demand. In the transport sector, fuel switching primarily from gasoline and diesel to electricity leads to increased electricity demand through to 2050, particularly in CN.
- The difference in electrification rates between the two scenarios is highest for the transport sector. In 2050, electricity accounts for 35% of transport energy use in CN, compared to 12% in REF. Whereas for industry, this is 42% in CN and 36% in REF; and for buildings, it is 49% in CN and 46% in REF.
- As of 2018, more than half of the electricity is generated by coal. However, coal power generation decreases in both scenarios. In CN, the share of electricity generated by coal has almost reached zero by 2050.
- In CN, power generation from fossil fuels declines to 18% in 2050, and a third of this is from gas with CCS. These gas-fired CCS units will be deployed from the early 2030s and gradually increase through 2050 to complement variable renewable generation while keeping emissions low.
- In CN, in 2050, renewables (hydro, solar and wind) and nuclear are dominant in power generation. The share of electricity generated by these four technologies reaches 80% in 2050.
- No hydrogen consumption in electricity generation is assumed as other technologies are expected to be more cost-competitive.
- As energy efficiency in generation technologies improves, the overall growth in fuel consumption will be lower than the growth in generation.

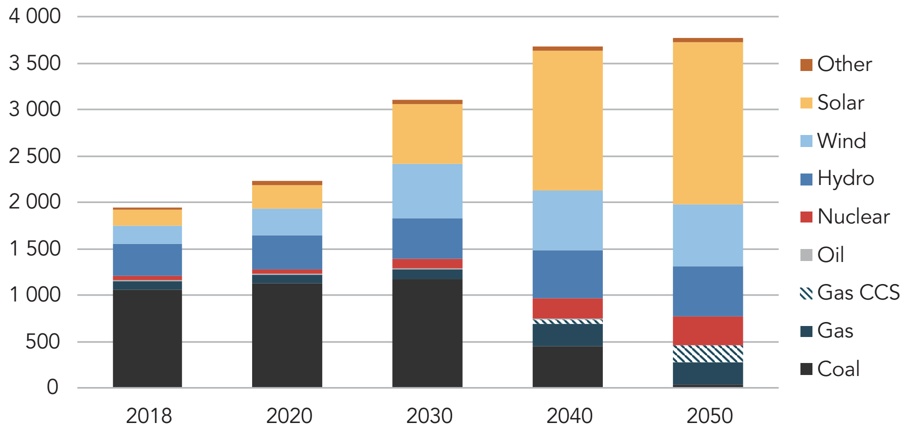
Generation capacity

Figure 5-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 5-16. Generation capacity in CN, 2018-2050 (GW)

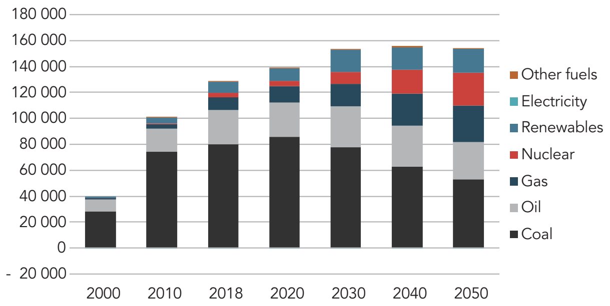


Sources: EGEDA, APERC analysis.

- In 2018, 55% of China's generation capacity consisted of coal-fired power plants, followed by hydro (18%), wind (9%), and solar (9%). Coal fired-power plant capacity is expected to peak and then decrease significantly in both scenarios due to government-led change. In CN, coal-fired power plant capacity is expected to decline to 36 GW (1% share of total generation capacity) by 2050.
- In December 2020, President Xi Jinping announced that China aims to bring its total installed capacity of wind and solar to over 1 200 GW by 2030, as part of its NDC. In both REF and CN, total installed capacity of wind and solar in 2030 will reach 579 GW and 644 GW, respectively, resulting in 1 223 GW total.
- In REF, over 1 260 GW of capacity is added between 2018 and 2050. The additions are mainly from solar, wind and nuclear. Coal capacity is the only capacity type to decline through the projection period.
- In CN, solar (+1 576 GW), wind (+476 GW) and nuclear (+266 GW) capacity is added between 2018 to 2050 to offset the phase out of coal-fired power (–1 027 GW).
- In CN, in 2050, nearly half of gas-fired power plants will be equipped with CCS.
- Massive installation of both solar and wind capacity is expected in both scenarios. In REF, between 2020 and 2050, solar and wind increase by an average of 18 GW and 12 GW, respectively each year. In CN, solar and wind increase by an average of 49 GW and 18 GW, respectively each year.

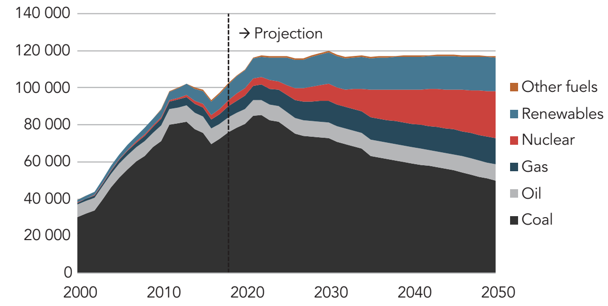
Energy supply in the Reference scenario

Figure 5-17. Total energy supply in REF, 2000-2050 (PJ)



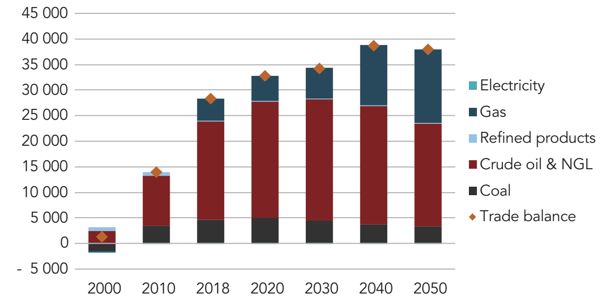
Sources: EGEDA, APERC analysis.

Figure 5-18. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-19. Energy trade in REF, 2000-2050 (PJ)

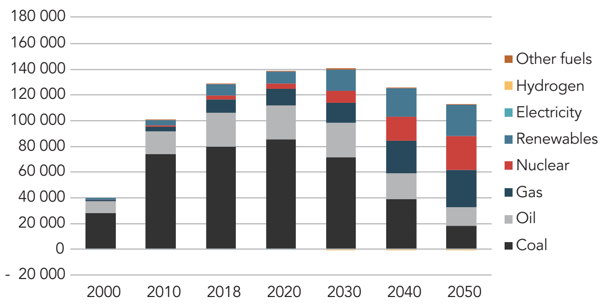


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Energy supply more than doubled from 2000 to 2018, with much of the rise due to coal, which almost tripled to 80 000 PJ. All fuel types increased, with notable increases from nuclear (17-fold) and gas (13-fold). Overall energy supply continues to grow before stabilising in the 2030s.
- As of 2018, more than half of the energy is supplied by coal, followed by oil and gas. While the share of coal and oil decreased from 2000, the share of gas, renewables, and nuclear increased.
- China's energy supply increases 14% from 2018 to 2050. Coal's share in energy supply peaked in 2005 and has since declined, though its relative prominence is still clear, accounting for 62% of China's energy supply in 2018. The share of coal and oil declines through to 2050, whereas the share of nuclear, renewables, and gas increases.
- China continues to be the third largest natural gas producer in the APEC region. Most of its production is consumed domestically.
- Domestic production increased 2.6 times from 2000 to 2018. Most of the increase was from coal production, which peaked in 2013. The post-COVID rebound will see coal reach a new peak in the early 2020s. Coal production accounted for almost three-quarters of China's total energy production in 2018. From the early 2020s, production is relatively flat. Beneath the surface, there is a switch from coal to nuclear, renewables, and gas. Coal's share of production is 43% in 2050.
- China continues to be a net importer of energy through to 2050. Overall energy imports grow 30% from 2018 to 2050, mainly driven by net gas imports, which rise three-fold.
- Gas import dependency rises from 2018 to 2050, which has implications for energy security. The degree to which China can sustain or surpass gas production levels shown here will determine the degree of import dependence.
- From 2018 to 2050, coal production falls 35% due to decline in domestic demand. Net imports of coal decrease nearly 30% for the same period.
- Oil production increases almost 10% from 2018 to 2050. Net imports of crude oil and NGLs increase by 5%.

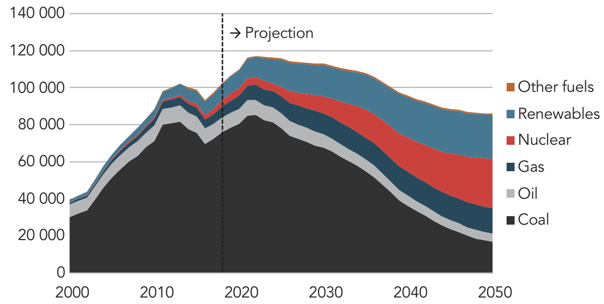
Energy supply in the Carbon Neutrality scenario

Figure 5-20. Total energy supply in CN, 2000-2050 (PJ)



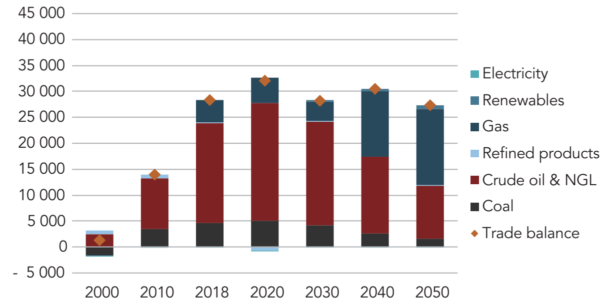
Sources: EGEDA, APERC analysis.

Figure 5-21. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-22. Energy trade in CN, 2000-2050 (PJ)

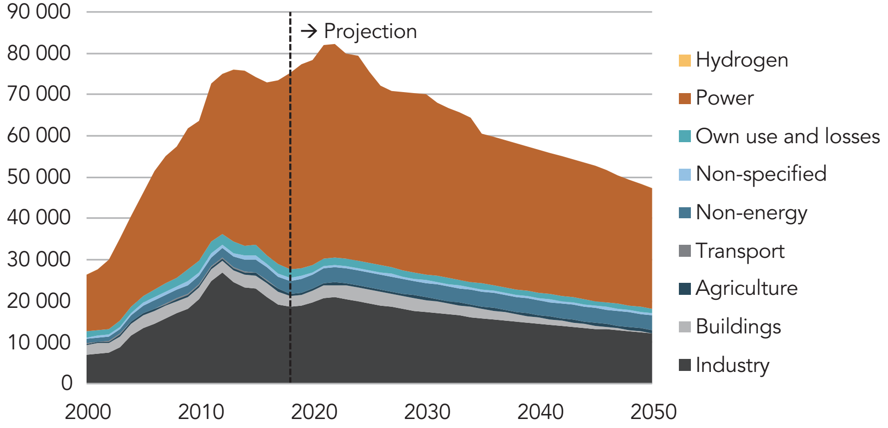


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- China's energy supply peaks in the early 2020s in CN. From there, energy supply declines to be 14% lower in 2050 relative to 2018.
- Coal's supply declines from a share of 62% in 2018 to only 16% in 2050. Oil also declines from 20% to 13% for the same period. Nuclear, gas, and renewables all increase to make up for the large declines in coal and oil. The rise in nuclear is particularly dramatic, increasing from a 2.5% share in 2018 to over 23% in 2050. Natural gas almost triples to over 28 000 PJ to become the largest source of supply in CN.
- Like supply, China's production peaks in the early 2020s, and then declines out to 2050, at a level 16% lower than in 2018. China's production composition changes are comparable to what happens in REF, though with a much larger decline in coal. The decline in coal production to the late 2020s is similar in both scenarios, but from there, coal production falls significantly faster in CN, to a level only one-fifth of the 2022 peak.
- Oil production falls by over 40% out to 2050 in CN. The falls in both coal and oil are offset by large increases in nuclear, renewables, and gas production, which is a story that mimics supply.
- Net energy imports fluctuate through the projection period in CN and are eventually 8% lower in 2050. There are large declines in crude oil and NGLs, coal, and refined products. However, imports of gas double through to 2050 in response to domestic production being unable to fulfil the entirety of the large increases in demand. Gas import dependency reaches almost the same level as in REF.
- Compared with REF, in CN, net energy imports are a third smaller in 2050, and much of this reduction is due to lower oil supply requirements. This result illustrates that reducing oil demand, via increased energy efficiency and EV deployment, can reduce import dependency and improve energy security.

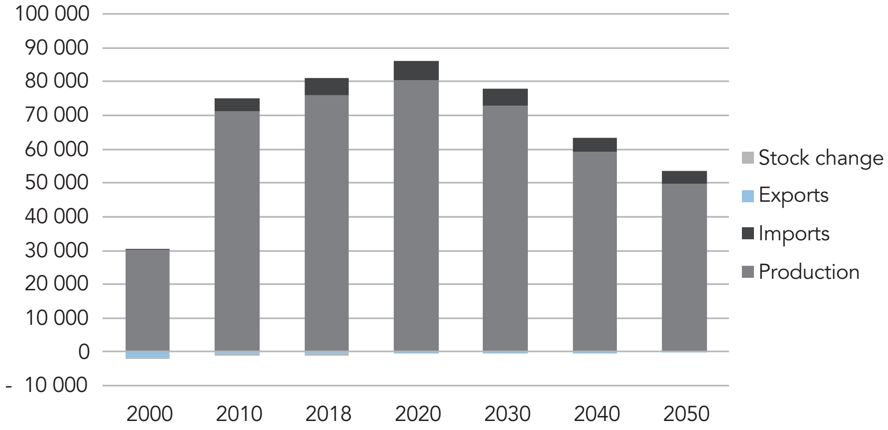
Coal in the Reference scenario

Figure 5-23. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-24. Coal production, imports, and exports in REF, 2000-2050 (PJ)

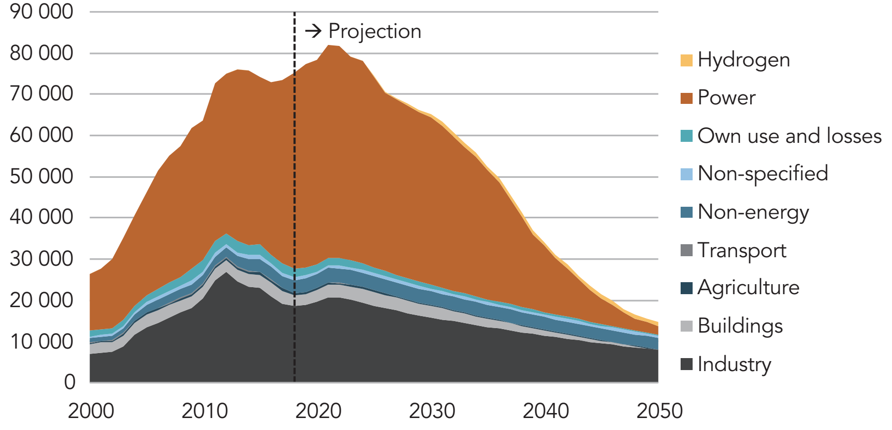


Sources: EGEDA, APERC analysis.

- China has significant coal resources and mines them primarily for its own consumption. Although the share of coal in end-use energy demand declined from 45% to 31% from 2000 to 2018, it is still at a high level relative to the rest of APEC.
- China has faced a challenge of overcapacity in coal mining. Many of the older state-owned mines have been unprofitable, though a process of consolidation and optimisation has led to multiple mine closures and a more sustainable industry.
- In 2021, the economic recovery from the COVID-19 pandemic and extreme weather led to a large increase in coal demand. Supply was insufficient to meet this surge in demand and has since led to increased production from previously closed mines and increasing coal imports. The surge in coal demand in the early 2020s is expected to be transitory, with a projected decline occurring from the mid-2020s.
- In 2018, the power sector accounted for almost two-thirds of coal consumption, followed by the industry sector which accounted for a quarter. China will control coal-fired power generation projects, strictly limit the increase in coal demand over the 14th FYP period and phase it down during the 15th FYP period.
- Most of the coal supply is provided by domestic production, though imports have been relied upon to meet the rapid growth in domestic demand since the late 2000s. Domestic production will satisfy most of China's demand out to 2050.
- China was a net exporter of coal until 2008. However, coal imports have since grown from less than 1 000 PJ in the mid-2000s to more than 5 000 PJ in 2018. Exports have fallen to 400 PJ in 2018, making China a net importer of coal.
- Industry coal consumption continues to decline through the projection period. However, switching away from coal is difficult for certain applications, such as in steel making, and so industrial coal demand is more robust than for other sectors.

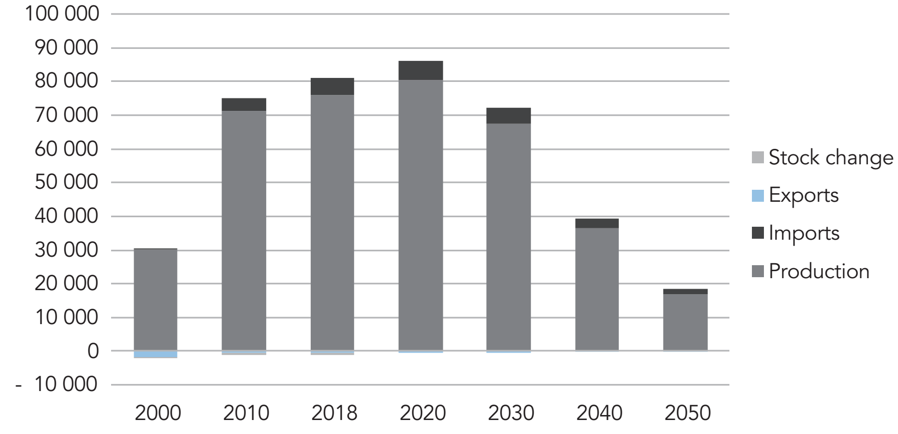
Coal in the Carbon Neutrality scenario

Figure 5-25. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-26. Coal production, imports, and exports in CN, 2000-2050 (PJ)

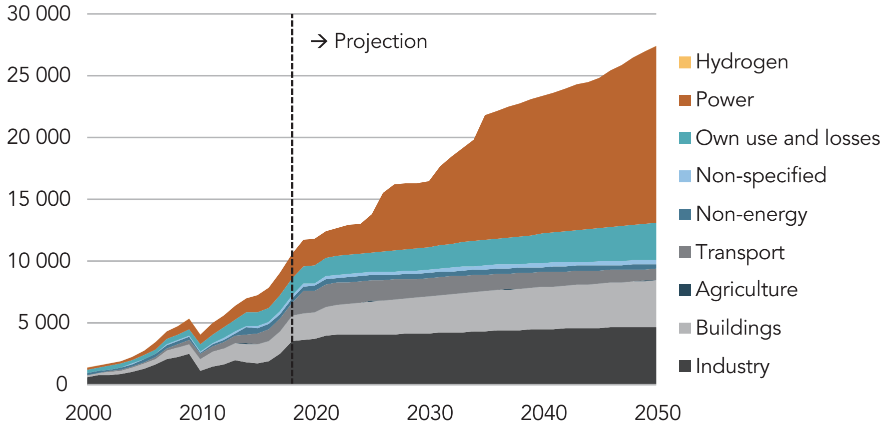


Sources: EGEDA, APERC analysis.

- In CN, coal demand peaks in the early 2020s, before declining to less than one-fifth of the peak in 2050. The decline is most notable in the power sector, with consumption falling by more than 95%. CN coal consumption is almost 70% lower than in REF in 2050.
- Like REF, most of the coal supply is provided by domestic production through to 2050. Coal production falls by 70% out to 2050 which is in response to the greatly reduced consumption levels.
- There is an increasing amount of hydrogen-based steel production in the CN scenario towards the end of the projection period. However, China's steel industry continues to rely on coking coal for a large portion of its output. Coal also remains prominent in other heavy industry applications, though the addition of CCS technologies allows this to continue while reducing emissions.
- The global markets for coal are expected to follow a similar decline to China's domestic markets for coal. China's coal exports in CN will be almost 40% lower than in REF in 2050 in response to this decline.
- Hydrogen production that uses coal is the one sector that sees growth out to 2050. This production is assumed to be coal gasification with CCS and increases to almost 1 000 PJ by the mid-2030s. Hydrogen sector consumption of coal then stabilises, with almost all the growth in hydrogen in the latter half of the projection from electrolysis using renewable electricity.

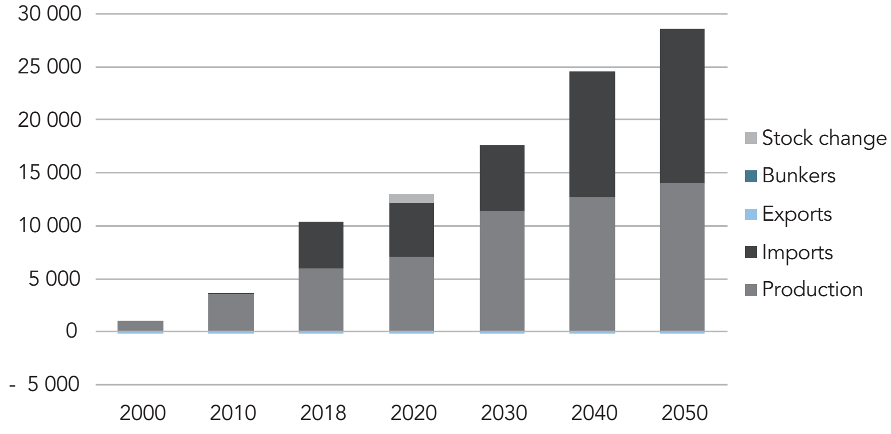
Natural gas in the Reference scenario

Figure 5-27. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-28. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

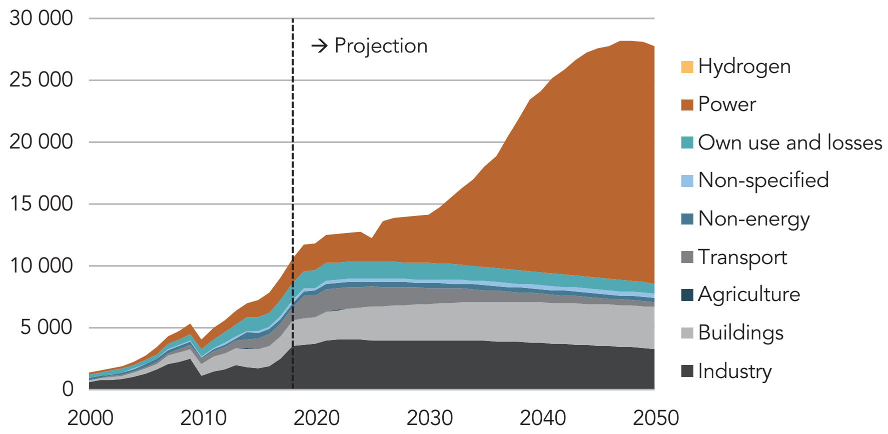


Sources: EGEDA, APERC analysis.

- China's gas consumption has increased dramatically since the turn of the century. In 2018, the industry sector was the most gas consuming sector followed by the buildings and power sectors.
- Gas demand continues to increase through to 2050, with all sectors consuming greater volumes of gas, except for the transport sector. The largest contributor to China's increased gas consumption is the power sector, which increases gas consumption seven-fold from 2018 to 2050. Gas-fired power becomes an increasingly important complement to increasing variable renewable generation.
- As demand for gas increases through to 2050, both production and imports are projected to increase. Domestic production increases more than 130% from 2018 to 2050. However, this growth is insufficient to meet the growth in demand. For the same period, natural gas imports increase by 230% to become the largest source of gas supply. This increased import dependency increases the risk of gas supply disruptions.
- China is increasing its gas storage. State-owned national oil companies and state-owned pipeline companies are aggressively developing storage capacity. Additional storage will help to meet the risk of gas supply disruptions and the price risk associated with winter LNG prices. LNG import capacity increases almost three-fold from 2018 to 2050.
- In 2014, Gazprom (Russian gas company) and China National Petroleum Corporation signed a 30-year agreement for the sale and purchase of gas supplied via the Power of Siberia gas pipeline. The Power of Siberia pipeline began operating in December 2019. The full capacity of 38 bcm per year is expected to be reached in 2024.

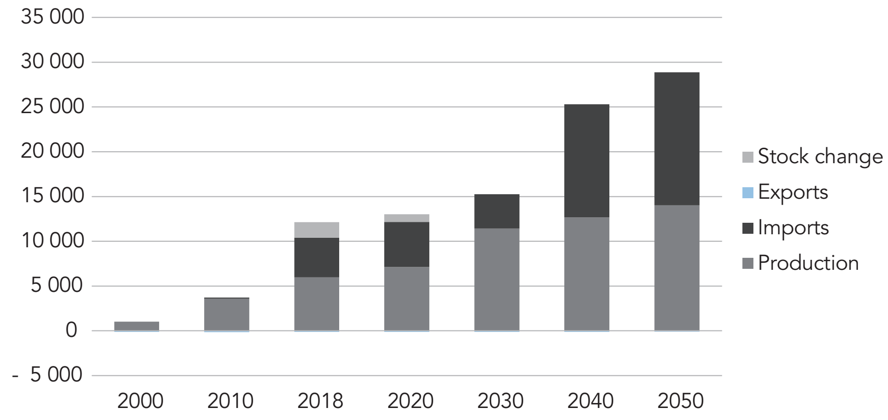
Natural gas in the Carbon Neutrality scenario

Figure 5-29. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-30. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

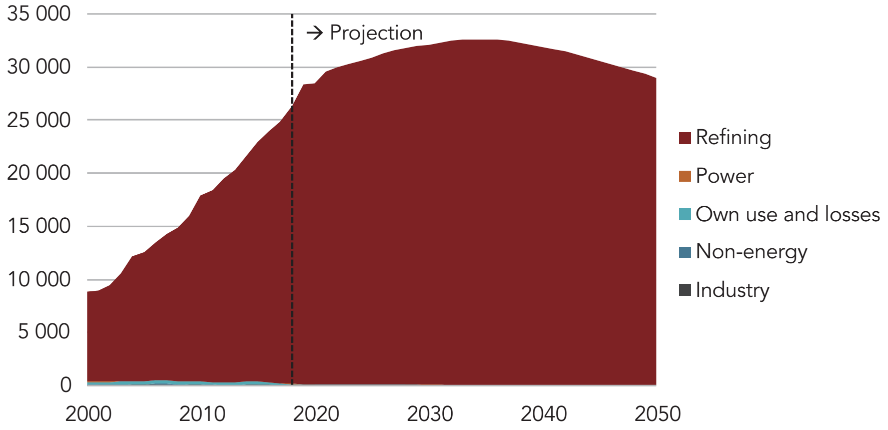


Sources: EGEDA, APERC analysis.

- The increase in natural gas consumption in CN is similar in magnitude to REF, though is more subdued through the 2020s. Power sector consumption in CN is a third more than in REF, with greater gas-fried generation facilitating a faster coal-fired power plant phase out. In all other sectors, natural gas consumption is lower in CN than in REF in 2050.
- By 2030, power sector consumption of natural gas in CN is about 1.9 times larger in 2018. This growth is significantly behind the growth in consumption in REF, with gas consumption almost 2.6 times larger for the same period. From 2030 to 2050, the growth in gas consumption by the power sector in CN is much faster than in REF, increasing more than nine-fold for the period from 2018 to 2050, versus less than seven-fold in REF.
- CCS technologies in gas-fired power plants are deployed in the early 2030s to allow gas to play a transitional role, while minimising emissions. In 2050, more than 50% of total gas electricity generation is generated by gas-fired power plants with CCS.
- In buildings, fuel switching from coal to gas and electricity occurs at a faster rate than in REF. This leads to an increase in gas demand in the buildings sector out to 2050. However, buildings gas consumption in CN is 10% lower than in REF, due to greater energy efficiency and electricity out-competing gas in many applications.
- Like REF, domestic production and imports of natural gas increase significantly in CN. Gas imports are 330 PJ larger than in REF, and gas import dependency increases from 2018 to 2050. The increased level of natural gas imports in CN is assumed to require more LNG infrastructure than in REF.
- For the industry sector, energy efficiency gains and electricity and hydrogen fuel alternatives mean that natural gas consumption is lower in CN than in REF. CCS for coal-reliant processes also lessens the need to transition to gas. Natural gas plays more of a role for industry in the REF scenario.

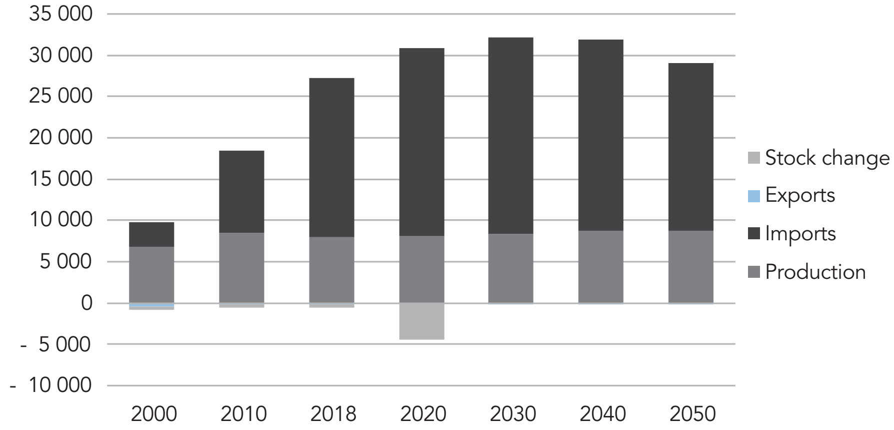
Crude oil and NGLs in the Reference scenario

Figure 5-31. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-32. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

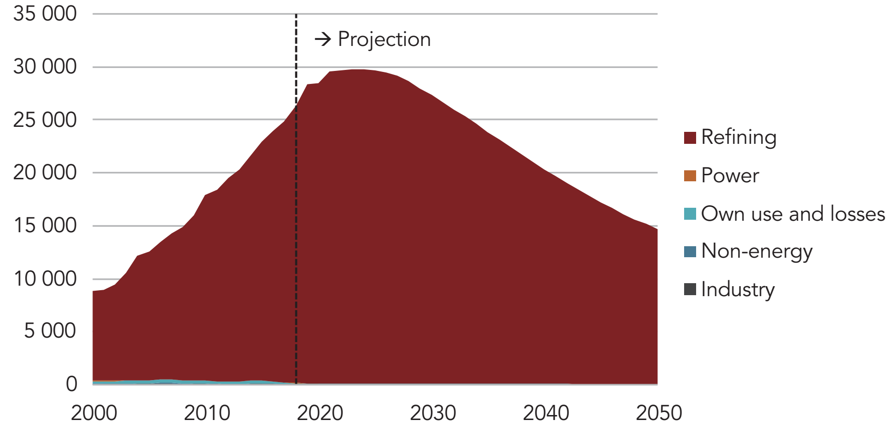


Sources: EGEDA, APERC analysis.

- China predominantly imports crude oil to produce refined products for domestic consumption in its refineries. Crude oil demand almost doubled over the past decade in line with rapid demand growth of refined products. From 2000 to 2018, oil demand growth drove oil imports up more than five-fold, while domestic production increased only 20%. As a result, import dependency rose in this period.
- Oil demand is expected to peak in the mid-2030s and then fall to a level that is 10% higher in 2050 than in 2018. The peak in the 2030s follows the peak of refined products use in the end-use sectors, particularly the transport sector. Transport activity for passenger vehicles is expected to start to slow in the 2030s, and as passengers shift to increased railway transportation, refined products demand continues to fall.
- From 2018 to 2050, crude oil and NGL imports trace a similar trajectory to the consumption needs of China's domestic refineries. Import dependency converges to current levels by 2050, after peaking in the 2030s. Increasing import dependence through to the 2030s will require more buffers to mitigate the risks of oil supply disruptions. China is addressing this by having increased its strategic petroleum reserve capacity by 30% during the pandemic. Additional investments may be required through the 2020s.
- Refinery capacity increases in China are equivalent to 2 000 PJ in REF, which is the highest increase in APEC. Capacity peaks in the mid-2030s, declining a ninth thereafter, as refineries are retired to maintain an overall utilisation rate of 83%. Higher utilisation rates than assumed here could support greater retirements and/or see China export greater volumes of refined products to the global market.

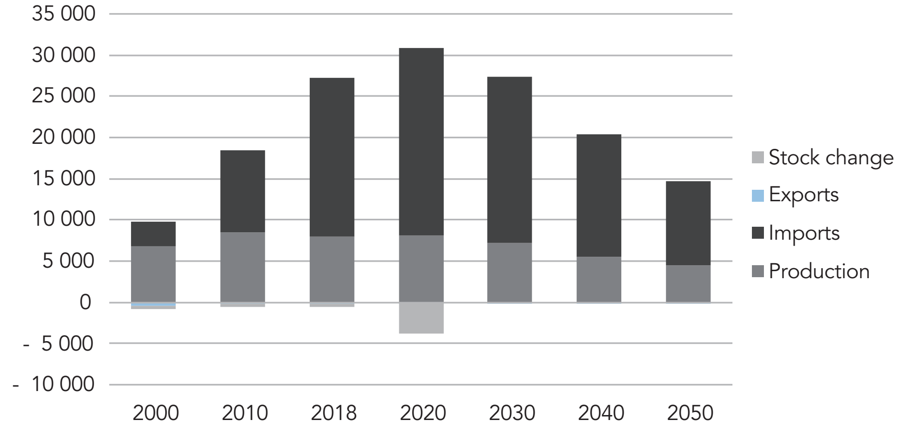
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 5-33. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-34. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

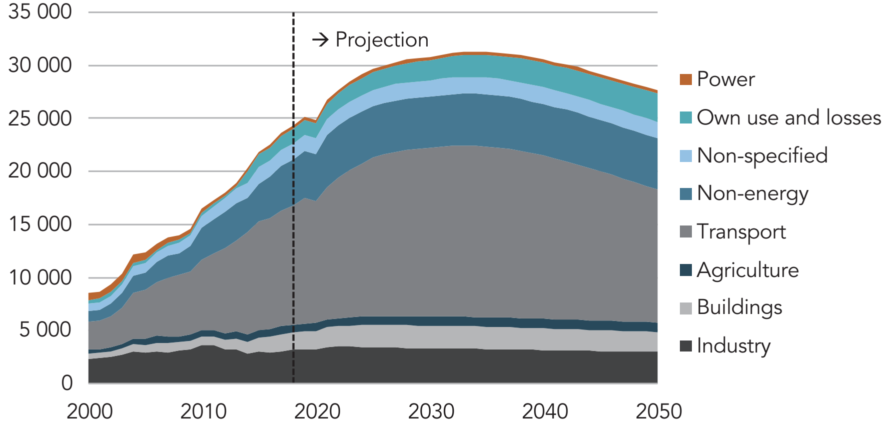


Sources: EGEDA, APERC analysis.

- Crude oil and NGL consumption by China's refineries follow the same trend as consumption of refined products by China's end-use sectors. In the transport sector, refined products consumption peaks in the mid-2020s. In CN, crude oil consumption is anticipated to peak in the mid-2020s and then fall by almost half out to 2050. The fall is tied closely to transport sector trends, with improved fuel efficiency, a greater move to public transportation, and higher adoption rate of EVs contributing to significantly lower demand for refined products in CN.
- In CN, global oil markets begin to diverge from REF in the early 2020s. Crude oil markets are almost 60% smaller than REF levels in 2050.
- Crude oil and NGL domestic production declines by more than two-fifths from 2018 to 2050, and imports decline by slightly more for the same period. Import dependency follows a similar trend to REF. China could reduce import dependency by elevating production levels in the face of declining domestic and global demand for oil.
- China's refiners maintain an average utilisation rate of 83% for much of the CN projection. In order to maintain this utilisation rate in CN, declining domestic and global demand for refined products leads to a two-fifth reduction in refinery capacity, which implies a much higher closure rate than in REF.
- This projection highlights the increased risk of investments in oil infrastructure becoming stranded as the world embraces carbon neutrality. Current investments in pipelines, refineries, storage, shipping containers, and import and export terminals, which are meeting current demand requirements, all face elevated stranded asset risk in CN.

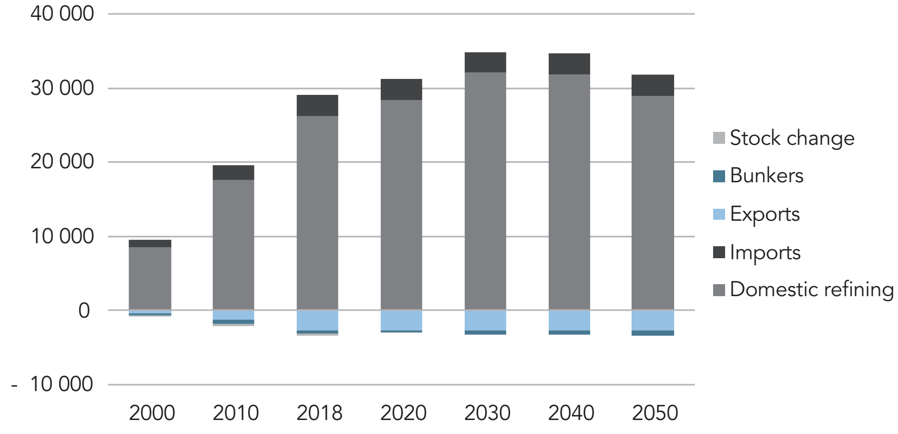
Refined products in the Reference scenario

Figure 5-35. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-36. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

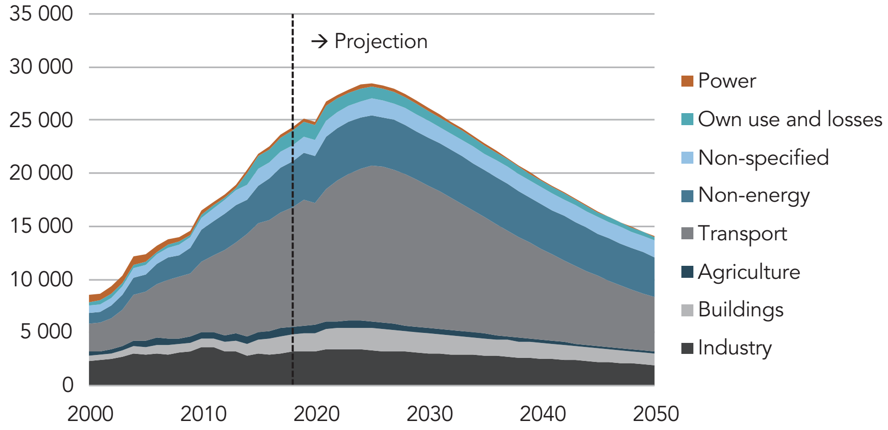


Sources: EGEDA, APERC analysis.

- Demand for refined products almost tripled from 2000 to 2018. The transport sector accounted for more than half of the demand growth, increasing more than four-fold. The non-energy sector, which uses refined products as inputs in petrochemical enterprises, buildings, own use, and industry all contributed to increasing levels of demand as well.
- The industry sector accounted for almost 30% of refined products consumption at the turn of the century. This share fell to 13% in 2018 and falls to only 11% by 2050.
- Demand for refined products peaks in the 2030s in REF and declines to a level that is 13% higher in 2050 than in 2018. This decline is partly due to less transport activity, as passengers opt for more energy-efficient and less oil-intensive modes of transport, like buses and trains. Improving fuel efficiency and a gradual transition to EVs also plays a role in limiting growth in refined products consumption.
- China produces most of its refined products domestically and this trend continues over the projection period.
- China's refining capacity begins to decline in the mid-2030s, which is in response to declining demand for refined products from end-use sectors.
- China began to supply the global refined products market in the past two decades, as shown by the rapid expansion in exports since 2000. Refined products exports are assumed to maintain current levels through to 2050. Higher refinery utilisation rates than assumed in this projection could lead to greater export levels. However, profitability will depend on the response of other global suppliers.
- China's mining sector is reliant on large quantities of refined products, particularly diesel. However, the decline in coal mining tempers own use demand growth for these fuels.

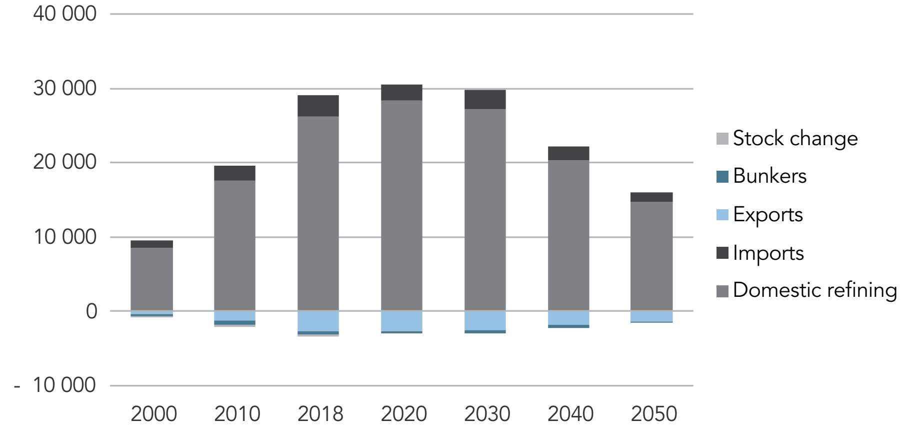
Refined products in the Carbon Neutrality scenario

Figure 5-37. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 5-38. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

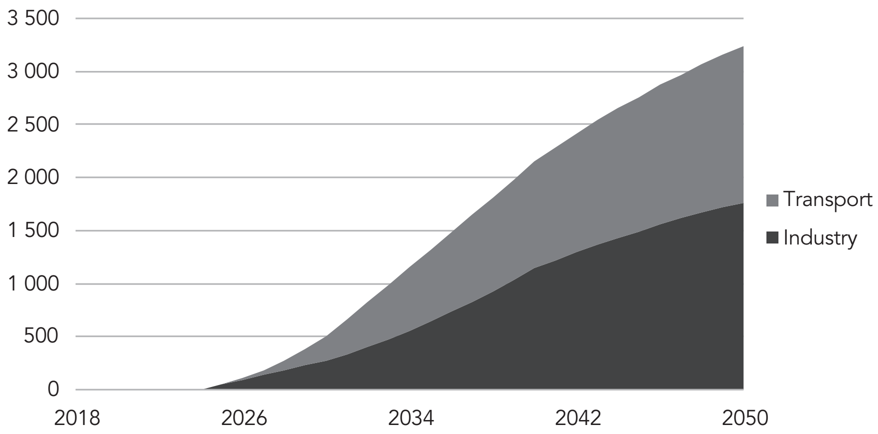


Sources: EGEDA, APERC analysis.

- In CN, refined products consumption peaks a decade earlier than in REF in the mid-2020s and then halves out to 2050. Rapidly declining demand from the transport sector is the main reason for this decline. The transport sector sees far greater fuel switching from gasoline and diesel to electricity and hydrogen in CN. There is also a greater shift from private vehicles to public railway transport and improved levels of fuel efficiency that lead to significantly lower consumption of refined products.
- Domestic refining and imports of refined products both fall through to 2050. Domestic supply of refined products is down by 44% from 2018 to 2050, while imports are down by half for the same period.
- The global demand for refined products is expected to fall significantly in CN. In response, China's exports of refined products are expected to decline by half from 2018 to 2050.
- China's refining capacity begins to decline in mid-2020s in response to declining demand from end-use sectors. The assumed closures of China's refineries are tied to assumptions about exports, which are assumed to decline at a similar rate to the decline in global demand for refined products.
- The decline in coal mining is even greater in CN than in REF. However, part of this decline in mining activity is offset by an increase in mining for critical and rare-earth minerals that will support manufacturing of low carbon technologies. This increase will support diesel consumption, though the support is limited due to increased electrification of certain mining processes.

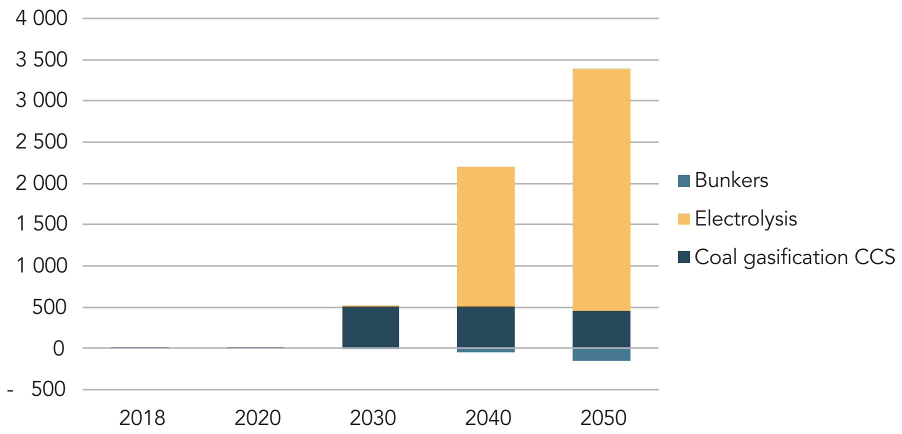
Hydrogen in the Reference scenario and Carbon Neutrality scenarios

Figure 5-39. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 5-40. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

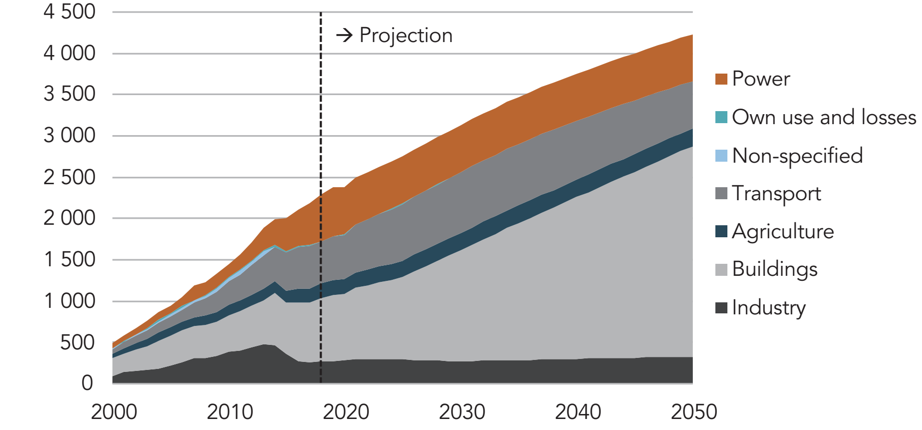


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- The 14th FYP labels hydrogen a 'frontier' area that the economy pledges to advance. Although an economywide strategy has yet to be developed, some provinces and cities launched their own plans to specifically feature hydrogen. For example, Beijing includes accelerated planning and construction of hydrogen refuelling stations. China is initiating a four-year program to support local governments in researching hydrogen technology and developing an industry chain.
- In REF (not shown), hydrogen demand grows rapidly from the late 2030s in the transport sector (fuel cell EVs) and in the industry sector (steel and chemicals sub-sectors).
- Hydrogen is produced by electrolysis from 2030. Before 2030, coal gasification is the main way to produce hydrogen in China. To ensure hydrogen does not contribute to emissions, CCS technologies are incorporated with coal-based hydrogen plants.
- In CN, hydrogen demand is 2.7 times greater than in REF in 2050. Industry sector use of hydrogen by the steel and chemicals sub-sectors is five times larger than in REF, reaching almost 1 800 PJ in 2050.
- Demand is expected to be fulfilled entirely by domestic production, with almost all the growth in production from 2030 and onwards attributable to electrolysis, which is powered by renewable electricity. Coal gasification production of hydrogen with CCS is still an important modality that meets end-use needs in the 2020s. This production modality continues to deliver hydrogen through to 2050.
- China is assumed to require zero imports. However, if end-use demand is greater than assumed in CN, there may be a need for China to secure supply from other producing economies.
- In 2050, China is expected to be the largest hydrogen consuming economy in the entire APEC region and its demand share in the APEC region reaches almost 30%.

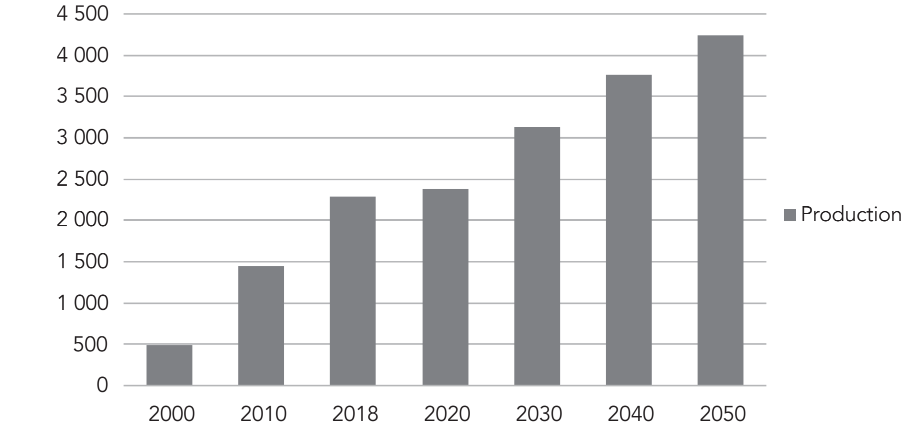
Bioenergy in the Reference scenario

Figure 5-41. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 5-42. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

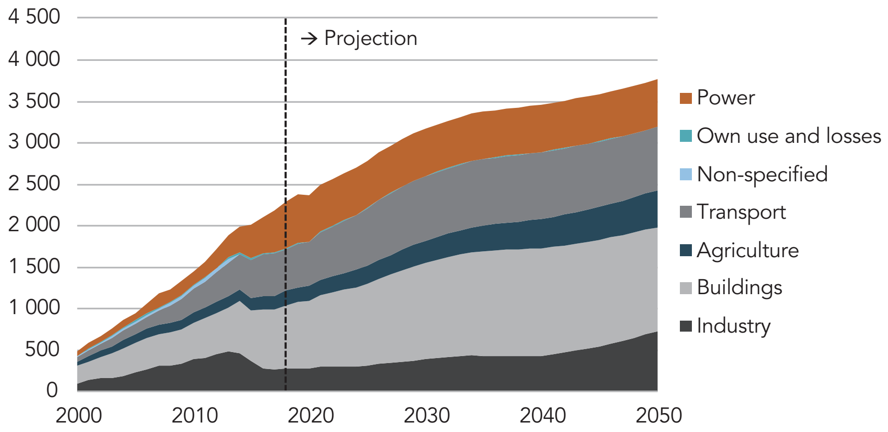


Sources: EGEDA, APERC analysis.

- From 2000 to 2018, solid and liquid renewables demand expanded nearly five-fold. The increase was led by the buildings sector and the transport sector.
- In REF, solid and liquid renewables demand is expected to increase almost 80% from 2018 to 2050. The increase is mainly driven by the buildings sector, where fuelwood, crop waste, and biomass pellets are assumed to be important sources. The share of biomass in buildings energy demand will increase from 6% to 12% for the 2018 to 2050 projection period.
- Solid and liquid renewables are currently sourced domestically. There is expected to be no need for imports or exports through to 2050.

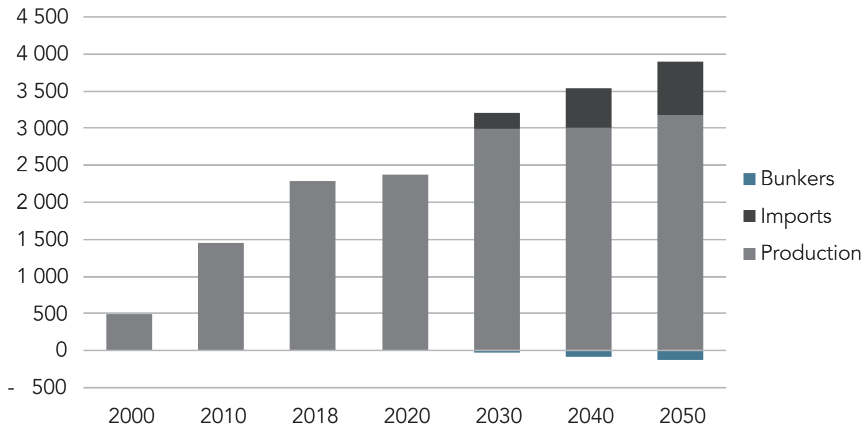
Bioenergy in the Carbon Neutrality scenario

Figure 5-43. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 5-44. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

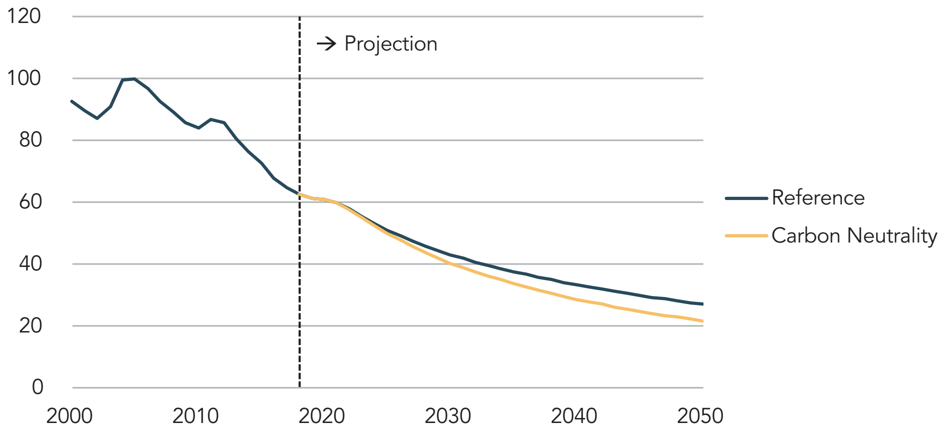


Sources: EGEDA, APERC analysis.

- In CN, renewables demand increases almost 60% from 2018 to 2050, which is below the 80% increase shown in REF. The increase is led by the buildings sector followed by the industry sector.
- In CN, demand for solid and liquid renewables is almost 10% lower in 2050 than in REF. Buildings sector consumption is lower than in REF due to other energy resources, such as electricity and gas, outcompeting biomass alternatives. In contrast, transport sector consumption of renewables is higher in CN than in REF, with more biofuels consumed due to higher assumed blending rates.
- Industry largely relies on CCS, electrification, and greater energy efficiency to decarbonise in CN. However, a switch to biomass in certain subsectors also contributes to decarbonisation, with the increased biomass consumption beginning to accelerate in the latter half of the projection.
- Biomass consumption in CN is expected to be less than half than in REF in 2050. This means that liquid renewables support much of the growth in CN.
- The significant increase of renewables into China and into bunkers (international marine and aviation) is due to biojet fuel increases and the assumption that biojet refining occurs outside China. The development of biorefining within the economy could result in higher production and lower import levels than shown here.

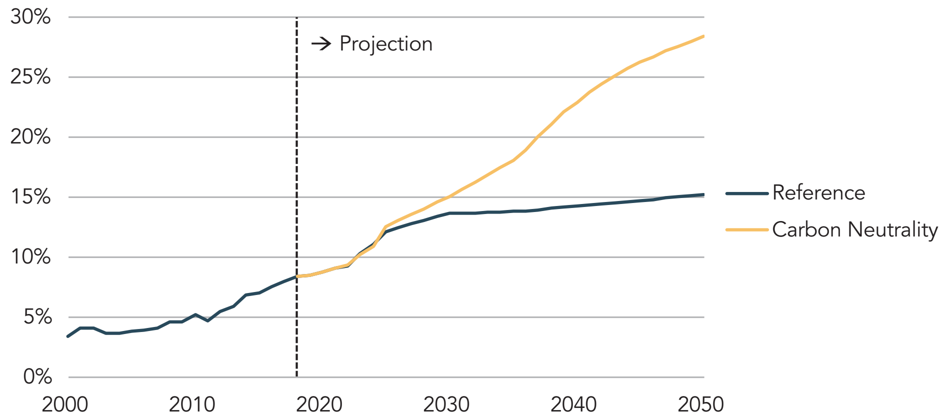
Energy intensity and modern renewables share

Figure 5-45. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 5-46. Modern renewables share in REF and CN, 2000-2050



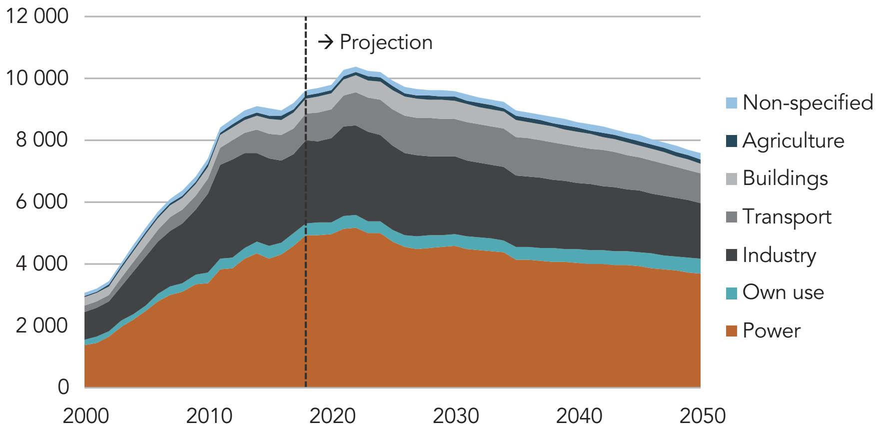
Sources: EGEDA, APERC analysis. Note: Includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- Final energy intensity improved about 37% from 2005 to 2018. About 70% of this improvement was driven by the industry sector, followed by the buildings sector (14%), the agriculture sector (6%), the transport sector (5%), and non-specified (4%). Final energy intensity improves significantly in both scenarios.
- According to the 14th FYP, over the 2021 to 2025 period, China aims to improve its energy intensity by 13.5%. This target is met in both scenarios. Energy intensity will be improved 15% and 17% in REF and in CN respectively during this period.
- In REF, the industry sector continues to be the main driver of the 57% energy intensity improvement from 2018 to 2050 followed by the transport sector and the buildings sector.
- In CN, there are significant improvements in energy intensity from all sectors, with industry, transport, and buildings being even more influential than in REF. From 2018 to 2050, energy efficiency is expected to improve by 66%.
- The share of modern renewables in the final energy mix increases in both scenarios, though the increase is significantly higher in CN. In REF, the modern renewables share increases to 15% in 2050. In CN, with the massive deployment of solar and wind in the power sector, the share will increase to 28% in 2050.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

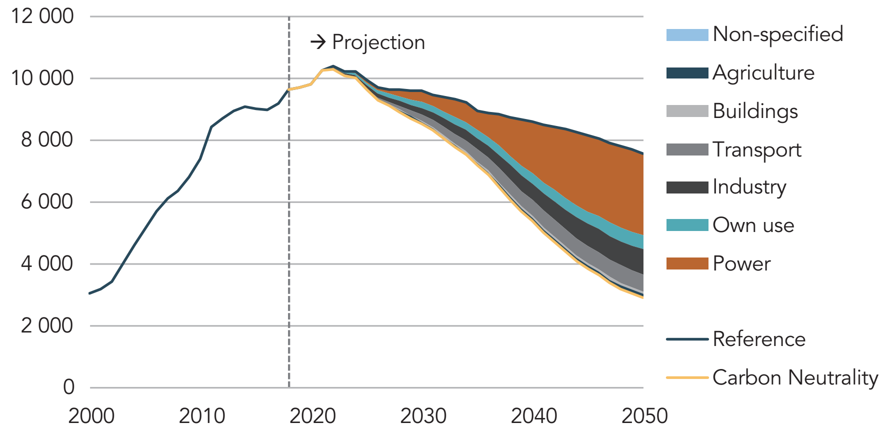
Gross CO_2 emissions

Figure 5-47. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 5-48. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

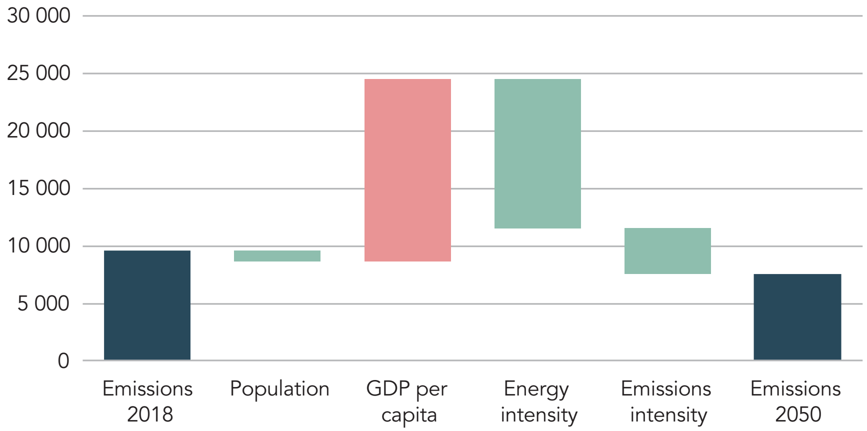


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- In China, CO_2 emissions more than tripled over the last two decades. Coal combustion is the largest source of CO_2 emissions followed by oil, and gas. In 2018, about a half of the CO_2 was emitted in the power sector, followed by the industry sector, and then the transport sector.
- The 14th FYP is already restricting coal consumption, and with additional falls anticipated out to 2050, emissions from coal fall significantly in REF. However, emissions from other fossil fuels will grow moderately.
- In REF, emissions decrease in the power, industry, and buildings sectors while emissions increase in other sectors. From 2018 to 2050, CO_2 emissions decrease 20%.
- In CN, a large decline in coal demand leads to significant emissions reductions. From 2018 to 2050, CO_2 emissions decline by almost 70%. Although emissions decline in all sectors in CN, decarbonisation in the power sector and by industry lead to the greatest level of reductions.
- In the power sector, a transformational transition leads to 90% electricity generation from low- or no-CO_2 sources (renewables, nuclear, and gas with CCS). In the transport sector, fuel switching from fossil fuels to electricity and hydrogen contribute to most of the reductions. Lower transport activity also contributes.
- In September 2020, President Xi Jinping declared that China aims to have its CO_2 emissions peak before 2030 and to achieve carbon neutrality before 2060.
- In both scenarios, CO_2 emissions peak prior to 2030. In CN, the CO_2 emissions reduction pathway appears on track to continue to carbon neutrality by 2060. There is flexibility depending on the contribution of sectors that are separate to the energy sector.
- In CN, around 2 900 million tonnes of CO_2 emissions remain in 2050. The remaining CO_2 emissions could be addressed using CO_2 sinks.

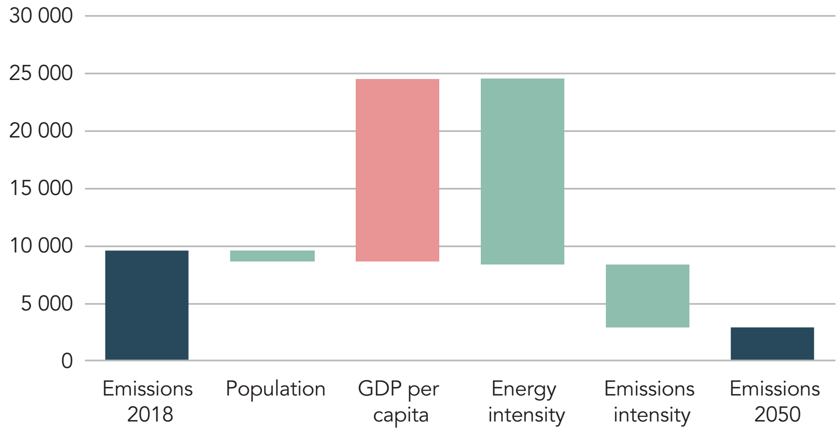
Components of CO_2 emissions

Figure 5-49. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 5-50. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- In 2018, China's CO_2 emissions from combustion were over 9 600 million tonnes.
- Looking at the components of CO_2 emissions, a projected population decrease will contribute to CO_2 emissions reductions while greater economic activity (GDP per capita) will lead to an increase, holding all else equal. Given that all else will not remain equal, improvements in both energy intensity and emissions intensity will contribute to CO_2 emissions reductions.
- In REF, it is estimated that emissions decrease to7 500 million tonnes by 2050. Energy intensity improvements are mainly driven by the industry sector. Emissions intensity improvements are seen in the power and industry sectors, in addition to the contribution from demographic changes. Increased economic activity is the only factor that places upward pressure on CO_2 emissions.
- In CN, it is estimated that emissions will decline to2 900 million tonnes. Like REF, energy intensity improvements contribute most to this reduction, with greater energy intensity improvements expected in all end-use sectors (excluding non-specified). The contribution from energy intensity improvements more than offsets the emissions increase that would occur to due to assumed increases in GDP per capita.
- In CN, greater emissions intensity improvements are seen in the power, industry, and transport sectors.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

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6. Hong Kong, China

Highlights

Demand

- Hong Kong, China's final energy demand grows by 0.1% in REF and declines by 23% in CN.
- The buildings sector remains the largest energy user in both scenarios, comprising almost two-thirds of total energy demand over the outlook period. Effective energy efficiency and energy conservation measures and initiatives have curbed the growing demand in the buildings sector.
- Transport sector demand falls by over half in CN. The sector achieves the low carbon mobility target for the road passenger segment with electric and fuel-cell vehicles comprising almost 80% of sales by 2050.
- Industry sector energy demand plateaus in REF. However, energy efficiency and electrification reduce energy demand marginally by 1.0 PJ below REF levels in CN.

Supply

- Total energy supply decreases by 25% in REF and 52% in CN.
- Gas becomes the largest energy supply source in both scenarios as it replaces coal in electricity generation.
- Hong Kong, China continues to rely on imports to fulfill its supply requirements in both scenarios. Imports of pipeline gas and refined products continue to flow from mainland China, as do electricity imports.
- Renewables supply increases significantly in both scenarios by 2050, quadrupling in REF and rising over eleven-fold in CN. This supports Hong Kong, China to reduce emissions in the power sector and meet higher renewables demand in both the buildings and transport sectors.

Power

- In REF, total electricity generation grows marginally, by 4.3%, and ends up at about 2018 levels at the end of CN.
- Hong Kong, China achieves its target of zero coal in the power sector in CN. Coal-fired generation falls sharply, reaching zero by the end of 2037. Gas and renewables replace coal over the outlook period.
- Generation capacity increases and peaks at over 13 GW in 2024 in both scenarios, before subsequently declining to below the 2018 level by 2050. This trend is supported by higher electricity imports from mainland China. However, the deployment of CCUS technology in gas-fired power plants and higher renewables capacity, especially solar, beyond 2030 lessens the decline in CN.

CO_2 emissions

- Total CO_2 emissions fall by 38% in REF and 74% in CN.
- Hong Kong, China achieves its NDC target of reducing carbon emissions between 26% to 36% compared with the 2018 level by 2030 in REF. In 2030, absolute carbon emissions are 37% below 2018 levels in REF.
- Hong Kong, China achieves emissions reductions that could enable it to be a carbon-neutral economy by 2050 in CN. However, the economy will have to find a way to offset or sequester the remaining 10 million tonnes of emissions.

Note: The *Outlook* is projecting CO_2 emissions instead of carbon emissions.

About Hong Kong, China

- Hong Kong, China is located at the southeastern tip of China, covering Hong Kong Island, Lantau Island, the Kowloon Peninsula, the New Territories and 262 outlying islands. It has about 1 110 square kilometres of total land area, but less than 25% of it is developed. Hong Kong, China's population was about 7.5 million in 2018. About 92% of the population are Chinese, and the remaining are mainly Filipino, Indonesian, and Indian.
- Hong Kong, China has been a Special Administrative Region of the People's Republic of China since 1997 and is administered under one country, two systems guiding principle with a high degree of autonomy.
- Hong Kong, China's economy is categorised as a highly developed free-market economy, with almost freeport trade, well-established international financial markets, low taxation, and minimum government intervention. It also ranked highly in the world index of economic freedom based on the annual survey published by the Fraser Institute in 2021.
- Hong Kong, China is a well-established service-based economy. The services sector, which includes financial, trade, tourism, retail, real estate, and transportation, has been the backbone of Hong Kong, China's economy for the past two decades and is expected to remain the main contributor to GDP growth. In 2019, the services sector contributed for 93% of Hong Kong, China's economy and provided 89% of total employment in the first three quarters of 2020.
- The increase of buildings and transport share in total energy demand for the past two decades reflected the transformation of Hong Kong, China's economy from a manufacturing-based economy to a service-based economy.
- Hong Kong, China has no indigenous fossil fuel resources and is dependent on imported coal, natural gas and oil to meet its energy transformation needs and end-use energy demand.

Table 6-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	7.5	0.3%	18
GDP	466	0.7%	17
TPES	600	0.2%	19
Production	4.6	0.0%	21
Imports	1 365	1.1%	14
Exports	11	0.0%	21
Electricity generation	37	0.2%	19
Heat production	0.0	0.0%	9
CO_2 emissions	35	0.2%	18

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 6-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	0	0	0	–
Natural gas	0	0	0	–
Oil	0	0	0	–
Uranium	0	0	0	–

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- Hong Kong, China continues to shape the future of the energy sector in the economy by balancing the competing demands of energy security and environmental sustainability. Hong Kong, China's government, led by the Environment Bureau, is responsible for formulating policies and plans on environmental protection, energy and nature conservation, and promoting sustainable development.
- The government released the Energy Saving Plan For Hong Kong's Built Environment 2015-2025+ in May 2015, focusing on green building transformation and energy saving in the buildings, transport, and power sectors, with the target to reduce energy intensity by 40% by 2025 compared with the 2005 level.
- To respond to Hong Kong, China's commitment to the Paris Agreement, and as a continuation of the plan released in 2015, the government announced its Climate Action Plan 2030+ in January 2017 with a new 2030 emission target and detailed plans and measures in the buildings, transport, and power sectors, and additional plans for waste management. The target is to reduce its carbon intensity by 65% to 70% below 2005 levels by 2030. This is equivalent to an absolute reduction of 26% to 36% and a per capita emission in the range of 3.3 to 3.8 tonnes in 2030. The plan also anticipated that carbon emissions in Hong Kong, China will peak before 2020. Besides energy efficiency and energy saving in buildings and public transport improvements, the plan also highlighted the target to reduce coal-fired electricity and increase the renewables share in electricity generation.
- In October 2021, prior to 2021 United Nations Climate Change Conference (COP26) in Glasgow, the government released Hong Kong, China's Climate Action Plan 2050. This includes a medium-term target to half total carbon emissions before 2035 from the 2005 level and a long-term goal of achieving carbon neutrality before 2050. Instrumental to achieving a carbon-neutral Hong Kong, China are the goals of achieving net-zero transport and power sectors before 2050. The detailed strategies and measures for net-zero carbon emissions in both sectors have been set out in the Hong Kong Roadmap on Popularisation of Electric Vehicles published in March 2021 and the Clean Air Plan for Hong Kong 2035 published in June 2021.
- Hong Kong, China currently relies on pipeline imports from mainland China for its gas requirements. Its first LNG import terminal, a 1.2 Mtpa floating storage and regasification unit (FSRU), is scheduled to come online in 2022. However, the persisting pandemic could delay part of the construction. A long-term LNG contract is in place to secure supply for the project upon commissioning.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- Hong Kong, China's government has focused on the strategies, measures, initiatives and incentives to address climate change since the beginning of 2010. The government continues to issue and review the mid-term and long-term decarbonisation policies and strategies across all sectors to shape the future of the economy's energy system.
- **The Reference (REF) scenario** reflects the recent trends, current policies, and initiatives in place, including relevant decarbonisation measures to reduce CO_2 emissions in Hong Kong, China's energy system by 2050.
- REF captures most of the targets in the Hong Kong, China's Climate Action Plan 2030+.
- In buildings, continuous enforcement of existing building energy regulations and energy efficiency ordinance for product labelling will improve energy efficiency for appliances and increase the energy saving in existing buildings. Implementing energy-saving projects at government buildings and schools will further reduce energy consumption.
- In transport, a gradual deployment of energy-efficient road vehicles supported by investment in charging infrastructure, the gradual reduction of diesel vehicles, and improvement of road and rail public transport network. This will reduce energy consumption and support a low-mobility carbon agenda.
- In the power sector, natural gas replaces coal gradually towards net-zero carbon emissions in electricity generation by 2050.
- **The Carbon Neutrality (CN) scenario** reflects a potential pathway with more significant reduction of CO_2 emissions that potentially allows for a carbon-neutral economy by 2050. The Hong Kong Climate Action Plan 2050, released in October 2021, consists of updated targets and an extended climate action plan up to 2050.
- Improvement of energy efficiency standards for buildings and appliances, higher energy saving rates at government buildings, schools, and public infrastructures, more substantial technology improvements, and higher rates of fuel switching away from coal and oil in the demand sectors will significantly reduce energy demand and CO_2 emissions by 2050.
- Hong Kong, China will achieve the target to be a carbon-neutral economy by 2050 in CN.

Table 6-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Hong Kong, China

Table 6-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium), GDP: APERC Solow-Swan model.	• Population: (UN medium), GDP: APERC Solow-Swan model.
Buildings	• Energy saving projects at government buildings • Energy conservation at existing buildings, 50% consume in average 40% less energy for space cooling by 2050. • Improvement in illumination, 10% increase by 2050. • Improvement in energy efficiency for appliances, 10% increase by 2050. • Electricity use by government buildings is reduced by 5% below 2014 levels in 2020.	• Improvement of energy efficiency standards for buildings • Energy conservation at existing buildings, 80% consume in average 40% less energy for space cooling by 2050. • Improvement in energy efficiency for appliances, 20% increase by 2050.
Industry	• Maintain current technology and fuel composition.	• Some fuel switching from oil to electricity in few industry sub-sector

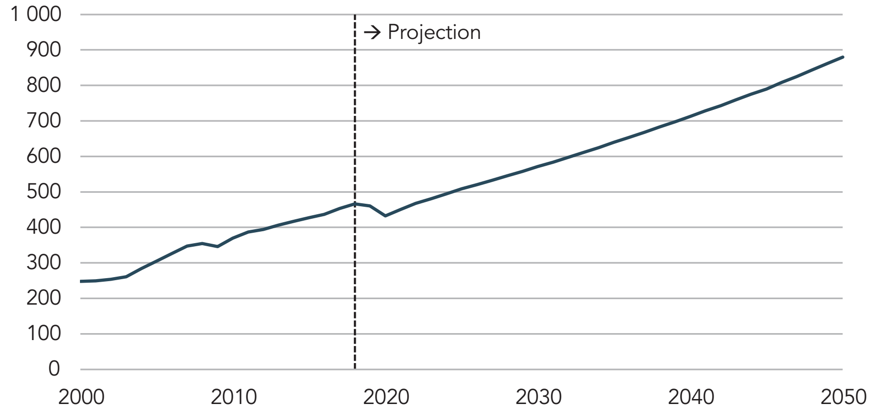
Transport	• Gradual reduction of diesel vehicles sales
	• Deployment of hydrogen fuel cell vehicles begins in 2038.
		• Improvement in public transportation systems, particularly rail and buses.
		• Rapid reduction of diesel vehicle sales from 2025, falling to 0% by 2050.
		• Earlier deployment of hydrogen fuel cell vehicles, starting in 2027.
		• Rapid increment of electric vehicles sales for passenger segment:
		  • 99% BEV for two wheelers by 2050
		  • 85% BEV and 15% FCEV for bus sales by 2050
		  • 95% BEV and 15% FCEV for light-truck and light-vehicle sales by 2050

Power and heat	• Reduction of coal and replace it with natural gas for electricity generation.	• Phasing out coal by 2037, replacing it with natural gas for electricity generation. • Adoption of CCUS-equipped gas from 2036 • Higher solar capacity by 2050, double compared to REF.
Supply	• 1.2 Mtpa FSRU commence operation in 2022.	• Supply natural gas after 2037 to complement coal phase-out • 1.4 Mtpa of LNG import capacity required in the 2030s.
Climate	• NDC targets: reduction of carbon intensity between 65% to 70%, or absolute CO_2 emission between 26% to 36% by 2030. • Reduction of energy intensity by 40% in 2025, base year 2005.	• Carbon neutral by 2050

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

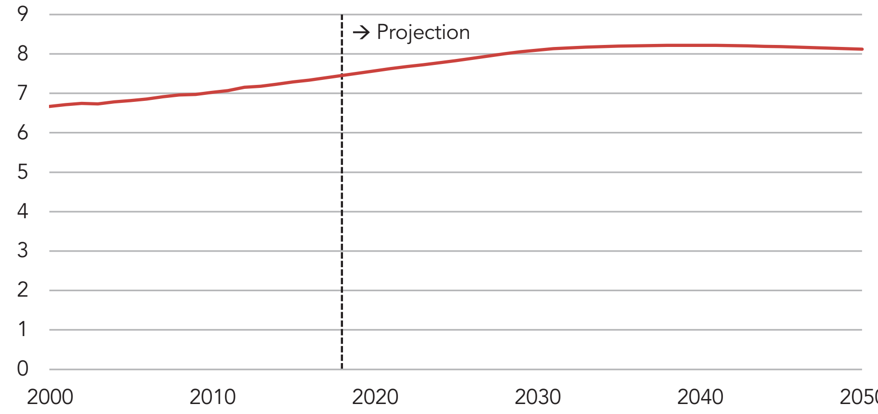
Macroeconomic backdrop

Figure 6-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from APERC Solow-Swan model and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 6-2. Population in millions, 2000-2050

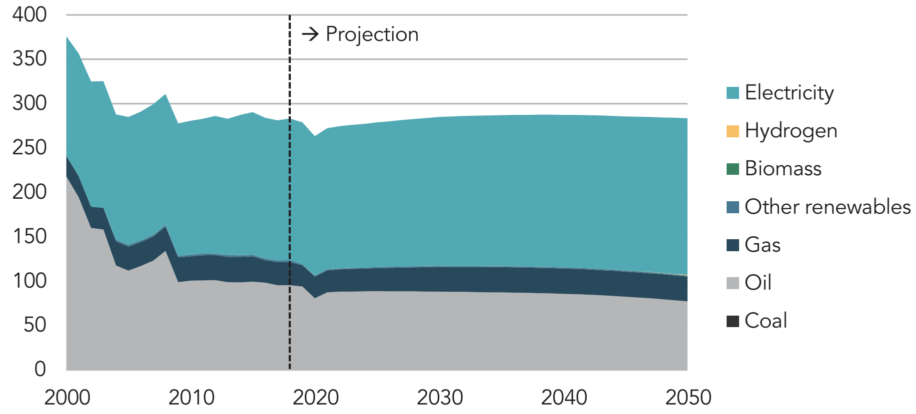


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- Hong Kong, China, recorded an average of 3.6% GDP growth per annum during the 2000 to 2018 period. The economy slightly contracted (1.2%) for the first time in a decade in 2019 and contracted 6.1% further in 2020 due to the impact of COVID-19 pandemic. In 2020, GDP real prices stood at USD 432 billion 2018 USD PPP.
- In March 2021, Hong Kong, China announced counter-cyclical measures worth over 15 billion USD to support its economy reeling from the COVID-19 pandemic. Hong Kong, China showed a rapid economic recovery for the first three consecutive quarters in 2021. In the third quarter of 2021, GDP expanded at 5.4% year-on-year and is expected to surpass the annual projection of 4.3% in 2021 after two consecutive years of negative GDP growth.
- Hong Kong, China economic output is expected to reach pre-pandemic levels in 2022.
- GDP steadily grows with an annual growth rate of 2.0% over the outlook period in both scenarios.
- The total population in Hong Kong, China is expected to grow slowly from 7.5 million in 2018, peak at 8.2 million in 2039, and then marginally decline to 8.1 million by 2050. This yields an annual growth rate of 0.3% over the outlook period.

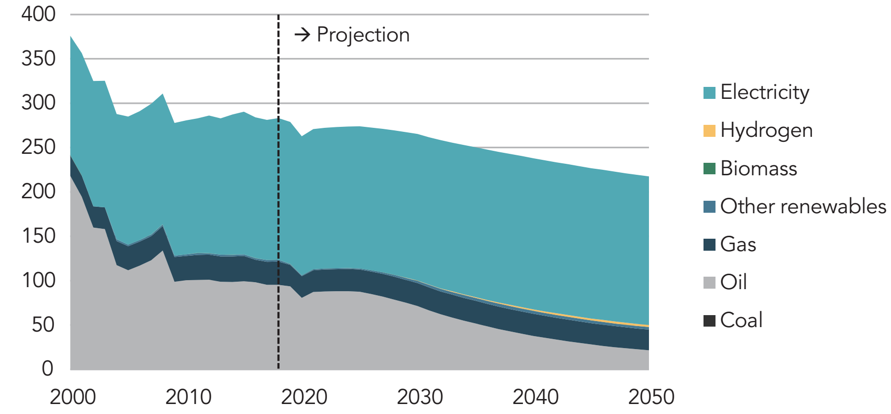
End-use energy demand

Figure 6-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 6-4. Energy demand in CN, 2000-2050 (PJ)

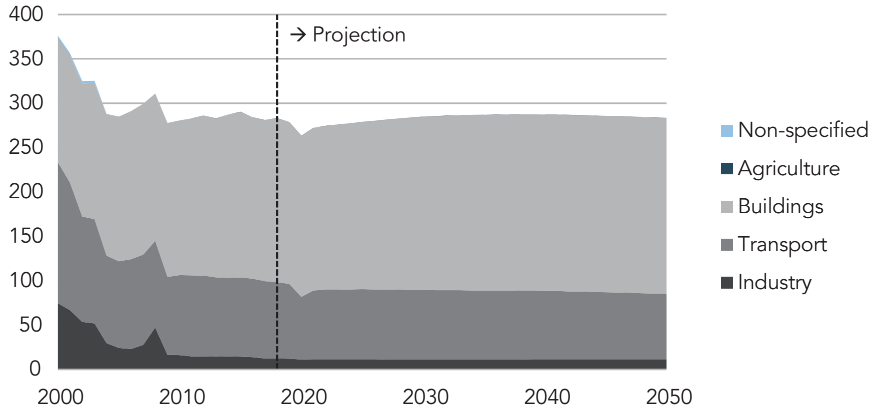


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Hong Kong, China's total energy demand showed a decreasing trend from 2000 to 2018, with a negative average growth of 1.6% per annum. The decreasing trend is attributable to the continuation of Hong Kong, China's structural shift from an industrial-based economy into a serviced-based economy and a ramp-up in public transit services. These factors mostly reduced demand in oil, particularly from both the industry and transport sectors.
- Hong Kong, China's industry sector occasionally uses coal for process heating purposes. However, demand dropped to zero in 2016, as the non-specified subsector looked to electrification and fuel switching to fuel its process heating requirements.
- Total energy demand fell 5.6% in 2020 due to mobility restrictions and lower output during the onset of the COVID-19 pandemic. While demand surpasses pre-pandemic levels in 2025 in REF, it never touches it again in CN.
- Total energy demand is mainly flat in REF, undergoing a marginal increase of 0.1% or 0.4 PJ by 2050. Electricity continues to dominate the fuel mix, growing 11% overall, and rising to almost two-thirds of the mix due to electrification in buildings and transport. Fossil fuels decline from 43% to 37%, mainly due to lower transport use following lower utilisation of ICE vehicles. Demand for gas, other renewables, biomass and hydrogen increased towards the end of outlook period due to fuel switching across all sectors.
- Energy efficiency gains, particularly in transport, reduce demand by about a quarter in CN. Electrification accelerates, rising to over three-quarters of the fuel mix by 2050. The share of fossil fuels declines from 43% of total energy demand in 2018 to 21% in 2050. Much of this is driven by oil, which declines about three-quarters due to electrification and fuel switching, particularly in the transport sector. The decrease in demand for fossil fuels supports the government's objective to reduce fossil fuel use and achieve carbon neutrality by 2050. The share of hydrogen, biomass and other renewables rises to 2.4% by 2050, up three-fold above REF levels.

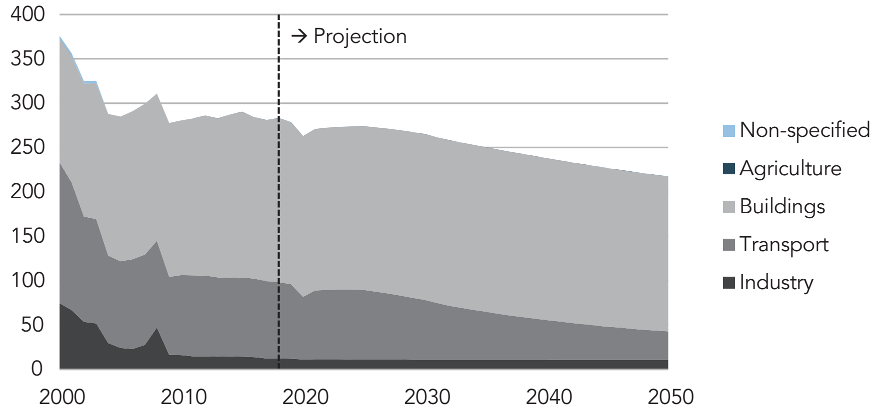
End-use energy demand by sector

Figure 6-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 6-6. Energy demand by sector in CN, 2000-2050 (PJ)

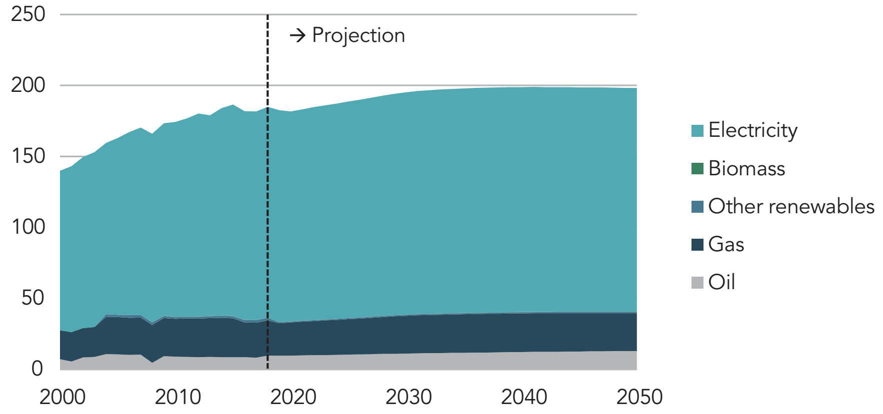


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- The buildings sector accounts for the largest share of energy demand in Hong Kong, China, followed by the transport, industry and agriculture sectors. This ranking continues throughout the outlook period in both scenarios.
- Existing energy efficiency and conservation initiatives, fuel efficiency and switching plans, and electric vehicle and other energy-efficient vehicle roll-up plans are expected to curb growing demand in industry, transport and buildings towards the end of the outlook period in REF.
- In REF, buildings energy demand grows by around 6.5%, or 13 PJ, as rising services demand more than offsets declines in residential buildings.
- Transport is predominantly responsible for the demand declines during the onset of COVID-19. Mobility restrictions reduced transport demand by a sixth in 2020. While transport demand recovers slightly in REF, it never reaches pre-pandemic levels. Higher vehicle efficiency and modal shifting towards public transit gradually reduces demand to a seventh below 2018 levels by 2050.
- Agriculture declines by over half over the outlook period. However, agriculture demand is relatively small, accounting for 0.02% of total energy demand in Hong Kong, China.
- In CN, energy demand throughout Hong Kong, China's economy is lower than REF, as higher energy efficiency and fuel switching reduces demand across the board.
- Transport share shows the most significant reduction in CN, falling almost two-thirds due to a higher uptake in energy-efficient vehicles, like EVs, modal switching to public transit, and the increased availability of vehicle charging infrastructure.
- Higher energy efficiency in CN reduces energy consumption by a sixth in industry and by 5.6% in buildings.

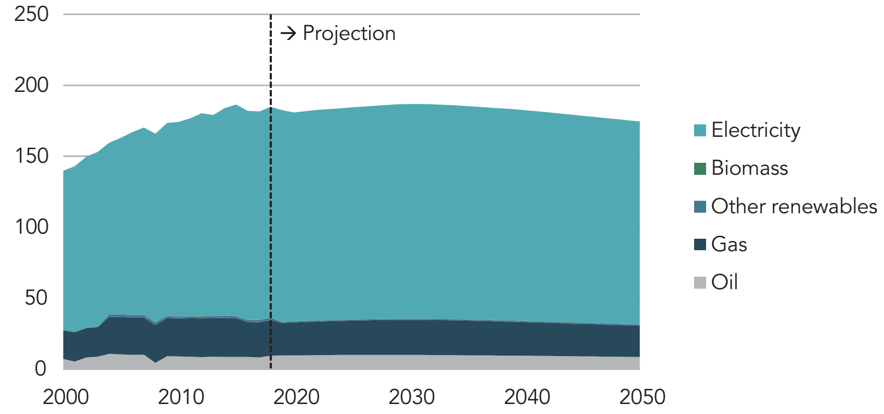
Buildings energy demand

Figure 6-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 6-8. Buildings energy demand in CN, 2000-2050 (PJ)

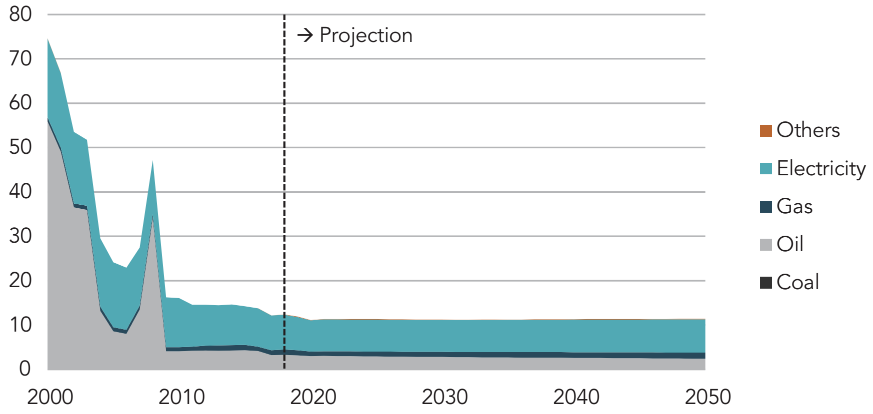


Sources: EGEDA, APERC analysis.

- Buildings energy demand has accounted for the majority of Hong Kong, China's final energy demand since 2004. Buildings demand grew at an average of 1.6% per annum during the 2000 to 2018 period. This historical trend supported by the structural shift towards a service economy, strong growth in GDP, and moderate growth in population and households.
- In 2018, about 26% of buildings energy demand in Hong Kong, China was used for space cooling. Air conditioning consumed more electricity than other end-use electrical appliances, 38% of total electricity supplied in the residential sub-sector and 31% in the services sub-sector.
- However, buildings energy demand grows slower during the outlook period with an average of 0.2% per annum in REF. This decoupling of demand from economic activity is driven by the energy savings and transformation plans for buildings laid out in the government's Energy Saving Plan For Hong Kong 2015-2025+.
- Hong Kong, China achieved its goal of reducing the electricity use in government buildings by 5% relative to 2014 levels in 2019, a year ahead of schedule.
- Electricity remains dominant in both scenarios, supplying with around 80% of fuel share, with fossil fuels supplying 18-20%, and renewables about 1%.
- Gas and oil are reduced by almost a quarter in CN due to electrification and energy efficiency.
- Buildings energy demand slightly decreases in CN, falling at an average of 0.2% per annum, as increasing appliance efficiency, energy conservation and higher energy efficiency standards reduce demand requirements.
- Hong Kong, China does not achieve the ambitious electricity reduction targets announced in Hong Kong's Climate Action Plan 2050 in either scenario. Buildings electricity demand falls 4.1% below 2015 levels in CN, well below the 20-to-40% targets. Further energy efficiency gains, and perhaps behavioral changes, will be required to hit these targets.

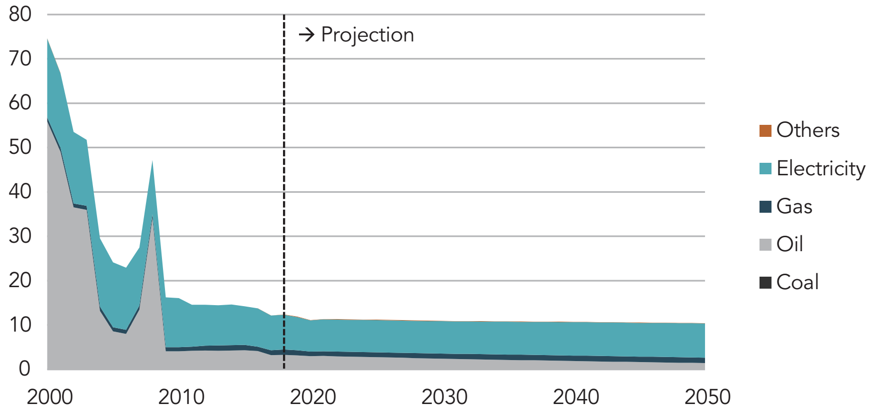
Industry energy demand

Figure 6-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 6-10. Industry energy demand in CN, 2000-2050 (PJ)

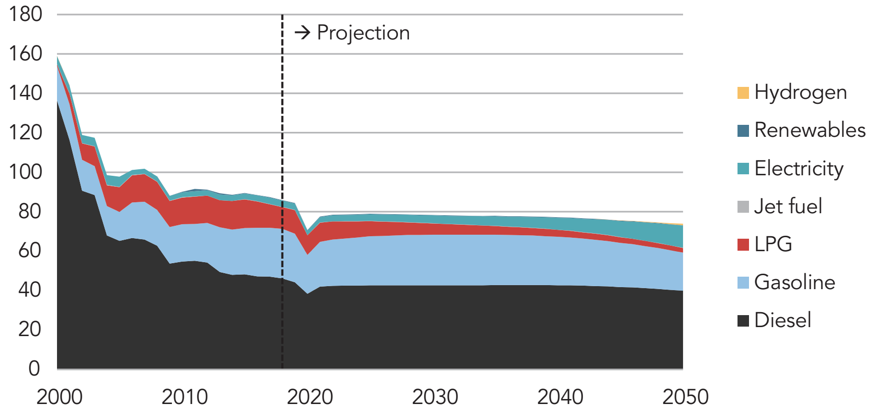


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industry energy demand accounts for around 20% of Hong Kong, China's total final energy demand in 2000. However, the share decreased significantly to about 4.4% in 2018, as an economic restructuring shifted Hong Kong, China from a light manufacturing-based economy to a service-based economy.
- The remaining industry demand comes from the non-specified subsector, comprised of non-manufacturing, food and beverages, metal and machinery, textile and wearing apparel and other industrial.
- With the restructuring of the economy mostly complete, Hong Kong, China's industry demand has stabilised between 11 to 12 PJ over the last decade.
- The exit of light industry from Hong Kong, China reduced the role of oil in the industry fuel mix. Electricity has been industry's dominant fuel since 2004.
- Industry demand plateaus in REF for most of the outlook period. While demand falls 8.2% below 2018 levels, most of this occurred during the onset of the COVID-19 pandemic.
- In REF, energy efficiency and electrification increase the role of electricity in industry at the expense of fossil fuels. Fossil fuels make up a third of the 2050 fuel mix, down from 36% in 2018, as falling oil use offsets a moderate increase in gas use. The share of electricity rises from under two-thirds in 2018 to two-thirds by 2050.
- In CN, higher energy efficiency and electrification reduces energy demand by 2.0 PJ, or 8.4%. This increases the share of electricity to nearly three-quarters by 2050, with the role of fossil fuels falling to a quarter. Compared to REF, oil use declines two-fifths and gas use a tenth.

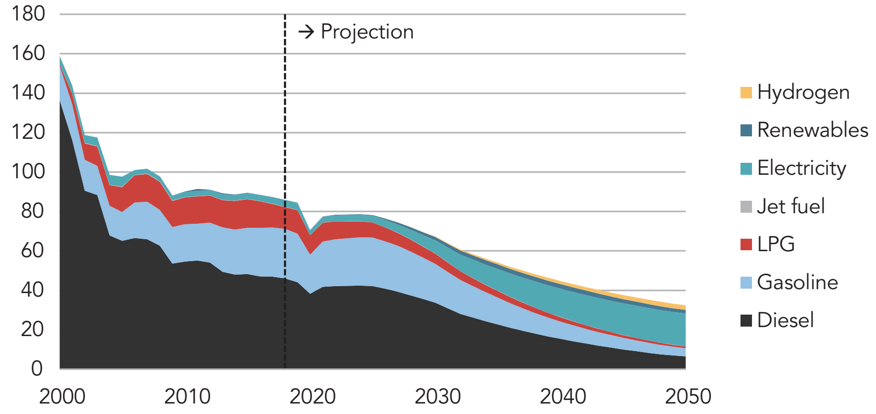
Transport energy demand

Figure 6-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 6-12. Transport energy demand in CN, 2000-2050 (PJ)

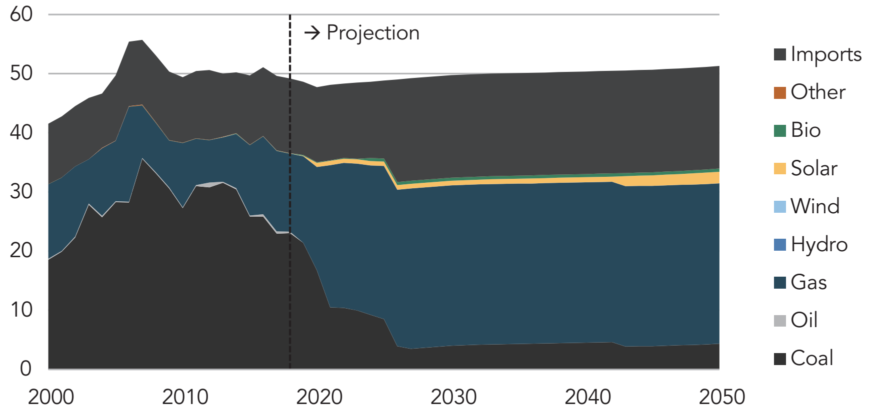


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport energy demand accounted for around 42% of Hong Kong, China's total final energy demand in 2000. Improvements in rail and bus services during the following two decades fostered increased ridership of public transit modes, which reduced energy demand, mainly diesel, by almost half.
- Mobility restrictions to contain the COVID-19 pandemic significantly reduced demand for transport in 2020, when demand dropped by 16%. It since rebounded to 78 PJ in 2021 after the government eased COVID-19 restrictions. The transport energy demand recovery is expected to peak at around 93% of pre-pandemic levels in both scenarios.
- In REF, transport demand decreases by 12 PJ over the outlook period, following higher vehicle efficiencies and modal shifting. While fossil fuels see their role reduced, they maintain their dominance, making up 84% of the fuel mix in 2050, down from 96% in 2018.
- Electricity demand almost quadruples due to higher EV adoption, an expansion of charging and railway networks, and the introduction of electric and hybrid ferries. This aligns with government policies and initiatives as stated in the Hong Kong Roadmap on Popularisation of Electric Vehicles and Clean Air Plan for Hong Kong 2035.
- In REF, renewables demand remains stable at 0.2 PJ over the outlook period, while hydrogen demand starts in 2038 due to the adoption of hydrogen fuel cells in some buses, light and heavy trucks, and light vehicles.
- In CN, demand decreases more than 53% to 32 PJ in 2050 due to lower consumption of refined products. This is driven by higher sales of electric and fuel-cell vehicles, increased charging infrastructure availability, higher electrification rates for passenger ferries and progressive phase-out of Euro IV diesel for commercial vehicles. Electric vehicle and fuel-cell vehicle sales reach almost 80% of total vehicle sales for the road passenger segment in 2050.
- Electricity becomes the main fuel for transport at 52% demand share, or 17 PJ, by 2050. Demand for hydrogen in CN starts in 2027, 11 years earlier than in REF.

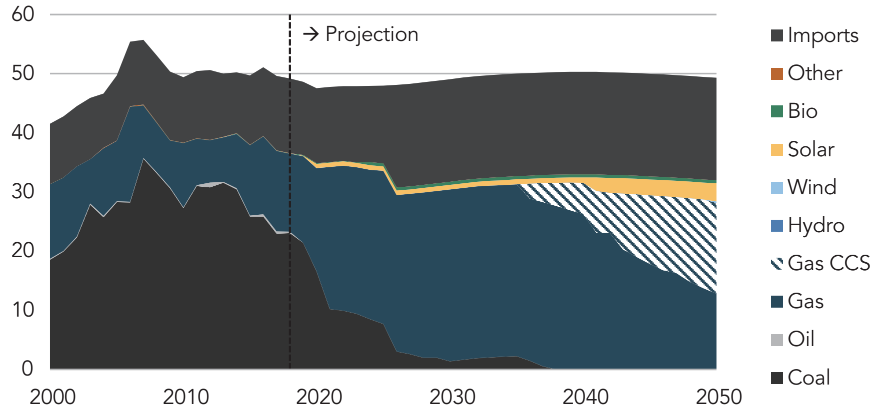
Electricity generation

Figure 6-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 6-14. Electricity generation in CN, 2000-2050 (TWh)



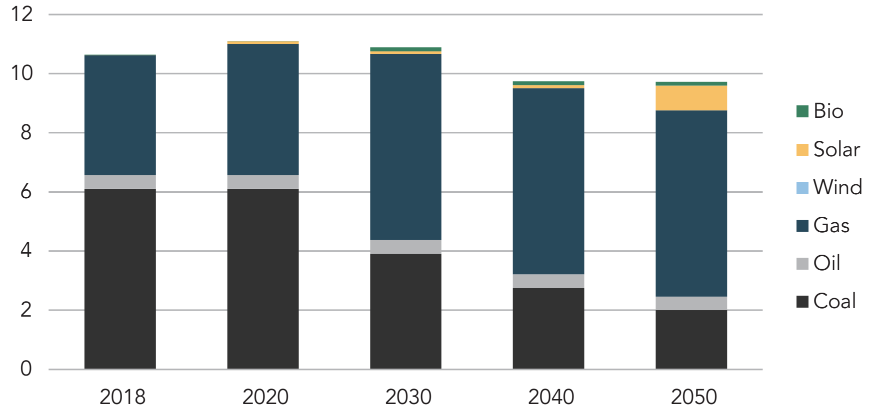
Sources: EGEDA, APERC analysis.

- Electricity generation requirements inclusive of imports in Hong Kong, China increased significantly in the early 2000s, peaking at around 56 TWh in 2007, and then declining gradually towards 49 TWh in 2018. Electricity generation was dominated by fossil fuels, particularly coal, while imports from the Guangdong nuclear plant in mainland China contributed about a quarter of electricity generation during the 2000 to 2018 period.
- Coal-fired generation has been yielding share to natural gas over the past decade. In 2017, Hong Kong, China announced plans to accelerate coal-to-gas switching to reduce carbon emissions, with the goal of achieving 2020 shares of 50% for natural gas and 25% for coal.
- In REF, electricity generation recovers from the COVID-19 fall by the late 2020s and grows slowly to 51 TWh by the end of outlook period. Fossil fuels continue to dominate the power mix, supplying 61% in 2050. The gas share increases significantly from 27% in 2018 to 53% in 2050, as gas replaces coal, which falls to 8.5%.
- Electricity imports from mainland China in REF increase 38% from 2018 to 2026 and then stabilise around 17 TWh for the remainder of the outlook period.
- While renewable generation grows significantly, mainly due to an eight-fold increase in solar deployment, its share remains relatively low, reaching 4.9% of the power mix by 2050. Solar contributes 79% of renewables in 2050.
- In CN, electricity generation falls 2.0 TWh below REF levels due to falling electricity demand. Coal-fired power plants are phased out by the end of 2037, leaving gas as the lone fossil fuel in the power mix for the remaining outlook period.
- In CN, CCUS-equipped gas generation starts in 2036 and surpasses unabated-gas generation in 2049. Gas, and thus fossil fuels, still dominate the fuel mix in 2050, at 58%. While renewables are 53% higher than REF, they only comprise 7.8% of the power mix in 2050.

Note: Potential Hong Kong, China's CO_2 storage is located at Pearl River Mouth basin, China.

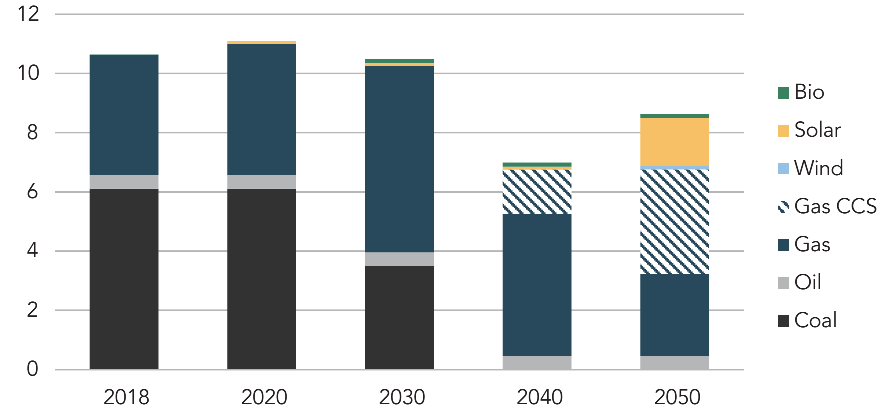
Generation capacity

Figure 6-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 6-16. Generation capacity in CN, 2018-2050 (GW)

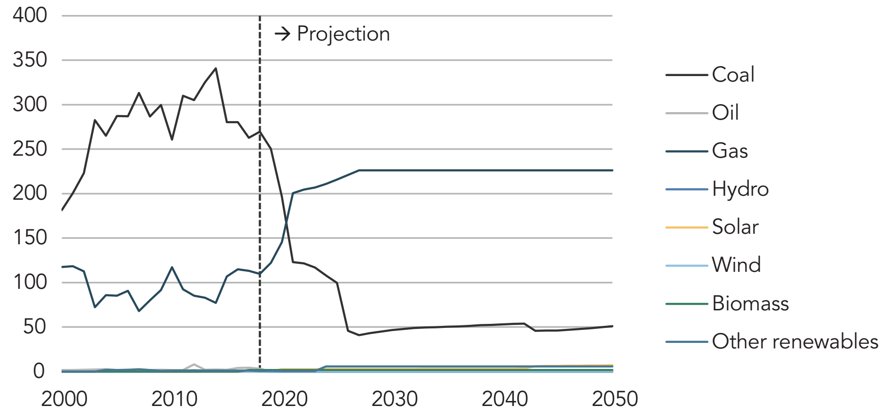


Sources: EGEDA, APERC analysis.

- In both scenarios, generation capacity increases by 2.4 GW, or a quarter, peaking in 2024 over 13 GW. Capacity declines thereafter, as higher imports from mainland China reduce generation requirements. The nature of the decline, however, differs between scenarios. In REF, gradual declines in coal capacity reduce overall capacity by a quarter from this peak. In CN, a phase-out of coal and half of unabated gas-fired generation drags capacity to a low of 7.0 GW, before solar additions in the 2040s lift it to 8.6 GW by 2050.
- In REF, coal capacity reduces gradually after 2026 to 2.0 GW in 2050. Coal retirements are mainly replaced by gas. Gas capacity grows 55%, or 2.2 GW, by 2050, which is lower than the coal retirements due to the higher capacity factors of gas power plants. Solar capacity increases by eight-fold in 2050. Solar generation, however, only doubles, due to its low-capacity factor and the degradation of solar panel performance over time. Oil, wind, and biofuel capacities remain stable over the outlook period.
- In CN, coal capacity is phased out by the end of 2037, which leads to a capacity trough of 7.0 GW until solar and wind additions take-off in the 2040s. CCUS-equipped capacity emerges in 2031, growing to 3.5 GW, but most of this is met by matching unabated gas retirements. Solar capacity is nearly double REF levels by 2050, and wind capacity starts growing to 0.13 GW in 2050.
- Oil capacity remains at 0.5 GW throughout both scenarios for peaking during extreme demand events.
- While the power capacity here puts Hong Kong, China within the range of developing a carbon-neutral power sector, it is not consistent with achieving its 2050 net-zero generation target. Achieving this will require higher deployment of renewables, both wind and solar, and imports of low-carbon energy than shown here.

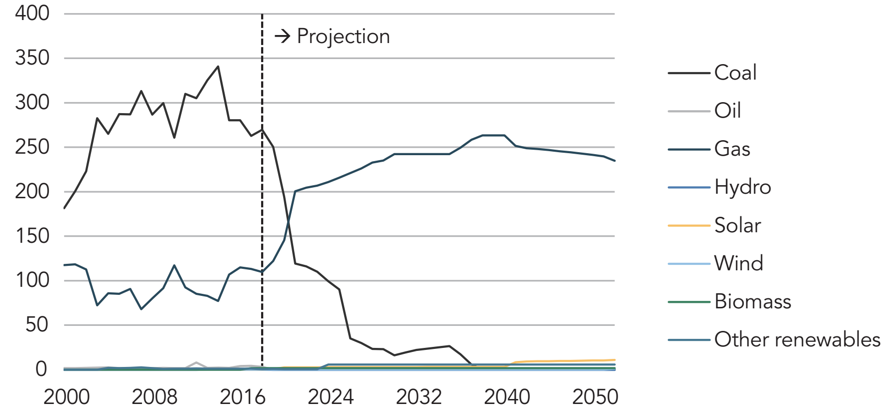
Fuel consumption by power sector

Figure 6-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 6-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

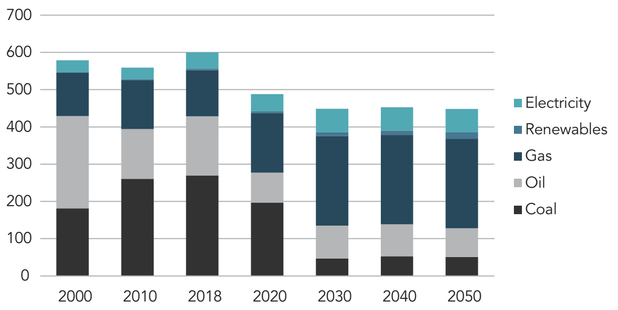


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- In both scenarios, gas replaces coal as the dominant power fuel in 2021. Gas share increases rapidly from 29% in 2018 to 78% in 2050 in REF due to declining coal capacity and increases further to 92% in CN due to a phase-out of coal capacity in 2037 and the increase of CCUS-equipped gas capacity.
- Other fuels, namely oil, hydro, solar, wind, biomass, and others account for less than five percent of the generation fuel mix throughout the outlook period for REF and less than eight percent in CN.
- Electricity imports from mainland China in both scenarios play a role in limiting the fuel consumption in both scenarios.
- Growing gas consumption by the power sector will require higher LNG imports into Hong Kong, China for the outlook period. While long-term contracts should cover most of these volumes, gas disruptions could be a key vulnerability for the economy in either scenario.

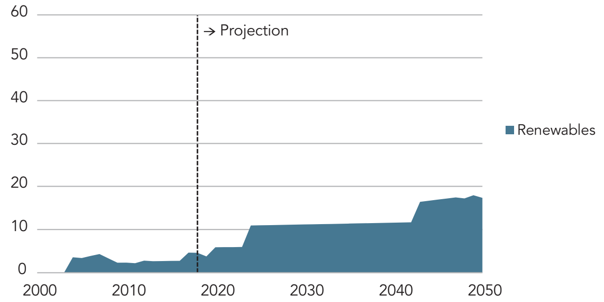
Energy supply in the Reference scenario

Figure 6-19. Total energy supply in REF, 2000-2050 (PJ)



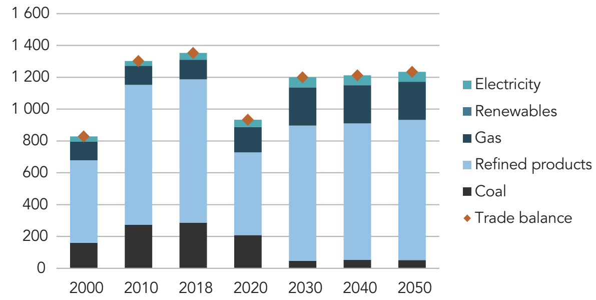
Sources: EGEDA, APERC analysis.

Figure 6-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 6-21. Net energy trade in REF, 2000-2050 (PJ)

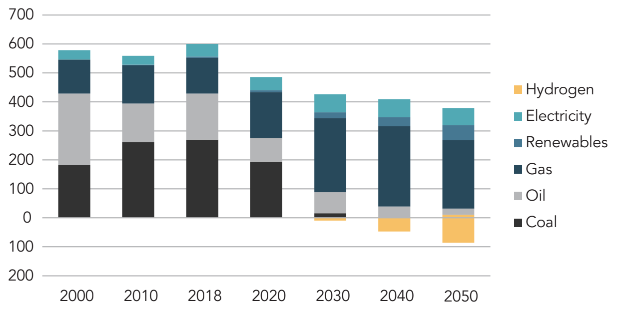


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Energy supply requirements fell 7.7% in 2020 during the onset of the COVID-19 pandemic. Supply never regains its pre-pandemic highs due to the reduction of lower-efficiency coal-fired generation, rising electricity imports from China and efficiency in the transport sector. In REF, the total energy supply decreases by 25%, or about 152 PJ, by 2050.
- Fossil fuels dominate energy supply over the outlook period, accounting for 92% of energy supply in 2018 but falling to 82% in 2050 due to rising electricity imports and some renewable penetration. There is much jockeying between the fossil fuels shares. Coal-to-gas switching reduces coal from 45% to a tenth of the supply mix and lifts gas from a fifth to over a half. Transport efficiency reduces oil's share from 27% to 17%. Renewable penetration increases from 0.8% to 3.9%. This composition of supply fuels is stable from 2030 onwards.
- Without indigenous energy resources, all of Hong Kong, China's energy production comes from power generation of renewable sources, including solar, biomass, and WtE units. This production increases four-fold following the government's policy to increase the share of renewables in the power mix.
- Hong Kong, China remains a net energy importer, and imports meet almost the entire energy supply throughout the outlook period. However, higher energy efficiency, from lower coal generation and transport energy efficiency, reduces imports by a tenth over the outlook period.
- Electricity imports from China are stable at 62 PJ between 2030 to 2050.
- Rising natural gas imports will be met by LNG, but pipeline gas imports from China continue to play a role in fuelling Hong Kong, China's gas supply.

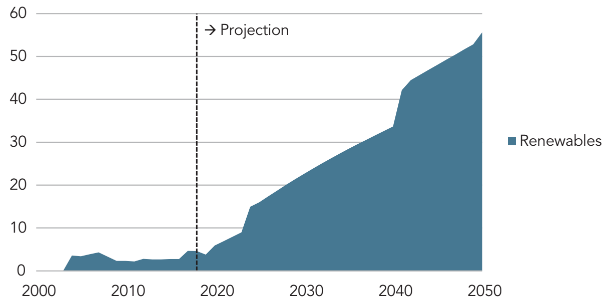
Energy supply in the Carbon Neutrality scenario

Figure 6-22. Total energy supply in CN, 2000-2050 (PJ)



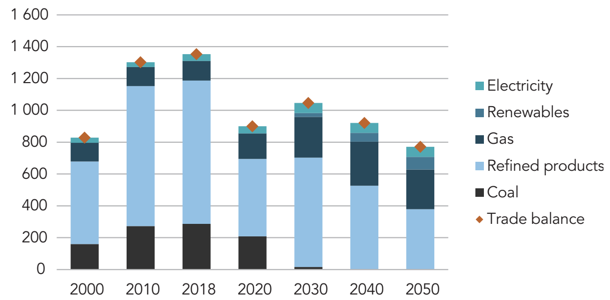
Sources: EGEDA, APERC analysis.

Figure 6-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 6-24. Net energy trade in CN, 2000-2050 (PJ)

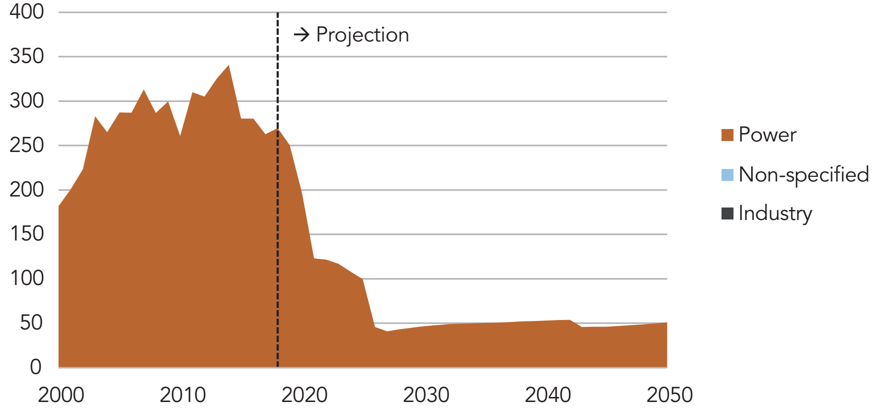


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, higher energy efficiency, stemming from the coal phase-out, modal shifts to public transport, and the adoption of fuel-efficient EVs decreases supply by almost half, or 251 PJ, which is a third below REF levels. Still, fossil fuels continue to dominate Hong Kong, China's energy supply throughout the outlook period.
- Natural gas requirements rise above REF levels, peaking 16% higher in the 2030s, and ending moderately above them by 2050. This is driven by high coal-to-gas substitution, as gas is called upon to replace phased out coal capacity in 2037. Modal shifting, fuel-switching, and energy efficiency in transport reduces oil requirements by over three-quarters. Higher solar deployment sees renewables triple over REF levels.
- Renewables production increases more than 12 times in CN to levels that are thrice that in REF. This is mainly due to higher solar deployment and biofuel blending in refined product fuel streams.
- Hong Kong, China remains a net energy importer in CN, and imports meet almost all of energy supply throughout the outlook period. However, imports decline due to higher domestic renewable production and improvements in energy efficiency in all sectors, including power.
- Hong Kong, China is a global hub for the movement of people and goods. The adoption of hydrogen as an aviation fuel in CN requires that Hong Kong, China source a significant amount of hydrogen for its bunkering services. This *Outlook* assumes that this is met through domestic electrolysis production in CN. However, it may need to be met through imports if the domestic production of hydrogen does not take off as shown here.
- Natural gas imports are slightly higher than in REF due to lower Chinese imports and a higher peak for imports in the 2030s. This will require a slight expansion to around 1.4 Mtpa of capacity, above the 1.2 Mtpa in REF.

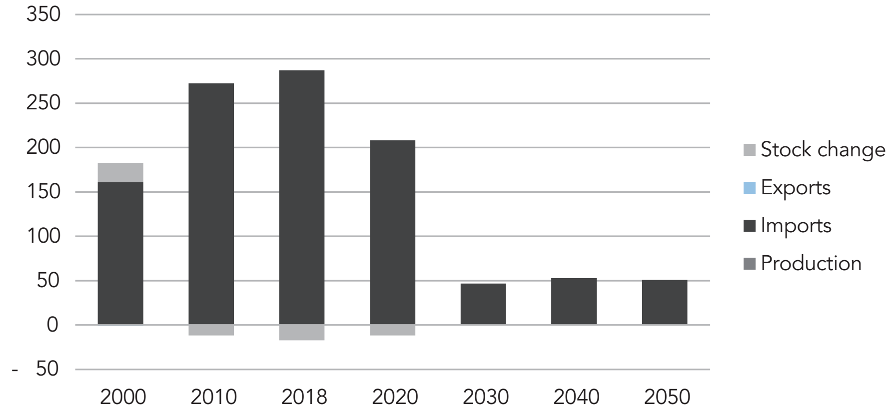
Coal in the Reference scenario

Figure 6-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 6-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

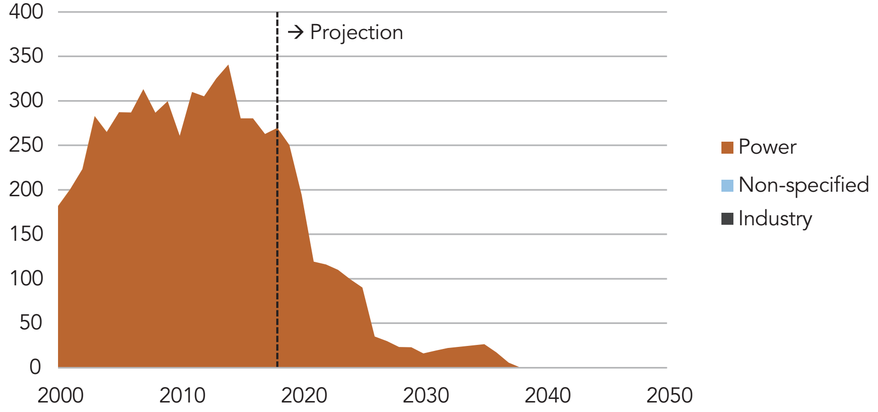


Sources: EGEDA, APERC analysis.

- The power sector is the only coal consumer in Hong Kong, China throughout the outlook period. Coal-to-gas switching and increases in electricity imports reduce coal consumption by over 80% by 2026 in REF. Consumption plateaus for the remainder of the outlook period as the power sector continues to use coal to diversify its fuel sources. However, use experiences some moderate increases and decreases, due to growing electricity demand and higher solar deployment, respectively.
- Hong Kong, China does not produce any coal and relies on imports from APEC economies for all its coal requirements. In 2021, 70% of thermal coal for power sector is imported from Indonesia, followed by Russia at 11%, and the remaining from Australia and Canada.
- Import requirements follow domestic supply requirements in REF, falling over 80% by the end of the projection period.

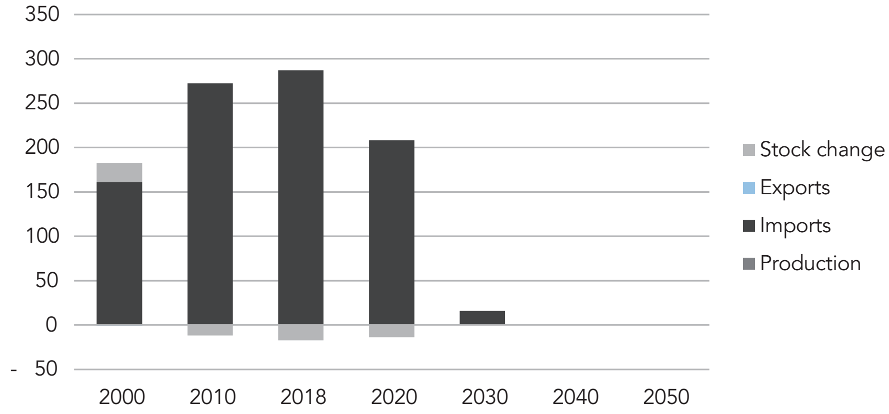
Coal in the Carbon Neutrality scenario

Figure 6-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 6-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

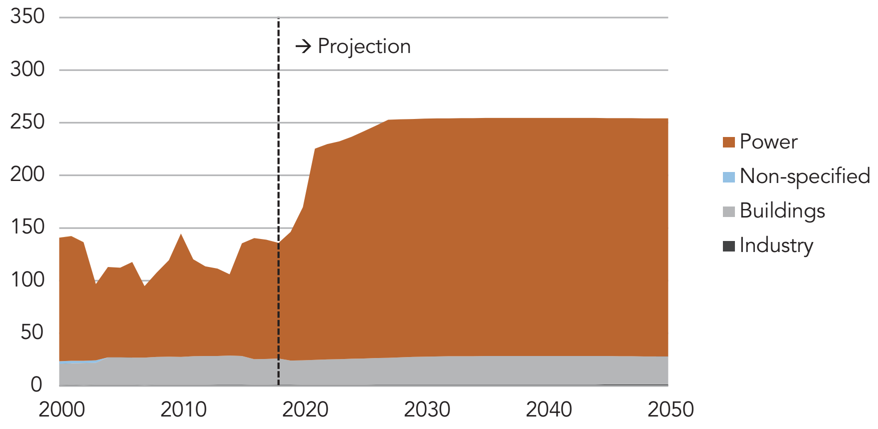


Sources: EGEDA, APERC analysis.

- In CN, Hong Kong, China ceases consumption of coal in 2037 as it pursues a phase-out in the power sector. This aligns well with the government's target aims to make Hong Kong, China a coal-free economy and is supportive of achieving carbon neutrality by 2050.
- Without domestic coal resources, coal imports continue to follow the lead of the power sector, falling to zero in 2037.

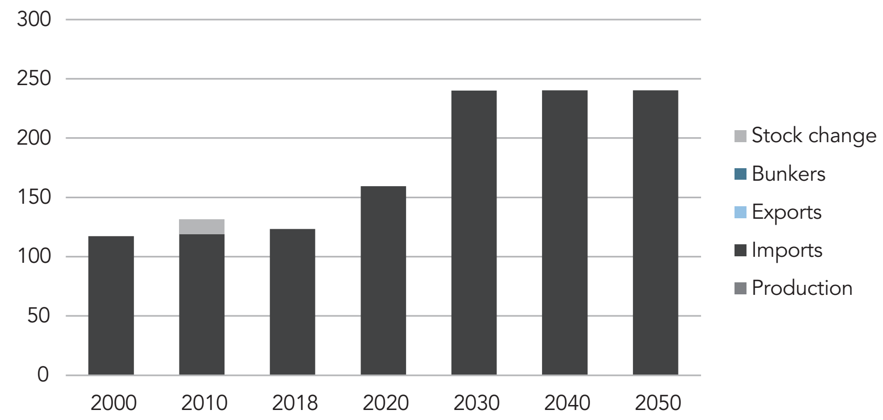
Natural gas in the Reference scenario

Figure 6-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 6-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

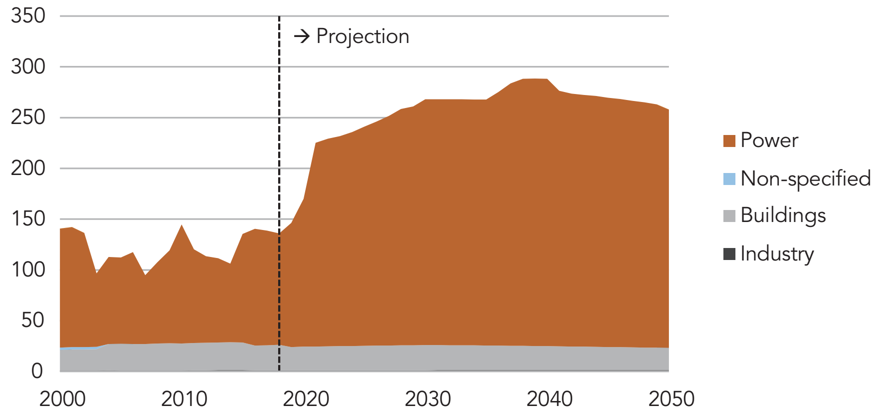


Sources: EGEDA, APERC analysis.

- In REF, natural gas consumption almost doubles by 2030 and stabilises at over 250 PJ for the remaining of the outlook period. This increase is almost entirely due to significant coal-to-gas switching occurring in the power sector.
- The power sector is the largest consumer of natural gas, followed by buildings, with the total share for both sectors surpassing 99% throughout the outlook period. Natural gas is blended with naphtha and a small portion of landfill gas to produce town gas for buildings consumption.
- Industry's natural gas consumption is relatively small and remains so, making up less than one percent of total natural gas demand throughout the outlook period.
- Without indigenous natural gas resources, Hong Kong, China relies on imports from China via submarine pipelines for all its current natural gas supply. The gas is distributed to three gas-fired power plants, namely the Black Point, Castle Peak, and Lamma Power Stations, for electricity generation, and the Tai Po Plant for town gas production.
- The first LNG import facility in Hong Kong, China, a 1.2 Mtpa FSRU, will be commissioned in 2022. LNG imports from this facility will enable Hong Kong, China to reduce coal-fired generation and emissions.
- Imports grow in line with natural gas consumption, nearly doubling by 2030 and maintaining that level for the remainder of the projection period. Pipeline gas imports grow 50%, while the remaining growth is met by LNG.
- While the introduction of LNG supply will diversify Hong Kong, China's gas supply sources, it could make the economy vulnerable to the volatility of global LNG spot markets if it requires volumes in excess of its current 1.2 Mtpa long-term contract.

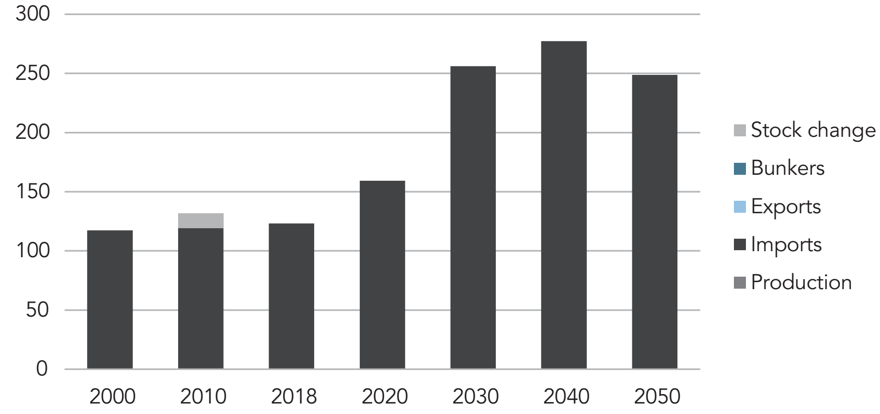
Natural gas in the Carbon Neutrality scenario

Figure 6-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 6-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

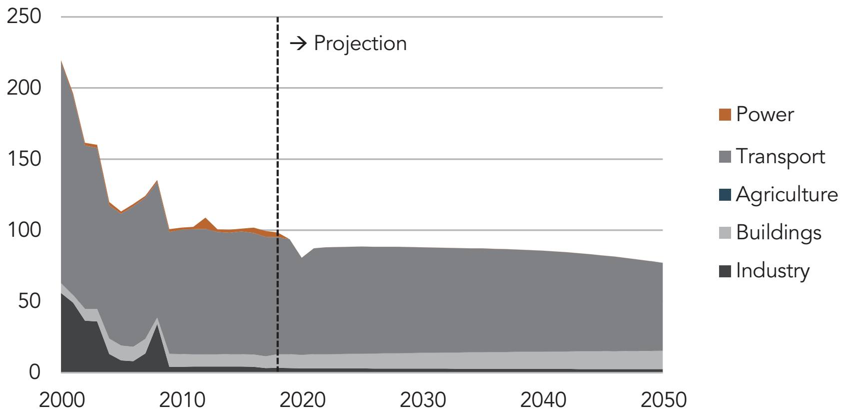


Sources: EGEDA, APERC analysis.

- Hong Kong, China employs a more aggressive coal-to-gas switch in CN, which pushes natural gas consumption above REF levels starting in 2028. By 2039, gas consumption peaks at 288 PJ, a tenth above REF levels, and falls to about REF levels by the end of the outlook period. The decline in the 2040s is driven by higher efficiency in the end-use sectors and renewable penetration in the power sector.
- Hong Kong, China's natural gas imports continue to mirror natural gas consumption trends in CN. Because gas consumption rises above those in REF, CN requires higher LNG import capacity, 1.4 Mtpa, to meet its peak requirements in the 2030s. It is assumed that this extra capacity is fully utilised for the rest of the outlook period to justify this investment in incremental capacity. Pipeline capacity declines slightly to balance out the declines in gas demand during the 2040s.

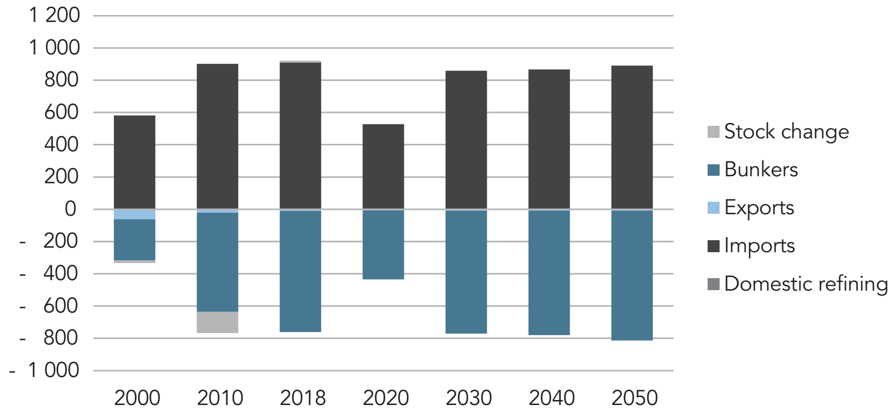
Refined products in the Reference scenario

Figure 6-33. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 6-34. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

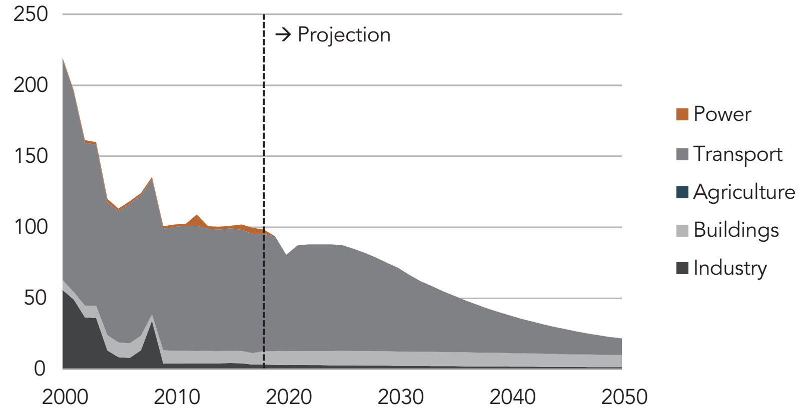


Sources: EGEDA, APERC analysis.

- Because there are no refineries in Hong Kong, China, the economy does not import any crude oil and relies on refined products imports to supply its refined product consumption. Transport is the largest consumer of refined products, followed by buildings, industry, and agriculture.
- Refined product consumption dropped in 2020 as mobility restrictions during the onset of the COVID-19 pandemic reduced transport activity, and in turn, reduced demand for diesel, gasoline, LPG, and jet fuel.
- Refined products consumption rebounds in 2021, but peaks in 2025, falling slowly thereafter to almost a quarter below 2018 levels by 2050. These reductions are mainly driven by fuel efficiency, the deployment of both EVs and hydrogen-fuel cells, and modal switching towards public transport. Efficiency gains in industry, buildings, and agriculture also support this trend.
- Hong Kong, China does re-export some of its refined product imports, mainly to China and Macao. Overall, the economy is a net importer of refined products. Refined products supply in Hong Kong, China is completely dependent on imports from neighbouring economies, such as China, Singapore and Malaysia, due to its lack of refining capacity.
- Hong Kong, China is also a global aviation hub. Thus, it must import a large amount of jet fuel to supply aviation bunkers with the energy required to sustain these aviation activities. Bunkers make up over 80% of import requirements, and together with re-exports account for around 91% of total imports during the outlook period. While bunker withdrawals grow 7.1% in REF, imports plateau due to declines in domestic consumption.

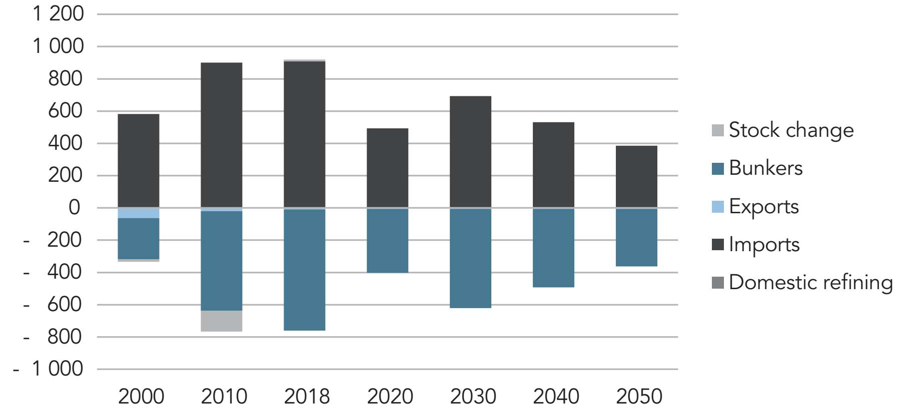
Refined products in the Carbon Neutrality scenario

Figure 6-35. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 6-36. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

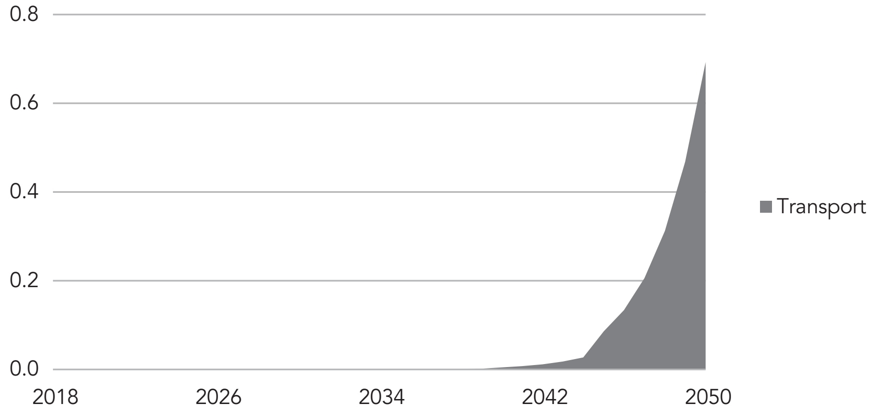


Sources: EGEDA, APERC analysis.

- In CN, Hong Kong, China's refined product consumption decreases steadily, falling three-quarters by the end of outlook period, as higher modal and fuel switching, and more rigorous energy efficiency improvements follow a stronger adoption of energy-efficient vehicles and ferries in the transport sector. However, buildings sector use of refined products remains elevated, falling only a tenth below REF levels.
- Imports of refined products in CN fall by half compared to REF levels, as both Hong Kong, China and the global aviation sector reduce their use of refined products.

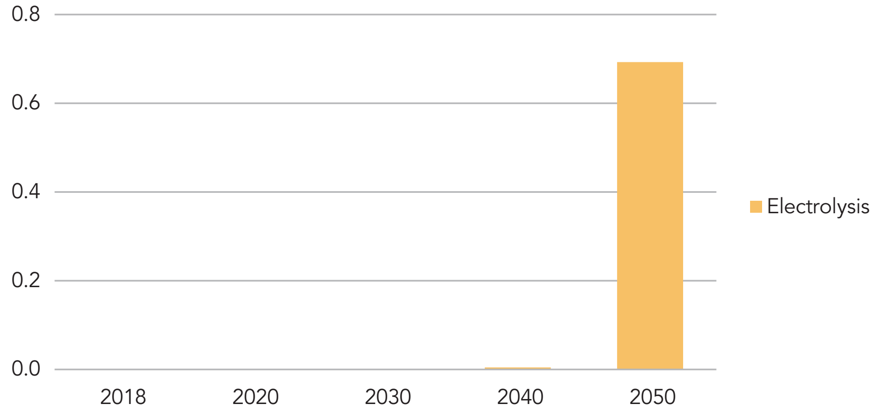
Hydrogen in the Reference scenario

Figure 6-37. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 6-38. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

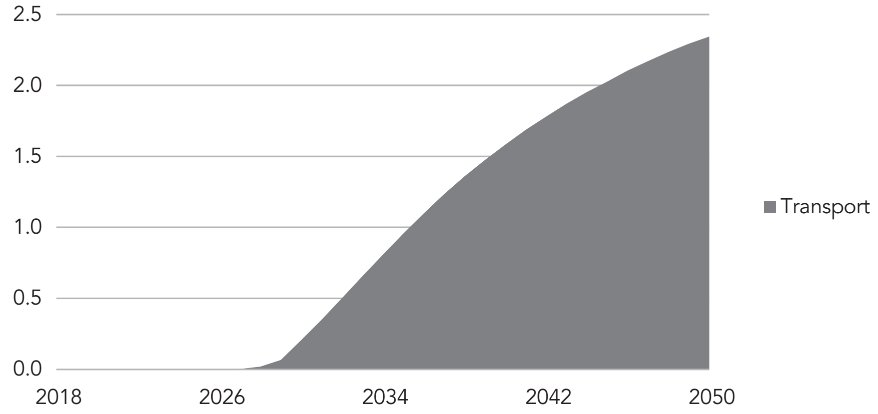


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- In REF, hydrogen consumption starts in 2038 with the deployment of hydrogen fuel-cell vehicles in the transport sector. Hydrogen consumption then grows slowly for five years and rises rapidly from 2043, as declining costs make hydrogen fuel-cell vehicles more competitive.
- Hydrogen supply in REF is domestically produced through the electrolysis process. There is uncertainty with regards to the viability of such a process in Hong Kong, China. If hydrogen cannot be produced domestically, Hong Kong, China would need to meet these demand requirements via imports.
- In December 2020, the government established the Green Tech Fund with a two-year allocation of $200 million to encourage research and development in green technology, including green transport development. It is part of government initiatives to promote decarbonisation, expedite low-carbon transformation, and enhance environmental protection in Hong Kong, China. Part of these funds could be used to support the development of the economy's hydrogen sector.

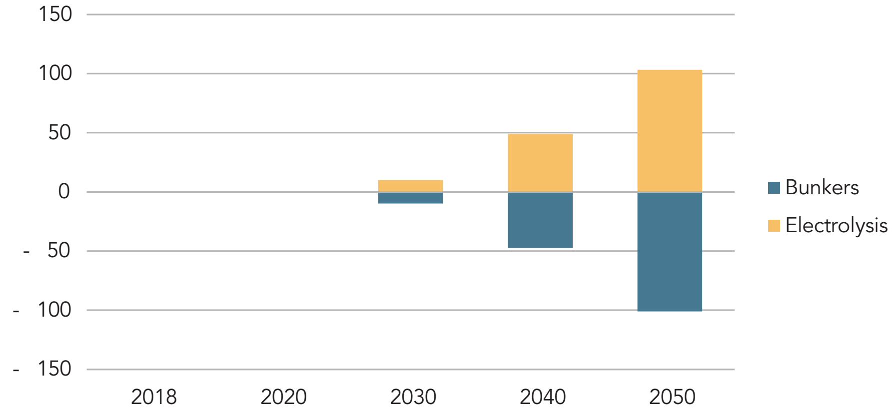
Hydrogen in the Carbon Neutrality scenario

Figure 6-39. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 6-40. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

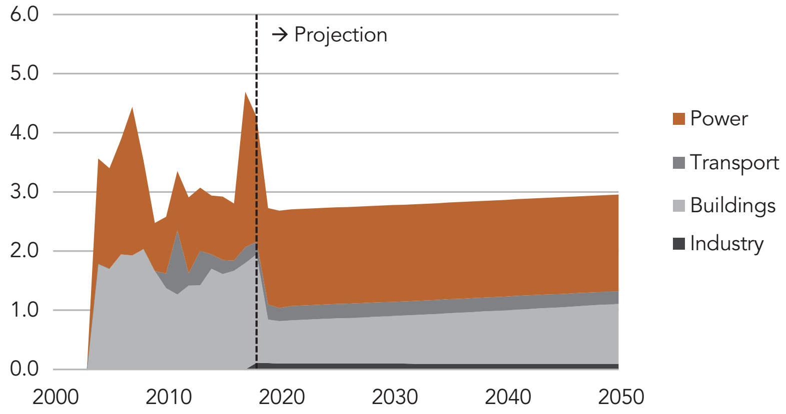


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- In CN, hydrogen consumption in the transport sector starts in 2027, about ten years earlier than REF. Hydrogen consumption increases rapidly, more than tripling by 2050 compared to REF levels, as hydrogen fuel-cell vehicles make further gains in the transport sector.
- The CN assumes that the aviation sector starts to utilise hydrogen as an aviation fuel in 2030. Due to its role as a global aviation hub, Hong Kong, China must source hydrogen to service this rising demand for hydrogen from aviation bunkers. Because the energy demand for bunker services is much higher than Hong Kong China's domestic transport sector, bunkering services are a key driver of the supply requirements for hydrogen in CN.
- Hydrogen supply requirements continue to be met by domestic electrolysis production in CN. By 2050, bunkering withdrawals for aviation make up 98% of this production. There is uncertainty with regards to the viability of such a process in Hong Kong, China. If hydrogen cannot be produced domestically, Hong Kong, China would need to meet these demand requirements via imports.

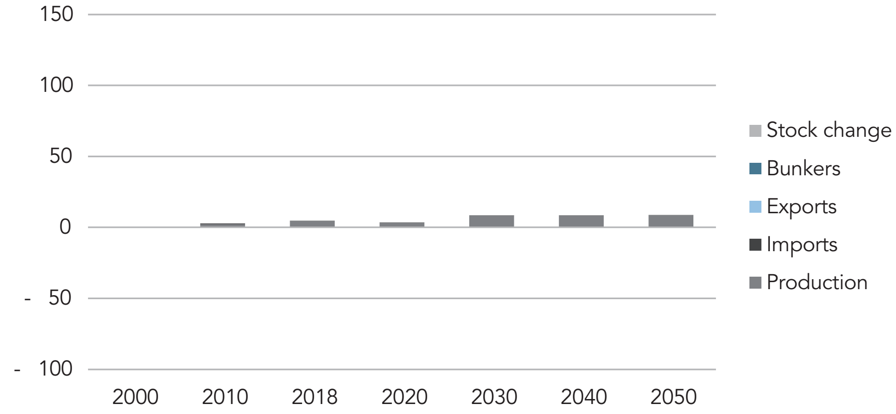
Bioenergy in the Reference scenario

Figure 6-41. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 6-42. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

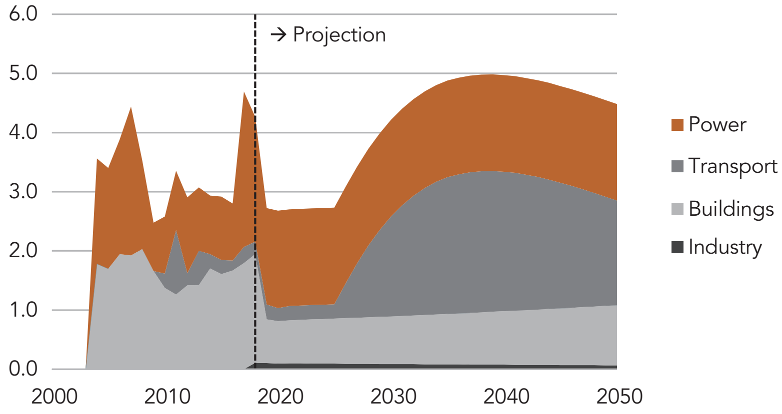


Sources: EGEDA, APERC analysis.

- Bioenergy is mainly consumed by the power and buildings sectors, but biodiesel blending also plays a small role in fuelling both the transport and industry sectors.
- In REF, solid and liquid renewables consumption declines in 2019 and grows 8.4% above 2019 levels throughout the outlook period. While the transport and industry sectors experience slight declines, and demand in the power sector remains stable, buildings use of biogas increases a third and is the main driver of rising Hong Kong, China consumption.
- Hong Kong, China produces more than 96% of solid and liquid renewables supply and imports the remainder to meet domestic demand.
- In 2021, biodiesel supplied in Hong Kong, China is produced by using locally collected waste cooking oil from restaurant and food manufacturers.

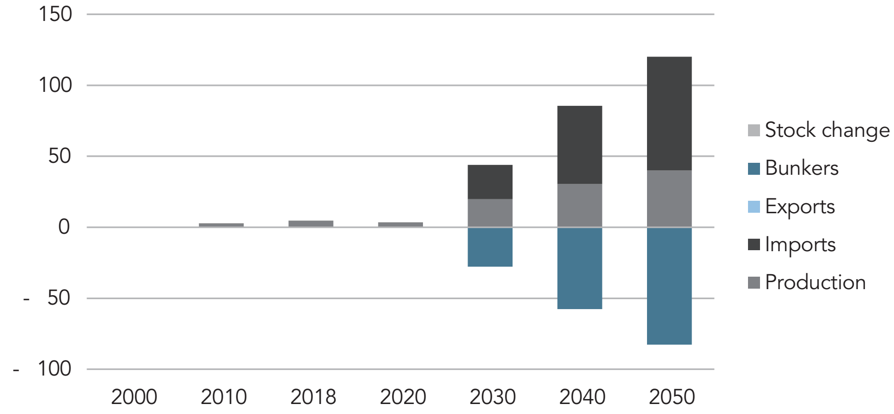
Bioenergy in the Carbon Neutrality scenario

Figure 6-43. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 6-44. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

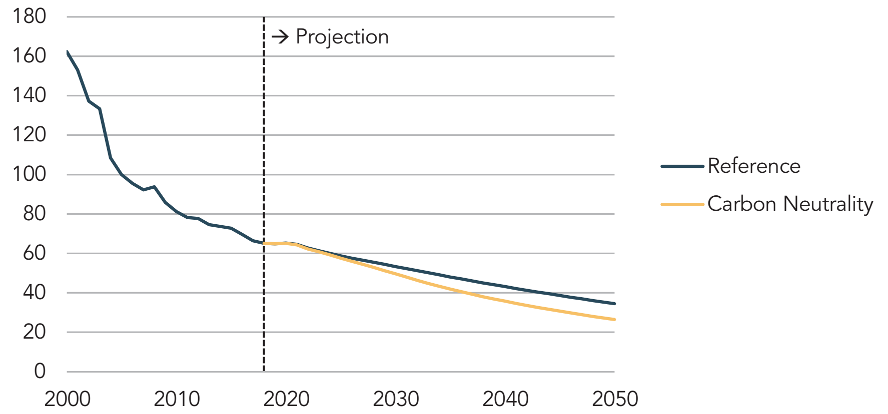


Sources: EGEDA, APERC analysis.

- In CN, Hong Kong, China's bioenergy consumption plateaus between 2018 to 2025 before increasing significantly into the 2030s due to higher biofuel blending in refined product fuel streams. Consumption then declines for the last decade of the outlook period, as demand for refined products streams fall due to energy efficiency gains and both fuel and modal switching in the transport sector.
- Transport becomes the largest solid and liquid renewables consumer starting in 2030.
- Domestic solid and liquid renewables production is sufficient to meet increasing domestic demand. However, imports of liquid renewables increases significantly from 2030 due to increasing demand for biojet fuel as bunker fuel in the global aviation sector.

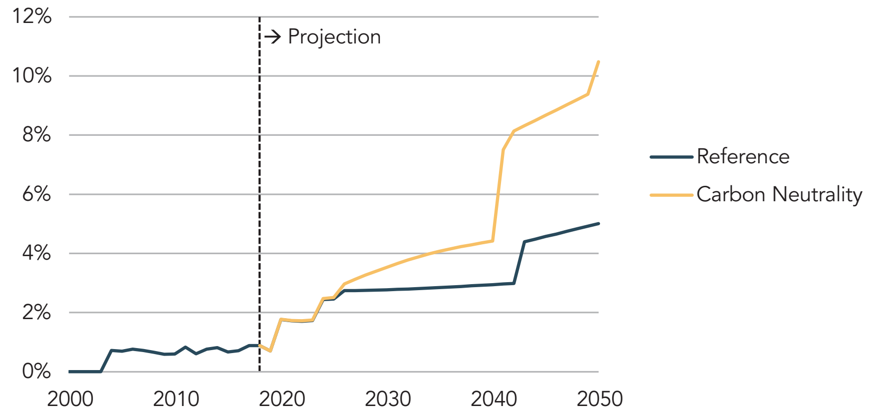
Final energy intensity and modern renewables share

Figure 6-45. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 6-46. Modern renewables share in REF and CN, 2000-2050



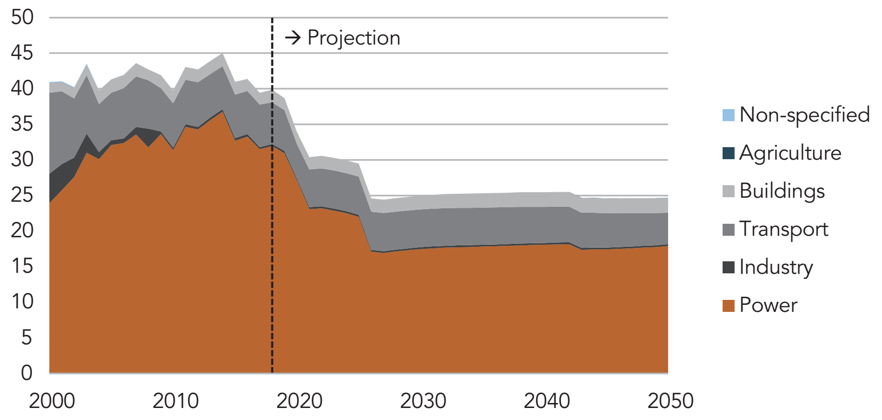
Sources: EGEDA, APERC analysis. Note: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- Hong Kong, China's final energy intensity has improved significantly since 2000, reaching 35% below 2005 levels in 2018. Much of this trend can be attributed to the structural shift in Hong Kong, China's economy, reducing its energy-intensive industrial activities in favour of higher-value services activity. While energy demand fell a quarter during these two decades, GDP nearly doubled.
- This strong decoupling of economic activity from energy use has resulted in Hong Kong, China recording the lowest energy intensity among APEC members in 2018.
- The improvement of energy intensity trend continues in both scenarios, albeit at a slower rate than history. This stems mostly from the fact that Hong Kong, China has already made large gains in reducing energy intensity through its structural shift towards a service economy. Energy intensity falls to 66% below 2005 levels to 2050 in REF and 74% in CN. The improvement is mainly driven by the transport sector with the increasing number of EVs and passengers electing to use public modes of transport.
- Hong Kong, China's efforts are consistent with APEC's goal of reducing energy intensity by 45% below 2005 levels by 2035. It does so in 2029 in REF and two years earlier in CN. These efforts also help APEC achieve the goal in both scenarios.
- Hong Kong, China's modern renewables share increases rapidly, rising eight-fold by 2050 in REF and 17 times in CN. Hong Kong, China's efforts are consistent with APEC's goal to double the share of modern renewables in the energy mix by 2030 in both scenarios, and thus help the region achieve the goal on an APEC-wide level.
- The rapid increase in modern renewables is driven by stronger deployment of solar and biofuels in the power sector, higher use of biogas in buildings and increased biofuel blending in transport. The power sector is the largest contributor.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

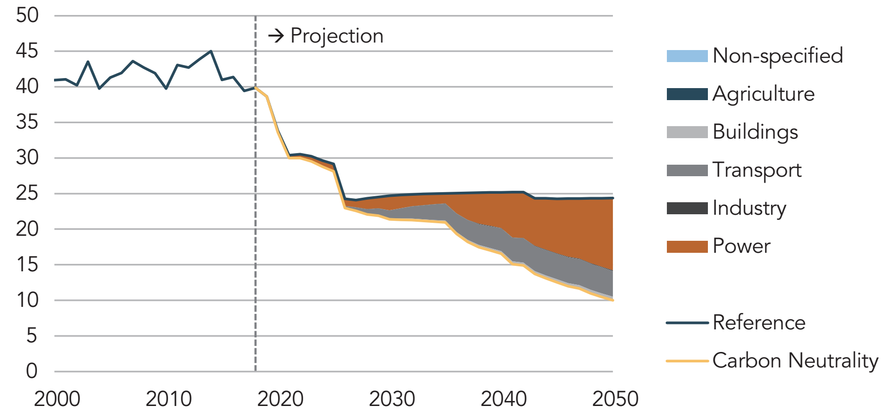
Gross CO_2 emissions

Figure 6-47. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 6-48. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

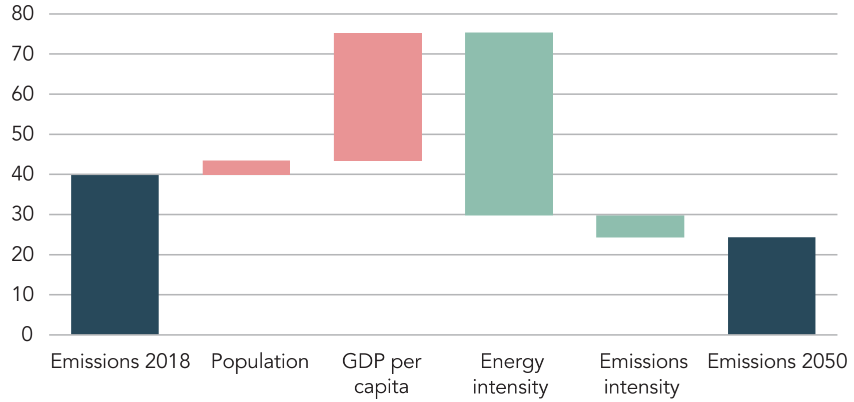


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Hong Kong, China's CO_2 emissions have been stable over the past two decades, as the structural changes in its economy led to declines in transport and industry that were offset by increases from rising coal-fired generation in the power sector. The power sector is responsible for 80% of emissions.
- In REF, emissions fall about at third by 2025 and are rangebound between 24 and 25 million tonnes for the rest of the outlook period. The main driver of the decline is Hong Kong, China's goal of lowering coal-fired generation. The power sector is responsible for over 90% emission reductions, while lower fossil fuel use and higher public transit activity in the transport sector is responsible for 9.3%.
- In CN, Hong Kong, China's CO_2 emissions from the power sector are half of REF levels in 2050 due to the phase-out of coal-fired power, the introduction of abatement via CCUS in gas-fired power plants, and higher renewable adoption. Buildings replace transport as the second-largest contributor of CO_2 emissions in CN, as a large reduction in diesel and gasoline consumption in the transport sector follows higher alternative vehicle adoption and modal switching.
- Hong Kong, China's NDC sets a target to reduce carbon intensity by 65% to 70% compared with 2005 levels by 2030. This is equivalent to a 26% to 36% absolute carbon emission reduction from 2018 levels. Hong Kong, China achieves the target in both scenarios and records a 37% absolute carbon emission reduction by 2030 in REF and 46% in CN.
- Hong Kong, China's combustible emissions are 49% below 2005 levels in 2035, just shy of achieving the 50% target in its Hong Kong Climate Action Plan 2050.
- With 10 million tonnes of remaining emissions, Hong Kong, China is within reach of achieving carbon neutrality if it can offset its remaining emissions or sequester them by means not discussed here.

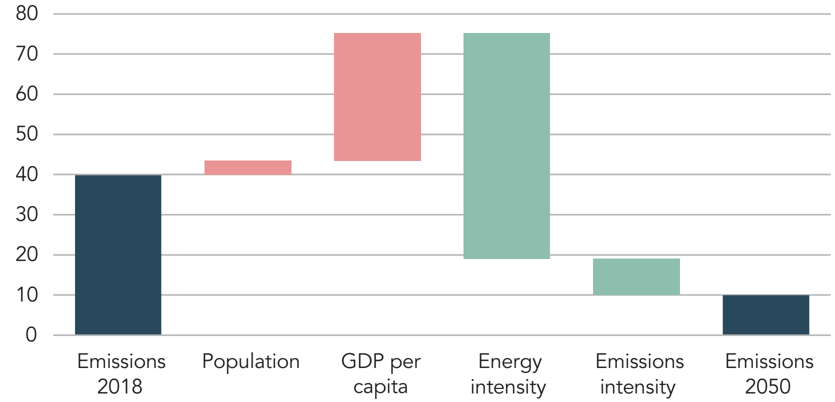
Components of CO_2 emissions

Figure 6-49. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 6-50. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- In 2018, Hong Kong, China emitted about 40 million tonnes of CO_2 or 0.2% of total APEC CO_2 emissions. In REF, CO_2 emissions fall by 39%, despite population and GDP per capita growth. Without energy efficiency or emission intensity improvements, emissions would grow over 75 million tonnes, with 3.6 million tonnes attributable to population growth and 32 million tonnes to growing income levels.
- However, improvements contribute 51 million tonnes of emissions reductions in REF. Increases in energy efficiency in all sectors improve energy intensity, reducing emissions by 45 million tonnes. Shifting the supply mix towards lower-emitting fuels, such as via the coal-to-gas switch in the power sector, reduces emissions by 5.4 million tonnes.
- CO_2 emissions in CN are 59% lower than REF, with energy intensity reductions rising by a quarter and emissions intensity by two-thirds. Further energy efficiency gains mainly result from fuel and modal switching in the transport sector, while emissions intensity improvements mainly stem from the phase-out of coal-fired generation in the power sector.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

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7. Indonesia

Highlights

Demand

- In REF, energy demand doubles to 2050. In CN, the growth in energy demand is more subdued, increasing by a half. Stronger energy efficiency initiatives, more efficient equipment used in industry and transport, and electrification in all sectors contributes to the lower demand in CN.
- In REF, oil maintains the largest share of energy demand out to 2050, and there is a significant increase in coal consumption due to rapidly increasing industrial demand. In CN, oil demand is significantly lower, which is mostly tied to electrification and fuel switching.
- In CN, electrification in all sectors leads to electricity demand almost quadrupling out to 2050. Electricity consumption is almost 80% greater than oil consumption in 2050. This is significantly changed from REF, where electricity is 40% lower than oil consumption in 2050. Hydrogen is an important component of the energy transition in CN and begins to be consumed from 2025.

Supply

- Energy supply increases by 2.6 times in REF. The largest growth is from renewables (five-fold increase) and gas (four-fold increase). The increase in gas supply contributes to fossils fuels more than doubling out to 2050. Coal and oil increase by two-thirds. Renewable energy sources, such as geothermal and hydro, account for more than 30% of Indonesia's energy supply in 2050.
- In CN, energy supply growth is lower than in REF, increasing by 2.2 times out to 2050. The share of fossils fuels in Indonesia's energy supply falls to 47% in 2050, which is much lower than the 69% share in REF, and 84% share in 2018.
- Renewables supply increases by more than 6.5 times in CN. By 2050, renewable energy sources account for more than 46% of Indonesia's energy supply. Nuclear begins to be deployed in 2040 in CN and grows to account for 7% of Indonesia's energy supply by 2050.
- Indonesia is one of the largest thermal coal producers in the world. Coal currently accounts for more than three-quarters of Indonesia's energy production, and almost two-thirds is exported. In REF, coal production declines gradually. In CN, falling domestic and international demand leads to coal production falling by more than 70% out to 2050.

Power

- Electricity generation more than triples in REF and more than quadruples in CN due to increasing electricity demand from all sectors. EVs are particularly influential in CN, with transport electricity demand increasing from less than 3 TWh in 2019 to more than 270 TWh in 2050.
- In both scenarios, natural gas generation surpasses coal generation, which is emblematic of the energy transition. In REF, gas increases more than seven-fold and accounts for 43% of the generation mix in 2050. In CN, gas plays more of an ancillary role to support fast-growing non-dispatchable generation. Coal and gas generation with CCS is implemented from the 2030s in CN.
- Renewables achieve the national target of a 23% share in total generation in 2025, as stated in the National Energy Policy. By 2050, renewable generation accounts for a 40% share in REF and 56% share in CN. Solar, hydro, geothermal, and wind all become prominent. In CN, nuclear is deployed to provide stable baseload power while minimising emissions.

CO_2 emissions

- In REF, CO_2 emissions from combustion almost double to reach 1 100 million tonnes in 2050. CO_2 emissions do not peak in REF due to growing energy demand and a high share of fossil fuel energy sources.
- In CN, CO_2 emissions in 2050 are 56% lower than in REF owing to stronger emissions mitigation actions. Widespread electrification, other fuel switching, energy efficiency, and CCS technologies in industry, own use, and power sectors are influential in reducing emissions.

Hydrogen

- The industry and transport sectors begin to use hydrogen from the mid-2020s in CN, but the future of hydrogen is still uncertain.
- In industry, hydrogen is used by the chemical and steel subsectors, enabling a switch away from fossil fuels for certain processes. Hydrogen consumption in the transport sector surpasses that in the industry sector in the mid-2030s, due to the increasing uptake of fuel cell vehicles. By 2050, the transport sector will account for 70% of hydrogen consumption.

About Indonesia

- Indonesia is the world's largest archipelagic state located in southeast Asia, straddling the equator. The economy's territory encompasses more than 16 thousand islands and covers a territorial area of 8.3 million square kilometres, constituting Indonesia's exclusive economic zone. The economy's total land area (25% of its territory) is approximately 1.9 million square kilometres, and its population was almost 268 million in 2018 (3rd in APEC).
- Indonesia had a gross domestic product (GDP) of USD 3 118 billion and GDP per capita of USD 11 647 in 2018 (2017 USD purchasing power parity [PPP]). The Indonesian government has been progressing in deregulating the economy and removing barriers to investment. Its 73rd rank in the World Bank's 2020 ease of doing business index is an improvement from 91st place in 2017.
- Indonesia is the largest economy in Southeast Asia and is projected to become a high-income economy by 2036 with the fifth largest global GDP in 2045. The Indonesian Government has boosted infrastructure development, including energy infrastructure, to support its economic growth and rapidly growing energy demand. Government spending on infrastructure projects doubled from 2014 to 2019.
- Indonesia has diverse fossil fuel and renewable energy sources. In 2018, proved fossil energy reserves comprised more than 14 000 PJ of oil, about 700 000 PJ of coal, and 45 000 PJ of natural gas. Most oil and gas resources are in western and eastern Indonesia, with deep-water technology required to exploit resources in the east. Recent liquefied natural gas (LNG) projects include Donggi-Senoro, Tangguh, and Abadi Masela, all located in eastern Indonesia. Indonesia is one of the largest thermal coal producers in the world, with 74% of production exported in 2019. Most coal is mined in South Sumatra and Kalimantan.
- Indonesia's abundant renewable energy potential includes 28.5 GW of geothermal, 94.3 GW of hydro, 208 GW of solar, 33 GW of bioenergy, 61 GW of wind power and 17.9 GW of ocean energy.

Table 7-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	267.7	9.2%	3
GDP	3 118	4.4%	5
TPES	8 948	2.6%	7
Production	19 514	5.7%	5
Imports	2 164	1.7%	12
Exports	10 684	9.8%	5
Electricity generation	284	1.7%	8
Heat production	-	-	-
CO_2 emissions	593	2.8%	6

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 7-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	701 978	62	3.2%	5
Natural gas	45 082	20	0.7%	6
Oil	14 928	9	0.1%	8
Uranium	8 400	NA	0.14%	7

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- **Indonesia's energy and natural resources policies:** Governed by Oil and Gas Law No. 22/2001, Energy Law No. 30/2007, Electricity Law No. 30/2009, Geothermal Law No. 21/2014, and Mineral and Coal Mining Law No. 3/2020. Government Regulation No. 79/2014 concerning the National Energy Policy (NEP) provides guidelines for formulating energy management policies to promote energy self-sufficiency and strengthen domestic energy security by making energy production equitable, sustainable, and environmentally friendly. Presidential Regulation No. 22/2017 on the General Plan of National Energy contains policies on managing the NEP.
- **Fossil fuels:** Indonesia's fossil fuels dependence is a fundamental characteristic of its national energy supply. Current energy supply is 85% coal, oil, and gas. The high demand for oil (refined products), especially by the transport sector, results in the depletion of foreign exchanges due to imports and leads to significant greenhouse gas (GHG) emissions. Indonesia is encouraging fuel diversification in the transport sector, via EVs and biofuels, to decrease fossil fuel dependence.
- **Energy security:** Indonesia has introduced policies to improve energy security and sovereignty. The policies prioritise local energy resources to meet domestic demand, and ensure use is optimised. The coal domestic market obligation, domestic energy pricing, oil fuel switching, and diversifying the use of coal through the development of dimethyl ether (DME) to replace LPG, are all examples of these policies. Mandatory blend rates for biofuels in the transport and power sectors are now in place for the industry and commercial sectors to improve energy security and support renewable energy. The NEP also establishes economy-wide targets, such as increasing the share of renewables to at least 23% in 2025 and 31% in 2050; reducing energy elasticity to less than 1 in 2025; reducing final energy intensity by 1% per year to 2025; and increasing per-capita electricity consumption to 2 500 kilowatt-hours (kWh) in 2025 and 7 000 kWh by 2050.
- **Ease of doing business:** The Government of Indonesia published the Omnibus Law on Job Creation in October 2020 to repeal overlapping regulations. Law No. 11/2020 aims to boost investment and create jobs by streamlining regulations and simplifying the licensing process. This will encourage activity in the energy and mineral resources sector. Indonesia is also drafting the Renewable Energy Law to foster the development of renewable energy and support the energy transition.
- **Emissions:** As an economy vulnerable to the adverse impacts of climate change, Indonesia is committed to reducing GHG emissions. Indonesia's NDC (updated in 2021) has an unconditional GHG emission reduction target of 29% and a conditional target of up to a 41% compared to business-as-usual in 2030. The energy sector contributes 60% to 70% of Indonesia's emissions. Reducing GHG emissions in the energy sector is crucial to achieving emissions targets stated in the NDC.
- **Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR 2050):** Indonesia developed the strategy in 2021 which aims to contribute to net-zero emissions while balancing economic growth, justice, and climate resilience development considerations. The strategy could see Indonesia peak GHG emissions by 2030 and reach 540 million tonnes of CO_2-equivalent by 2050. There are opportunities to reach net-zero emissions by 2060 or sooner. Indonesia uses the following four guiding pillars to design a long-term low carbon strategy in the energy sector: (i) implementation of energy efficiency; (ii) utilise decarbonised electricity in transport and buildings; (iii) fuel switch from coal to gas and renewables in industry; (iv) enhance renewable energy in power, transport, and industry. Indonesia also continues to address issues related to energy access, smart and clean technology, and financing in the energy sector to support the achievement of the Paris Agreement targets.
- **Carbon markets:** Indonesia has recently issued two regulations intended to set the instrument for carbon markets in Indonesia. These two regulations are the new tax law (Law No. 7/2021) that introduces a carbon tax and the Presidential Regulation No. 98/2021 concerning the implementation of carbon pricing to achieve NDC targets and control GHG emissions. A trial of the carbon trading system with a voluntary scheme is currently being carried out at several coal-fired power plants. Eventual full implementation of the Law will incorporate cap-and-trade and a tax mechanism.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- Indonesia's national energy policy is formulated to support energy security, independence/sovereignty, and resilience. Energy resources are optimised to support national development and prosperity.
- **The Reference scenario (REF)** reflects recent trends and existing policy frameworks and programs in place or planned to capture the evolving nature of the energy system. It serves as a baseline of comparison for **the Carbon Neutrality scenario (CN)**. National energy planning and the Energy Grand Strategy are influential for trends in both scenarios.
- Indonesia's Long-Term Strategy for Low Carbon and Climate Resilience 2050 (LTS-LCCR 2050) increases ambitions for GHG reductions and aims to achieve net-zero emissions by 2060 or sooner. The strategy was compiled in the lead-up to COP 26 and is reliant on global technological innovation and financial support. The modelling in the REF and CN scenarios was developed prior to Indonesia's net-zero commitment.
- On the demand side, energy efficiency, fuel economy standards, and fuel shifting policies continue current trends and gradually improve. The transport sector will gradually see an increase in EVs and mandatory biofuel. Natural gas vehicles will also be implemented. The moratorium on new coal generation will remain in the power sector, together with the early retirement program. There is lower scale adoption of wind and solar in REF than in CN. On the supply side, domestic gas and coal production are prioritised for domestic use over export.
- CN investigates potential hypothetical pathways to achieve net-zero emissions through more aggressive energy efficiency, fuel switching, and advanced technology deployments, such as renewables, nuclear, hydrogen, and CCS.
- Technology maturity, economic feasibility, and financial support are critical for achieving the CN target. Hydrogen from electrolysis will begin in 2025 at a small scale, supplying transport and industrial end-use cases. Nuclear development is predicated on high levels of safety and socio-political considerations. Competitively priced solar and wind will be one of the keys to decarbonising the power sector. CCS technologies will use Indonesia's storage potential to reduce CO_2 emissions in the power sector and heavy industry.

Table 7-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Indonesia

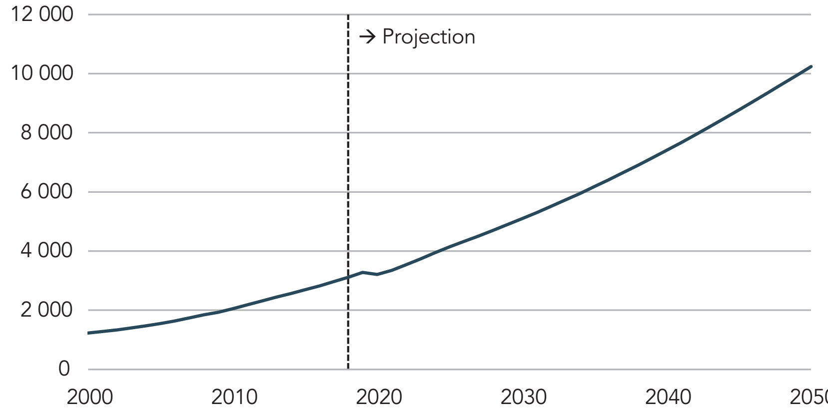
Table 7-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium). • GDP: World Bank (historical), OECD (projections), IMF (COVID-19 impacts).	• Same as Reference
Buildings	• Higher energy efficiency standards and more comprehensive appliance energy labelling schemes. 15% of energy savings by 2050. • Cleaner cooking technology dispersion, especially in rural areas.	• Mandatory energy efficiency standards and more comprehensive appliance energy labelling schemes, 20% extra of energy saving in 2050 compared Reference. • Increased electrification, reaching 80% of final energy demand by 2050. • More aggressive technology replacement for cooking
Industry	• Energy efficiency and electrification follow historical trends. • Fuel switching to biofuels in some subsectors and incorporation of biofuels mandatory program. • No CCS or hydrogen	• CCS uptake for heavy industry (steel, non-metallic minerals, chemicals) begins 2030 • Hydrogen for steel and chemical industries begins in 2025. • Greater energy efficiency improvements and electrification. Material efficiency requires less heavy industry production to deliver the same end-use needs. • Numerous fuel switching assumptions in different industries
Transport	• Gradual uptake of electric vehicles • Biofuels mandatory program. Biodiesel 30% (2025) and 40% (2045) . • Reactivate natural gas vehicle program, inland transportation, and marine.	• Biodiesel 30% (2025) and 50% (2045) • More rapid uptake of passenger electric vehicles reaching 40% sales by 2035 and more than 90% sales by 2050. • Hydrogen fuel cell vehicles for heavy trucking reach 20% of sales in 2050.
Power and heat	• Coal and gas-fired units are used to meet rapidly increasing electricity demand. • Lower scale adoption of solar and wind projects.	• CCS-equipped gas and coal adoption from 2035 • Higher scale adoption of solar and wind projects • Nuclear reactors adoption from 2040
Supply	• Refining: Considered new and additional capacity projects. • Thermal coal: production is driven by the evolution of export markets. • Oil and condensate rise to 1.0 Mb/d in 2030 (target hit), fall thereafter. • Gas production target not hit, rises to 8 bcf/d in 2030, falling thereafter. • Gas supply preference is for domestic demand rather than export markets.	• Refining: retire refining capacity in line with declining demand. • Fossil fuels are driven by domestic demand and export market trends. • Thermal coal exports fall 87%, weighing down production. • Lower global oil demand in a Carbon Neutrality world reduces oil production. • Gas production, pipeline trade, and LNG exports infrastructure the same as Reference
Climate	• NDC	• Net-zero in 2060

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

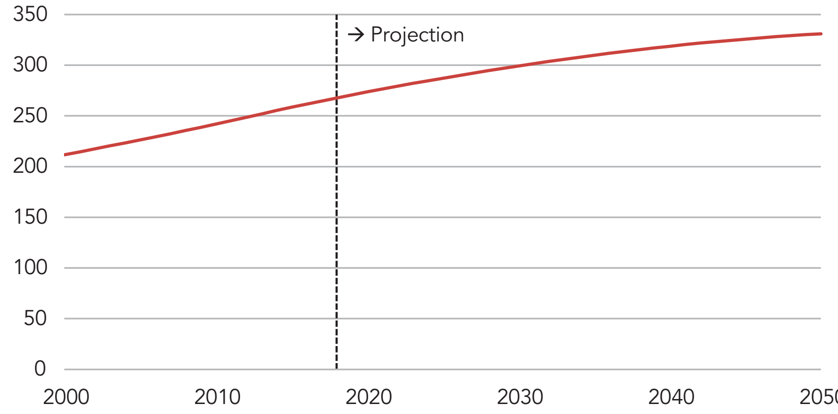
Macroeconomic backdrop

Figure 7-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 7-2. Population in millions, 2000-2050

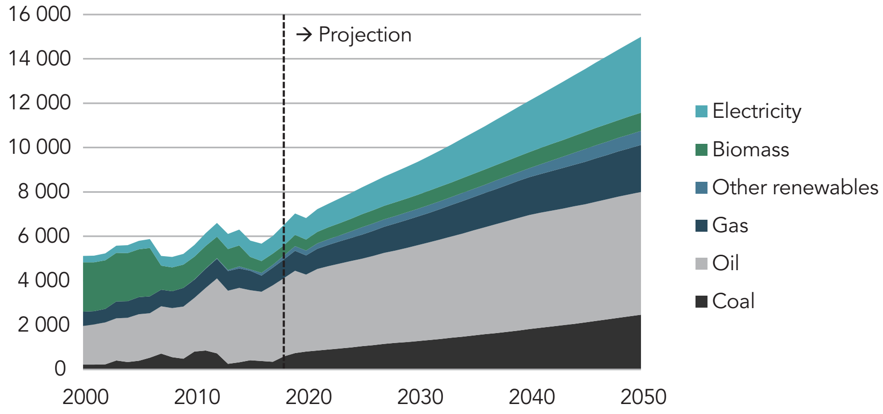


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- Indonesia's economy has grown continuously from 2000 to 2018, with average GDP growth of 5.3%. Increasing population and living standards will see GDP continue to grow strongly over the next 30 years. GDP grows at an annual average of 3.7%, with a 4.8% average growth for the first decade. The impact of the COVID-19 pandemic on Indonesia's economy was pronounced, with negative GDP growth in 2020. Output recovered to near the pre-pandemic level in 2021.
- The GDP projections from the World Bank and IMF are lower than domestic projections, such as the Indonesia Vision 2045: 2016-2045 and Indonesia Mid Term Planning (2020-2024). The World Bank and IMF GDP projections are used for all APEC economies.
- Indonesia's oil, gas, and coal reserves have been an important source of energy, industrial raw materials, and foreign exchange revenues. Recent development of industrial and manufacturing capacity has increased the share of manufacturing in Indonesia's GDP. Significant domestic and international demand for Indonesia's coal means that the coal industry plays a leading role in Indonesia's economic growth.
- Sustainable economic development is one of the pillars of the "Visi Indonesia 2045" (Vision of Indonesia 2045). The vision seeks to transforms Indonesia into a developed economy, driven by investment and trade, industry and creative economy, tourism, maritime, and services.
- Indonesia's population is projected to increase from 268 million in 2018 to 331 million in 2050, which is an average of 0.6% per year. This growth rate is half of the population growth that occurred from 2000 to 2018. Family planning programs and policies are part of the reason why population growth is slowing.

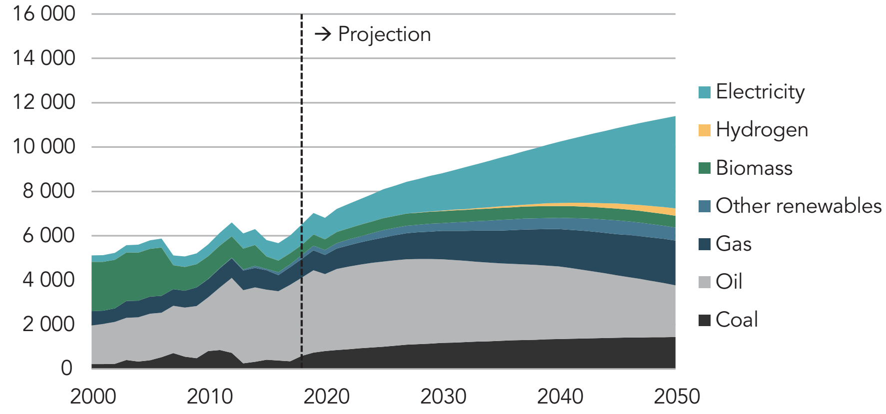
End-use energy demand

Figure 7-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 7-4. Energy demand in CN, 2000-2050 (PJ)

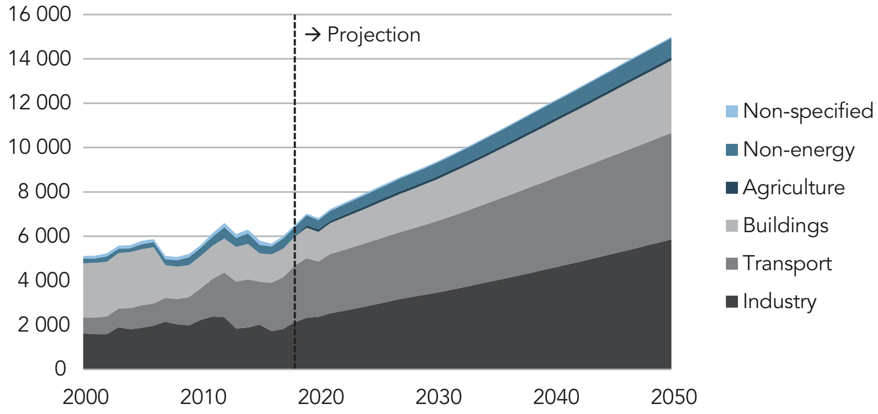


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Indonesia's end-use energy demand increased with substantial infrastructure development from 2016 to 2019. In 2020, demand fell slightly due to the COVID-19 pandemic and associated restriction in economic activity. Demand is projected to have rebounded in 2021 and will increase significantly in both scenarios out to 2050.
- In REF, energy demand increases at an average rate of 2.5% per year, doubling to 2050. In CN, the growth in energy demand is more subdued, increasing by a half by the end of the projection period. Stronger energy efficiency initiatives, more efficient equipment used in the industry and transport sectors, and electrification in all sectors contributes to the lower demand in CN.
- In REF, oil maintains the largest share of energy demand out to 2050, and there is a significant increase in coal consumption due to rapidly increasing industrial demand. Industry and buildings also contribute to a significant increase in gas demand.
- In CN, oil demand is significantly lower, which is mostly tied to electrification and fuel switching. Greater uptake of EVs and increasing biofuel blends in transport are large contributors to this fall. Coal use in CN is more than two-fifths lower than in REF in 2050, though coal still grows significantly due to strong industry growth. Natural gas consumption acts as more of a transitional fuel with consumption in CN only marginally lower than in REF by 2050. The share of natural gas in end-use consumption is almost one-fifth in CN, which is higher than in REF.
- In CN, electrification in all sectors leads to electricity demand increasing by a factor of 3.7 out to 2050. Electricity consumption is almost 80% greater than oil consumption in 2050. This is significantly changed from the REF, where electricity is 40% lower than oil consumption in 2050.
- Hydrogen is an important component of the energy transition framework and begins to be consumed from 2025 in CN. Hydrogen is projected to be used in the transport and industrial sectors. Hydrogen production cost is one of the main factors that will influence its uptake. Long-term hydrogen development policy, technical research, and hydrogen demand creation will help to spur an increase in hydrogen demand.

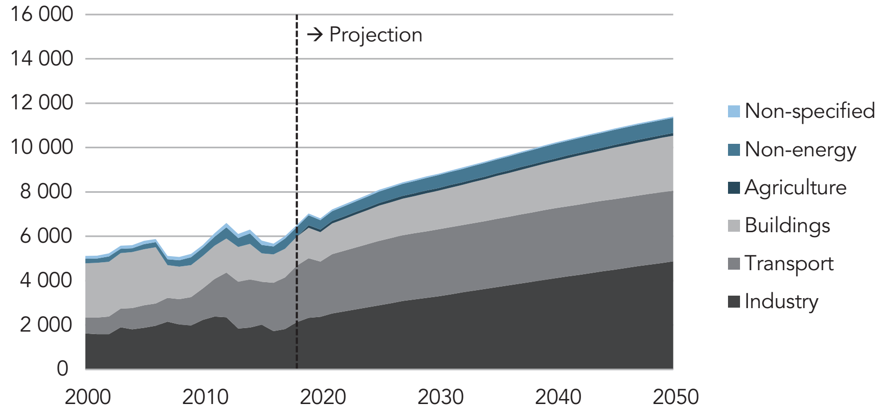
End-use energy demand by sector

Figure 7-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 7-6. Energy demand by sector in CN, 2000-2050 (PJ)

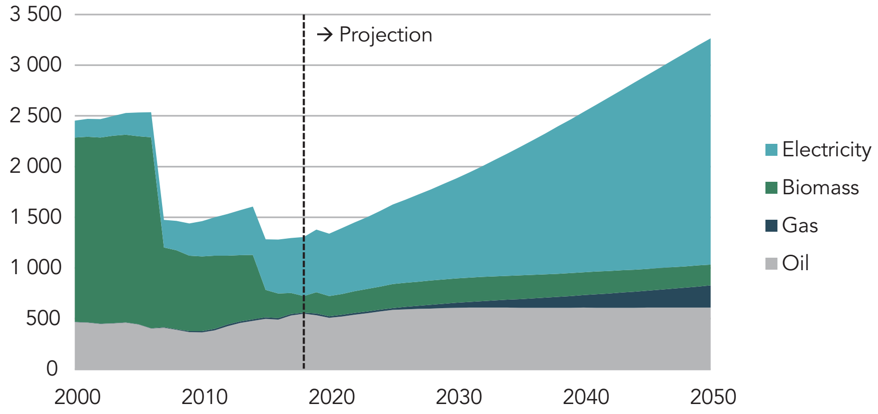


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Projections show that the sectoral distribution of end-use energy demand maintains a similar breakdown through to 2050. Industry, transport, and buildings account for more than 90% of final energy demand in both scenarios out to 2050.
- In REF, the demand and share of industry and buildings increases through the projection period. Transport energy consumption has grown by the largest amount since 2000, and while it continues to grow, fuel efficiency and a shift from private to mass transportation, means growth is not as strong as for the industry and buildings sectors. Transport's share of end-use energy consumption falls from 39% to 32% in 2050.
- In CN, energy demand in 2050 is 24% lower than in REF, with all sectors consuming less energy. Energy efficiency, fuel shifting, material efficiency and other factors contribute to this reduction. There is a large reduction in transport demand due to more aggressive efficiency programs and a widespread shift to EVs. Buildings sector demand is lower by a quarter due to greater appliance/equipment efficiency and a shift to cleaner and more efficient fuels. Energy efficiency gains and material efficiency leads to industry energy demand being 17% lower than REF in 2050.
- The industrial sector becomes the largest energy consuming sector in both scenarios. This is associated with the large projected growth in industrial output that will occur as Indonesia transitions to a developed economy.
- Non-energy sector consumption of energy commodities will increase in both scenarios. This sector consumes natural gas and refined products as a building block for final goods such as fertilisers and plastics. While growth is strong, non-energy only accounts for a 6% share of end-use energy demand by 2050.
- In CN, greater levels of energy efficiency, electrification, and a move to modern farming practices mean that agricultural energy demand is 15% lower than in REF.

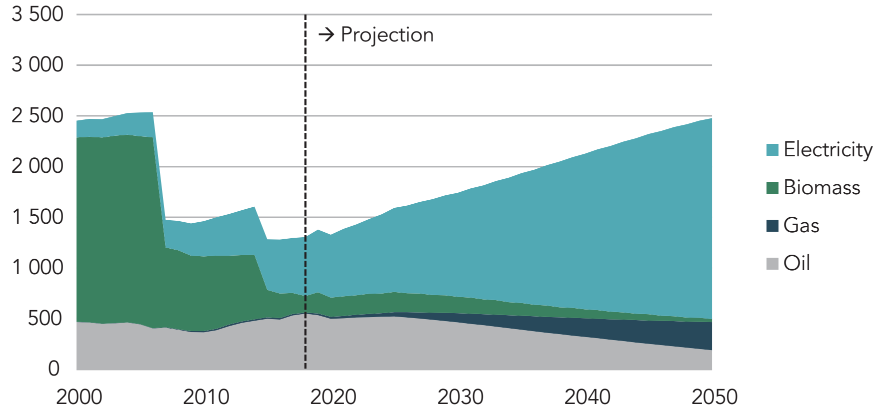
Buildings energy demand

Figure 7-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-8. Buildings energy demand in CN, 2000-2050 (PJ)

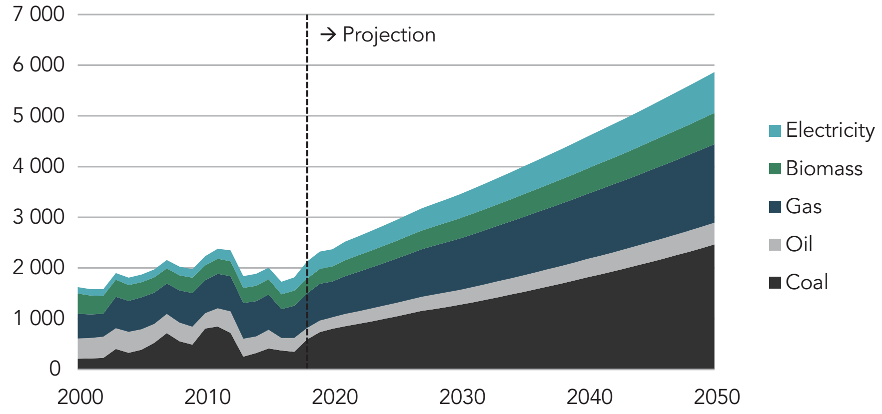


Sources: EGEDA, APERC analysis.

- Residential energy demand (primarily cooking) dominates Indonesia's buildings sector. Biomass and kerosene have traditionally fulfilled most of this need, though there has been a gradual shift from kerosene to LPG, which has been supported by official government policy promoting this switch since 2015. The high proportion of biomass prior to 2014 is due to legacy data reporting issues.
- In REF, fuel switching from biomass to gas and electricity for cooking slow the growth in biomass and oil out to 2050. The dispersion of Indonesia's population means that biomass will still be used as the main cooking energy source for many rural parts of the economy.
- In CN, a stronger fuel switching trend to gas and electricity is expected, due to more widespread coverage of the household gas network and more extensive electric stove conversions. The increasing availability of gas and electricity leads to biomass, and oil consumption falling significantly through to 2050.
- The household electrification ratio will reach 100% in 2022, improving living standards and contributing to increased electricity consumption. Buildings energy consumption more than doubles in REF with most of this increase due to an increase in electricity. In CN, enhanced efficiency programs mean that buildings energy consumption is almost one-quarter lower than in REF in 2050.
- Electricity consumption in both scenarios is driven by the greater use of lighting, air conditioners, and other electrical appliances, including electric cooking stoves, and is spurred by a significant increase in living standards. By 2050, the share of electricity in buildings energy demand is 68% in REF, though is much greater at 80% in CN.
- Gas, though small in share, increases significantly, partly due to an oil-to-gas fuel-shifting program. Increased development of the city gas networks is ongoing. These developments are assumed to be more widespread in CN, with gas replacing oil and biomass to a greater degree than in REF. In CN, gas reaches an 11% share of buildings energy demand in 2050.

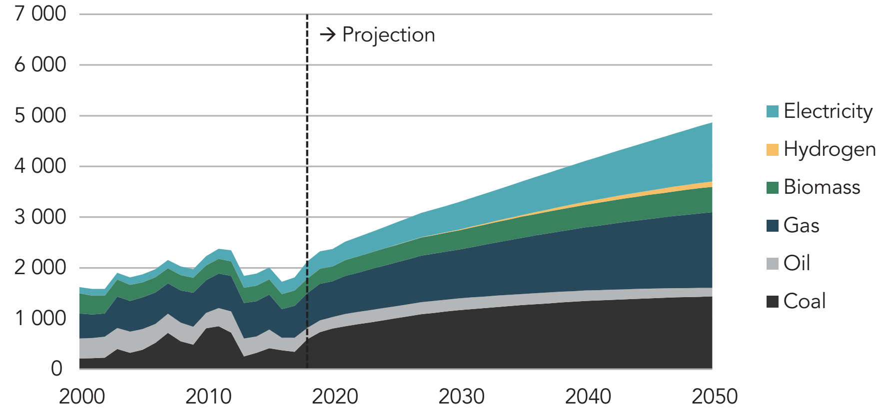
Industry energy demand

Figure 7-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 7-10. Industry energy demand in CN, 2000-2050 (PJ)



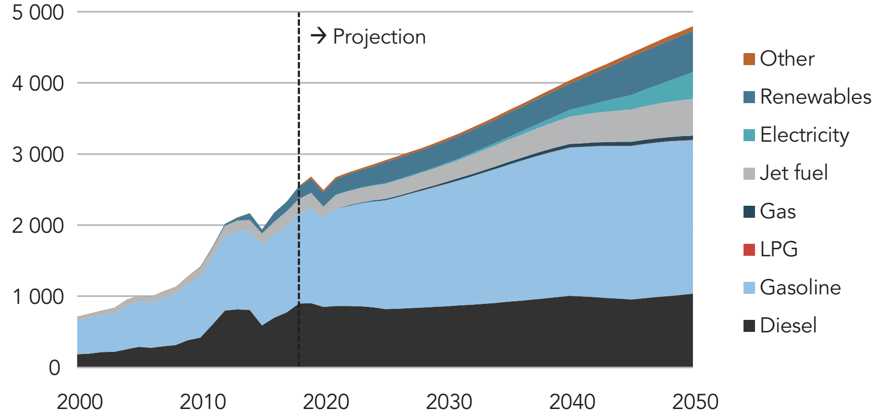
Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industrial energy demand increases significantly through the projection period in both scenarios. Industrial development is one of the top priorities in Indonesia's national development planning and explains why industrial energy demand almost triples in REF and more than doubles in CN.
- Data coverage for Indonesia's industrial subsectors is currently limited. A large proportion is classified as non-specified. By the end of the projection, heavy industry, comprising steel, non-metallic minerals, and chemicals accounts for well over half of all industry energy demand.
- In REF, industry energy demand increases by an average of 3.0% per year. Indonesia's Master Plan of National Industry Development (RIPIN) projects more than eight percent of industrial output growth from 2020 to 2035. Energy demand and economic output are not directly comparable. However, the projections of this *Outlook* are likely less optimistic than RIPIN's projections.
- The most prominent fuels used by industry are gas and coal. By 2050, their combined share reaches more than two-thirds in REF and three-fifths in CN. Coal quickly surpasses gas as the most prominent fuel due largely to a rapid growth in cement production.
- In CN, greater energy efficiency, electrification, material efficiency in heavy industry, and additional changes such as a lower clinker-to-cement ratio, leads to 17% lower energy consumption than in REF by 2050.
- Greater electrification in CN will see industry electricity consumption increase at an average annual rate of 4.0% through the projection period. Almost one-quarter of industry energy demand is met by electricity in 2050.
- In CN, switching from coal to gas, hydrogen and/or biomass, means that coal consumption is more than two-fifths lower than in REF. Material efficiency also contributes to lower coal use. Hydrogen is incorporated in the steel and chemicals subsectors, such as in direct reduction of iron processes. However, its 2% share of industry energy consumption remains relatively low. Its use may become more prominent, depending on how hydrogen use applications diffuse through industry.
- In CN, heavy industry begins to incorporate CCS for certain fossil fuel reliant processes in a subset of heavy industry facilities from 2030.

Note: Modelled hydrogen use by the steel sector incorporates transformation and end-use applications.

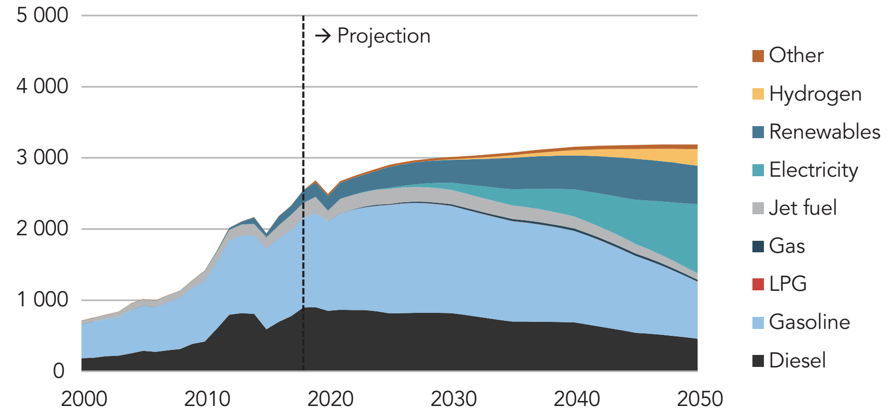
Transport energy demand

Figure 7-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 7-12. Transport energy demand in CN, 2000-2050 (PJ)

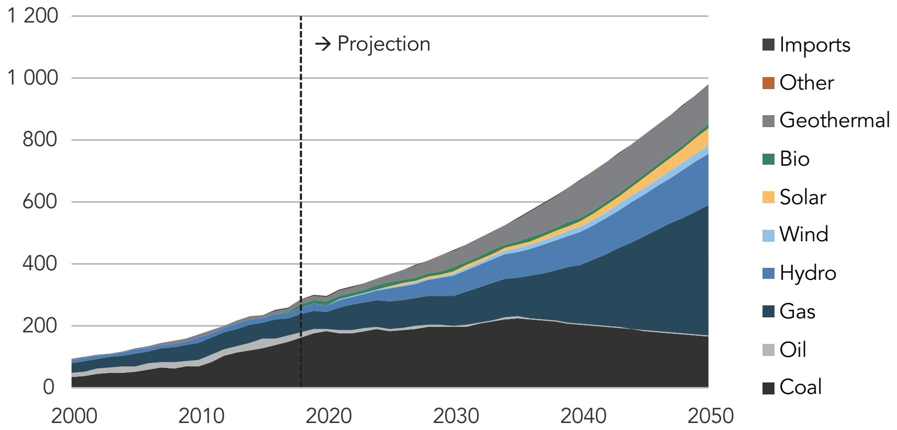


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Passenger and commercial transport demand increases strongly through the projection period. Transport demand growth is driven by increasing population density in city centres and the surrounding urban areas. Government initiatives to improve island connectivity, such as through the Sea Highways Program which supports marine transportation, will lead to even greater transportation demand.
- The primary energy sources for transport are oil fuels (diesel, gasoline, and jet fuel), electricity, and biofuels. Biofuels made from crude palm oil (CPO) blended with petroleum diesel have been prominent for the past ten years, with use instituted by the government. The biofuel blending ratio has been gradually increasing and is now at 30% (B30). In REF, the gradual uptake of EVs, including electric motorcycles, is in line with current policy to encourage electrification in the transport sector.
- Implementation of a mandatory biofuels program, B30 by 2025, has increased the share of renewables in the transport energy mix. A blend of 40% (REF) and 50% (CN) by 2045 will lead to additional increases. Reactivating oil-to-gas fuel-switching programs for inland transportation and marine is part of an initiative to promote cleaner fuels and reduce oil import dependency.
- In CN, electrification, higher biofuels penetration, and hydrogen utilisation will contribute to transport decarbonisation. Improved fuel efficiency of combustion engines for road and aviation transport will also help to reduce fuel consumption in CN, resulting in 34% less energy demand than REF in 2050.
- In CN, the more rapid uptake of EVs, including motorcycles and light-duty EVs, with sales of more than 90% in 2050, increases electricity demand and leads to a significant fall in refined products demand. Transport electricity consumption is 2.6 times higher than REF in 2050. Hydrogen fuel cell vehicles for heavy trucking reach 20% of sales in 2050 and contribute to additional decarbonisation.

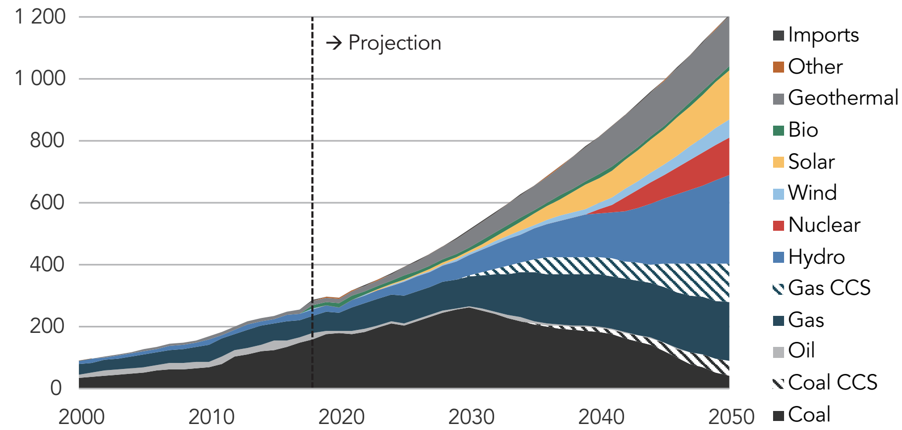
Electricity generation

Figure 7-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 7-14. Electricity generation in CN, 2000-2050 (TWh)

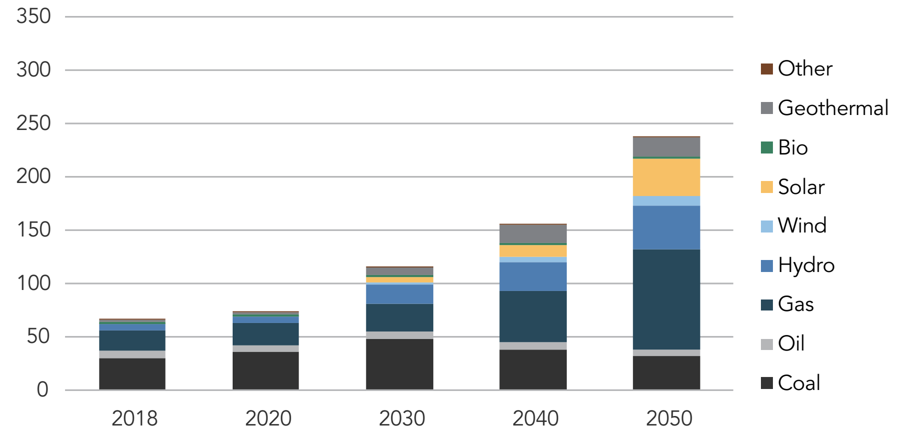


Sources: EGEDA, APERC analysis.

- Electricity generation more than triples in REF and more than quadruples in CN due to increasing electricity demand throughout all sectors of the economy. EVs are particularly influential in CN, with transport electricity demand increasing from less than one TWh in 2019 to more than 270 TWh in 2050. Electricity generation increases by an annual average of 3.9% in REF and 4.6% in CN through to 2050.
- Coal-fired power remains influential in both scenarios. In REF, coal generation increases to the mid-2030s before slowly declining, due partly to a moratorium policy on new coal power generation. The decline in coal is increasingly supplanted by natural gas and hydro. In CN, additional efforts to accelerate the closure of coal-fired power plants means that coal generation begins to decline from 2030.
- In both scenarios, natural gas generation will surpass coal generation, which is emblematic of the energy transition. In REF, gas increases more than seven-fold and accounts for 43% of the generation mix in 2050. In CN, gas plays more of an ancillary role to support fast-growing non-dispatchable generation from solar and wind.
- Increased decarbonisation efforts in CN lead to the incorporation of gas and coal-fired power plants with CCS technologies from 2030. The use of CCS in gas and coal generation will result in more than 40% of electricity generation from fossil fuels being subject to carbon capture technologies. These assumptions mean that coal can be compatible with carbon neutrality ambitions.
- In both scenarios, renewables achieve the national renewable generation target of 23% in 2025, as stated in the National Energy Policy. By 2050, renewable generation accounts for a 40% share in REF and a 56% share in CN. Solar grows most rapidly, followed by wind. Hydro power increases almost eight-fold in REF and over 13-fold in CN to contribute to baseload power needs. The growth in geothermal is also significant, increasing 11-fold in CN.
- In CN, nuclear power plants will begin to be deployed from 2040 to help provide zero-emission baseload power supply.

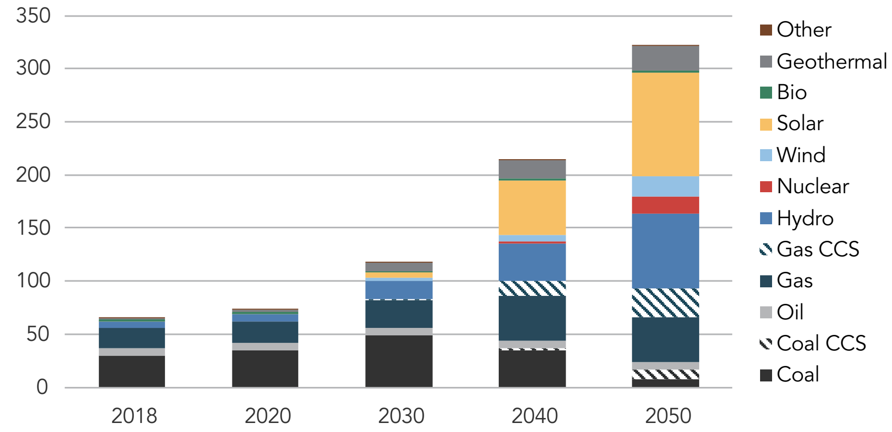
Generation capacity

Figure 7-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 7-16. Generation capacity in CN, 2018-2050 (GW)

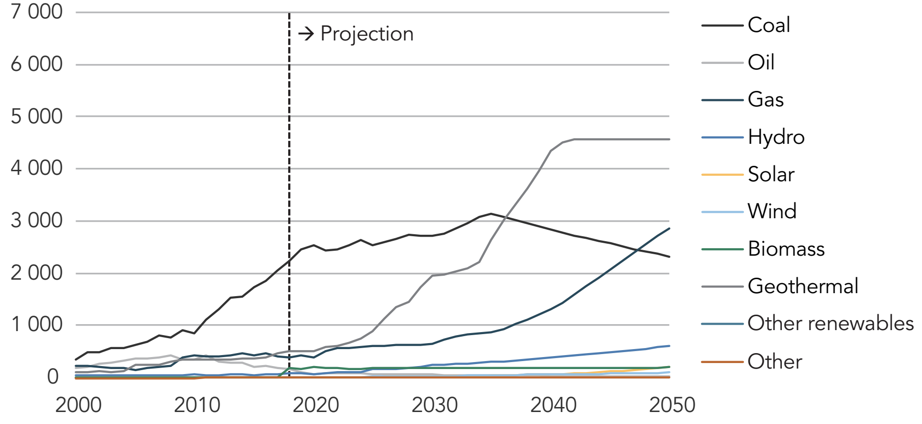


Sources: EGEDA, APERC analysis.

- Indonesia's generation fleet is currently dominated by coal, followed by gas, and then renewables, which is mostly hydro and geothermal.
- In both scenarios, coal capacity falls significantly. By 2050, capacity mostly transitions to gas in REF and to renewables, particularly solar and hydro, in CN. The power sector decarbonises significantly in CN through massive renewable deployment, earlier retirement of coal-fired power plants, and deployment of CCS technologies for both gas and coal-fired power plants.
- In REF, renewable capacity increases 10-fold, to more than 95 GW of additional capacity by 2050. In CN, the increase in renewables is more than double what occurs in REF, with an additional 200 GW, mostly from solar, hydro, geothermal, and wind. The declining cost of renewables, especially solar, availability of green funding, and assumed robust policies to achieve net-zero emissions will contribute to the significant increases in renewable capacity in CN.
- Non-dispatchable solar dominates Indonesia's generation capacity in CN. Gas-fired power plants and hydro with fast response times are required to meet the dispatch challenge associated with high levels of variable generation. Improved grid interconnection, energy storage, and demand-side management will also be important for improving power system flexibility while enhancing reliability.
- In CN, nuclear is deployed to provide stable baseload power while minimising emissions. Nuclear capacity will increase from 2 GW in 2040 to 16 GW in 2050. Available technologies such as pressurised water reactors (PWR) for large nuclear power plants and small modular reactors (SMR) will also play a role, depending on the varying energy needs of different regions throughout Indonesia.

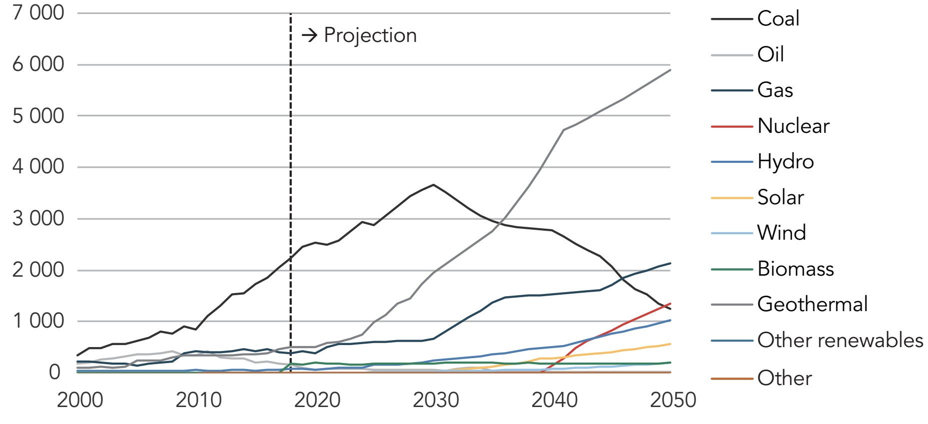
Fuel consumption by power sector

Figure 7-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 7-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

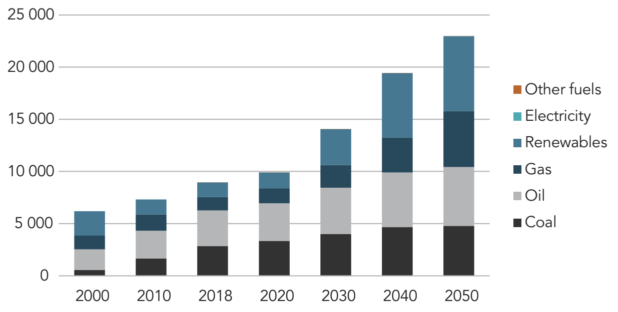


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- Coal remains the most prominent fuel consumed by the power sector in both scenarios through to the 2030s. In REF, coal consumption begins to decline in 2035, whereas the decline begins five years earlier in CN.
- Gas consumption increases six-fold in REF and four-fold in CN out to 2050. Indonesia's fuel diversification program, availability of low-cost gas supply, and increasing concern for cleaner power generation drive the increase in gas-fired power.
- The increase in natural gas consumption is also due to its crucial role in providing flexible generation, which is needed to enable the large increase in variable renewable generation. The ancillary role of natural gas capacity is mostly via open cycle gas 'peaking' plants.
- The consumption attributable to renewables increases more than seven-fold in REF, and more than 10-fold in CN.
- Geothermal energy consumption is the most prominent of all fuel types out to 2050 in both scenarios. However, low levels of efficiency mean that its share of generation remains lower than most other generation sources. Geothermal peaks in 2040 in REF, though continues to increase out to 2050 in CN.
- Hydro, nuclear, and geothermal play an important role in providing low-emissions baseload power (nuclear is only deployed in CN). The rise in these technologies is what leads to the significant decline in coal. There is also a diminished role for baseload gas generation due to the rise of these technologies.
- Power sector oil consumption is low and falls rapidly due to the switch to gas and renewables in both scenarios.

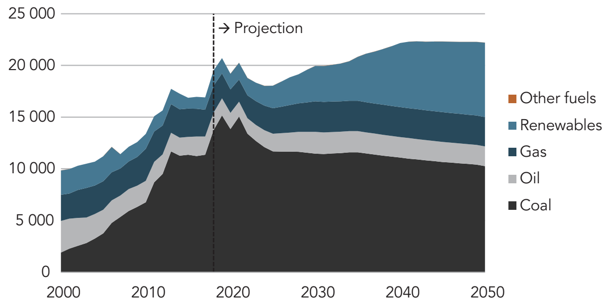
Energy supply in the Reference scenario

Figure 7-19. Total energy supply in REF, 2000-2050 (PJ)



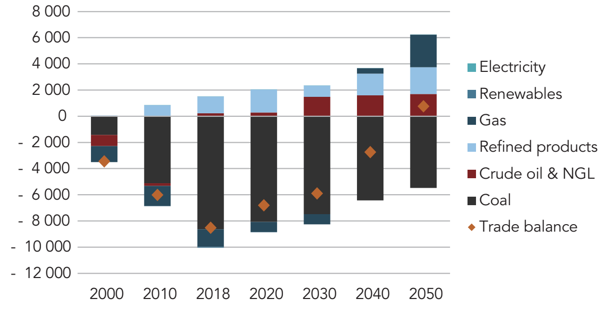
Sources: EGEDA, APERC analysis.

Figure 7-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-21. Net energy trade in REF, 2000-2050 (PJ)

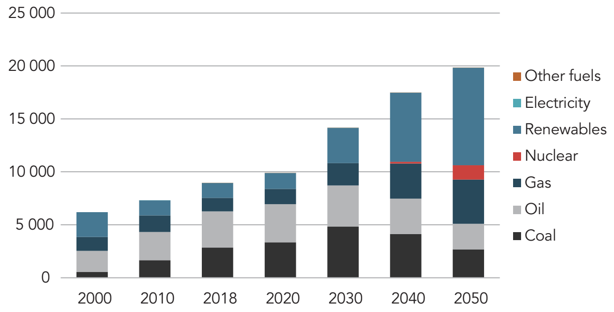


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Total energy supply increases by a factor of 2.6 in REF. The largest growth is from renewables (five-fold increase) and gas (four-fold increase).
- The increase in gas supply contributes to fossils fuels more than doubling out to 2050. Coal and oil increase by two-thirds. The increase in gas supply is tied mostly to the power and industrial sectors. While oil increases, its share of Indonesia's energy supply falls from 40% to 25% out to 2050.
- Renewable energy sources account for more than 30% of Indonesia's energy supply in 2050. These projections are consistent with Indonesia's national planning renewable energy target.
- Indonesia is one of the largest thermal coal producers in the world, having increased production by a factor of eight since 2000. Coal currently accounts for more than three-quarters of Indonesia's energy production, and almost two-thirds is shipped to international markets. Declining domestic and international demand for thermal coal will lead to coal production declining gradually out to 2050. Export markets will account for a declining share of Indonesia's coal production out to 2050.
- Renewable energy production increases almost five-fold out to 2050. The increase is mostly attributable to geothermal, hydro, solar, and wind.
- Oil and gas production increase slightly by optimising existing resources and operating several new oil and gas projects such as the Abadi LNG Project.
- Indonesia currently imports more crude oil and refined products than it exports. Indonesia's oil (and products) import dependency is projected to increase and corresponds to increasing transport energy demand and increased domestic refinery output. Indonesia is projected to rely on gas imports to meet its rapid growth in gas demand out to 2050. The decline in coal exports and growth in imports of all other energy products will mean that Indonesia transitions to a net energy importer by the late 2040s. This transition has implications for Indonesia's energy security.

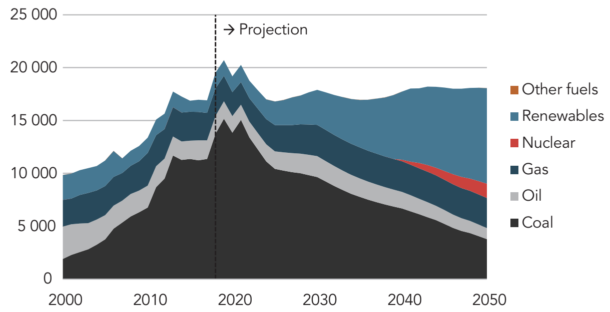
Energy supply in the Carbon Neutrality scenario

Figure 7-22. Total energy supply in CN, 2000-2050 (PJ)



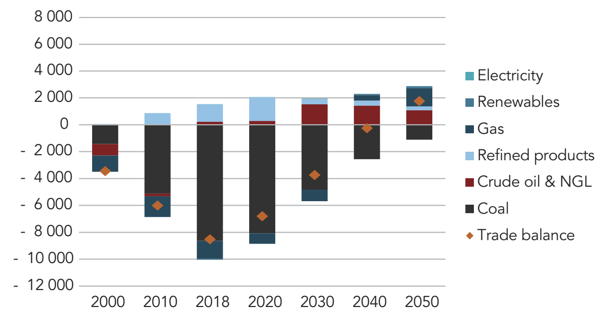
Sources: EGEDA, APERC analysis.

Figure 7-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-24. Net energy trade in CN, 2000-2050 (PJ)

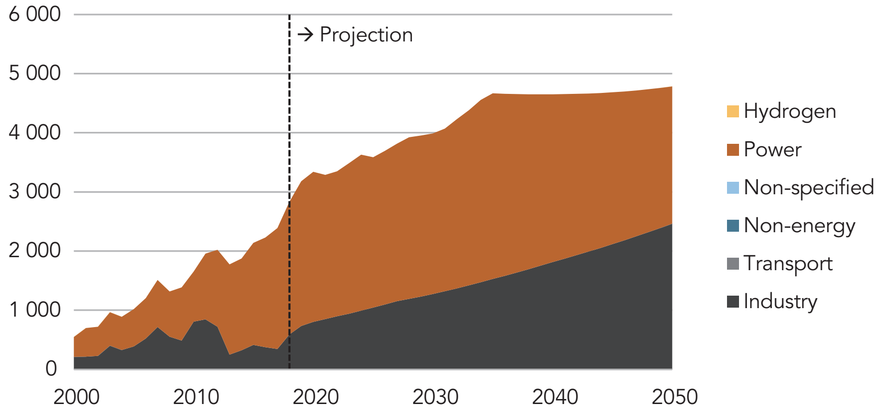


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, energy supply growth is lower than in REF, increasing by a factor of 2.2 out to 2050. The share of fossils fuels in Indonesia's energy supply falls to 47% in 2050, which is much lower than the 69% share in REF, and 84% share in 2018.
- Coal supply peaks in 2030 and is slightly lower than 2018 levels by the end of the projection.
- Renewables supply increases by more than 6.5 times in CN, due to an even greater level of renewable initiatives. By 2050, renewable energy sources account for more than 46% of Indonesia's energy supply.
- Nuclear begins to be deployed in 2040 and grows to account for 7% of Indonesia's energy supply by 2050. The combination of renewables and nuclear means that more than half of Indonesia's energy supply is zero emissions by 2050.
- An even greater reduction in domestic and international demand for coal leads to coal production falling by more than 70% out to 2050.
- Renewable production increases more than six-fold out to 2050, with the significant increase in solar and wind contributing to most of the increase above which occurs in REF.
- Net imports of crude oil and refined products persist in CN. However, lower refined product demand from transport out to 2050, means that oil (including refined products) import dependence is lower than in REF. Lower gas demand from the power sector in CN requires less gas imports than in REF.
- Far lower coal exports means that Indonesia transitions from a net energy exporter to a net energy importer in the early 2040s. However, Indonesia's oil (including refined products) and gas net import requirements are much lower than in REF.

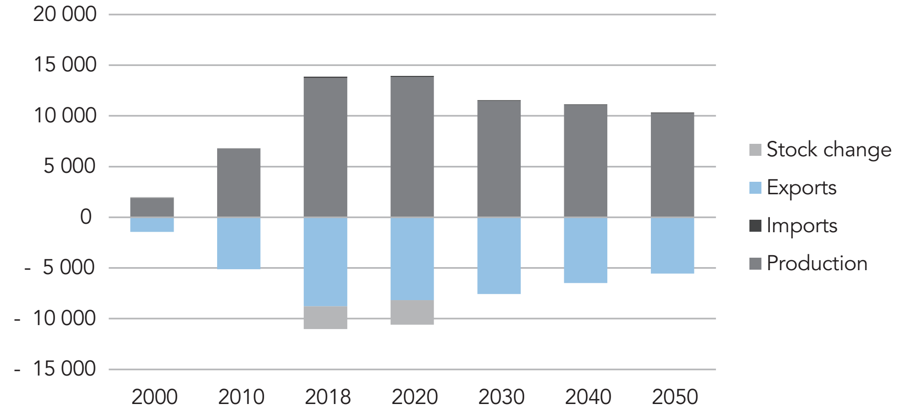
Coal in the Reference scenario

Figure 7-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

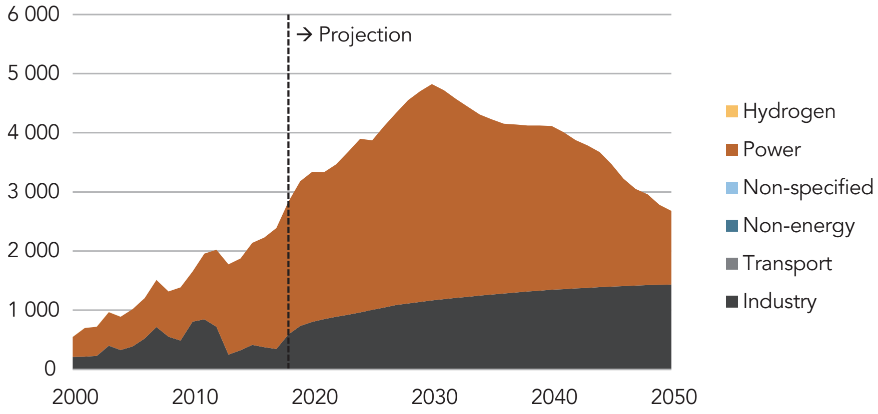


Sources: EGEDA, APERC analysis.

- Coal-fired power plants account for 80% of current coal consumption in Indonesia. By 2050, Indonesia's coal consumption is equally split between the power and industry sectors.
- Coal consumption in the power sector peaks in 2035. This projection is consistent with the moratorium on new coal-fired developments that is currently in place. Coal-fired power decreases gradually following the peak, partially as a result of phasing out programs and older plants beginning to be retired.
- Coal consumption in the industrial sector increases more than four-fold out to 2050. Industrial activity increases with the development of new industrial areas, the development of mineral smelters, and a large increase in output from the cement industry.
- Coal mining in Indonesia is located mainly in Sumatera and Kalimantan (Borneo) islands, with the production supplying domestic and international markets. In 2019, three-quarters of Indonesia's coal production was exported to predominantly China and India.
- Indonesia's coal production falls by a quarter out to 2050, while exports fall by more than a third. Domestic demand provides more support than international markets for Indonesia's coal production. The share of coal exports to coal production declines from just under two-thirds to 54% in 2050.
- Much of the domestic support for coal is tied to the strong growth in industrial demand for coal, rather than demand from the power sector.

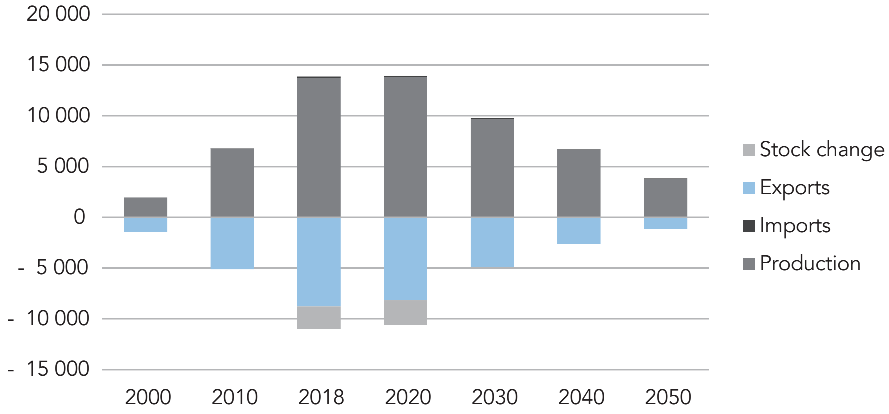
Coal in the Carbon Neutrality scenario

Figure 7-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

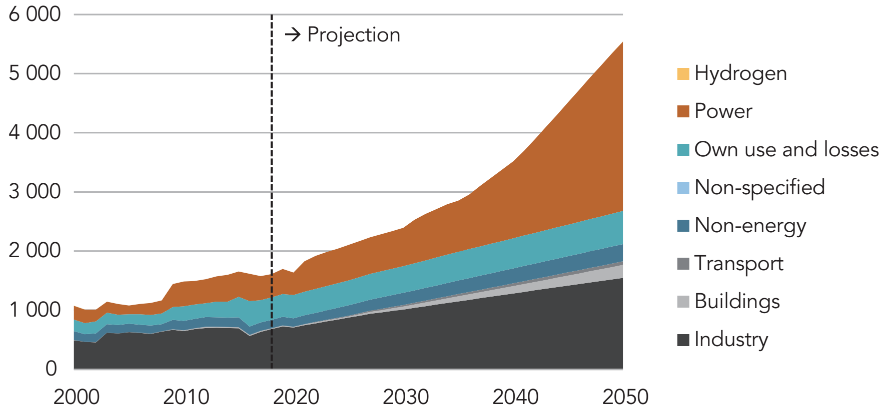


Sources: EGEDA, APERC analysis.

- By 2050, coal consumption is 44% lower in CN than in REF. Coal-fired power plant consumption peaks in 2030 and is then two-thirds lower than the peak by 2050. Energy intensity improvements, material efficiency, and increased fuel switching to alternative fuels mean that industrial sector consumption of coal is more than two-fifths lower than in REF.
- The decline in coal consumption by the power sector occurs earlier and at a more rapid rate than in REF. Accelerated phase-out of coal-fired power plants and an increase in renewables penetration contributes to this more rapid decline.
- The decline in coal-fired generation is slowed by the adoption of CCS technologies. Coal-fired generation with CCS is gradually incorporated from 2035, and by 2050, 54% of coal fired generation is provided by coal-fired power plants that incorporate CCS technologies. The average capture rate is 80%.
- In CN, coal production declines more than in REF due to the declining domestic demand and a diminishing market for exports driven by global decarbonisation initiatives.
- Indonesia's domestic consumption of coal account for a larger proportion of production out to 2050. The share of coal exports to coal production declines from just under two-thirds in 2018 to only 30% by 2050. The continued need for coal by a rapidly expanding industry sector combined with demand from coal-fired power plants with CCS technologies, supports Indonesia's domestic coal production.

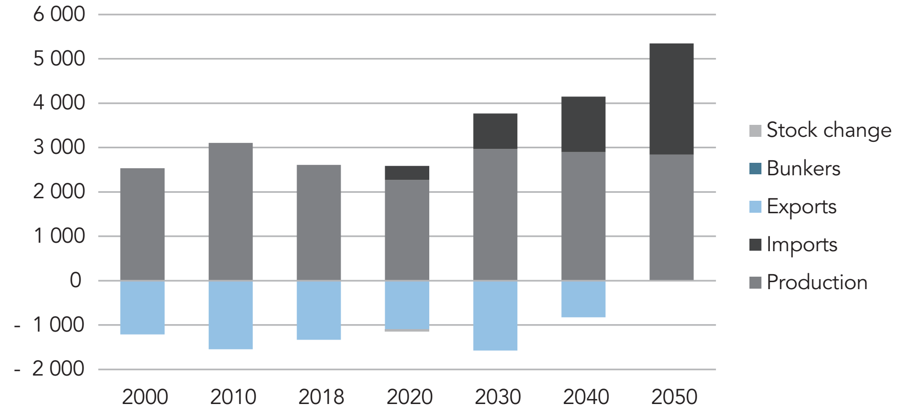
Natural gas in the Reference scenario

Figure 7-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

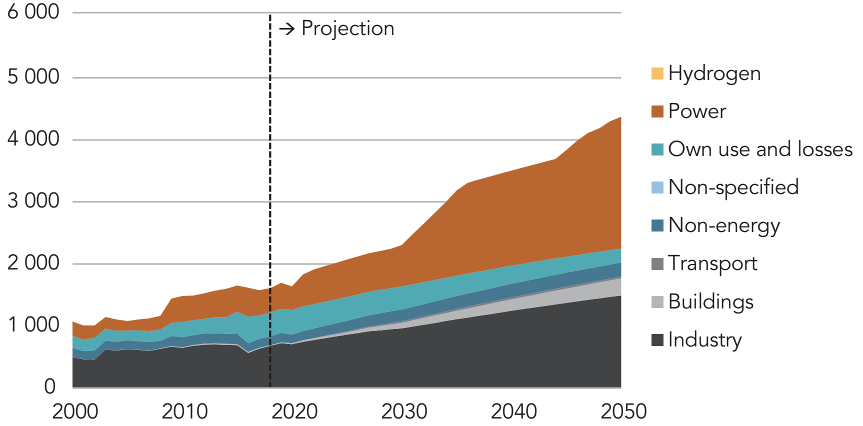


Sources: EGEDA, APERC analysis.

- In REF, gas consumption is driven by rapidly expanding demand for gas by the power sector, especially towards the end of the projection period. Industry sector demand is also influential in increasing demand, with projected gas consumption increasing by a factor of 3.4 out to 2050.
- Demand for gas declined in 2020 due to activity restrictions and an economic slowdown that was brought on by the COVID-19 pandemic. The largest portion of the decline in gas consumption was attributable to the power sector.
- The power sector surpasses industry as the highest gas consuming sector in 2040. By the end of the projection period, the power sector accounts for more than half of Indonesia's gas consumption (52%). The industry sector accounts for just over a quarter (28%). Increasing gas consumption by all sectors aligns with efforts for Indonesia to shift to less emissions intensive fuels.
- Indonesia's is currently prioritising energy resources for domestic purposes via explicit policies. Gas exports are initially expected to increase to 2030. However, rapidly increasing domestic demand will see natural gas exports fall to close to zero by 2050.
- Prioritising natural gas for domestic uses is having short-term impacts. For example, pipeline gas exports to Singapore are anticipated to fall to zero in 2023.
- Several notable LNG projects such as Tangguh T3 and Abadi are expected to reverse the current declining trend of natural gas production. Indonesia will remain a net exporter of natural gas until the 2030s. From 2040, Indonesia will transition to net importer of natural gas due to surging demand.
- By 2050, more than 30% of gas demand will rely on import supply. The large levels of gas consumption by the power sector towards the end of the projection period presents a challenge for Indonesia's energy security.

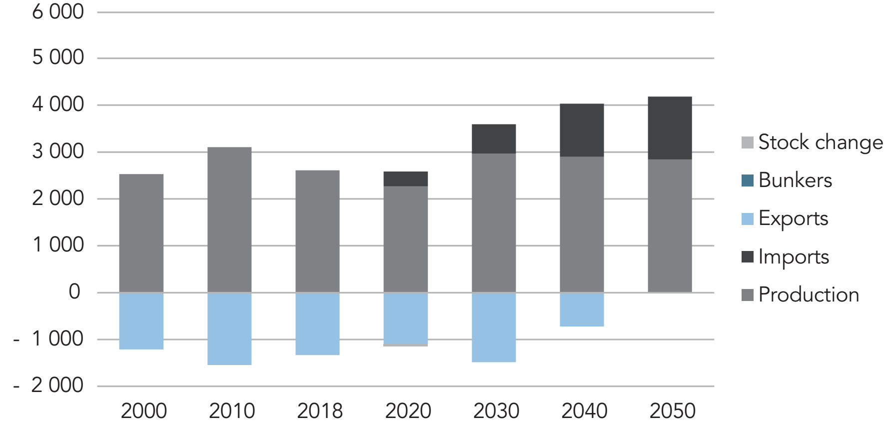
Natural gas in the Carbon Neutrality scenario

Figure 7-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

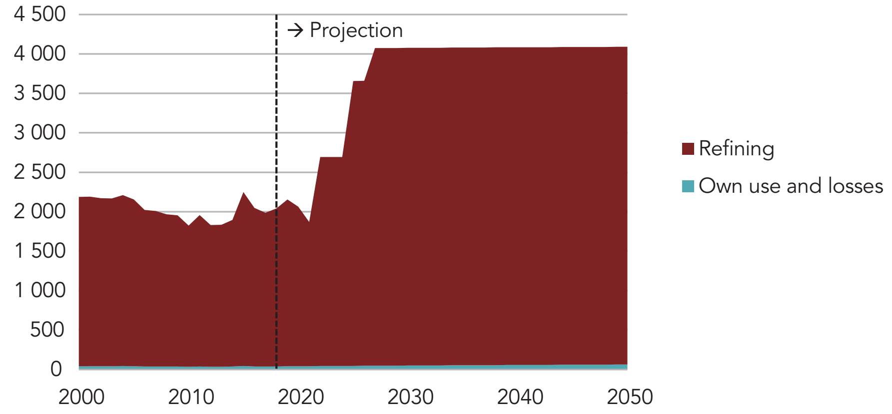


Sources: EGEDA, APERC analysis.

- In CN, natural gas consumption increases by a factor of 2.7, though is one-fifth lower than REF in 2050.
- Industry sector consumption of natural gas is only slightly lower than in REF. Energy efficiency and material efficiency gains that lead to less natural gas are partially offset by increased consumption of natural gas in place of coal in certain industrial processes.
- Natural gas consumption by the power sector is significantly lower than in REF due to a larger role for renewables and nuclear supplanting gas generation needs. However, the flexible characteristic of gas generation remains crucial for power system reliability. The 'peaking' role for natural gas is even more important in CN due to the much higher growth in non-dispatchable renewables such as solar and wind.
- The power sector surpasses industry as the largest gas consuming sector in the early 2030s. By 2050, the power sector accounts for half of Indonesia's natural gas consumption. Industry accounts for just over a third of natural gas consumption in 2050.
- Gas consumption increases markedly in the buildings sector out to 2050, as Indonesia moves away from traditional biomass. The move away from traditional biomass is facilitated by an increase in household gas network coverage.
- In contrast to buildings, an increased role for EVs leads to lower natural gas consumption by the transport sector in CN.
- In CN, the trends in natural gas supply track closely with the trends in REF. The main difference is that imports are lower, owing to the lower domestic demand. Indonesia transitions to a net gas importer in the mid-2030s, with domestic production still insufficient to satisfy domestic demand.

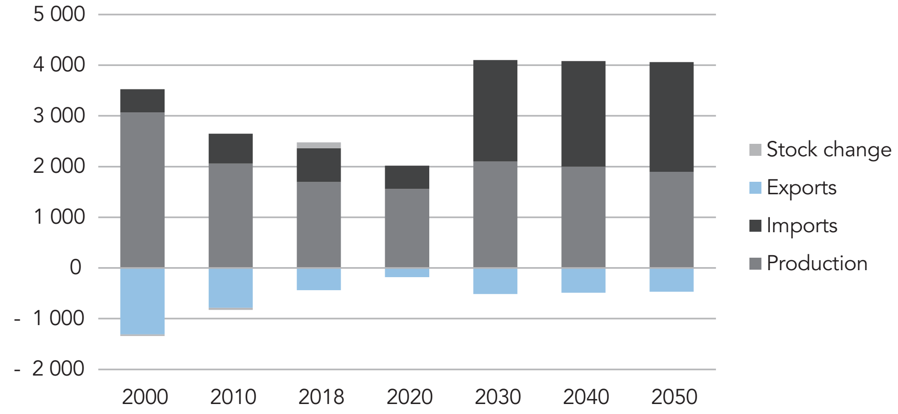
Crude oil and NGLs in the Reference scenario

Figure 7-33. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-34. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

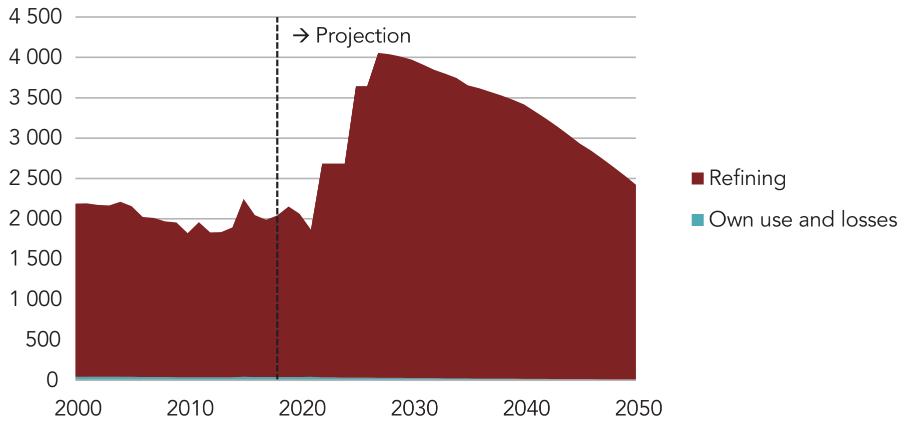


Sources: EGEDA, APERC analysis.

- Indonesia's total crude oil and NGL consumption reaches just over 4 000 PJ in 2027 and remains relatively constant through to 2050. Almost all consumption is by Indonesia's domestic refineries.
- Indonesia is expanding the refinery capacity of existing refineries and developing new projects, such as in Tuban and Bontang. The new projects and capacity additions are expected to increase capacity to around 1.4 million barrels per day.
- Indonesia's crude oil and NGL production will increase in the first decade of the projection, reaching a peak in 2030, before declining out to 2050. Production in 2050 will be 10% lower than the peak.
- Crude oil and NGL exports increase at a similar rate to production to 2030, before declining marginally out to 2050. Most of Indonesia's crude oil and NGL exports are the portion of production that is not suitable for domestic refineries, based on technical characteristics.
- Indonesia's crude oil imports increase more than five-fold from 2019 to 2027 in order to supply the much larger domestic refinery capacity. Refined product imports will decline during this period to make way for the additional domestic refinery output.
- Crude oil imports account for more than half of Indonesia's refinery consumption from 2035 through to 2050. Indonesia's domestic refinery capacity is assumed to reach a new high level in 2027. The slight increase in crude oil imports from 2027 to 2050 corresponds to declining domestic crude oil and NGL production.

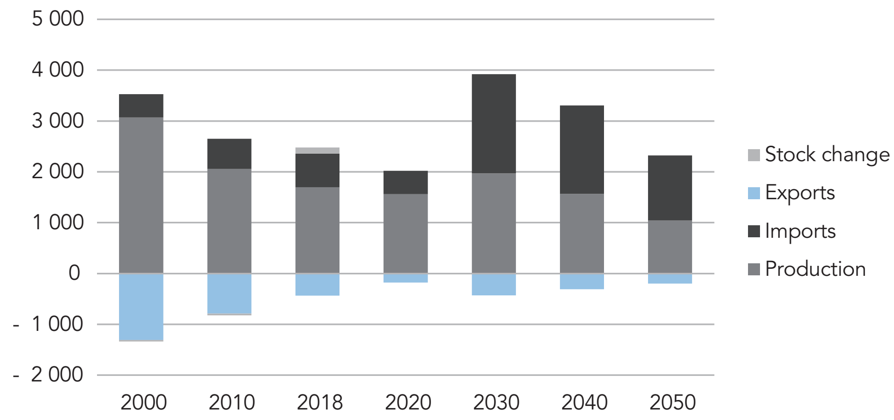
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 7-35. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-36. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

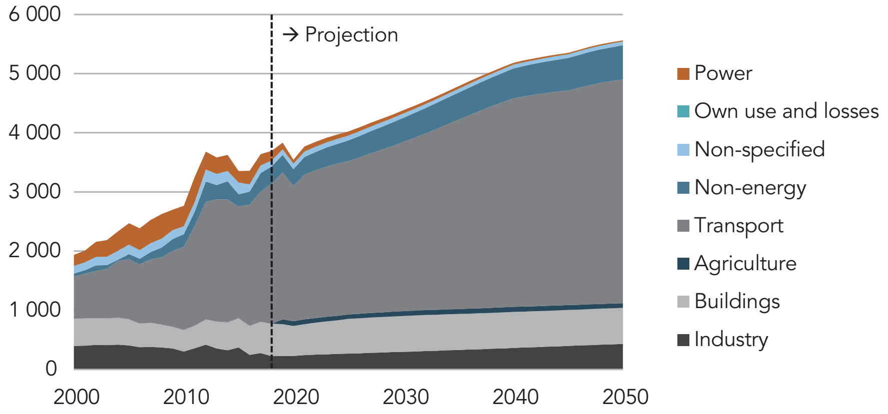


Sources: EGEDA, APERC analysis.

- In CN, oil consumption by Indonesia's domestic refineries is largely the same as in REF for the initial years of the projection. From 2027, refinery consumption declines with the declining demand for refined products from all sectors. Higher uptake of EVs and improved fuel efficiency in the transport sector is most influential in bringing about lower refined product consumption out to 2050.
- From 2027, crude oil and NGL consumption declines by 40% out to 2050, though this level of consumption remains higher than before the planned refinery capacity additions. Plans to increase refinery capacity are justifiable in this context.
- Indonesia's crude oil and NGL production increases to 2030, following the same pattern as in REF. Following this initial increase to 2030, production gradually declines through to 2050. Crude oil and NGL production in CN is half of the production levels in REF in 2050.
- Exports of crude oil and NGLs decline by even more than production out to 2050, falling to a level that is only two-fifths of the level in REF. The additional fall in exports is due to the rapid move away from refined products in many international markets. Another contributing factor to the fall in Indonesia's exports is that lowest cost sources of supply, such as from the Middle East, begin to take a larger and larger share of the international market for crude oil and NGLs.
- Indonesia's crude oil and NGL imports also decline significantly. The fall in imports aligns with the fall in domestic refinery consumption. In CN, crude oil and NGL imports in 2050 are 40% lower than in REF.

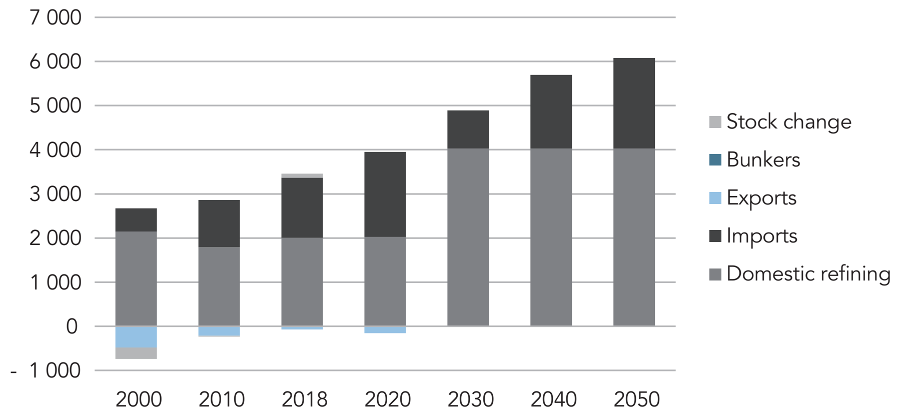
Refined products in the Reference scenario

Figure 7-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

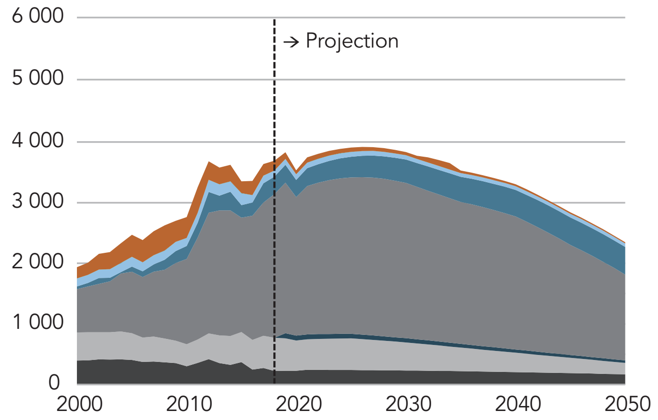


Sources: EGEDA, APERC analysis.

- In REF, refined products consumption grows with increasing activity and economic output. Most of the growth is tied to the transport sector. The COVID-19 pandemic led to a notable fall in consumption in 2020. Refined products consumption moves higher than the pre-pandemic level in 2022.
- The transport sector accounts for 64% of Indonesia's refined products consumption in 2018, with this increasing to 68% by the end of the projection. The buildings sector is the next most prominent consumer of refined products, with a significant portion of current consumption being kerosene for residential cooking. The growth in kerosene for cooking is limited due to phase-out initiatives that aim to replace it with more efficient fuels and electrification.
- Non-energy sector consumption of refined products doubles out to 2050 due to a significant increase in Indonesia's petrochemical enterprises. Industry sector consumption of refined products grows at a slightly slower rate. Diesel for mining accounts for a large share of this consumption.
- Indonesia's dependency on imported refined products has increased rapidly in recent decades. Refined products supply is currently close to an equal split between domestic refineries and imports.
- Domestic refineries begin to play a larger role in supplying Indonesia with refined products due to the significant increase in domestic refining capacity occurring through to 2027. By 2030, more than 80% of Indonesia's supply is from domestic refineries. This share falls out to 2050 due to increasing demand and no new planned capacity additions after the 2020s.

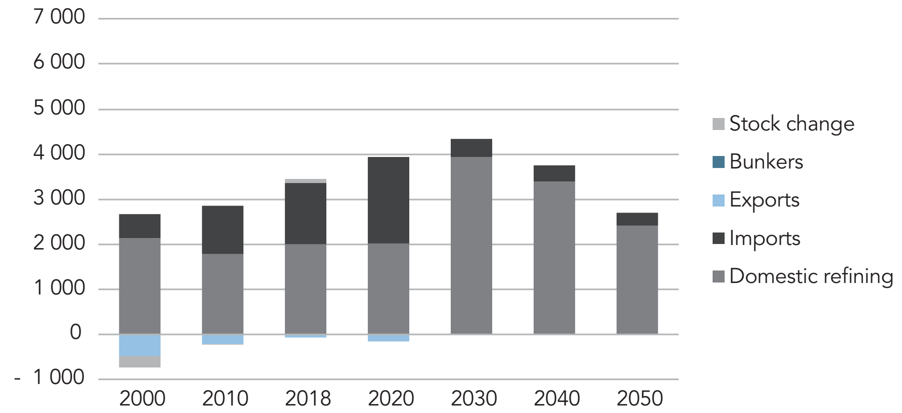
Refined products in the Carbon Neutrality scenario

Figure 7-39. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 7-40. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

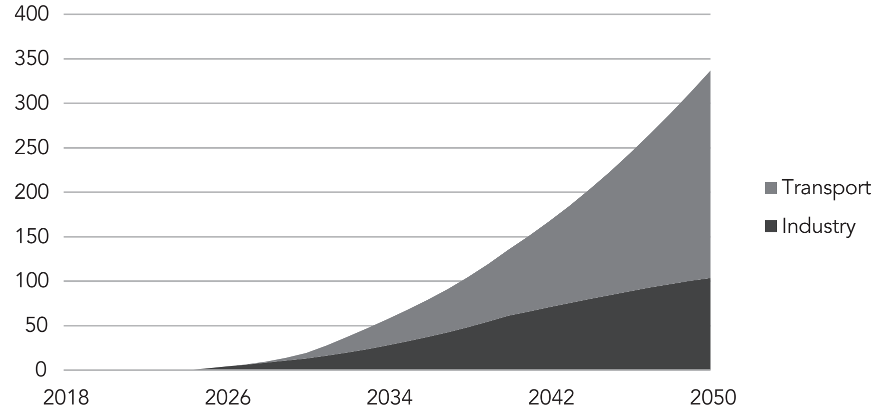


Sources: EGEDA, APERC analysis.

- Both scenarios show a post-COVID-19 rebound pattern for the short-term. However, lower demand for refined products from almost all sectors begins to compound and means that consumption peaks in the mid- to late 2020s.
- Refined products consumption is almost 40% lower than in 2019, and is almost 60% lower than REF, at the end of the projection. The large fall in refined products by the transport sector is largely due to massive levels of electrification. Increased fuel efficiency and the more widespread adoption of mass public transportation is also influential in reducing demand for refined products.
- Consumption of refined products by the buildings sector falls by almost two-thirds out to 2050. The fall is due to fuel-switching to gas and electricity, that is supported by Indonesian government initiatives. Industry and agriculture consumption falls as well, but by a smaller amount than for transport and buildings.
- The non-energy sector is the only sector with increasing consumption of refined products out to 2050. This is due to the assumed significant growth in petrochemical enterprises.
- In CN, the increase in domestic refining capacity is the same as in REF. Declining domestic demand for refined products will mean domestic refineries are able to meet a larger share of supply out to 2050 (in place of imports). However, domestic refining output will still fall in response to the large fall in demand.
- Fewer imports of refined products in CN is advantageous for Indonesia, as it improves energy-security, in line with national energy policy.
- While Indonesia becomes more self-sufficient in supplying refined products, imports persists as its refinery fleet is not configured to produce the entire suite of its demand requirements.

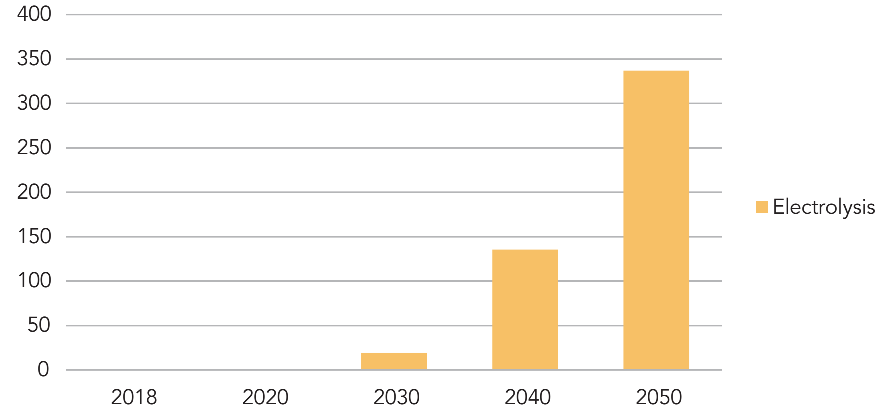
Hydrogen in the Carbon Neutrality scenario

Figure 7-41. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 7-42. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

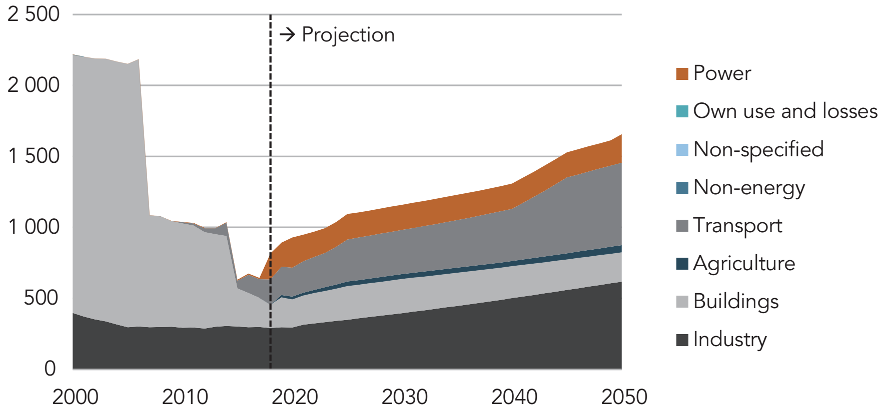


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- Hydrogen is currently produced by refineries for use as a feedstock in hydrocracking and hydroprocessing of oil and refinery products in both the refining and upgrading process. However, this *Outlook* only models the production and consumption of hydrogen as an energy carrier in the end-use sectors.
- Hydrogen does not yet exist in end-use commercial operations in Indonesia. Outside technological considerations, the economic viability of hydrogen is one of the principal roadblocks to its adoption. Hydrogen is assumed to only be developed in CN due to the challenges of adoption.
- In CN, the industry and transport sectors begin to use hydrogen from the mid-2020s. The consumption from these two sectors will increase to reach more than 300 PJ by 2050. The future for hydrogen is still very uncertain. Government policy, technical research, and hydrogen demand creation will support the level of hydrogen use, as shown in CN.
- In industry, hydrogen is used by the chemical and steel subsectors, enabling a switch away from fossil fuels for certain processes. Hydrogen consumption in the transport sector surpasses industry consumption in the mid-2030s, due to the increasing uptake of fuel cell vehicles. By 2050, the transport sector will account for 70% of hydrogen consumption.
- Domestic hydrogen consumption is assumed to be supplied by hydrogen produced by electrolysis. The electrolysis production is powered by renewable energy.
- There is assumed to be no hydrogen exports by Indonesia, due to significant competition from other APEC and global economies.

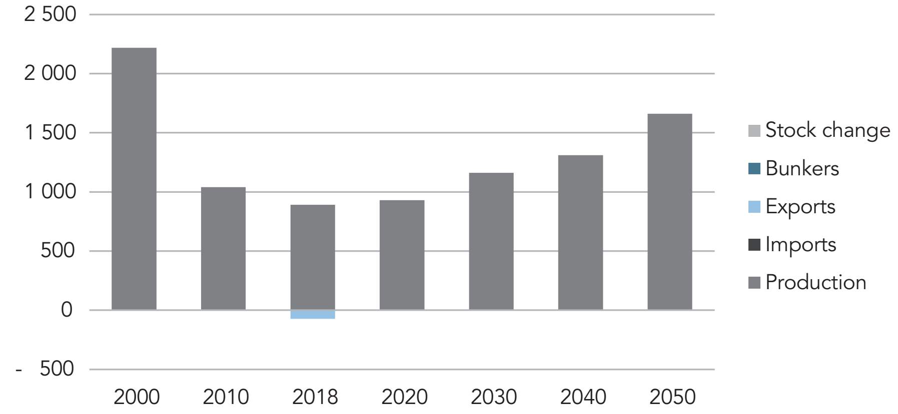
Bioenergy in the Reference scenario

Figure 7-43. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 7-44. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

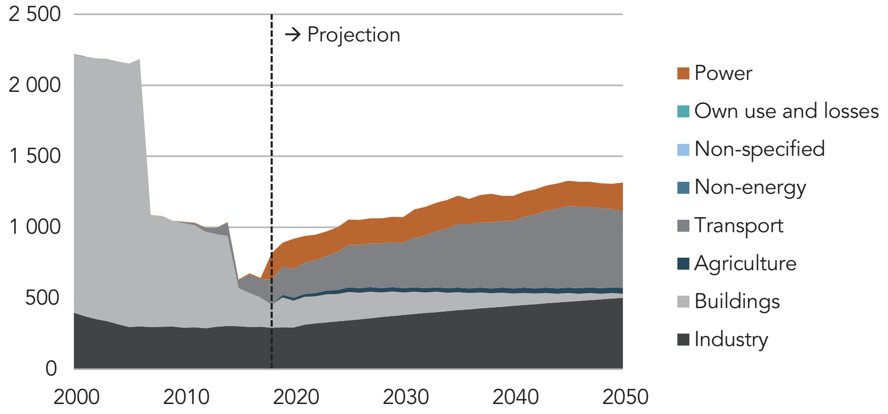


Sources: EGEDA, APERC analysis.

- Solid and liquid renewables were almost exclusively consumed in the buildings and industry sectors over the last few decades. Demand for biomass, such as wood and charcoal for cooking, has decreased significantly due to fuel-switching to LPG and, more recently, electrification. In REF, biomass is still used for cooking out to 2050, mainly in rural areas.
- Solid and liquid renewables consumption doubles through to 2050. These renewables transition to being primarily consumed in the industry and transport sectors. These two sectors account for almost three-quarters of total consumption by 2050.
- Solid and liquid renewables, such as palm oil shells, rice straw, and black liquor, are used as fuel in the industry sector, primarily by palm plantations, some food and beverage applications, and the paper and pulp subsector. Industry demand for these renewables grows at a CAGR of 2.4%, doubling out to 2050.
- Transport demand for these renewables increases at a CAGR of 3.5%, almost tripling in consumption out to 2050. The increase in transport consumption is due to the mandatory biodiesel fuel-blend program.
- In the power sector, consumption of solid and liquid renewables is assumed to increase by a small amount out to 2050.
- The supply of solid and liquid renewables used in all energy-consuming sectors is exclusively from domestic production sources.

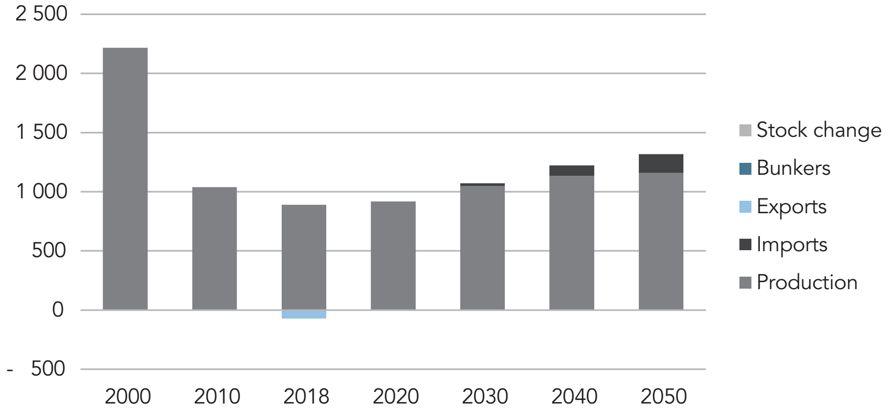
Bioenergy in the Carbon Neutrality scenario

Figure 7-45. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 7-46. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

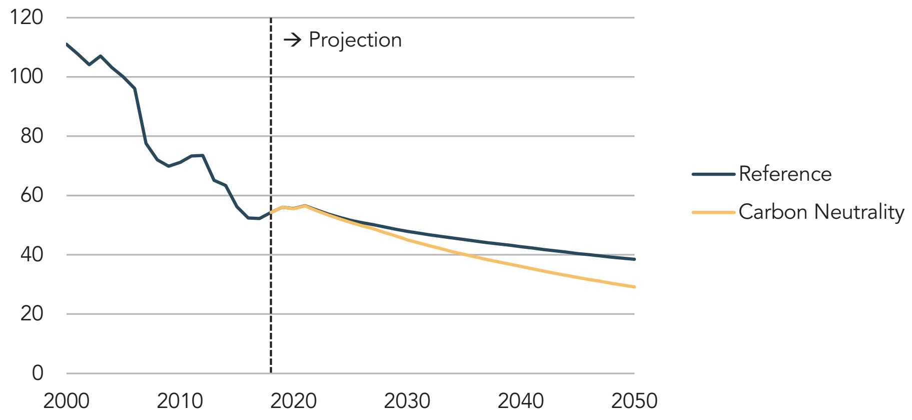


Sources: EGEDA, APERC analysis.

- In CN, demand for solid and liquid renewables is slightly lower than in REF. The transport sector surpasses the industry sector as the largest consuming sector in the mid-2030s.
- Industry demand for these renewables will increase by more than 70% out to 2050. This increase is lower than in REF due to stronger energy efficiency initiatives and the increasing role of electricity and hydrogen.
- Consumption of solid and liquid renewables increases more significantly than in REF due to stronger implementation of the mandatory biofuels program and growing biojet demand. However, demand for these fuels peaks in the mid-2040s due to the increasing penetration of EVs, and the lower role for ICE vehicles.
- By 2050, the transport sector is assumed to account for more than 40% of consumption. Biofuels in Indonesia mainly use palm oil as the raw input material. The increasing demand for biofuels presents a challenge in terms of prioritisation of palm oil usage. For example, transport and industry applications will compete against each other to secure available supply.
- The buildings sector consumption of biomass decreases rapidly due to greater electrification and fuel-switching to gas for cooking. This switch is supported by more ambitious policy in CN. Buildings biomass consumption falls by more than 80% out to 2050.
- In CN, most of the solid and liquid renewables come from domestic production sources. The imports that begin in 2030 are biojet fuels used in transportation.

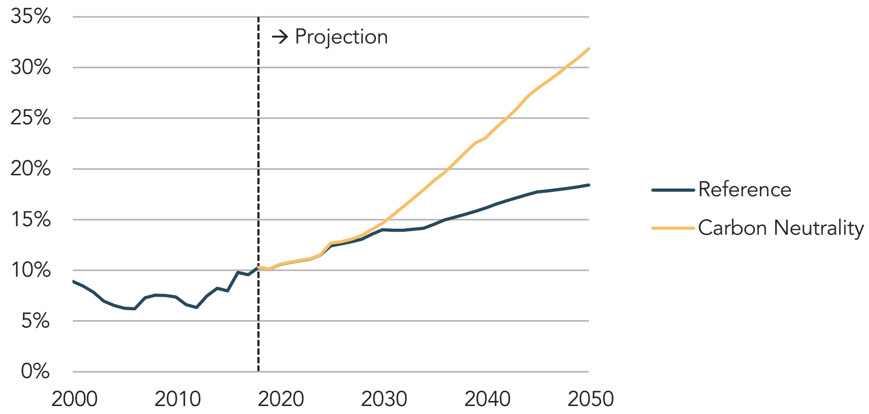
Energy intensity and modern renewables share

Figure 7-47. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 7-48. Modern renewables share in REF and CN, 2000-2050



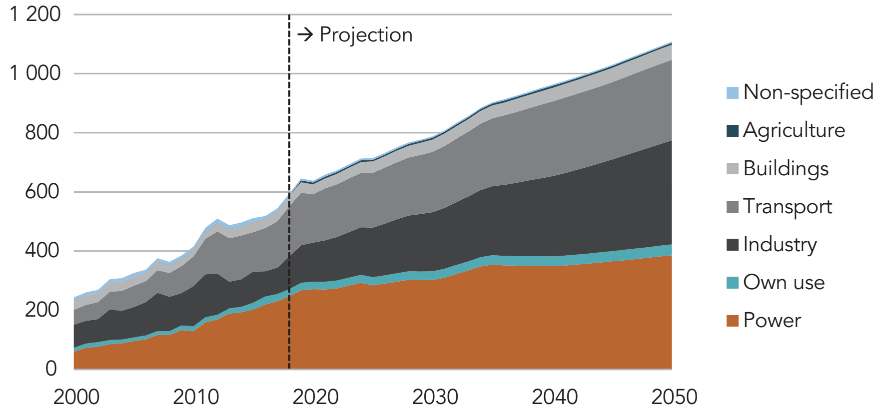
Sources: EGEDA, APERC analysis. Note: Modern renewables includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- Indonesia's final energy intensity has improved by 50% over the previous two decades, supported by significant GDP growth, increasing infrastructure development, and energy efficiency and energy conservation in all sectors.
- Final energy intensity is expected to improve by over 60% from 2005 to 2050 in REF. Increasing economic output and ongoing efforts to improve energy efficiency will support this improvement. In CN, energy intensity is expected to improve by over 70% for the same period, owing to stronger energy efficiency measures.
- Modern renewables have increased to a 10% share in total final energy consumption in 2018. In REF, modern renewables increase to almost one-fifth of total final energy consumption in 2050. This growth is supported by the ongoing effort to develop renewable power generation and the continued ramp-up in the mandatory biofuels program.
- Modern renewables grow at a much more rapid rate in CN, reaching a 32% share of total final energy consumption by 2050. The increase is due to stronger initiatives supporting renewables power generation, a more significant phase-out of coal-fired power generation, and more ambitious mandatory biofuels programs. The significant uptake of EVs is also influential in increasing the share of modern renewables in the final energy mix.
- In CN, the electricity generated from modern renewables in 2050 is fifteen times greater than in 2019, owing to the massive development of hydro, geothermal, and solar and wind energy in the power system.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

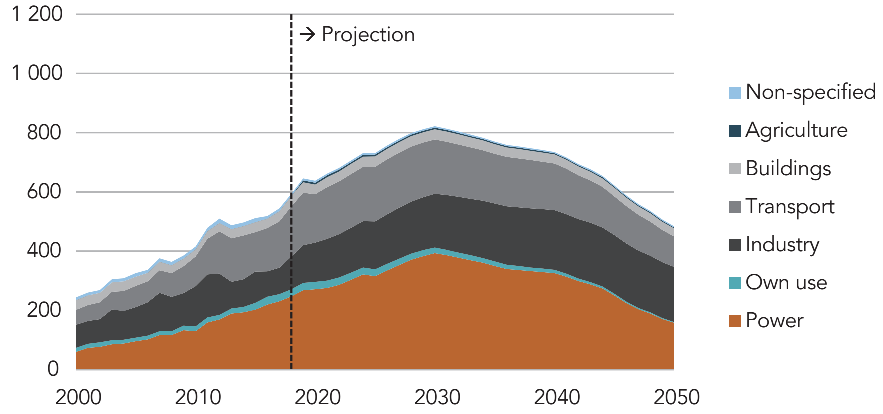
Gross CO_2 emissions

Figure 7-49. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 7-50. Gross CO_2 emissions in CN, 2000-2050 (million tonnes)

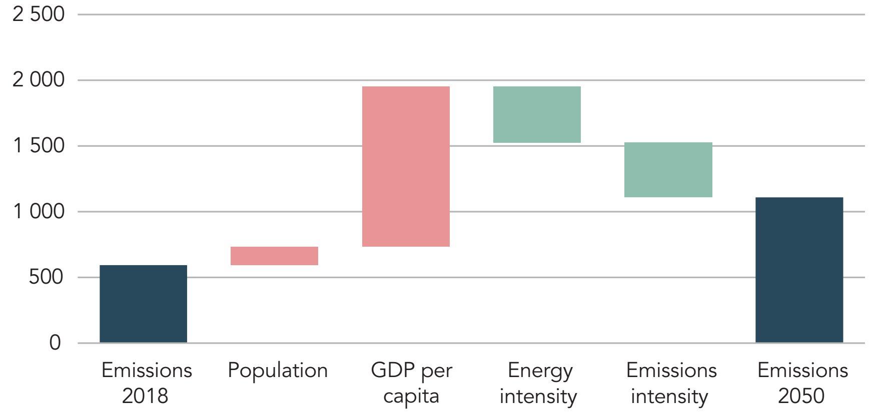


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- In 2021, Indonesia submitted its updated Nationally Determined Contribution (NDC) to strengthen Indonesia's commitment to reduce GHG emissions to 29% below a business-as-usual level by 2030. There is a conditional reduction target of up to 41% below business-as-usual level by 2030 with international support.
- In REF, CO_2 emissions from combustion almost double to reach 1 100 million tonnes in 2050. CO_2 emissions do not peak in REF due to growing energy demand and a high share of fossil fuel energy sources.
- In CN, CO_2 emissions in 2050 are 56% lower than in REF owing to stronger emissions mitigation actions. These actions involve energy efficiency measures in all subsectors, fuel shifting to less emissions intensive energy sources, especially widespread electrification, utilisation of CCS technologies in industry, own use, and power sectors, and material efficiency improvements. CO_2 emissions peak in 2030 at just over 800 million tonnes before falling to 484 million tonnes in 2050.
- The power sector accounts for the largest share of Indonesia's CO_2 combustion emissions until right near the end of the projection in CN. Industry accounts for the largest share of Indonesia's CO_2 emissions at the end of the projection in CN. However, industry CO_2 emissions are significantly lower than in REF, at just over half that level in 2050.
- In CN, transport sector CO_2 emissions are less than two-fifths of the level in REF by 2050. For the power sector, that proportion is just over two-fifths.
- The energy sector accounts for the largest portion of Indonesia's total emissions. Reducing GHG emissions in the energy sector is crucial to achieving the emissions targets stated in the NDC.

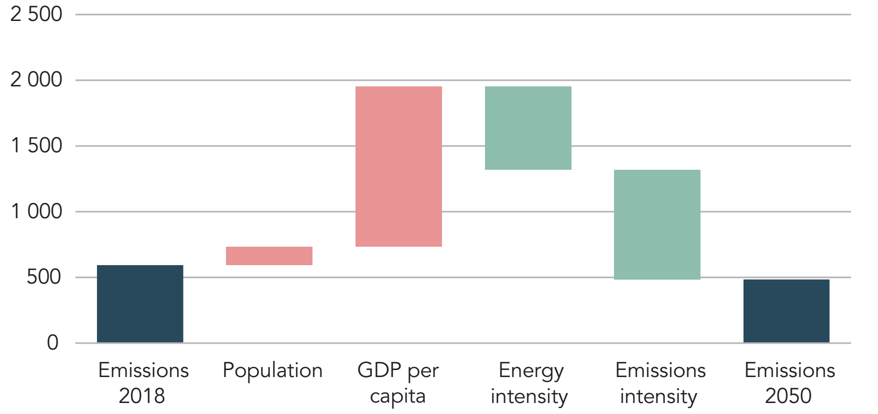
Components of CO_2 emissions

Figure 7-51. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 7-52. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Indonesia emitted just under 600 million tonnes of CO_2 in 2018, which amounted to less than 3% of APEC CO_2 emissions. Indonesia has low emissions per capita, placing at number 18 of the 21 APEC economies.
- In a world with no energy intensity or emissions intensity improvements, Indonesia's projected population and GDP growth would lead to CO_2 emissions more than tripling out to 2050, to 1 950 million tonnes. Population increases place upward pressure on emissions, but it is the projected growth in GDP per capita that contributes to the most significant upward pressure on Indonesia's CO_2 emissions.
- In REF, improvements in energy intensity and emissions intensity mean that CO_2 emissions less than double to 1 100 million tonnes in 2050. CO_2 emissions reductions are attributable to energy intensity and emissions intensity in a roughly even split.
- In CN, emissions falls to 484 million tonnes in 2050. This is a fall of almost 20% from 2018 levels, and is 56% lower than emissions in REF.
- Emissions intensity improvements in CN are double that which occur in REF. These improvements are associated with fuel switching and CCS technologies which are prominent for Indonesia in CN. Energy intensity improvements are 50% larger in CN than in REF. These improvements are related to achieving the same outcome with less energy inputs. The improvements are fostered by improved market incentives and assumed greater policy support by the Indonesia government in CN.
- To compensate for the positive CO_2 emissions by the energy sector in CN, CO_2 emissions sinks from the non-energy sectors, such as land use and forestry sector, are needed to achieve carbon neutrality ambitions.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

National Energy Planning. https://www.esdm.go.id/en/publication/ruen

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8. Japan

Highlights

Demand

- Energy demand in Japan has been declining for more than a decade. This is mainly due to improvements in energy efficiency and a declining population.
- In REF, energy efficiency trends and a falling population will see energy demand fall at a moderate pace. The share of oil will fall to 45% in 2050, while the share of electricity, gas, and hydrogen will increase. From 2018 to 2050, energy demand will decline 26%.
- In CN, there will be a more drastic decline in energy demand. The share of oil will fall to less than 30%, supplanted by higher relative shares of electricity, gas, and hydrogen. Fuel switching will lead to the share of coal and oil declining substantially. From 2018 to 2050, energy demand will decline 42%.

Supply

- In 2018, the share of fossil fuel supply was 88% while the share of renewables, nuclear, and other fuels was 12%. In REF, the share of fossil fuels will decline to 65%, and renewables and nuclear will expand. The energy supply will decrease 28% from 2018 to 2050.
- In CN, energy supply will decrease by almost half from 2018 to 2050. This reduction will mainly come from oil followed by coal and gas. While fossil fuel energy supply will decrease, the energy supply from renewables and nuclear will increase. Imported hydrogen also increases and becomes a prominent source of supply.

Power

- Although Japan's energy demand decreased in the past two decades, electricity generation was more resilient. The relatively robust demand for electricity was due to electrification in the buildings sector (from a 45% share to 55%), with buildings consuming 61% of all electricity. Industry was the second largest electricity consuming sector for the period, followed by transport.
- In the Sixth Strategic Energy Plan issued in 2021, the Japanese government aims to have the electricity generation mix in FY2030 as follows: renewables (36% to 38%), nuclear (20% to 22%), LNG (20%), coal (19%), oil (2%), and hydrogen and ammonia (1%). The results in REF and CN see a smaller role for coal, and a larger role for gas and nuclear.
- Energy efficiency gains keep the level of electricity generation required in CN is about the same as in REF. Much higher levels of offshore wind contribute to significant additional decarbonisation in CN.
- Both REF and CN assume widespread re-openings of nuclear power plants. However, there are no new additions, except for three reactors which are currently under construction. No replacements are assumed through to 2050.

CO_2 emissions

- In REF, CO_2 emissions are projected to fall by more than 50% from 2018 to 2050. Power sector emissions decline by more than three-quarters, with the reduction accounting for two-thirds of the total fall. Transport, buildings, and then industry account for the next largest reductions.
- In CN, power sector emissions decline by more than 90% out to 2050. Offshore wind and the introduction of gas with CCS contributes to the additional emissions reductions. Transport sector emissions decline by 80% which is the largest sectoral reduction relative to REF. The emissions reduction contribution from all sectors leads to Japan's CO_2 emissions falling by 80% out to 2050.
- In April 2021, the Japanese government set a new emissions reduction target for FY2030, which estimates to reduce energy-related CO_2 emissions 45% from FY2013 to FY2030. CO_2 emissions are projected to decline by 41% for this period in REF, and by 48% for this period in CN.

Energy imports

- With few domestic energy resources, Japan is a net importer of energy products (coal, crude oil, refined products, gas, renewables, and hydrogen). In 2018, the ratio of imported energy products to total energy supply was 96%. In REF, imports will decrease about 40% and the import ratio will decline to 74%.
- In CN, energy imports will decrease by 70% and Japan's import ratio to total energy supply will decline to 56%. These reductions are due to the large decline in supply, particularly coal and oil. The CN import ratio is also lower than in REF due to the higher share of renewables and nuclear in total primary energy supply.

About Japan

- Japan, which is in northeast Asia, comprises several thousand islands, the largest being Honshu, Hokkaido, Kyushu and Shikoku. Most of its land area is mountainous and thickly forested. Japan is the third-largest economy in the world on a purchase power parity (PPP) basis after fellow APEC economies, China and the United States. The population of 127 million people enjoyed a per capita income of more than USD 41 000 in 2018.
- Japan's energy resources are scarce, which means that it imports large volumes of energy to sustain economic activity. Japan's total primary energy supply was 17 800 PJ in 2018, which represents an annual decrease of 1.4% from the previous year. Oil constituted the largest share (39%), followed by coal (27%), and gas (23%).
- Net imports of energy made up 91% of Japan's total primary energy supply in 2018.
- Final energy consumption (excluding non-energy) decreased 2.8% to 10 400 PJ in 2018. Oil constituted the largest share at 45%, electricity and others accounted for 34%, gas constituted 12%, and coal 8.2%. Renewables grew 0.9% in 2018, though its share in final energy consumption was still low at 1.9%.
- Non-energy uses of energy products amount to an additional 1 400 PJ of final consumption (with a decrease of 6.2% in 2018). Including non-energy makes final consumption 11 800 PJ. The industry sector uses 29% of this final consumption, followed by the transport sector (25%). The residential sector's final energy consumption decreased by 7.8% in 2018 and accounts for 15% of final consumption. The commercial sector accounted for 17% of final consumption.

Table 8-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	126.5	4.4%	5
GDP	5 354.2	7.6%	3
TPES	17 835.7	5.2%	4
Production	2 107.1	0.6%	11
Imports	16 999.1	13.6%	3
Exports	783.9	0.7%	11
Electricity generation	1 050.4	6.1%	4
Heat production	23.1	0.2%	6
CO_2 emissions	1 077.5	5.1%	4

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 8-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	8 605	453	0%	11
Natural gas	–	–	–	–
Oil	–	–	–	–
Uranium	6.6	–	–	8

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- **Top Runner Program:** It sets targets based on the value of the most energy-efficient products in the market and has delivered household energy conservation improvements. Japanese citizens became increasingly aware of energy conservation following the Great East Japan Earthquake in 2011.
- **Green Growth Strategy:** In October 2020, Japan declared to aim to achieve carbon neutrality by 2050. The government issued "the Green Growth Strategy" as an action plan to achieve carbon neutrality. The strategy includes various plans for 14 industries which will be supported by government funds, tax systems, financial markets, regulations, and international collaborations.
- **Decarbonisation:** Japan has identified installation of offshore wind, ammonia mixed power generation, and hydrogen use in fields such as steelmaking and power generation, as important areas of decarbonisation that will help to achieve carbon neutrality.
- **Sixth Strategic Energy Plan:** In this most recent plan issued in 2021, the Japanese government aims to have the electricity generation mix in FY2030 as follows: renewables (36% to 38%), nuclear (20% to 22%), LNG (20%), coal (19%), oil (2%), and hydrogen and ammonia (1%).
- **Independent development ratio of oil and natural gas:** Japan is aiming to improve its independent development ratio of oil and natural gas, which is defined as the share of the offtake amount of oil and natural gas under the control of Japanese enterprises (including domestic production) relative to the total amount of imported and domestically-produced oil and natural gas. The new target released in the Sixth Strategic Energy Plan is to increase this ratio to over 50% in FY2030, and 60% in FY2040. In FY2020, the independent development ratio reached 40%.
- **Emissions reductions target:** In April 2021, the Japanese government set a new emissions reduction target for FY2030. The target aims to reduce GHG emissions 46% from FY2013 to FY2030. The GHG emissions reduction target had previously been a 26% emissions reduction from FY2013 to FY2030. The target was upgraded as part of concerted efforts to achieving carbon neutrality by 2050.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- **The Reference scenario (REF)** illustrates a pathway where recent trends in energy efficiency, technology deployment and policy frameworks continue throughout the projection period. This scenario provides a baseline for comparison.
- **The Carbon Neutrality scenario (CN)** illustrates a hypothetical pathway where energy efficiency, fuel switching, and technology advances significantly to reduce CO_2 emissions from fossil fuel combustion by 2050.
- In CN, some of the policies included in the Green Growth Strategy (an action plan that the government issued in 2020) are considered. For example, utilisation of hydrogen in steel-making, greater sales of EVs and fuel cell EVs, and a large-scale installation of offshore wind power are assumed.
- The electricity generation mix target in FY2030 set in the Sixth Strategic Energy Plan is considered as a benchmark for electricity generation in CN.
- The upgraded GHG emission reduction target that estimates reducing energy-related CO_2 emissions 45% from FY2013 to FY2030 is considered as an initial pathway to eventually achieving carbon neutrality in CN by 2050.
- For a better comparison between REF and CN, the macroeconomic backdrop (GDP and population) is the same for both scenarios.

Table 8-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Japan

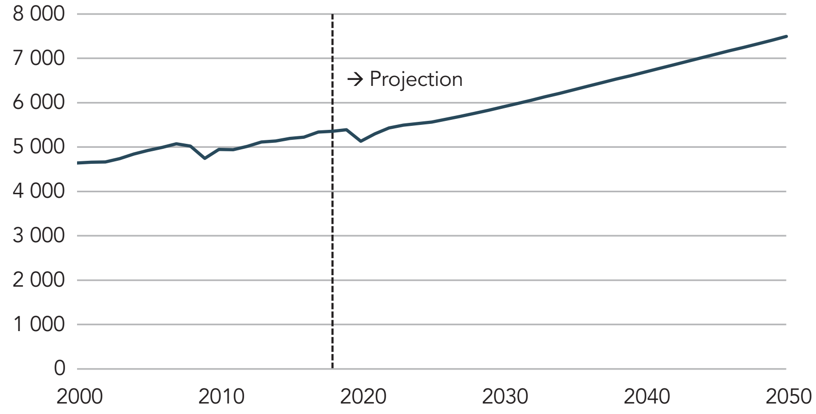
Table 8-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: UN (medium). • GDP: World Bank (historical), OECD (projections), IMF (COVID-19 impacts).	• Population: UN (medium). • GDP: World Bank (historical), OECD (projections), IMF (COVID-19 impacts).
Buildings	• Building energy demand declines mainly due to lower population and higher energy efficiency standards. • Improvements in energy efficiency standards of appliances due to labelling.	• Aggressive energy efficiency policies promote higher energy savings in buildings (20% by 2050). • Switching from oil products to natural gas and electricity.
Industry	• CCS uptake for heavy industry (steel, non-metallic minerals, and chemicals) begins in 2040. • Small amount of hydrogen use for steel and chemical industries begins in 2035.	• CCS uptake for heavy industry (steel, non-metallic minerals, chemicals) begins in 2030. • Hydrogen utilisation for steel and chemical industries begins in 2030. • Material efficiency in steel, non-metallic minerals, and chemicals leads production of these products and is about 10% lower in 2050 relative to reference. • Improving clinker-to-cement ratio in CN relative to REF. • Greater energy efficiency improvements • Greater electrification in all industries • Numerous fuel switching assumptions in different industries, typically away from coal and other fossil fuels to gas (transition fuel), biomass, electricity, and/or hydrogen.
Transport	• Historic trend in fuel economy continues. • Battery electric and fuel cell electric vehicle uptake grows modestly.	• By mid-2030s, battery electric and fuel cell electric vehicles hold a 60% and 10% share of new light vehicles sales, respectively. • Fuel cell electric vehicles make up a 30% share and battery electric vehicles hold a 20% share of heavy truck sales by 2035. • By 2050 close to all vehicle sales are either electric or fuel cell electric.
Power	• Partial adoption of offshore wind projects • 30 nuclear units under operation by 2030 with plant lifetime extensions of up to 60 years • Renewable energy share reaches 40% by 2040.	• Unabated coal phased out by the 2040s and CCUS-equipped gas adoption from the 2030s. • Large scale adoption of offshore wind projects • 30 nuclear units under operation by 2030 with plant lifetime extensions of up to 60-years. • Renewable energy share reaches 50% by 2040.
Supply	• Expansion of LNG storage and regasification terminals • Introduction of LNG re-exports peaking at around 40 cargoes per annum in the 2040s. • Domestic fossil fuel production declines at natural rates.	• LNG re-exports continue in CN at a similar trajectory but are 25% below REF levels by 2050.
Climate		• Carbon neutrality in 2050 relies on carbon sinks from sectors outside the energy sector.

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

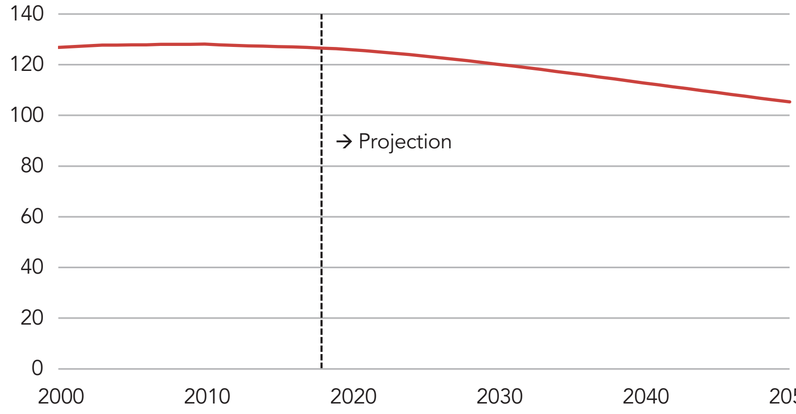
Macroeconomic backdrop

Figure 8-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 8-2. Population in millions, 2000-2050

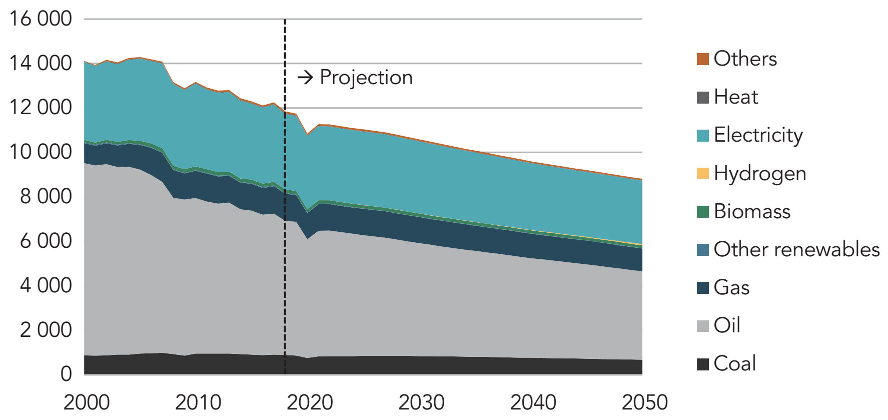


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- The structural composition of Japan's economy has been relatively stable over the last two decades. In 2020, the tertiary industry (wholesale and retail trade, real estate, and others) occupies the largest portion of the economy (73%), followed by the secondary industry (mining, manufacturing, and construction) accounting for 26%, and then primary industry (agriculture, forestry, and fishing) accounting for 1%.
- The COVID-19 pandemic in 2020 led Japan to experience its largest decline in GDP since the global financial crisis and associated downturn in 2009. The extent of the decline has meant that Japan will not return to its pre-pandemic 2019 output level until 2022.
- As Japan is a mature economy, its GDP growth will be moderate relative to other emerging APEC economies.
- Japan's population peaked in 2010. As the birth rate in Japan has been low in the last few decades, the population is projected to continue to decrease throughout the projection period.
- With modest economic growth and a declining population, GDP per capita is projected to grow more rapidly than has been the case in recent decades.

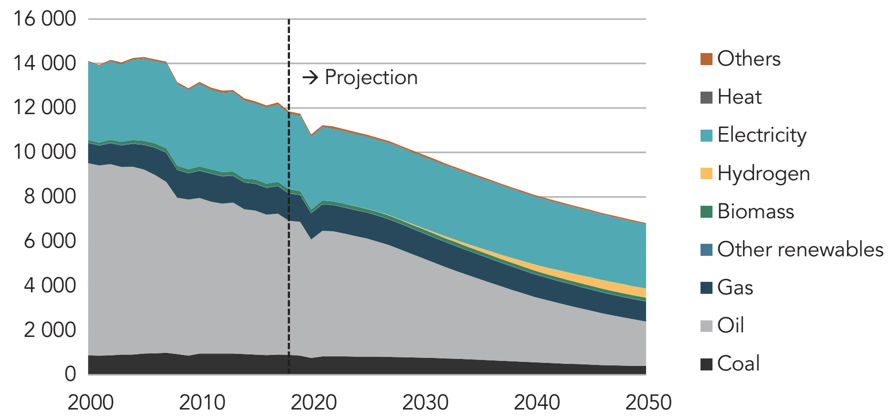
End-use energy demand

Figure 8-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 8-4. Energy demand in CN, 2000-2050 (PJ)

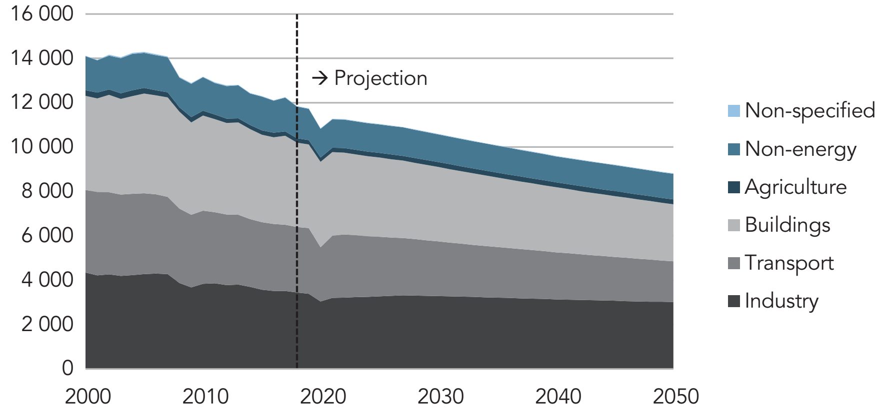


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Energy demand in Japan has been declining for more than a decade. This is mainly due to improvements in energy efficiency.
- Oil currently accounts for just over half of total energy demand. Oil demand initially declined after the oil crises in the 1970s and then recovered in the late 1980s due to lower prices. Since the mid-1990s, oil has been declining with alternative fuels used more. Refined products (oil) are mainly consumed by the transport sector, followed by the buildings sector.
- The global financial crisis in 2008 and 2009 caused Japan's economic activity to fall by 1% and 5%, respectively. Energy demand fell by 7% and 2% as a result of this economic slowdown.
- Japan instituted four state of emergency periods during the COVID-19 pandemic, suppressing economic activity. In FY2020, energy demand declined 7%, and economic activity is still lower than prior to the pandemic.
- In REF, energy efficiency trends and a falling population will see energy demand fall at a moderate pace. The share of oil will fall to 45% in 2050, while the share of electricity, gas, and hydrogen will increase. From 2018 to 2050, energy demand will decline 26%.
- In CN, there will be a more drastic decline in energy demand. The share of oil will fall to less than 30%, supplanted by higher relative shares of electricity, gas, and hydrogen. Fuel switching will lead to the share of fossil fuels (coal, oil and gas) declining to less than half. From 2018 to 2050, energy demand will decline 42%.

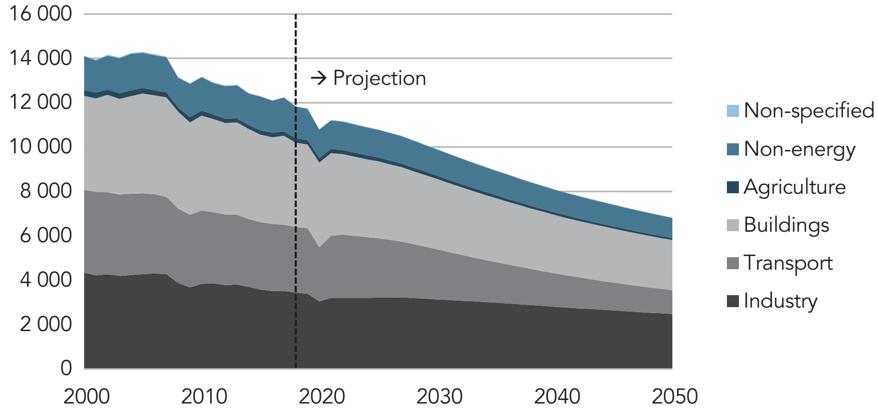
End-use energy demand by sector

Figure 8-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 8-6. Energy demand by sector in CN, 2000-2050 (PJ)

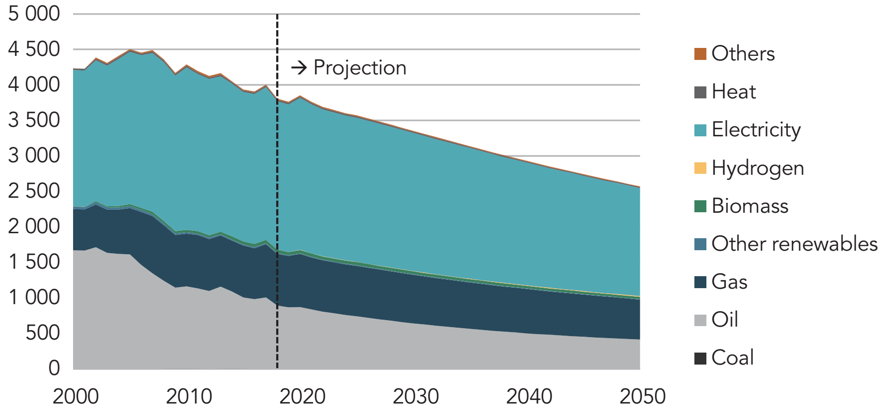


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- The buildings sector has accounted for the largest portion of energy demand in recent decades, followed by industry and transport. In 2018, buildings accounted for a 32% share, industry was 29%, and transport was 25%.
- In REF, energy demand is expected to decline by 1% per year out to 2050, which is close to the historical trend. Transport sector consumption will decline most (38%), followed by buildings (33%), and industry (12%). Even though the relative decline in transport is larger, the prominence of the buildings sector, means that it contributes most to the overall decline in energy demand (41% contribution).
- The historical oil crises already brought about significant energy efficiency improvements in industry. The decline in industrial energy consumption is modest out to 2050, partially due to a lower association with population decline.
- In CN, all major end-use sectors will see reductions in energy demand and these reductions will be significantly deeper than in REF.
- In CN, the transport sector will decline by 64%, followed by the buildings sector (41%), and the industry sector (28%). The decline in industry is more than double the decline projected in REF and is mostly achieved via greater energy efficiency and material efficiency.
- In CN, energy demand is expected to decline by 2% per year out to 2050.

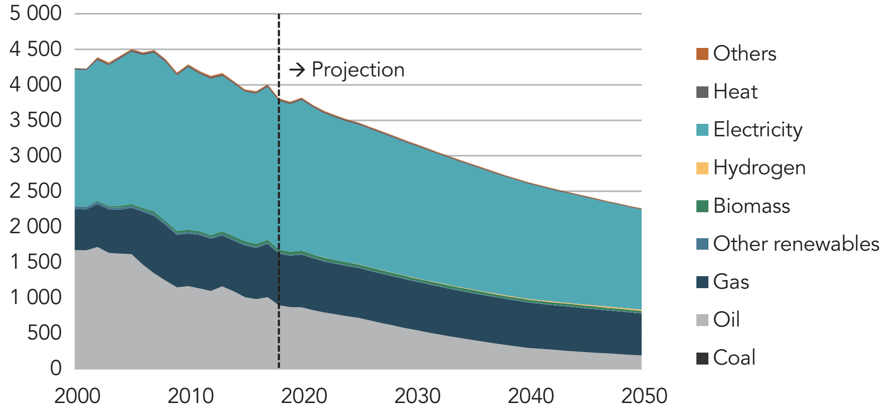
Buildings energy demand

Figure 8-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-8. Buildings energy demand in CN, 2000-2050 (PJ)

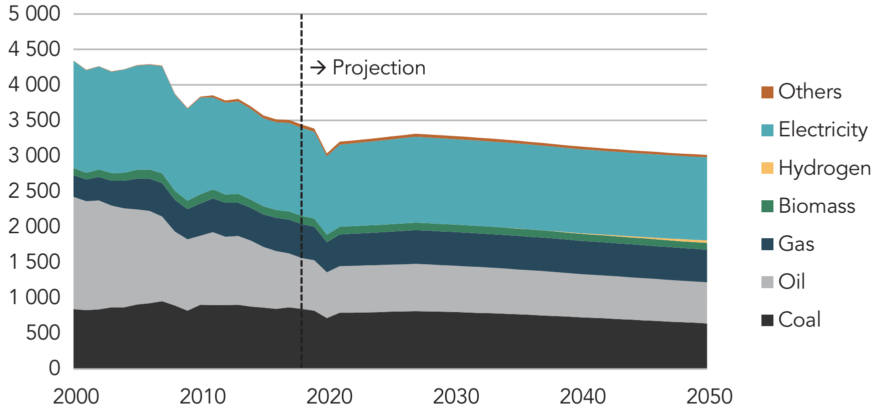


Sources: EGEDA, APERC analysis.

- In the buildings sector, energy demand peaked in 2005. The Top Runner Program, which sets targets based on the most energy-efficient products in the market, has enabled significant energy conservation by households in Japan. The Great East Japan Earthquake in 2011 has also led to greater awareness of energy conservation.
- In 2018, electricity (55%) accounted for the largest share of buildings energy consumption, followed by oil (23%), and gas (19%). There has been significant fuel switching, with the shares of electricity and gas increasing from 45% and 14% in 2000, and oil's share falling from 39%.
- The trend of switching to electricity and gas will continue through to 2050. Electricity will account for a 60% share in both scenarios.
- Significant buildings energy demand declines are expected in both scenarios. CN energy demand will be 12% lower than in REF in 2050 due to greater energy efficiency in appliances, space heating, and cooling.
- In 2018, the residential and services share of buildings was 47% and 53%. This structure has been historically stable and is expected to remain relatively stable through to 2050 in both scenarios.
- Japan is currently at the global frontier in promoting hydrogen use, as established in the Basic Hydrogen Strategy. This translates into Japan being one of the few economies in APEC to incorporate hydrogen use in the buildings sector. Hydrogen consumption grows in both scenarios, reaching 9 PJ in REF and 17 PJ in CN.

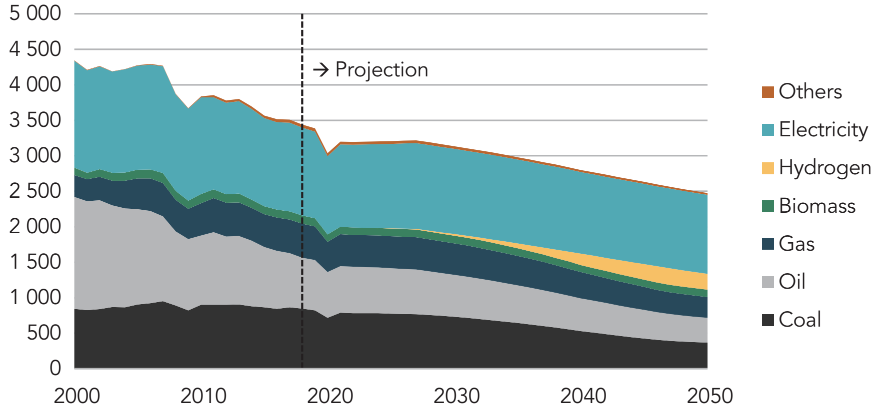
Industry energy demand

Figure 8-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 8-10. Industry energy demand in CN, 2000-2050 (PJ)

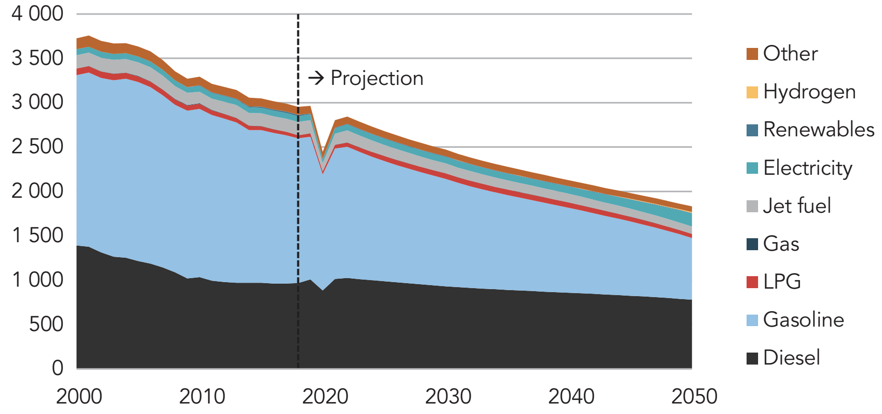


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industrial energy demand has been declining for more than a decade. The global financial crisis brought about large falls in 2008 and 2009, and the economic impact of the Great East Japan Earthquake led to reduced industrial activity as well.
- In 2020, industrial energy demand fell by 10% due to the economic slowdown caused by COVID-19. Industrial activity has recovered, however, the level of energy demand in 2021 is 5% below the level in 2019.
- There are two main reasons behind the energy demand decline in the industry sector in the past five decades. First is that energy efficiency advanced especially after the two oil crises in 1970s. Second, industrial structures have shifted from the most energy intensive materials industries (steel, chemicals, cement, and pulp and paper), to processing and assembly (food, textiles, machinery, non-ferrous metals, and others).
- In both scenarios, energy demand will continue to decrease through to 2050. CN will see a deeper decline compared with REF due to greater energy efficiency. There is also significant material efficiency improvements in heavy industry sectors of steel, cement, chemicals.
- A small amount of hydrogen is incorporated into steel and chemicals subsectors in REF. Development of hydrogen reliant applications in these heavy industries is far more rapid in CN, beginning from the mid-2020s. Hydrogen accounts for 9% of all industrial energy use in CN in 2050.
- Fossil fuels account for two-fifths of Japan's industrial energy demand in 2050 in CN. This reflects that is difficult to substitute away from fossil fuels for certain industrial processes. To achieve deep levels of decarbonisation, almost 30% of fossil fuels consumed by heavy industry (steel, cement, and chemicals) are subject to some form of CCS technology. The average capture rates of these unspecified CCS technologies is 80%.

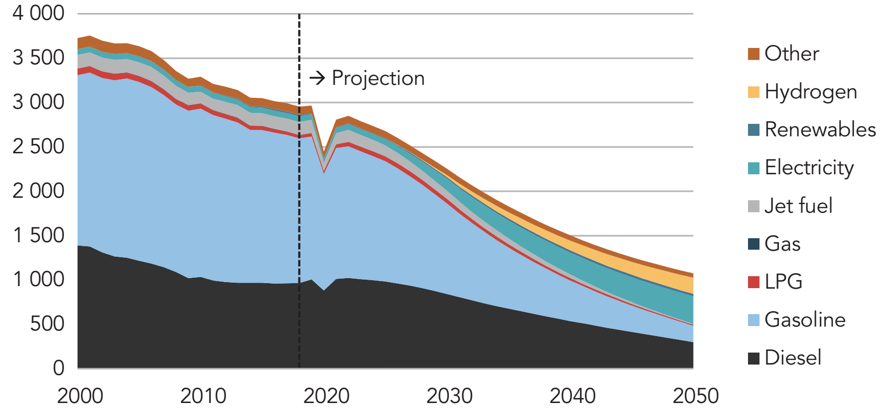
Transport energy demand

Figure 8-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 8-12. Transport energy demand in CN, 2000-2050 (PJ)

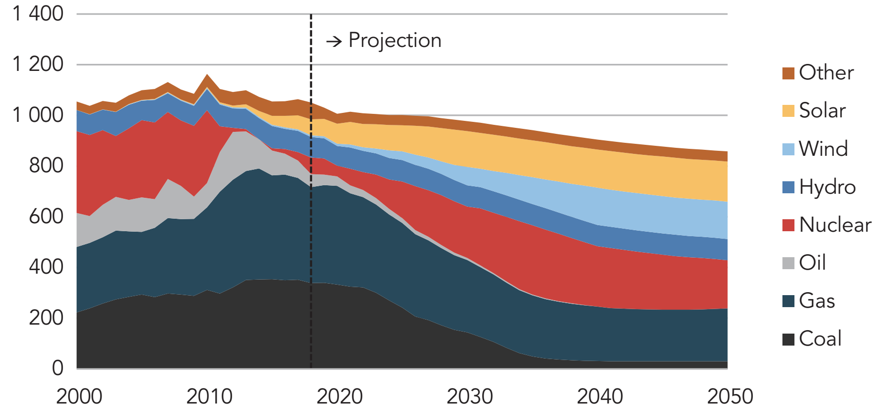


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Energy demand decreased 21% between 2000 and 2018 in the transport sector. This is mainly due to improvements in energy efficiency as well as an increased share of less energy consuming vehicles, such as compact cars and hybrid vehicles.
- By transport mode, in 2018, road transport had the largest share (88%) followed by aviation (5%), marine (4%), and rail (2%). This structure will remain relatively stable in both scenarios through to 2050.
- In REF, the decline in energy demand will continue at a similar pace to the last two decades.
- In CN, as the share of energy efficient vehicles increase, the demand for gasoline will fall dramatically out to 2050.
- In CN, the share of battery electric or fuel cell electric in new vehicle sales will increase remarkably by 2050. This will lead to a significant increase in demand for hydrogen and electricity.
- EVs are expected to account for 40% of sales of passenger vehicles (light truck, light vehicle, and buses) by 2030, and by 2050, the increasing levels of EVs are expected to contribute to 87 TWh of transport electricity consumption. This level of consumption is five times greater than in 2018.
- In 2018, almost all electricity was consumed by railway transport in the transport sector. In CN, electricity demand from battery EVs is assumed to account for 85% share in 2050.

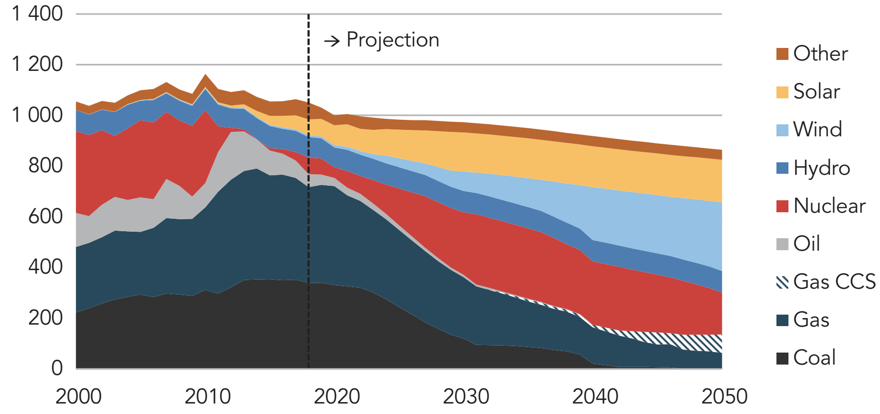
Electricity generation

Figure 8-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 8-14. Electricity generation in CN, 2000-2050 (TWh)

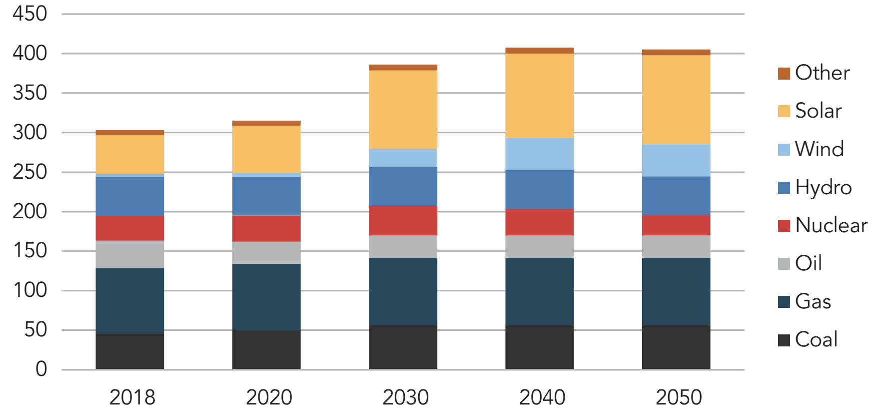


Sources: EGEDA, APERC analysis.

- Although Japan's overall energy demand decreased in the past two decades, electricity generation was more resilient. The relatively robust demand for electricity was due to electrification in the buildings sector (from 45% share to 55%), with buildings consuming 61% of all electricity. Industry was the second largest electricity consuming sector for the period, followed by transport.
- Significant electrification will continue in all sectors in both scenarios out to 2050: buildings (REF: 59%, CN: 62%), transport (REF: 8%, CN: 29%), and industry (REF: 39%, CN: 45%).
- From 2000 to 2018, the generation mix shifted significantly. In 2000, nuclear had the largest share (31%) followed by gas (24%), coal (21%) and oil (13%). Renewables accounted for 9%.
- After the Fukushima Daiichi nuclear power plant incident in 2011, most of the nuclear power plants closed. In response, gas- and coal-fired generation increased to shares of 39% and 32% in 2018. The share of renewables also increased (to 17% in 2018), with part of that increase due to the feed-in tariff system that was introduced in 2012.
- In the Sixth Strategic Energy Plan issued in 2021, the Japanese government aims to have the electricity generation mix in FY2030 as follows: renewables (36% to 38%), nuclear (20% to 22%), LNG (20%), coal (19%), oil and others (2%), and hydrogen and ammonia (1%). The results in REF and CN see less of a role for coal, and more of a role for gas and nuclear.
- Energy efficiency gains mean that the level of electricity generation required in CN is about the same as in REF. Much higher levels of offshore wind contribute to significant additional decarbonisation in CN.
- Gas with CCS to complement variable renewable generation is needed less than in other APEC economies due to relatively high levels of nuclear out to 2050.
- Low (gas with CCS) or zero (renewables and nuclear) generation accounts for over 90% of electricity generation in 2050 in CN.

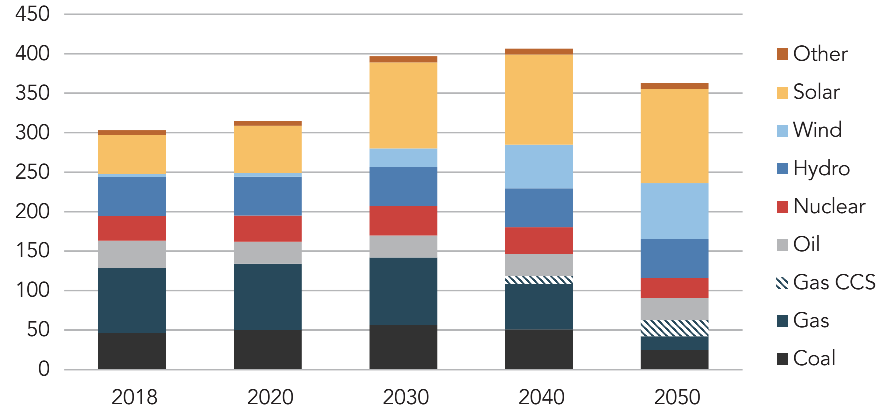
Generation capacity

Figure 8-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 8-16. Generation capacity in CN, 2018-2050 (GW)

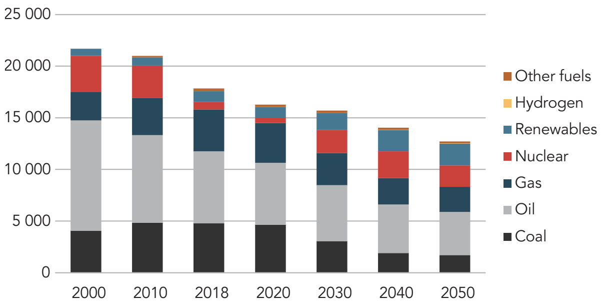


Sources: EGEDA, APERC analysis.

- As of 2018, the total generation capacity was 303 GW. Gas occupied the largest share (27%) followed by solar (16%), hydro (16%), coal (15%), oil (11%), and nuclear (10%).
- Both REF and CN assume widespread re-openings of nuclear power plants. However, there are no new additions, except for three reactors which are currently under construction. No replacements are assumed through to 2050.
- In REF, generation capacity will increase by a third to over 400 GW in 2050, even though generation requirements will be lower. The higher capacity is due to the lower capacity factors of variable renewable generation (solar and wind).
- In CN, the generation capacity will peak in the 2030s and then fall to 363 GW in 2050. The fall in capacity is mostly due to the closure of coal and gas power plants that otherwise remain online in REF. Generation requirements are similar in both scenarios, though the excess fossil fuel capacity is assumed to be shutdown in CN.
- As stated in the Green Growth Strategy, decarbonisation of the power sector is crucial to achieve carbon neutrality. The CN will see deeper decarbonisation mostly due to lower utilisation of gas-fired power. While coal capacity remains in both scenarios, there is only very low levels of generation in the last decade of the projection in both scenarios.
- Renewables additions are assumed to mainly come from solar PV (70 GW) and offshore wind (60 GW) in CN.
- In CN, renewable capacity (hydro, solar, wind, biomass, and geothermal), combined with nuclear and gas-fired power plants with CCS, will reach 80% of total capacity in 2050.

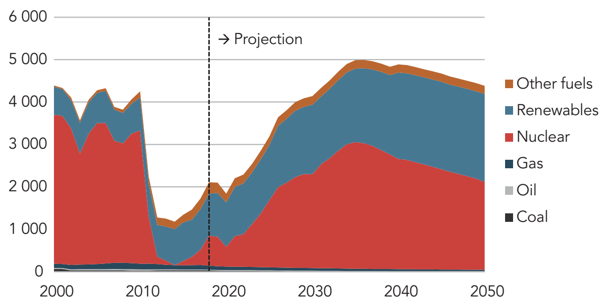
Energy supply in the Reference scenario

Figure 8-17. Total energy supply in REF, 2000-2050 (PJ)



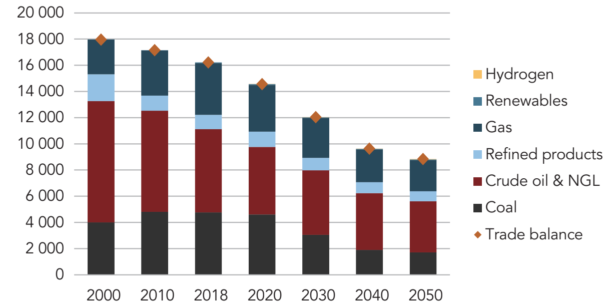
Sources: EGEDA, APERC analysis.

Figure 8-18. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-19. Net energy trade in REF, 2000-2050 (PJ)

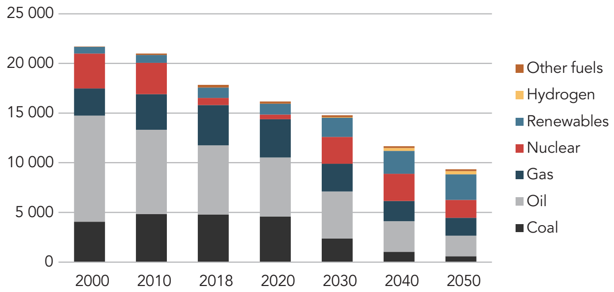


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Energy supply has fallen 20% from 2000 to 2018. Oil contributed most to this reduction. Nuclear decreased significantly due to the Fukushima Daiichi power plant incident. The energy supply from gas, coal, and renewables increased to compensate for these reductions.
- In 2018, the share of fossil fuel supply was 88% while the share of renewables and nuclear and other fuels was 12%. In 2050, the share of fossil fuels will decline to 65%. Renewables and nuclear will expand. The energy supply will decrease 28% from 2018 to 2050 in REF.
- Japan's energy self-sufficiency ratio (domestic production to total primary energy supply) was 20% in 2010. The Fukushima nuclear power plant incident saw the ratio fall to 12% in 2011, and then 6% in 2014 with the closure of all of Japan's nuclear power plants.
- The 2012 introduction of the feed-in tariff system has spurred significant installations of solar and increased domestic energy production. Approval for multiple nuclear power plants to restart has also increased production. Japan's energy self-sufficiency ratio reached 12% in 2018 and will increase to 34% in 2050, due to increased production (nuclear and renewables) and falling supply.
- Japan is aiming to improve its independent development ratio of oil and natural gas. This is defined as the share of the offtake amount of oil and natural gas under the control of Japanese enterprises (including domestic production) relative to the total amount of imported and domestically-produced oil and natural gas. The new target released in the Sixth Strategic Energy Plan is to increase this ratio to over 50% in FY2030, and 60% in FY2040. In FY2020, the independent development ratio reached 40.6%.
- With few domestic energy resources, Japan is a net importer of energy products (coal, crude oil and NGL, refined products, gas, renewables, and hydrogen). In 2018, the import ratio of energy products to total energy supply was 96%. In REF, from 2018 to 2050, imports will decrease about 40% and the import ratio will decline to 74%. Energy supply from fossil fuels is expected to decrease and energy supply from renewables and nuclear will increase.

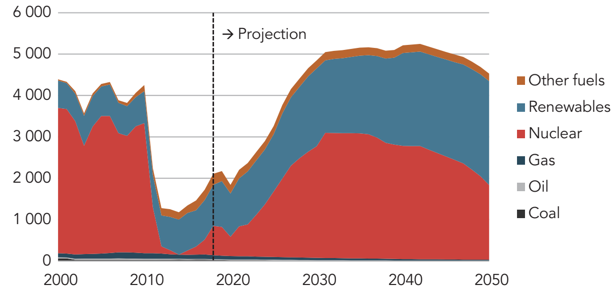
Energy supply in the Carbon Neutrality scenario

Figure 8-20. Total energy supply in CN, 2000-2050 (PJ)



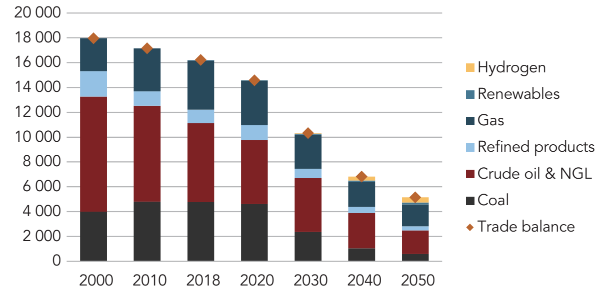
Sources: EGEDA, APERC analysis.

Figure 8-21. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-22. Net energy trade in CN, 2000-2050 (PJ)

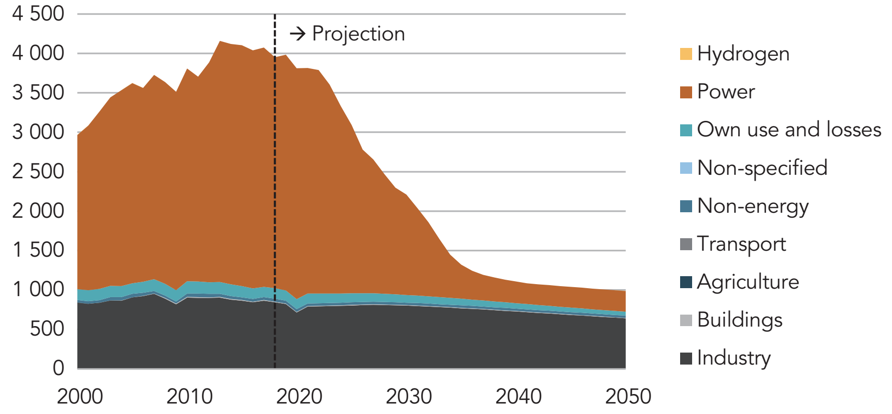


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, energy supply will decrease by almost half from 2018 to 2050. This reduction will mainly come from oil followed by coal and gas. While fossil fuel energy supply will decrease, the energy supply from renewables and nuclear will increase. Imported hydrogen also increases and becomes a prominent component of Japan's energy supply.
- In 2050, the share of fossil fuels in total energy supply will decline to less than half (48%), which is much lower than in REF (65%).
- Japan's energy self-sufficiency ratio will increase to 48% in 2050 in CN. Domestic energy production mainly consists of renewables followed by nuclear. In CN, as large-scale wind power will be installed and wind power production will be greater than in REF, overall renewables share of energy production will be larger than in REF. The lower energy supply ultimately contributes to higher self sufficiency.
- From 2018 to 2050, energy imports will decrease by 70% and Japan's import ratio to total energy supply will decline to 56% in CN. These reductions are due to the large decline in supply of fossil fuels. The CN import ratio is also lower than in REF due to the higher share of renewables and nuclear in total primary energy supply.
- Japan is assumed to import and eventually produce a relatively small amount of hydrogen in REF for use in domestic applications. In CN, hydrogen production is larger, and is complemented by a much greater volume of hydrogen imports to supply domestic transport, industry, and buildings demand. Hydrogen accounts for 8% of net imports, on an energy content basis, in 2050 in CN.

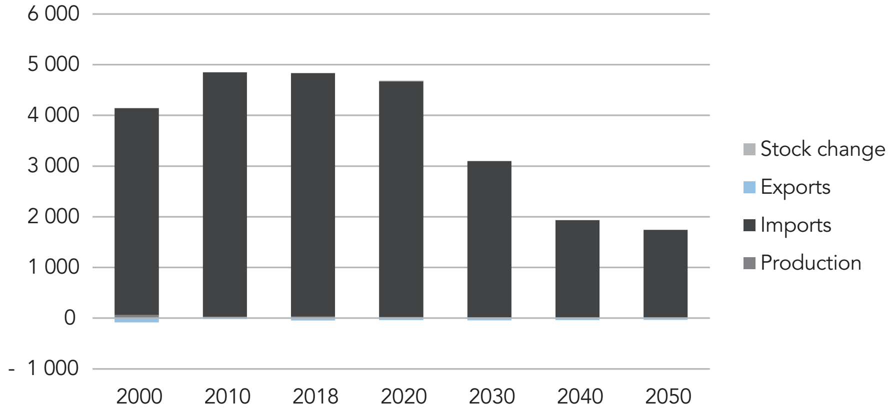
Coal in the Reference scenario

Figure 8-23. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-24. Coal production, imports, and exports in REF, 2000-2050 (PJ)

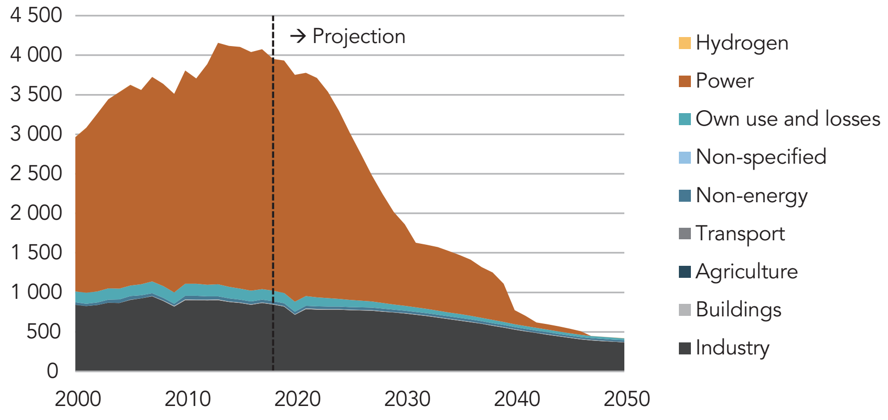


Sources: EGEDA, APERC analysis.

- The power sector accounted for almost three-quarters of coal consumption in 2018, followed by the industry sector (mainly the steel and cement subsectors).
- Coal consumption by the power sector reached a peak in 2015, with growth in the early 2010s tied to the closure of Japan's nuclear reactors, following the Fukushima Daiichi power plant incident. Coal consumption began to decline in 2015 as electricity generation from other technologies increased.
- In REF, coal consumption will decrease more than 70% from 2018 to 2050. The power sector will account for most of this decline, falling by more than 90% by 2040.
- Domestic coal was less price competitive than imported coal from the 1980s. This disparity in price has led to Japan's coal supply being almost entirely sourced from coal exporting economies, such as Australia and Indonesia.
- Japan is one of the largest importers of coal in the world. Large quantities of thermal coal are required for its coal-fired power plants, and large quantities of metallurgical coal, are needed for its steel sector. Australia is the largest supplier of both thermal and metallurgical coal to Japan, and this relationship is expected to continue through the projection period. Japan also imports coal supplies from Indonesia, the United States, and Russia.
- As coal consumption declines, coal imports will decline more than 60% from 2018 to 2050. Metallurgical coal imports will become relatively more prominent out to 2050, as demand for thermal coal from Japan's power sector rapidly declines.

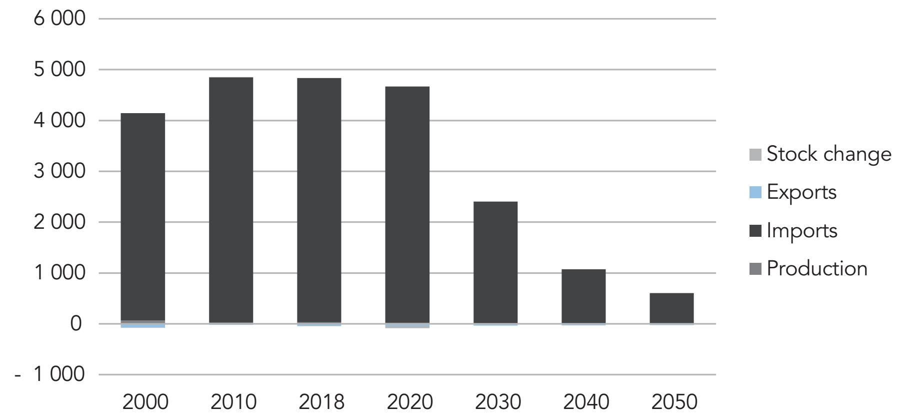
Coal in the Carbon Neutrality scenario

Figure 8-25. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-26. Coal production, imports, and exports in CN, 2000-2050 (PJ)

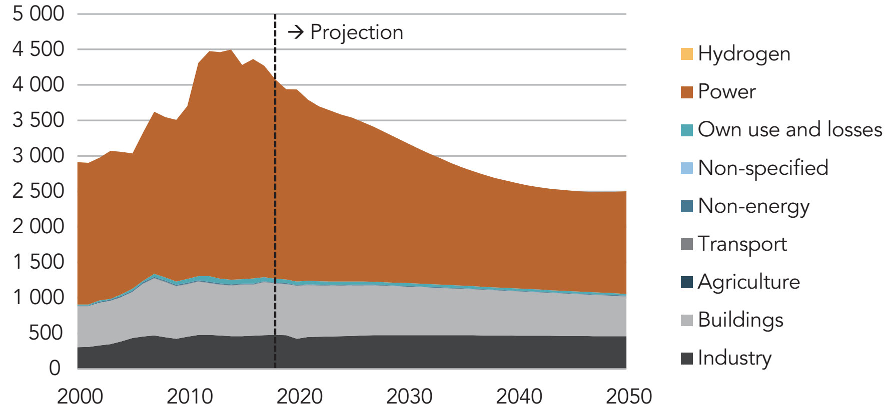


Sources: EGEDA, APERC analysis.

- Coal consumption will decline by almost 90% through to 2050 in CN. The decline is mostly a result of a coal-fired power phase out in the power sector. Coal-fired generation ceases in the 2040s, though there is a larger role for coal in the 2030s than in REF due to less gas-fired power.
- Industry consumption of coal in CN is less than three-fifths of coal consumption in REF. The reduced consumption is mostly due to improved energy efficiency, and material efficiency in heavy industry sectors. Material efficiency leads to a roughly 10% reduction in energy use in 2050.
- Coal currently has an advantage in terms of stable supply and competitive cost. However, in the Sixth Strategic Energy Plan released in 2021, Japan promotes a phase out of inefficient coal-fired plants. Both scenarios are consistent with this planned phase out.
- Although coal-fired power is expected to play an adjustment role amid maximum installation of renewable power, Japan aims to reduce the share of coal-fired power generation while securing stable electricity supply.
- Imports follow trends in energy consumption. Like REF, imports of metallurgical coal will become more prominent, due to a faster decline in thermal coal, which is mostly consumed by the power sector. Coal imports decline nearly 90% from 2018 to 2050.

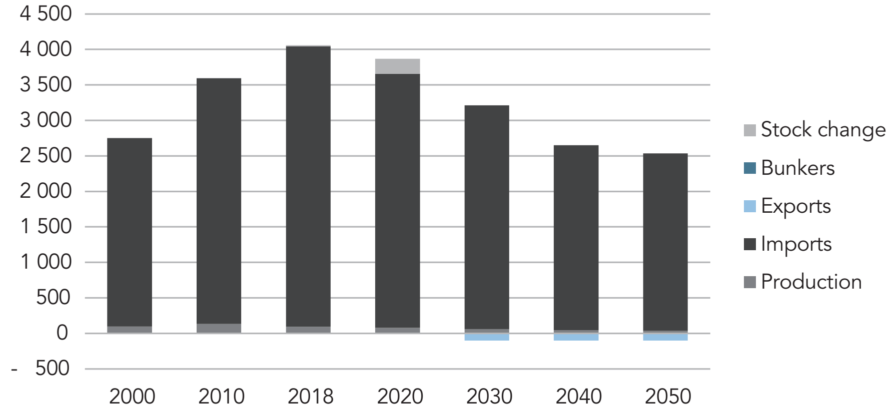
Natural gas in the Reference scenario

Figure 8-27. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-28. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

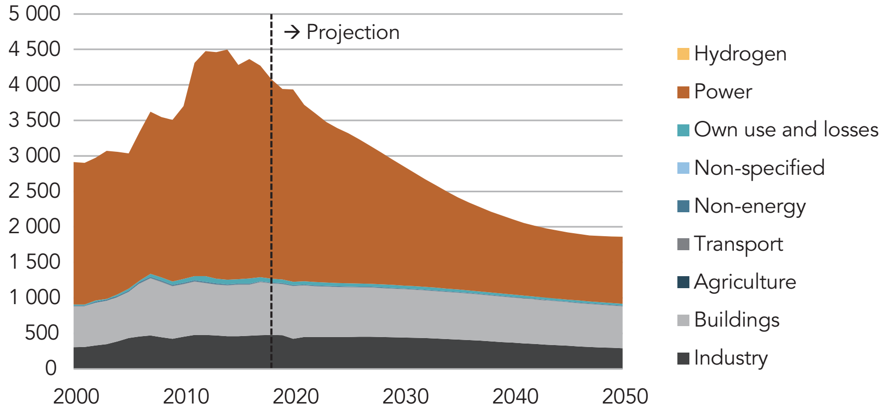


Sources: EGEDA, APERC analysis.

- From 2000 to 2018, natural gas consumption increased by two-fifths. The increase was driven by the power sector, with notable increases in the buildings and industry sectors as well. The power sector has accounted for more than 60% of Japan's gas consumption over the last two decades. In 2011, power sector consumption increased significantly in response to nuclear power plant closures brought on by the Fukushima Daiichi power plant disaster. The approval for multiple nuclear power plants to begin operating in 2015 has since led to a fall in natural gas consumption by the power sector.
- Almost all Japan's gas is imported due to limited domestic reserves. In FY2019, domestic production (produced mainly in Niigata, Chiba, and Hokkaido) only accounted for a 2% share of Japan's total gas consumption.
- Japan imports all its natural gas in the form of LNG.
- In REF, gas consumption is expected to continue the declining trend of the last few years, falling by more than a third to 2040. Power sector consumption levels are anticipated to stabilise in the 2040s, with Japan's total gas consumption eventually 40% lower in 2050, relative to 2018.
- The increases in domestic consumption of gas have been fully facilitated by LNG imports. Imports are assumed to decline at almost the same rate as the decline in consumption. Japan is expected to develop re-export capability, and so imports do not fall quite as far.
- Some of the most prominent sources of LNG are from fellow APEC economies, including Australia, Malaysia, and Russia. Long-term contracts are in place for a significant proportion of Japan's LNG import needs to ensure supply.

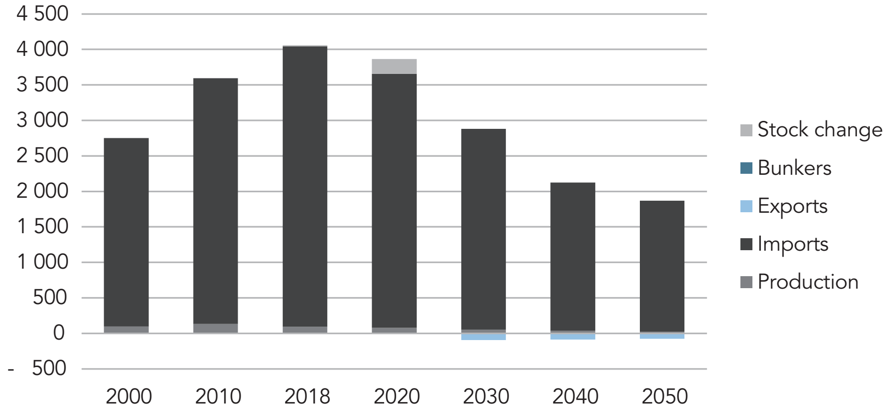
Natural gas in the Carbon Neutrality scenario

Figure 8-29. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-30. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

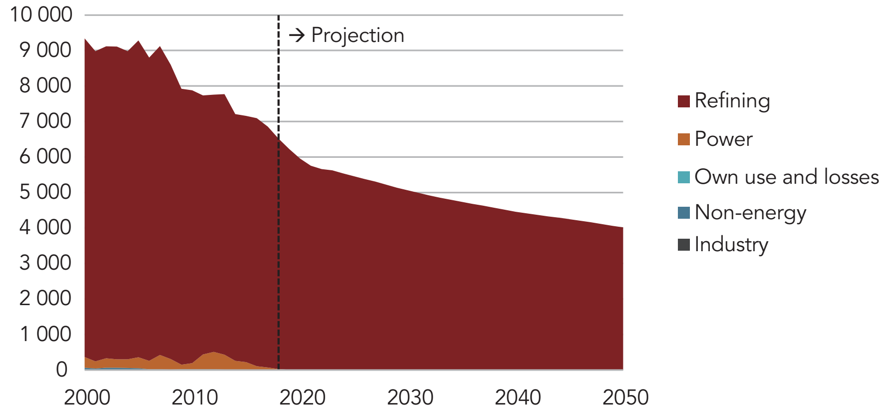


Sources: EGEDA, APERC analysis.

- In CN, from 2018 to 2050, natural gas consumption declines by more than 50%. The reduction in gas consumption is deeper than in REF and mainly led by the decline from the power sector, which relies on greater levels of offshore wind generation. Improved levels of energy efficiency in buildings and industry also contribute to the additional decline in natural gas consumption in CN.
- The fall in natural gas consumption in CN is less than the decline for coal and oil (including refined products), which supports the idea that gas plays a transitional role in decarbonisation.
- Like REF, LNG imports will decrease at the same rate as the decline in consumption, falling by 50% from 2018 to 2050. Gas imports in CN are almost 30% lower than REF in 2050.
- Re-export capability will allow Japan greater flexibility in matching supply to demand.

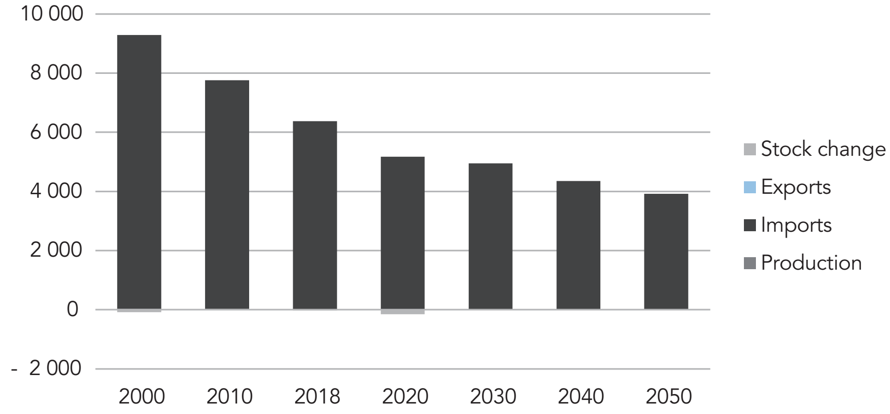
Crude oil and NGLs in the Reference scenario

Figure 8-31. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-32. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

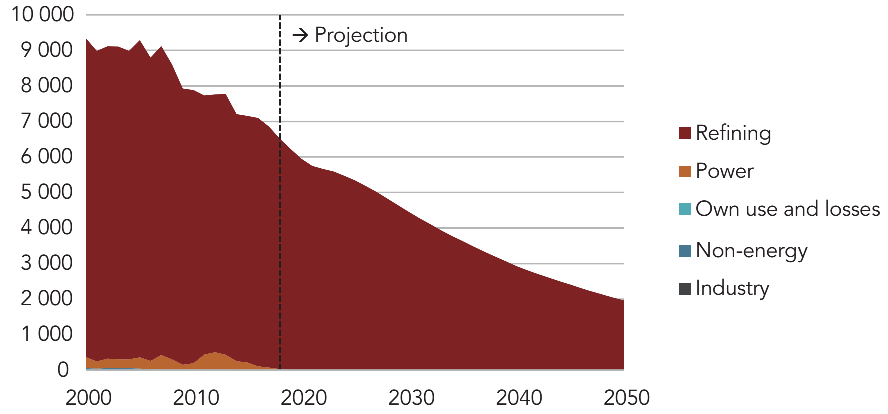


Sources: EGEDA, APERC analysis.

- Crude oil consumption has been declining since the 1990s due to a move to alternative energy resources and promotion of vehicle energy efficiency.
- From 2000 to 2018, consumption of crude oil and NGLs decreased by about 30%. The power sector has historically been a small consumer of crude, but as of 2018, crude oil is consumed almost entirely by Japan's domestic refineries.
- In REF, it is projected that crude oil and NGLs consumption will continue to decline (nearly 40% from 2018 to 2050) as the demand for refined products falls out to 2050. Transport sector consumption trends drive these falls.
- Like coal and gas, domestic production of crude oil and NGLs is minimal. Japan is almost entirely reliant on imports for its oil supply. In FY2019, 34% of crude oil was imported from Saudi Arabia, followed by the United Arab Emirates (33%), and Qatar (9%).
- From 2000 to 2018, imports fell by nearly 30% in response to lower demand from Japan's refineries. Crude oil and NGL imports are expected to decline 38% from 2018 to 2050 in REF.

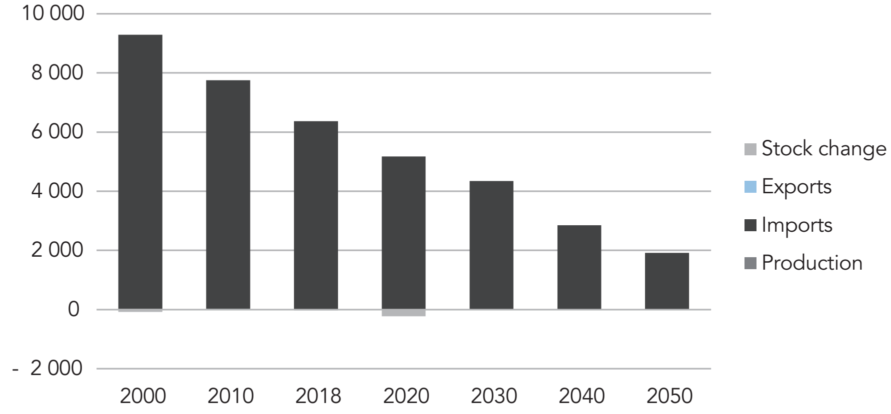
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 8-33. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-34. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

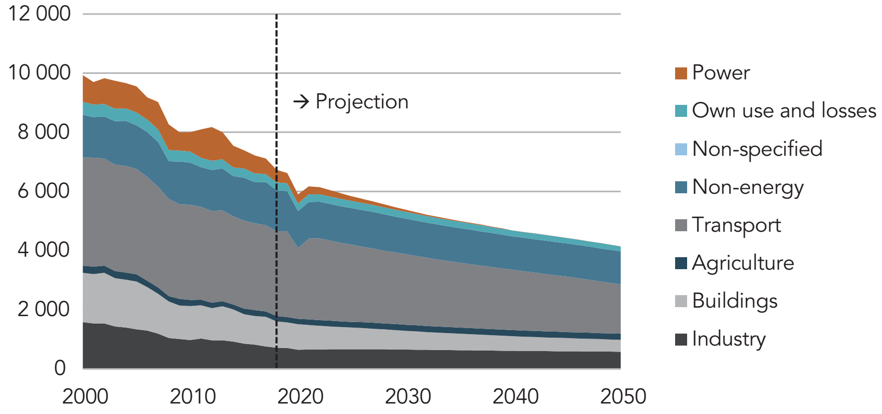


Sources: EGEDA, APERC analysis.

- In CN, it is projected that crude oil and NGLs consumption will decline by 70% from 2018 to 2050. The level of refinery consumption in 2050 in CN is less than half of the consumption level in REF.
- The rise of EVs in CN and greater levels of energy efficiency in all end-use sectors drive the decline in crude oil consumption by Japan's domestic refineries.
- Japan's domestic refineries are assumed to continue to meet most of the demand for refinery products in CN. The falls in domestic consumption of crude oil and NGLs will be greater if Japan instead chooses to rely on importing a greater quantity of refined products out to 2050.
- From 2018 to 2050, the fall in imports of crude oil (70%) matches the fall in consumption of crude oil by refineries. In CN, imports of crude oil and NGLs in 2050 is less than half of the level in REF.

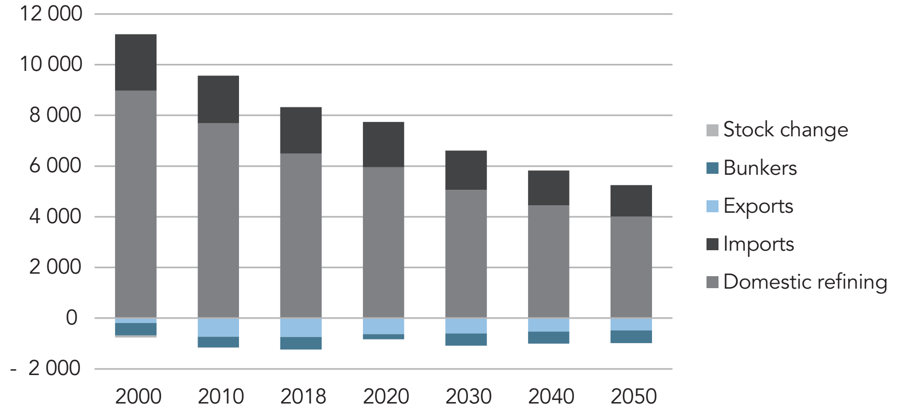
Refined products in the Reference scenario

Figure 8-35. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-36. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

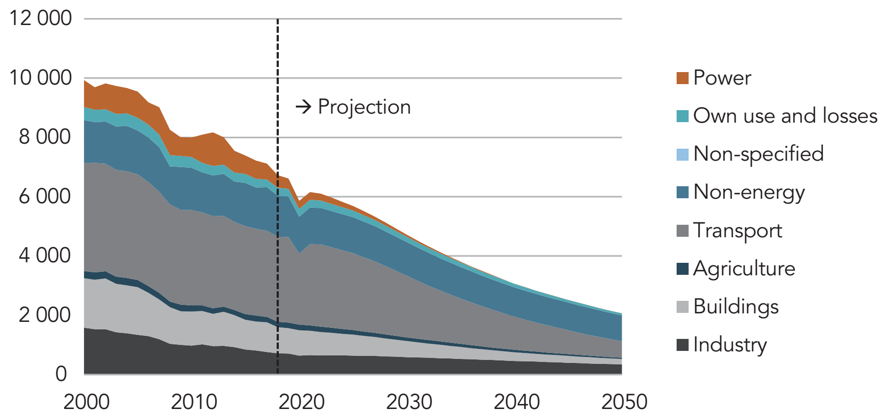


Sources: EGEDA, APERC analysis.

- From 2000 to 2018, refined products consumption decreased more than 30%. The decrease was mainly driven by the industry sector, followed by the buildings sector, and then the transport sector.
- In REF, consumption of refined products will decrease nearly 40% from 2018 to 2050. For the projection period, transport becomes the most influential sector in driving down consumption. The buildings sector and power contribute to additional declines out to 2050 as well. Power sector consumption of refined products falls to zero in 2040.
- The industry sector has already enacted significant energy efficiency improvements in past decades, and so demand reduction out to 2050 will be minimal.
- In 2018, domestic refining accounts for most of Japan's refined products needs. Some of the refined products that are produced by Japan's refineries are exported to economies such as Korea, Singapore, and Australia.
- In 2018, exports of refined products amounted to more than 700 PJ. Close to 500 PJ of refined products were also consumed by international aviation and maritime applications, as captured by bunkers. From 2018 to 2050, bunkers supply is assumed to maintain a similar level. In contrast, exports decline by a third. The decline in exports is associated with declining global demand for refined products.
- In REF, imports and domestic refining will continue to decline as domestic demand for refined products declines. Falling international demand for refined products will also contribute to the reduction in Japan's domestic refinery output.

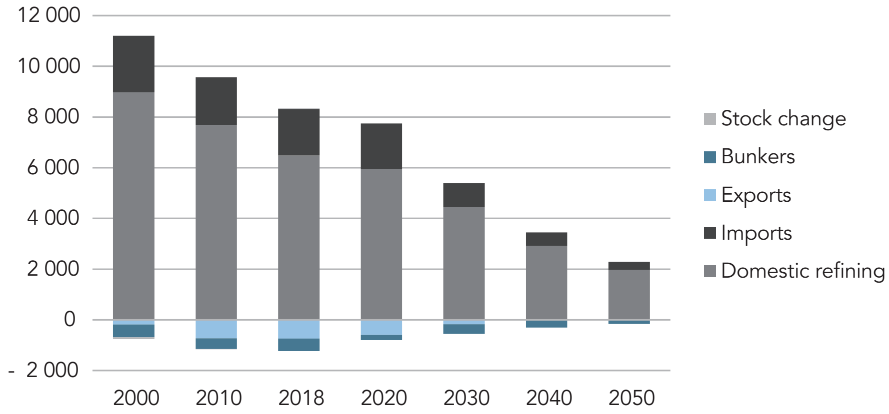
Refined products in the Carbon Neutrality scenario

Figure 8-37. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 8-38. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

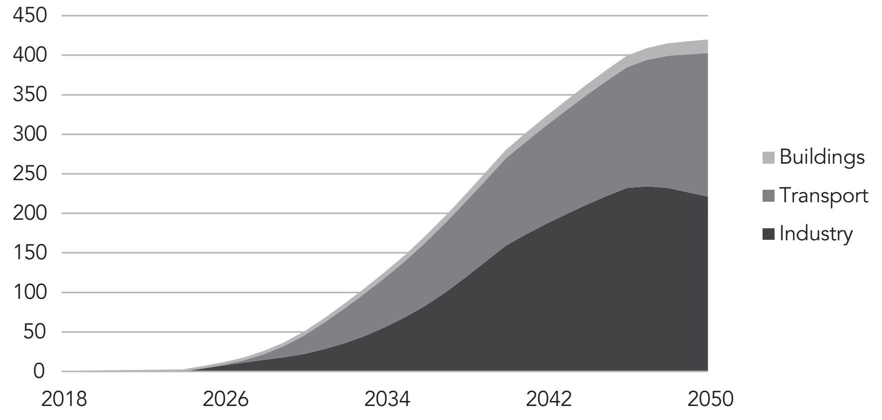


Sources: EGEDA, APERC analysis.

- Consumption of refined products decreases at a much more rapid rate in CN, falling by nearly 70% from 2018 to 2050. Electrification of road transport is the main driver, with greater levels of fuel efficiency in transport also contributing to the fall. Energy efficiency improvements in the buildings, non-energy, and industry sectors leads to a decline in refined products consumption as well.
- The power sector ceases to consume refined products from 2040 in CN, which is the same as in REF.
- In 2050, refined products consumption in CN is half of the REF level. This much lower level of consumption aligns with the crude oil and NGLs results.
- In CN, imports, domestic refining, and exports all decline in concert with the decline in consumption. Domestic refineries are still the main source of Japan's refined products out to 2050.

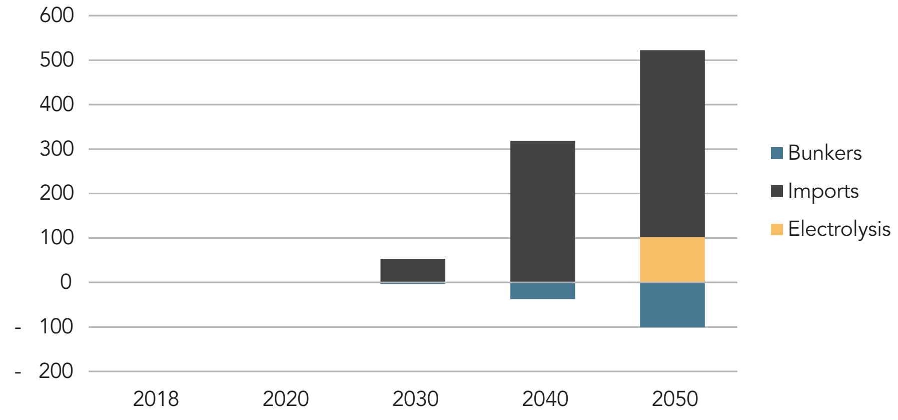
Hydrogen in the Reference and Carbon Neutrality scenarios

Figure 8-39. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 8-40. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)



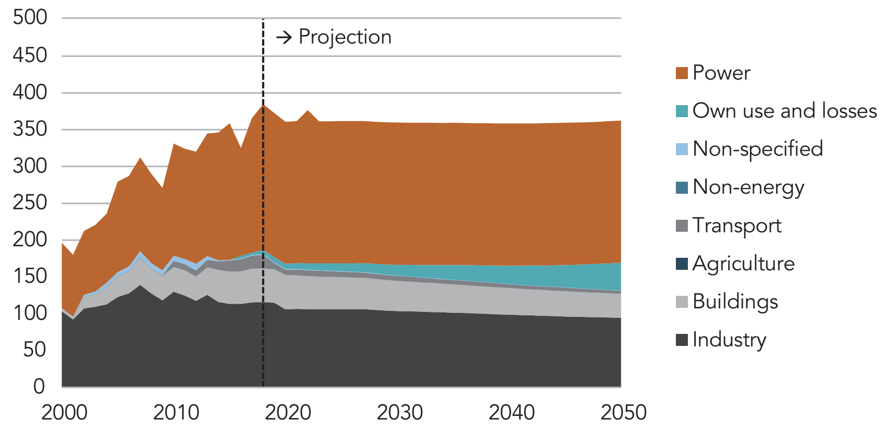
Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- Hydrogen is currently produced by refineries for use as a feedstock in hydrocracking and hydroprocessing of oil and refinery products in both the refining and upgrading process. However, this *Outlook* only models the production and consumption of hydrogen as an energy carrier in the end-use sectors.
- In the Green Growth Strategy released in 2020, hydrogen is regarded as a 'key technology' to achieve carbon neutrality. Hydrogen adoption is touted in steelmaking and in the transport sector, by way of hydrogen fuel cell vehicles, in applications such as heavy trucking.
- In REF (not shown in the figures), hydrogen consumption is anticipated to be used by industry, transport, and buildings, and grow to almost 60 PJ in 2050. Hydrogen supply will be solely reliant on imports until 2040. Electrolysis production of hydrogen will then rapidly grow to meet more than half of Japan's hydrogen demand by 2050.
- In CN, hydrogen consumption increases at a much faster rate to 2050, though it slows in the last few years before 2050 due to shrinking options for growth in the industry sector. Hydrogen consumption in CN will be more than seven times larger than in REF.
- In CN, hydrogen growth will be largest in the industry sector, in steel and chemicals applications. The chemicals subsector begins to incorporate hydrogen from the mid-2020s, while the steel sector begins to incorporate hydrogen from the 2030s.
- Imports are the sole source of supply for Japan's hydrogen and eventually increase to more than 420 PJ in 2050 in CN. Domestic electrolysis production of hydrogen powered by renewable energy begins in 2040, increasing to more than 100 PJ by 2050. Imports and domestic production will meet Japan's domestic needs and contribute to international aviation and maritime demand as captured by bunkers supply.

Note: REF hydrogen demand and supply figures are available in the supporting data file.

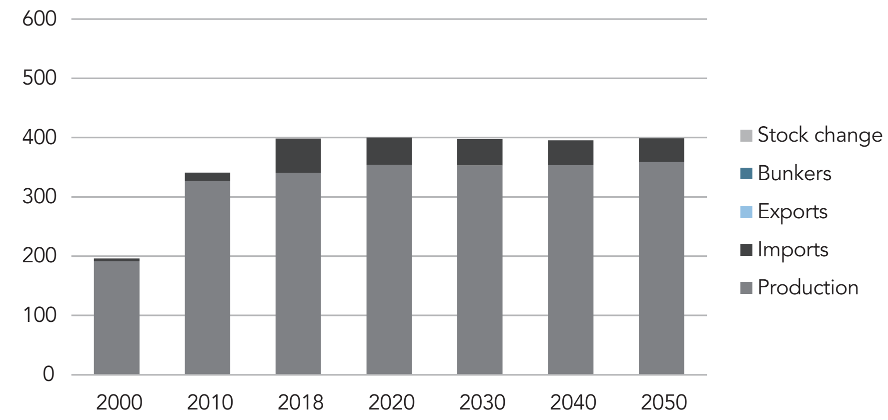
Bioenergy in the Reference scenario

Figure 8-41. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 8-42. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

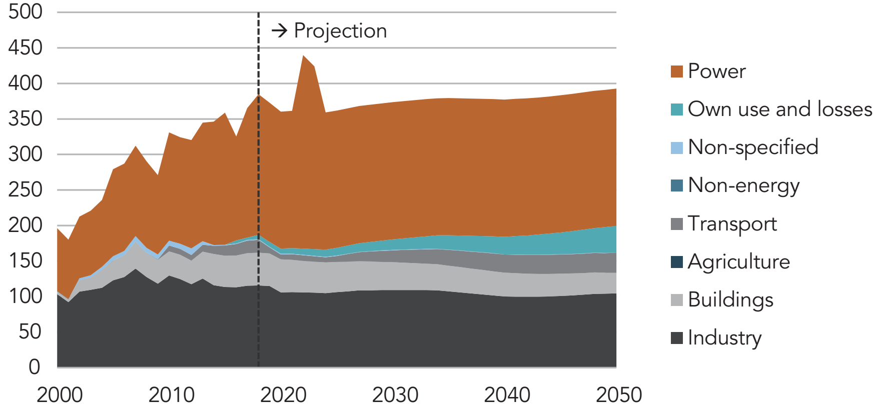


Sources: EGEDA, APERC analysis.

- Bioenergy is mostly biomass and renewable waste, while liquid renewables are biofuels (such as ethanol), that are derived from biomass sources. There are emissions associated with the combustion of these renewables. However, they are considered carbon neutral because the emissions released in combustion are roughly equal to the emissions captured through growth of the plant (photosynthesis).
- Biomass and renewable waste powered electricity has increased in Japan from 2000 to 2018. Buildings sector consumption of biomass has also increased, while industry consumption of solid and liquid renewables has remained more stable through to 2018.
- In REF, from 2018 to 2050, solid and liquid renewables consumption is anticipated to remain flat. The buildings sector posts a notable decline, which is tied to population decline and energy efficiency improvements. Most of the industry sector consumption is associated with the pulp and paper sector, with consumption remaining relatively stable out to 2050.
- The ratio of renewable imports to supply increased from 2% in 2000 to 12% in 2018. Wood pellets imports grew significantly in the past several years, outpacing domestic production. Labour shortages and underutilisation of forestry resources has contributed to the domestic supply and demand mismatch. This mismatch led to a rapid increase in the role of imported wood pellets to meet Japan's burgeoning domestic demand. Imports are expected to persist through to 2050.

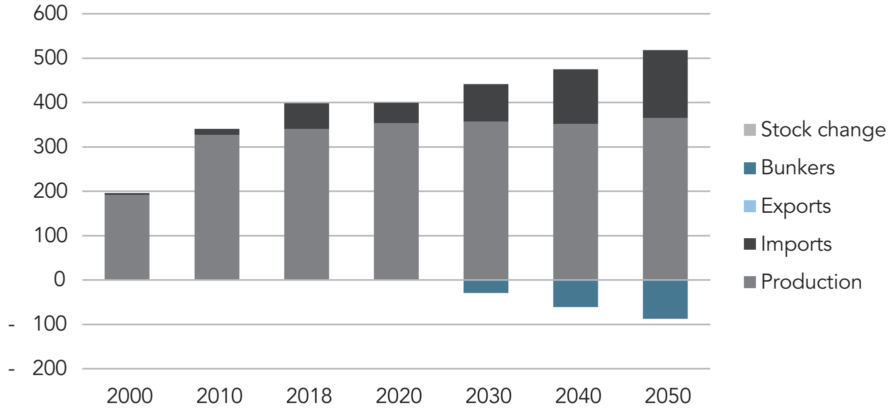
Bioenergy in the Carbon Neutrality scenario

Figure 8-43. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 8-44. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

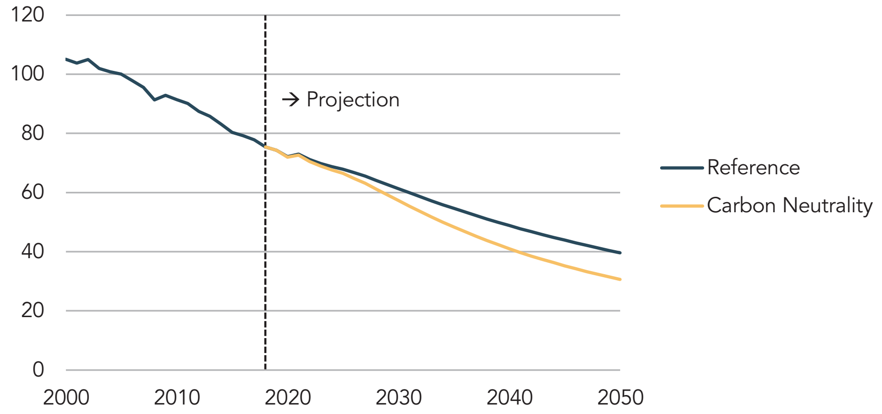


Sources: EGEDA, APERC analysis.

- The most notable difference in CN is that there is a significant increase in consumption of biofuels by the transport sector. Biojet fuel consumption is expected to begin in the mid-2020s and will expand modestly through the projection period.
- Alternative biofuels are cited by Japan's Green Growth Strategy as a way for the aviation sector to begin to decarbonise.
- The ratio of renewable imports to renewables supply will increase to 36% in CN, which is much higher than in REF (10%). Renewable imports reach more than 150 PJ by 2050, and three-quarters of these imports are biojet fuel. Biojet fuel imports are available for domestic consumption, but the largest consumption source is international aviation, as captured by bunkers supply.
- Biomass is a viable option for decarbonising multiple industry subsectors. However, in CN, electricity and hydrogen outcompete biomass in many applications, resulting in relatively flat industrial consumption of biomass through to 2050.
- In CN, solid and liquid renewable consumption is 8% higher in 2050 than in REF.

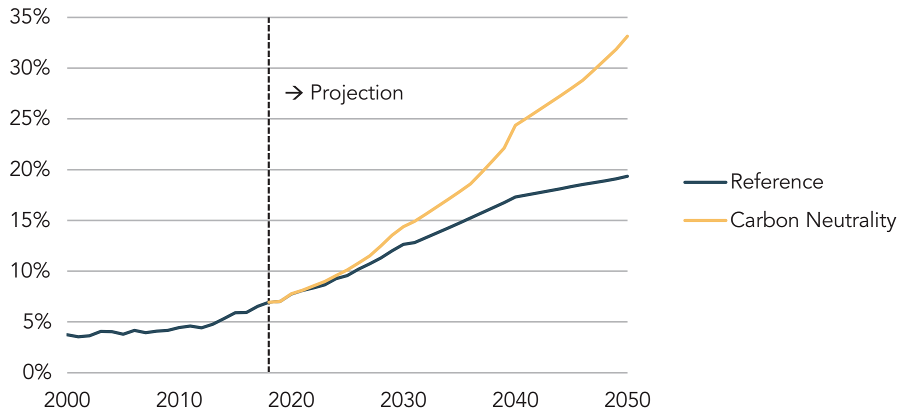
Energy intensity and modern renewables share

Figure 8-45. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 8-46. Modern renewables share in REF and CN, 2000-2050



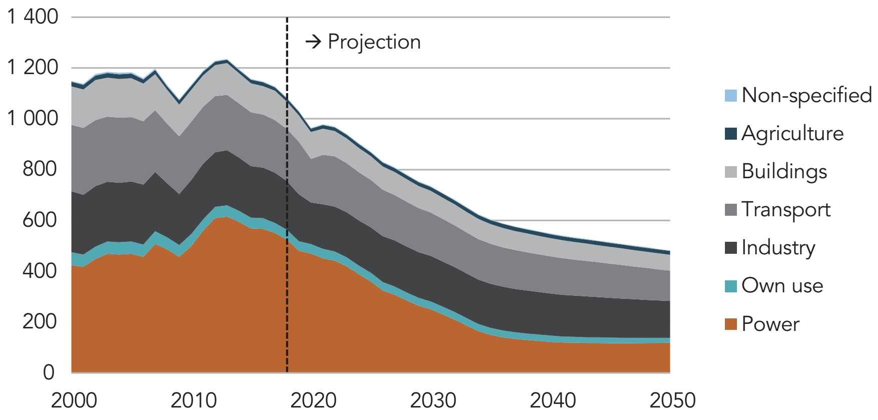
Sources: EGEDA, APERC analysis. Note: Includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- The two oil crises of the 1970s prompted Japan to promote energy efficiency improvements, especially in the manufacturing sector. Multiple energy saving products were developed in this time. While low oil prices contributed to increasing energy demand in the 1990s, higher oil prices in the mid-2000s contributed to falling energy demand once more.
- Japan's final energy intensity improved 25% from 2005 to 2018. About 36% of this improvement was due to the industry sector. The buildings sector accounted for 32% of the improvement and the transport sector accounted for 29%. Final energy intensity is assumed to continue improving significantly in both scenarios.
- From 2018 to 2050, energy intensity will improve by almost half in REF (47%), and by almost three-fifths in CN (59%).
- The buildings sector accounts for 47% of the improvement in energy intensity in REF, followed by the transport sector and the industry sector. These sectors will make similar, albeit larger, contributions in CN.
- The share of modern renewables in Japan's final energy demand was just under 7% in 2018. This share will increase significantly in both scenarios, almost tripling to 2050 in REF (19%), and increasing almost five-fold to 2050 in CN (33%). The large increase in offshore wind is the main reason for the significantly higher share in CN.
- In CN, renewable generation increases from a share of 17% in 2018 to 63% in 2050. In REF, the share is not too far behind, reaching 48% in 2050. This transition to a much larger share of renewable generation emphasises that Japan's power sector will undergo transformational change over the next few decades.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

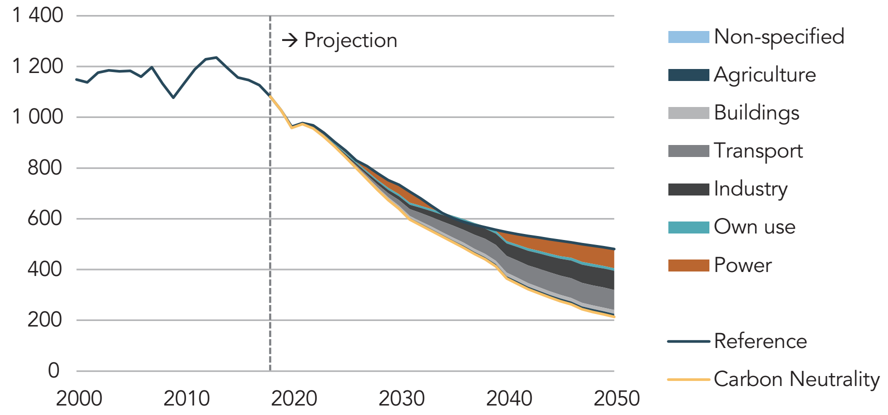
Gross CO_2 emissions

Figure 8-47. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 8-48. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

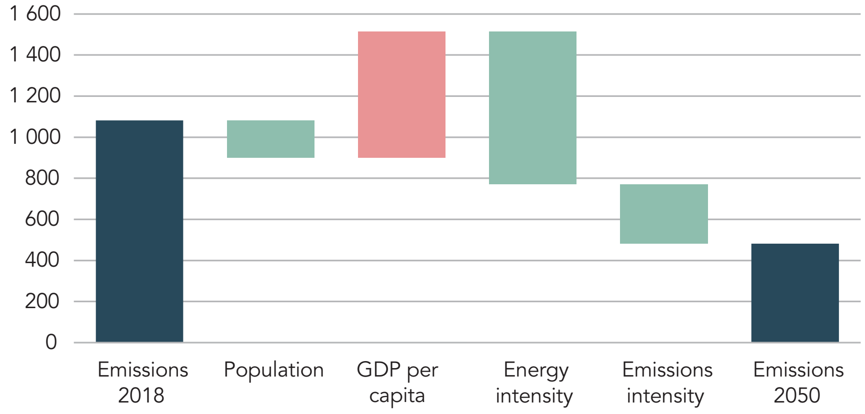


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- In Japan, CO_2 emissions fell significantly in 2008 and 2009 due to the global financial crisis, and then increased due to the Fukushima Daiichi power plant incident and heightened reliance on fossil fuel power generation. Emissions have been falling since 2014, which is partly due to the reintroduction of nuclear generation.
- In 2018, just under half of Japan's CO_2 emissions are from the power sector, followed by the transport and industry sectors, which account for just under one-fifth each.
- In REF, CO_2 emissions are projected to fall by more than 50% from 2018 to 2050. Power sector emissions decline by more than three-quarters, with the reduction accounting for two-thirds of the total fall. Transport, buildings, and then industry account for the next largest reductions.
- In CN, power sector emissions decline by more than 90% out to 2050. Offshore wind and the introduction of gas with CCS contribute to the additional emissions reductions. Transport sector emissions decline by 80% which is the largest sectoral reduction relative to REF. The reduction is mostly due to widespread electrification of road transport. The emissions reduction contribution from all sectors leads to Japan's CO_2 emissions falling by 80% out to 2050.
- Industry sector CO_2 emissions fall by almost two-thirds in CN due to further energy efficiency and material efficiency improvements, CCS in heavy industry, and a switch away from fossil fuels to electricity and hydrogen. The emissions reductions in CN is 2.7 times larger than in REF.
- In April 2021, the Japanese government set a new GHG emissions reduction target for FY2030, which estimates to reduce energy-related CO_2 emissions 45% from FY2013 to FY2030. CO_2 emissions are projected to decline by 41% for this period in REF, and by 48% for this period in CN.

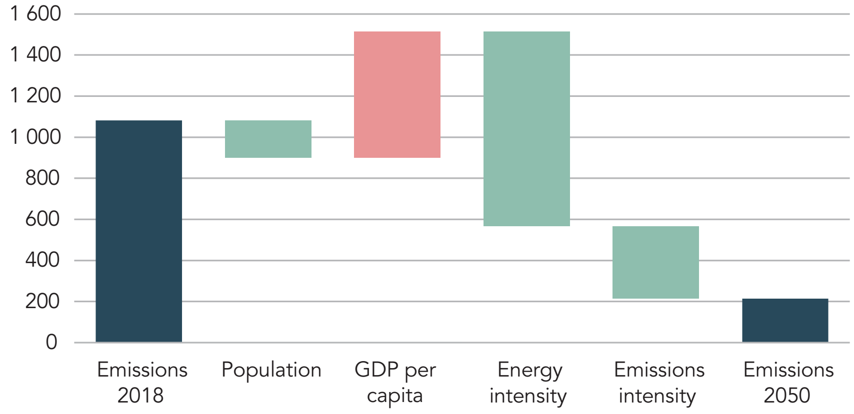
Components of CO_2 emissions

Figure 8-49. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 8-50. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- In 2018, Japan's CO_2 emissions from combustion were almost1 100 million tonnes. Japan is the fourth largest CO_2 emitting economy in APEC and fifth in the world.
- Holding all else equal, Japan's population decrease would lead to an emissions reduction out to 2050. However, this reduction attached to population decline would be more than offset by emissions increases associated with increases in GDP per capita. Without any energy intensity or emissions intensity improvements, Japan's CO_2 emissions would balloon to more than 1 500 million tonnes in 2050.
- Improvements in both energy intensity and emissions intensity lead to significant CO_2 emissions reductions in both scenarios.
- In REF, it is estimated that CO_2 emissions will decrease by well over half, to 481 million tonnes by 2050. Energy intensity improvements account for the largest share of the decline. Emissions intensity improvements brought by switching to renewable power generation leads to reductions as well.
- In CN, it is estimated that emissions will decline by 80% to 214 million tonnes. Energy intensity improvements mainly in the buildings sector contribute to the largest share of these emissions reductions and are 28% greater than in REF. The increased share of renewable generation and more widespread use of CCS mean that emissions intensity reductions are 22% greater than in REF.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

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9. Korea

Highlights

Demand

- Since the 2000s, energy demand has been dominated by oil and electricity. As of 2018, oil and electricity accounted for 77% of energy demand. However, awareness of environmental and energy issues has been increasing the proportion of renewable energy and energy transition policies in response to climate change are accelerating this trend.
- In REF, energy demand will generally increase steadily until 2050 (+16%) although the COVID-19 pandemic brought a temporary impact in 2020 with a decrease in oil demand of around 5.0%. Specifically, industrial energy demand gradually increases, whereas energy demands of transport and buildings may enter a moderate decline around 2040.
- Meanwhile, CN assumes more efficiency improvement of energy facilities in all sectors and fuel switching, leading to lower energy demand (–12%). The role of electric and hydrogen vehicles is more than double that in REF.

Supply

- Energy supply generally reflects the trend of energy demand, showing steady growth in REF while resulting in a decrease in CN.
- Although Korea has been one of the largest oil and gas importers in the world, the share of oil and gas will be significantly affected by the increase of renewable energy supply in both scenarios.
- Coal supply peaked in 2018 and declines in both scenarios. Coal has no place in CN with the halting of power generation of coal-fired power plants that have not reached maturity in 2050. According to the 9th Electricity Supply and Demand Basic Plan (2020-2034), the proportion of nuclear power plants will also be gradually reduced.
- The decline in the share of coal and nuclear power will be largely replaced by renewables. However, the energy mix with natural gas differs between the two scenarios. While natural gas supply as a stable energy source is expected to continue to increase in REF, it is assumed that renewables will supplement the part of the reduced gas since the 2040s.

Power

- The progress of electrification steadily increases power generation in both scenarios. Through the 3020 Renewable Energy Initiative Implementation Plan, the Korean government plans to produce 20% of its total power generation from renewable energy by 2030. The increase in the share of renewable energy generation will be even more pronounced within CN. Additionally, LNG power will serve as a bridge power source as coal and nuclear power generation decline.
- It is necessary to secure gas or gas CCS capacity under the assumption that this government policy is maintained. From 2021, R&D projects for the commercialisation of CCS technology for LNG power generation have been conducted by KEPCO. Meanwhile, changes in the power generation system are also anticipated by expanding the distributed power generation system. The government expects that more than 15% of the power generation will be supplied by the distributed power generation system by 2035.

CO_2 emissions

- CO_2 combustion emissions decrease through 2050 in REF, arrive back at 2000 levels. In CN, it decreases even more with the complete phase-out of coal power generation by 2050.
- In CN, the power sector is expected to make the largest contribution to emissions reductions, led by the decommissioning of all coal power generation and a dramatic increase in renewables. New technologies and industrial processes that improve energy efficiency will further reduce emissions along with the accelerated spread of EVs and hydrogen vehicles.
- To accelerate the transition towards carbon neutrality, the Korean government announced the Green New Deal policy in 2020. This is a plan that accompanies a large investment to promote lower carbon energy infrastructure.

About Korea

- Korea is in northeast Asia, situated between China and Japan. Its population density is very high. The geography consists of hills and mountains with wide coastal plains in the west and the south. The climate is relatively moderate, with four distinct seasons. Over the past few decades, Korea has become one of Asia's fastest growing and most dynamic economies. Economic activity has been driven by an export-oriented manufacturing sector such as in semiconductors, cars, steel and petrochemicals. However, the share of the manufacturing industry is expected to decrease slightly in the future as the service industry grows faster.
- Korea's energy supply more than tripled between 1990 and 2018. Korea has limited domestic energy resources; thus, a significant portion of Korea's energy supply is imported. Its fuel mix has focused on a stable energy supply with expansion of renewable energy from 2000 to 2018. As of 2018, oil supply was proportionally higher, whereas the other categories were relatively lower. Korea's total final consumption in 2018 was 7 629 PJ. The non-energy and industrial sectors accounted for the largest shares at 28% and 27%, while the transport sector accounted for 19%. In general, consumption in the agriculture sector has weakened since the late 1990s, and consumption in the industry, transport and commercial sectors has gradually increased.
- Korea's economic growth has led to a substantial increase in electricity consumption over the past few decades. Between 2000 and 2018, total power generation doubled from 289 TWh in 2000 to 586 TWh in 2018. Looking into each generation fuel, 44% of Korea's electricity was generated by coal in 2018. However, the share of coal power generation is expected to considerably decrease in the future with the rise of carbon neutrality ambitions. In addition, Korea has continuously promoted policies to expand renewable energy in response to climate change and for sustainable growth.

Table 9-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	51.6	1.8%	10
GDP	2 225.8	3.2%	7
TPES	11 817.5	3.4%	6
Production	1 893.8	0.6%	12
Imports	13 542.0	10.8%	4
Exports	2 970.1	2.7%	9
Electricity generation	586.2	3.4%	6
Heat production	252.7	2.2%	4
CO_2 emissions	607.5	2.9%	5

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 9-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	N/A	–	N/A	N/A
Natural gas	N/A	–	N/A	N/A
Oil	N/A	–	N/A	N/A
Uranium	–	–	–	–

Notes: Statistics not available for Korea. Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- In the past, Korea's energy policy has focused on ensuring a stable energy supply to sustain economic growth. However, as the demand for lower carbon energy gradually increased, the government announced its energy transition roadmap in October 2017 that aims to adjust to focus more on energy policy towards reducing coal use and increasing use of renewables. In June 2019, **Korea's 3rd National Energy Master Plan** for a mid- to long-term (2019–2040) energy framework was announced with suggestions for sustainable development that fully considers the 3Es: energy, economy, and environment. The plan became the basis for the series of energy policies, suggesting the following major policy strategies which include a transition to a 'clean and safe energy mix.'
- In December 2020, the **9th Electricity Demand and Supply Plan** for five years (2020-2034) materialised from the 3rd National Energy Master Plan and the previous plan of renewables. In December 2017, the government released the **3020 Renewable Energy Initiative Implementation Plan**. According to the plan, renewable energy's share of the energy mix will increase from its level of 7% in 2016 to 20% by 2030, through the provision of 49 GW in new generating capacity. Additionally, the 3rd National Energy Master Plan set the share of renewables in the power generation mix to be expected to increase to 30-35% by 2040. On the other hand, coal-fired generators that have been in operation for 30 years will be abolished and converted to LNG fuel. **Affected by this influence, the 14th Natural Gas Demand and Supply Plan** for fifteen years (2021-2034), which was released in April 2021, shows the annual average increase in demand for city gas and power generation at 1.73% and 0.48%, higher than the 13th plan.
- Korea has been paying attention to hydrogen as one of the new future available resources for low-carbon conversion of existing industrial processes. In January 2019, the government announced the **Roadmap to Promote Hydrogen-based Economy**, aiming to become an exemplary hydrogen economy leader. The government has been enforcing the Hydrogen Economy Fostering and Hydrogen Safety Management Act since February 2021 to promote the development of the hydrogen industry efficiently and to determine matters related to safety management. In response to the government's hydrogen economy policy, private companies have continued investment and leading groups are trying to formulate a hydrogen-value chain. The Korea H2 Business Summit, which is a private consultation body for the hydrogen economy, was launched with the participation of 15 Korean companies such as Hyundai Motor, POSCO, SK, and Hyosung in September 2021.
- As the COVID-19 pandemic caused structural changes in society, it has forced people to re-evaluate the effect and urgency of the climate change crisis. The government announced the **Korean New Deal** in July 2020 and the **Korean New Deal 2.0** in July 2021, presenting the 'Green New Deal' as one of the main axes to expand the scale of government-private investment. In these policies, $53 billion of financial support with institutional improvement will be on progress for the Green New Deal by 2025, which includes expansion of eco-friendly vehicles and commercialisation of CCUS.
- In December 2020, Korea **released the 2050 Carbon Neutral Strategy** after the declaration of carbon neutrality by 2050 in October 2020. In this strategy, the government mentioned that GHG emissions reduction will be promoted in all areas of the economy and an institutional base will be intensified for carbon neutrality. In April 2021, Korea announced it will end all public financing for new overseas coal-fired power plants at the Leaders Summit on Climate. In May 2021, the government established the Presidential Committee on Carbon Neutrality. This committee released its upgraded road maps in two scenarios for the 2050 carbon neutrality goal in October 2021 with the announcement of a strengthened CO_2 emissions reduction goal, which is from 26.3% to 40% by 2030 compared with 2018 levels.
- Meanwhile, Korea elected a new president through the presidential election on March 9, 2022. The Presidential Transition Committee announced that the new government plans to consistently foster the energy industry and seek a feasible energy mix including prospects for the utilisation of nuclear power. The new government started on May 10, 2022.

Note: Policy context and notable developments are current as of May 2022.

Scenarios in the 8th Edition

- This edition of the *Outlook* considers two scenarios. The hypothetical pathways presented in the *Outlook* are intended to provide reference material to support APEC member economies in navigating the uncertain energy landscape.
- **The Reference scenario (REF)** reflects recent trends and current policies in place or planned to capture the evolving nature of the energy system. Based on the basic premise of Korea's population and economic growth by international organisations, this scenario has been prepared with reference to Korea's 3rd National Energy Master Plan announced in 2019, specific government plans released thereafter (till the end of 2021), and reports from international organisations such as the IEA. In this scenario, Korea expands renewables, while lower coal power and gradually slowing oil and gas consumption growth throughout the outlook period (2018-2050).
- **The Carbon Neutrality scenario (CN)** investigates a hypothetical decarbonisation pathway through 2050. The presidential committee on carbon neutrality in Korea released Korea's 2050 Carbon Neutral Scenarios in October 2021. This includes two policy road maps including scrapping coal-fired power generation to achieve Korea's carbon neutrality goal by 2050.
- Meanwhile, CN is slightly different from those scenarios in Korea as some limits on the energy efficiency and decarbonisation measures have been implemented across all APEC economies. Although there are differences in some factors that affect the magnitude of the results, the basic policy direction in Korea's scenarios has been incorporated into the assumptions of CN. Over the outlook period, Korea shuts down coal power and reduces its oil and gas supply, while solar and wind power and energy efficiency improvements will be further strengthened.
- CO_2 emissions do not reach zero in 2050. The remaining emissions highlight the magnitude of CO_2 additional measures, including removals, that would be required to reach 'full' carbon neutrality.

Table 9-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Korea

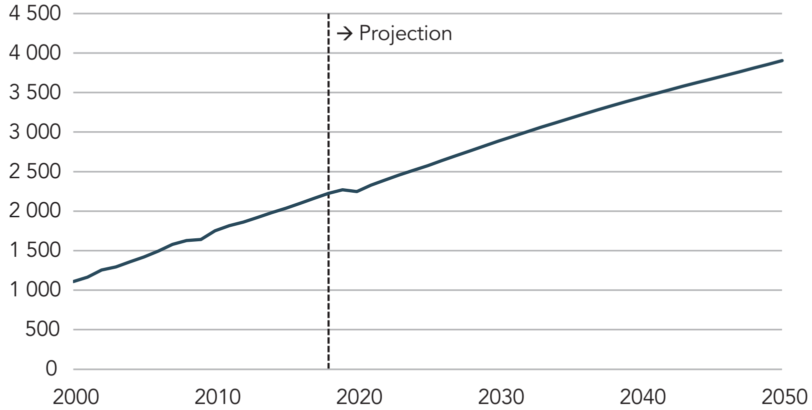
Table 9-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium), GDP: World Bank, IMF.	• Population: (UN medium), GDP: World Bank, IMF.
Buildings	• Reinforcement of energy efficiency standards for home appliances and building insulation equipment	• Improvements of energy efficiency and expansion of fund support for ZEBs (Zero Energy Buildings)
Industry	• Gradual improvement for energy efficiency through incentives for industry • Implementation of EERS (Energy Efficiency Resource Standard) to public suppliers • FED at an average annual growth rate of 0.34% in heavy industry (iron and steel, chemicals) along with gradual energy transition to lower carbon resources.	• Expansion of EERS through adjustment of the reduction target upward • Applying new technologies for making steel, cement and chemicals (e.g., hydrogen reduction process, CCUS by using gas separation membranes). • Increasing use of low-carbon fuels such as hydrogen.
Transport	• Decrease of diesel consumption and increase of LPG, electricity, and hydrogen vehicles.	• Scaling up deployment of various mobilities such as electricity vehicles, two wheelers, and LNG-fueled ships.
Power and heat	• Decrease of coal power generation and expansion of renewable and LPG power generation • 20% of total power generation from renewable sources by 2030	• Phase-out of coal power generation and acceleration of wind and solar • Application of CCS technology to gas-fired power plants
Supply	• Following a combination of current trends and natural decline in hydrocarbons. • Refinery expansion to cope with increasing demand.	• Making a projection of fossil fuels which is driven by domestic demand trends. • Reduction of refinery utilisation to meet declining demand over the projection.
Climate	• Trying to keep CO_2 emissions 536 million tonnes CO_2-eq by early 2030.	• Carbon neutral economy by 2050

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

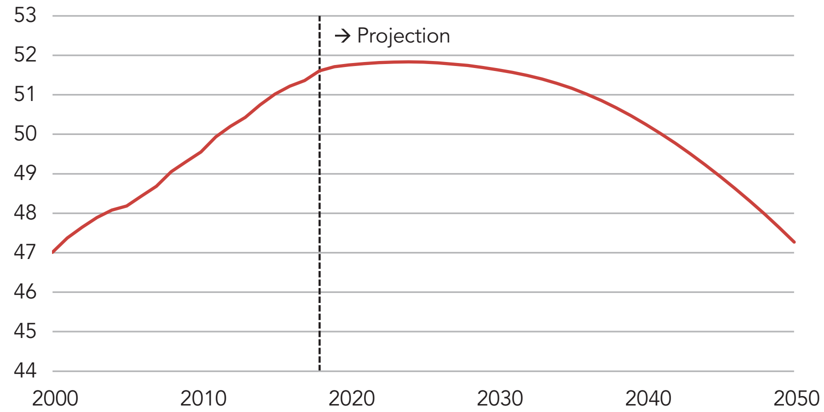
Macroeconomic backdrop

Figure 9-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 9-2. Population in millions, 2000-2050

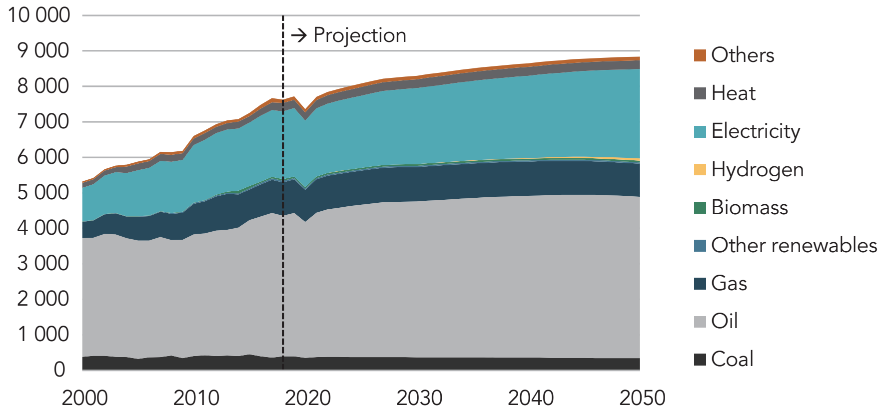


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- The Korean economy, which was stagnant due to the 1997 foreign exchange crisis, rebounded strongly after 1999 and continued to grow in the 2000s. Exports showed a steep increase under the progress of semiconductors and electronic products except for provisional decline in the 2000s. As of the end of 2018, the export amount exceeded US$600 billion.
- Except for the GDP growth rate of 0.8% in 2009, which was in the aftermath of the global financial crisis, Korea has generally maintained a stable growth rate of 2-3%. In 2018, Korea's GDP growth rate was 2.9%.
- Meanwhile, Korea is aging rapidly with the declining fertility rate, though the total population has been increasing since the 1950s due to the influence of the baby boomer generation. The population density of Korea was 514 people per km^2 as of 2018. The population density in the metropolitan area is increasing.
- Over the outlook period (2018-2050), there are no drastic structural changes in the economy in terms of GDP trend. Although GDP is steadily increasing, the economic growth rate continues to slow down in the long run. Meanwhile, GDP in 2020 fell temporarily to –1% due to the COVID-19 pandemic. However, it is expected to rebound later with a gradual economic recovery. Structural changes such as demographics are considered in the background of this GDP forecast. The major changes to be expected are a decrease in the working-age population and a decrease in capital due to an increase in the proportion of dependents.
- The total population in Korea steadily declines in the late 2020s, though it will increase at a moderate rate until the late 2020s. The background of the population decline from the late 2020s is mainly the rapid aging of the population due to a relatively high life expectancy and the natural decrease of the population due to the low birthrate.

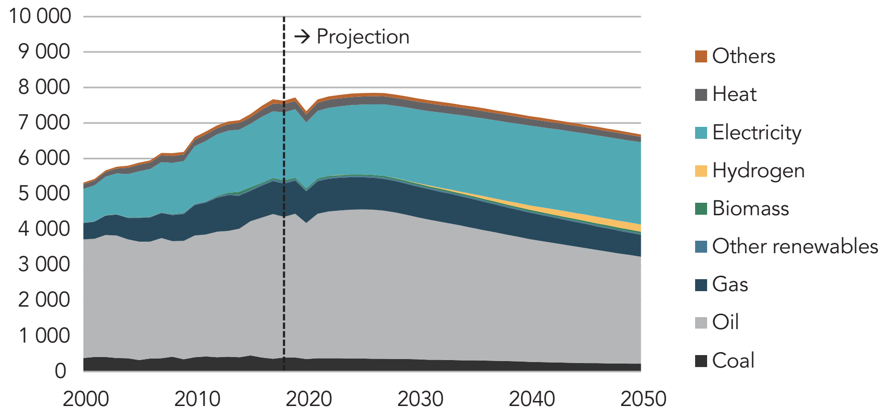
End-use energy demand

Figure 9-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 9-4. Energy demand in CN, 2000-2050 (PJ)

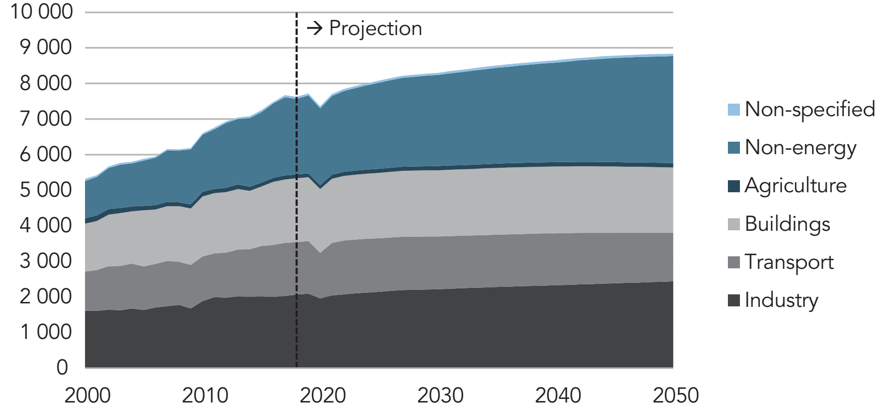


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Historically, Korea's economic growth including the development of industries and technologies changed the main energy source for business and daily life from coal to oil and electricity. Additionally, the new awareness of environmental and energy problems has gradually increased the proportion of gas, heat, and renewables. This recognition also means that the focus of energy policy is to shift from supply expansion to demand management.
- Specifically, energy demand has been dominated by oil and electricity since the 2000s. In 2018, oil accounted for 52% and electricity represented 25% of energy demand. In the case of oil, the proportion of gasoline and diesel for transportation and industry is much higher than that of buildings. In electricity, the proportion of industrial consumption is higher than that of other uses, accounting for more than half.
- Although total end-use energy demand was temporarily impacted in 2020 mainly by a drop in oil demand of around 5.0% due to the COVID-19 pandemic, it shows steady growth in REF (2018-2050).
- Meanwhile, there is a gradual decrease from the mid-2020s in CN. This declining trend is mostly due to the relatively significant decrease in demand for coal and oil compared to REF. In the case of oil (petroleum products) consumption, it declines mostly for building heating and vehicles, which decreases more in CN compared to REF with faster growth of more efficient vehicles and fuel switching for heating applications.
- Electricity and hydrogen grow in both scenarios, reflecting the policy direction for energy transition. Hydrogen demand more than triples in CN, dependent on increased demand from the industry and transport sectors.

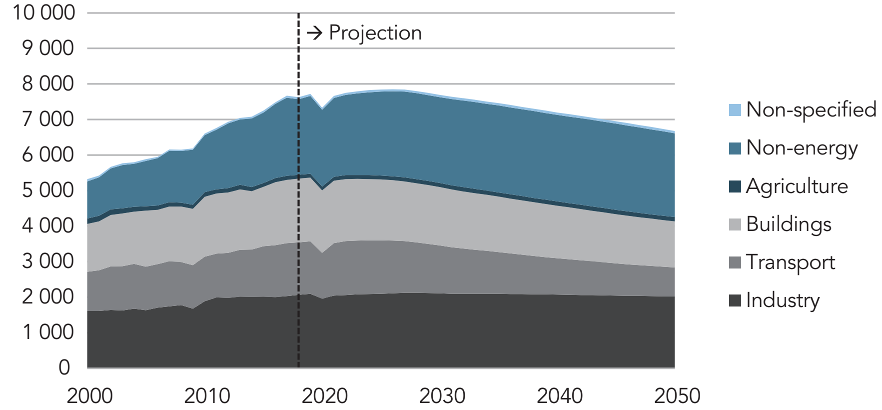
End-use energy demand by sector

Figure 9-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 9-6. Energy demand by sector in CN, 2000-2050 (PJ)

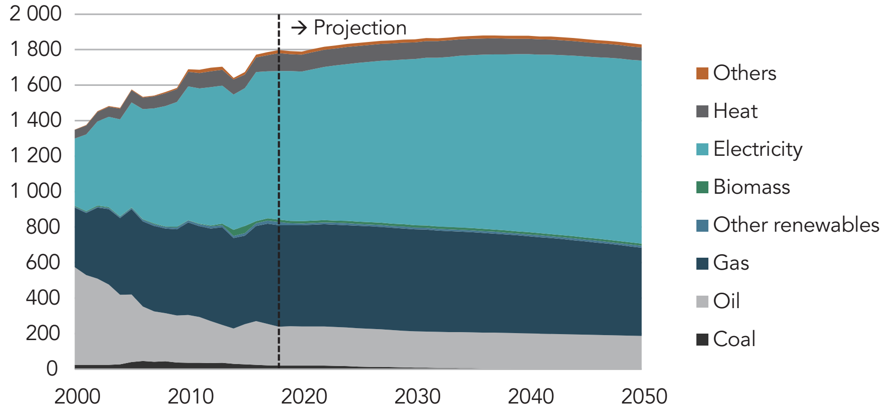


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- The largest shares of demand sectors in 2018 were non-energy (28%) and industry (27%). Non-energy includes energy consumed to make products such as plastics and fertilisers.
- Buildings (24%), transportation (19%) and agriculture (1%) compose the remaining end-use energy demand.
- From 2018 to 2050, end-use demand for almost all sectors increases slow in REF. Only the transport sector shows a decrease in energy demand.
- The share of industrial and non-energy demand increases from 55% (2018) to 62% (2050) in REF, reflecting the importance of these sectors to the Korean economy and the challenge of improving energy efficiency and carbon intensity.
- In both scenarios, improvements in energy efficiency will play a role in curbing energy demand. More advanced technologies for energy efficiency and expansion of its investment support is assumed in CN. Despite this demand management, energy demand is mainly driven by the industrial and non-energy sectors in both scenarios.

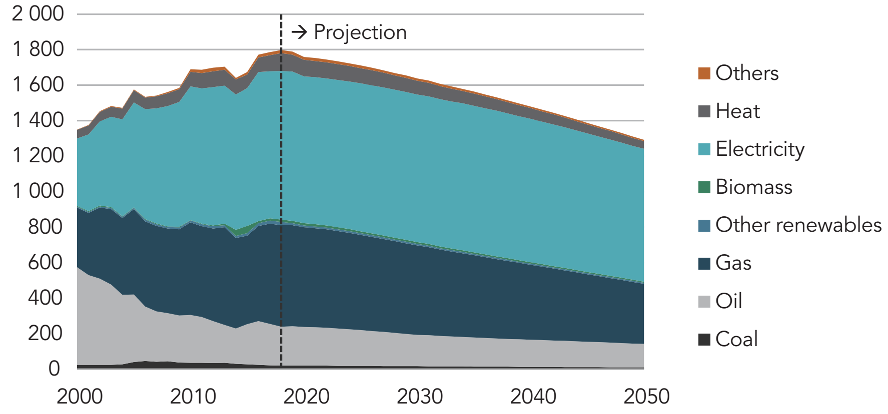
Buildings energy demand

Figure 9-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-8. Buildings energy demand in CN, 2000-2050 (PJ)

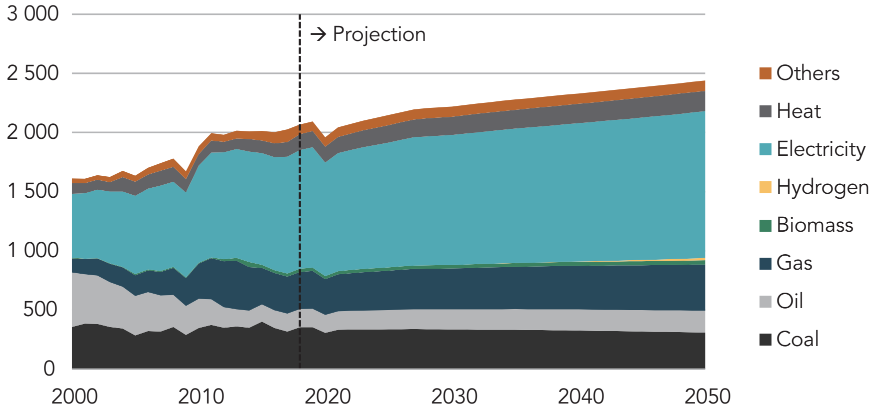


Sources: EGEDA, APERC analysis.

- Korea has significant climatic variability with relatively hot summers and cold winters. These temperature changes tend to increase the impact on energy consumption.
- Overall, buildings energy demand shows a gradual decrease from the late 2030s in REF while it has relatively steep decline in CN.
- Korea has trends of slowing population growth and continuous energy efficiency improvement. Regarding energy efficiency, managing efficiency standards and individual equipment (for example, home appliances and office equipment) supports sustained energy efficiency in REF. In CN, higher efficiency improvements (205) are assumed.
- In REF, electrification has an impact on electricity demand due to the increase in the expansion of cooling demand and the stock of home appliances. In CN, buildings energy demand is managed by more developed systems such as advanced buildings with energy efficiency and reinforced government efforts to improve the energy efficiency.
- Meanwhile, energy demand in the residential sub-sector gradually declines due to population decline in REF. However, energy demand steadily increases in the services sub-sector as the health, information and telecommunication, and leisure service industries grow.
- In CN, energy consumption efficiency of residential buildings will be enhanced by distributing high-efficiency electronic devices and expanding the labelling system to improve energy. Solar water heating and electrification of cooking will increase while oil products consumption gradually declines.
- In the services sub-sector, energy efficiency will expand through mandatory installation of BEMS (building energy management systems) and zero energy building systems.

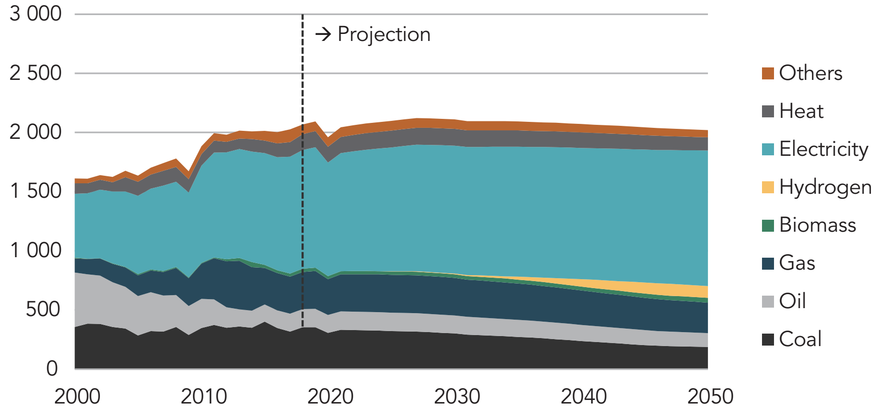
Industry energy demand

Figure 9-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 9-10. Industry energy demand in CN, 2000-2050 (PJ)

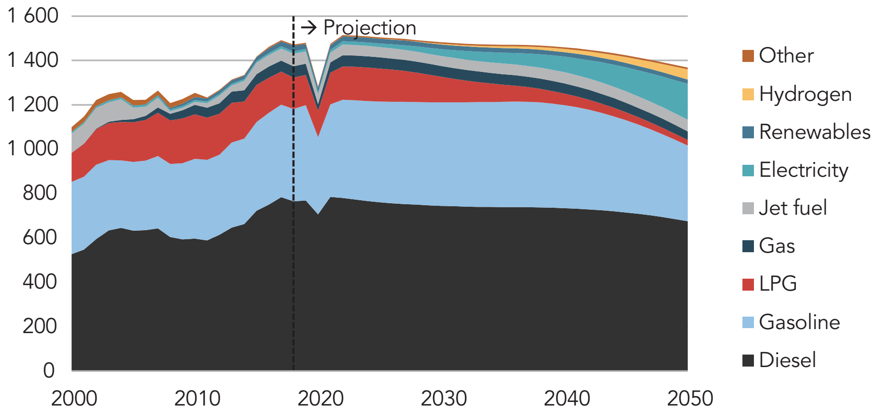


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Historically, Korea's industry has grown from 1 600 PJ (2000) to 2 060 PJ (2018) mainly due to the growth of energy-intensive sectors such as petrochemicals, non-metals, and steel. The outlier is the global financial crisis.
- In 2020, the COVID-19 pandemic temporarily reduced industrial energy demand and this temporary decline in demand occurred in almost all fuels and sub-industry sectors. However, the sharp decline will not continue and is expected to recover gradually from 2021.
- From 2018 to 2050, industry energy demand gradually in REF while gradually declines in CN. REF assumes an increase in manufacturing activities with no major improvements in efficiencies. CN assumes energy and material efficiency improvement of energy facilities and high efficiency of existing facilities.
- Electricity and gas are driving the increase as main fuels in energy demand of the industrial sector in both scenarios. Additionally, increased utilisation of by-product hydrogen and hydrogen reduction process is seen in CN.
- Korea's electricity, electronics, and semiconductor-focused export strategy is expected to remain steady. Additionally, the assembly metal sector will continue to make a significant contribution to energy demand in the industry sector.
- In the case of heavy industry, not only the efficiency improvement of the existing energy facilities, but also the active replacement of the existing facilities with high-efficiency facilities are made in CN.
- The use of hydrogen and electricity increases in CN.

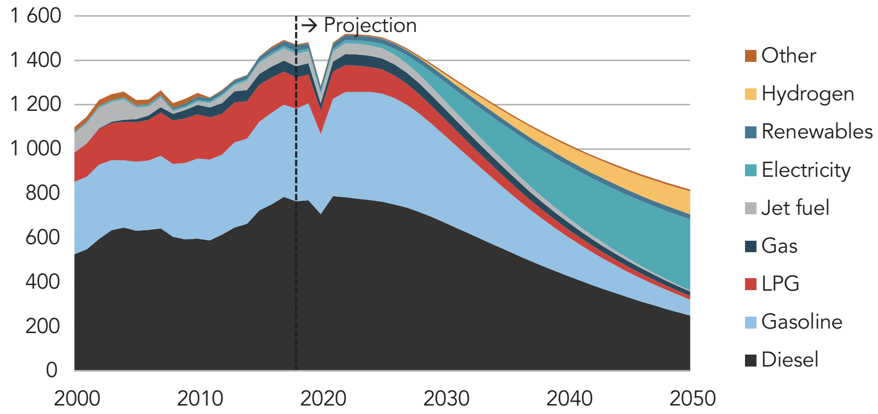
Transport energy demand

Figure 9-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 9-12. Transport energy demand in CN, 2000-2050 (PJ)

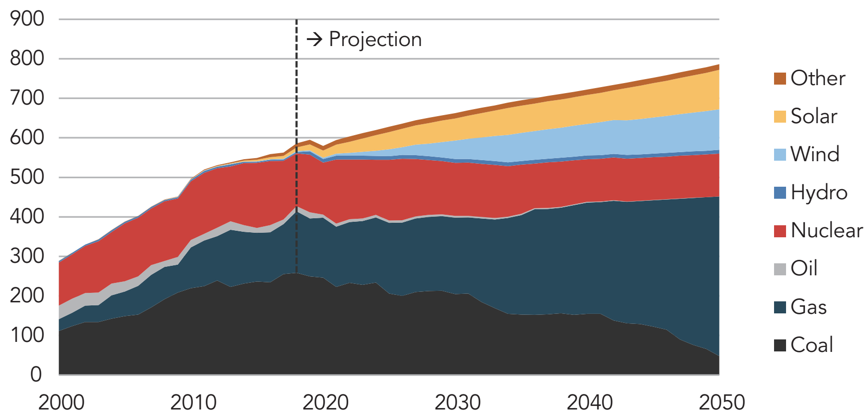


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Traditionally, energy demand in Korea's transport sector has been strongly affected by oil prices. In particular, demand slowed during the global financial crisis in 2008. Meanwhile, demand increased rapidly from 2015 to 2017 due to the low oil price trend that arrived in the second half of 2014. However, there was an unexpected impact from the COVID-19 pandemic in 2020, which led to a decrease in energy demand in the transport sector.
- Generally, transport sector energy demand grows moderately until the early 2040s in REF. However, stricter fuel efficiency regulations and enhanced technology continues from the mid-2020s leading to a decline in energy demand in CN.
- The share of diesel and gasoline consumption in the transport sector continues to decrease due to the replacement by more efficient vehicles. LPG consumption is also reduced because electric vehicles are rapidly increasing their market share thanks to fuel subsidies instead of LPG vehicles. In 2050, conventional internal combustion locomotives, which account for a dominant proportion in REF, are expected to decline sharply in CN, accounting for less than half.
- On the other hand, the supply of electric vehicles and hydrogen vehicles is expanding to keep up with consumer demand in both scenarios. In 2050, electric vehicles nearly double and hydrogen cars more than double in CN compared to REF. In CN, electric vehicles and hydrogen vehicles attain more than half of the vehicle stock.
- In REF, demand for energy in the road sector is expected to decrease after about 2040 due to a decrease in the number of vehicles with internal combustion engines, improvements in fuel efficiency of internal combustion engines, and the expansion of electric and hydrogen vehicles. Moreover, more than half of carbon-free or low-carbon vehicles, such as electric and hydrogen vehicles, will be supplied by 2050 in CN.
- Additionally, energy demand in the aviation sector is expected to be maintained steadily due to the expansion of airport infrastructure and an increase in domestic and foreign tourists in REF. Meanwhile, a significant proportion of jet fuel consumption is expected to be replaced by other fuels such as biojet fuel by 2050 in CN.

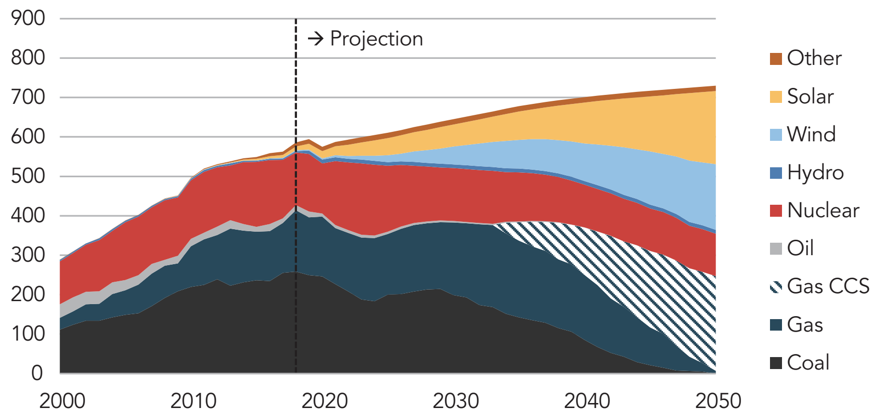
Electricity generation

Figure 9-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 9-14. Electricity generation in CN, 2000-2050 (TWh)

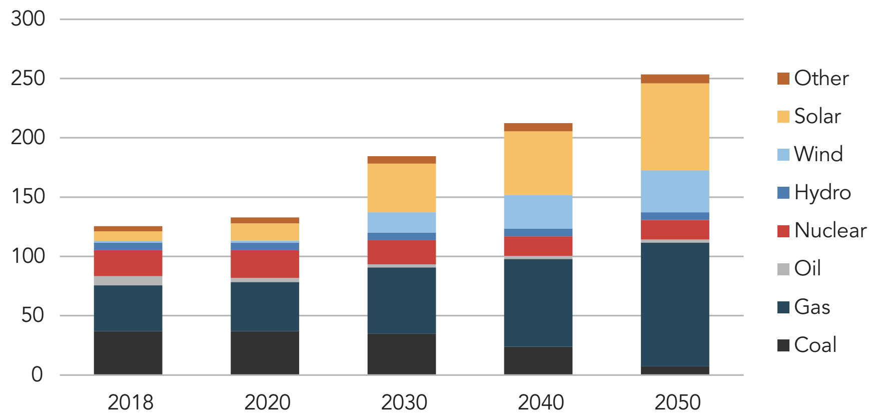


Sources: EGEDA, APERC analysis.

- As electrification progresses in sectors such as industry, transportation, and buildings, the total electricity generation steadily increases in both scenarios. For example, electricity demand in the transportation will increase the fastest due to the proliferation of electric vehicles.
- Additionally, nuclear and coal power generation is expected to decrease while renewable generation is expected to increase in both scenarios. Coal power generation will be phased out completely by 2050 in CN.
- According to the 3020 Renewable Energy Initiative Implementation Plan of Korean government, 20% of total power generation is expected to be produced from renewable sources by 2030. The share of renewable (wind and solar) energy generation will increase further within CN by 2050.
- As one of the bridge power sources for carbon neutrality, LNG power generation is expected to play a complementary role to renewable energy power generation in REF. Meanwhile, it is expected that gas with CCS will be applied to LNG power generation for reducing CO_2 emissions in CN. KEPCO, a public electric power corporation in Korea, started a R&D project to achieve commercialisation of CCS technology for LNG power generation in November 2021.
- By sector, the share of electricity utilisation will still be in the order of industry, buildings, and transport over the outlook period. Industries such as assembly metal and electric devices that are becoming more popular will increase electricity demand in the industry and buildings. Additionally, electricity will significantly replace diesel and gasoline, accounting for 12% in REF and 39% in CN in 2050 in transport. As a result, it is expected that the difference of the electricity generation in CN will be close double that of REF in 2050.
- The distributed power system will also be expanded. The Korean government expects that more than 15% of the power generation will be supplied as a distributed power generation system by 2035.

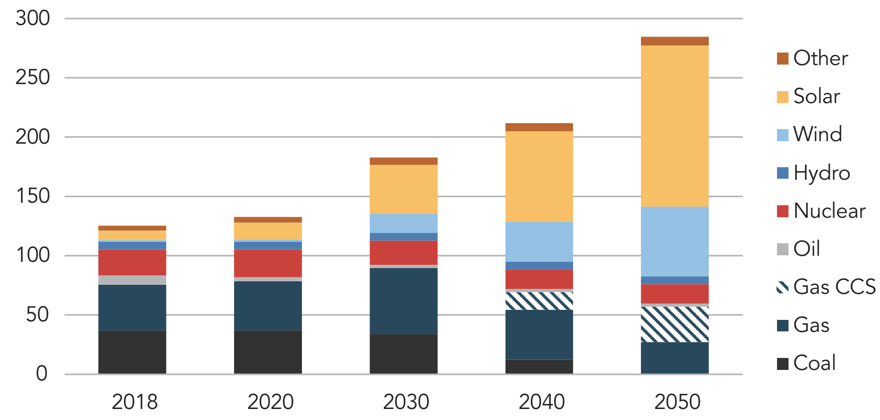
Generation capacity

Figure 9-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 9-16. Generation capacity in CN, 2018-2050 (GW)

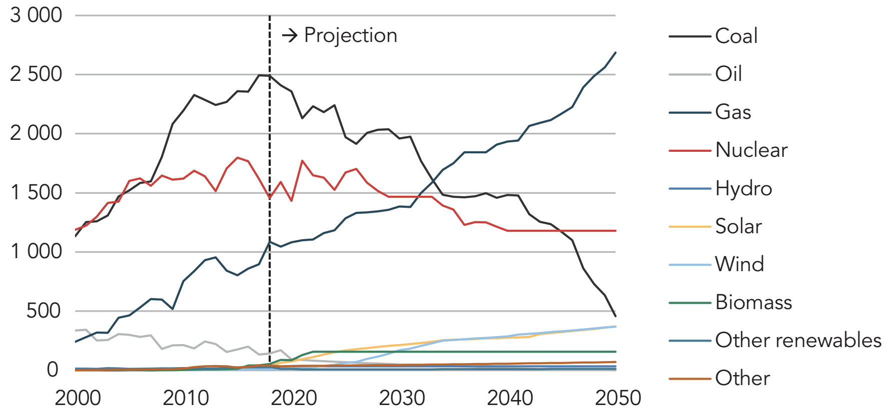


Sources: EGEDA, APERC analysis.

- New nuclear generators will be operating by the mid-2020s, and facility capacity will increase, but it is expected to decrease gradually as older nuclear power plants are decommissioned. Despite this trend, nuclear power will still contribute to carbon-free generation during the outlook period as one of the stable power supply facilities.
- Coal capacity is expected to gradually decrease as coal power plants whose design life have expired are phased out in REF. Coal power plant capacity is completely phased out by 2050 in CN.
- This deficit is expected to lead to an increase in capacity due to the policy support for renewable power generation technology and the large-scale renewable energy investment plan. In 2050, the share of renewables (wind and solar) is close to half of the total capacity in REF whereas it is expected to take a dominant position for a low-carbon economy as it increases to more than two-thirds in CN.
- Additionally, gas power generation will serve as a bridge for energy transition in REF, but it is coupled with CCS in CN. In both scenarios, the role of gas or gas CCS is important, assuming that government policies restricting new entry and continued operation of nuclear and coal power plants are maintained. In particular, the extent to which gas or gas CCS capacity fills the gap between the reduction of base generation and the expansion of renewable generation distinguishes REF and CN.
- Meanwhile, Korea appreciates the potential for hydrogen to become a part of its power generation capacity on condition that its related technology is commercialised. If hydrogen is consumed for power generation, it may be mixed with gas or partially replace gas or gas CCS capacity in both scenarios.

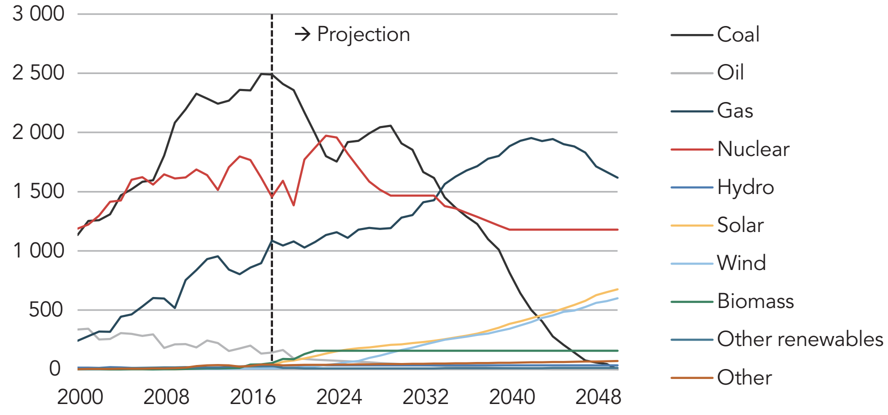
Fuel consumption by power sector

Figure 9-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 9-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

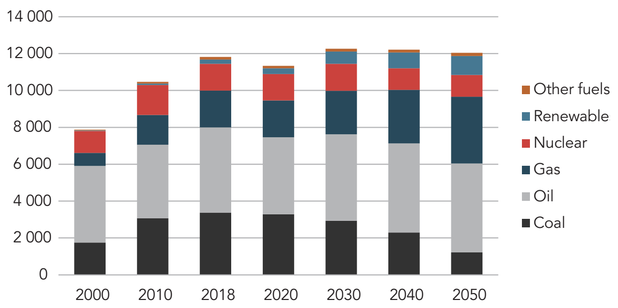


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- Consumption of coal power decreases in stages with the abolition of old power plants in REF while declining sharply in CN.
- Gas power consumption continues to increase in REF, while it tends to decrease slightly after 2040 in CN. This is the impact of replacing gas consumption with the increase of renewables such as solar and wind power.
- Consequentially, the order of fuel consumption by power sector in 2050 is expected to be as follows. In REF, the proportion of gas is relatively high, that of nuclear and renewables is at a similar level and that of coal and oil has the lowest.
- In CN, the share of gas and renewables is the highest with similar levels, a smaller amount of nuclear (uranium), while coal and oil are negligible.

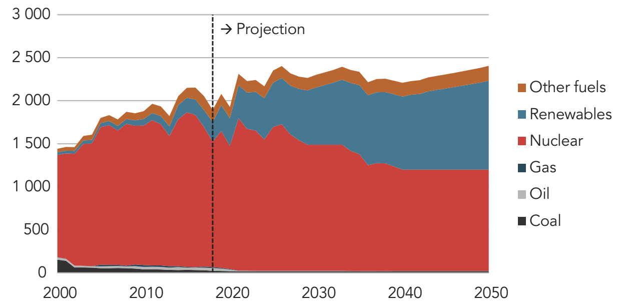
Energy supply in the Reference scenario

Figure 9-19. Total energy supply in REF, 2000-2050 (PJ)



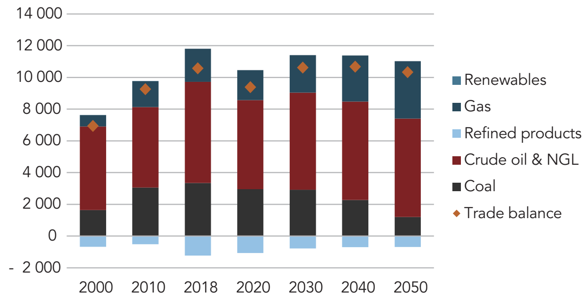
Sources: EGEDA, APERC analysis.

Figure 9-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-21. Net energy trade in REF, 2000-2050 (PJ)

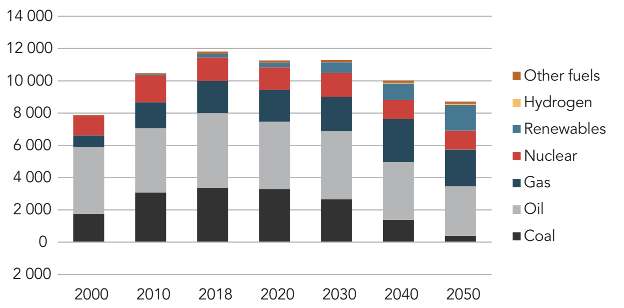


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- While total energy supply remains flat in REF during the outlook period, there are notable changes to the fuels in the supply mix. Specifically, renewables and gas increase at the expense of nuclear and coal.
- Coal traditionally supplied the industrial sector and thermal power generation, making up a third of supply in 2018. However, Korea's 3rd National Energy Master Plan (2019–2040) set the direction to drastically reduce coal power generation in order to respond to the greenhouse gas problem. This trend is expected to reduce coal's role during the outlook period to 4.0% in 2050. Gas will replace much of the coal decline, increasing about 80% over REF. Meanwhile, oil supply will remain largely stable over the outlook period.
- Most Korean energy production is nuclear and renewable energy. The Korean government stated that it plans to gradually reduce nuclear power by not extending the lifespan of old nuclear power plants and not promoting new nuclear power plant construction through the 9th Electricity Supply and Demand Basic Plan (2020-2034). This reduces nuclear production by a sixth in 2050 compared to 2018. Growth in solar and wind deployment leads to a more than tripling of renewables production.
- Net energy imports are flat through REF, as declines in coal and petroleum product imports are offset by increases in gas imports.
- Korea is one of the world's largest importers of oil and gas and is working to improve its energy security. Korea is improving measures to prepare for changes in demand such as diversifying the natural gas import portfolio. This leads to expanding flexibility of energy management and to providing stable imports to support energy transition policies.
- Korea is a key exporter of refinery products to global markets. These exports fall by half in REF, as refinery output is increasingly used to meet domestic demand.

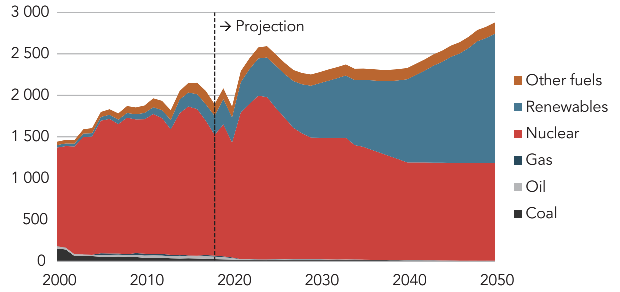
Energy supply in the Carbon Neutrality scenario

Figure 9-22. Total energy supply in CN, 2000-2050 (PJ)



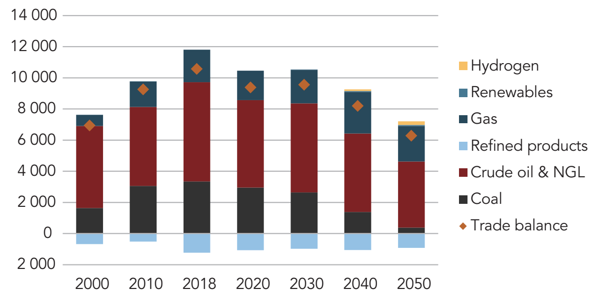
Sources: EGEDA, APERC analysis.

Figure 9-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-24. Net energy trade in CN, 2000-2050 (PJ)

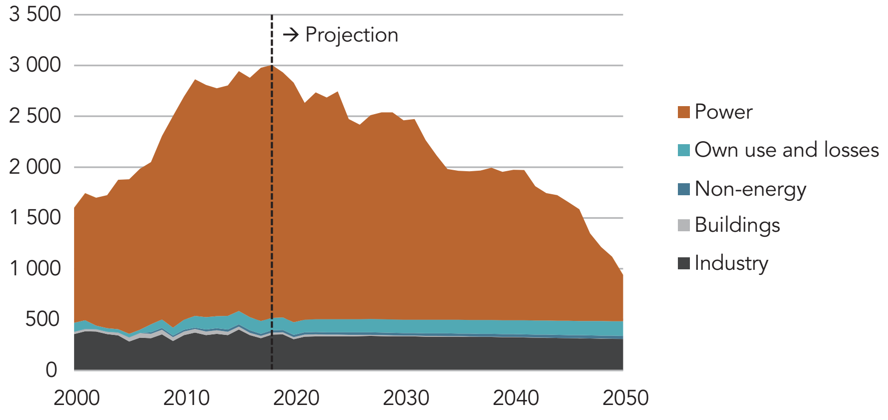


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, energy supply decreases from the start of the projection. In particular, the share of renewable energy in CN increases compared to REF, while the proportion of coal decreases sharply as it approaches 2050.
- Like REF, nuclear and renewable energy account for most of the domestic energy production. However, the proportion of renewable energy increases rapidly as it approaches 2050.
- Although most of Korea's imports are still concentrated on oil and gas, the rapid growth of domestic production with renewables is expected to replace imports of oil and gas.
- If renewable energy is reliably produced on a large scale towards 2050, that could improve energy security, because Korea is one of the largest importers of oil and gas in the world. Relying excessively on foreign energy sources can be a vulnerable structure in terms of energy security when the commodity market is unstable in the external environment.

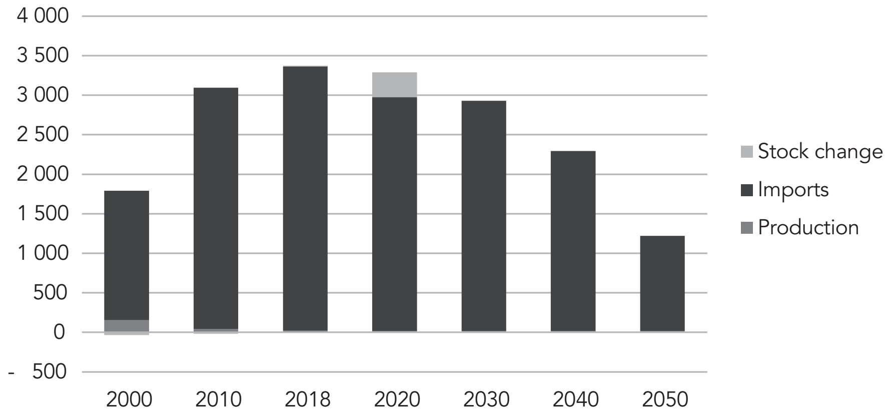
Coal in the Reference scenario

Figure 9-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

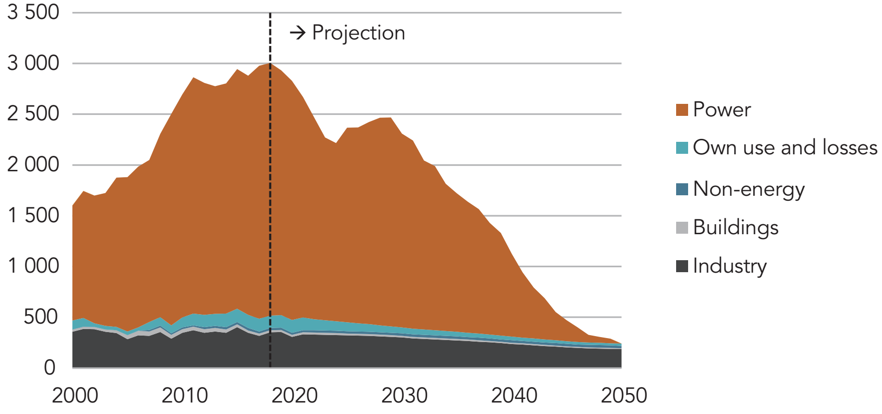


Sources: EGEDA, APERC analysis.

- Coal consumption increased rapidly over the last two decades for use in thermal power generation, peaking in 2018. However, policies targeting the reduction of coal use in the power sector reduces coal use in Korea by over two-thirds over the projection period.
- Although coal contributed to securing a stable power supply to support economic growth in the past, stringent environmental standards to reduce fine dust and global efforts to challenge climate change are accelerating the decline in the proportion of coal power over the outlook period.
- According to the 9th Electricity Supply and Demand Basic Plan (2020-2034), old coal power plants will be gradationally phased out and some of the coal power plants under construction will be abolished or converted to run of natural gas. However, coal will still account for a portion of the electricity supply in 2050.
- The industrial sector continues to use coal to fuel its steel and cement sectors but declines slightly due to fuel switching.
- Coal supply in Korea is predominantly met by imports. Imports fall two-thirds over the projection period, in line with the reductions in consumption. A small amount of coal production coal continues throughout the projection.

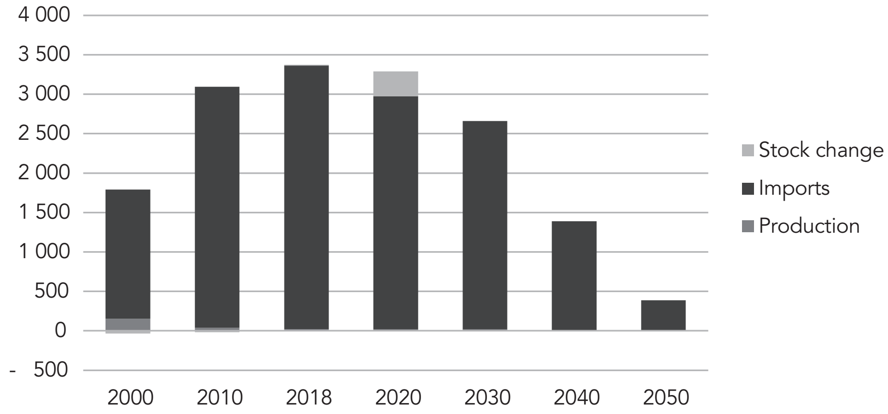
Coal in the Carbon Neutrality scenario

Figure 9-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

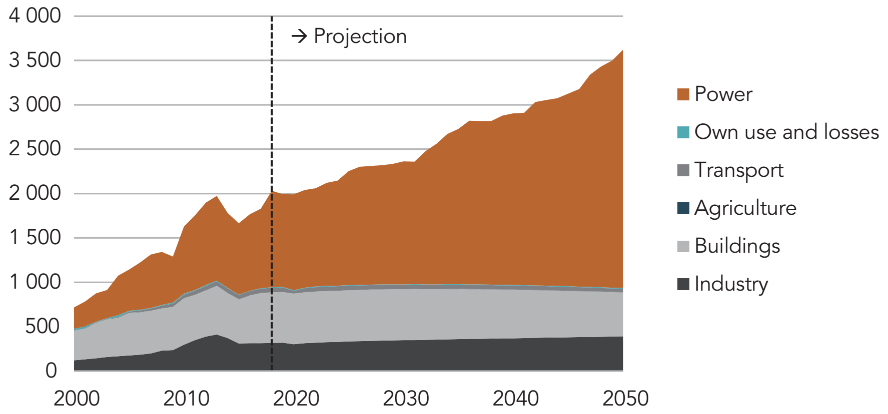


Sources: EGEDA, APERC analysis.

- Old coal power plants will be phased out and coal power plants that have not reached the expiration date will also stop generating power by 2050. In 2050, coal power generation no longer has a role. As coal consumption for power decreases compared to REF, the coal which is mostly imported from abroad will also be reduced.
- Unlike coal for power generation, demand for industrial coal slightly decreases by 2050, by applying new technologies for making steel, cement, and chemicals. In the iron and steel industry, Korea plans to develop a reduction process using hydrogen to replace carbon-based processes and expand crude steel with iron scrap electric furnaces. In addition, the cement industry will continue to replace bituminous coal with other energy sources in the production of cement.

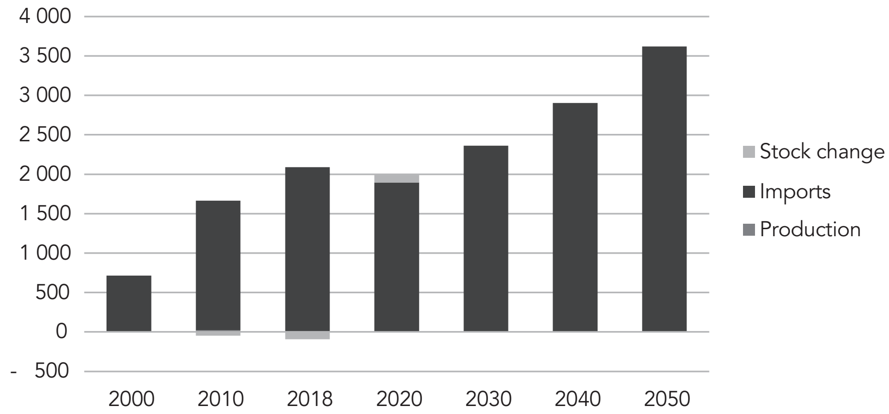
Natural gas in the Reference scenario

Figure 9-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

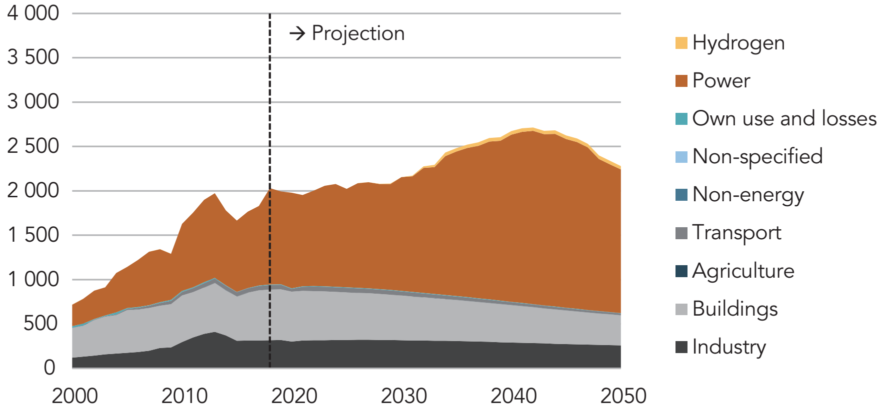


Sources: EGEDA, APERC analysis.

- Natural gas use in Korea has grown significantly over the past two decades, mainly on the back of use in power generation and industry. Gas consumption growth in REF continues to be driven by these sectors, growing three-quarters over the projection period.
- The share of natural gas for power generation continues to grow rapidly due to higher power demand and the coal-to-gas conversions of existing coal units. The need for new gas plants to replace nuclear retirements also plays a factor. With the pre-planned coal-fired power plants in the 9th Electricity Supply and Demand Basic Plan (2020-2034), the increase in natural gas supply will likely stagnate before early 2030.
- As old coal-fired power plants are retired one after another in the long-term, natural gas supply will continue to increase as a stable energy source after the early 2030s.
- Most natural gas will need to be imported. According to the 14th Natural Gas Demand and Supply Plan (2021-2034), Korean government continue to promote purchases in consideration of the diversification of LNG import routes and strategic partnerships, supporting the steadily increasing demand for natural gas.
- Meanwhile, the Korean government does not currently have plans to develop an additional LNG trading hub. However, the government plans to support LNG bunkering by constructing infrastructures and LNG re-export by expanding bonded areas.

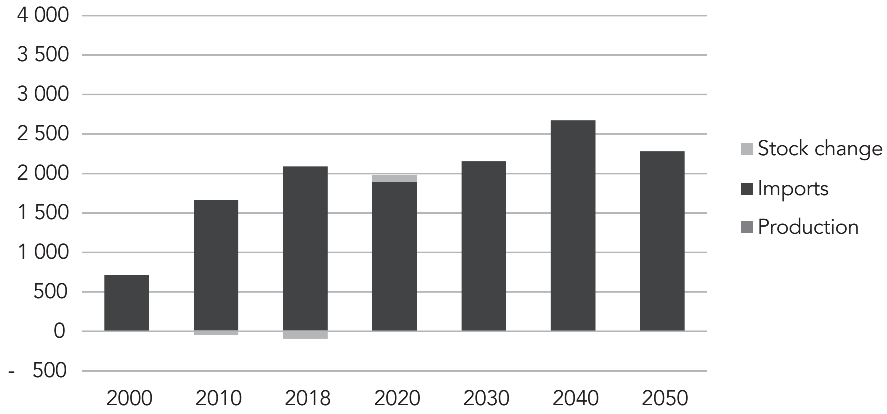
Natural gas in the Carbon Neutrality scenario

Figure 9-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

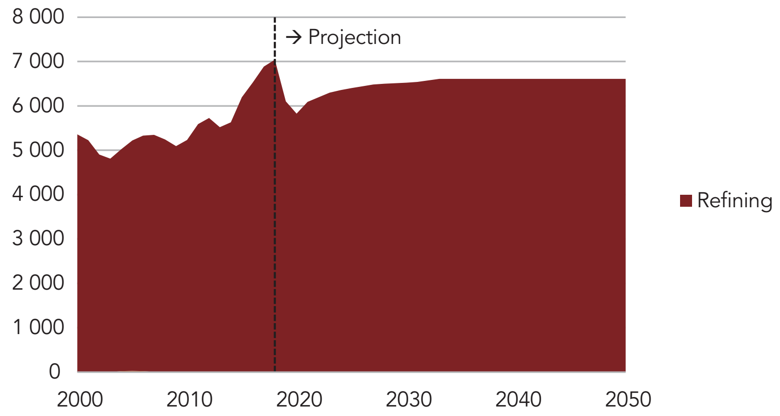


Sources: EGEDA, APERC analysis.

- By replacing natural gas through ambitious expansion of renewable energy, the proportion of natural gas decreases after the 2040s. This decline is expected to be particularly noticeable in the power sector. This is distinct from buildings, which tend to decline substantially throughout the outlook period, driven by trends such as accelerated electrification.
- In the buildings sector, it is expected that the growth rate of the number of houses slows down while the energy performance of buildings improves, while gas consumption for heating also decreases.
- During the projection period, imports of natural gas continue to grow until the 2040s. In the 2040s, imported natural gas decreases during the same period compared to REF. This is mainly based on the assumption that renewables will supplement the portion of reduced gas imports since the 2040s.
- Meanwhile, some of the imported natural gas will be utilised by domestic companies to produce hydrogen. For example, KOGAS, a public natural gas corporation in Korea, plans to promote domestic hydrogen production through natural gas as a pre-step to introduce green hydrogen into Korea from 2030. Thus, hydrogen supply chain infrastructure and R&D projects including CCS technology will be strengthened in order to smoothly supply extracted hydrogen from natural gas and to treat CO_2 in the production process compared to REF.

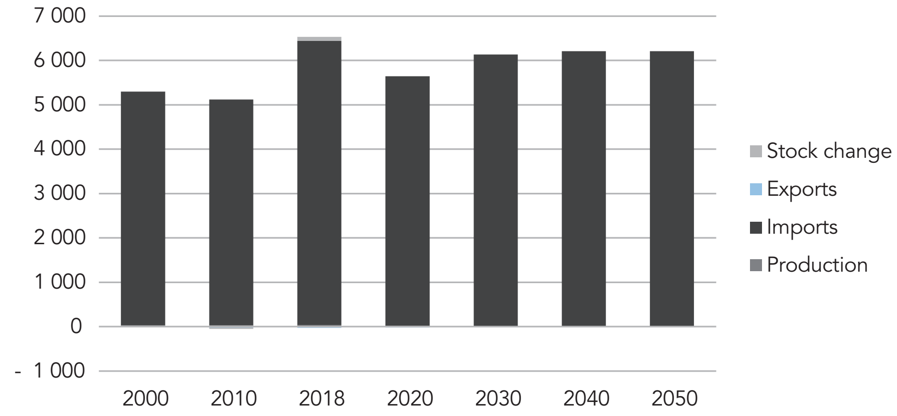
Crude oil and NGLs in the Reference scenario

Figure 9-33. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-34. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

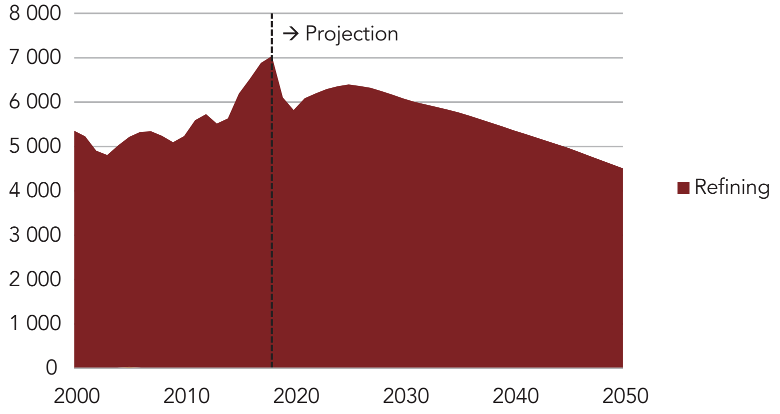


Sources: EGEDA, APERC analysis.

- Supply of crude oil and NGLs have grown steadily although they fluctuate up and down depending on oil prices and the global economic situation. From 2014 to 2018, the supply of petroleum products increased as consumption for industry and transportation surged in the short-term due to the expansion of petrochemical facilities and the sharp drop in international oil prices. This had a significant impact on the sudden increase in the imports of crude oil and NGLs in the mid-2010s.
- In 2020, COVID-19 brought an unexpected demand crisis for crude oil and NGLs. As the global economy contracted rapidly along with the declaration of a pandemic, the demand for oil plummeted.
- In REF, the normalisation of the petrochemical industry following the recovery of the real economy under post-COVID conditions is expected to continue.
- Korea's supply of crude oil is mostly dependent on imports. In 2018, almost all crude oil was imported as well and 74% of its imports came from the Middle East. The increase is expected to slow down due to a decrease in the supply of conventional vehicles.

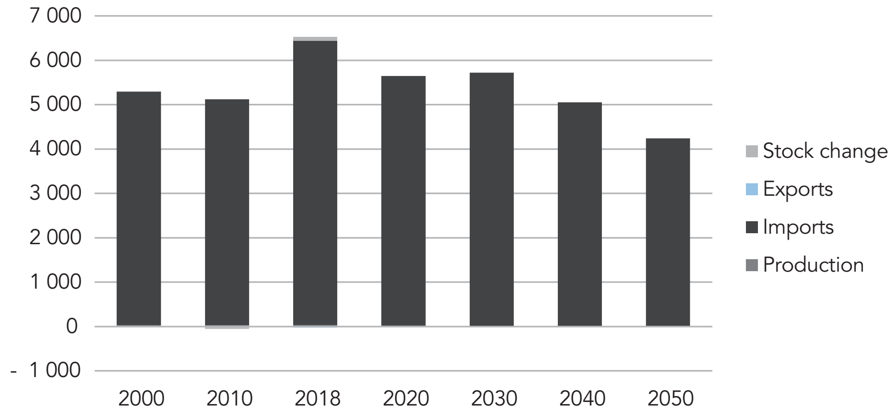
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 9-35. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-36. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

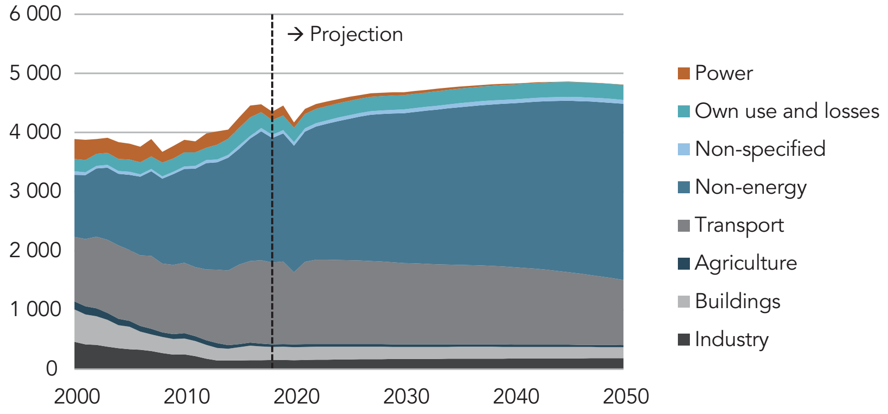


Sources: EGEDA, APERC analysis.

- Although there is a similarity with REF in that crude oil and NGLs mostly depend on imports, a continuous decrease of imports is expected for the energy transition trend.
- Specifically, slowing growth in the oil refining sector and the steeper expansion of renewable energy for carbon neutrality will create a continuing downward trend. This decreasing trend will be closely related to the trend of using refined products in transportation.

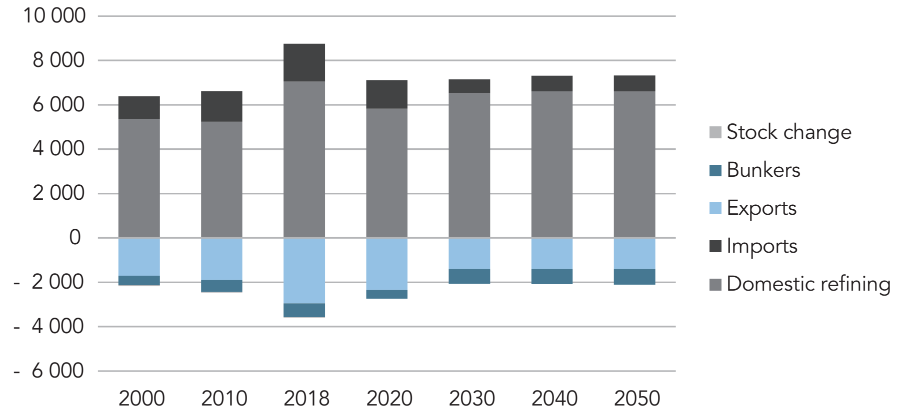
Refined products in the Reference scenario

Figure 9-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

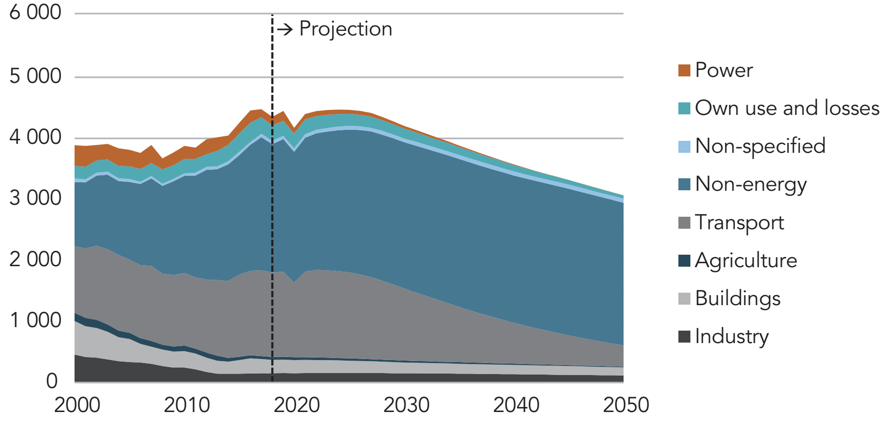


Sources: EGEDA, APERC analysis.

- The continuous increase in consumption for raw materials in the petrochemical industry is expected to drive demand for petroleum products in the non-energy sector. Specifically, the petrochemical industry in Korea will try to maintain competitiveness based on economies of scale, high productivity, and high value-added by-products.
- The supply to buildings will slightly continue to dwindle as consumption declines. This is mainly due to steady energy transition, insulation technology development, and improved device efficiency.
- Consumption of petroleum products by the transport sector will remain though there is a continued decline in conventional vehicles including diesel vehicles. The proportion of electric vehicles and hydrogen vehicles will gradually increase from gasoline and diesel vehicles, following the demand trend.

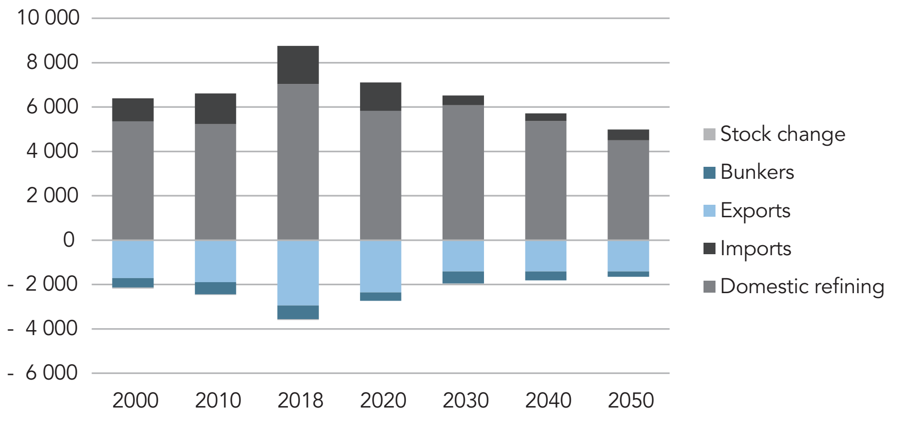
Refined products in the Carbon Neutrality scenario

Figure 9-39. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 9-40. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

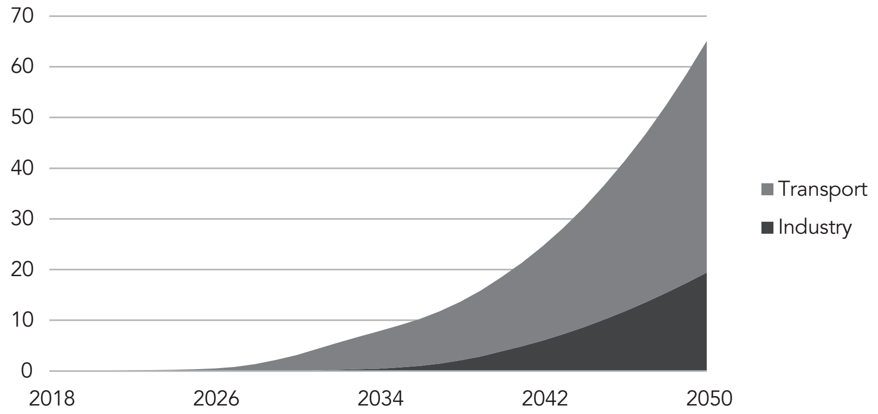


Sources: EGEDA, APERC analysis.

- Slowing growth in the oil refining industry and the much larger expansion of renewable energy and EVs contributes to a downward trend for consumption.
- Advances in EVs and hydrogen vehicles in CN lead to a drastic decrease in the supply of refined products such as gasoline and diesel. The fuel transition in the transport sector will be accelerated further compared to REF.
- Meanwhile, it is expected that the increasing trend will slow down in the non-energy sector and then turn into a downward trend. Social pressure on high-carbon industries such as heavy industries and increase of the petrochemical alternative industry for carbon neutrality contribute to the decreasing consumption. Specifically, private companies in this type of industry might need to convert fuel and raw materials based on the existing fossil fuel through the advancement of production processes and respond to the demand for bioplastics that replace the existing petroleum-based plastics.

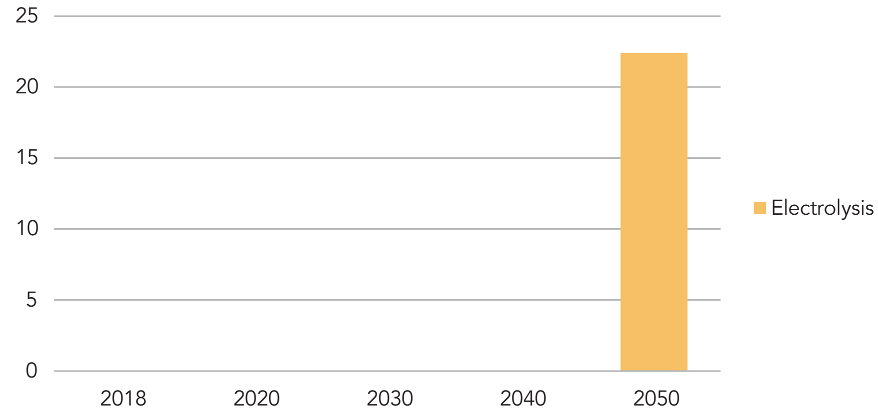
Hydrogen in the Reference scenario

Figure 9-41. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 9-42. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

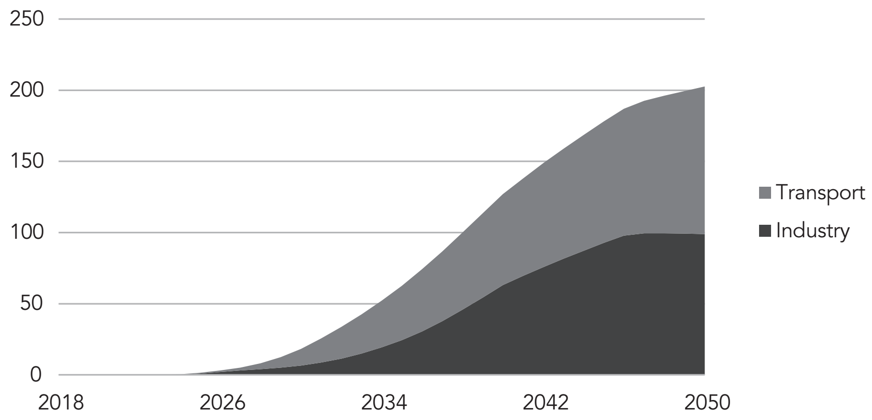


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- The Korean government announced its Hydrogen Economy Roadmap in 2019, and it is expected that domestic hydrogen consumption will gradually increase through investment by private companies. Some companies in Korea have unveiled their investment plans to build an entire value chain from hydrogen production to distribution, which stimulates user's demand for hydrogen and induces a virtuous cycle in the hydrogen ecosystem.
- As of 2020, 70 hydrogen charging stations are being built to build infrastructure, and hydrogen fuel cell vehicles are being expanded. Some of the demand will be supplied to hydrogen refuelling stations through hydrogen production.
- Hydrogen is also used as fuel in the hydrogenation process and production process in the oil refining industry. Private companies such as Hyosung-Linde and SK in Korea started their own projects that produce hydrogen as by product. The projects include the construction of liquid hydrogen plants to utilise by-product hydrogen that is incidentally produced in the petrochemical process or steelmaking process.

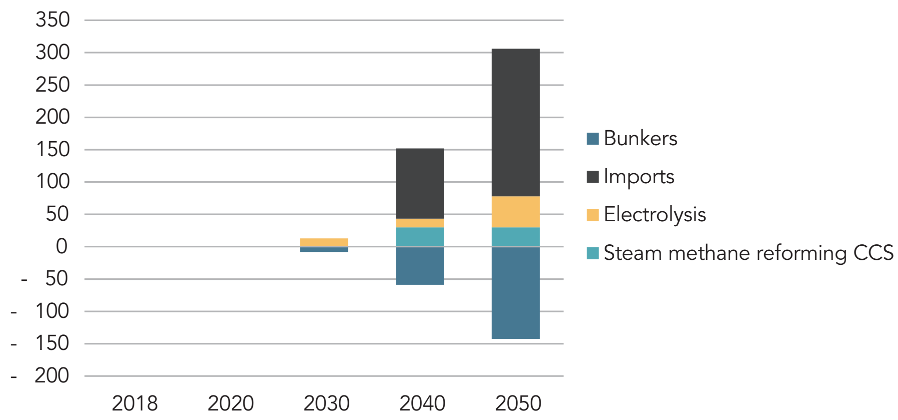
Hydrogen in the Carbon Neutrality scenario

Figure 9-43. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 9-44. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

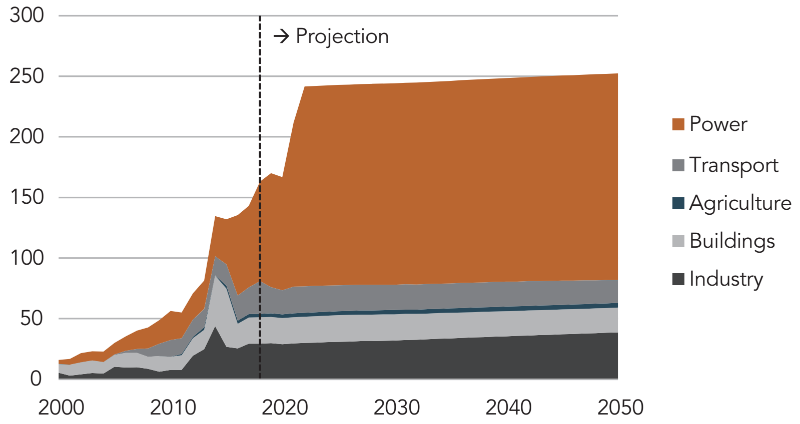


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- As the demand for hydrogen in the transportation and industry sectors grows, the supply of hydrogen will increase.
- By utilising imported, electrolysed, and by-product hydrogen, green hydrogen, blue hydrogen, and grey hydrogen are supplied in various ways. Compared to REF, the proportion and supply of blue hydrogen and green hydrogen significantly increases.
- In the transport sector, production of hydrogen vehicles is expected to expand, leading to increased consumption. For infrastructure, hydrogen refuelling stations will need to be to keep pace with the increasing stock of hydrogen vehicles.
- In the industry sector, technologies for using hydrogen, such as CO_2 reduction steelmaking will be introduced to replace coal for coke production with hydrogen. For the refining industry, hydrogen will be used as fuel in the hydrogenation process.

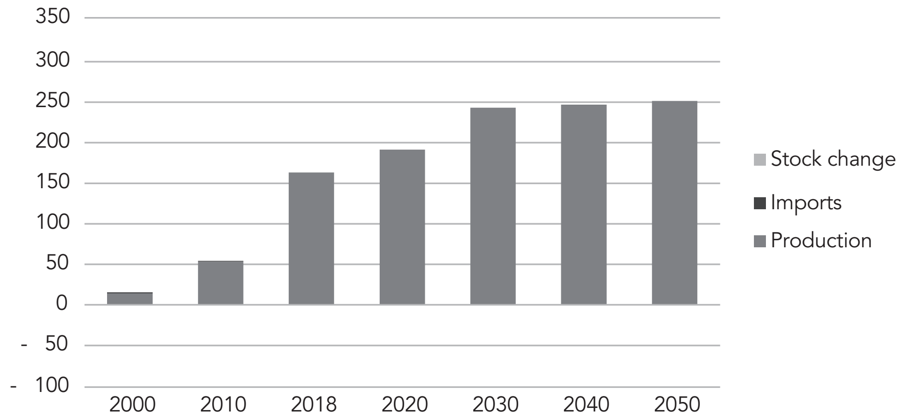
Bioenergy in the Reference scenario

Figure 9-45. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 9-46. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

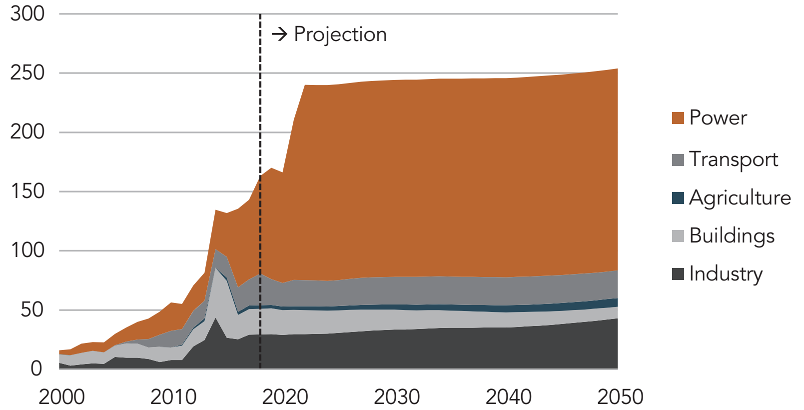


Sources: EGEDA, APERC analysis.

- Bioenergy has potential in Korea as one type of renewable energy, but it also has limitations due to the lack of resources. In terms of technology development strategy, biofuel production technology for transportation is relatively promising.
- According to 3020 Renewable Energy Initiative Implementation Plan by Korean government, renewable energy generation accounts for 20% of total power generation in 2030. The share of bio energy out of total renewable energy is expected to occupy a minor portion.
- The biodiesel blending ratio from 3.0% will be gradually raised to around 5% by 2030, expanding the Renewable Fuel Standard (RFS) in stages.

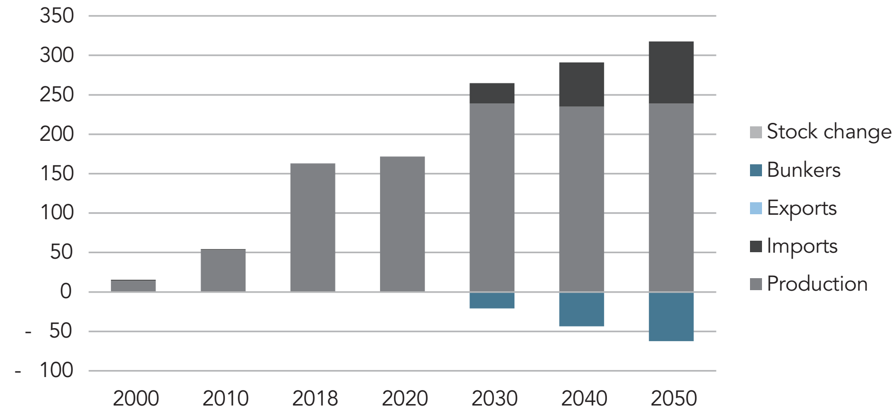
Bioenergy in the Carbon Neutrality scenario

Figure 9-47. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 9-48. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

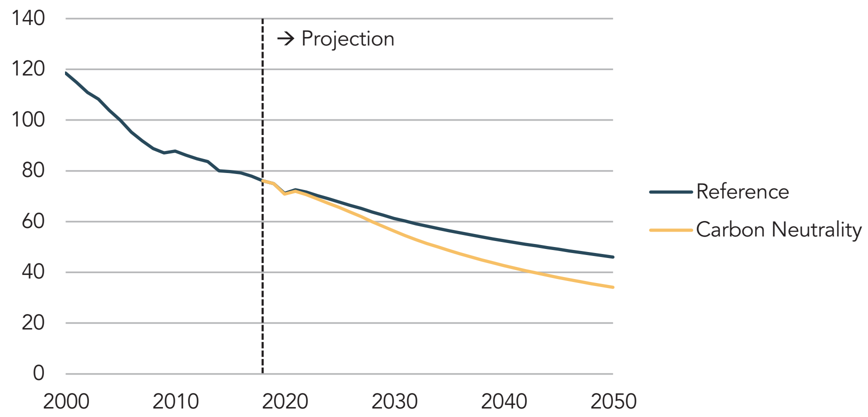


Sources: EGEDA, APERC analysis.

- Compared to REF, the proportion of bioenergy is expected to increase after 2030 as the proportion of renewable for carbon neutrality will be strengthened by 2050 and biomass-related technologies will be developed.

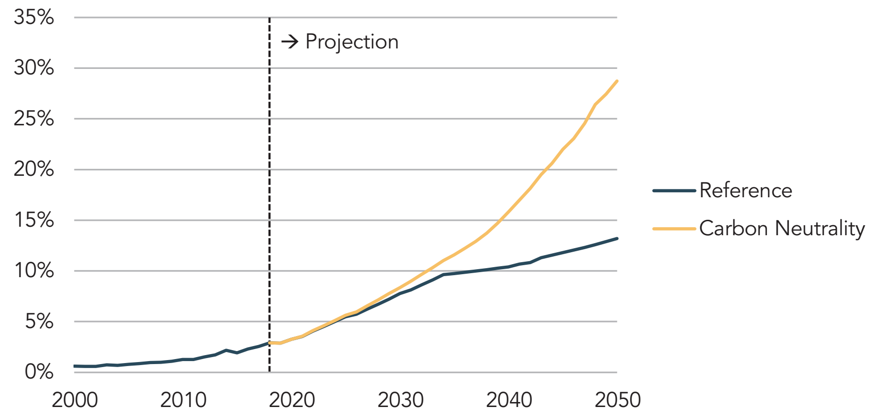
Energy intensity and modern renewables share

Figure 9-49. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 9-50. Modern renewables share in REF and CN, 2000-2050



Sources: EGEDA, APERC analysis. Note: Modern renewables includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

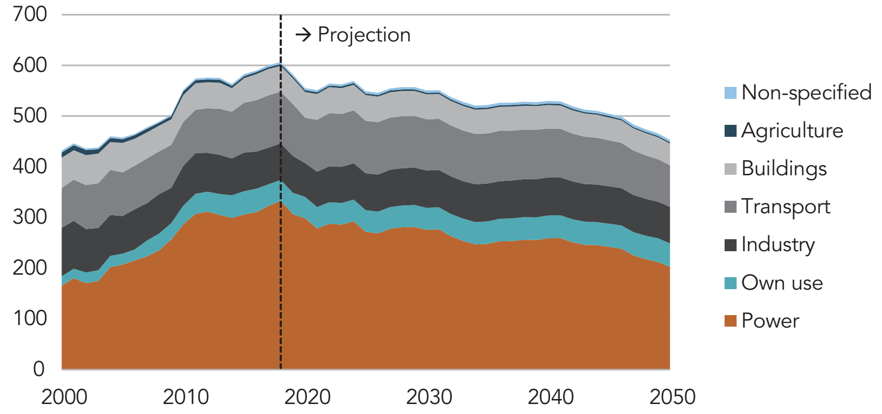
- Energy intensity tracks the relationship between GDP growth and energy consumption (excluding non-energy). In REF, the energy intensity in 2050 is 65% of what it was in 2005, while it is 65% less in CN. Korea will continue to strengthen its demand management policies in various ways.
- For example, the government expands the establishment of the Factory Energy Management System (FEMS) for energy-consuming places of business and supports the replacement of old boilers with high-efficiency boilers at industrial sites in connection with Energy Efficiency Resource Standards (EERS). In addition, demand management utilising data will be promoted through the distribution of Advanced Metering Infrastructure (AMI) such as smart meters and the high-efficiency home appliance distribution system will be persistently updated.

- According to the 2030 Renewable Energy Initiative Implementation Plan in 2017, renewable's share of the energy mix will increase from its level of 7.0% in 2016 to 20% in 2030 through the provision of 49 GW in new generating capacity. In CN, it is close to 25% with the rapid increase in the share of modern renewable energy generation after 2030, widening the gap with REF.
- The share of modern renewables increases in both scenarios, but additional renewable electricity capacity in CN leads to a marked increase through 2050.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

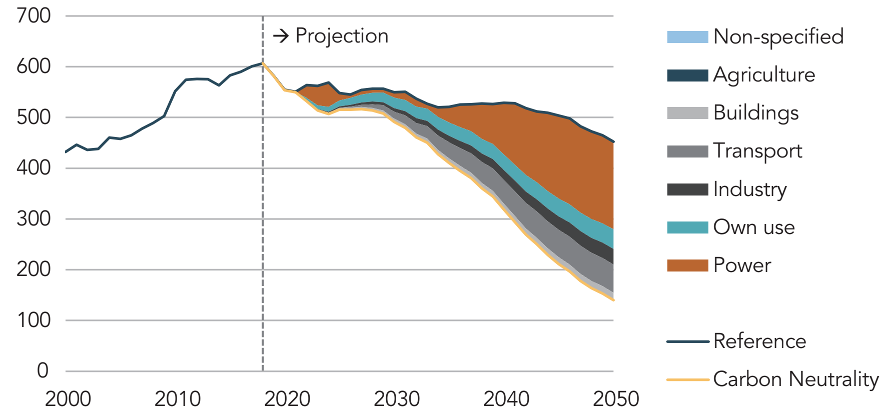
Gross CO_2 emissions

Figure 9-51. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 9-52. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

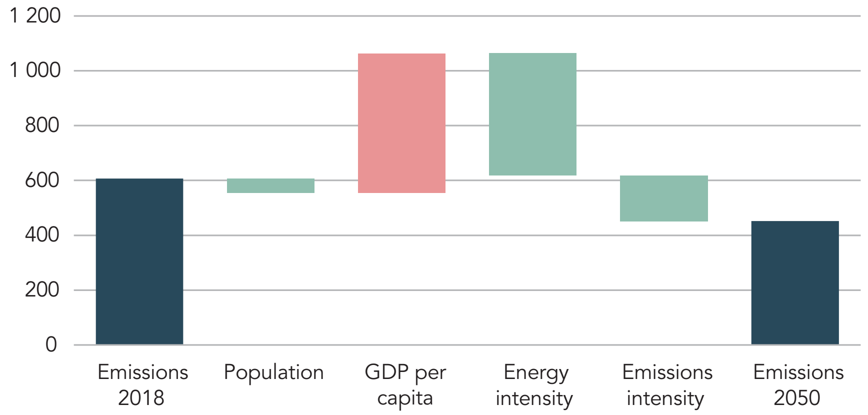


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Generally, reducing more fossil fuels and applying new technologies like CCS reduce carbon emissions in all sectors. CO_2 combustion emissions are trending down in REF. As expected, emissions fall even more in CN. From the base year, the reduced CO_2 combustion emissions by 2050 will be about three times larger in CN than in REF.
- The power sector shows the most scope for CO_2 reductions. In CN, the complete phase-out of coal power generation by 2050 and the application of CCS in LNG power generation achieve an absolute reduction in carbon emissions along with a steeper increase in renewable energy.
- In the industry sector, steelmaking and petrochemical manufacturing are the fundamental fields along with mobility, shipbuilding and semiconductors. Developing new technology and introducing industrial processes for change of product design can reduce CO_2 emissions more by improving energy efficiency in CN. For example, hydrogen-based CO_2 reduction steelmaking, biomass, and carbon capture can contribute to carbon neutrality.
- In transport, the supply of electric vehicles and hydrogen vehicles expands in CN. Transportation demand management such as expansion of public transportation will be strengthened in CN and contributes to reducing emissions.
- CO_2 emissions do not reach zero in 2050. The remaining emissions highlight the magnitude of additional measures or removals that would be required to reach 'full' carbon neutrality.
- Meanwhile, Korea announced new scenarios for 2050 carbon neutrality goal in October 2021. Compared with Korea's plan, CO_2 reductions in CN could be conservative because Korea is open to commercialisation of new technologies and considers non-energy impacts on CO_2 removal such as direct air capture, which are not included in CN.

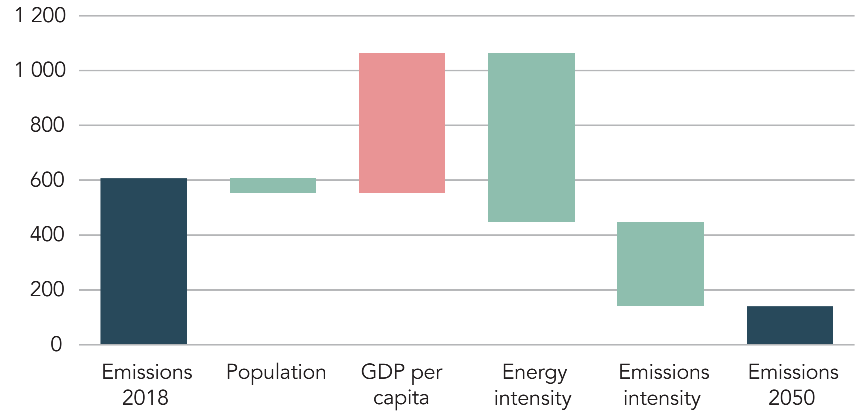
Components of CO_2 emissions

Figure 9-53. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 9-54. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Korea emitted around 587 million tonnes of CO_2 in 2018, which amounted to close to 3.0% of total APEC emissions. Although this quantity of CO_2 emissions is relatively small compared to some APEC economies, Korea ranks fifth in APEC after Russia and Japan. In both scenarios, energy intensity is the component that accounts for the largest share of reducing carbon dioxide emissions.
- Population and GDP per capita have the same contribution in both scenarios. The assumed decrease in the population due to a low birthrate and an aging population in the future will reduce emissions by 51 million tonnes. On the other hand, GDP growth increases emissions by 508 million tonnes. By 2050, the rate of increase in CO_2 emissions due to GDP growth is expected to reach 84% of the CO_2 emissions in 2018.
- In both scenarios, energy intensity and emissions intensity improves offset the increase in emissions from economic activity.
- In CN, energy intensity and emissions intensity are expected to contribute to further mitigating CO_2 emissions. In CN, energy intensity reduces CO_2 emissions by 38% more than REF.
- Additionally, emissions intensity improvement in CN is an 85% increase over REF. For example, expansion of renewable electricity generation or the spread of electric vehicles contribute to improving emissions intensity.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

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10. Malaysia

Highlights

Demand

- Increasing economic activity and population growth cause Malaysia's energy demand to nearly double, from 2 602 PJ to 5 166 PJ in REF. Malaysia's economy continues to rely heavily on fossil fuels for the outlook period.
- Energy demand in 2050 of CN is a fifth lower than REF levels, as electrification and energy efficiency reduce energy requirements. The share of fossil fuels falls to about half of the mix, and electricity rises to almost 40%.
- The transport sector remains the largest energy user in REF, while the industry sector replaces the transport sector as the largest energy user beyond 2046 in CN due to a slight decline from the transport sector in the last 5 years of the outlook period.

Supply

- Malaysia's energy supply almost doubles from 4 007 PJ to 7 606 PJ in REF. Gas remains its largest share of energy supply in both scenarios.
- Compared with REF, energy supply in CN is a fifth, or 1 437 PJ, lower by 2050, as efficiency reduces requirements in all sectors.
- Renewables supply more than triples in both scenarios as Malaysia deploys more renewable capacity to meet increasing electricity demand, particularly from the transport sector.

Power

- Malaysia's electricity generation increases over 2.5 times in REF and about 2.7 times in CN, with thermal generation continuing to be the dominant mode of generating electricity.
- Natural gas becomes the main source of electricity generation beyond 2030 in both scenarios as Malaysia embrace coal-to-gas switching to reduce its emissions intensity from the power sector.
- Total generation capacity reaches 67 GW in REF and 78 GW in CN, with fossil fuels accounting for more than two-thirds of total capacity in both scenarios.
- Malaysia reaches almost 19 GW of renewable capacity in REF and nearly 25 GW in CN.

CO_2 emissions

- CO_2 emissions increase almost 80% by 2050 in REF. In contrast, emissions rise and peak in 2027 before declining to 10% below the 2018 level in CN.
- Gas becomes the largest source of CO_2 emissions by 2050 in both scenarios due to its fuel transition role in the power sector.
- Malaysia's NDC target for a 45% improvement in greenhouse gas emissions intensity per unit GDP on an unconditional basis by 2030, compared with 2005 levels, is not achieved in either scenario. Emissions intensity increases slightly in the 2020s. However, CN emissions intensity fall a third under 2005 levels by 2050. Achieving its NDC target will require Malaysia to frontload energy efficiency improvements and deploy lower-emitting power capacity at a faster rate than shown here.
- While Malaysia continues to emit almost 200 million tonnes of CO_2, carbon neutrality is within reach if the economy utilises offsets through further advancement in energy efficiency and emissions intensity and pursues emissions reductions in non-energy sectors.

Trade

- Malaysia became a net energy importer in 2019 and remains one in both scenarios.
- Malaysia will become a net gas importer in 2033 in both scenarios as gas demand, particularly from the power sector, increases three-fold in both scenarios.

About Malaysia

- Malaysia is situated in southeast Asia with a total territory of about 330 241 square kilometres and is composed of two non-contiguous regions, namely Peninsular Malaysia and East Malaysia, which are separated by the South China Sea.
- Malaysia's population was almost 32 million in 2018 and is estimated to reach almost 33 million in 2021. Malaysia is a multi-ethnic economy, with Malay and Bumiputera contributing 70% of the population, Chinese at 22%, Indians at 7%, and others at 1%.
- Malaysia is categorised as an upper-middle-income economy with diversified economic activities and is expected to achieve its transition to a high-income economy by 2024. In 2020, services activity contributed almost 59% of GDP, followed by manufacturing at 22%, mining and quarries at 7%, agriculture at 7%, and construction at 5%.
- The energy sector has become the backbone driving most of the economic activities in Malaysia. Total energy demand and supply in Malaysia have increased significantly for the past two decades, driven by strong GDP growth of 5.4% per annum since 2000. Electricity generation was slightly more, at almost 5.6% per annum, from 2000 to 2018.
- Malaysia is blessed with a considerable amount of energy resources, including oil, gas, coal, and renewables. Approximately two-thirds of energy reserves are in East Malaysia, and the rest are in Peninsular Malaysia.
- As of 2020, total gas and oil proved reserves are estimated at 32 696 PJ and 16 713 PJ, respectively. Both energy reserves will run out in 12 and 13 years, respectively, with the current R/P ratio.

Table 10-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	32	1.1%	13
GDP	890	1.3%	13
TPES	4 007	1.2%	12
Production	4 205	1.2%	8
Imports	2 374	1.9%	10
Exports	2 465	2.3%	10
Electricity generation	171	1.0%	13
Heat production	0.0	0.0%	9
CO_2 emissions	219	1.0%	13

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 10-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	25 770	629	0.2%	12
Natural gas	32 696	12	0.5%	7
Oil	16 713	13	0.2%	7
Uranium	–	–	–	N/A

Notes: Coal (PJ) in 2018 from Energy Commission, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

Energy policy context

- Malaysia's existing energy-related policies generally have multiple objectives related to energy security, energy equity, and environmental sustainability.
- Malaysia's main energy policies are published in energy planning and decision making by ministries, regulatory agencies, and industry players. These include: the National Petroleum Policy 1975, National Energy Policy 1979, National Depletion Policy 1980, Four-Fuel Diversification Policy 1981, Five-Fuel Diversification Policy 2000, National Policy on the Environment 2002, National Biofuel Policy 2006, National Green Technology Policy 2009, National Policy on Climate Change 2010, National Renewable Energy Policy and Action Plan 2010, New Energy Policy 2010, National Energy Efficiency Action Plan 2016-2025, Green Technology Master Plan 2017-2030, and Nationally Determined Contribution 2019.
- Several energy-related acts have been passed by Parliament to support the implementation of the energy-related policies, namely: Petroleum Development Act 1974, Electricity Supply Act 1990, Gas Supply Act 1993, Energy Commission Act 2001, Renewable Energy Act 2011, and Sustainable Energy Development Authority Act 2011.
- Malaysia's energy sector is governed by multiple key ministries and regulatory agencies with clear roles and responsibilities as defined in the energy-related acts. The key ministries are: the Economic Planning Unit (EPU) of Prime Minister's Department, Ministry of Energy and Natural Resource, Ministry of Primary Industry and Commodities, and Ministry of Domestic Trade and Consumer Affairs. These ministries are supported by: Ministry of Transport; Ministry of Industry and Trade; Ministry of Housing and Local Government; Ministry of Rural Development; Ministry of Federal Territories; Ministry of Environment and Water; Ministry of Science, Technology, and Innovation; and the EPU of Sarawak and Sabah. Coordinated collaboration among key and supported ministries is crucial to achieve the energy policy objectives and targets.
- Malaysia's energy sector will play a key role to ensure the energy-related targets contained in both the Shared Prosperity Vision 2030 and the United Nation's Sustainable Development Goals 2030 are timely achievable.

Recent developments

- The EPU of the Prime Minister's Department is finalising a holistic and comprehensive National Energy Policy for the 2021 to 2040 period. Together with specific action plans, the policy will serve as the planning and development agenda for the economy's energy sector as it transitions towards a low-carbon future.
- Ministry of Energy and Natural Resources is developing a new Energy Efficiency and Conservation Act with the objective to achieve minimum energy savings and compliance to building energy codes across key sectors. It will accelerate energy efficiency initiatives and their implementation to achieve an 8% reduction in electricity consumption 8% by 2025 and reduce GHG emissions. The Energy Efficiency and Conservation Bill is pending approval from Parliament and will be enforced immediately once it is formalised. The enforcement date is crucial to meet the 2025 electricity reduction target.
- The Energy Commission completed the 4th cycle of the competitive bidding process in March 2021 for the development of 823 MW of large-scale solar PV plants in Peninsular Malaysia for commercial operation in 2022 and 2023. The new large solar PV plants will help achieve the target of 40% of generation capacity consisting of renewables by 2035.
- The announcement of Malaysia's commitment to become a carbon-neutral economy by 2050 has been made together with the release of the Twelfth Malaysia Plan, 2021-2025 on 27 September 2021.
- The Twelfth Malaysia Plan comprises a medium-term plan for Shared Prosperity Vision 2030, with the objective of 'A Prosperous, Inclusive, Sustainable Malaysia.' Under the plan, the energy sector will focus on addressing the energy trilemma, especially on energy security and sustainability.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- **The Reference scenario (REF)** reflects the recent trends and current policies in place or planned, including decarbonisation strategies to capture the evolving nature of the energy system in Malaysia.
- The Green Technology Master Plan 2017-2030, Peninsular Malaysia Generation Development Plan 2020, National Energy Efficiency Action Plan 2016-2025 and Nationally Determined Contribution (NDC) target by 2030 are among the key policies adopted for projecting energy demand across sectors and electricity generation in REF.
- Policies and programs on energy efficiency and technology improvement gradually moderate the demand growth in buildings. Other than efficient energy management, green technology application and switching to greener fuels are the focus in the industry sector, with sub-industry shares almost unchanged throughout the outlook period.
- In the transport sector, improving fuel economy standards, increasing biofuel blending, and deploying electric and fuel-cell vehicles throughout the outlook period support the low-carbon mobility agenda.
- Natural gas generation meets most incremental electricity demand due to its cost and lower emissions than coal. However, some renewables capacity, primarily solar, meets incremental demand through its build-out in capacity to over 18 GW by 2050.
- **The Carbon Neutrality scenario (CN)** reflects a potential pathway for a more significant reduction of CO_2 emissions towards a carbon-neutral economy by 2050. Additional energy efficiency, more substantial technology improvements, and fuel switching in CN significantly reduce energy demand and CO_2 emissions across all sectors.
- No new coal-fired power plants are assumed throughout the outlook period in CN, in line with the policy announced by the government in September 2021.
- The deployment of CCS technology in the industry and power sectors, higher use of hydrogen by industry, and higher adoption of EVs and fuel-cell vehicles further reduces energy demand and CO_2 emissions in CN.
- Both scenarios use historical data through 2018, with projections starting in 2019 and running through 2050.

Table 10-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Malaysia

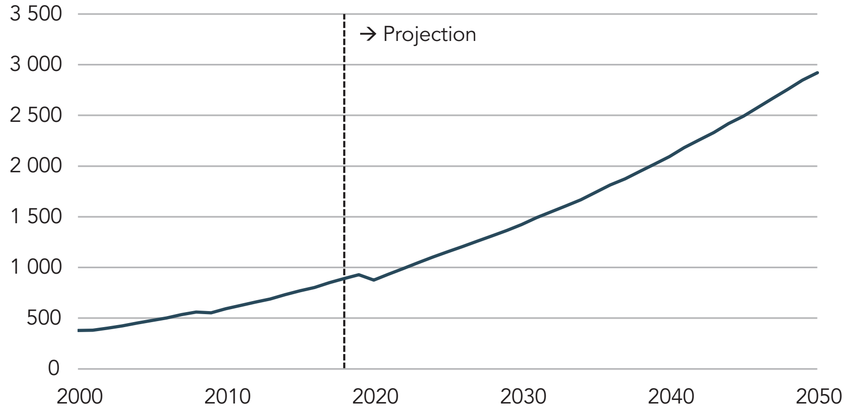
Table 10-4. Key assumptions for the Reference and the Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium). • GDP: World Bank (historical), APERC Solow-Swan model (projections), IMF (COVID-19 impacts).	• Same as Reference
Buildings	• Efficient Management of Electrical Energy Regulations 2008 • Minimum Energy Performance Standards (MEPS) • Green Technology Master Plan 2017-2030 implemented. • Technology improvements for heating lead to 0.5% improvement in energy consumption by 2030.	• More stringent energy efficiency standards for buildings, mandatory energy efficient building design, and green energy office resulting in a 20% reduction in energy consumption by 2050. • Electrification of cooking and water heating, switching from LPG to electricity. • Technology improvements for heating lead to 1% improvement in energy consumption by 2030.
Industry	• National Energy Efficiency Action Plan 2016-2025 • Application of energy efficiency technologies (such as solar or renewables projects for own consumption or under Net Energy Metering program), energy efficiency building and data centre, and integrated waste management. • Biodiesel Program: B7 implemented and promotion of cogeneration. • Technology improvements for heating lead to 0.5% improvement in energy consumption by 2030.	• CCS uptake for chemical and cement subsectors starts in 2030. • Hydrogen use for chemical production starts in 2025; for cement, 2030. • Material efficiency improvement in steel, chemical, and cement subsectors reduce output requirements and energy demand by 10% in 2050. • Technology improvements for heating lead to 1% improvement in energy consumption by 2030. • Fuel switching from coal and other fossil fuels to gas, biomass, electricity, and hydrogen.
Transport	• Low Carbon Mobility Blueprint 2021-2030 and ASEAN Fuel Economy Standards • Biodiesel Program: B20 implemented by 2022, and B30 by 2030. • Gradual electric vehicles and other zero-emission vehicles including hydrogen fuel cell vehicles uptake. Hydrogen fuel cell vehicles uptake starts in 2026. • 40% modal share of public transport and 100% energy efficiency vehicles (EEV) for private transport by 2030.	• Biodiesel Program: B40 implemented by 2040. • More rapid electric vehicles and zero-emission vehicles uptake. Hydrogen fuel cell vehicles uptake starts 2025. • Higher rail-based public transport modal share by 2050
Power and heat	• Peninsular Malaysia Generation Development Plan 2021-2039 • Moderate adoption of solar projects beyond 2030 • Gas and renewables power plants to replace retired coal plants. • Oil generating capacity remains for energy security and severe peaking purposes.	• More renewables in electricity generation, particularly solar, with 18 GW of renewables capacity target achieved by 2035. • CCS-equipped gas adoption from 2029 • No hydrogen consumption or co-firing (coal and biomass) fuel blends
Supply	• National Depletion Policy 1980 • Oil production with enhanced oil recovery techniques • Coal imports is driven by domestic demand. • Gas pipeline exports stop in 2031 to balance domestic supply. • LNG import capacity is sufficient until 2036; grows 4.5 times to 33 Mtpa by 2050.	• Lower oil production due to declining global demand for oil. • LNG import capacity is sufficient until 2036; grows 4.5 times to 34 Mtpa by 2050.
Climate		• Carbon neutral economy by 2050

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

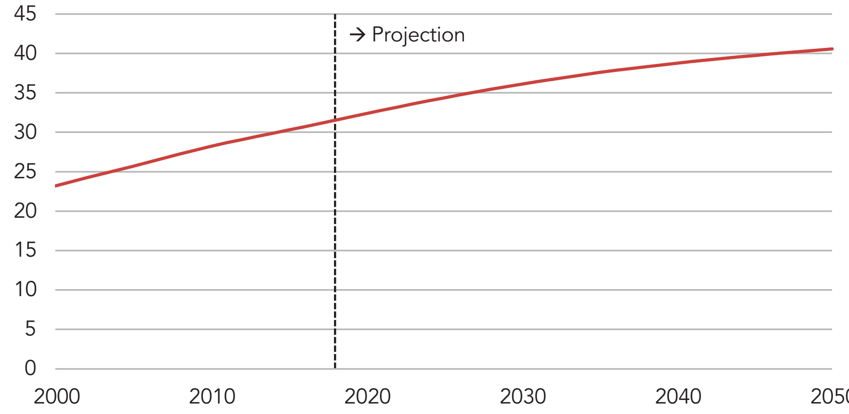
Macroeconomic backdrop

Figure 10-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from APERC Solow-Swan model and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 10-2. Population in millions, 2000-2050

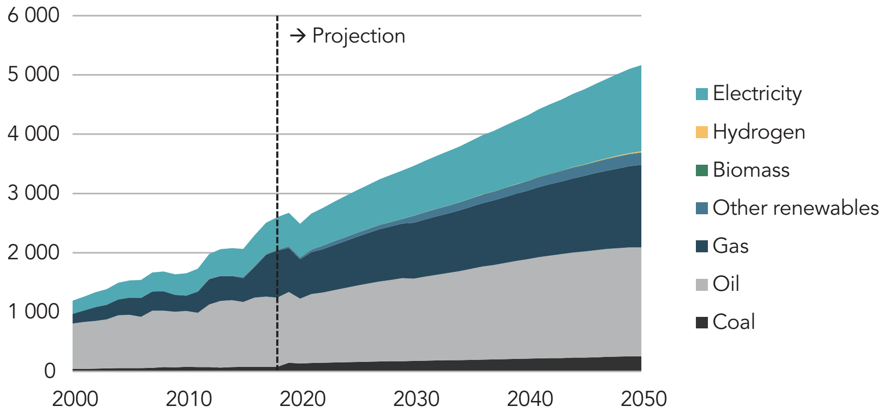


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- Malaysia's economy grew consistently at an average of 4.8% per annum from 2000 to 2019.
- In 2020, Malaysia's economy contracted 5.6%, its first reduction since 2009. The contraction is due to the restrictions on economic activity resulting from the containment measures in response to the COVID-19 pandemic.
- Malaysia has announced a total of RM 380 billion economic stimulus packages, namely PRIHATIN, PENJANA, PERMAI and PEMERKASA, as assistance to lessen the economic burden during the pandemic.
- The *Outlook* assumes that Malaysia's GDP surpasses pre-pandemic levels in 2021 and grows at a compound annual growth rate of 4.1%, tripling over the outlook period. Services and manufacturing activities will continue to be the main contributors to Malaysia's economy. The *Outlook* assumes that no significant structural changes to the economy occur over the outlook period.
- The persistence of the pandemic could affect these GDP projections in the short to medium term.
- Malaysia's population rises a quarter over the outlook period, from about 32 million in 2018 to almost 41 million in 2050, as estimated by UN DESA in 2019.
- Population grows at a slower rate over the outlook period than the last two decades due an aging population and smaller family numbers.

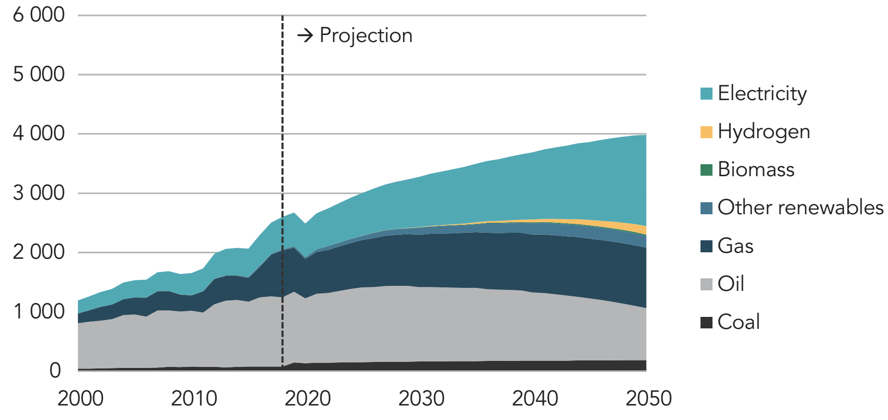
End-use energy demand

Figure 10-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 10-4. Energy demand in CN, 2000-2050 (PJ)

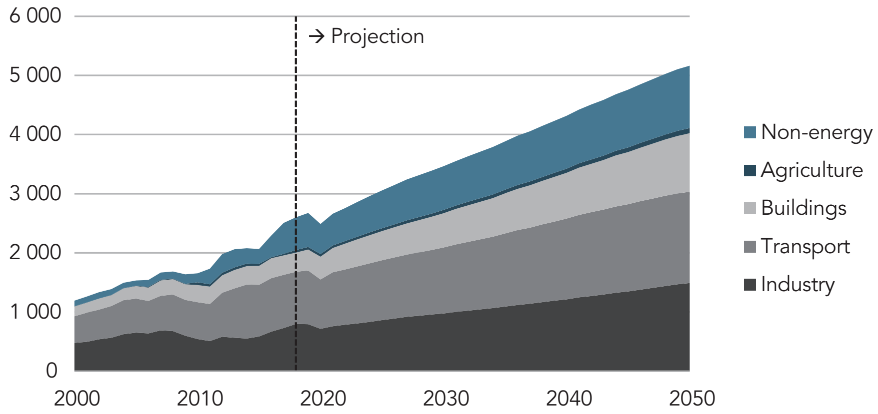


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Malaysia's total energy demand showed an increasing trend from 2000 to 2018, with an average growth of 4.4% per annum. This aligns well with the underlying fundamental of increasing economic activities, which saw GDP growth average 5.4% per annum over the same period.
- In 2020, total energy demand dropped by 6.9% as government restrictions to contain the coronavirus outbreak resulted in lower demand for coal, oil, and gas from all sectors. In both scenarios, demand reverts to pre-pandemic level in 2022.
- Total energy demand continues to grow over the outlook period, albeit at a slower pace than history, with around 2.2% per annum in REF and 1.3% in CN. Total energy demand almost doubles above 2018 levels in REF and increases by more than half in CN.
- In 2050, total energy demand in CN is almost a quarter lower than REF due to the lower demand for fossil fuels, specifically oil, which contributes about 80% of the difference due to energy efficiency and fuel switching in transport.
- While fossil fuels remain dominant over the projection period in both scenarios, their grip on the fuel mix falls from three-quarters in 2018 to two-thirds in REF and half in CN. Coal and natural gas maintain similar shares in both scenarios, but oil falls from 36% in REF to 22% in CN.
- The share of non-fossil fuels increases toward 2050 in CN due to more electrification programs, greater energy efficiency across sectors, higher demand for hydrogen, and fuel-switching, especially from coal to renewables.
- While electricity grows into the second-largest fuel in REF, it surges to the largest in CN, taking up 39% of demand in 2050. Other renewables, biomass, and hydrogen similarly make up almost a tenth of 2050 demand in CN, doubling their share in REF.

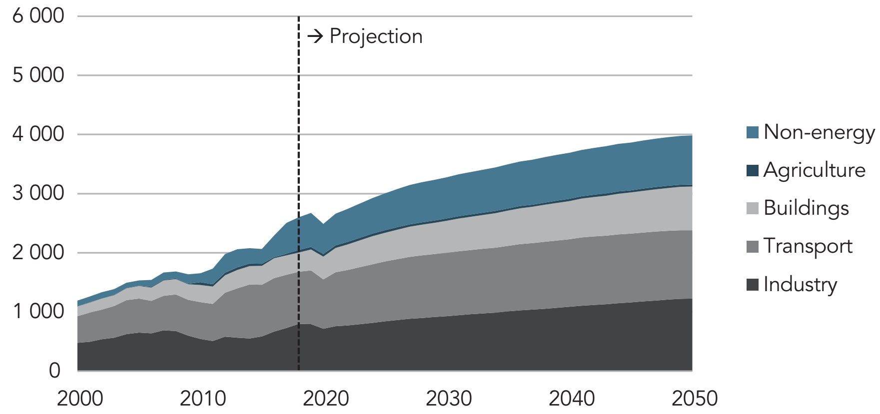
End-use energy demand by sector

Figure 10-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 10-6. Energy demand by sector in CN, 2000-2050 (PJ)

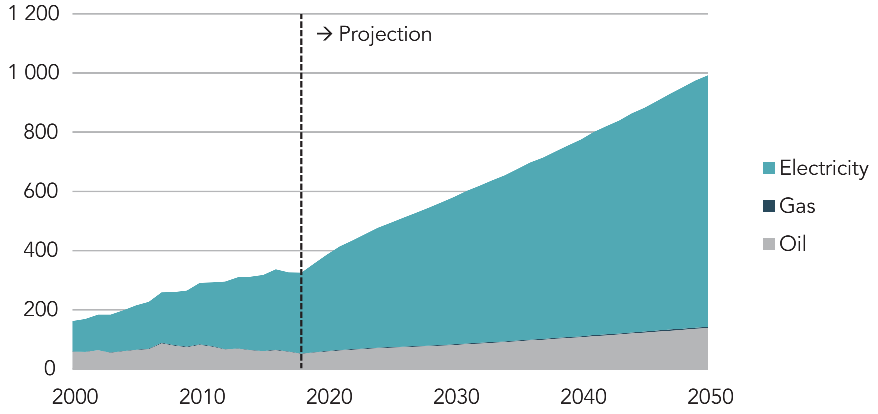


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Malaysia's population and strong GDP growth drive demand higher for all sectors in REF, with total end-use doubling by 2050. All sectors, except agriculture, continue to grow in CN, as efficiency improvements limit Malaysia's total end-use growth to about 53%.
- Energy demand from all sectors is lower in CN as compared to REF, as more ambitious energy efficiency efforts across the economy help decouple energy use from economic activity.
- The transport sector remains the largest energy consumer throughout the outlook period in REF. However, transport becomes the second-largest energy consumer in 2046 of CN, in favour of industry, due to its deployment of efficient technologies, like electric and fuel-cell vehicles. By 2050, transport demands falls a quarter relative to REF levels.
- The industry becomes the largest energy-consuming sector in CN partly because of the limitations in employing energy-efficient technologies at a commercial scale for many of its end-use processes. However, some gains in energy and material efficiency help reduce energy use by almost a fifth in CN. Non-energy faces similar issues, but some improvement and electrification help it reduce demand by a fifth, too.
- Buildings energy use triples in REF to fuel rising demand for services and space cooling. In CN demand falls a quarter below REF, as more stringent regulations encourage the construction of energy-efficient buildings and the deployment of energy-efficient appliances.
- Agriculture demand doubles in REF, and electrification is instrumental in reducing its energy use by over a half below REF levels in CN.

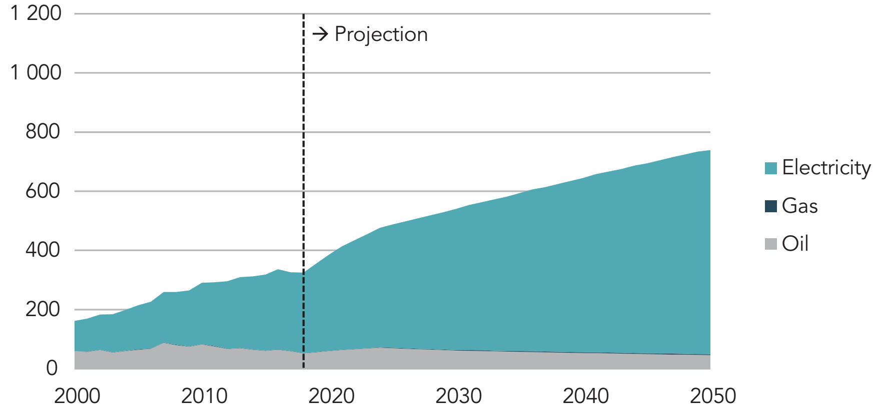
Buildings energy demand

Figure 10-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-8. Buildings energy demand in CN, 2000-2050 (PJ)

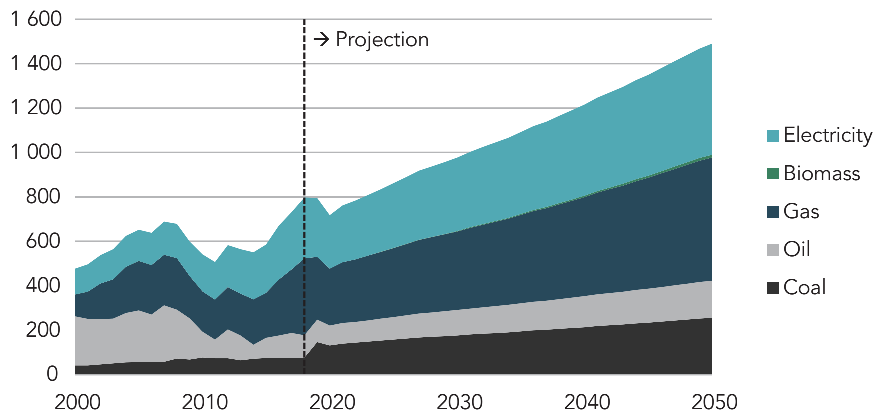


Sources: EGEDA, APERC analysis.

- Buildings constitute almost 13% of Malaysia's total energy demand in 2018 and about 19% in 2050. Rising macroeconomic fundamentals, like population and GDP, drive demand for energy higher in both scenarios. Energy demand in buildings triples in REF, and energy efficiency limits demand growth to more than doubling in CN.
- A main driver of buildings demand in Malaysia is electricity, which is mainly used for space cooling. Malaysia experiences hot and humid weather throughout the year, with an average daily temperature between 24 to 33 degrees Celsius recorded in 2019.
- An expansion of services drives much of buildings growth in the outlook period. In both scenarios, services grow from comprising just over half of buildings demand in 2018 to two-thirds in 2050. Services demand growth more than triples in REF and grows 2.6 times in CN.
- Electricity continues to dominate energy demand for buildings throughout the outlook period, rising from an 84% share in 2018 to 86% in 2050 in REF and 93% in CN.
- Oil use mainly consists of LPG used in cooking and demand for it grows 2.7-fold in REF. This is significantly decreased in CN, as technology improvement and stove electrification results in more switching away from oil.
- Buildings energy demand is reduced by a quarter below REF levels in CN. Essential to unlocking this energy demand savings is support for the distribution and adoption of more efficient electrical appliances and the development of a more stringent building code to support the construction of more efficient building envelopes. This goes beyond the National Energy Efficiency Action Plan 2016-2025, which guides the energy efficiency trends in REF.

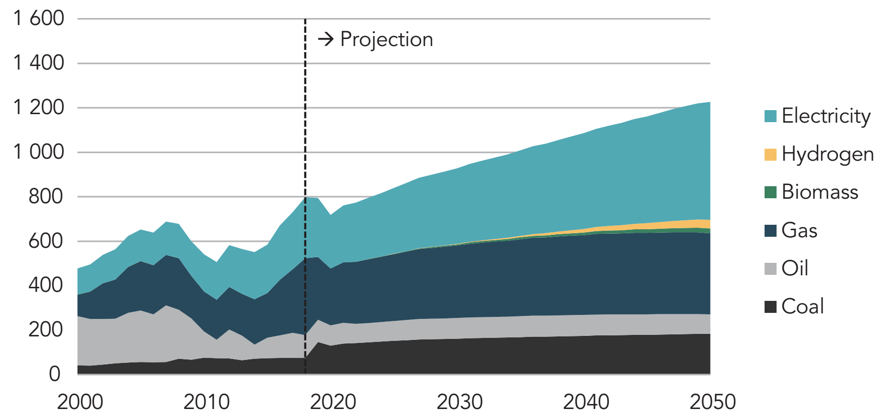
Industry energy demand

Figure 10-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 10-10. Industry energy demand in CN, 2000-2050 (PJ)

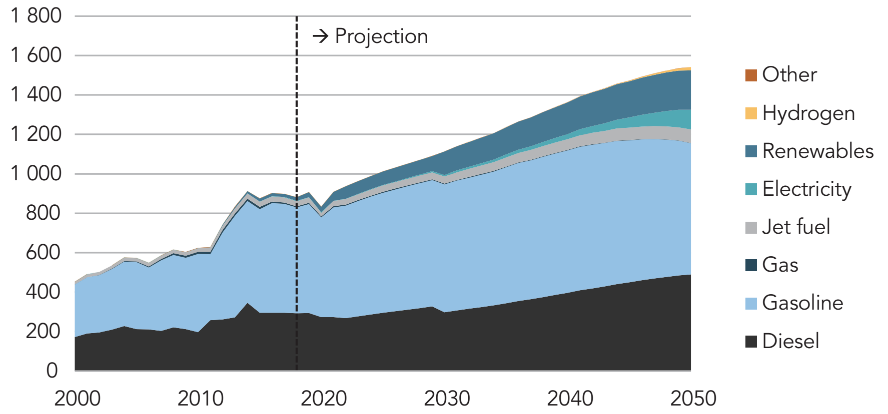


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industry is the second-largest energy consumer in Malaysia. Demand fell about a tenth in 2020 due to lower output during the onset of the coronavirus and returns to pre-pandemic levels by 2023 in both scenarios. Robust growth drives energy demand higher at a 2.0% annual rate in REF. This is lower than historical rate of 3.0% per annum in the 2000 to 2018 period.
- Fossil fuels continue to play a large role in fuelling industry, maintaining two-thirds of its fuel mix by 2050. Coal use increases the most, driven by a near-doubling of demand from both cement and the non-specified subsectors. Oil use grows two-thirds due to rising output from the chemicals, pulp and paper, and non-specified subsectors. Gas demand grows 60% on doubling requirements from both the non-specified and steel subsectors.
- Industry's energy demand in CN falls 18% below REF due to improvements in both material efficiency and energy efficiency. The latter results especially from technology improvements in process heating.
- More fuel switching occurs in CN, as subsectors typically move away from coal and oil to gas, biomass, electricity, and hydrogen. Fossil fuels see their role increase to 80% of the industry fuel mix, but their demand is a third below REF levels.
- Electricity grows at similar rates in both scenarios, nearly doubling, and reaching a third of the industry fuel mix in REF and over two-fifths in CN. Electrification and energy savings in CN see it become the most-used fuel in the 2020s.
- In CN, both hydrogen and CCS are introduced into the industry sector. The chemical and steel subsectors start using hydrogen in 2025 and 2030, respectively, while CCS in chemical and cement subsectors starts abating some emissions from fossil fuels in 2030. Hydrogen demand reaches 3.2% of industry demand by 2050.
- The non-specified subsector, including food and beverages, textiles, and other industries, remains the highest energy user among industry throughout the outlook period.

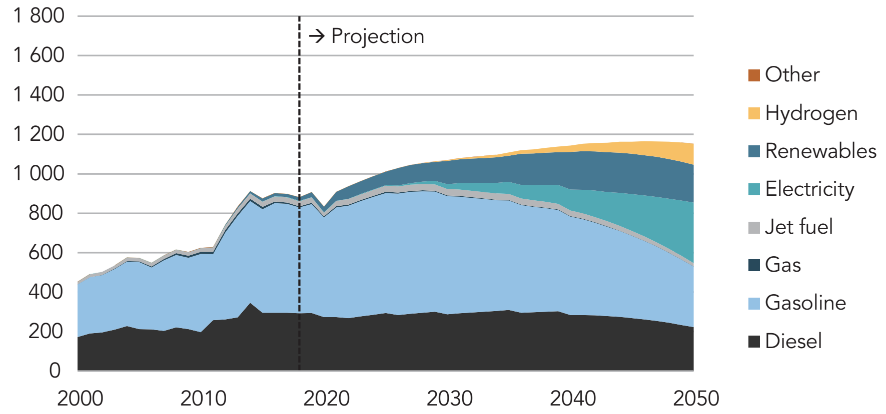
Transport energy demand

Figure 10-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 10-12. Transport energy demand in CN, 2000-2050 (PJ)



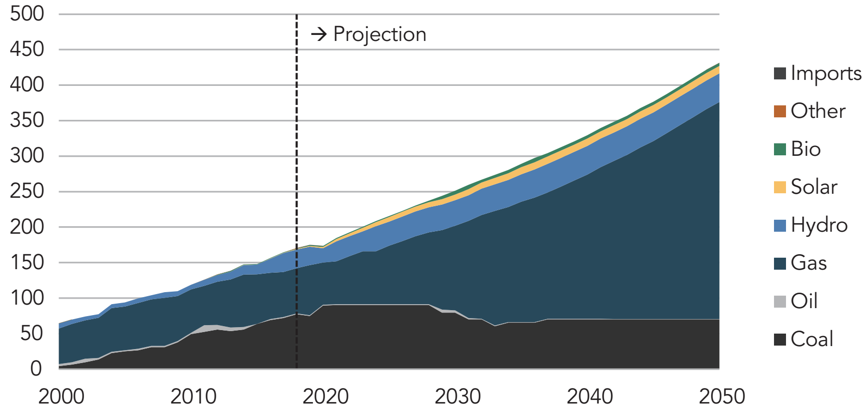
Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- The transport sector remains the largest energy consumer in Malaysia throughout REF, but its share shrinks from 34% in 2018 to 30% in 2050.
- In REF, energy demand in transport increases almost three-quarters in 2050 compared to 2018 and increases around a third in CN. The energy demand growth during both scenarios is lower than historical growth due to efficiency improvements across the road, rail, marine, and aviation modes.
- Diesel and gasoline remain the largest fuel source for transport in both scenarios. Their share decreases from 94% in 2018 to 75% in 2050 in REF, as EVs, fuel cells, and the implementation of the B20 and B30 programs introduce more electricity, hydrogen, and biofuels to the transport mix. This share falls below half in CN, as higher penetration of zero-emission vehicles, the B40 program, and a shift towards public transport by passengers reduces demand for gasoline and diesel. More efficient ICE vehicle deployment stipulated by the National Automotive Policy 2020 also reduces demand in both scenarios.
- Policy supports an increase in biofuel consumption in both scenarios, up from 2.1% of transport demand in 2018 to 14% in 2050 in REF and 17% in CN.
- Electricity demand increases significantly in both scenarios, from under 2.0 PJ in 2018 to over 100 PJ in REF and over 300 PJ in CN. EV adoption is instrumental, as EVs grow to comprise 17% of the vehicle stock in REF and 41% in CN. Furthermore, the National Land Public Transport Master Plan shifts some passenger trips from private vehicles to public transit, putting upward pressure on electricity demand.
- Road transport remains the dominant energy consumption mode in both scenarios. However, rail transit grows significantly following the completion of the LRT Bandar Utama–Klang Line (LRT3), Gemas-Johor Baharu Double Tracking project, Mass Rapid Transit line 2 and 3, Klang Valley Double Tracking (KVDT), East Coast Rail Link (ECRL), Malaysia-Singapore Rapid Transit System (RTS) and High-Speed Rail (HSR) throughout the outlook period. Policy and planning help rail demand increase three-quarters above REF levels in CN.

Notes: Renewables also defined as other renewables in transport. This can include ethanol, biodiesel, renewable diesel and biojet fuel.

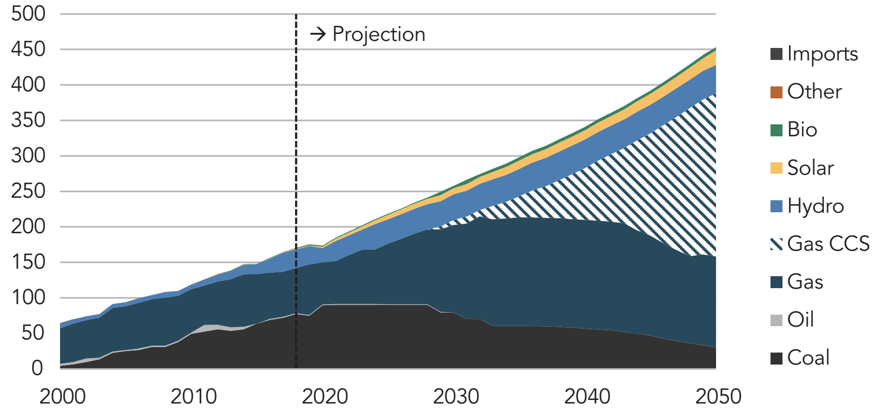
Electricity generation

Figure 10-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 10-14. Electricity generation in CN, 2000-2050 (TWh)

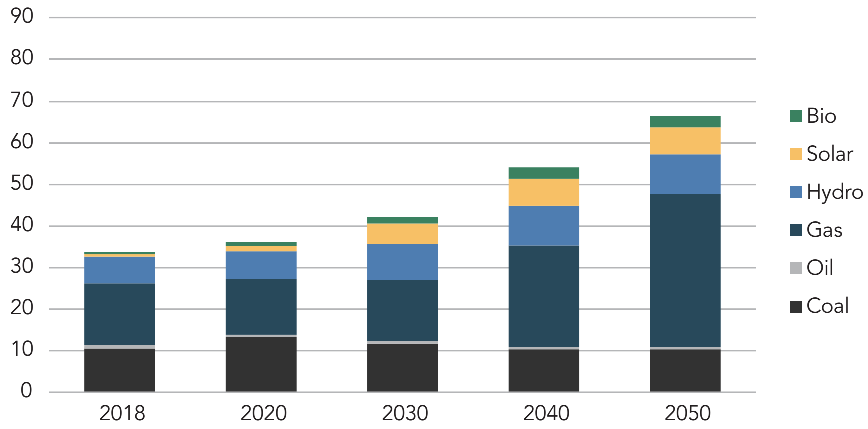


Sources: EGEDA, APERC analysis.

- Malaysia's electricity generation nearly tripled over the past two decades and its electricity mix has shifted from gas to coal, with gas falling from three-quarters of generation in 2000 to over a third in 2018. This substitution was driven by both economics, with coal being a least-cost option, and energy security concerns following a fire incident at Bekok C gas platform in 2010.
- Malaysia's strong GDP growth fuels electricity demand, and in turn generation requirements, over the outlook period. Notable drivers are buildings and industry, contributing about 85% of incremental demand in REF and two-thirds in CN. Electricity generation grows 2.5-fold in REF, from 171 TWh in 2018 to 432 TWh in 2050, and inches higher to 453 TWh in CN.
- Thermal generation remains the primary means of generating electricity in both scenarios, with fossil fuels increasing from a share of 83% in 2018 to 87% in REF and 86% in CN. Both scenarios see a reversal of historical trends, with generation switching from coal to gas, as part of Malaysia's commitments to reduce economy-wide CO_2 emissions. Oil is nearly phased out in both scenarios.
- Coal-to-gas switching reduces coal from about half the mix currently to 16% in REF and down to 7% in CN.
- The share of gas-fired generation increases from around a third now to 71% in REF and 79% in CN. However, over half of gas-fired generation in CN is equipped with CCS technology to partially abate emissions.
- Renewable generation doubles in REF and nearly triples in CN on the back of robust solar and wind growth and higher hydrogeneration. However, its share of generation remains similar to current levels by the end of the outlook period.
- Solar records the highest growth as a source for electricity generation during the outlook period, increasing 16-times in REF and 31-times in CN.

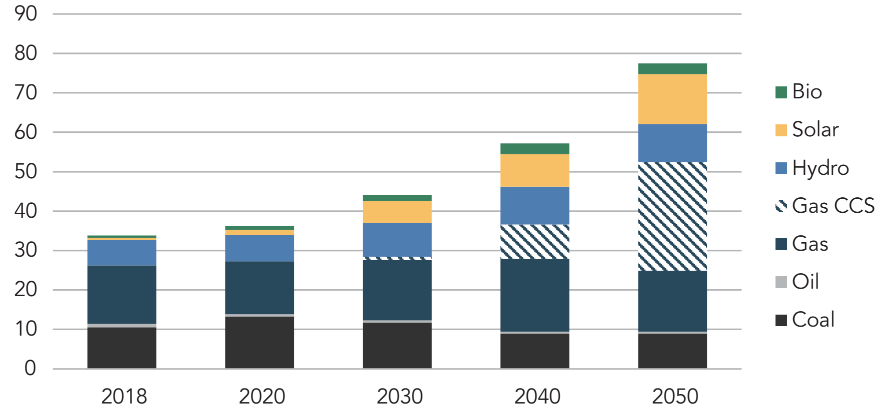
Generation capacity

Figure 10-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 10-16. Generation capacity in CN, 2018-2050 (GW)

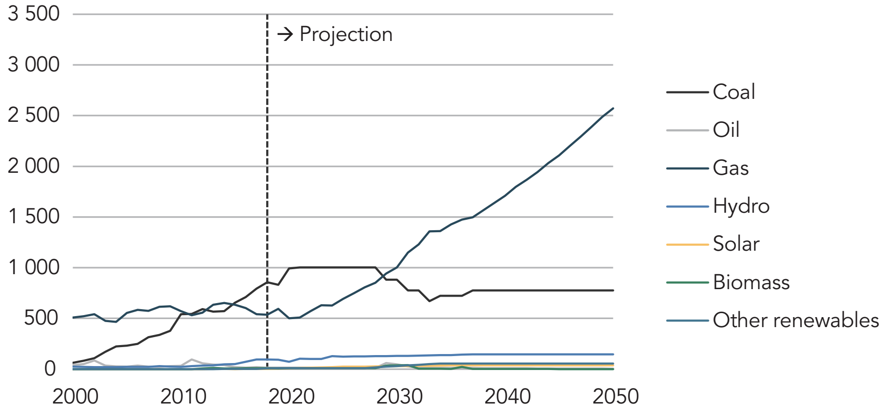


Sources: EGEDA, APERC analysis.

- Generation capacity doubles in REF, from 34 GW to 67 GW. The growth is less than that of electricity generation due to the increasing share of higher-efficiency combined cycle gas turbine (CCGT) plants from 2030 onwards.
- Coal and gas power plants are operated to meet increasing electricity demand, while oil generation capacity remains for energy security purposes to safeguard against extreme demand events. Gas capacity nearly triples in REF, to over 36 GW, and triples in CN to over 43 GW.
- Coal capacity falls to 10 GW in REF on lower utilisation as Malaysia employs coal-to-gas switching as part of its plan of decarbonising the power sector. Capacity falls further to 8.9 GW in CN, as Malaysia follows through on its commitment to build zero new coal power plants.
- Renewable capacity grows to 19 GW in 2050 in REF and nearly 25 GW in CN. The capacity outlook is consistent with Malaysia's estimated target of 18 GW by 2035, with moderate adoption of renewable energy capacity in both scenarios. However, at 37% in REF and 38% in CN, the renewable capacity is slightly below Malaysia's commitment to meet 40% of the capacity mix with renewables. This results from the *Outlook* having a higher fossil fuel capacity in both scenarios than the Peninsular Malaysia Generation Development Plan 2021.
- Renewable energy in generation capacity grows at a slower pace after 2030 as Malaysia elects to build gas capacity to fuel its incremental electricity requirements.
- Generation capacity from the CCS-equipped gas power plants in CN gradually increases from 0.50 GW in 2029 to 27 GW in 2050. Underlying this development is the assumption that geological storage capacity is commercially viable in Malaysia by the late 2020s. Unabated gas capacity of 15 GW remains by 2050 in CN.

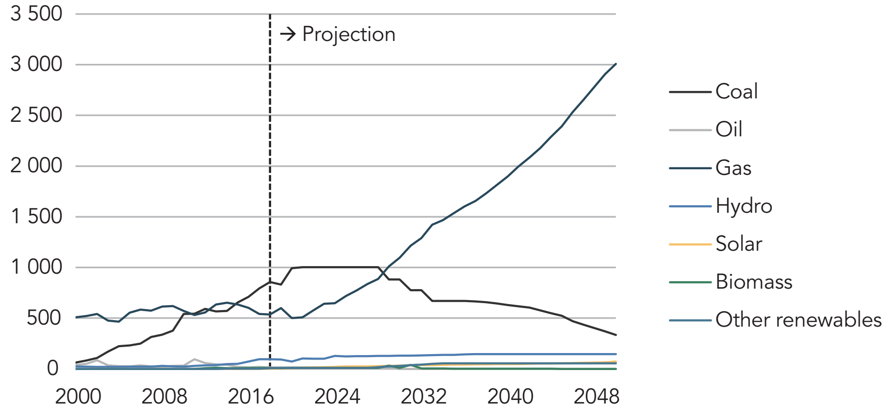
Fuel consumption by power sector

Figure 10-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 10-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

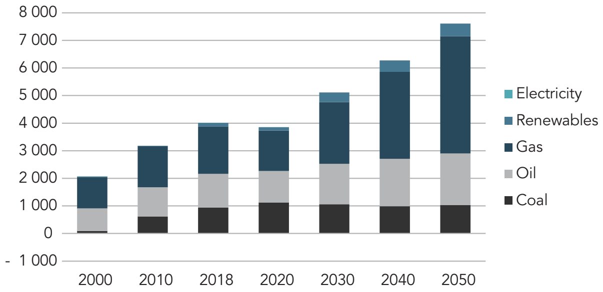


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- Fuel consumption in the power sector follows generation trends, more than doubling above 2018 levels to 3 590 PJ in REF and edging higher to 3 615 PJ in CN.
- Coal-to-gas switching and higher generation requirements drive up gas consumption five-fold in REF and six-fold in CN. The large increase in gas use by power plants in Peninsular Malaysia will require significant increases in LNG imports into Malaysia in both scenarios.
- Coal consumption peaks in the 2020s around 1 000 PJ in both scenarios, as coal-to-gas switching and a capacity moratorium in CN starts to bind consumption. Retirements drive use down further in REF to a plateau around 775 PJ in the late 2030s. In CN, additional retirements and competition from abated gas and renewables push it down to 335 PJ by 2050.
- Renewable energy consumption by power sector remains low, but doubles over the outlook period in REF and grows 2.4 times in CN.

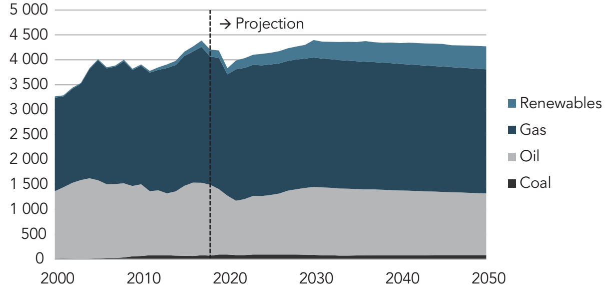
Energy supply in the Reference scenario

Figure 10-19. Total energy supply in REF, 2000-2050 (PJ)



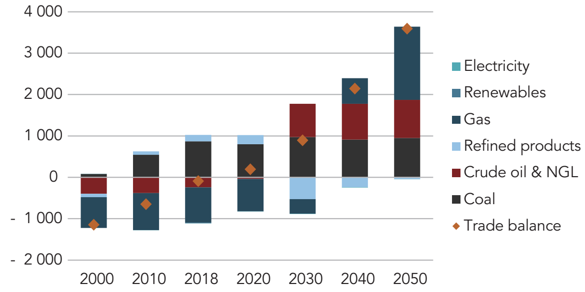
Sources: EGEDA, APERC analysis.

Figure 10-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-21. Net energy trade in REF, 2000-2050 (PJ)

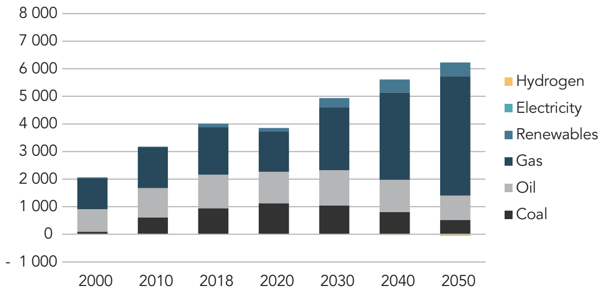


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In REF, Malaysia's total energy supply almost doubles to 7 606 PJ by 2050. Fossil fuels continue to dominate the supply mix throughout the outlook period, accounting for 97% of the total energy supply in 2018 and 94% in 2050. Growing electricity demand helps lift gas supply requirements by nearly 2.5 times during this period.
- In 2020, the total energy supply dropped by 3.5% due to lower demand for coal, oil, and gas during the onset of the COVID-19 pandemic.
- Total energy production increases marginally, by about 66 PJ. Oil and gas dominate Malaysia's total energy production over the outlook period. Energy production from gas peaks in 2021 as demand recovers from the onset of the COVID-19 pandemic. However, production from both oil and gas decreases marginally towards the end of the outlook period due to the production cap under National Depletion Policy 1980 and the depletion of existing oil and gas fields. Energy production from coal remains stable between 70 PJ to 82 PJ during the outlook period.
- Renewables production more than triples by 2050, as demand for renewables increases significantly. This is in the form of biofuels in transport and solar and hydro in the power sector.
- Malaysia became a net energy importer in 2019, seven years earlier than in the *7th Edition Outlook*, due to the significant increase of crude oil imports in 2019, a substantial increase in gas demand towards the end of outlook period, and a gradual increase of other fuels imports.
- Malaysia will become a net gas importer in 2033 as production from Bintulu, Sarawak is gradually diverted away from both pipeline and LNG exports and towards the domestic market to meet increasing gas demand in the power sector. The supply shortfall will be met by LNG imports, which soar to over 1 700 PJ by 2050.
- Electricity exports rise to 5.5 PJ by 2025 and stay there throughout the outlook period in both scenarios.

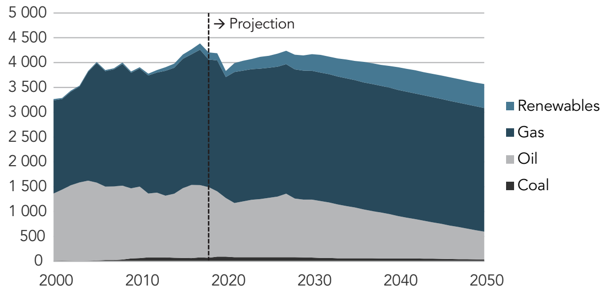
Energy supply in the Carbon Neutrality scenario

Figure 10-22. Total energy supply in CN, 2000-2050 (PJ)



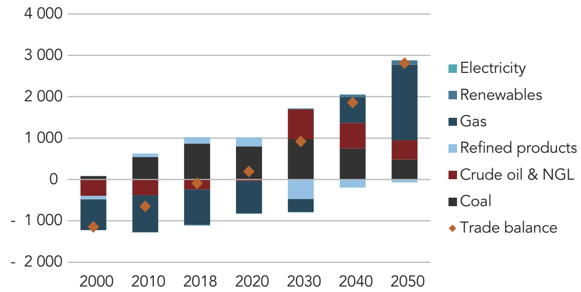
Sources: EGEDA, APERC analysis.

Figure 10-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-24. Net energy trade in CN, 2000-2050 (PJ)

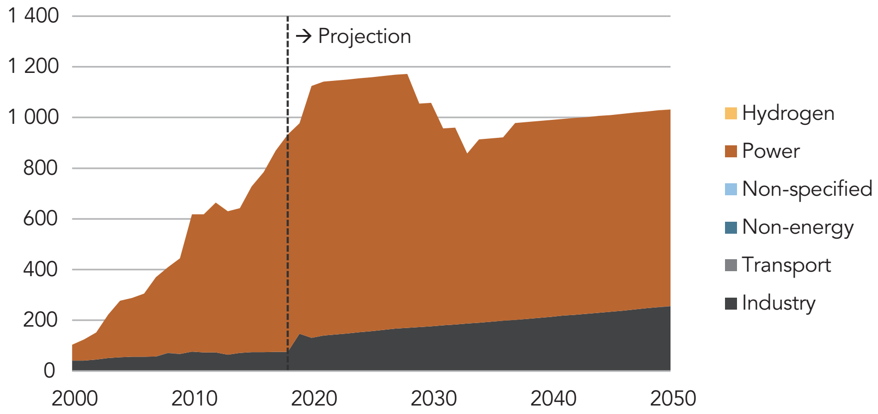


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, Malaysia's total energy supply increases 54% to over 6 000 PJ, which is about a fifth below REF levels. Fossil fuels continue to dominate energy supply throughout the outlook period, accounting for 97% of the supply mix in 2018 and 93% in 2050.
- Gas supply increases slightly over REF levels due to increased demand from all sectors, especially for electricity generation. Coal and oil see their supply requirements fall by half compared to REF.
- Renewables and hydrogen supply increase marginally above REF levels due to increasing demand in both transport and industry.
- Energy production gradually recovers from the COVID-19 pandemic and peaks at 4 239 PJ in 2027 before declining steadily from 2031 onwards. Energy production ends up declining about a sixth below REF levels by 2050, and this is mostly due to lower domestic and global demand for oil. Renewable production rises moderately over REF levels, by about 4.2%. Gas production mirrors that of REF.
- While Malaysia continues to increase its reliance on energy imports due to rising power and crude demand in CN, lower supply requirements reduce net energy imports by over a fifth below REF levels.
- Malaysia will become a net gas importer in 2033 in CN, the same year as in REF. Gas exports mirror the declines of REF but reach a quarter below its levels due to the world reducing gas demand as it embraces carbon neutrality. Imports increase throughout the outlook period to meet increasing gas demand, especially in the power sector. LNG imports are slightly higher than REF levels due to a small uptick in gas requirements.

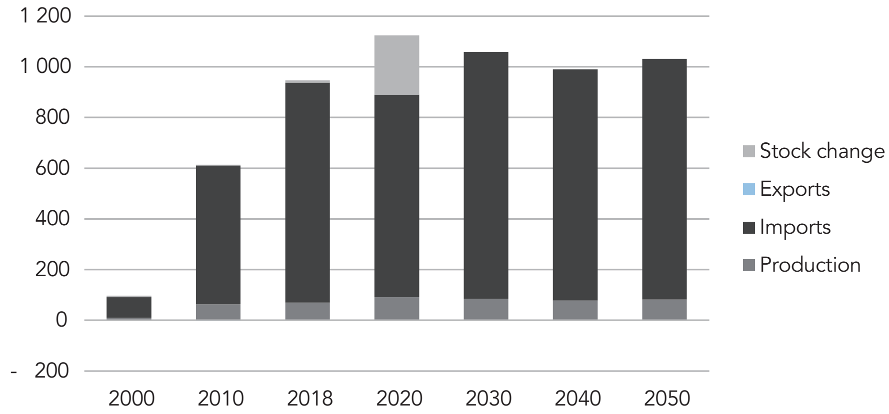
Coal in the Reference scenario

Figure 10-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

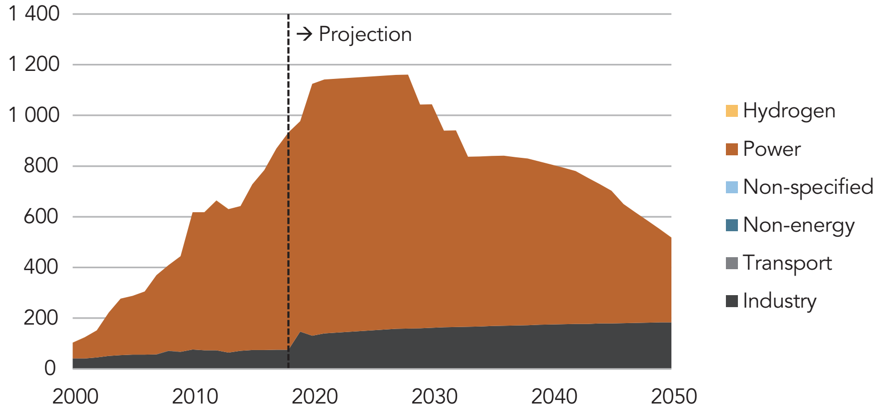


Sources: EGEDA, APERC analysis.

- Coal is primarily used in the power sector, which makes up 92% of Malaysia's use. However, its combustion also provides process heat for industry, particularly in the cement subsector. Iron and steel manufacturers are also coal consumers.
- Malaysia has some indigenous resources that produce a small amount of coal in the Sarawak region but relies heavily on imports to meet its demand requirements. Over the past two decades, coal's low cost and availability made it a choice fuel by Malaysia to improve the security of its growing electricity fuel supply requirements. Expansions in coal-fired generation capacity drove consumption up nine-fold over this period.
- In REF, the power sector remains the main consumer of coal in Malaysia. Coal consumption by the power sector peaks at about 1 002 PJ in 2028 and starts to decrease in stages to a low point at about 671 PJ in 2033. This trajectory assumes that the retirements of a few existing coal power plants follow the expiry date of their Power Purchase Agreements. Furthermore, increasing renewables in the electricity generation mix, specifically solar, reduces the economic case for continuing the life of these assets. However, rising electricity demand results in additional coal capacity in 2034 and 2037, which lifts consumption to 776 PJ per annum towards the end of outlook period.
- Coal consumption by industry grows at almost 3.9% per annum from 76 PJ in 2018 to 255 PJ in 2050. Coal use grows 10% over the projection period.
- Coal imports increase about 10%, or 82 PJ, from 2018 to 2050, in line with demand increases. Imports continue to supply the lion's share of supply, around 92% throughout most of the outlook period.
- Malaysia imports most thermal coal from Kalimantan, Indonesia. Indonesia will likely remain a key supplier for Malaysia over the outlook period.

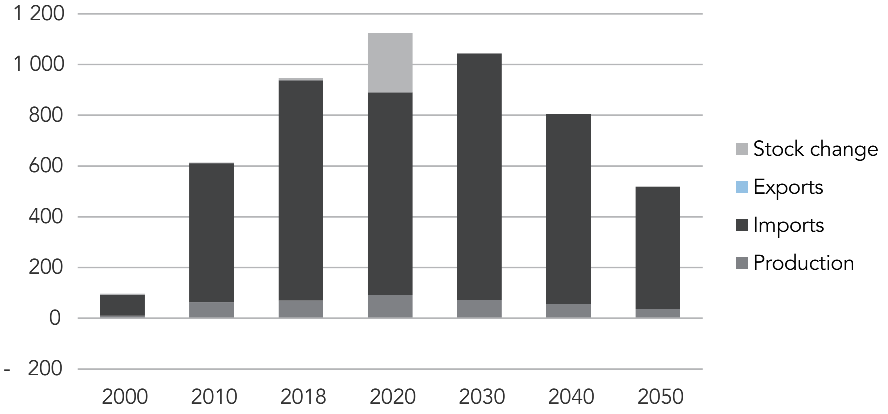
Coal in the Carbon Neutrality scenario

Figure 10-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

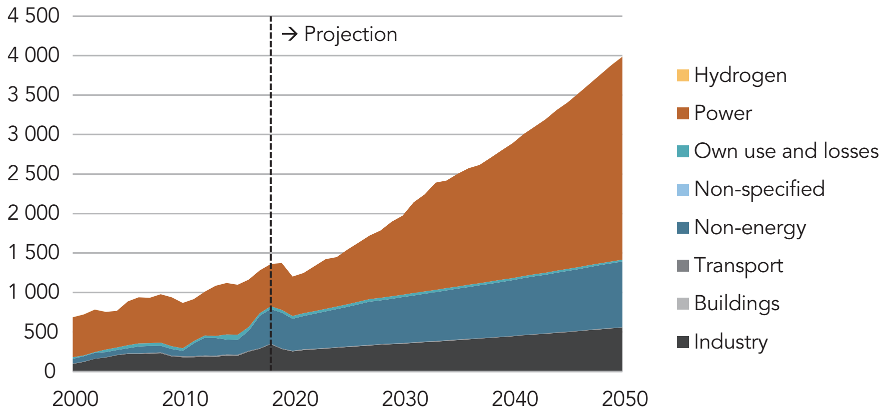


Sources: EGEDA, APERC analysis.

- Coal consumption is halved in CN relative to REF as both the power and industry sectors switch away from coal to support Malaysia's long-term goal of achieving carbon neutrality.
- In CN, coal use in the power sector follows a similar trajectory to REF until 2033. Thereafter, coal retirements, improved efficiency in coal power plants, higher coal-to-gas switching, and a higher penetration of renewables reduce coal consumption to half of REF levels.
- Fuel switching from coal to gas and the electrification of some end-uses in the industry sector reduces its coal consumption in CN. Coal consumption by industry grows at around 2.8% per annum from 76 PJ in 2018 to 183 PJ in 2050, a quarter below REF levels.
- In line with lower coal consumption from power and industry, coal production and imports decline by almost half compared to REF. Malaysia remains a net importer of coal throughout CN and continues to rely on other APEC members for coal supply.

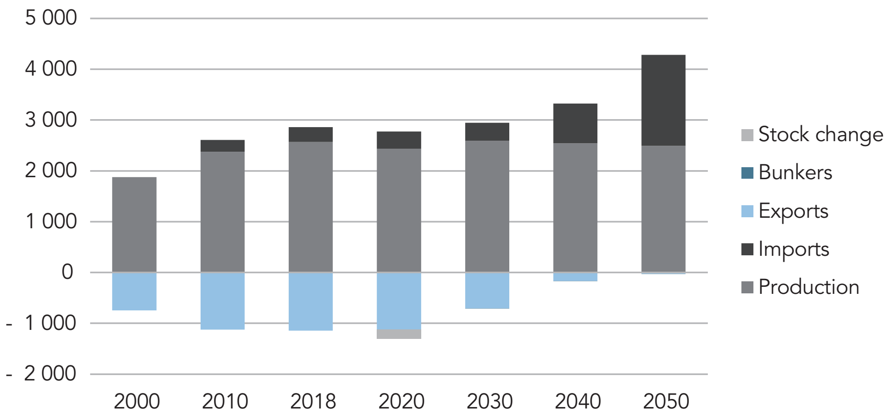
Natural gas in the Reference scenario

Figure 10-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

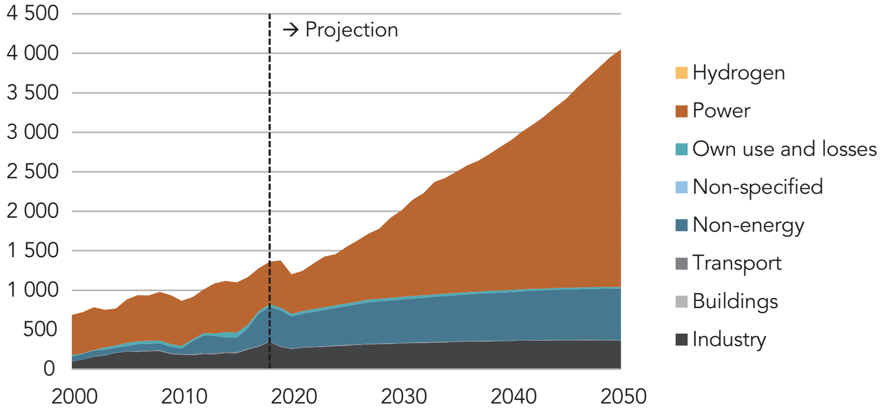


Sources: EGEDA, APERC analysis.

- Gas is predominantly used in the power, non-energy, and industry sectors, which together account for 97% of total Malaysia gas use in 2018. After doubling over the past two decades and a brief decline during the onset of the pandemic, gas demand triples in REF due to increases in gas-fired generation and fuel switching in industry and non-energy. A higher proportion of gas usage, particularly at the expense of coal, is in line with Malaysia's goal of reducing the carbon content of its energy supply.
- Two floating liquefaction facilities, namely PFLNG Satu and PFLNG Dua, have started operations in 2016 and 2021, respectively, to support gas production and exports in Malaysia.
- Gas production is flat over the outlook period, as declines from the depletion of existing gas fields in the east coast of Peninsular Malaysia and Sarawak is partially offset by increasing production from Sabah.
- Gas exports decline drastically from 2030 onwards as preference is given to diverting production towards the domestic market. LNG exports fall from 2024 onwards, hitting nearly zero in 2050, while gas pipeline exports end in 2031.
- Gas imports increase drastically from 2040 onwards to meet increasing gas demand. Current LNG imports capacity is sufficient to meet the demand trends until 2035, but 26 Mtpa of new capacity is required thereafter to meet 33 Mtpa of imports in 2050.
- Securing gas supply becomes an essential condition of Malaysia's economic prosperity. Malaysia turns from a net gas exporter into a net gas importer in 2033, and gas imports make up 42% of supply by 2050. Policy will need to focus on minimising and mitigating potential gas supply disruptions.

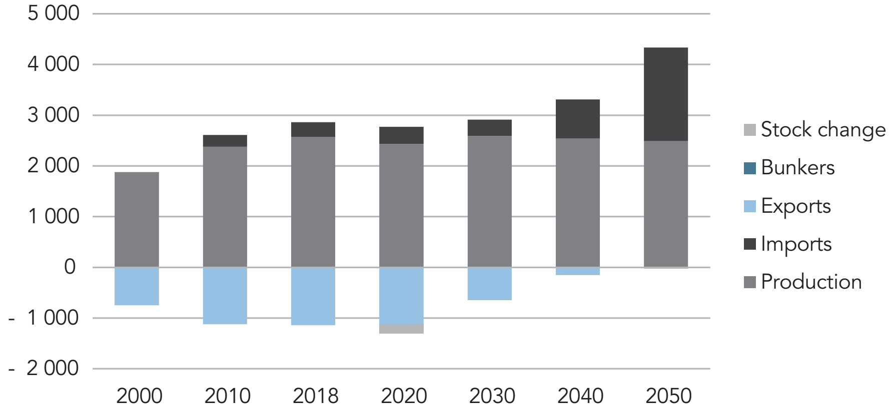
Natural gas in the Carbon Neutrality scenario

Figure 10-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

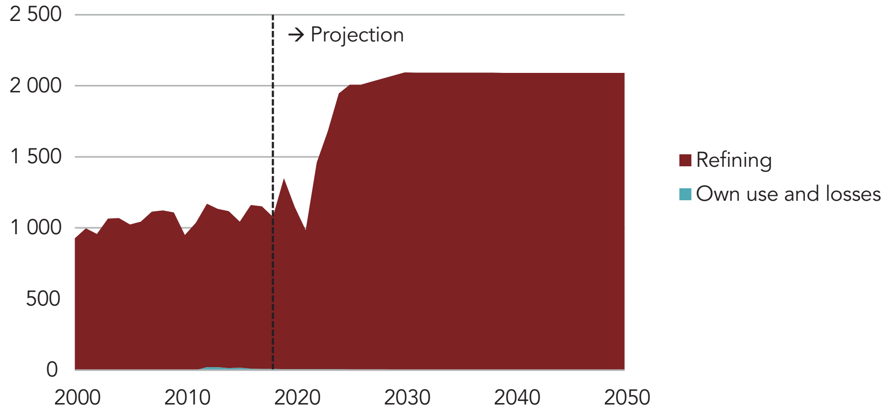


Sources: EGEDA, APERC analysis.

- Malaysia's gas consumption follows similar trends to REF, tripling over the outlook period. However, sectors do experience different trajectories. Electrification and energy efficiency reduces demand in the end-use sectors by about a quarter, while coal-to-gas switching raises power consumption a sixth. Overall, demand edges 1.6% higher as Malaysia looks to use natural gas as a transition fuel towards carbon neutrality.
- Similarities in aggregate gas demand trends in both scenarios yield similar production and trade trends. Gas production follows the same trajectory. Gas imports mirror REF, albeit with higher LNG imports to meet higher demand requirements. Exports decline in line with REF as Malaysia continues to funnel gas production into the domestic market. However, a smaller global market results in LNG exports falling a quarter below REF levels.
- The existing two LNG import facilities are located in Peninsular Malaysia, with a total capacity of 7.3 Mtpa. Both LNG import facilities capacities are sufficient to meet the increasing demand trends until 2035. However, 27 Mtpa of new LNG import capacity will be required thereafter to meet 34 Mtpa of imports in 2050.
- Securing gas supply becomes an essential condition of Malaysia's economic prosperity. Malaysia turns from a net gas exporter into a net gas importer in 2033, and gas imports make up 43% of supply by 2050. Policy will need to focus on minimising and mitigating potential gas supply disruptions.

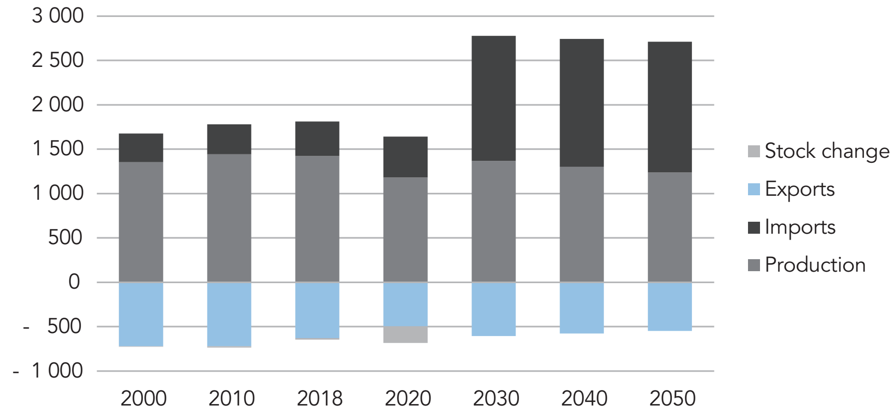
Crude oil and NGLs in the Reference scenario

Figure 10-33. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-34. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

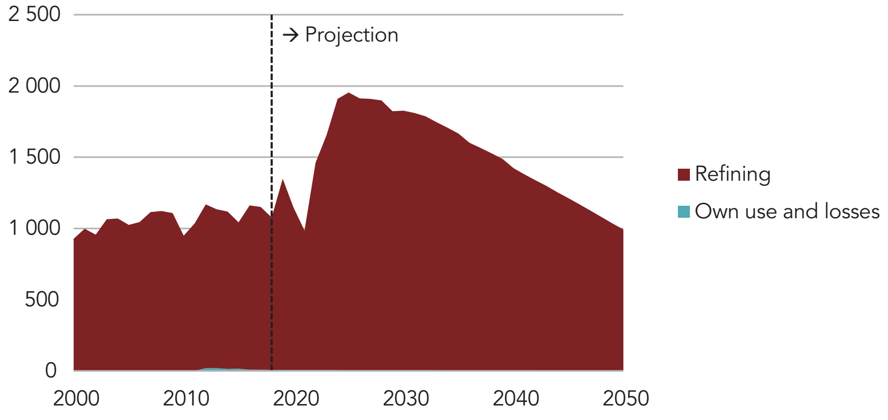


Sources: EGEDA, APERC analysis.

- Crude oil is used predominantly by refineries to create refined oil products for domestic consumption and export. As of 2021, all existing refineries are concentrated in Peninsular Malaysia, with a total capacity of 601 kb/d. The projection for both scenarios is based on the existing and new refining capacities. Refinery capacity is set to increase by three-quarters in the 2020s. In REF, it is assumed that all existing and new refineries continue to operate throughout the outlook period.
- Total crude oil consumption set a historical peak of 1 349 PJ in 2019 but dropped about a quarter below this in 2021 as the COVID-19 pandemic reduced demand for refinery products. Consumption rebounds in 2022 with increased refined products demand and the full commissioning of Pengerang RAPID refinery in the second quarter of 2022. The increasing trend of crude oil consumption continues into the 2030s, where it stabilises around 2 090 PJ.
- Enhanced oil recovery (EOR) techniques are being used to offset the declining production at maturing fields, particularly in the shallow waters offshore of Peninsular Malaysia. This helps recover production slightly this decade. However, declines start again in the 2030s, and production falls about a tenth over the projection.
- Malaysia's crude oil is categorised as a sweet and high-quality crude oil, but its refineries are configured to process low-grade crude assays. As part of its energy security strategy, Malaysia exports about 44% of total crude oil production and imports low-grade crude to run through its refineries. In REF, exports fall in line with production, while imports almost quadruple to meet incremental demands from new refineries.
- With crude oil supply requirements increasingly met via imports over the outlook period, Malaysia's sees its vulnerability to oil supply disruptions increase in REF. Policy should focus on mitigating and minimising such disruptions.

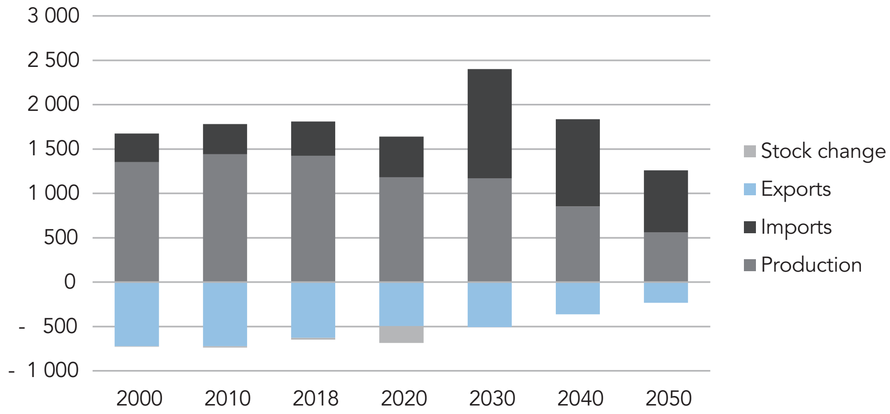
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 10-35. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure10-36. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

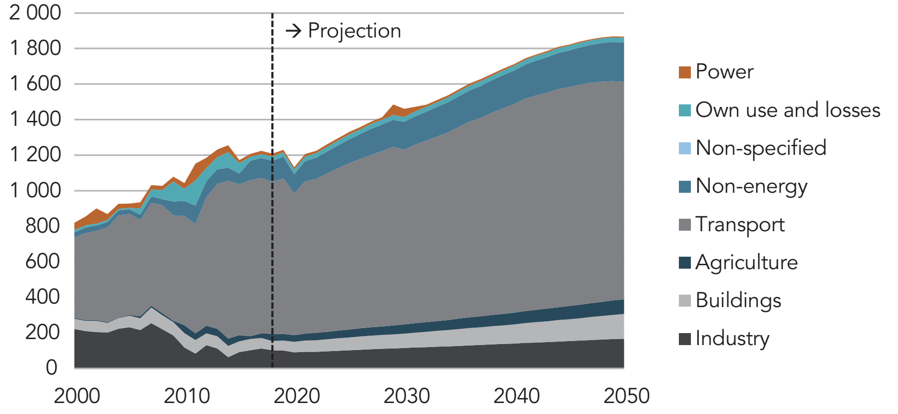


Sources: EGEDA, APERC analysis.

- In CN, crude oil and NGLs consumption follows a similar trend to REF until 2025, as refinery additions and expansions proceed as currently planned. However, declining demand for refinery products in both domestic and global markets reduces output to near-current levels by 2050.
- With refinery product demand falling to half of REF levels in 2050, Malaysia seeks to preserve a high refinery utilisation rate of 95% and retires excess capacity. This results in the retirement of half of its refinery fleet by 2050. The large-scale nature of this retirement illustrates the risk in investing in oil infrastructure in the 2020s, as such investments could become stranded assets as the world embarks on a path to carbon neutrality.
- Production, exports, and imports are all reduced by over half of REF levels in CN. A world embracing carbon neutrality results in lower refinery runs, and in turn lower crude oil imports, and a declining export market, which in turn reduces oil production.
- Malaysia could limit its refinery retirements and crude oil production declines by opting to funnel domestic production into its refinery fleet. However, this will require investments to reconfigure the refineries to process its sweeter, higher-quality crude.

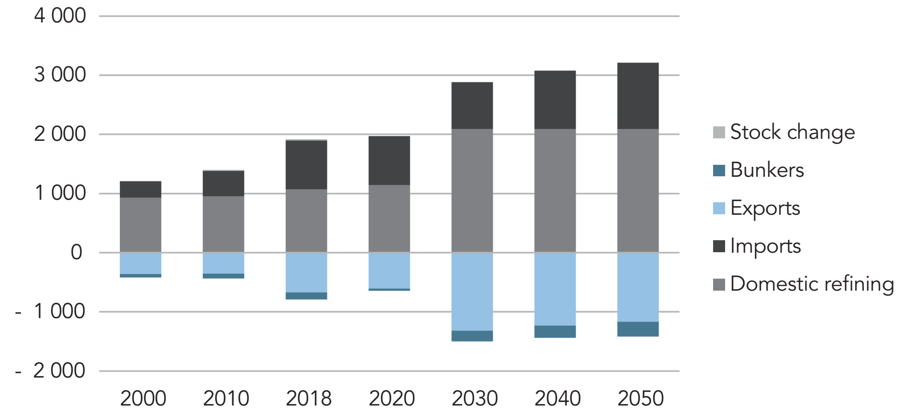
Refined products in the Reference scenario

Figure 10-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

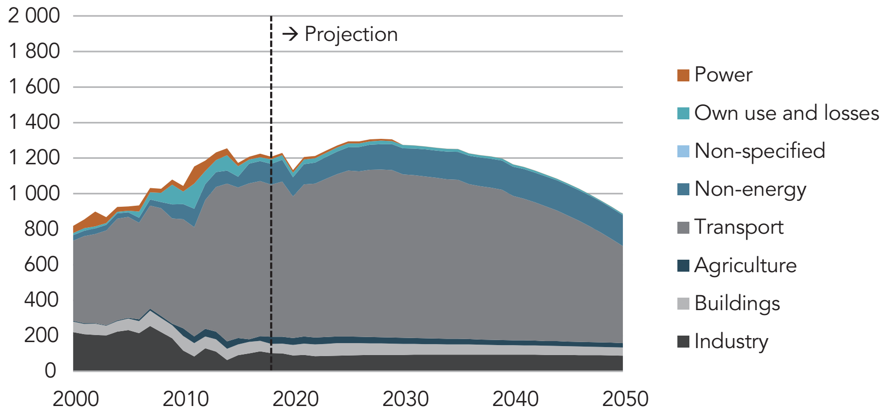


Sources: EGEDA, APERC analysis.

- Transport is the largest consumer of refined products, accounting for over two-thirds of total refined products consumption during the outlook period. Other consuming sectors include non-energy, industry, buildings, agriculture, and power sectors.
- Refined product consumption fell by 7.9% in 2020, as the onset of COVID-19 prompted government restrictions that reduced domestic mobility and lowered demand for industrial products. Refined products consumption returns to pre-pandemic levels in early 2023 and increases by half to 1 866 PJ.
- Higher transport use, due to fuel rising demand for moving goods and people, is the main driver of refined product consumption gains in REF. However, a near-doubling of use by other sectors occurs due to rising cooking fuel demand in buildings and higher output from the agriculture, industry and non-energy sectors.
- The implementation of the B20 and B30 renewable fuel standards limit refined product demand gains in REF.
- Malaysia's total refining capacity totals around 601 kb/d. This includes six facilities located in Peninsular Malaysia. Refining capacity will increase to 1 052 kb/d by 2025, with new facilities commissioning in Tanjung Bin and Pengerang.
- Malaysia has been a net importer of refined products since 2010. However, it becomes a net exporter of refined products in the 2020s of REF, as elevated refinery output outpaces a steady increase in domestic refined product consumption. The excess supply is exported to global markets. In REF, refined products imports increase by over a third, and exports increase by almost three quarters.

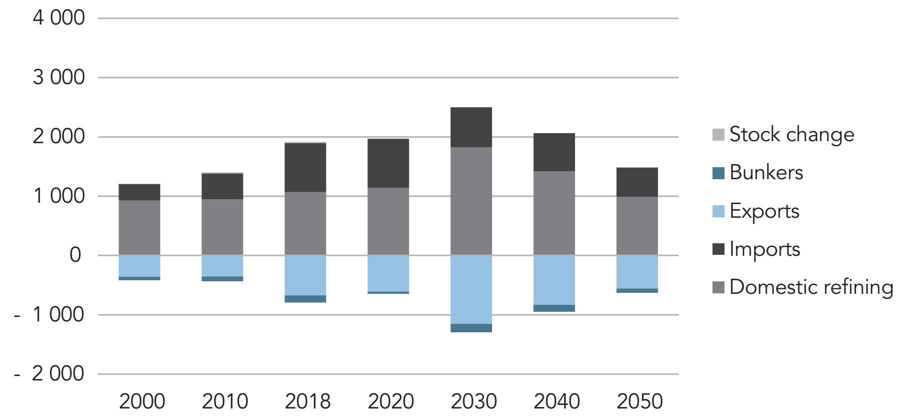
Refined products in the Carbon Neutrality scenario

Figure 10-39. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 10-40. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

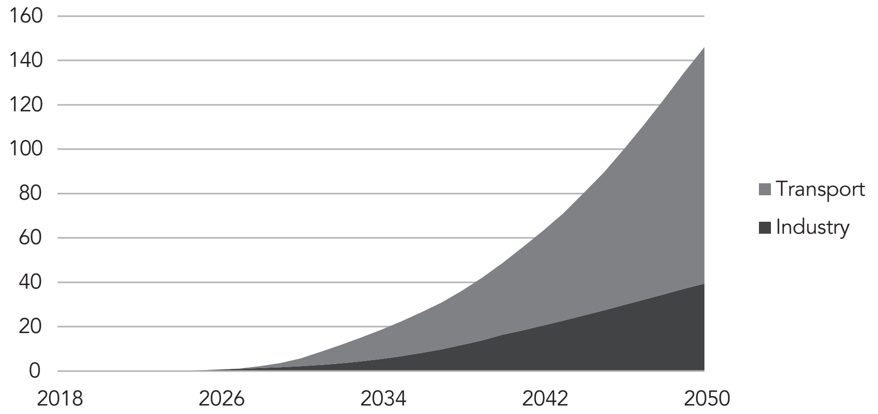


Sources: EGEDA, APERC analysis.

- Significant reductions in refined product demand in the transport sector result in a peaking of Malaysian consumption at 1 308 PJ in 2028. This is followed by a steady decrease to 886 PJ in 2050, about half below REF levels. While transport makes up over two-thirds of this decline, demand is reduced across all sectors in CN.
- Declining refined products consumption is consistent with Malaysia's policy objectives to reduce oil consumption, increase electrification, and introduce higher biofuel content into liquid fuel streams via the B40 program.
- Refined products imports fall drastically in line with these demand trends to 492 PJ in 2050. This is 56% lower than REF. Exports fall steeply, too, by over half, as global demand for refined products declines throughout the outlook period. With domestic and global demand significantly lower, refineries ratchet down their capacities and crude runs by half the levels of REF.
- Malaysia maintains its status as a net refined product exporter in CN.

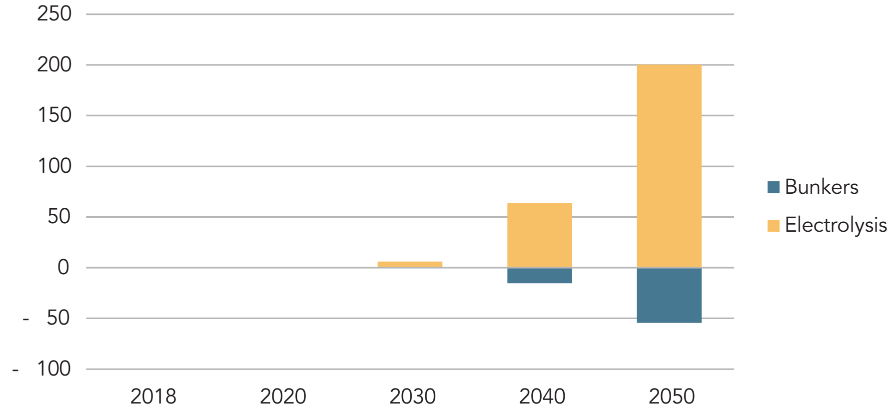
Hydrogen in the Carbon Neutrality scenario

Figure 10-41. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 10-42. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

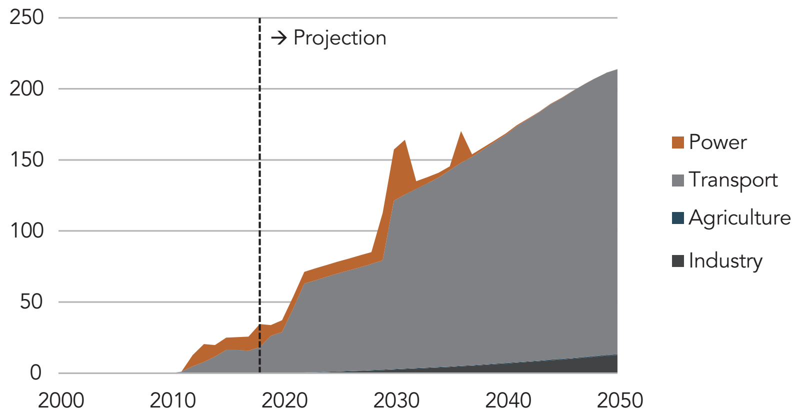


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- Hydrogen is considered an attractive emerging energy carrier due to the absence of carbon emissions associated with its combustion. However, hydrogen policy and direction in Malaysia remains undefined, likely due to the uncertainty surrounding the fate of the energy carrier in the global energy system. Hydrogen has yet to demonstrate its technical viability at a commercial level, nor has industry been able establish a supply chain to support commercial development.
- Despite the lack of hydrogen policy and direction at the economy level, Sarawak's state government has launched southeast Asia's first Integrated Hydrogen Production Plant and Refueling Station in 2019 to power Malaysia's first hydrogen-powered vehicles. The pilot plant can produce up to 130 kg of hydrogen per day at a purity of 99.999%. Furthermore, its capacity can handle refuelling of up to five hydrogen-powered buses and ten hydrogen-powered cars per day.
- In REF (not shown), hydrogen consumption in transport starts in 2026 and increases significantly after 2040 as government support lowers the price of hydrogen vehicles.
- In CN, hydrogen consumption in transport and industry sectors starts in 2025, a year earlier than REF. Hydrogen makes in-roads in other end-uses in CN, such as providing process heat for chemicals and cement production. Industry is the largest user until 2030, when it is surpassed by transport for the rest of outlook period. Hydrogen consumption multiplies rapidly in CN and is almost 100-times REF levels in 2050.
- Hydrogen removals for bunkering international aviation and marine activity starts in 2030 with 0.4 PJ and reaches 54 PJ by 2050 in CN.
- Hydrogen is produced domestically by the electrolysis method throughout the outlook period in both scenarios. Steam methane reformation is possible, but would require a higher supply requirements, and thus LNG imports, to satisfy its fuel requirements.

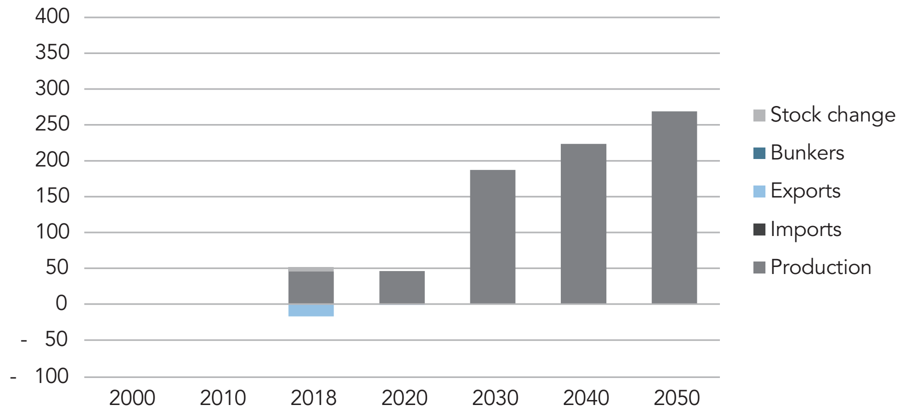
Bioenergy in the Reference scenario

Figure 10-43. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 10-44. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

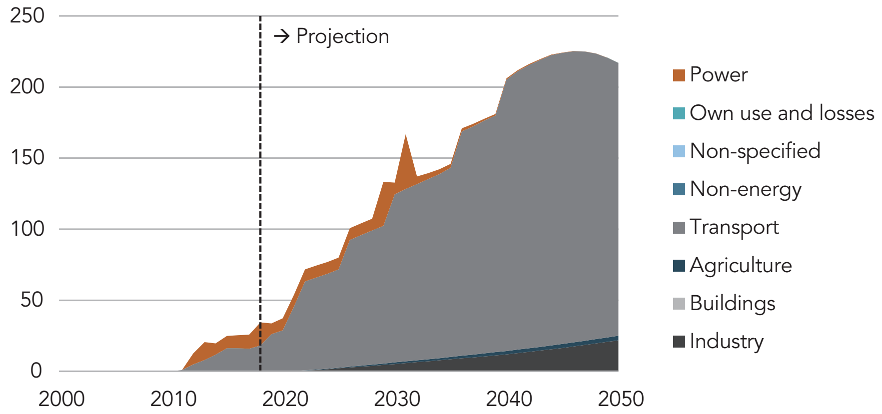


Sources: EGEDA, APERC analysis.

- Bioenergy is mainly consumed by the power and transport sectors. The driving force behind demand trends in the outlook period is the B20 and B30 renewable fuel programs, which propel biofuel use in transport eleven times higher and total solid and liquid renewable consumption up by six-fold. Transport accounts for 53% share of demand in 2018 and will increase significantly to 94% in 2050.
- The power sector experiences volatile spikes in demand for bioenergy in key years where it functions to fill-in for declines in coal-fired generation. For example, from 2029 to 2031, it spikes to 38 PJ, and in 2036, spikes to 22 PJ.
- Industry started consuming bioenergy, mainly biomass, in 2022 via the non-specified subsector. This biomass consumption will grow from 0.2 PJ in 2022 to 13 PJ in 2050.
- Agriculture consumes some bioenergy, specifically in fishing activities. This increases from 0.2 PJ to 0.5 PJ over the outlook period.
- Bioenergy demand in Malaysia is assumed to be met by domestic production throughout the outlook period. The production increases four-fold by 2030 and almost six-fold by 2050, mirroring demand trends. Exports are assumed to scale down to zero by 2022 to give priority to domestic demand.

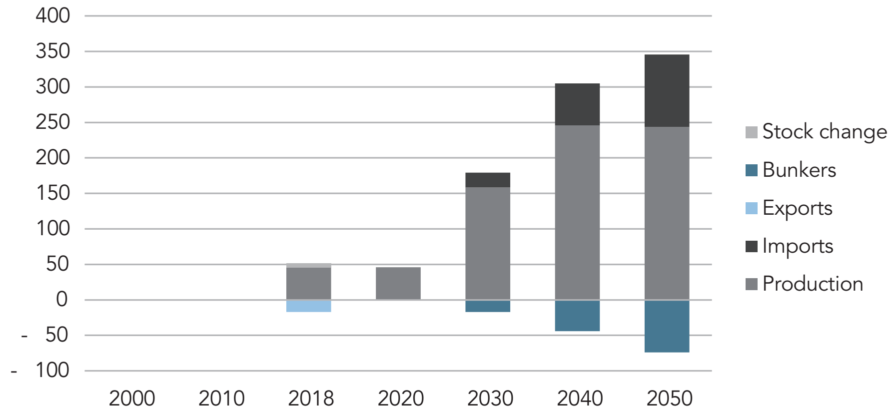
Bioenergy in the Carbon Neutrality scenario

Figure 10-45. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 10-46. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

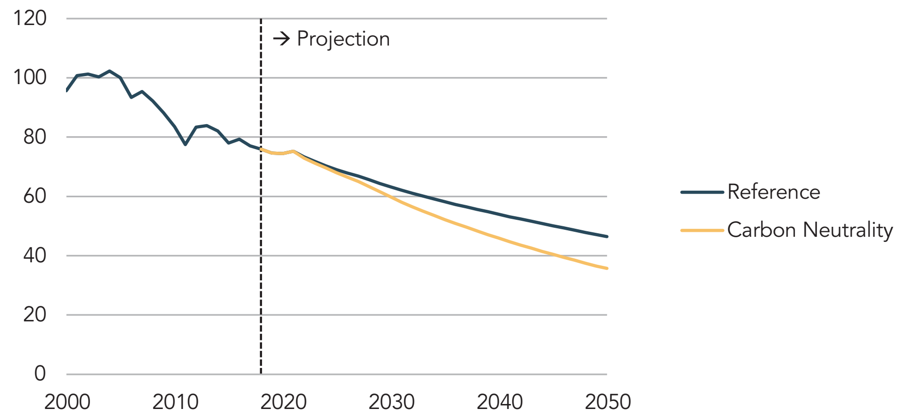


Sources: EGEDA, APERC analysis.

- Like REF, CN demand trends for bioenergy are driven by policy in the transport sector. In addition to B20 and B30, the B40 program yields even higher biofuel blending in oil products, and biojet fuel emerges as a blending option for aviation fuels. However, because biofuels are blended with conventional liquid products, renewable trends follow the lead of refined products. Higher adoption rates of EVs and fuel cell vehicles reduce refined products demand, and in turn biofuel use. Declining use of conventional vehicles drives renewable consumption to a peak in the 2040s and consumption falls to a marginally higher level than REF by 2050.
- Renewables consumption increases significantly between 2020 to 2040 in the transport sector due to the mandatory biodiesel program blending rate increasing to 40% in 2040. This target is 10% higher than REF.
- Industrial renewable use increases 70% above REF levels, as the chemicals and pulp and paper subsectors began to integrate biomass into their fuel mix in the 2020s.
- While CN continues to assume that most renewable fuels are produced domestically, unlike REF, it assumes that biojet fuel requirements are completely imported. However, Malaysia must import significantly more biojet fuel than it uses domestically to fuel bunkers, which here represent international aviation. Thus, while renewable imports rise to over 100 PJ, only a quarter of it is used by Malaysia.
- CN presents a unique opportunity to repurpose underutilised refineries as biofuel refineries. This could help mitigate the stranded asset problem Malaysia faces in this scenario and help reduce its reliance on imports for biofuels to meet its mandates. Furthermore, it could become a strategic supplier of biofuels in the APEC region.

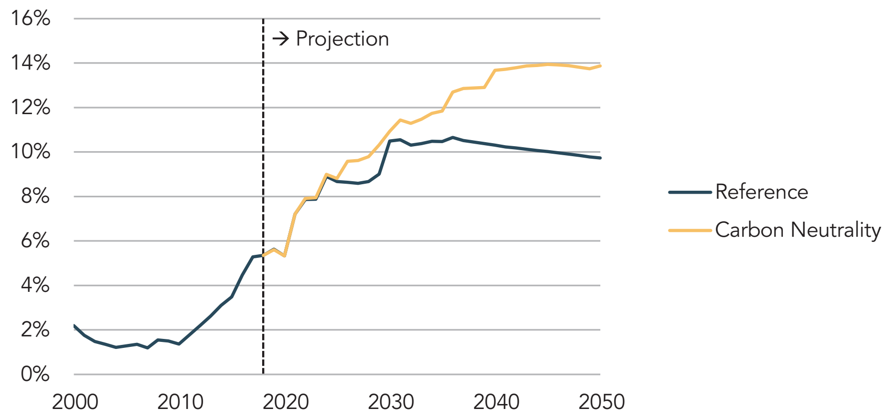
Energy intensity and modern renewables share

Figure 10-47. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 10-48. Modern renewables share in REF and CN, 2000-2050



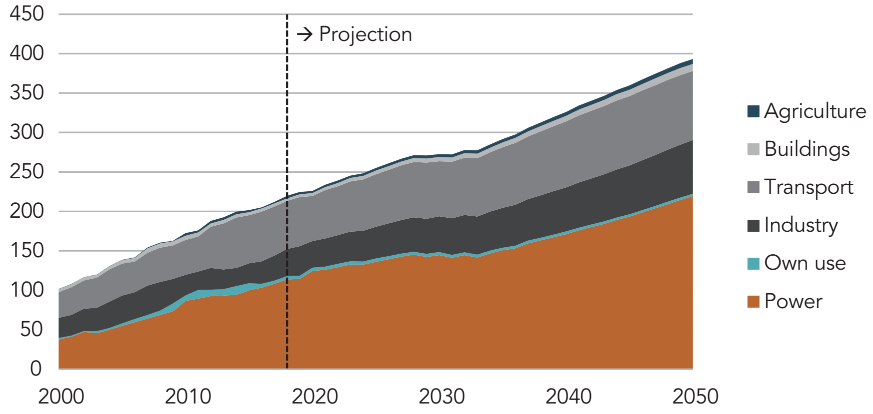
Sources: EGEDA, APERC analysis. Note: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- APEC has two aspirational goals: to reduce energy intensity by 45% in 2035, relative to the 2005 baseline and double modern renewables' share for the 2010 to 2030 period. The goals are non-binding and do not impose these targets onto individual economies. Any improvement that an individual economy makes is conducive to meeting the APEC goal. However, it is possible to track respective APEC economies' progress relative to the overarching proportional improvement.
- Strong economic growth and improvements in energy efficiency across end-use sectors have reduced Malaysia's energy intensity over the past two decades. This decoupling of energy from economic activity continues over the outlook period. While GDP grows about 4.0% annually during the outlook period, energy demand grows at an annual rate of 2.2% in REF and 1.3% in CN. By 2050, energy intensity falls 54% below 2005 levels in REF and 64% in CN.
- In REF, Malaysia does not achieve a 45% reduction in energy intensity below 2005 levels until 2039. However, its efforts do help APEC achieve its goal by 2034, a year ahead of schedule. In CN, Malaysia's 48% reduction by 2035 relative to a 2005 baseline is consistent with the APEC goal. Furthermore, these efforts helps APEC hit its goal in 2031, four years ahead of schedule.
- Malaysia's share of modern renewables has increased significantly since 2010 and surpassed the doubling of its 2010 modern renewables share in 2014.
- Biofuel policy, particularly the B20 and B30 mandates, drives modern renewables higher in REF, to over 10% by 2030, where it hovers for the rest of the outlook period. Modern renewables are lifted higher in CN, to 11% by 2030 and higher to 14% by 2050, as the more stringent B40 mandate increases biofuel use and because of additional renewable deployment from higher solar, hydro, and biomass capacity in the power sector.
- While Malaysia already achieved results consistent with the APEC modern renewable doubling goal, its efforts help APEC achieve the goal in 2026 in REF and 2025 in CN, ahead of schedule in both scenarios.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

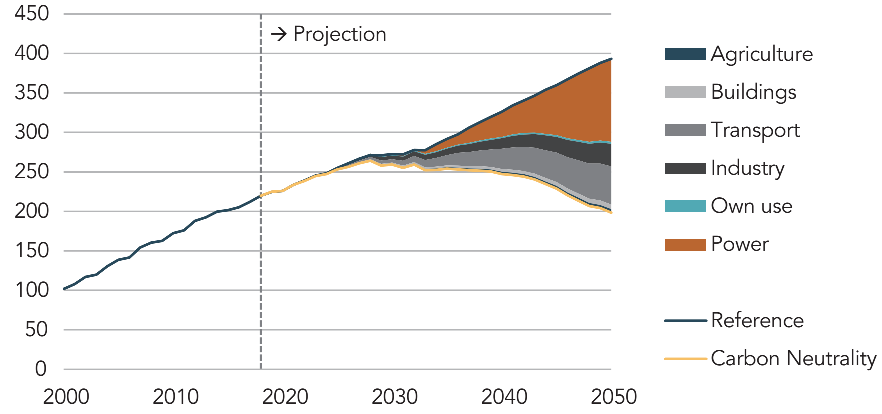
Gross CO_2 emissions

Figure 10-49. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 10-50. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

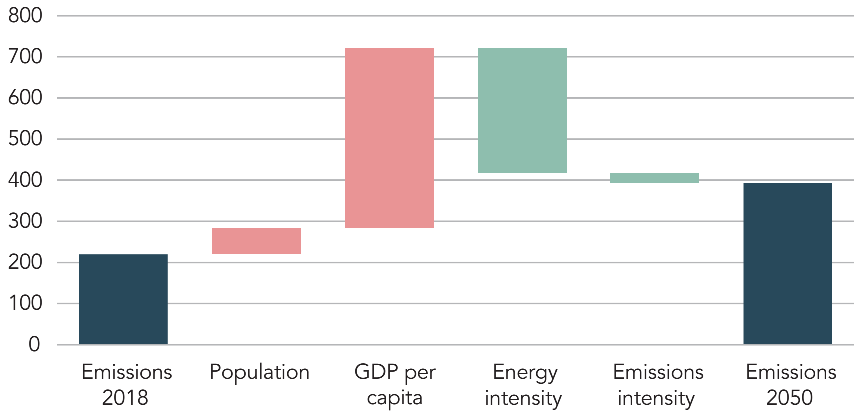


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Malaysia's CO_2 emissions increase steadily in REF due to an increasing trend in supply and demand for fossil fuels across all sectors. The CO_2 emissions increase 1.8 times from 220 million tonnes in 2018 to 393 million tonnes in 2050.
- In both scenarios, the power sector remains the dominant source of CO_2 emissions throughout the outlook period. In REF, the transport sector is the second-largest contributor of CO_2 emissions, followed by industry, buildings, agriculture, and own use.
- In CN, CO_2 emissions peak at 264 million tonnes in 2028, plateau through the 2030s, and start to steadily decline in the 2040s. CO_2 emissions are about half of REF levels in 2050. The contributing factors are electrification, fuel switching, and the deployment of CCS by both the power sector and industry.
- Malaysia revised its NDC in July 2021 with an updated target to reduce 45% of GHG emissions intensity of GDP by 2030 compared to the 2005 level unconditionally. Malaysia does not achieve its target in either scenario, where the CO_2 emissions intensity of GDP increases by 6.5% in REF and 5.0% in CN. However, the CO_2 emissions intensity of GDP will reduce by 36% in CN by 2050.
- To become a carbon-neutral economy, Malaysia will need to find ways to further sequester or offset its near 200 million tonnes of carbon emissions in CN. This could include further domestic sequestration, exporting the carbon for use elsewhere, purchasing offsets, or other making emission reductions in other areas, like land use.
- While Malaysia aims to leverage its offshore CCS potential to store carbon and yield higher oil production in the 2020s, if global oil demand declines, it will need to unlock this storage potential without the aid of hydrocarbon production.

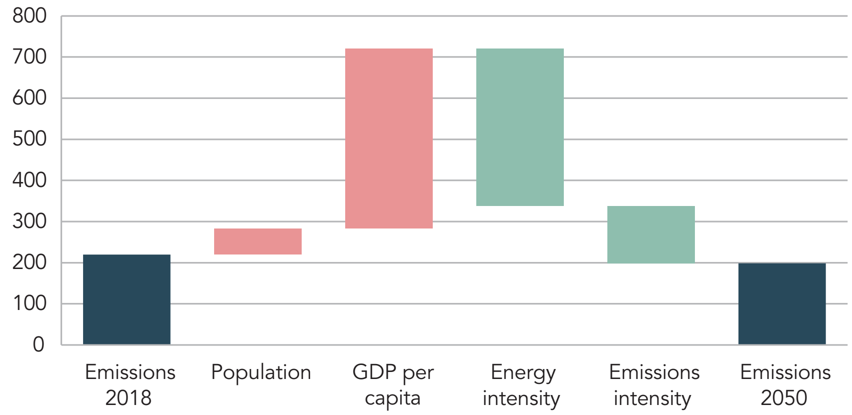
Components of CO_2 emissions

Figure 10-51. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 10-52. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- In 2018, Malaysia emitted 220 million tonnes of CO_2, or about 1.0% of total APEC CO_2 emissions. Population and GDP per capita contribute to an increase in emissions if all else were held equal. Malaysia's population growth would increase emissions by 63 million tonnes, while income growth would increase emissions by 438 million tonnes.
- Energy intensity and emissions intensity do, however, evolve across both scenarios, as policy assumptions and market trends foster energy efficiency improvements and fuel switching towards lower-emitting sources.
- In REF, the energy-related regulations, policies, plans, and measures in place will nearly halve the expected CO_2 emissions increase without improvements. This occurs mostly through energy efficiency improvements, which contribute 93% of these reductions. However, switching to lower-emitting fuels, like electricity, biofuels, and renewables, improves emissions intensity, which accounts for the remaining 7.3%.
- In CN, higher energy efficiency lifts energy intensity reductions by a quarter and stronger fuel switching, carbon sequestration, more stringent biofuel blending mandates, and higher renewable deployment in the power sector cause emission intensity reductions to rise by nearly six-fold over REF.
- As Malaysia does not meet its NDC targets in both scenarios, achieving carbon neutrality or further emission decreases may require further advances in energy efficiency and emissions intensity. Besides a comprehensive National Energy Policy, Malaysia will release the detailed measures for carbon reduction under the long-term strategic review of the low-carbon development strategies by the end of 2022. This will support its aspiration and commitment to becoming a carbon-neutral economy by 2050.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

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11. Mexico

Highlights

Demand

- Mexico's energy demand increases by 41% out to 2050 in REF. In CN, energy demand peaks in 2040 and is 7% higher in 2050 than in 2018.
- Electricity's share of energy demand increases from 19% in 2018 to 30% (REF) and 49% (CN) in 2050.
- Traditional biomass, an important fuel in the residential sector, is reduced in both scenarios because more people have access to cleaner options for cooking and water heating such as LPG, natural gas, and electricity.
- Hydrogen emerges as an important energy source in CN, reaching 5% of total energy demand in 2050.

Supply

- Mexico maintains a high dependence on fossil fuels in REF. Natural gas supply increases 46% to become the most prominent fuel from the late 2030s. Oil supply maintains a level of just above 4 000 PJ for most of the projection period. In contrast, coal supply falls 44%, while renewable sources increase 45% through to 2050.
- In CN, Mexico's energy supply increases slightly out to 2030, and then falls to a level that is less than two-thirds of REF energy supply in 2050. The most striking result of CN is that renewable energy supply increases in share from 9% in 2018 to 51% in 2050, displacing natural gas and oil products from the energy supply mix.
- Mexico's fuel import volumes in the CN scenario are 82% less than in REF by 2050, making this scenario more aligned to the objective of increasing energy security and independence.

Power

- In REF, the share of variable renewable solar and wind grows from 7% in 2019 to 29% in 2050. In CN, solar and wind grow to account for 83% of Mexico's generation. This massive increase in intermittent sources of electricity requires significant improvements in power system flexibility.
- In REF, natural gas generation more than doubles out to 2050 (408 TWh). The contrast is stark in CN with natural gas peaking in 2023 (215 TWh), and then declining to 83 TWh by 2050. Natural gas with CCS technologies begins to be deployed in the early 2030s in CN and accounts for most natural gas generation by the end of the projection period.

CO_2 emissions

- In 2018, energy related CO_2 emissions were 415 million tonnes, with most emissions attributable to power (35%) and transport (34%).
- In REF, CO_2 emissions increase by 19% to 533 million tonnes in 2050. Energy intensity and emissions intensity improvements are insufficient to offset the increasing emissions pressures associated with an increase in population and increases in living standards (GDP per capita).
- In CN, energy related CO_2 emissions peak at 428 million tonnes in 2023. Increased wind and solar penetration in the power sector, CCS technologies, greater energy efficiency, electrification, material efficiency, and other influencing factors see CO_2 emissions fall to 149 million tonnes in 2050.

Trade

- Despite increases in gas demand in REF, a lack of upstream investments increases Mexico's dependency on imported natural gas. By 2050, 83% of the 5 063 PJ of natural gas consumed in Mexico will be imported.
- In CN, natural gas production is 64% lower in 2050 than in REF. Most of the domestic demand for gas is met with imported gas (87%), coming mostly from the United States (90%). Even with the high import dependence, natural gas imports are 2 650 PJ (63%) lower in 2050 than in REF.
- Mexico's oil trade dynamics consist of exporting its heavy crude oil to the international market, particularly the US, while importing refined products such as gasoline, diesel, and jet fuel. Mexico's domestic refining capacity is insufficient to satisfy domestic demand. However, with declining demand for refined products in CN, a greater and greater share of demand for refined products will be met by domestic refining output.

About Mexico

- Mexico is a federal republic bordered by the US to the north, Belize and Guatemala to the south, and the Atlantic and Pacific Oceans on the east and west. Mexico is in North America, though it is also part of Latin America, for cultural and historical reasons.
- Mexico is home to 126 million people and is the world's largest Spanish-speaking and the 11th most populated economy in the world. It is the sixth most populated member in APEC.
- Mexico's GDP grew by 2.0% per year between 2000 and 2018 to USD 2 523 billion (2017 USD purchasing power parity). GDP per capita growth was significantly lower, increasing by 0.7% per annum for the same period. Income inequality remains an urgent challenge in Mexico, with 42% of the population living in poverty and a Gini index coefficient of 45.4 in 2018.
- Mexico is the 15th largest economy in the world and the sixth largest economy in APEC, economically comparable with Spain or Australia. The service industry accounts for the largest share of GDP (60%). Manufacturing accounts for 17% of GDP, and most exports are manufactured goods.
- Economic reforms and free trade agreements introduced in the 1990s have resulted in macroeconomic stability, increased flows of foreign direct investment, and the development of a manufacturing industry that is closely integrated with the US.
- Energy, particularly crude oil, has historically been a significant component of the Mexican economy. Following an overall economic diversification and declining production, crude oil accounted for 5.3% of Mexico's total export value in 2019, compared with 37% in 1990. Despite this declining trend, Mexico still relied on crude oil rent for 10% of its government budget in 2019. However, this is low compared to the greater than 30% share for 2004-2014.
- Mexico has a rich and diverse potential for renewable energy, conservatively estimated to be 2 593 gigawatts (GW). While the potential is overwhelming for wind and solar energy, there are also prospects for hydropower, geothermal, and bioenergy. Mexico's average daily solar PV potential is one of the highest in the world, exceeding 4.5 kilowatt hours per installed kilowatt of capacity (kWh/kWp).

Table 11-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	126	4.3%	6
GDP	2 584	3.7%	6
TPES	7 562	2.2%	8
Production	6 622	1.9%	7
Imports	4 306	3.4%	7
Exports	3 077	2.8%	8
Electricity generation	336	2.0%	7
Heat production	0.0	0.0%	–
CO_2 emissions	448	2.1%	8

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 11-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	9	185	0.1%	9
Natural gas	11	6	0.1%	11
Oil	5	9	0.4%	5
Uranium	N/A	N/A	N/A	N/A

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- **Electricity Industry Law and Hydrocarbons Law (2014):** Legislative initiatives, or amendments, were published in March and May 2021. The ultimate purpose of these amendments is to strengthen the state-owned Federal Electricity Commission (CFE; Spanish acronym) and the state-owned oil company Petroleos Mexicanos (Pemex). Amended provisions include granting a dispatch preference to CFE's power plants, removing the obligation from service suppliers to undertake actions to procure electricity, and revoking self-supply permits. The legislative initiatives have been contested in court.
- **Revocation of asymmetrical regulation to Pemex:** This law amendment takes away the faculty of the Energy Regulatory Commission (CRE; Spanish acronym), to impose asymmetrical regulations on Pemex's oil, gas, fuels, and petrochemicals activities. The asymmetric regulation provided for in the thirteenth transitory article, in force since 2014, was intended to limit the power of Pemex against different actors, to promote the participation of economic agents for the efficient and competitive development of the hydrocarbon sector.
- **CENACE Resolution:** In April 2020, CENACE, the independent electricity system and market operator indefinitely suspended pre-operational tests for new solar and wind projects and modified the rules for grid access. The resolution was instituted to guarantee the efficiency, quality, reliability, continuity, and stability of the National Electric Grid.
- **Pemex purchase of the Deer Park refinery:** Pemex, the state-owned oil company, agreed to a USD 596 million deal to buy Shell's majority interest in the joint-venture 340 000-barrels-per-day refinery in Deer Park, Texas.
- **Construction of the Dos Bocas refinery:** A key element of Mexico's oil policy is boosting domestic refining. The construction of the emblematic Dos Bocas refinery is one of the landmark infrastructure projects of the current federal administration. The 340 000 barrels per day refinery is expected to increase refining capacity by 25%, with a wholly government-funded investment of an original estimate of USD 8 billion (that is now at least 4 billion dollars over budget), and it is expected to be operational by 2024.
- **Natural gas infrastructure projects:** These new projects in Mexico contribute to the expansion of natural gas flows from the US to Mexico. The final segment of the Wahalajara system, which connects the Waha Hub to Guadalajara in Central Mexico, is called the Villa de Reyes-Aguascalientes-Guadalajara (VAG) pipeline. It is owned by Fermaca and began commercial operations in October 2020 and has a capacity of 0.9 billion cubic feet per day. Carso Energy's 0.5 billion cubic feet per day Samalayuca-Sasabe pipeline entered operations in January 2021 and connects natural gas from the Permian Basin to northwest Mexico.
- **Energía Costa Azul (ECA) LNG Final Investment Decision:** In November 2020, the American company Sempra reached a final investment decision to develop a natural gas liquefaction facility called Energía Costa Azul (ECA) LNG Phase 1. ECA LNG, located in Mexico's north-western Pacific coast, will use feed-in gas production mostly from Texas to export LNG to Asian markets. It is the first project to export US shale gas from the Pacific coast and is expected to start operations in 2024.
- **Construction of an LNG receiving terminal in Pichilingue:** In July 2021, the American company New Fortress Energy inaugurated a small-scale regasification facility of 0.8 million tonnes per annum with a 135 MW power plant and truck loading bays. The plant will also supply CFE's power plants and other users in La Paz, Baja California Sur, which is set to be operational in 2021.
- **Renewable energy capacity additions:** In Mexico, political and regulatory uncertainty remains a barrier and key risk for new investments in this sector. The cancellation of the long-term electricity auctions in 2018 has constrained growth in renewable capacity. However, distributed PV projects (under 0.5 MW) are rapidly expanding in the country as they do not require permits under the current legal framework and are economically attractive amid rising electricity tariffs. Distributed PV capacity is expected to more than double during 2021-2026.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- **The Reference scenario (REF)** reflects recent trends and current and planned policies to capture the evolving nature of the energy system. REF identifies potential risks and problems that might arise if the energy sector develops according to current trends.
- Mexico has not explicitly defined a dateline to reach carbon neutrality but has committed to reducing 22% of greenhouse gas (GHG) emissions by 2030 under the Nationally Determined Contributions (NDCs).
- Mexico's emphasis of energy security and independence has been incorporated, which has supply implications.
- NDC measures such as improvement of energy efficiency, electrification of industry demand, promotion of electric vehicles, and the increase of clean energy electricity generation are implemented in REF.
- Hydrogen production is considered in REF and is driven by domestic demand.
- **The Carbon Neutrality scenario (CN)** illustrates the additional transformation required to supply energy under the aspirations of reaching carbon neutrality by 2050. More ambitious goals are set for several NDC measures.
- In CN, solar water heaters in the buildings sector, a higher share of electric vehicles, higher penetration of solar and wind energy, thermal plants with CCS technologies in electricity generation and in industry, and faster replacement of fuelwood and electricity are among the most effective measures that were modelled to reduce net CO_2 emissions.
- In addition to domestic use, international aviation and maritime transport (bunkers) is another large source of hydrogen demand.
- The scenarios do not represent APERC's recommendation or advocacy for a pathway or set of policies.
- Long-lasting effects of COVID-19 on human behavior such as the increase of teleworking and reduction on commuting have not been included as they are still to be determined.

Table 11-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Mexico

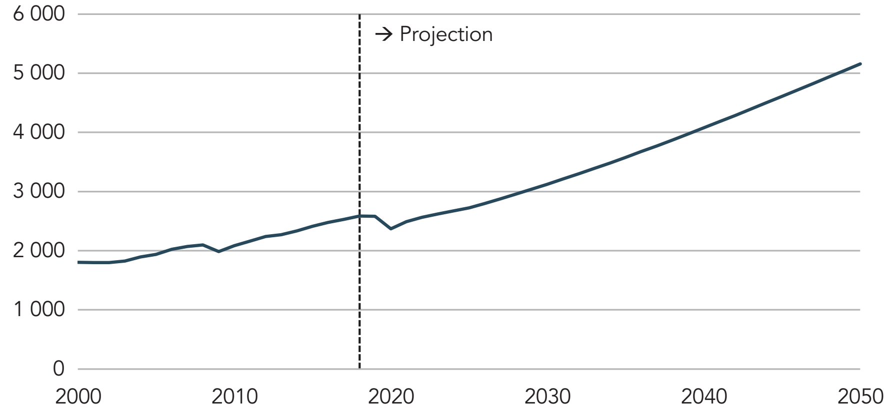
Table 11-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: WDI (historical), UN DESA growth rates (projection). • GDP growth from World Bank data • CO_2 emissions are from combustion.	• In general, follows CO_2 reductions from IPCC P3 pathway. • Macro: same as Reference scenario.
Buildings	• Energy efficiency ratings promote increases in appliance energy efficiencies. • Electrification of the demand for thermal use • Switching from traditional biomass to liquified petroleum gas (LPG) and electricity.	• Increase in the quantity of solar water heaters being installed in the residential sector • Electrification of demand in the buildings sector including for cooking purposes • More intense switch from traditional biomass to LPG and from LPG to electricity
Industry	• Fuel switching from coal to biomass and gas in the steel sector from 2030 • Energy efficiency for aluminum and pulp and paper improves by roughly 0.5% per annum. • Limited electrification • Switch away from most high-carbon fossil fuels to gas (and some biomass) in non-specified sector.	• Uptake of CCS for industry subsectors starting in 2030. • Hydrogen used in combustion applications in chemicals and steel subsectors from late 2020s. • Fuel-switching from coal to biomass and gas from 2025 in the steel sector • Additional energy efficiency improvements and higher electrification than Reference • Additional effort to shift from diesel to electricity in the mining sector • Switch from fossil fuels in pulp and paper and prominent non-specified category
Transport	• New rail developments offset growth in passenger and air transport. • Increase in vehicles fleet fuel efficiency	• Electric vehicle sales increase in light and heavy transportation but not at the same rate as other North America economies. • New public transportation growth is faster than in the Reference scenario.
Power and heat	• No inclusion of new coal plants. Economic dispatch is assumed.	• No inclusion of new nuclear plants • CCS for gas-fired plants
Supply	• Hydrogen demand follows conservative expectations in transport. • No increase of refinery capacity after Dos Bocas in 2024	• Oil import dependence declines due to greater renewable energy supply. • International marine and aviation demand for hydrogen (captured by bunkers) will be satisfied by green hydrogen.
Climate Change	• NDC mitigation measures are incorporated for electricity generation and energy efficiency.	• More ambitious implementation of NDC mitigation measures to achieve carbon neutrality by 2050.

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

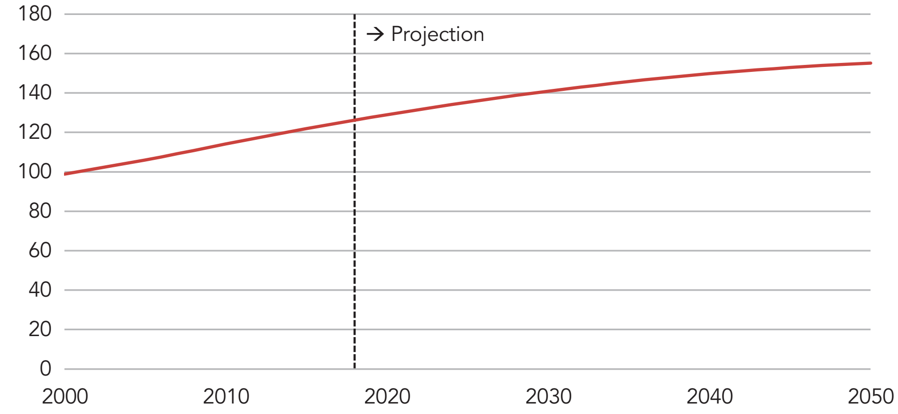
Macroeconomic backdrop

Figure 11-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 11-2. Population in millions, 2000-2050

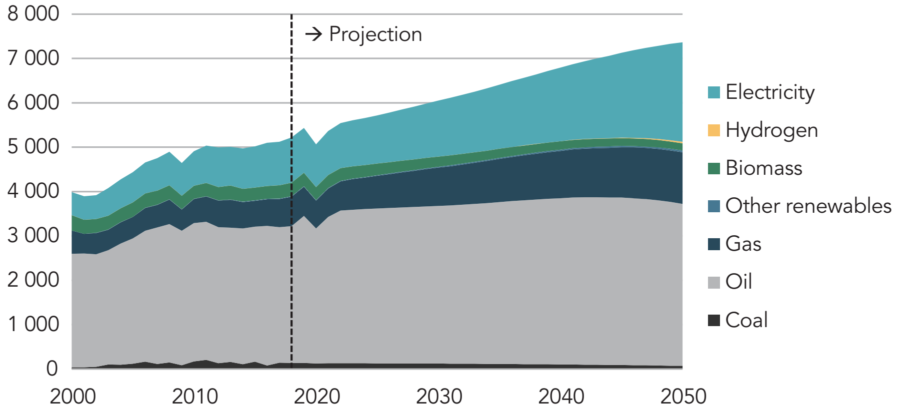


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- From 2000 to 2018, Mexico's population grew at an annual growth rate of 1.4%, which is a faster rate of growth than for the APEC region.
- Population growth is expected to slow from 2018 to 2050, with an annual average growth rate of 0.6%. The population of 126 million in 2018 is expected to be 141 million in 2030 and 150 million in 2050. Population is projected to peak not long after 2050.
- The impact of the COVID-19 pandemic in Mexico has been included, as shown by the large drop in GDP in 2020. From 2022 to 2050, GDP is projected to grow by an average of 3.1%. This projection represents a slowdown from the 4.5% annual growth from 2009 to 2019.
- By 2050, Mexico's economy is expected to double from the 2018 level in real purchase power parity (PPP) terms.
- Continued economic growth and an increasing population will impose increasing demands for energy in Mexico. Meeting this demand in a sustainable and efficient manner is a challenge that all APEC member economies face. While energy intensity is decoupling from economic growth, GDP and population are still the most influential drivers of energy demand projections in both the REF and CN.
- Mexico's services sectors account for roughly 60% of its economic output. The industry sector accounts for almost 30%, with these shares being relatively stable for multiple decades. Oil and gas has been an important foundation for Mexico's economy for multiple decades. However, there has been an ongoing pivot to manufacturing, which is partly facilitated by natural gas supply.

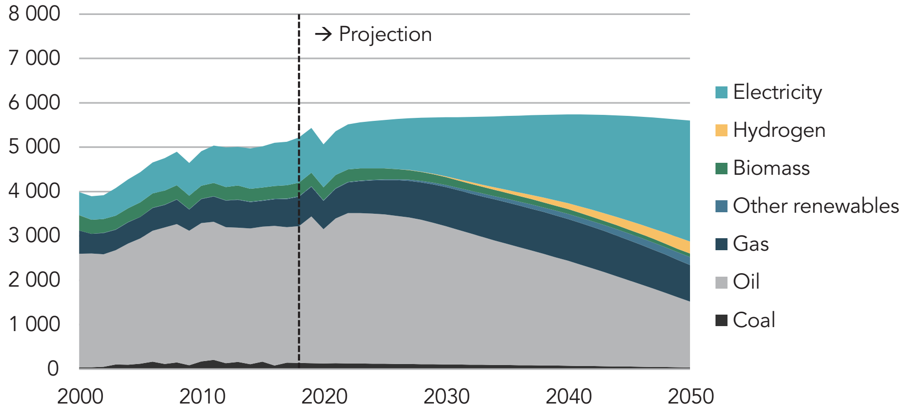
End-use energy demand

Figure 11-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 11-4. Energy demand in CN, 2000-2050 (PJ)

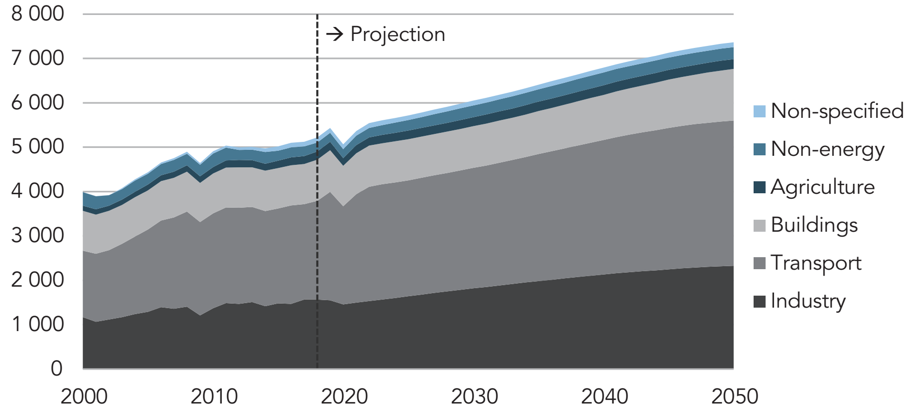


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- In REF, Mexico's energy demand grows by 41% out to 2050, which is on par with the observed growth from 2010 to 2018; Mexico's energy demand grew at a compound annual growth rate (CAGR) of 1.1% during that period.
- In CN, energy efficiency, material efficiency, fuel switching, and technological innovations curb demand so that it peaks in 2040. Energy demand in 2050 is 7% higher than in 2018, though is beginning to trace a declining trajectory.
- In REF, oil demand grows until 2045 with a peak at 3 776 PJ, 14% higher than 2019 levels. Oil demand grows at a slower rate than total energy demand; oil share falls from 61% in 2019 to 50% in 2050. On the other hand, the shares of electricity and natural gas increase from 12% and 19% in 2019 to 16% and 30% in 2050, respectively.
- In CN, oil demand peaks at 3 393 PJ in 2023 and then decreases at a CAGR of –3%. In 2050, oil demand is 1 484 PJ, 45% of 2019 levels. For the period 2019–2050, electricity demand grows faster in CN (CAGR of 3.3%) than in REF (CAGR of 2.6%). This is the result of intensive electrification throughout almost all sectors of the economy.
- Hydrogen emerges as an important energy carrier in final energy demand in CN. The share of hydrogen reaches 5% of total energy demand in 2050.
- Traditional biomass, an important fuel in the residential sector, is reduced in both scenarios because more people have access to cleaner options for cooking and water heating such as LPG, natural gas, and electricity.
- End-use coal consumption is already relatively low, though consumption falls in both scenarios out to 2050. This trend is driven by energy efficiency and fuel switching measures in industry, specifically the steel subsector, that lead to even lower levels of coal consumption.

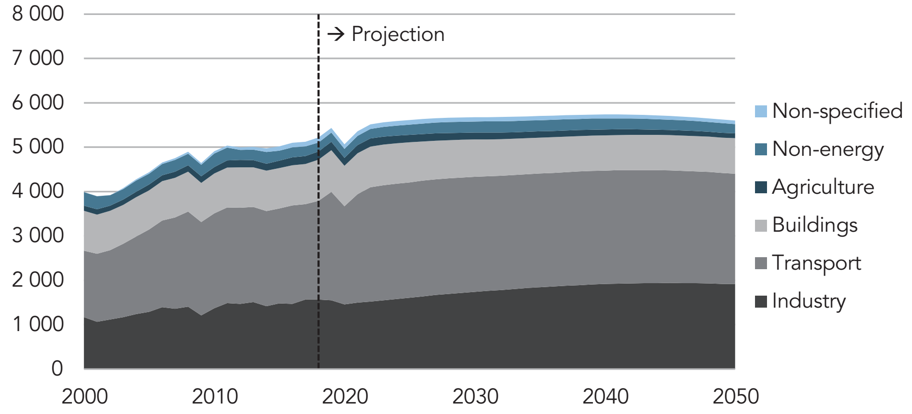
End-use energy demand by sector

Figure 11-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 11-6. Energy demand by sector in CN, 2000-2050 (PJ)

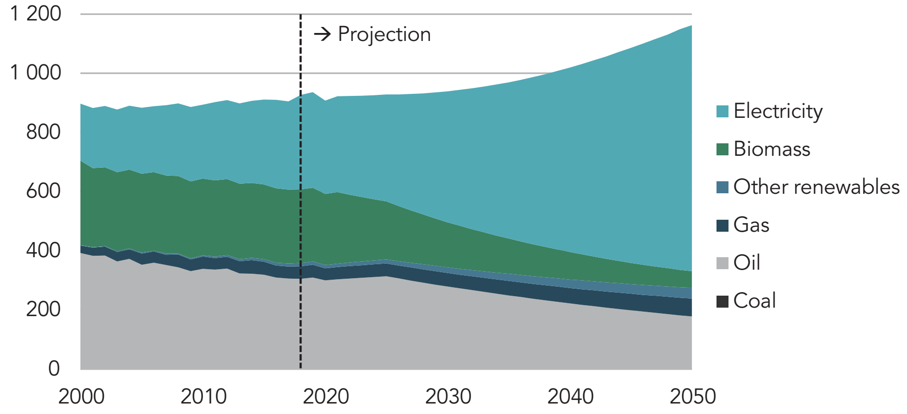


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- The shares of energy sectors are relatively constant throughout the projection period in REF, except for industry that increases its share from 30% in 2018 to 32% in 2050. The transport sector, which is the largest end-use energy sector, accounts for almost 45% of final energy demand in 2050, while the buildings sector accounts for 16% in 2050. The contribution of agriculture, non-energy, and non-specified is 8%.
- In CN, industry sector energy consumption is lower than in REF out to 2050, but its share of end-use energy consumption increases to 34% through the projection period. Meanwhile, buildings decrease from a share of 18% in 2018 to 14% in 2050.
- Transport remains the largest energy consuming sector in both scenarios. Its share of approximately 45% of end-use energy consumption is maintained until 2050 in both REF and CN.
- These results emphasise the prominence of the transport and industry sectors in Mexico. Together, they account for approximately three-quarters of Mexico's energy demand. Decarbonisation measures within these sectors, such as electrification of road transport or the use of hydrogen in chemicals and steel production, are key to achieving carbon neutrality.
- The effects of energy efficiency measures and fuel switching assumed in CN are observed across all sectors and curbs demand in all sectors. Industry demand is 18% lower in CN relative to REF in 2050. In transport, that difference is 24%; buildings is 31%; agriculture is 51%; and non-energy is 22% lower.

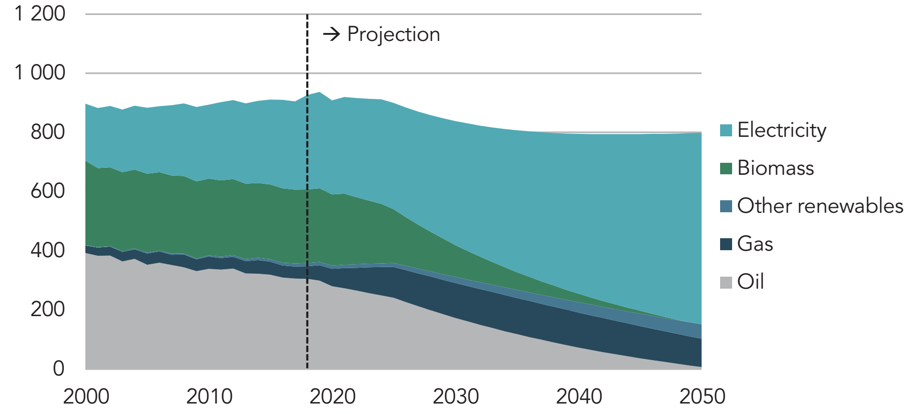
Buildings energy demand

Figure 11-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-8. Buildings energy demand in CN, 2000-2050 (PJ)

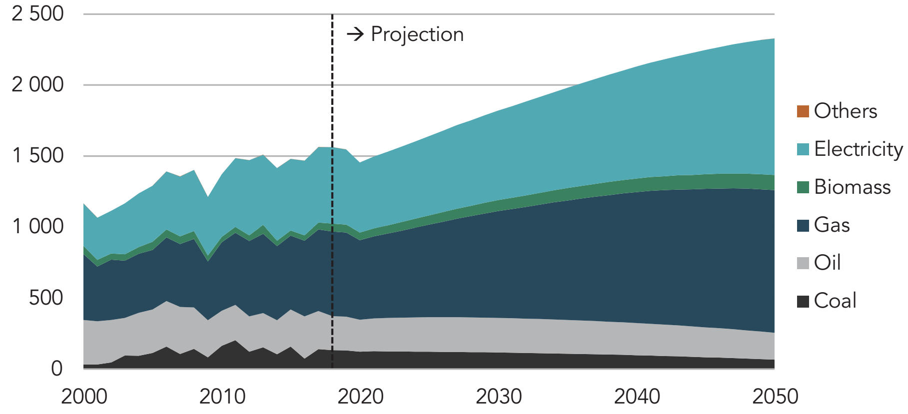


Sources: EGEDA, APERC analysis.

- Buildings sector demand grows from 936 PJ in 2019 to 1 162 PJ in 2050 representing an increase of 24% in REF. Energy efficiency measures are outweighed by population increases and increased demand associated with a higher standard of living and income.
- In CN, energy demand falls to 798 PJ in 2050, which is 15% lower than 2019 levels. Increased accessibility of natural gas facilitates fuel switching away from traditional biomass. Increased electrification also contributes to the traditional biomass phase-out.
- Electricity is the most prominent fuel used in Mexico by 2050. In REF, electricity increases from 324 PJ in 2019 to 832 PJ in 2050. In CN, electricity demand only increases to 647 PJ, though its share is higher than in REF. The results show that electricity demand will be between 2 and 2.5 times higher than 2019 levels.
- Natural gas increases at a CAGR of 1.1% in REF and by 4.8% in CN. These growth rates are faster than the overall energy demand growth rate and is explained by mass adoption of natural gas throughout the buildings sector.
- In CN, oil products demand falls at a CAGR of –12% due to strong electrification of thermal uses. The widescale deployment of gas pipeline systems and increased accessibility that comes with that deployment also contributes to the fall in oil products.
- Long-term behavioural changes because of the impact of COVID-19 in the buildings sector, for example people adopting teleworking even after the crisis is over, have not been assumed.
- The main driver for the curb in residential demand is the replacement of traditional biomass due to the use of more efficient technologies that consume cleaner fuels.
- Increased energy efficiency in home and buildings appliances contributes to a reduction of energy demand by electric equipment in REF. This energy saving is higher in CN.
- New buildings comply with more stringent energy efficiency building codes. The energy demand impact of these codes is greatest for the services/commercial sector.

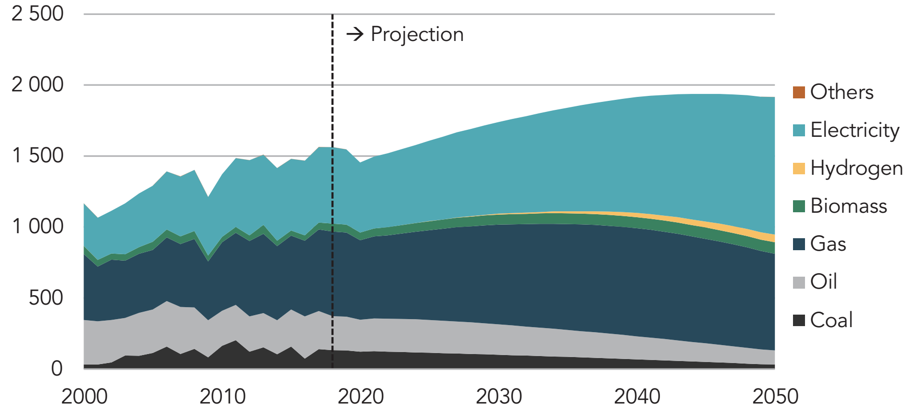
Industry energy demand

Figure 11-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 11-10. Industry energy demand in CN, 2000-2050 (PJ)

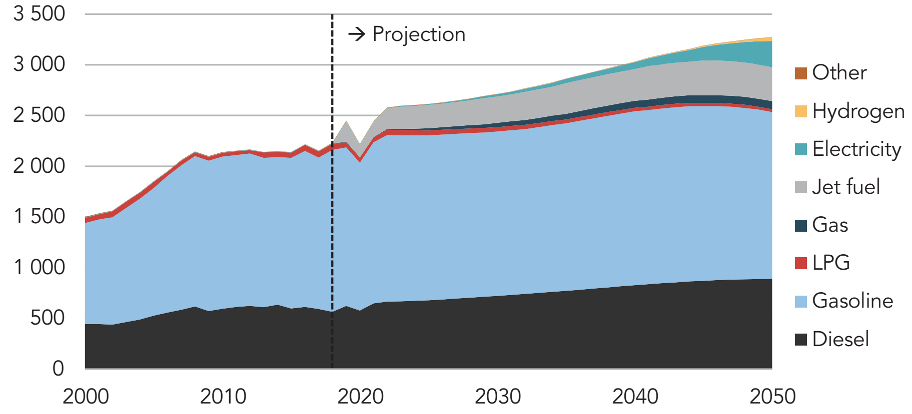


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industry demand increases by almost half from 2018 to 2050 in REF. There is a gradual movement from the most carbon-intensive energy sources, coal and oil, to more natural gas and electricity. Coal and oil decline by 46% and 36% respectively, while natural gas and electricity grow by 44% and 49% respectively from 2020 to 2050.
- In CN, industry demand peaks at 1 937 PJ in 2045; demand then falls to 1 916 PJ in 2050. However, industrial output continues to increase through to 2050. The beginnings of a decline in energy demand is explained by improvements in energy intensity.
- In CN, material efficiency is also important to temper energy demand growth. Approximately 10% less steel, chemicals, and cement production is required to deliver the same final output. For example, materials innovation is assumed to mean that buildings constructed in 2050 require less steel and cement than in REF, where that innovation has occurred at lower levels.
- Electricity accounts for nearly 34% of the demand in industry in 2019. The share of electricity increases to 41% in 2050 in REF. In CN, electricity increases to 50.6% in 2050.
- Industry consumes mainly fossil fuels for its thermal processes. But fossils fuels decline from a share of 62% in 2018 to 54% (REF) and 42% (CN) out to 2050. Natural gas runs against this trend in REF by increasing from a share of 38% in 2018 to 43% in 2050. In CN, the share of natural gas is slightly lower, at 36% in 2050.
- Hydrogen begins to be incorporated by the chemicals subsector in 2025 in CN and is then later adopted by processes within the steel subsector. Hydrogen consumption grows to account for 3% of industry energy demand by 2050. It is assumed to be sourced from electrolysis using renewable generation (so called 'green hydrogen').
- CCS is incorporated by heavy industry sectors comprising steel, chemicals, and cement subsectors in CN. Deployment is assumed to begin in 2030. Almost 30% of fossil fuels are subject to some form of carbon capture technology, with capture rates averaging 80%.

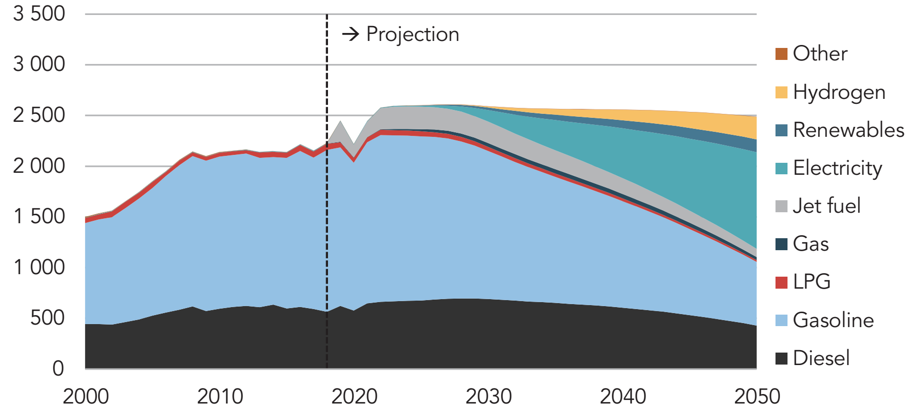
Transport energy demand

Figure 11-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 11-12. Transport energy demand in CN, 2000-2050 (PJ)

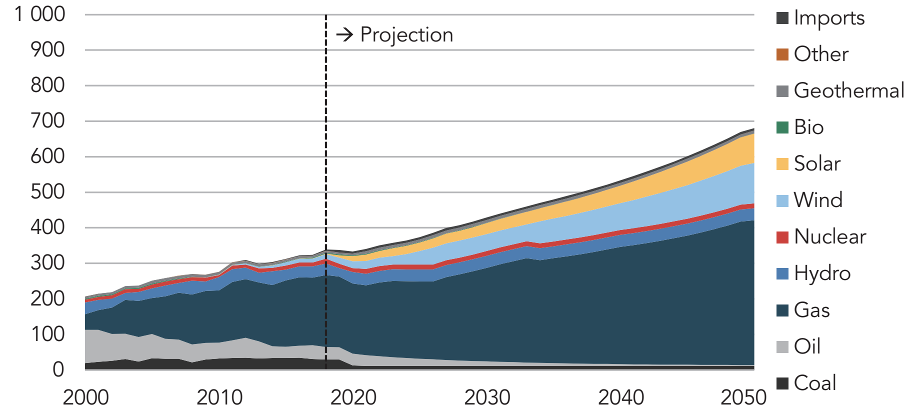


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport continues to be the largest energy consuming sector in Mexico in REF. Demand rises at a CAGR of 1.2% through the projection period, which delivers an increase in transport energy consumption of 47% from 2018 to 2050.
- In CN, energy demand peaks at 2 610 PJ in 2027 and maintains a high plateau for the remainder of the projection period. The high plateau occurs in the context of significantly higher transport activity; fuel efficiency offsets the activity increase.
- The inclusion of more efficient road vehicles, such as battery and fuel cell EVs in passenger and freight transport, are instrumental in reducing the demand for diesel and gasoline in CN.
- Electricity becomes the most prominent fuel in the CN, increasing to 953 PJ in 2050 (38% of transport energy demand). Almost 35% of Mexico's electricity consumption in 2050 is consumed by the transport sector.
- In CN, battery and fuel cell EVs account for 75% of the vehicle stock in 2050, and 95% of those vehicles have electric batteries.
- Hydrogen appears slowly in 2025 in CN, though does not begin to increase significantly until 2030. Hydrogen represents 9% of transport energy demand in CN and is sourced solely from electrolysis using renewable generation (so called 'green hydrogen').
- Road transport is the dominant mode of transport, accounting for almost 90% of consumption in REF and CN. This emphasises that electrification has the most impact via this modality.
- In CN, electric heavy transport and fuel cell EVs grow to 30% and 5% of new sales by 2035.
- New public transport, in the form of buses and railroads, grows at a faster rate in CN than in REF, reducing the demand for private road transport and aviation.
- In CN, light passenger transport is 10% lower than in REF, though part of this fall is offset by growth in public transport.

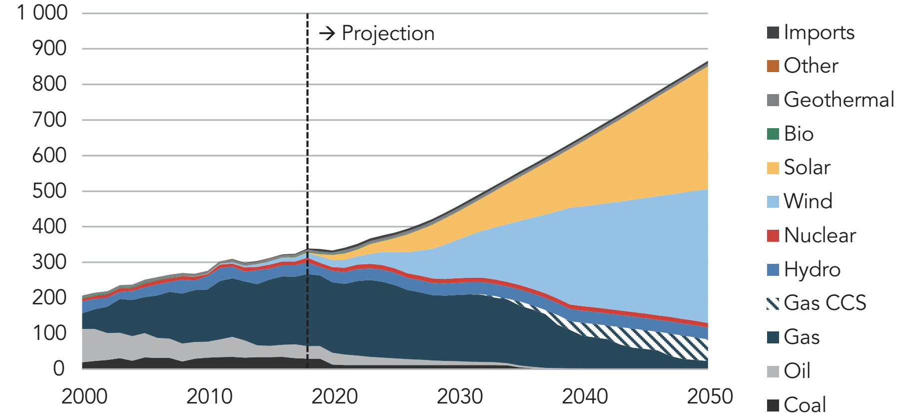
Electricity generation

Figure 11-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 11-14. Electricity generation in CN, 2000-2050 (TWh)

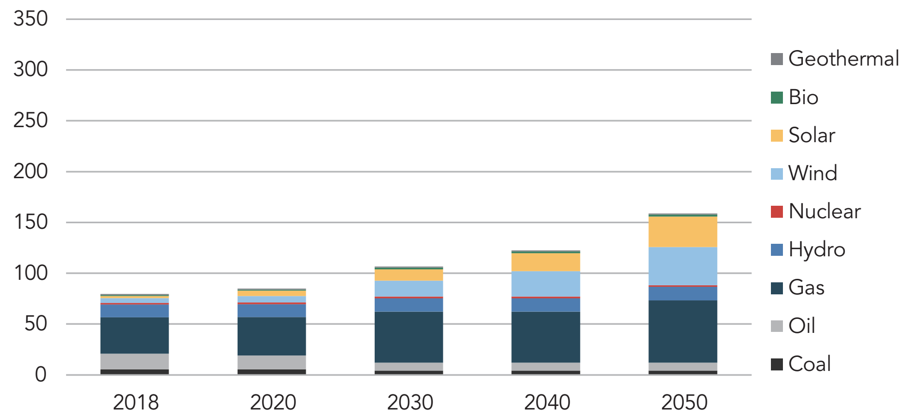


Sources: EGEDA, APERC analysis.

- In REF, electricity generation is expected to more than double from 337 TWh in 2019 to 681 TWh in 2050.
- In CN, generation reaches 866 TWh in 2050. The increase in generation in both scenarios is driven by an increase in population, from 126 million in 2018 to 155 million by 2050, higher standards of living, and in the case of CN, significant electrification of end-use energy demand applications.
- Natural gas is the main generation source in Mexico and has grown from a much smaller share of 21% in 2000 to 60% in 2018.
- In REF, the share of variable renewable solar and wind grows from 7% in 2019 to 29% in 2050. In CN, solar and wind grow to account for 83% of Mexico's generation. This massive increase in intermittent sources of electricity requires significant improvements in power system flexibility.
- In 2018, oil and coal account 29 TWh and 48 TWh, respectively. Oil and coal-fired generation continue to decline in both scenarios and are phased-out fully in CN by the early 2040s.
- In REF, the decline in oil and coal-fired generation is offset by increases in gas and renewable generation. Hydro generation remains flat, accounting for 34 TWh through 2050 in both scenarios.
- In REF, natural gas generation more than doubles out to 2050 (408 TWh), and accounts for the same share of the generation mix at 60%. The rise in natural gas displaces other fossil fuels and restricts the growth of renewable energy.
- The change in trend for natural gas in CN is significantly different to REF. Natural gas generation peaks in 2023 (215 TWh), and then declines to 83 TWh by 2050. Natural gas with CCS technologies begins to be deployed in the early 2030s, and these units account for more than 70% of natural gas generation by 2050.

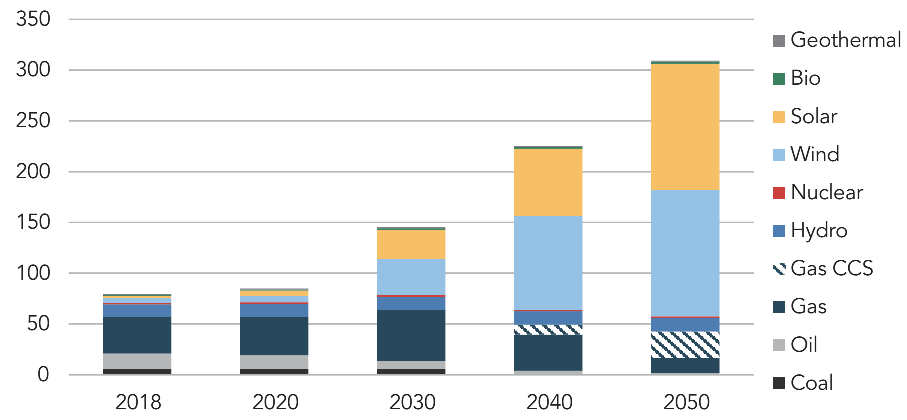
Generation capacity

Figure 11-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 11-16. Generation capacity in CN, 2018-2050 (GW)

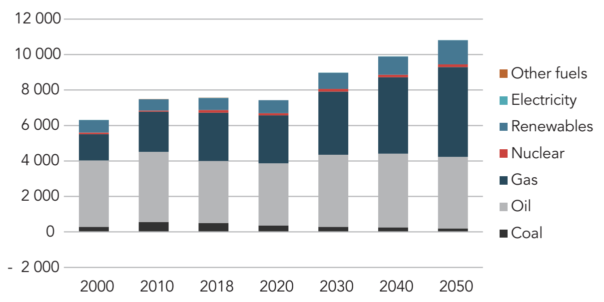


Sources: EGEDA, APERC analysis.

- Renewable energy generation capacity plays an important role in power sector decarbonisation. In REF, wind capacity increases more than six-fold to 37.5 GW in 2050. Solar capacity increases nine-fold to 30.1 GW. Decreases in the cost of wind and solar technologies drive this installed capacity growth.
- In REF, natural gas capacity increases 70% to 61.5 GW in 2050, which is a capacity that is comparable to the combined capacity of solar and wind. REF is consistent with Mexico's policies concerning the development of the national electric systems and adhering to NDC mitigation measures with natural gas playing the main role in electricity generation. The increase in natural gas capacity ultimately restricts the growth in renewable energy capacity.
- CN requires an additional 87 GW of wind capacity and 95 GW of solar capacity out to 2050. The capacity of natural gas without CCS initially increases to 50 GW by the late 2020s, but then declines to less than 15 GW in 2050. Natural gas capacity with CCS grows from zero in 2030 to 26 GW in 2050.
- In CN, total capacity is 310 GW in 2050, which is almost double the capacity in REF. Renewable energy capacity, including hydro, geothermal, and biomass, accounts for more than 80% of the grid's total installed capacity. This result is consistent with lower capacity factors of solar and wind power plants, of 36% and 32% respectively. The lower capacity factors are partially compensated for by their lower operational costs.
- Capacity factors for the remaining fossil fuel plants (oil and natural gas), decline out to 2050. Oil falls to close to zero and natural gas without CCS falls to 18%. This reinforces the fact that these power plants will only generate during peak times or provide reserve margin complementing renewable energy power generation.
- Natural gas-fired power plants with CCS will operate at an average capacity factor of 43% in 2040 and 26% in 2050.

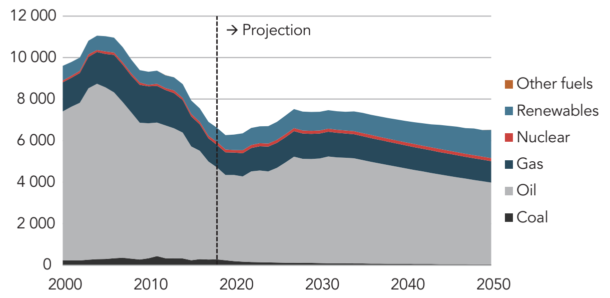
Energy supply in the Reference scenario

Figure 11-17. Total energy supply in REF, 2000-2050 (PJ)



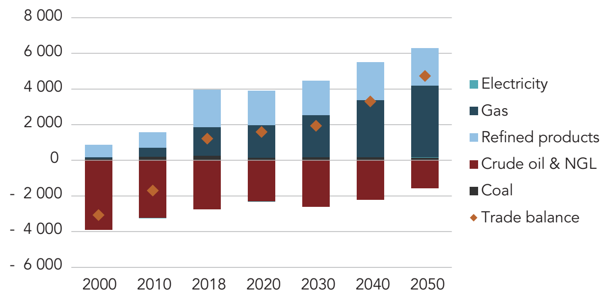
Sources: EGEDA, APERC analysis.

Figure 11-18. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-19. Net energy trade in REF, 2000-2050 (PJ)

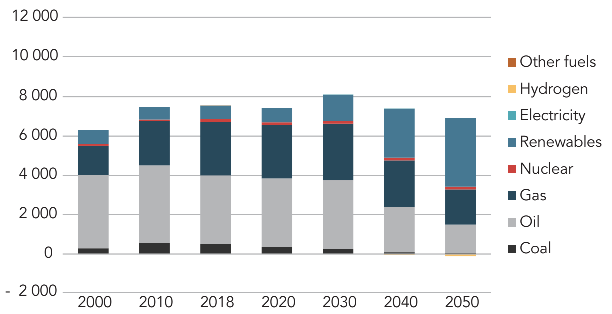


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Mexico maintains a high dependence on fossil fuels in REF. Natural gas supply increases 46% to become the most prominent fuel from the late 2030s. Oil remains steady. In contrast, coal supply falls 44%, while renewable sources increase 45% by 2050.
- Energy supply increases 30%, mostly as a result of the increase in natural gas, which displaces more carbon-intensive and less efficient coal and fuel oil in the power sector.
- In 2004, oil production reached its peak of 8 440 PJ. Production has seen a steep decline since then, halving through to 2019. Several oil rounds held after the energy reform of 2014 leads to an uptick in production in the early 2020s. However, discontinued oil bidding rounds means that Mexico's oil production declines over the long-term. Crude oil exports are assumed to begin a long-term decline from the early 2030s in REF.
- Natural gas production is maintained at similar levels through the projection period, increasing the need for natural gas imports. The natural gas production-supply deficit doubles out to 2050, reaching a total deficit of 2 106 PJ by 2050.
- Mexico's vast natural gas resources remain largely undeveloped. This is due to a de facto ban on unconventional activity and readily available supplies of natural gas from the US. Natural gas price increases have the potential to spur development. However, there is government opposition to hydraulic fracturing, and cancellation of oil bidding rounds creates an additional barrier.
- Mexico's oil trade dynamics consist of exporting its heavy crude oil, particularly to the US, while importing refined products. Mexico's domestic refining capacity is insufficient to satisfy domestic demand.
- Mexico has six refineries and is building a seventh in Dos Bocas, Tabasco (all owned by Pemex). The refineries operated at an average utilisation rate of 36% in 2020 due to operational issues that resulted from a lack of investment and maintenance. Low utilisation rates have increased Mexico's volume of oil and gas imports.

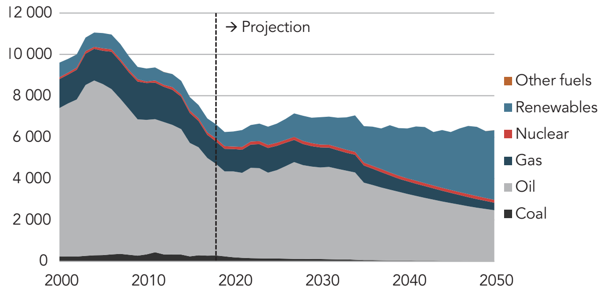
Energy supply in the Carbon Neutrality scenario

Figure 11-20. Total energy supply in CN, 2000-2050 (PJ)



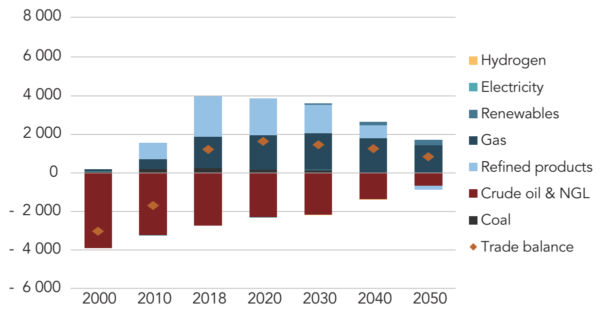
Sources: EGEDA, APERC analysis.

Figure 11-21. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-22. Net energy trade CN, 2000-2050 (PJ)

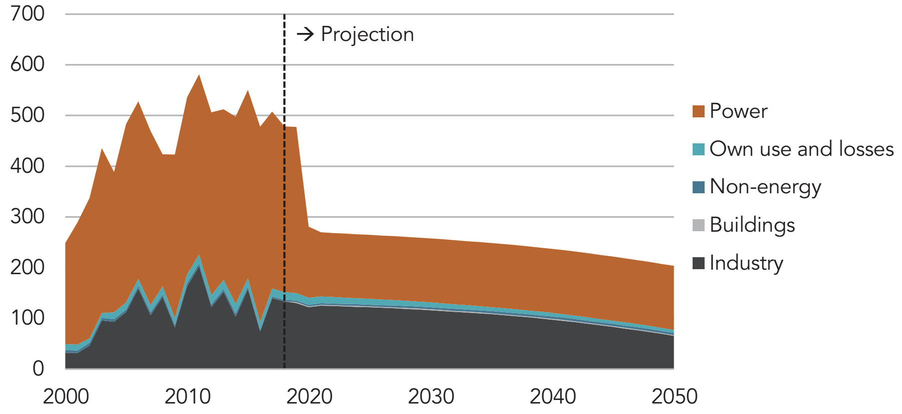


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, Mexico's energy supply increases slightly out to 2030, and then falls to a level that is less than two-thirds of REF energy supply in 2050. The most prominent feature is that renewable energy supply increases in share from 9% in 2018 to 51% in 2050, displacing natural gas and oil products from the energy supply mix.
- In CN, increased renewable energy production means that total energy production maintains similar levels to REF; renewables displace fossil fuels production. Total production in 2050 is 6 333 PJ in CN compared to a total production of 6 516 PJ in REF.
- Oil production falls 60% from the peak in 2027 out to 2050. This has a direct impact on Mexico's associated natural gas production.
- Natural gas production peaks in 2024, and then falls by 40% by the end of the projection period. Increasing natural gas demand is met by imports in both CN and REF.
- By 2050, Mexico's net import volumes are 82% lower in CN than in REF. Coal, crude oil, refined products, and natural gas are all significantly lower.
- In CN, natural gas imports peak in the early 2030s before declining to 1 563 PJ in 2050. Natural gas is mainly used for backup power generation for intermittent renewable generation. The scale of the increase in intermittent renewables is captured by the almost five-fold increase in renewable energy production out to 2050. In contrast, renewable energy production only increases by 83% in REF. Natural gas imports provide more of the basis for Mexico's energy supply in REF, reaching over 4 200 PJ in 2050.
- By 2050, renewable energy production reaches 3 362 PJ in CN, which is much larger than the 1 360 PJ in REF. The similar levels of production but much smaller energy supply in CN, means that Mexico is less reliant on energy imports in CN.

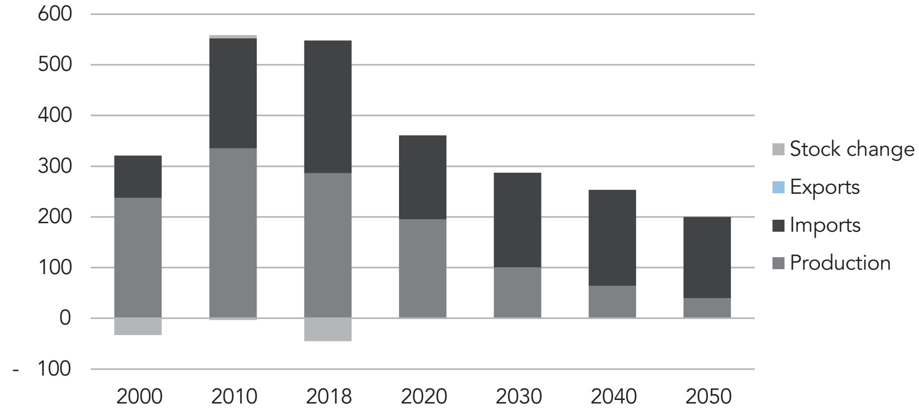
Coal in the Reference scenario

Figure 11-23. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-24. Coal production, imports, and exports in REF, 2000-2050 (PJ)

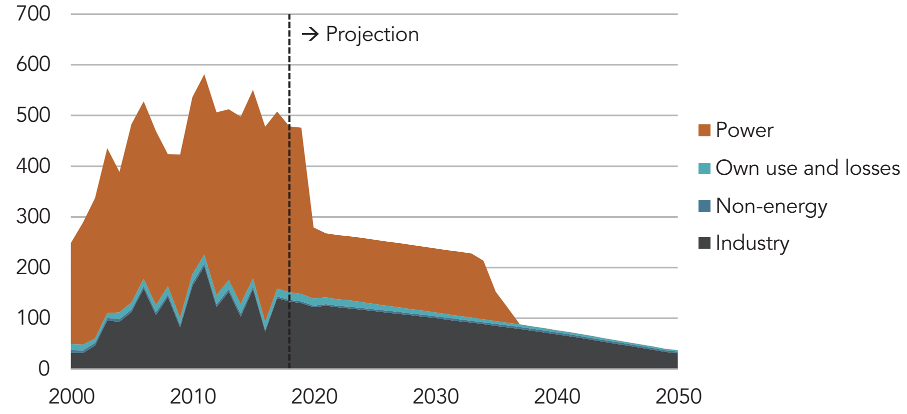


Sources: EGEDA, APERC analysis.

- The power and industry sectors are the main consumers of coal in Mexico. Power sector coal consumption falls significantly in 2020 due to the COVID-19 pandemic and then maintains a similar level out to 2050.
- The move away from coal-fired power is driven by economic, environmental, and efficiency reasons. Industry reliance on coal as a source of heat declines due to an increased availability of gas imported from the US.
- Coal displacement in Mexico is facilitated by readily available access to affordable gas from the US. Over the last decade, Mexico has expanded its natural gas pipeline capacity, with the state-owned utility company CFE acting as an anchor consumer of this gas and increasing gas-fired power capacity to satisfy a growing electricity demand. This has allowed a large portion of US gas, mainly coming from the Permian Basin, and priced on the Waha Hub benchmark (one of the most economically priced benchmarks in the world) to flow into Mexico.
- Coal consumption, production, and imports decline through to 2050. Domestic coal production declines by 83%, as a result of falling coal consumption across all sectors. Industry consumption of coal, mainly in the steel subsector, declines by 46% from 2020 to 2050, due to improvements in energy efficiency and fuel-switching from coal to natural gas.
- Lower domestic demand drives the fall in production and imports. Coal imports fall at a CAGR of –2% from 2018 to 2050, though even with these falls, 80% of coal consumption in 2050 is imported.
- Coal imports are largest just before the COVID-19 pandemic,. By 2050, coal imports are 160 PJ, which is only 6 PJ less than 2020 import levels.

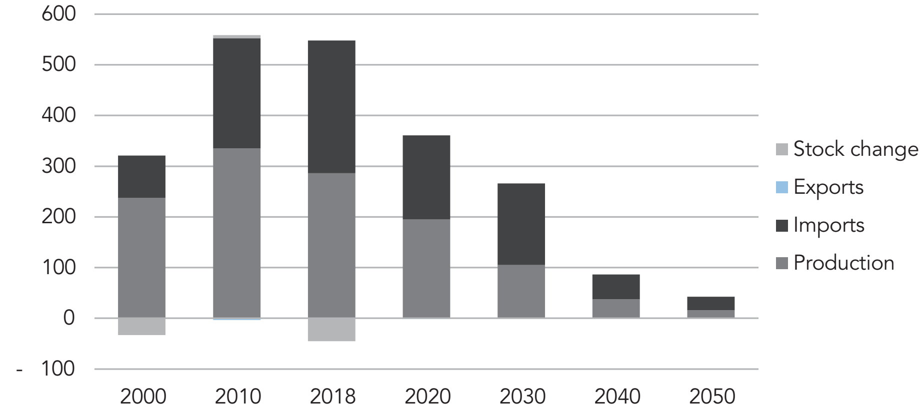
Coal in the Carbon Neutrality scenario

Figure 11-25. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-26. Coal production, imports, and exports in CN, 2000-2050 (PJ)

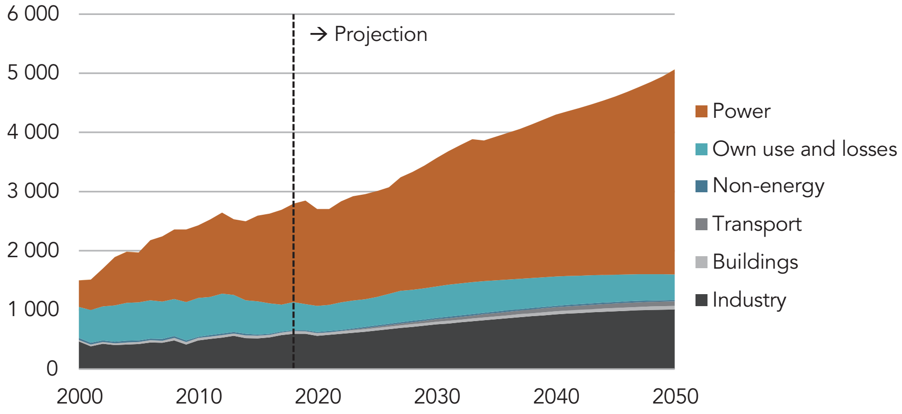


Sources: EGEDA, APERC analysis.

- Coal currently accounts for 7% of Mexico's energy supply. In CN, coal is phased out from the power sector by 2037, due to the decommissioning of CFE's coal-fired power plants. These closures are assumed to be partially driven by renewable energy capacity additions outcompeting coal-fired power plants in electricity auctions.
- Industry sector coal consumption falls by almost three-quarters from 2020 to 2050 as a result of improved energy intensity and fuel switching. Industry subsectors such as steel remain an important driver of coal consumption throughout the projected period.
- In 2050, the industry sector consumes 31 PJ of coal, which is 75% lower than in 2020. Heavy industrial activity, for example cement production, remains reliant on coal to meet energy density requirements in some industrial processes. Energy efficiency improvements and fuel switching to alternative fuels and energy carriers, such as natural gas and hydrogen, lead to the reduced industry consumption of coal out to 2050.
- As in REF, consumption, production, and imports of coal all diminish by 2050. Coal imports fall 83% from 2020 to 2050, while local coal production declines by 92% for the same period.
- Coal imports peak just before the COVID-19 pandemic at a level of 278 PJ in 2019. Power sector demand eventually falls to zero, and it is mostly industry that still relies on imports equivalent to 27 PJ in 2050.
- Domestic coal production follows a similar trajectory to the decline in consumption and imports. Ultimately, coal's relatively small share of Mexico's current energy supply falls to negligible levels by the end of the projection period in CN.

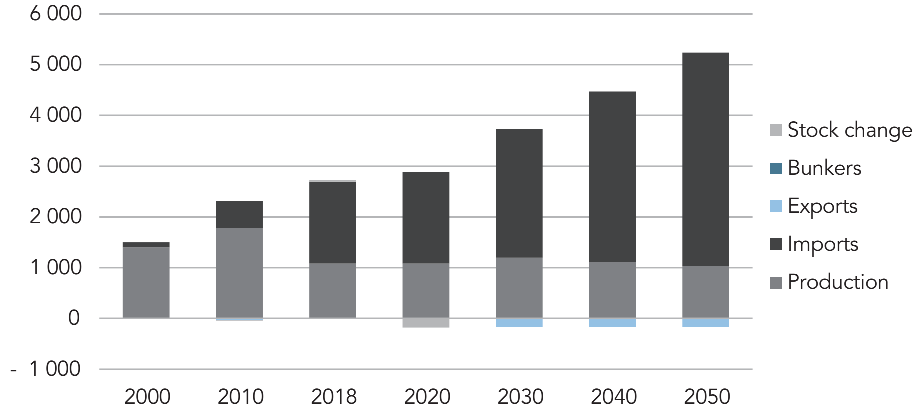
Natural gas in the Reference scenario

Figure 11-27. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-28. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

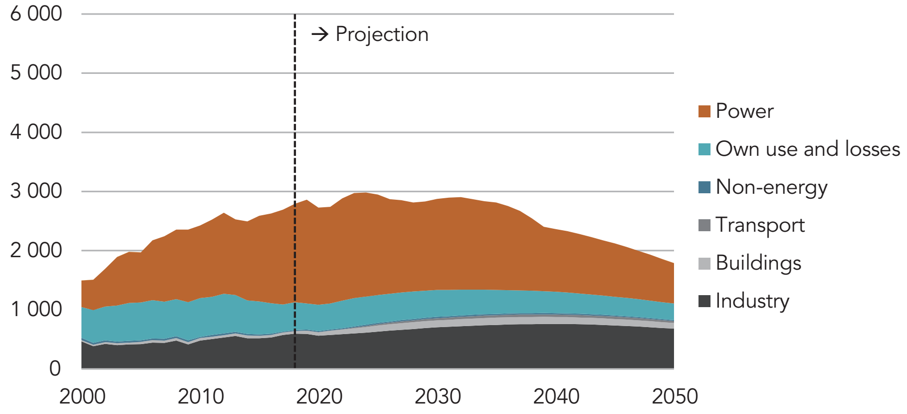


Sources: EGEDA, APERC analysis.

- Natural gas consumption in the power sector will more than double by 2050 with respect to 2018 levels. Industry consumes 68% more natural gas in 2050 than in 2018.
- Despite the increase in demand, the lack of upstream investments increases the dependency on imported natural gas. By 2050, 83% of the 5 063 PJ of natural gas consumed in Mexico will be imported.
- The energy reform that was passed in 2014 ended Mexico's energy monopoly that lasted over 70 years. This led to a liberalisation of the energy market in Mexico, and since then, the country has expanded its natural gas pipeline infrastructure to allow an increasing flow of competitively priced and high-quality natural gas from the US.
- The power and industrial sectors are the main drivers of natural gas demand. Mexico's state-owned utility company, CFE, generates 38% of the economy's electricity and has been an anchor consumer for new natural gas projects. Most gas pipelines feed directly into CFE's combined cycle gas turbines (CCGT). As of 2020, CFE's installed CCGT capacity was 10 310 MW. The private sector manages 7 561 MW of CCGT capacity.
- The southern region of Mexico lacks access to gas due to limited infrastructure. This is limiting current natural gas consumption growth. Nevertheless, the REF projects a substantial increase in consumption, as new natural gas infrastructure projects, such as pipelines and CCGTs, are built.
- There is fuel switching from coal and oil to natural gas in the industrial sector. Gas consumption in this sector increases from 560 PJ in 2020 to 681 PJ in 2050.

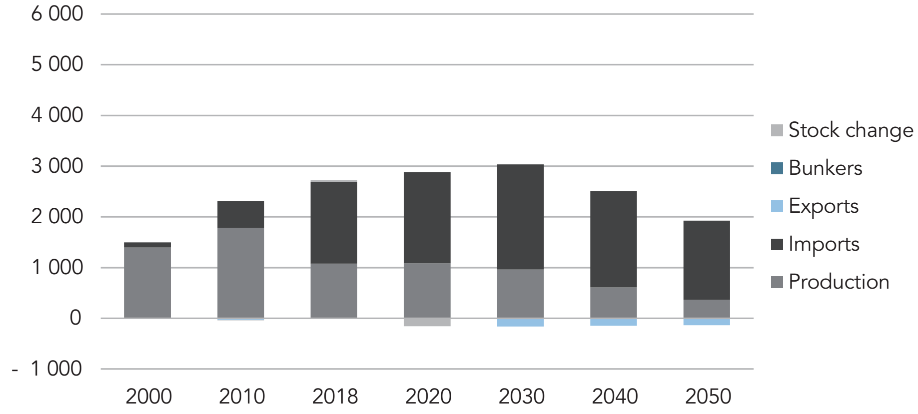
Natural gas in the Carbon Neutrality scenario

Figure 11-29. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-30. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

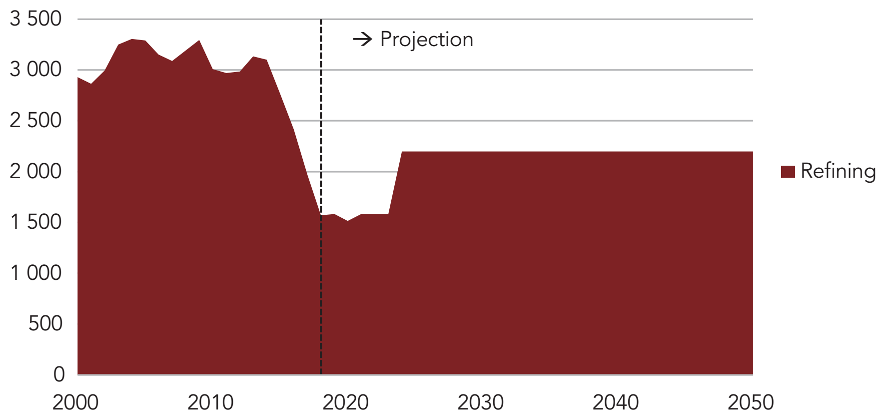


Sources: EGEDA, APERC analysis.

- There is a significant difference in the role of natural gas in Mexico's economy out to 2050 in CN. Consumption peaks in the 2020s before tapering to a level that is only one-third of the consumption level in REF: 1 789 PJ compared to 5 063 PJ in 2050.
- The power sector accounts for most of the difference in natural gas consumption between the two scenarios. By 2050, the power sector only consumes a 38% share of natural gas in Mexico, whereas the share is 68% in REF. Consumption in the other sectors is also lower than in REF due to improved energy efficiency and fuel switching away from fossil fuels.
- The rise of renewable energy capacity additions, particularly from wind and solar, is the largest factor that impacts growth in natural gas consumption by the power sector.
- From 2018 to 2050, industry and buildings sector natural gas demand grows by 12% and 56%, respectively. For industry, the increase in natural gas consumption is tied to increased industrial output and a movement away from coal and fuel oil. Buildings consumption of natural gas remains relatively small, accounting for 5% of total gas consumption in 2050. Transport sector natural gas consumption almost doubles with a switch away from more polluting diesel and gasoline. However, its share of total gas consumption also remains small, at only 2% in 2050.
- In CN, natural gas production is 64% lower in 2050 than in REF. Most of the domestic demand for gas is met with imported gas (87%), coming mostly from the United States (90%). Even with the high import dependence, the energy content of natural gas imports is 2 650 PJ (63%) lower in 2050 than in REF. Increasing renewable energy generation means that Mexico diversifies away from natural gas supply.
- It is assumed that Mexico will exploit its natural advantages and will produce green hydrogen instead of importing additional natural gas to produce grey or blue hydrogen.

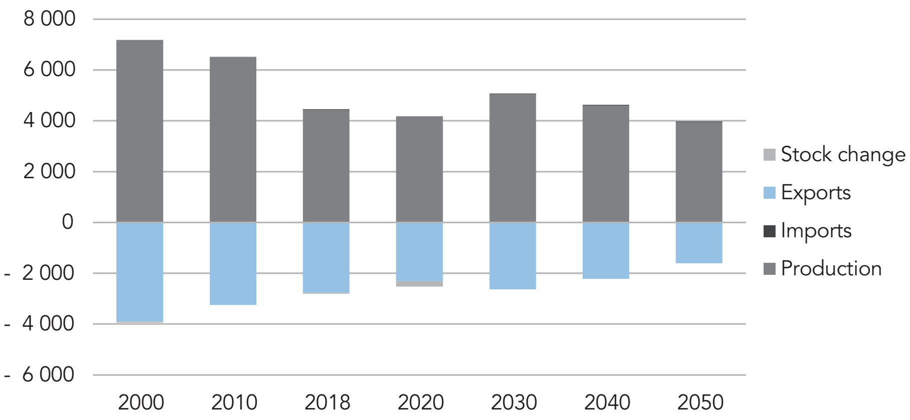
Crude oil and NGLs in the Reference scenario

Figure 11-31. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-32. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

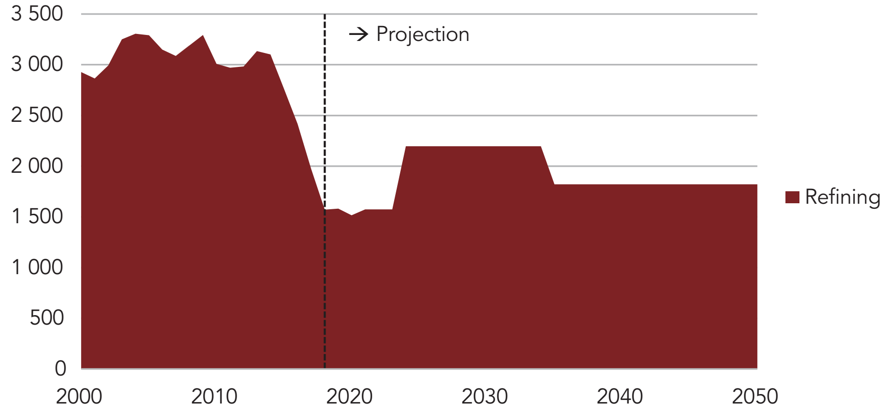


Sources: EGEDA, APERC analysis.

- Mexico is a crude oil producer and, at the same time, a net importer of refined products. This is in part driven by the trade dynamics it has with the United States. Historically, Mexico's main export market has been the United States, which at a time lacked oil production. In addition, the United States has a large refining capacity that enables Mexico to import competitively priced refined products.
- Crude oil consumption by Mexico's refineries halved in the few years leading up to the COVID-19 pandemic but, in 2024, is expected to rise to almost 2 200 PJ. This is the year the Dos Bocas refinery is expected to begin operation.
- Crude oil production increases by 21% from 2020 to 2030. After 2030, production follows a declining trend that can be explained by a long-term decrease in global demand and a discontinuation of oil auctions.
- Oil contracts awarded in the oil auctions held shortly after the passing of the energy reform start to bring higher volumes of oil production online. Nevertheless, a discontinuity of oil auctions since 2019 prevents a substantial increase in oil production over the long-term.
- The level of crude oil exports decreases at a CAGR of –1.2%. This is partly due to a drop in global oil demand and partly due to an increased use of domestic crude oil by domestic refineries in pursuit of energy independence.
- A recent policy announcement from Mexico's government states it plans to reduce oil exports to 435 000 b/d in 2022 and halt them completely by 2023.
- If Mexico is unable to increase oil production to meet domestic refinery crude processing and output needs, or if its revamped refining capacity is eventually unable to process its heaviest oil output, it will need to import crude oil to satisfy its national refinery system demand.

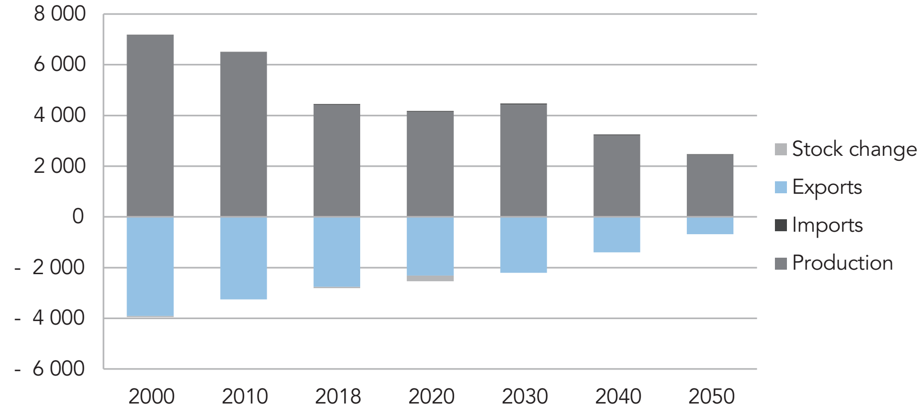
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 11-33. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-34. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

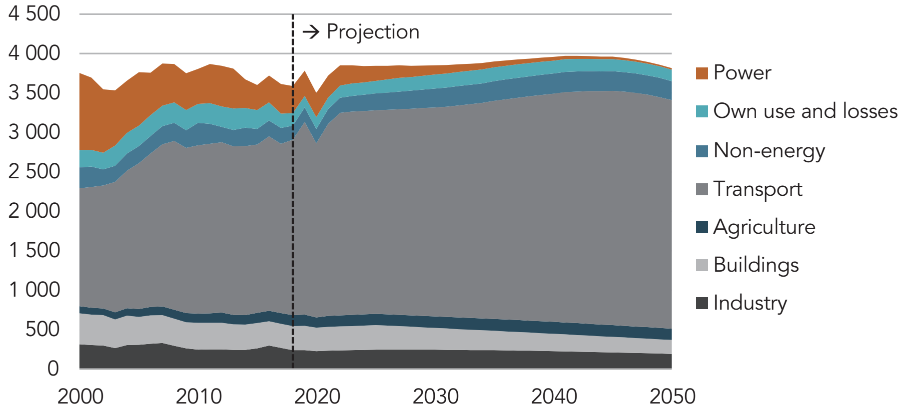


Sources: EGEDA, APERC analysis.

- In CN, crude oil consumption follows the REF trend until 2035. There is then an assumed reduction in consumption associated with the decommissioning of the Salina Cruz refinery.
- Production falls by 45% from 4 424 PJ in 2018 to 2 451 PJ in 2050. This fall in production is in response to a declining export market, with crude oil exports falling by three-quarters from 2 765 PJ to 681 PJ for the same period.
- The fall in CN crude oil and NGLs exports is much larger than the 42% fall that occurs in REF. Higher levels of electrification and improved fuel efficiency means there is less and less demand for refined products in APEC and throughout the world.
- In 2050, crude oil consumption in CN is 38% lower than in REF, due to a strong decarbonisation push and increased electrification in the transport sector that reduces demand for refined products.
- Mexico's oil import dependence falls in CN due to lower levels of domestic demand for refined products, which is partly facilitated by increased production of domestic renewable energy sources. The move to domestic sources of renewable energy rather than imported fossil fuels increases Mexico's fuel security.

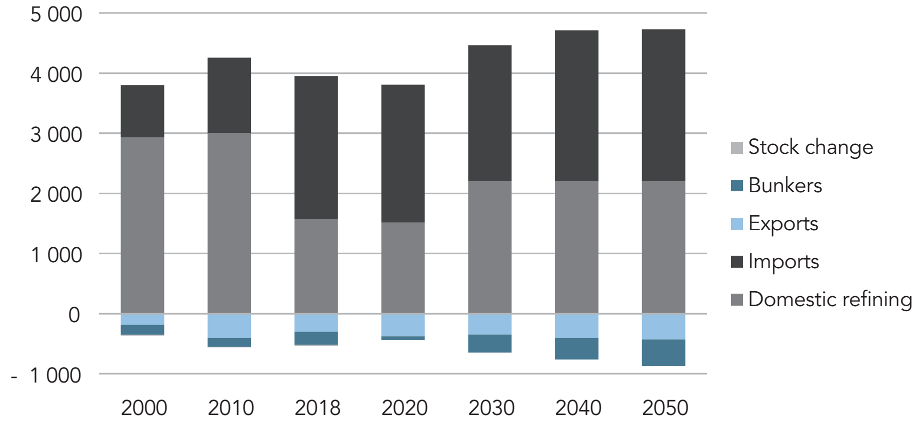
Refined products in the Reference scenario

Figure 11-35. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-36. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

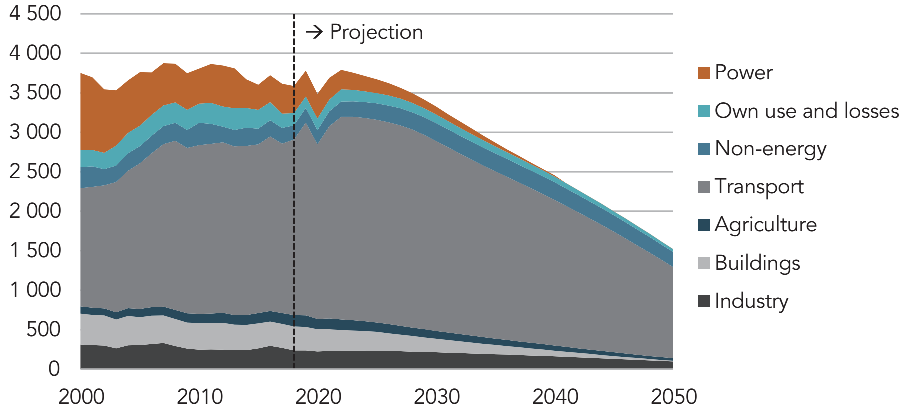


Sources: EGEDA, APERC analysis.

- Refined products such as gasoline and diesel are mainly consumed in the transport sector, accounting for a 71% share of all refined products consumption. The transport sector demand for these fuels increases at a CAGR of 0.8%.
- A government proposed electricity reform that seeks to modify the dispatch rules in the power sector could extend the use of refined products for power generation. One of the main objectives of this policy is to increase CFE's market share to 54% of total power generation in Mexico.
- CFE has a large installed capacity of power plants that consume fuel oil and diesel, though they are currently offline. If electricity reform is approved these plants could become operational, replacing private sector electricity generation from mostly natural gas and renewable energy.
- From 2030 to 2050, domestic refined production maintains a level of close to 2 200 PJ; refinery capacity and capacity factors remain largely the same for the period.
- Mexico's refining system is known as the Sistema Nacional de Refinación (SNR) and is composed of six existing refineries. A seventh refinery named Dos Bocas is under construction and expected to come online by 2024. All seven refineries are owned and operated by PEMEX.
- In 2018, the government announced an initiative called the National Refining Plan to achieve energy self-sufficiency by 2022. As part of this plan, the government has mandated a rehabilitation of the SNR, and it also intends to completely purchase the Deer Park refinery from Shell, located in Texas.
- Total refined products imports account for almost two-thirds of domestic consumption through most of the projection period.

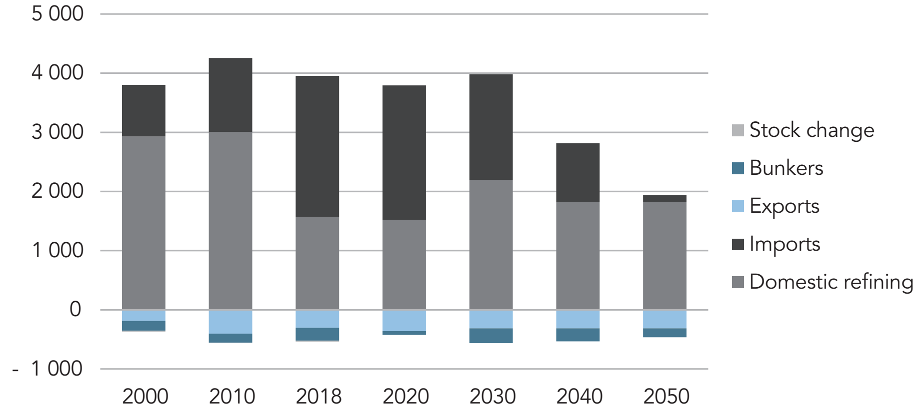
Refined products in the Carbon Neutrality scenario

Figure 11-37. Refined product consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 11-38. Refined product production, imports, and exports in CN, 2000-2050 (PJ)

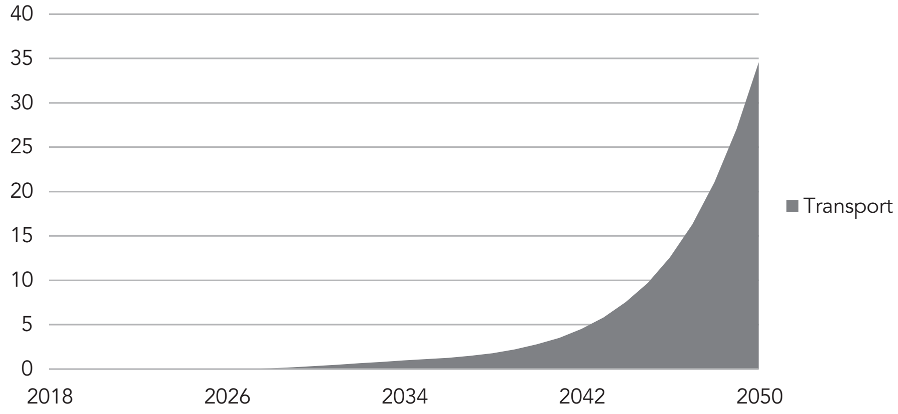


Sources: EGEDA, APERC analysis.

- From 2018 to 2050, demand for refined products by Mexico's power sector declined by more than half. The power sector has reduced refined products with natural gas and renewable energy. CN projects a phase-out of refined products for power generation by 2041.
- Mexico is one of the largest gasoline markets in the world. In order to satisfy a growing gasoline demand, Mexico currently imports over 60% of its consumption, mostly from the United States.
- In CN, increased electrification in the transport sector significantly reduces the demand for refined products. By 2050 in CN, transport sector consumption of refined products is only two-fifths of the level of consumption in REF.
- Transport sector consumption of refined products halves through to 2050 in CN. The falling demand means that almost all of Mexico's demand for refined products is satisfied by its domestic refineries. Imports of refined products fall by 95% through the projection period.
- Even with increased electrification in transport, reliance on refined products, such as gasoline and diesel remains substantial through to 2050. In CN, the transport sector still consumes more than 1 150 PJ of refined products in 2050. Continued use of refined products is due to assumed high levels of fuel combustion engine vehicle ownership and reliance on automobile transportation systems.

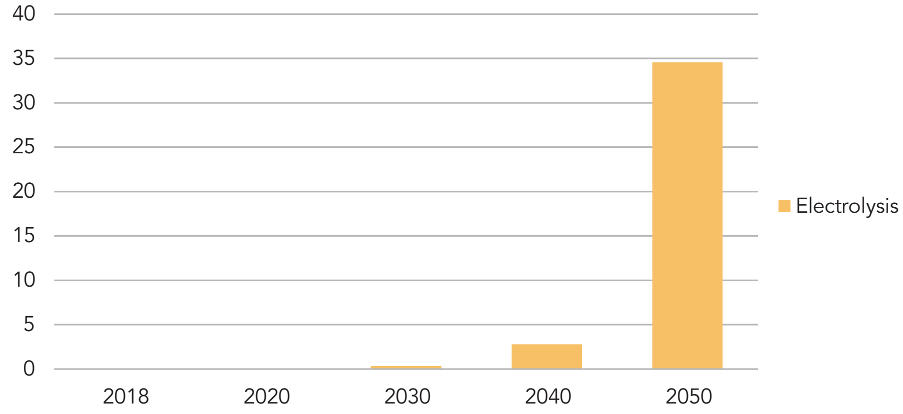
Hydrogen in the Reference scenario

Figure 11-39. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 11-40. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

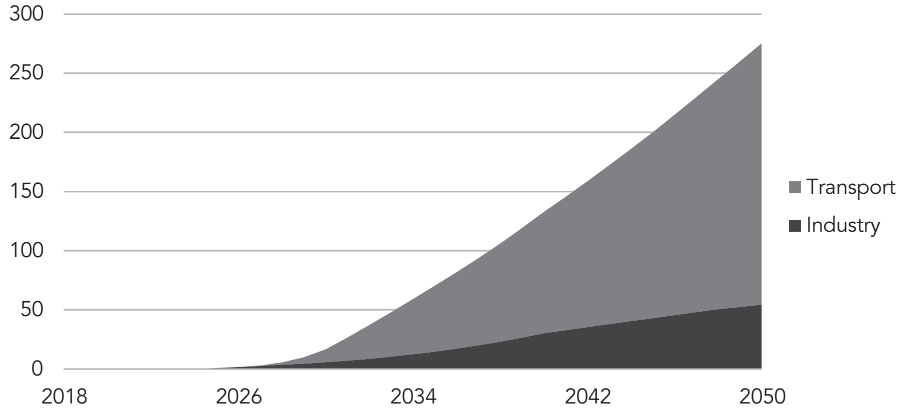


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- Hydrogen is currently produced by refineries for use as a feedstock in hydrocracking and hydroprocessing of oil and refinery products in both the refining and upgrading process. However, this *Outlook* only models the production and consumption of hydrogen as an energy carrier in the end-use sectors.
- There is high uncertainty on the future demand of hydrogen as it depends on the development and growth of several technologies that are currently being developed. Mexico already has experience with hydrogen, though it is restricted to refining and petrochemistry. Hydrogen is produced by PEMEX.
- While there are studies that explore hydrogen potential in Mexico, there is not an official hydrogen plan. Nevertheless, hydrogen is mentioned in the Mexican energy national development plan as a potential future energy carrier.
- Hydrogen development in REF is limited to transport, with the development of fuel cell trucks and buses for long distance transportation. Hydrogen accounts for 1.1% of transport energy consumption in 2050.
- Hydrogen can be produced from fossil fuels through gasification or steam methane reforming and from electricity through electrolysis. Mexico has substantial renewable energy resources making it a potential candidate to become a green hydrogen producer. It is assumed that Mexico will exploit its natural advantages and will produce green hydrogen instead of importing additional natural gas to produce grey or blue hydrogen.
- Hydrogen production reaches 35 PJ in 2050 (almost 291 kt) to accommodate domestic consumption and requires around 1.5 GW of electrolysers operating at full capacity.

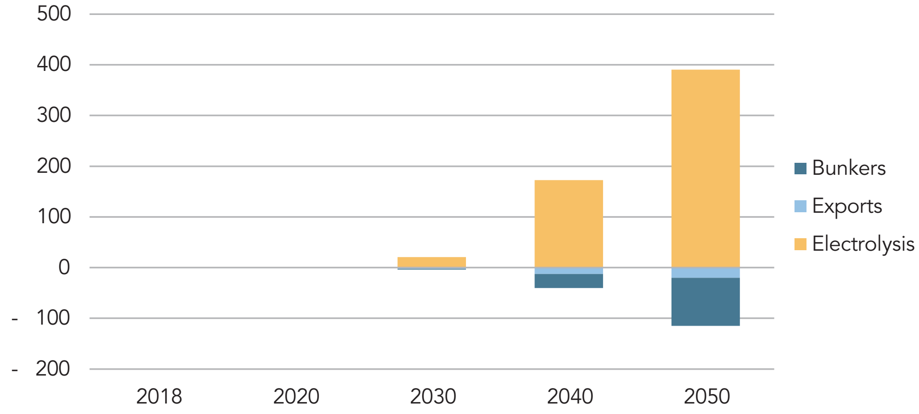
Hydrogen in the Carbon Neutrality scenario

Figure 11-41. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 11-42. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

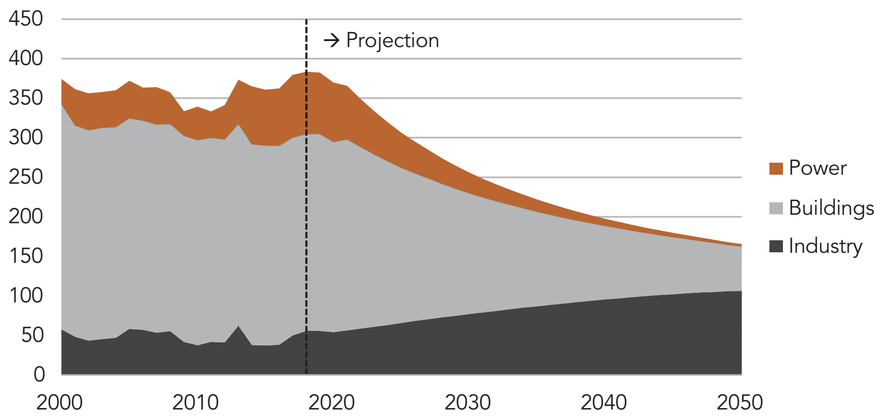


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- Hydrogen consumption increases at a much faster rate in CN, due to higher sales of fuel cell vehicles for long distance freight and more use applications for passenger transport. Industry consumption of hydrogen also contributes to increased demand that is almost 6.5 times higher than in REF in 2050.
- Industry consumes hydrogen in the chemical and steel subsectors to provide energy and heat. This consumption is energetic and is different from the current demand as feedstock for refining or ammonia production. In 2050, hydrogen accounts for 2.8% of industry energy consumption, though it accounts for more than 12% of energy consumption in the chemicals and steel subsectors.
- Hydrogen begins to become prominent in international maritime and aviation applications in CN, which is captured by bunkers supply. More stringent environmental standards are assumed to be implemented for international transportation, particularly maritime transportation. These standards spur development of hydrogen for use by these sectors and requires close to 100 PJ of additional hydrogen production in 2050.
- In CN, hydrogen production by electrolysis is more than 11 times greater than in REF in 2050. Domestic users (transport and industry) consume most of this production, followed by international aviation and shipping (bunkers). Mexico also begins to supply hydrogen to international markets. Hydrogen exports increase to more than 20 PJ in 2050.

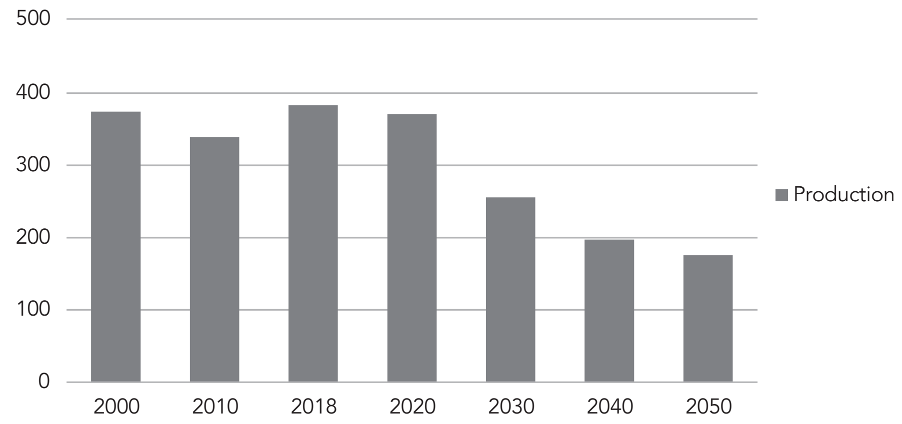
Bioenergy in the Reference scenario

Figure 11-43. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 11-44. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

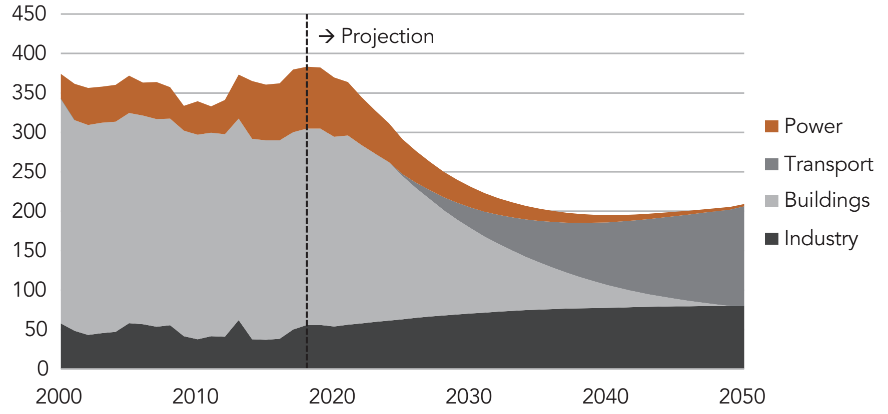


Sources: EGEDA, APERC analysis.

- Traditional biomass (such as fuelwood) is one of the most prominent sources of energy in Mexico's residential sector.
- Negative health impacts associated with its use has led the government to implement programs that intend to reduce traditional biomass consumption for cooking purposes in rural areas.
- Biomass consumption by buildings declines by 80% from 2018 to 2050, due to switching from fuelwood to LPG and, to a lesser extent, electricity. Increases in the energy efficiency of fuelwood stoves also contributes to declining consumption.
- In contrast, renewables consumption in industry, mostly in the form of biomass (pellets, and other types of energy-rich biomass), almost doubles out to 2050.
- Bagasse, the fibre that remains after crushing sugarcane, is used for power generation for distributed generation in sugar mills. This type of generation decreases at CAGR of –9.7% from 2018 to 2050 as other options such as solar energy become available at competitive cost.
- As demanded solid and liquid renewables are locally produced, production decreases according to the trend of renewables consumption.

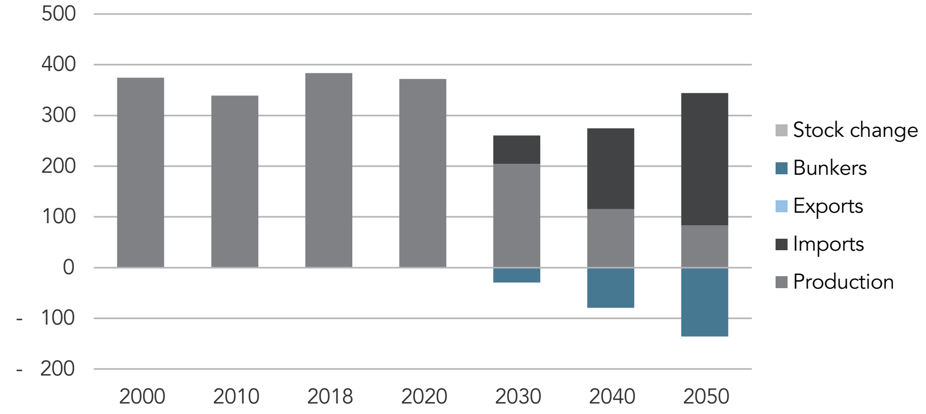
Bioenergy in the Carbon Neutrality scenario

Figure 11-45. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 11-46. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

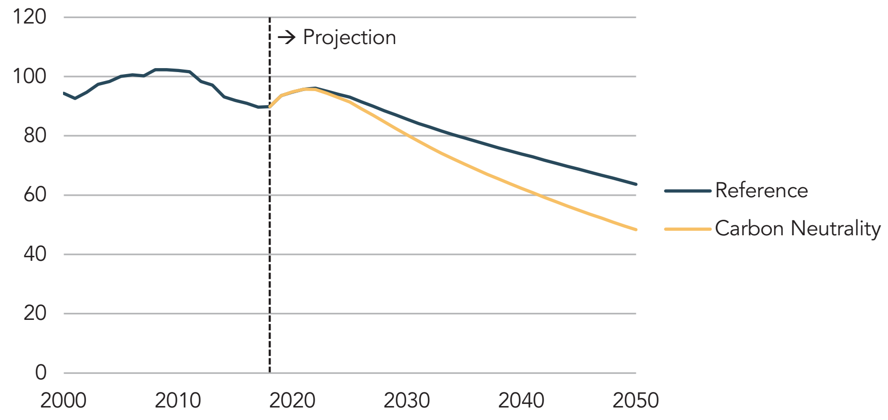


Sources: EGEDA, APERC analysis.

- In the buildings sector, replacement of biomass with more efficient fuels such as LPG and electricity is stronger in CN. Traditional biomass is completely displaced by 2048, indicating that alternative sources of energy will have reached 100% of the Mexican population.
- Transport consumption of biofuel, particularly biojet fuel used in aviation, starts in 2025 and reaches 126 PJ in 2050. In CN, the rise in renewables fuels consumed by the transport sector means that these fuels account for 5% of transport energy consumption in 2050.
- Renewables consumption by industry is 25% lower in CN than in REF by 2050, which is mainly due to additional improvements in thermal energy efficiency. Part of the reduction is due to electricity and hydrogen outcompeting biomass in some end-use industry applications.
- The increasing demand for biofuels by transport requires imports of these fuels to satisfy demand. Additional imports are required to satisfy the demand from international aviation, as captured by bunkers supply. The assumption is that domestic refineries will not supply these fuels, and by 2050, imports reach 260 PJ to meet domestic transport demand and international transport demand (bunkers supply).
- Lower domestic consumption of biomass means that domestic production requirements in CN are just over half of the production required in REF in 2050.

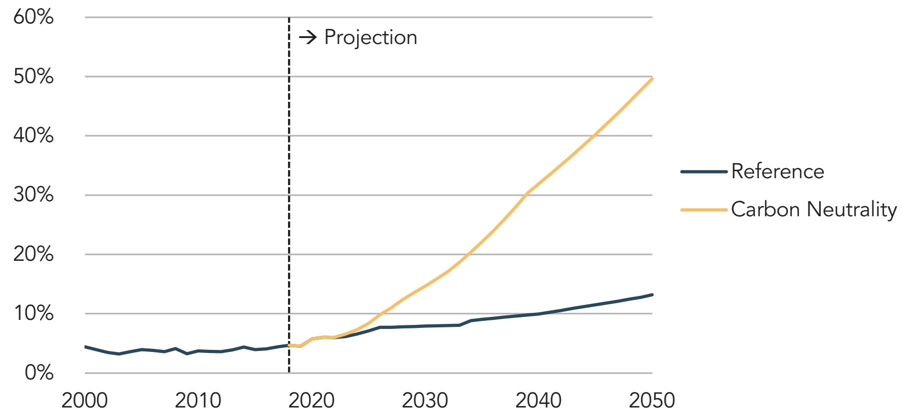
Energy intensity and modern renewables share

Figure 11-47. Final energy Intensity in REF and CN, relative to 2018 (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 11-48. Modern renewable energy share in REF and CN, relative to 2018



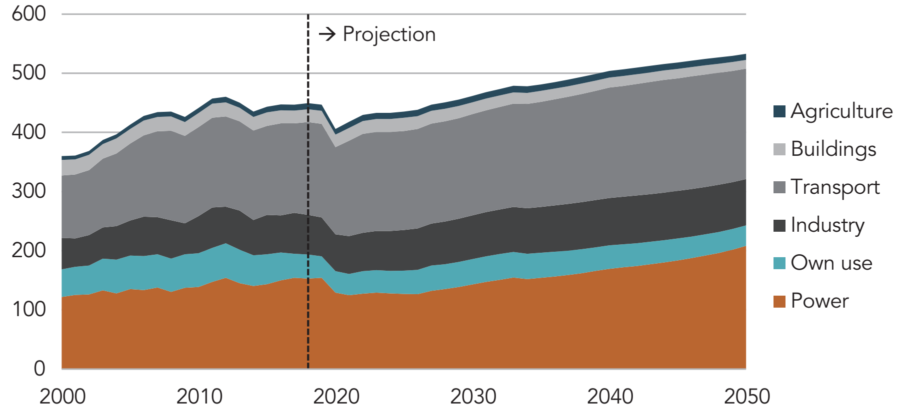
Sources: EGEDA, APERC analysis. Note: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy) and the share of electricity produced by renewable sources.

- Mexico's energy intensity improved from 2009 to 2016, though began to increase to 2018. The increase is largely due to significant growth in oil consumption mainly by the transport sector. In 2018, final energy intensity was 7% lower than in 2005.
- Energy intensity is projected to continue increasing through to 2021. In REF, energy intensity then begins to improve at a rate of just over 1% through to 2050. By the end of the projection period, energy intensity will be 36% lower than in 2005.
- In CN, the slower growth of energy demand, particularly the reduction of oil product demand, accelerates the improvement in energy intensity beyond that which occurs in REF. Energy intensity improves by almost 2% per year. By 2050, energy intensity is 52% lower than in 2005.
- The share of modern renewables in Mexico's energy mix has remained relatively stable for the previous two decades. In REF, modern renewables more than double to 2030, relative to 2010. In CN, modern renewables almost quadruple for the same time period.
- The increase in modern renewables in both scenarios is mostly as a result of the increase of renewable energy in Mexico's electricity generation mix. The results showcase the extent to which renewables can integrate into Mexico's energy system.
- In CN, modern renewables reach a share of almost half. The massive increase in solar and wind generation is the reason for this result.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

Gross CO_2 emissions

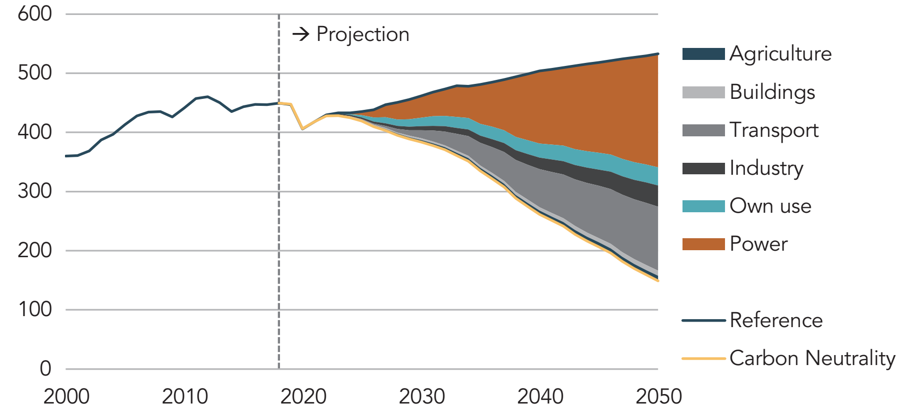
Figure 11-49. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Emissions results are direct combustion only and are limited to CO_2 rather than all GHGs. In 2018, energy related CO_2 emissions were 449 million tonnes, with most emissions attributable to power (35%) and transport (34%).
- In REF, CO_2 emissions increase to 533 million tonnes in 2050. Transport CO_2 emissions peak at 191 million tonnes in 2046 before falling to 186 million tonnes in 2050. Power sector CO_2 emissions increase from 129 million tonnes in 2020 to 208 million tonnes in 2050. The level of solar and wind penetration is too low to prevent power sector emissions from increasing. Under REF, CO_2 emissions reach 462 million tonnes by 2030, which is 62% of the unconditional NDC goal (773 million tonnes CO_2-eq).
- In CN, energy related CO_2 emissions peak at 428 million tonnes in 2023. Increased wind and solar penetration in electricity generation and the implementation of CCS technologies for natural gas-fired generation reduce CO_2 emissions to only 16 million tonnes in 2050. Transport CO_2 emissions peak at 167 million tonnes in 2024 and then fall to 78 million tonnes in 2050. The rise in EVs accounts for most of this decline, though fuel efficiency also plays a role. Total CO_2 emissions in CN fall to 149 million tonnes in 2050. By 2030, the 384 million tonnes of CO_2 emissions represents 50% of the unconditional NDC goal (773 million tonnes CO_2-eq).

Figure 11-50. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

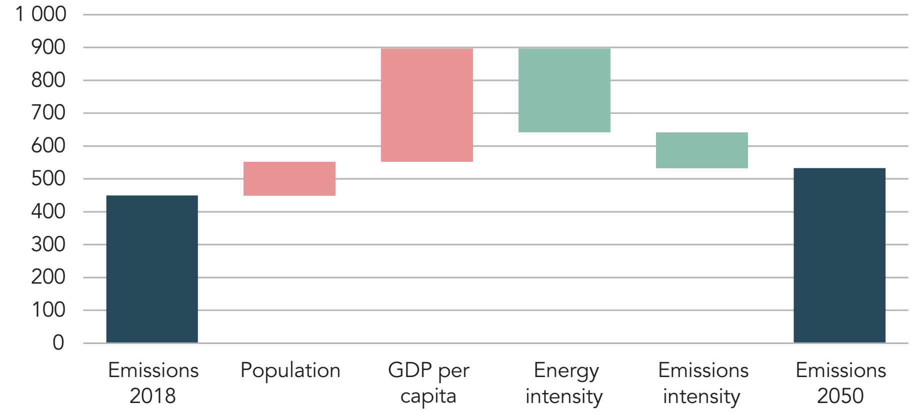


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- The wedge chart indicates that power and transport sector decarbonisation measures have the biggest impact on CO_2 emissions reductions. The main measures are the move to renewable generation and the rise of EVs.
- Remaining CO_2 emissions from the energy sector in CN will need to be offset with negative emissions from natural sources (for example, forests) or technologies (for example, direct air capture) to achieve carbon neutrality.

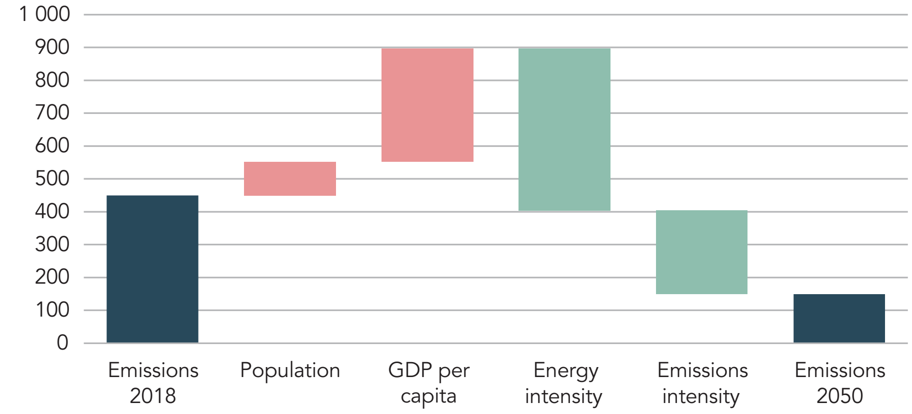
Components of CO_2 emissions

Figure 11-51. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 11-52. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Mexico's CO_2 emissions were 449 million tonnes in 2018, making Mexico the sixth largest emitting economy in APEC.
- The projected increase in population and increase in GDP per capita will place significant upward pressure on CO_2 emissions out to 2050. Without any improvement in energy intensity or emissions intensity, both population and GDP per capita increases would see Mexico double its CO_2 emissions out to 2050. Growth in GDP per capita (or living standards) is the component that exerts the largest upward pressure on emissions.
- In REF, improvements in energy intensity and CO_2 emissions intensity contribute to a significant reduction in CO_2 emissions from the level that would occur without these improvements. Energy intensity improvements account for 70% of the reduction, while CO_2 emissions intensity improvements account for the remaining 30%. Instead of CO_2 emissions doubling, Mexico's energy sector CO_2 emissions only increase by 19%, to 533 million tonnes.
- In CN, energy intensity improvements reduce CO_2 emissions by 55% below the level of emissions that would occur without energy intensity or emissions intensity improvements. Energy intensity improvements are mostly due to improved energy efficiency throughout all sectors of the economy.
- A switch away from gas and oil leads to lower CO_2 emissions due to improved emissions intensity. Gas-fired power plants with CCS also improve emissions intensity, as does the use of carbon capture technologies by industry. Mexico's energy sector CO_2 emissions are 149 $MtCO_2$ in 2050. This level of CO_2 emissions is 72% lower than in REF.
- Positive energy sector CO_2 emissions in CN will need to be countered by negative emissions in other sectors for Mexico to achieve carbon neutrality.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

Base de Indicadores de Eficiencia Energética. https://www.biee-conuee.net/

Secretaria de Energía SENER. https://www.gob.mx/sener

Comisión Federal de Electricidad. https://www.cfe.mx/Pages/default.aspx

Infraestructura Del Sistema Eléctrico Nacional, 2020. https://www.gob.mx/cms/uploads/attachment/file/610958/Cap4_-_Infraestructura_del_Sistema_Ele_ctrico_Nacional_WEB.pdf.

Programa para el Desarrollo del Sistema Eléctrico Nacional (PRODESEN), 2020. https://www.gob.mx/sener/articulos/programa-para-el-desarrollo-del-sistema-electrico-nacional

México comprometido con sus CND hacia una economía verde y baja en carbono. https://www.gob.mx/inecc/prensa/mexico-comprometido-con-sus-cnd-hacia-una-economia-verde-y-baja-en-carbono?idiom=es

12. New Zealand

Highlights

Demand

- Final energy demand peaks prior to the COVID-19 pandemic in both REF and CN, falling by almost one-fifth and over two-fifths in each respective scenario.
- Electricity becomes the most prominent energy source in both scenarios, increasing to over two-fifths of demand in REF and almost two-thirds in CN. Refined products, mostly used by transport, falls in tandem, from the largest component of end-use demand now to the second-largest by 2050.
- The Tiwai Point aluminium smelter is slated to close in the mid-2020s due to overseas competition. The closure leads to a large 5.0 TWh drop in electricity generation requirements in both scenarios.

Supply

- Fossil fuel production is comparable for both scenarios, though from the mid-2030s onward it falls at a slightly quicker pace in CN.
- Renewables are very prominent in New Zealand's energy supply in REF. This prominence reaches new highs in CN, with renewables accounting for almost 95% of New Zealand's energy supply and production in 2050.
- Government restrictions on the exploration and production of hydrocarbons and diminishing demand limits the role of natural gas in either scenario.
- In REF, a reserve replacement ratio of 30% will be required to sustain gas supply requirements through to 2050. A more rapid decline in consumption in CN means that existing reserves are sufficient to meet demand.
- The Marsden Point refinery is scheduled to convert to an import-only terminal in 2022. Crude oil imports are replaced by refined product imports thereafter.

Power

- The closure of the Tiwai Point aluminium smelter reduces electricity demand and frees up a large portion of hydroelectric generation from the Manapouri dam (800 MW) to supply electricity to the rest of the economy, instead of more expensive generation types.
- Thermal generation peaked in the mid-2000s and is expected to continue declining in both scenarios. While both coal and oil are phased out by 2030 in both scenarios, natural gas persists until 2044 in REF and 2040 in CN.
- Wind power meets most of the growth in electricity demand. By 2050, wind accounts for over a third of generation in both scenarios.
- Despite lower solar potential than many other APEC economies, solar generation increases to provide almost 10% of total generation by 2050 in both scenarios.

CO_2 emissions

- The closure of the aluminium smelter causes an abrupt fall in power sector CO_2 emissions in 2025, as renewable generation sources meet a much larger portion of New Zealand's remaining electricity demand.
- CO_2 emissions continue to decline in REF to 16 million tonnes in 2050. This represents a halving of New Zealand's emissions from peak levels. CO_2 emissions reductions are significantly greater in CN, falling to less than five million tonnes in 2050.
- In CN, the transport and industry sectors provide most additional reductions, with emissions falling by more than 80% in both sectors. While buildings sector CO_2 emissions fall over 95%, the smaller relative size of the sector means that its contribution to the economy-wide emission reduction is lower.
- Energy sector CO_2 emissions in CN will need to be countered by a drop in emissions in other sectors for New Zealand to achieve its net-zero ambitions. The challenge becomes slightly larger when including process emissions and other greenhouse gases in the calculation.

About New Zealand

- New Zealand consists of two main islands, the North Island and South Island, which are separated by the Cook Strait. More than three-quarters of the population live on the North Island, and almost half of that population live in Auckland, which is near the northern tip of the landmass. There are no connecting road or rail links between the islands, though the high voltage DC Inter-Island link connects the two electricity networks.
- New Zealand has abundant renewable resources, with hydro, geothermal, wind, and bioenergy accounting for a large proportion of current electricity generation. Geothermal resources account for over half of renewable energy supply, but low transformation efficiency translates into geothermal providing less than one-fifth of generation.
- There is a significant and growing share of wind generation due to New Zealand's abundant wind resources. These developments boast some of the highest capacity factors in the world due to the winds being unimpeded by the any nearby landmasses.
- In contrast to many other developed economies, New Zealand has lower emissions per capita than the APEC average due to the already high use of renewable resources.
- New Zealand is a large net importer of energy, which is mostly in the form of refined products that satisfy demand from the transport sector. Crude oil is also imported to supply New Zealand's oil refinery at Marsden Point. However, these imports will cease in 2022 with the closure of the facility.
- New Zealand has significant reserves of coal, though current production is relatively low. The coal reserves are predominantly lignite and located on the South Island. The bulk of these reserves are likely to remain in the ground. Production has been declining since the mid-2000s, and the planned phase-out of coal from the generation mix and from industrial processes means there is limited future use for coal in New Zealand.

Table 12-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	4.8	0.2%	20
GDP	214	0.3%	19
TPES	858	0.2%	18
Production	649	0.2%	16
Imports	359	0.3%	19
Exports	92	0.1%	19
Electricity generation	44	0.3%	18
Heat production	1.3	0.01%	8
CO_2 emissions	29.8	0.1%	19

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 12-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	91 500 PJ	>500	0.7%	7
Natural gas	2 074 PJ	11	<0.1%	13
Oil	344 PJ	8	<0.1%	13
Uranium	–	–	–	-

Notes: Coal in 2020 from BP. Natural gas, and oil (PJ) in 2020 from MBIE. See Appendix for conversion to other units.

Energy policy context and recent developments

- New Zealand's relative isolation, small population, and large amount of renewable resources is a combination that contributes to a unique energy policy environment.
- The Climate Change Response Act 2002 was initially legislated to create a legal framework for New Zealand to ratify the Kyoto Protocol. The Act formed the basis for implementation of an emissions trading scheme in 2008, which is the government's main policy tool for reducing greenhouse gas emissions.
- New Zealand legislated the Climate Change Response (Zero Carbon) Amendment Act in 2019, which provides a framework to develop and implement climate change policies that contribute to realising the Paris Agreement while also allowing for preparation for, and adaption to, the effects of climate change. The amendment sets a domestic target for New Zealand to reduce greenhouse gas emissions (except for biogenic methane) to net zero by 2050 and requires the setting of shorter-term emissions budgets to act as steppingstones towards this long-term target. The amendment will lead to radical changes within New Zealand's energy sector and a drastic reduction in the intensity of emissions over the next 30 years, with the goal of facilitating a net-zero economy by 2050.
- New Zealand's electricity sector already has a large share of renewable generation, though the government has an aspirational target that 100% of electricity will be generated from renewable sources by 2030.
- In November 2021, New Zealand also updated its Paris Agreement NDC to reduce net greenhouse gas emissions to 50% below gross 2005 levels by 2030. This commitment is reliant on achieving renewable electricity generation targets, as well as continued ambitious decarbonisation efforts in the transport, industry, building and construction, and energy sectors. It should also be noted that the NDC also covers methane, so the agricultural sector will play a key role in achieving the target.
- New Zealand's minerals and petroleum resources strategy for Aotearoa New Zealand covers 2019 to 2029 and was developed with a low-carbon economy basis. The 10-year strategy will facilitate a phase-out of oil and gas while facilitating a transition to clean-tech minerals such as lithium. A government review of the Crown Mineral Act 1991 is ongoing with implications for the speed of the proposed phase-out.
- Hydrogen development is part of New Zealand's strategy for transitioning to a net-zero carbon emissions economy by 2050. A 2019 green paper frames discussion for the role that New Zealand's government can play in hydrogen production and the use of hydrogen in both mobility and industrial processes.
- In order to meet the challenge of a low emissions economy and its net-zero 2050 target, the government will release its first emissions reduction plan in May 2022. The plan will include measures to reduce emissions across the economy, including in the energy and industry sectors. This includes measures to improve energy efficiency, ensure the electricity system is ready to meet future needs, reduce fossil fuel reliance while supporting low emissions alternatives, and reduce emissions and energy use in industry. The plan will also include measures to address distributional impacts and ensure that energy is both secure and affordable and supports the wellbeing of all New Zealanders.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- In the lead-up to finalising the modelling for this version of the *Outlook*, many economies in APEC (and throughout the world) have made commitments to achieving net-zero emissions.
- New Zealand was one of the first global economies to make a net-zero 2050 commitment and formalised the commitment with their Climate Change Response (Zero Carbon) Amendment Act in 2019.
- Many policies that accompanied New Zealand's commitment to achieving net-zero have been incorporated into **the Reference scenario (REF)**. However, where policies are absent, or less ambitious than they need to be, the *Outlook* defaults to assumptions that are in line with historical trends. New Zealand's Reference scenario achieves greater decarbonisation than many other APEC economies, but it does not achieve a net-zero result.
- REF and **the Carbon Neutrality scenario (CN)** share the same GDP and population projections. However, CN incorporates behavioural changes such as increased material efficiency in industry and less transport activity due to greater levels of work from home.
- Energy efficiency and fuel switching in REF mostly follows the historical trends of the most recent decades. For CN, more optimistic assumptions are imposed, driven by either explicit or implicit policy intervention.
- CN involves assumptions that lead to positive emissions in 2050 for the New Zealand energy sector. It is beyond the scope of this report to model the non-energy sectors, such as land use, land-use change, and forestry. However, the implicit assumption is that the other sectors will deliver negative emissions, and thus deliver a 'carbon-neutral' outcome.
- CN makes explicit assumptions that trace a trajectory for energy and emissions out to 2050. The assumptions deliver one credible path for New Zealand to meet decarbonisation ambitions while maintaining economic prosperity. The ultimate path New Zealand takes is almost certain to differ from the one that is laid out by the modelling.

Table 12-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with CN.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for New Zealand

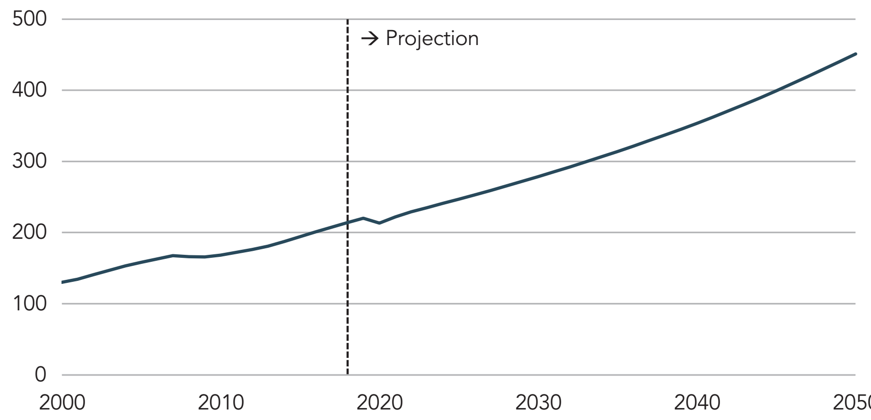
Table 12-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• REF incorporates recent trends and in-place policies and does not assume that aggressive action will be taken to meet global emissions reduction goals.	
Buildings	• Residential energy efficiency improves due to healthy homes standards and an increase in electrification of heating and cooking. • Coal phased out by 2030. • Increase in electrification and energy efficiency of heating and cooking	• More stringent building and appliance standards, resulting in higher building efficiency. • Natural gas phased out by 2050. • Increased electrification of space heating and cooking; more solar water heaters in the residential subsector.
Industry	• Coal and gas gradually phased out. • Small amount of hydrogen for steel and chemicals sectors starting in 2035. • Energy efficiency and electrification improvements continue historic trends. • Small amount of fuel switching, primarily to electricity and biomass. • Aluminium plant closes in 2024; chemicals subsector declines due to decreasing gas supply to 2050.	• Coal and gas aggressively phased out, replaced with electricity. • Hydrogen for steel and chemical subsectors begins in 2030. • Material efficiency in steel, non-metallic minerals, and chemicals reduces production by about 10% in 2050 relative to REF. • Greater energy efficiency improvements • Improving clinker-to-cement ratio in NZS relative to REF.
Transport	• Energy efficiency of vehicle fleet improves. • EV sales grow gradually, reaching 60% of light passenger sales (40% stock) by 2050. • Passenger transport activity grows 50%.	• EV sales share of 90% in 2035, increasing to 100% in 2050; this yields a stock share of 80% of light passenger vehicles. • Hydrogen fuel cell vehicles utilised for heavy road transport. • Aviation sector gradually adopts biojet and hydrogen fuels after 2025.
Power and heat	• Assumed an optimal transmission system operation in the event of the future closure of New Zealand's aluminium smelter at Tiwai. • After 2023, hydroelectricity will reduce the role of natural gas. • Coal is phased out by 2030; gas stays for backup but is also phased out by 2044.	• Gas is replaced with pumped storage in the 2030s. • Coal is phased out before 2030. • No hydrogen consumption due to other technologies being more cost-competitive. • Large-scale adoption of renewables, particularly onshore wind projects.
Supply	• While oil exploration ceases, a 30% reserves replacement ratio is required to maintain gas production to meet demand; it is assumed that some onshore gas exploration occurs to maintain this. • Thermal coal production follows domestic demand, metallurgical production follows trends of APEC export markets. • Green hydrogen is the dominant type of hydrogen produced in NZ.	• No new offshore oil or gas reserves discovered - current fields decline, production meets demand. • NZ produces green hydrogen for export. • Fossil fuel production is driven by domestic demand reductions; metallurgical coal production follows trends of APEC export markets.
Climate	• Included NDC to reduce net greenhouse gas emissions to 50% below gross 2005 levels by 2030.	• Net zero achieved primarily through emissions reduction. CCS is not used in New Zealand. • While offsets are not modelled, they will be required to meet carbon neutrality.

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

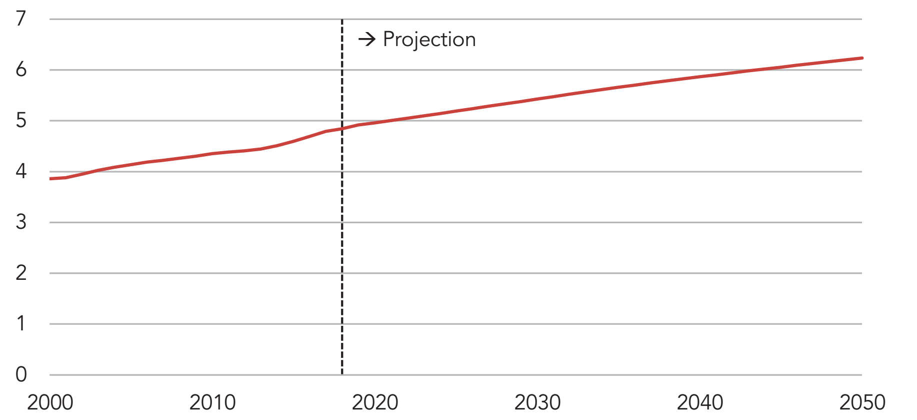
Macroeconomic backdrop

Figure 12-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 12-2. Population in millions, 2000-2050

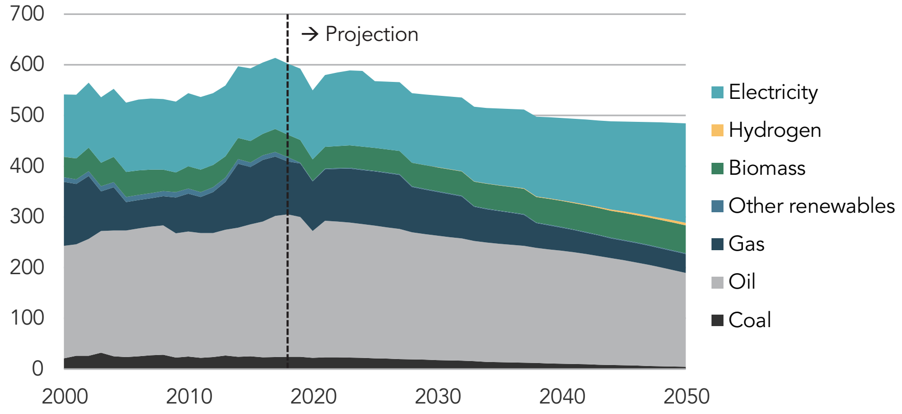


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- New Zealand has the second-smallest population in APEC. Its high-skilled workforce and services-dominant economy combine to deliver APEC's eighth-highest GDP per capita of more than USD 44 000 in 2018 on a purchase power parity (PPP) basis.
- New Zealand is APEC's largest exporter of milk products as well as a major exporter of horticultural products, wood, and meat, such as lamb. China was the top export destination, receiving over a quarter of New Zealand's exports, with nine out of the top 10 export markets being APEC economies.
- New Zealand instituted one of the strictest border closures in the world in the early stages of the pandemic. This, plus its remote location, enabled New Zealand to successfully contain the virus for a long duration, which allowed unimpeded domestic economic activity when many other regions of the world were being hit with rolling lockdowns and successive waves of infection. While outbreaks of Delta and Omicron have shifted New Zealand to a policy of suppression rather than eradication, economic activity has outperformed many other regions around the world. Real GDP only fell 2.1% in 2020, the fifth-best performance in APEC.
- The UN estimates that New Zealand's population will reach 6.2 million people in 2050. This is on the low end of domestic population projections from Stats NZ, that estimate population to be between 6.3 and 7.1 million, depending largely on the ongoing size of New Zealand's migration program.
- The Reserve Bank of New Zealand is one of the few global central banks to have raised rates in the latter half of 2021. The hikes have been in response to the meteoric rise in housing prices that accelerated during the pandemic. The moves by the Bank are attempting to balance the need to suppress rapid asset price growth without constraining economic activity in this time of pandemic uncertainty. The impact of these rate rises on this *Outlook* is uncertain.
- Current assumptions will see New Zealand's economic output more than double to USD 450 billion 2018 PPP in 2050. While services, such as science, finance, and insurance, will continue to rise, primary agricultural industries will maintain their importance. These industries are important in supporting higher value-added manufacturing, and for sustaining multiple export-facing enterprises.

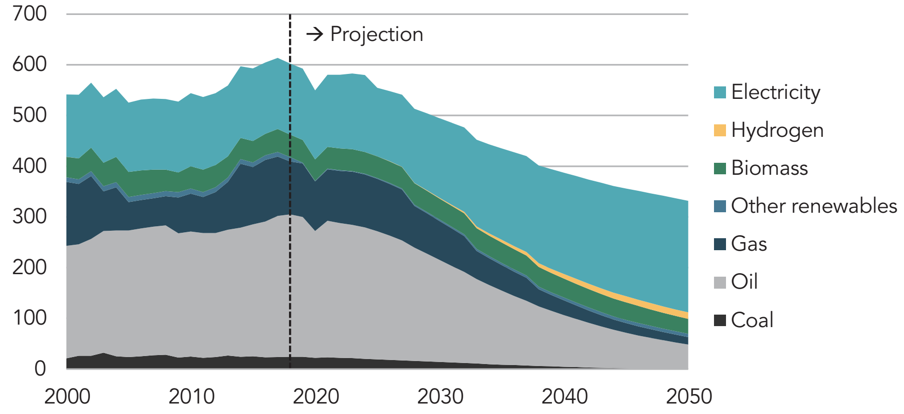
End-use energy demand

Figure 12-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 12-4. Energy demand in CN, 2000-2050 (PJ)

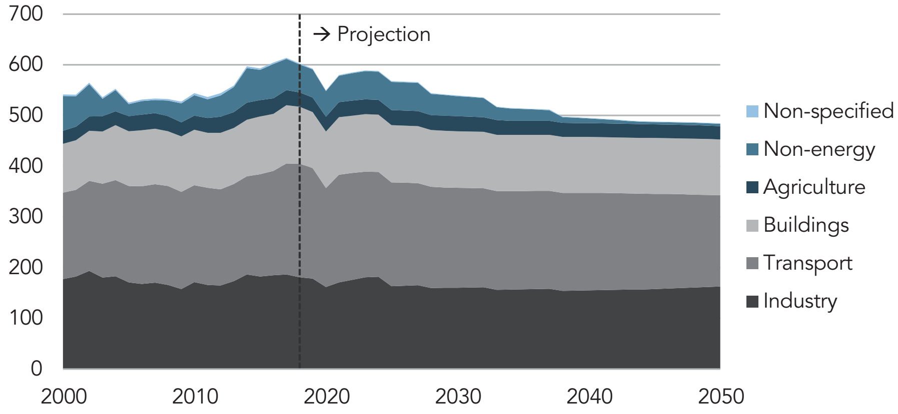


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Final energy demand peaks prior to the COVID pandemic in both REF and CN, falling by almost one-fifth and over two-fifths in each respective scenario. Continued improvements in energy efficiency and higher electrification are key drivers of this result.
- There will be a decrease in energy use from oil, gas, and coal in both scenarios, with CN seeing larger effects. Generally, this is caused by supply constraints of gas, electrification of transport replacing refined products, and a phase-out of coal in industry, buildings, and the power sector.
- Electricity currently accounts for one-quarter of New Zealand's end-use energy demand, while refined products (oil) accounts for almost half. Over the projection period, electricity becomes the most prominent energy source in both scenarios, increasing to over two-fifths of energy demand in REF and almost two-thirds in CN.
- While oil use has been increasing for decades, it is projected to decline due to the electrification of the transport sector. New Zealand's clean car standard and clean car discount are key contributors to this shift in the early part of the projection period. Declining costs of EVs in CN push oil use declines over 80% by 2050.
- The electrification of the transport, industry, buildings, and agriculture sectors will drive significant energy use reductions. Less demand for heavy industry products (material efficiency) is also influential in driving down energy demand in CN. Energy efficiency in all sectors, such as via weatherising buildings, will also drive down energy demand.
- Hydrogen applications begin to penetrate the market from the late 2020s in both scenarios, though by 2050 hydrogen demand in CN is more than double the demand in REF. Hydrogen applications in industry trail transport's due to the small size of heavy industry in New Zealand.
- New Zealand's move from REF to CN is less of a leap than for many other APEC economies. This is on the back of a more advanced commitment by the New Zealand government to achieving carbon neutrality in its current slate of policies.

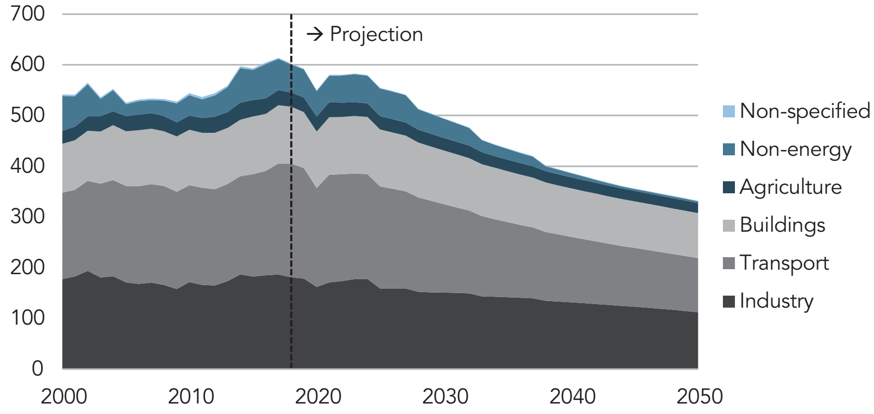
End-use energy demand by sector

Figure 12-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 12-6. Energy demand by sector in CN, 2000-2050 (PJ)

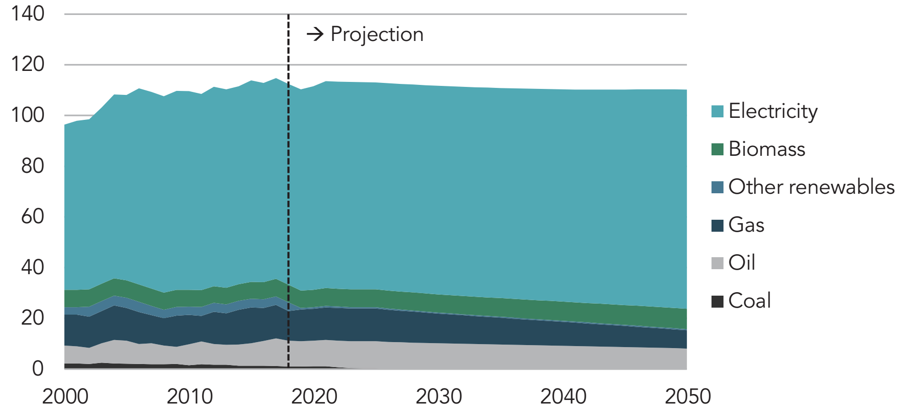


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Transport is currently the largest energy-consuming sector in New Zealand, accounting for almost 40% of end use prior to the pandemic.
- The transport sector posts a fall of more than 10% in 2020, which is the largest fall for any of the energy sectors, due to the impacts of pandemic mobility restrictions limiting the movement of New Zealand residents.
- The composition of sectoral energy demand by sector remains generally similar over the projection period, with improvements in energy efficiency largely offsetting greater levels of activity and output. The non-energy sector is the most notable exception, with consumption tracking the forecast fall in supply of natural gas, which is an integral feed-stock for this sector.
- Energy consumption falls significantly for all sectors in CN. Transport falls by over half due to improved energy efficiency and behavioural change, as increased rates of working from home leads to less transport activity.
- The industry sector posts a fall of almost two-fifths in CN due to diminishing gas supply, greater energy efficiency, and increased material efficiency for heavy industrial goods, such as cement. The closure of the Tiwai Point aluminium smelter in 2025 leads to a large fall in electricity consumption in both scenarios, driving down the overall energy intensity of the New Zealand economy.
- Buildings sector energy consumption falls by one-fifth in CN. The resilience in buildings energy consumption in REF and CN is due to most buildings already being electrified.
- Agriculture consumption falls by 30% in CN, as widespread electrification improves the energy efficiency of the sector. Electricity accounts for almost three-quarters of agricultural energy consumption in CN in 2050.

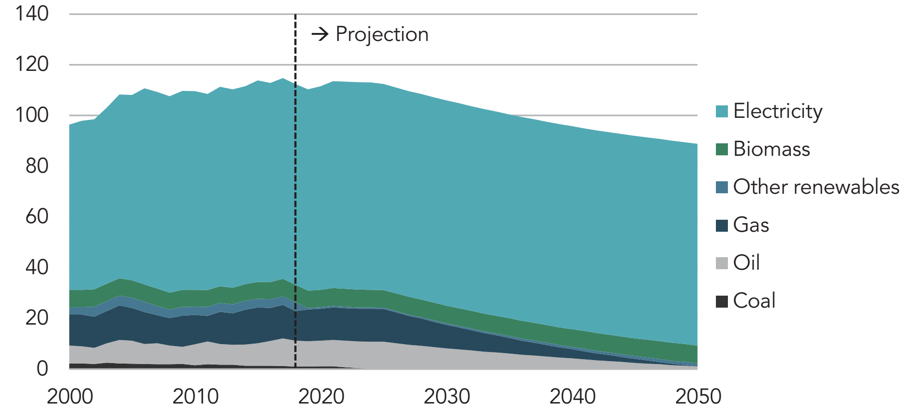
Buildings energy demand

Figure 12-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-8. Buildings energy demand in CN, 2000-2050 (PJ)



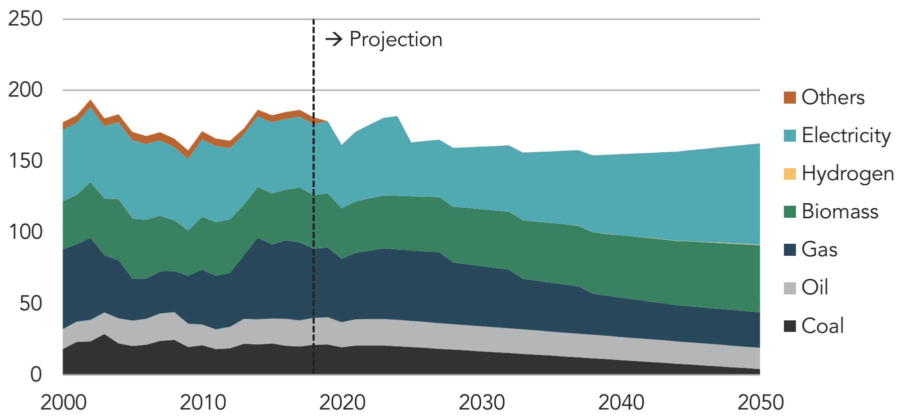
Sources: EGEDA, APERC analysis.

- Robust GDP and population growth drive energy demand growth in REF. However, increasing efficiency causes energy consumption to remain relatively flat out to 2050.
- Policies, such as the Healthy Homes Standard, help improve energy efficiency alongside a general rate of technological improvement throughout REF. In CN, electrification and higher building efficiency reduces energy consumption by more than one-fifth from both its peak and REF levels in 2050.
- Cooling demand increases throughout the projection period, though this will not be as influential in driving electricity demand as it is for southeast Asia economies due to the cooler weather associated with the temperate climate that covers most of New Zealand.
- In REF, gas supply for residential and commercial consumers remains, albeit at a declining rate. A significant amount of fuel switching to electricity takes place, as policy support and diminishing natural gas supplies make electric applications increasingly cost competitive. Subsidies incentivise switching to electric heating, hot water heating, and cooking systems in residential properties, and funds encourage public buildings, such as schools and hospitals, to switch away from gas connections and LPG appliances whenever possible. Buildings regulation amendments are also constraining the consumption of gas and LPG.
- In CN, additional government intervention accelerates the phase-out of natural gas and LPG. Electricity accounts for 90% of buildings energy consumption by 2050.
- Policy measures against coal consumption in public buildings and emissions regulations targeting domestic use drive coal consumption to zero by 2030 in both scenarios.
- Oil consumption falls near 90% in CN, with a remainder left to fuel some cooking and heating requirements. However, most of it is expected to be replaced by electricity and solar water heaters (other renewables).
- New Zealand's move from REF to CN is less of a leap than for many other APEC economies due to the highly electrified status of its current buildings stock.

Notes: While the use of biofuels and biomass, such as biogas or wood pellets, is a possible pathway for reducing fossil fuel use by buildings in CN, it is assumed that these are to remain niche solutions and were not modelled in this *Outlook*.

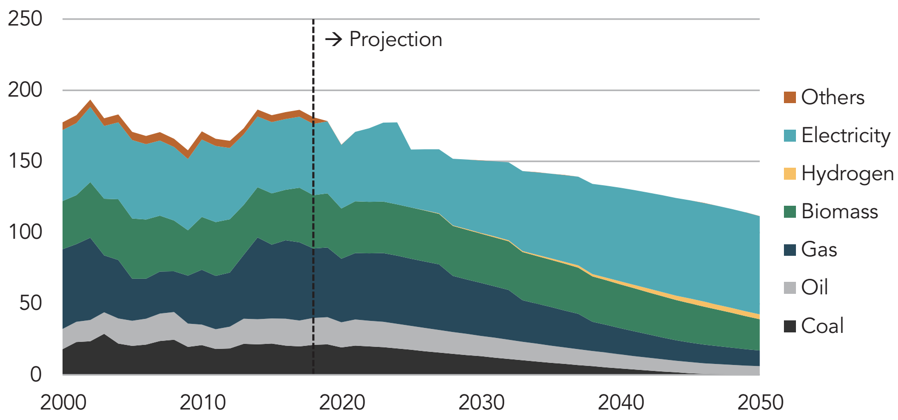
Industry energy demand

Figure 12-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 12-10. Industry energy demand in CN, 2000-2050 (PJ)

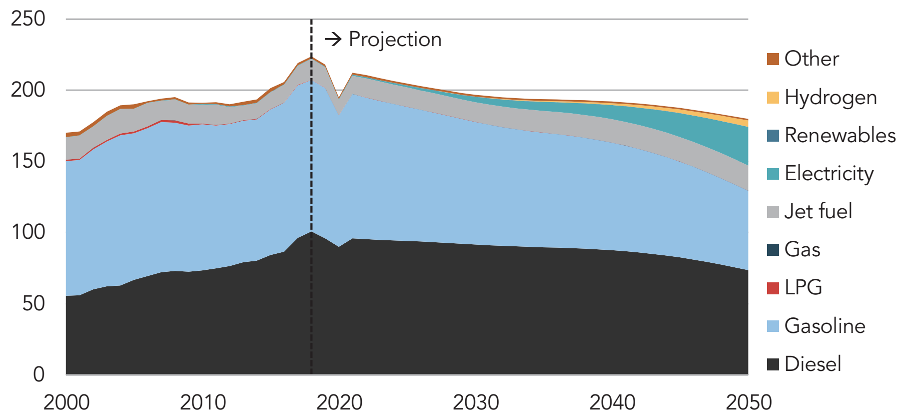


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industrial sector energy consumption has been somewhat volatile over the past two decades due to the decline and subsequent recovery in chemicals in the early 2000s to mid-2010s. Food and beverage manufacturing continues its multidecade growth spurt over the outlook period, as the subsector's high value-added products continue to be demanded in growing markets, like Asia.
- Demand for industrial products remains robust for the projection period. However, facility closures and energy efficiency improvements in REF mean that industry energy demand is slightly lower in 2050 than its pre-COVID peak. Greater energy efficiency and material efficiency in CN result in even greater declines in energy consumption.
- Industry sector energy consumption is anticipated to be impacted by two prominent facility and plant closures for the projection period in both scenarios. The Tiwai Point aluminium smelter is scheduled to close in 2025, leading to industry electricity demand falling by more than one-third. In the chemicals sector, all three Methanex facilities are assumed to gradually phase down operations from 2025 due to increasingly tight natural gas supply. Falls in production are expected to continue until they cease operating in 2040 in both scenarios.
- Process heat derived from coal in subsectors like steel is gradually but steadily replaced by biomass or electricity in REF. Further support for coal reduction in other subsectors is supported by government policy to reduce coal-fired process heat throughout the New Zealand economy. These policies are applied more aggressively to other subsectors in CN.
- A small amount of CCUS is adopted by the chemicals subsector in CN.
- Hydrogen begins to be incorporated in various steel making processes from as early as the mid-2030s in CN. Hydrogen use remains niche, comprising 3.0% of the demand mix by 2050.
- Despite the closure of New Zealand's aluminium smelter, electricity comprises more than two-fifths of industry demand by 2050 in REF. In CN, while electricity grows less due to higher material and energy efficiency, it accounts for almost two-thirds of the fuel mix in 2050.
- Biomass grows to account for 30% of the industry energy mix in REF. In CN, due to being less dependable for process heat than electricity, its role is reduced to 20% of the mix.

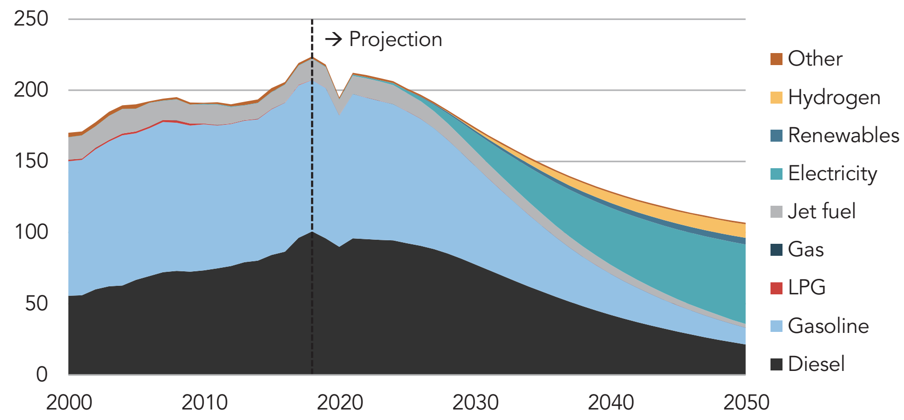
Transport energy demand

Figure 12-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 12-12. Transport energy demand in CN, 2000-2050 (PJ)

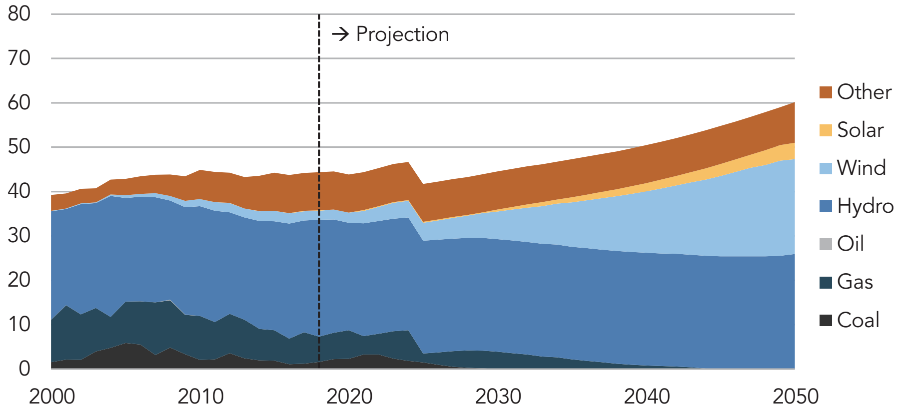


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Energy consumption falls by over 10% in 2020 due to the imposition of mobility restrictions to contain the coronavirus. Gasoline use falls by almost 13% and jet fuel by more than a quarter. In both scenarios, energy efficiency improvements ensure that transport demand never reaches its pre-pandemic peak.
- Gasoline demand falls by almost half in REF, driven by fuel economy improvements and electrification trends. Policies such as the clean car standard and clean car discount contribute to this reduction. In CN, more aggressive electrification policies targeting transport results in gasoline use falling almost 90%.
- EVs grow significantly, from their current low base to almost two-fifths of the fleet in REF. Adoption is significantly higher in CN, with EVs comprising half of the light fleet by 2037 and 80% by 2050. Battery EVs account for over 55 PJ, or almost 60% of New Zealand's road transport energy consumption in 2050.
- Diesel demand falls by almost a quarter in REF, which is only half the rate of decline seen from gasoline. Fuel economy and logistical efficiency drive the decline in diesel, with electrification only having a minor impact. In CN, diesel falls three times REF levels, or nearly an 80% reduction. The electrification of freight and transit is more extensive in CN, with half of heavy trucks and 70% of buses electrified by 2050.
- In CN, jet fuel is gradually replaced by low carbon biojet and hydrogen alternatives, leading to more than an 80% decline in jet fuel use. Biojet blending is introduced from 2025 with aviation consumption of biofuels overtaking jet fuel in 2040. Trials of hydrogen-fuelled aircraft are assumed to begin in 2030, with the optimistic assumption that these aircraft will be successful and grow gradually to be transporting 20% of New Zealand domestic air passengers by 2050.
- Growth in heavy trucking and aviation applications propel hydrogen consumption to almost 10 PJ in CN. This represents almost 10% of New Zealand's transport energy demand.

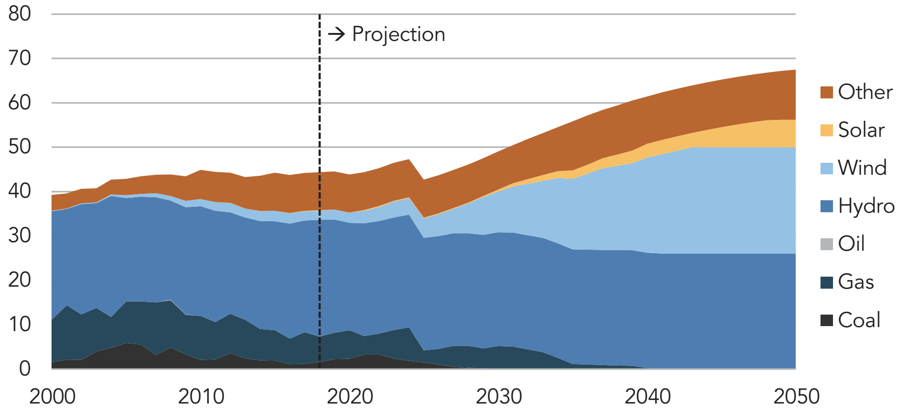
Electricity generation

Figure 12-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 12-14. Electricity generation in CN, 2000-2050 (TWh)

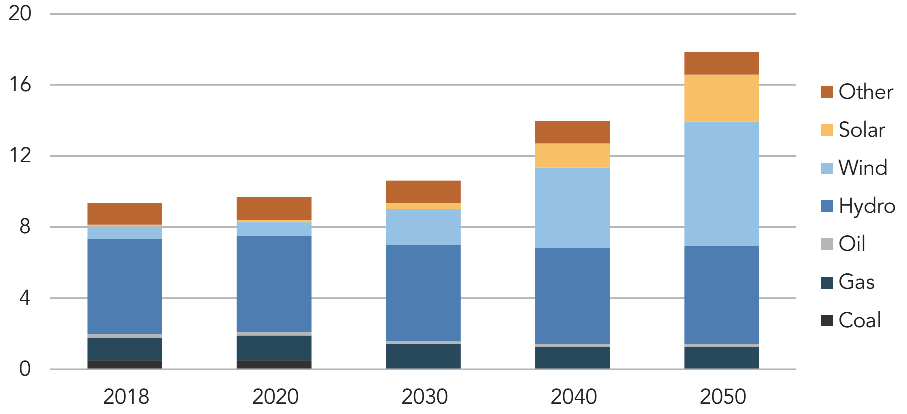


Sources: EGEDA, APERC analysis.

- New Zealand has one of the highest shares of renewable generation in the world, currently amounting to over 80% of the generation mix. Hydro accounts for almost three-quarters of this share, with geothermal and wind, which increased generation by a third during the last decade, making up the remainder.
- Most hydro generation occurs on the South Island, and a high voltage DC Inter-Island link transports electricity to the more densely populated North Island. While hydro was even more prominent in decades past, the risk of low output in dry seasons spurred the development of thermal power plants.
- In contrast to hydro generation installations, New Zealand's largest natural gas and coal-fired power plants are situated relatively nearby to the main population centres on the North Island. The Huntly power plant, near Auckland, is New Zealand's largest thermal power station and consumes both natural gas and coal to power five operational turbines.
- Generation from thermal generation facilities peaked in the mid-2000s and continues declining in both scenarios. Coal is phased out by 2030, though natural gas persists until 2044 in REF and 2040 in CN.
- The planned closure of the Tiwai Point aluminium smelter on the South Island, and the subsequent fall in demand in 2025, leads to a 5.0 TWh drop in generation requirements, with natural gas comprising nearly all the declines, due to the higher costs associated with its usage. However, the fall is predicated on the assumption that there is sufficient transmission capacity to move the freed-up hydro capacity from the Manapouri dam in the south to major load centres in the north.
- In REF, generation takes 10 years to reach the same levels as was in place with the Tiwai Point smelter. Higher electrification reduces this term to five years in CN.
- New Zealand's high onshore wind potential and declining turbine costs allow wind to dominate generation gains in both scenarios. Wind grows nine-fold in REF and ten-fold in CN, increasing from 5.0% of the fuel mix in 2020 to over a third in both scenarios.
- Despite lower solar potential than many other APEC economies, solar generation increases to provide almost four TWh in REF and over six TWh in CN by 2050.

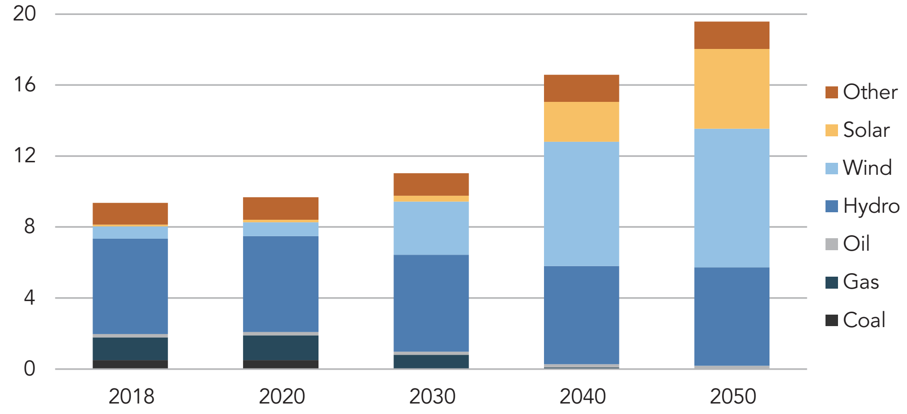
Generation capacity

Figure 12-15. Technology capacity in REF, 2017-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 12-16. Technology capacity in CN, 2017-2050 (GW)

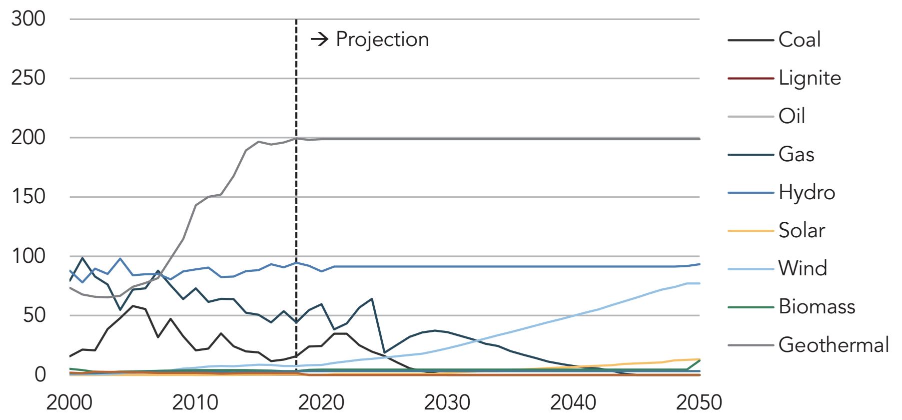


Sources: EGEDA, APERC analysis.

- New Zealand's power fleet is dominated by South Island hydroelectric installations which make up approximately two-thirds of its total capacity. Hydro capacity is projected to remain stable through to 2050 in both scenarios.
- In years of low rainfall, there is greater reliance on fossil fuel generation due to the relatively low storage of New Zealand's hydro assets. The government is currently investigating solutions to interannual hydro variability via the NZ Battery Project. An increasing share of wind and solar emphasises the importance of this project. Additional hydro capacity development may be the most viable way to meet the challenge of variable generation, even with the large physical, environmental, and cost challenges that come with additional hydro capacity.
- Most natural gas capacity in REF is maintained for the entire projection period as a backup for the large build-up of variable renewable capacity, although it is not utilised after 2044. In CN, natural gas capacity declines from 1 400 MW to only 100 MW in 2035. The last natural gas unit is assumed to be retired in 2045.
- Wind capacity grows by a factor of 10 in REF, and by a factor of 11 in CN, surpassing hydro to become the most prominent capacity source in 2044 and 2036, respectively. Growth in wind capacity is largely due to New Zealand's low latitude and isolation from other landmasses that delivers world-class wind potential. Multiple potential sites will host wind farms that have some of the highest capacity factors in the world. Offshore wind in New Zealand is not currently considered because of the high availability of onshore wind resources, and their relatively lower cost.
- Outside wind, all other additional capacity is assumed to be from renewable sources. Solar grows by a factor of almost 30 in REF, and by more than 50 in CN. Most of this solar development occurs on the North Island, where solar radiation is more consistent. Geothermal capacity maintains a constant level in REF, though expands by 30% in CN in the mid-2030s.

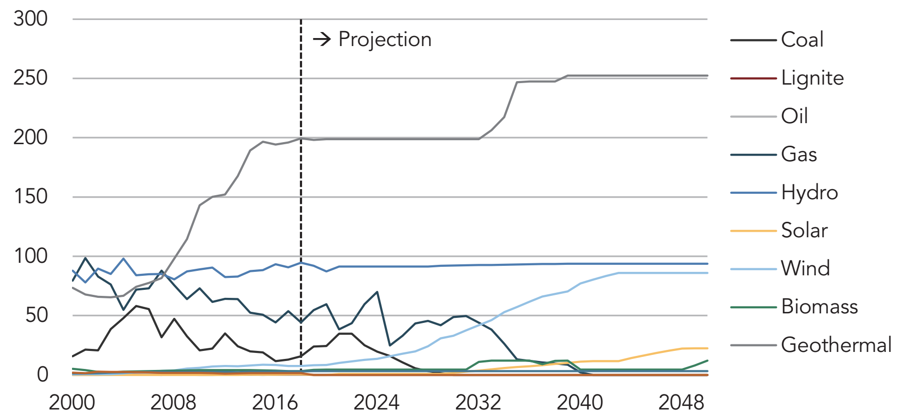
Fuel consumption by power sector

Figure 12-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 12-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

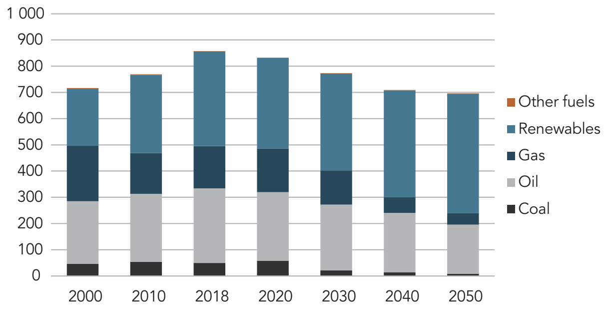


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- The use of geothermal resources in the power sector is significantly larger than that of other fuels in both scenarios. However, this large level of consumption does not translate into similarly large levels of generation due to the low transformation efficiency of geothermal power. Thus, despite having half the energy use, hydroelectricity makes up significantly more of New Zealand's generation output.
- Fuel consumption rises almost a tenth in REF and over a quarter in CN. While higher generation plays a role, growing an eighth over REF levels, the main driver is due to higher geothermal generation and its low transformation efficiency.
- This low efficiency explains why hydroelectricity is the most prominent source of generation in New Zealand. It also explains why fuel use in the power sector rises nearly a fifth in CN over REF levels, while generation only rises an eighth.
- The large fall in electricity demand that occurs with the closure of the Tiwai Point aluminium smelter in 2025 is almost entirely met by a fall in natural gas generation. Natural gas temporarily recovers more strongly in CN due to higher electricity demand. However, by the early 2030s, natural gas consumption in CN falls below natural gas consumption in REF, due to rising levels of wind and geothermal resources.
- Hydro power consistently sustains past levels of generation, and thus fuel use, throughout both scenarios. While there is no forecast growth in hydro in either scenario, demand for electricity from the North Island is assumed to wholly replace the large reduction in electricity demand from the Tiwai Point aluminium smelter on the South Island. There are multiple proposed upgrades to the Inter-Island link to ensure South Island hydro installations can continue to operate at past levels while serving a greater portion of demand from the North Island.

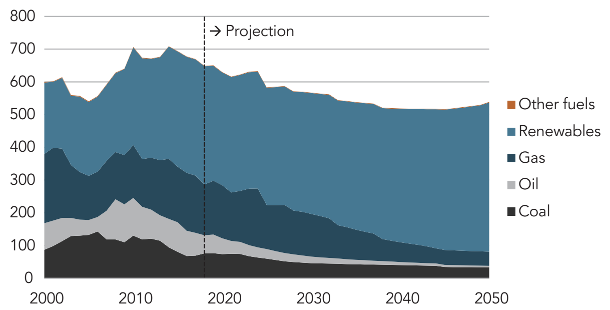
Energy supply in the Reference scenario

Figure 12-19. Total energy supply in REF, 2000-2050 (PJ)



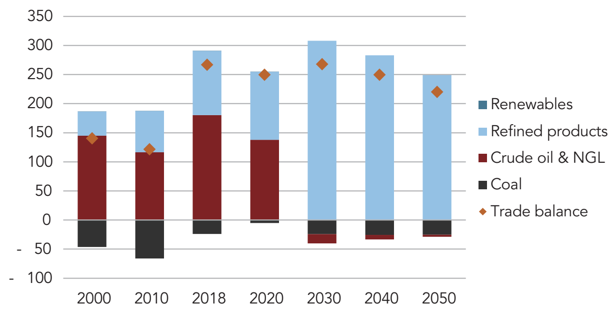
Sources: EGEDA, APERC analysis.

Figure 12-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-21. Net energy trade in REF, 2000-2050 (PJ)

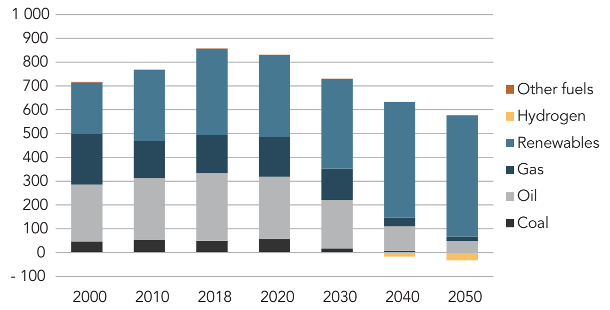


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Production from New Zealand's abundant hydro and geothermal resources contribute to over two-fifths of supply in 2019. Renewable production expands to over 450 PJ by 2050 in REF, accounting for almost two-thirds of supply and almost 85% of domestic energy production. The rise in wind power accounts for most of the incremental gains, adding to its already large share of hydro and geothermal production.
- Oil production occurs predominantly in the western side of the North Island from multiple fields in the Taranaki region. The output is mostly a light-sweet crude oil and is almost exclusively exported to Australia. Production has been declining since 2008 and continues declining throughout the projection period to very low levels in 2050.
- The Maui gas field was the largest natural gas producing field in New Zealand until the early 2000s following the exploitation of new fields in Taranaki, such as the Pohokura and Kupe. While these fields partially offset the decline in Maui's output, total production is still at a lower level than its 2001 peak. Production declines by almost three-quarters throughout the projection period. This fall essentially follows domestic consumption levels, given that there is no import or export capability for natural gas in New Zealand.
- New Zealand's sole refinery at Marsden Point relies on an imported blend of medium-sour crude oil, with output from the refinery currently meeting the majority of New Zealand's domestic demand for refined products. The Marsden Point refinery is scheduled to convert to an import-only terminal of refined products in 2022. This means that refined products imports will supplant crude oil imports, with the overall trade balance maintaining a similar level. Imports of refined products will track the slow decline in their demand for the outlook period.
- A decline in coal-fired power generation is associated with a 40% fall in New Zealand's coal production in the last decade. However, the large Huntly power station near Auckland is mostly reliant on thermal coal imports from Indonesia. While coal-fired power is expected to be phased out by 2030 in REF, demand from export markets will support West Coast (South Island) production of metallurgical coal for the remainder of the projection period.

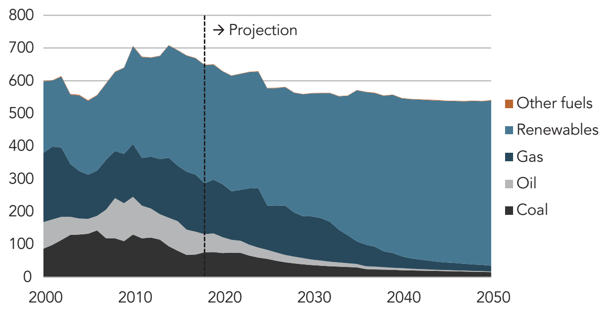
Energy supply in the Carbon Neutrality scenario

Figure 12-22. Total energy supply in CN, 2000-2050 (PJ)



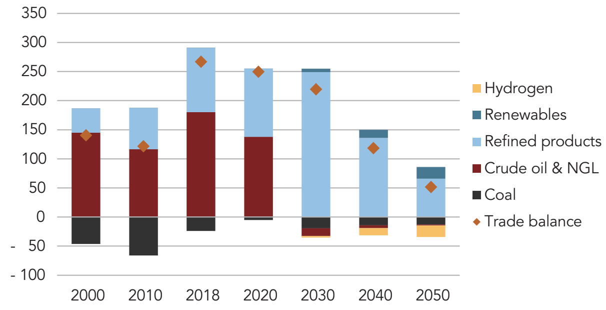
Sources: EGEDA, APERC analysis.

Figure 12-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-24. Net energy trade in CN, 2000-2050 (PJ)

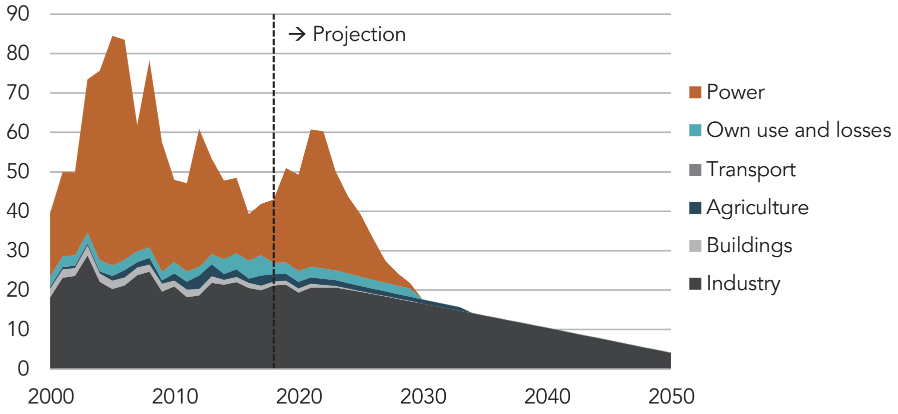


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Renewables are already very prominent in New Zealand's energy supply in REF. This prominence reaches new highs in CN, with renewables accounting for almost 95% of New Zealand's energy supply and production in 2050. Like REF, the growth in wind power accounts for most of the growth in renewables in CN.
- Fossil fuel production is comparable for both scenarios, though production falls at a slightly more rapid pace in CN from the mid-2030s onward. During the late 2020s and early 2030s, increased natural gas generation offsets lower natural gas consumption from all other sectors. However, alternative generation technologies meet the challenge of increased electricity demand for the latter half of the projection, which eventually pushes gas supply below REF levels.
- The establishment of a hydrogen export industry is a notable development in CN. Production by electrolysis (green hydrogen) begins in 2025 and increases to almost 50 PJ in 2050. Over two-fifths of this production is exported, while an additional one-third is destined for bunkers, which satisfy demand by international aviation and shipping. Hydrogen overtakes coal in the mid-2040s to be the most prominent energy export for New Zealand on an energy content basis. The export markets for this hydrogen are assumed to be predominantly in Asia. The development of a cost-competitive green hydrogen industry both at home and globally is a key uncertainty in this *Outlook*.
- Refined products increase significantly following the closure of the Marsden Point refinery in 2022. However, the rapid decline in domestic demand for refined products sees imports decline by around 80% over the outlook period from 330 PJ in 2022. Crude oil imports fall close to zero in 2023 following the refinery closure, and New Zealand's crude oil exports, mostly to Australia, fall close to zero by 2050. The fall is due to declining domestic production that occurs in concert with declining global demand for refined products.
- New Zealand's net energy imports fall by 15% through the projection period in REF. In contrast, net imports fall by more than 80% in CN, largely due to the electrification of the transport sector and declining oil dependence. Some of the fall in refined products imports is offset by imports of biojet fuels for the domestic aviation sector.

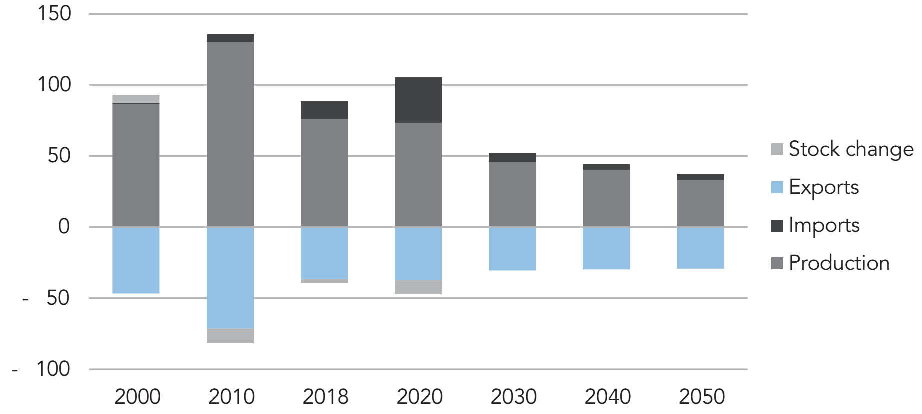
Coal in the Reference scenario

Figure 12-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

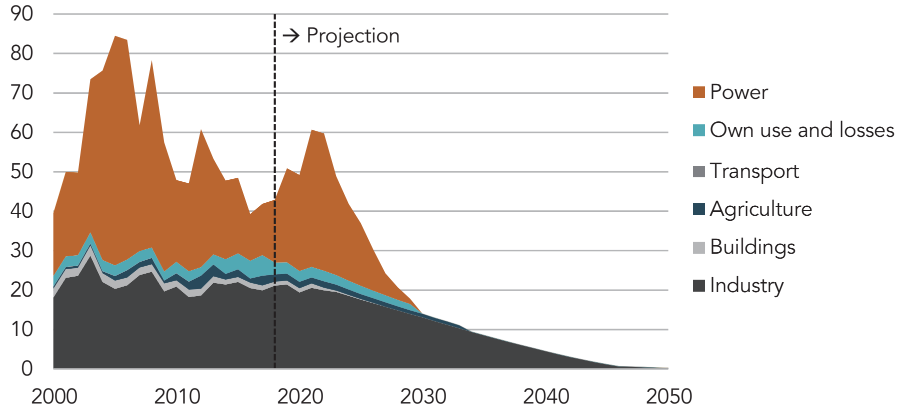


Sources: EGEDA, APERC analysis.

- New Zealand's power sector has been the most prominent consumer of coal over the past two decades. Consumption is relatively volatile and reflects that coal-fired generation is inversely related with the availability of both hydro and natural gas.
- Coal-fired power generation on the North Island has been an important back-up for planned and unplanned outages of the Inter-Island link, which delivers hydro generation from the south to the north. For example, a fault in one of the three Cook Strait cables led to reduced capacity of the link for six months in 2004, which partly explains the greater consumption of coal in the mid-2000s.
- Outside the power sector, coal consumption is largest in industry. Food and beverage manufacturing and the cement subsector rely on coal for its consistent heating properties, while the steel subsector consumes coke, a coal product derived from metallurgical coal. Industry coal consumption falls by 80% through the projection period due to electrification and other fuel switching to fuels such as biomass. Industry is the only sector in New Zealand to consume coal from the mid-2030s.
- Coal is phased out of the buildings and power sectors by 2030 and the agriculture sector by 2034. The post-COVID recovery relies on a significant uptick in coal-fired generation. However, this rapidly declines from the mid-2020s due to expanding wind capacity.
- Despite rapidly diminishing coal consumption, coal production remains more robust out to 2050, supported by export markets that continue to demand New Zealand metallurgical coal production from the West Coast on the South Island.
- Domestic industry consumption of thermal coal falls to very low levels by the mid-2040s, with imports assumed to meet this remaining level of demand. There is also a small amount of coke demand by the steel sector that is met by imports out to 2050.

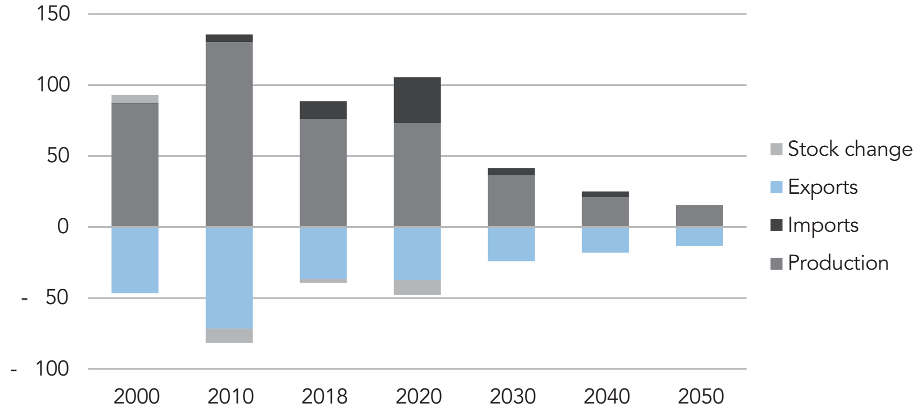
Coal in the Carbon Neutrality scenario

Figure 12-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

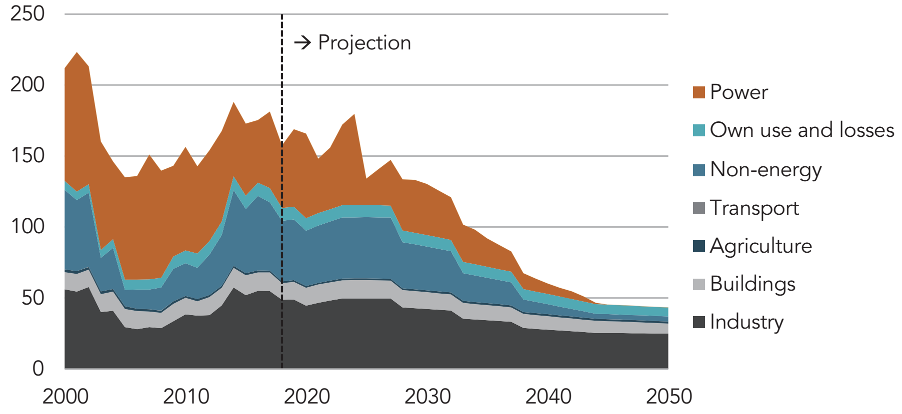


Sources: EGEDA, APERC analysis.

- New Zealand coal consumption in CN is very similar to REF. The power sector phase-out of coal is identical, and the fall in consumption in the buildings and agriculture sectors is only slightly more rapid.
- Industrial coal consumption is the sector that is subject to the largest change in CN. Hydrogen takes share away from coal in New Zealand's heavy industry and there is an even greater level of electrification for all industry subsectors. Coal consumption falls to close to zero in the mid-2040s.
- Global demand for metallurgical coal remains more robust than global demand for thermal coal in CN. This provides support for continued production of metallurgical coal from the West Coast of the South Island for export. However, metallurgical coal production and exports still fall by almost 60% over the projection period. Coal exports in CN are less than half of the export level in REF in 2050.
- Thermal coal production is assumed to cease in 2035 due to the dwindling size of the domestic market for thermal coal. This forces the remaining few industrial consumers to meet their demand for thermal coal and coke from suppliers overseas.

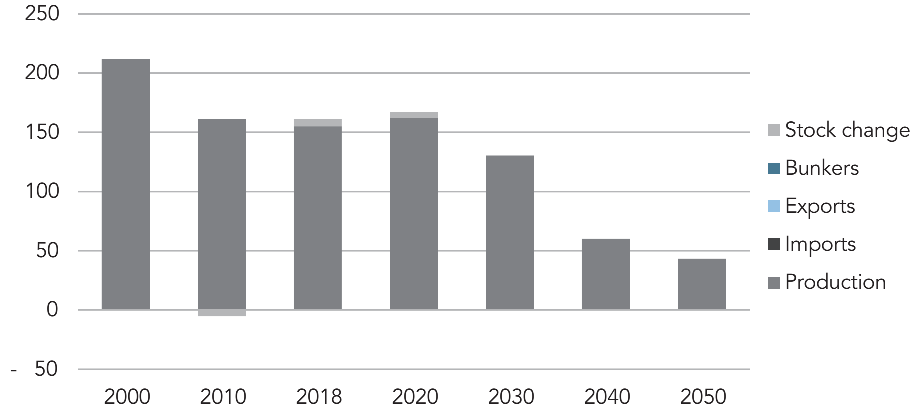
Natural gas in the Reference scenario

Figure 12-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

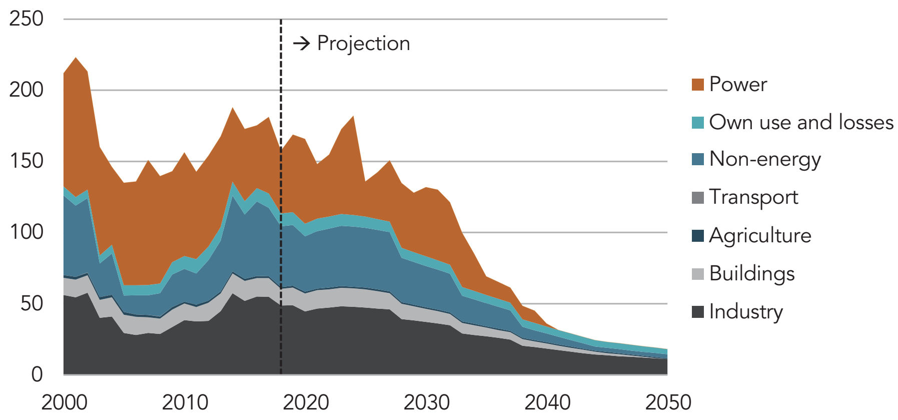


Sources: EGEDA, APERC analysis.

- New Zealand's natural gas market remains isolated, meaning that domestic consumers are wholly dependent on domestic suppliers, and vice versa. The Maui gas field in the Taranaki region of the North Island was the largest producing field in New Zealand through the 1980s to early 2000s. Production is still occurring out of Maui, but at much lower levels. More recently developed fields, such as Pohokura and Kupe, have supported New Zealand's gas production though the late 2000s and 2010s.
- Natural gas is consumed throughout the economy, with the power and industry sectors being the most prominent users over the last two decades.
- New Zealand's methanol and fertiliser production is sensitive to readily available and affordable natural gas supply, which is imperative to remain cost competitive with international markets. The large fall in industry and non-energy consumption of natural gas in the early 2000s was partly due to Methanex scaling back production in response to tight gas supply. Production recovered in the 2010s with the development of additional gas fields. While output remains at similar levels throughout most of this decade, diminishing natural gas supply causes a significant fall in production from these industrial subsectors in the last two decades of the outlook period.
- Natural gas consumption declines in other industrial subsectors, as well as the buildings and agriculture sectors, due to diminishing supply and decarbonisation policies that favour electricity and biomass.
- In November 2018, the Crown Minerals (Petroleum) Amendment Act restricted the exploration and production of oil and gas to current permit holders only. Future exploitation remains uncertain, and given the diminishing prospects on the demand side, it is likely for natural gas to trace a less prominent trajectory. A reserve replacement ratio of 30% will be required to sustain supply assumptions through to 2050 in REF. Exploration within remaining areas by existing producers may allow supply to meet demand, absent the development of any LNG import terminals.

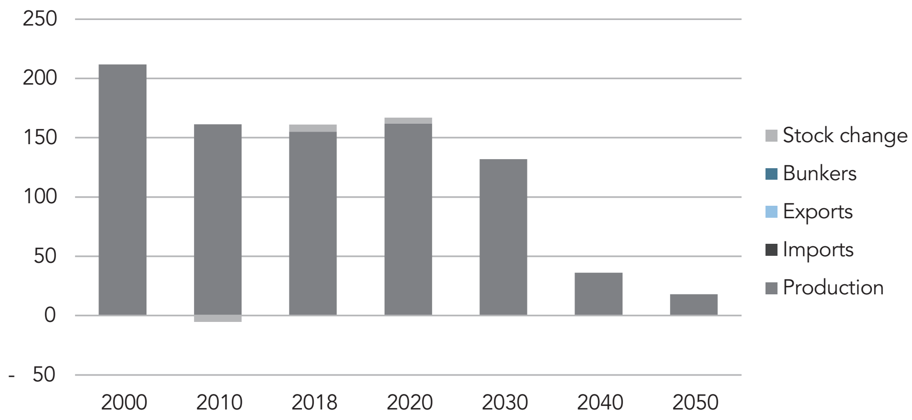
Natural gas in the Carbon Neutrality scenario

Figure 12-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

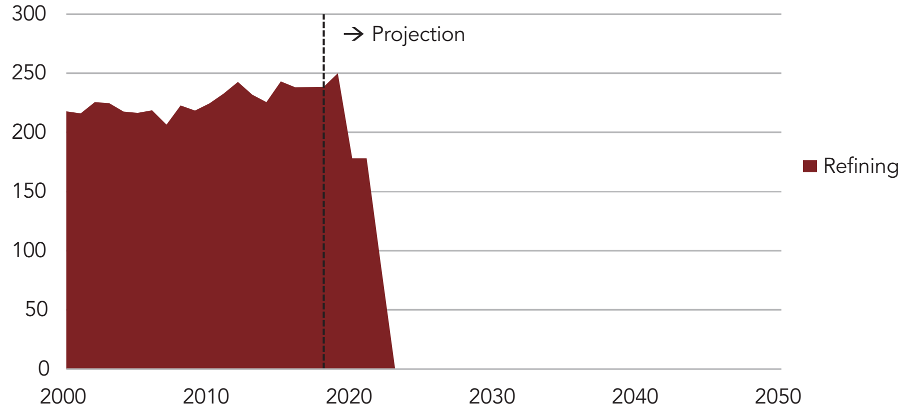


Sources: EGEDA, APERC analysis.

- The CN natural gas story is comparable to REF, with a slightly more aggressive phase-out in consumption, which occurs in concert with a similarly-sized supply response. Existing reserves are sufficient to meet CN demand trajectory, which suggests that further exploitation is not required.
- The phase-out of natural gas in the power sector occurs in 2040, four years earlier than in REF. However, natural gas consumption is higher in CN out to the early 2030s due to increased electricity demand from all end-use sectors.
- Supply constraints combined with increased policy ambitions in CN curb natural gas consumption in the buildings sector to zero by 2050. This displacement is almost entirely met by electricity.
- Industry sector gas use is more robust than in the buildings sector, though still falls to a level that is less than half REF levels in 2050. Electricity facilitates most of this reduction, but biomass and hydrogen also assist with the transition in heavy industry subsectors.
- The fall in natural gas supply and demand is already very large in REF. In CN, production in 2050 is almost 60% lower than in REF and is only 10% what it was just prior to the pandemic.
- Most of the reduction in natural gas use occurs after 2030, which emphasises its transition role for New Zealand in the context of decarbonisation ambitions. A more aggressive move away from natural gas in the 2020s would be difficult to achieve without a significant increase in New Zealand's energy costs and a potential reduction in economic output.
- Process heat makes up most of the industrial energy use and more than a third of process heat is for high temperate applications (for instance, those greater than 300 degrees Celsius); furthermore, half of such processes use natural gas. The government does not see a pathway to decarbonising high-temperature process heat with current technologies. This could result in fewer switching from natural gas to electricity than has been shown in both scenarios.

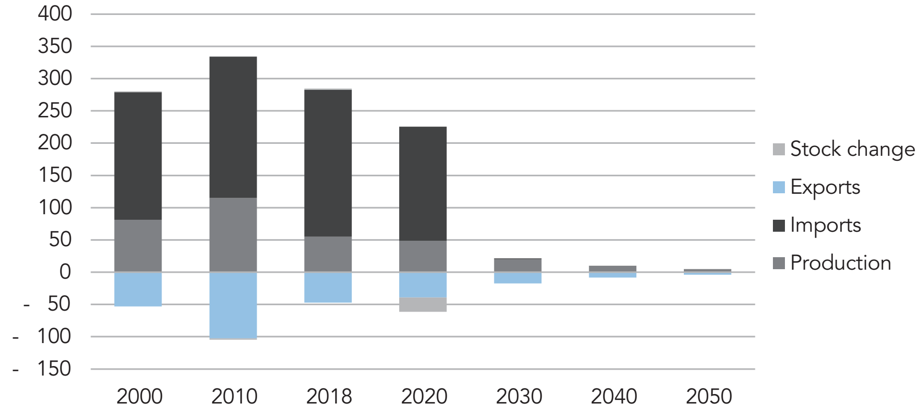
Crude oil and NGLs in the Reference scenario

Figure 12-33. Crude oil and NGL consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-34. Crude oil and NGL production, imports, and exports in REF, 2000-2050 (PJ)

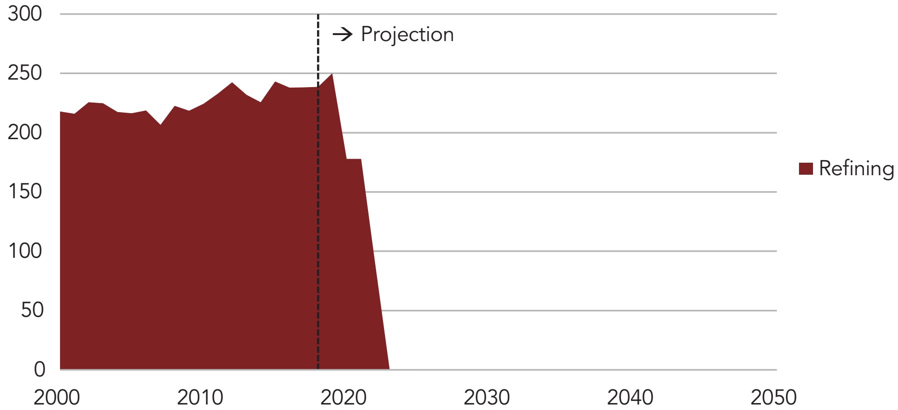


Sources: EGEDA, APERC analysis.

- Marsden Point refinery is located on the northern tip of the North Island and is New Zealand's only oil refinery. The operator, Refinery NZ, has confirmed its decision to close the refinery in April 2022 due to consistently poor profitability stemming from strong competition with Asian refiners. The location will convert to being an import terminal for refined products in the same year.
- New Zealand will be wholly reliant on importing refined products to meet domestic demand once the Marsden Point refinery closes. The closure of the refinery will cause fuel security risks to shift from a combination of refined products and crude oil suppliers to refined products suppliers only.
- Almost all crude oil production out of New Zealand is from the Taranaki region of the North Island, and most of this production is exported to Australia due to refinery compatibility and proximity. The Maui oil and gas field was the most prominent crude oil producing field until the Pohokura field surpassed it in the mid-2000s. While oil production spiked in the late 2000s with the development of multiple new fields, it has been declining through most of the 2010s. Crude oil and natural gas liquids (NGLs) production just prior to the COVID pandemic was less than half of what it was a decade prior.
- Production and exports of crude oil are expected to continue to decline as New Zealand's remaining oilfields are depleted. However, a small amount of NGLs from gas fields will continue to support a small level of exports through to 2050.

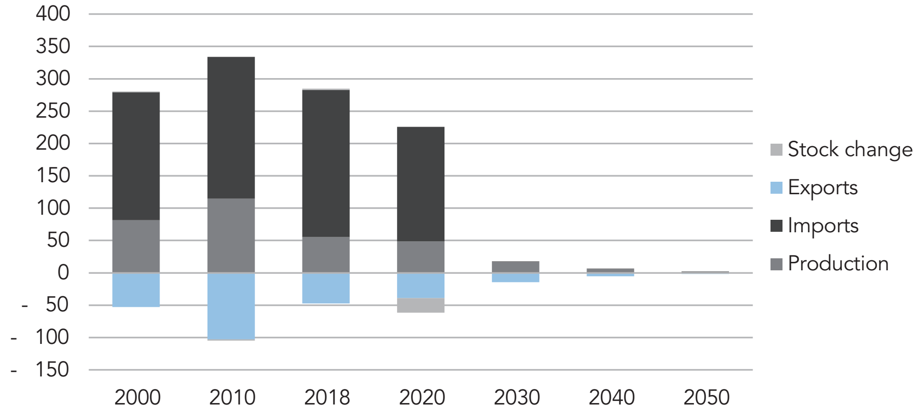
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 12-35. Crude oil and NGL consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-36. Crude oil and NGL production, imports, and exports in CN, 2000-2050 (PJ)

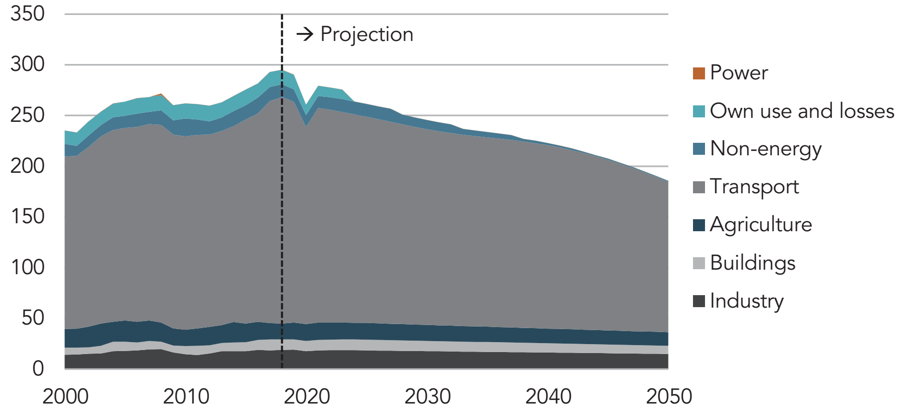


Sources: EGEDA, APERC analysis.

- CN outlook for crude oil and NGLs is almost indistinguishable from REF, but production diminishes at a slightly more rapid rate out to 2050, as export markets decline as the world embraces carbon neutrality.
- The Middle East has been the most prominent source of New Zealand's crude oil imports for the life of the Marsden Point refinery, which began operating in 1964. Russia and other parts of Asia have also been major sources of crude oil inputs for the refinery.
- The axis of New Zealand's fuel security risk will pivot to Asia due to no longer having to rely on the Middle East and Russia for crude oil imports. New Zealand will instead rely on Asia for refined products.
- Import dependence will be lower in CN because of electrification, efficiency, and lower demand for oil products. This will reduce New Zealand's vulnerability to negative consequences in the event of a refined product supply disruption.

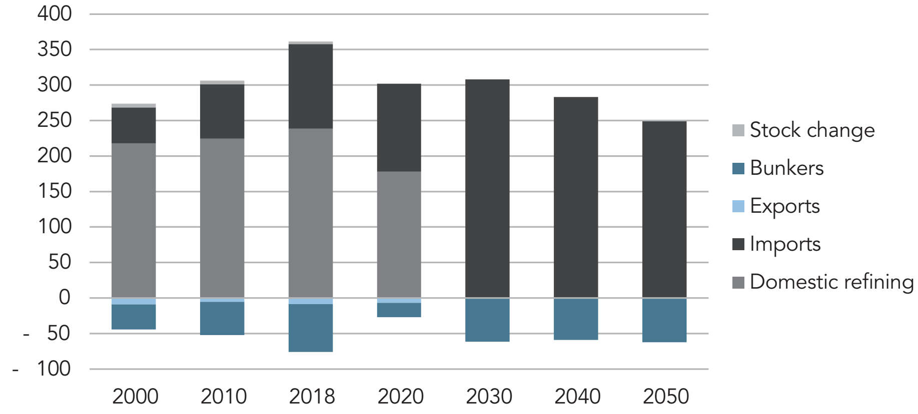
Refined products in the Reference scenario

Figure 12-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

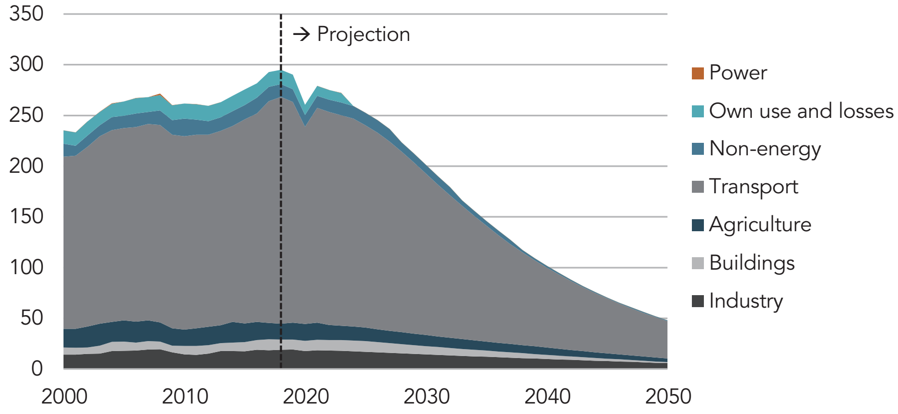


Sources: EGEDA, APERC analysis.

- The transport sector currently accounts for three-quarters of New Zealand's refined products consumption.
- Government restrictions to contain the coronavirus resulted in refined products demand falling a tenth in 2020. Mobility restrictions pushed down transport use by 11%, and industry demand fell by 8.0% due to widespread shutdowns of non-essential businesses. In contrast, buildings consumption increased slightly, as at-home energy consumption more than offset the closure of non-essential commercial businesses.
- Transport sector use of refined products declines by almost a third in REF due to increasing levels of fuel efficiency and fuel switching to electricity, biofuels, and a small amount of hydrogen.
- For the buildings, industry, and agriculture energy sectors, refined products consumption falls by approximately one-fifth. Non-energy consumption falls close to zero due to the diminishing size of New Zealand's chemicals subsector.
- The Marsden Point refinery, near the northern tip of the North Island, has been the main source of New Zealand's refined products supply for many decades. Low margins combined with the age of Marsden Point, which began operating in 1964, led to its closure in April 2022. The closure implies that New Zealand will have to meet its refined products demand via imports only.
- Bunkers capture the significant levels of diesel and jet fuel demand from international aviation and shipping. Bunkers consumptions falls by more than two-thirds in 2020 as lower aviation activity results from border closures during the COVID-19 pandemic. Withdrawals to these sources maintain similar levels for the remainder of the outlook period.

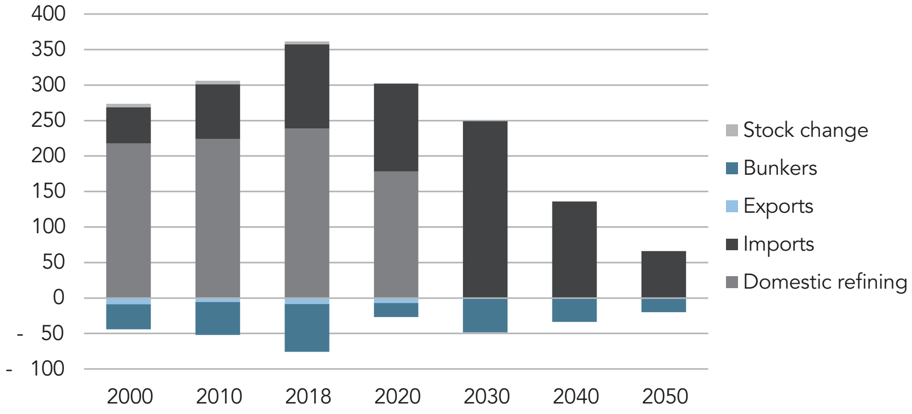
Refined products in the Carbon Neutrality scenario

Figure 12-39. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 12-40. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

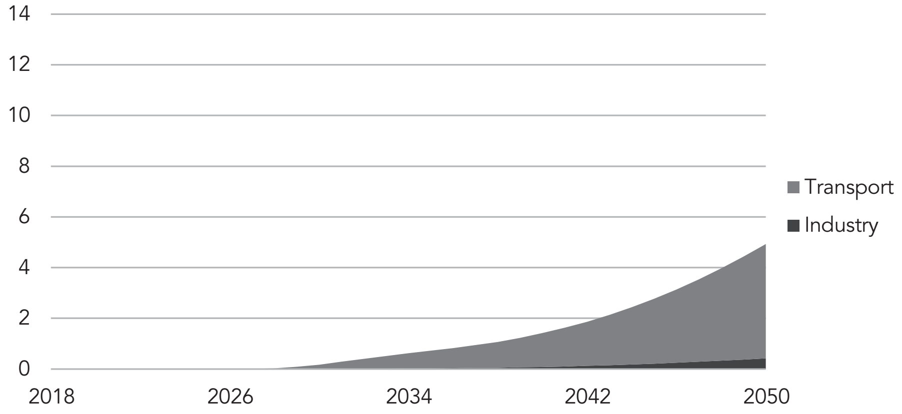


Sources: EGEDA, APERC analysis.

- In CN, refined products demand falls more than twice the amount in REF, falling over 80% from its pre-pandemic peak. The rapid move to electricity for many transport modalities, combined with higher levels of energy efficiency, and additional fuel switching to biofuels and hydrogen, drive the fall.
- Buildings sector consumption of LPG and diesel falls by over 90%, replaced mostly by electricity. Industrial consumption of refined products is mostly in the form of diesel to fuel construction, mining, and a few other subsectors. These end-use sectors are also subject to electrification with consumption falling by 70% through to 2050. Agriculture is also subject to significant electrification, with refined products consumption falling by almost four-fifths.
- Like REF, New Zealand is wholly reliant on refined products imports from 2023 onwards in CN. However, with a far more rapid decline in refined products demand, imports fall by more than 80% from the 2023 peak to the end of the projection period. Rapidly declining import dependence in CN bring large fuel security benefits to the New Zealand economy.
- Demand for refined products by international aviation and international shipping (bunkers) falls by 70% in CN out to 2050. The rise in biojet fuels, including those for blending, and hydrogen, drive this reduction.

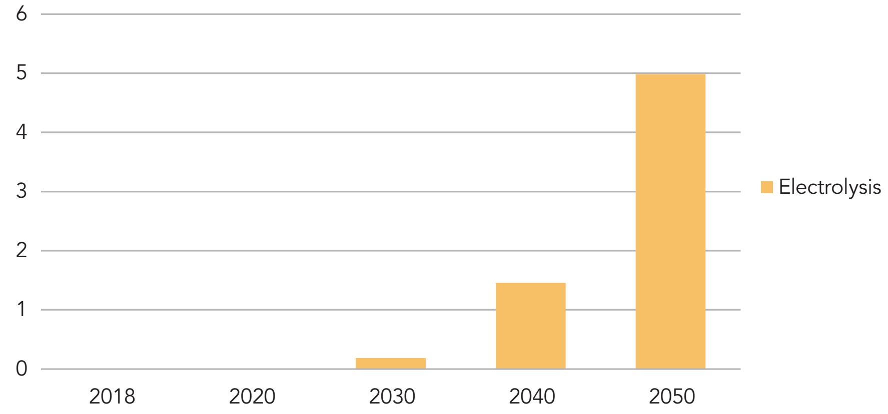
Hydrogen in the Reference scenario

Figure 12-41. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 12-42. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

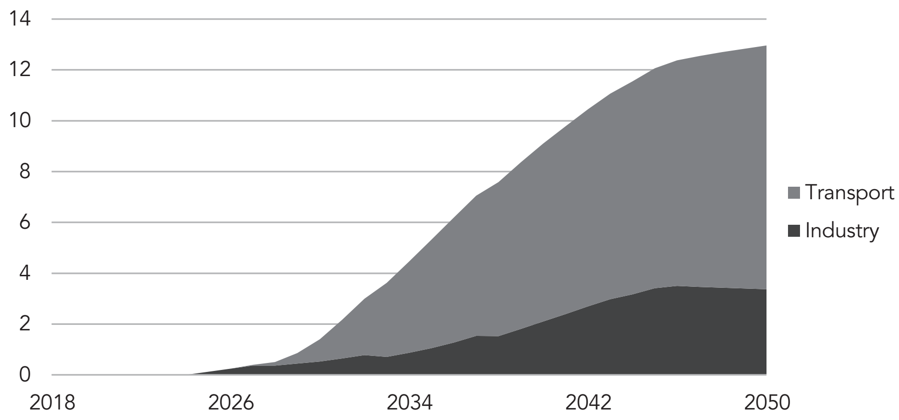


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- The most viable use-cases for hydrogen in New Zealand are in the transport sector, specifically in applications such as heavy trucking. Growth begins in the late 2020s and accelerates to almost five PJ by 2050. In industry, there is a small number of applications that begin to develop in the chemicals and steel subsectors. New Zealand's relatively small heavy industry limits the use of hydrogen by its industry sector.
- Domestic consumption of hydrogen in the transport and industry sectors is met entirely by domestic production via electrolysis. Almost eight PJ of electricity is required to produce five PJ of hydrogen, with this electricity assumed to be sourced entirely from off-grid renewable sources.
- There is no trade of hydrogen in REF owing to the limited development of global hydrogen use-cases and the limited development of an economically viable supply chain.
- The future of hydrogen is uncertain. End-use cases are reliant on continued technological development occurring at the same time as the provision of adequate and economic supply. In REF there is only limited development of use-cases that are supported by a relatively small level of production.

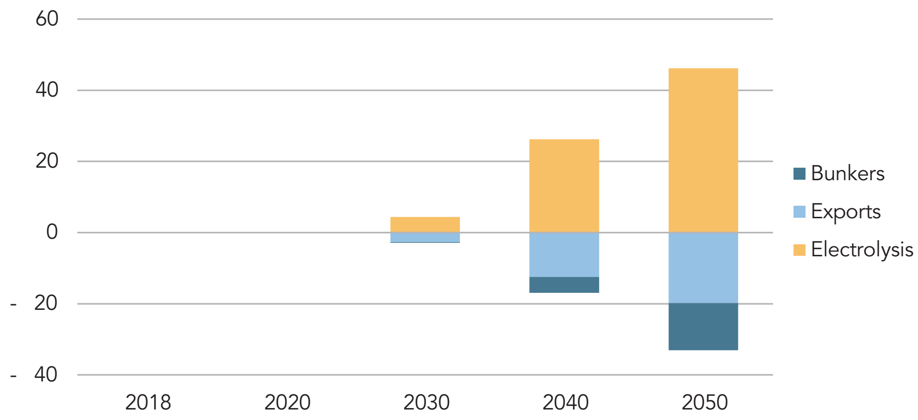
Hydrogen in the Carbon Neutrality scenario

Figure 12-43. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 12-44. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

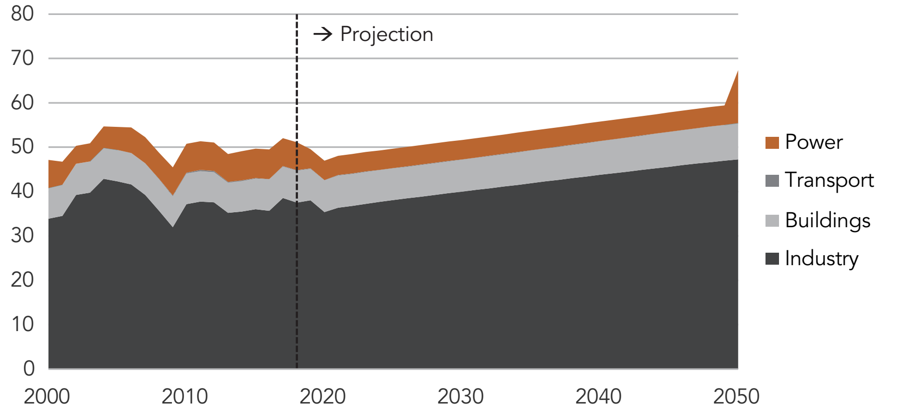


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue hydrogen) or electrolyser processes (green hydrogen).

- In contrast to REF, markets for hydrogen gain traction in CN and grow at a much greater rate due to the development of the hydrogen supply chain both within New Zealand and around the world. Domestic demand from industry and transport doubles over REF levels, reaching almost 13 PJ, and production is nine times greater.
- New Zealand's cheap and plentiful supply of renewable generation resources is assumed to support large growth in export-driven green hydrogen production. Electrolysis is assumed to be the production method, and, like REF, it is self-contained, separate from the grid infrastructure that supplies New Zealand's electricity.
- Considerable potential for hydrogen by both heavy trucking applications and domestic aviation abounds in CN. Transport is the largest hydrogen-consuming sector, accounting for almost three-quarters of end-use hydrogen demand in 2050.
- Industry demand for hydrogen is modest due to the relatively small size of heavy industry in New Zealand's economy. Growth is also limited due to the ongoing downsizing of the chemicals subsector, a large potential consumer of hydrogen.
- The successful development of hydrogen applications for aviation sees domestic demand for hydrogen grow rapidly after 2030. International aviation demand is slower on the up-take, but when combined with international shipping applications, bunkers demand soon outpaces domestic demand to reach over 13 PJ by 2050. An additional 13 PJ is consumed by domestic transport and industry applications. The remaining 20 PJ of production is exported, primarily to markets in Asia.

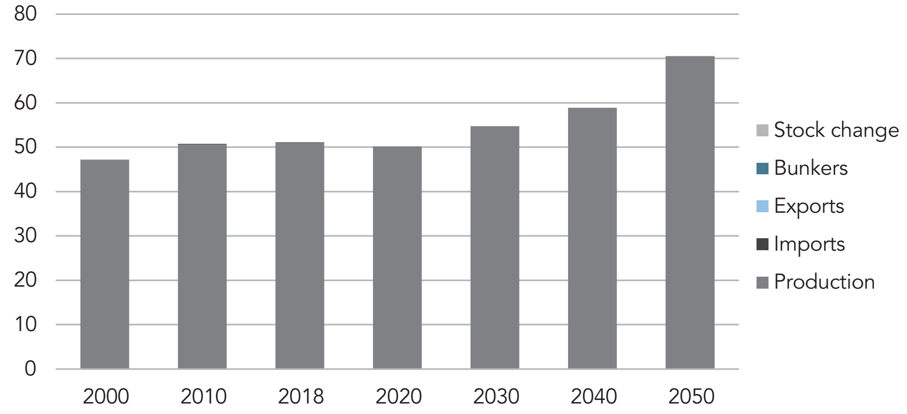
Bioenergy in the Reference scenario

Figure 12-45. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 12-46. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

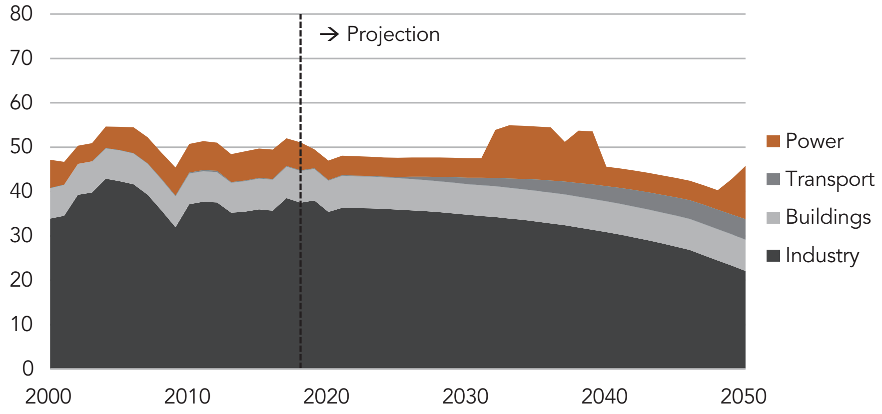


Sources: EGEDA, APERC analysis.

- New Zealand's industry sector has consumed between 30 and 40 PJ of biomass annually for the previous two decades. Coal-to-biomass fuel switching in subsectors like food and beverage manufacturing will see biomass consumption increase by almost 40% out to 2050. This is facilitated by government policies that encourage a switch away from coal for process heat applications.
- Biomass consumption by the power and buildings sectors remains stable for the projection period, continuing trends from the previous two decades.
- Domestic demand for solid and liquid renewables is met almost entirely by domestic production. There are multiple regions with biomass resources throughout New Zealand, with wood waste from the Bay of Plenty on the North Island being one of the largest sources. Auckland is a major source for municipal wood waste.

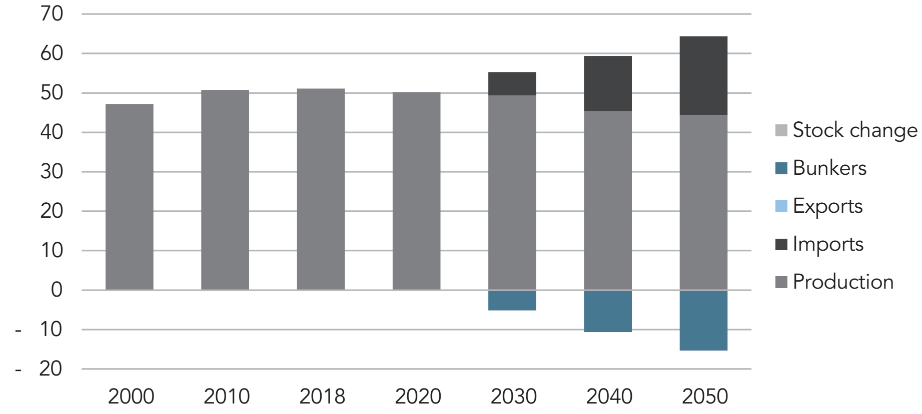
Bioenergy in the Carbon Neutrality scenario

Figure 12-47. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 12-48. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

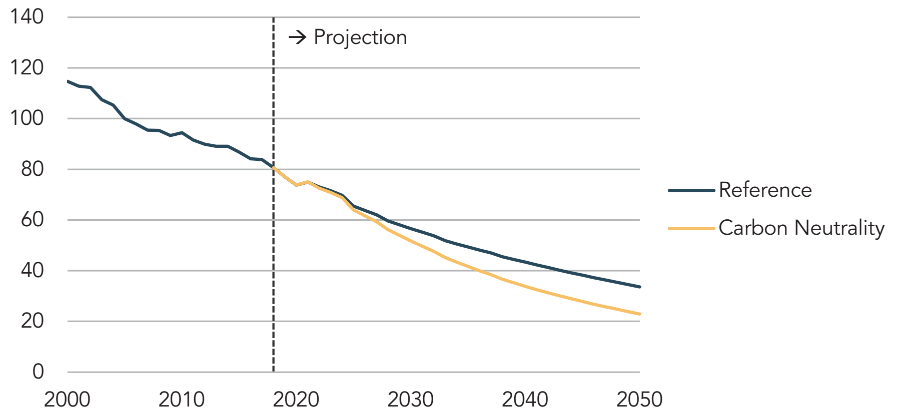


Sources: EGEDA, APERC analysis.

- Unlike in REF, consumption of bioenergy falls in CN. Industry consumption of biomass falls by more than 40%, as opposed to increasing by 40% in REF. While there is a greater level of industrial fuel switching away from coal in CN, the switch instead favours electricity and hydrogen over biomass. An increased level of energy efficiency and material efficiency in industry also drives a reduction in consumption of all fuels, including biomass.
- A notable change in CN is the growth of liquid renewables that are consumed by aviation applications. Biojet blending is introduced from 2025, with aviation consumption of biofuels overtaking jet fuel in 2040.
- There is also a growth in liquid renewables consumed by international aviation, as captured by the growth in bunkers. Biojet fuel consumed by international aviation increases to more than 15 PJ in 2050, which is more than three times larger than consumption by domestic aviation.
- In contrast to biomass demand being wholly met by domestic production, liquid biojet fuel demand is met entirely by imports.

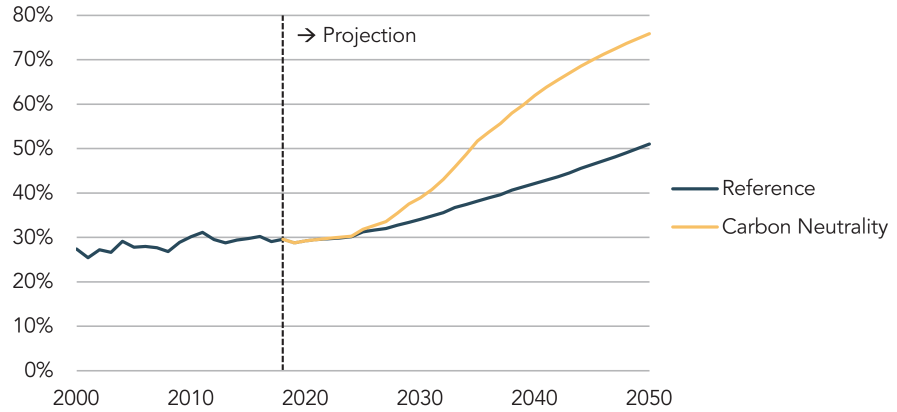
Energy intensity and modern renewables share

Figure 12-49. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 12-50. Modern renewables share in REF and CN, 2000-2050



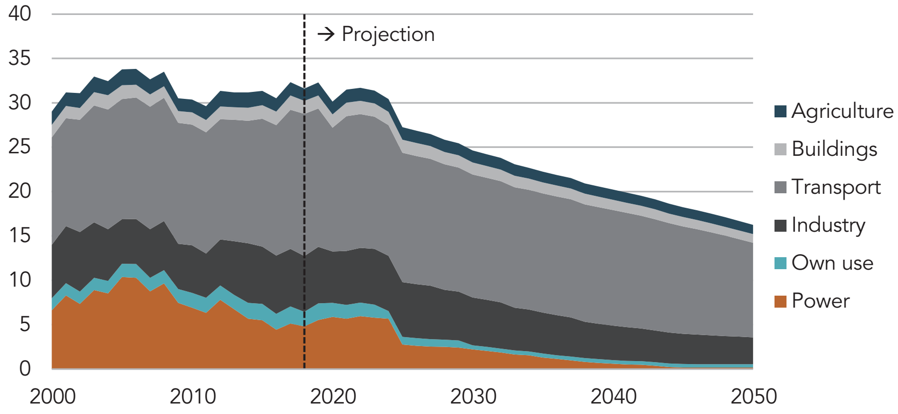
Sources: EGEDA, APERC analysis. Note: Includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- New Zealand's final energy intensity has improved by approximately one-third over the previous two decades. Improvement slowed in the years following the global financial crisis, but strong GDP growth in the years before and after the crisis, a continued move to a more service-intensive economy, and higher physical energy efficiency in all sectors have all contributed to intensity reductions.
- Final energy intensity is expected to continue improving in both scenarios, falling 65% below 2005 levels in REF, and by over 75% in CN.
- New Zealand's efforts are consistent with APEC's aspirational goal of reducing energy intensity by 45% below 2005 levels by 2035. It does so by 2032 in REF and 2029 in CN. These efforts also help APEC achieve the goal in both scenarios.
- New Zealand's share of modern renewables in its energy mix has been slowly rising from the relatively high level of just under 30% at the turn of the millennium. The fluctuations in the last two decades are mostly tied to the variable availability of hydro generation.
- The share of modern renewables is expected to maintain similar levels in both scenarios until the mid-2020s. From this point, the rise of electrification, particularly in the transport sector, and the rise of wind power will see the share of modern renewables increase to 50% in REF. Even greater levels of electrification will see the share of modern renewables reach more than 75% in CN.
- The rise of liquid biofuels and hydrogen also play a role in displacing fossil fuels in multiple sectors to improve the share of modern renewables in the energy mix.
- New Zealand's large levels of hydro and geothermal generation already had renewables comprising close to 70% of the electricity mix in 2000. This share of renewables rose above 80% prior to the pandemic. The share is projected to continue to rise through the projection period and reach close to 100% in the 2040s of both scenarios.
- While New Zealand's efforts are not consistent with APEC's goal to double the share of modern renewables in the energy mix by 2030 in both scenarios, its increases do help the region achieve the goal on an APEC-wide level.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

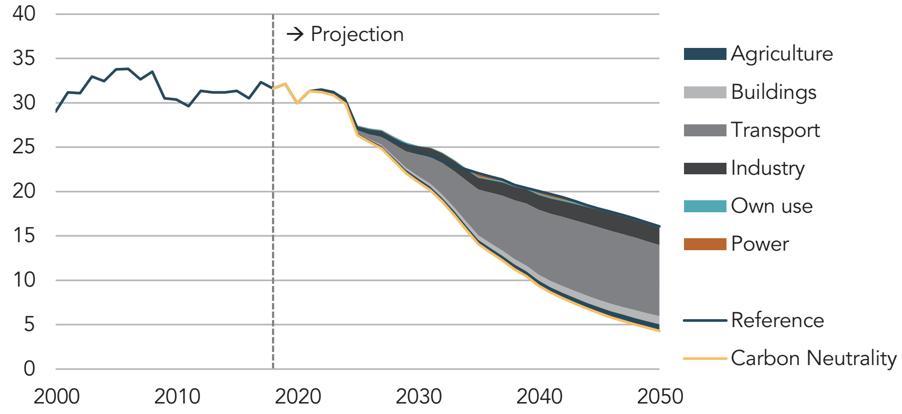
Gross CO_2 emissions

Figure 12-51. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 12-52. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

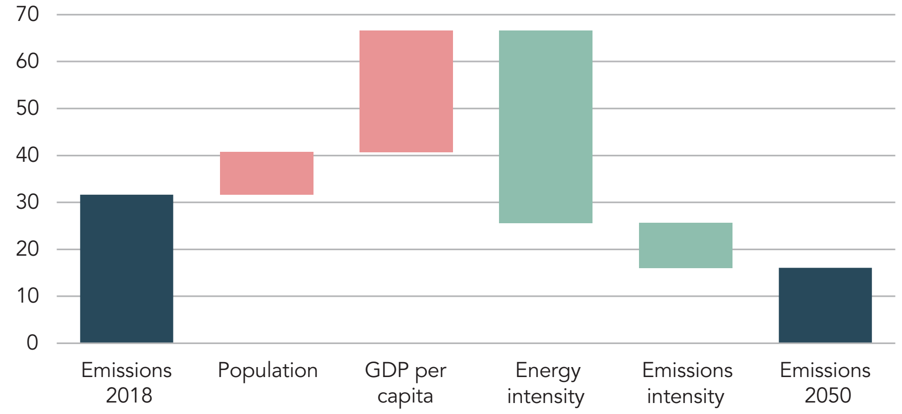


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- New Zealand's CO_2 emissions from combustion activities peaked at just under 34 million tonnes in 2005. Since falling by 8.9% in 2009 after the global financial crisis, emissions have been gradually increasing to reach a level just short of the previous peak.
- The COVID pandemic brought about another significant fall in CO_2 emissions of 6.7% in 2020. Emissions rebound but never reach the pre-pandemic peak in either scenario, stabilising in the early 2020s, before declining significantly in 2025 due to the closure of the Tiwai Point aluminium smelter. This closure leads to an abrupt fall in power sector CO_2 emissions because the decline is born by gas-fired generation. If transmission constraints do not allow for hydro to make up for this decline, then New Zealand's emissions will be higher than shown here.
- CO_2 emissions continue to decline in REF to 16 million tonnes in 2050. This represents a halving of New Zealand's emissions from peak levels. CO_2 emissions reductions are significantly greater in CN, falling to less than five million tonnes in 2050.
- Power sector emissions fall close to zero in REF, which means that the power sector will not contribute to additional emissions reductions in CN. Instead, the transport and industry sectors perform the heavy lifting, with emissions falling by over 80% for both sectors. Buildings sector CO_2 emissions fall by more than 95%, though the smaller relative size of the sector means that its contribution to economy-wide emissions reduction is lower.
- New Zealand's current NDC is to reduce net greenhouse gas emissions to 50% below gross 2005 levels by 2030. In REF, CO_2 combustion emissions in 2030 are 27% lower than the 2005 level, and CN brings them 37% lower. Since they do not reach the NDC (50%), additional reductions will be needed from non-energy sectors (including negative emissions from forestry and non-CO_2 emissions) and/or offshore mitigation.

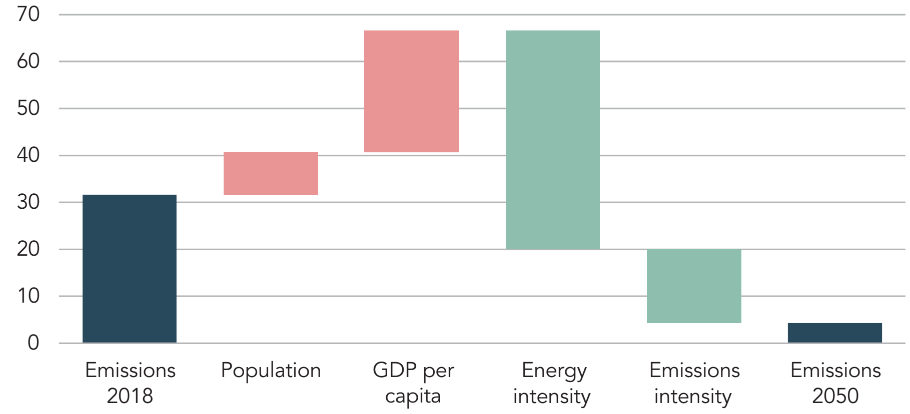
Components of CO_2 emissions

Figure 12-53. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 12-54. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- New Zealand emitted almost 32 million tonnes of CO_2 in 2018, which amounts to only one-thousandth of total APEC emissions. Despite a low contribution to APEC-wide emissions, New Zealand has relatively high emissions per capita, ranking 12th out of the 21 APEC economies.
- Given the assumptions about New Zealand's population and GDP growth, emissions would more than double to over 66 million tonnes of CO_2 in 2050, holding all else equal.
- However, all else does not remain equal. In REF, reductions from improvements in energy intensity and emissions intensity yield emissions of 16 million tonnes of CO_2 in 2050. Energy intensity improvements account for 81% of this reduction while emissions intensity improvements account for the remaining 19%.
- In CN, energy intensity improvements contribute to CO_2 emissions reductions that are 14% greater than in REF, while emissions intensity improvements in CN are 66% greater than in REF. These additional improvements mean that 2050 energy sector CO_2 emissions are only 15% of what they were in 2018.
- Positive energy sector CO_2 emissions in CN will need to be countered by reductions in other sectors for New Zealand to achieve net-zero ambitions. The challenge is slightly larger when including process emissions and all other greenhouse gases in the calculation. CN is only one of many plausible paths for New Zealand to prosper while also meeting the goal of reducing CO_2 emissions in line with its international commitments.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

Ministry of Business, Innovation and Employment (MBIE). https://www.mbie.govt.nz/

MBIE Energy in New Zealand annual report. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-publications-and-technical-papers/energy-in-new-zealand/

MBIE NZ battery project. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/nz-battery/

Ministry for the Environment (MFE). https://environment.govt.nz/

MFE information on New Zealand's emissions targets. https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/emissions-reduction-targets/greenhouse-gas-emissions-targets-and-reporting/

Climate Change Commission (CCC). https://www.climatecommission.govt.nz/

Stats NZ. https://www.stats.govt.nz/

Transpower. https://www.transpower.co.nz/

Electricity Authority. https://www.ea.govt.nz/

13. Papua New Guinea

Highlights

Demand

- Economic growth brings a doubling of energy consumption in the Reference scenario (REF). Compared with REF, energy consumption in the Carbon Neutrality scenario (CN) ends up 20% lower. This comes as a result of efficiency gains and electrification in all sectors.
- In REF, electricity grows from a tenth to almost a third of energy demand. This is mostly driven by electrification in industry and buildings as Papua New Guinea (PNG) furthers the development of its electricity system. Electricity use grows more in CN, to about a 40% share of total energy use.
- Oil use in transport and industry continues to grow steadily. Oil continues to dominate the fuel mix in both scenarios. Some oil use will be replaced by electricity, and this occurs at a higher rate in CN.
- Most of PNG's population lacks access to electricity, prompting the buildings sector to use traditional biomass for much of its energy requirements. Traditional biomass makes up half of current energy use and will continue to be used if electricity is unavailable.
- Biomass use persists in REF but increasing use of substitutes (oil and electricity) reduces its demand share to a fifth. In CN, further declines reduce the role of biomass to a tenth of the fuel mix.

Supply

- Energy supply more than doubles in REF, as strong economic development, including a quadrupling of real GDP, and population growth drive energy requirements for the economy higher.
- PNG's LNG export capacity reaches 14 Mtpa by 2030, as rising global demand gives a strong incentive to build LNG export infrastructure.
- In CN and REF, natural gas production and LNG exports increase quickly to 2030. In REF, production continues to grow out to 2050 to meet rising domestic supply requirements. However, in CN, both LNG exports and gas production decreases in the 2030s as the world reduces its gas consumption. CN gas production and LNG exports are a quarter lower than REF levels in 2050.

Power

- Only a fifth of PNG's population currently has access to electricity. The economy is aiming to increase electricity access to 70% in 2030 and 100% by 2050 under the National Electrification Rollout Plan (NEROP). A key difficulty in achieving this will be the construction of a distribution system to connect PNG's rural population across its rugged topology.
- Natural gas increases in use from 6.7 PJ in 2018 to 14 PJ and 8.9 PJ in 2050 in REF and CN, respectively.
- In 2050, renewable capacity accounts for 59% of electric capacity in REF and 76% in CN. These increases come from solar, wind and geothermal development, with solar increasing the most.
- Oil use in generation decreases and is replaced by natural gas and renewables. This allows the economy to reduce its dependence on oil imports.

CO_2 emissions

- PNG's CO_2 emissions increase at an increasing rate in REF and triple over the outlook period. Rises come mostly from power, as surging gas-fired generation causes it to comprise half of emissions by 2050. Transport and industry continue to increase their emissions, albeit at slower rates.
- Emissions in CN are a third lower than in REF because of higher renewable deployment in electricity generation, energy efficiency improvement and the introduction of biofuels in transport.
- PNG's status as a rapidly growing economy makes it an unlikely candidate to peak or decrease CO_2 emissions over the outlook period. In both scenarios, fossil fuels remain an important component of the energy system. Fueling a growing population and economy with natural gas and oil results in rising emissions.

Other

- PNG's energy trade continues to be defined by product imports and LNG exports. LNG exports continue to be a major source of GDP for the economy and could be an economic boon for PNG if elevated energy prices persist into the medium or longer term.

About Papua New Guinea

- Papua New Guinea (PNG) is a very culturally diverse country, with hundreds of tribes and over 800 indigenous languages spoken.
- PNG's population was 8.6 million in 2018, with most of it (87%) living in rural areas. The provision of basic energy services continues to be a challenge, with only a fifth of the population having access to electricity.
- The economy has two land tenure systems: the alienated system, which adapts the European model where the state owns the land; and the customary system, where the local indigenous people have ownership over the land. About 97% of the land comes under the customary system.
- PNG has rugged, mountainous terrain, and 78% of it is tropical forest. This makes it difficult to build infrastructure that would connect the rural population with the rest of the economy.
- PNG is well endowed with natural resources, including gold, copper, oil, gas, timber, and agricultural products. The two main economic drivers are the export-earning sector (i.e. minerals extraction and energy) and the labor-intensive sectors (i.e. agriculture, fishing, and forestry). However, most of the workforce is based in the informal sector, like farming.
- PNG exported 445 PJ of LNG in 2019. The LNG production facility, completed in 2014, is a significant factor in PNG's economic growth, allowing it to valorise its large natural gas reserves in the global commodities market.
- PNG currently relies on diesel for a significant amount of electricity generation. However, it is expected that this will change as the economy invests in exploiting its own resource endowments for electricity generation. PNG has a variety of renewable generation options, and its natural gas reserves provide a useful baseload and peaking option.
- Energy intensity and energy use per person is relatively low in PNG compared to the APEC average. This is a result of the low amount of economic development within the economy.

Table 13-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	8.6	0.3%	17
GDP	37	0.1%	20
TPES	196	0.1%	20
Production	240	0.1%	19
Imports	112	0.1%	20
Exports	153	0.1%	18
Electricity generation	4.7	0.0%	20
Heat production	0	0.0%	9
CO_2 emissions	7.6	0.0%	21

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 13-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	–	–	–	–
Natural gas	5 873	14	0.1%	12
Oil	968	24	0.01%	13
Uranium	–	–	–	–

Notes: Natural gas (PJ) in 2020 from BP. Oil (PJ) from EIA, 2020. See Appendix for conversion to other units.

Energy policy context and recent developments

- Energy policies in PNG have historically focused on developing its rich natural resources. Focus is shifting recently towards strengthening the governance and institutional frameworks underlying this resource development, meeting future challenges in the energy sector, such as climate change, and supporting a more rapid and inclusive rollout of electrification. Part of the groundwork for this has been laid by the Vision 2050 document, released in 2011. This document was designed to map out the future direction for the economy and reflect the aspirations of the people of PNG.
- In 2017, the National Energy Policy was released. The overall goals of the 2018-2028 National Energy Policy are to: attain sustainable energy exports, reduce the cost of energy in PNG, ensure that PNG is a globally competitive economy for investment; and meet PNG's economic development goals while protecting and conserving the environment. It also calls for structural reform in the energy sector with the goals of promoting competition and fostering investments in innovation and technology to achieve its overall goals.
- PNG's electrification goals are managed by the National Electrification Rollout Plan (NEROP), which has a focus on expanding the distribution grid and establishing mini-grids to increase electricity access from a fifth to 70% of households by 2030. PNG also has a long-term goal of achieving 100% electrification by 2050.
- The Energy Authority Bill, passed in April 2021, decommissioned all the regulatory powers and functions of PNG Power Limited and vested them with the National Energy Commission. The Energy Commission will create a level-playing field to promote private sector investments in the sector. The competition will ease consumer prices, making energy more affordable, and address capacity and reliability issues in the electricity sector. Market reforms will also promote efficiency and robustness across the electricity service industry.
- On 10 June 2020, the Parliament of PNG passed the Mining and Oil and Gas (Amendment) Bills, which amend the Mining Act and the Oil and Gas Act. The Mining Amendments introduce a 'live data' reporting obligation and give state entities priority in tenement applications over 'reserved land'. The Oil and Gas Amendments give the Minister greater flexibility in determining whether to grant or refuse petroleum development licences (PDLs) and affect the sanctity of petroleum agreements and gas agreements.
- In December 2015, PNG was one of the first economies in the world to produce its Nationally Determined Contribution (NDC). The target was 100% renewable energy in the electricity sector by 2030, contingent on funding being made available.
- The Enhanced NDC (2020) revised the NDC to target a 78% share of installed capacity of renewable energy by 2030. PNG also has a goal to reach 100% renewable capacity by 2050 (part of the National Energy Policy).
- LNG policy and developments are very important to PNG, generating a large amount of revenues and economic activity for the economy. As of 2020, PNG has 5 873 PJ of proven gas reserves. PNG also has two LNG production trains, which are a part of the PNG LNG Project, with a combined capacity of 8.3 million tonnes per annum (Mtpa) (almost 500 PJ) per year.
- Another LNG project, Papua LNG, is under consideration and expected to get a greenlight in 2023. The project involves two LNG production trains, each with 2.7 Mtpa of capacity. The *Outlook* assumptions are consistent with this development. Following the commissioning of the project in 2030, total LNG export capacity in PNG reaches 14 Mtpa. These LNG developments will also drive associated developments for new gas fields to feed the export facilities.
- LNG development has not occurred in PNG without controversy. The PNG LNG expansion project was partly cancelled due to the disputes around the amount of benefit that the domestic economy was getting from these exports and the associated gas developments.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- **The Reference scenario (REF)** is built around recent trends and current policies. It provides a baseline for comparison with CN.
- **The Carbon Neutrality scenario (CN)** explores a way that could assist PNG in achieving carbon neutrality by 2050. The ultimate path PNG takes is almost certain to differ from the one that is laid out by the modelling.
- REF and CN are reliant on the exact same GDP and population projections.
- Electrification of PNG's population is a major factor in the expected development of PNG's energy system. Both REF and CN assume that PNG's goals of 70% electrification by the end of 2030 and 100% by 2050 are achieved.
- Improvements to energy efficiency in buildings, the uptake of EVs and the development of renewable electricity generation capacity are all assumed in REF. In CN, more ambitious versions of these assumptions are imposed, driven by either explicit or implicit policy intervention. For example, the buildings sector adopts more stringent energy efficiency standards and faster proliferation of clean cooking technologies.
- CN should put the APEC region on a possible pathway of achieving carbon neutrality with the aid of non-energy emissions reductions and carbon offsets. It is intended as a guide to show the magnitude of CO_2 reductions possible in the context of the assumptions made about technology diffusion, costs, and global trends enroute to achieving carbon neutrality.
- CN can be used to quantify the magnitude of remaining CO_2 emissions that would require further action from policymakers, industry participants, and researchers.

Table 13-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with CN.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Papua New Guinea

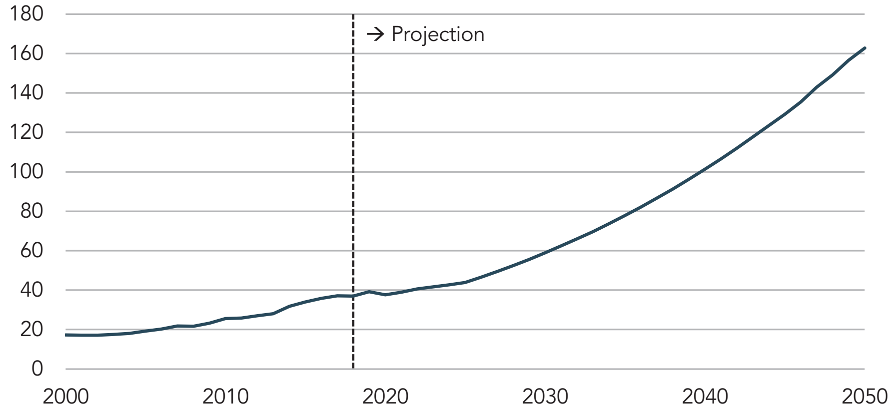
Table 13-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium). • GDP: World Bank (historical) • IMF (COVID-19 impacts; 2021 - 2025) • Swan-Solow model (projections 2026 - 2050)	• Same as Reference
Buildings	• 70% of PNG's population will have access to electricity by 2030, 100% by 2050. • Improvements to appliance efficiencies. • Adoption of clean cooking technologies and fuel switching reduces biomass use.	• Solar water heating in residential sector. • More rapid electrification than in REF. • Stringent energy efficiency standards. • Faster adoption of clean cooking technologies.
Industry	• Industry continues to grow in line with GDP assumptions. • 4.8 PJ of natural gas begins to be consumed by an industrial facility from 2030.	• Increased energy efficiency and fuel switching to electricity.
Transport	• Energy efficiency of vehicle fleet improves. • EVs are introduced into the fleet but grow slowly until after 2035. • EVs make up 40% of light passenger vehicle sales in 2050.	• More rapid improvements in fuel efficiency. • Faster uptake of EVs, reaching 20% in 2035 and 50% by 2050. • Biofuels blending in aviation sector reduces emissions intensity.
Power and heat	• Access to electricity increases to 70% by 2030 and 100% by 2050. • Gas-fired units are used to meet rapidly increasing electricity demand and reduce generation from oil products. • Small adoption of new geothermal projects.	• Moderate adoption of solar projects. • Hydroelectricity becomes the leading technology to meet incremental capacity requirements. • Moderate adoption of new geothermal projects.
Supply	• Oil remains constant with growth in NGLs following natural gas production. • Gas grows to meet LNG projects and domestic demand. • PNG LNG expansion cancelled (February 2021); not included. • Papua LNG goes ahead online in 2029 (both trains; 5.4 Mtpa).	• Export market for oil and NGLs declines by half relative to REF. • Export market for LNG shrinks a quarter below REF levels, but PNG's proximity to global markets helps mitigate its declines. • Carbon Capture and Storage (CCS) for natural gas own use starts in 2022 and ends up at 75% in 2050.
Climate	• Share of renewables in electricity capacity is guided by the Enhanced NDC.	• Carbon neutral by 2050

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

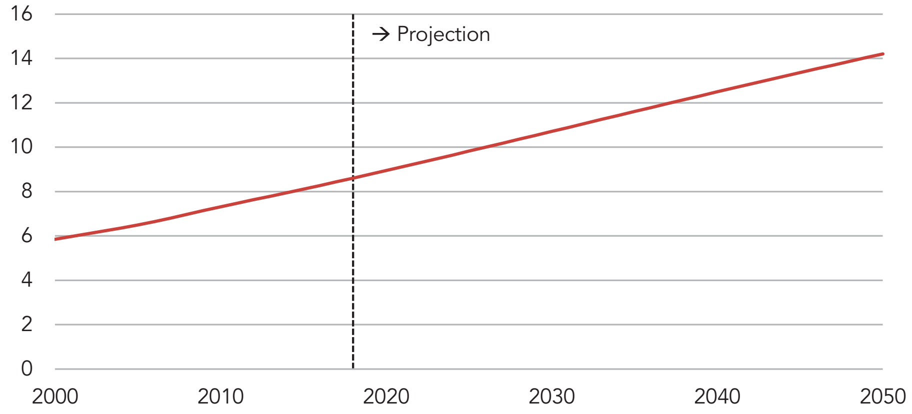
Macroeconomic backdrop

Figure 13-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 13-2. Population in millions, 2000-2050

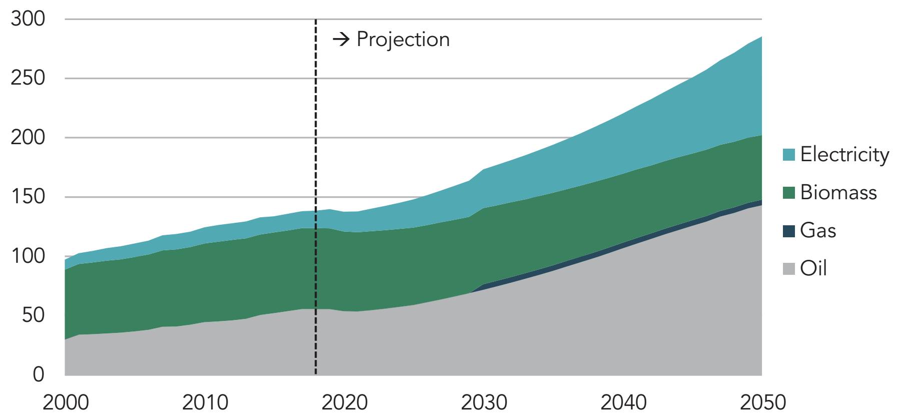


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- PNG has a low population density, with 87% of the population living in rural areas. However, the population is projected to more than double to 14 million in 2050. PNG has very a young population, with nearly 50% under 20 years of age.
- Mining and petroleum account for more than a quarter of GDP, with the production and export of LNG, which began in 2014, underpinning recent GDP growth. The proposed Papua LNG, expected to start commissioning in 2029, will bring further LNG exports out of the economy.
- PNG's reliance on the extractive industry makes it susceptible to boom and bust cycles. The economy intends to reduce this reliance by developing value-added manufacturing and processing sectors, such as timber milling and a non-descript industrial use of PNG's natural gas reserves.
- While PNG experienced positive economic growth from 2015 to 2019, a decline in its extractive industries combined with disruptions related to the COVID-19 pandemic has taken its toll on the economy. PNG's real GDP declined by 3.9% in 2020.
- In the outlook period, GDP is projected to grow at around the same rate as the last 10 years, an average growth rate of 5.0%, to USD 163 billion in 2050.
- The government remains highly reliant on foreign aid, and debt has climbed to almost 50% of GDP in recent years.
- PNG is by far the largest recipient of Official Development Assistance in the APEC region, receiving a total of USD 4.5 billion of aid between 2012 and 2017. Australia is the largest donor providing USD 2.7 billion in support over this period. The second-largest donor was China, with USD 440 million, followed by the Asia Development Bank, Japan, the World Bank, and Aotearoa New Zealand (USD 132 million). The governance and civil society sector received the highest amount of support (over USD 1 billion), followed by transport, health, and education. Further cooperation from APEC members may be necessary to continue the strong economic activity of PNG shown here.

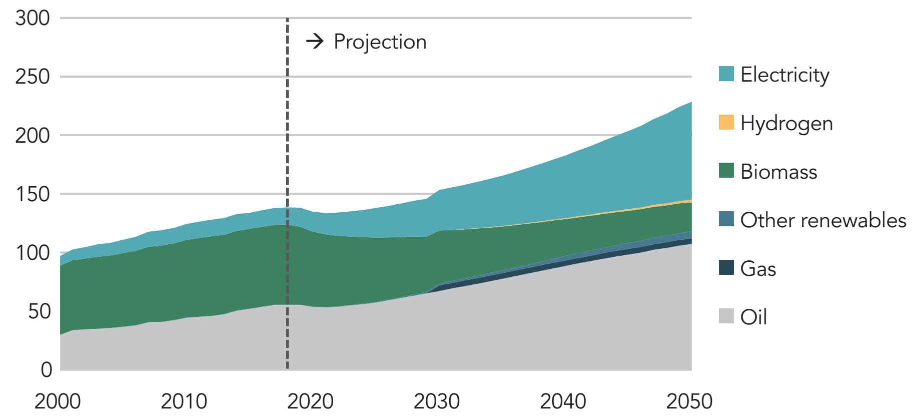
End-use energy demand

Figure 13-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 13-4. Energy demand in CN, 2000-2050 (PJ)

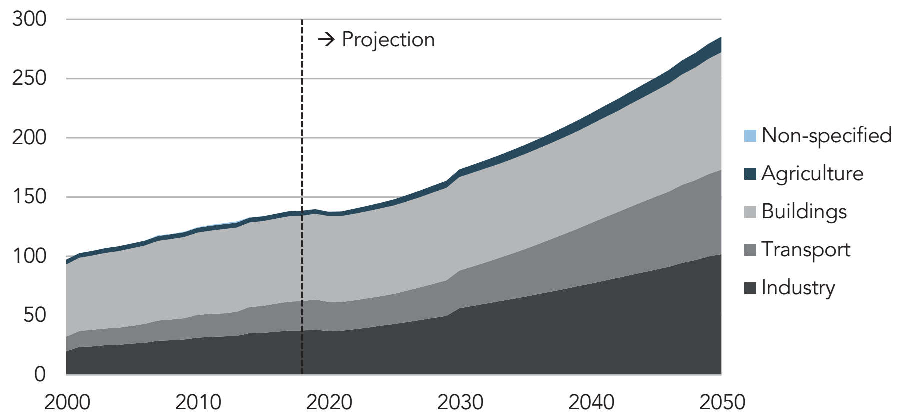


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Since 2000, demand has been increasing slowly, driven mostly by rising oil use, specifically diesel. However, renewable energy still contributes the largest share of demand, with traditional biomass used in the residential sector accounting for half of the renewables share.
- REF energy consumption more than doubles by 2050. This is largely driven by economic growth, which causes growth in oil consumption in the transport and industrial sectors.
- Compared to REF, energy consumption ends up 20% lower in CN. This comes as a result of efficiency gains and electrification in all sectors, which decreases total energy use.
- PNG plans to increase its electrification rate to 70% by 2030 and 100% by 2050 under the NEROP. It is assumed that this NEROP goal will be achieved in both scenarios.
- Distribution expansions and higher generation capacity support higher electrification in all sectors, increasing electricity use from a tenth to almost a third of energy demand by 2050 in REF. Even higher electrification across all sectors in CN increases electricity use even further, to about 40% of the fuel mix.
- Oil consumption continues to grow steadily, making up most of the consumption throughout the outlook period in both scenarios. This growth in oil consumption comes from growth in the transport and industry sectors. However, growth is limited by the electrification of some end-uses.
- In REF, absolute demand for traditional biomass persists but increasing demand for oil and electricity lowers its share of the fuel mix to a fifth by 2050, down from almost half currently. In CN, higher electrification reduces the role of biomass significantly, to about a tenth of total energy use by 2050.
- Use of a portion (4.8 PJ) of the economy's natural gas resources for end-use begins in 2030 as a result of the expected development of a domestic industrial enterprise. This use remains constant throughout the rest of the outlook period.
- CN introduces other renewables to PNG's energy mix. This is a result of efforts to decarbonise transport, with imported biojet fueling aviation, along with the adoption of some solar water heating in the buildings sector.

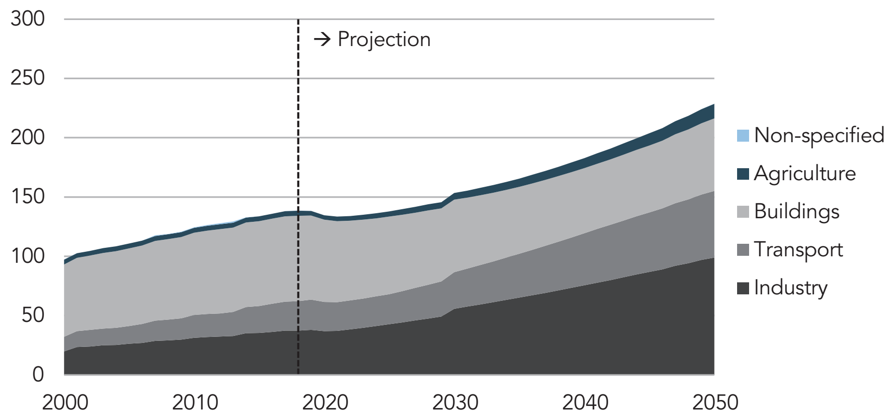
End-use energy demand by sector

Figure 13-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 13-6. Energy demand by sector in CN, 2000-2050 (PJ)

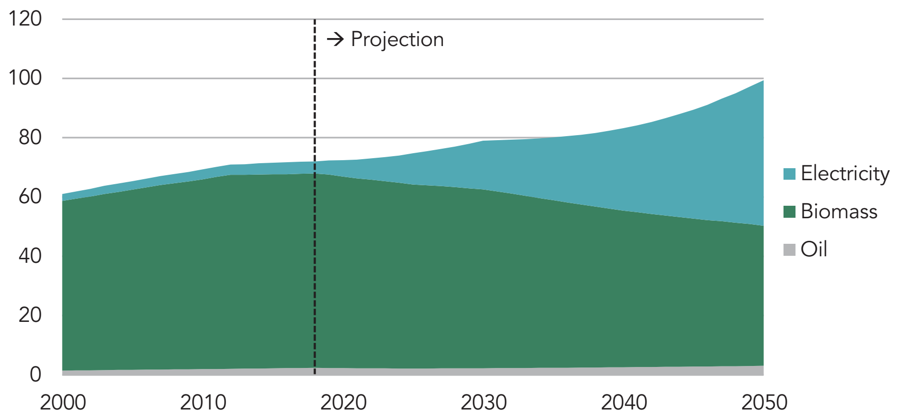


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Since 2000, energy demand from PNG's transport and industry sectors has doubled in tandem with the economic development of the economy. While buildings energy use increased at a slower rate, it accounts for most of PNG's current energy demand. The prominence of buildings is partly due to its large reliance on the inefficient process of combusting traditional biomass for cooking and lighting.
- Industry demand is the biggest driver of energy growth, nearly tripling and increasing in prominence from around 30% to 40% in both scenarios. These increases are expected to come mostly from the mining subsector. PNG's major mining sectors are currently gold, copper, nickel, silver and cobalt. There is expected to be significant growth in the mining sector as a result of increasing global demand for these minerals.
- Variations in the trajectory of the buildings and transport sectors are the main driver of the differences in total energy demand between both scenarios. In CN, both sectors are affected by efficiency gains, especially from electrification.
- PNG transport demand grows significantly in both scenarios, nearly tripling in REF and more than doubling in CN, as passenger and freight activity is lifted by both rising economic activity and population. Its share increases from around 20% to 25% of demand in both scenarios. Energy efficiency helps limit gains in CN, particularly due to a higher adoption of EVs.
- Building's energy demand increases gradually in REF, as a steady population and income increases are countered partially by the efficiency gains of switching from traditional biomass to electricity for many end-uses. Faster electrification causes end-use to dip in the early years of CN because of these efficiency gains, but demand rises thereafter to a seventh below 2018 levels by 2050.
- Agricultural energy demand, although relatively low, slowly increases throughout the outlook period in both scenarios.

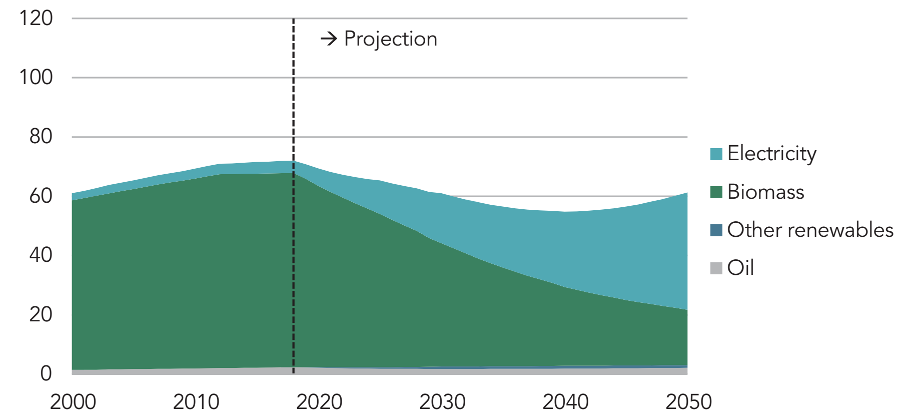
Buildings energy demand

Figure 13-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 13-8. Buildings energy demand in CN, 2000-2050 (PJ)

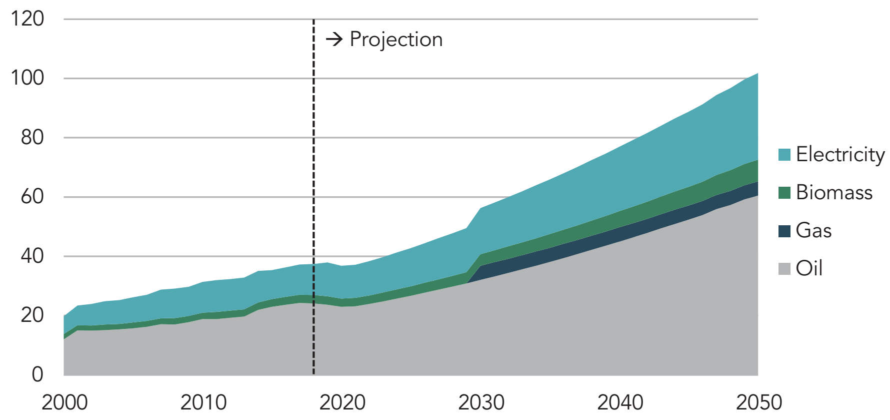


Sources: EGEDA, APERC analysis.

- Buildings energy use has been increasing at a similar rate to the APEC average since 2000.
- Buildings energy demand increases over a third in REF, as the growing fundamentals of population and economic activity are partially offset by the efficiency improvements associated with replacing traditional biomass with electricity, as well as from improvements in appliance efficiency. This is driven by the economy's goal of providing 70% of the population access to electricity by 2030 and 100% by 2050.
- In CN, higher electrification and more stringent energy efficiency standards reduces energy demand. While some growth occurs in the 2040s, demand in 2050 will be 15% lower than it was in 2018.
- CN introduces a small uptake of solar thermal energy (shown as Other renewables) to fuel water heating in the buildings sector.
- Because a fifth of PNG's current population lacks access to electricity, many use traditional biomass to fuel their building end-uses. The use of traditional biomass poses health risks to the PNG population. During the outlook period, biomass continues to be used when electricity is not available. As for the electrification rate rises, traditional biomass use declines in both scenarios.
- In 2019, PNG buildings used 1.3 PJ of imported kerosene, and 0.1 PJ of imported LPG. This oil is mostly used for lighting (kerosene) where electricity is not available or too costly. This continues in REF. However, kerosene use in buildings also poses health risks. In CN, its use is lowered a third, partly due to higher electrification of building end-uses.
- In recent years there has been growth in use of solar powered lighting. This is not shown in the energy data. This growth could remove the need for kerosene lighting, reducing oil demand beyond what has been indicated in either scenario.
- It is difficult to move straight from biomass to electricity because of the infrastructure development necessary to start supplying and using electricity. As such, LPG and kerosene could become transition fuels for PNG with higher demands that persist beyond the values shown here.

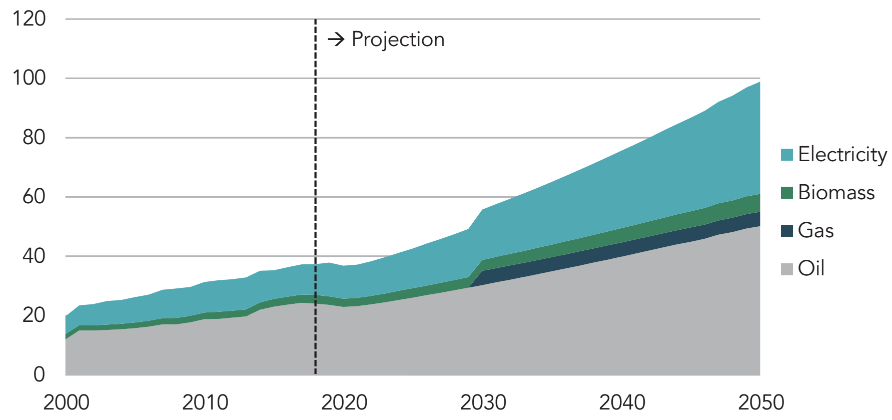
Industry energy demand

Figure 13-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 13-10. Industry energy demand in CN, 2000-2050 (PJ)



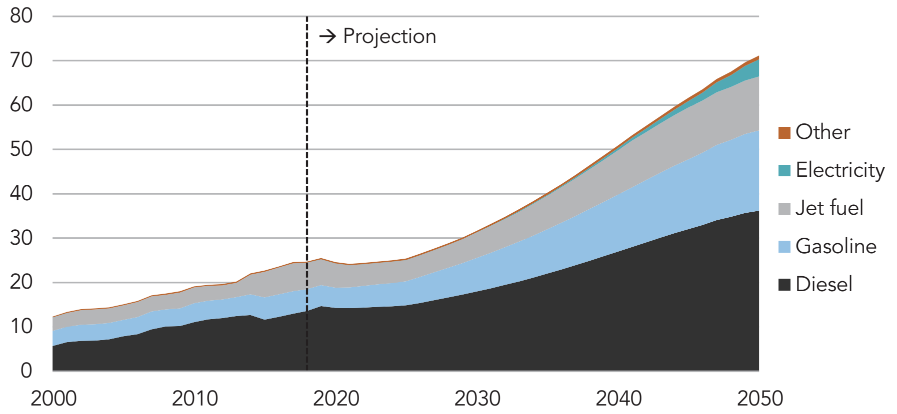
Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industrial energy use has doubled since 2000, at a similar rate to GDP over this period. Most demand is in the form of oil (diesel) use by the mining subsector. However, electricity use has also doubled since 2000.
- Both scenarios see demand almost triple over the outlook period. Most of this growth is expected to come from the mining subsector, due to growing global demand for minerals.
- Oil (diesel) remains a large portion of total use in both scenarios due to the expense of electrifying mining equipment and the lower reliability of the electricity grid reaching remote mining operations.
- Compared to REF levels, higher electrification in CN reduces industry oil use by a sixth and increases electricity use by almost a third.
- Both scenarios assume that the development of a gas-intensive industrial enterprise leads to a 4.8 PJ increase in gas use in 2030. This use remains constant throughout the rest of the outlook period.
- While energy efficiency assumptions are greater in CN, the mining subsector's energy use increases slightly, as it is assumed that activity rises to exploit more rare earths and other resources as the world embraces carbon neutrality.
- The non-specified and other (comprising multiple manufacturing enterprises) subsectors grow at a rate proportional to GDP growth, albeit from small bases. These other industries are not expected to become close to the size of the mining subsector because of the challenges in kickstarting such subsectors in many economies. Furthermore, the *Outlook* does not assume significant structural changes to any economy.
- It is expected that a large portion of the industrial sector is comprised of autoproducers that generate electricity independently of the economy's distribution infrastructure. Embracing more autoproduction may enable industrial electricity users to build their own generation capacity on demand with less upfront investment. This could cause electricity use to increase faster than what the modelling shows in either scenario.

Note: Oil used for transport purposes at heavy mining operations is classified as industrial use, except when driven on public roads.

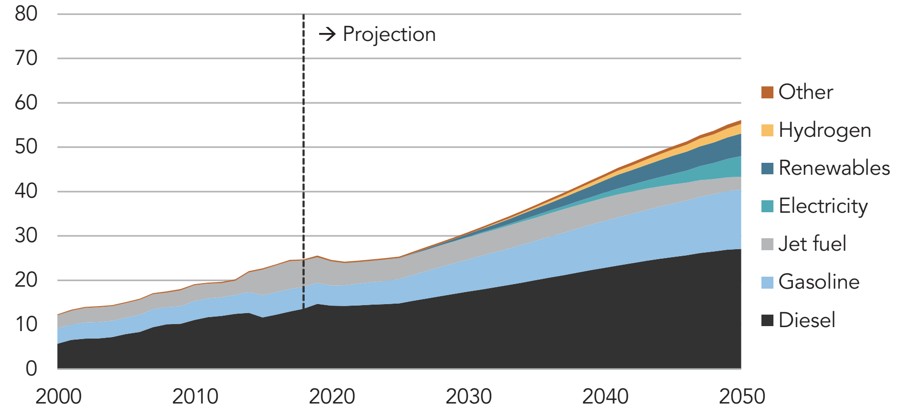
Transport energy demand

Figure 13-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 13-12. Transport energy demand in CN, 2000-2050 (PJ)

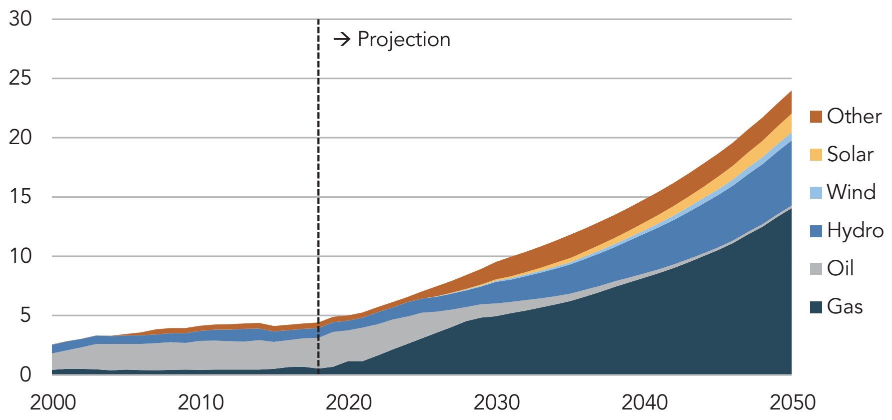


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- PNG's transport system and energy use is a function of its geography. Its rugged, mountainous terrain is more suited to powerful diesel engines than gasoline-powered vehicles. This explains the higher growth in diesel usage since 2000. The terrain also prevents road travel to the capital, Port Moresby, which is not linked to any other major town. Because of this, air and sea transport are crucial for reaching many areas and will continue to be in the future.
- Economic growth and development in PNG propels transport activity in both scenarios. End-use demand nearly triples in REF, resulting in steady growth in all of PNG's transport fuel varieties. Growth is limited somewhat in CN, but still more than doubles, as higher rates of EV adoption and efficiency improvements limit demand increases.
- Currently, PNG's per capita transport energy use is a tenth of the APEC average. This grows to about a quarter by 2050 in both scenarios.
- Diesel is expected to continue to be used for 50% of consumption in both scenarios.
- In REF, EV adoption begins to take off in 2026, and EVs make up 40% of light passenger vehicle sales in 2050. This corresponds to 1.1 TWh of electricity, or 5.5% (3.9 PJ) of the transport fuel mix. In CN, EV uptake is quicker, reaching 50% of sales by 2050, which results in nearly 10% of transport energy demand coming from electricity by 2050, or 1.3 TWh (4.7 PJ).
- CN incorporates liquid biofuels for aviation, which is the main contributor to the drop in jet fuel use. It also causes a decrease in emissions intensity.

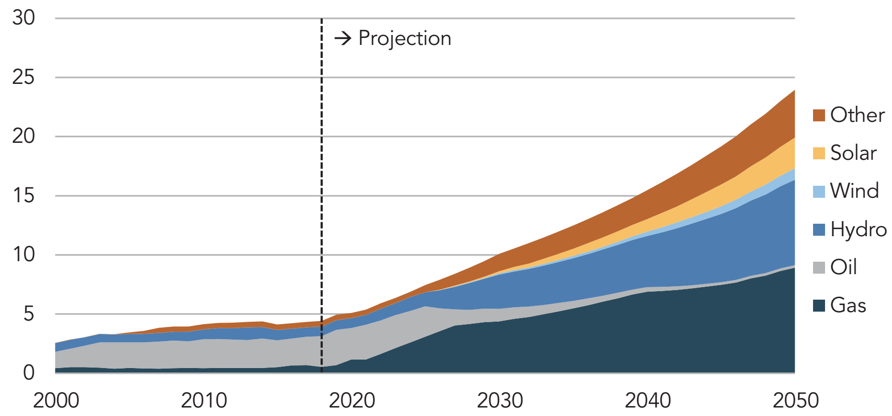
Electricity generation

Figure 13-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 13-14. Electricity generation in CN, 2000-2050 (TWh)

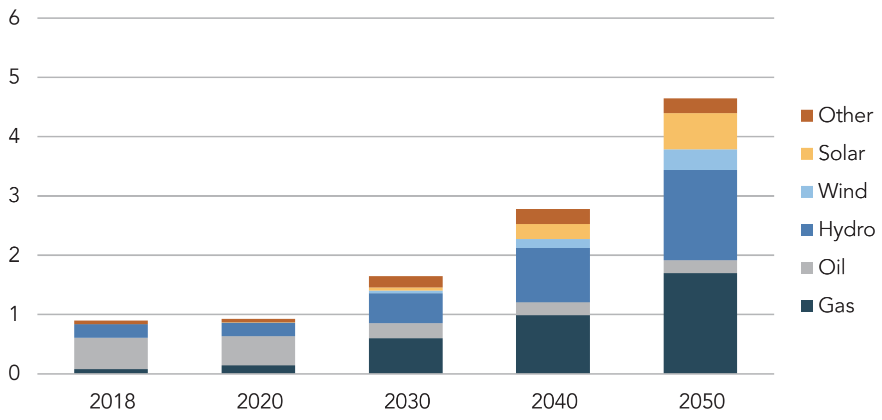


Sources: EGEDA, APERC analysis.

- Electricity generation in PNG has historically been dominated by oil. In 2018, oil-fired generation comprised 59% of electricity production, with a small portion coming from hydro (19%) and a smaller portion coming from gas (12%) and geothermal (11%).
- Only a fifth of PNG's population currently has access to electricity. However, the economy plans to increase electrification to 70% by 2030 and 100% by 2050 under the NEROP. Because the *Outlook* assumes the achievement of these NEROP goals, electricity demand surges, and generation requirements grow 5.4-fold, to reach 24 TWh by 2050 in both scenarios.
- PNG leverages its natural gas reserves by increasing gas-fired generation in both scenarios. Gas-fired generation increases quickly, becoming the dominant fuel in the power mix by 2024 in REF and 2025 in CN. Gas satisfies the majority of electricity demand growth over the outlook period. By 2050, gas makes up 60% of total generation in REF. This is limited to 37% in CN, as increases in hydro, geothermal and variable renewable capacity reduce gas requirements.
- Renewable generation types (wind, solar, geothermal and hydroelectric) slowly increase throughout REF, making up 40% of generation by 2050. Hydro maintains the largest share at 23%, with geothermal (other) taking up 8.1%, solar 6.6% and wind 2.8%.
- In CN, renewable generation becomes a larger portion of the power mix. Renewables make up almost two-thirds of generation by 2050, with 30% being used for hydro, 17% for geothermal (other), 11% for solar and 4.0% for wind.
- Geothermal generation output will be much smaller than the total geothermal input. This is because geothermal has a very low conversion efficiency of approximately 15%. This means that the total amount of supply (geothermal heat) will greatly exceed demand (electricity use).

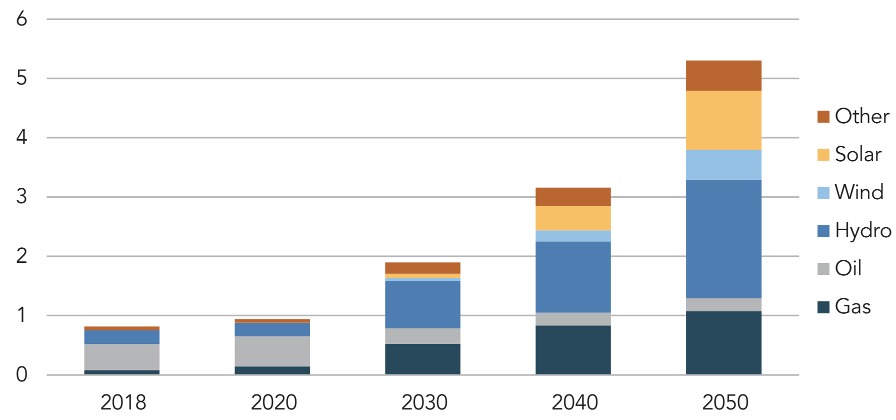
Generation capacity

Figure 13-15. Technology capacity in REF, 2017-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 13-16. Technology capacity in CN, 2017-2050 (GW)

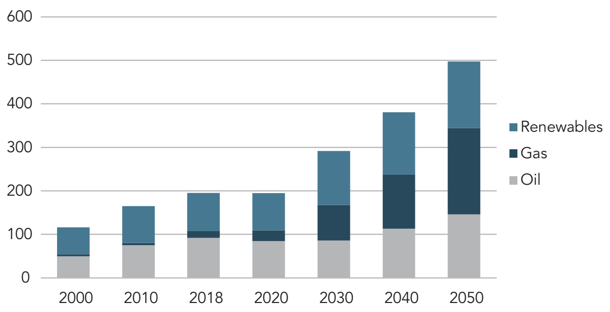


Sources: EGEDA, APERC analysis.

- PNG's current generation capacity is dominated by oil generators and hydroelectric dams. However, its endowment of natural gas and potential for solar, geothermal and wind deployment provides the opportunity to diversify its capacity structure over the next few decades.
- Electricity generation capacity increases over five-fold in REF, rising to 4.6 GW. Even though total generation is the same in both scenarios, total capacity will be 14% greater in CN. This occurs because of the inherently low capacity factors of solar and wind resources, which generate a higher share of electricity in CN.
- By 2050, REF renewable capacity reaches 59% and CN reaches 76%. Both scenarios fall short of PNG's Enhanced NDC targets of 78% renewable capacity by 2030 and 100% by 2050.
- Half of oil generation capacity is retired in both scenarios and replaced by natural gas and renewable capacity. This serves the dual purpose of reducing PNG's dependence on imports for fueling electricity generation, as well as decreasing the emissions intensity of generation. Switching out oil begins in 2022, until 2031, when oil use bottoms out at 217 MW.
- In REF, gas and hydro capacity will grow at a similar rate through to 2050, reaching 37% and 33% of capacity, respectively. Wind and solar capacity also grow quickly, albeit from lower bases, reaching 7.5% and 13% of capacity, respectively. Gas and hydro help to balance out the intermittency of wind and solar.
- CN sees more renewable development, with 38% of capacity taken up by hydro, 19% by solar, 9.5% by geothermal (other), and 9.4% by wind. At 1.1 GW, gas only makes up 20% of capacity in 2050, down a third from REF levels.
- Because of its rugged and undeveloped terrain, one of PNG's biggest challenges for electrification is the difficulty of building out its distribution and transmission systems. The lack of distribution networks is part of the reason why two-thirds of electricity is produced separately from the main grid, mostly by autoroducers. Looking forward, the development of a series of isolated mini-grids could be more effective at growing the availability of electricity for the population than prioritising connections to a main grid. The potential for solar off-grid systems in PNG has been growing in emphasis in recent years.

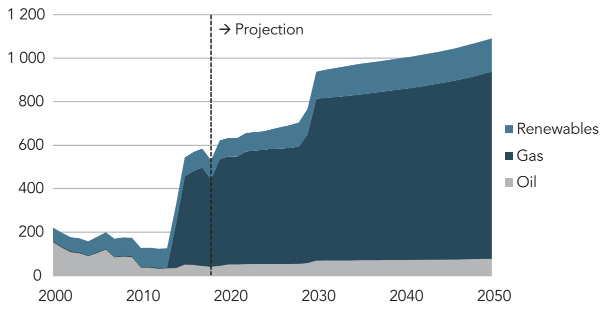
Energy supply in the Reference scenario

Figure 13-17. Total energy supply in REF, 2000-2050 (PJ)



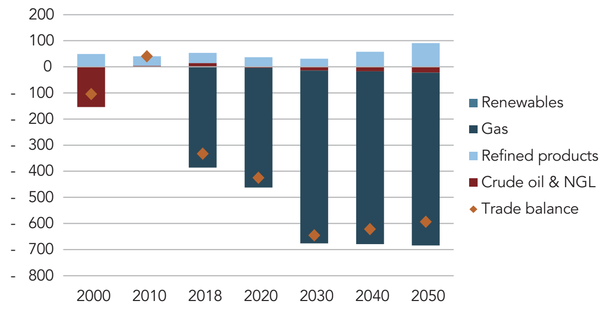
Sources: EGEDA, APERC analysis.

Figure 13-18. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 13-19. Net energy trade in REF, 2000-2050 (PJ)



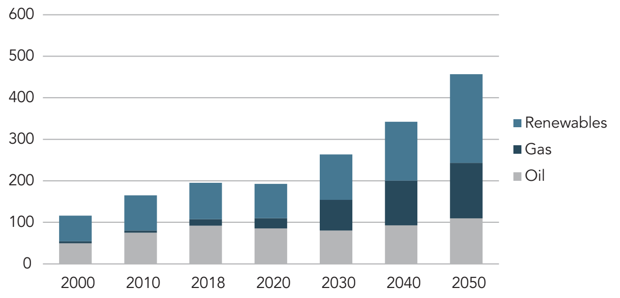
Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- PNG energy supply is currently dominated by a split of renewables (47%) and oil (45%). Renewables mainly consists of traditional biomass to fuel the building sector and oil mainly fuels transport. While natural gas makes up over three-quarters of energy production, it only comprises 8.1% of energy supply, reflecting its small presence in the domestic market.
- PNG supply grows 2.5-fold in REF, as strong economic development and population growth drive energy requirements higher. Gas becomes PNG's choice fuel, making up two-fifths of supply in 2050, as the economy finds domestic use for its gas endowment. The deployment of renewable electricity capacity, particularly geothermal, but also solar and wind, is the main driver of renewables supply. Renewables make up a third of supply in 2050. Two-thirds of this is for electricity generation, while the rest is traditional biomass use in the buildings sector (see note).
- Oil supply remains flat until 2027, as decreases in refined product use by the power sector counteracts increases in demand by industry and transport. Supply rises as power declines flatten thereafter. Oil production grows, but mainly in the form of natural gas liquids (NGLs) that are associated by-products of natural gas production.
- The doubling of energy production in REF is largely a natural gas story. Gas production doubles to fuel an LNG export expansion and rising domestic use in the power, own use and industrial sectors.
- PNG's effective LNG export capacity reaches 14 Mtpa by 2030, up from 8.3 Mtpa in 2018, as rising global demand gives a strong incentive to build LNG export infrastructure. PNG exports rise by three-quarters in REF.
- PNG becomes a more significant net energy exporter in REF but rising refined product imports reduce the export tilt of the trade balance after 2030. This higher dependence on oil product imports will increase its vulnerability to disruptions to the refinery product supply chain.
- LNG is a major source of GDP for the economy. A persistence of current high LNG prices could foster higher economic benefit to PNG over the outlook period.

Note: Renewable supply and production is much higher than its utilisation by the demand and power sectors due to the low conversion efficiency of geothermal generation (~15%).

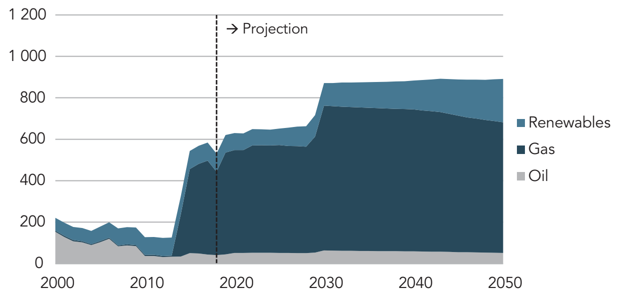
Energy supply in the Carbon Neutrality scenario

Figure 13-20. Total energy supply in CN, 2000-2050 (PJ)



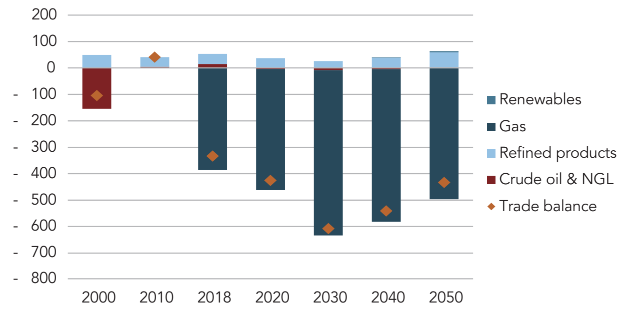
Sources: EGEDA, APERC analysis.

Figure 13-21. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 13-22. Net energy trade in CN, 2000-2050 (PJ)

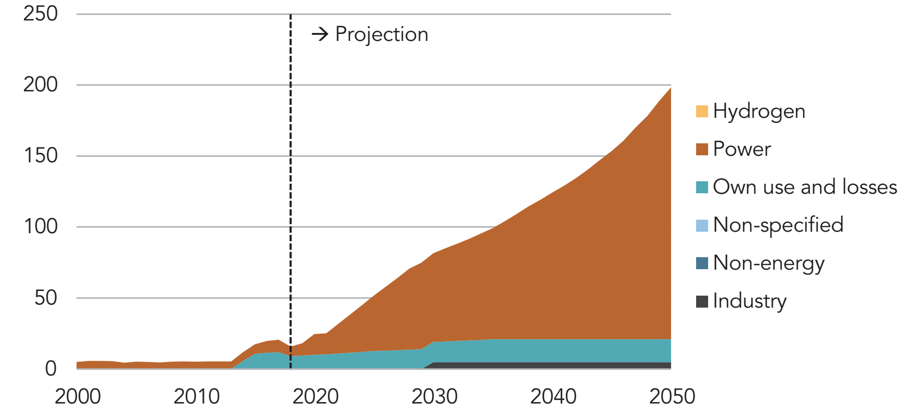


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- PNG supply grows 2.3-fold in CN, ending 8.1% below REF levels, as higher efficiency and electrification reduce supply requirements. However, a doubling of geothermal generation in the power sector inflates this value due to its low conversion efficiency of 15%.
- Renewables play a larger role in fueling supply in CN, reaching 47% compared to 31% in REF. This is mostly a result of increased renewables capacity in electricity generation and, in later years, biojet use in transport.
- Supply of oil and gas in 2050 is 20% and 30% lower than in REF, respectively. This is largely a result of higher electrification in all sectors and a higher allocation of incremental power capacity to renewables.
- Energy production in 2050 of CN is 200 PJ, 20% lower than REF. This is largely due to a declining export market for LNG and crude oil, but partly due to lower domestic demand for natural gas. Rising LNG export capacity still drives natural gas production higher into the 2030s like in REF, but it declines thereafter.
- While oil exports decline by half, oil production only falls a third, as the associated NGL production continues to track rising natural gas output.
- PNG's trade balance follows a similar path to REF out to 2030 but diverges thereafter as a declining global market for fossil fuels lowers oil and LNG exports. Net exports are about a quarter below REF levels by 2050. Refined product imports, however, are also lower due to efficiency gains and higher EV adoption.

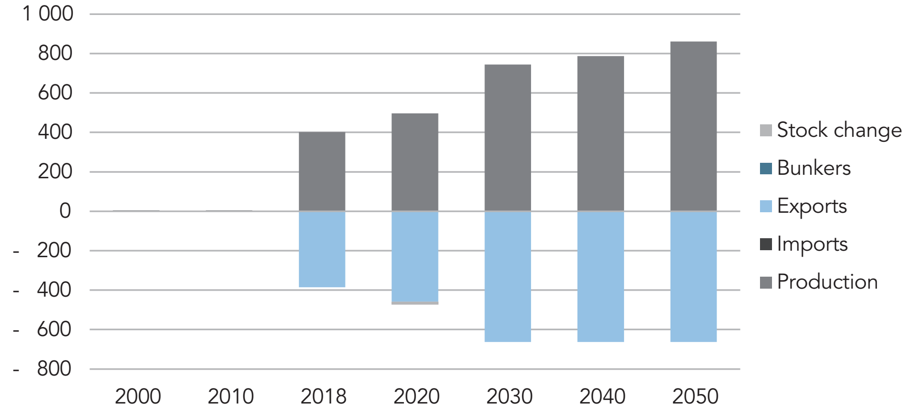
Natural gas in the Reference scenario

Figure 13-23. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 13-24. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)



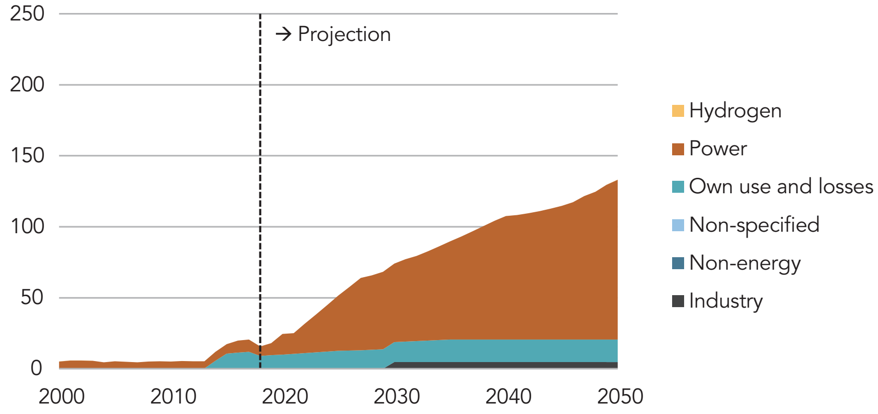
Sources: EGEDA, APERC analysis.

- In 2018, natural gas consumption is split 60% towards own use and losses, and 40% towards power generation. Own use gas consumption predominantly occurs in the liquefaction process that transforms natural gas into LNG.
- Natural gas consumption increases by more than 11 times in REF. This is an increase of 182 PJ and occurs mainly in the power sector, as PNG leverages its abundant natural gas reserves to help kickstart the rapid electrification of the economy.
- The *Outlook* assumes that PNG leverages a small amount of its natural gas resources to fuel a domestic industrial pursuit in the 2030s. This non-descript project utilises 4.8 PJ of natural gas per annum for the remainder of the projection. This is supported by PNG's National Energy Policy, which stipulates that 15% of all gas output is made available for domestic use.
- PNG's natural gas consumption for own use and losses comes from its upstream natural gas supply chain. This is for production, liquefaction and the export of LNG. These are expected to track LNG exports, rising 70% and peaking in the early 2030s, before leveling off for the rest of the outlook period.
- LNG export capacity rises from 8.3 Mtpa currently to almost 14 Mtpa on the assumed completion of the Papua LNG project in 2030.
- PNG's natural gas exports are made up completely by LNG. Rising global demand for LNG in REF results in an expansion of LNG export capacity, which lifts exports by almost three-quarters over the outlook period. Even with the rapid growth in domestic gas use in the power sector, three-quarters of gas production is diverted towards the LNG export market.
- The utilisation rate of PNG's LNG facilities is historically very high, sometimes 115%. LNG exports could go higher than illustrated if it is able to sustain those high utilisation rates with current and future LNG capacity increases.

Notes: Papua New Guinea's LNG production is the source of all it's natural gas exports. These begun in 2014.

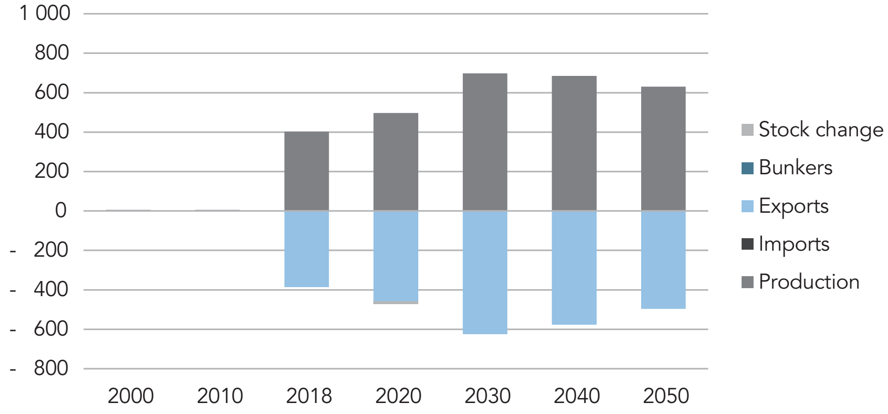
Natural gas in the Carbon Neutrality scenario

Figure 13-25. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 13-26. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

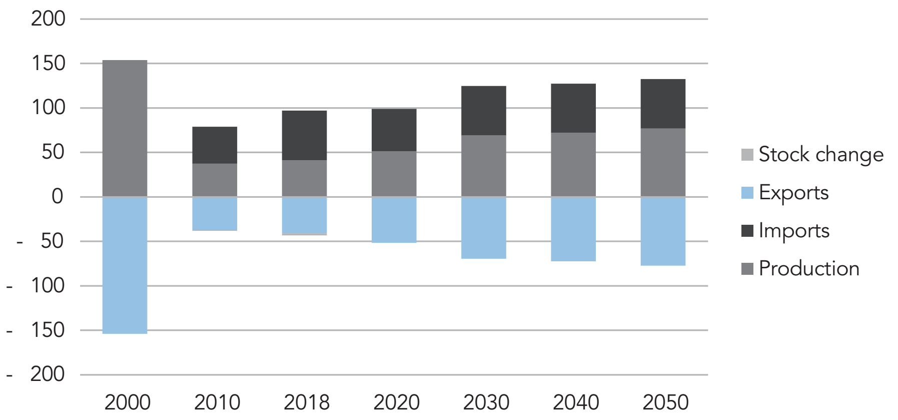


Sources: EGEDA, APERC analysis.

- While natural gas shows strong growth in CN, growing over eight-fold, it loses some prominence, with use falling a third below REF levels by 2050. This is mainly due to lower use in the power sector, which uses a third less gas due to the increased uptake of renewables.
- Like REF, in CN natural gas production, and LNG exports, increase quickly, with production rising about 60%, to 2030. However, afterwards, both exports and production start to decrease as the world reduces its gas consumption. CN gas production and LNG exports are both a quarter lower than REF levels by 2050.
- There is uncertainty around how the global LNG market will evolve as the world embraces carbon neutrality, which could lead to both lower or higher LNG exports and production than shown here.
- PNG's strategic location, close to the large potential growth markets in China and south-east Asia, could enable it to maintain a higher global market share in a declining market, leading to higher exports and production than shown here.
- Unmitigated methane leakages in the global natural gas supply chain have the potential to push global consumers away from natural gas use if the world embarks on a carbon-neutral pathway. To mitigate this, PNG is a signatory to the Global Methane Pledge, which aims to reduce global methane emissions by 30% below 2020 levels by 2030.

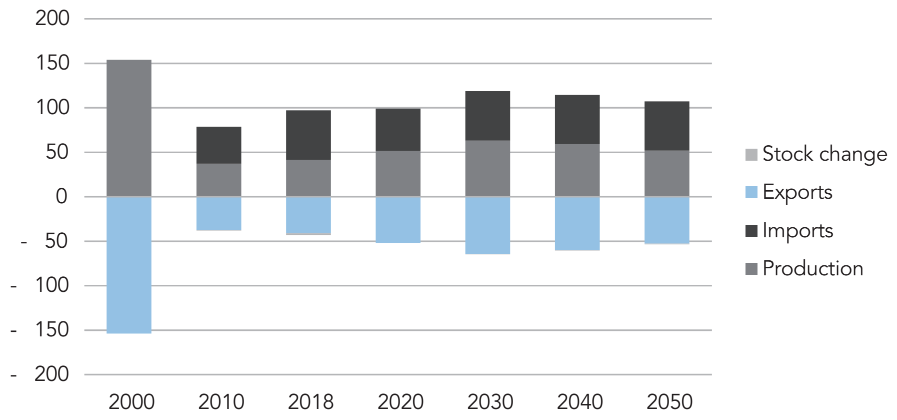
Crude oil and NGLs in both scenarios

Figure 13-27. Crude oil and NGL production, imports, and exports in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 13-28. Crude oil and NGL production, imports, and exports in CN, 2000-2050 (PJ)

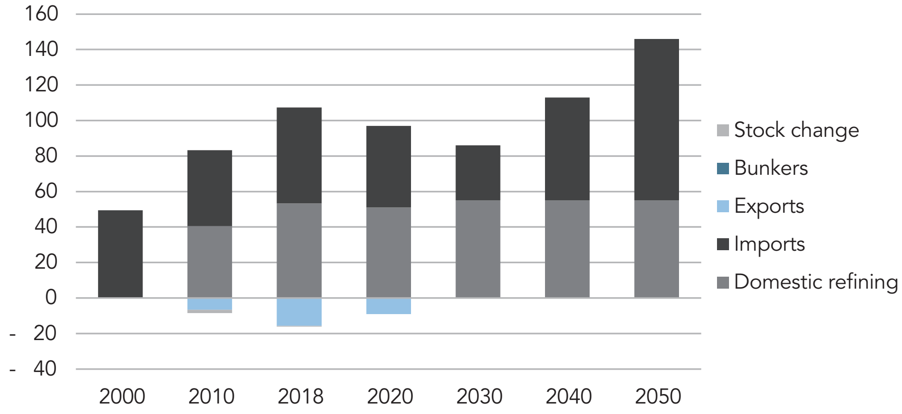


Sources: EGEDA, APERC analysis.

- PNG produces crude oil and NGLs for export, with the latter being associated with natural gas production. In 2018, PNG exported 12 PJ of crude oil and 30 PJ of NGLs.
- In 2018, PNG imported 56 PJ of crude oil, which it uses to refine petroleum products. PNG imports crude oil because its refinery is not configured to process the sweet crude oil that it produces domestically.
- PNG's supply of crude oil and NGLs consist entirely of the runs of its refining sector. After dropping 7.3% in 2020 during the onset of the pandemic, PNG's refinery runs crude oil at pre-pandemic levels for the duration of both scenarios. In turn, crude oil imports remain similarly constant, around 56 PJ for the entirety of both scenarios.
- Exports and production in the outlook period are mainly driven by the NGLs associated with natural gas production. Rising LNG exports lift production and exports of crude and NGLs quickly to 70 PJ in 2030, and then they slowly increase to around 80 PJ in 2050. In CN, exports and production begin to decrease after 2030, following lower gas production.
- PNG relies on the Singapore spot market for its crude oil requirements and the refined products that its refinery does not produce. Threats to oil supply security can be mitigated by diversifying supply sources and ensuring that volumes in both bunkers and storage maintain a good level of coverage over the outlook period. Vulnerabilities to oil security could be further mitigated by lowering refined product demand below the levels shown in either scenario via higher efficiency and electrification.

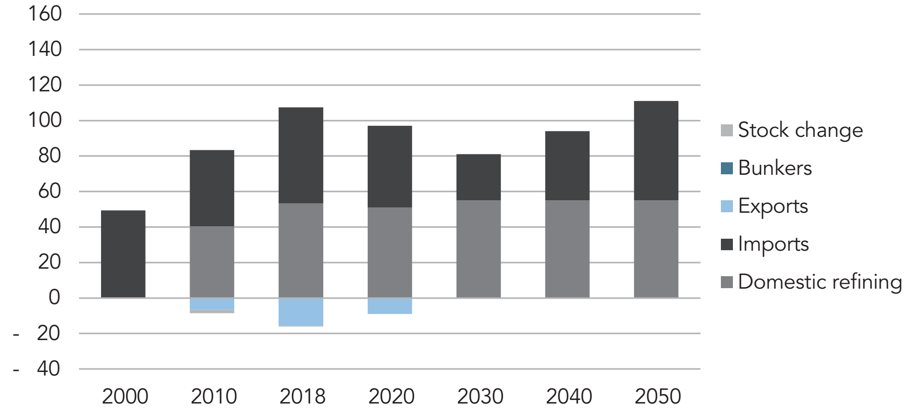
Refined products in both scenarios

Figure 13-29. Refined products production, imports, and exports in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 13-30. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

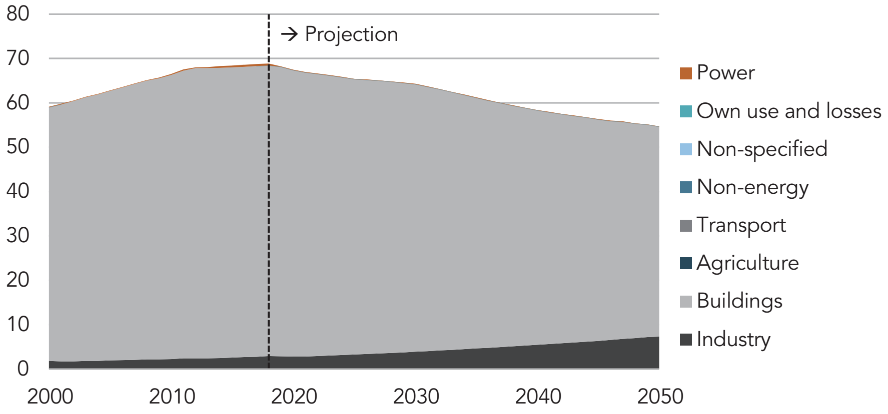


Sources: EGEDA, APERC analysis.

- PNG has a refinery capacity of 33 thousand barrels per day at the Puma Energy Napa Napa Refinery. PNG's refinery will continue to produce the same amount in both scenarios, as it is assumed it is best to use its capacity as much as possible. Exports, however, will decrease to zero, as PNG aims to secure its refined product supply for the domestic market.
- PNG refined products consumption has historically been driven by diesel use in industry and transport. The power sector also uses a significant amount of fuel oil and some diesel use in electricity generation.
- Increases in refined products consumption are driven by rising demand from transport and industry in both scenarios. Demand grows two-thirds in REF, but electrification, biofuel blending and efficiency gains stymie growth to a quarter in CN. In CN, the consumption of refined products is a quarter below REF by 2050.
- PNG does not have the refining capacity to meet domestic demand requirements. Absent higher refining capacity, PNG will need to import more refined products as refined product demand increases. In REF, imports will increase by two-thirds, in line with domestic demand growth. In CN, imports barely increase and finish a third below REF levels.
- In both scenarios, imports and consumption of refined products decline throughout the 2020s, as the power sector halves its use of diesel and fuel oil enroute to embracing the use of gas and renewables. Growing transport and industry demand begin to outweigh the decline in power by the late 2020s, lifting imports along with it.
- Importing refined products can result in lower upfront investment than building refining capacity to fulfill growing demand for oil products. However, the current price spike in product markets illustrates how relying on refined product imports can expose economies to high energy costs and availability concerns in the event of a supply disruption.

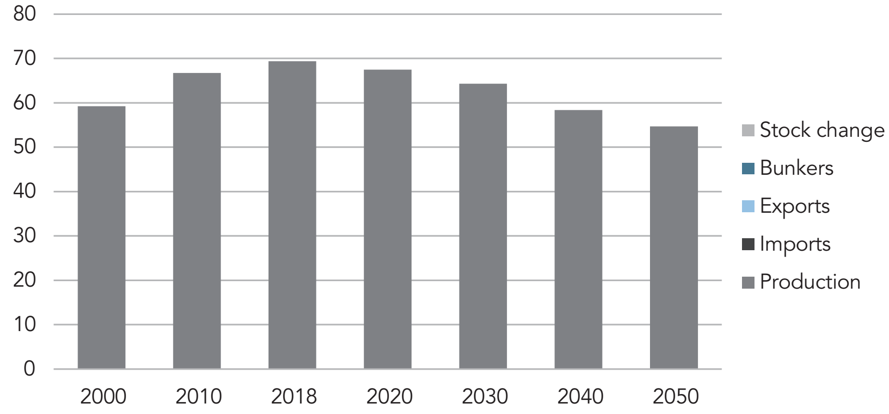
Bioenergy in the Reference scenario

Figure 13-31. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 13-32. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

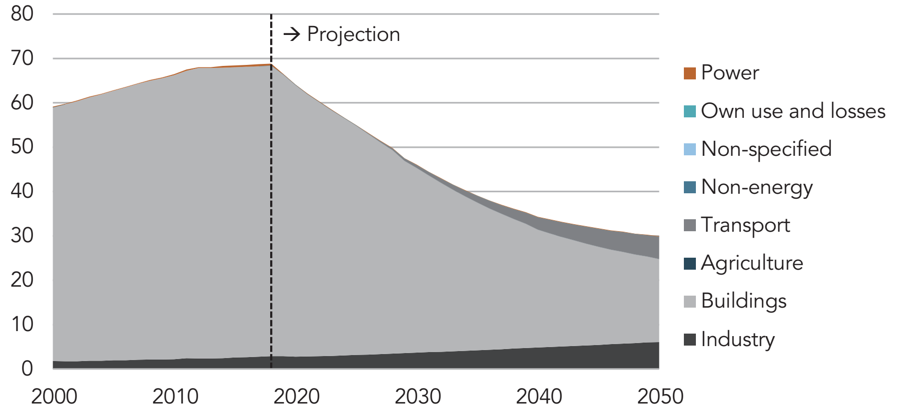


Sources: EGEDA, APERC analysis.

- The predominant use of bioenergy in PNG is fuelwood (traditional biomass) by the buildings sector. This is for uses such as cooking, lighting and water heating.
- In REF, the consumption and production of bioenergy decreases by a fifth, as electrification results in lower traditional biomass use. This electrification relies on an increase in generation capacity and investing in the distribution networks required to increase access to electricity. This investment is necessary to fulfill the NEROP policy goals of achieving a 70% electrification rate of the PNG population by 2030 and 100% by 2050.
- Industry use of renewables increases slowly to 7.3 PJ in 2050. This growth occurs in the manufacturing sector, in the form of solid biomass by palm oil mills.
- Biomass is a niche fuel for a minute amount of power generation. This continues throughout the projection.
- Production of renewables follows its consumption. There are no imports or exports of solid or liquid renewables in REF.
- Household consumption of traditional biomass is assumed to generally be unsustainably harvested and have negative effects on human health. These costs make the electrification of PNG's population an even more important goal.

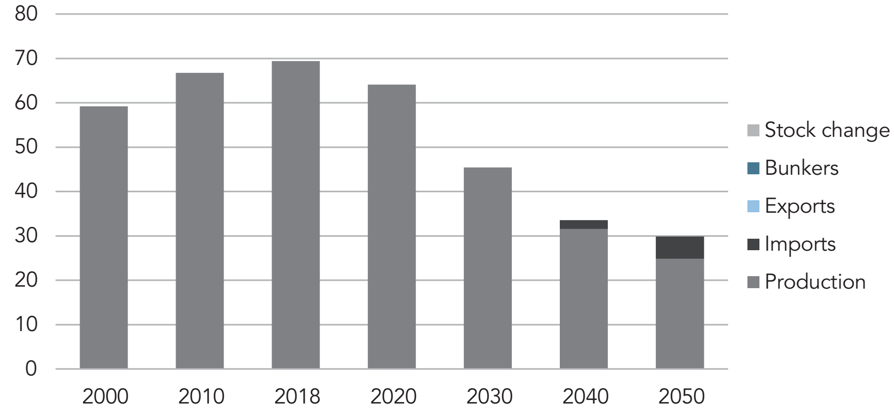
Bioenergy in the Carbon Neutrality scenario

Figure 13-33. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 13-34. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

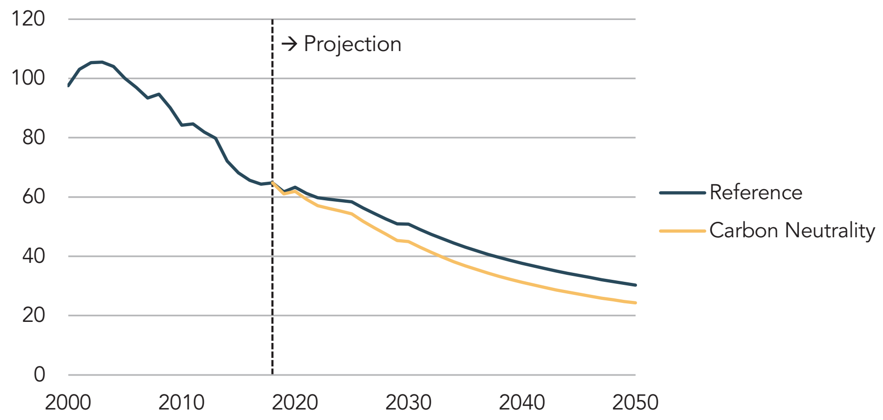


Sources: EGEDA, APERC analysis.

- In CN, bioenergy consumption drops by almost 60% and end the outlook period at almost half of its REF value. The main driver of this is a reduction in traditional biomass use in buildings. This occurs due to a faster rate of electrification and an increase in fuel-switching in CN. This switching occurs strongly early in the outlook period and weakens towards 2050. This results in the prominence of biomass in buildings to fall to 31% in 2050, compared to 48% in REF. Industry use of solid biomass continues as it does in REF, albeit at a lower rate. By 2050, use is about one PJ below REF levels.
- The introduction of liquid biofuels in PNG's transport sector comes entirely from imported biojet fuel for aviation. Starting in 2025, imports rise to meet demand, hitting 5.1 PJ by 2050.
- Unlike REF, when production mirrored declines in consumption, production in CN falls further than consumption, about two-thirds, because PNG begins to rely on imports to meet part of its renewable fuel requirements.
- There is a significant amount of uncertainty surrounding buildings use of traditional biomass. This trajectory depends on the success of the NEROP policy to get 70% of PNG's population access to electricity by 2030 and 100% by 2050. It also depends on ensuring an affordable and reliable grid to encourage the adoption of electricity for a variety of home uses.
- Household consumption of biomass has negative effects on human health. Switching to electricity would provide co-benefits of expanding electricity access and reducing negative health effects.

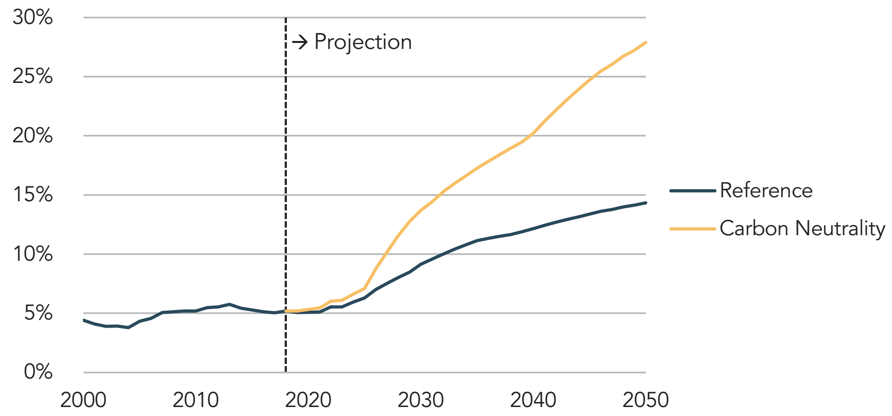
Energy intensity and modern renewables share

Figure 13-35. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 13-36. Modern renewables share in REF and CN, 2000-2050



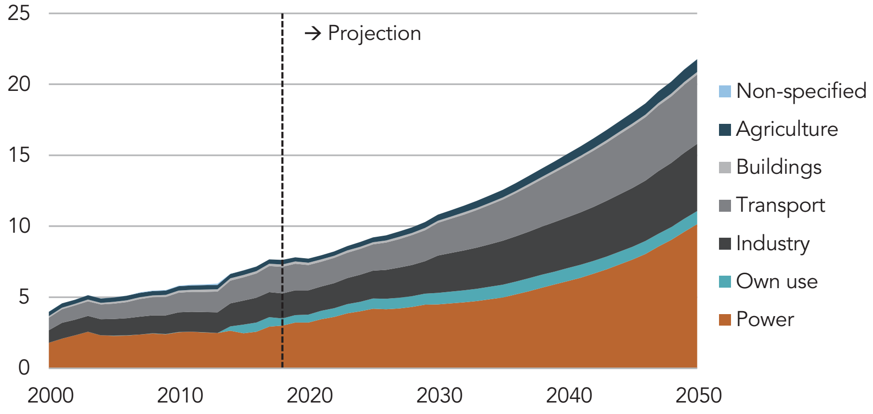
Sources: EGEDA, APERC analysis. Note: Includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- PNG's final energy intensity has improved by almost a third over the past two decades, as the rate of GDP growth outpaces increases in energy use. The improvement in intensity is expected to continue as more efficient fuels and technologies are introduced. However, improvement levels off during the 2040s after the bulk of PNG's electrification goals are achieved.
- In REF, final energy intensity is expected to decrease by 53%, compared to a 63% drop in CN. The improvements in intensity in CN mostly reflect a faster shift from traditional biomass to electricity within the buildings sector.
- PNG's energy efficiency efforts help APEC achieve its goal of reducing energy intensity by 45% below 2005 levels by 2035 in both scenarios. Furthermore, its reductions are consistent with that goal in both scenarios, achieving it by 2034 in REF and 2030 in CN.
- In both scenarios, PNG's modern renewable share is driven higher by electrification and the rising share of renewables in the power mix. Electrification of buildings is particularly effective, reducing the inefficient use of traditional biomass, while pursuing higher renewables in the power mix compounds these gains.
- In both scenarios, PNG's higher use of modern renewables helps APEC achieve its goal of doubling APEC's share of modern renewables over 2010 levels, from 6% to 12%, by 2030. However, it is only consistent with the goal in CN, with doubling occurring in 2032 in REF and 2027 in CN.
- Renewable power deployment is instrumental in increasing modern renewables use in PNG. Renewables share of generation rises from 30% to 35% in REF, which lifts the modern renewable share to 15%.
- In CN, higher electrification and deployment lifts renewables to 60% of the power mix by 2050. There is also an increasing amount of biojet blending. The combination of these factors leads to the modern renewables share reaching 28% in 2050.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

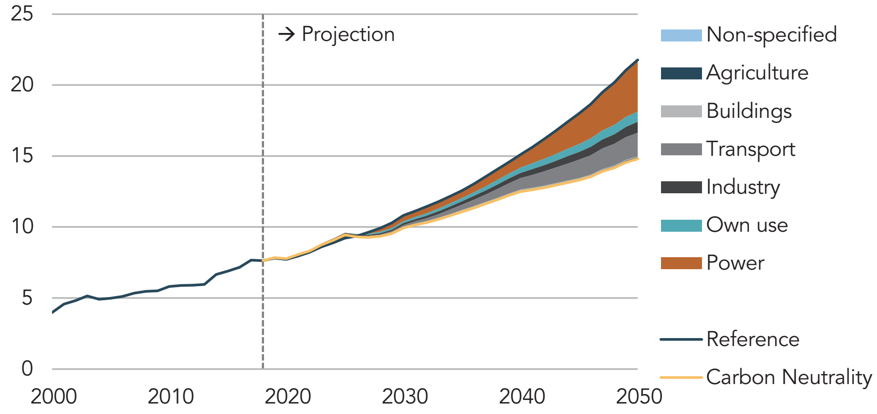
Gross CO_2 emissions

Figure 13-37. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 13-38. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

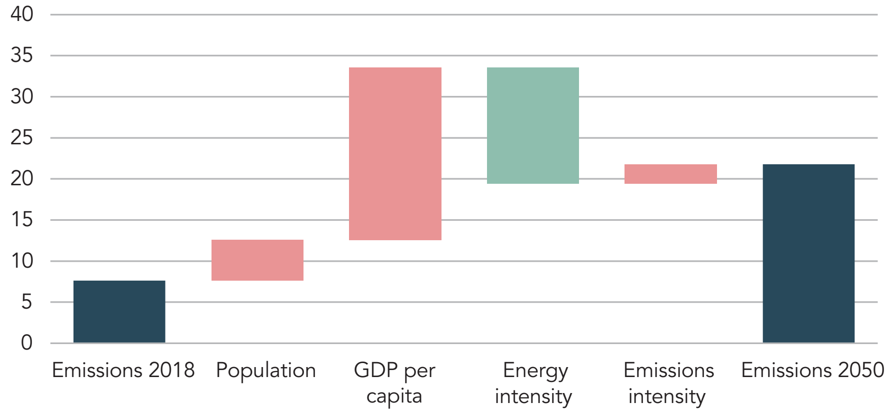


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- PNG emitted almost eight million tonnes of CO_2 in 2018, which amounted to only one thousandth of APEC emissions. This makes PNG the lowest emitter of all APEC economies. Currently, 40% of PNG's emissions come from electricity generation, 20% from transport, 20% from industry and 10% from own use.
- In REF, CO_2 emissions increase at an increasing rate, ending three times higher than 2018 levels. Increases come mostly from power, which comprises half of PNG emissions in 2050 due to a higher use of gas-fired generation. Transport and industry emissions also grow, albeit at slower rates.
- Currently, 90% of CO_2 emissions are from oil use, with the rest coming from gas. Even though gas has a lower emissions intensity, the rate of gas growth for power generation leads to rising emissions.
- CO_2 emissions continue increasing in CN. However, the introduction of renewable energy into the transport and power sectors curbs the growth of emissions. As a result, total emissions are a third lower than REF levels by 2050.
- Because PNG is a rapidly growing economy, it is unlikely that its CO_2 emissions will stop increasing during the outlook period. In both scenarios, fossil fuels remain an important component of the energy system as PNG's population grows, its economy develops, and electricity access permeates to all households.
- Gross emissions are currently the lowest among APEC members, and this continues in both scenarios. Even in CN, PNG's combustible energy sector emissions approach 15 million tonnes. Achieving carbon neutrality will require offsets or reductions from non-energy sectors, such as via sequestration from forestry. This can occur via efforts to reduce deforestation and degradation and encouraging sustainable forest management.

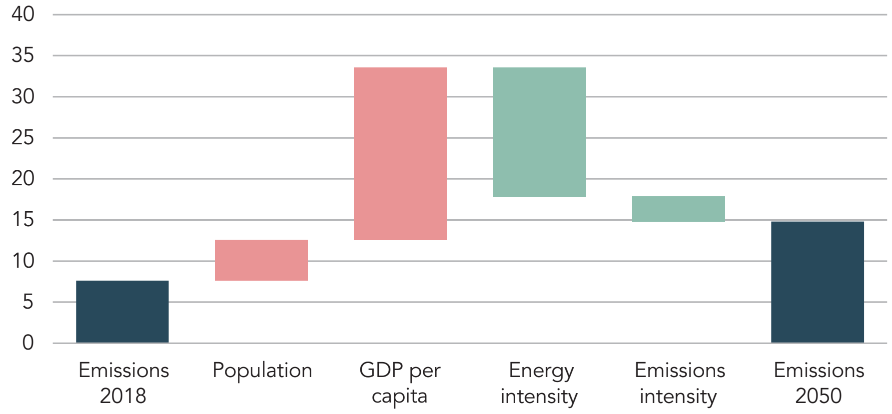
Components of CO_2 emissions

Figure 13-39. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 13-40. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- PNG emissions intensity is below the APEC average. However, the significant role of low-efficiency traditional biomass and geothermal energy makes PNG an above-average APEC member in terms of energy intensity.
- In both scenarios, absent of energy intensity reductions or fuel-switching, a rising population and income growth would increase emissions 4.4-fold. However, energy efficiency and fuel-switching do occur in both scenarios.
- In REF, large improvements in energy intensity reduce emissions by 14 million tonnes. This occur due to a declining role of both traditional biomass and geothermal energy, as well as improving efficiency in all sectors. However, emissions intensity increases emissions by 2.3 million tonnes, as a larger share of power generation begins to come from fossil fuels, particularly natural gas. While a reduction in oil-fired generation reduces emission intensity, the declining share of geothermal, a non-emitting power source, in favor of natural gas, an emitting power source, yields increasing emission intensity. Emissions reach 22 million tonnes in REF, which is a third lower than they would be absent changes in energy and emissions intensity.
- In CN, energy intensity reductions are reduced by an additional 1.6 million tonnes compared to REF due to higher efficiency improvements and electrification across most sectors. Much of these gains from electrification come from switching away from traditional biomass, but higher EV adoption also contributes.
- Emissions intensity declines 3.0 million tonnes, instead of increasing 2.3 million tonnes as it did in REF, as electrification of end uses, the introduction of biojet fuel into the aviation sector, and higher renewable deployment by the power sector reduce the CO_2 content of PNG's energy supply. These additional improvements limit the growth in CO_2 emissions to half that of REF.

Note: The above charts are a representation of the Kaya identity which is $CO_2 \text{ emissions} = \text{Population} * \frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2 \text{ emissions}}{\text{Energy supply}}$.

Additional information

National Energy Policy 2018-2028. https://postcourier.com.pg/renewable-energy-main-focus-policy/

National Energy Policy 2017-2027. https://policy.asiapacificenergy.org/sites/default/files/National%20Energy%20Policy%202017-2027.pdf

Vision 2050. https://png-data.sprep.org/dataset/papua-new-guinea-vision-2050

PNG NDC Electricity Roadmap. https://pngreddplus.org/wp-content/uploads/2021/11/PNG-NDC-Electricity-Roadmap_final.pdf

PNG Medium term development plan. https://png-data.sprep.org/dataset/medium-term-development-plan-iii-2018-2022-volume-1

APERC peer review on low carbon energy policies. https://png-data.sprep.org/resource/peer-review-low-carbon-energy-policies-papua-new-guinea

PNG Enhanced Nationally Determined Contribution. https://png-data.sprep.org/resource/papua-new-guineas-enhanced-nationally-determined-contribution-2020

14. Peru

Highlights

Demand

- Energy demand nearly doubled during the period 2000–18. In REF, Peru energy demand grows by 50% from 2018 to 2050.
- Transport accounts for almost 49% of energy demand in REF, and 46% in CN, in 2050. The results highlight that the transport sector is most important for designing an effective and efficient energy policy in Peru.
- The industry and buildings sectors each account for close to a quarter of final energy demand.
- Traditional biomass demand declines in both scenarios because of policies that intend to replace traditional fuelwood stoves with more efficient stoves, and to switch from biomass to LPG. The CN involves a more intense replacement.
- One-third of the electricity generated in CN, 35 TWh, is consumed by electric vehicles in transport by 2050.
- Hydrogen emerges as an energy carrier in CN. The share of hydrogen reaches 5.0% of total energy demand in 2050 and is consumed mainly in transport.

Supply

- In REF, energy supply increases by more than 41% through to 2050. Around three quarters of the supplied energy comes from fossil fuels.
- In CN, energy supply increases to 2030 and maintains a stable level of around 1 150 PJ until 2040. Energy supply then falls to 1 090 PJ by 2050.
- Peru becomes a natural gas importer in both scenarios in the 2040s. Production levels decline due to lack of investments to increase production. The need for imports is lower in CN, due to lower natural gas demand.
- In CN, oil production in 2050 is 12% lower than REF due to lower domestic and international demand. In contrast, renewable production is 19% greater than in REF.
- In CN, imports of fossil fuels are lower in 2050. For instance: gas imports are 92% lower than REF, refined products are 84% lower, and crude oil is 34% lower.

Power

- Electricity generation grows by 80% from 49 TWh to 88 TWh by 2050 in REF. CN requires an additional 24 TWh in 2050, more than doubling the levels of generation in 2018. This result is the consequence of electrification throughout the economy and expansion of electricity access to unserved populations.
- In REF, the share of variable renewable energy, solar and wind, grows from 3.5% in 2018, to 19% in 2030, and to 30% in 2050. In CN, these shares increase to more than 22% in 2030 and more than 51% in 2050.
- In REF, wind capacity reaches 3 600 MW in 2050, almost 10-times the installed wind capacity in 2018. Solar capacity reaches 3 500 MW in 2050, 13-times the installed solar capacity in 2018.
- In CN, there is an additional 4 850 MW of wind capacity and 3 100 MW of solar capacity on top of REF in 2050. Wind capacity is 2.3-times greater than REF in 2050. Solar capacity is 1.9-times greater.

CO_2 emissions

- In REF, CO_2 emissions increase from 54 $MtCO_2$ to 62 $MtCO_2$ in 2030, and 81 $MtCO_2$ in 2050.
- In CN, emissions peak at 58 $MtCO_2$ in 2025 then fall to 42 $MtCO_2$ in 2050. In this scenario, emissions are 57 $MtCO_2$ by 2030.
- In CN, the transport sector drives CO_2 emission reductions. Given the share of transport in final energy demand, measures focused on that sector are key to achieve the economy's decarbonisation goals. Transport emissions drop to 44 $MtCO_2$ in 2050, which is 62% of the transport emissions in 2018.
- Given the increase in electricity demand in CN, emissions in the power sector rise faster than in REF. However, after 2043, this trend changes as additional solar and wind electricity capacity is incorporated. Power sector CO_2 emissions fall to 10 $MtCO_2$ in 2050 in CN (3 $MtCO_2$ less than the result in REF).

About Peru

- Peru is a democratic constitutional republic with a multiparty system. Land area of 1.28 million square kilometres (km2) makes Peru the eighth-largest economy in APEC. Peru located in South America, bordered by the Pacific Ocean to the west, Chile to the south, Ecuador and Colombia to the north, and Brazil and Bolivia to the east. Peru possesses a great range of climates as well as biodiversity. Peru has been traditionally divided into three geographical regions: the coastal region to the west, where most of the population lives, the mountain region (Andes Mountains), and the Amazonian region.
- Peru has 25 administrative regions called regiones. In 2019, the population was 32.1 million, with 20.2% of inhabitants considered poor, and 2.9% under the extreme poverty line according to the National Institute of Statistics and Informatics (INEI). The major population centre of Peru is Lima, with 10.4 million people, nearly one-third of the total population; the urbanisation rate is 72%.
- In 2018, Peru's GDP was USD 419 billion (2018 USD PPP) with GDP per capita increasing 0.4% from 2017.
- The industrial sector accounts for 30% of Peru's GDP. Peru has a large and dynamic mining industry, mainly engaged in copper and gold extraction. The mining industry accounts for 10% of Peru's GDP and 60% of its exports.
- In 2019, Peru was the second-largest producer of silver, copper, and zinc, the third-largest producer of lead, the fourth-largest producer of tin and molybdenum, and the eighth-largest supplier of gold, which demonstrates the importance of the mining sector to the economy.
- Peru has the nineth-largest natural gas reserves and the 11th-largest oil reserves in APEC. Peru also has abundant renewable energy potential.

Table 14-1. Peru statistics, 2018

	2018	APEC share	APEC ranking
Population	32.0	1.1%	12
GDP	418.9	0.6%	18
TPES	1 067.1	0.3%	17
Production	1 002.6	0.3%	14
Imports	500.0	0.4%	18
Exports	442.1	0.4%	15
Electricity generation	55.0	0.3%	16
Heat production	0.0	0.0%	-
CO_2 emissions	53.3	0.3%	16

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 14-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	–	–	–	–
Natural gas	9 412	22	0.1%	9
Oil	4 566	16	0.0%	11
Uranium	33 400	–	–	–

Notes: Coal (PJ) in 2018 from Peru's National Energy Balance 2018, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- **COVID-19 impacts:** The social, economic, and health impacts of the pandemic have hit Peru particularly hard. Economic recovery will require the design and implementation of domestic strategies that promote the development of a sustainable and reliable energy system that can support economic growth, satisfy local demand, and strengthen the competitiveness of Peru in the international market.
- **Natural gas coverage:** Peru is developing new policies to expand natural gas access to regions where distribution concessions are not currently in place. The Peruvian government will be responsible for developing the required infrastructure in several regions of the highlands and the jungle of Peru.
- **Natural gas for households:** The Ministry of Energy and Mines approved projects to extend the coverage of natural gas for the residential sector. The Bonogas Residencial program will reach an additional 285 000 houses, totalling 883 000 beneficiaries. This program finances new natural gas residential connections. Bonogas vehicular is an additional program that promotes the conversion of conventional gasoline fuelled vehicles into natural gas fuelled vehicles. It is projected to reach 18 500 users by 2021.
- **Talara refinery modernisation:** This upgrade is close to being finalised. The new refinery is expected to start to operate by mid 2022, increasing its crude oil processing capacity from 65 000 barrels per day to 95 000 barrels per day.
- **Renewable energy targets:** There is a goal of 15% of non-conventional renewable energy (solar, wind, geothermal, biomass, and tidal up to 20 MW) in the electricity generation matrix by 2030. To achieve this goal, reforms in the regulatory framework are necessary.
- **Renewable energy projects:** Four non-conventional renewable energy projects entered operation in 2020: the hydroelectric project Manta (20 MW), biomass project Callao (2.4 MW), and wind projects Huambo (18.4 MW) and Duna (18.4 MW).
- **Nationally Determined Contribution (NDC):** Peru updated its NDC in 2020, increasing its GHG emission reduction goals to 40% by 2030, from which 10% is conditioned on external support.
- **Climate change adaptation:** Peru has approved the National Plan for the Adaptation to Climate Change in June 2021. The document guides the process of adaptation to climate change in Peru, identifies high risk areas, creates a vision for the 2030-2050 period, and prescribes strategic actions to achieve its objectives. NAP is an input for the update of the National Strategy against Climate Change.
- **Carbon Neutrality:** In July 2021, the government announced that Peru will work to reach carbon neutrality by 2050.
- **Electrification:** In 2018, rural electrification reached 87% and total electrification was 92%. The policy target is to reach 100% by 2022. The National Plan for Rural Electrification contains projects located in several areas of Peru. Renewable energy projects are considered for Loreto and Ucayali in the Peruvian Amazon region.
- **Transport sector transitions:** Peru approved laws to facilitate the development of a market for electric and hybrid vehicles and supply infrastructure.
- **Energy production:** Peru has a goal to increase oil production to 100 000 bpd, and natural gas production to 1 500 MMSCFD by 2025.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- Long-lasting effects of COVID-19 on human behavior such as the increase of teleworking and reduction on commuting have not been included as they are still to be determined.
- **The Reference scenario (REF)** in Peru reflects recent trends and current policies in place or planned to capture the evolving nature of the energy system. REF tries to identify potential risks and problems that might arise if the energy sector develops according to that trend, especially if some goals and domestic strategies such as the NDCs and the National Adaptation Plan against Climate Change are considered.
- In REF, increase in oil and natural gas reserves was not assumed.
- **The Carbon Neutrality scenario (CN)** illustrates the additional transformation in the energy sector required to supply energy under the aspirations of reaching carbon neutrality by 2050. CN is performed as a bottom-up analysis by making assumptions about efficiency improvements, fuel switching, technology commercialisation and deployment, and potential policy guidelines with more emphasis on decarbonisation.
- The resultant CO_2 emissions should be understood as gross emissions from the energy sector that need to be compensated with negative emissions from natural sources (for example, forests) or technologies (for example, direct air capture), in order to achieve specific goals.
- Electrification of demand in all sectors (especially in transport through the promotion of electric vehicles), solar and wind energy shares in electricity generation that are higher than aspirational goals, increases in energy efficiency in building and industry sectors, and faster replacement of fuelwood with natural gas and electricity are among the most effective measures that were modelled to reduce net CO_2 emissions.
- Demand for hydrogen in freight transport, marine bunkers, and in industry replacing fossil fuels and reducing energy imports was assumed.
- The CN does not represent APERC's recommendation or advocacy for a pathway or set of policies.

Table 14-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Peru

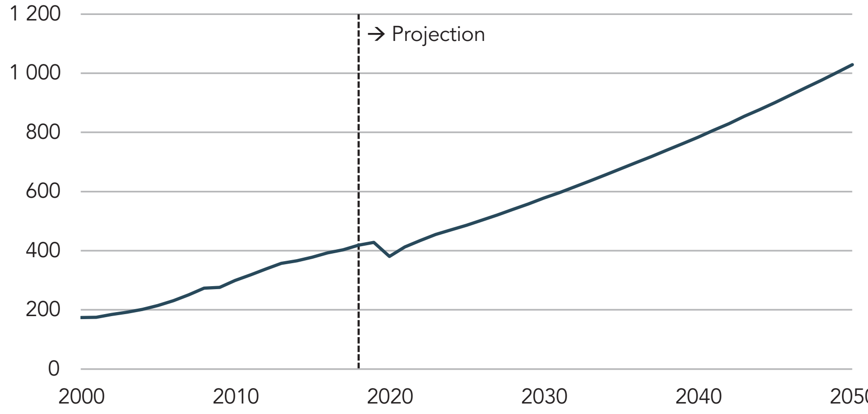
Table 14-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: World Population Prospective 2019 (UN medium). • GDP: World Bank (historical), MEF (Pre-electoral Projection 2016–2021), and APERC Solow-Swan model.	• Same as REF
Buildings	• No structural changes. • Energy efficiency improvements due to energy labelling policies. • Fuel switching from biomass to LPG.	• Water heating by solar thermal. • Increased efficiency for houses and public buildings. • Increased efficiency of appliances (energy efficiency labelling).
Industry	• No CCS • No hydrogen • 0.5% p.a. improvement in energy efficiency for GVA data subsectors and aluminium and pulp and paper. • Limited electrification.	• Energy efficiency improvements and electrification occurs more rapidly than in REF (ISO 50001 to reduce emissions 4.423 $MtCO_2$ 2010–2030). • No CCS • Small amount of hydrogen in steel subsector. • Material efficiency sees roughly 10% lower steel production than in REF. • Fuel switching to gas in certain subsectors.
Transport	• EV participation is market driven.	• More rapid uptake of EVs reaching 40% sales by 2035 and 100% by 2050. • Hydrogen fuel cell vehicles for heavy trucking reach 20% of sales in 2050. • Biofuels and hydrogen introduced as aviation transport fuels.
Power and heat	• Moderate scale adoption of renewables. • Coal phased out by 2023. Some coal-fired units used by auto-producers in the industry sector remain.	• Gas-fired units begin to decommission in 2040, with a combination of renewables set to replace them. • No hydrogen consumption or co-firing gas units as we expect other technologies to be more cost competitive. • CCS in power was not assumed.
Supply	• Increase in demand of oil products drives increase in refinery capacity. • Interconnection with other economies has not been considered.	• Natural gas, coal, and oil production is reduced. • Increase in refinery capacity is not expected.
Climate	• There are some NDC measures that have been implemented, such as implementation of renewable energies, higher energy efficiency, solar water heaters, and EV.	• NDC measures assumed in REF are strengthened. • Carbon neutrality by 2050

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

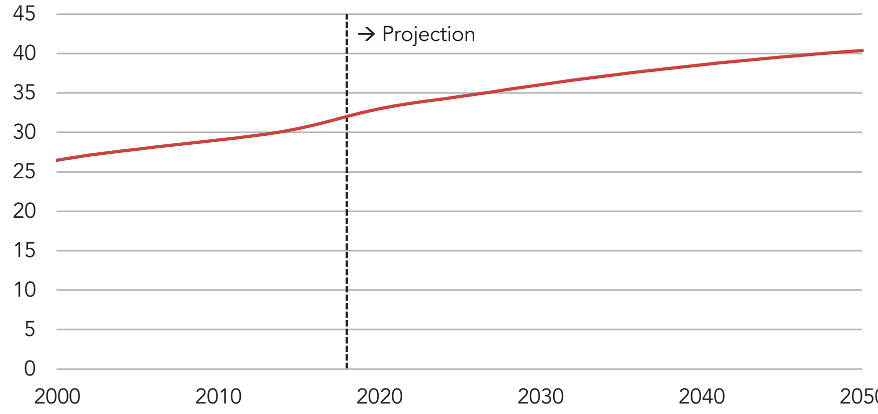
Macroeconomic backdrop

Figure 14-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 14-2. Population in millions, 2000-2050

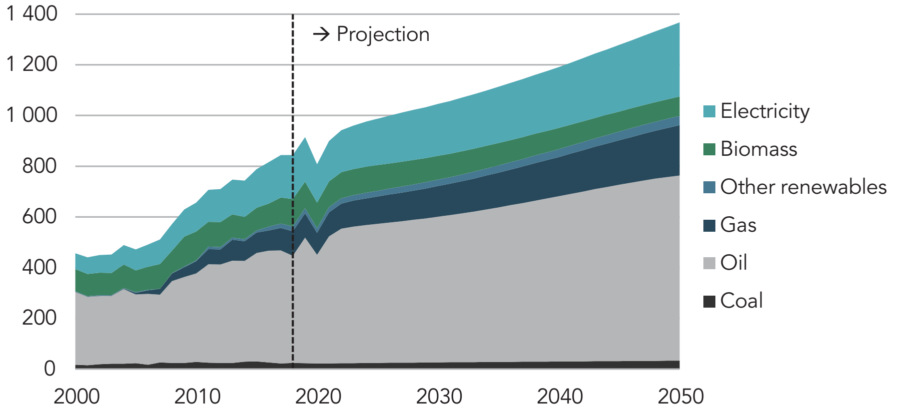


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- From 2000 to 2018, Peru's population grew at a CAGR of 1.1%. This rate was higher than the growth rate for the APEC region. From 2018 to 2050, the population is expected to grow 26%, making Peru one of the fastest growing populations in APEC. Under this assumption, Peru will grow from 32 million people in 2018 to 36 million by 2030, and 40 million by 2050.
- The Peruvian economy has been one of the fastest growing economies in APEC, growing at a CAGR of 5% from 2000 to 2018. However, Peru has been severely impacted by the COVID-19 pandemic, affecting that positive trend. This effect has been included in our data. Peru's GDP falls 11.1% in 2020. It is assumed that GDP will reach the 2018 level by 2022. From 2022 to 2050, GDP annual growth increases at an average of 3.1%, which is lower than recent decades. Peru's economy will be 146% larger in 2050 than in 2018.
- GDP and population are the main drivers of the energy demand projection in the scenarios that have been constructed. The challenge for meeting increasing energy demand is to meet the demands of the end-user in a satisfactorily sustainable and efficient manner.
- Even though the macroeconomic projections are the same in both scenarios as a simplifying assumption, global efforts to reach carbon neutrality might highly increase demand of critical minerals for electrification and impact the assumed economic growth in CN. Peru is currently the second largest copper producer in the world, a vital mineral for electrification, and has lithium reserves that can be exploited in the future. Nevertheless, the evolution of the global economy in a path toward carbon neutrality is uncertain.
- The evolution of Peru's GDP follows historical developments. Major structural changes to the economy have not been explicitly assumed. However, the shifting of GDP from both industry and manufacturing to services continues, with the latter converging to account for half of Peru's GDP by 2050.

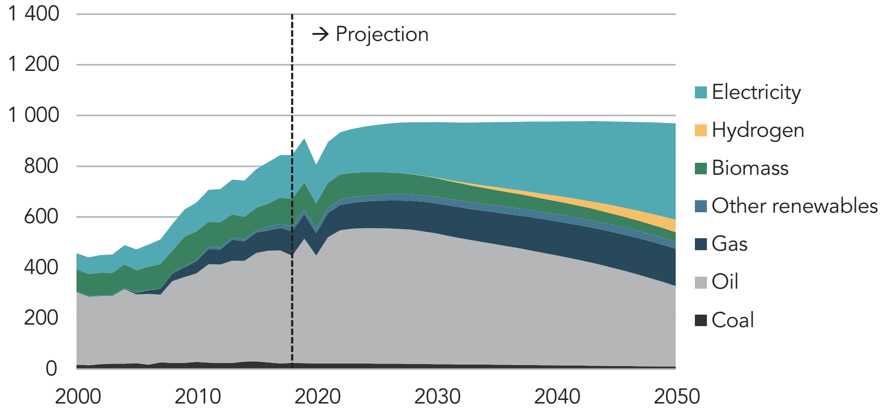
End-use energy demand

Figure 14-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 14-4. Energy demand in CN, 2000-2050 (PJ)

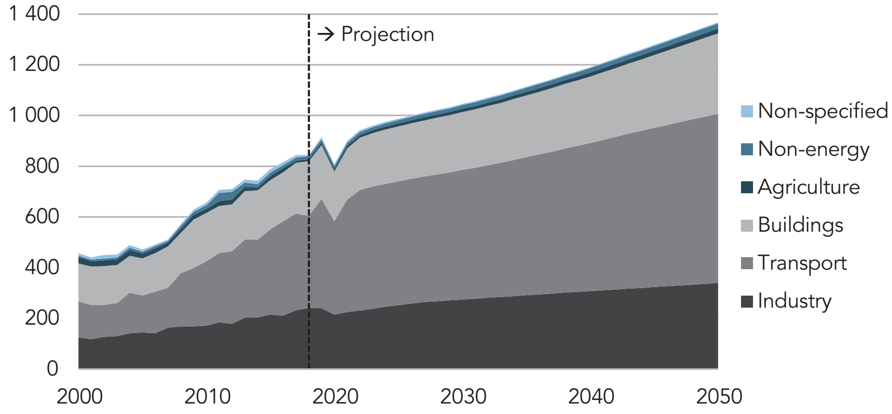


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Energy demand trends are affected by energy-related policies, technological innovations and other relevant assumptions that are stated in the assumption slide.
- Energy demand has almost doubled for 2000–2018. In REF, Peru's energy demand in 2050 is 50% higher than in 2018. Energy efficiency, fuel switching, and technological innovations curb demand in CN so that energy consumption is only 7% higher at the end of the projection. The energy demand growth rates in both scenarios are lower than the historical growth rate. It is important to indicate that energy demand peaks in 2043 and then starts a slow decline in CN.
- The share of fossil fuels are important in both scenarios, demonstrating how challenging it is to replace these fuels in Peru. In REF, the share of oil and gas increases from 64% in 2018 to 68% in 2050. This is mostly due to natural gas doubling through to 2050, which is a result that is consistent with domestic policies that promote the use of natural gas in buildings, industry, and vehicles.
- In CN, gas and oil demand increases to 2027 and then decreases gradually in CN due to additional energy efficiency improvements and fuel switching to electricity and hydrogen. The share of fossil fuels in 2050 is 48%.
- In REF, electricity demand in 2050 is 70% higher than in 2018. In CN, electricity demand is 30% higher than in REF by the end of the projection. This result is a consequence of higher electrification for applications in all energy sectors in CN.
- Hydrogen emerges as an energy carrier in final energy demand in CN. The share of hydrogen reaches 5% of total energy demand in 2050 and is consumed mainly in transport.
- Traditional biomass plays an important role in the historical energy mix as it is a fuel used for cooking and water heating in underserved populations. This demand is reduced in both scenarios because of policies that intend to replace traditional fuelwood stoves with more efficient stoves, and switch from biomass to LPG. The CN involves a more intense replacement.

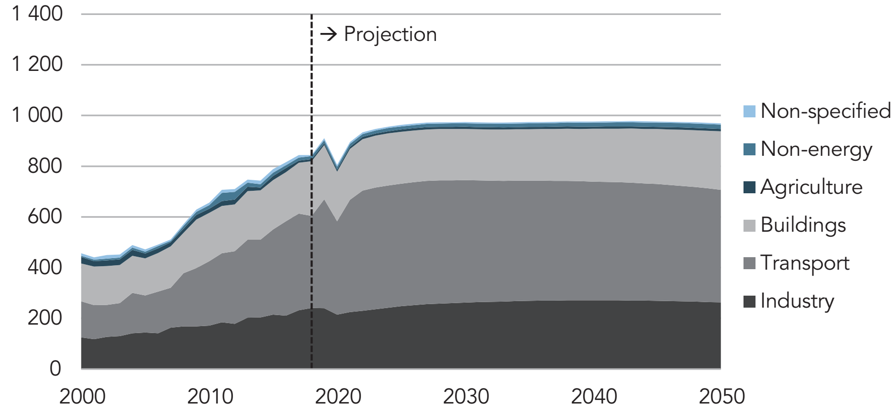
End-use energy demand by sector

Figure 14-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 14-6. Energy demand by sector in CN, 2000-2050 (PJ)

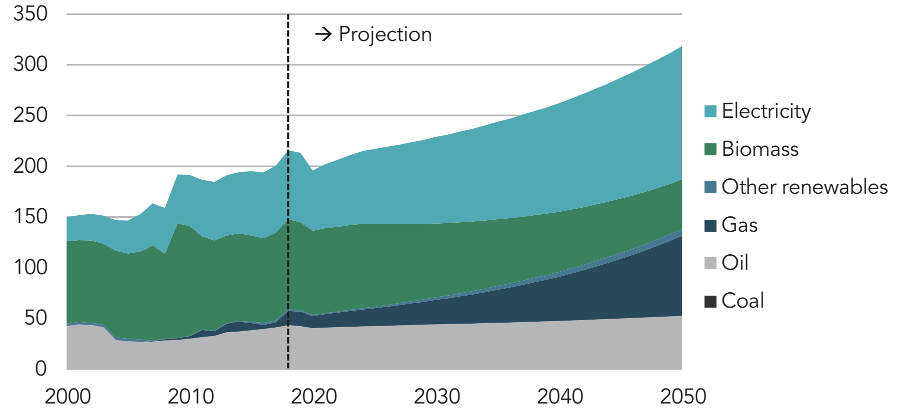


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Energy demand in the transport, buildings, and industry sectors grows more slowly in the projection of both scenarios than for the historical trend from 2000–2018. Deceleration of economic growth and increasing energy efficiency slows energy demand growth for all the sectors.
- Energy demand drops drastically in 2020 due to the COVID-19 pandemic. Transport energy demand returns to the 2018 level in 2021. Energy demand in industry and buildings is less severely impacted but takes additional time to recover. Economic reactivation and the normalisation of activities does not occur until all restrictions implemented during the pandemic are finally lifted.
- Energy demand growth is restricted in CN in all sectors due to more ambitious energy efficiency that is brought about by technologies, more stringent energy efficiency standards, and the replacement of certain fuels with more efficient alternatives. When compared with REF, energy demand is lower by 23% for industry; 33% for transport; and 28% for buildings in 2050.
- Transport accounts for almost 49% of the demand in REF, and 46% in CN, in 2050. The reduced share between the two scenarios is due to the outsized gains in efficiency that result from electrification. Industry accounts for 25% in REF and 27% in CN. Buildings account for 23% in REF and 24% for CN. Agriculture and non-energy are relatively inconsequential.
- The results highlight the dominant role of transport in designing an effective and efficient energy policy in Peru. However, the industry and buildings sectors require significant consideration as well.

Buildings energy demand

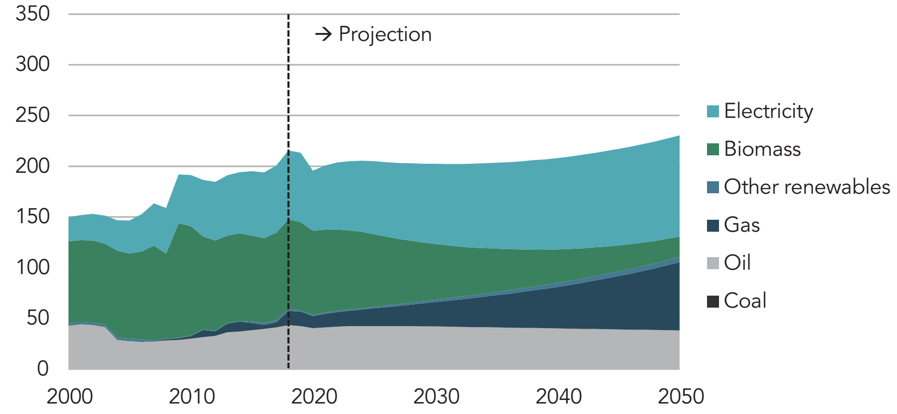
Figure 14-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

- Buildings energy demand grows in both scenarios. Energy demand increases by 49% in REF and by 8% in CN between 2018 and 2050. This increase is due to energy efficiency measures being outweighed by population and economic growth.
- In both scenarios, electricity is the largest energy carrier used by 2050. Electricity's share rises from 30% in 2020 to 41% in REF and to 43% in CN. This growth considers universal access to electricity by 2030.
- Natural gas rises at a CAGR of 7% in the REF and 6% in CN. These growth rates are faster than for overall energy demand due to the implementation of programs and projects that promote mass adoption of natural gas in the buildings sector in different areas of Peru. Example initiatives are the Bonogas program and the project of natural gas distribution in 7 regions.
- In CN, oil products demand, mainly LPG, peaks in 2024. From 2024 to 2050, oil products demand falls by an annual average of 0.4% due to assumed higher levels of urban switching from LPG to electricity and natural gas. This higher level of urban switching outweighs the effect of rural households switching from traditional biomass to LPG.
- The replacement of traditional biomass with more efficient technologies that consume cleaner fuels is the main factor that curbs residential energy demand.

Figure 14-8. Buildings energy demand in CN, 2000-2050 (PJ)

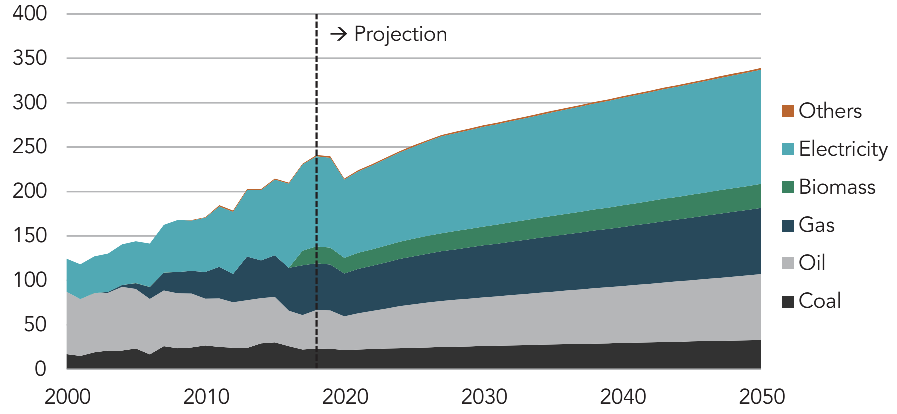


Sources: EGEDA, APERC analysis.

- Energy efficiency labelling, and public awareness, improves appliance energy efficiency in both scenarios. However, a more ambitious inclusion of highly efficient appliances in CN leads to an energy saving of 22 PJ by 2050.
- New buildings comply with more stringent building codes. This will require the construction of new highly efficient buildings and retrofitting existing ones. In CN, the more efficient buildings consume approximately 40% less energy than non-efficient buildings. In 2050, 60% of existing buildings will be efficient.

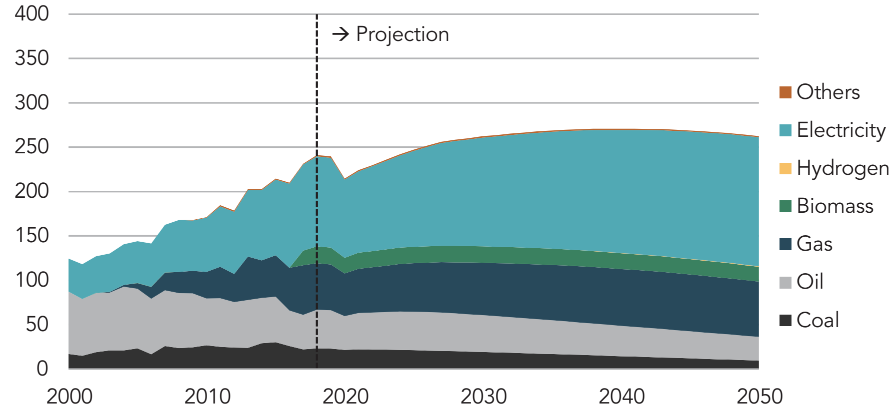
Industry energy demand

Figure 14-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 14-10. Industry energy demand in CN, 2000-2050 (PJ)

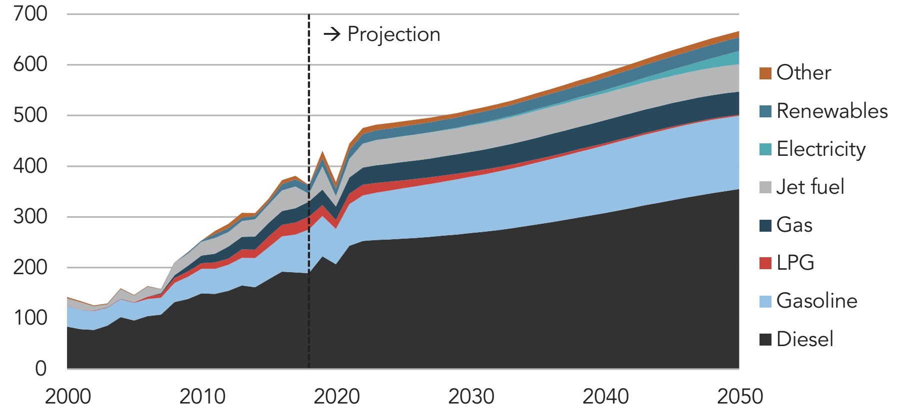


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industry demand rises constantly in REF. Energy demand in 2050 is 42% more than in 2018.
- In CN, industry demand grows slowly, peaking in 2041 then falling through to 2050. The growth in industrial energy demand is slower than the historical rate and partly due to a slowing rate of economic growth out to 2050. The reduction in CN energy demand is also explained by greater energy efficiency measures and fuel switching.
- Electricity accounts for nearly 42% of industrial energy demand in 2018. The share of electricity decreases to 38% in REF and increases to 55% in CN in 2050. The increase emphasises the significant potential for electrification by certain industrial processes.
- Peruvian industrial infrastructure is relatively new when compared with other APEC economies. Investment in energy efficiency improvements technologies may therefore prove challenging. Improvements in energy efficiency mainly come from newly built infrastructure throughout all industrial subsectors.
- In Peru, the energy demand from subsectors such as food, chemicals, cement, and paper could not be disaggregated due to lack of detailed data. Much of this industrial demand is categorised as non-specified. The analysis shows that this group accounts for 68% of industrial energy demand.
- The non-specified category consumes mainly fossil fuel for thermal processes. In addition to energy efficiency measures and the implementation of standards such as ISO 50001, energy demand in industry falls due to fuel switching from oil products to electricity, natural gas, and hydrogen in CN.
- Mining sector energy demand depends on the expected development of new mining projects. Mining demand is expected to double in REF and to grow 70% in CN by 2050 with respect to 2018. Most of the difference is due to energy efficiency and electrification.
- Mining energy demand may be affected by a global increase in the demand for critical minerals such as copper and lithium for battery storage and electric vehicles. But for Peru, mining output is consistent for both scenarios.

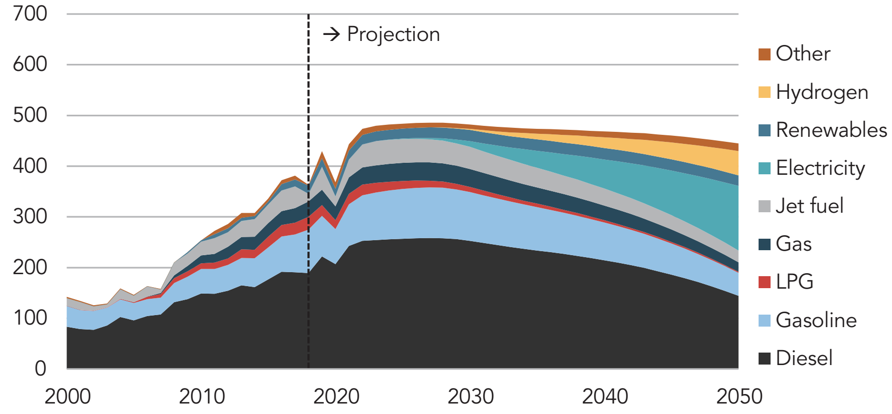
Transport energy demand

Figure 14-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 14-12. Transport energy demand in CN, 2000-2050 (PJ)

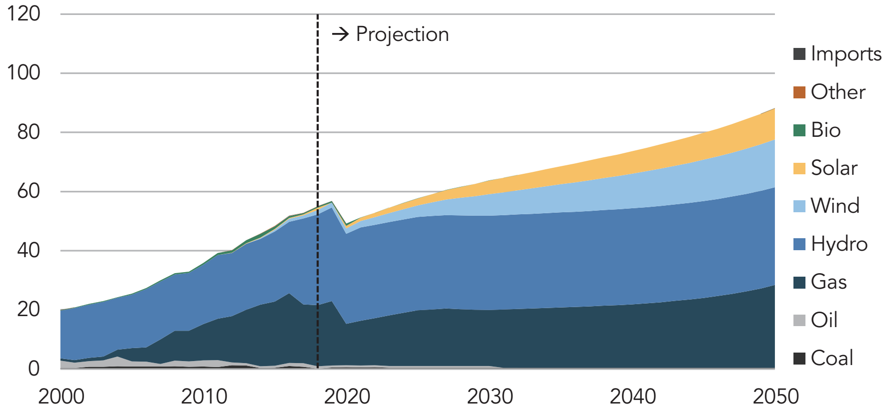


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport is the largest energy consuming sector in Peru. Given its size and challenging geography, road transport plays a major role of supporting economic development as products and people move within the economy and to export hubs. An increase of economic activity will require an increase of activities in the transport sector.
- Transport energy demand tripled for the 2000–2018 period. In REF, transport demand is expected to grow by an additional 50% out to 2050. In CN, transport demand peaks in 2028, 15% higher than in 2018, and then declines to almost the same level of the base year by 2050. The main difference between both scenarios is the use of more efficient vehicles (hybrid, battery, and fuel cell) in the transportation of passengers and freight, reducing the demand for diesel and gasoline.
- Diesel and gasoline represent almost 70% of total energy consumption in 2018. In REF, this share reaches 75% in 2050. In contrast, the share of diesel and gasoline falls to a 42% share in CN.
- Battery EVs will account for almost 18% of the stock of vehicles in REF and 76% in CN by 2050. In CN, EV sales increase to account for almost all light passenger vehicles in 2050. There are still sales of ICE vehicles in other vehicle segments. However, hydrogen fuel cell vehicles take market share from fossil fuel vehicle sales.
- The share of electricity increases from zero to over 28% in 2050 in CN. Electricity brings about significant efficiency gains and is influential in seeing transport energy demand fall after 2028.
- In CN, hydrogen appears in 2026 but only grows noticeably beginning in 2030. Hydrogen vehicles become most prominent in freight transport, reaching a 15% share of the stock of these vehicles by 2050.
- Promotion of more efficient transport modes such as rail decreases energy demand in CN relative to REF.

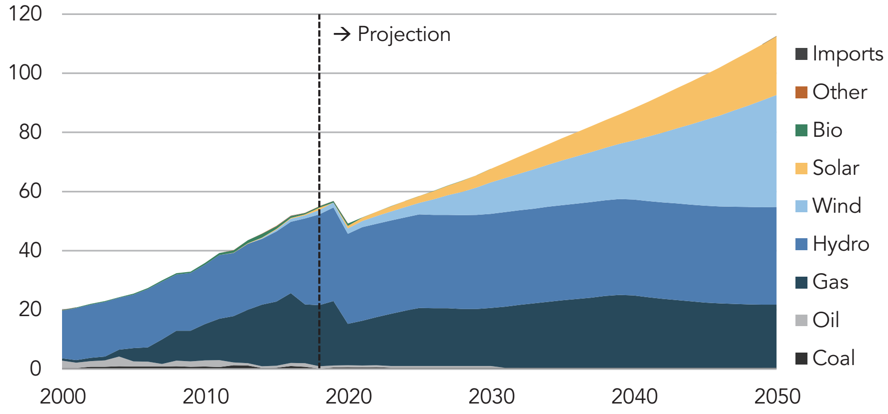
Electricity generation

Figure 14-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 14-14. Electricity generation in CN, 2000-2050 (TWh)

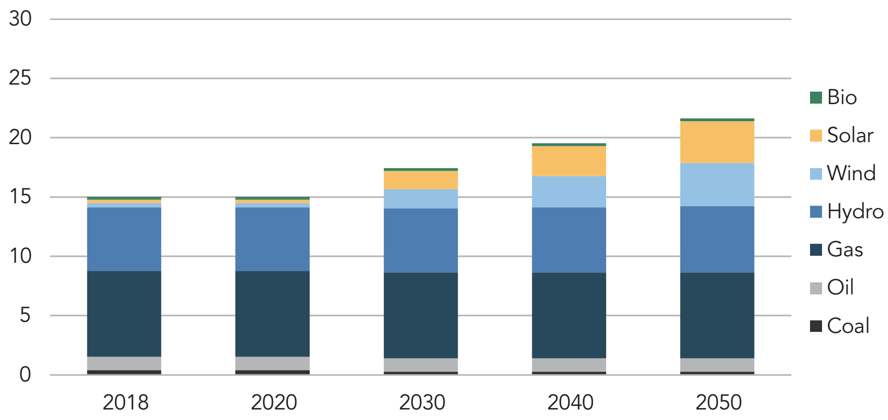


Sources: EGEDA, APERC analysis.

- Electricity generation grows by 80% from 49 TWh to 88 TWh by 2050 in REF. CN requires an additional 24 TWh in 2050, more than doubling the levels of generation in 2018. This result is the consequence of electrification throughout the economy and expansion of electricity access to unserved populations.
- Peru's electricity sector has been dominated by natural gas and hydropower in the past. The share of variable renewable energy (solar and wind), grows from 4% in 2018 to more than 18% in 2030, and more than 30% in 2050 in REF. In CN, these shares increase to more than 22% in 2030 and more than 51% in 2050.
- Increasing penetration of wind and solar is due to the low cost of variable renewable energy generation. However, higher penetration in the electricity grid will require an improvement in power system flexibility as well as adaptation of the electricity market to deal with the uncertainty in the prediction of market conditions and network constraints.
- The abundance of low-carbon resources for electricity generation, and the challenge of finding suitable storage sites, mean that carbon capture technologies are not competitive with renewable energy generation. No carbon capture project is incorporated into the power system in either scenario.
- Oil and coal are phased out by 2030 in the interconnected electric grid. Marginal coal electricity generation remains in both scenarios and is associated with industrial producers that generate electricity for their own use to support their primary activity.
- Natural gas generation doubles in REF from the trough posted in 2020. In CN, natural gas generation peaks in 2039 and is one-quarter lower than REF by 2050. Although gas generation begins to fall in CN, it remains an important auxiliary source that complements renewable generation.
- The transport sector consumes 7 TWh of electricity at the end of the projection period in REF. Consumption is five-times greater in CN, at 35 TWh in 2050. The CN consumption accounts for almost one-third of final electricity demand in 2050.

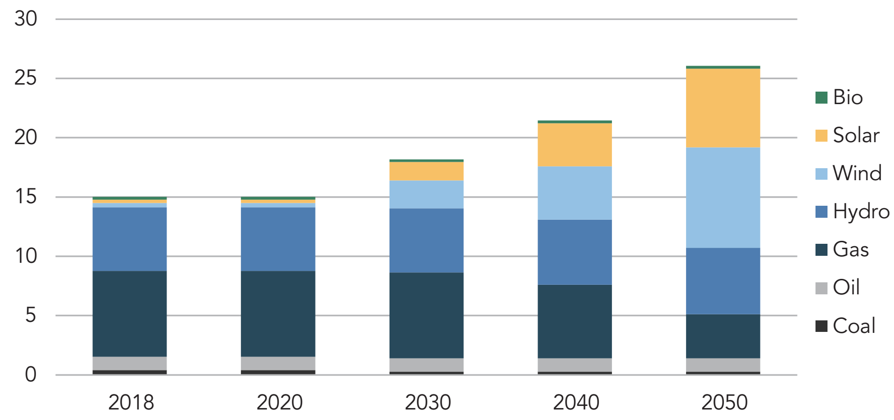
Generation capacity

Figure 14-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 14-16. Generation capacity in CN, 2018-2050 (GW)

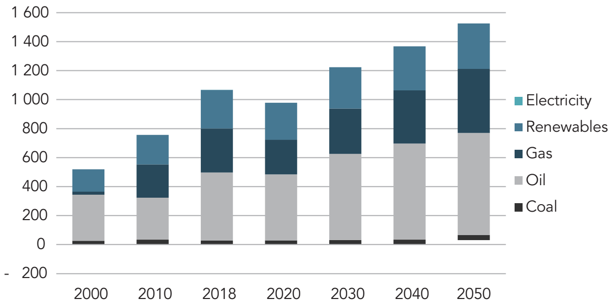


Sources: EGEDA, APERC analysis.

- Solar and wind play an important role in decarbonising the power sector. In REF, wind capacity reaches 3 600 MW in 2050, almost 10-times the installed wind capacity in 2018. Solar capacity reaches 3 500 MW in 2050, 13-times the installed solar capacity in the base year.
- In CN, there is an additional 4 850 MW of wind capacity and 3 100 MW of solar capacity on top of REF in 2050. Wind capacity is 2.3-times greater than REF in 2050. Solar capacity is 1.9-times greater.
- A scenario with high penetration of variable renewable energy, mainly solar and wind, requires a flexible and firm grid. For Peru, those requirements are met by hydropower and natural gas power plants.
- In REF, natural gas power plants will start to adjust their role as baseload power plants and become variable renewable energy integrators by load balancing. Around a quarter of the installed capacity by 2050 corresponds to natural gas power plants.
- In CN, the transformation of the electricity generation capacity requires the decommissioning of 3 500 MW of natural gas capacity as most of the baseload demand is satisfied by renewable energies. This result is relevant for the natural gas industry, as the power sector is currently the main consumer of this fuel.
- Hydropower capacity increases by a small amount (250 MW) from 2018 to 2050 in both scenarios. The increase in hydropower capacity is restricted by costs, environmental concerns, and opposition due to water usage.
- A small fraction of the capacity corresponds to oil-fired power plants because these plants can provide operational reserve and are not expected to run as the baseload.

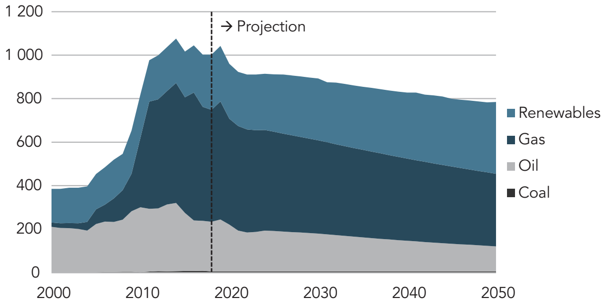
Energy supply in the Reference scenario

Figure 14-17. Total energy supply in REF, 2000-2050 (PJ)



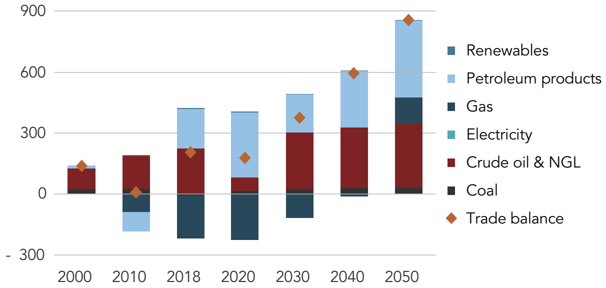
Sources: EGEDA, APERC analysis.

Figure 14-18. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-19. Net energy trade in REF, 2000-2050 (PJ)

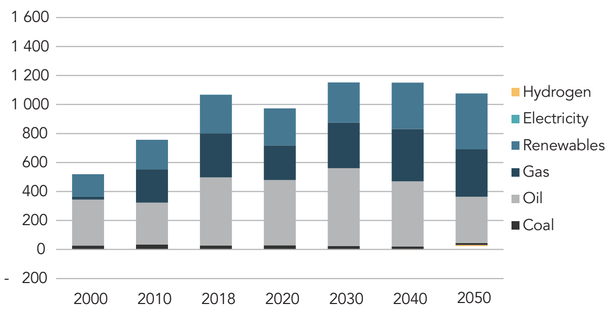


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Total energy supply increases by more than 41% between 2018 and 2050 in REF. Fossil fuels in Peru's energy supply increase from 75% in 2018 to 79% in 2050. This energy supply is consumed in transformation processes (for example, refinery and power), and in end-use demand sectors like transport, buildings, and industry.
- Natural gas became an important source of energy during the first decade of the 21st century. The share of natural gas increases from 27% in 2018 to 30% in 2050. This is explained by the increase of natural gas demand from the power sector and thermal uses in industry and buildings. The increase is the result of laws that were promulgated to incentivise natural gas demand in several economic sectors of Peru.
- Despite the increase in domestic production of oil to 100 000 barrels per day by 2023, the lack of new investment in exploration will constrict natural gas and oil production levels in the medium-term. Between 2018 and 2050, oil production falls 49% while gas production falls 35%. These production falls increase Peru's dependency on imported fuels to satisfy growing internal energy demand, a trend that has been observed since 2010.
- Another consequence of the declining production of natural gas is that Peru will become a net importer of natural gas by 2040 (Figure 14-21). Crude oil and refined products net imports are currently offset by LNG exports. However, from 2040, LNG exports fall to zero, and Peru will require imports of natural gas for the first time. The net energy trade deficit for all energy commodities increases significantly because of this gas trade reversal.
- Imports and exports of electricity through interconnections with neighboring economies such as Ecuador and Chile are marginal and do not appear in the net energy trade balance for the projection period.

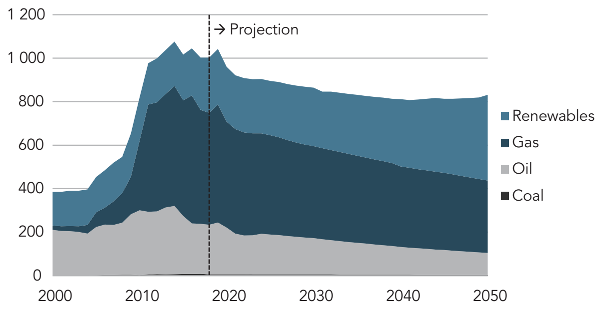
Energy supply in the Carbon Neutrality scenario

Figure 14-20. Total energy supply in CN, 2000-2050 (PJ)



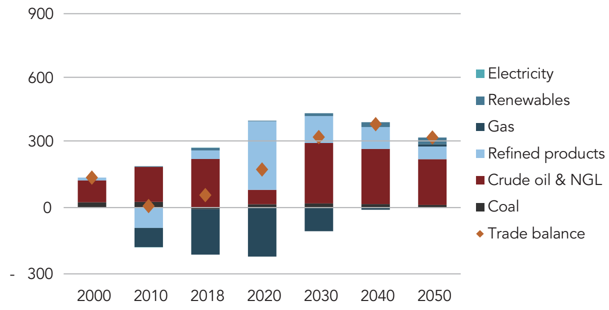
Sources: EGEDA, APERC analysis.

Figure 14-21. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-22. Net energy trade in CN, 2000-2050 (PJ)

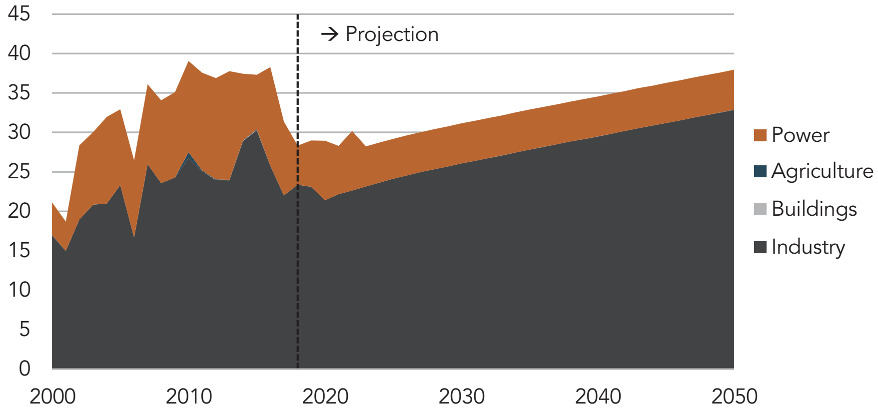


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, energy supply increases until 2030 and stays at a stable level of around 1 100 PJ until 2040. Peru's energy supply begins to fall as a consequence of the declining trend in demand discussed in the opening portion of this chapter.
- Oil declines from a 44% share of supply in 2018 to 31% in 2050. Gas increases in its share of supply from 28% to 32%. The largest growth is in renewables supply, which increases from a 25% share (predominantly hydro) to 37%. Most of this growth in renewables supply is due to the increasing levels of wind and solar power generation.
- Oil production in 2050 will be 12% lower than in REF because of the decrease in oil (refined products) demand from all end-use sectors. In CN, renewable energy production is 19% larger than REF by the end of the projection.
- Despite efforts to reduce fossil fuel demand and implement decarbonisation measures, Peru will continue to be a net energy importer due to persistent demand for crude oil and refined products out to 2050. Nevertheless, crude oil imports are one-third lower in CN than in REF. Refined products are more than 80% lower.
- In CN, Peru continues to export LNG through to the late-2040s. However, like REF, domestic production of gas is insufficient to meet domestic supply requirements. Peru requires additional gas from external sources at the end of the projection, though these requirements in 2050 are more than 90% lower than in REF.
- Energy trade in CN is more balanced, with net energy imports peaking in 2040 and slowly declining through to 2050. In CN, net energy imports are 62% lower than REF in 2050, at a level of approximately 325 PJ in CN, as opposed to 850 PJ in REF.

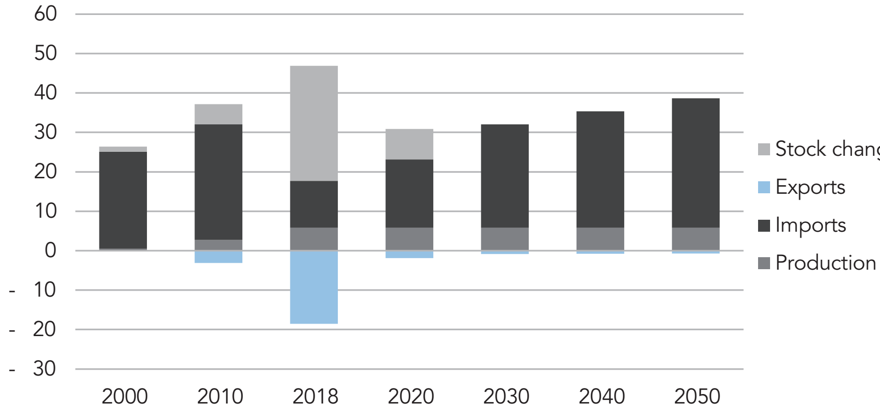
Coal in the Reference scenario

Figure 14-23. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-24. Coal production, imports, and exports in REF, 2000-2050 (PJ)

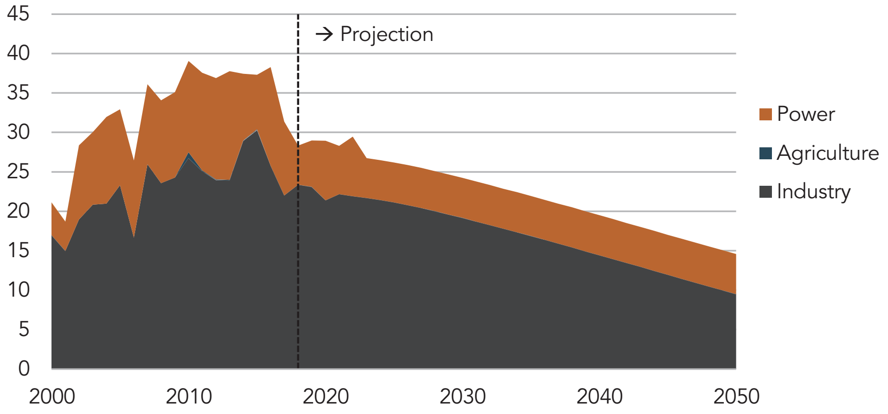


Sources: EGEDA, APERC analysis.

- Coal is consumed mainly in industry, particularly in the cement and metallurgical subsectors. The increase in activity in those subsectors will drive an increase in coal demand through to 2050.
- Peru's coal consumption increased from 20 PJ at the beginning of the millennium to a higher plateau near 35 PJ in the early-2010s. The increase in natural gas generation, and excise taxes that were imposed on coal in the late-2010s, have contributed to an observed fall in power sector coal consumption since 2016. The increase in Peru's coal consumption out to 2050 is attributable solely to the industry sector.
- Coal-fired generation in Peru's interconnected electric system (SEIN) will phase-out by 2023. The remaining lower level of power sector coal consumption is from producers that generate electricity for their own use, independent of the SEIN.
- The most abundant coal reserves in Peru are anthracite, with most of the locally produced coal corresponding to this higher energy content coal type. Bituminous coal is mostly imported, and it is this type of coal that is relied upon by domestic consumers. Colombia was the main source of bituminous coal in 2019.
- In REF, coal production will remain at historical levels of around 6 PJ through to 2050. Peru's increasing demand for metallurgical and thermal coal will be met by an increase in coal imports.
- After a fluctuating increasing trend that started in 2000, coal exports, mainly anthracite that is exported to Brazil and other markets, falls in 2020. Declining external coal demand keeps Peru's coal exports at a low level.

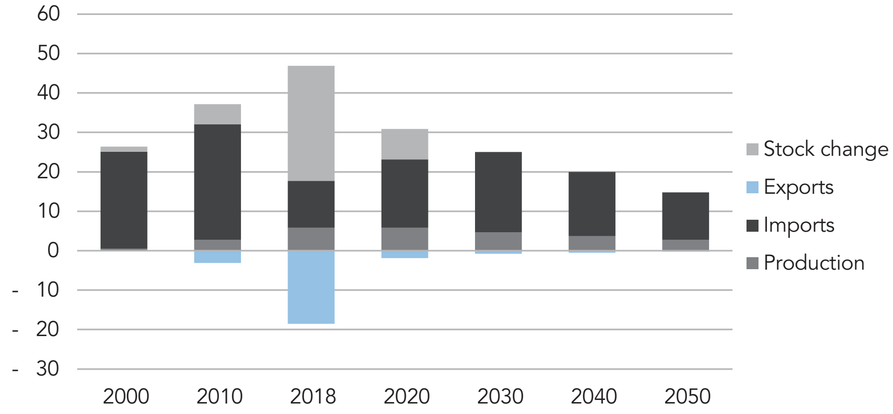
Coal in the Carbon Neutrality scenario

Figure 14-25. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-26. Coal production, imports, and exports in CN, 2000-2050 (PJ)

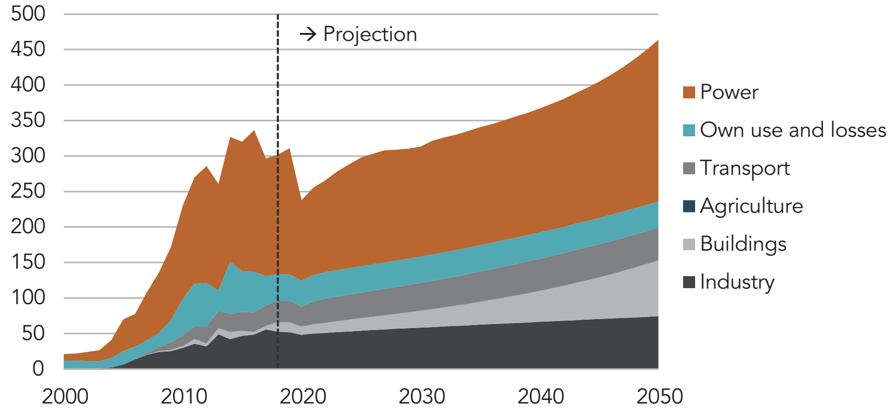


Sources: EGEDA, APERC analysis.

- In contrast to REF, industrial coal consumption in CN falls through to 2050. Power sector consumption by producers that are separate from the grid is maintained, with the fall in industrial demand driving the reduction.
- The fall in industrial demand for coal is part of the portfolio of actions that Peru is considering (and is assumed to enact) to achieve its NDC goals.
- Peru's coal consumption falls by 42% from 2018 to 2050, with consumption being 62% lower than in REF by the end of the projection.
- Improved energy efficiency, fuel switching to natural gas, and some electrification of thermal energy demand in cement facilities, brick factories, and steel-making are the main contributors to the fall in coal demand.
- The fall in coal consumption reduces the needs for domestic coal production and imports. Coal production more than halves out to 2050.
- Coal imports initially increase to more than 20 PJ in 2030, but then decline to 12 PJ by 2050. Peru's coal imports in CN are 63% lower than in REF at the end of the projection period.
- Coal accounts for a small 1.3% of Peru's energy supply by the end of the projection period in CN. However, coal's share of Peru's energy supply was still relatively low in 2018, at 2.7%. In REF, the share of coal in energy supply falls slightly to 2.4% by the end of the projection.

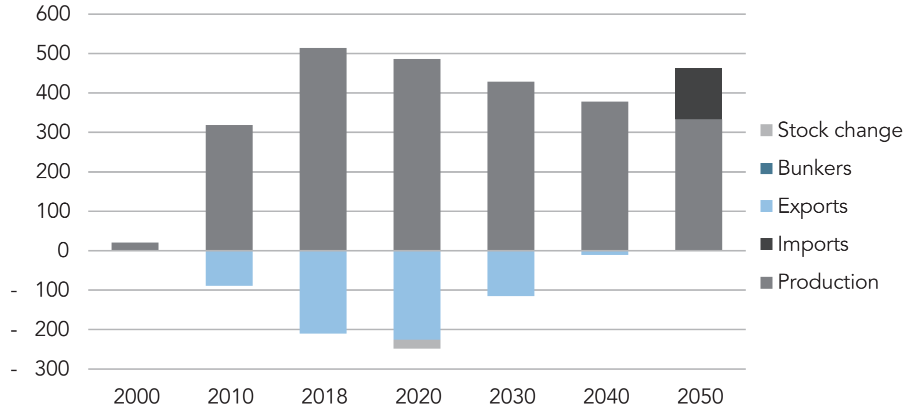
Natural gas in the Reference scenario

Figure 14-27. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-28. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

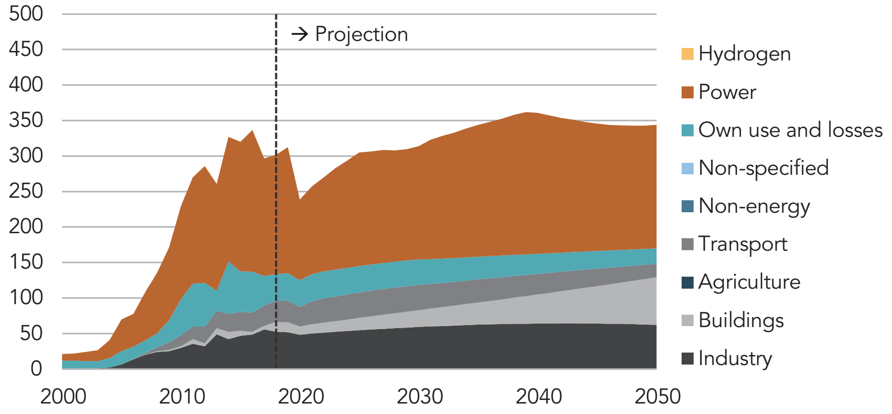


Sources: EGEDA, APERC analysis.

- Peru's main natural gas project, Camisea, became operational in 2004. Since then, and because of the implementation of policies that promoted the use of natural gas in Peru, consumption has grown seven-fold through to 2018. The power sector has driven much of this increase. Gas consumption is expected to recover from the large fall that occurred due to COVID-19, and eventually be 50% higher than 2018 levels by 2050.
- Natural gas consumption in buildings increases five-fold in REF. This sector is where the largest growth in natural gas consumption is expected because of the implementation of policies that expand natural gas coverage to different regions of Peru for residential users.
- Natural gas consumption in transport grows as more gasoline and LPG vehicles are converted to natural gas vehicles with the support of programs such as the Program for the Conversion of Vehicles to Natural gas vehicles with FISE funds.
- The power sector remains the largest natural gas consuming sector for the entire projection period. Increasing natural gas generation will be required to meet the challenge of the increased deployment of variable solar and wind capacity.
- By 2050, Peru will transition to becoming a net importer of natural gas. Natural gas production levels are anticipated to decline due to lack of investments to increase production. Natural gas imports begin in 2041 and increase to 130 PJ by 2050. Peru's energy self-sufficiency will fall due to reliance on these imports.
- A larger and larger proportion of domestic natural gas production is consumed by domestic consumers, until exports eventually cease in 2040. Domestic production is then insufficient to meet domestic demand, necessitating imports. Peru's transition from a natural gas exporter to importer will negatively impact Peru's balance of trade. Natural gas is currently an important source of trade income for Peru.

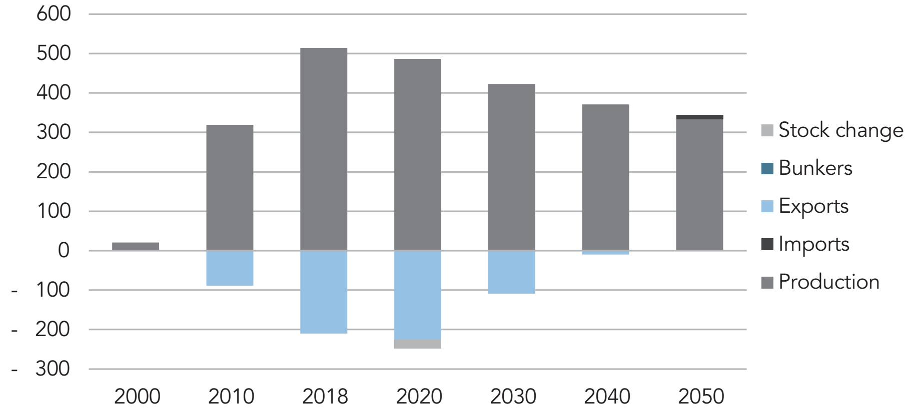
Natural gas in the Carbon Neutrality scenario

Figure 14-29. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-30. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

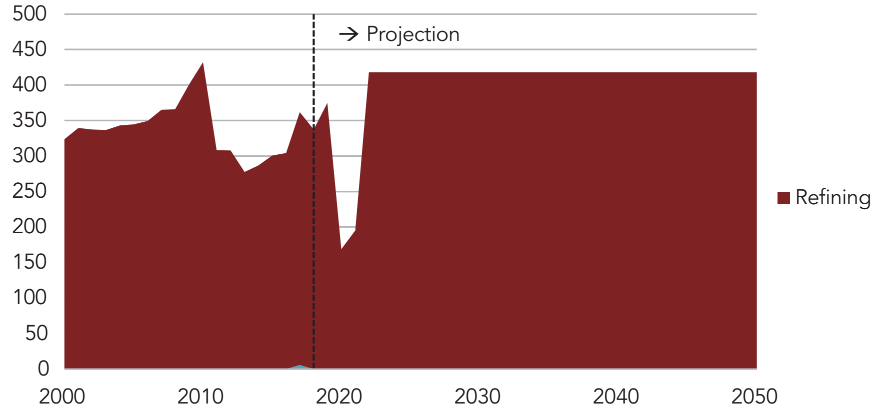


Sources: EGEDA, APERC analysis.

- In CN, natural gas consumption peaks in 2039 at 360 PJ. The main reason for this peak is that higher penetration of solar and wind begins to displace baseload natural gas generation. Peak natural gas consumption is only marginally higher than the more recent peak in 2016.
- When compared with REF, natural gas consumption falls by 25% in 2050. Consumption in the power sector is lower by 24%; transport by 59%; buildings by 15%; and industry by 16%.
- While natural gas consumption by buildings in CN is lower than in REF, there is still significant growth from current consumption levels. This result emphasises the importance of natural gas to enable residential consumers to switch away from traditional biomass. The lower levels of buildings consumption of natural gas in CN is partially due to greater levels of energy efficiency.
- Natural gas imports begin, and exports cease, in 2048. The modelled levels of imports in CN are 92% lower than in REF by the end of the projection period.
- In 2050, natural gas imports account for only 3% of natural gas supply (10 PJ). The relatively low level of imports may instead be met by a reduction in domestic natural gas consumption, such is the uncertainty that accompanies modelled results at the end of the projection.
- Peru has an export LNG port terminal, but gas imports will require additional investment in infrastructure for LNG regasification and storage or the construction of a network of gas pipelines to transport imported gas.

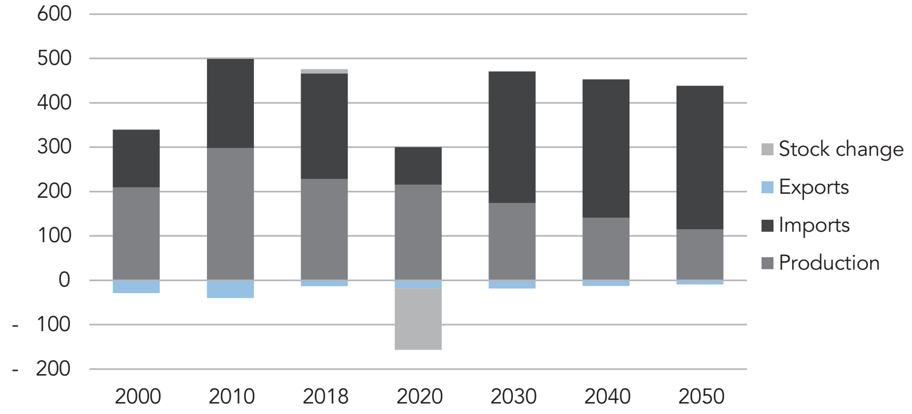
Crude oil and NGLs in the Reference scenario

Figure 14-31. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-32. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

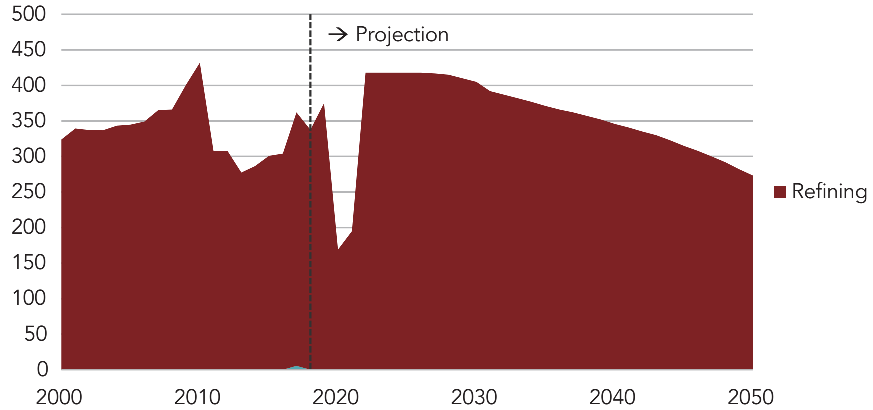


Sources: EGEDA, APERC analysis.

- Peru has seven refineries with a total capacity of 216 700 barrels per day (equivalent to 402 PJ per year). The main two refineries are La Pampilla and Talara.
- In 2022, the Talara refinery will be upgraded, increasing its capacity to 95 000 barrels per day. This increase will mean that Peru's total refining capacity will increase 456 PJ per year. From 2022 to 2050, it is assumed that there is no additional capacity and that refineries operate at a 90% capacity factor.
- Crude oil production declines at a CAGR of 2% from 2020 to 2050, which is an extension of the downtrend observed from 2010 to 2018. The decline highlights that crude oil production will decline unless investment in exploration is increased. The assumptions made in REF show that crude oil production will halve out to 2050.
- In order to sustain refining output with declining domestic production of crude oil, imports of crude oil will increase at a CAGR of 4.6% from 2020 to 2050. The increase in imports of crude oil will sustain domestic refining output so that domestic refineries continue to satisfy a large proportion of Peru's demand for refined products.
- Lower crude oil production ultimately increases Peru's oil import dependence.

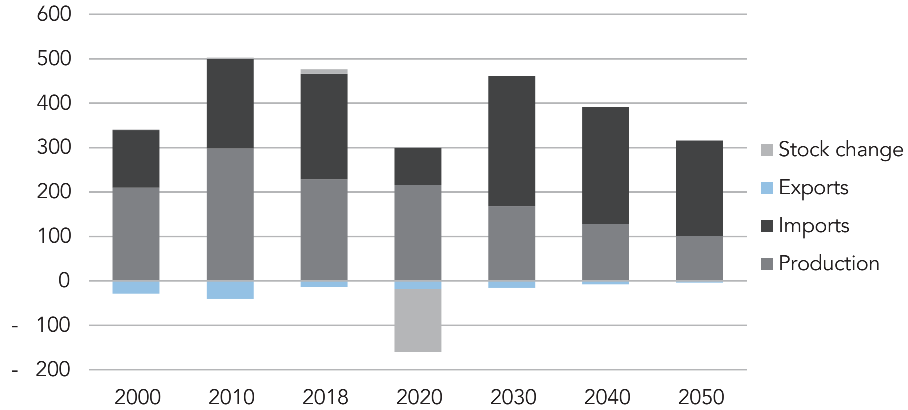
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 14-33. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-34. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

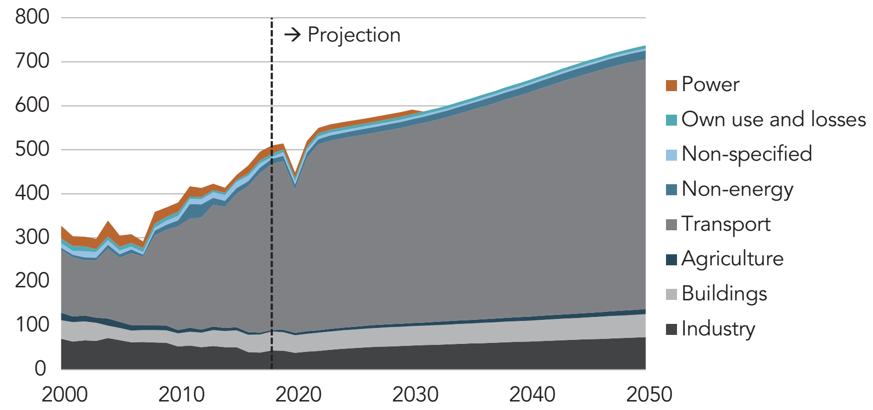


Sources: EGEDA, APERC analysis.

- Crude oil consumption declines in CN due to declining demand for refined products in end-use sectors, particularly within the transport sector.
- There are no assumed refinery closures in Peru in CN. A greater reliance on domestic refinery output, rather than imports of refined products, supports Peru's refineries. However, refinery capacity factors fall, given the very large fall in demand for refined products out to 2050.
- Refinery crude oil consumption falls by 35% from 2022 to 2050.
- In CN, crude oil production falls at a slightly faster rate than in REF. Production more than halves out to 2050, at a level of just over 100 PJ.
- Crude oil imports are assumed to recover strongly following the lower demand from refineries in 2020, that resulted from the COVID-19 pandemic. Peru's refineries are assumed to be consuming crude oil at pre-pandemic levels by 2022.
- Like REF, the fall in crude oil production requires significant crude oil imports to feed Peru's domestic refineries. However, the peak in demand for refined products in the mid-2020s means that crude oil imports also peak in the mid-2020s, at just over 300 PJ. Imports of crude oil then proceed to fall to 210 PJ by the end of the projection.

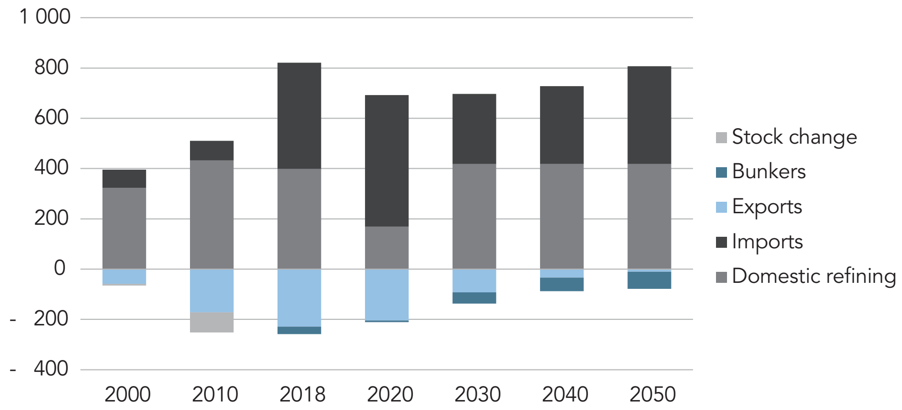
Refined products in the Reference scenario

Figure 14-35. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-36. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

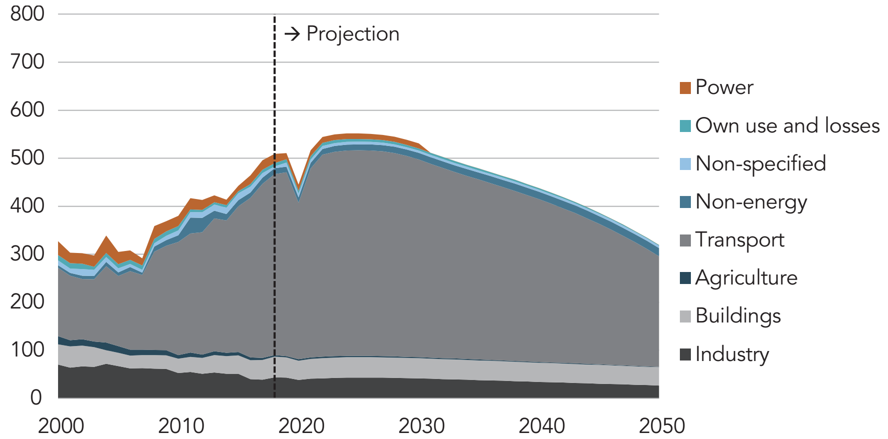


Sources: EGEDA, APERC analysis.

- Gasoline and diesel are the main refined products consumed in Peru, and consumption is mainly within the transport sector. Around 52% of the consumption in transport is diesel, and 24% corresponds to gasoline in 2018.
- Diesel's relative share of transport consumption in Peru is much higher than in most other APEC economies. This is because of the high demand in heavy duty vehicles for passenger and freight and the lack of road infrastructure and other long-distance transport modes such as trains. Additionally, Peruvian geography requires the connection of low-altitude and high-altitude regions which is challenging for alternative fuels such as gaseous ones.
- Industry consumption of refined products grows to become the second largest consuming sector by the end of the projection period. Much of this consumption is associated with Peru's mining industry.
- Domestic refinery output stabilises following the COVID-19 pandemic and remains at a constant level through to 2050. To meet increasing demand, Peru will rely on an increasing level of refined products imports. Imports will grow to account for almost half of Peru's demand for refined products by 2050.
- Exports of refined products decline drastically in REF, falling from 199 PJ in 2018 to 10 PJ in 2050. The fall in exports is predicated on the fact that domestic consumption is prioritised ahead of export market demand.
- Bunkers supply, which represents international marine and aviation consumption of refined products, about tenfold from 7 PJ to 69 PJ in 2050.

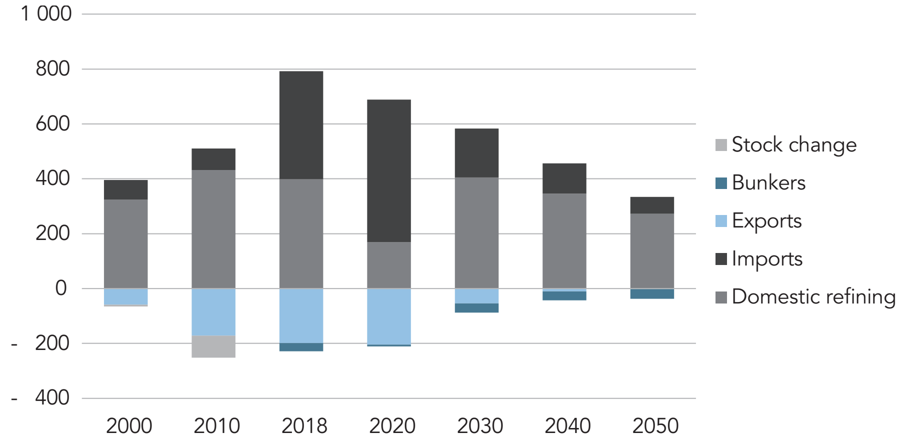
Refined products in the Carbon Neutrality scenario

Figure 14-37. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 14-38. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

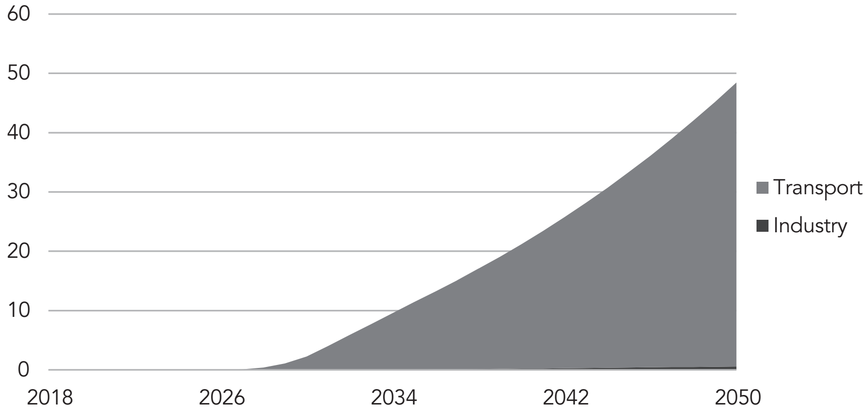


Sources: EGEDA, APERC analysis.

- The consumption of refined products in CN is still largely driven by the trends in the transport sector. However, consumption of refined products is lower than REF in all sectors. The lower levels of consumption are mostly associated with fuel efficiency and electrification in multiple end-use applications.
- In transport, diesel consumption falls by 24% and gasoline falls by 47% from 2018 to 2050. Diesel demand is more robust due to greater difficulty in switching away from diesel in applications such as heavy trucking.
- Domestic output of refined products increases from 2018 to the mid-2020s, though there is a fall of more than half associated with the COVID-19 pandemic in 2020.
- Following peak refinery output in the mid-2020s, refinery output falls to 260 PJ in 2050. An increasingly large share of the output is consumed by the domestic market. Exports of refined products are close to zero in 2050 in CN.
- Imports of refined products fall by 74% from 2018 to 2050. The share of imported refined products that satisfy internal demand declines to 19% in 2050. For 2020, imports are larger than domestic consumption, though this was an anomalous year with atypical behaviour due to the pandemic.
- The very low levels of exports by 2050 is partially due to diminishing demand for refined products in international markets. Domestic demand is also assumed to be prioritised ahead of exports.

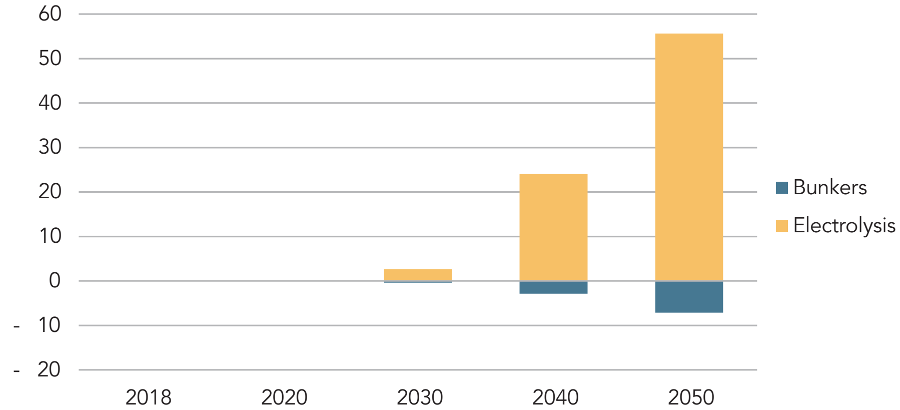
Hydrogen in the Carbon Neutrality scenario

Figure 14-39. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 14-40. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

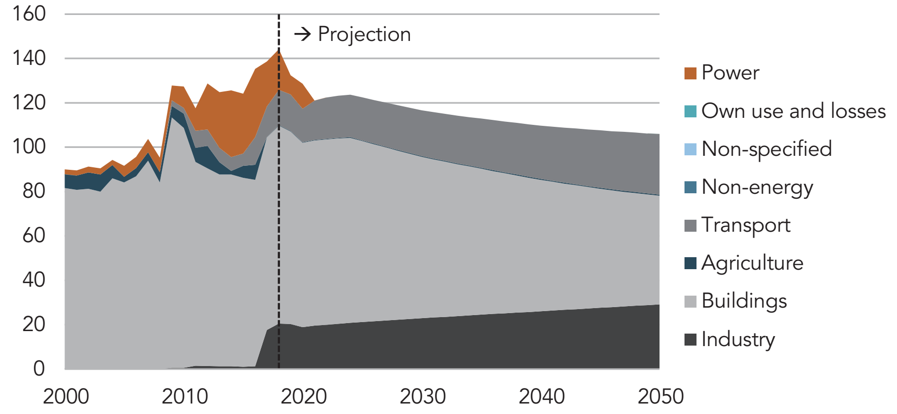


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolyser processes (green).

- Peru does not have an official document that describes a strategy regarding hydrogen. The demand for hydrogen was primarily estimated using potential markets for fuel cell vehicles.
- As a result of the demand projections, hydrogen begins to be consumed in 2026 in CN. The initial consumption is from small pilot projects, with commercial use of hydrogen ramping up from around 2030.
- Hydrogen vehicles penetration is greatest for freight transport, with these vehicles growing to account for 15% of the freight vehicle stock by 2050.
- Hydrogen and derivatives, such as ammonia, is assumed to be used for international maritime transportation, as captured by bunkers supply. In a world that is aiming to achieve carbon neutrality, it is assumed that green hydrogen is preferred whenever possible. Such a preference is likely to be supported by policy intervention.
- Abundant renewable energy resources, such as hydro, solar, and wind, make Peru a candidate for being a competitive green hydrogen producer.
- There are potential geological sites that can be used for carbon storage on the eastern side of the Andes. However, the potential sites are difficult to access. Access difficulties means that carbon capture technologies are unlikely to be implemented in Peru. It is assumed that Peru will produce green hydrogen through electrolysis and renewable electricity.

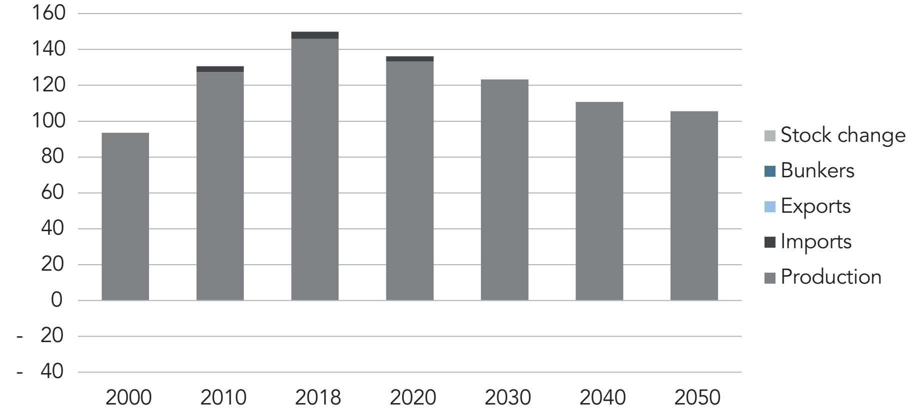
Bioenergy in the Reference scenario

Figure 14-41. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 14-42. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

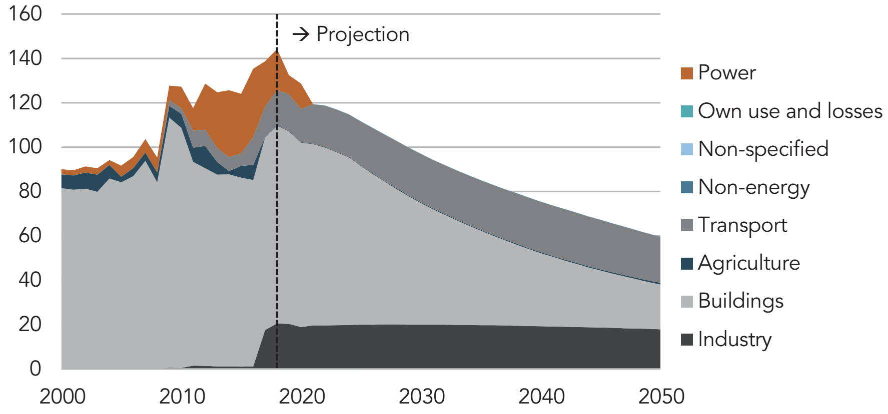


Sources: EGEDA, APERC analysis.

- Traditional biomass, such as fuelwood, is currently the main source of energy consumed by Peru's residential sector. Peru has been implementing programs that intend to reduce traditional biomass consumption for cooking in rural areas due to negative health and emissions effects.
- Buildings sector biomass consumption falls by 45% through to 2050. The reduction is due to an increase in energy efficiency of fuelwood stoves and widespread switching from fuelwood to LPG, and to a lesser extent, electricity. The reduction of this type of renewable energy consumption is a desirable outcome.
- Bioenergy consumption in industry is in the form of modern biomass, such as pellets and other types of energy-rich biomass. Peru's industry sector output increases through the projection period, and a significant portion of this output continues to rely on modern biomass energy sources. Industrial consumption of renewables increases by 42% out to 2050.
- Peru has biofuel blending requirements for gasoline (7.8% ethanol) and diesel (5% biodiesel) in multiple Peruvian regions. A projected increase in refined products in those regions will drive a 70% increase in biofuels consumption from 2018 to 2050.
- Domestic supply of bioenergy is assumed to be met almost exclusively by domestic sources.

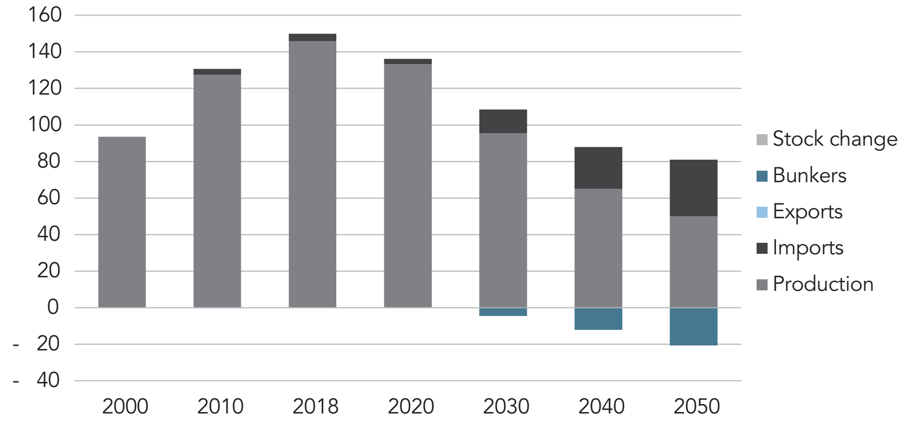
Bioenergy in the Carbon Neutrality scenario

Figure 14-43. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 14-44. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

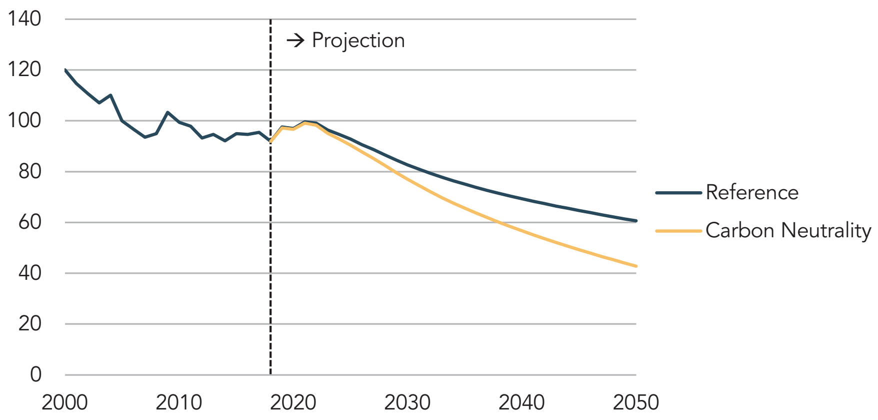


Sources: EGEDA, APERC analysis.

- Replacement of fuelwood with more efficient fuels such as LPG and electricity is much higher in the residential buildings sector in CN. Improved energy efficiency also contributes to even lower biomass consumption levels in buildings.
- While efficiency and fuel switching levels are significant, traditional fuelwood is not eliminated due to challenges in reaching isolated populations with effective alternative fuels. Fuelwood consumption in 2050 is 23% of the 2018 level. Part of the remaining consumption of fuelwood is from restaurants in the commercial and services portion of the buildings sector.
- Transport biofuels consumption in CN is almost one quarter lower than in REF. Greater fuel efficiency and lower demand for refined products is what drives this result. An increasing role for biofuels in domestic aviation mean that biofuels consumption does not fall as much as refined products consumption.
- Industrial sector consumption of modern biomass is lower than in REF due to greater levels of energy efficiency, and electricity out-competing biomass in certain end-use industrial applications.
- Local production of bioenergy falls further than domestic consumption. This is because the increase in demand for refined biofuels for aviation is assumed to be met by imports.
- In CN, bunkers supply captures the demand for biofuels by international aviation.

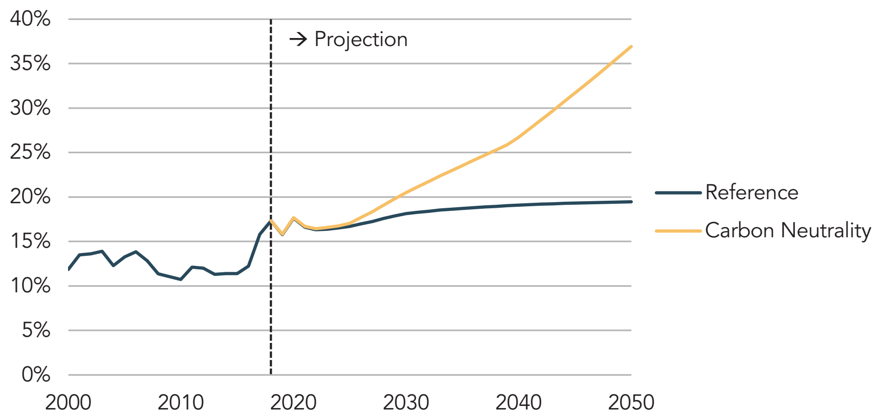
Energy intensity and modern renewables share

Figure 14-45. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 14-46. Modern renewables share in REF and CN, 2000-2050



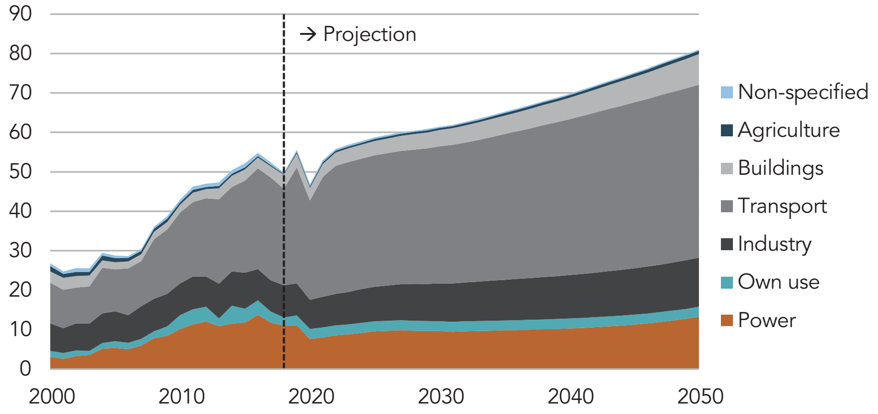
Sources: EGEDA, APERC analysis. Note: Modern renewable include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- APEC aspirational energy goals are set at the aggregate regional level and are not goals for each individual economy. The first goal is to reduce energy intensity by 45% by 2035 (base year 2005). The second goal is to double the share of modern renewables in the energy mix by 2030 (base year 2010). Modern renewables do not include traditional biomass, such as fuelwood consumed in isolated areas for cooking, but includes electricity generated from renewable energy sources.
- Peruvian final energy intensity declined from 2005 to 2014, then increased to 2018 when it reached almost the same level as in 2005. This behavior is due to the deceleration of economic growth after 2014.
- After a brief decline from 2018 to 2020, and growth due to COVID-19, energy intensity improves at a CAGR of 1.6% from 2020 to 2050 in REF. This rate is higher than the CAGR trend of 1.1% observed from 2000 to 2020. Energy intensity improves 25% by 2035 (base year 2005). The improvement is 40% by 2050.
- In CN, energy intensity improves from 2020 to 2050 at a CAGR of 2.7%. Energy intensity is 35% lower by 2035 (base year 2005). The improvement is 57% by 2050.
- Traditional biomass is very important in the Peruvian energy mix with implications for pollution, deforestation, and unsustainability. Traditional biomass is an indicator of lack of access to modern and more efficient renewable energies. In contrast, modern renewables are associated with desirable outcomes.
- In REF, Peru's modern renewable energy share increases from 16% to almost 20% by 2050. In CN, the share increases to almost 37% by 2050. The main difference between both scenarios is the increase in electricity generated from modern renewable sources, mainly wind and solar.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

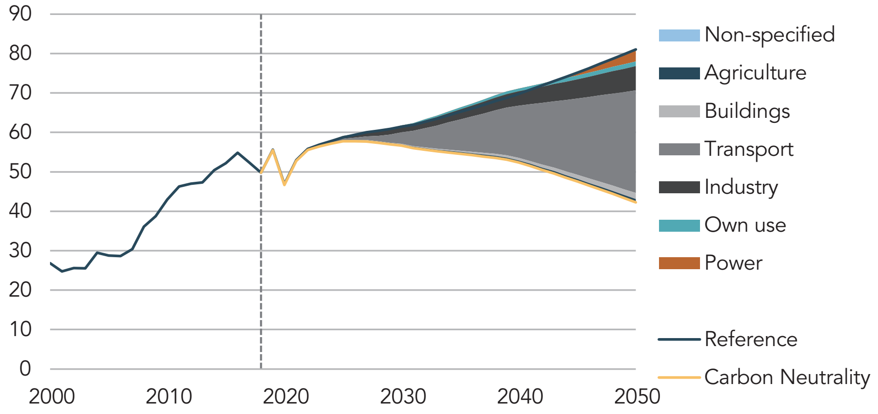
Gross CO_2 emissions

Figure 14-47. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 14-48. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

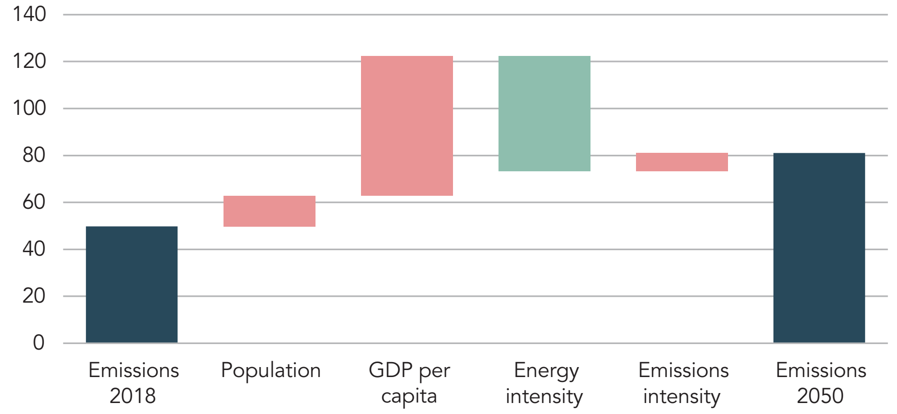


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- CO_2 emissions are calculated from direct combustion, and do not account for other GHG emissions. In 2018, energy related emissions reached 54 $MtCO_2$. Over half of these emissions came from the transport sector (54%).
- In REF, emissions rise to 81 $MtCO_2$ in 2050. Under this path, emissions reach 62 $MtCO_2$ by 2030, which represents 29% of the new unconditional NDC goal (209 $MtCO_2$-e). Under this scenario transport continues to be the most emitting sector in Peru.
- In CN, transport drives CO_2 emission reductions. Given the share of transport in the final energy demand, measures focused on that sector are key to achieving the economy's decarbonisation goals. Transport CO_2 emissions reach 44 $MtCO_2$ in 2050, 62% of the transport emissions in 2018.
- In CN, total emissions peak at 58 $MtCO_2$ in 2025. Assumed decarbonisation measures drive emissions down to 42 $MtCO_2$ by 2050. Under this path, emissions are 58 $MtCO_2$ in 2030, which represents 27% of the new conditional NDC goal (209 $MtCO_2$-e). Transport emissions fall to 17.9 $MtCO_2$ in 2050, a reduction of 59% when compared to REF.
- Given the increase in electricity demand in CN, emissions in the power sector grow faster than in REF from 2018 to 2043. The early rise of electricity demand will require additional investment in natural gas thermal power generation in addition to renewable energy power generation. However, after 2043, this trend changes as additional solar and wind electricity capacity is incorporated.
- Power sector CO_2 emissions fall to around 10 $MtCO_2$ in 2050 in CN (3 $MtCO_2$ less than the result in REF). This result shows that electrification of energy demand as a decarbonisation measure is effective when it is coupled with the decarbonisation of the power sector. This is particularly relevant when discussing the promotion of EVs.

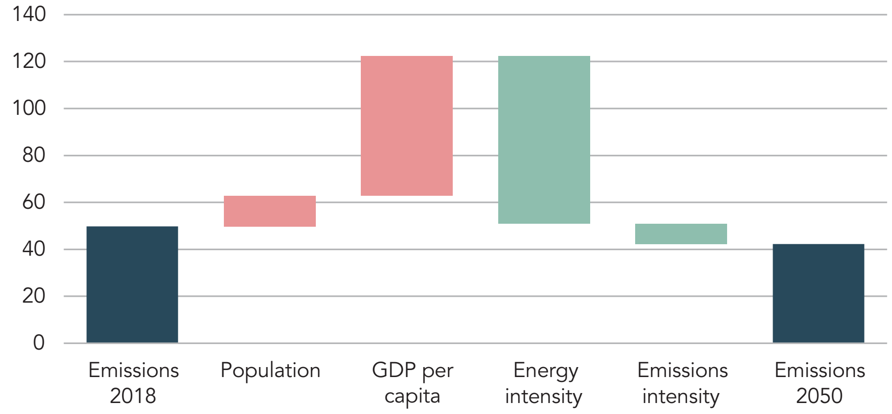
Components of CO_2 emissions

Figure 14-49. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 14-50. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- The energy sector in Peru emitted 54 $MtCO_2$ in 2018, which is the 16th highest in APEC (out of 21 economies).
- Economic and population growth drive emissions. It was estimated that an additional 79 $MtCO_2$ could be emitted in 2050 because of those factors alone, which is more than double the 2018 level.
- In REF, emissions growth is curbed by improvements in energy intensity due to an overall increase of energy efficiency. This reduction is estimated to be 49 $MtCO_2$. On the other hand, emissions intensity increases emissions by almost 8 $MtCO_2$ due to the use of fossil fuels to support economic growth, mainly in transport and industry. CO_2 emissions in 2050 are 81 $MtCO_2$, 51% more than in 2018. This represents an increase in emissions per capita of 18% by 2050.
- In CN, due to more ambitious energy efficiency goals and a more aggressive transition away from fossil fuels, there are greater improvements in energy intensity and emission intensity. Energy intensity improvements save 71 $MtCO_2$ and emissions intensity improvements save 8 $MtCO_2$. Emissions at the end of the projection are 15% lower than in 2018.
- Emissions intensity can be further improved by decreasing the share of fossil fuels in the energy supply. The effect of electrification on emissions intensity is observed in the simulated scenarios. One strategy to improve emissions intensity is more aggressive electrification, especially in transport, accompanied by higher participation of renewable energies in electricity production.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

APEC Energy fact-sheets. https://www.apec.org/about-us/about-apec/fact-sheets/energy

COES. https://www.coes.org.pe/Portal/home/

International Energy Agency. https://www.iea.org/countries/peru

Ministry of Energy and Mines. https://www.gob.pe/minem

Ministry of Environment. https://www.gob.pe/minam

National Energy Balance. https://www.gob.pe/institucion/minem/colecciones/3209-balance-nacional-de-energia

National Energy Policy 2010-2040. https://www.gob.pe/institucion/osinergmin/normas-legales/738497-064-2010-em

NDC updates report. https://www.gob.pe/institucion/minam/informes-publicaciones/1682641-reporte-de-actualizacion-de-las-ndc-del-peru-al-2030

Osinergmin. https://www.osinergmin.gob.pe/SitePages/default.aspx

15. The Philippines

Highlights

Demand

- End-use energy demand is expected to increase 126% between 2018 and 2050 in REF. Electricity accounts for 42% of total demand, followed by oil and refined products (39%).
- In CN, energy demand grows only 71%. The share of electricity increases to 58%, followed by oil and refined products (26%).
- Buildings sector energy demand grows 166% in REF, driven by increased electricity use within the services and residential subsectors. In CN, enhanced efficiency measures limit demand growth to 96%.
- Demand in the transport sector increases 59% (REF). In CN, transport demand grows by only 13%, driven by reduced refined products demand. Electricity reaches 28% share of transport energy demand.
- Industry sector energy demand (excluding non-energy) grows 152% as the Philippines continues to boost industrial outputs. Coal demand grows the most to support non-metallic minerals, pulp and paper, and the iron and steel subsectors. In CN, enhanced fuel switching sees electricity replacing coal as the dominant fuel (21% share).

Supply

- Energy supply more than doubles in REF (2018-2050).
- Gas production from Malampaya field declines leading to LNG imports, with gas supply increasing over 600%. The increasing reliance on imports, particularly of refined products and LNG, decreases the self-sufficiency level from 49% to 35% (2018-2050).
- In CN, energy supply grows at a slower rate by almost double between 2018 and 2050.
- The decreasing share of coal and oil pushes the renewables share up to 35% in 2050 in CN. In addition, improvements in the domestic production increases the overall self-sufficiency to 43% in 2050.

Power

- Electricity generation increases over 320% in REF (2018-2050), with generation from gas being the most dominant after coal. Around 40 GW of solar and wind capacity is installed by 2050.
- Electricity generation grows a similar amount in CN. Solar and wind power capacity grows more significantly, reaching 51 GW in 2050.
- Moratorium directives from the government are expected to halt new coal-fired power plants. Carbon capture and storage (CCS) units begin operating in 2035, which help further decarbonise the power sector.

CO_2 emissions

- Strong energy demand and reliance on fossil fuels lead to CO_2 emissions growing over 140% in REF. The power sector remains the largest source of energy-related CO_2 emissions in 2050.
- Half of the CO_2 emissions reduction in CN comes from the power sector, driven by significant transition towards renewables power and the use of CCS units. In addition, large-scale electrification in the transport sector further reduces CO_2 emissions by 33%.
- Achieving "full" carbon neutrality in the Philippines would require additional measures from non-energy sectors, particularly through CO_2 sequestration from the forestry sector through forest rehabilitation and reforestation as indicated in the Philippine's updated NDC. This could be an area for collaboration between APEC economies in the future.

About the Philippines

- The Philippines is an archipelago located in the Pacific Ocean near the equator. Covering a total area of 343 448 square kilometres (km^2), it comprises 7 641 islands, about 2 000 of which are inhabited. The archipelago comprises three major island groups: Luzon, Visayas, and Mindanao. The capital city, Manila City, is located on Luzon island.
- The Philippines has substantial geothermal energy resources, due to its proximity along the Pacific 'Ring of Fire'. The economy was the third-largest geothermal energy producer in the world in 2019, with 1.9 GW of installed geothermal power capacity. Based on IRENA's compilation, this placed the Philippines behind the United States (2.6 GW) and Indonesia (2.1 GW).
- In 2018, GDP was around USD 908 billion in 2018, a 6.3% increase from 2017. Investment and business activities were the main drivers for this growth, despite weak performance in energy net exports.
- Population grew by over one million people in 2018 from 2017.
- Energy self-sufficiency remains an issue for which the government is committed to improve through strengthening of indigenous exploration and production of oil and gas, in addition to deployment of renewable energy resources.
- The Philippines has 215 million barrels of oil reserves (including condensate) and 2 360 million tonnes of coal reserves that are potentially recoverable.
- The Philippines' Department of Energy (DOE) estimated that its natural gas reserves figure stood at 3 376 PJ in 2018. However, with the anticipation of Malampaya gas field depletion, the Philippines through the DOE has outlined plans to develop LNG infrastructure to facilitate imports.

Table 15-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	106.7	3.7%	7
GDP	930.4	1.3%	12
TPES	2 648.5	0.8%	14
Production	1 403.4	0.4%	13
Imports	1 580.4	1.3%	13
Exports	204.0	0.2%	17
Electricity generation	99.8	0.6%	14
Heat production	0	0%	9
CO_2 emissions	127.2	0.6%	14

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 15-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	24 842	46	–	–
Natural gas	3 376	32	–	–
Oil	1 315 370	49	–	–
Uranium	–	–	–	–

Notes: Coal, natural gas, and oil (PJ) in 2018 from the Philippines Department of Energy (DOE). See Appendix for conversion to other units. Years of production are approximate.

Note: GDP is expressed in terms of Purchasing Power Parity (PPP), constant 2018 USD.

Energy policy context and recent developments

- In conjunction with the government's long-term vision of *AmBisyon Natin 2040* (Our Ambition 2040), the DOE reaffirms its commitment to attain clean energy future, in line with inclusive and equitable growth, in addition to enhance its energy security. This is reflected in the recent publication by the government on the updated Philippines Energy Plan (PEP) 2020 – 2040.
- The impending depletion of the Philippines' largest offshore gas field, Malampaya, implies that the government must ensure continuity in maintaining and increasing the domestic gas supply, particularly for the power sector. Therefore, the DOE has approved seven potential LNG terminals projects within the Batangas and Quezon provinces in the main Luzon island.
- Being a net importer of crude oil and refined products also poses various challenges in maintaining and enhancing its domestic crude oil supply. As much of its crude oil supply is sourced from the Middle East counterparts, occasional conflicts and crisis within the region makes the Philippines vulnerable to supply disruption. To mitigate this, the DOE has lifted the moratorium on oil and gas activities within the West Philippine Sea (WPS), in line with President Rodrigo Duterte's policy on the Philippines' energy security and exercise of the Philippines' sovereign rights.
- In April 2019, President Duterte signed into law the Energy Efficiency and Conservation Act (Republic Act No. 11285) that allows the Philippines to institutionalise and scale up its goal of sustainable and efficient use of energy. This will also allow incentives to be granted to energy efficiency and conservation projects. The Act sees the establishment of an Inter-Agency Energy Efficiency and Conservation Committee (IAEECC) which functions to evaluate and approve the government's energy efficiency and conservation projects as well as provide strategic direction towards establishment of the Government Energy Management Program (GEMP). In making energy efficiency a 'Way of Life' in the Philippines, the Clean Energy Scenario under the PEP 2020 – 2040 seeks to attain the 5.0% energy savings from oil and electricity by 2040.
- Renewable energy deployment in the Philippines has been governed under the Renewable Energy Act (Republic Act No. 9513) since it was first enacted in 2008. The Act functions to establish the framework to expedite development of renewable energy and utilisation of alternative fuels in the economy, which has seen increases in its share in both power and power-applications.
- In December 2020, the government issued a moratorium that will be enforced on green-field coal-fired power projects, aiming at building more sustainable, resilient and flexible power systems that can accommodate new and cleaner technological innovations. In line with the moratorium, the government now allows a complete foreign ownership in large-scale projects on geothermal energy, ranging from exploration, development and utilisation.
- The Philippines recently updated its Nationally Determined Contributions (NDC) in April 2021 that aims to reduce the economy's 2030 emissions by 75%, which is 5.0% higher than the target laid out in the previous NDC. Out of the 75% target, 72.29% reduction shall be met through international support while the remaining 2.71% is via domestic action. Despite this ambitious target, energy sector only accounts for between 1.0% and 2.0% of the overall target, as the government appears to pursue forest reforestation, rehabilitation and conservation.
- In February 2022, President Duterte signed the Executive Order 164 – Adopting a National Position for a Nuclear Energy Program and for Other Purposes. This signals the economy's first step towards inclusion of nuclear into the Philippines' energy supply mix, as the Philippines aims to reduce its reliance on coal-fired power plants to achieve its NDC target.

Note: Policy context and notable developments are current as of February 2022.

Scenarios in the 8th Edition

- **The Reference scenario (REF)** is guided by *AmBisyon Natin 2040* and the PEP 2018 – 2040. With Duterte's administration centering its economy rebuilding around 'Build, Build, Build' (BBB) Program, energy supply and demand are set to continue trending upwards.
- **The Carbon Neutrality scenario (CN)** is somewhat guided by the PEP's Clean Energy Scenario but considers other potential options that the Philippines can consider to support carbon neutrality, while realising its *AmBisyon Natin 2040* and the BBB Program.
- Both REF and CN incorporate the same macroeconomic projections for GDP and population.
- In REF, energy demand projections are based on historical trends and influenced by projected growth of the Philippines' economic developments. On the supply side, fossil fuels continue to play an important role in accompanying economic growth, albeit with gradual penetration of renewables.
- LNG imports are expected to secure the Philippines' gas supply, with the impending depletion of Malampaya field being considered in REF and CN. This ensures a secure and continuous supply of LNG for the power sector, which has been the consumer of Malampaya gas since 2001. While gas and coal remain important fuels for providing baseload electricity in the power sector, the government aspires to increase the share of renewables electricity in REF. Carbon capture and storage (CCS) units are expected to further decarbonise the economy's power sector, in addition to significant expansion of renewables.
- The electric vehicles (EVs) fleet is expected to gradually enter the transport sector mix with policy interventions. The industry sector is expected to follow the historical trend.
- CN is intended as a guide to show the magnitude of CO_2 reductions possible in the context of the assumptions made about technology diffusion, costs, and global trends.
- CN can be used to quantify the magnitude of remaining CO_2 emissions that would require further action from policymakers, industry participants, and researchers.

Table 15-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for the Philippines

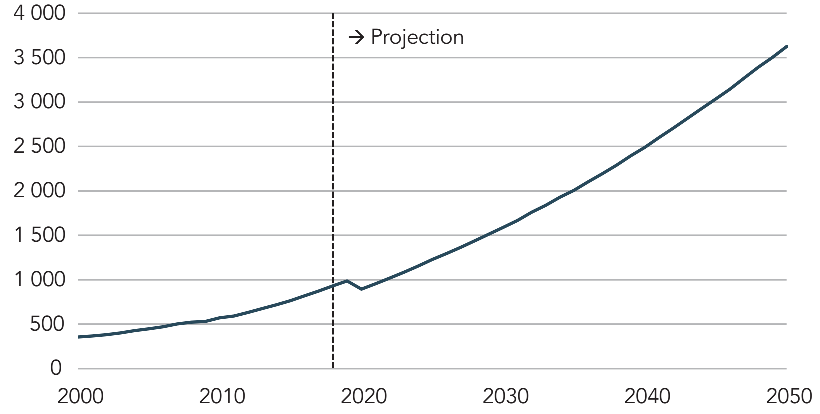
Table 15-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• GDP: APERC Solow-Swan model • Population: WDI, UN DESA projections	• GDP: APERC Solow-Swan model • Population: WDI, UN DESA projections
Buildings	• Guidelines on Energy Conserving Design on Buildings • Development and compliance to Minimum Energy Performance (MEP) standards • 100% household electrification of all off-grid areas	• Guidelines on Energy Conserving Design on Buildings • Development and compliance to MEP standards • Net-zero buildings
Industry	• Demand continues to expand, following the government's Manufacturing Resurgence Program (MRP) and BBB Program.	• CCS uptake for heavy industries begins in 2030 • Hydrogen uptake for steel and chemical industries begins 2030 • Fuel-switching from coal and oil to gas, biomass, electricity, and hydrogen • Clinker-to-cement ratio improvement in cement industry
Transport	• Gasoline and diesel remain the dominant fuels (91% share) • EVs make up about 8% of the total vehicles stock by 2050	• EVs make up about 32% of the total vehicles stock by 2050 • Fuel-cell vehicles (FCVs) share increases to 11% of the total stock
Power and heat	• Coal and gas-fired units are used to meet rapidly increasing electricity demand	• CCS-equipped gas power plants adoption from 2035 • Increased adoption of renewables technologies • No hydrogen consumption or co-firing coal units as we expect other technologies to be more cost competitive
Supply	• Coal: production to reach almost 300 million tonnes • Oil: production follows a general natural decline • Gas: The Malampaya field is expected to be depleted in 2025 Production continues in new fields in 2029 that ramps up to full capacity in 2036. • LNG: A total of six new LNG terminals are considered by 2050.	• Projection of fossil fuel is driven by domestic demand trends in CN, plus assumption of export markets and some APEC-driven coal trends.
Climate	• 75% emissions reduction by 2030 (updated NDC)	• Carbon neutral in 2050

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

Macroeconomic backdrop

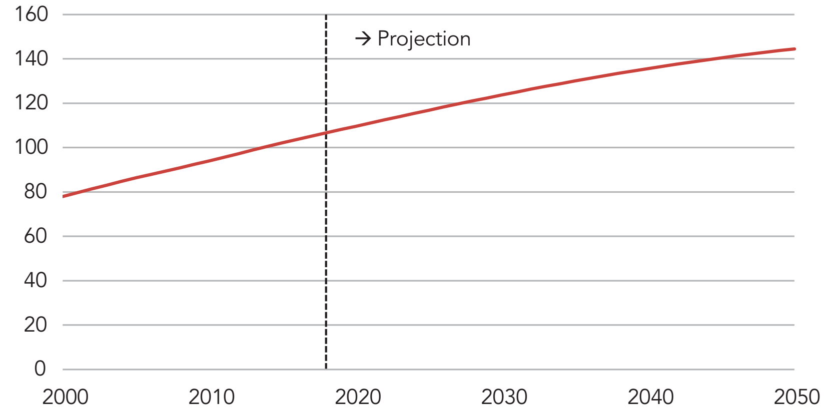
Figure 15-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

- Over the past two decades, the Philippines has experienced impressive economic growth, posting an average growth of 5.4% per year between 2000 and 2018, due to significant economic and fiscal reforms. The services sector has been the leading sector, which now employs more than half of the economy's total workforce, and therefore accounting for more than half of the overall sectoral GDP share.
- The substantial growth in services sector has been largely driven by its Business Process Outsourcing (BPO) industry. The success of this industry is due to the workforce that comprises young and educated Filipinos with high English proficiency. In addition, it continues to entice global investments, particularly from the United States, which is the Philippines' largest market. As of the end of 2017, Reuters reported that over one million people have been employed by the BPO industry alone.
- The success of export services through Overseas Filipino Workers (OFWs) provides another impetus to the economy's GDP growth. Remittances from abroad continue to expand, reaching 10% of total GDP in 2018.
- The outbreak of COVID-19 plunged the Philippines into its first recession in 2020 as domestic demands and business investments were severely hit due to strict lockdowns.

Figure 15-2. Population in millions, 2000-2050

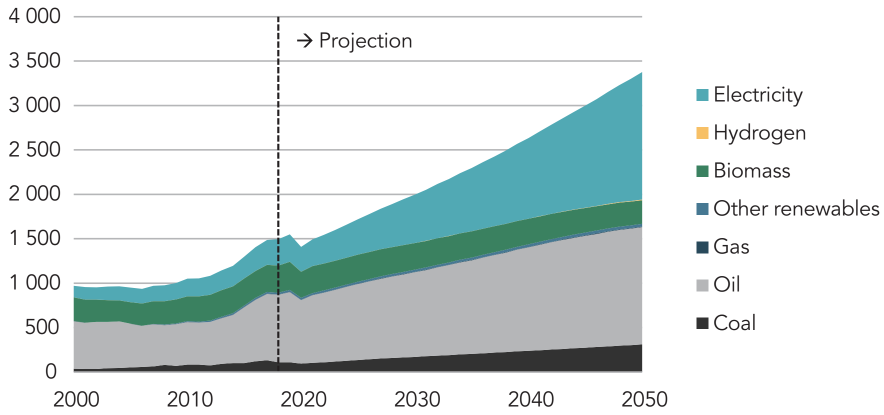


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- The economy is set for a rebound from 2021 onwards, in line with its *AmBisyon Natin 2040*, in addition to accelerating vaccine inoculation, strengthening of monetary and fiscal policies and the push for infrastructure projects. BPOs and OFWs are expected to expand substantially too.
- The population is expected to reach over 140 million people by 2050 at 0.95% growth per annum.

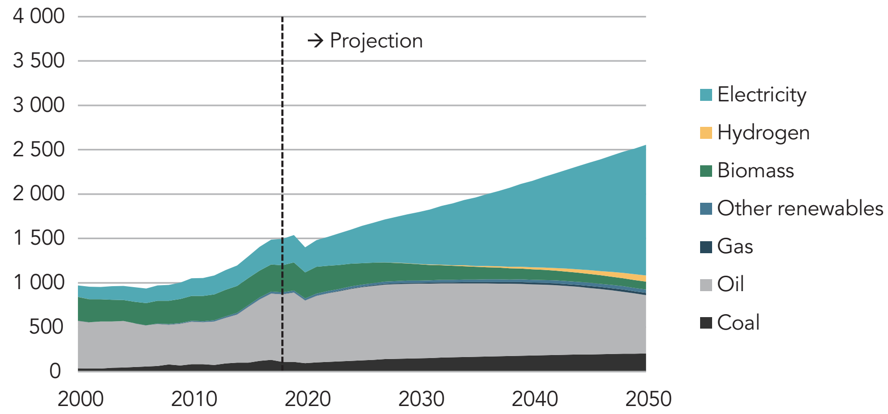
End-use energy demand

Figure 15-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 15-4. Energy demand in CN, 2000-2050 (PJ)

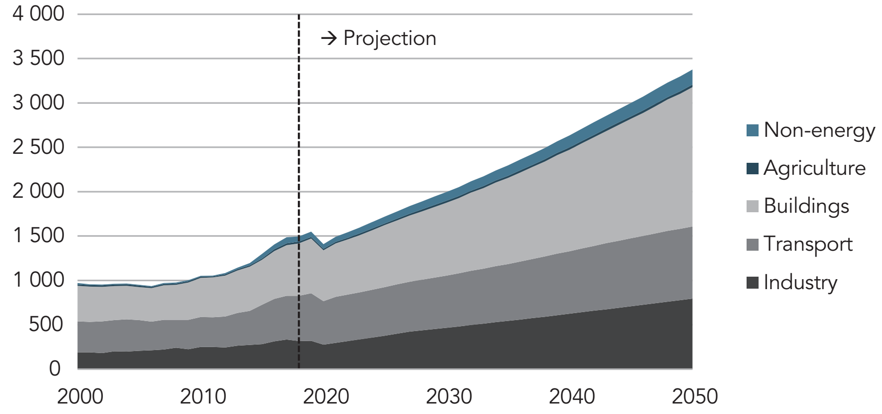


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Energy demand increases by more than 120% in REF (2018-2050). Demand for gas, renewables, hydrogen, and electricity is driven by increasing economic activity.
- In REF, oil (in the form of refined products) is the most consumed fuel in 2040, which is consistent with the DOE's PEP 2020-2040.
- Beyond 2040, electricity surpasses oil as the leading fuel in 2050, accounting for 42% of end-use demand due to the expansion of electricity demand across all sectors. The share of oil in end-use energy demand falls to 39% in 2050.
- Coal demand grows substantially (2018-2050), as developments in the industry sector necessitate the continuous use of this fuel. The share of coal and gas remains minimal in 2050 (9.2%).
- End-use gas consumption is negligible.
- In CN, energy demand in 2050 is about 24% lower than REF. The fall in oil demand contributes most to the reduction, followed biomass and coal.
- Electricity consumption is expected to be more prominent in CN, increasing by almost 400% over REF in 2050.

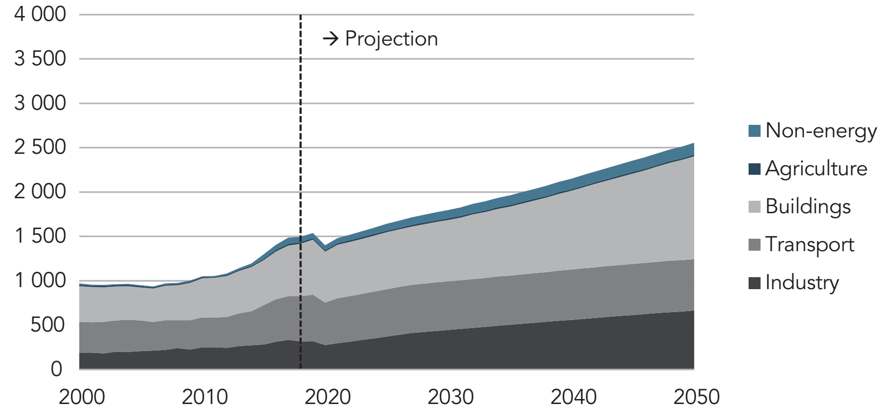
End-use energy demand by sector

Figure 15-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 15-6. Energy demand by sector in CN, 2000-2050 (PJ)

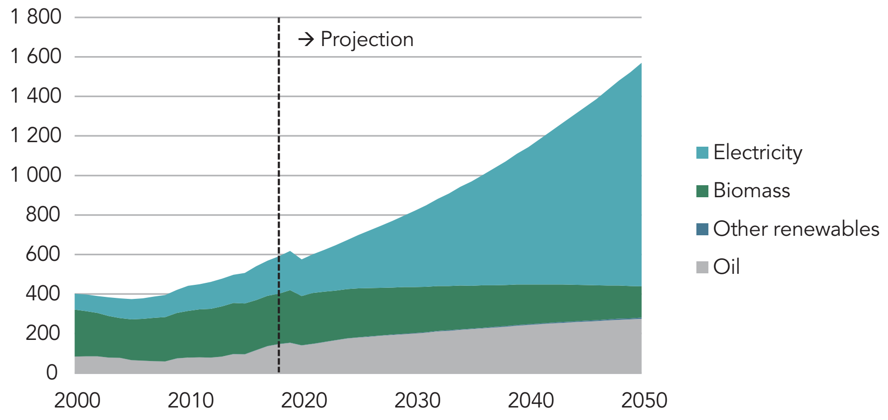


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- The buildings sector, comprising residential and services subsectors, is set to account for the largest share of energy demand by 2050 in REF, amounting to almost half of the total demand.
- The significant increase in buildings energy demand is driven by the implementation of the economy's *2040 National Housing and Urban Development Sector Plan*, which is expected to spur new housing developments.
- At the same time, continued growth in BPOs and e-commerce firms, especially within Manila City, drive up demand for office space. Consequently, buildings energy demand grows 166% in REF (2018-2050). In CN, energy efficiency measures in appliances and increasing number of certified green buildings are expected to reduce the demand by 26% from REF.
- Several major policy reforms and packages introduced by the government are expected to help the Philippines drive growth within its industry sector to support the government's BBB Program. As a result, the industry sector energy demand in REF grows 150% (2018-2050). In CN, substantial industrial modernisation sees a combination of fuel switching and higher efficiency measures, which leads to 16% reduction from REF in 2050.
- The transport sector is essential in the Philippines' economic growth. Transport sector energy demand grows 59% in REF (2018-2050). Concurrently, passenger vehicles, particularly tricycles and jeepneys, are expected to undergo significant electrification.
- Further enhancement to mass transit and railway systems, fuel diversification, and efficiency standards programme reduces transport demand by almost 29% from REF in 2050.

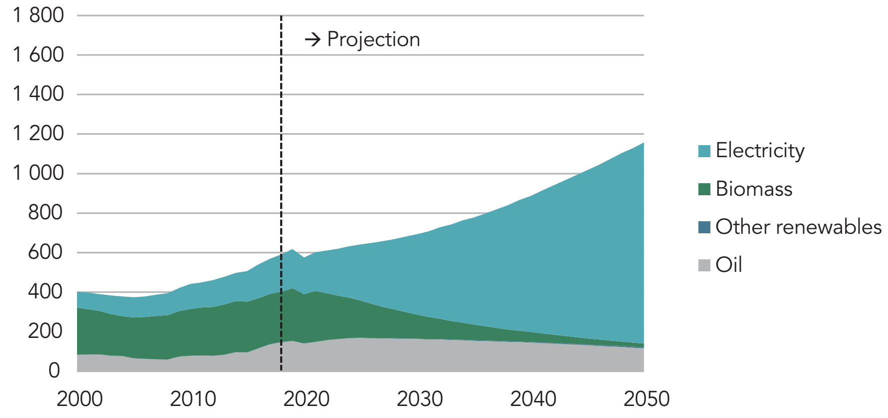
Buildings energy demand

Figure 15-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-8. Buildings energy demand in CN, 2000-2050 (PJ)

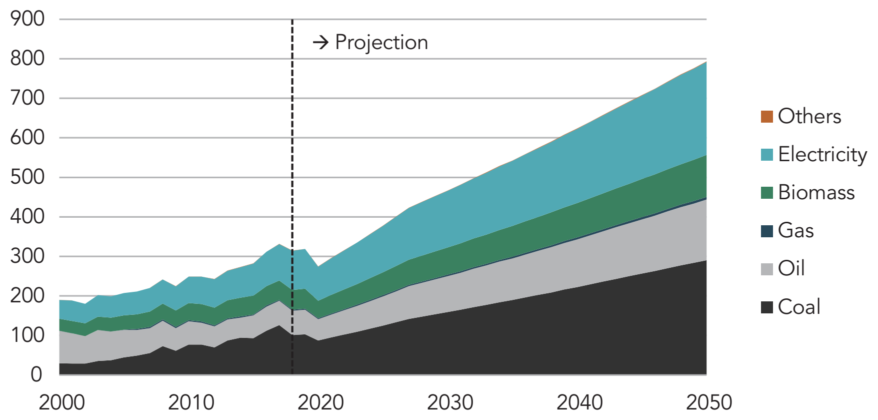


Sources: EGEDA, APERC analysis.

- Buildings sector energy demand grows 166% in REF (2018-2050).
- The services subsector is a major driver of economic growth. Services energy demand grows over 300% in REF (2018-2050), surpassing the residential subsector. Emerging outsourcing firms, e-commerce companies, and data centers drive demand for new office space as the Philippines continue to become a major BPO hub.
- Electricity consumption in services is expected to rise by nearly five times in 2050 from 2018 levels in REF.
- In the residential subsector, electricity grows to 72% of subsector demand. Economic growth allows for greater access to modern fuels, which includes LPG.
- Consumption of LPG doubles (2018-2050) while demand for biomass falls. This trend is in line with the government's *2040 National Housing and Urban Development Sector Plan*.
- In CN, buildings energy demand in 2050 is 26% lower than in REF, with slower growth expected between 2018 and 2050.
- Comparing REF and CN, stringent efficiency measures in appliances yield a 10% reduction in buildings electricity demand in 2050.
- In CN, electricity accounts for 93% of overall residential energy demand. As a result, a substantial reduction in oil (refined products) demand is expected, with a phasing out of kerosene and a fall in biomass demand.
- Electricity is expected to be dominant within the services subsector in CN, as commercial and services establishments as fuel switching and adoption of more energy-efficient appliances and improvements in building energy efficiency take shape.

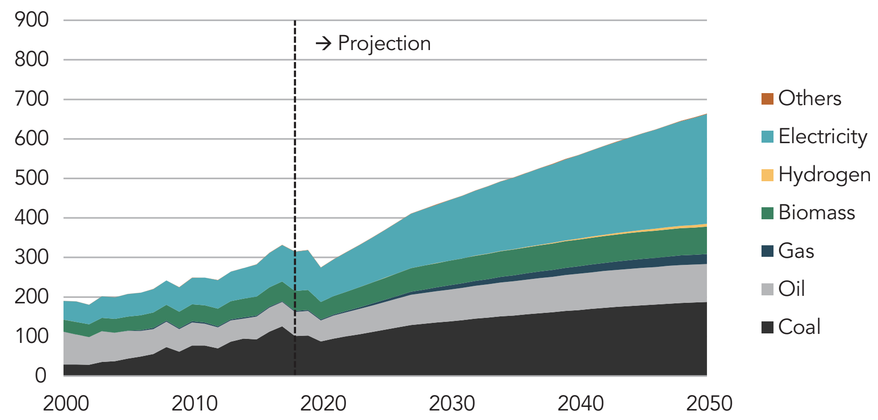
Industry energy demand

Figure 15-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 15-10. Industry energy demand in CN, 2000-2050 (PJ)

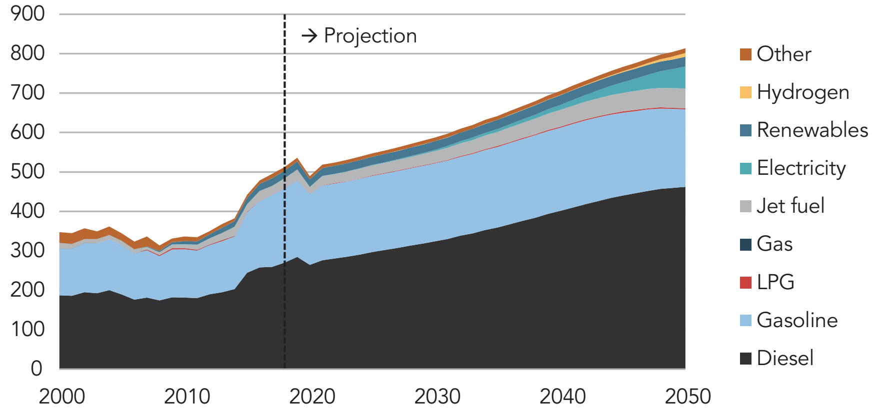


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- The industry sector is a major source of economic output, with the manufacturing subsector constituting more than half of the economy's industrial output. Food, beverages, and tobacco generate the highest value-added.
- The Philippines aims to further boost its industrial output. Together with the Manufacturing Resurgence Program (MRP), stimulus packages and major policy reforms have been introduced, such as Corporate Recovery and Tax Incentives Reform Act (CREATE), the Philippine Inclusive Innovation Industrial Strategies (i3s), the Financial Institutions Strategic Transfer (FIST), and Comprehensive Tax Reform Program (CTRP). In addition, implementation of the Construction Industry Roadmap 2020-2030 is expected to amass seven million workforces within the construction subsector by 2030.
- The recent signature of Executive Order (EO) No. 130 underscores the importance of the mining and quarrying subsector in revitalising the Philippines' economy following the COVID-19 pandemic. In addition to supporting the government's BBB Program, the growth of subsector is expected to continue in the long run.
- In REF, industry sector energy demand grows 152% (2018-2050).
- Coal remains the dominant fuel in 2050 (REF) due to growth in in the non-metallic minerals, pulp and paper, and iron and steel subsectors.
- Continued activities in the manufacturing and construction subsectors in REF increase demand for oil, particularly diesel, by 2.9% per year between 2018 and 2050.
- Biomass consumption increases by 2.4% per year driven by the sugar and food manufacturing industries.
- In CN, industry energy demand grows 111%. Modernisation and fuel-switching, lead to electricity replacing coal as the dominant energy carrier.
- Hydrogen consumption, particularly in manufacturing, remains small (CN).

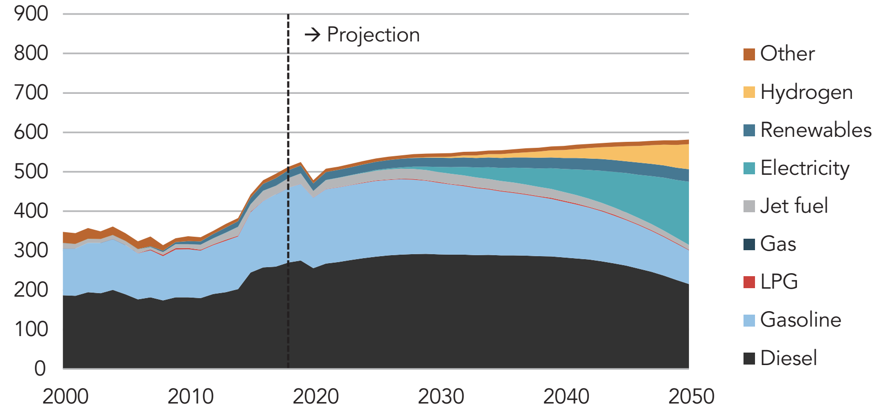
Transport energy demand

Figure 15-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 15-12. Transport energy demand in CN, 2000-2050 (PJ)

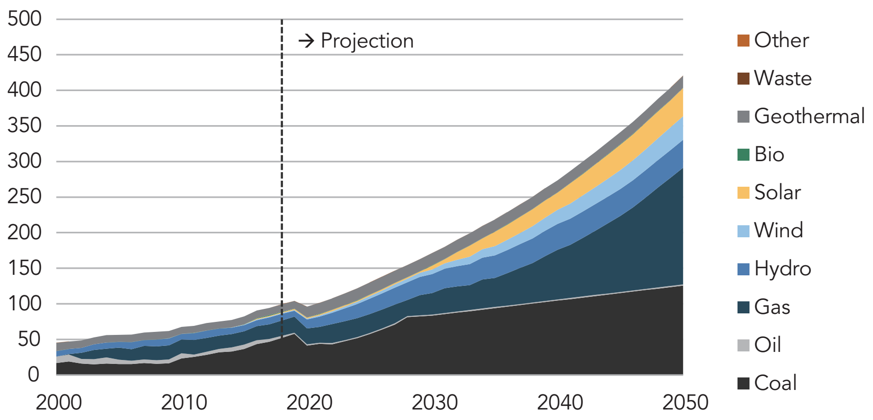


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Two- and three-wheelers account for 60% of passenger transport (2018). Gasoline-powered motorcycles and motorised tricycles are used frequently within the local public transport modes. Light trucks in the form of diesel-powered jeepneys are also prevalent amongst passengers.
- In REF, transport energy demand grows 59% (2018-2050).
- By 2050, the shares of gasoline and diesel vehicles are expected to decline. Gasoline vehicles share decreases 76% to 48% (2018-2050). The share of diesel vehicles declines only 1.0%, although absolute numbers of heavy-duty and light trucks and passenger vehicles (buses and jeepneys) grow.
- The Senate Bill No. 1382 (SB1382) on Electric Vehicles and Charging Stations Act was recently approved by the Senate, which is expected to pave the way for the formulation of a roadmap on EVs.
- In REF, the share of electricity demand reaches 6.8% (2050). Conventional passenger tricycles and jeepneys are expected to gradually become electrified.
- In CN, transport energy demand is 29% lower than REF in 2050.
- In CN, 63% of vehicles are electric in 2050. Electricity becomes 28% of transport energy demand, more than gasoline (15%).
- Hydrogen fuel-cell passenger and freight vehicles are also deployed. Hydrogen infrastructure would need to accompany these new vehicle fleets.

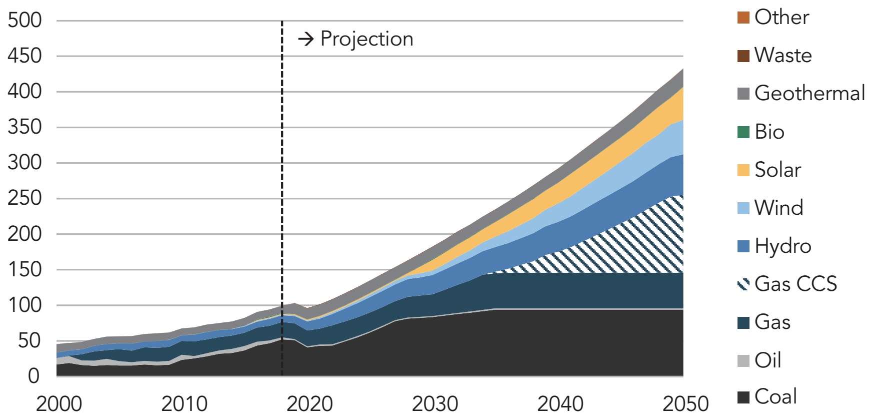
Electricity generation

Figure 15-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 15-14. Electricity generation in CN, 2000-2050 (TWh)

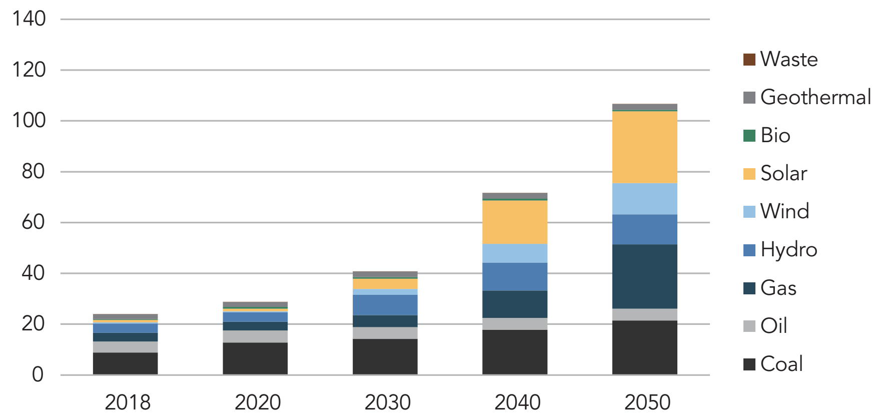


Sources: EGEDA, APERC analysis.

- Electricity generation increases to around 420 TWh in REF, growing 322% (2018-2050).
- Gas power plants become the largest source of incremental electricity generation by 2050. Generation from gas (164 TWh) exceeds coal (126 TWh) in 2050.
- Generation from solar and wind grows the largest in percentage terms, generating 40 TWh and 33 TWh, respectively in 2050, but individual shares remain under 10%.
- In CN, electricity generation grows a similar amount (334%). As in REF, generation from gas becomes the largest source of electricity.
- CCS is utilised for gas power plants to reduce the CO_2 intensity of electricity generation. About 110 TWh of electricity is generated from plants with CCS compared to only 50 TWh from plants without CCS units.
- Increased generation from renewables (solar, wind, and geothermal) offsets declines in generation by coal.
- The significant rise in electricity generation in both scenarios corresponds to the substantial increase in electric vehicles deployment. By 2050, electricity demand of 16 TWh is required to power the fleet of EVs in REF. In CN, this demand is expected to reach 45 TWh by the same year.

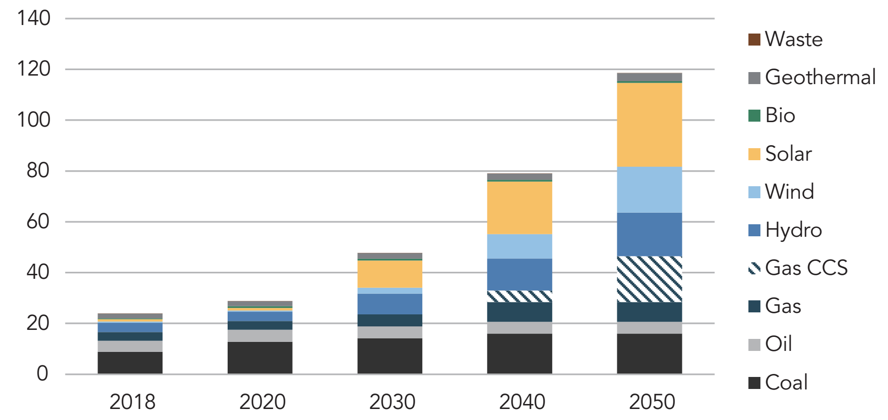
Generation capacity

Figure 15-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 15-16. Generation capacity in CN, 2018-2050 (GW)

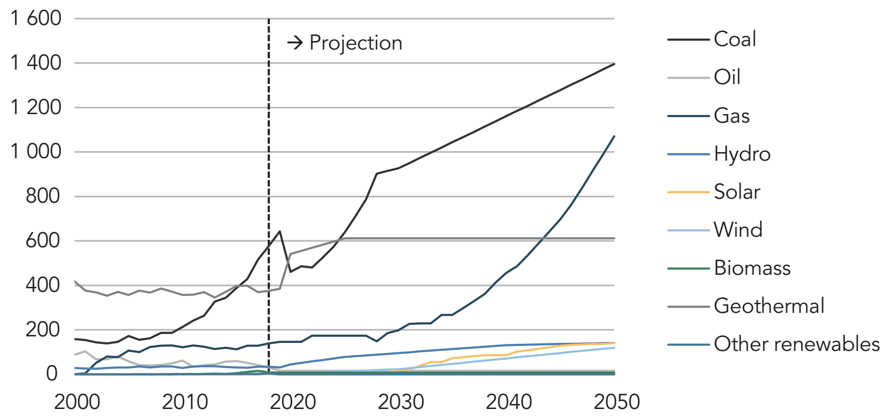


Sources: EGEDA, APERC analysis.

- In REF, gas power plant capacity is expected to increase over 630%, while coal-fired capacity grows 142% (2018-2050). This results in a cumulative total of over 21 GW in 2050, averaging 0.40 GW of new installations per year.
- The additional gas-fired capacity relies on increased levels of gas consumption. LNG imports would offset the decline in gas production from Malampaya.
- The first LNG import occurs in 2022, when the new 650 MW combined-cycle power plant is expected to come online sometime in 2023. Cumulatively, close to 26 GW of gas-fired power plant capacities would come online in 2050, averaging above 0.70 GW per year of new installations.
- In REF, solar PV capacity reaches 28 GW in 2050 (2018-2050). Wind capacity also shows significant growth of almost 30 times, reaching 12 GW.
- In CN, solar PV becomes the largest installed capacity, reaching 33 GW in 2050.
- Wind power capacity reaches 18 GW in 2050 (CN).
- In CN, about 18 GW of capacity is equipped with CCS in 2050 to enable post-combustion CO_2 capture.
- In CN, coal-fired capacities start to plateau from 2035 onwards. Beyond 2035, no new coal capacity is expected to be invested in and constructed.

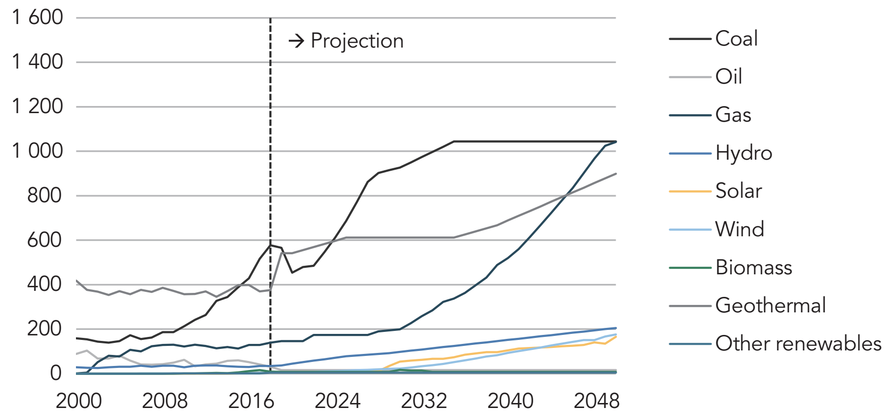
Fuel consumption by power sector

Figure 15-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 15-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

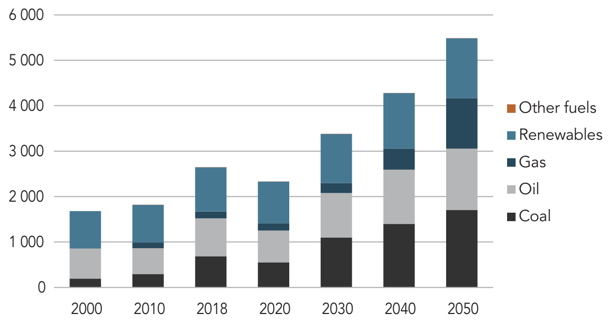


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- Despite gas being the major source of electricity generation in the Philippines, coal becomes the dominant fuel in REF, rising to almost 1 400 PJ in 2050 compared to just over 1 000 PJ of gas input.
- The relatively lower gas input compared to coal input for electricity generation is attributable to the high overall efficiency attained through adoption of combined cycle gas turbines in gas power plants. Coal, on the other hand, is required at a larger volume to generate electricity due to lower average thermal efficiencies.
- In CN, gas input is set to match coal in 2050 as coal requirement for electricity generation plateaus starting 2036.
- Alongside gas and coal, geothermal is also becoming a predominant source for baseload electricity generation, especially in CN, where its input reaches almost 900 PJ compared to just over 600 PJ in REF in 2050.

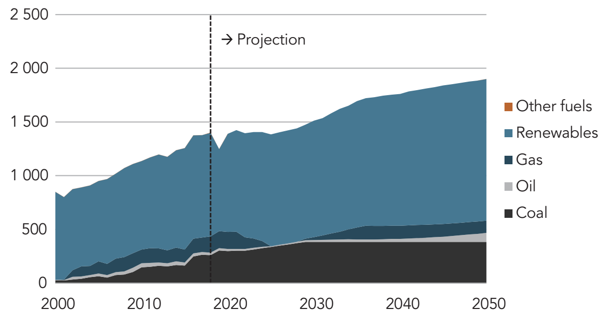
Energy supply in the Reference scenario

Figure 15-19. Total energy supply in REF, 2000-2050 (PJ)



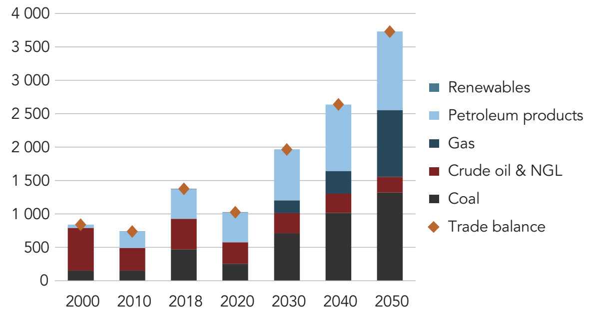
Sources: EGEDA, APERC analysis.

Figure 15-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-21. Net energy trade in REF, 2000-2050 (PJ)

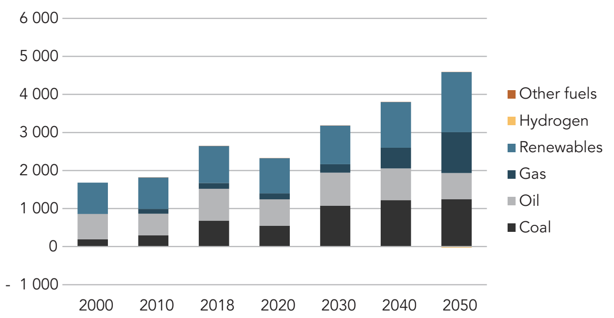


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Prior to 2018, the Philippines' energy supply has been mostly oil and renewables (particularly biomass). Closer to 2018, coal supply increased in line with consumption in the power sector.
- Energy supply is expected to grow 107% in REF (2018-2050).
- Coal supply increases 149% as it remains an important source for baseload power generation and for meeting industrial needs. Domestic coal production increases until 2029 then remains flat towards 2050.
- Oil supply expands 61% driven by growth of domestic demand for refined products, reaching 25% share of energy supply in 2050. Crude oil, NGL, and refined products imports remain important as Shell shifted to importing refined products after the closure of the Tabangao refinery.
- Renewables supply grows 25%. The composition of renewables expands to include more solar, wind, hydro, and geothermal. Concurrently, there is a decline in the consumption of fuelwood and wood waste.
- Gas supply increases to 20% in 2050 due to LNG imports for power sector consumption.
- The Malampaya gas field's imminent depletion further increases net energy trade.
- The reliance on imports, particularly refined products and LNG, lowers the energy self-sufficiency level from 49% to 35% (2018-2050).

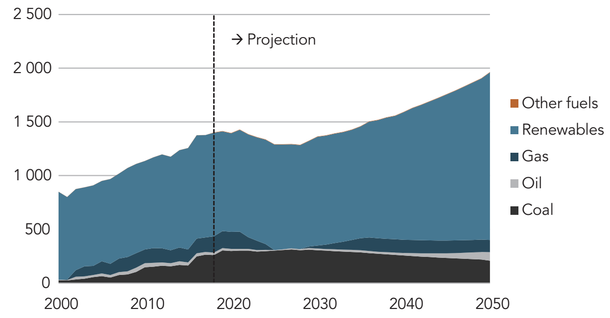
Energy supply in the Carbon Neutrality scenario

Figure 15-22. Total energy supply in CN, 2000-2050 (PJ)



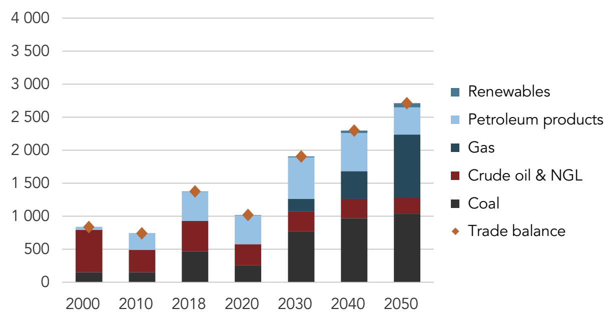
Sources: EGEDA, APERC analysis.

Figure 15-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-24. Net energy trade in CN, 2000-2050 (PJ)

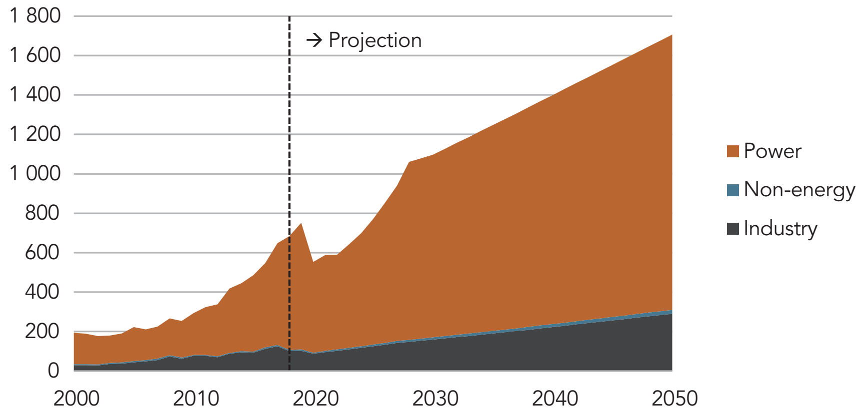


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Energy supply is expected to increase by 72% in CN, a slower growth compared to REF's trend. This is driven by reduced demand for fossil fuels, particularly coal and oil, and traditional biomass.
- Renewables energy supply expands faster in CN, due to increasing utilisation of solar, hydro, and wind in the power sector. Traditional biomass in the buildings sector declines. By 2050, renewables are the largest share of energy supply.
- The share of coal supply decreases to 27% in 2050, due to declining utilisation within the power and industry sectors.
- The largest decrease in share comes from oil, with only 15% share in 2050, driven by enhanced electrification within the transportation sector, as well as preference towards non-fossil fuels in the industry sector.
- Production increases in CN, which can be attributed to increased promotion and exploitation of domestic energy sources, particularly renewables. Increased domestic production is expected to improve the economy's energy self-sufficiency to 43% in 2050, compared to 35% in REF.
- Hydrogen supply starts in 2025 as it is utilised as a source of energy for power to replace coal for base load generation and in some transport applications.

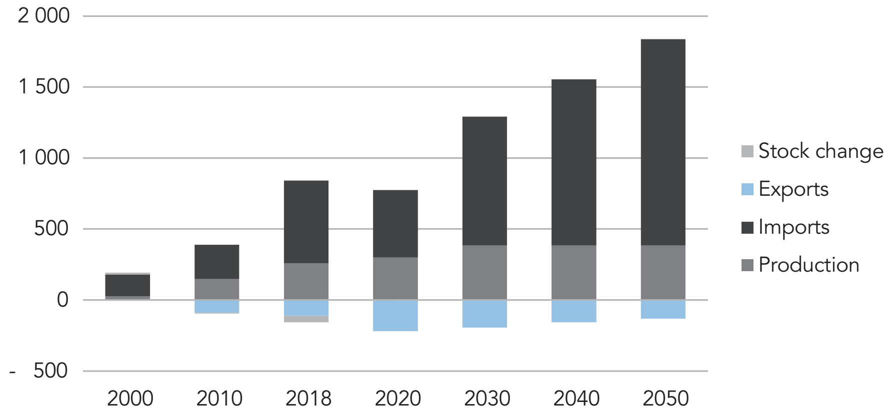
Coal in the Reference scenario

Figure 15-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

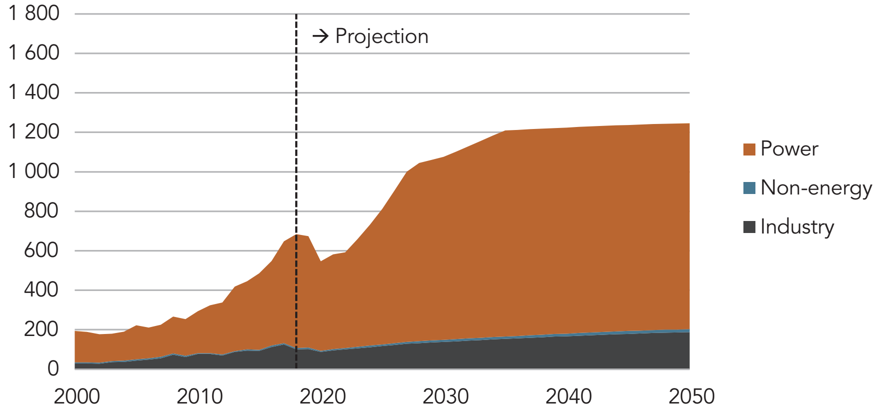


Sources: EGEDA, APERC analysis.

- Coal demand increases 149% through 2050, driven by increased consumption in the power and industry sectors.
- The expansion of coal-fired power plants substantially increases coal consumption, leading to increased coal imports.
- Coal production increases nearly 50% (2018-2050). The target of achieving the government's aspirational target of 282 million tonnes (Mt) is expected by 2040, which is maintained through 2050.
- The Philippines has been importing the bulk of its coal requirements from Indonesia, and the remaining from Australia, Russia, and Viet Nam. The increase in coal demand requires 2.5 times higher volume of high-quality coal to be imported in 2050.
- Imported coal is expected to continue to be supplemented by domestic coal mines, which can supply about 20% of the Philippines' overall coal demand.

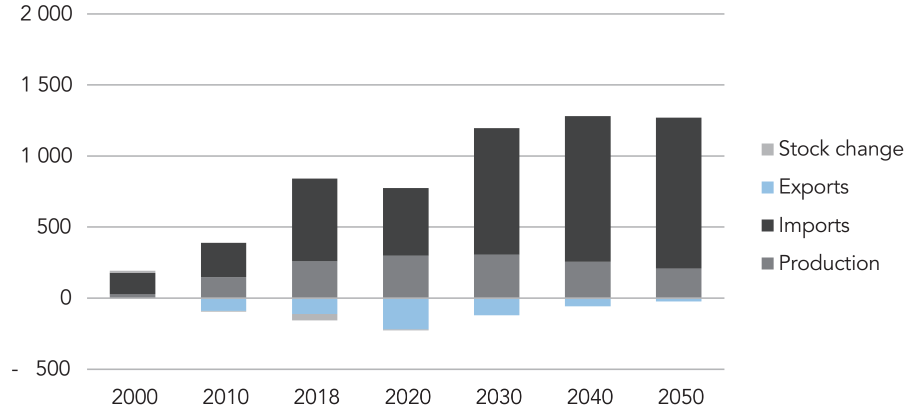
Coal in the Carbon Neutrality scenario

Figure 15-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

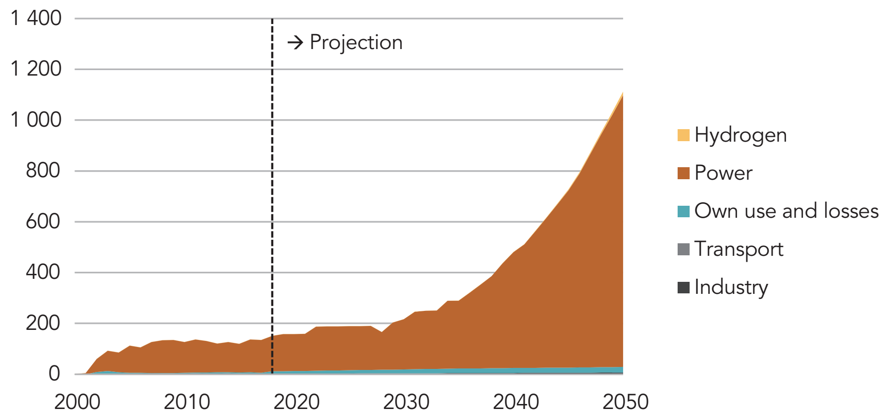


Sources: EGEDA, APERC analysis.

- Coal-fired power plants are not expected to increase in capacity due to the moratorium on greenfield coal power projects, issued by the government in late 2020. Thus, coal consumption by the power sector is not expected to substantially increase.
- Coal consumption within the industry sector is expected to increase at a slower pace as the sector transitions towards gas and electricity.
- Domestic coal production declines by 20% (2018-2050), as a result of slower demand growth.
- Coal imports are 27% lower than REF in 2050.

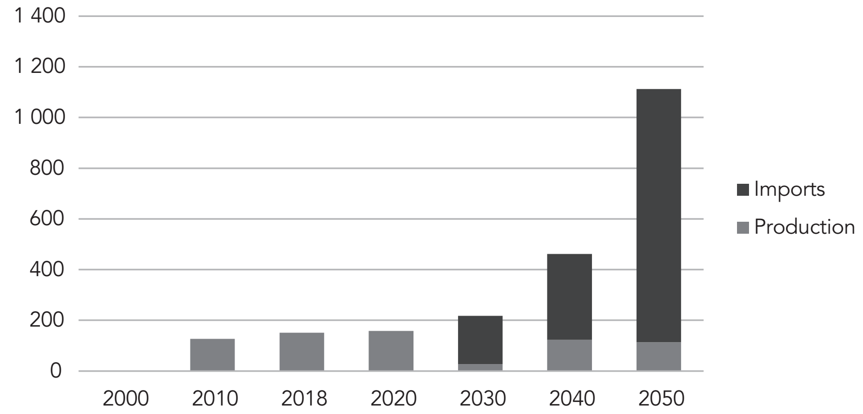
Natural gas in the Reference scenario

Figure 15-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

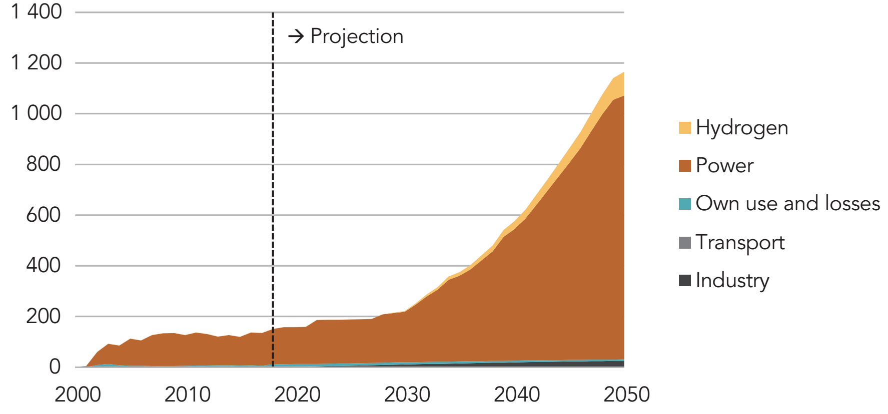


Sources: EGEDA, APERC analysis.

- Nearly all gas was consumed by the power sector in the Philippines between 2000-2018 and is expected to continue through 2050. Gas consumption is expected to expand by more than 600% 2018-2050.
- The Malampaya offshore gas field has supplied the economy's natural gas power plants since 2001. With the field nearing depletion, the government has made LNG imports one of the key priorities to keep existing power plants running and new gas power plants to come online.
- The government approved six LNG projects with a combined capacity of 22 million tonnes per annum. The first two projects – the FGEN LNG Corporation and Atlantic Gulf & Pacific Company of Manila (AG&P) Inc – are expected to be operational by 2022. By 2050, all LNG imports are expected to be covered by these projects.
- However, much of this LNG import capacity will not be required until the latter part of the outlook period. The two LNG projects built in 2022 will be sufficient to handle the projected imports until the late 2030s. The final 6.0 million tonnes per annum of capacity will not be required until 2045.
- Building the entire slate of currently approved six LNG import terminals before the mid-2030s would be an inefficient use of capital and could risk stranding some of the terminal investments.

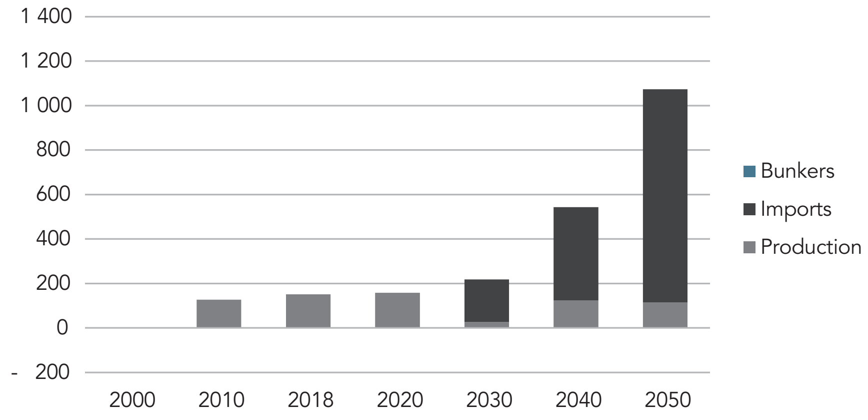
Natural gas in the Carbon Neutrality scenario

Figure 15-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

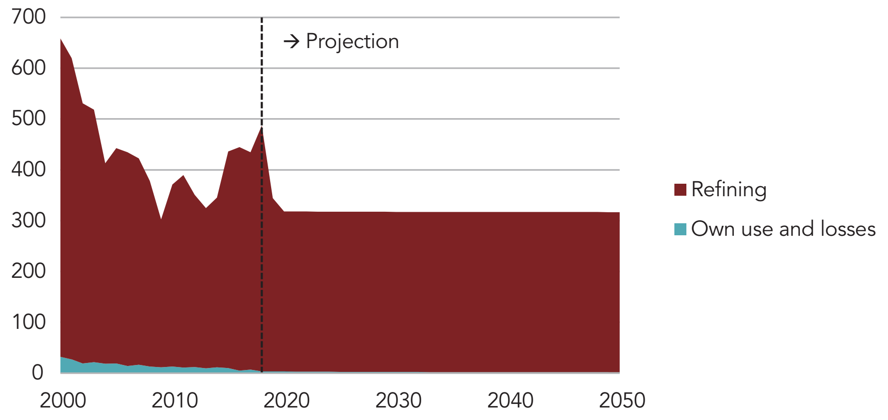


Sources: EGEDA, APERC analysis.

- Demand for natural gas in CN is slightly higher than in REF. This increase is driven by the significant transition from coal to natural gas use in the industry sector, within which the consumption of natural gas in this scenario is over 280% higher in 2050 than in REF. The power sector remains the dominant gas consumer.
- The significant push for domestic hydrogen production through steam methane reforming is expected to further increase the demand for natural gas.
- The LNG import terminal projects in CN are similar to REF. The 3.9% lower level of consumption in 2050 (compared to REF) implies lower utilisation rate of these import terminals. Nonetheless, these are still assumed to remain operational by 2050, albeit with a 90% utilisation rate, compared to 94% in REF.
- With similar demand and import requirements to REF, and much of the utilisation occurring after the 2030s, the risks of stranding investments in LNG terminals highlighted in REF also applies in CN.

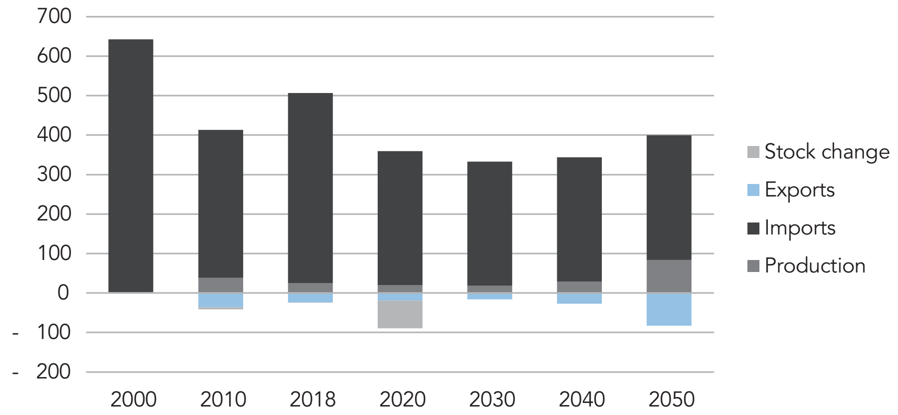
Crude oil and NGLs in the Reference scenario

Figure 15-33. Crude oil and NGL consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-34. Crude oil and NGL production, imports, and exports in REF, 2000-2050 (PJ)

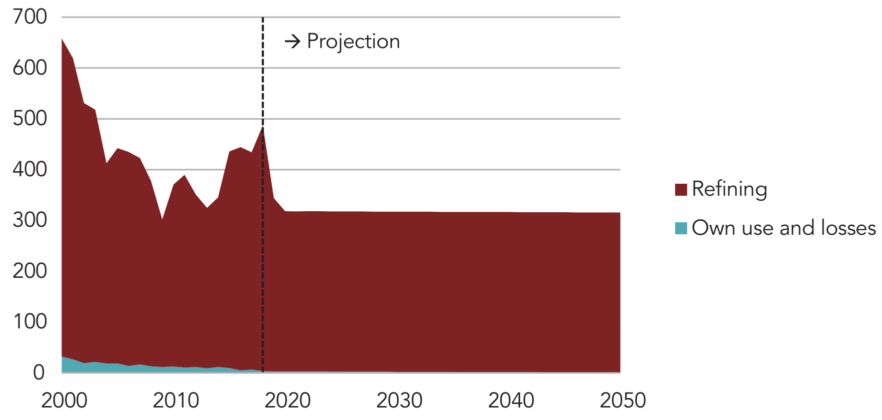


Sources: EGEDA, APERC analysis.

- The Philippines has been a net importer of crude oil and remains one through 2050 in REF. Much of the crude oil import is sourced from the economies in APEC and the Middle East.
- Historically, all crude oil imports were fed into two major oil refineries: Shell Tabangao Batangas and Petron Bataan, on Luzon island.
- The impact of the ongoing COVID-19 pandemic caused the suspension of operations of the Shell Tabangao Batangas refinery in the first half of 2020, and it was eventually permanently closed in August 2020.
- Since then, the refinery has been operating as an import terminal and effectively making the Petron refinery the sole operating refinery in the Philippines. The closure of the Shell Tabangao Batangas refinery has decreased the overall domestic refinery output by about half.
- The continuous reliance on imported crude oil implies that the Philippines is still at risk in terms of its energy security. Disruptions due to geopolitical and economic instabilities may present challenges in maintaining the Philippines' overall energy supply.

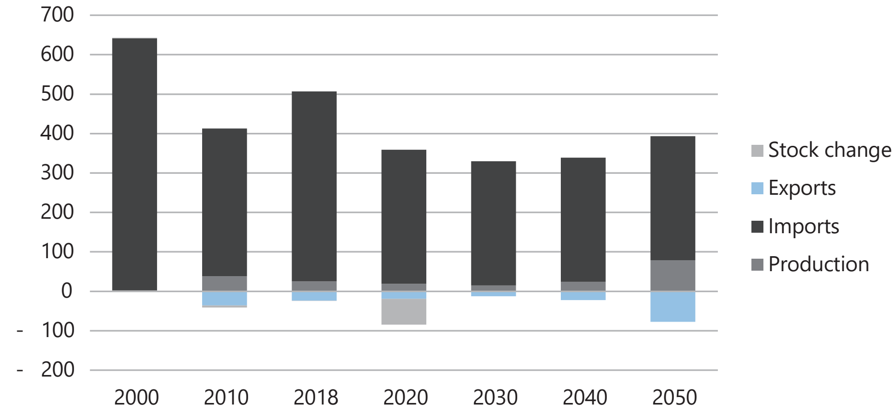
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 15-35. Crude oil and NGL consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-36. Crude oil and NGL production, imports, and exports in CN, 2000-2050 (PJ)

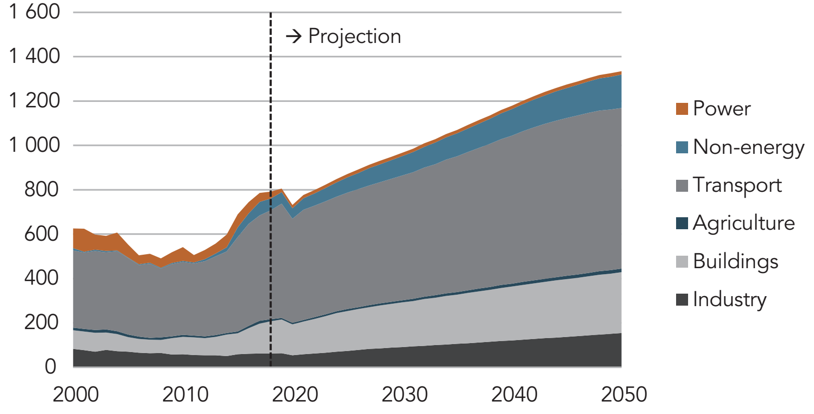


Sources: EGEDA, APERC analysis.

- Crude oil consumption by refineries is similar to REF as the Petron refinery continues to operate at its maximum capacity following the closure of the Shell Tabangao Batangas refinery.
- Lower demand for refined products leads to lower imports of crude oil. The Petron Bataan refinery is expected to continue operations to satisfy demand.
- The only notable differences lie on its domestic production and exports. The level of production in 2050 is assumed to be 6.4% lower than that in REF, while exports are about 6.5% lower than REF.

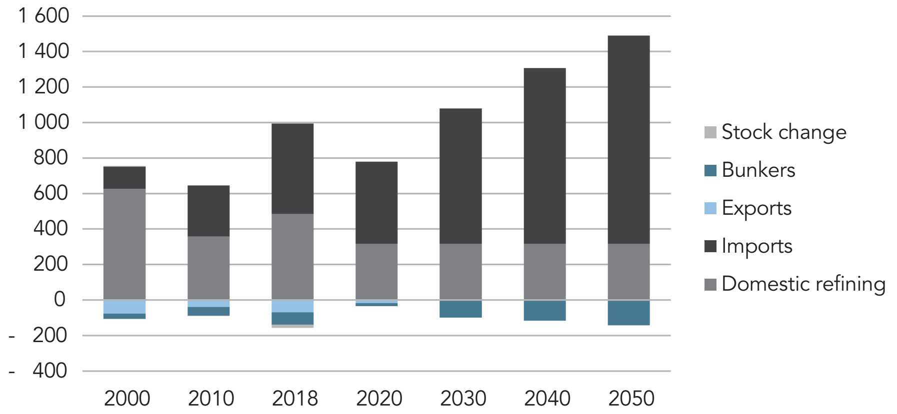
Refined products in the Reference scenario

Figure 15-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

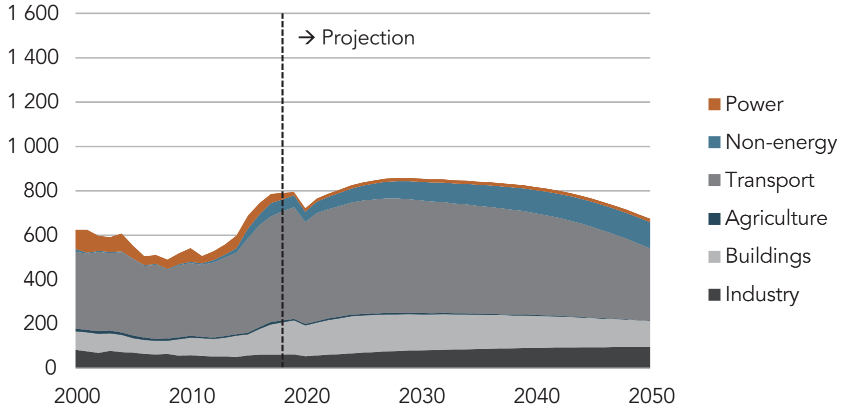


Sources: EGEDA, APERC analysis.

- Demand for refined products increases by almost 70% in REF, 2018-2050.
- In terms of sectoral share, the transport sector consumes the most refined products (54% in 2050). Refined products consumption in the transport sector slows in the 2040s due to fuel switching to biofuels and electric vehicles.
- Refined products demand increases in the industry and non-energy sectors.
- Although refinery production output dropped significantly in 2020 due to the closure of the Shell Tabangao Batangas refinery, imports of refined products continue to supplement the production from the Petron Bataan refinery at its maximum capacity. In 2050, about 87% of the Philippines' refined products needs is expected to come from imports.

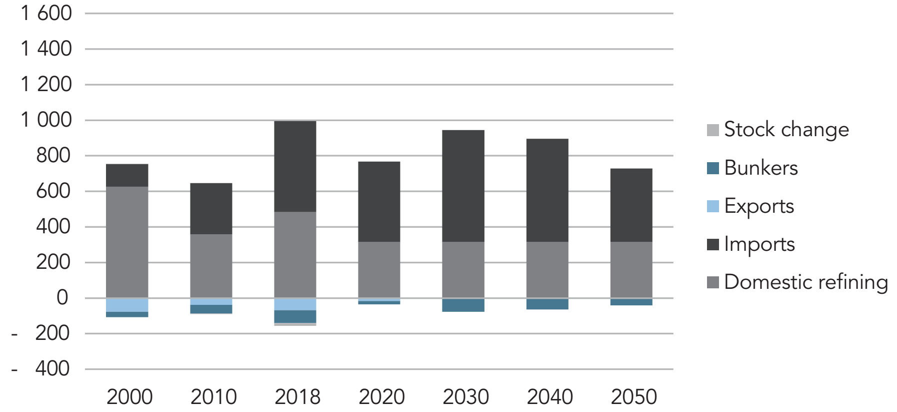
Refined products in the Carbon Neutrality scenario

Figure 15-39. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 15-40. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

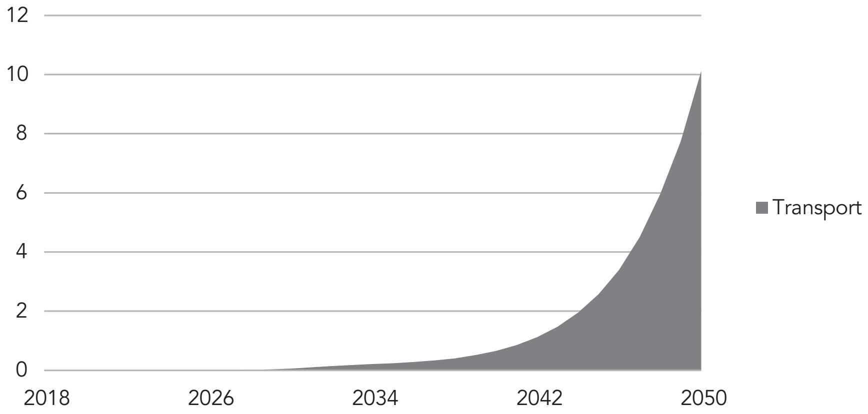


Sources: EGEDA, APERC analysis.

- Demand for refined products in CN declines by 14% (2018-2050).
- The wide-scale fuel diversification in the transport sector also decreases demand for gasoline and diesel fuels in the sector. This diversification is mainly driven by significant deployment in electric vehicles as well as gradual increase in the use of hydrogen fuel-cell vehicles.
- On the other hand, demand in the industry sector is still expected to increase although at a slower growth compared to REF, driven by fuel switching and electrification.
- The agriculture sector is a small consumer of refined products but shows the most significant reduction (around 70%). Enhanced electrification and energy efficiency measures are the main drivers for this reduction, in support of the government's plan to scale up renewable energy utilisation in agriculture and fishery sectors through Renewable Energy Program for the Agriculture and Fishery Sector (REP-AFS). In addition, the government aims to modernise the agriculture sector through adoption of advanced technology and smart farming methods to maximise local produce.
- Consequently, there is a reduction in both production output and import volumes by almost 20% (2018-2050). Despite this reduction, the Petron Bataan refinery is expected to continue operating at its maximum capacity.

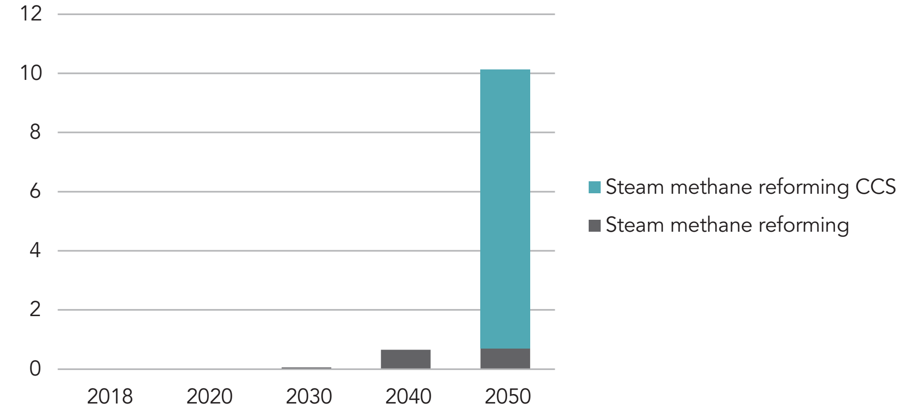
Hydrogen in the Reference scenario

Figure 15-41. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 15-42. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

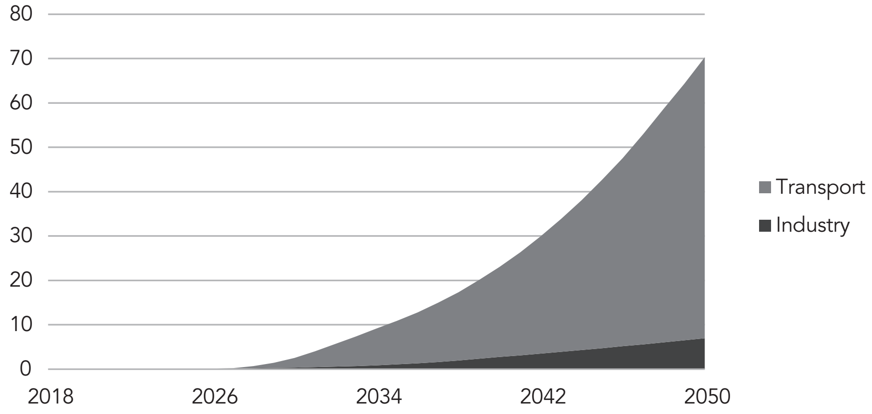


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- Hydrogen is assumed to be utilised solely in the transport sector in REF, eventually reaching 10 PJ in 2050.
- Hydrogen is not considered as an input fuel in the power sector. However, the government aspires to utilise hydrogen within the power sector, particularly as a back-up for the grid and as an alternative option for off-grid areas. Hydrogen consumption may be higher than in REF.
- Hydrogen is expected to be locally produced through a steam methane reforming process. This is in line with the Philippines' aim to explore the use of new and emerging technologies in the realisation of energy transition targets. With this, construction of an integrated hydrogen manufacturing facility at Shell's former Tabangao refinery is in place. Upon completion, the refinery is set to produce 'blue' hydrogen from fossil fuels (utilising CCS).

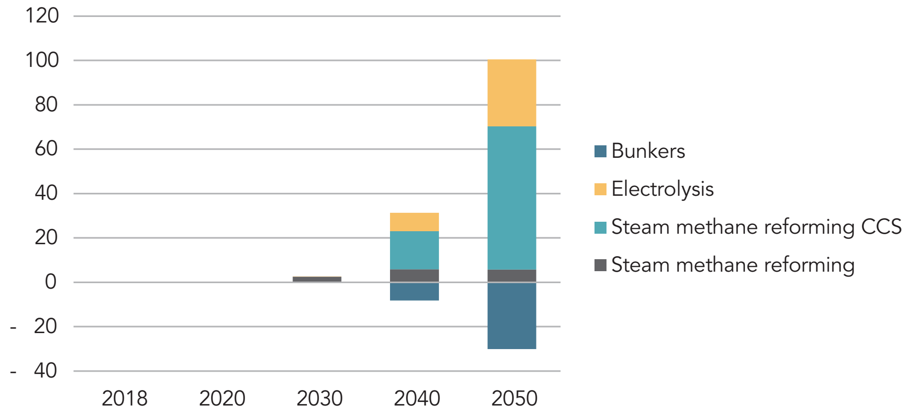
Hydrogen in the Carbon Neutrality scenario

Figure 15-43. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 15-44. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

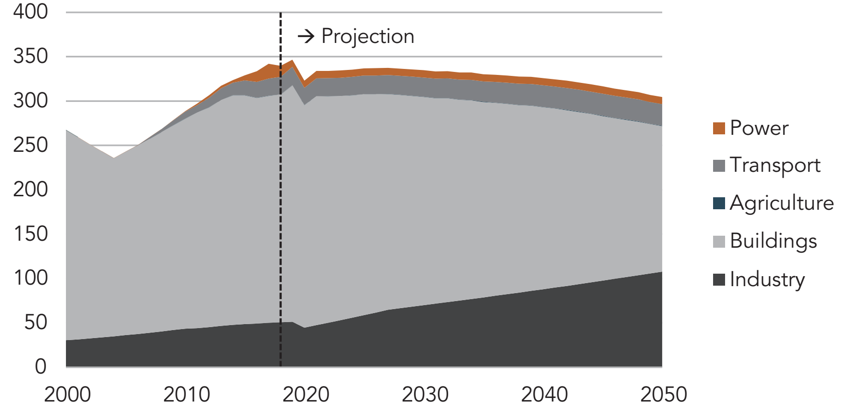


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- Significant deployment of fuel cell vehicles in the Philippines increases hydrogen demand to over 70 PJ in 2050.
- The industry sector gradually consumes more hydrogen as fuel switching increases in CN.
- In CN, hydrogen is also produced via electrolysis, to supplement the conventional grey and blue hydrogen production.
- Hydrogen is also utilised for maritime transport (bunkers). By 2050, hydrogen use for bunkers reaches 30 PJ in 2050. For an archipelago like the Philippines, maritime transport continuously plays a vital role in ensuring a coordinated and holistic transport network, given that this mode of transport accounts for 90% of the overall domestic trade.

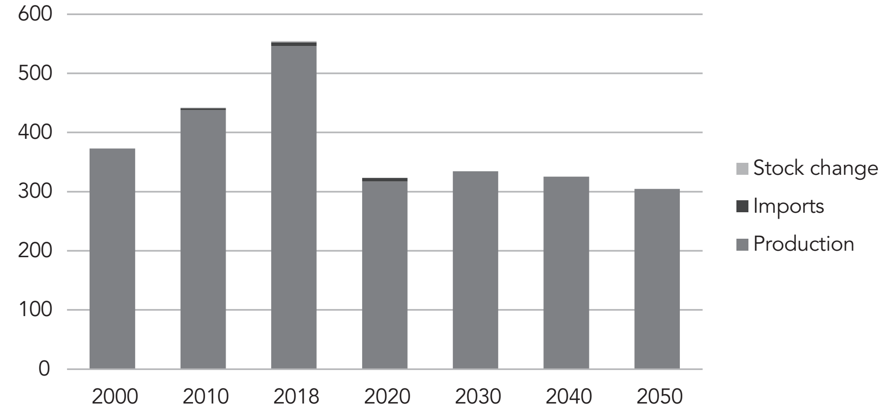
Bioenergy in the Reference scenario

Figure 15-45. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 15-46. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

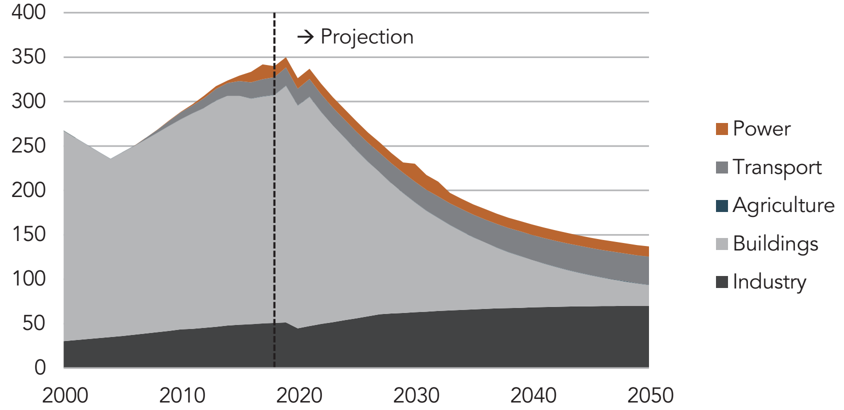


Sources: EGEDA, APERC analysis.

- The Philippines has abundant supplies of biomass, with fuelwood and wood waste accounting for more than half of the total supplies on average. Bagasse and charcoal make up the remaining shares.
- The utilisation of traditional biomass, particularly for cooking, in households has been predominant and it is expected to continue. However, consumption declines as new households are expected to transition to modern cooking practices.
- The industry sector consumes solid biomass in the form of bagasse and other agricultural wastes, as well as a small amount of fuelwood and wood waste. Solid biomass consumption is expected to grow with increased industrial activities.
- The implementation of the Philippines Biofuels Act of 2006 in 2007 has seen the utilisation of liquid biofuels in various sectors.
- A small amount of biodiesel has been blended with petroleum diesel in the buildings sector, particularly in the commercial and public services, as well as the industry sector.
- Petroleum gasoline and diesel consumed by road vehicles in the transport sector are blended with biogasoline (bioethanol) and biodiesel, respectively. Increased biofuels blend mandated by the government is expected to see a 20% increase in biofuels consumption by road vehicles in 2050 from 2018 levels.
- The overall decline in bioenergy production is attributed to the decline in domestic fuelwood and wood waste production, due to reduced demands from households. Domestic biofuels production continue to almost double in 2050 relative to 2018 levels, with declining imports.

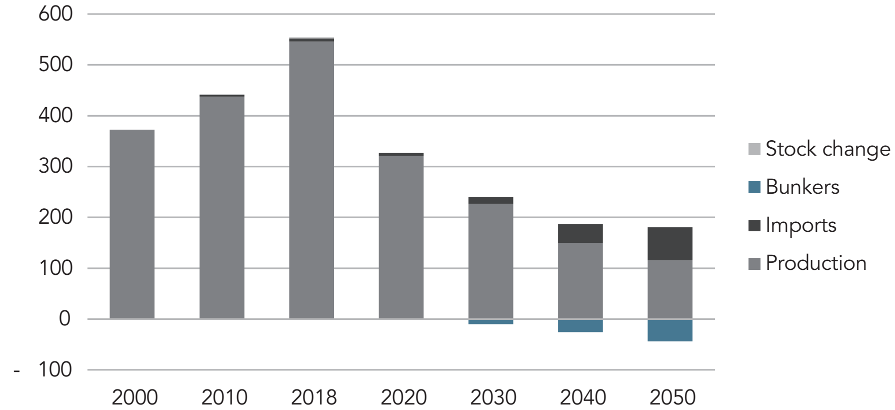
Bioenergy in the Carbon Neutrality scenario

Figure 15-47. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 15-48. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

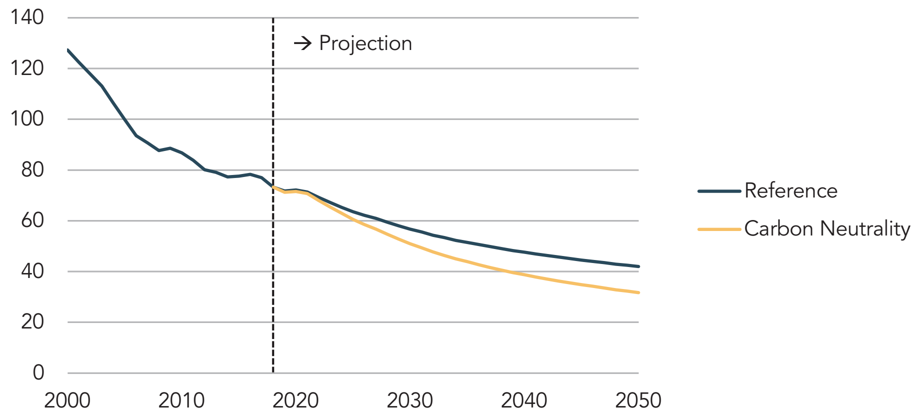


Sources: EGEDA, APERC analysis.

- Traditional biomass consumption is expected to decline rapidly in CN, spurred by increased access to modern energy technologies by new households for cooking and heating.
- The consumption of biofuels in the transport sector grows nearly 60% (2018-2050), in support of the Philippines' target to increase the mandated biofuels blend.
- To augment the local production of biofuels, the economy is expected to increase the import by 11% in 2050 relative to 2018 levels.

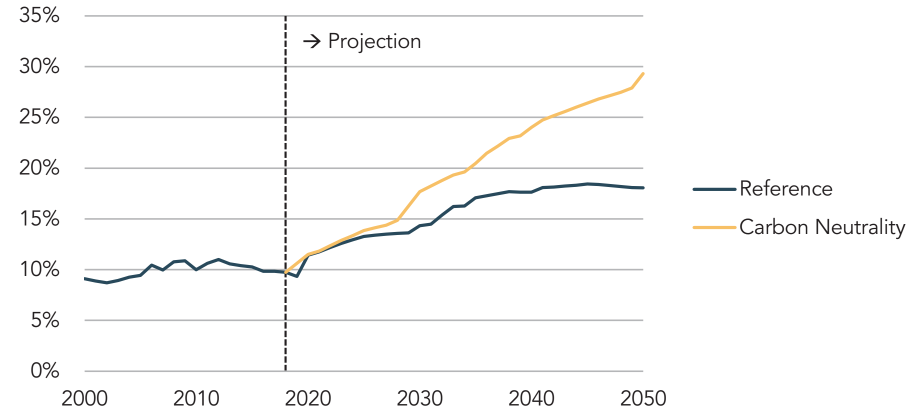
Energy intensity and modern renewables share

Figure 15-49. Final energy intensity in REF and CN (2005=100).



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 15-50. Modern renewables share in REF and CN, 2000-2050.



Sources: EGEDA, APERC analysis. Note: Includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

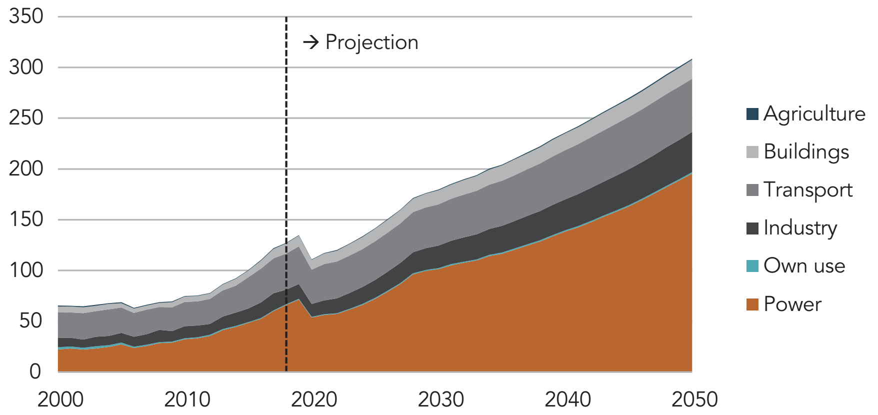
- Energy intensity and the share of modern renewables continue to improve, in support of APEC's aspirational goals.
- In REF, energy intensity is reduced by almost 49% from 2005 to 2035, surpassing an APEC-wide energy intensity reduction goal of 45%. A further reduction of 10% is expected to be reached by 2050.
- In CN, a reduction of 56% is projected (2005-2035). A further 12% reduction is expected to be reached by 2050.
- Alongside the growth in the economy of the Philippines through 2050, energy intensity is also achievable through current policies laid out by the Philippines. Nevertheless, enhanced policy measures are required to achieve the energy intensity reduction trend in CN.

- Relative to 2010 levels, the share of modern renewables in both scenarios is to be achieved by 2030. This is also in line with the Philippines' doubling target.
- The high share of renewables in CN in 2030 is attributable to the boost in renewable electricity, particularly from solar where overall installed capacity is almost 11 GW, which is 6.7 GW higher than in REF.
- On the demand side, the buildings sector sees a decrease in the modern renewables share as households opt for fuel switching between traditional biomass and electricity for cooking purposes. A similar trend is also noticeable in the agriculture sector, in line with its modernisation.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

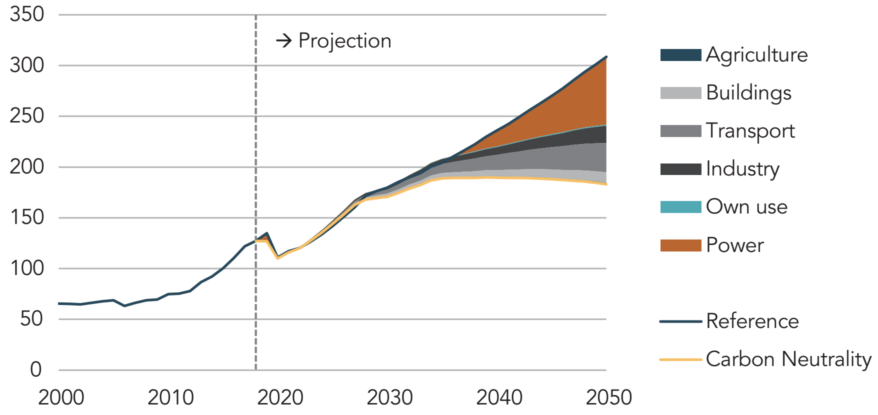
Gross CO_2 emissions

Figure 15-51. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 15-52. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

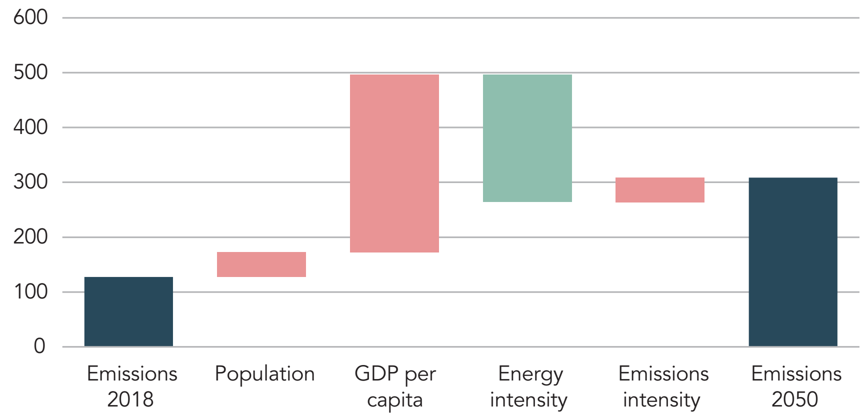


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Despite a significant decline of 20% between 2018 and 2019 due to the COVID-19 pandemic, gross CO_2 emissions are projected to grow 142% in REF (2018-2050). The power sector remains the largest source of energy-related CO_2 emissions in 2050.
- Half of the CO_2 emissions reduction in CN comes from the power sector, driven by mora-torium on greenfield coal projects, a significant transition towards renewables power, and the use of CCS units.
- Large-scale electrification in the transport sector further reduces CO_2 emissions by 33%.
- Reaching 'full' carbon neutrality in the Philippines would require additional measures from other non-energy sectors, particularly through CO_2 sequestration from the forestry sector through forest rehabilitation and reforestation as indicated in their updated NDC. This could be an area for collaboration between APEC economies in the future.

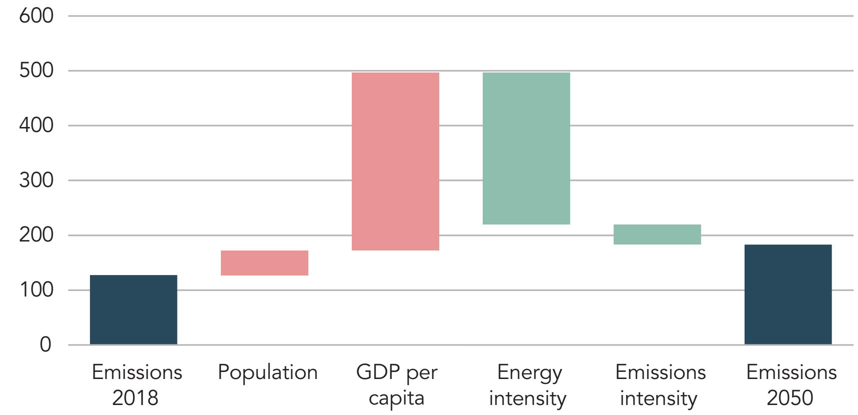
Components of CO_2 emissions

Figure 15-53. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 15-54. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- These figures show CO_2 emissions as the product of population, GDP per capita, primary energy intensity, and emissions intensity (see notes). In this context, primary energy and emissions intensities are calculated using energy supply, which includes inputs to the refining and power sectors.
- Macroeconomic activity increases CO_2 emissions between 2018 and 2050.
- Energy intensity (energy supply per unit of GDP) offsets a large portion of the CO_2 increase.
- Emissions intensity further contributes to CO_2 emissions growth with the prevalence of fossil fuels in energy supply.

- In CN, macroeconomic activity leads to the same CO_2 emissions increase as in REF. Energy intensity and emissions intensity both improve. However, the improvements are not enough to fully offset the CO_2 increases.
- The decrease in emissions intensity is driven by the plateauing of coal in the energy supply of the Philippines, as the coal input is not expected to be increased in the power sector. This significantly affects the overall carbon content of the economy's energy supply as the share of renewables increases.

Note: The Kaya identity is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

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16. Russia

Highlights

Demand

- Russian energy demand has increased by almost a quarter over the last two decades, though heat consumption fell significantly (22% decline), supplanted mostly by gas. Energy consumption in buildings decreased by 7% due to improved energy efficiency, but still accounts for one-third of demand and remains the largest energy consuming sector.
- REF assumes a 14% increase in total demand by 2050 over 2018 levels. About 90% of that increase will come from the non-energy use of natural gas as feedstock for chemical and petrochemical industries.
- CN assumes a 15% reduction in total demand out to 2050, relative to REF. Conventional energy carriers begin to be replaced by electricity and hydrogen, and energy efficiency also tempers demand. Direct consumption of fossil fuels remains important, still accounting for three-fifths of end-use demand.

Supply

- Enormous reserves of fossil fuels and uranium ore are sufficient to supply Russia's energy needs. Russia's energy production also supplies a large share of the global market for oil, gas, and coal.
- Primary energy production increased by more than 50% from 2000 to 2018. The driver of growth, far exceeding the growth in domestic consumption, was the almost doubling in fossil fuel exports.
- In REF, gas exports are anticipated to increase due to the launch of the Power of Siberia export pipeline operating at full capacity, as well as the introduction of multiple LNG projects. Beginning in the second half of the 2030s, coal and oil (including refined products) exports will decline, with oil exports falling at a faster rate.
- In CN, Russia's energy exports decline by 40% out to 2050. The composition of exports also shifts, with a much lower share of oil and refined products, and a much larger share of natural gas. An almost doubling of nuclear power generation will offset significant reductions in coal and oil supply.

Power

- REF assumes an increase in electricity generation of 16% to 1 300 TWh in 2050. The share of thermal generation will decline by 10%, though within that share, gas-fired generation will slightly increase. Three-fifths of the increase in generation out to 2050 will be provided by nuclear, which corresponds to the national energy strategy.
- In CN, electricity generation is 16% higher than in REF. The generation mix includes three significant changes: almost complete displacement of coal, additional growth of natural gas generation with deployment of carbon capture and storage (CCS) technologies starting in the 2030s, and accelerated development of nuclear.
- In REF and CN, a conservative estimate of the role of renewables in electricity generation is adopted: the share of renewables in 2050 will be 2.5% in REF and 3% in CN.
- Heat supply is important to provide comfortable living conditions for most of the population for most of the year. Heat supply remains prominent in REF and CN, but its role in Russia's energy system diminishes.

CO_2 emissions

- In REF, increased energy demand occurs at the same time as a move away from the most carbon intensive forms of energy supply. The net effect is that CO_2 emissions remain relatively stable out to 2050.
- CN assumes a 56% reduction of emissions compared with the REF by 2050. The power sector accounts for more than half of this reduction. The reduction results from an almost complete phase-out of coal generation, accelerated development of nuclear, and commissioning of renewable energy sources. The contribution of CCS technologies in CN will not exceed 10% of the total reduction of emissions in the power sector.
- Only 3% of the decline in emissions in CN relative to REF, will be from the buildings sector. This is because a large share of buildings' energy mix (more than 60%) is composed of secondary energy carriers, electricity and heat. The remaining share of emissions reductions will be split roughly equally between industry, transport and energy sector's own use.
- The emissions trajectory in CN is in line with the statement made by the President of Russia before COP 26 about the plans to achieve carbon neutrality by 2060.

About Russia

- Russia has the largest land area globally, spanning over 17 million square kilometres (km^2) in both Eastern Europe and Northern Asia. Most of the territory and the resident population are located north of the 50th parallel. In comparison, most of Canada's territory, an APEC member economy in the Western Hemisphere, is north of the 50th parallel. However, most of the population lives further south, along the US border.
- The combination of geography and population settlement in Russia makes it necessary to use a significant amount of energy to provide comfortable living conditions for most of the population for most of the year. These are key factors contributing to Russia having the highest energy intensity of all economies in APEC.
- Energy requirements have been foundational for the development of Russia's centralised power supply systems, and centralised heat supply systems. The dual needs have led to thermal power plants with combined heat and power generation. Russia now has the world's largest district heat supply systems in most major cities.
- In 2018, Russia's gross domestic product (GDP) reached USD 011 billion 2018 USD PPP, the fourth largest in APEC. Its population of 144 million people lives mostly in urban areas (74%). 68% of the population lives in the European part of Russia, which only accounts for 21% of Russian territory.
- Russia was the third-largest energy producer in APEC in 2018, accounting for 18% of total APEC energy production. About half of the energy produced was consumed within the economy, while the rest was exported. Russia is the world's largest energy exporter overall, exporting about 30 PJ in 2018.
- Russia was the third-largest power producer in APEC, accounting for 6.5% of APEC's total electricity generation in 2018 and was also the largest heat producer.
- In 2018, Russia remained the third-largest CO_2 emitter in APEC, accounting for 6.9% of APEC's total.
- Russia has significant reserves of fossil fuels as well as uranium reserves.

Table 16-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	144.5	5.0%	4
GDP	4 011	5.7%	4
TPES	31 792	9.2%	3
Production	62 138	18.3%	3
Imports	1 116	0.9%	17
Exports	30 479	28.1%	1
Electricity generation	1 113	6.5%	3
Heat production	5 482	47.3%	1
CO_2 emissions	1 464	6.9%	3

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 16-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	2 745	407	15.1%	2
Natural gas	1 346	59	19.9%	2
Oil	660	28	6.2%	2
Uranium	211	73	5.6%	3

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- **Energy Strategy of the Russian Federation until 2035:** This is the main document defining the directions of the economy's energy sector development, adopted in June 2020. It was developed before the COVID-19 pandemic and could not foresee its consequences. Some of its projections, especially fossil fuel exports, now appear optimistic. In addition, for more than a year since its adoption, the Energy Strategy 2035 did not answer questions about ways to reduce CO_2 emissions. This is a limiting factor against the backdrop of numerous statements about the commitment to lower emissions and goals to achieve carbon neutrality by 2050 or in the next decade. In May 2019, the Russian Federation's Energy Security Doctrine was approved, declaring the global movement toward low-carbon energy and a move away from fossil fuels as a threat to national energy security.
- **Developing an emissions strategy:** The Presidential Decree "On Reducing Greenhouse Gas Emissions", adopted in November 2020, instructed the government of the Russian Federation to develop a Strategy for Socio-Economic Development of the Russian Federation with Low Greenhouse Gas Emissions until 2050.
- **Instituting the emissions strategy:** The Strategy of Socio-Economic Development of the Russian Federation with Low Greenhouse Gas Emissions up to 2050 was approved at just before the COP 26 summit, in October 2021. The Strategy recognises the development of nuclear power generation and the expansion of the AFOLU absorption capacity as the most significant contributors to the reduction of net GHG emissions. The global community considers both areas as insufficient to reduce Russia's contribution to GHG emissions. Nevertheless, the Strategy demonstrates significant progress in understanding the problem and in attempting to find ways to reduce emissions. It is currently Russia's only strategic development document that looks out as far as 2050.
- **Decarbonisation:** In 2021, essential documents were adopted that set the contours of the development of energy sub-sectors that promote decarbonisation: Federal Law "On Limiting Greenhouse Gas Emissions" (July 2021), "The concept of the development of hydrogen energy in the Russian Federation until 2035" (August 2021), and "The concept for the development of production and use of electric vehicles in the Russian Federation until 2030" (August 2021).
- **Hydrogen:** The development of hydrogen in the Russian Federation for the period to 2035 aims to realise Russia's national potential in production, export, and industrial use cases, so that Russia can be a world leader in hydrogen and maintain a competitive edge in the context of a global energy transition. Russia's hydrogen exports could grow to: 0.2 million tonnes in 2024; 2–12 million tonnes in 2035; and 15–50 million tonnes in 2050. The upper values are optimistic. The Concept confirmed the statements of the Energy Strategy of Russia until 2035, with additional projections to 2050.
- **Electric vehicles (EV):** The "Concept for the Development of Production and Use of Electric Vehicles in the Russian Federation until 2030" provides three scenarios. The target scenarios propose an increase in production of EVs to 217 000 units (100 times growth) by 2030, an increase in the share of EVs in the overall vehicle fleet to 15%, and an increase in the number of charging stations to over 14 000 units (8 times growth).
- **Emissions law:** Federal Law "On Limiting Greenhouse Gas Emissions" provides the introduction of a staged model for regulating emissions. The model incorporates mandatory carbon reporting, collected and summarised by the authorised government body. Emissions reporting requirements will phase-in, dependent on the volume of emissions of reporting entities (the largest emitters will report first). The Law introduces the notion of a "greenhouse gas emission reduction target". It will be set by the government, at an economy-wide level, and account for AFOLU and the need to ensure sustainable and balanced socio-economic development. The Law proposes the creation of a roster of GHG emissions. This roster will be the state information system, which the authorised federal executive body will maintain.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- **The Reference scenario (REF)** assumes maintaining the current energy consumption structure by sector and by fuel. The scenario considers gradual energy efficiency improvements in the consuming sectors. The REF is a conservative scenario and does not assume the significant use of hydrogen and CCS technologies.
- **The Carbon Neutrality scenario (CN)** explores opportunities to decarbonise the consuming sectors, and electricity and heat production. This *Outlook* is one of the first attempts to explore possible directions for decarbonising Russia's economy and energy sector.
- The geography and settlement location of the population necessitate significant amounts of energy to maintain comfortable living conditions for most of the year. These features, combined with substantial volumes of heat generated by combined heat and power plants, pose unique challenges and suggest, in a sense, "non-trivial" solutions to decarbonise the economy.
- The leaders of decarbonisation in Russia will be primarily export-oriented sectors: iron and steel, fertilisers, and oil and gas. Therefore, the CN assumes a significant transformation of energy consumption in industry: electrification of technological processes, use of hydrogen, increased energy efficiency, and use of CCS.
- Transport in Russia is assumed to follow global trends in using EVs. It should be noted that a significant share of energy resources is consumed by pipeline transport. The CN assumes partial electrification of compressor stations and measures to improve energy efficiency.
- Buildings remain the most conservative sector, as they consume significant amounts of secondary energy: electricity and heat. Nevertheless, there is an accelerated renovation of residential buildings and the abandonment of the use of coal closer to the end of the projection period, following development of the national gas supply system.
- In power and heat generation, development of nuclear power plants follows national policy documents. CCS use at gas-fired power plants is also incorporated.

Table 16-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the CN.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Russia

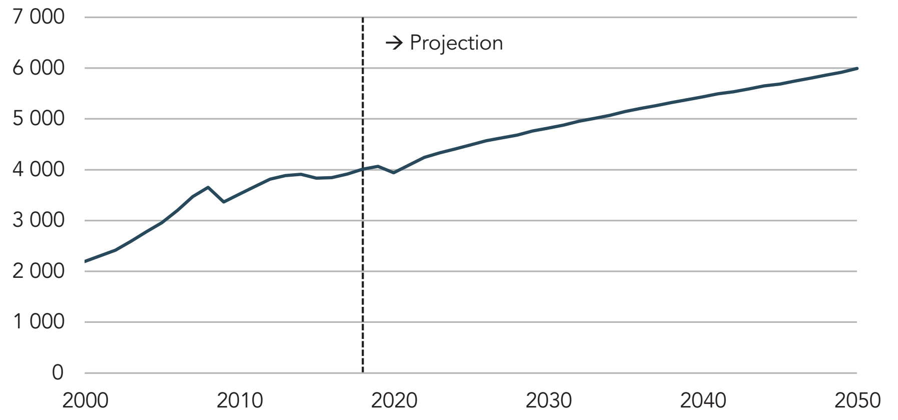
Table 16-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• The main efforts are focused on improving energy efficiency.	• Significant energy efficiency improvements. • The use of environmentally friendly technologies in carbon-intensive industries.
Buildings	• Energy efficiency improves gradually. • Reduced energy intensity • Regional differences in access to clean fuels are incorporated.	• Almost complete renovation of residential buildings by 2050. • Significant energy efficiency improvements. • Accelerated substitution of coal and refined products for natural gas and electricity.
Industry	• Current trends are expected to continue. • Moderate energy conservation	• Some processes in iron & steel and chemicals incorporate hydrogen, while CCS is deployed in steel, cement, and chemical subsectors beginning in 2030. • Higher electrification rates in all subsectors, especially mining. • Energy intensity improvements are greater than in REF.
Transport	• Current trends are expected to continue. • Moderate energy conservation	• Replacing refined products with electricity and hydrogen. • Significant renewal of the car fleet with EVs. • Wide-scale substitution of jet fuel with sustainable aviation fuel.
Power and heat	• Maintaining the existing structure of installed capacity of power plants. • Gradual replacement of coal.	• Significant increase in the capacity of nuclear power plants. • Gradual decommissioning of coal-fired power plants. • Use of CCS in 60% of gas-fired power plants. • Slight increase in the capacity of the solar and wind power plants.
Supply	• Projection of fossil fuel production and exports are relevant to Russia energy strategy 2035. • The launch of the Power of Siberia export pipeline at full capacity and the implementation of LNG projects under construction are incorporated.	• Projection of fossil fuel production and exports is driven by domestic demand trends in the CN. • Assumption of export markets and some APEC-driven coal trends.
Climate	• NDC taken into account.	• Electrification and use of hydrogen and CCS would hypothetically achieve more ambitious emission reduction goals than those set in the NDC.

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

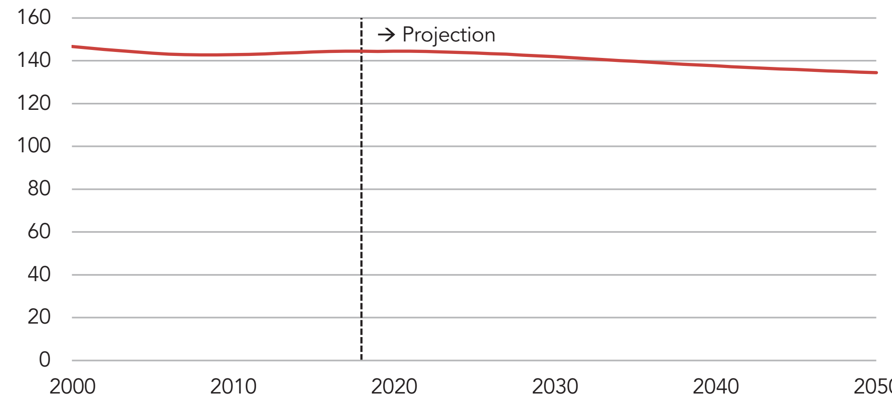
Macroeconomic backdrop

Figure 16-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 16-2. Population in millions, 2000-2050

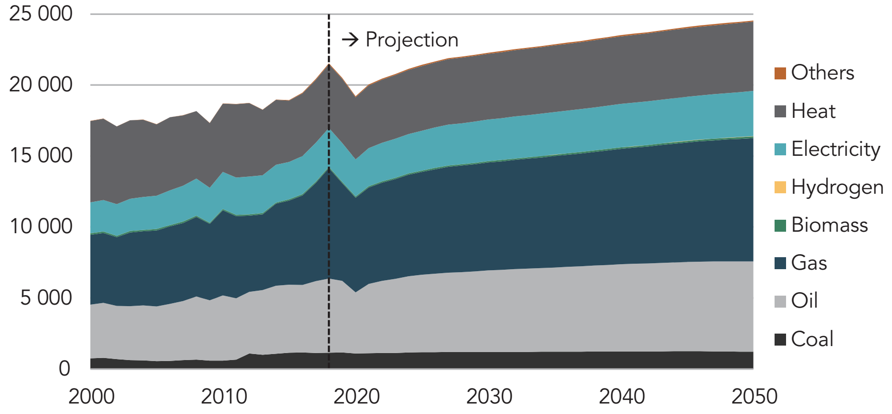


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- Russia's GDP grew at a high rate in 2000–2008 (6.5% annual average). The global financial crisis led to a 7.8% fall in GDP in 2009. Following the relatively strong recovery of 2010–2012, economic growth has been relatively weak. In 2015, GDP fell by 2% due to decisions made in response to international sanctions. For 2016–2019, Russia's GDP only increased by 6%. In 2020, restrictions imposed as a response to the COVID-19 pandemic, led to a 3.1% decline in Russia's GDP.
- The *Outlook* uses a forecast by the International Monetary Fund, which covers 2021–2023; thereafter, the average annual growth rate is estimated using historical data as a guide. This forecast generally reflects Russia's current economic development trends and the slow diversification of the economy. According to this forecast, GDP will grow by 44% from 2018 to 2050, significantly lower than the APEC average.
- The decline in Russia's population, which began in the early 1990s, continued through the 2000s. This decline was due to a combination of two major factors: the small generation of World War II children starting to become parents, and the consequences of the collapse of the Soviet Union and the associated economic and social crises. By 2010, the generation born in the 1980s (baby boomers' children) were beginning to enter adulthood, after which the population started to grow again. Growth peaked in 2013–2015 when the population grew by an average of 300 000 people a year. The positive trend has continued through 2018.
- The *Outlook* uses UN DESA's population projection. According to forecasts, the population will remain stable during the first half of the 2020s, then is expected to decline by 10 million people by 2050. Population projection considers current downward trends in the birth rate and unfavorable demographic trends going back to World War II. Increased life expectancy partly counteracts some of these factors.
- In 2018, Russia's GDP per capita was USD 27 762 on a purchase power parity basis. This was 12th in APEC, which is a significantly lower rank than Russia's fourth-highest GDP. GDP per capita begins to grow at a faster rate than GDP due to population decline. However, Russia's GDP per capita grows at a slower rate than for the APEC region out to 2050.

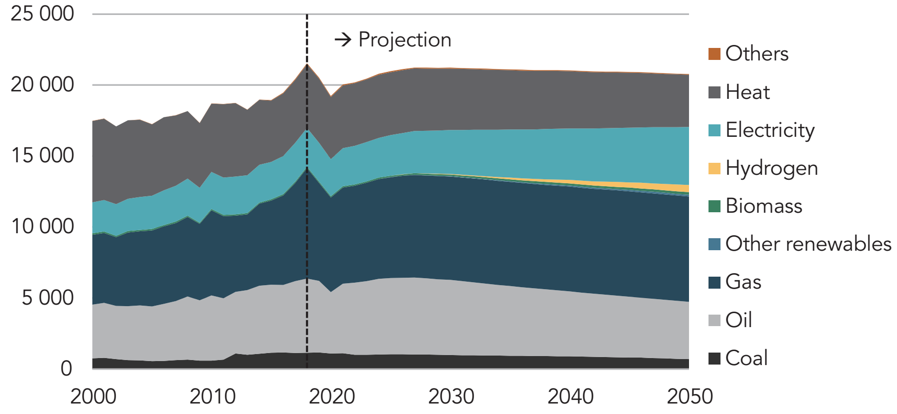
End-use energy demand

Figure 16-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 16-4. Energy demand in CN, 2000-2050 (PJ)

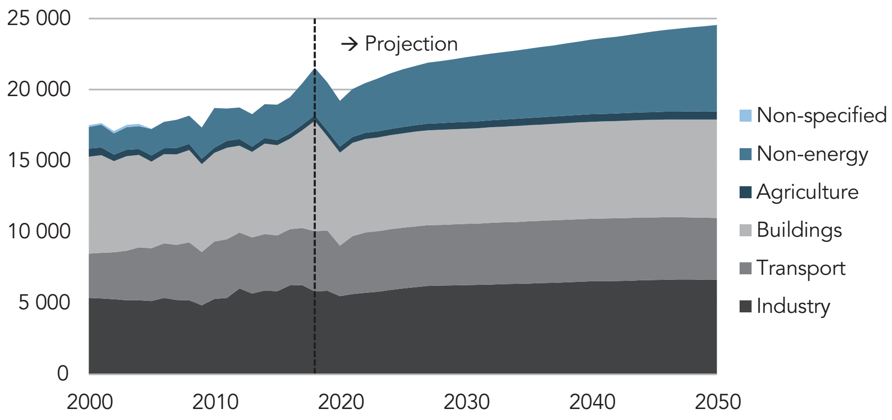


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- During 2000–2018, final energy demand increased by 23%. A significant change in the structure of final energy demand was a 22% decrease in heat consumption and a 12% decrease in its share. The share of fossil fuels increased by a comparable value, with natural gas accounting for the most significant increase.
- Two “upticks” can be noted in the statistics: a 66% increase in coal consumption in 2012, and a 10% increase in gas consumption in 2017, with an additional 12% increase in 2018. The rise in coal consumption, according to EGEDA, came from the use of coke in iron & steel. The increase in gas was from residential buildings. Looking ahead, we note that the 2017–2018 data was not used to project gas consumption in buildings.
- The forecast considers the impact of the COVID-19 pandemic on energy consumption. In 2020, most fuel consumption fell by an average of 5-6%. Refined products consumption was more severely impacted, declining by 15% in 2020.
- In REF, after the accelerated recovery growth of 2021–2023, the consumption of all energy carriers is expected to increase. Refined products and gas will account for 80% of the consumption growth, increasing by 34% and 38%, respectively. Electricity and heat will account for 19% of the consumption growth with roughly equal shares. Coal and other energy carriers’ consumption will remain relatively stable. The REF reflects the current trends and structure of energy consumption, including ongoing improvements in energy efficiency and increased use of gas.
- CN assumes a 15% reduction in total demand out to 2050, relative to REF. Coal and refined products are almost 40% lower, and gas (15%), and heat (25%) are lower too. Conventional energy carriers will be replaced by electricity and hydrogen, with electricity increasing by 50% out to 2050 and hydrogen consumption increasing from zero to more than 500 PJ. Nevertheless, fossil fuels still account for three-fifths of end-use consumption. CN explores the possibility of replacing fossil fuels in the end-use sectors, as well as a reduced role for heat consumption and improvement of residential buildings energy efficiency.

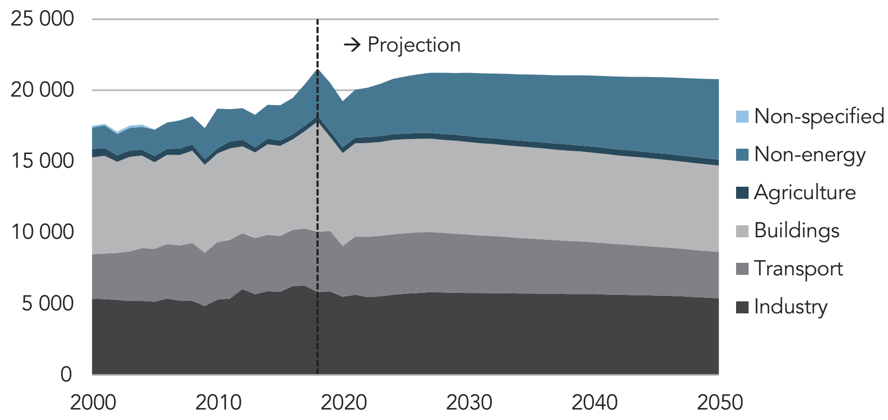
End-use energy demand by sector

Figure 16-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 16-6. Energy demand by sector in CN, 2000-2050 (PJ)

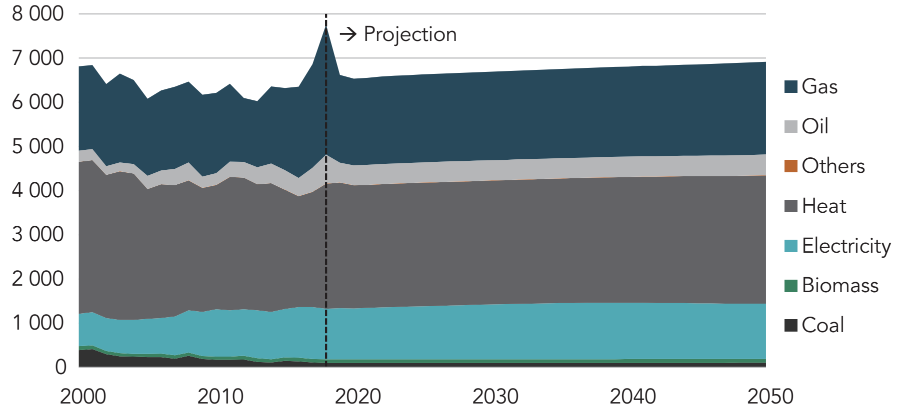


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- During 2000–2018, the share of industry was about 30%, and transport was 20%. Energy consumption in buildings decreased by 7% due to improved energy efficiency, though is still the largest sector, accounting for one-third of final energy consumption in 2018. Non-energy use more than doubled during 2000–2018. The primary consumers of hydrocarbons are Russia's oil and gas chemical plants.
- Restrictions caused by the COVID-19 pandemic have been most impactful for transport. Transport consumption is estimated to have declined by 15%, which is a fall that is double the impact of the global financial crisis of 2009. Industry has also been impacted, with consumption in 2020 approximately 5-6% below 2018 levels.
- In REF, following accelerated recovery growth for 2021–2023, consumption of all energy carriers is expected to increase gradually. Industry and non-energy will account for 80% of the increase in consumption. The contribution of increased energy use in industry will be about 20%, and more than 60% will come from increased use of energy as feedstocks. Consumption in buildings will increase by 10–15%. The increase in transport will be by no more than 5%.
- CN assumes a 15% reduction in total energy use in 2050 compared to the REF. The contribution of industry in reducing consumption will be more than a third of the total decline. This will be mainly achieved by greater levels of energy efficiency and material efficiency. CCS used in the steel, cement, and chemical sectors from 2030 will lead to increased industry energy consumption but lead to reduced emissions.
- About 30% reduction in consumption appears to be achievable through a substantial change in the transport energy mix through the meaningful use of electricity and hydrogen.
- The contribution of buildings to reducing energy consumption in CN could reach 25%. This will require retrofits of almost all outdated residential buildings. The retrofits will result in greater energy efficiency and an accelerated replacement of coal and refined products for natural gas and electricity.

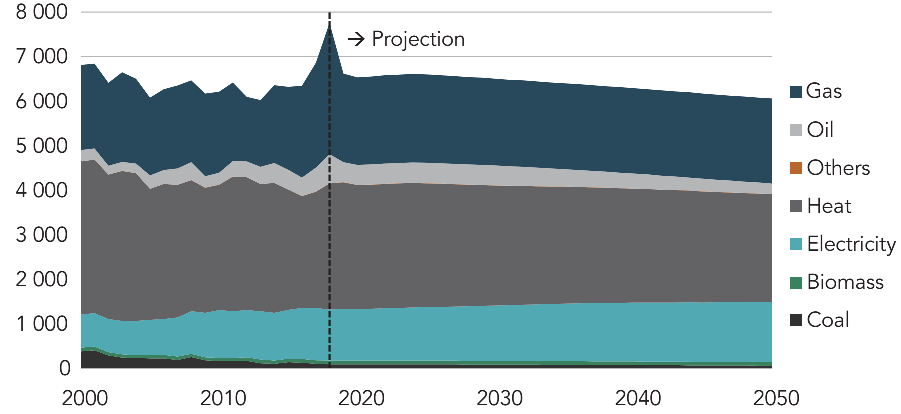
Buildings energy demand

Figure 16-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-8. Buildings energy demand in CN, 2000-2050 (PJ)

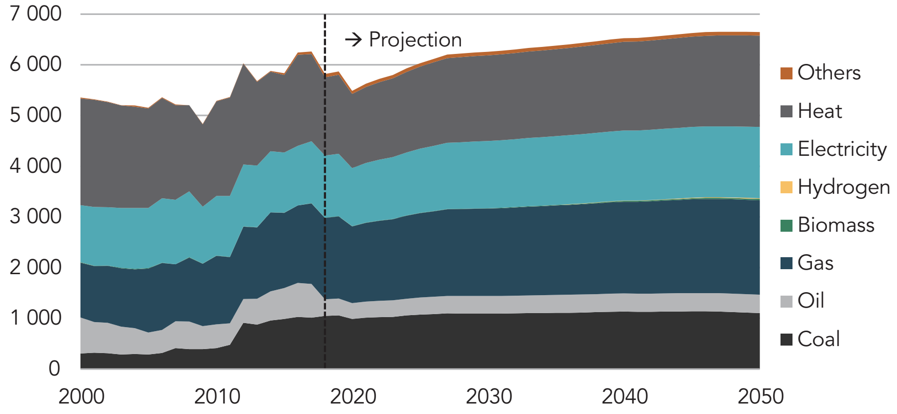


Sources: EGEDA, APERC analysis.

- From 2000–2016, buildings energy consumption decreased by 7%. Coal consumption fell by two-thirds, and refined products (mainly LPG) increased 60%. But the share of coal and oil in the consumption structure did not exceed 9-10%. Consumption of natural gas continued to grow, facilitated by significant pipeline infrastructure development. In contrast, the share of heat decreased from 50% to 40%, with consumption falling by almost a quarter.
- The fall in heat consumption is mainly due to energy savings measures implemented by building occupants, including residents. Newly commissioned buildings are also meeting modern energy efficiency standards, contributing to less heat demand.
- According to EGEDA, consumption of natural gas and oil products (mostly LPG) in buildings (residential) has grown significantly in 2017 and 2018. These figures are not consistent with national statistics. Because of this, it was decided not to use 2017–2018 data as the basis for the forecast.
- In REF, buildings energy consumption is assumed to maintain the current structure with a small amount of growth (4%) out to 2050. Improved living standards contribute to the growth in energy consumption, despite the fall in population. Both electricity and heat are anticipated to increase slightly.
- CN, in general, implements a conservative energy mix forecast for buildings. The scenario explores the possibility of accelerated substitution of direct use of fossil fuels and LPG through electrification. However, the main factor in reduced energy use is energy efficiency. Large-scale retrofits of residential buildings are assumed, which lead to significant energy efficiency improvements, and a reduction in heat consumption of almost 20% in 2050, relative to REF.
- Climatic conditions, characteristics of settlement, and a large district heating role, mean that the buildings sector is the most challenging sector to decarbonise in Russia.

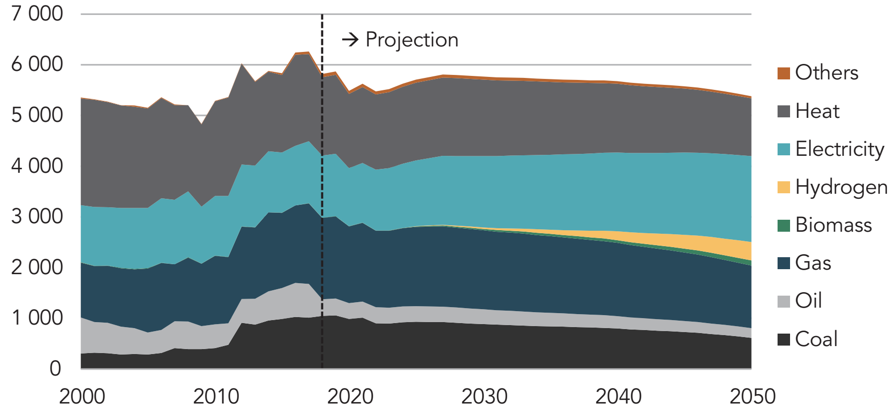
Industry energy demand

Figure 16-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 16-10. Industry energy demand in CN, 2000-2050 (PJ)

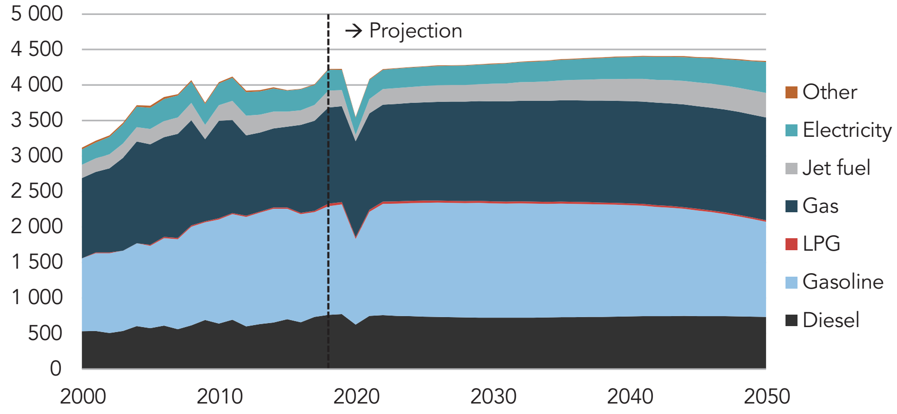


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industry is the second-largest consumer of energy after buildings. From 2000–2018, energy consumption in industry increased by about 10%, though the consumption structure has shifted. The most significant change, as in buildings, is due to a decrease in heat use of more than 25%, and a decrease in its share from about 40% in 2000 to 27% in 2018. This is mainly due to changes in technology.
- Two significant shifts can be seen in the reported data. First, coal consumption (mainly coking coal) almost doubled in 2012, and second, the consumption of refined products halved in 2018. These changes may be due to methodological issues of statistical data collection and processing. According to our estimates, energy consumption in industry will decrease by 5-6% in 2020 due to COVID-19 pandemic restrictions.
- REF assumes that the current structure of energy consumption in industry will be preserved, with an increase in total consumption of about 15%. Consumption of gas, electricity, and heat will grow higher than that of coal and refined products. By the end of the period, Russia is expected to begin using hydrogen in a small number of high-temperature processes.
- CN proposes widespread technological change, aiming to reduce fossil fuels. Some processes in iron and steel and chemicals incorporate hydrogen, while CCS is deployed in steel, cement, and chemical subsectors beginning in 2030. Higher electrification rates in all subsectors, especially mining, will see electricity's share increase from 21% in 2018 to 31% in 2050.
- In CN, energy intensity improvements, and material efficiency gains, lead to industry consumption being one-fifth lower than REF in 2050. Consumption of coal, refined products, gas, and heat declines by 30%, relative to REF. These declines are partially offset by the increased use of hydrogen and electrificity. Hydrogen accounts for almost 7% of industry energy use in CN in 2050.
- Decarbonisation assumptions in CN reflect ambitions of export-oriented industries. These industries are most interested in reducing their emissions due to carbon border adjustment mechanisms or similar.

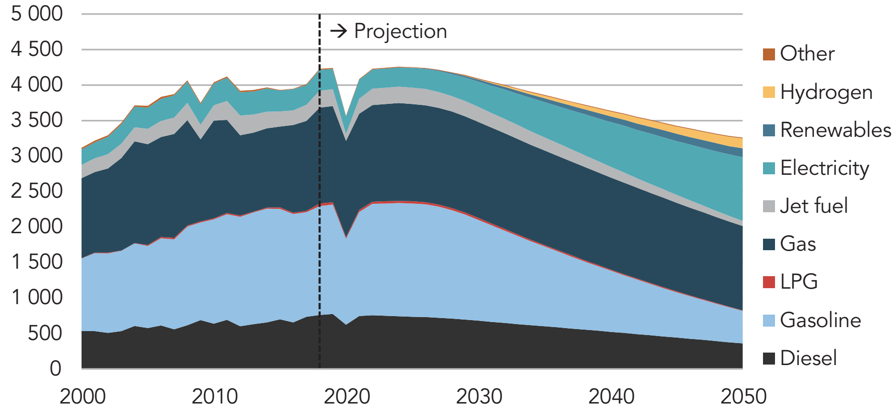
Transport energy demand

Figure 16-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 16-12. Transport energy demand in CN, 2000-2050 (PJ)

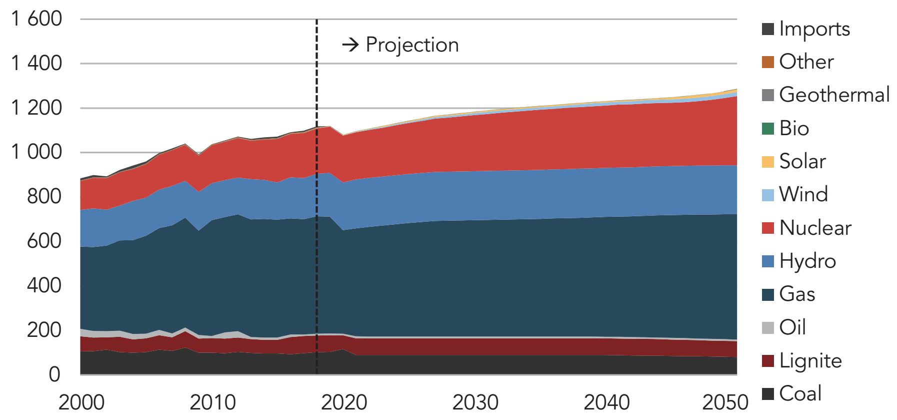


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport is the third-largest end-use sector, accounting for about 20% of end-use consumption. The share of gas is particularly large in Russia, with almost all of this associated with pipeline transport. Despite the very large consumption by pipelines, road transport is the largest consumer, accounting for just over half of total consumption in 2018. Railroads and aviation accounted for 13% of transport consumption in 2018.
- Transport energy consumption has grown at a much faster rate than other sectors. In 2018, consumption was 34% higher than in 2000. The relative share of different fuels has remained stable.
- Like the rest of the world, the transport sector in Russia has been most impacted by the restrictions imposed in response to the COVID-19 pandemic. According to our estimates, transport sector consumption declined by 15% in 2020. If excluding pipelines (which were largely unaffected by the restrictions), consumption fell by 23%. Gasoline consumption fell by 20% in 2020 and jet fuel fell by almost 60%.
- REF assumes the restoration of pre-pandemic levels of energy consumption within two years. Growth in consumption out to 2050 will be relatively subdued, at a level about 5% greater than in 2018. There is assumed substitution of refined products to gas and an accelerated deployment of EVs. Aviation, and associated jet fuel consumption, is anticipated to increase by almost 60%.
- The transport sector will undergo significantly more changes in CN. This is reflected by a rapid reduction in refined products consumption in road transport of more than 60%. The vehicle fleet will feature a significantly higher proportion of battery EVs and hydrogen fuel cell vehicles. In aviation, the consumption of traditional jet fuel will decline by 80% by 2050, replaced mostly by imported biojet fuel and hydrogen starting in the 2030s. CN also considers an increased use of electrically-driven compressors to run gas pipelines, which will reduce gas consumption by 20%.
- Energy consumption in CN is 25% lower than in REF, which is the most significant reduction out of all end-use sectors.

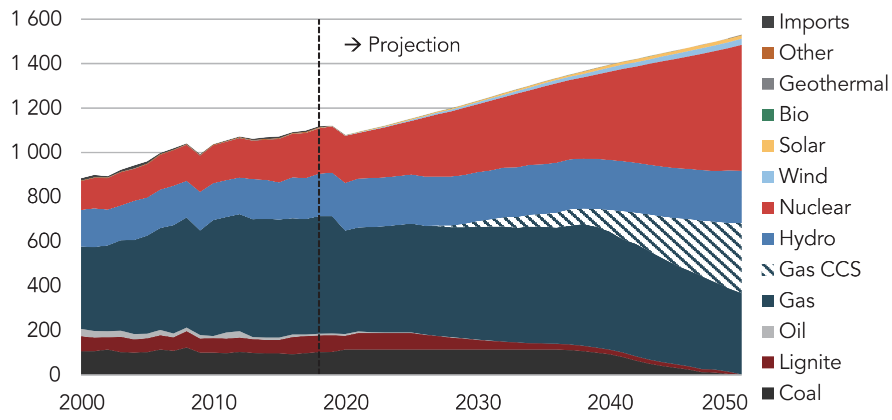
Electricity generation

Figure 16-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 16-14. Electricity generation in CN, 2000-2050 (TWh)

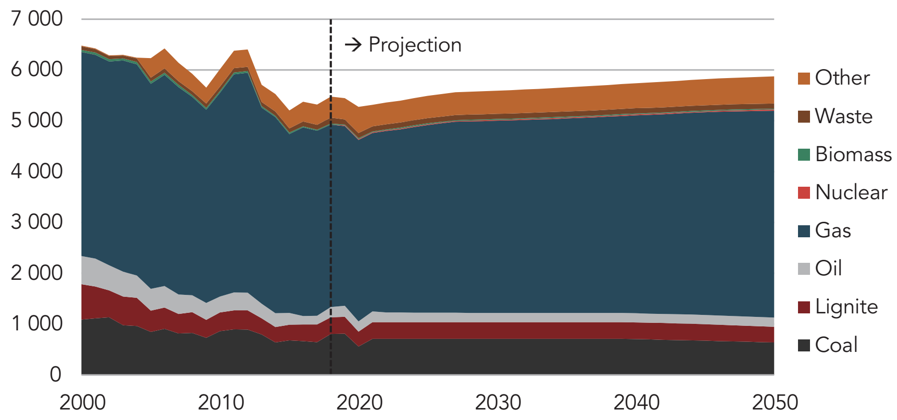


Sources: EGEDA, APERC analysis.

- In 2018, electricity generation was 25% higher than in 2000 and amounted to more than 1 100 TWh. Three-fifths of the increase was due to increased output from gas-fired thermal power plants (TPPs), 30% was from nuclear power plants (NPPs), and 10% from hydropower plants (HPPs). From 2000–2018, about 65% of electricity generation came from TPPs. The increase in gas-fired generation has seen its share increase from 42% in 2000 to 47% in 2018. Low-carbon NPPs and HPPs accounted for about a third of total electricity generation. The share of NPPs has been growing steadily.
- Electricity generation in 2020 fell by no more than 3%, which is significantly less than the fall in 2009. Power generation from NPPs increased slightly in 2020, while generation from HPPs increased by more than 10% due to favourable water conditions. The main contribution to balancing the market was made by TPPs, primarily gas-fired.
- The REF assumes an increase in electricity generation of 16% to 1 300 TWh in 2050. The share of TPPs in generation will decline by 10%, which will mean current generation volumes are maintained. However, gas-fired power plants will account for a higher proportion of TPP generation. Three-fifths of the increase in generation out to 2050 will be provided by NPPs, which corresponds to the national energy strategy. The share of nuclear will grow to 24% of total electricity generation. In REF, a conservative estimate of the role of renewables in electricity generation is adopted: the share of renewables will be no more than 2.5% by 2050.
- In CN, electricity generation is 16% higher than in REF. The generation mix includes three significant changes: almost complete displacement of coal, additional growth of natural gas generation with deployment of CCS technologies starting in the 2030s, and accelerated development of NPPs.
- According to our estimates, two-thirds of the increase in electricity generation in CN, relative to REF, will come from NPPs. Growth in renewables is higher than in REF, but their share is still relatively low, with a generation share of less than 3%.

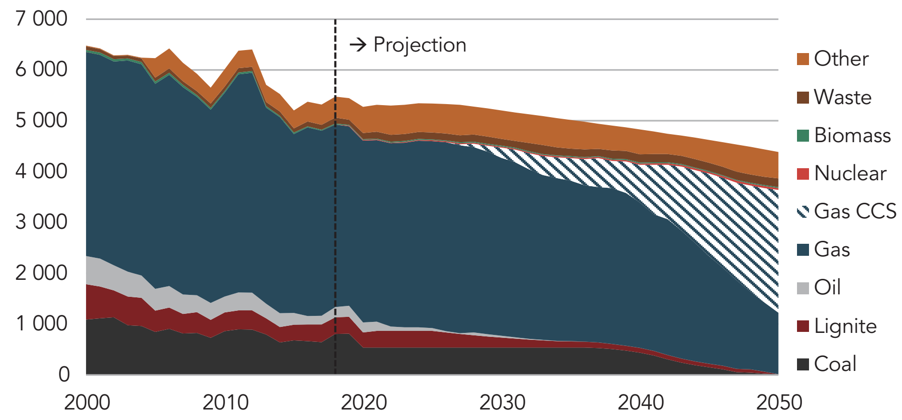
Heat production

Figure 16-15. Heat generation in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-16. Heat generation in CN, 2000-2050 (PJ)

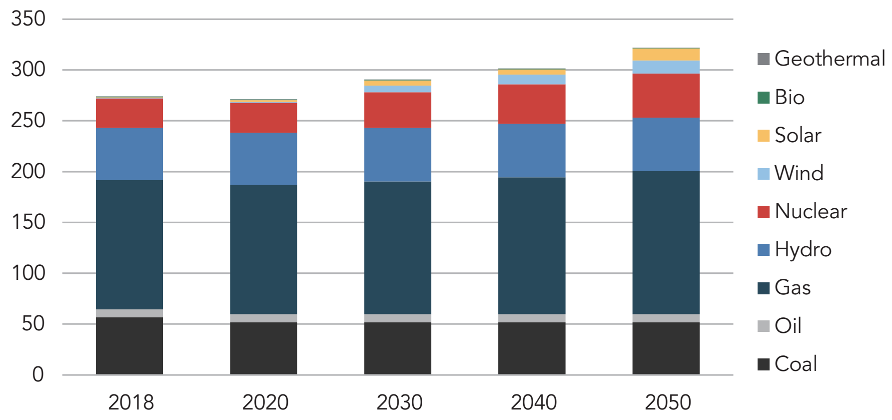


Sources: EGEDA, APERC analysis.

- Heat supply is one of the most important energy supply systems in Russia and is an essential life support system. The geography of settlements in Russia makes it necessary to use a significant amount of energy to provide comfortable living conditions for most of the population for most of the year. Russia currently has the world's largest district heating systems in most major cities. Heat supply to buildings accounts for two-thirds of all heat consumption. Industry consumes most of the remainder.
- From 2000–2018, buildings heat consumption declined by 18%, whereas industry heat consumption fell by 25%. Heat demand is supplied by combined heat and power, and heat-only power plants, in roughly equal shares.
- Gas-fired combined heat and power, and heat-only power plants, account for two-thirds of heat production. Most of these plants are in the west of Russia, fed by the large-scale development of gas pipeline distribution systems. In the east, coal-fired thermal power plants dominate, accounting for about 20% of all heat produced. About 10% of the heat is produced by industrial cogeneration plants and boilers using production waste and heat recovery units.
- In REF, heat generation is expected to increase by 7% out to 2050, with improved living conditions counteracting a modest improvement in energy-saving measures. Some of the production at coal-fired plants will be supplanted by gas-fired plants. This relies on large-scale development of gas supply systems in the eastern part of the country.
- More significant changes are assumed in CN on both the demand and production sides. Large-scale retrofits of residential buildings and improved energy efficiency lead to a 20% reduction in heat consumption out to 2050. Gas plants will provide more than 80% of the heat demand, and some of the plants with combined generation are expected to be equipped with CCS systems.

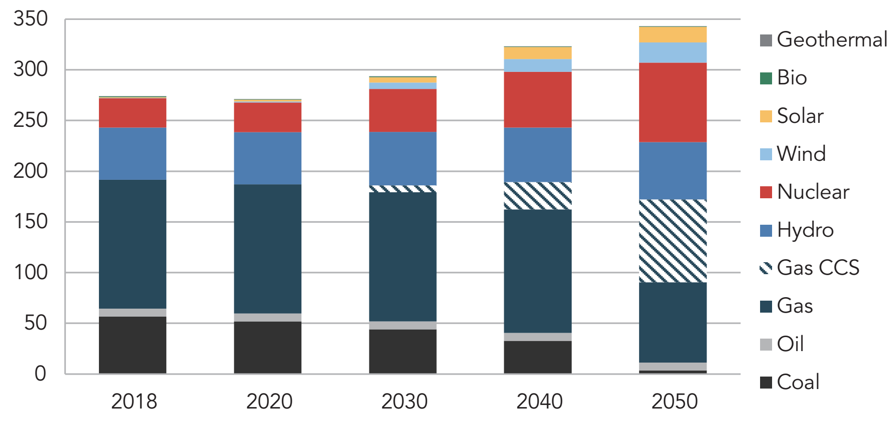
Electricity generation capacity

Figure 16-17. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 16-18. Generation capacity in CN, 2018-2050 (GW)

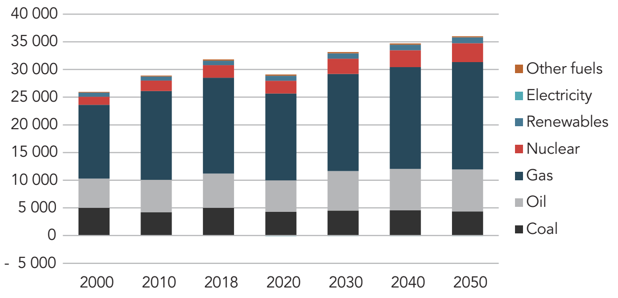


Sources: EGEDA, APERC analysis.

- Power plant capacity was almost 275 GW in 2018. TPPs accounted for a 70% share of this capacity, and two-thirds of these were gas-fired TPPs. The share of HPPs was about 20%, while NPPs accounted for slightly more than 10%. NPPs providing baseload generation, at a high average capacity factor of 80%, means that nuclear capacity is less than half of the share of nuclear generation. The renewables share of capacity was less than 0.5% in 2018.
- In REF, capacity will increase by almost 20% (50 GW) out to 2050. Gas-fired TPPs and NPPs will each account for almost 30% of the increase, while wind and solar will each account for about 25%. The fall in coal-fired capacity will offset some of these gains. The increase in nuclear capacity will represent a 50% increase from 2018 levels.
- In REF, the share of TPPs will decrease by about 10% out to 2050, due to a decline in coal and an accelerated increase in the capacity of nuclear and renewables. The share of HPPs will decrease from 19% in 2018 to 16% in 2050, and the share of NPPs will increase to 13%.
- REF assumes wind capacity increases to 20 GW and solar capacity increases to 15 GW. The share of these renewables in total installed capacity reaches 8%.
- In CN, increased demand for electricity requires more than 20 GW of additional capacity than REF. Installed capacity approaches 350 GW by 2050.
- In CN, TPP installed capacity declines due to the almost complete decommissioning of coal-fired TPPs. The commissioning of additional gas-fired TPPs will require the development of gas supply systems in the eastern part of the economy.
- NPP capacity increases by 170% in CN, which leads to a capacity that is more than 80% greater than in REF. Nuclear capacity is almost 23% in CN, which is a share that is almost 10% greater than in REF.
- CN assumes more ambitious renewables commissioning targets, with solar and wind increasing to reach a combined 10% share of total installed capacity.

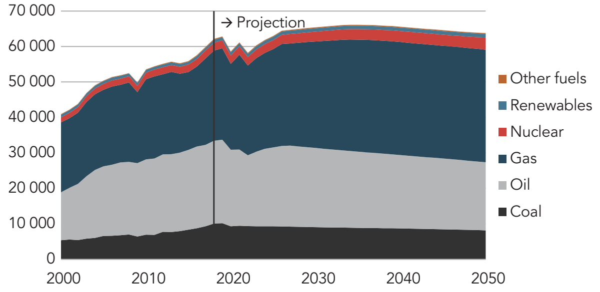
Energy supply in the Reference scenario

Figure 16-19. Total energy supply in REF, 2000-2050 (PJ)



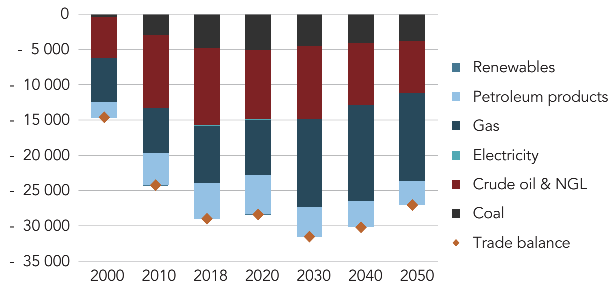
Sources: EGEDA, APERC analysis.

Figure 16-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-21. Energy trade in REF, 2000-2050 (PJ)

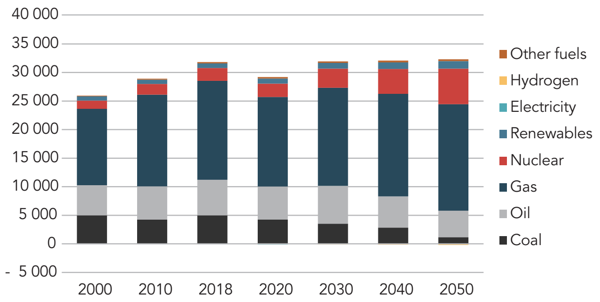


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Enormous reserves of fossil fuels and uranium ore are sufficient to supply Russia's energy needs. However, Kazakhstan has supplied small quantities of coal, and until recently, central Asian economies have supplied small volumes of natural gas.
- Energy supplies have increased by about a quarter from 2000 to 2018, in response to increased domestic demand. Two-thirds of the increase in supply has been from natural gas, a quarter from oil, and about 15% from increased nuclear power generation. Coal consumption has remained at roughly the same level.
- Primary energy production increased by more than 50% from 2000 to 2018. A doubling in energy exports, and increases in domestic consumption, has spurred this production growth. Refined products exports have doubled, and crude exports have increased 80%, so that oil (and derived products) now account for over half of Russia's energy exports. Coal exports increased more than five-fold, albeit from a lower base, while gas exports increased 30%.
- There have been significant impacts from COVID-19 on Russia's energy production and trade. Moving forward, gas exports are anticipated to increase due to the launch of the Power of Siberia export pipeline operating at full capacity, as well as the introduction of multiple LNG projects. Starting from the second half of the 2030s, coal and oil (including refined products) exports will decline, with oil exports falling at a faster rate.
- The decline in oil exports occurs at the same time as an increase in domestic demand for refined products in REF. Increases in domestic demand are not sufficient to offset the decline in exports, and so oil production falls out to 2050.

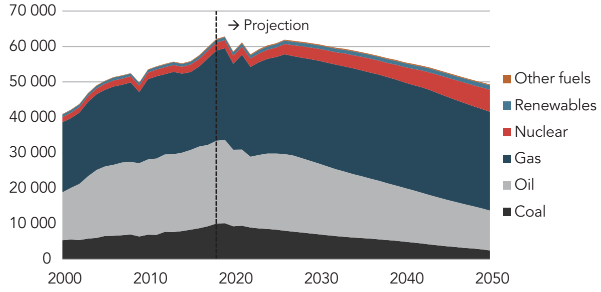
Energy supply in the Carbon Neutrality scenario

Figure 16-22. Total energy supply in CN, 2000-2050 (PJ)



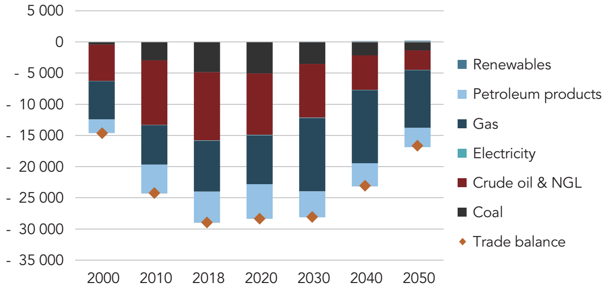
Sources: EGEDA, APERC analysis.

Figure 16-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-24. Energy trade in CN, 2000-2050 (PJ)

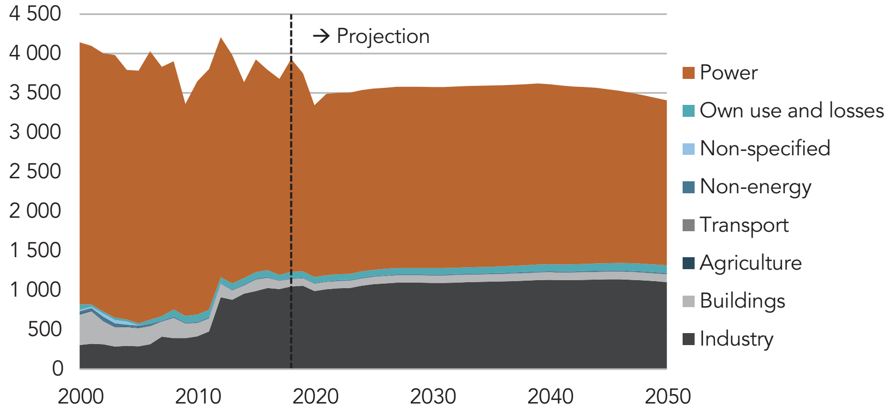


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- CN assumes changes in the structure of final energy consumption through more intensive implementation of energy efficiency measures, electrification, and the use of hydrogen. These trends lead to Russia's energy supply maintaining 2018 levels for the remainder of the projection (after recovery from COVID-19 impacts by the mid-2020s).
- An almost doubling of nuclear power generation will offset significant reductions in coal and oil supply. Gas consumption will remain stable beyond the 2030s. Gas will retain its dominant share of domestic energy supply. By 2050, gas and nuclear account for 80% of supply, which is a significant increase from the current share of 60%.
- In CN, fossil fuel production in 2050 is almost a third lower than in REF due to the global transition to renewable energy sources. External demand will be more influential than domestic demand in the declines in coal and oil, which fall by three-quarters and one-half. The transition role of gas will mean that production peaks in the late-2030s before slowly declining.
- Russia's energy exports decline by 40% out to 2050. The composition of exports also shifts, with a much lower share of oil and refined products, and a much larger share of natural gas. Like REF, gas exports are anticipated to increase due to the launch of the Power of Siberia export pipeline operating at full capacity, as well as the introduction of multiple LNG projects.
- Natural gas will play an important transitional role in CN. However, natural gas exports from Russia will be only three-quarters as large as they are in REF.

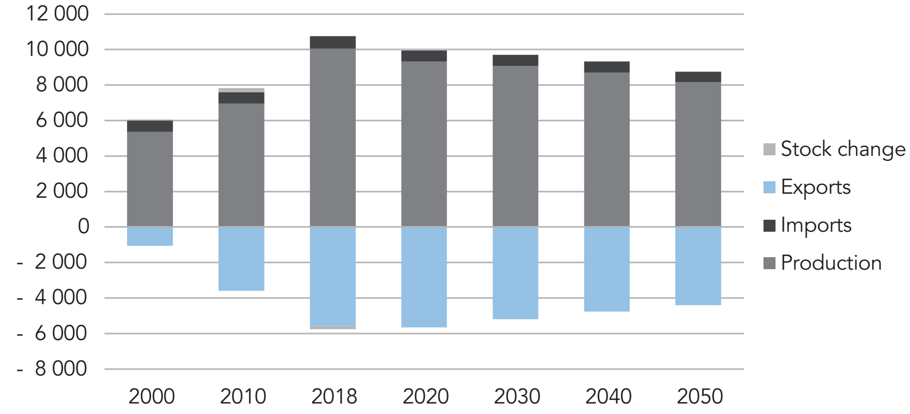
Coal in the Reference scenario

Figure 16-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

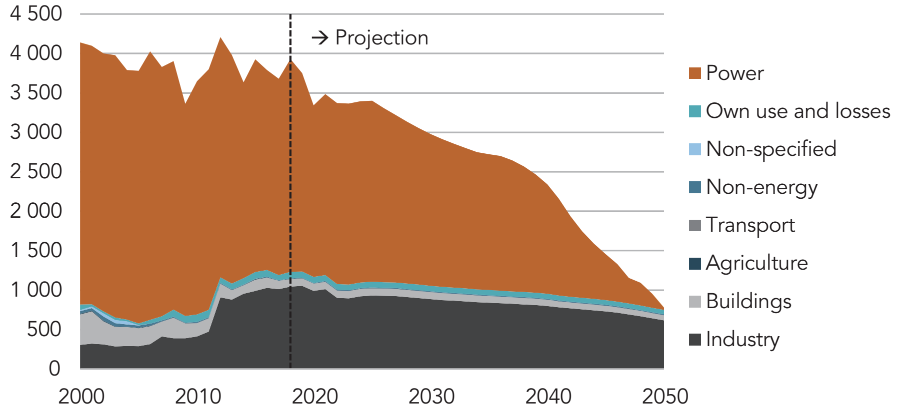


Sources: EGEDA, APERC analysis.

- The power sector is the largest consumer of coal in Russia. An update in data methodology in 2012 now means that power accounts for 70% of Russian coal consumption. But even accounting for this data issue, increased gas generation has led to declining coal generation from 2000 to 2018.
- The industrial sector currently accounts for about one-third of coal consumption, with large volumes of consumption within the steel subsector. Buildings consumption of coal remains, but it is relatively low, used mainly to heat private homes in small settlements in coal-producing regions. Increased availability of gas via gas distribution systems has led to less buildings consumption of coal.
- REF coal consumption is assumed to maintain current levels out to 2050, with a slight decline in power sector consumption. Steel sector consumption is anticipated to increase, with production largely reliant on current technology. While consumption levels are maintained, the share of coal in Russia's domestic energy supply declines to 12% due to increasing gas and nuclear. Coal's share of Russia's supply was 16% in 2018.
- Coal production has almost doubled since 2000, due to a more than three-fold increase in exports. Railroad capacity and the capacity of maritime coal terminals have increased to support this significant increase in exports. Russia also imports coal, with a fifth of coal consumption in the power sector imported from Kazakhstan. This coal is destined for several large coal-fired power plants in the Urals, designed to use Kazakh coal.
- In REF, relatively stable domestic coal consumption means that production is most influenced by export volumes. Global coal consumption is assumed to decline in REF. Russian exports are expected to fall by 20% through to 2050 due to this declining global demand, with a corresponding fall in Russian coal production.

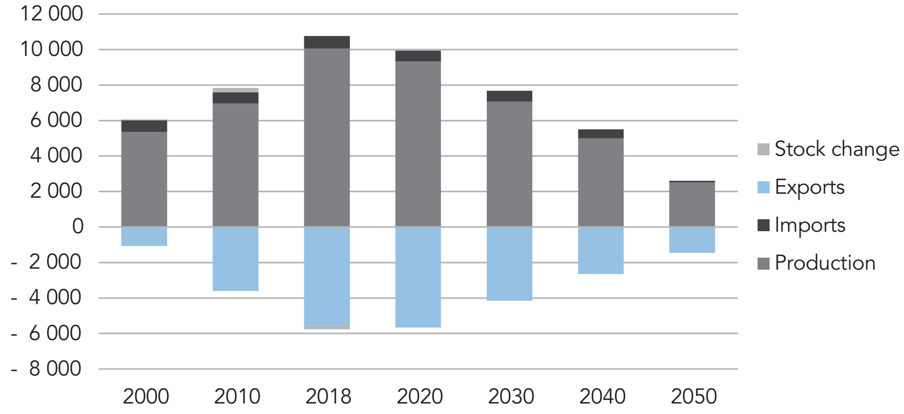
Coal in the Carbon Neutrality scenario

Figure 16-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

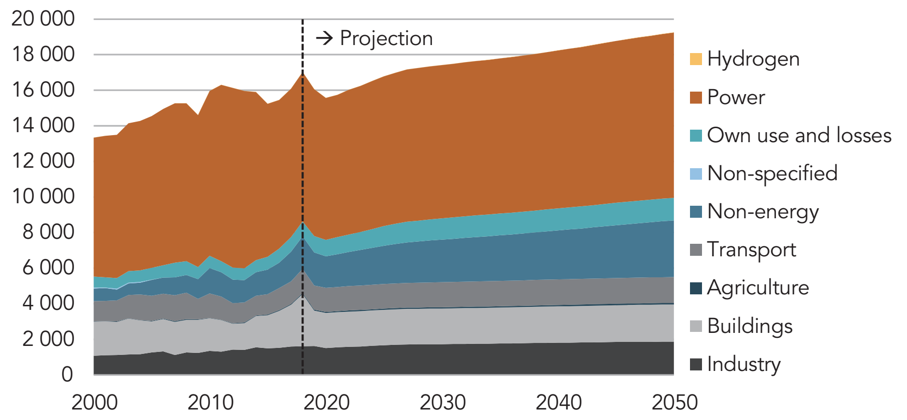


Sources: EGEDA, APERC analysis.

- Russia's power sector is anticipated to rapidly move away from coal in CN, with close to zero coal generation by 2050. Industrial coal consumption is more than two-fifths lower in CN than in REF by 2050, whereas buildings consumption is more robust, at a level one-third lower than in REF in 2050. The net impact is that coal consumption falls by four-fifths, accounting for less than 4% of Russia's domestic energy supply in 2050.
- The reduction in power sector coal consumption will be subject to multiple influencing factors. Coal is the most carbon-intensive fossil fuel, with its share of emissions exceeding its share in primary energy supply by 1.5 times. Initial moves away from coal are likely to occur at the end of 2020s. However, a continued movement away from coal is reliant on development of gas supply infrastructure in Russia's eastern regions.
- The Power of Siberia and Power of Siberia 2 gas export projects currently have priority over domestic gas infrastructure. This means that the gas transportation infrastructure that will facilitate a move away from coal in the eastern regions is unlikely to be available until the second half of the 2030s. The eventual availability of the infrastructure is reflected in a sharp decline in the use of coal in the power sector, starting in the late 2030s.
- A rapid decline in domestic and international coal consumption will lead to a nearly five-fold reduction in Russia's coal production through to 2050.
- The evolution of Russia's coal industry will be the result of a difficult compromise between the consequences of diminished export markets, the development of gas transportation infrastructure in the eastern regions, and the speed of implementation of decarbonisation measures.

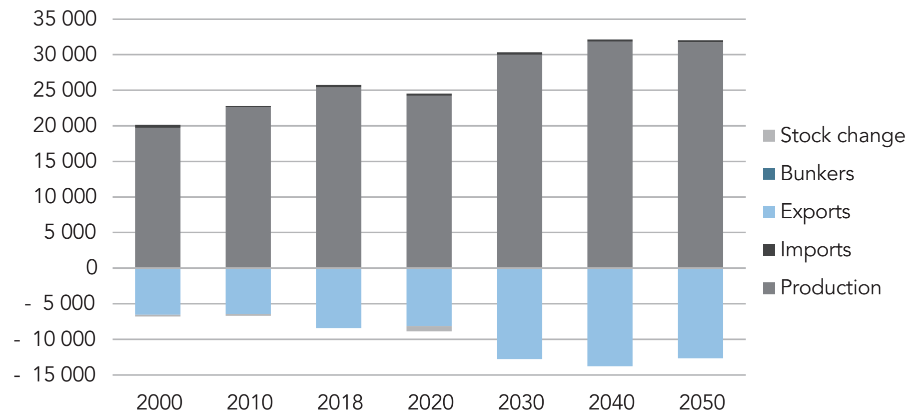
Natural gas in the Reference scenario

Figure 16-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

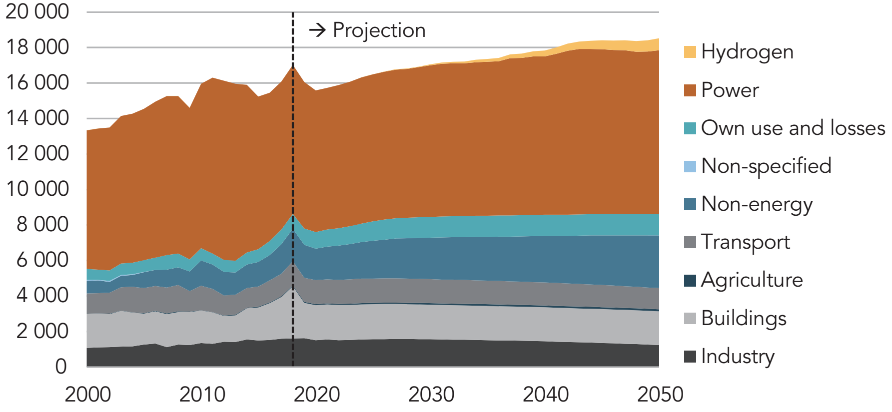


Sources: EGEDA, APERC analysis.

- Gas is the major energy carrier in Russia's energy supply, accounting for a 52–56% share for the past two decades. The largest consumer of gas is the power sector, historically accounting for close to 60% of all gas consumption. More than 90% of power sector gas consumption (for heat and electricity) is consumed in the western part of the economy, facilitated by a well-developed gas distribution infrastructure.
- Buildings account for about 15% of gas consumption. However, 2017 and 2018 buildings gas consumption data is anomalous.
- Industry, transport, and the non-energy sector (which uses gas as a feedstock in petrochemicals production) each account for close to 10% of total gas consumption. In transport, gas is primarily used to power the compressor stations of gas pipelines.
- In REF, gas consumption increases by about one-quarter through to 2050. Almost half of the increase is due to the use of gas as a raw material in the non-energy sector.
- Power sector gas consumption increases by more than 10% out to 2050. This growth is due to electricity demand growth and the beginning of a substitution away from coal in the eastern regions. Industry and transport (gas pipelines to move increased volumes) consumption will also increase.
- About 70% of Russia's gas production is consumed domestically. The REF assumes that exports to the European market via pipelines will continue at current levels, that the Power of Siberia gas export pipeline will reach its total capacity of 38 bcm per year, and that all stages of the Arctic LNG-2 plant (currently under construction) will begin operations. Total gas exports will peak in the second half of the 2030s, and then fall by a small amount out to 2050.

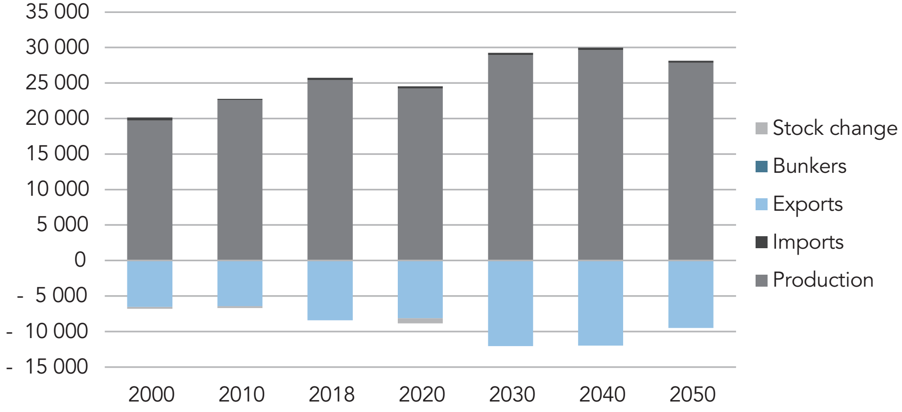
Natural gas in the Carbon Neutrality scenario

Figure 16-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

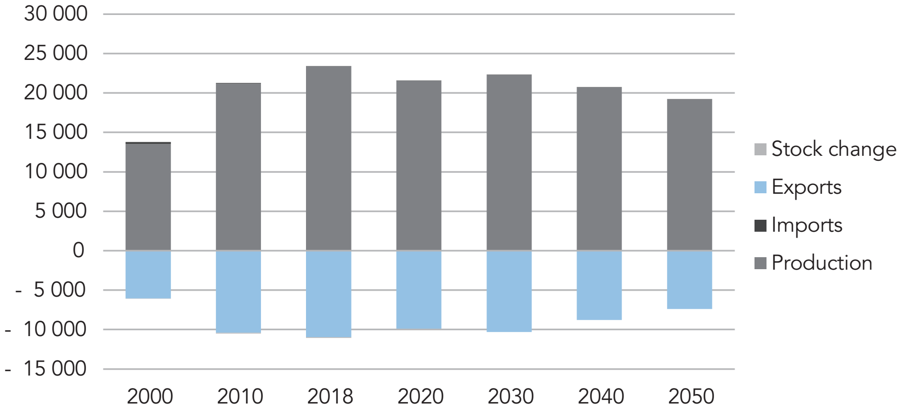


Sources: EGEDA, APERC analysis.

- In CN, gas use in power, buildings, and transport stabilises due to wide-scale implementation of energy-savings measures and electrification in end-use sectors. Industry sector consumption of gas will fall by almost a quarter out to 2050 due to energy efficiency, material efficiency, a switch to hydrogen in steel and chemicals subsectors, and electrification of select processes.
- In CN, the use of gas as a feedstock will follow a similar trajectory to non-energy gas consumption in REF. Increased development of oil and gas fields and deposits is associated with increased ethane-containing gas processing, production of NGLs, and polymer production.
- The Power of Siberia gas pipeline project will significantly contribute to petrochemical activities in the second half of the 2020s. The gas produced from the East Siberian fields (Kovykta and Chayanda) will be processed at the Amurskiy gas processing plant, with the methane then exported to China.
- Russia is developing LNG plant projects that take advantage of the associated extraction of NGLs. The additional LNG plant projects will lead to additional petrochemical applications.
- CN assumes that gas exports trace a slightly lower trajectory than in REF, with the energy transition impacting the international market for Russia's gas.
- The reduction of gas exports to the European market will likely begin in the 2030s. North Asia and Southeast Asia will become more influential for Russia's gas exports in the latter half of the projection. With domestic consumption stabilising in the 2040s, exports will be the main factor that drives production changes. If Asian economies begin to move away from gas, Russian gas production will inevitably decline.

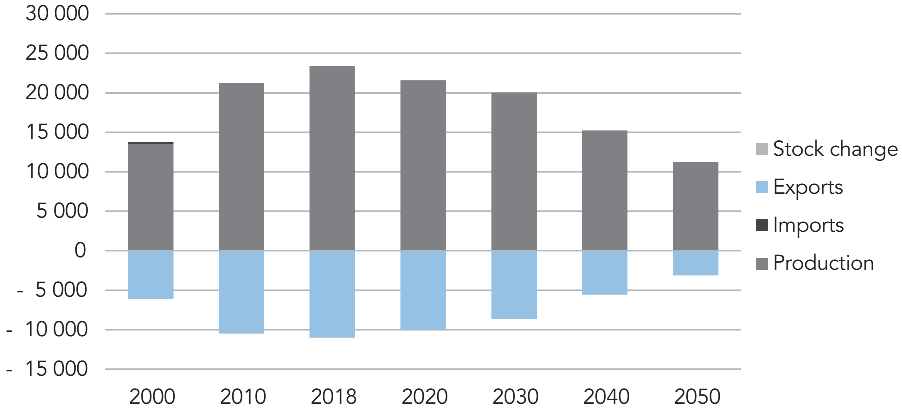
Crude oil and NGLs

Figure 16-33. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-34. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

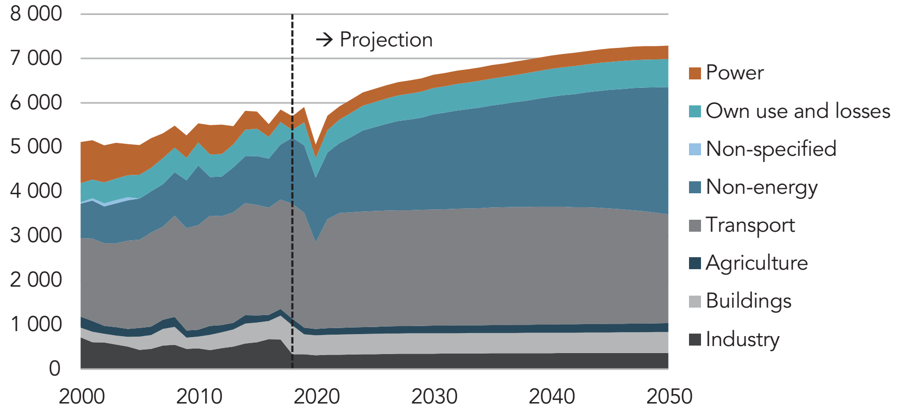


Sources: EGEDA, APERC analysis.

- Russia has significant oil reserves. The share of Russian oil on the world market is 10–12%. Nearly half of the oil produced is exported. It is supplied to the European market, as well as to the markets of northeast Asia. Exports are made both by pipeline and by sea. Commissioning of the East Siberia-Pacific Ocean oil pipeline in 2009 and its further development allowed Russian producers to begin intensive development of oil reserves in Eastern Siberia and significantly increase oil supply to the growing Asian market.
- REF assumes stabilisation of domestic consumption of refined products in all sectors, except for use as a feedstock (see Refined products in REF). However, the growth of LPG consumption as a feedstock will be provided not only by refined products but also by increasing LPG production from gas processing.
- Oil production in 2020–2021 was lower than the peak levels of 2018–2019. This is due to the restrictions on production and compliance with the terms of the OPEC+ agreement. Given the availability of reserves, the dynamics of production, and the combination of external conditions, it can be assumed that it will be difficult to maintain production at current levels.
- Russia's Energy Strategy 2035, objectively assessing the prospects of the Russian oil industry, does not expect an increase in oil production against the 2018 level and allows for a gradual reduction, starting from the second half of the 2030s. This trend is reflected in REF. With domestic demand for refined products remaining unchanged, it is the reduction in the global market for oil that leads to a reduction in oil production and exports.
- CN assumes that peak oil production in Russia has already occurred. In the future, the oil production industry will be under pressure from shrinking domestic and international demand (see Refined products in CN). Russian oil exports fall by a factor of more than three out to 2050, due to the assumptions about declining global demand. Oil production also falls, but only by half, buoyed by more robust domestic refinery demand. The fall in production will require less investment. Renewable energy investment projects will attract some of these displaced capital flows.

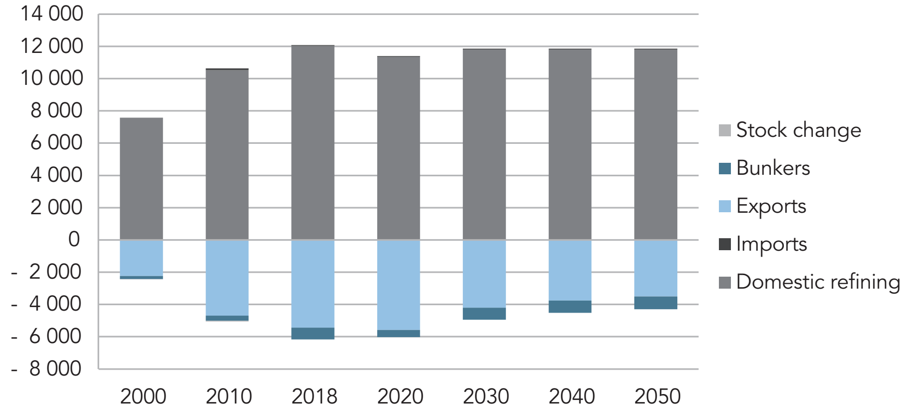
Refined products in the Reference scenario

Figure 16-35. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-36. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

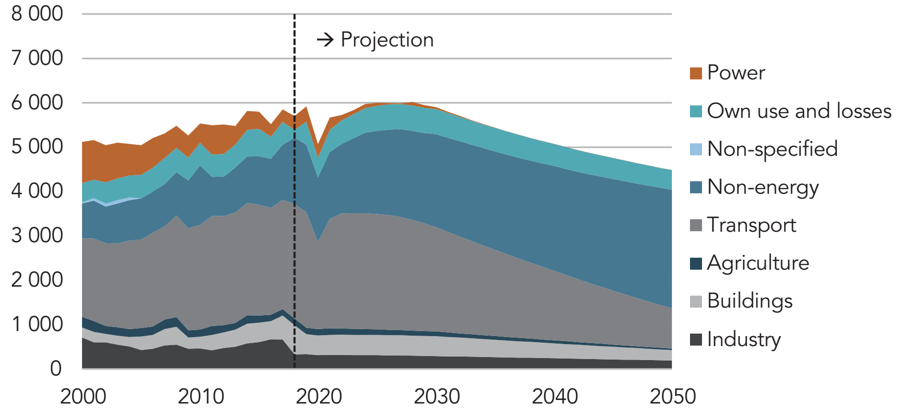


Sources: EGEDA, APERC analysis.

- Refined products increased by approximately 11% from 2000 to 2018. The sectoral structure of refined product consumption has changed during 2000–2018. In 2000, industry, power, and non-energy (feedstock in petrochemicals enterprises) each accounted for roughly 15% of consumption. Since then, non-energy use (mostly LPG) has almost doubled due to the increasing size of the petrochemical industry. In contrast, the use of refined products in the power sector (mainly fuel oil), decreased by two-thirds. Transport's share has increased from 35% to 45% for the same period.
- A contradictory trend has been recorded in the consumption of refined products in the industry and buildings sectors in 2017–2018. According to EGEDA, industry consumption of refined products halved. Whereas buildings increased by a roughly equal amount. This discrepancy is likely due to data collection issues.
- Transport activity fell significantly due to the COVID-19 restrictions in 2020. These activity falls led to transport consumption of refined products falling by almost a quarter. Demand from other sectors was more robust, meaning that the total fall in refined product consumption was only 14%.
- The REF assumes recovery growth in demand for 2021–2022. After that, the consumption of refined products in all sectors, except non-energy, stabilises. Non-energy consumption of refined products, mainly LPG, almost doubles by 2050, and drives an overall increase in refined products of almost 28%.
- Oil refining output is relatively stable in the long term. A significant increase in domestic use of refined products will compensate for the reduction in exports.

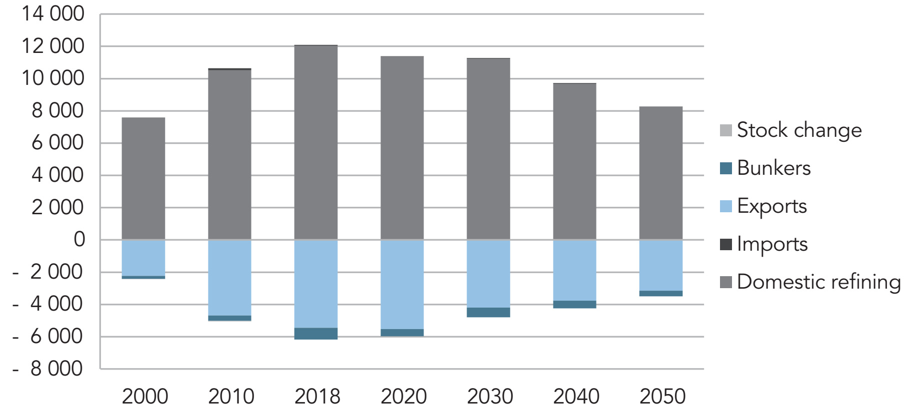
Refined products in the Carbon Neutrality scenario

Figure 16-37. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 16-38. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

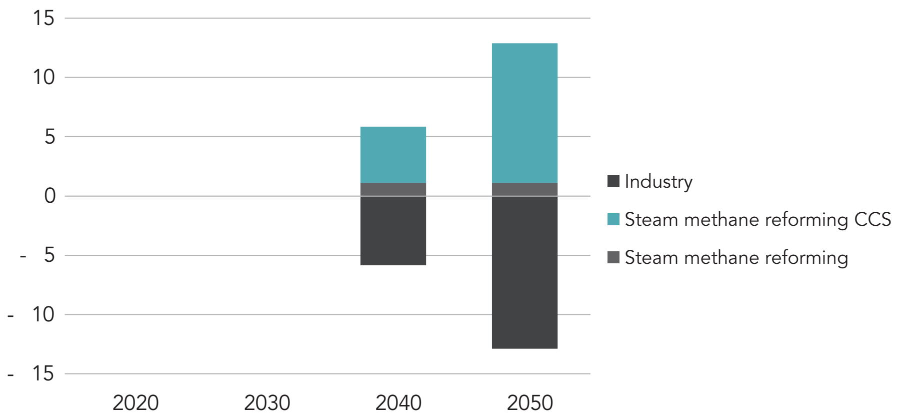


Sources: EGEDA, APERC analysis.

- In CN, refined products consumption falls by 21% out to 2050, and is 38% lower than in REF by 2050. More than half of the decline, relative to REF, is achieved by a large reduction in road and air transport consumption of refined products.
- The transport sector undergoes the largest change in CN. Road transport refined products consumption falls by more than 65%. The car fleet will be replenished by battery-powered electric cars and hydrogen fuel cell vehicles. In aviation, the consumption of traditional jet fuel will fall by 70% by 2050, replaced by biofuels and hydrogen, beginning in the 2030s.
- The evolution of the aviation sector in a world that is attempting to decarbonise will rely on projects to produce aviation jet biofuels. For Russia to produce these fuels domestically would be an optimistic assumption, given that Russian airlines are only beginning to study the possibility of using such fuels. CN instead assumes imports of jet biofuel aviation fuels.
- A significant reduction in the demand for refined products in the end-use sectors will place severe pressure on Russian oil refining volumes. Export volumes of refined products in CN are slightly lower than in REF. This means that the move away from refined products by domestic end-use sectors will see oil refining volumes fall by almost a third out to 2050.
- The lower refinery volumes have implications for oil refinery operational lifetimes, capacity utilisation, and investment. Stranded asset risk will be higher in CN.

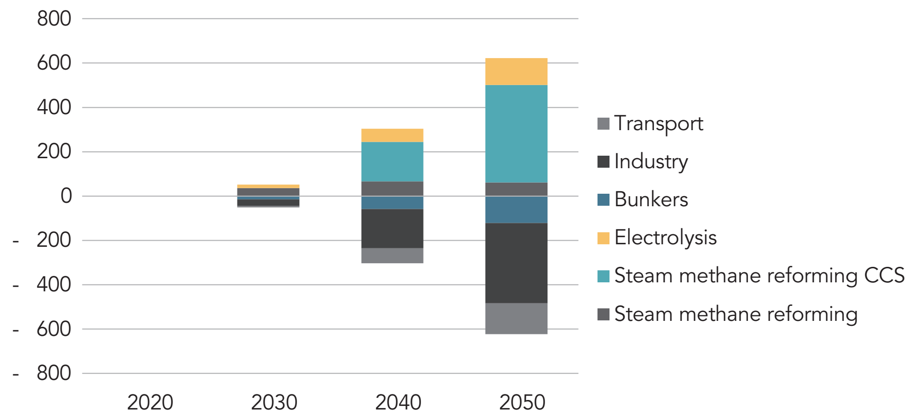
Hydrogen

Figure 16-39. Hydrogen production, consumption, imports, and exports in REF, 2000-2050 (PJ)



Note: Consumption appear as negative.

Figure 16-40. Hydrogen production, consumption, imports, and exports in CN, 2000-2050 (PJ)

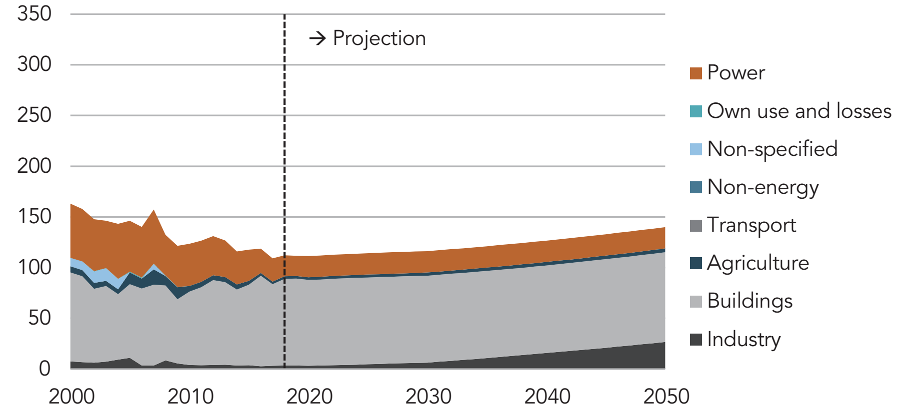


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- Russia considers the potential production of hydrogen as an opportunity to maintain its position as an energy exporter. The concept of hydrogen energy development in the Russian Federation for the period till 2035 (the Concept) establishes the benefits for Russia to pursue hydrogen production and exporting opportunities, as well as domestic industrial use cases. Hydrogen can potentially play an important role in facilitating the global energy transition.
- According to the Concept, potential hydrogen exports from the Russian Federation are 0.2 million tonnes in 2024, 2–12 million tonnes in 2035, and 15–50 million tonnes in 2050. The upper values are marked as optimistic. In principle, this Concept confirmed the provisions of the Energy Strategy of Russia until 2035, except for the goal for 2050. Perhaps, the critical problem for achieving the declared objectives is the lack of a clear understanding of the possibility of producing "green" hydrogen in such volumes with the practically inexhaustible possibilities of producing less demanded "grey" and "blue" hydrogen.
- In REF, the use of hydrogen as an energy carrier is very low, not exceeding several tens of thousands of tons per year, starting from the 2030s. In this conservative forecast, the most likely consumer of hydrogen will only be export-oriented chemicals producers.
- CN assumes far more wide-scale use of hydrogen in technological processes and transport. The share of hydrogen in the fuel mix of industry and transport could be about 5% by 2050. Despite a relatively optimistic assessment of the possibilities of hydrogen application in the end-use sectors, its use will not exceed 1 million tonnes by 2035 and 4 million tonnes by 2050, which is below the minimal export limits stated in the Hydrogen Concept. This emphasises the significant export ambitions of the Russian Federation in the emerging hydrogen market.
- Steam reforming of methane with CCS is supposed to be the primary hydrogen production technology; "green" hydrogen is used exclusively for bunkering purposes.

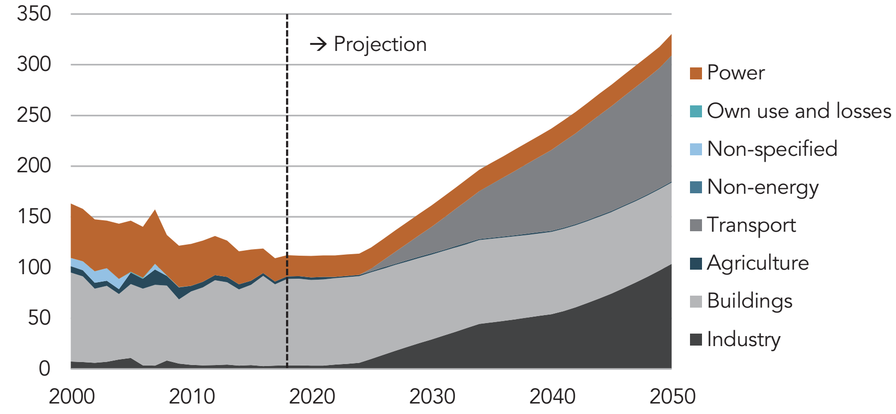
Bioenergy

Figure 16-41. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 16-42. Bioenergy consumption by sector in CN, 2000-2050 (PJ)

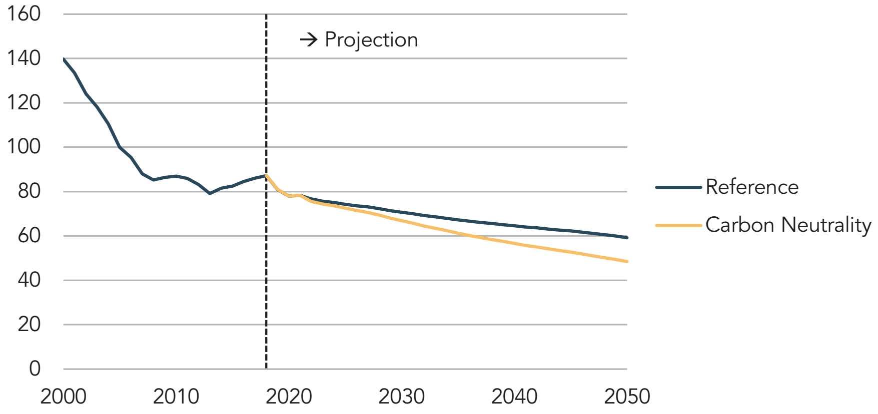


Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

- Consumption of bioenergy accounts for a very small share, no more than 1%, of the final energy consumption fuel mix. More than 80% is fuelwood used for heating dwellings, located mainly in rural areas where there is no access to gas supply infrastructure. The second most important consumer is small heat-only power plants, also located mainly in rural areas, where there is no access to gas distribution infrastructure. They are also fueled by different types of wood fuel.
- In REF, direct space heating and heat-only power plants maintain their use of fuelwood. REF also assumes an increase in the use of renewable fuels in a small number of industrial pursuits starting in the second half of the 2030s, to reduce their carbon footprint.
- In CN, there are more ambitious prospects for the use of new renewable fuels in industry, as well as large-scale use of liquid renewable fuels, starting in the second half of the 2020s. The use of solid and liquid renewables in industry and transport is more than double the consumption of wood fuel used for heating by 2050. The main industrial consumers will be metallurgy and the chemicals subsectors — export sectors of the Russian economy most interested in reducing the carbon footprint of their products.
- CN assumes imports of sustainable aviation fuel due to the lack of declared projects to produce this type of aviation fuel in Russia. However, most likely, this need will eventually be met by domestic production.
- Bioenergy will make a noticeable contribution to the increase in modern renewables share (see Energy intensity and modern renewables share) in CN by 2050. Nevertheless, the energy efficiency factor will dominate.

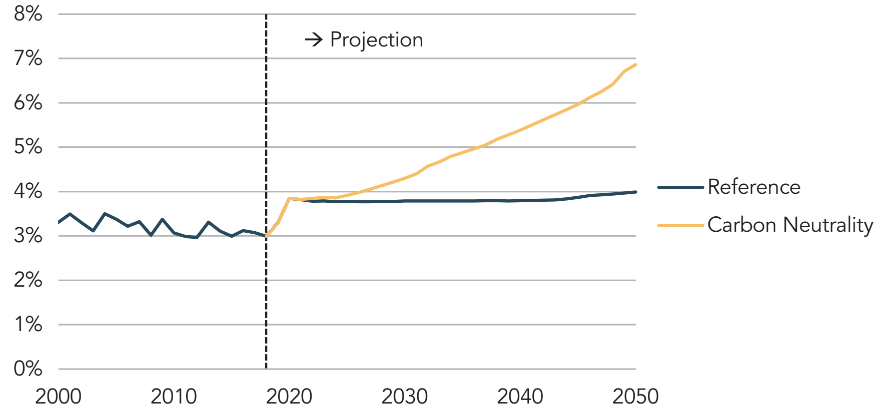
Energy intensity and modern renewables share

Figure 16-43. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 16-44. Modern renewables share in REF and CN, 2000-2050



Sources: EGEDA, APERC analysis. Note: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

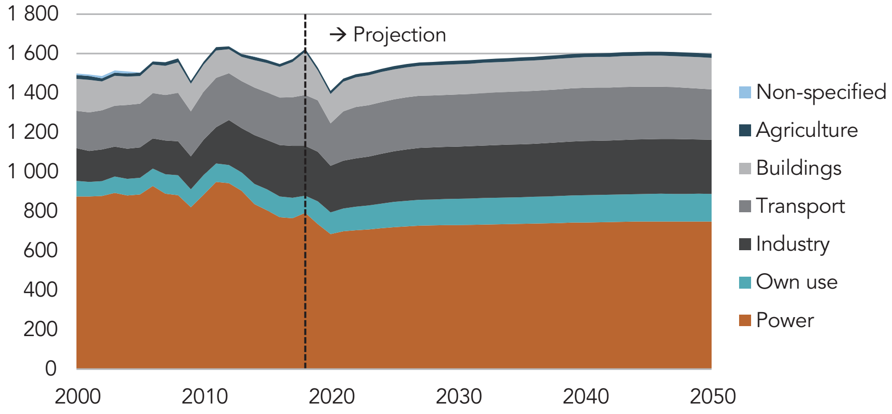
- The period of the most significant improvement in energy intensity was before the 2008-2009 global financial crisis. From 2000 to 2008, GDP grew by more than 6% per year, while energy consumption remained roughly unchanged.
- GDP growth since 2009 has been far lower, which has slowed the reduction in energy intensity. Energy intensity reached a minimum in 2013, 43% below the 2000 level. GDP growth has since stalled while energy consumption increased, leading to increased energy intensity to 2018.
- As noted on previous slides, natural gas in residential buildings has accounted for a significant portion of the increase in energy consumption, for 2017-2018, according to EGEDA. These increases are not consistent with Russia's statistics and have yet to be reconciled. The flow through impacts to energy intensity are not necessarily accurate.
- Russia has the highest energy intensity of GDP among APEC economies. Nevertheless, REF assumes that energy intensity will improve 32% by 2050. In CN, the improvement will be 44%.

- The share of modern renewables in final energy consumption is about 3% in 2018. In 2020, while final consumption decreased by 7%, modern renewables consumption was nearly the same, and so the share increased by 0.5%, reaching almost 4%.
- REF assumes modern renewables and total consumption grow at the same rate so that the share of modern renewables will remain at the current level through to 2050. In CN, higher electricity generation from wind and solar, as well as wide-scale substitution of jet fuel with biojet fuel increases modern renewables consumption by export-oriented industries.
- Biojet fuels and electricity from wind and solar will provide more than 70% of the growth in modern renewables, relative to REF. However, the crucial contribution to increasing the share of modern renewables to 7% will be a reduction of total energy consumption by almost 20% out to 2050. The decrease in consumption is due to improved energy efficiency and changes in the final energy consumption fuel-mix.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

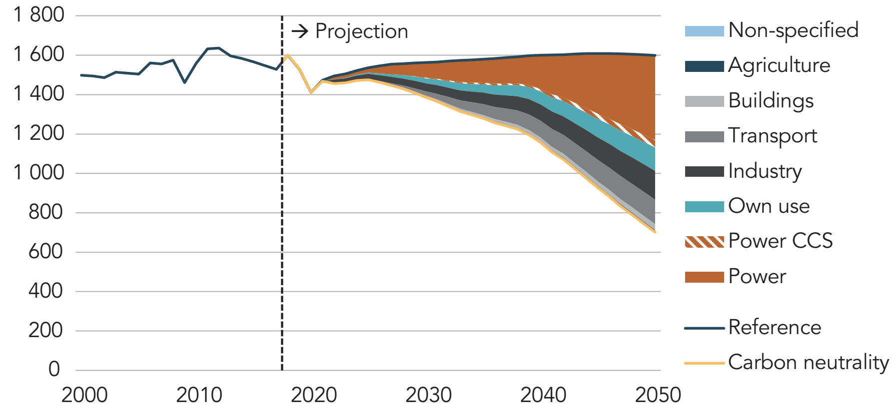
Gross CO_2 emissions

Figure 16-45. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 16-46. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

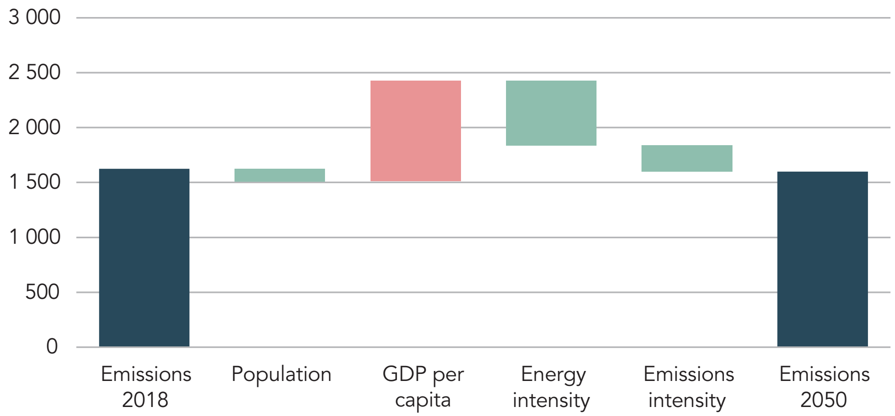


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Over the period from 2000 to 2018, CO_2 emissions reached their highest level in 2012, at the peak of the recovery from the 2008-2009 global financial crisis. In the 2009 crisis year, CO_2 emissions were at their lowest level.
- During 2000–2012, the structure of emissions by sector remained almost constant: the power sector accounted for about 60%, industry and own use was 16–17%, transport was 13–15%, and buildings was 9–10%. After 2012, the power sector's contribution decreased from 58% to 47%. Total CO_2 emissions by the power sector fell by 15%. This resulted from the replacement of coal-fired TPPs with gas-fired TPPs. The share of transport was steady, while the shares of industry (with own use) and buildings rose to 23% and 16%, respectively.
- REF assumes a continuation of current trends, so emissions are also expected to remain flat at 2018 levels.
- CN assumes a 56% reduction of emissions compared to the REF by 2050. The power sector will make the most significant contribution, more than 50%, to this reduction. This significant emissions reduction will result from an almost complete phase-out of coal use, accelerated development of nuclear power plants, and commissioning of renewable energy sources. The contribution of CCS technologies in CN will not exceed 10% of the total reduction of emissions in the power sector.
- Only 3% of the decline in emissions in CN relative to REF will be from the buildings sector. This is because a large share of buildings' energy mix (more than 60%) is composed of secondary energy carriers, electricity and heat. The remaining share of emissions reductions will be split roughly equally between industry, transport and own use.
- This CN trajectory is very much in line with the statement made by the President of Russia before COP 26 about the plans to achieve carbon neutrality by 2060.

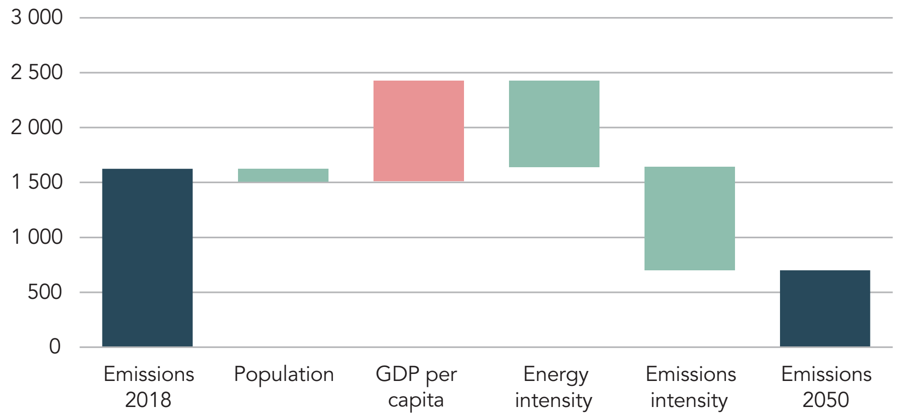
Components of CO_2 emissions

Figure 16-47. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 16-48. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Russia's projected decline in population will relieve emissions pressure. However, without energy intensity and CO_2 emissions intensity improvements, growth in Russia's standard of living (GDP per capita) would see CO_2 emissions increase by 50% out to 2050.
- In REF, emissions reductions contributions are mainly achieved by an increasing use of gas and nuclear in the power sector. In the end-use sectors, energy efficiency plays a dominant role. Increased use of electricity and district heat instead of fossil fuels leads to emissions reductions in buildings. In industry, the use of more efficient energy carriers of gas, electricity, and heat instead of coal and refined products contribute to emissions reductions, The use of hydrogen in high-temperature processes plays a small role by the end of the period. In transport, substitution of refined products for gas and accelerated development of EVs begins to drive emissions down as well.
- An accelerated implementation of energy efficiency measures in CN achieves significantly more emissions reductions than in REF. Such measures involve large-scale retrofits of residential buildings, accelerated substitution of fossil fuels by electricity and hydrogen in energy-intensive high-temperature processes, and renewal of the car fleet with EVs.
- In CN, the contribution of measures for reducing CO_2 emissions is more than four times greater than in REF. This significant contribution is provided, on the one hand, by a radical reduction of the carbon intensity of the end-use sectors and generation of electricity and heat, and, to a lesser extent, using CCS technologies in the power sector and industry.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

Energy Strategy of the Russian Federation 2035. http://static.government.ru/media/files/w4sigFOiDjGVDYT4IgsApssm6mZRb7wx.pdf

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Federal Law "On Limiting Greenhouse Gas Emissions". http://ips.pravo.gov.ru:8080/default.aspx?pn=0001202107020031

The concept of the development of hydrogen energy in the Russian Federation 2035. http://static.government.ru/media/files/5JFns1CDAKqYKzZ0mnRADAw2NqcVsexl.pdf

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Rosseti, Public Joint Stock Company (PJSC ROSSETI). http://www.rosseti.ru/eng/

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Association NP Market Council. http://www.en.np-sr.ru/

Gazprom. http://www.gazprom.com/

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Transneft. http://www.en.transneft.ru/

17. Singapore

Highlights

Demand

- Energy efficiency continues to decouple energy demand from GDP in both scenarios, with demand growing almost 20% in the Reference scenario (REF) and falling 5% in the Carbon Neutrality scenario (CN).
- Fossil fuels, on the back of strong demand in industry and non-energy, remain dominant in either scenario, falling slightly below three-quarters in REF and two-thirds in CN. Electrification and efficiency improvements are main drivers, and electricity grows to nearly three-tenths of the fuel mix in REF and over a third in CN.
- Policy is instrumental in reducing fossil fuel usage in the transport sector, which falls 40% in REF and 60% in CN. Modal shifting and freight optimisation also help reduce demand in CN.
- The Certificate of Entitlement (COE) and vehicle incentive schemes enable a rapid adoption of electric vehicles (EVs), as Singapore does not achieve its aspiration to phase out ICE vehicles in either scenario. ICE vehicle sales fall to 7.4% at the end of REF and to zero by 2036 in CN. However, by 2050, ICE vehicles retain 41% of the stock in REF and 12% in CN.
- Buildings demand follows rising data center activity in the 2020s, boosting electricity use in both scenarios. REF end-use demand rises 40% overall, while improvements in space cooling efficiency in CN cause demand to peak in 2029, falling 12% over the final two decades.
- Oil and gas continue to fuel buildings in REF, while the electrification of cooking phases out oil by 2036 and reduces gas use in CN.
- Industrial and non-energy demand grow by 25% in REF, while energy and material efficiency keep demand flat in CN. Fossil fuels continue to dominate industrial demand in REF, holding over two-thirds of the fuel mix, while higher fuel switching towards hydrogen and electricity reduces the share to 55% in CN.
- Hydrogen demand grows significantly but remains a niche fuel in both scenarios. In REF, use is limited to fuel cells, while CN sees use in process heat of the chemical subsector and in marine transport.

Supply

- Supply grows a sixth in REF, as rising electricity demand lift gas requirements by 45% to two-fifths of the fuel mix. Oil supply remains flat, as industrial and non-energy increases are offset by transport declines. Supply requirements are almost a quarter lower in CN and remain predominantly met by fossil fuels.
- Net imports grow a tenth in REF, as surging LNG volumes offset declining imports from gas pipelines. Oil imports decrease due to lower refining capacity. Net imports fall a quarter in CN.

Power

- Singapore surpasses its solar targets of 1.5 GWp by 2025 and 2.0 GWp by 2030. While REF capacity remains flat at 3.3 GWp after 2030, lower costs prompt capacity increases to 4.9 GWp in CN.
- Gas-fired generation continues to dominate the power mix at its current proportion of about 95% in REF. Without any new gas builds, the utilisation rates of existing capacity increase over REF. Gas share falls to two-thirds in CN as the commissioning of the Australian Sun Cable link meets 25 to 30% of electricity demand.
- Coal and oil-fired generation are phased out in both scenarios, as is unabated gas generation in CN. However, capacity remains as back-up for security purposes.

CO_2 emissions

- Emissions grow 8.5% in REF and fall 66% in CN.
- Singapore achieves both of its Nationally Determined Contribution (NDC) items, with emissions intensity falling 46% below 2005 levels in 2030 and emissions complying to its 65 $MtCO_2$-e constraint. In CN, Singapore's emissions fall three-quarters below this constraint, more than meeting the halving required by its Long-term Low-Emissions Development Strategy (LEDS). A main driver of this is carbon capture and storage (CCS) covering all gas-fired generation by 2050. The roll-out of CCS in the chemicals subsector also plays a factor.
- Singapore will require offsets or sequestration to mitigate its remaining 16 $MtCO_2$ of annual emissions in 2050.

About Singapore

- Singapore is a completely urbanised city-state in southeast Asia with a land area of approximately 720 square kilometres (km^2). Despite lacking domestic energy and mineral resources, it enjoys the highest standard of living in APEC through extensive value-added service and manufacturing sectors, and by being a global hub for multiple industries, including tourism, shipping, petrochemicals and refining.
- Singapore is completely reliant on trade for its fossil fuel requirements and is the fifth-largest energy importer in APEC. However, imports far exceed consumption, as much of its oil imports are transformed into refined oil products for re-export through its oil and refining hub. As such, Singapore is also a significant energy exporter, ranked 5th in APEC.
- Singapore's energy security is dependent on promoting a diverse and robust network of trading partners. Almost all natural gas imports are used domestically (for electricity generation). Singapore built an LNG terminal in 2013 to reduce its dependence on pipeline imports from Malaysia and Indonesia.
- Over 95% of Singapore's power mix comes from natural gas, and over 97% from fossil fuel sources. Singapore is pursuing grid integration with neighboring economies to reduce emissions and improve energy resilience and security. It is also looking into assessing its geothermal potential.
- Singapore has quality solar irradiance, but its small land area restricts deployment potential. To overcome land constraints, Singapore is pursuing the deployment of solar panels on water reservoirs and rivers, as well as in conjunction with industrial facilities.
- While its absolute energy requirements and emissions are low, on a per capita basis, Singapore is one of the highest energy users (4th) and a mid-level GHG emitter (9th) in the APEC region. This results from both the industrialised nature of the economy and the combustion of fossil fuels making up almost 98% of its TPES.

Table 17-1. Singapore statistics, 2018

	2018	APEC share	APEC ranking
Population	5.6	0.19%	19
GDP	565	0.81%	15
TPES	1 581	0.46%	16
Production	26	0.01%	20
Imports	7 473	6.0%	5
Exports	3 565	3.3%	6
Electricity generation	53	0.31%	17
Heat production	0	0.00%	9
CO_2 emissions	47	0.22%	17

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 17-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	0	0	0%	21
Natural gas	0	0	0%	21
Oil	0	0	0%	21
Uranium	0	0	0%	21

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- **Singapore's NDC and LEDS:** Singapore strengthened its NDC in 2020, pledging to peak emissions at 65 $MtCO_2$-e around 2030 and reduce absolute emissions to half of this peak by 2050, on the road to its Long-term LEDS of achieving net-zero emissions as soon as possible in the latter half of the century. In early 2022, Singapore further improved its ambitions by announcing its plan to achieve net-zero emissions by or around mid-century. Its 2015 pledge includes an intention to reduce energy intensity by 26% below 2005 levels by 2030.
- **Carbon tax:** Singapore's carbon tax of SGD 5 per tCO_2-e began in 2019 and covers the LNG, power and industrial facilities that annually emit at least 25 000 tCO_2-e. Singapore will increase the tax to SGD 25 per tCO_2-e in 2024 and SGD 45 per tCO_2-e in 2026, with the aim of reaching SGD 50 to 80 per tCO_2-e by 2030.
- **Vehicles and transport:** Singapore is targeting an ICE vehicle phase-out by 2040. Short-term support for this includes lower registration fees via the early EV adoption program and vehicle emission schemes that use rebates and levies to reduce the relative cost of low-emitting vehicles. A Vehicle Quota System effectively sets a capacity on vehicle ownership, and the COE system effectively limits grants a ten-year period license to operate a registered vehicle.
- **Efficiency in buildings:** The Mandatory Energy Labelling Scheme and Mandatory Energy Performance Standards are improving energy efficiency in cooling, heating, and appliances. The Green Building Masterplans contains several initiatives aimed at increasing energy efficiency and reducing energy demand in buildings.
- Singapore is deferring the development of its Forward Capacity Market due to significant uncertainty in current electricity and natural gas markets.
- **Solar:** Singapore achieved its goal of 350 MWp in 2020 and is targeting 1.5 GWp by 2025 and 2.0 GWp in 2030. Success will be driven by the SolarNova Programme deploying 540 MWp on HDB housing blocks by 2030 and the development of floating PVs on rivers and reservoirs and deploying on integrated industrial facilities.
- **Low-carbon technology:** Through domestic R&D and collaboration, Singapore is aiming to find low-carbon solutions to reduce its emissions and diversify its energy sources. Solutions include CCUS and hydrogen.
- **Regional power grids:** To overcome resource constraints, Singapore is pursing the development of regional power grids to access low-carbon electricity in other economies. A 100 MW import trial with Malaysia is ongoing, and a Sun Cable project with Australia could bring solar resources to the city-state. Singapore is aiming to have 30% of its electricity demand met by imports in 2035.
- Singapore is researching ways to improve the energy efficiency of its gas-fired generators. Singapore is also researching its geothermal potential.
- **Gas supply:** Indonesia supply disruptions led to curtailments of pipeline imports into Singapore in 2021. LNG imports will have an increasing role in fueling Singapore as gas requirements rise and piped-gas suppliers prioritise their domestic markets.
- **LNG re-exports:** Singapore often re-exports LNG across Asia and in 2021 committed to delivering 0.5 mt per year to China on small-scale vessels.
- **Energy Security:** High prices and natural gas supply disruptions are prompting some retailers to cease operations and increasing the cost of energy bills. Energy Market Authority (EMA) is establishing stand-by power units to back-stop wholesale electricity markets to improve the resiliency of the electricity grid.
- Shell is planning on halving its Pulau Bukom's refinery capacity to 250 000 b/d by 2023.

Scenarios in the 8th Edition

- Energy policy in Singapore is dynamic and exists at the nexus of public and private sector objectives. The two scenarios are intended to illustrate potential long-term pathways for energy demand, transformation, and supply in Singapore with respect to uncertainty about the future.
- **The Reference scenario (REF)** is a pathway where existing trends in technology development and deployment, and policy frameworks continue in a similar manner. REF potentially represents an upper boundary on energy demand and a lower boundary on decarbonisation.
- Energy efficiency and fuel economy standards continue to improve gradually. Electrification of the transport sector accelerates significantly, which is supportive of the aspirational fulfillment of an ICE phase-out. The industry sector is assumed to gradually make improvements in energy efficiency and fuel switching. Singapore achieves its solar targets in both scenarios.
- **The Carbon Neutrality scenario (CN)** illustrates a potential pathway where energy efficiency, fuel switching, and technology advances substantially to reduce CO_2 emissions from fossil fuel combustion by 2050.
- Emissions reductions in CN are more ambitious than Singapore's LEDS pathway. CN represents one plausible lower boundary on energy demand and upper boundary on the decarbonisation progress.
- Technology maturity and commercial availability are key assumptions in CN. Hydrogen supply is assumed to be available at scale starting in 2030 to serve end-use applications in the industry, and transport sectors. While technically possible, hydrogen consumption by the power sector is not considered. Energy storage does not play a significant role in Singapore's future in either scenario, but grid connectivity does increase in CN via the Sun Cable.
- Global export markets for fossil fuels are assumed to decline at rates similar to those of APEC's TPES relative to REF, leading to lower re-exports of LNG and crude oil, and lower oil product exports.

Table 17-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Singapore

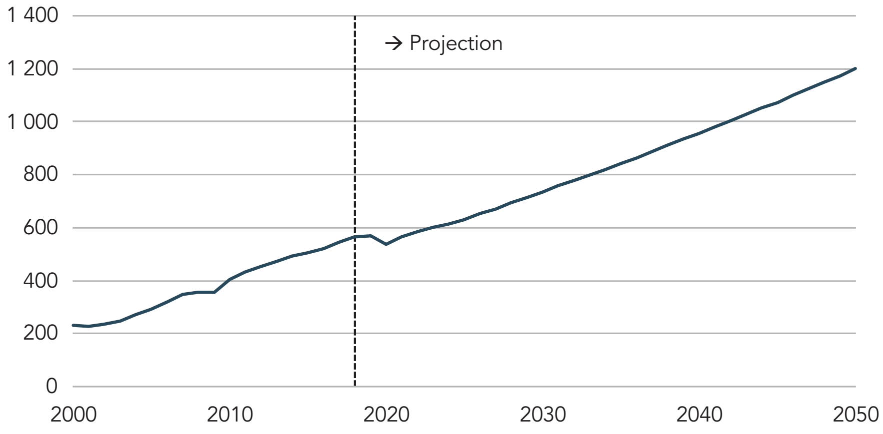
Table 17-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium) • GDP: World Bank (historical) • OECD (projections) • IMF (COVID-19 impacts)	• Same as Reference
Buildings	• Gradual improvements to efficiency • Soaring electricity demand in services sector consistent with the EMA's expectation of data center-driven growth over the next decade.	• Energy efficiency measures applied in building with an average increase of energy efficiency of 20% by 2050.
Industry	• Small amount of hydrogen for chemicals subsector starting in 2035. • Energy efficiency and electrification improvements continue historic trends. • Small amount of fuel switching to gas.	• Material efficiency improvements for chemicals subsector. • Hydrogen for chemicals subsector introduced from 2030. • Higher fuel switching rates to electricity and gas. Energy efficiency improvements more rapid than REF.
Transport	• COE enables a rapid turnover of ICE vehicles into zero emission vehicles (ZEVs). • ICE vehicle stock, mainly in HDVs, remains in both scenarios, but aspires close to a phase-out in both scenarios. • Moderate modal switching from vehicles to rail in both scenarios.	• Steeper transition to 100% ZEV sales in 2035 enabled by higher stock turnovers; some stock remains by the end of the period. • Modal switching and freight optimisation reduce activity transport activity requirements.
Power and heat	• Solar targets: 1.5 GWp in 2025; 2.0 GWp in 2030 • 100 MW electricity import trial with Malaysia starts in 2025 • Coal phased out by 2027	• Gas-fired CCS introduced in 2031, makes up 100% of active gas capacity by 2050. • Sun Cable with Australia online in 2028, ramping imports up to 17 TWh per annum from 2029 to 2050. • Solar deployment increases further, but still under its full potential.
Supply	• Shell Pulau Bukom refinery capacity to 250 000 b/d by 2023 • Soaring demand in gas demand in Indonesia and Malaysia stops pipeline imports to cease in 2023 and 2031. • SLNG import facility expands to 15 Mtpa limit by 2025; 6 Mtpa of FSRU by 2050. • LNG re-exports rise with LNG import capacity.	• Refinery capacity same as Reference but the utilisation decreases significantly with decreasing demand. • Lower gas demand implies that a 15 Mtpa SLNG facility can handle LNG imports throughout the projection period (i.e. no FSRU required). • LNG re-exports rise with LNG import capacity.
Climate	• NDC of a 65 $MtCO_2$-e peak to emissions by 2030. • Carbon tax of 5 SGD per tCO_2-e, rising to 15 SGD by 2030.	• LEDS target: reducing emissions to 32 $MtCO_2$-e by 2050, enroute to net-zero emissions in the second half of the century.

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

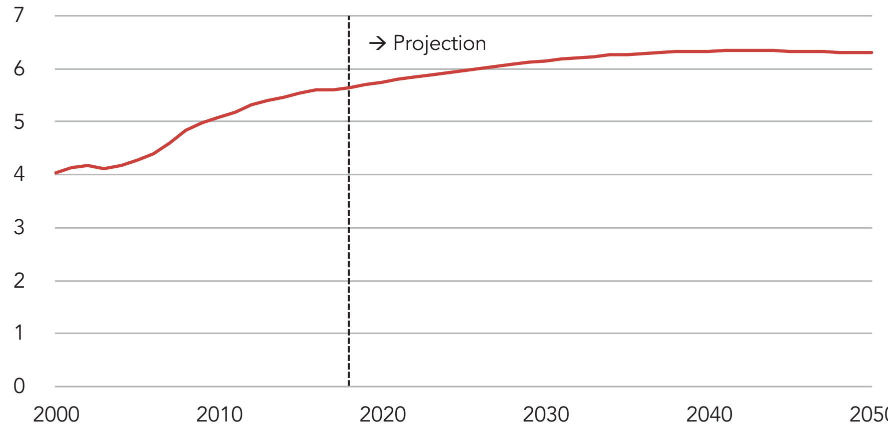
Macroeconomic backdrop

Figure 17-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 17-2. Population in millions, 2000-2050

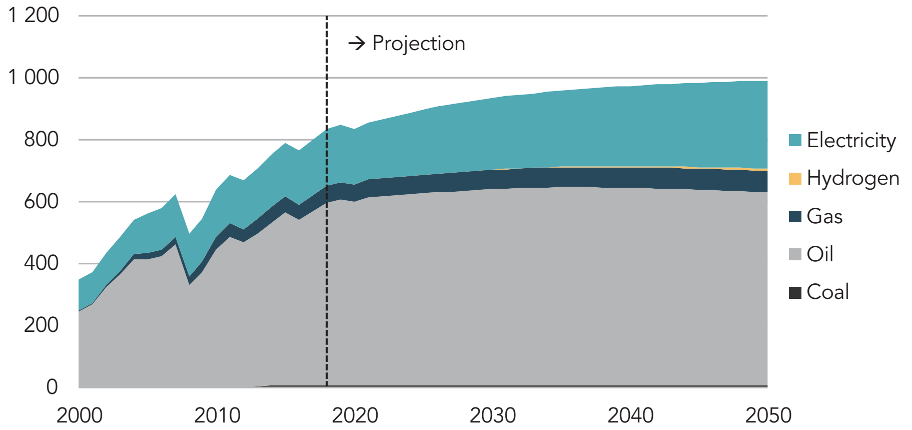


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- The economic impact of COVID-19 on the Singaporean economy is significant. In percentage terms, the 5.4% drop in real GDP in 2020 is the fifth-most in APEC and surpasses the drop seen during the aftermath of the dot-com bubble in 2001. While output is recovering, the duration and evolution of the pandemic continues to add down-side risk to these GDP projections.
- Singapore's GDP grows more rapidly in the early 2020s following the lows of the COVID-19 recession and surpasses 2019 levels in 2022. Economic growth grows at a slower pace than the first two decades of the millennium, at a CAGR of 2.4%.
- Singapore's population continues to grow, but at a slower rate than the last 20 years, plateauing around 6.3 million in the 2040s. GDP per capita nearly doubles over the projection period.
- As a simplifying assumption, the macroeconomic assumptions are the same in both scenarios. However, in a jurisdiction like Singapore, the potential economic impacts of a contraction of fossil fuel markets observed in CN could impact economic growth.
- However, the evolution of both the Singaporean and global economy in a carbon neutral future is uncertain, and Singapore could leverage its economic diversity to make up for lower fossil fuel export revenue with higher sales in services and manufacturing.
- The *Outlook* assumes that no major structural changes to the economy occur over the projection in either scenario but continues the evolution of historical trends.
- In Singapore, the shifting of GDP from both industry and manufacturing to services continues, with the latter converging to about two-thirds of GDP by 2050.

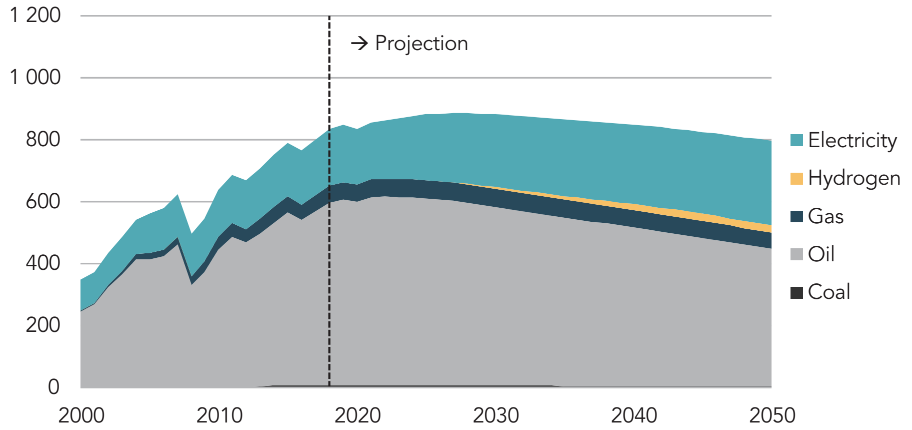
End-use energy demand

Figure 17-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 17-4. Energy demand in CN, 2000-2050 (PJ)

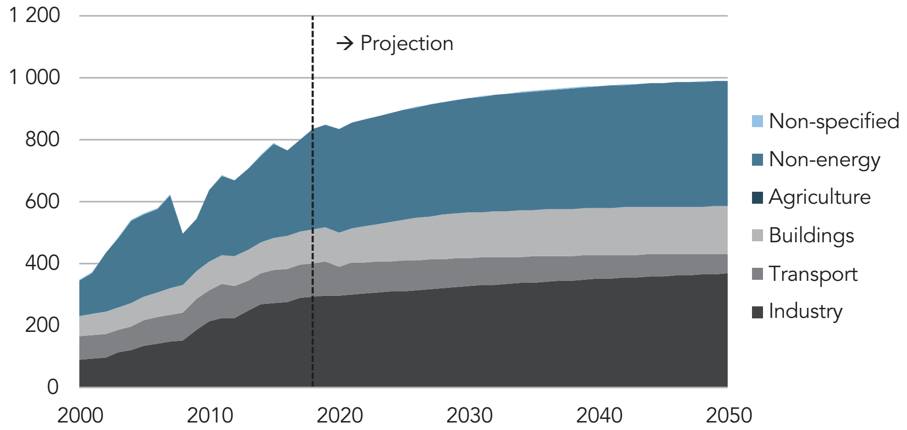


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Energy demand increases slightly in REF, following the slow growth of economic drivers, like GDP and population, and a continuation of the historical decoupling of energy use from economic growth due to advances in energy efficiency.
- Electrification of end-uses throughout all sectors increases in both scenarios, reducing the role of fossil fuels in the fuel mix. Transport plays a significant part of this story due to the relative efficiency of EVs compared to ICE vehicles. Electricity increases to almost three-tenths of the fuel mix in REF and over a third in CN.
- Fossil fuels continue to provide a significant role in fueling energy demand in both scenarios. The continual presence of oil in the fuel mix reflects the difficulty in reducing oil use in non-energy and heavy industry. Efficiency improvements and moderate fuel switching lower oil's share from two-thirds in REF to about half in CN. Gas continues its minor role in the fuel mix in both scenarios, mostly to process heat in fuel industry, as a feedstock in non-energy and cooking in buildings.
- Hydrogen makes up 0.7% of demand by 2050 in REF but rises to 3.1% in CN on the back of transport, industrial applications, and blending in the buildings sector.
- Resiliency in building and industrial demand limits the pandemic-driven fall in energy demand to 1.5% in 2020, and in 2022 demand rebounds past 2019 levels. This fall is much lower than the impact of the Great Financial Crisis in 2008, when demand fell by a fifth.
- Energy efficiency prevents demand from surpassing 1 000 PJ in REF and causes a peak in 2028 of CN.
- New technologies in industry and non-energy will be required to reduce the role of oil lower than the results shown in this *Outlook*.

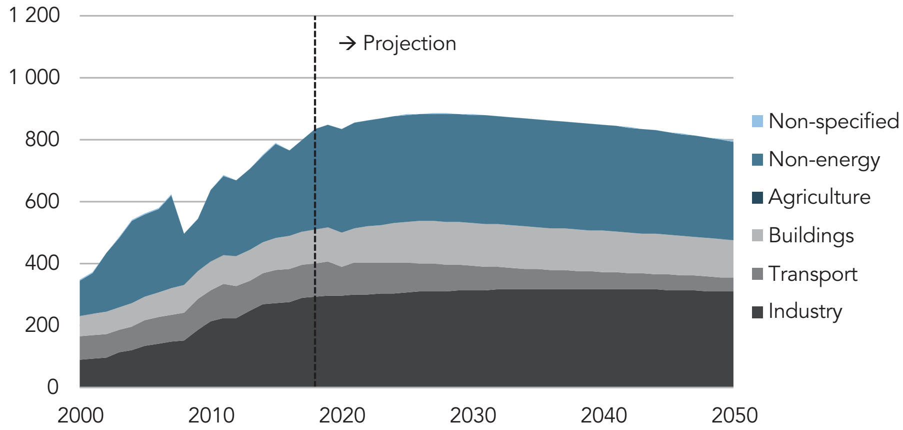
End-use energy demand by sector

Figure 17-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 17-6. Energy demand by sector in CN, 2000-2050 (PJ)

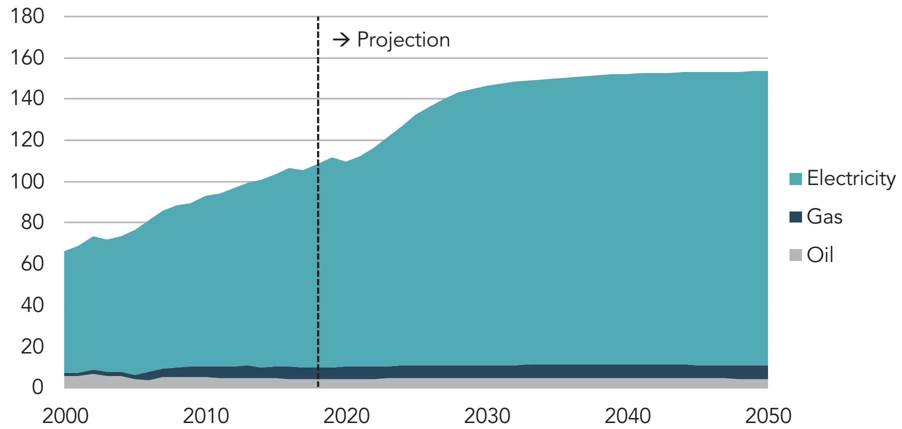


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- COVID-19 has a brief impact on demand in all sectors, but resiliency and a rapid rebound see most sectors surpassing their peaks early in the projection. The exception is transport, where efficiencies ensure that demand never surpasses 2019 levels.
- Efficiency improvements and the electrification of road transport is instrumental in reducing transport energy demand by a two-fifths in REF and, with the aid of some behavioral changes, three-fifths in CN. Transport demand in 2050 is 29% lower than REF demand in the same year.
- As a high value-added manufacturer and industrial hub, demand from industry and non-energy continue to make up about three-quarters of demand in both scenarios. Demand grows by a quarter in REF and is flat in CN.
- Significant growth in data centers in the 2020s drives buildings sector demand 40% higher in REF. Part of this is offset by moderate efficiency improvements in traditional buildings stemming from standards, labeling schemes and improvements in space cooling.
- Energy demand levels in CN are a fifth below REF levels in 2050.
- In CN, higher efficiencies see buildings demand peak in 2029, then falling an eighth.

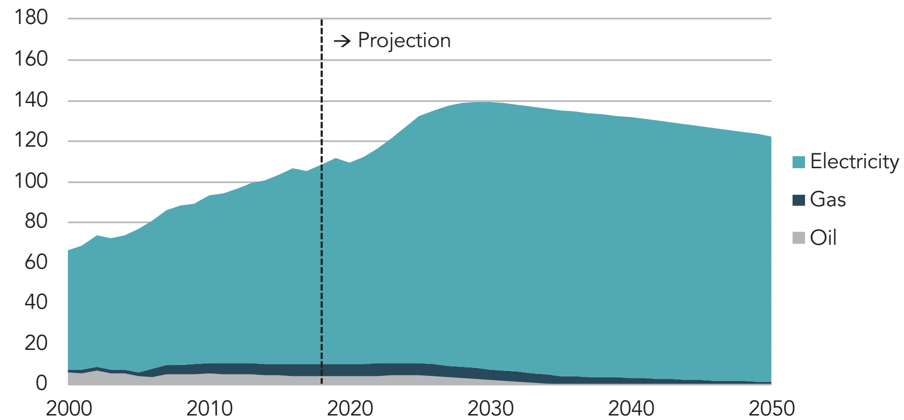
Buildings energy demand

Figure 17-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-8. Buildings energy demand in CN, 2000-2050 (PJ)



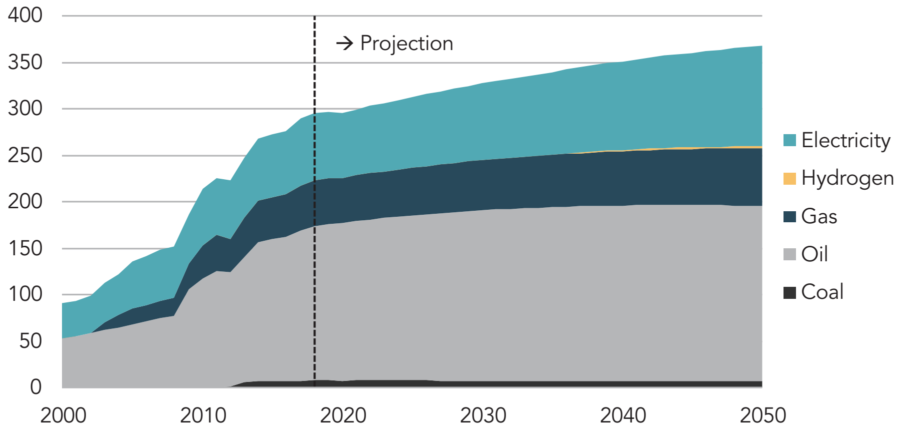
Sources: EGEDA, APERC analysis.

- Buildings demand growth in both scenarios is front-loaded, driven by rising electricity load from data centers in the 2020s. REF demand rises a third in the 2020s, and a further 4.7% over the following two decades. CN rises a quarter in the 2020s, before falling an eighth from this peak on efficiency improvements.
- Electricity continues to be the predominant carrier fuelling the buildings sector in both scenarios. Improvements in energy efficiency, particularly in space cooling via the connection of almost all the building stock to distributed districting cooling (DDC) networks, helps reduce electricity use by a seventh below REF levels in CN.
- In REF, gas and oil, in the form of LPG, continue to fuel cooking. In CN, electrification of cooking leads to a phase-out of oil use by 2036 and a reduction in gas use by three-quarters.
- A key uncertainty in these projections is the pace of data center growth over the projection period. A setback in the growth of data requirements could limit electricity growth over the projection period, while an embrace of cryptocurrency and data use could fuel further growth.
- LNG handlers and data centers all operate with significant cooling requirements. There is potential for synergies between users that would reduce energy use by sharing excess cooling services. Singapore LNG (SLNG) is currently researching how to viably realise this energy saving potential. Success in such research could reduce future electricity demand for Singaporean data centers.

Note: Space cooling reductions from DDC in CN are consistent with a recent SP Group study (2021).

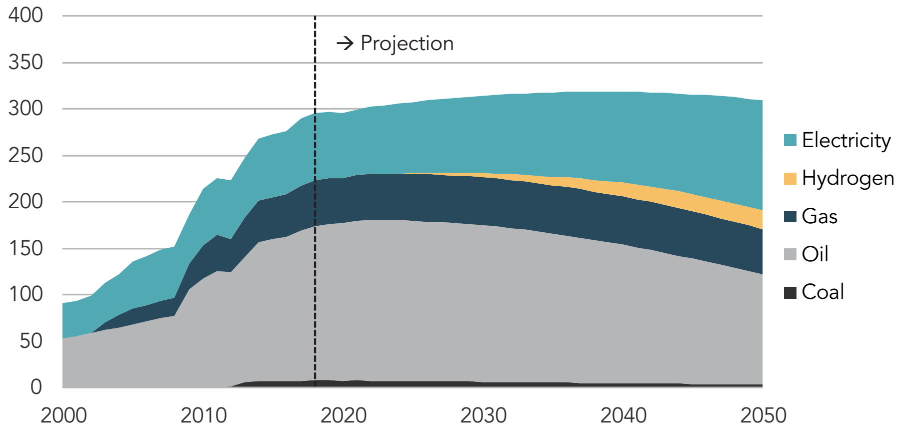
Industry energy demand

Figure 17-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 17-10. Industry energy demand in CN, 2000-2050 (PJ)

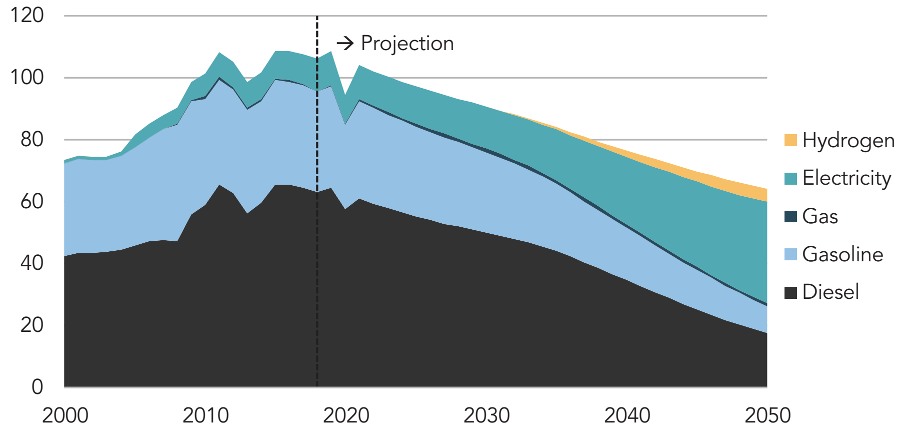


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industry demand remained resilient during the pandemic, with total demand falling 0.5% in 2020, as strong chemicals activity is outweighed by lower manufacturing output. Industry demand surpasses 2019 levels in 2021.
- REF industrial demand grows at a slower pace to the previous decade, while faster efficiency improvements, plus material efficiency improvements in the chemicals sub-sector, contribute to demand reductions in CN.
- Fuel switching towards electricity continues moderately in REF, and an acceleration of fuel switching lifts electricity demand 10% over REF levels in CN. Electricity makes up 29% of the industrial fuel mix in REF and rises to nearly two-fifths in CN.
- Fossil fuels remain dominant in both scenarios, comprising 70% of the 2050 fuel mix in REF and 55% in CN. Fossil fuel use falls a quarter in CN, with coal falling a half, oil a third, and gas remaining flat.
- Hydrogen is introduced in 2025 in select sub-sectors of both scenarios, but adoption accelerates more rapidly in CN, with demand hitting eight-times REF levels by 2050. Despite significant growth, hydrogen remains a niche fuel.
- In 2050 hydrogen only makes up 6.5% of the industrial fuel mix in CN and 0.7% in REF.
- CCS adoption by the petrochemical subsector begins in 2035 in CN, while no industrial use of CCS occurs in REF.

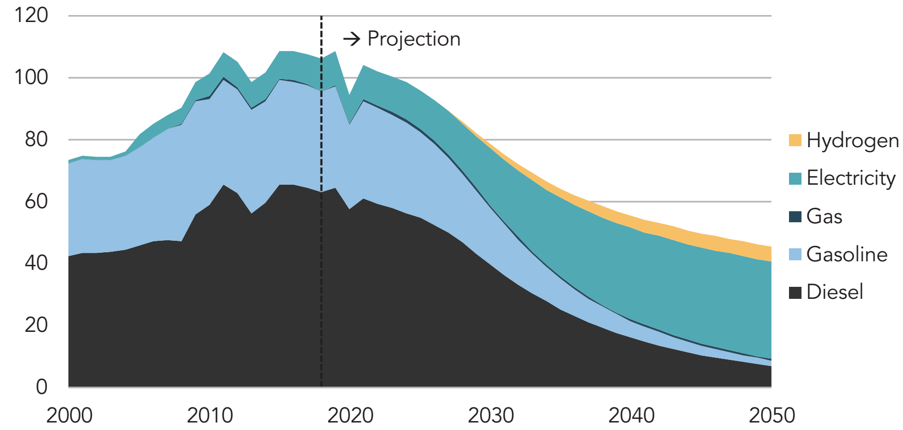
Transport energy demand

Figure 17-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 17-12. Transport energy demand in CN, 2000-2050 (PJ)

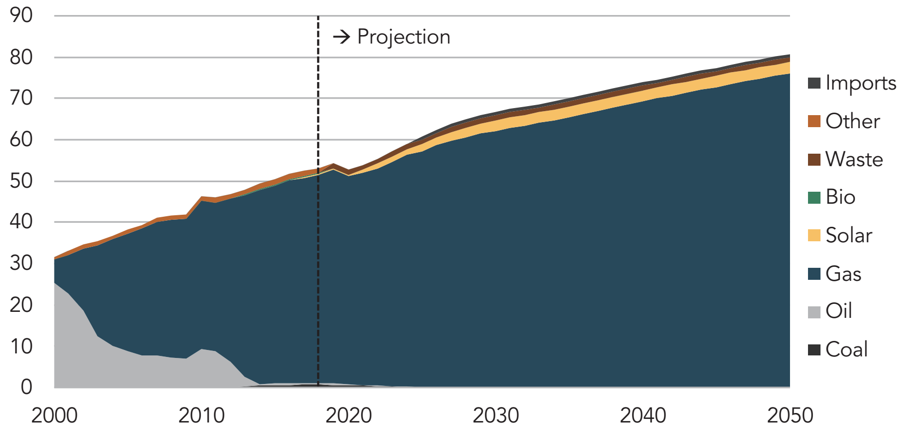


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- The onset of COVID-19 reduced demand by 13% in 2020. Demand rebounds quickly but starts to decline again in the early 2020s due to efficiency improvements.
- Policy is instrumental in improving energy efficiency and driving down energy use in the transport sector. The aspirational ICE phaseout, COE and vehicle incentive schemes foster a rapid adoption of EVs, which reduces oil product demand and total energy use due to the higher relative efficiency of EVs. The incentive scheme also helps improve the efficiency of the remaining ICE stock.
- REF demand falls two-fifths, driven mainly by road transport policy, but also efficiency improvements in the rail and marine sectors. Higher electrification, the penetration of hydrogen, modal changes, and freight optimisation reduce energy use by almost three-fifths in CN.
- The share of electricity in the transport mix rises from 10% (2018) to over half in REF and over two-thirds in CN. Hydrogen adoption, predominantly in freight, drives up its share in REF to 6.7%, while adoption by marine ships and buses increase its role to 10% in CN.
- Singapore falls short of its 2040 ICE phaseout in both scenarios, but significant progress is made. In REF, ICE sales fall from 98% in 2018 to 36% in 2040 and 7.4% in 2050, when zero emission vehicles (ZEV) rise to 60% of the stock. In CN, ICE sales are phased out by 2036, but retain a sixth of the stock in 2050. Vehicle buybacks may be required to phase out the remaining ICE stock.
- Modal changes and optimisation also drive energy reductions in CN. Compared to REF, road passengers shift a quarter of road activity from vehicles to two-wheelers. Furthermore, an optimisation of supply chains reduces freight activity requirements by a quarter.
- The scenarios do not consider any biofuel blending in the gasoline and diesel fuel streams. A fuel standard, either intensity-based, like in California or Canada, or a blending mandate, could reduce oil product demand and help further decarbonise the transport sector.

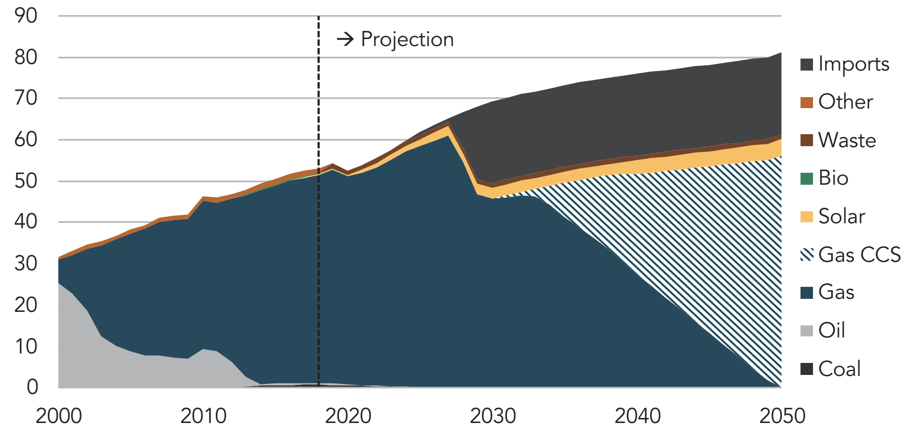
Electricity generation

Figure 17-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 17-14. Electricity generation in CN, 2000-2050 (TWh)

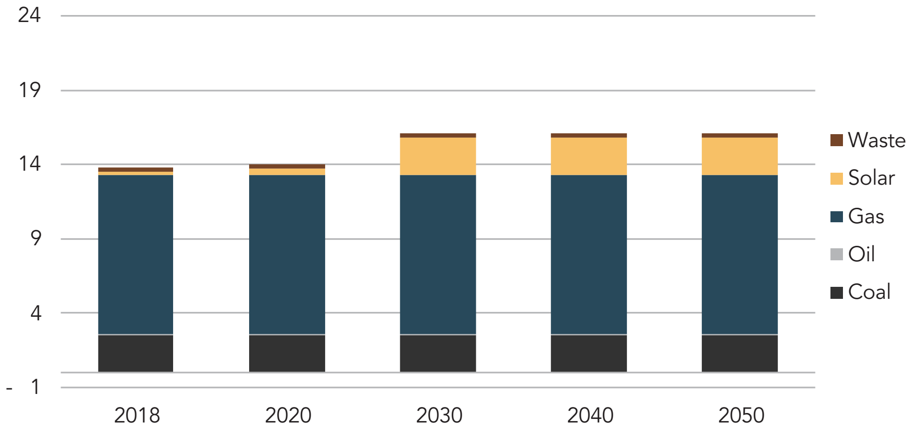


Sources: EGEDA, APERC analysis.

- Electricity demand fell 3.3% in 2020 due to the onset of COVID-19 but an economic recovery propels it past pre-pandemic levels in 2022 in both scenarios. In the longer term, macroeconomic drivers, a growing base of electricity-intensive data centers, and higher electrification across other sectors, drive loads higher, which increase by about half in both scenarios.
- Fossil fuels, particularly natural gas, retain their dominant grip on Singapore's power mix in both scenarios. In REF, gas remains around its current share, while higher solar generation, and imports from Australia push gas down to two-thirds of generation by 2050, with unabated gas being completely phased-out in favor of CCS-equipped generation. Coal and oil use are phased-out by the mid 2020s in both scenarios.
- Singapore solar generation rises from around 0.5% currently to 3.3% in REF and to 4.9% in CN. Waste-to-energy (WtE) plants continue to play a role in generating electricity, generating about 1.2 TWh per annum throughout both scenarios.
- The share of generation met by imports ranges between a quarter and 30% in CN after the commissioning of the Sun Cable in 2028.
- The development of an ASEAN power grid could see Singapore play a more significant role as an electricity trading partner than presented in either scenario. For example, higher imports from the Sun Cable could be exported to other economies. An integrated grid could also further decarbonisation of the power sector via low-emitting imports, reducing the need to rely on gas imports and CCS to reduce emissions.
- Singapore is currently researching several topics that could reduce power emissions and improve energy security, including the viability of co-firing hydrogen at natural gas units and researching the geothermal potential of the city-state.
- The scenarios do not consider any significant development in energy storage over the projection. Progress on recent pilot projects, like floating energy storage systems and other battery initiatives, could help Singapore further reduce both energy imports and power emissions.

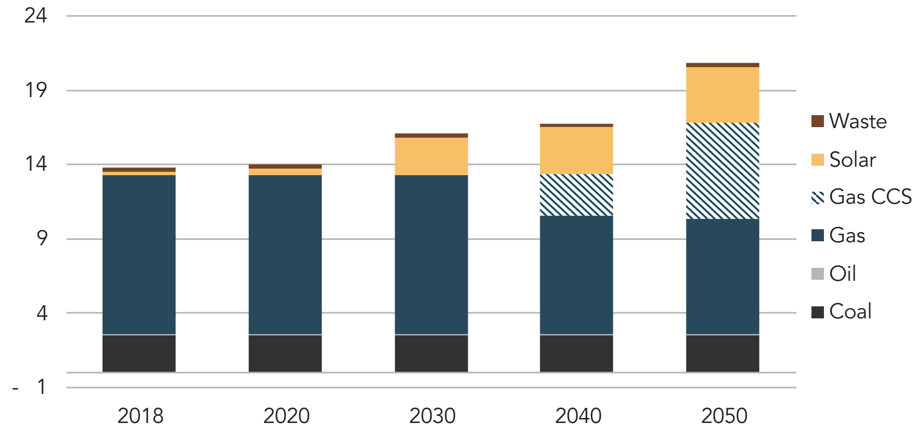
Generation capacity

Figure 17-15. Generation capacity in REF, 2017-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 17-16. Generation capacity in CN, 2017-2050 (GW)



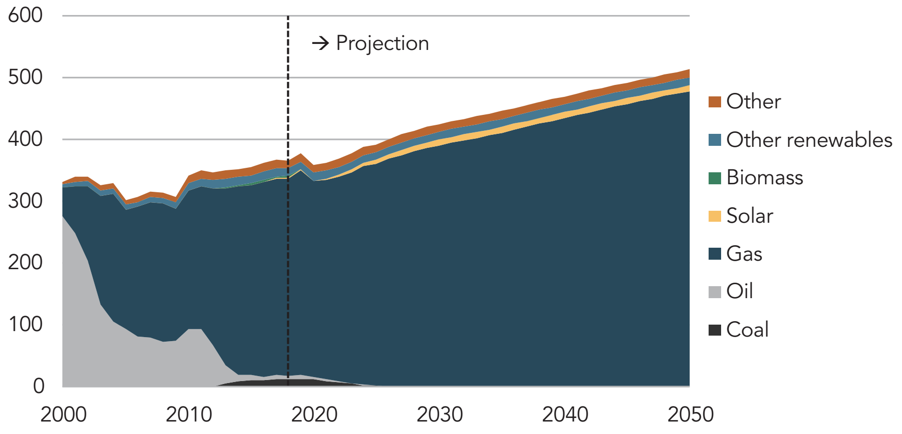
Sources: EGEDA, APERC analysis.

- Singapore's generation capacity grows by half in both scenarios on the back of solar additions.
- Singapore achieves its solar ambitions of 1.5 GWp by 2025 and 2.0 GWp by 2030 via front-loaded growth, surpassing 1.9 GWp in 2025 and 3.3 GWp in 2030. While REF capacity remains flat at 2030 levels, lower costs prompt a further increase of capacity to 4.9 GWp in CN.
- Gas capacity continues to dominate generation capacity in both scenarios. While it remains constant in REF, 3.0 GW of unabated gas units are retired in favour of 6.4 GW of CCS gas units in CN. In REF, capacity utilisation of gas rises from 54% to over 81% by 2050.
- Neither scenario assumes the use of utility-scale long-duration battery storage within Singapore. The arrival of this could support further solar growth and reduce gas requirements.
- A significant portion of unutilised capacity remains in both scenarios, including 0.1 GW of oil and 2.6 GW of coal in both scenarios, as well as 7.7 GW of unbated gas capacity in CN. While back-up capacity would mitigate the economic impact of supply disruptions from gas or electricity imports, there may not be enough land area in Singapore to house this capacity.
- CCS storage requires significant land requirements, making the implied land footprint of 100% coverage of gas-fired facilities potentially impossible with conventional CO_2 capture technology without technological advancement. Thus, much of the existing gas units may need to be retired and demolished in CN.
- A key uncertainty to the fuel consumption outlook is the successful deployment of CCS-equipped technology to capture emissions from gas-fired generation. Without demonstrative success with this technology, it will be unlikely that natural gas remains in the fuel mix as the world approaches carbon neutrality.
- CN trajectory depends on the successful execution of the Sun Cable link with Australia. Further grid integration, via an ASEAN power grid or higher Sun Cable imports, could support higher levels of solar capacity if Singapore can creatively overcome its land constraints.

Notes: Capacity is presented in GWac. Conversions to GWp can be made by dividing capacity by 0.77.

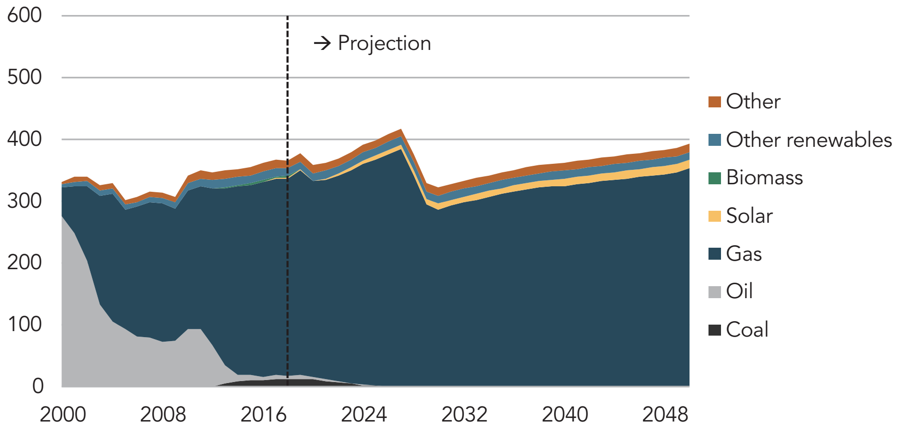
Fuel consumption by power sector

Figure 17-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 17-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

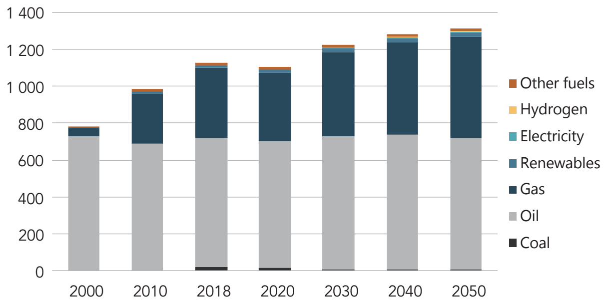


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- Rising electricity demand increases fuel consumption by the power sector by two-fifths in REF. In CN, electricity imports from the commissioning of the Sun Cable reduce gas requirements by a quarter between 2027 and 2030. However, rising electricity demand and the adoption of CCS technology lifts gas requirements above current levels by 2050.
- Fuel consumption by WtE units rise slightly in the early 2020s and remain constant for the rest of the projection in both scenarios. Oil and coal consumption are phased out in the 2020s in both scenarios.
- Fuel consumption falls 2.7% in 2020 due to lower activity during the onset of COVID-19 but recovers in 2023 in both scenarios.
- Another key uncertainty for natural gas consumption is the success in mitigating methane leakages in the natural gas supply chain. With a global warming potential nearly 30 times that of CO_2, methane venting and fugitive emissions contribute significantly to global warming. Failing to contain these emissions would likely divert many economies away from using natural gas in a world progressing towards carbon neutrality.
- Singapore is a signatory on the Global Methane Pledge, wherein 70% of the global economy are committing to reducing global methane emissions by 30% below 2020 levels by 2030, and the development of tools to track methane emissions and the adoption of best-available technology to further increase methane reductions.

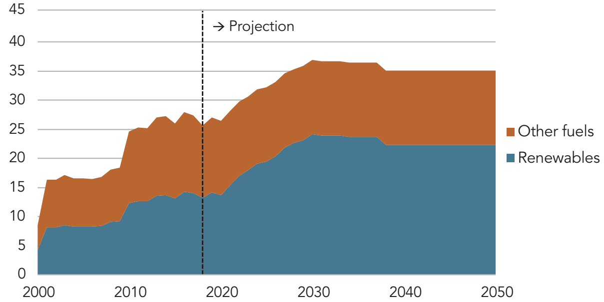
Energy supply in the Reference scenario

Figure 17-19. Total energy supply in REF, 2000-2050 (PJ)



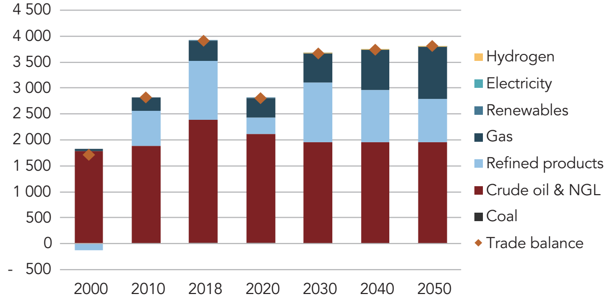
Sources: EGEDA, APERC analysis.

Figure 17-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-21. Net energy trade in REF, 2000-2050 (PJ)

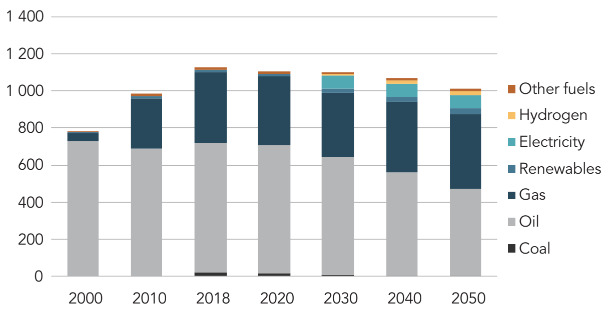


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Singapore's supply grows a sixth in REF and fossil fuels continue to hold onto the majority share of the fuel mix. There is some jostling between the relative roles of oil and gas. Electrification of transport limits oil growth from the industry and non-energy sectors, which reduces its share from three-fifths to over half. Gas, due to rising demand for use in the power sector, is responsible for most supply increases and its share rises from a third to two-fifths. Solar drives renewable use higher, but it still makes up less than 2.0% of supply by 2050, while coal falls to close to zero, buoyed by coal product use in the industrial sector.
- Singapore's domestic production remains to be power produced from WtE plants and solar panels. Overall, production grows by a third in REF.
- Singapore's net imports grow a tenth over the *Outlook*, as surging LNG imports more than make up for declines in piped gas imports and crude import requirements from lower refining capacity.
- Singapore remains a global supplier of crude oil, oil products, and bunkering services over the projection period after recovering from a decline in 2020. During the onset of the pandemic, mobility restrictions reduced global demand for oil, which drove net trade down a fifth, and travel bans reduced tourism, dragging bunkers down a quarter.
- Singapore remains a key supplier of refined products in REF, but at a slightly lower level than 2018 (7.0%), due to reductions in refinery capacity.

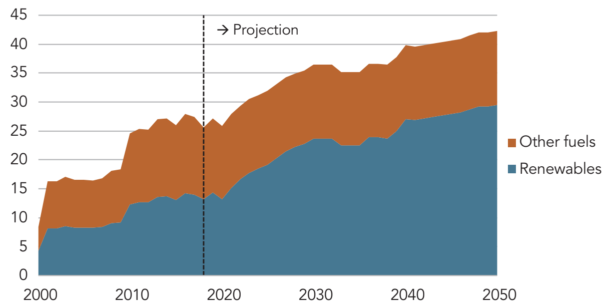
Energy supply in the Carbon Neutrality scenario

Figure 17-22. Total energy supply in CN, 2000-2050 (PJ)



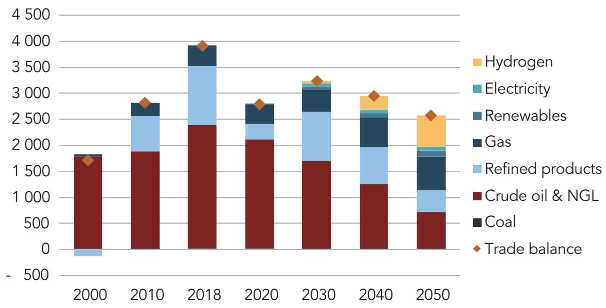
Sources: EGEDA, APERC analysis.

Figure 17-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-24. Net energy trade in CN, 2000-2050 (PJ)

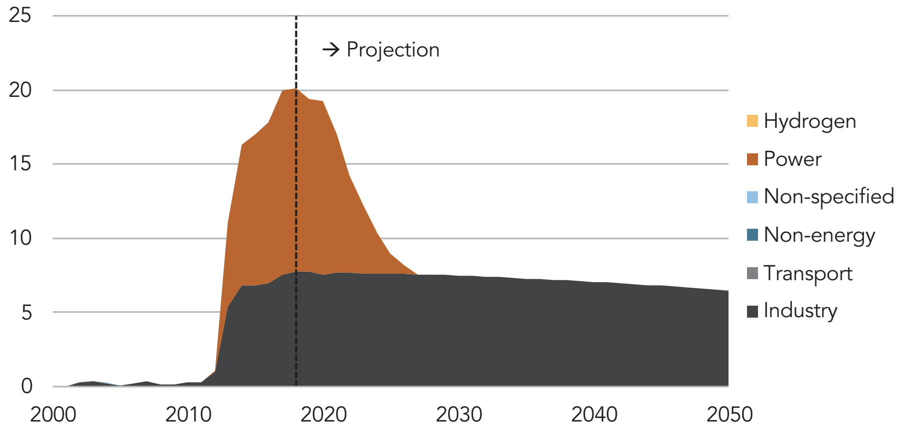


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Supply declines by a tenth in CN.
- Oil remains the choice fuel in Singapore, as electrification and mode-shifting reduce requirements but continued use in non-energy and chemicals buoys its use. CCS technology enables the relative share of gas to grow significantly. Electricity imports make up 7.0% of supply by 2050. Use by transport and industry increases hydrogen demand, but it remains a niche fuel, comprising 2.5% of supply in 2050.
- Energy production grows two-thirds in CN, as higher solar capacity boosts renewable production, while WtE continues to produce at similar levels to REF. Like REF, this scenario assumes little that Singapore does not produce hydrogen domestically.
- Lower supply requirements and declining global demand for refined oil products reduce net imports by a quarter in CN. Imports of crude oil, NGLs and petroleum products decline to under half the share of net imports, while hydrogen imports, predominantly for bunkering services, grow to a quarter of net imports by 2050. Electricity imports also grow significantly, making up over 2.8% of imports by 2050.
- Lower global demand for fossil fuels in CN reduces Singapore's role as a supplier of oil products and bunkering services. Net exports fall a quarter and bunkering demand withdrawals fall a third. Declining utilisation of its oil, refining and bunkering hubs risks stranding large-scale assets that offer these services.

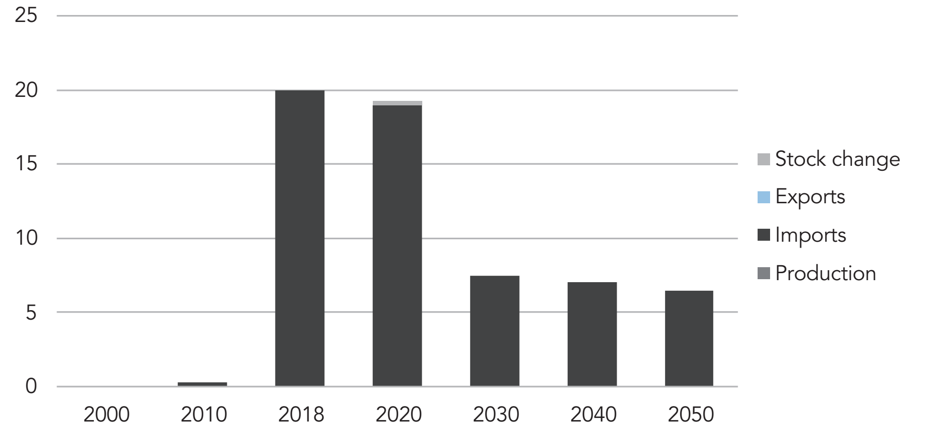
Coal in the Reference scenario

Figure 17-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

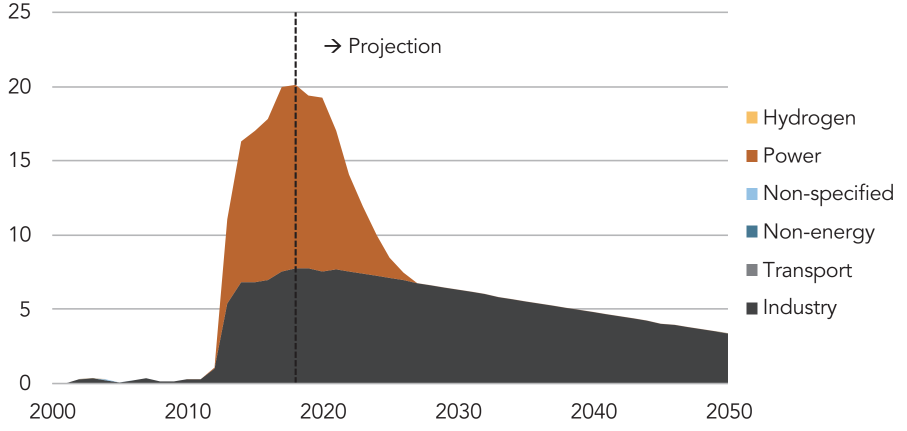


Sources: EGEDA, APERC analysis.

- A phase-out of coal-fired generation in the power sector and moderate fuel switching in industry drives coal use down two-thirds in REF. Use by industry is more resilient than power, declining about a sixth over the projection.
- Because Singapore relies on imports to meet all its coal requirements, imports fall in line with supply, by two-thirds over the projection.

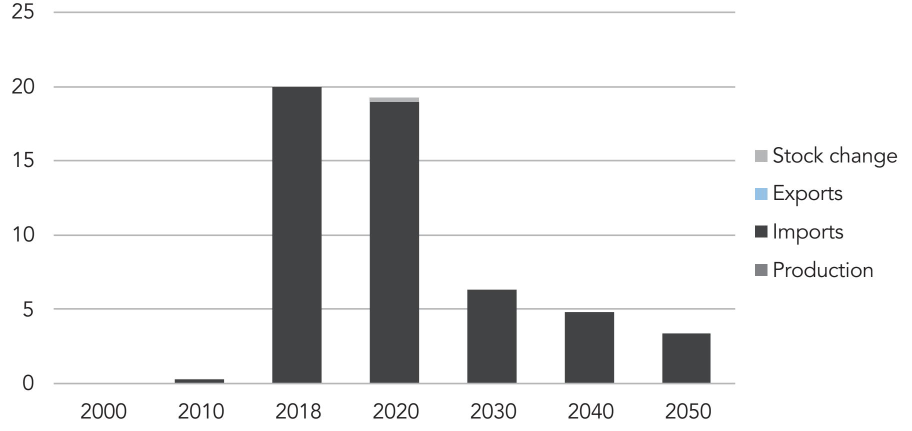
Coal in the Carbon Neutrality scenario

Figure 17-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

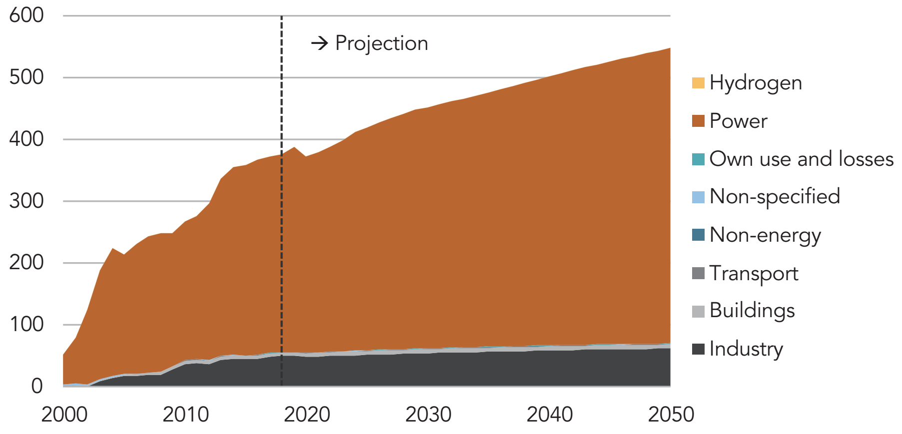


Sources: EGEDA, APERC analysis.

- A phase-out of coal-fired generation in the power sector and more significant fuel switching in industry drives coal use down by 83% in CN. While industrial use of coal falls by more than half, but use remains in 2050.
- Because Singapore relies on imports to meet its coal requirements, imports fall in line with supply, by 83% over the projection.
- An industrial coal phase out could help Singapore further reduce emissions and bring it closer to achieving carbon neutrality.

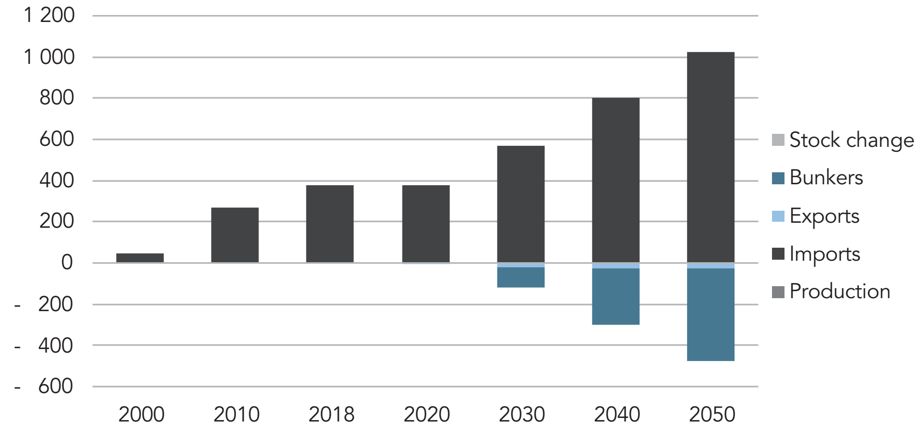
Natural gas in the Reference scenario

Figure 17-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

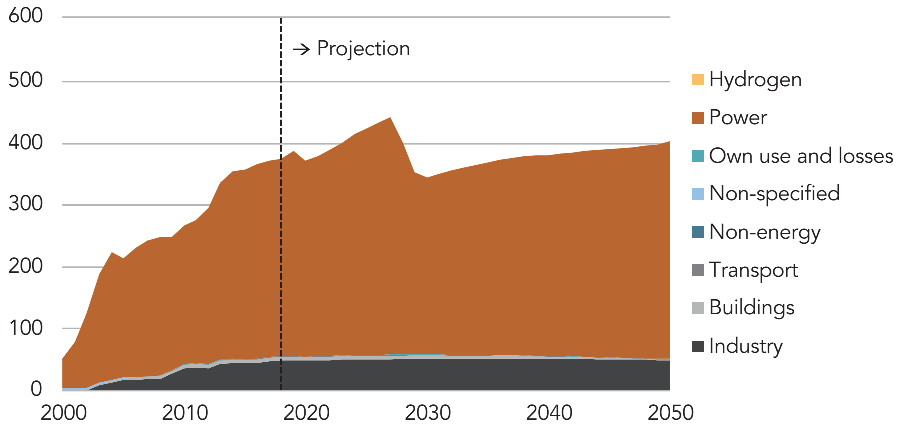


Sources: EGEDA, APERC analysis.

- Natural gas consumption rebounds from a 4.0% drop in 2020 to grow 45% over the projection on rising electricity demand and fuel switching in the industrial sector.
- Growth in gas demand mostly comes from power, which increases a half. However, fuel switching drives industrial use up a quarter and buildings cooking requirements rise 11%. Small amounts of gas continue to be used in the own use, non-specified and transport sectors.
- Due to a lack of domestic natural resources, Singapore relies completely on imports to meet its natural gas requirements. This continues over the projection.
- However, energy security concerns in neighbouring Indonesia and Malaysia reduce pipeline imports by 80% in the mid-2020s and to zero by 2032. LNG imports rise almost ten-fold over the projection, requiring the SLNG terminal to expand to its 15 Mtpa limit by 2025, and an additional 6 Mtpa of FSRU capacity by 2050.
- Singapore's role as an LNG and bunkering hub, together with the adoption of LNG as a marine fuel, lead to significant withdrawals of natural gas from Singapore in the form of marine bunkers. Bunkers make up over two-fifths of LNG imports by 2050.
- Singapore's role as an LNG re-exporter grows over the projection in line with its LNG import capacity. By 2050, Singapore is exporting the equivalent of seven or eight typical 170 000 m^3 LNG carriers per annum.

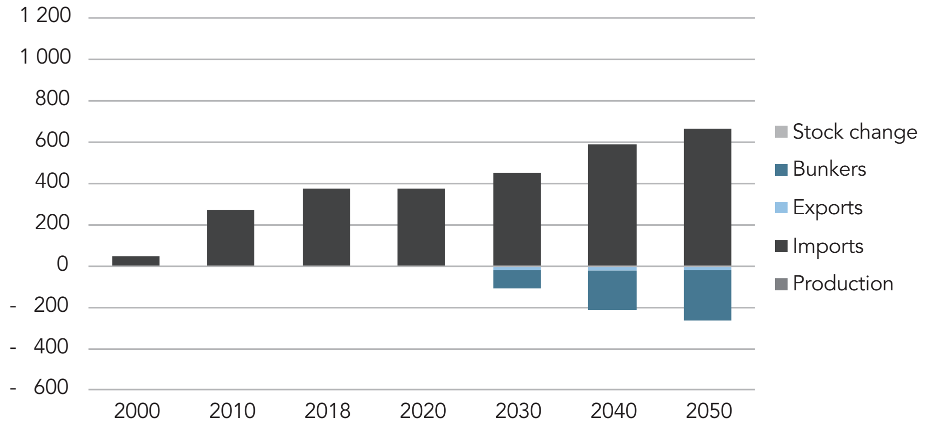
Natural gas in the Carbon Neutrality scenario

Figure 17-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

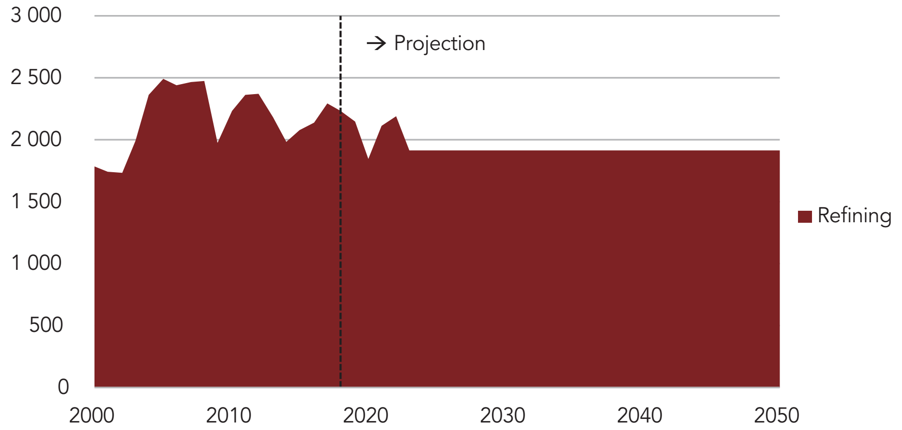


Sources: EGEDA, APERC analysis.

- Natural gas consumption peaks in 2027 before the commissioning of the Sun Cable reduces electricity generating requirements in the economy.
- However, growing electricity generation increases gas requirements 7.2% above current levels by 2050, which is down a quarter from REF. Stronger fuel switching and efficiency improvements in other sectors, particularly in industry and buildings, also contribute to demand reductions.
- Lower gas supply requirements lead to lower LNG import requirements. LNG imports rise over six-fold over the projection, a third below REF levels. While this requires the SLNG terminal to expand to its 15 Mtpa limit, and an additional 6 Mtpa of FSRU capacity by 2050, it does not require an additional FSRU expansion.
- As the world embraces carbon neutrality in CN, there is a lower global market for natural gas, including LNG re-exports and LNG bunkering services. Marine bunkering withdrawals thus only make up a third of LNG imports in CN and LNG re-exports peak around five or six LNG carrier shipments per annum, which are both down from REF.

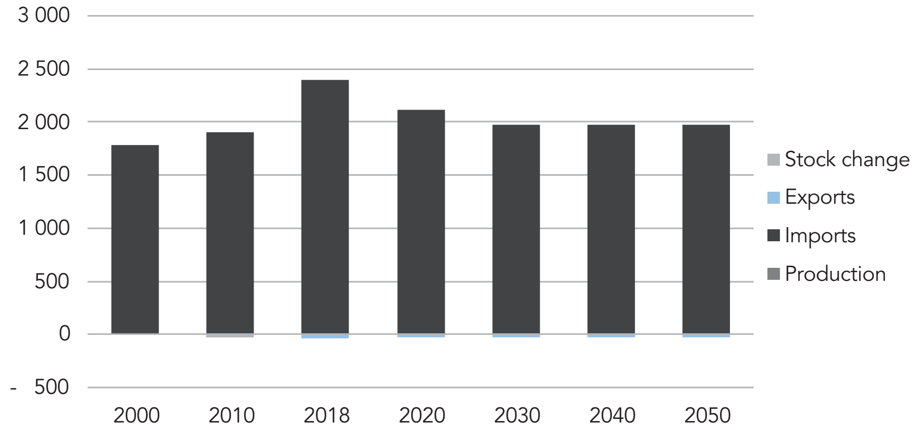
Crude oil and NGLs in the Reference scenario

Figure 17-33. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-34. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

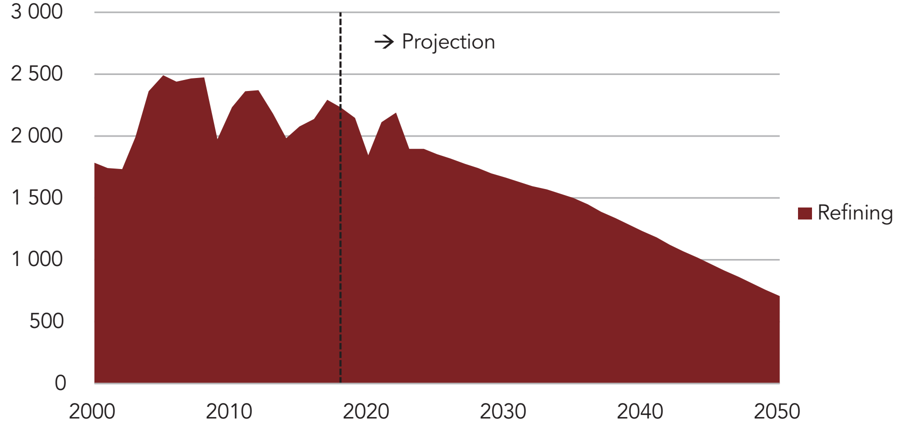


Sources: EGEDA, APERC analysis.

- Crude oil and NGL use in Singapore is completely by refineries to make oil products for both domestic use and export. After falling 14% due to lower demand during the onset of COVID-19, refinery runs briefly recover close to pre-pandemic levels.
- The halving of capacity at Shell's Pulau Bukom refining limits crude oil requirements to around 15% below 2018 levels starting in 2023.
- Singapore refineries import all their crude oil requirements. Thus, import levels essentially mimic the trajectory of supply over the longer term.
- Crude oil exports level off at around a quarter below 2018 levels for REF.

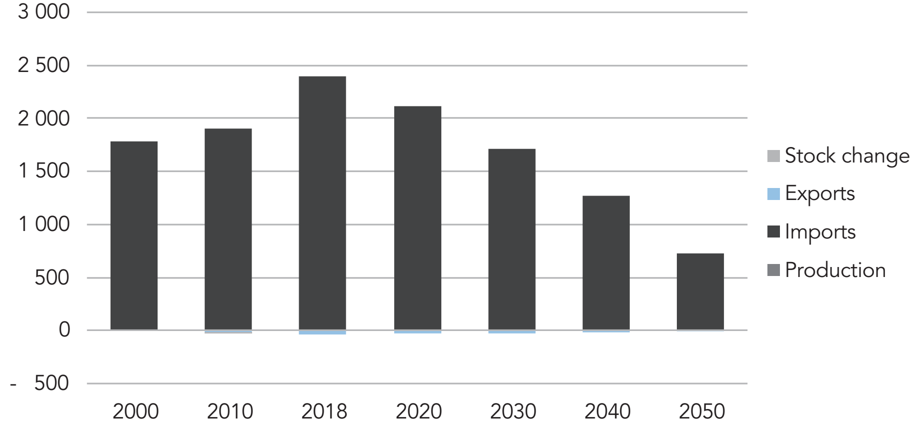
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 17-35. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-36. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

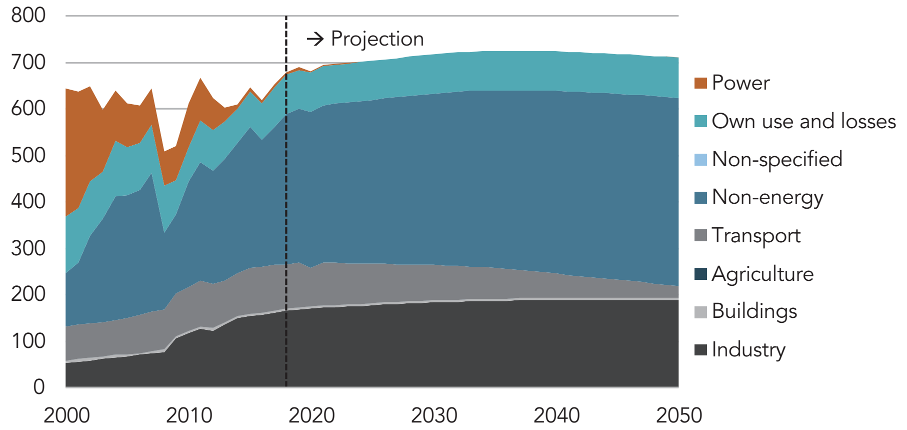


Sources: EGEDA, APERC analysis.

- Refinery runs are significantly lower in CN due to declining oil use both within Singapore and abroad, as well as lower oil product use in marine and aviation bunkering. Crude oil and NGL supply requirements and imports begin a steady decline in 2023, falling two-thirds, or 63% below REF levels in 2050.
- A reduction in the global demand for crude oil in CN reduces exports by 72%.
- The reduction in global demand for oil products risks stranding a significant portion of Singaporean assets dedicating to providing oil product services, including refining and bunkering.
- Global demand for crude oil and oil products will likely decline if the world embraces carbon neutrality. Maintaining market share in a declining market will require significant competition across incumbent and growing refining hubs.
- While Singapore will be strategically located close to high-demand areas, particularly southeast Asia and China, many of these markets are currently growing their domestic refining capacity. Remaining competitive on cost, carbon intensity, and diversity of energy product services in CN will require significant and continued investments in innovation.

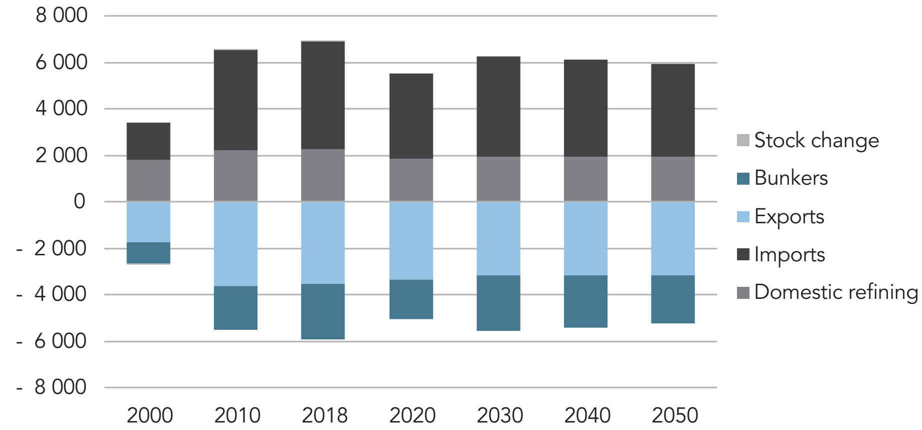
Refined products in the Reference scenario

Figure 17-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

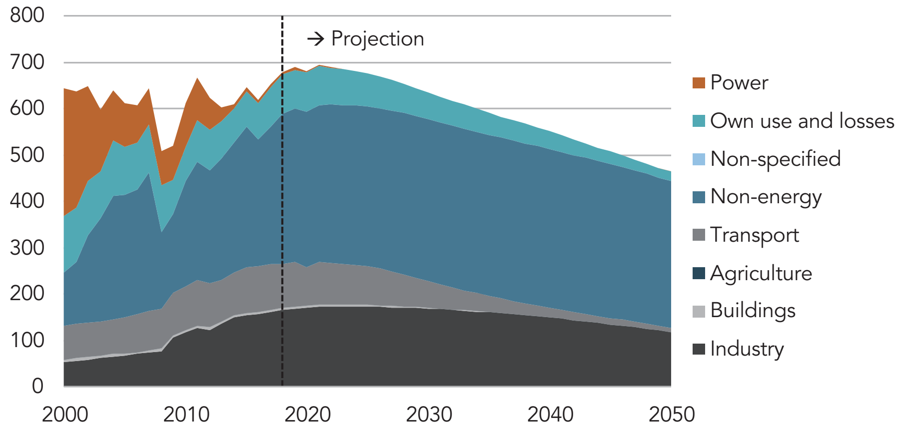


Sources: EGEDA, APERC analysis.

- Oil product demand is flat in REF, as reductions stemming from the electrification of transport are offset by increases in non-energy and industry.
- Transport's share of refined product demand falls from 14% in 2018 to 3.7% in 2050, while the share of industrial and non-energy, rises from 72% to 84%. Shares of own use and buildings remain stable, and power use of oil is phased out in the 2020s.
- Oil product demand fell 1.3% in 2020, as mobility restrictions reduced transport activity during the onset of COVID-19. However, demand rebounds quickly, surpassing 2019 levels in 2021. In the longer term, oil product demand peaks in 2036 and falling gradually over the rest of the projection.
- Oil product imports follow domestic demand trends, while both exports and bunkering services follow refinery output trends in the longer term.

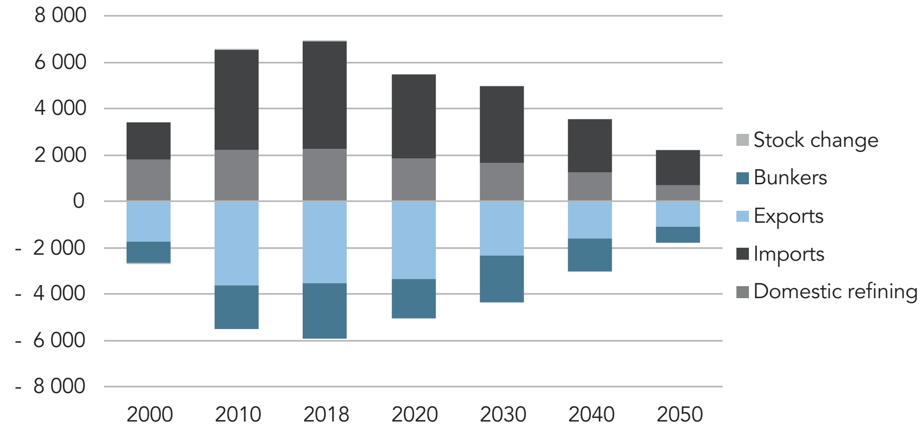
Refined products in the Carbon Neutrality scenario

Figure 17-39. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 17-40. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

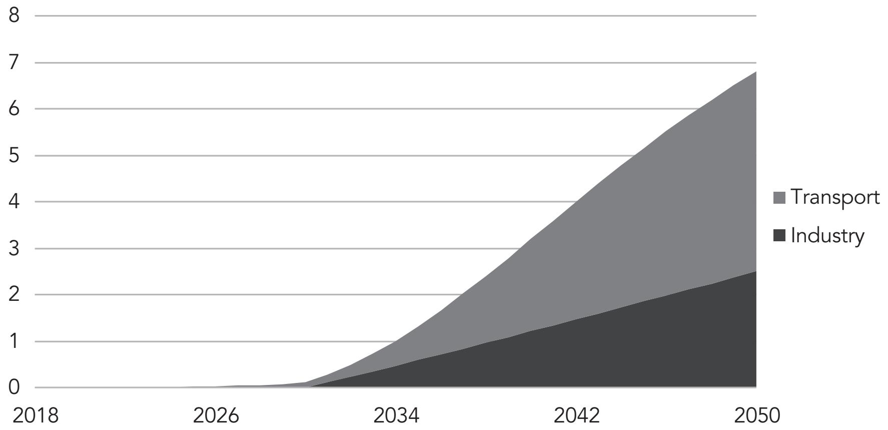


Sources: EGEDA, APERC analysis.

- Oil product demand falls a third as electrification and efficiency led to significant reductions in transport, buildings, and own use, while both fuel switching and efficiency improvements lead to moderate declines in other sectors.
- Industrial activity, including both industry and non-energy use, makes up 94% of all oil demand requirements by 2050 in CN. Further reductions in oil use and emissions will require decarbonising the end-uses of these sectors.
- Refinery production, bunkering withdrawals, and oil product trade all fall around two-thirds as declining global demand for oil in a world approaching carbon neutrality lowers oil trading volumes.
- The reduction in global demand for oil products risks stranding a significant portion of Singaporean assets dedicating to providing oil product services, including refineries and bunkering. The low utilisation rates implied by this trajectory risks stranding a significant portion of current capacity.

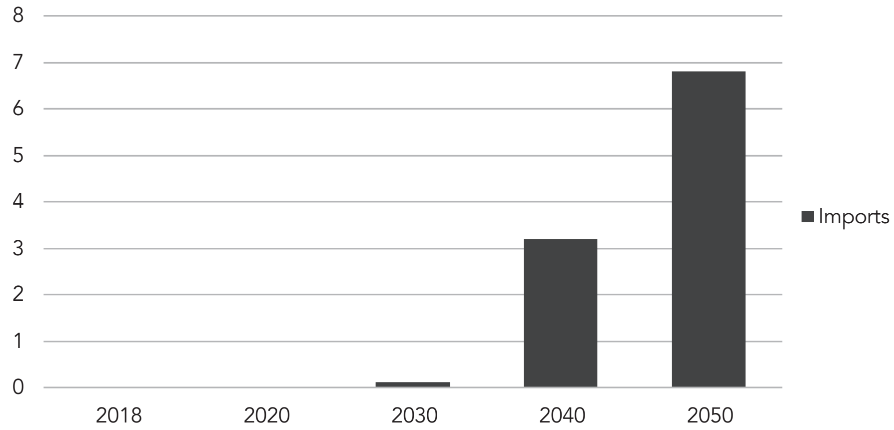
Hydrogen in the Reference scenario

Figure 17-41. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 17-42. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)



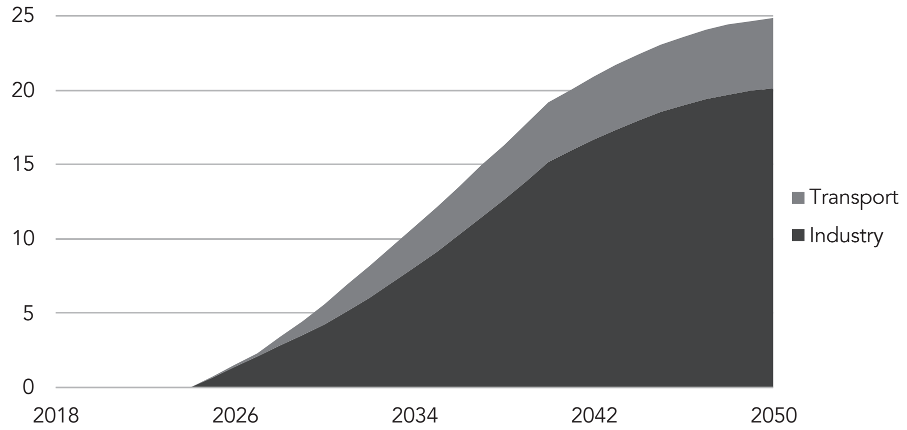
Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- Hydrogen use emerges in the transport and industry sectors in the 2020s, growing to almost 6.8 PJ by 2050 (0.053 Mt). Use in transport is driven by fuel-cell freight vehicles. Industry uptake is driven by adoption in the petrochemical sector.
- Due to the lack of indigenous resources and land constraints limiting solar resources, it will be challenging for Singapore to become a producer of hydrogen. Singapore is assumed to import all hydrogen requirements.
- The global and Singaporean hydrogen market is in its infant stages. While Singapore's limited resources and land constraints will limit its role as a hydrogen producer, it could still become a development leader as an importer by investing in R&D and collaborative initiatives to develop a low-cost global supply chain.
- Singapore is currently researching how to fit hydrogen into its regulatory regime and is embarking on several MOUs with other economies, including Chile and Australia, to help establish a hydrogen supply chain to support demand growth in Singapore.

Notes: Senoko Gasworks currently produces a small but unknown amount of hydrogen from steam methane reforming to create a synthetic gas to blend with natural gas and naphtha to generate city gas in Singapore. This analysis does not consider these volumes.

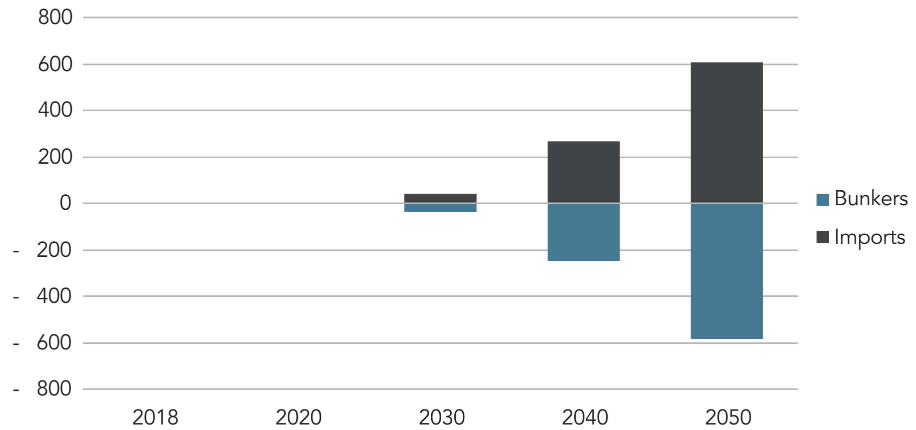
Hydrogen in the Carbon Neutrality scenario

Figure 17-43. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 17-44. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)



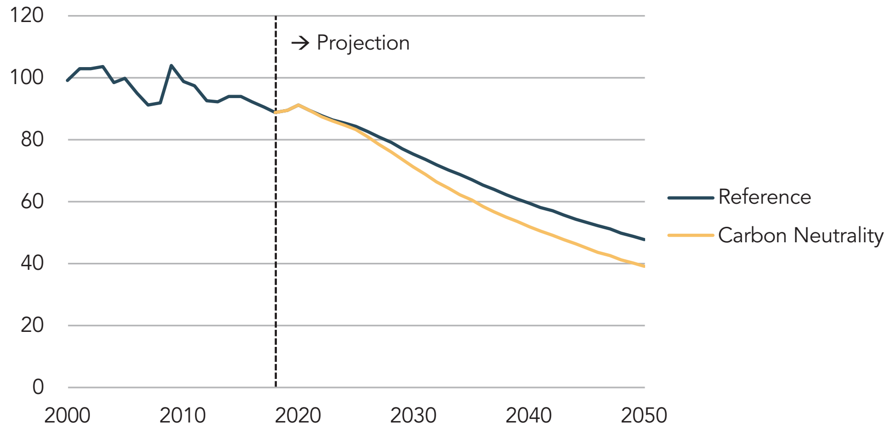
Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- In CN, demand for hydrogen begins in the early 2020s, growing to almost 25 PJ (0.2 Mt) by 2050. This tripling over REF levels comes from the utilisation of the energy carrier in new end-uses, such as in marine and passenger transport, and higher adoption in both freight transport and the petrochemical sector.
- Hydrogen is assumed to not be used in the power sector. However, Singapore is researching the potential for hydrogen to generate power via combustion, co-firing with natural gas in combined-cycle technology, or via fuel cells to power on-site generation for end-users like data centers. A successful demonstration from such projects could lead to higher hydrogen supply requirements than presented here.
- Singapore is assumed to not produce its own hydrogen for domestic consumption, instead relying completely on imports. Producing low-cost hydrogen consistent with carbon neutrality would likely be via electrolysis and require a steady flow of low-carbon electricity from other economies via an interconnected grid. Thus, integrating Singapore into a regional electric grid could yield an energy future where it begins to produce low-carbon hydrogen.
- The emergence of hydrogen as a marine fuel and Singapore's continued role as a supplier for bunkering services drives hydrogen trade in CN. While imports grow to 608 PJ (4.7 Mt), 96% of these are withdrawn from the economy by marine bunkers. Singapore could potentially leverage its learnings, strategic location and infrastructure from being a large-scale refining and oil trading hub to also become a global hub for the hydrogen storage and trading.
- Singapore has significant potential for hydrogen demand and supply beyond the values shown here and must develop large-scale projects to illustrate the viability of the energy carrier.

Note: These tonnage measurements of hydrogen assume that one Mt of hydrogen converts to about 129 PJ of energy.

APEC energy goals

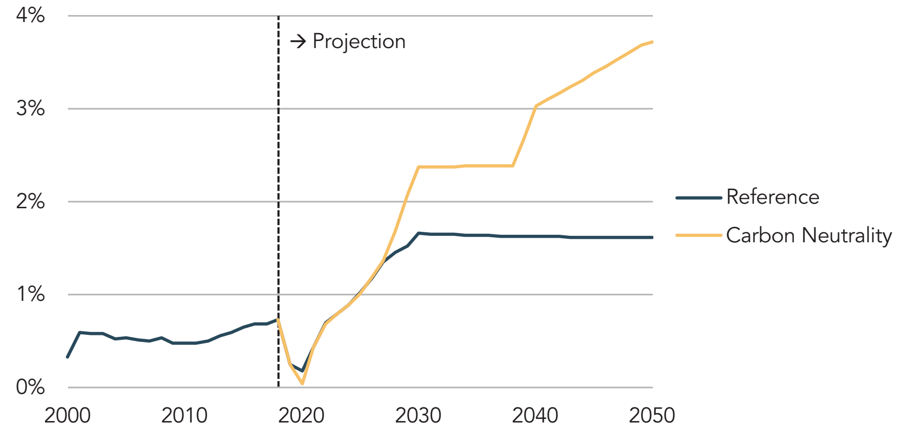
Figure 17-45. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

- Singapore continues to decouple energy use from economic activity in both scenarios. In REF, energy intensity declines continue at their historical pace, falling to 48% of 2005 levels in 2050, nearly halving from 2018 levels. Decoupling increases more rapidly in CN, falling to 39% of 2005 levels and over half of 2018 levels.
- These improvements support the shared APEC goal to achieve its energy intensity goals of reducing energy intensity by 45% below 2005 levels by 2030 in both scenarios.
- Achieving Singapore's solar targets helps it align with the APEC energy goal of doubling 2010 modern renewables shares by 2030.
- However, Singapore started from a very small base, at 0.5% in 2010, compared to an APEC-wide share of 6%. By 2030, the share increases to 1.7% in REF. In CN, the introduction of imports from the Sun Cable reduces the non-renewable fuel use in the economy, lifting the 2030 share higher, to 2.4%. Continued deployment of solar in the final two decades lifts the share to 3.7% by 2050.

Figure 17-46. Modern renewables share in REF and CN, 2000-2050



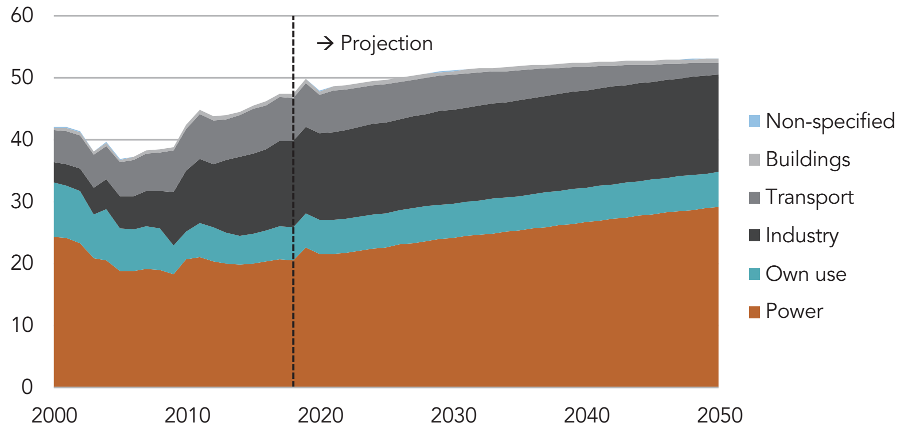
Sources: EGEDA, APERC analysis. Notes: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- There is room to further grow the role of modern renewables in Singapore's economy. For example, the utilisation of energy storage would help reduce the non-renewable fuel requirements and encourage further utilisation of solar resources, and introducing renewable fuel mandates or standards would increase biofuel blending.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

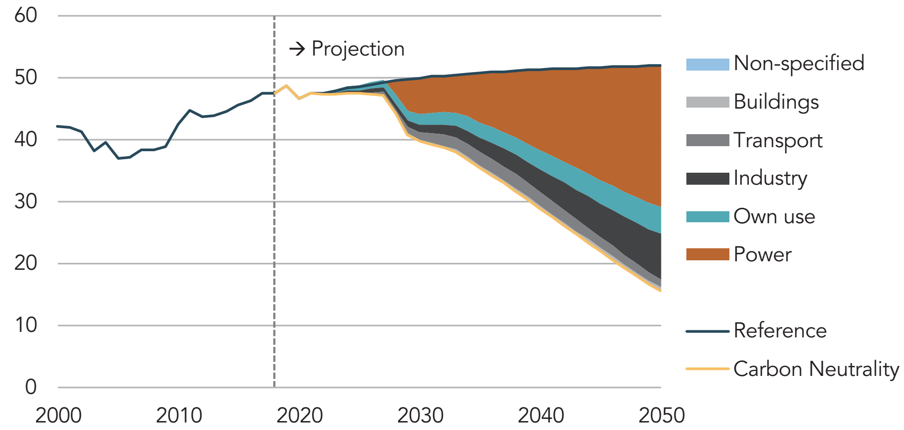
Gross CO_2 emissions

Figure 17-47. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 17-48. Change in gross CO_2 emissions, 2000-2050 (million tonnes)



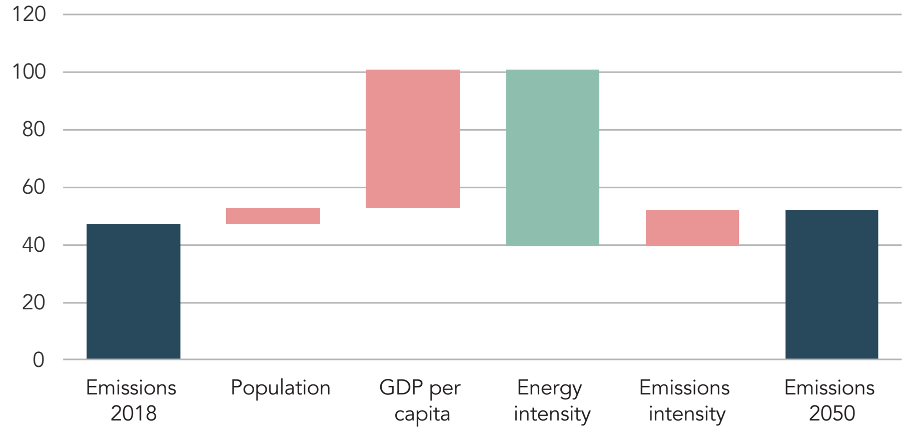
Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Singapore's CO_2 emissions grow 8.4% in REF, as transport electrification offsets growth from both power and industry. While emissions do not plateau by 2030, they are well below Singapore's updated NDC of limiting emissions below 65 $MtCO_2$-e. However, REF is not consistent with Singapore's long-term LEDS of halving emissions to around 33 $MtCO_2$-e by 2050.
- Emissions in CN decline by 66% from 2018 reaching 16 Mt in 2050. CN emissions are almost a quarter below the NDC constraint, meeting and exceeding Singapore's LEDS commitment.
- Emissions intensity (emissions per unit of GDP), falls 46% below 2005 levels by 2030 in REF, achieving Singapore's first NDC item, which commits to a 36% reduction. Emissions intensity is halved over the entire projection. The decoupling of emissions from economic activity is stronger in CN, falling over four-fifths by 2050.
- Two-thirds of emissions reductions in CN come from the power sector due to higher solar deployment, the displacement of thermal generation with electricity imports and abatement from the CCS-fired natural gas fleet. CCS also helps reduce industrial emissions via the petrochemical sector.
- CN pathway hinges on the development of both utilisation and storage pathways to permanently store carbon sequestered from its combustible emissions. A more stringent carbon pricing system, in terms of price level and coverage, would help manifest these pathways.
- Singapore lacks the geological formations necessary to permanently store captured CO_2 domestically. The storage pathway requires the development of a carbon supply chain to export its sequestered carbon and enable the storage potential in other economies.

Notes: Combustion emissions make up ~94% of Singapore's emissions. Assuming that holds, Singapore would need to keep combustion emissions below ~61$MtCO_2$-e to remain compliant with its NDC.

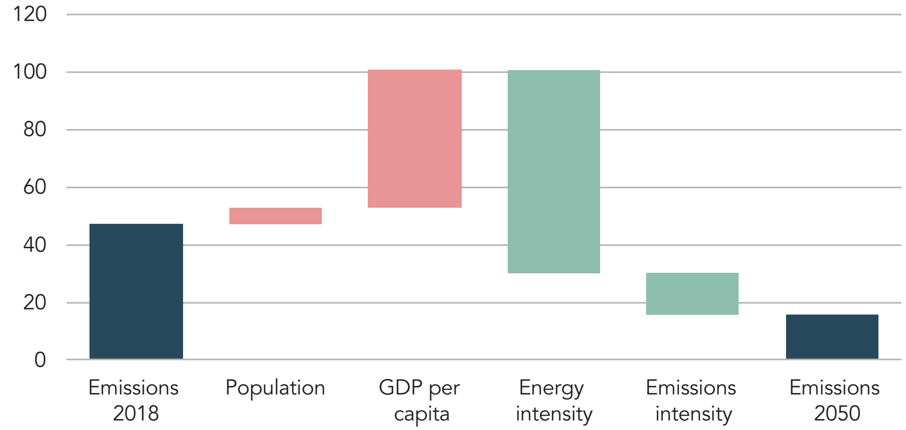
Components of CO_2 emissions

Figure 17-49. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 17-50. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Both population and GDP per capita components contribute the same amount to the evolution of emissions in either scenario. A growing population increases emissions by 5.6 Mt and rising incomes (GDP per capita) lift emissions by 48 Mt.
- Energy intensity and emissions intensity evolve across both scenarios as differing policy assumptions lead to different levels of energy efficiency and fuel choices.
- In REF, energy efficiency improvements reduce emissions by 46 Mt, almost making the increases from higher incomes. Energy efficiency plays a key role in limiting further emission increases. Emission intensity (emissions per energy supply) contributes a 3.9 Mt reduction, as end-user and the power sector switches away from carbon-intensive fossil fuels and towards lower-emitting alternatives.
- Higher efficiencies in CN increases energy intensity declines by 28% to 59 Mt and emissions intensity reductions by seven-fold over REF levels, to nearly 28 Mt.
- Emissions intensity improvements are mostly attributable to CCS, which covers all gas-fired generation in the power sector, and the introduction of the Sun Cable offsetting gas-fired generation with electricity imports. However, efficiencies fuel switching, and higher solar adoption also play a factor.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

Australia-Singapore Sun Cable. https://suncable.sg/

Advancing Singapore's energy transition. https://www.ema.gov.sg/media_release.aspx?news_sid=20211025JxngSPJ9UClo

Cooling Technology For Data Centres. https://www.slng.com.sg/nus-keppel-and-slng-join-forces-develop-new-energy-efficient-cooling-technology-data-centres

CCUS: Decarbonisation Pathways for Singapore's Energy and Chemicals Sectors. https://www.nccs.gov.sg/docs/default-source/default-document-library/ccus-study-report.pdf

EMA to study Geothermal potential in Singapore. https://www.ema.gov.sg/media_release.aspx?news_sid=20211023kEitG26TOhWn

Global Methane Pledge. https://ec.europa.eu/commission/presscorner/detail/en/statement_21_5766

Green Building Masterplans. https://www1.bca.gov.sg/buildsg/sustainability/green-building-masterplans

ICE Phaseout. https://www.lta.gov.sg/content/ltagov/en/industry_innovations/technologies/electric_vehicles.html

NDC and LEDS. https://www.nccs.gov.sg/media/press-release/submission-of-singapores-enhanced-nationally-determined-contribution-and-long-term-low-emissions-development-strategy

Pre-emptive measures to enhance Singapore's energy security and resilience. https://www.ema.gov.sg/media_release.aspx?news_sid=20211019jGdGgQ0nLhyb

Singapore increasing carbon tax and raising climate ambition. https://www.nccs.gov.sg/media/press-release/singapore-will-raise-climate-ambition

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Study of Hydrogen Imports and Downstream Applications for Singapore. https://www.nccs.gov.sg/docs/default-source/default-document-library/hydrogen-study-report.pdf

Vehicle Emissions Scheme. https://www.nea.gov.sg/media/news/news/index/increased-rebates-for-cleaner-vehicles-under-enhanced-vehicular-emissions-scheme

18. Chinese Taipei

Highlights

Demand

- Energy demand in Chinese Taipei has historically increased along with economic growth and relied substantially on oil (refined products).
- During the outlook period, energy demand gradually decreases in REF and experiences a steeper decline in CN. Strengthening energy efficiency policies and accelerating electrification of mobility support the demand reductions in CN.
- Since 2000, there has been no significant difference in the share of oil in annual energy demand as oil accounted for 58% in 2000 and 55% in 2018. However, oil demand can be overtaken by electricity demand for carbon neutrality by 2050 in CN.

Supply

- Chinese Taipei has been dependent on fossil fuels for more than 80% of its energy supply, most imported from abroad. The share of fossil fuels in energy supply has been increasing and accounted for 86%, 88%, and 91% in 2000, 2010, and 2018, respectively.
- Chinese Taipei has continuously pursued an energy transformation policy that reduces the proportion of coal supply and expands renewable energy capacity.
- In both scenarios, the energy supply decreases through 2050. In REF, coal shows a relatively steep supply decline in the 2020s as the proportion of coal-fired power generation decreases, while natural gas increases more than 60% in 2030, as compared with 2020 levels.
- Oil gradually declines in the buildings, industry, and transport sectors. In CN, the supply of coal and oil decreases more radically.
- With the significant decline in the transportation sector's gasoline demand in CN, both import and domestic refined products are expected to reduce.
- Gas supply remains reliant on imports (LNG), which presents energy security challenges.

Power

- All nuclear power will be shut down by 2025 in both scenarios, provided that Chinese Taipei continues to adhere to the goal of a non-nuclear homeland.
- In REF, coal power generation gradually decreases while gas power generation and renewable energy generation are taking their place. In 2050, coal will account for only 15%, while gas will account for 49%, with solar and wind power accounting for 29%.
- In CN, coal-fired power generation will be phased out by the mid-2040s. Consequently, gas-fired generation with carbon capture and storage (CCS) and renewable energy generation will increase dramatically. By 2050, renewable energy generation is expected to account for 45%, followed by gas with CCS (28%) and unabated gas (19%).

CO_2 emissions

- CO_2 emissions from combustion in the energy sector decline in both scenarios.
- On a sector-by-sector basis, the most significant reduction in CO_2 emissions in CN occurs in the power sector due to coal phase-outs, expansion of renewable energy, and CCS for gas-fired generation.
- Significant declines are also expected in the transport sector due to electrification and fuel efficiency improvement.
- In both scenarios, we can observe that the decline of population, energy intensity, and emission intensity help Chinese Taipei reduce its CO_2 emissions. The growth of GDP per capita is expected to have positive effect on CO_2 emissions. With greater CO_2 deduction brought by energy intensity and emissions intensity in CN, the CO_2 emissions is expected to be 66.1 million tonnes in 2050 (CO_2 emissions in REF are expected to be 177.9 million tonnes).

About Chinese Taipei

- Chinese Taipei is an archipelago located off the southeast coast of China and the south-west coast of Japan. Its subtropical climate permits multi-cropping of rice and perennial growth of fruit and vegetables, though only 20% to 25% of the land is arable.
- With a population of 24 million, Chinese Taipei is one of the economies with the highest GDP per capita in the APEC region, at USD 56 482 (2018 PPP), in 2018. As of 2018, Chinese Taipei's economic structure continued to be driven by the service sector, which accounted for 63% of the economy's GDP, followed by the industry sector (35%) and the agricultural sector (2%).
- Chinese Taipei's total primary energy supply (TPES) reached 4 686 PJ in 2018. Oil comprised 38% of TPES as a major fuel source, followed by coal (36%), gas (18%), and others (9%). The economy has tiny deposits of energy reserves and relies on imported energy to meet its energy demand.
- Net imports accounted for more than 90% (4 416 PJ) of TPES in 2018, mainly oil (52%) and coal (32%). Total final consumption (TFC) in 2019 was 3 489 PJ. The industrial sector was the largest energy-consuming sector in Chinese Taipei, with a 34% share in TFC in 2018. Chemicals and petrochemicals are the biggest industry sub-sector. The non-energy sector is proportionally more significant than that of the APEC region. In contrast, the transport sector is not as prominent in Chinese Taipei.
- Chinese Taipei's electricity generation reached 276 TWh in 2018. The economy's electricity generation mix was dominated by thermal energy, which constituted 84% of the mix in 2018. Among thermal energy sources, coal was the largest (56%), followed by gas (40%) and oil (4.0%). The relatively high proportion of gas is mainly because the use of LNG for power generation has expanded to meet the growing electricity demand.
- Chinese Taipei aims to increase renewables and reduce coal and nuclear energy in the power mix.

Table 18-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	23.6	0.8%	15
GDP	1 331.8	1.9%	9
TPES	4 685.7	1.4%	11
Production	410.9	0.1%	18
Imports	5 189.5	4.1%	6
Exports	773.4	0.7%	12
Electricity generation	275.5	1.6%	9
Heat production	100.6	0.9%	5
CO_2 emissions	270.1	1.3%	10

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 18-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	N/A	–	N/A	N/A
Natural gas	N/A	–	N/A	N/A
Oil	N/A	–	N/A	N/A
Uranium	–	–	–	–

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- Since the Greenhouse Gas Reduction and Management Act was promulgated in July 2015, Chinese Taipei has been establishing an energy transformation policy. To actively achieve the goal of energy transformation, the government announced its New Energy Policy in May 2016. It expanded the core values of the Guidelines on Energy Development (initially released in 2012) in April 2017. This guideline suggests the three goals of non-nuclear homeland, stable power supply, and air pollution improvement as a governance framework of energy transformation in energy security, green economy goals, environmental sustainability, and social equity.
- Chinese Taipei's numerical target is 50% of gas-fired power generation, 20% of renewable energy generation, 27% of coal-fired power generation, and 3.0% of other energy generation by 2025. This means that the government will increase the share of clean energy in the power mix by increasing the renewable energy share to 20% (from 4.0% in 2015) and the natural gas share to 50% (from 31% in 2015) by 2025. As a result, the share of coal in the power mix will be reduced from 45% in 2015 to 30% in 2025. In November 2020, the government released an Energy Whitepaper to promote the energy transition, including more detailed measures and policy tools for future energy system development. Additionally, the government aims to submit annual reports summarising achievements and to conduct periodic reviews every five years.
- Although Chinese Taipei adheres to the goal of a non-nuclear homeland, the Ministry of Economic Affairs (MOEA) has no preset position on the issue of nuclear power generation. According to the referendum result in 2018, a paragraph in Article 95 of the Electricity Act, which states that "all nuclear-energy-based power-generating facilities shall cease to operate by 2025", was repealed. Meanwhile, a new referendum was held in December 2021 that asked whether the government should continue activating a stalled fourth nuclear power plant in New Taipei City. In this referendum, there was another LNG issue of whether the Guantang LNG terminal should be relocated from a site that affects a Taoyuan's Datan algal reef. As a result, restarting the fourth nuclear reactor and relocating the LNG terminal were rejected in the referendum.
- The COVID-19 pandemic is slowing Chinese Taipei in accelerating its energy transition policy. The government supports renewable energy projects, but some projects could risk falling behind schedule. For example, the escalation of COVID-19 cases has affected the overall construction of the solar PV power generation system. In response to an unexpected difficulty of solar PV developers, the government relieved the market pressure by applying the renewable energy feed-in tariffs (FiT) scheme for solar PV flexibly. Meanwhile, two blackouts were triggered in Kaohsiung in May 2021. This situation of tighter energy supply during the COVID-19 period could become a challenge to the current government policy in terms of a stable energy supply.
- Despite these practical issues, the direction of government policy for energy transition has been constant. In response to climate change, the government's target is to reduce GHG emissions by 20% below the 2005 level by 2030 and by 50% below the 2005 level by 2050. Recently, Chinese Taipei has begun to assess and plan a possible path to reach carbon neutrality by 2050. Chinese Taipei announced its ambition to achieve the goal of net-zero greenhouse gas emissions by 2050 in April 2021 at the annual Innovation Forum organised by the American Innovation Center. Following this policy direction, the Minister of Economic Affairs suggested a 2x2 framework for the transition to net zero in October 2021, consisting of a "low carbon - zero emissions" dimension and an "energy - industries" dimension.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- This edition of the *Outlook* considers two scenarios. The hypothetical pathways presented in the *Outlook* are intended to provide reference material to support APEC member economies in navigating the uncertain energy system landscape.
- **The Reference scenario (REF)** reflects recent trends and current policies in place or planned to capture the evolving nature of the energy system. Since the launch of the energy transition policy in 2016, Chinese Taipei has created a governance framework for energy transformation, enlarging the share of clean energy. Thus, REF reflects these policy tenets of Chinese Taipei.
- **The Carbon Neutrality scenario (CN)** investigates a hypothetical decarbonisation pathway through 2050. Chinese Taipei is planning its official strategy and has not yet proposed a formal path to reach carbon neutrality by 2050.
- CN assumes an acceleration of Chinese Taipei's energy transition policy that include improvements to energy efficiency, increased electrification, and an expanded share of renewable energy generation from 4.0% in 2015 to 20% in 2025.
- CN is intended as a guide to show the magnitude of CO_2 reductions possible in the context of the assumptions made about technology diffusion, costs, and global trends.
- CN can be used to quantify the magnitude of remaining CO_2 emissions that would require further action from policymakers, industry participants, and researchers.

Table 18-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current policies, trends in energy efficiency and renewable energy deployment, and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Chinese Taipei

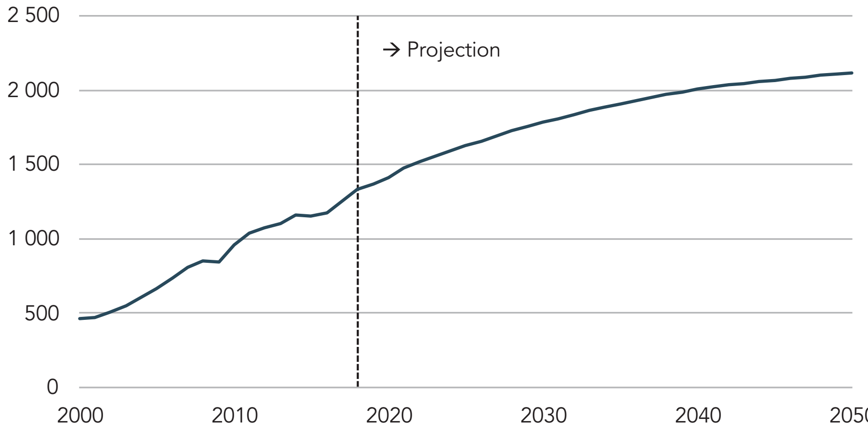
Table 18-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium) • GDP: World Bank, IMF	• Population: (UN medium) • GDP: World Bank, IMF
Buildings	• Improvements in energy efficiency	• Improvements in energy efficiency • Electrification of cooking and water heating • Increased use of solar water heaters
Industry	• Pursuing energy efficiencies in manufacturing processes.	• Increased energy efficiency, hydrogen availability, CCUS in some sub-sectors
Transport	• Promoting energy saving vehicles (e.g. electric vehicles (EVs)) and smart transportation systems.	• Accelerating the electric mobility: EVs account for 90% of new sales by 2035 and 100% of new sales by 2050; FCEVs account for 5% of new sales for light passenger vehicles by 2035. • Two-wheelers rapidly electrified with batteries. • Supporting the use of public transportation: 50% larger rail passenger demand and 25% less light vehicle demand than REF. • Supporting work from home and active transportation.
Power and heat	• Nuclear phaseout by 2025 • Renewable energy share reaches 20% of electricity generation by 2025. • 12GW of new gas-fired units by 2025, replacing coal-fired units	• Nuclear phaseout by 2025 • CCS technology starts to be applied to gas power plants by 2030. • No new coal-fired units will be commissioned after 2025. • Large scale deployment of offshore wind projects
Supply	• Following a combination of current trends and natural decline in hydrocarbons (2019 to 2021: Chinese Taipei and EGEDA data). • Refinery capacity retirement to meet decreasing demand • LNG import terminals: 35.4 Mtpa by 2030	• Projection of fossil fuel that is driven by domestic demand trends. • Reducing refinery capacity and import/export activities to reflect declining demand.
Climate	• Reducing emissions through energy transformation based on the principle of developing renewable energy, increasing the use of natural gas, and reducing reliance on coal.	• Carbon neutral by 2050

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

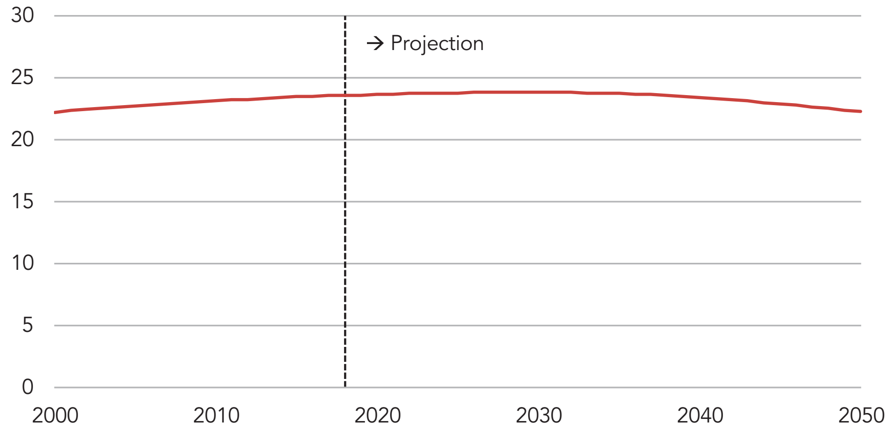
Macroeconomic backdrop

Figure 18-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 18-2. Population in millions, 2000-2050

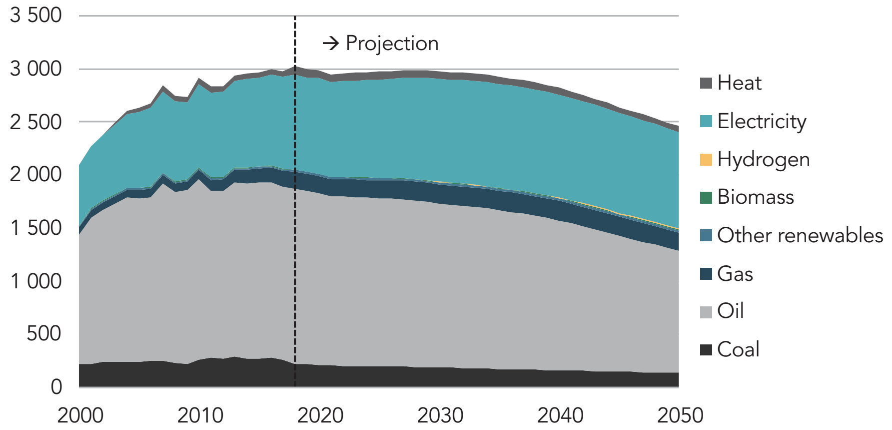


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- Big structural changes to GDP are not expected. Although GDP is steadily increasing over the projection period, the economic growth rate slows down in the long run. The background of the GDP assumption comes from a decrease in the working-age population.
- Meanwhile, Chinese Taipei is an economy with one of APEC's highest GDP per capita. Despite the global pandemic, the GDP growth rate was positive in 2020 (3.1%). This was due to the measures against COVID-19, an increase in exports of IT products, and OEM-oriented production methods.
- Total population is gradually declining, with a peak in 2034. It is assumed that a low birthrate and increased aging are the main reasons for the declining trend.

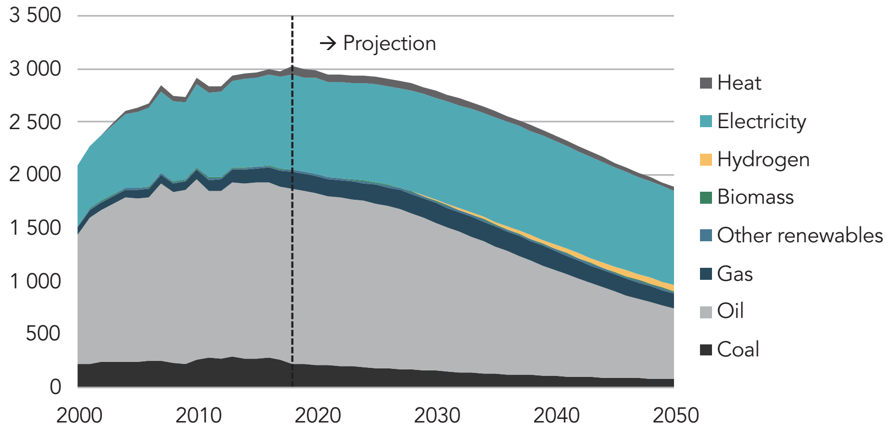
End-use energy demand

Figure 18-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 18-4. Energy demand in CN, 2000-2050 (PJ)

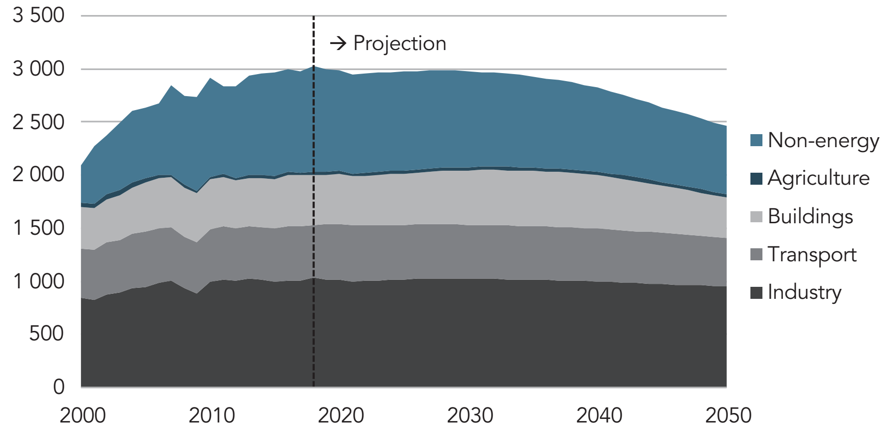


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Historically, the largest shares of energy demand were oil and electricity. In 2018, oil accounted for 55%, and electricity formed 29% of energy demand.
- Generally, energy demand declines in REF. Energy demand decreases much more in CN over the same period. In CN, demand for coal and oil is reduced by a little less than half compared to REF.
- These declining trends after 2018 are the result of strengthening energy saving by policies and taking preliminary management on energy use through the best-commercialised technology.
- Meanwhile, demand for electricity in both REF and CN will broadly remain steady. In both scenarios, electricity is expected to be consumed at a similar level between 2018 and 2050, near 900 PJ per year.

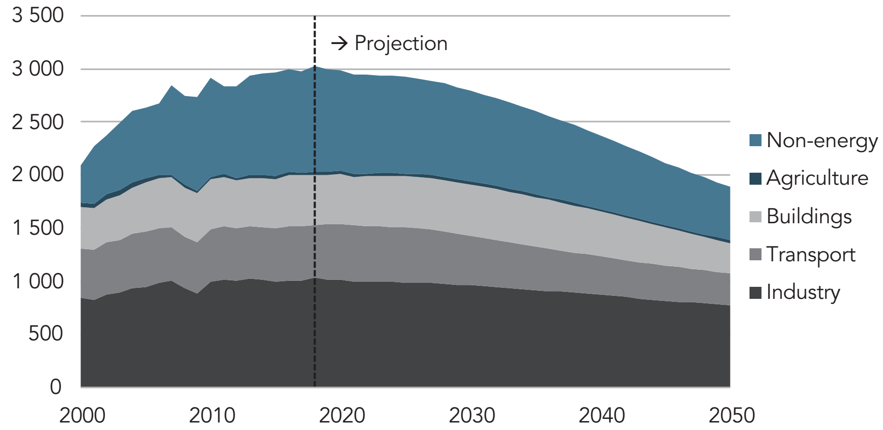
End-use energy demand by sector

Figure 18-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 18-6. Energy demand by sector in CN, 2000-2050 (PJ)

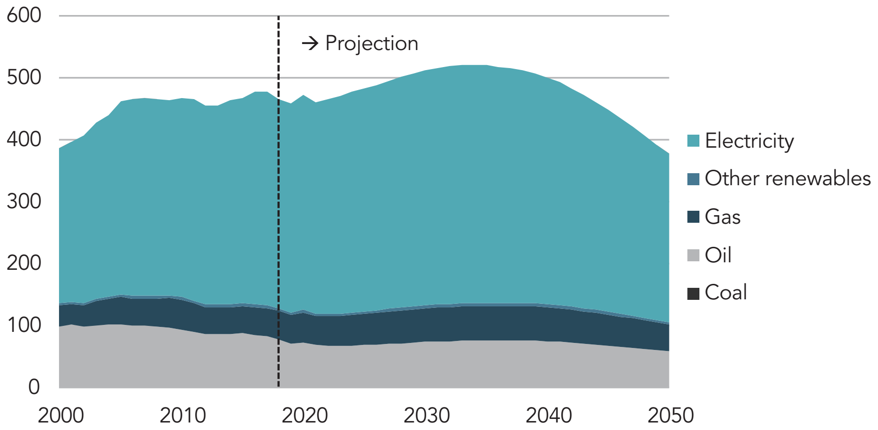


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- The largest shares of demand sectors in 2018 were industry (34%) and non-energy use (33%), followed by transportation (17%), buildings (15%), and agriculture (1.0%).
- In 2020, the COVID-19 pandemic reduced end-use energy demand in most APEC economies. However, demand in Chinese Taipei was only marginally affected. It is in sharp contrast to the demand from 2008 to 2009, when demand only recovered in 2010 due to the global financial crisis.
- Specifically, additional government spending for companies and individuals and effective COVID-19 containment measures have supported the economy during the pandemic. Although a temporary movement restriction was issued from May 2021 after a domestic outbreak of COVID-19, the impact on transportation and buildings was negligible.
- In REF, demand steadily decreases after 2040. The transport and non-energy sectors continue to decline from the 2020s, whereas the industry and buildings sectors peak in 2028 and 2034, respectively.
- In CN, there are steeper declines mainly in buildings, transport, and non-energy from 2018 to 2050. Measures for reducing energy consumption in buildings, improving fuel efficiency, and supporting the industry's energy and material efficiency measures drive these trends.

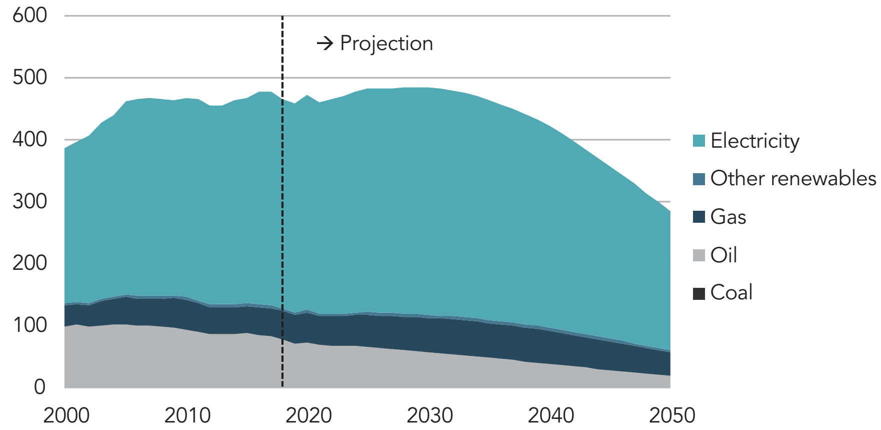
Buildings energy demand

Figure 18-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-8. Buildings energy demand in CN, 2000-2050 (PJ)

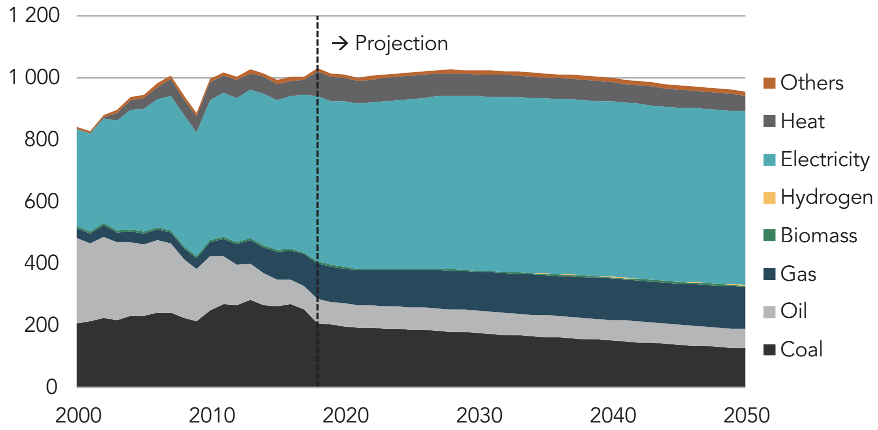


Sources: EGEDA, APERC analysis.

- From 2000 to 2018, electricity has dominated buildings' energy demand. The share of electricity in 2018 was 73%, followed by oil (16%), gas (10%), and other renewables (0.8%). The dominance of electricity in buildings is expected to continue through 2050.
- From 2018 to 2050 in REF, there is a transition to a decreasing trend after a gradual increase until the 2030s. Meanwhile, CN shows a relatively faster and steeper decline over the same period.
- Long-term demographic trends could affect energy demand for buildings. Additionally, the subtropical climate of Chinese Taipei, which leads to air conditioning activities, is an important factor influencing energy demand in buildings.
- With the trend of structural changes in the economy, the continuous growth of the service sector leads to an increase in energy demand. However, the development of energy-efficient appliances and government regulations have a moderating effect on energy demand. Efforts to improve energy efficiency have a greater impact on CN, such as more efficient air conditioners.
- In both scenarios, oil demand for space and water heating is likely to decline, switching to more efficient gas and electricity.

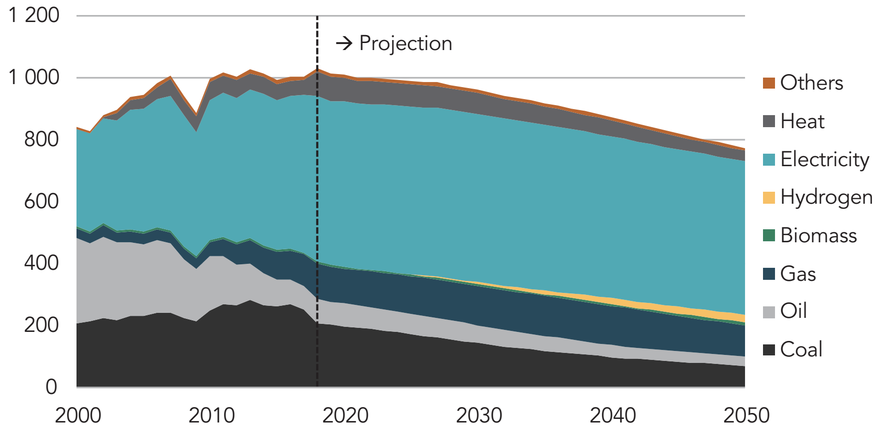
Industry energy demand

Figure 18-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 18-10. Industry energy demand in CN, 2000-2050 (PJ)



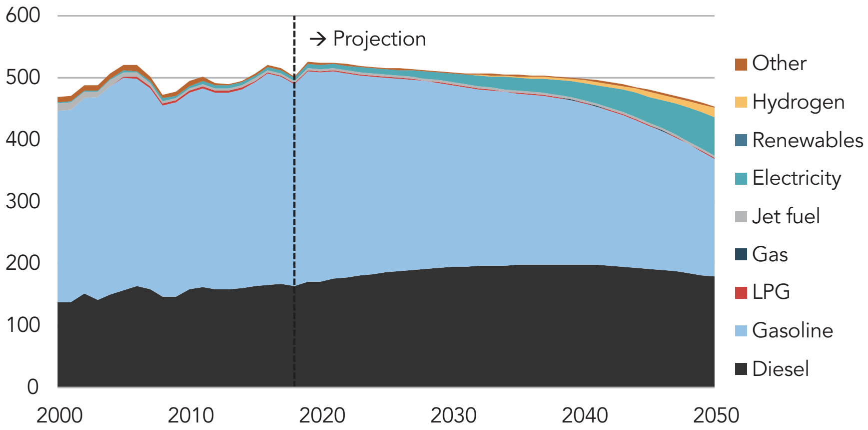
Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industry is the largest energy-consuming sector in Chinese Taipei, accounting for 34% of demand in 2018. Industry energy demand in REF gradually decreases after the 2020s, whereas in CN, demand declines from the beginning of the projection (2018).
- Despite COVID-19, the GDP growth of Chinese Taipei in 2020 was robust, which did not significantly affect the industry energy demand trend. The manufacturing industry, such as the semiconductor sector, continued to thrive even after the pandemic.
- In REF, electricity and gas demand increases through the 2020s, driven by manufacturing growth. Meanwhile, in CN, material and energy efficiency measures support a reduction in energy demand.
- Industry's dominance in energy consumption is primarily attributable to the chemicals and "others" subsectors. The efficiency of manufacturing processes and the strengthening of energy-saving policies will accelerate the decline of energy demand in CN.
- Demand for hydrogen is negligible in REF.
- Hydrogen plays a more important role in CN. The use of hydrogen in industrial applications increases starting in the mid-2020s. By 2050, around 3.2% of industry demand is hydrogen.
- In both scenarios, electricity plays a significant role. Additionally, manufacturing based on information technology, an important pillar of industrial structure in Chinese Taipei, will rely on electricity. However, electricity demand does not grow in CN due to the limitations of electrifying some industrial processes.

Note: The impact of global supply chain issues after COVID-19 are not considered.

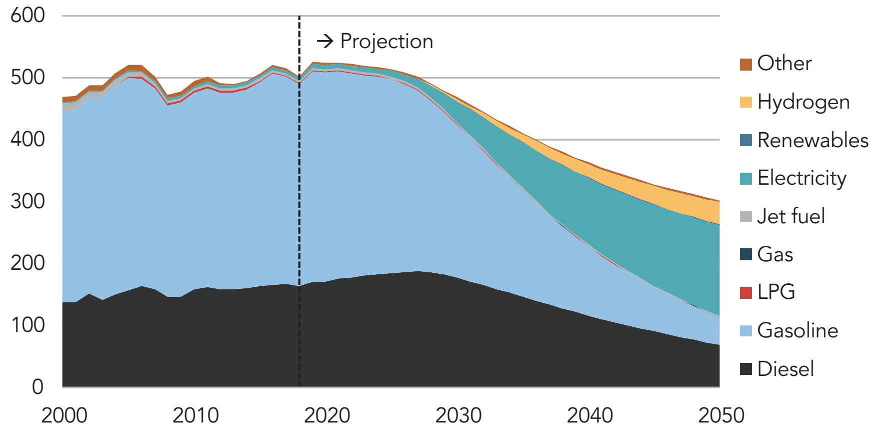
Transport energy demand

Figure 18-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 18-12. Transport energy demand in CN, 2000-2050 (PJ)

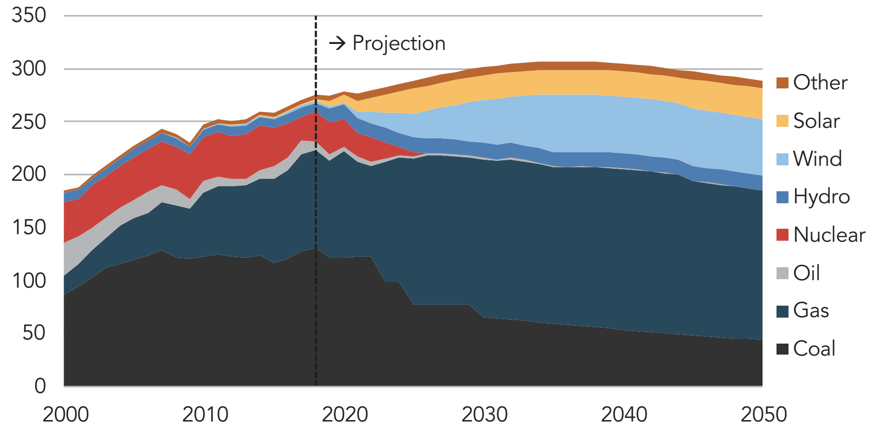


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport energy demand has remained relatively stable between 2000 and 2018, with gasoline and diesel composing nearly all fuel demand.
- Transport energy demand in REF gradually decreases as the vehicle stock turns over, introducing more efficient vehicles on the road. Despite efficiency improvements, gasoline and diesel dominate the fuel mix in REF.
- However, in CN, improved utilisation due to advancements in engine technology and government support for public transportation gains speed. It leads to a substantial reduction in transport energy demand starting before 2030.
- Electrification of mobility accelerates in CN, leading to decreased gasoline and diesel consumption. By 2035, EVs will account for 90% of new vehicle sales, reaching 100% by 2050.
- Due to the characteristics of Chinese Taipei as a small archipelago, roads make up most of the transportation demand by mode. The need for energy in the road sector is expected to decrease after about 2040 due to a decrease in the number of vehicles with internal combustion engines, the improved fuel efficiency of internal combustion engines, and the expansion of EVs.
- CN assumes that the energy demand for road transport is rapidly reduced by the retirement of heavy-duty diesel vehicles, the expansion of public transport capacity, fuel economy improvements, and the electrification of passenger cars.
- In both scenarios, strong government support for phasing out internal combustion engines (including two- and three-wheelers) leads to an increase in the share of electricity and hydrogen.

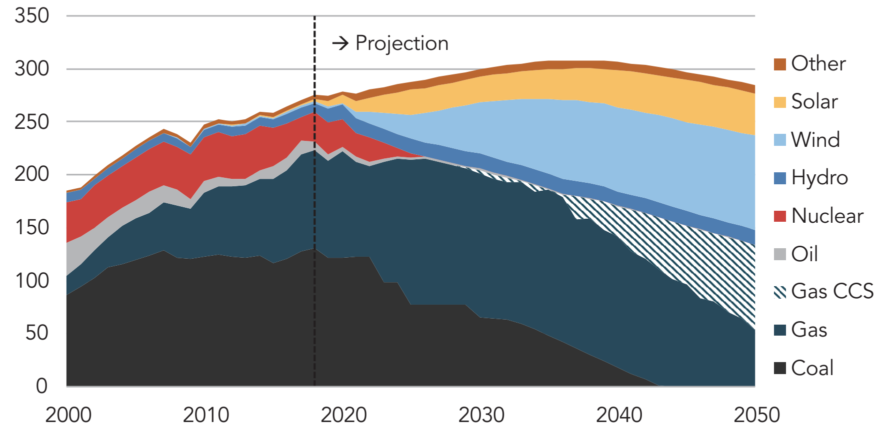
Electricity generation

Figure 18-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 18-14. Electricity generation in CN, 2000-2050 (TWh)

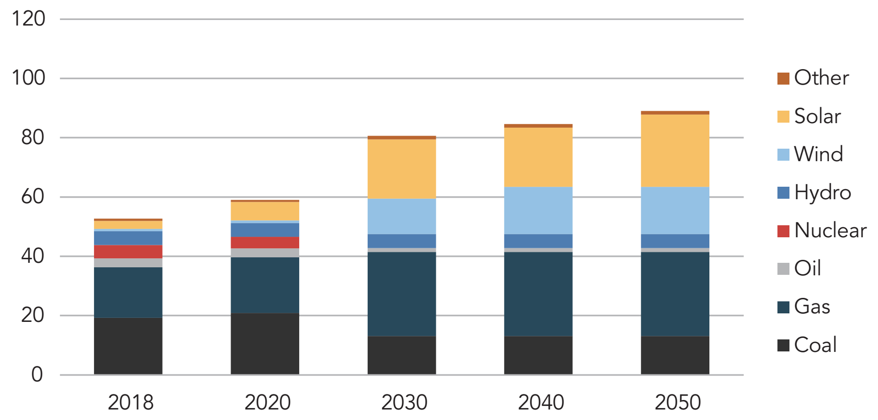


Sources: EGEDA, APERC analysis.

- As a result of electrification trends, total electricity generation steadily increases until the 2030s in REF and CN. After the 2040s, electricity generation declines slightly more in CN than in REF.
- In REF, generation by coal power plants is gradually reduced in proportion. On the other hand, it is phased out rapidly for carbon neutrality by 2050 in CN.
- Meanwhile, gas power generation remains a stable resource in both scenarios. Renewables rapidly replace nuclear power and then reach a balance in proportion with gas power consumption.
- Specifically, concerns about the risk of nuclear disaster have made people more cautious about using nuclear power in both scenarios. The assumption here is that nuclear power operations will cease by 2025. In December 2021, there was a referendum regarding the commercial operation of the fourth nuclear power plant, and then the issue of restarting was rejected.
- The government is pursuing an energy transition strategy to achieve 20% renewable energy generation by 2025. In particular, wind and solar are the primary sources of renewable energy.
- CN assumes that CCS technology will be gradually applied to gas power plants in the future. In this scenario, CCS with gas exceeds unabated gas-fired generation by 2040.
- The expansion of EVs will consume more generated electricity. In REF, about 17 TWh of electricity will be used in 2050, about 6% of total electricity generation. In CN, about 41 TWh of electricity will be consumed in 2050, about 14% of all generated electricity.

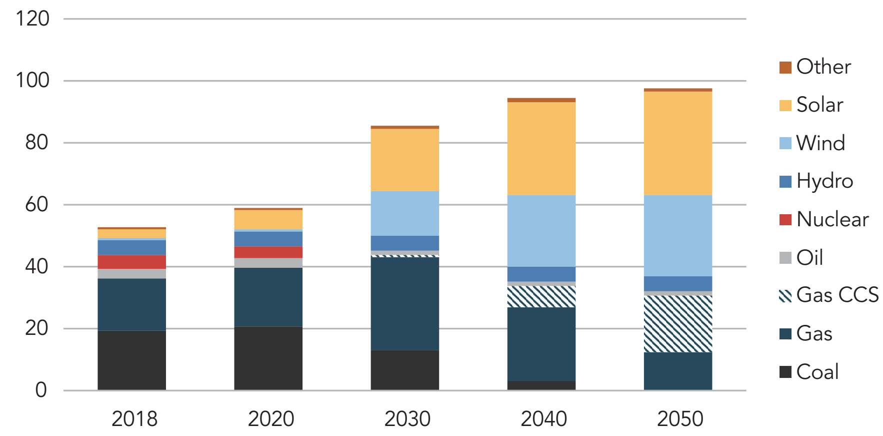
Generation capacity

Figure 18-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 18-16. Generation capacity in CN, 2018-2050 (GW)

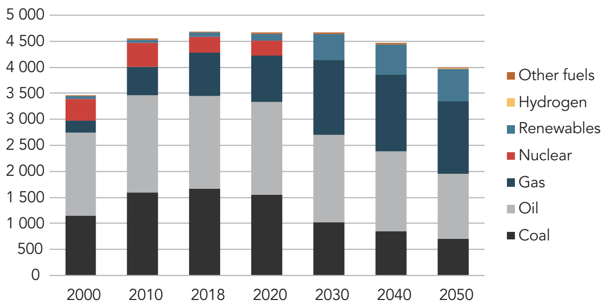


Sources: EGEDA, APERC analysis.

- The power sector in Chinese Taipei has significantly relied on imported fossil fuels, such as coal. However, in CN, coal power will be phased out by 2050 to support carbon neutrality.
- As Chinese Taipei currently adheres to the non-nuclear policy, by 2025, all nuclear power plants will be closed, and there won't be any nuclear generation capacity.
- In both scenarios, the capacity of renewables in the generation mix significantly increases by 2050, displacing the shutdown nuclear power plants.
- In particular, the government in Chinese Taipei plans to expand offshore wind power to a total of 15 GW of capacity from 2026 to 2035. From 2026 to 2031, it will release the development capacity up to 9.0 GW as the first stage. This increase in renewables capacity will bring greater generation capacity in CN than in REF towards 2050.
- Gas power, abated and unabated, will become an important power source for Chinese Taipei in the future to ensure a stable power supply while considering the reduction of greenhouse gas emissions like CO_2.

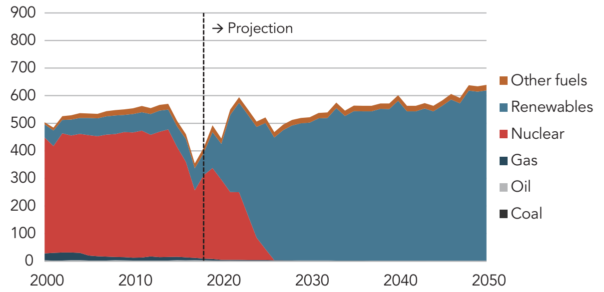
Energy supply in the Reference scenario

Figure 18-17. Total energy supply in REF, 2000-2050 (PJ)



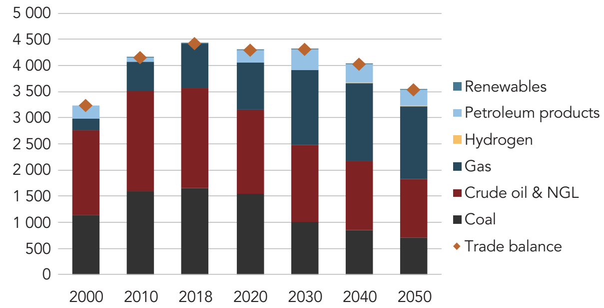
Sources: EGEDA, APERC analysis.

Figure 18-18. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-19. Net energy trade in REF, 2000-2050 (PJ)

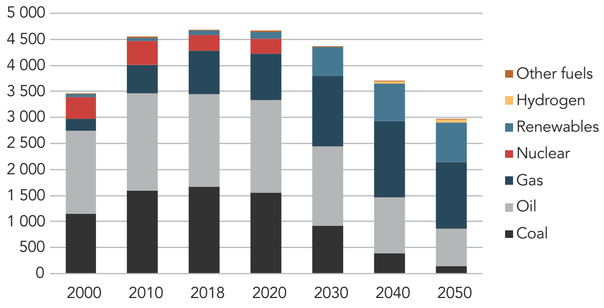


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Traditionally, fossil fuels account for a large share of the energy supply in Chinese Taipei. As of 2018, oil accounted for 39% of the energy supply, coal 34%, gas 18%, and nuclear 6%. The share of renewable energy was only 2.3% in 2018.
- Supply requirements fall a sixth from 2018 to 2050 due to coal, oil, and nuclear declines. Oil use reductions in industry, non-energy, and the transport sector are key drivers of the decrease.
- The retirement of nuclear reactors and coal-fired generators shifts supply requirements to natural gas, which grows by two-thirds. Fossil fuels will still make up 84% of the supply by 2050. Renewables share rises to 15% on the back of offshore wind and solar.
- The role of gas in supply will increase, surpassing a third of the supply mix by 2050. Chinese Taipei imports most of its gas in the form of LNG. Thus, it is important to build sufficient LNG terminal capacity to support its planned nuclear phase-out.
- Regarding the expansion of LNG terminal, there was a referendum in December 2021 about relocating the Guantang LNG terminal. As a result, the current policy of building a terminal in Datan Borough was supported. If the terminal is built on schedule, it will commence operations in 2024.
- Chinese Taipei has a few domestic energy reserves and imports most of its energy requirements. Production from nuclear and renewables does provide some supply; however, nuclear power production will drop to zero in 2025 following plans to retire the existing nuclear fleet.
- Still, falling supply requirements reduce net imports by a quarter in REF. Reductions in coal use in the power sector and oil use by refineries are instrumental to this drop.
- Energy security will be a concern following the shutdown of the nuclear fleet as a stable supply of energy, particularly LNG, is available to support the trends illustrated here.

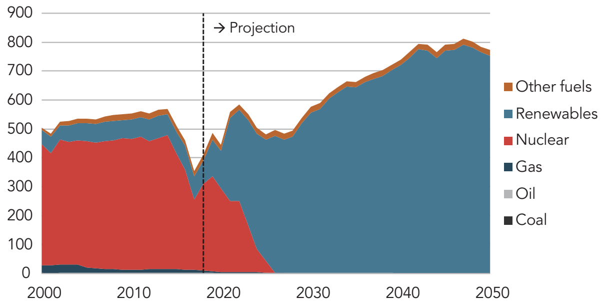
Energy supply in the Carbon Neutrality scenario

Figure 18-20. Total energy supply in CN, 2000-2050 (PJ)



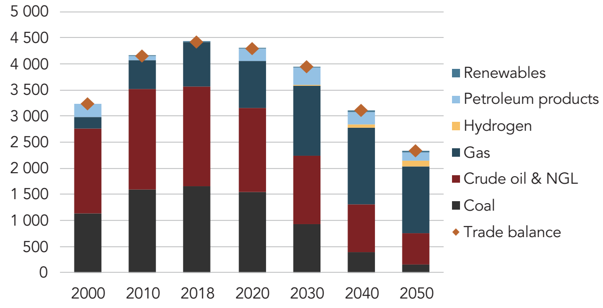
Sources: EGEDA, APERC analysis.

Figure 18-21. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-22. Net energy trade in CN, 2000-2050 (PJ)

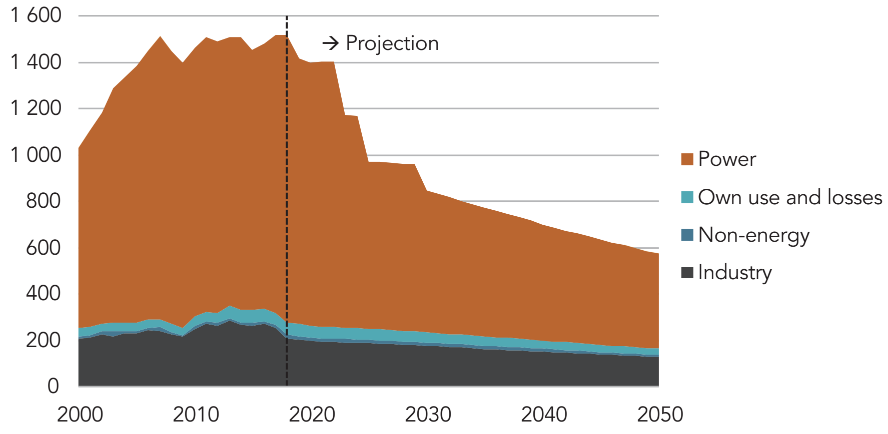


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, a steeper decline in energy supply lies compared to REF. Although the share of coal supply decreases as the year approaches 2050 in both scenarios, a significant share of fossil fuels such as oil and gas remains.
- The share of gas supply increases more in CN compared to REF. Gas will remain an important fuel.
- As in REF, nuclear and renewables have the highest shares of energy production in CN. Meanwhile, the focus on renewables will accelerate in CN, and thus domestic production of renewables will increase more in CN by 2050.
- A move toward carbon neutrality could reduce imports of coal and oil relative to REF, particularly in Chinese Taipei, where there is limited domestic production of traditional resources. This is due to the relative increase in domestic production of renewable energy. In addition, the import of hydrogen as an energy source for carbon neutrality gradually increases.

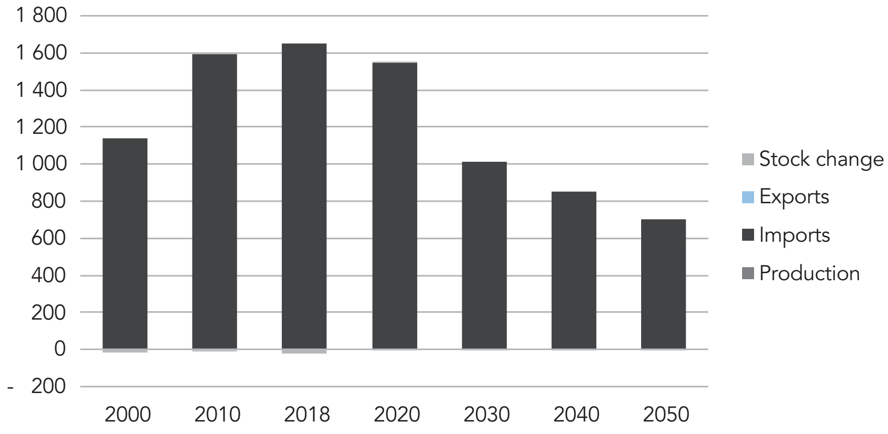
Coal in the Reference scenario

Figure 18-23. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-24. Coal production, imports, and exports in REF, 2000-2050 (PJ)

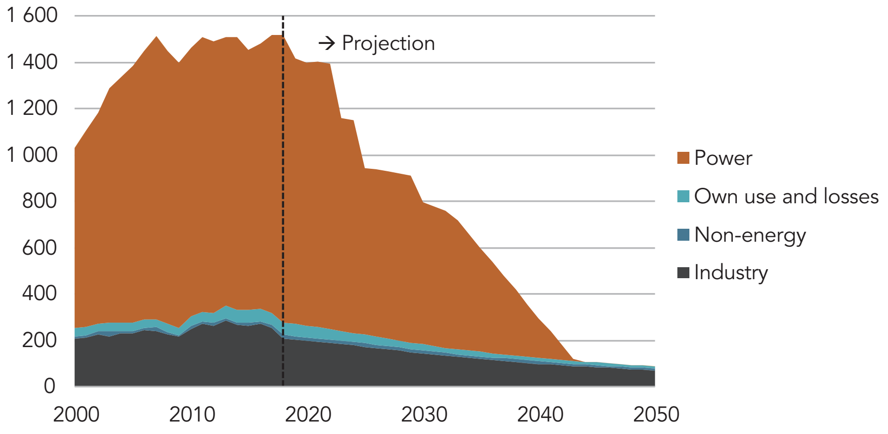


Sources: EGEDA, APERC analysis.

- While coal continues to supply Chinese Taipei's economy with energy, consumption falls almost two-thirds due to fuel-switching in industry and coal capacity reductions in the power sector.
- Reducing the share of coal power generation to less than 30% by 2025 is one of Chinese Taipei's energy transition policies. As Chinese Taipei continues to embrace the energy transition, the role of coal in supply could continue to narrow further than shown in REF.
- However, the movement is not to completely exclude the advantages of coal in REF. Chinese Taipei still recognises the benefits of coal, such as stability of supply and ease of storage. According to the National Electricity Supply and Demand Report (2018), coal-fired power generation is expected to maintain a role in diversifying energy supply sources in the power sector.
- Because it does not produce coal domestically, Chinese Taipei's coal supply depends entirely on imports. Coal imports thus track closely with consumption and are more than halved by 2050. The consumption will be mainly reduced due to the decrease in coal-fired generation.
- This trend contrasts with natural gas, which is expected to increase its imports because natural gas is recognised as a relatively low-carbon resource in Chinese Taipei.

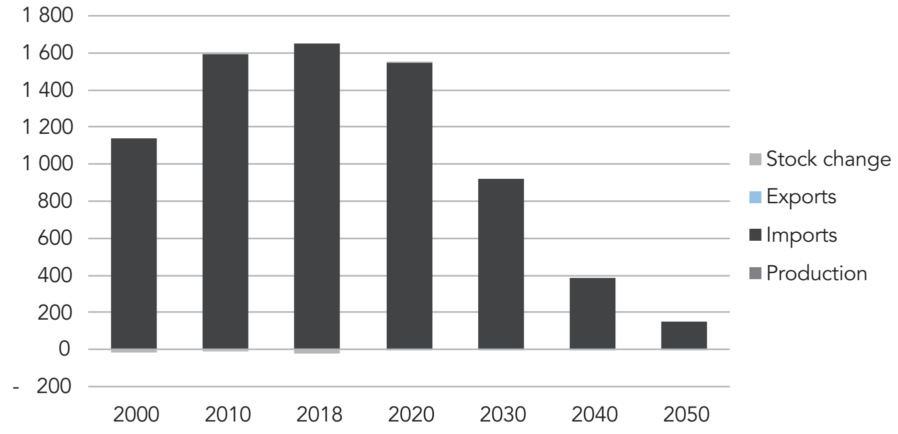
Coal in the Carbon Neutrality scenario

Figure 18-25. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-26. Coal production, imports, and exports in CN, 2000-2050 (PJ)

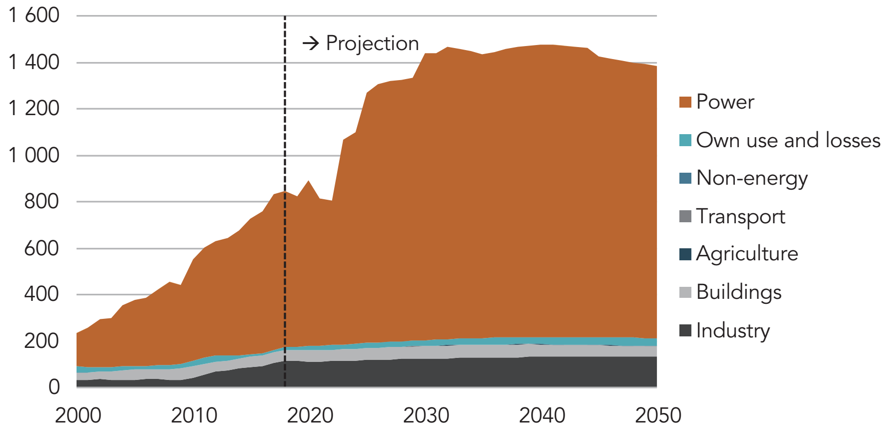


Sources: EGEDA, APERC analysis.

- As in REF, Chinese Taipei aims to reduce the share of coal-fired power generation to be less than 30% by 2025. After 2025, coal power plants will also be phased out, and coal power generation will decline to zero by 2050. As manufacturing processes in the industry also shift from fossil fuels to low-carbon energy, coal use declines.
- As coal use rapidly declines in power, coal imports fall sharply. This trend can reduce their dependence on foreign economies for Chinese Taipei, which imports most of its energy sources from abroad.

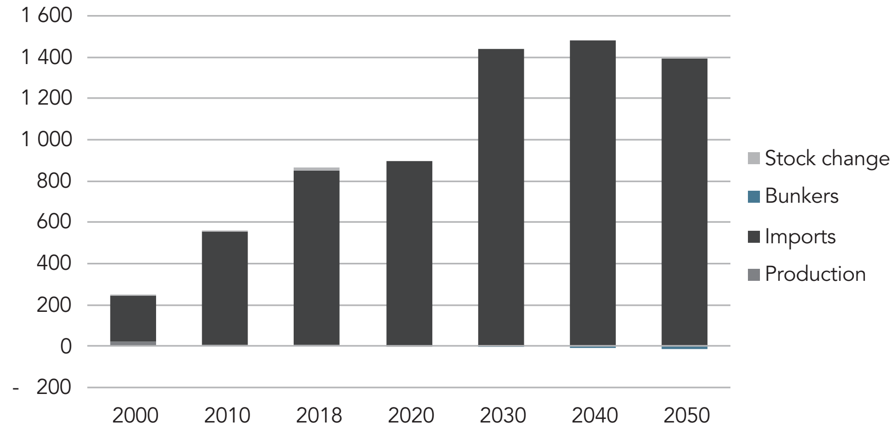
Natural gas in the Reference scenario

Figure 18-27. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-28. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

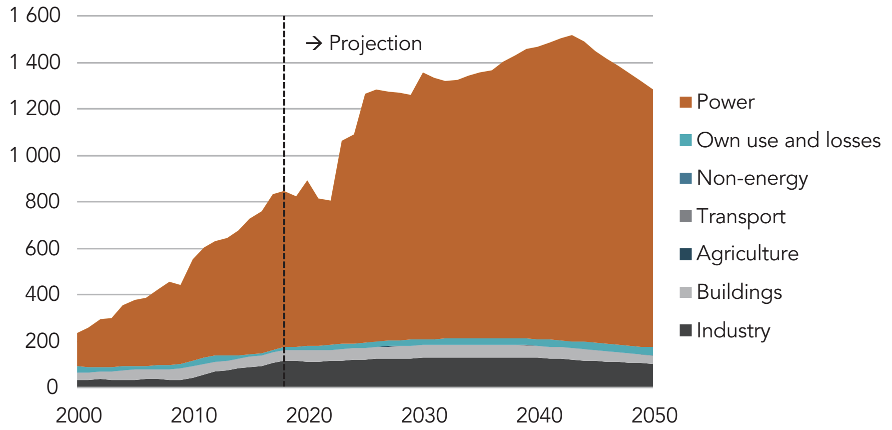


Sources: EGEDA, APERC analysis.

- A doubling of gas used by the power sector over the next decade drives overall consumption by three-quarters in REF. The rapid rise in gas consumption is supported by government plans to retire the nuclear fleet and reduce the role of coal in the electricity mix.
- During the transition to renewable energy in power, an increase in natural gas can support a stable energy supply. The government aims to increase gas power generation share to 50% by 2025. The sharp increase in volume is maintained until 2050.
- Import requirements increase in line with domestic consumption requirements, about three-quarters. Since most of them will be imported in the form of LNG and still be vulnerable to unexpected external volatility, the rapid increase in natural gas supply requirements could create energy security tensions for Chinese Taipei, particularly over the next decade. The period coincides with the gradual retirement of nuclear and coal power plants and the construction of new LNG terminals.
- Specifically, the government has conducted the construction plan of LNG terminals to increase its LNG receiving and storage capacity. The *Outlook* follows the government plans for LNG terminal newbuilds or expansions at the time of analysis.
- New LNG capacity includes CPC's Guantang terminal (new), Taichung terminal (expansion), Taipower's Xiehe terminal (new), and Taichung port terminal (new), which are estimated to supply 26 million tons per annum (Mtpa) of LNG import capacity in 2025 and 38 Mtpa by 2030.

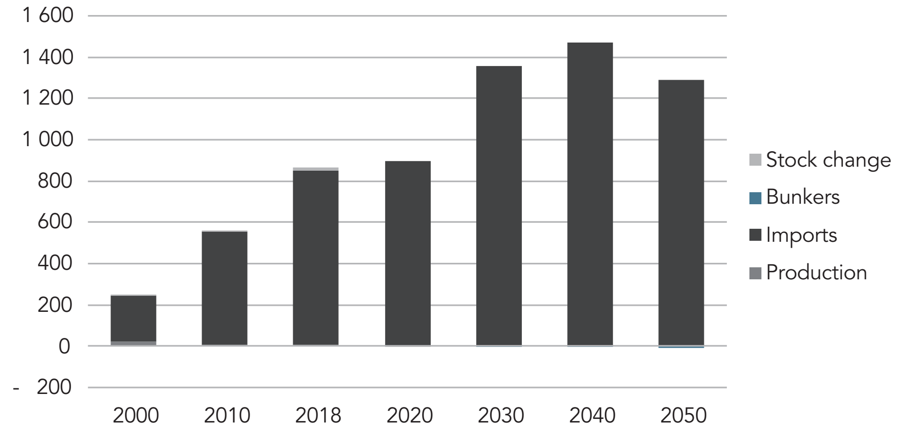
Natural gas in the Carbon Neutrality scenario

Figure 18-29. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-30. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

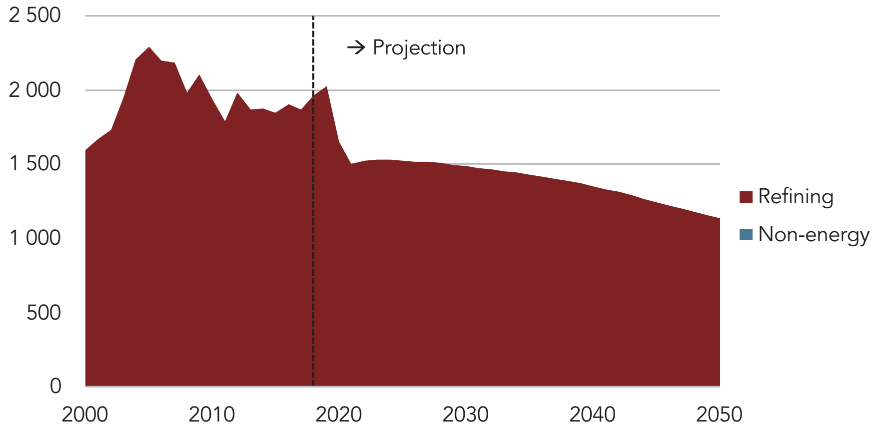


Sources: EGEDA, APERC analysis.

- As in REF, the share of natural gas will increase rapidly through 2043 in CN. However, the advance of renewable energy due to technological advancement starts to replace the gas supply in the 2040s.
- Furthermore, gas is still dependent on imports in CN though its share will gradually decrease in the 2040s. The trend of declining gas imports since the 2040s implies that domestic supply from renewable energy generation will increase more than that of REF. The decline in natural gas in the 2040s can be considered when Chinese Taipei determines its plan for LNG terminal construction.

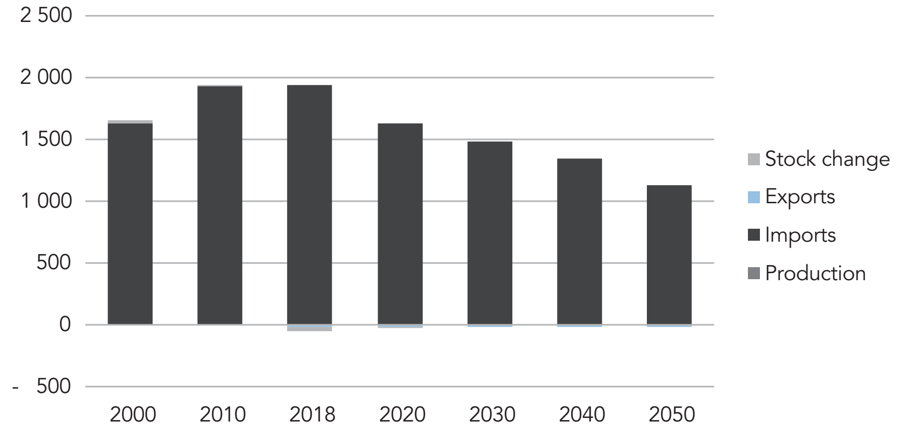
Crude oil and NGLs in the Reference scenario

Figure 18-31. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-32. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

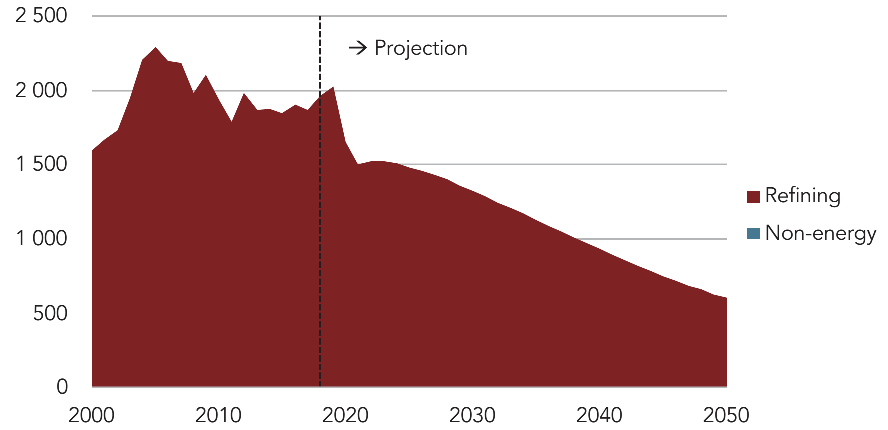


Sources: EGEDA, APERC analysis.

- Crude oil and NGL are consumed entirely by refining processes. From 2014 to 2018, the supply of petroleum products increased as consumption for industry and transportation surged in the short term due to the expansion of petrochemical facilities and the sharp drop in international oil prices. However, refinery runs of crude oil and NGLs fall a third over the outlook period. Part of the reason is due to lower domestic requirements for oil products.
- About refining, the chemical and petrochemical subsector for refining accounts for a major portion of energy consumption in the industry. Chinese Taipei's chemical and petrochemical subsector development originated early in the 20th century. The largest petrochemical industry is currently located in the Mailiao Industrial Zone, accounting for more than 70% of the production value. Petrochemical raw materials with most of their feedstock from their refineries have been produced. However, with trends of the energy transition, Chinese Taipei is not expanding any chemical and petrochemical plants, nor its refining capacity. Refinery capacity falls a third in REF.
- Imports also fall over a third in line with declining domestic refining requirements.

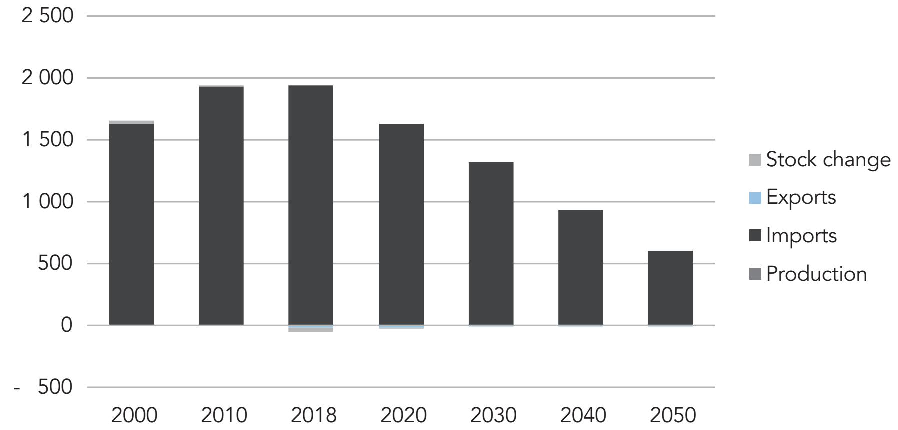
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 18-33. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-34. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

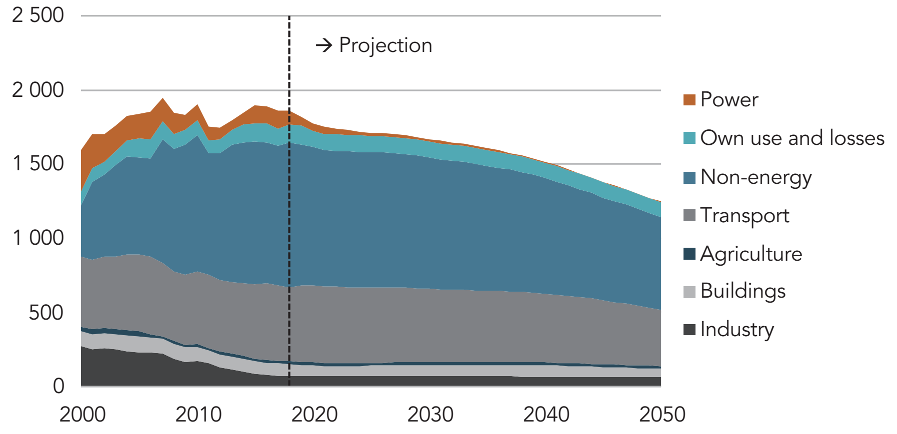


Sources: EGEDA, APERC analysis.

- The trend in CN is similar to REF in that most crude oil and NGLs depend on imports, but the slope and speed of the decline are steeper than REF. This means that energy supply trends will gradually shift from crude oil and NGLs to other energy sources in the industry, buildings, and transport sectors. For example, less demand for oil products will accelerate in the transport sector as EVs replace conventional vehicles.

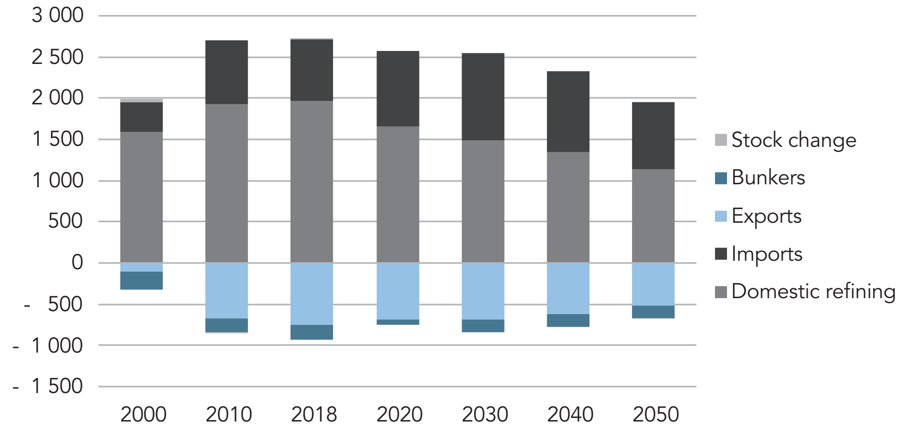
Refined products in the Reference scenario

Figure 18-35. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-36. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

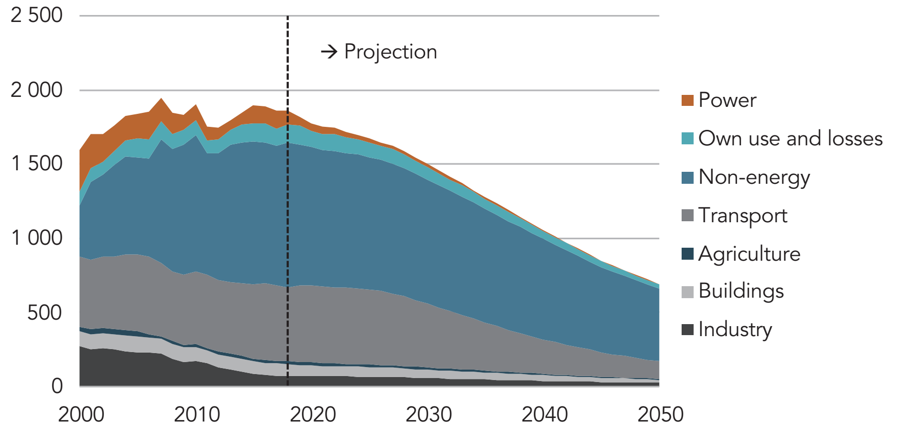


Sources: EGEDA, APERC analysis.

- Refined products in REF fall a third by 2050. Refined product consumption in industry and buildings declines by 20% during the outlook period. That of non-energy is reduced by one-third during the same period. Transportation demand for diesel and gasoline is sustained. However, there will be a slight decline by improved utilisation of conventional vehicles and a decrease in their number.
- Before 2000, Chinese Taipei imported a significant quantity of refined petroleum products. However, the refining capacity of Chinese Taipei was increased in 2000 with the opening of a refinery at Mailiao owned by Formosa Petrochemical Company (FPC). Meanwhile, Chinese Taipei is an exporter and importer of refined petroleum. In 2018, Chinese Taipei is estimated to import refined petroleum primarily from Korea, Iran, the United Arab Emirates, India, and Malaysia (the estimation was conducted by CEPII and cited by OEC).

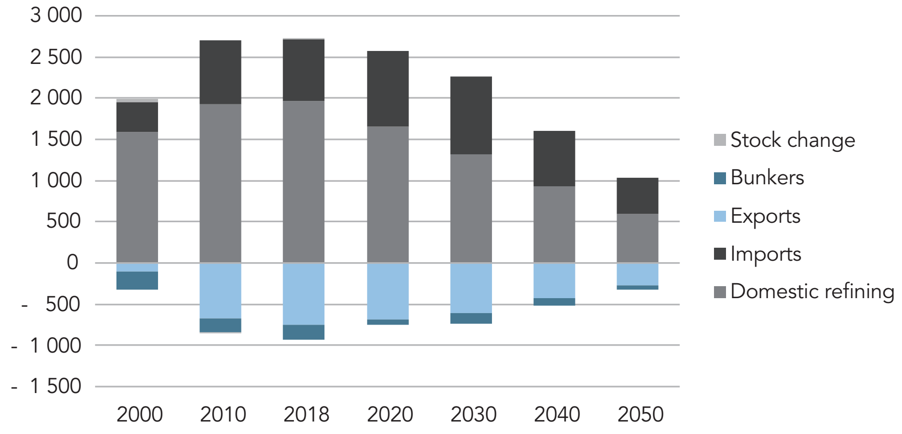
Refined products in the Carbon Neutrality scenario

Figure 18-37. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 18-38. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

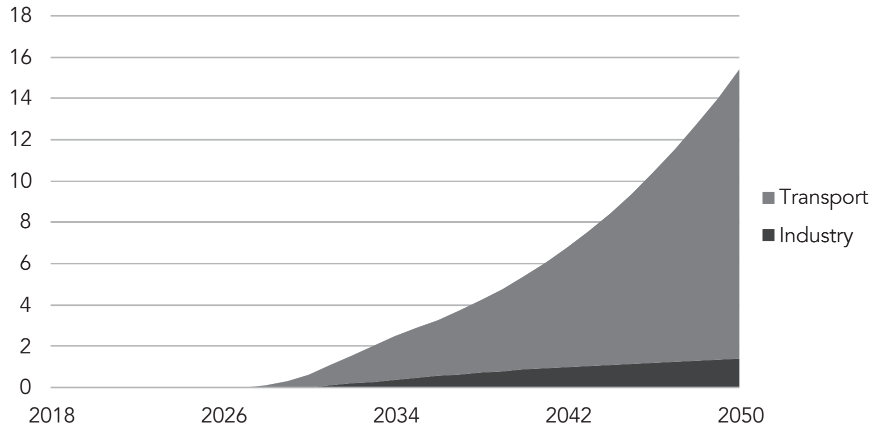


Sources: EGEDA, APERC analysis.

- Regarding non-energy, a gradual decline in the refining and the steeper expansion of renewables will accelerate a downward trend.
- The proportion of electric vehicles becomes greater than diesel and gasoline vehicles, which significantly reduces the consumption of refined products.
- During the outlook period, the share of exports, imports, and domestic refining of Chinese Taipei's petroleum products will be further reduced compared to REF. This implies that a global carbon neutrality pathway will also affect the declining trend of refined products in Chinese Taipei.

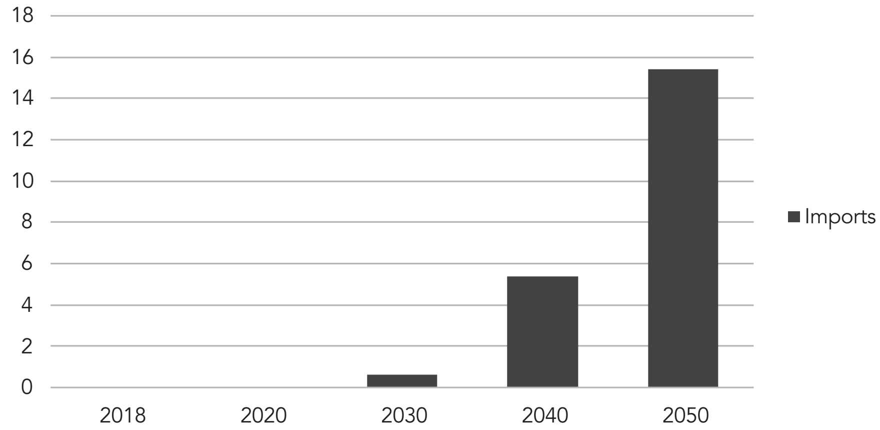
Hydrogen in the Reference scenario

Figure 18-39. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 18-40. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

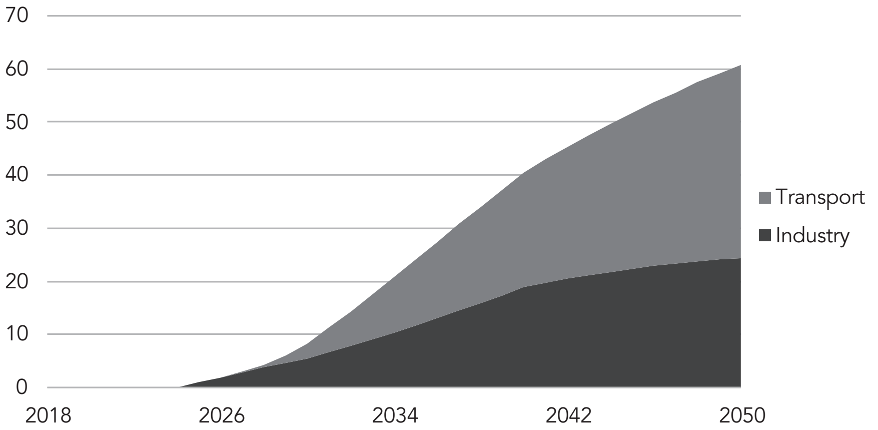


Note: Hydrogen as an industrial feedstock is not considered.

- Chinese Taipei has almost no domestic market for hydrogen until the start of the projection. However, consumption gradually increases with imported hydrogen in the 2020s, though the volume will be less than 20 PJ in 2050.
- Transportation accounts for most of the share of hydrogen though the domestic market for hydrogen is relatively small compared to other energy sources. However, Chinese Taipei might build infrastructure for hydrogen energy and fuel cells because it has been involved in the hydrogen fuel cell industry for decades.
- Chinese Taipei is building a partnership for hydrogen energy in terms of technology and international cooperation. The government has established the Hydrogen Energy Promotion Alliance that encompasses the public and private sectors to promote the technology of hydrogen energy technology. In addition, Chinese Taipei has partnerships with traditional energy partners like Australia to explore opportunities for hydrogen energy.

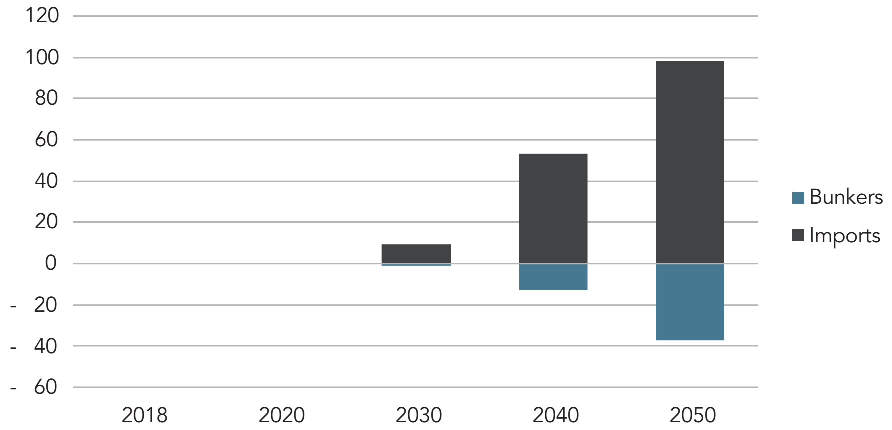
Hydrogen in the Carbon Neutrality scenario

Figure 18-41. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 18-42. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

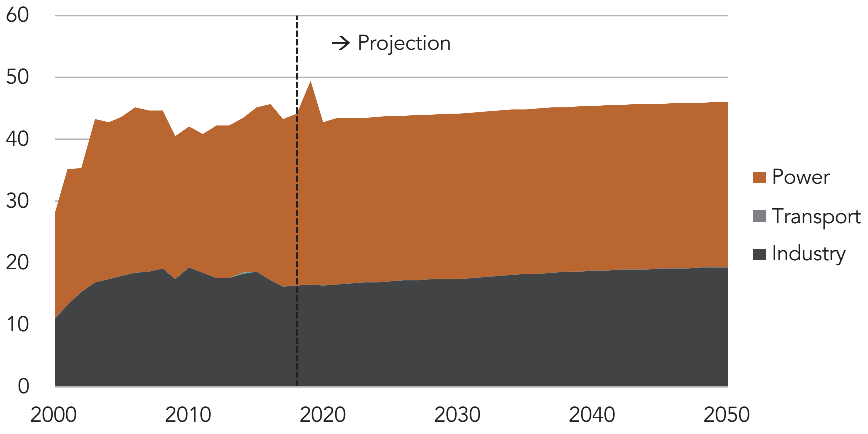


Note: Hydrogen as an industrial feedstock is not considered.

- As the government has ambitious goals to promote renewable energy, hydrogen can become one of the options for carbon neutrality. Under the Renewable Energy Development Act of Chinese Taipei, hydrogen energy and fuel cells are mentioned as one of the renewables. Government support for reducing fossil fuels will increase the share of hydrogen.
- In CN, despite the remarkable increase in hydrogen in the industry sector, the transport sector has a relatively larger share from 2034. Compared to REF, it is expected to more than double by 2050.
- Industry is the largest energy-consuming sector in Chinese Taipei. Controlling CO_2 emissions from manufacturing processes remains a challenge. In particular, chemical and petrochemical companies could utilise hydrogen as one of the fuels in the hydrogenation process.
- A long-term goal for hydrogen supply and demand by the government is still under reviewing process.

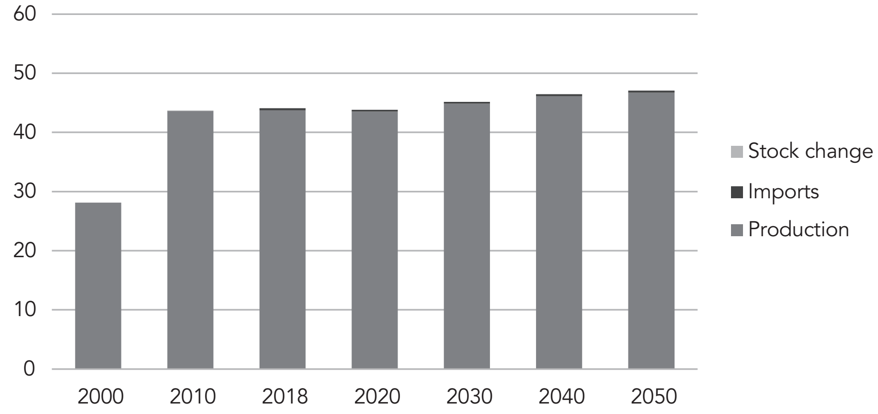
Bioenergy in the Reference scenario

Figure 18-43. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 18-44. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

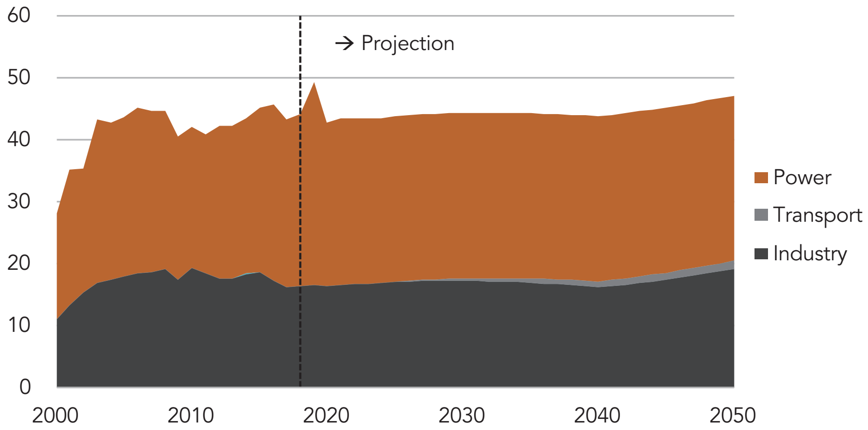


Sources: EGEDA, APERC analysis.

- Bioenergy, in the form of solid biomass, is mainly used in the power and industry sectors in Chinese Taipei. Although its volume is larger than that of hydrogen, its share in the total renewables is small.

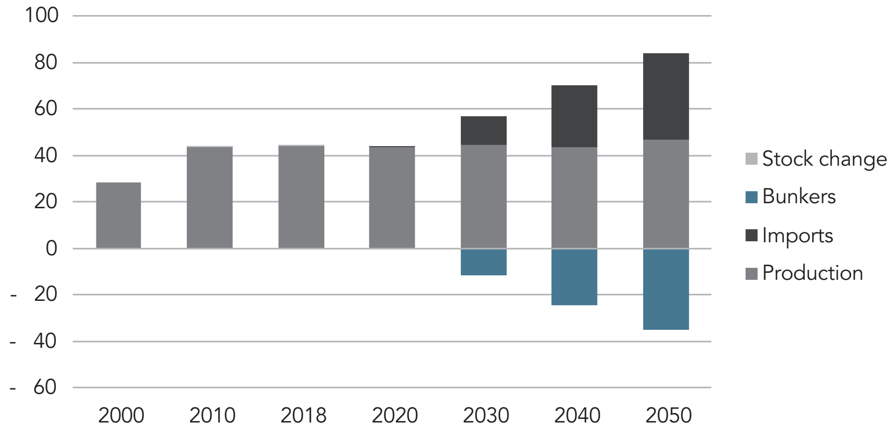
Bioenergy in the Carbon Neutrality scenario

Figure 18-45. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 18-46. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

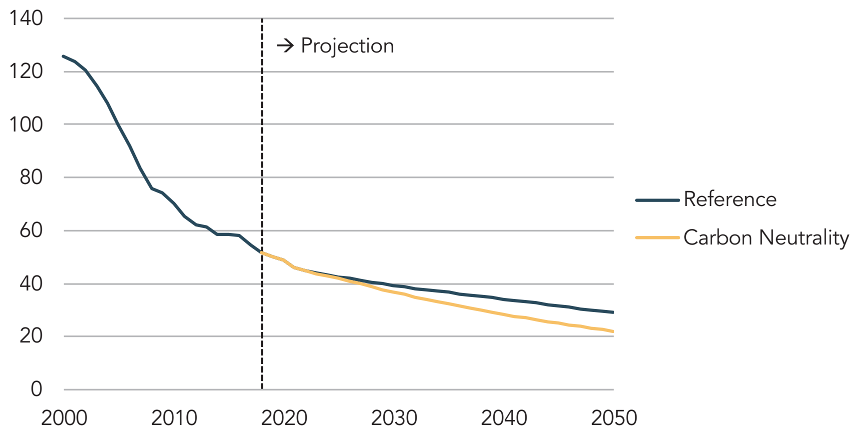


Sources: EGEDA, APERC analysis.

- Compared to REF, there is no drastic change in the overall trend except a little more volume in the 2040s.
- Regarding energy production and trade, bioenergy is procured by imports and domestic production.

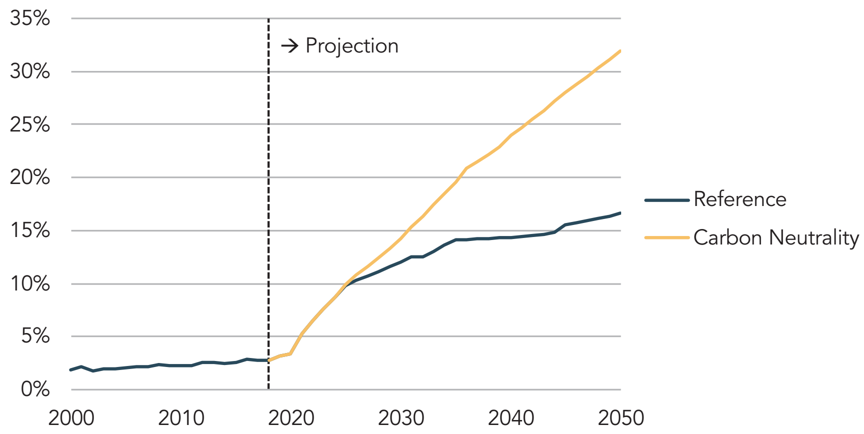
Energy intensity and modern renewables share

Figure 18-47. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 18-48. Modern renewables share in REF and CN, 2000-2050



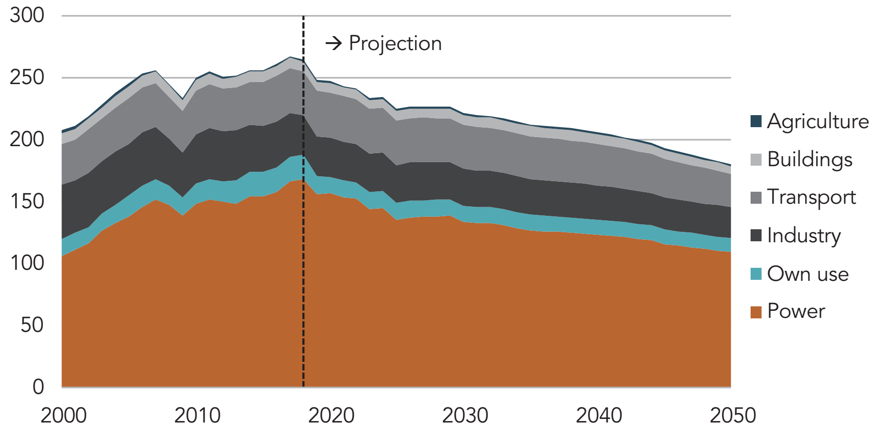
Sources: EGEDA, APERC analysis. Notes: Modern renewables includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- Key assumptions of energy intensity include a high share of advanced vehicles like EVs and improvements to energy efficiency in end-use sectors.
- In REF, the energy intensity in 2050 is 29% of what it was in 2005, while it is less than 22% in CN. From 2028, the energy intensity of CN shows a trend to be lower than that of REF. This is because the rate of decline in energy consumption compared to the previous year was slightly greater in CN than in REF during the outlook period.
- In both scenarios, the share of modern renewables reaches 20% of electricity generation by 2025 in the government plan. After 2025, the graph slope in CN is much steeper than that of REF, with the advance of modern renewables such as large-scale wind power generation.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

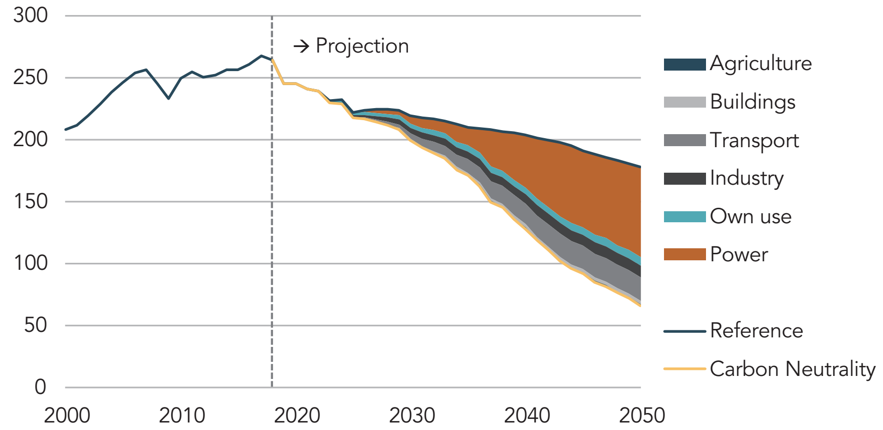
Gross CO_2 emissions

Figure 18-49. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 18-50. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

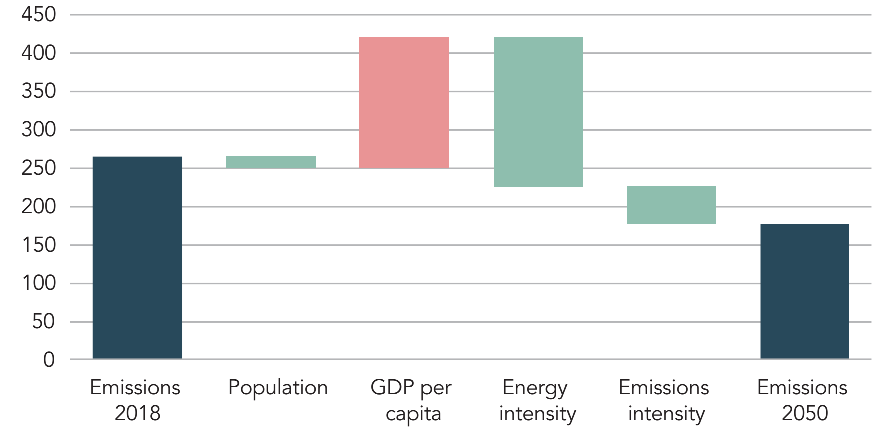


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Expanding renewables and promoting energy efficiency help reduce CO_2 combustion emissions in all sectors in REF (-32%).
- Coal accounts for the largest share of CO_2 combustion emissions in REF. However, emissions are less than 50% in 2050 compared to the 2005 level in REF.
- In CN, emissions decline 74% (2018-2050) due to large contributions by the power and transport sectors.
- About power, a key assumption in the change is that renewables will continue to expand significantly beyond 2025, with renewables replacing gas to some extent.
- Gas is important as a resource to fill the gap between variability introduced by renewable energy growth and the absence of nuclear power. In REF, the increase in gas power generation makes it difficult for CO_2 emissions to be below 50% in 2050 compared to the 2005 level.
- Chinese Taipei is currently reviewing a carbon-neutral roadmap.

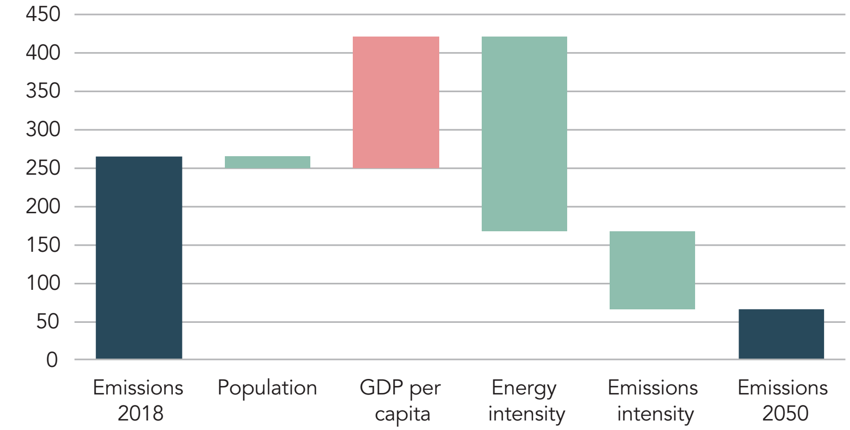
Components of CO_2 emissions

Figure 18-51. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 18-52. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Chinese Taipei emitted 253.4 million tonnes of CO_2 in 2018, which amounted to around 1.3% of total APEC emissions.
- In both scenarios, the population trend for Chinese Taipei reduces CO_2 emissions (-15 million tonnes) while GDP per capita increases emissions (+171 million tonnes).
- Meanwhile, energy intensity completely offsets the emissions increases in both scenarios. Emissions intensity further reduces emissions by 48 million tonnes. By 2050, gross emissions will be 178 million tonnes in REF.
- In CN, additional energy efficiency improvements in end-use sectors show an increase in CO_2 emissions reductions (-252 million tonnes). The expansion of renewables and decrease in gas-fired power generation further improve emissions intensity (-102 million tonnes). By 2050, CN emissions will be 66 million tonnes.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

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19. Thailand

Highlights

Demand

- Thailand's end-use energy consumption increases over the projection from 2018 to 2050 along with gross domestic product (GDP) growth while population decreases in both scenarios. The total final energy demand increases by 64% and 15% respectively during the period in REF and CN.
- Efficiency improvements, technology advancement, and energy conservation lead to slower growth of energy demand in all sectors in CN.
- Share of fossil fuels in final energy demand decreases to less than 50% in CN, in line with Thailand's National Energy Plan to increase renewables in the energy mix.
- COVID-19 disrupted demand growth in 2019-2020 and reduced energy demand by 5% in 2020 before starting to recover in 2022.
- Industry sector continues to be the largest energy consumer, followed by transport and building. Energy consumption for industry continues to grow throughout the projection both in REF and CN. Fossil fuels, including coal, remain to be major sources of energy in both scenarios.
- Transport sector electrification increases in both scenarios, rising moderately in REF. In CN, the share of electricity in the fuel mix is more than double.
- The adoption of electric vehicles (EVs) contributes to reducing oil demand in both scenarios but is more pronounced in CN.
- Transport dominates more than 60% of refined products consumption in 2050 in REF and contributes about 50% share in CN.
- Building sector grows modestly in REF while remains almost unchanged in CN due to improvements in energy efficiency and building energy codes.

Supply

- Fossil fuels are continuously dominant in the energy mix in both scenarios for Thailand. The share of fossil fuels accounts for almost 80% of the total energy supply in REF, while decreasing to about three-quarters of it in CN.
- Thailand relies heavily on imports of crude oil due to limited crude oil reserves and productions, and is more reliant on LNG imports due to declining gas reserves.
- Oil production declines 67% in REF and more than 80% in CN, while natural gas production declines by almost 40% in both scenarios, prompting LNG imports to increase significantly and dominate energy supply.
- Significant growth in gas-fired power generation presses Thailand to invest in additional LNG regasification capacity up to 50-60 Mtpa in 2050.
- Thailand's modern renewables continue to grow to reach one-fifth of total energy mix in REF and over 30% in CN by 2050.

Power

- Electrification of end-uses increases electricity demand by 102% and 140% in REF and CN, respectively.
- Solar and wind generations increase more than eight times in REF. In CN, solar increases by 18 times and wind grows by 36 times.
- Power generation capacity increases by 40 GW in REF, driven mainly by additions in gas (21 GW) and solar (18 GW).
- Higher electricity demand leads capacity to more than triple from about 40 GW to almost 130 GW in CN (2018-2050).
- Capacity additions in CN are primarily met with renewables and gas-fired power plants with carbon capture and storage (CCS) facilities.
- By 2050, renewables dominate more than half of power capacity in CN.
- The share of renewables power capacity in CN starts to exceed the share of natural gas capacity in 2037, which is currently the mainstay of its power generation sector.

CO_2 emissions

- In REF, CO_2 emissions increase 45% (2018-2050) mainly from power, transport, and industry sectors. In CN, CO_2 emissions decrease 35% contributed from transport, own use, and power. By 2050, CN emissions are 56% lower than REF.
- In relation to Thailand's COP26 goals, CO_2 emissions in CN peak in 2030, inline with Thailand's peak greenhouse gas (GHG) target. The gross CO_2 emission in CN of 174 million tonnes in 2050 is also inline with Thailand's CO_2 emission target of under 200 million tonnes in 2050.
- Oil and gas combustion contribute about 80%-90% of the CO_2 emissions in both scenarios in 2050 while coal contributes 10%-20% of CO_2 emissions.

About Thailand

- Thailand is known as 'the window to South-East Asia'. The economy is surrounded by Myanmar, the Lao People's Democratic Republic (Lao PDR), Cambodia to the north and east, and Malaysia to the south. Thailand has an area of 513 120 square kilometers and had a population of 69 million in 2018. In 2018, its GDP reached USD 1 286.3 billion (2018 USD purchasing power parity [PPP]), a 4.2% increase from 2017.
- Thailand has limited domestic energy resources. At the end of 2018, Thailand had proven reserves of 293 million barrels of oil, 6 224 PJ of natural gas, and 1 063 million tones of coal. Based on the current rates of production, its domestic supply will soon become depleted – oil resources within two years and natural gas within five years. Most coal-fired power plants in Thailand use low-quality, domestically produced lignite. Thailand is highly dependent on energy imports, particularly oil, with approximately 92% of oil and 43% of gas supply coming from imports.
- Most of Thailand's proven coal reserves are lignite coal, which has a low calorific value. For this reason, Thailand relies on coal imports to meet the energy demands of both the power and industrial sectors. In 2018, the coal supply was 809 PJ, an increase of 49% from the previous year.
- The natural gas supply in 2018 was 1 888 PJ, an 8.9% decrease from 2017. Natural gas is not only used for power generation in Thailand but was also consumed in the transport sector as a replacement for conventional petroleum products such as diesel and gasoline in heavy trucks and taxis, but with the current decline of usage due to the policy to lower price subsidy. Thailand has increased its reliance on imported natural gas in the form of piped gas from Myanmar and LNG from Qatar and Malaysia.

Table 19-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	69.4	2.4%	9
GDP	1 286.3	1.8%	10
TPES	6 162.0	1.8%	9
Production	3 160.4	0.9%	9
Imports	3 734.6	3.0%	8
Exports	534.3	0.5%	13
Electricity generation	187.4	1.1%	12
Heat production	0.0	0.0%	9
CO_2 emissions	238.0	1.1%	11

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 19-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	11 189	80	0.1%	10
Natural gas	6 224	5	0.1%	13
Oil	1 546	2	0.01%	12
Uranium	N/A	N/A	N/A	N/A

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. See Appendix for conversion to other units.

Energy policy context and recent developments

- **Power Development Plan 2018 (PDP 2018 Revision 1):** The PDP 2018 has set a goal of achieving a power capacity of 77 200 MW, of which renewable energy projects are planned to account for 29 400 MW by 2037.
- The PDP 2018 has set the following goal for fuel mixes in 2037: natural gas = 53%, non-fossil fuels = 37% and coal = 12%.
- **National Energy Plan (NEP):** Thailand is on the verge of releasing a new energy plan, the NEP, to supersede the previous energy plans. The NEP is scheduled to be officially released in 2022 with the details of new development to guide Thailand to an era of carbon neutrality.
- **Energy Efficiency Plan 2018 (EEP 2018):** The EEP 2018 has set a goal sanctioned by the National Energy Policy Council (NEPC) to reduce the energy intensity by 30% by 2037 compared to 2010, equivalent to a decrease of final energy consumption by 2 500 PJ.
- At the COP26 meeting, Thailand pledged to achieve carbon neutrality in 2050 and net-zero emissions in 2065. Additionally, a more ambitious target of reducing its GHG emissions by up to 40% could be achieved if financial and technological support is provided, resulting in net-zero emissions in 2050.
- The Climate Change Master Plan (CCMP 2015–2050), developed by the Office of Natural Resources and Environmental Policy and Planning (ONEP), is designed to help Thailand achieve sustainable low-carbon growth and climate change resilience by 2050.
- **Alternative Energy Development Plan 2018 (AEDP 2018):** AEDP 2018 sets a goal to increase the proportion of renewable energy to 30% (electricity=6%, heat=21%, and biofuel=3%) of the total energy consumption by 2037.
- The AEDP 2018 sets a goal of a new power capacity from RE of 29 358 MW. Solar energy is planned to account for 15 574 MW or about 53% by 2037. As of 2022, 2 849 MW has already been installed and 12 725 MW is to be installed by 2037.
- The remaining renewable-based power production (by 2037) is expected to come from: Biomass 5 786 MW (20%); Wind 2 989 MW (10%); Hydro 2 918 MW (10%); Biogas 928 MW (3%); Municipal waste 900 MW (3%); Small hydro 188 MW (0.6%); and Industrial waste 75 MW (0.3%).
- The contribution of renewables for heat generation is expected to come from biomass, compressed bio-methane gas, biogas, waste, and solar.
- Under the AEDP 2018 plan, consumption targets for both gasohol and biodiesel in 2037 will reportedly be increased to 7.5 million liters/day and 8.0 million liters/day, respectively.
- **Energy 4.0:** Energy 4.0 is conceptualised to combine initiatives such as SMART grid, energy storage, EVs and charging stations, and technology for heat production from renewables to develop clean energy, protect the environment, and promote citizen wellbeing.
- **LNG Terminal Development Plan:** The 2nd PTT LNG import terminal (T-2) - 7.5 Mtpa capacity, completion in 2022; the 3rd PTT LNG import terminal (T-3) - 10.8 Mtpa capacity, completion in 2027. However, the 1st floating storage regasification unit (FSRU) project (F-1) - 5 Mtpa capacity, of the Electricity Generating Authority of Thailand (EGAT) has been put on hold as EGAT decided to join in a 50:50 investment with PTT in the T-2 LNG import terminal.
- **Eastern Economic Corridor (EEC):** Development of infrastructure in eastern Thailand to encourage investment, uplift innovation, and advanced technology in Thailand.
- **Map Ta Phut Phase III:** The project is an extension to the Map Ta Phut Industrial Port and will help reduce congestion at the port and develop logistical facilities to support the EEC.
- **Hydro-Floating Solar Hybrid:** The EGAT project will install 16 floating solar farms with a combined capacity of 2.7 gigawatts by 2037.
- **Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP):** The multilateral cross-border power trade aims to improve people's quality of life and the electrification and economic growth of the region.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- Energy policies in Thailand have been developed to tackle domestic energy issues while simultaneously reflecting the technological and environmental changes in a global scale.
- The two scenarios are intended to illustrate potential long-term pathways for energy demand, transformation, and supply in Thailand concerning uncertainty about the future.
- **The Reference scenario (REF)** is a pathway where existing trends in technology development and deployment, and policy frameworks continue in a similar manner.
- On the demand side, energy efficiency and fuel economy standards continue to improve gradually. Electrification of the transport sector begins as electric vehicle sales increase, but without strong policy incentives. The industry sector is assumed to gradually make improvements in energy efficiency and fuel switching. In the power sector, fuel switching from coal to gas and renewables continues while nascent technologies like CCS are not incorporated.
- **The Carbon Neutrality scenario (CN)** illustrates a potential pathway where energy efficiency, fuel switching, and technology advances substantially to reduce CO_2 emissions from fossil fuel combustion by 2065.
- Technology maturity and commercial availability are key assumptions in CN. Hydrogen supply chains are assumed to be available earlier than REF at small scale starting in 2025, then growing steadily to serve end-use applications in the industry and transport sectors. While technically possible, hydrogen consumption by the power sector is not considered.
- CN is intended to show the magnitude of CO_2 reductions possible in the context of the assumptions made about technology diffusion, costs, and global trends.
- CN can be used to quantify the magnitude of remaining CO_2 emissions that would require further action from policymakers, industry participants, and researchers.

Table 19-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Thailand

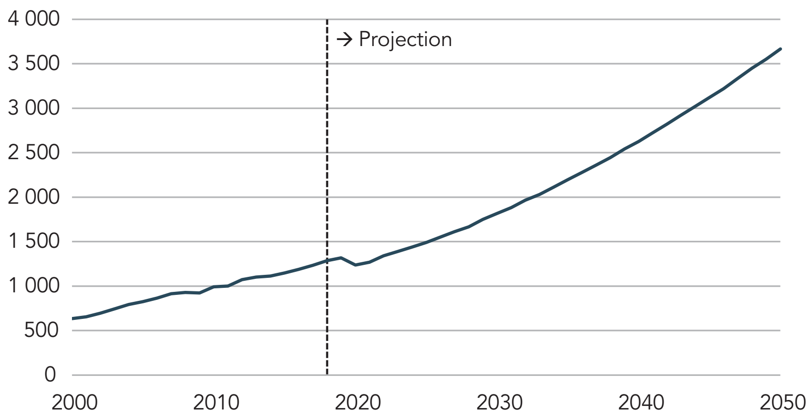
Table 19-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium) • GDP: World Bank (historical), OECD (projections), IMF (COVID-19 impacts)	• Same as the Reference scenario
Buildings	• Gradual improvements to efficiency due to Building Energy Code (BEC), High Energy Performance Standards , and Minimum Energy Performance Standard.	• More aggressive improvement in energy efficiency, mainly in space cooling.
Industry	• Energy efficiency and electrification improvements continue historic trends to 2050. • No major fuel switching in industry subsectors • Hydrogen starts its adoption in 2031 at small scale with slow penetration rate.	• Material efficiency improvements and electrification digitalisation for steel, cement, and chemicals subsectors. • Higher fuel switching rates from coal to biomass, electricity, natural gas. • Hydrogen adoption starts at small scale in 2025 and gradually increased as technology is more available and more competitive. • Energy efficiency more rapid than the Reference scenario.
Transportation	• Fleet remains mostly ICEs. • Improved fuel efficiency • EVs and charging stations grow slowly towards 2037. • Increase ethanol and biodiesel consumptions to 7.5 million liters/day and 8.0 million liters/day, respectively, by 2037. • FCEV starts penetration in small scale in 2026 and progresses slowly.	• Improved fuel efficiency and hybridization. • Higher EV penetration rate and number of charging stations by 2050. • More mass transportation to replace transportation by passenger cars. • Aviation sector gradually adopts biojet after 2025. • Higher FCEV penetration as the technology and infrastructure is more accepted.
Power and heat	• Electricity generation based on revised PDP 2018 • Gas-fired units are used to meet rapidly increasing electricity demand. • Moderate adoption of Solar and Biofuels projects (Biomass, MSW and Biogas) • Wind Power projects aligned with AEDP 2018 targets.	• CCS-equipped gas adoption from 2029 • Moderate scale adoption of solar and wind projects. • No hydrogen consumption or co-firing coal units as we expect other technologies to be more cost competitive.
Supply	• LNG import capacity reaches 34.8 Mtpa by 2027, brownfield expansions to 50 Mtpa of new LNG capacity start in 2036 with an additional 20 Mtpa of newbuilds start in 2044, bringing total capacity to 70 Mtpa. • Gas pipeline import from Myanmar declines to zero by 2031. • Crude oil and natural gas production fall with declining reserves. • Thai Oil expansion delayed to 2023-2024 due to pandemic effect.	• Projection of fossil fuel is driven by domestic demand trends, plus assumption of export markets and some APEC-driven coal trends. • Mid-term LNG brownfield expansions start earlier, in 2031, due to higher gas demand, but long-term capacity needs are similar (70 Mtpa of total capacity). • Gas production matches the Reference scenario, oil lower on lower global demand and depleting oil reserves. • Refinery capacity retirement to meet declining demand
Climate	• NDC targets not explicitly considered.	• Carbon neutral energy sector by 2060

Notes: The base year is 2018. Projections begin in 2018. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

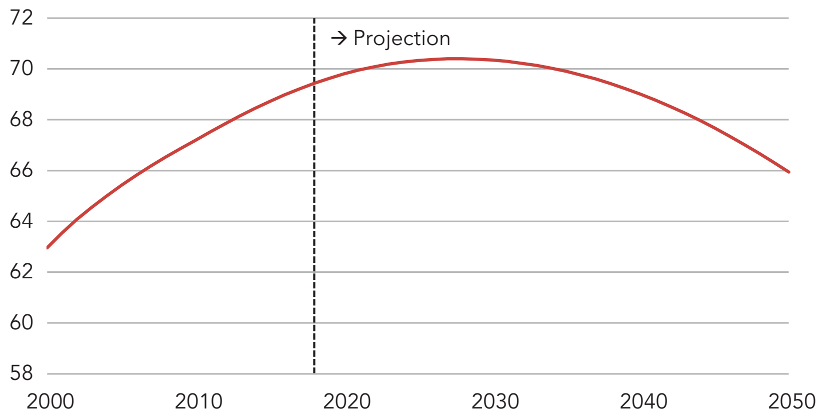
Macroeconomic backdrop

Figure 19-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 19-2. Population in millions, 2000-2050

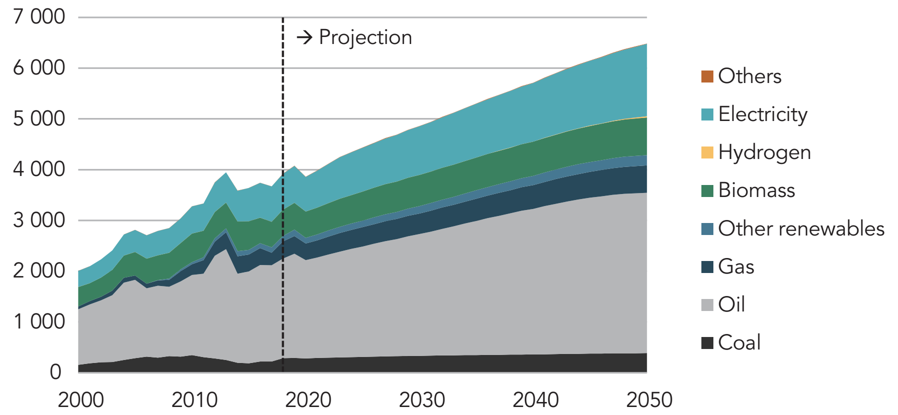


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- Thailand's GDP dropped by 6.1% in 2020 due to the COVID-19 pandemic, subsequent lockdowns, and subsequent reduced economic activity.
- Real GDP appears to have bounced back from the impact of the pandemic and is expected to grow 2.6% in 2021 and averaged at a 3.7% annual growth rate towards 2050, in line with 3.9% projected by the National Economic and Social Development Council (NESDC).
- Widespread vaccinations, easing of lockdown restrictions, higher governmental expenditures, and accommodative monetary policies have all contributed to robust GDP growth.
- Thailand's population has grown from 63 million in 2000 and is expected to peak at 70 million in the late 2020s before starting to decline to 66 million in 2050 due to the low population birth rate.
- Strong economic growth and a declining population trend have subsequently tripled the GDP per capita from USD 18 500 in 2018 to 55 600 in 2050.

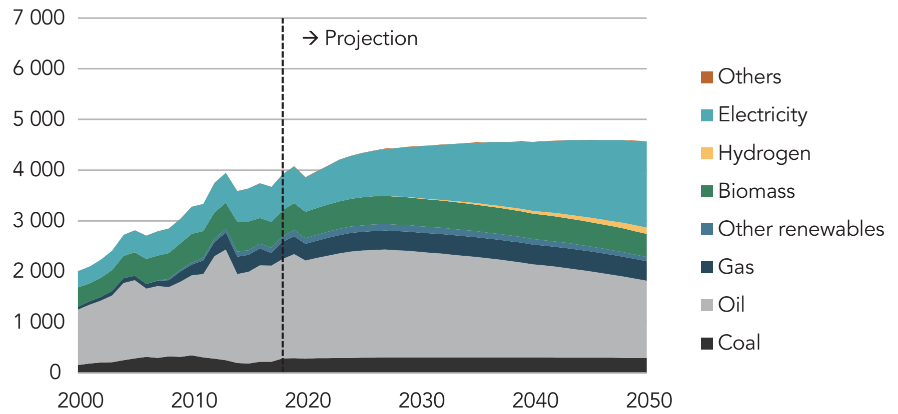
End-use energy demand

Figure 19-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 19-4. Energy demand in CN, 2000-2050 (PJ)

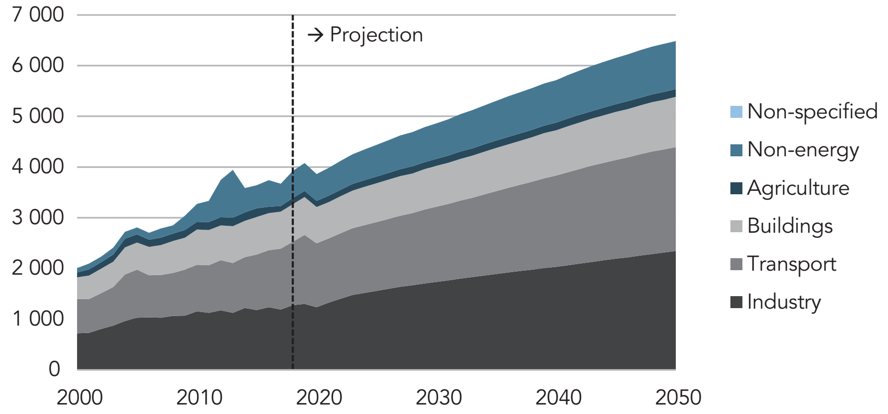


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Energy demand from 2000 to the start of the COVID-19 pandemic in 2020 has grown steadily in line with the increasing population and economic activities.
- COVID-19 resulted in restricted travel, interrupted business activities, and a slowdown in energy consumption in the 2019-2020 period before demand recovered to pre-pandemic trends.
- Energy demand increases by 65% in REF and by 17% in CN (2018-2050).
- Fossil fuel consumption dominates end-use energy demand but declines slightly from 66% to 63% in REF. The share drops to 48% in CN in line with Thailand's NEP to accommodate more EVs and renewables into the fuel mixes.
- Oil dominates end-use energy demand in both scenarios largely due to the prominence of the transport sector but diminishes through 2050 in CN.
- Continued technology improvements and more stringent fuel economy standards are assumed to gradually reduce oil consumption in both scenarios.
- Electrification increases significantly in both scenarios reflecting fuel switching especially in the transport sector.
- Hydrogen as an energy carrier slowly grows in CN with limited share. The limited growth presents a possible outcome where the economics of hydrogen do not advance rapidly enough relative to other energy carriers.

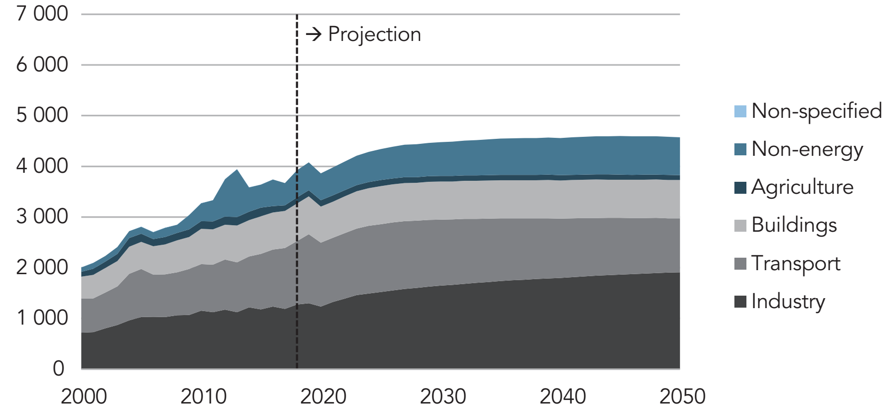
End-use energy demand by sector

Figure 19-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 19-6. Energy demand by sector in CN, 2000-2050 (PJ)

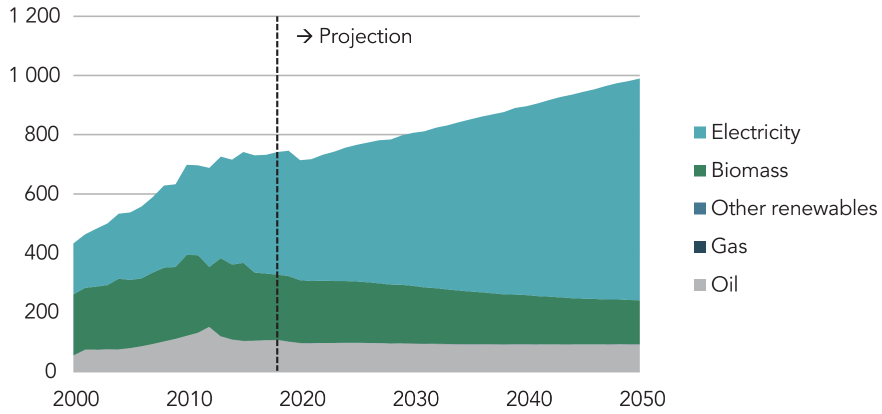


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Thailand's energy consumption continues to grow despite negative population growth (2018-2050). Increasing economic activity drives increasing energy demand in REF.
- Stable demand in CN is mostly explained by improvements in energy efficiency in end-use sectors, with energy consumption only marginally higher in 2050 relative to the pre-COVID demand level.
- Relative consumption by end-use sectors remains consistent through 2050 in REF.
- In CN, the industry sector becomes the largest share of energy demand. Absolute energy demand by the transport sector is lower than REF due to fuel and material efficiency improvements.
- Energy demand in the transport sector declines 15% in CN due to fuel economy improvements and electrification of the vehicle stock (2018-2050).
- Both sectors account for about two-thirds of end-use energy consumption at the end of the projection period.
- Demand in all sectors increases at a slower rate in CN due to energy efficiency improvements and material efficiency gains.

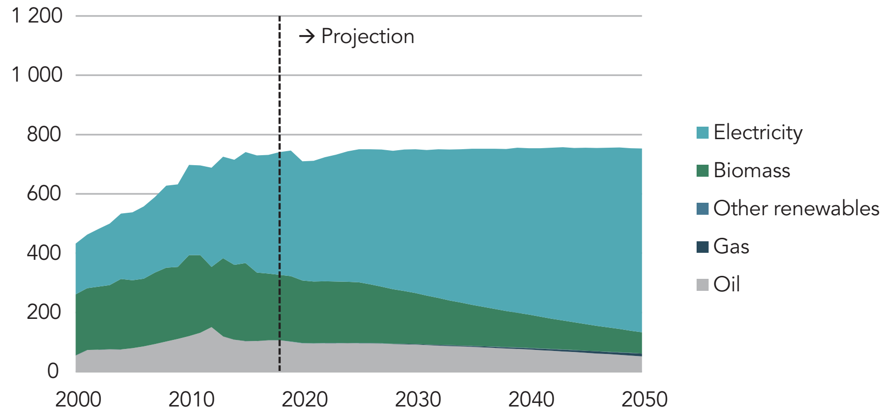
Buildings energy demand

Figure 19-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-8. Buildings energy demand in CN, 2000-2050 (PJ)

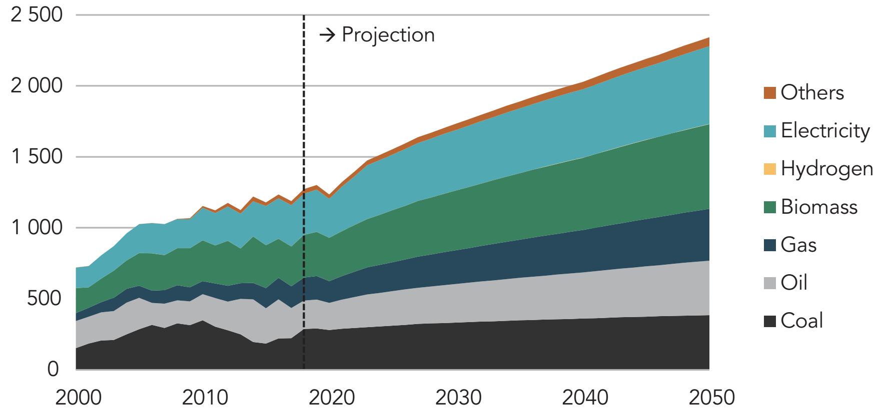


Sources: EGEDA, APERC analysis.

- The buildings sector is the third-largest end-use consumer of energy in Thailand. In recent years, more than half of all buildings energy consumption occurred in the residential sub-sector, due partly to population growth; however, service sub-sector consumption has also been increasing. This trend continues in both scenarios.
- COVID-19 saw a decline in energy consumption in 2020 and 2021 due to lockdowns that forced many commercial businesses to close or reduce operating hours. Reduced commercial buildings' energy consumption was partly counteracted by an increase in residential energy consumption, due to increased time spent at home and work from home.
- Gradual improvements to efficiency in buildings due to Building Energy Code (BEC), High Energy Performance Standards (HEPS), and Minimum Energy Performance Standards (MEPS) result in 34% growth in energy consumption by 2050 in REF while it is limited to only 2% growth in CN.
- Over half of Thailand's buildings sector demand was satisfied by electricity in 2018. Electricity is used for end-use activities such as lighting, heating, cooking, and cooling.
- Electricity demand increases substantially in both scenarios and is projected to account for 76% of buildings energy consumption in REF and over 80% in CN in 2050.
- Biomass consumption in buildings continues to decline over the projection reflecting Thailand's attempt to reduce inefficient biomass use, especially in the residential subsector.
- Biomass energy share decreases by one-third by 2050 in REF and more than two-thirds in CN.

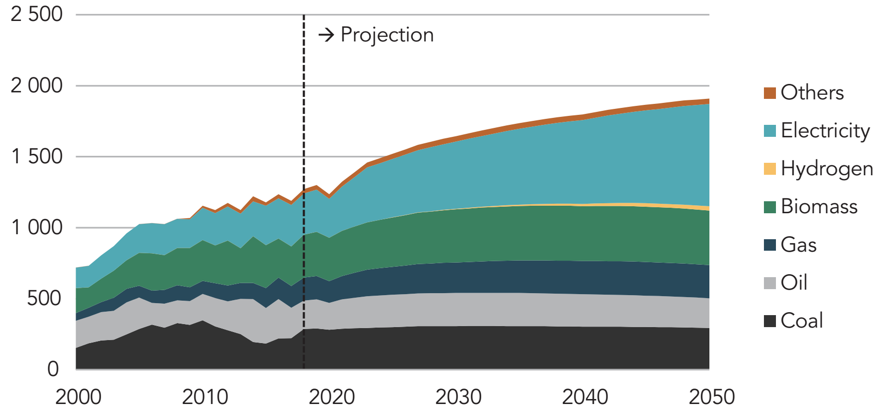
Industry energy demand

Figure 19-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 19-10. Industry energy demand in CN, 2000-2050 (PJ)

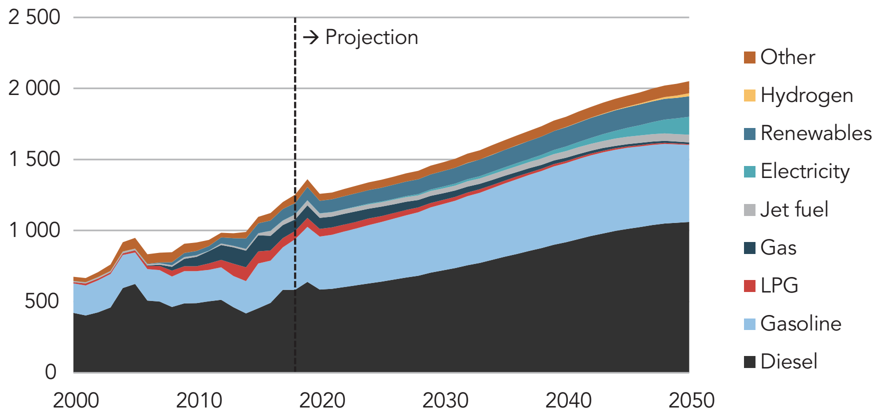


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- The industry sector is the largest end-use consumer of energy in Thailand. Textiles, construction, and machinery ("Other") sub-sectors consume over 40%, followed by cement ("non-metallic minerals"), chemicals, pulp & paper, iron & steel production, and many other smaller sub-sectors.
- Despite the economic slowdown in manufacturing in Thailand, industrial energy consumption has progressed well in the past decade before the COVID-19 pandemic.
- Industrial output is assumed to be the same in both scenarios, with no notable changes in sub-sector shares through 2050.
- REF assumes improvements in material and energy efficiency, as well as electrification and digitalization, consistent with historical rates. Ambitious assumptions are made for increased material and energy efficiency and fuel switching in CN.
- Fossil fuels are an essential input, comprising about half of the total industrial processes in Thailand. Electricity and biomass are the most consumed fuel at the beginning of the projection and remain the largest share in REF.
- Coal represented over 20% of industrial fuel demand in 2018, but fuel switching from coal to biomass, electricity, and natural gas in multiple industry subsectors are increasing in both scenarios.
- Coal consumption tapers towards 2050 reflecting Thailand's position to phase out coal, but it is not fully eliminated due to technical process requirements.
- Biomass consumption decreases in CN and is substituted by electricity.
- Hydrogen technology is developed and consumed in both scenarios. In REF, hydrogen is assumed to be available in small amounts starting in 2031 and progresses slowly as its uptake is limited and cannot displace a lot of gas or other energy carriers.
- Hydrogen plays a more important role, but still with limited share, in CN as it is assumed to be more available and more cost competitive starting in 2025, and viable as a substitute for natural gas.
- The non-energy is not included in the industry subsector.

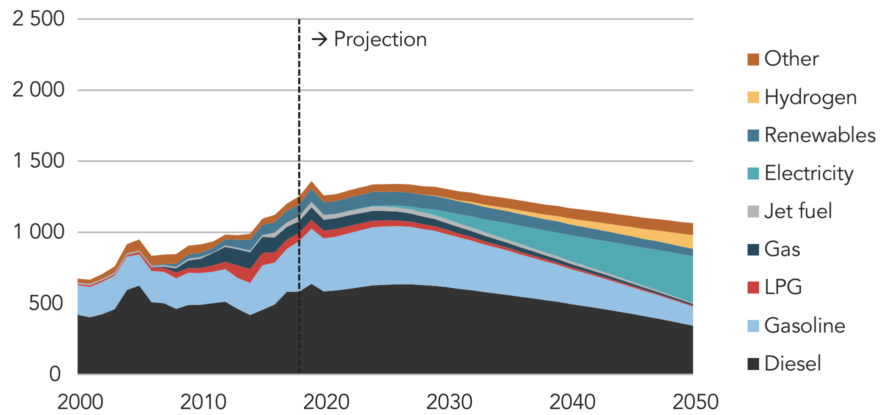
Transport energy demand

Figure 19-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 19-12. Transport energy demand in CN, 2000-2050 (PJ)

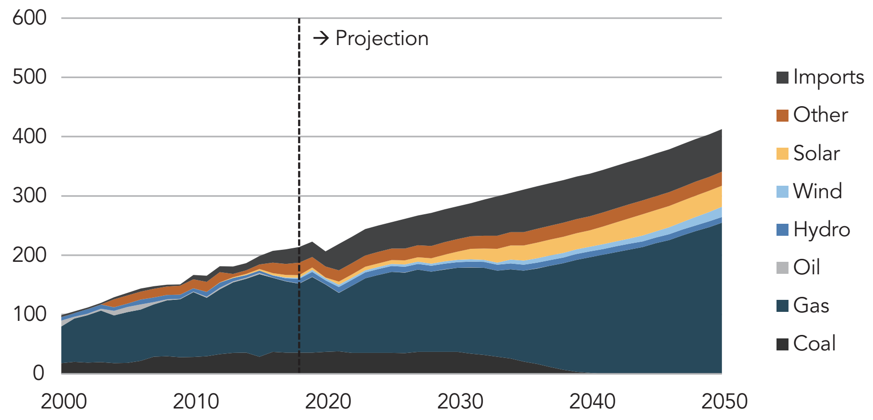


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport is the second-largest end-use demand sector in Thailand.
- Over 90% of all domestic transport-related demand in 2018 is related to road transport. Heavy-duty trucking and light-duty vehicles each dominate road demand at 30% share of total road demand in 2018, followed by light-duty trucking including pickup trucks and SUVs (28%).
- The transport sector was most affected by COVID-19 lockdowns and the shift to work from home for some workers. After a large decrease in fuel consumption in 2020 to 2021, demand rebounds as mobility resumes in 2022 in REF.
- The transport sector becomes about 32% of total end-use energy demand over the projection, in line with Thailand's energy plan.
- Demand by marine, aviation, and rail, which includes passengers and freight, combine to a smaller share of transport energy demand (8.0%). These shares remain relatively constant in REF through 2050.
- CN assumes a big divergence from REF and demand steadily declines in the mid-2020s due to continued fleet fuel economy improvements. Fuel switching from gasoline to electricity leads to additional demand reduction beginning in the late 2020s through 2050. Diesel is still utilised for trucking and buses, although fuel switching to hydrogen begins in the mid-2030s.
- The fleet remains mostly ICEs and it continues as part of the vehicle stock in REF while there is improved fuel efficiency and hybridisation in CN where the electrification of the transport fleet increases rapidly as the share of EVs reaches 34% by 2050 compared to 6% in REF. Charging infrastructure and EV manufacturing capability are assumed to be sufficient to support this level of expansion.
- In CN, the rail sector steadily expands to gain a bigger share (4%) of the transport sector by 2050 due to major development in the commuter and freight train system in metropolitan and around big cities in Thailand.
- The aviation sector gradually adopts biojet and road transport adopts hydrogen fuels after 2025 in CN.

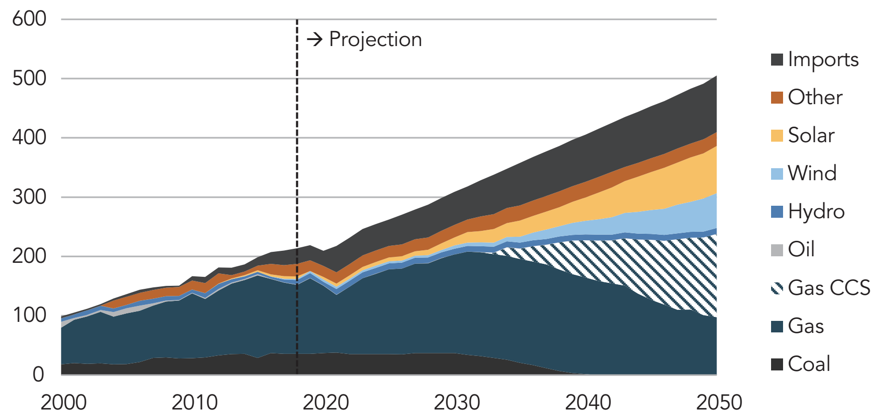
Electricity generation

Figure 19-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 19-14. Electricity generation in CN, 2000-2050 (TWh)

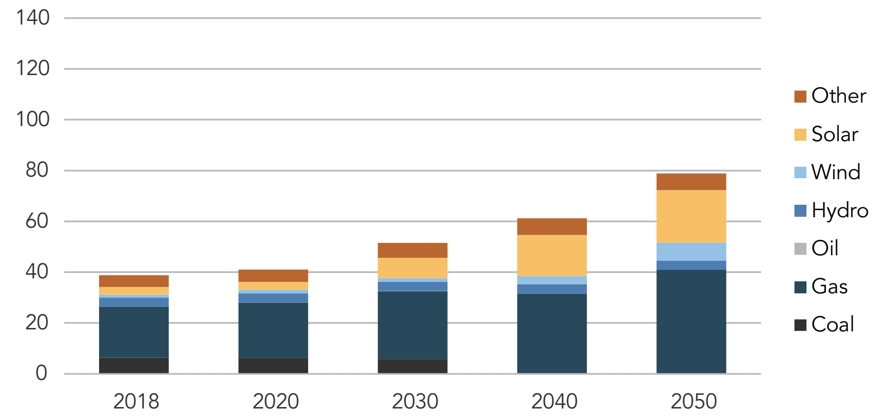


Sources: EGEDA, APERC analysis.

- Electricity generation is projected to grow by 93% in REF and 136% in CN, driven by steady growth in electrification in major end-use sectors.
- Coal (including lignite) and natural gas have historically been the most important sources of electricity generation for Thailand. Both coal and lignite provide important baseload generation in both scenarios, though their relative prominence diminishes steadily, reaching zero generation with the phase-out of coal-fired power plants in the 2040s.
- The buildings sector contributes to almost half of the electricity demand increase in REF, while fuel switching in industry leads to another 30% of the increase in electricity demand. EVs in transport add another 35 TWh of demand in 2050.
- In CN, the most growth in electricity demand is from the industry, followed by the transport sector.
- Electricity demand from the transport sector in CN is five times greater in 2050 than in REF as the sales share of EVs increases from less than 1% in 2018 to over 30% in 2050. Electrification of buildings contributes to additional demand.
- In REF, the share of gas-fired generation remains high, increasing from 54% to 62% (2018-2050).
- In CN, CCS-equipped gas generation begins in 2030 and its contribution increases to about one-third of the electricity generation in 2050.
- Coal is phased out in both scenarios.
- Additional generation is increasingly supplied by non-fossil fuels and hydro-power imports in both scenarios.
- Solar and wind generation make up about one-seventh of electricity generation in 2050 in REF and almost one-third in CN.
- Imports fulfill another one-fifth while coal-fired generation decreases significantly and phases out completely by 2040 in both scenarios.

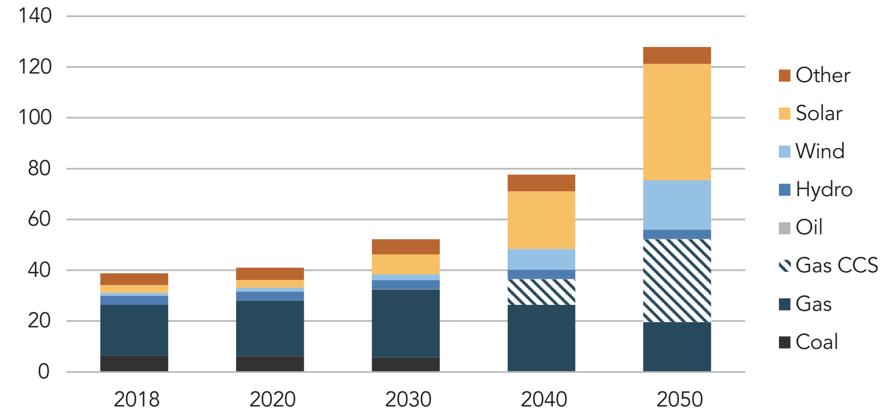
Generation capacity

Figure 19-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 19-16. Generation capacity in CN, 2018-2050 (GW)

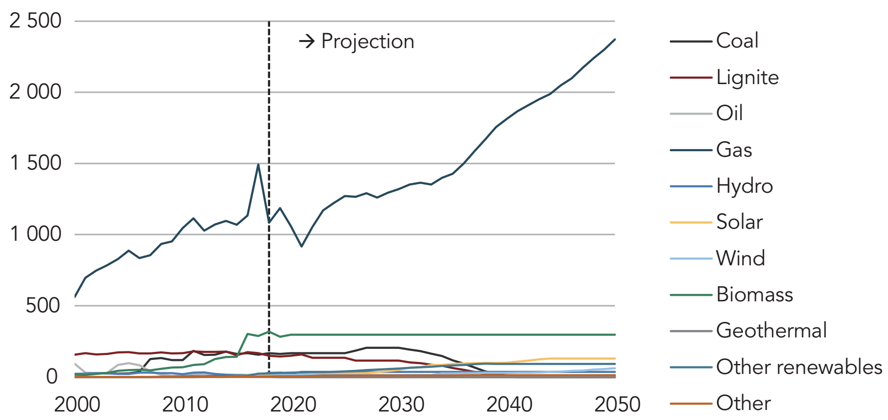


Sources: EGEDA, APERC analysis.

- The additions of 40 GW installed capacity in the power sector is dominated by gas (52%), followed by solar (44%) and wind (15%), with the phase-out of 6 GW coal (-16%) in REF.
- In CN, the fuel switching and decarbonisation trends are more apparent looking at the installed capacity of generation technologies. The combined capacity increases as solar and wind additions are about 69% of the 90 GW capacity additions, followed by gas with a share of 37% of capacity additions.
- Over the past decade, the development of wind and solar started slowly in Thailand reaching about 1.1 GW and 3.0 GW, respectively. The growth of wind and solar continues but with a more aggressive rate in both scenarios.
- In REF, wind and solar capacities increase by 6.0 GW and 18 GW, respectively (2018-2050). Capacity expansion outpaces electricity demand growth (102%) due to the low-capacity factors of solar and wind technologies.
- In CN, the pace of wind and solar capacity expansion increases by 18 GW and 43 GW, respectively.
- Gas capacity increases slowly in REF while in CN, unabated gas capacity decreases. CCS retrofitting of gas-fired units begins in 2030 and continues until more than half of gas capacity has CCS in 2050.
- Coal capacity slowly declines, reflecting the ongoing trend of fuel switching from coal to gas and renewables before phasing out completely in 2040 in both scenarios.
- Modern renewables continue to increase their importance from 22.6% generation capacity mix in 2018 to 43.4% and 56.2% in 2050 in REF and CN, respectively. In CN, the 43% share of modern renewables in 2037 starts to exceed the share of natural gas capacity, which is currently the mainstay of Thailand's power generation.
- CCS retrofits of gas-fired units are considered in favor of coal-fired units given the lower carbon intensity of gas units.
- However, the trend towards higher CCS gas-fired generation needs to be monitored as policy makers in Thailand need to balance between decarbonisation and affordability on power price.

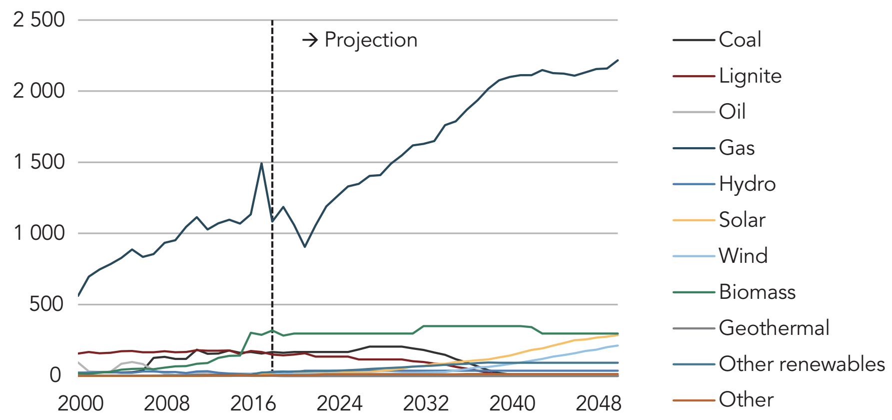
Fuel consumption by power sector

Figure 19-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 19-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

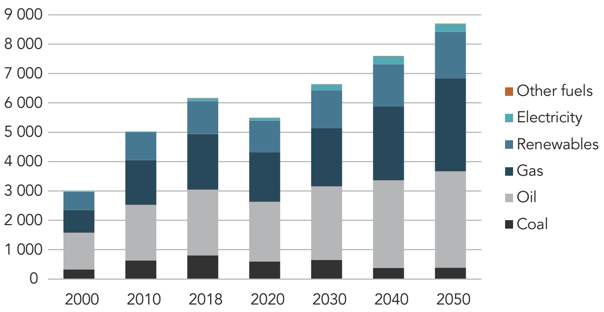


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- Coal (including lignite) has been the foundation of electricity generation in Thailand for the past few decades. Its relative prominence diminishes and reaches zero generation with the phase-out of coal-fired power plants in the 2040s in both scenarios.
- Even with a very large increase in solar and wind, the drive to decarbonise and reduce coal consumption means that gas maintains a high level of consumption through the entire projection period for both scenarios.
- In CN, natural gas consumption is 7.0% lower in 2050, though decarbonisation is achieved with the building and deployment of natural gas generation with CCS technology.
- The large increase in solar and wind consumption in CN is almost triple that in REF.

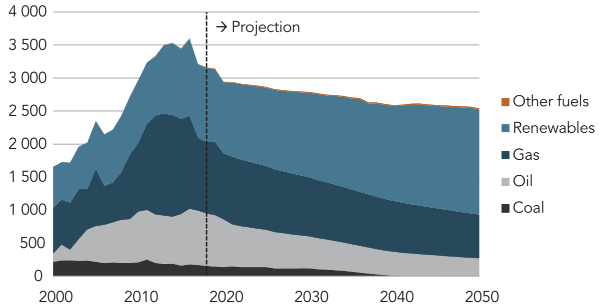
Energy supply in the Reference scenario

Figure 19-19. Total energy supply in REF, 2000-2050 (PJ)



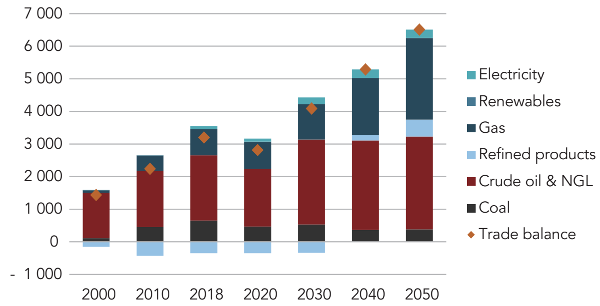
Sources: EGEDA, APERC analysis.

Figure 19-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-21. Net energy trade in REF, 2000-2050 (PJ)

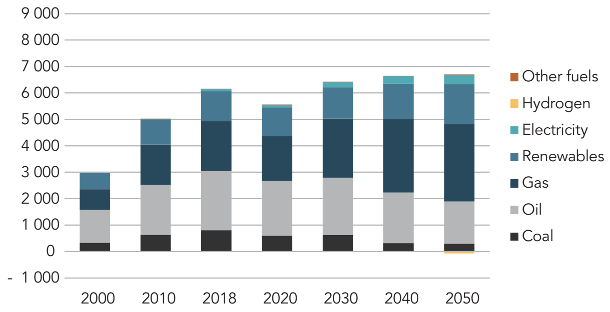


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Energy supply increased by 107% between 2000-2018. Gas contributed the most to this increase, followed by oil and renewables.
- In REF, the share of fossil fuels supply reaches about 80% in 2050 while the share of renewables and other fuels grows to 20%.
- About two-thirds of production was evenly split between gas and renewables in 2018. Oil represented around one-fourth, while coal (and lignite) and others made up the remainder.
- While coal (and lignite) production decreases over the projection to almost zero, oil and gas trends continue, declining from 60% share of production to less than 40% by 2050.
- Domestic renewables take a significant role in compensating this shortage, increasing the share of production to over 60% by 2050.
- The high demand for natural gas for petrochemicals and electricity generation has resulted in the development of LNG regasification facilities over the years as natural gas reserves are depleting in Thailand. The NEP, to be released in 2022, has targeted the future fuel mix to contain more renewables.
- The six refineries are expected to continue operating in REF at relatively high utilisation to stabilise refined products supply and to balance energy security risks between crude oil and refined products and other fuels.
- As crude oil and natural gas reserves in Thailand are depleting. Thailand has been a net importer of energy for the past decades. In 2018, oil imports were 60% of total energy imports and natural gas was another 20%. The proportion of oil imports decreases to about 50% in 2050. Natural gas imports almost double from 20% share to 40% (2018-2050).

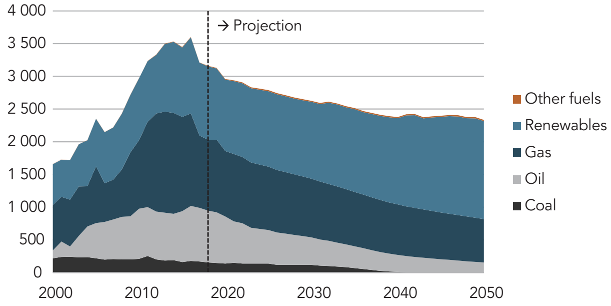
Energy supply in the Carbon Neutrality scenario

Figure 19-22. Total energy supply in CN, 2000-2050 (PJ)



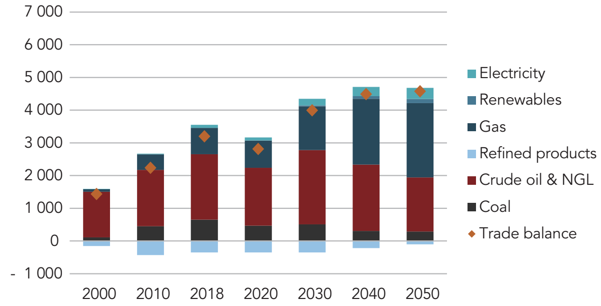
Sources: EGEDA, APERC analysis.

Figure 19-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-24. Net energy trade in CN, 2000-2050 (PJ)

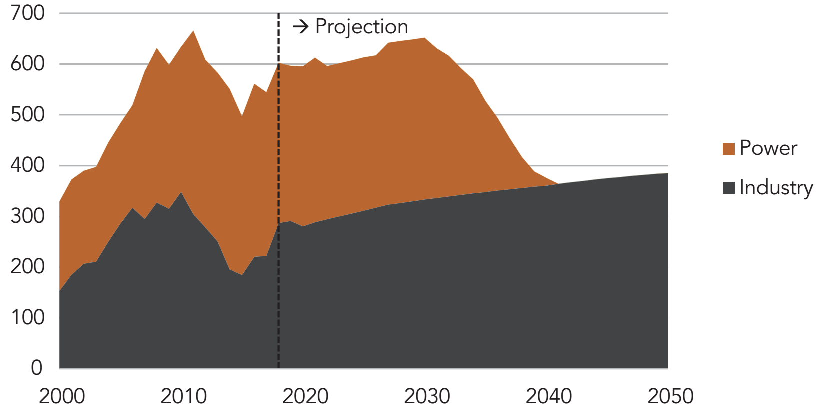


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- In CN, the share of fossil fuel supply declines to about three-quarters of the total energy supply in 2050 while the renewables expand to cover 21% of supply share.
- The shrinking demand and supply and the strategy to accommodate more renewables into the supply mix in CN have resulted in Thailand acquiring significantly lower energy imports in 2050.
- Solar, wind, and biofuels in CN dominate renewables production significantly, increasing their share from one-third of the total energy production in 2018 to more than 60% by 2050.
- Coal and lignite production in CN drops to almost zero in 2050. Oil and gas production decreases from 60% share of production to about one-third of total energy imports by 2050.
- Domestic renewables take a more significant role in compensating this shortage, increasing its production share to over 60% by 2050.
- Natural gas production is expected to decrease from 34% of total energy production in 2018 to 30% of the total energy production in 2050. This is slightly higher than the natural gas production in REF (26%), compensating the less oil production in CN (7% vs. 10%) in 2050.
- The penetration of solar, wind, biofuels, and electricity into the supply mix is higher in CN, while the share of fossils decreases to less than three-quarters of the total energy supply.
- In CN, oil import decreases from about 60% of the total energy import in 2018 to less than 40% level in 2050 while natural gas import more than doubles from a 20% share to almost 50% of the total energy import in 2050.
- The fossils import still dominate but decrease their share from almost 100% to 90% of the total energy imports in 2050. The level of import dependence remains high over the projection and the net energy trade will increase by more than 40% in 2050.

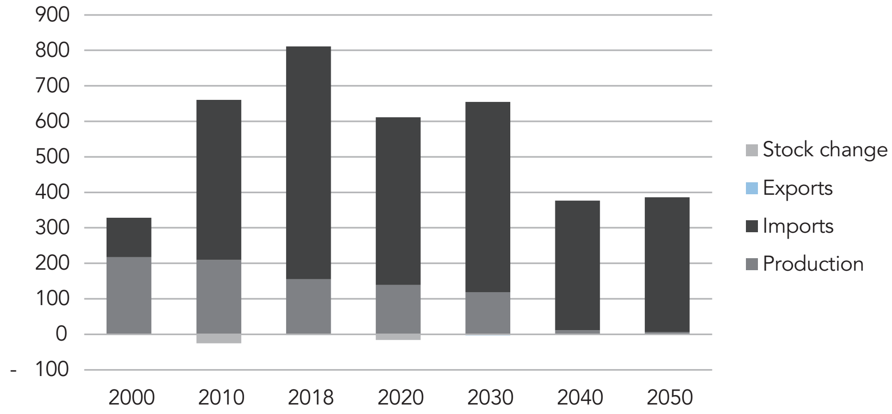
Coal in the Reference scenario

Figure 19-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

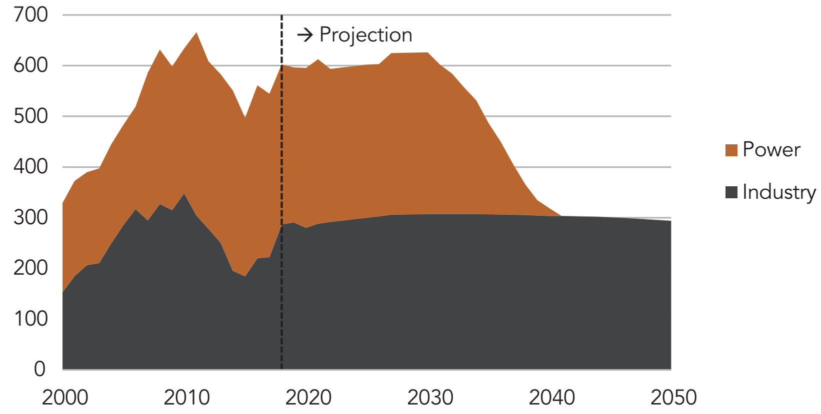


Sources: EGEDA, APERC analysis.

- Coal constitutes almost one-fifth of the fuel used for power generation in 2018 with peak consumption of 320 PJ occurring in the late 2030s before falling to zero in 2040.
- The decade-long decline in REF reflects the phase-out of coal-fired power plants in Thailand as these facilities reach the end of their operational lifetime.
- It is assumed that no more new coal-fired power plants are built in either scenarios due to the rapidly increasing capacity of alternative generation technologies such as solar, wind, and other renewable energy.
- Coal-fired power plant utilisation rates have been falling with the rise of variable renewable generation, with this fall in utilisation also contributing to coal consumption in the power sector.
- While coal in the power sector is phasing out slowly, multiple industrial subsectors continue to rely on coal for processes that require consistent heating-value properties. Demand by these subsectors has gained momentum and increased more than 30% towards 2050.
- The industry sector continues to increase coal consumption after the phase-out in the power sector in 2040 and becomes the single largest consuming sector.
- With a limited reserve of lignite and low heating value, coal imports are necessary to fulfill the coal requirement.
- Most of Thailand's coal imports are metallurgical followed by thermal. Metallurgical coal accounts for 90% of all coal imports in 2050, which is up from less than about 70% currently. Imports are assumed to have peaked before the COVID-19 pandemic, and gradually tapering through 2050, falling by more than 40% reflecting the coal phase-out in the power sector.

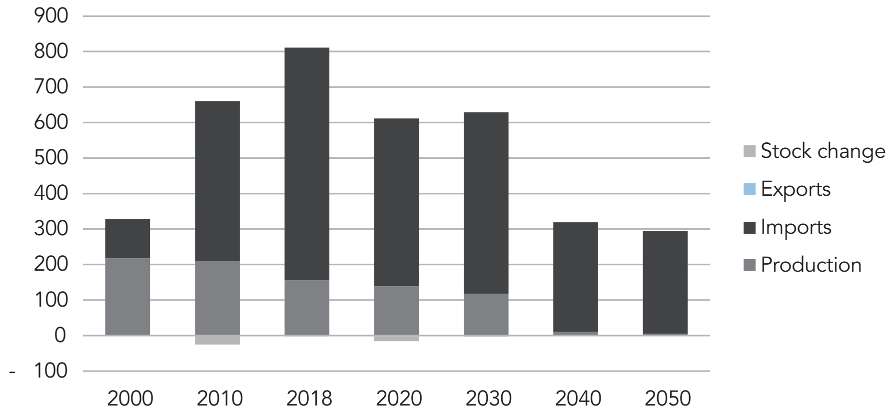
Coal in the Carbon Neutrality scenario

Figure 19-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

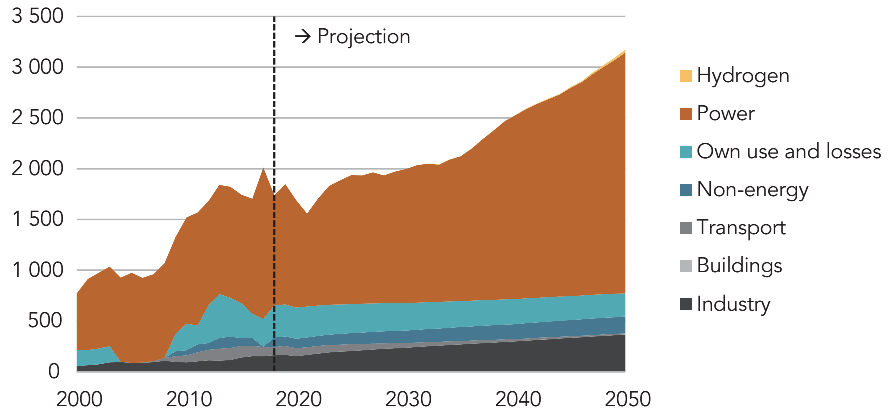


Sources: EGEDA, APERC analysis.

- In CN, coal also declines to zero in 2040 to reflect the phase-out of the coal-fired power plants in Thailand as the facilities reach the end of their operational lifetime.
- There are no new coal-fired power plants built in CN, due to the rapidly increasing capacity of alternative generation technologies such as solar, wind, and other renewable energy.
- Coal-fired power plant utilisation rates have been falling with the rise of variable renewable generation, with this fall in utilisation also contributing to coal consumption in the power sector.
- In CN, the multiple industrial subsectors continue to rely on coal for processes that require consistent heating-valued properties. However, the demand of these subsectors is maintained relatively constant over the projection, with a growth of about 2.0% between 2018-2050.
- Coal imports are cut by 56% by 2050. Metallurgical coal accounts for 90% of all coal imports in 2050, which is up from less than about 67% (2018).

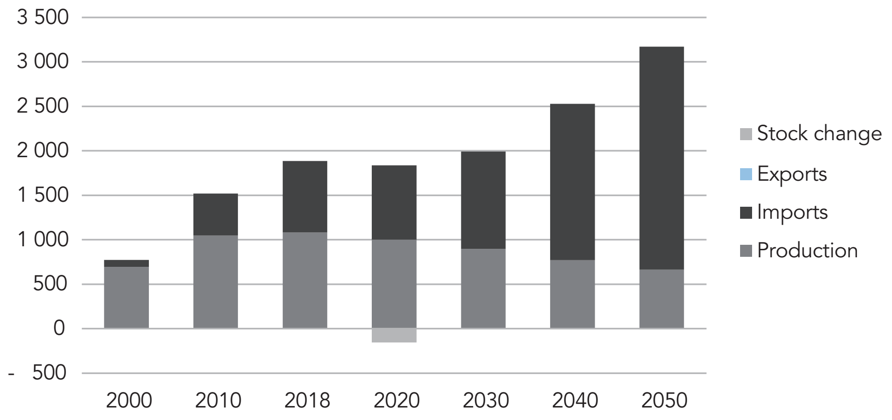
Natural gas in the Reference scenario

Figure 19-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)



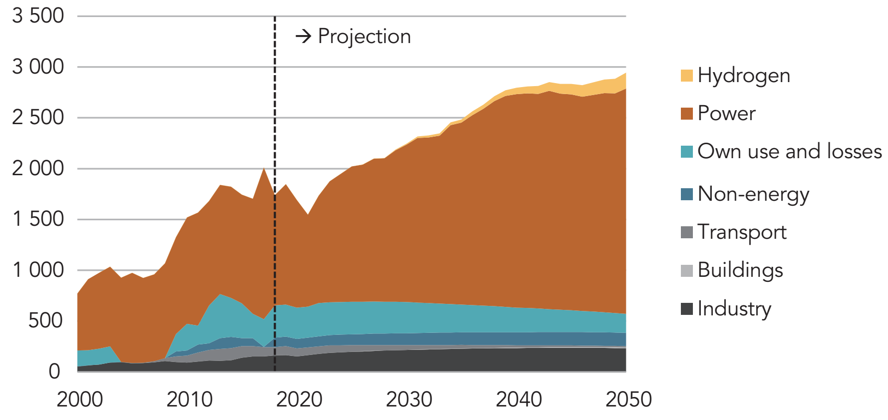
Sources: EGEDA, APERC analysis.

- Thailand's natural gas consumption is dominated by power generation followed by industry and non-energy over the projection.
- Natural gas is also promoted in the transport sector as a replacement for conventional petroleum products, such as diesel and gasoline.
- Total gas consumption has grown substantially between 2000-2018, with much of the growth contributed from gas-fired power capacity additions. The demand trend continues to increase; by 2050 natural gas consumption expands by over 80%.
- In the industry sector, natural gas has increased its role as an important fuel for combustion because of its competitive prices and lower carbon content than coal. Gas consumption in industry increases 126% (2018-2050).
- The limited natural gas reserve from Erawan and Bongkot concessions has resulted in production declining about 40% by 2050. This decline leads Thailand to increase reliance on natural gas imports in the form of piped gas from Myanmar and LNG from Qatar, Malaysia, and others.
- LNG regasification operations have become key facilities to supply more natural gas into power plants and simultaneously enhance natural gas supply security.

- REF assumes that Thailand's requirement of over 50 Mtpa by 2050 is necessary.

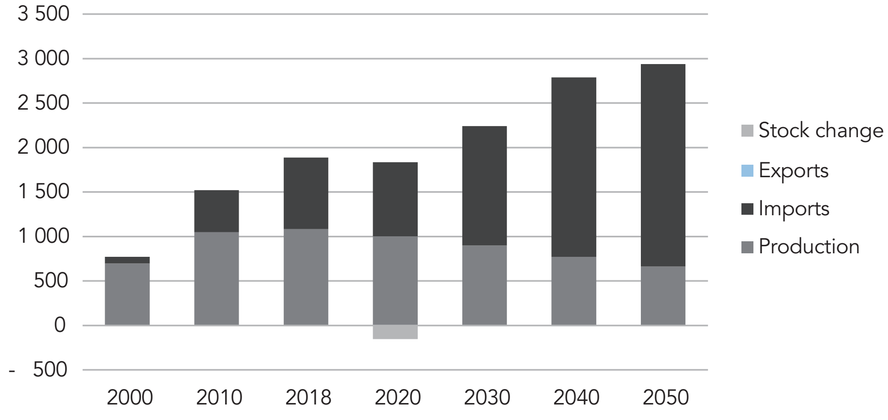
Natural gas in the Carbon Neutrality scenario

Figure 19-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

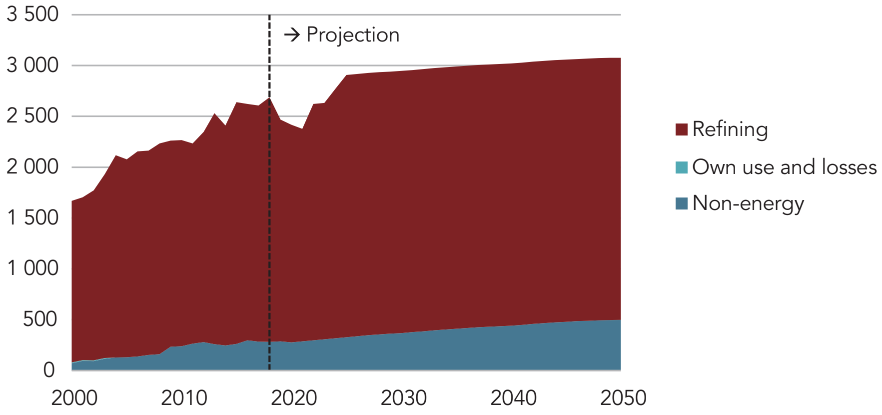


Sources: EGEDA, APERC analysis.

- In CN, natural gas consumption increases by almost 70% by 2050. The key user is power, contributing about three-quarters of total consumption in 2050.
- Significant gas-fired power capacity additions continue to drive gas demand in CN.
- Power sector consumption is uneven due to an increased role in meeting the challenge of greater variable renewable generation, hampered by lower coal-fired generation.
- Reduced natural gas consumption in many of the other consuming sectors is due to improved energy efficiency and fuel switching, particularly to electricity.
- The hydrogen sector begins to consume gas from the late 2020s. Steam methane reforming will grow slowly to capture over 5.0% share of total natural gas consumption in 2050.
- The role of natural gas consumption in the industry sector remains important and the growth of natural gas consumption in industry is more than 40% in 2050.
- Like REF, natural gas production in CN is anticipated to decline slowly from current levels.
- Reliance on natural gas imports is still required in the form of piped gas and LNG.

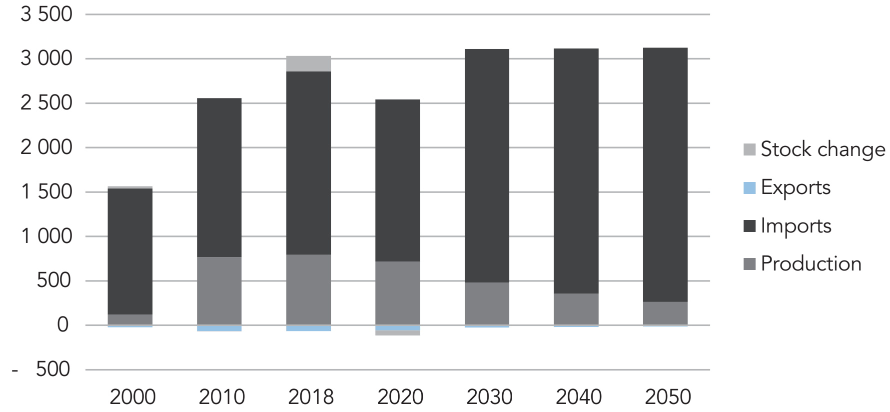
Crude oil and NGLs in the Reference scenario

Figure 19-33. Crude oil and NGL consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-34. Crude oil and NGL production, imports, and exports in REF, 2000-2050 (PJ)

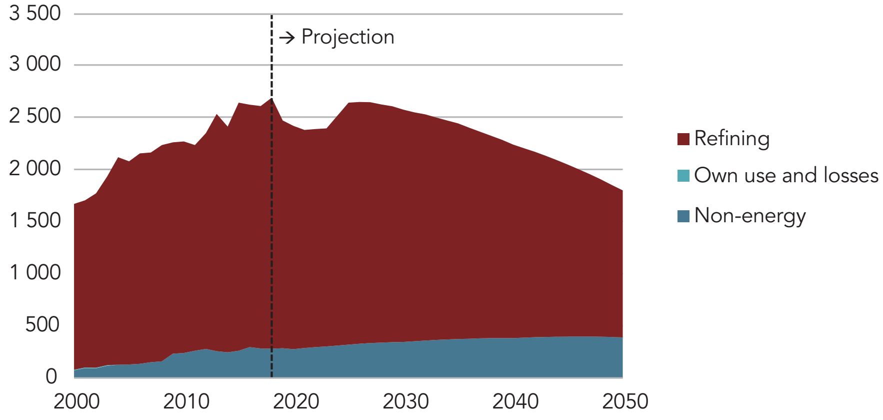


Sources: EGEDA, APERC analysis.

- In REF, 90% of crude oil consumption is dominated by the refining sector followed by non-energy (petrochemicals) in 2018. The crude oil influence is assumed to decrease slightly to 85% in 2050 implying that petrochemicals progress well over the projection.
- Crude oil production is modest in comparison to coal and natural gas production, due to limited reserves. With the current rate of crude oil production, oil reserves are estimated to last only two years. Crude oil production is projected to decrease almost 70% in REF (2018-2050).
- Declining oil production has prompted Thailand to rely heavily on a large quantity of imported crude oil to meet the required processing capabilities of the six existing refineries. Crude oil import increases almost 40% by 2050.
- Thailand refineries have been running their facilities at an approximated 90% utilisation rate. Thai Oil refinery is the only refinery that has a plan to install a facility to handle heavy crude oil and expand its capacity by 125 000 barrels per day in the 2024-2025 timeframe.
- The situation of the refinery overcapacity and the saturation of the oil market in the region has been the barrier that prevents other Thai refineries to expand their facilities.
- Importing a large quantity of crude oil has become a financial burden and indirectly increased risks in energy security. Diversification of energy consumption from petroleum oil products to gas, renewables, and electricity has been marginal in REF. The share of oil out of total demand is about 50% of throughout the projection.
- In REF, the six refineries are assumed to continue operating until 2050.

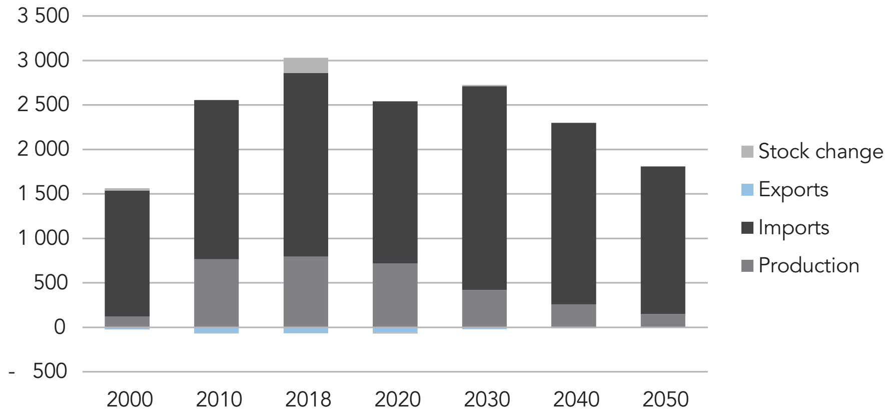
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 19-35. Crude oil and NGL consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-36. Crude oil and NGL production, imports, and exports in CN, 2000-2050 (PJ)

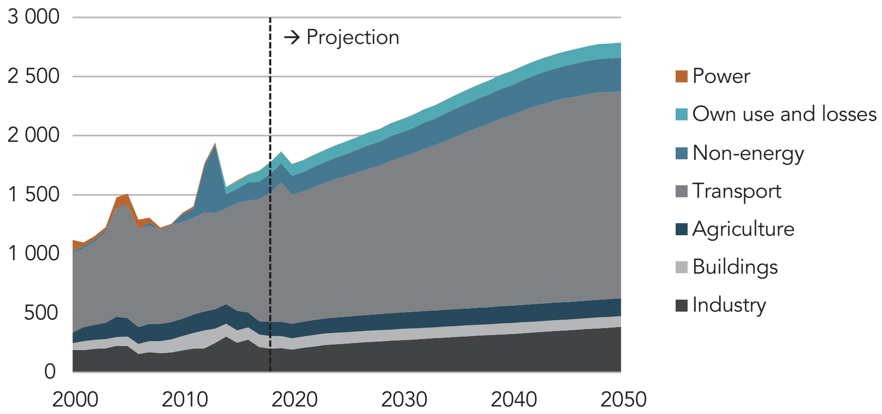


Sources: EGEDA, APERC analysis.

- While crude oil consumption increases more than 14% by 2050 in REF, crude oil consumption in CN is projected to decrease by 33% to supplement Thailand's target to acquire carbon neutrality in 2050 and net-zero by 2065.
- Crude oil consumption is still dominated by the refining sector in CN but the proportion of crude oil consumption for refineries falls further from 85% in REF to below 80% in 2050.
- In CN, the non-energy sector, which includes petrochemicals, doubles its share of crude oil consumption signifying its stronger advancement than in REF.
- Lower crude oil consumption has prompted crude oil production in CN to decrease more than 80%. Crude oil imports also decline by 20% (2018-2050).
- Importing less crude oil in CN has lessened the financial burden for Thailand in crude oil acquisition and lowered risks in energy security compared to REF.
- In CN, the diversification of the energy consumption from petroleum oil products to natural gas, renewables, and electricity has been significant, decreasing share of oil in energy demand from about 49% (2018) to 33% (2050).
- Like REF, the six refineries are assumed to continue operating until 2050 and the Thai Oil refinery is scheduled for the expansion in 2024-2025 timeframe.

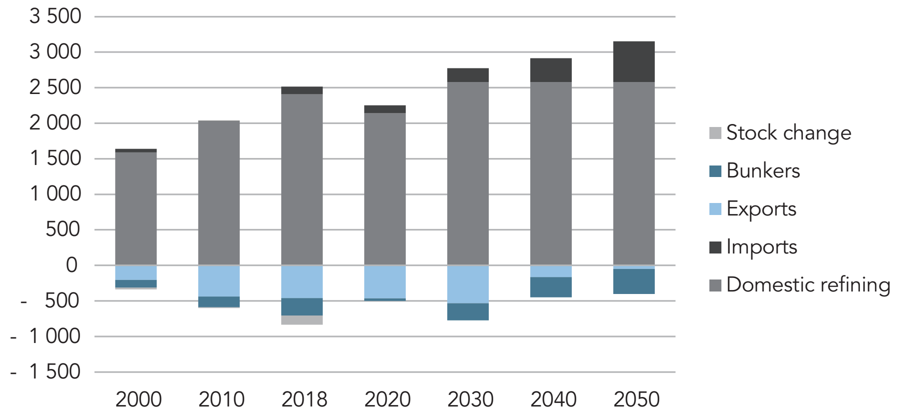
Refined products in the Reference scenario

Figure 19-37. Refined product consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-38. Refined product production, imports, and exports in REF, 2000-2050 (PJ)

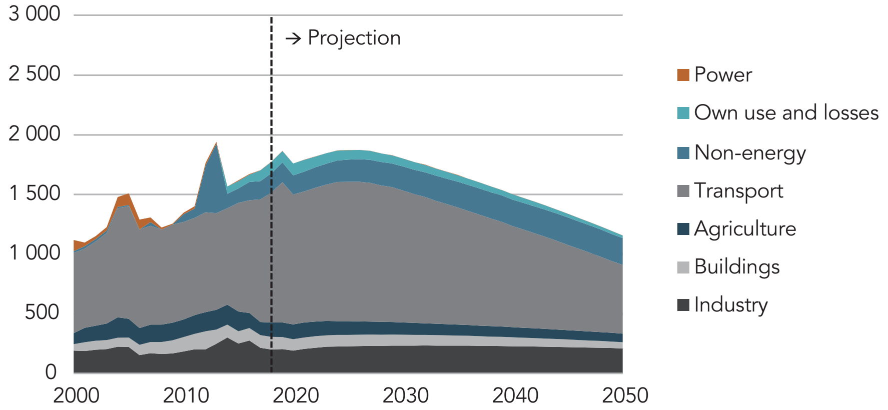


Sources: EGEDA, APERC analysis.

- In REF, refined product consumption increases by 1.4% annually. Demand is somewhat tempered by the declining population, increased energy efficiency, and some fuel switching.
- ICE vehicles have dominated road transportation in Thailand, and it is assumed that they will maintain their important role over the projection.
- The most visible impact on petroleum product consumption is in the transport sector with its average share of two-thirds of total refined product consumption throughout, increasing almost 60% (2018-2050).
- Industry and non-energy also consume a large amount of petroleum products, each of which takes about a 10% share of the total petroleum product consumption in 2018.
- While non-energy maintains its share over the projection, demand growth in the industry sector is accelerated to almost 15% in 2050.
- Bunkers supply, which captures demand from international aviation and maritime, shows a large increase by over 40% in 2050.
- Imports of petroleum products have grown slowly since 2000 due to steady growth in consumption. Imports of petroleum products as a proportion of supply have increased slightly from 4.0% in 2000 to 6.0% in 2018.
- In both scenarios, the capacity of the six existing refineries is assumed to be constant after the Thai Oil expansion in 2025.
- In REF, insufficient refining capacity to catch up with the petroleum product demand has resulted in imports expanding by more than five times over the projection to supplement the shortage.
- Imports of petroleum products as a proportion of supply have increased significantly to about 20% in 2050.

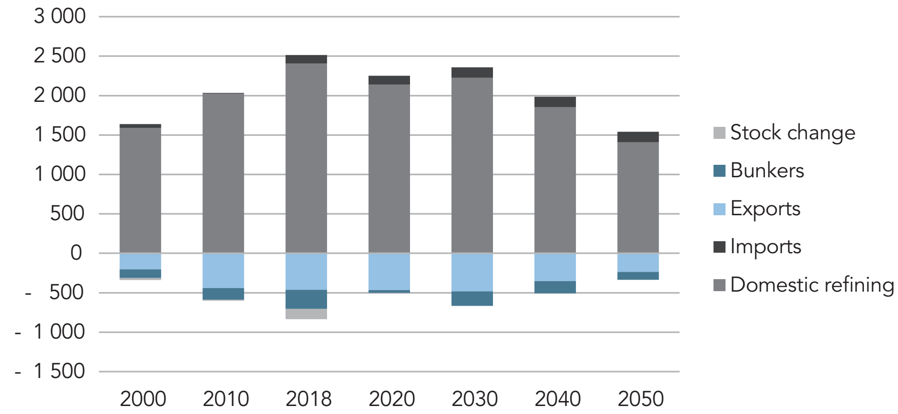
Refined products in the Carbon Neutrality scenario

Figure 19-39. Refined product consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 19-40. Refined product production, imports, and exports in CN, 2000-2050 (PJ)

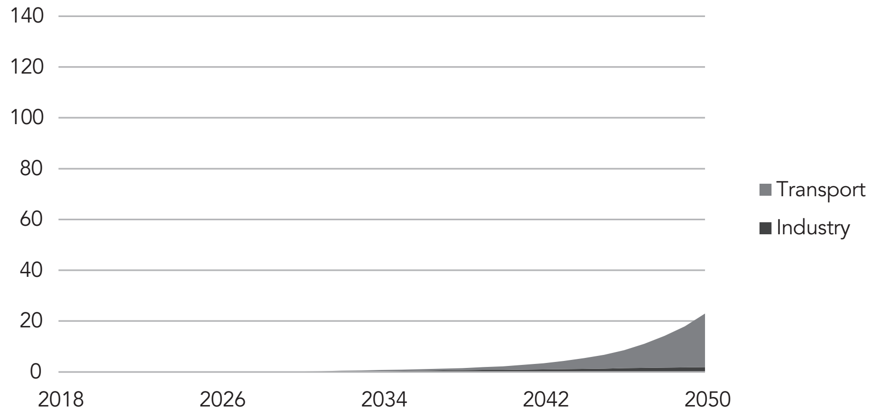


Sources: EGEDA, APERC analysis.

- The initial post-COVID-19 rebound is similar in both scenarios. However, improved energy efficiency performance in CN combined with a decrease in people traveling spurred by behavioral change leads to a divergence from the REF trajectory.
- In CN, consumption of petroleum products peaks in 2026 before falling by more than one-third towards 2050. This is in line with Thailand's attempt to move forward to achieving carbon neutrality in 2050 and zero-emissions in 2065.
- All sectors are assumed to decrease consumption of petroleum products except in the non-energy sector, of which the petroleum product is still required as feedstock, resulting in continuous growth in the non-energy sector by almost 40%.
- The transport sector maintains its dominance over the petroleum product consumption, but its consumption decreases by half. By 2050, the share of transport sector petroleum consumption falls to 50%.
- Non-energy increases consumption of petroleum products to feed petrochemicals operations.
- Bunkers supply also diminishes and shows a decrease of bunker sales by almost 60% by 2050.
- In CN, the requirement for imported petroleum products is lower due to declining demand. Imports still increase but at a lower degree than REF.

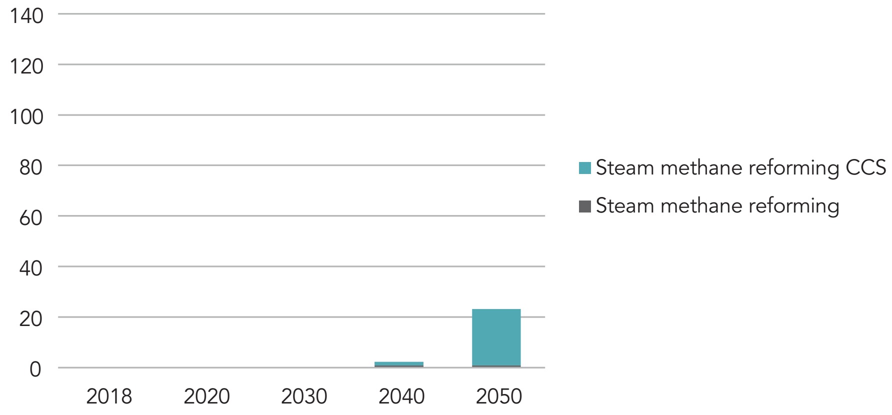
Hydrogen in the Reference scenario

Figure 19-41. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 19-42. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

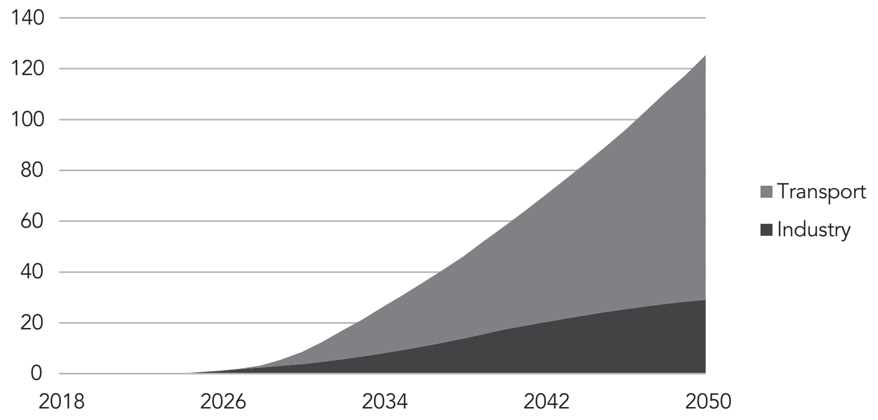


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCS (blue) or electrolysis processes (green).

- The future of hydrogen remains uncertain, with domestic consumption applications reliant on the successful development and competitiveness of the technology coupled with an available and ready supply.
- In REF, there is a small amount of consumption by the transport sector. In industry, there are a small number of use cases. This small amount of hydrogen demand is met by domestic production using steam methane reforming with CCS technology.
- The purpose of including hydrogen in REF is to reflect the possibility that hydrogen use cases are likely to develop as pilot programs and testing progress, but uptake remains slow.

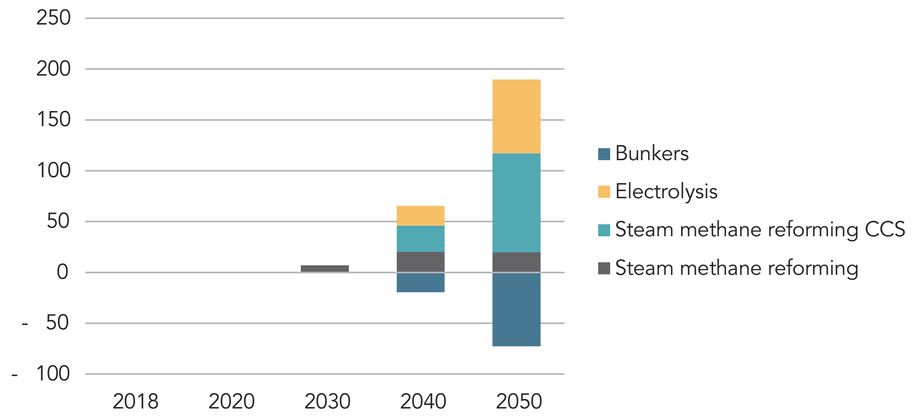
Hydrogen in the Carbon Neutrality scenario

Figure 19-43. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 19-44. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

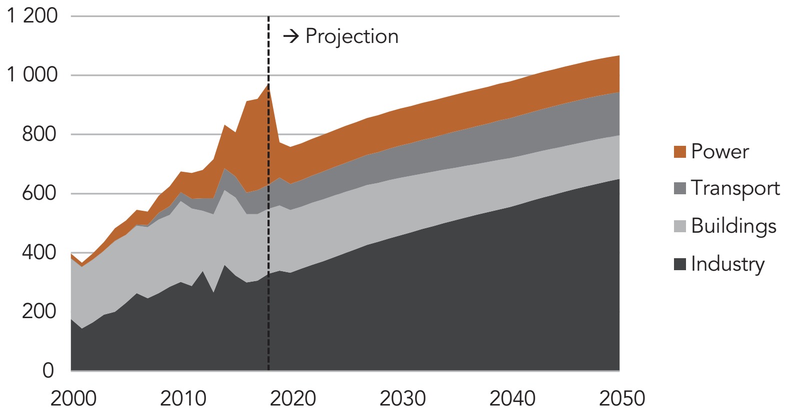


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolysis processes (green).

- In contrast to REF, the consumption of hydrogen grows rapidly in CN with multiple industry and transport use cases as the technology becomes more mature and cost competitive.
- For Thailand, hydrogen transport demand grows to almost 100 PJ with applications in trucking, aviation, and maritime activities.
- In CN, industrial hydrogen applications are developed faster than REF, reaching almost 30 PJ in 2050. Hydrogen begins to be incorporated in the industry subsectors from the late 2020s.
- While domestic consumption use cases remain modest, hydrogen production grows to almost 200 PJ by 2050, supporting an export market of 70 PJ.
- Hydrogen production from both electrolysis and steam methane reforming with CCS is dominant and grows at a similar rate from the 2040s. The combined hydrogen production from steam methane reforming and reforming with CCS is more than 60% of total hydrogen production, while the remainder of hydrogen production is from electrolysis.

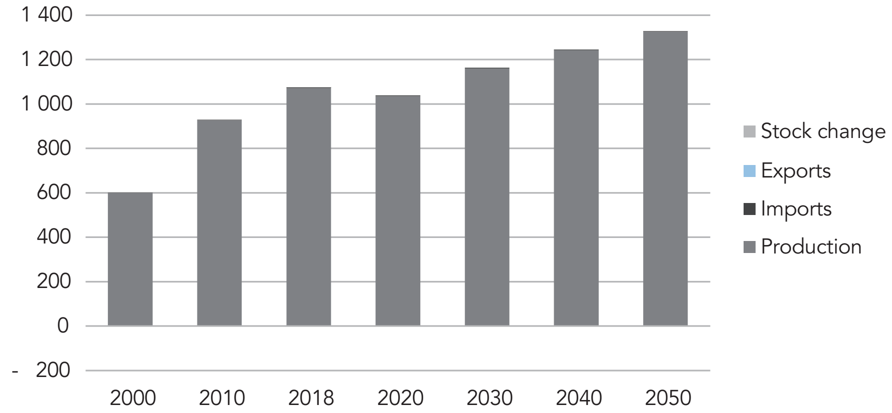
Bioenergy in the Reference scenario

Figure 19-45. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 19-46. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

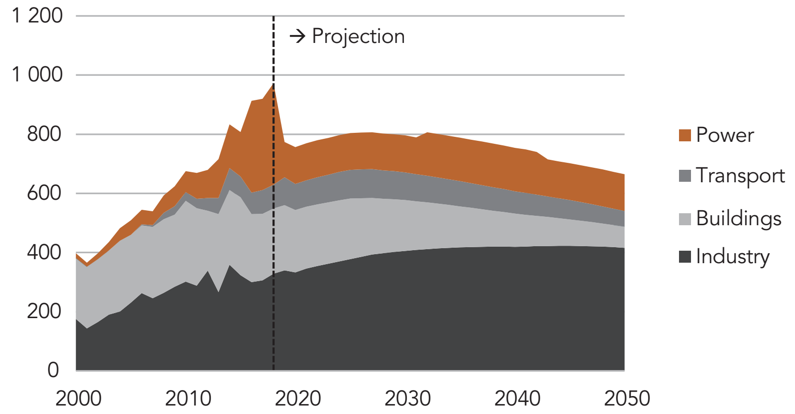


Sources: EGEDA, APERC analysis.

- Consumption of bioenergy peaked in 2018 then declined because of COVID-19. Consumption resumes in 2022 and increases almost 40% over the projection period, with the sectoral composition of the consumption shifting significantly.
- Biomass consumed by the power sector remains relatively constant while traditional biomass used in the buildings sector falls by one-third, due mostly to electrification.
- Biomass consumption doubles in the industry sector, displacing a small amount of fossil fuels in some subsectors. Industry accounts for over 60% of the consumption of these renewables by 2050.
- Biofuels consumption in the transport sector increases by 80% as a result of the Thai government moving forward with the plan to boost bioethanol and biodiesel consumption.
- The supply of bioenergy used in the different energy-consuming sectors is exclusively from domestic production sources.

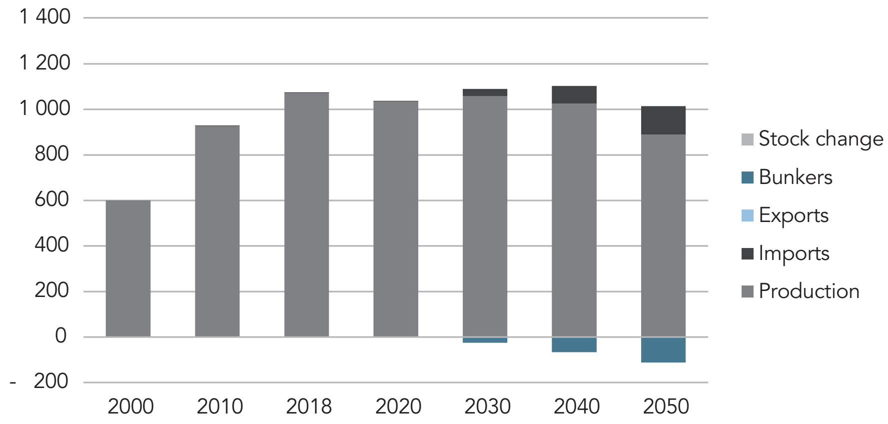
Bioenergy in the Carbon Neutrality scenario

Figure 19-47. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 19-48. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

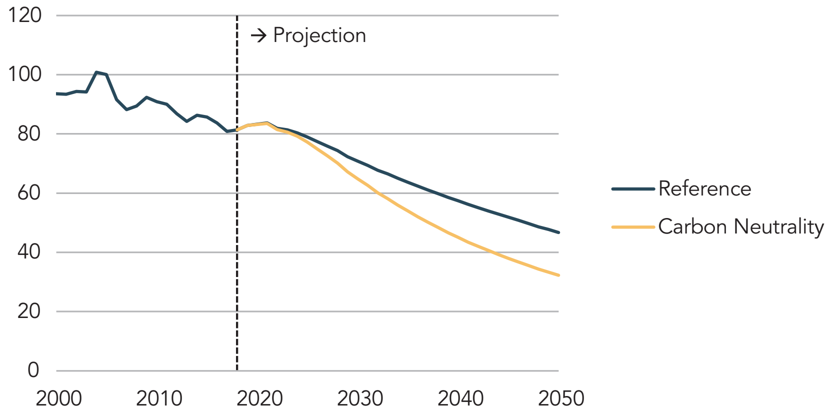


Sources: EGEDA, APERC analysis.

- Total consumption of bioenergy declines in CN despite a slight increase in 2022. Biomass consumption by the power sector is mostly unchanged.
- In the buildings sector, consumption falls by almost 70% due to increased electrification and reduced energy demand.
- Unlike the double growth in REF, biomass consumption in the industry sector increases by 27% by 2050. This is due to the increased role of electricity and hydrogen in CN, which out-competes biomass in many applications.
- The change in consumption patterns in this scenario is contributed partly to the rise of biojet fuel used by the aviation sector. Consumption of total biofuels nevertheless decreases by 30% in 2050.

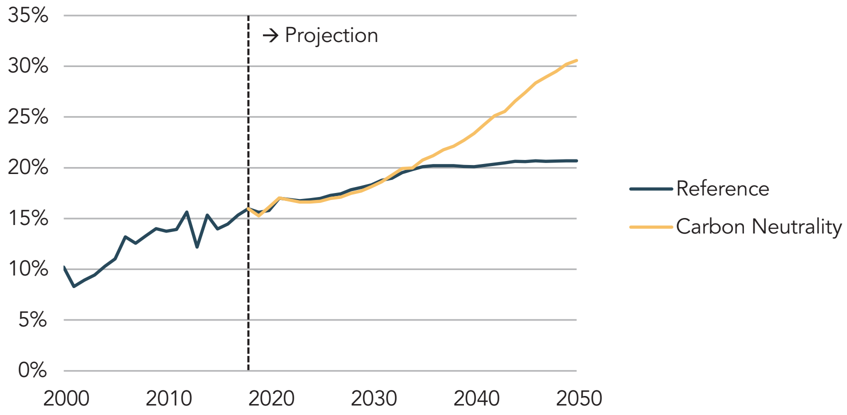
Energy intensity and modern renewables share

Figure 19-49. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 19-50. Modern renewables share in REF and CN, 2000-2050



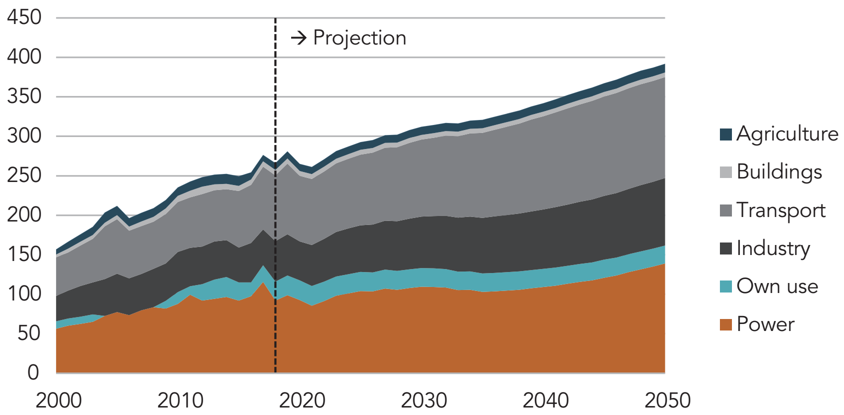
Sources: EGEDA, APERC analysis. Notes: Includes direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- Thailand's final energy intensity has improved by about 10% over the previous two decades. The relatively slow progress was mainly due to the counter-balance of relatively strong GDP growth and strong demand growth during the period.
- Final energy intensity is expected to advance more in the projection from the improvement in energy efficiency in all sectors, by over 50% for the period 2005 to 2050 in REF, and by over 70% in CN.
- Thailand's share of modern renewables in its energy mix has recently increased to more than 15%, following a rapid rise in household rooftop solar in the last decade, and increasing utility-scale renewable generation.
- Modern renewables growth is expected to continue recent historic trends and reach one-fifth of Thailand's energy mix in 2050 in REF. This growth is supported by the continued build-up of solar and wind capacity, which is rapidly displacing fossil fuel generation.
- In CN, modern renewables grow to over 30% of Thailand's energy mix in 2050. This rapid rise is mostly facilitated by rapid electrification of the transport sector, with electrification in all other sectors playing a role as well.
- Renewable generation accounts for almost one-fourth of all generation in REF, and over 40% of generation in CN.
- The rise of liquid biofuels and hydrogen also play a role in displacing fossil fuels in multiple sectors to improve the share of modern renewables in the energy mix.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

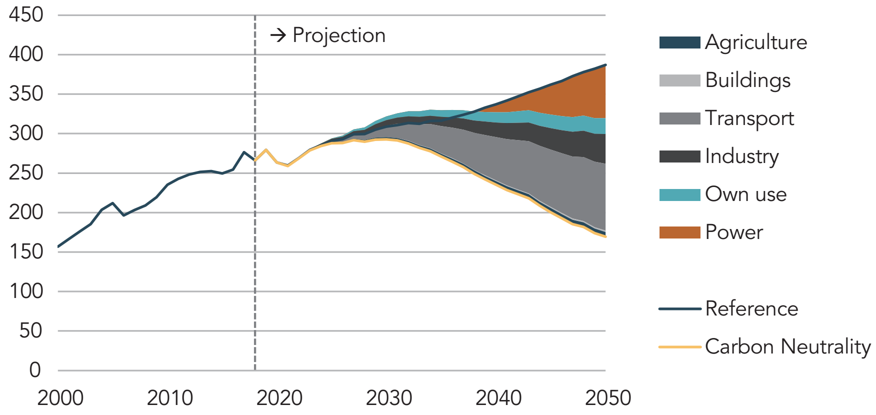
Gross CO_2 emissions

Figure 19-51. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 19-52. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

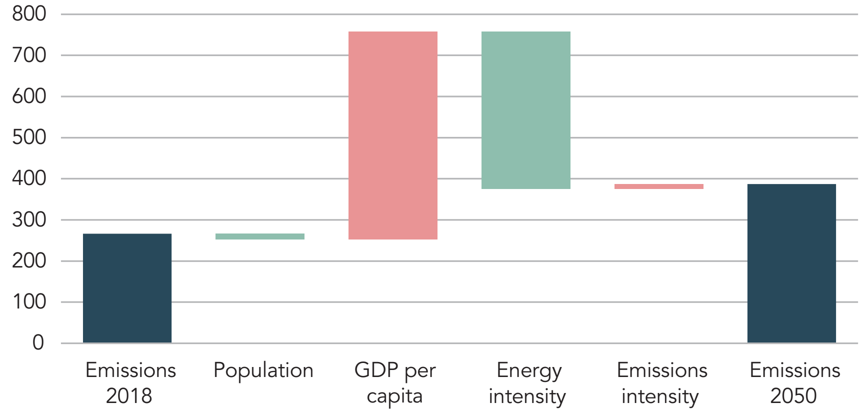


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Thailand's CO_2 emissions have increased over 70% 2000-2018, with some fluctuation in the mid-2010s due to the initial attempt to moderate the increasing trend of CO_2 emissions.
- Around 90% of Thailand's CO_2 emissions have been in the power, transport, and industry sectors. In both scenarios this dominance continues.
- In REF, despite the continued phase-out of domestic coal-fired power plants and the rise of renewable generation, power sector CO_2 emissions grow by 51% (2018-2050) due to the growth of gas-fired generation.
- It is assumed that the three key CO_2-emitted sectors start to decarbonise in the REF, as indicated from their lower rates of CO_2 emissions of 1% to 2% annually over the projection as compared to the rate of CO_2 emissions in the past decade that increased by an average of 3% annually in the same sectors.
- In REF, the power and transport sectors each produce about one-third of total CO_2 emissions. The industry sector is also important in Thailand, representing a fifth of total CO_2 emissions in 2050.
- In CN, the transport sector shows the largest absolute CO_2 emissions reduction (48%) due to wide-scale electrification, greater fuel efficiency, limited and less transport activity, and the rise of biofuels. The share of CO_2 emissions by the transport sector decreases to 25% in 2050.
- Power sector CO_2 emissions decline by 22% in due to the combination of the coal phase-out, CCS for gas-fired power plants, and incremental solar and wind generation.
- The industry sector is difficult to decarbonise, but still achieves a 6.0% reduction (2018-2050). Compared to REF, the industry emissions are 44% lower in CN. The reductions are due to material efficiency and electrification improvements.
- Thailand's current NDC aims to reduce all GHG emissions by 20% to 25% from the 2005 level by 2030. CN shows that energy sector CO_2 emissions increase by 40% between 2005 and 2030, which implies that additional efforts are necessary to satisfy Thailand's current NDC.

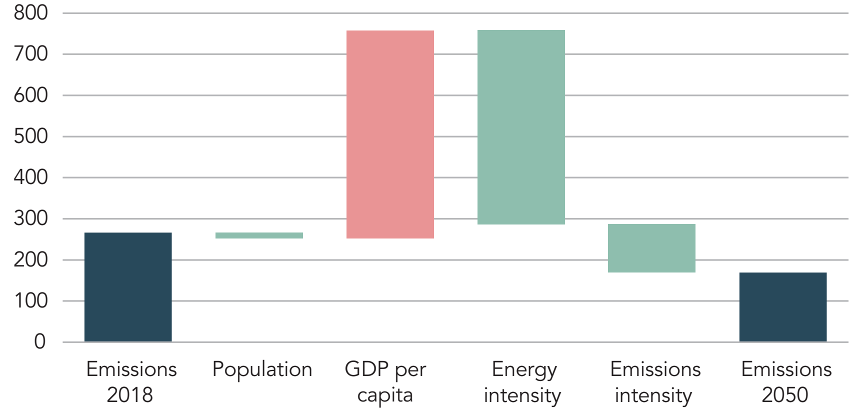
Components of CO_2 emissions

Figure 19-53. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 19-54. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- Thailand emitted 266 million tonnes of CO_2 from combustion in 2018, which amounted to about 1% of total APEC CO_2 emissions. Thailand has relatively low CO_2 emissions per capita, placing it at number 16 out of the 21 APEC economies.
- In both scenarios, the declining population does not add to CO_2 emissions, but the growth in economic activity (GDP per capita) leads to a massive increase (505 million tonnes), all else equal.
- In REF, energy intensity improvements (energy supply per GDP) offsets a large portion of the emissions increase, illustrating a decoupling of CO_2 emissions and economic activity.
- In REF, emissions intensity (per energy supply) adds to CO_2 emissions.
- In CN, both energy and emissions intensity lower CO_2 emissions, more than offsetting the increase from GDP per capita. By 2050 energy sector CO_2 emissions are about 60% of lower than 2018.
- Remaining energy sector CO_2 emissions in CN would need to be countered by negative emissions to achieve "full" carbon neutrality in 2050 and net-zero ambitions in 2065. The challenge will be even greater when including process emissions and all other greenhouse gases in the calculation.
- However, these challenges are not insurmountable. CN is only one of many plausible paths for Thailand to prosper while also meeting the goal of reducing emissions in line with its international commitments.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2 \text{ emissions}}{\text{Energy supply}}$.

Additional information

Energy Policy and Planning Office (EPPO), Energy Statistics, 2020. http://www.eppo.go.th/index.php/en/en-energystatistics/summary-statistic?orders[publishUp]=publishUp&issearch=1.

Department of Mineral Fuels (DMF), Annual Report 2020. https://dmf.go.th/public/list/data/index/menu/668/groupid/1

PTT Public Company Limited (PTT), Annual Report 2020. https://www.pttplc.com/en/Media/Publications/Report.aspx

20. United States

Highlights

Demand

- Energy demand returns to pre-pandemic levels and increases only slightly, 2% in REF, through 2050 as energy demand continues to gradually decouple from economic activity.
- Substantial demand reductions (25%) are seen in CN from a combination of technological improvements (material and energy efficiency), behavioral changes, and electrification, which are supported by policy interventions and technological progress.
- In CN, electricity becomes half of all end-use energy demand due in large part to electrification of the transport sector.

Supply

- Energy supply, which includes production, imports, and exports, remains dominated by fossil fuels in REF (70% share in 2050).
- In CN, the share of fossil fuels in energy supply falls to 39% as renewables grow substantially through 2050.
- The United States remains a net energy exporter in both scenarios, although less so in CN as global markets for fossil fuels decline.

Power

- Electricity demand is expected to grow by 44% in REF driven by steady growth in all major end-use sectors. Solar and wind generation contribute the largest increment to electricity generation through 2050 while coal-fired generation decreases by 60% from 2018 levels.
- In CN, electricity demand grows 80% due to increased electrification of the transport and industry sectors.
- Electricity demand from the transport sector more than doubles REF levels in 2050 due to electric vehicle adoption.
- The additional electricity demand, coupled with retirements of coal generation by 2035, leads to a large expansion of wind and solar generation in CN.
- In CN, natural gas power plants equipped with carbon capture and storage (CCS) begin in 2030 and generate more electricity than unabated gas plants by the mid-2040s. No large-scale deployment of CCS is assumed in REF.

CO_2 emissions

- Gross energy-related CO_2 emissions in the United States declined 14% between 2000 and 2018. This trend continues in REF with emissions declining a further 26% by 2050.
- In CN, energy sector CO_2 emissions decline by nearly 80% between 2018 and 2050, led by decarbonisation of the power and transport sectors.
- The largest incremental emissions reductions in CN relative to REF are achieved in the transport sector, primarily from the displacement of gasoline and diesel by electricity.
- In CN, gross energy sector CO_2 emissions of around 1 000 million tonnes remain in 2050 and would need to be offset via natural or technological means (e.g. direct air capture) to achieve full carbon neutrality.

About the United States

- Situated in North America between the Atlantic and Pacific Oceans, the United States is the world's third largest economy in terms of land area (9.15 million km^2) and population (327 million in 2018).
- The United States economy has accounted for more than 15% of global economic output since 1990. Gross domestic product (GDP) was USD 20.6 trillion (2018 USD, purchasing power parity) and per-capita GDP was the fourth-highest in the APEC region, at USD 57 193 (the APEC average was USD 22 536). US GDP increased 2.3% annually in real terms between 2000 and 2018.
- The United States has one of the highest levels of per-capita final energy demand in APEC. In terms of energy intensity, the United States had the sixth highest level in APEC at slightly less than 3.0 PJ per billion USD of GDP (PPP). This level is driven partly by high energy demand in the transport and buildings sectors, as vehicle ownership and use is greater than in other APEC economies and residential homes are larger. Per-capita energy demand and energy intensity vary considerably among the 50 states.
- The United States is the second-largest producer and consumer of energy in APEC and is the largest oil and largest natural gas producer in the world. The high levels of indigenous oil and natural gas production are primarily the result of technical innovations that enabled the commercial production of oil and gas from shale formations.
- In 2019, the United States held 4.0% of the world's natural gas reserves. Production takes place in 34 states but is concentrated in Texas, Louisiana, Oklahoma and Pennsylvania, which account for almost 60% of dry gas production. Since the mid-2000s, horizontal drilling and hydraulic fracturing have drastically increased natural gas production.
- Coal is mined throughout the United States, with major reserves in Wyoming, Illinois and West Virginia. Crude oil is produced mainly in Texas, North Dakota, and the Gulf of Mexico.
- Renewable resources can be found throughout the United States. Broadly speaking, the best solar resources are in the south-western continental United States as well as in Hawaii. For wind, the highest potential extends from North Dakota through Texas as well as offshore on both coasts and the western portion of the Gulf of Mexico. Geothermal potential is concentrated in the western half of the continental United States and biomass is available everywhere.
- The energy systems of the three economies in North America are well integrated with robust energy trade between the United States, Canada, and Mexico.

Table 20-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	326.7	11.3%	2
GDP	20 580	29.3%	2
TPES	93 397	27.0%	2
Production	90 959	26.7%	2
Imports	24 462	19.5%	2
Exports	21 084	19.4%	2
Electricity generation	4 433	25.9%	2
Heat production	477	4.1%	3
CO_2 emissions	5 177	24.4%	2

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh). CO_2 (million tonnes) includes the non-energy sector. Modelled CO_2 emissions exclude the non-energy sector and will differ.

Table 20-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	5 789 271	514	23.2%	1
Natural gas	454 273	14	6.7%	2
Oil	420 645	11	4.0%	3
Uranium	4 790 000	N/A	0.77%	N/A

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. Uranium (tonnes) recoverable at 130 USD kgU at the end of 2019 from OECD. See Appendix for conversion to other units.

Energy policy context and recent developments

- US energy policy is formulated at the federal, state and local levels, which has resulted in a multi-layered policy structure and numerous stakeholders. Since the energy crises in the 1970s, and the establishment of the U.S. Department of Energy in 1977, major pieces of federal energy legislation have been enacted approximately once every 10 years to address energy security, energy efficiency, taxes and subsidies, domestic energy production and consumption, including the production of renewable energy, and research and commercialisation of new energy technologies.
- The Biden Administration has a two-part strategy: i) accelerate the clean energy transition at an unprecedented rate; and ii) ensure affordable, reliable, and secure energy for all citizens.
- The United States rejoined the Paris Agreement in January 2021. The updated NDC emphasises a whole-of-government approach to climate change policy with a target of reducing net greenhouse gases (GHGs) by 50-52% by 2030 (relative to 2005).
- Other climate change goals include a zero-carbon power sector by 2035, and a net-zero economy by 2050.
- Also, in January 2021, President Biden withdrew the federal permit for the Keystone XL pipeline and postponed future federal oil and gas lease sales and slowed drilling permits on existing leases. Subsequently, the Administration has proposed to include a social cost of carbon component in the Environmental Impact Statements required for oil and gas lease sales.
- The Administration views research and commercialisation programs designed to address climate change as a major economic opportunity. It has set goals for three ambitious "Earthshots":
  - Develop the technology to produce green hydrogen at 1.00 USD/kg
  - Develop long duration energy storage (batteries with >10 hours capacity at utility scale)
  - Reduce the cost of Carbon Dioxide Recovery (CDR) technologies to 100 USD/ton
- With respect to LNG trade, the Administration has not yet decided whether to approve the LNG expansion proposals from Sempra, Magnolia, and Venture Global.
- The 1 trillion USD Bipartisan Infrastructure Bill was signed into law in November 2021. It includes several important energy provisions:
  - 65 billion USD for clean energy transmission and electric grid upgrades
  - 66 billion USD to expand rail and transit
  - 7.5 billion USD for EV charging stations
  - 8.1 billion USD for CDR, CO_2 pipelines and large scale CCUS projects
- With respect to energy security, the Administration is conducting a variety of studies focusing on critical mineral supply chains. There is also increased funding for cybersecurity programs to harden energy infrastructure against cyber attacks.
- Several states are also adopting policies to accelerate the energy transition. California has implemented perhaps the widest array of carbon-related policies:
  - Committed to reduce carbon emissions to 1990 levels by 2030
  - Renewable Portfolio Standard (RPS) that sets continuously escalating renewable energy procurement requirements for the state's load-serving entities
  - State financing for energy efficiency upgrades for low-income households
  - Demand response programs designed to shift usage away from times of peak usage and toward times of peak supply
  - Feed-in tariff programs for residential solar
  - Implementation of a Low Carbon Fuel Standard (LCFS) designed to encourage the production and use of low-carbon transportation fuels.
  - An Executive Order that requires all new cars and passenger trucks sold in California by 2035 to be zero-emission vehicles

Note: Policy context and notable developments are current as of February 2022.

Scenarios in the 8th Edition

- The two scenarios are intended to illustrate potential long-term pathways for energy demand, transformation, and supply in the United States with respect to uncertainty about the future.
- **The Reference scenario (REF)** is a pathway where existing trends in technology development and deployment, and policy frameworks continue in a similar manner. REF represents an upper bound on energy demand and lower bound on decarbonisation progress.
- On the demand side, energy efficiency and fuel economy standards continue to improve gradually. Electrification of the transport sector begins as electric vehicle sales increase, but without strong policy incentives. The industry sector is assumed to gradually make improvements in energy efficiency and fuel switching. In the power sector, fuel switching from coal to gas and renewables such as large-scale PV continues while nascent technologies like CCS are not incorporated. Global demand for oil, gas, and coal continues and provides an export market for the United States.
- **The Carbon Neutrality scenario (CN)** illustrates a potential pathway where energy efficiency, fuel switching, and technology advance substantially to reduce CO_2 emissions from fossil fuel combustion by 2050.
- While CN is more conservative than the existing NDC and policy ambitions, it is broadly in line with other leading decarbonisation studies of the United States. CN represents one possible decarbonisation pathway.
- Technology maturity and commercial availability are key assumptions in CN. Hydrogen supply chains – blue and green – are assumed to be available at scale starting in 2030 to serve end-use applications in buildings, industry, and transport sectors. While technically possible, hydrogen consumption by the power sector is not considered.
- CCS is assumed to be commercially available. CCS is utilised earlier (2030) and in greater quantities in industry. CCS retrofits and new-builds become available in the power sector starting in 2030.
- CN is intended as a guide to show the magnitude of CO_2 reductions possible in the context of the assumptions made about technology diffusion, costs, and global trends.
- CN can be used to quantify the magnitude of remaining CO_2 emissions that would require further action from policymakers, industry participants, and researchers.

Table 20-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for the United States

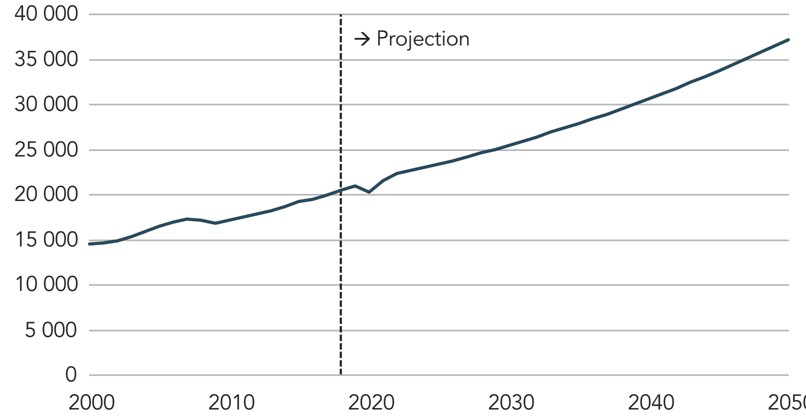
Table 20-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UN medium) • GDP: World Bank (historical), OECD (projections), IMF (COVID-19 impacts)	• Same as Reference
Buildings	• Gradual improvements to efficiency	• More aggressive improvement in energy efficiency, mainly in space heating and cooling starting in 2025. • Reduction of heating oil in residential sector. • Increased electrification of water and space heating and cooking. • Hydrogen blending with natural gas
Industry	• Small uptake of CCS for steel, cement, and chemical starting in 2040. • Small amount of hydrogen for steel and chemicals sectors starting in 2035. • Energy efficiency and electrification improvements follow historic trends to 2050. • Small amount of fuel switching in multiple industry subsectors, primarily to electricity, biomass, and gas.	• Material efficiency improvements for steel, cement, and chemicals subsectors. • Hydrogen for steel production and chemicals introduced in 2025. • Higher fuel switching rates from coal to biomass, electricity, and natural gas in multiple industry subsectors. Energy efficiency more rapid than REF. • Uptake of CCS for steel, cement, and chemicals starting in 2030.
Transport	• Fleet remains mostly ICEs • Fuel efficiency follows recent trends • Electric vehicles sales grow slowly reaching 60% by 2050.	• Improved fuel efficiency and hybridization. • New vehicle sales share reach 90% EVs in 2035 and increase to 100% in 2050. • Hydrogen fuel cell vehicles utilised for heavy road transport. • Aviation sector gradually adopts biojet and hydrogen fuels after 2025.
Power and heat	• Minimal production of electricity using coal-fired power plants. Only units under a technical minimum operation basis will remain after 2035 in some US regions. • Small deployment of offshore wind. • No CCS is deployed	• Approaching carbon neutral power sector by 2035. • Retain existing nuclear fleet, with expansion only using small modular reactors. • Large-scale adoption of offshore wind projects. • CCS adoption for natural gas plants starting in 2030.
Supply	• LNG export capacity reaches 123 Mtpa by 2027; peaks at 135 Mtpa in 2030s. • Gas pipeline exports guided by EIA AEO 2021. • Crude oil production guided by EIA AEO 2021. • Natural gas production and exports increase to meet export markets demand. • Coal exports and production fall in response to declining internal and overseas demand.	• Lower oil and natural gas production on federal lands. • Exports decline to match lower global oil, gas, and coal demand in the long term. • Export market for oil is 75% below REF levels in 2050; gas 42%; coal 82.5% • Coal exports and production fall in response to declining internal and overseas demand.
Climate	• NDC targets not explicitly considered	• Carbon neutral energy sector by 2050 (excluding removals and negative emissions)

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

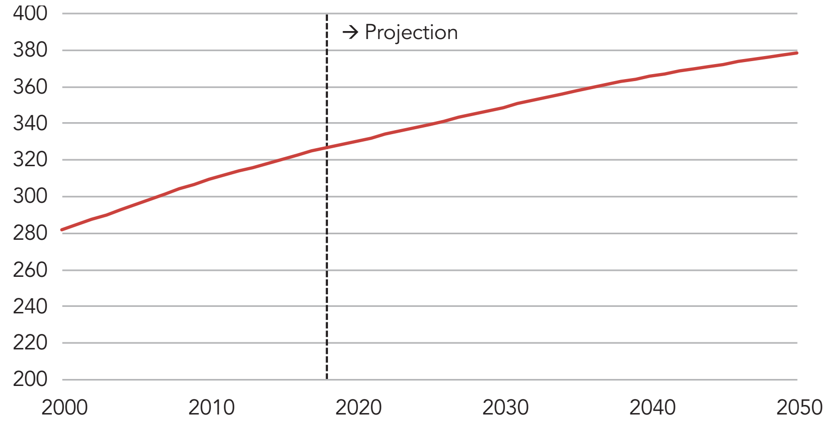
Macroeconomic backdrop

Figure 20-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from OECD and internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 20-2. Population in millions, 2000-2050

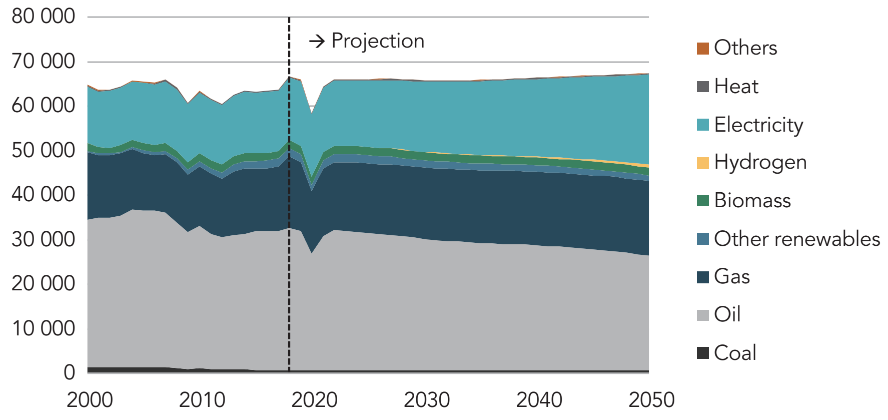


Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- Real GDP dropped by 3.5% in 2020 due to lockdowns and reduced economic activity associated with the COVID-19 pandemic.
- As of October 2021, the US economy appears to have bounced back strongly in 2021 and is expected to grow 6% in 2021.
- Inflation has been higher and more sustained than many thought likely earlier in 2021. It is now expected to be 4.3% for the year.
- Widespread vaccinations, easing of lockdown restrictions, higher federal expenditures, and accommodative monetary policies have all contributed to robust GDP growth and higher inflation.
- Further federal stimulus and increased taxes on corporations and high-income individuals, as reflected in the Biden Administration's Build Back Better legislation, is uncertain. But if enacted as proposed it would likely contribute to higher GDP growth and inflation.
- The 2020 Census recorded a US population of 331 million and reflects an average annual growth rate of 0.7%.
- GDP and population assumptions are the same for both scenarios.

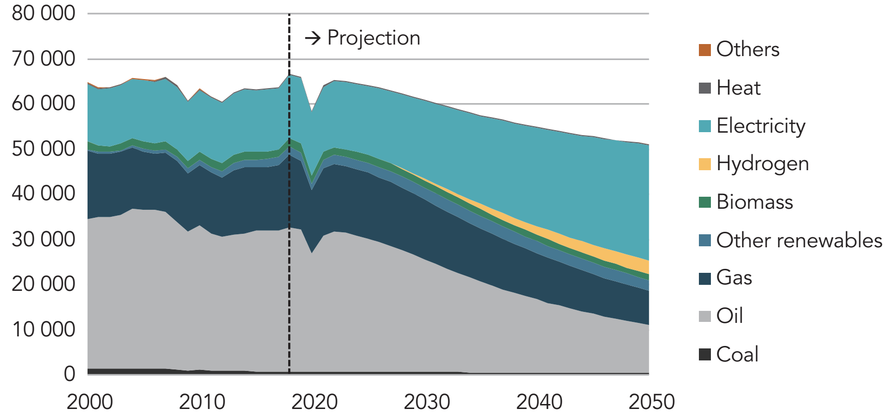
End-use energy demand

Figure 20-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 20-4. Energy demand in CN, 2000-2050 (PJ)

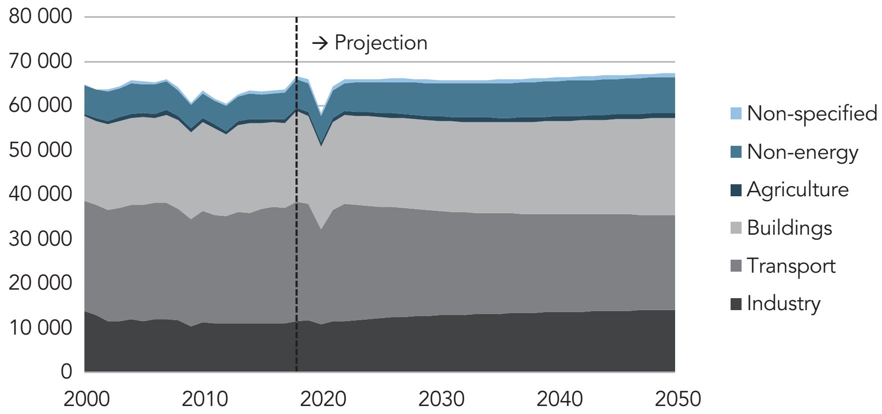


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Energy demand from 2000 to the start of the COVID-19 pandemic in 2020 was relatively flat despite the steadily growing population and economic activity. In 2020, travel restrictions and a shift to "work from home" resulted in a demand decrease larger than the 2008 Global Financial Crisis. Demand is assumed to follow a "v-shaped" recovery in both scenarios when travel restrictions are removed and return to office policies are implemented.
- In REF, demand returns to pre-pandemic levels and increases only slightly (2%) through 2050 as energy demand continues to gradually decouple from economic activity.
- Substantial demand reductions are seen in CN from a combination of technological improvements (material and energy efficiency), behavioral changes, and fuel switching (electrification), which are supported by policy intervention.
- Prior to the pandemic, oil was the most consumed energy carrier at end-use due to the predominance of the transport sector. Continued technology improvements from manufacturers and fleet fuel economy standards are assumed to gradually reduce oil consumption in REF.
- Electricity increases in both scenarios, reflecting increased fuel switching in all end-use sectors. In the buildings sector, heat pumps, electric boilers, heaters, and cooking appliances lead to a shift away from gas to electricity in REF.
- CN assumes optimistic yet practical limits to technology adoption. As a result, some oil consumption remains in certain regions of the United States where fuel switching is not practical.
- Hydrogen as an energy carrier slowly grows in REF. The limited growth presents a possible outcome where the economics of hydrogen do not advance rapidly enough relative to other energy carriers.
- More favourable economics for hydrogen are assumed in CN, leading to increased penetration in the industry and transport sectors supported by initiatives like the U.S. Department of Energy's Hydrogen Energy Earthshot, which aims to reduce the cost of "clean" hydrogen by 80% in one decade.

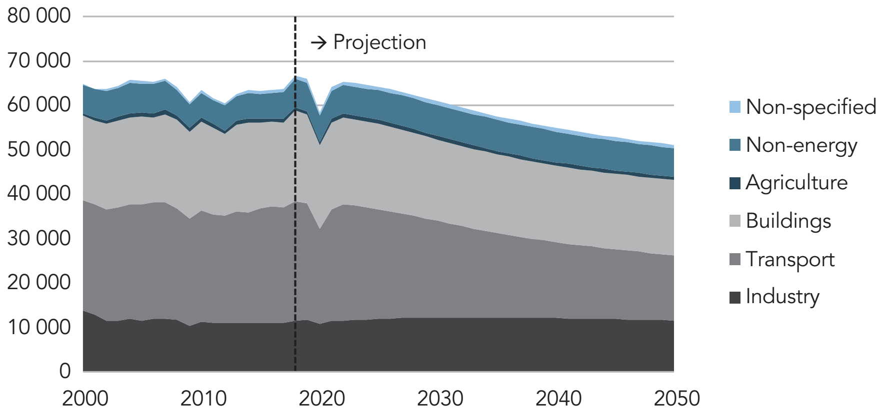
End-use energy demand by sector

Figure 20-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 20-6. Energy demand by sector in CN, 2000-2050 (PJ)

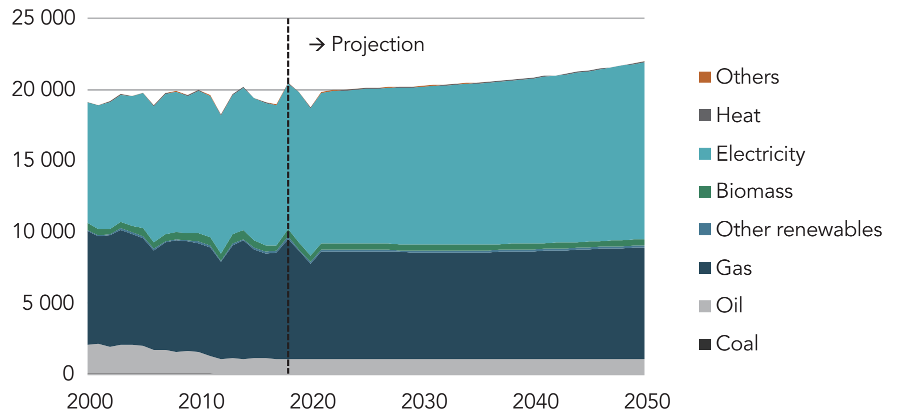


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- Unlike rapidly growing economies in APEC, no significant structural shifts in sectoral energy demand are anticipated in the United States.
- The sectoral composition of energy demand remained relatively unchanged prior to COVID-19, with transport and buildings sectors consuming most of the energy, respectively. The transport sector registered the largest decrease between 2019 and 2020 – by nearly one-fifth – from travel restrictions and a shift to work from home practices.
- In REF, demand recovers and grows slightly from pre-pandemic levels. Growth in demand from the industry (including non-energy) and buildings sectors offset declines in the transport sector.
- In CN, increased levels of material and energy efficiency improvements, and fuel switching mean that the same amount of service demand (passenger-kilometers, space heating, etc.) are met with roughly one-fourth less energy demand compared to REF in 2050.
- The largest reduction in energy consumption (45%) occurs in the transport sector through a combination of efficiency improvements (CN). Light and heavy-duty vehicles remain the bulk of the US transport fleet. A large transition to mass transit options is not assumed. More stringent fuel economy standards are implemented, which reduce liquid fuel consumption. Electrification of the transport fleet increases rapidly as the share of EVs reaches 90% by 2035 then increases to 100% by 2050.
- Demand by the buildings sector declines by almost one-fifth due to strengthened energy efficiency measures. Policies at the federal level (as well as state and utility efficiency programs) provide incentives and subsidies for energy improvements. Federal and state minimum energy efficiency standards drive mandatory improvements as new equipment is installed in buildings.

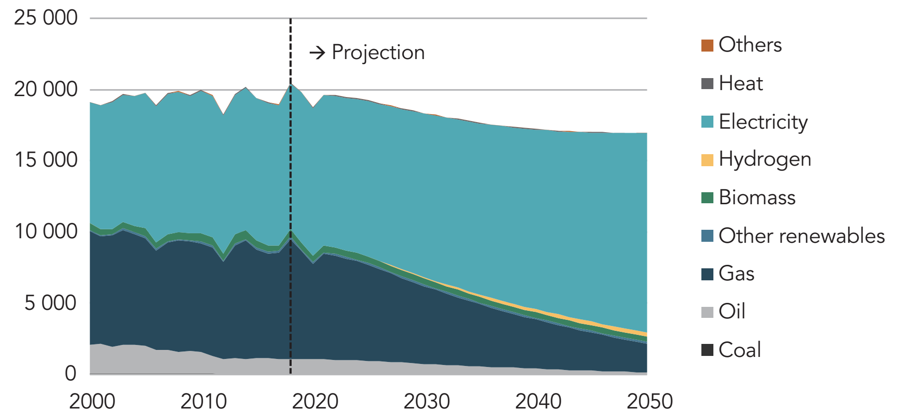
Buildings energy demand

Figure 20-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-8. Buildings energy demand in CN, 2000-2050 (PJ)

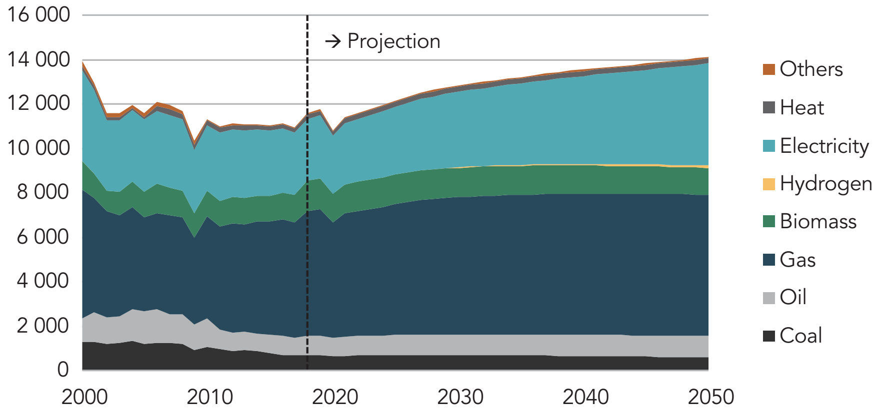


Sources: EGEDA, APERC analysis.

- The buildings sector is the second largest end-use consumer of energy in the United States. In recent years, more than half of all buildings energy consumption occurred in the residential sub-sector, due partly to population growth. However, service sub-sector consumption has been increasing. This trend continues in both scenarios.
- Around half of the United States buildings sector demand was satisfied by electricity in 2018. Electricity is used for end-use activities such as lighting, heating, cooking, and cooling. Electricity increases in both scenarios. In REF, electricity consumption continues to increase on the margin without displacing other fuels like gas or oil.
- Electricity consumption increases substantially in CN. Heat pumps, electric boilers, heaters, and cooking appliances lead to a shift away from gas to electricity. There are limits to technology shifts and fuel switching. Limits include economic, behavioral, infrastructure, and local ordinances. As a result, not all gas is displaced by electricity.
- Additionally, the United States is a large and diverse geographic area with different climate types, which have influenced the heating and cooling solutions. Some oil consumption remains in regions of the United States where fuel switching is not practical or economic.
- Energy efficiency measures are essential for reducing energy demand. Policies at the federal level (as well as state and utility programs) provide incentives and subsidies for energy improvements. Federal and state minimum energy efficiency standards drive mandatory improvements as new equipment is installed in buildings. Municipal level building codes are also assumed to improve energy efficiency for existing and new building stocks.
- Hydrogen and biomass play a small role in CN. Assumed hydrogen applications in the building sector are limited to fuel cells to produce electricity. Uncertainties around commercially competitive appliances and lack of infrastructure limit the penetration of hydrogen in the buildings sector.

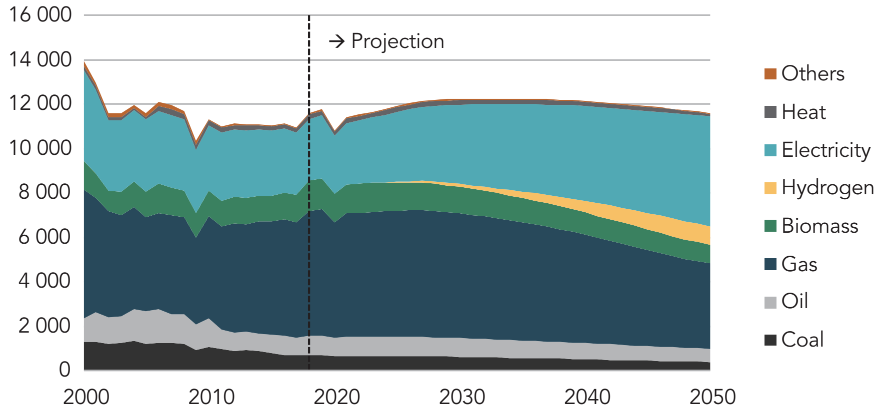
Industry energy demand

Figure 20-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 20-10. Industry energy demand in CN, 2000-2050 (PJ)

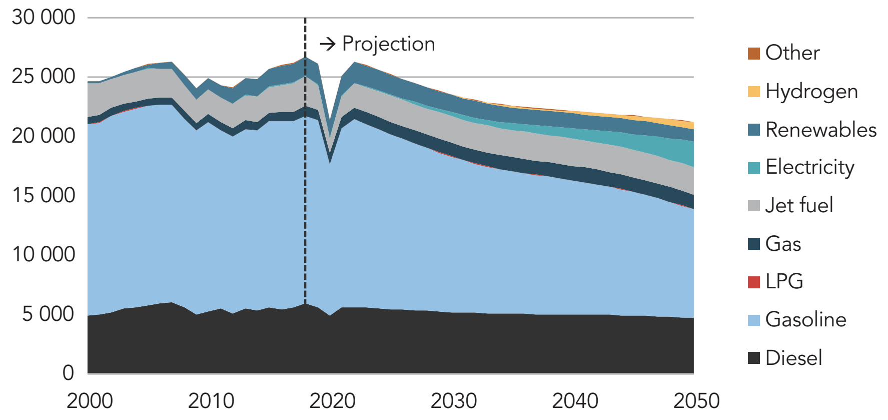


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- The industry sector is the third largest end-use consumer of energy in the United States (2018). Together, the chemicals and pulp & paper sub-sectors comprise over 40% of industry energy demand, excluding non-energy. Over 25% is consumed by smaller sub-sectors such as textiles, construction, and machinery, followed by cement ("non-metallic minerals") and iron & steel production.
- Industrial output is assumed to be the same in both scenarios, with no notable changes in sub-sector shares through 2050. REF assumes improvements in material and energy efficiency consistent with historical rates.
- Ambitious assumptions are made for increased material and energy efficiency and fuel switching in CN. These assumptions lead to a peak in industry sector energy demand in the early 2030s that slowly declines to levels seen in the early 2020s.
- Fossil fuels are an essential input for industrial processes. Gas is the most consumed fuel in the beginning of the projection and remains the largest share in REF. Gas consumption decreases in CN and is substituted by biomass and hydrogen. Coal is used primarily for steel production where it is combined with iron ore. Coal consumption tapers in both scenarios but is not fully eliminated due to technical process requirements.
- Hydrogen is consumed in both scenarios. In REF, cost-competitive hydrogen is assumed to be available in small amounts starting in 2035. While hydrogen is already produced as a byproduct in several industrial processes, uptake is limited and does not displace a lot of gas or other energy carriers.
- Hydrogen plays a more important role in CN. It is assumed to be cost competitive starting in 2030 and viable as a substitute for natural gas. Continued development along the entire hydrogen supply chain by the private and public sector is assumed to support the viability of hydrogen.
- Electricity becomes the most consumed energy carrier in CN. However, there are limits to electrification. Some sub-sectors like iron & steel have stringent requirements for process heat. In other sub-sectors, displacing gas with hydrogen or biomass can be more cost effective when considering the ability to use existing infrastructure with the "drop-in" replacements.

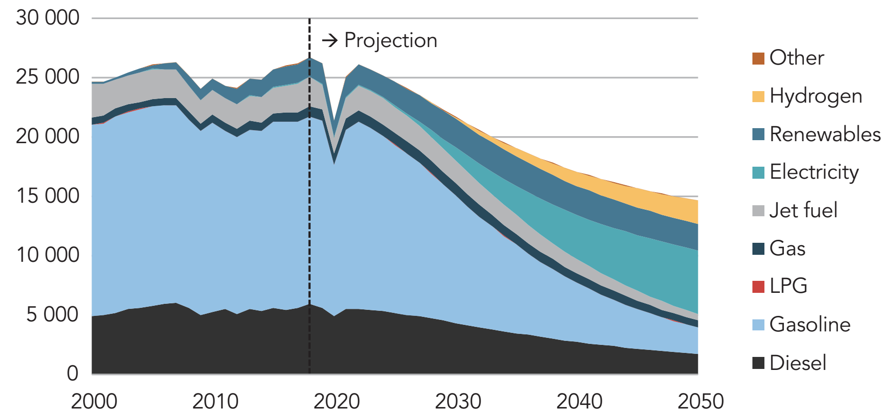
Transport energy demand

Figure 20-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 20-12. Transport energy demand in CN, 2000-2050 (PJ)

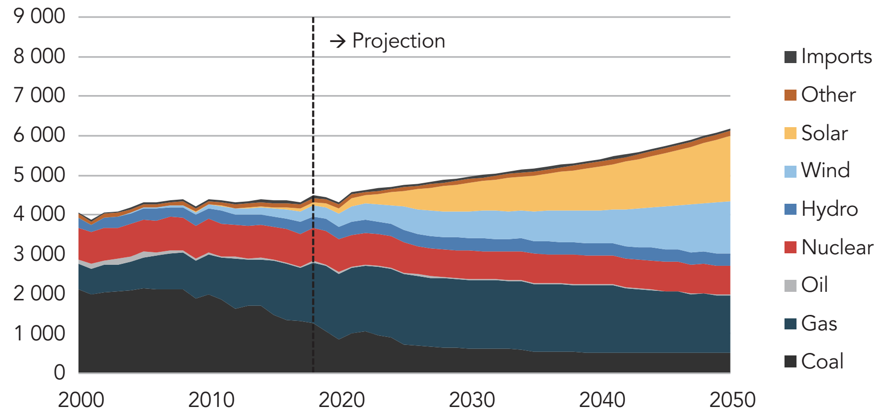


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport is the largest end-use demand sector in the United States. Around 85% of all domestic transport-related demand in 2018 is related to road transport. Light-duty trucking, which includes pickup trucks and SUVs, dominates road demand (42%) followed by heavy trucking (29%) and light duty vehicles (27%). Demand by rail, which includes passengers and freight, is a small share of transport demand (1.0%) and a low starting point for any shifts in modal consumption.
- The transport sector was most affected by COVID-19 related lockdowns and shift to work from home for some workers. After a large decrease in fuel consumption in 2020, demand rebounds as mobility resumes. After 2022, energy consumption in both scenarios breaks from the pre-COVID-19 trend and declines.
- In REF, demand steadily declines in the mid-2020s due to continued fleet fuel economy improvements. Fuel switching from gasoline to electricity leads to additional demand reduction beginning in the late 2020s through 2050. Diesel is still utilised for heavy trucking and buses, although fuel switching to hydrogen begins in the mid-2030s.
- CN assumes an even greater divergence. Energy consumption falls by over 40% partly due to fuel switching from gasoline, and to a lesser extent, diesel. The fuel mix diversifies as electricity, renewables (biofuels), and hydrogen make up most of the fuel consumption by 2050.
- An implicit ban on full ICE vehicle sales is implemented through more stringent fleet fuel economy standards inspired by the proposed updates for 2024-2026 by the U.S. National Highway Traffic Safety Administration. Using current technology, only hybrid vehicles achieve the standards. ICEs continue as part of the vehicle stock until their useful life is reached.
- Electrification of the transport fleet increases rapidly as the share of EVs reaches 90% by 2035 then increases to 100% by 2050. Charging infrastructure and EV manufacturing capability is assumed to be sufficient to support this level of expansion. The inherent conversion efficiency of EVs vis-à-vis ICEs contributes to lower energy consumption for the same level of service demand.
- Hydrogen mostly displaces diesel consumption in fleet vehicles, such as buses and heavy-duty trucking.

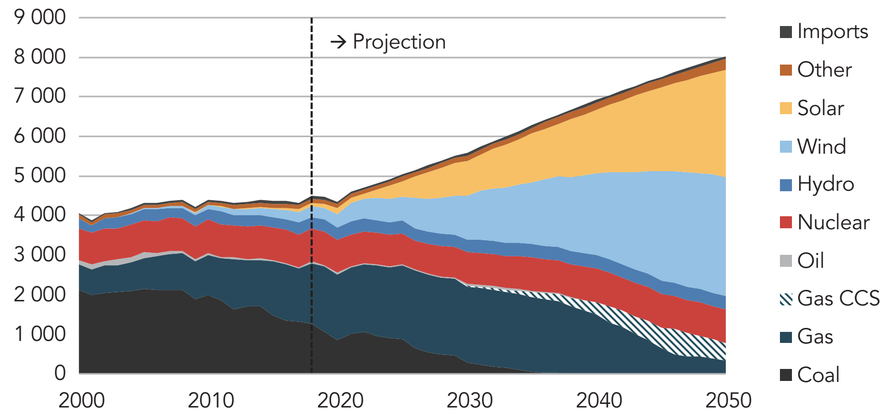
Electricity generation

Figure 20-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 20-14. Electricity generation in CN, 2000-2050 (TWh)



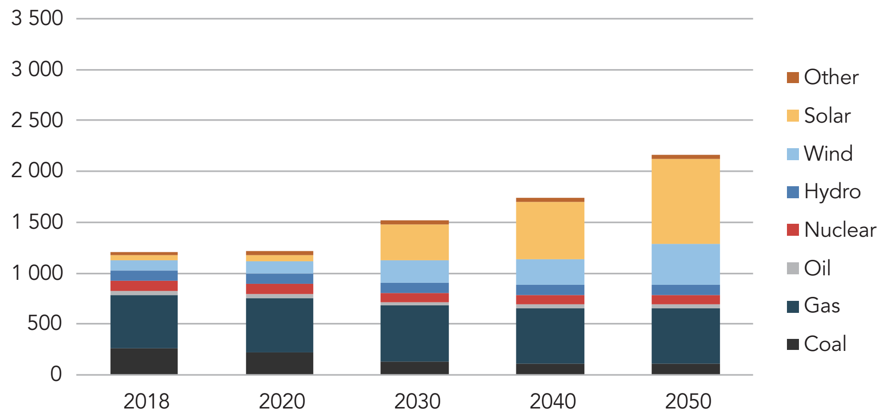
Sources: EGEDA, APERC analysis.

- Coal has dominated electricity generation in the United States. However, in the last decade, there has been a substantial shift to gas.
- In 2018, more electricity was generated by gas than coal. In both scenarios, electricity generation is expected to grow from 2018 levels to meet rising demand.
- Electricity demand is expected to grow by 44% in REF, driven by steady growth in all major end-use sectors.
- In the industry sector, fuel switching leads to a two-thirds increase in electricity demand. In transport, sales of EVs add over 2 000 TWh of demand in 2050. This demand is satisfied increasingly by non-fossil fuels. Solar and wind generation make up the largest incremental electricity generation in this period while coal-fired generation decreases by 60% from 2018 levels. Gas remains resilient.
- Electricity demand increases over 80% in CN (2018-2050). In the transport sector, EV sales shares increase from 90% in 2035. Transport sector electricity demand more than doubles from REF levels. In industry, electrification of some industrial processes contributes additional demand.
- The additional electricity demand, coupled with retirements of coal plants by 2035, leads to the expansion of wind and solar generation in CN. Offshore wind is assumed to be available along the eastern seaboard beginning in the late 2020s.
- The share of generation by fossil fuels falls to under one-third by 2035. By 2050, gas is the only fossil fuel generation remaining. CCS-equipped gas generation begins in 2030 and generates more electricity than unabated gas by the mid-2040s.
- Nuclear generation is relatively constant in both scenarios. While generation from nuclear expands in CN, it is not a major driver of power sector decarbonisation. A reduction in nuclear generation would require additional generation from firm technologies, possibly gas or offshore wind.
- Electricity generation in CN is less ambitious than other estimates of a "carbon pollution free" United States electricity system by 2050. Comparatively, CN assumes higher barriers for technology adoption.

Note: CCS refers to carbon capture and storage.

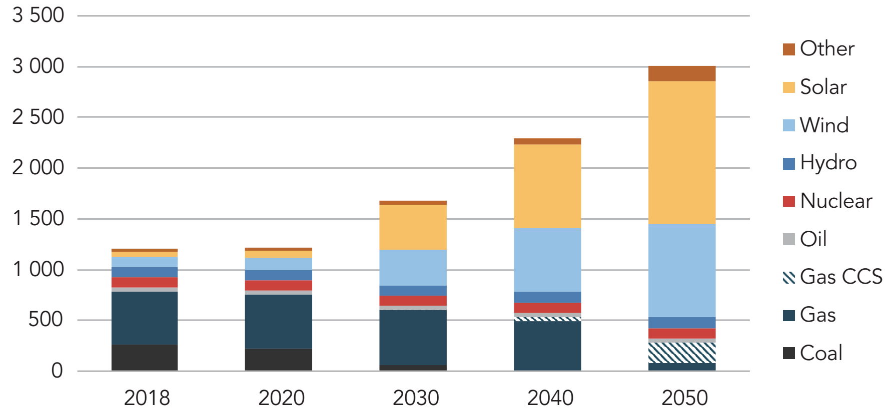
Generation capacity

Figure 20-15. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 20-16. Generation capacity in CN, 2018-2050 (GW)



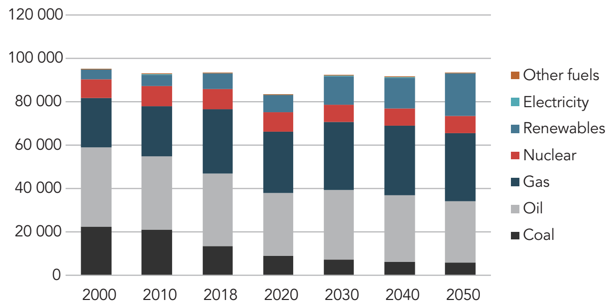
Sources: EGEDA, APERC analysis.

- Capacity increases in both scenarios as solar and wind additions are used to meet increased electricity demand. Total generation capacity increases by roughly 80% in REF and over 150% in CN.
- Nearly all capacity additions are solar and wind technologies. Between 2018-2030, solar capacity increases an average 25 GW (REF) and 32 GW (CN).
- Capacity expansion outpaces electricity demand growth (50%) due to the low capacity factors of solar and wind technologies. The pace of solar capacity expansion increases in CN, with an average of 32 GW installed annually in REF, increasing to 48 GW per year between 2030 and 2050.
- Wind, both onshore and offshore, generates more electricity than solar in CN, but requires less additional capacity due to higher capacity factors than solar. Offshore leases are assumed to be approved to allow for a nine-fold increase in capacity. Over 25 GW per year of wind capacity is added in CN.
- Battery storage capacity increases as solar and onshore wind capacity grows. Storage capacity additions accelerate in the 2040s. By 2050, 98 GW of battery capacity is deployed (shown in Others). Additional battery storage is possible given improvements in economics and efficiencies.
- Coal capacity slowly declines in REF, reflecting the ongoing trend of fuel switching from coal to gas. Coal is not completely phased out to illustrate a potential pathway where some support for the technology remains.
- In CN, it is assumed that coal is phased out instead of retrofitting existing units with CCS capability. CCS retrofits of gas-fired units is considered in favour of coal-fired units given the lower carbon intensity of gas units. Retrofitting of gas-fired units begins in 2030 and continues until two-thirds of gas capacity has CCS. By 2050, nearly all (96%) power capacity is zero or low CO_2 emission technologies.
- The existing nuclear fleet is retained in CN. No new large-scale facilities are considered.

Notes: CCS refers to carbon capture and storage. No CCS for coal is assumed.

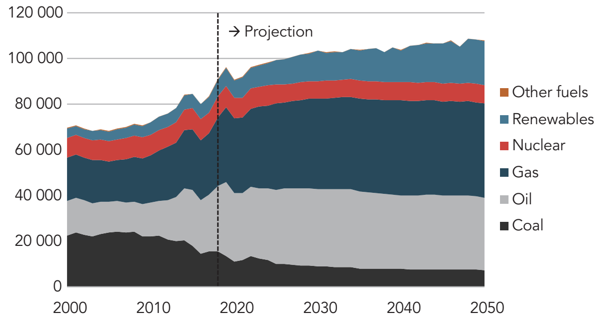
Energy supply in the Reference scenario

Figure 20-17. Total energy supply in REF, 2000-2050 (PJ)



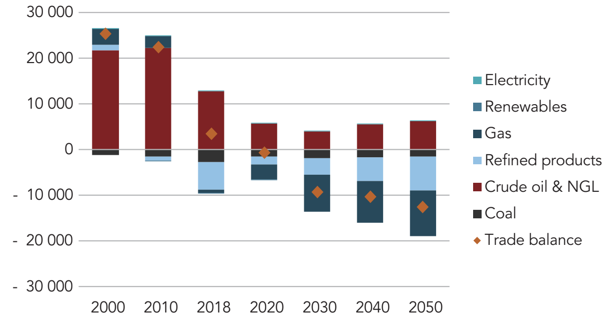
Sources: EGEDA, APERC analysis.

Figure 20-18. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-19. Net energy trade in REF, 2000-2050 (PJ)

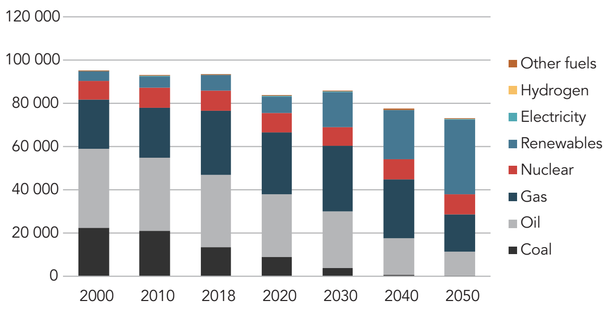


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- US energy supply is dominated by fossil fuels (coal, oil, and gas). Nuclear (uranium) and renewables (including solar and wind energy equivalents) comprise the remainder of energy supply.
- Over three-quarters of energy production is fossil fuels. Coal production has declined since the 2000s based on changing consumption trends in the power sector, where natural gas has increasingly been substituted for coal.
- Oil and gas production has expanded due to technological and commercial advances in horizontal drilling and hydraulic fracturing. This technology has unlocked oil and gas resources in various regions across the United States including Montana, Texas, Louisiana, and Pennsylvania.
- The United States becomes a net energy exporter through the end of the projection period. The United States remains a net exporter of gas and petroleum products, and to a lesser extent, coal.
- The United States continues its rise from a net importer of natural gas to a net exporter over the past decade. Growth in LNG export capacity over the past decade and the commissioning of pipeline projects to Mexico increase gas exports. Imports from Canada decline in favor of lower-cost domestic supplies.
- Crude oil and NGLs net imports have dropped substantially from the 2000s. The United States remains a net importer of crude oil and NGLs for use in refineries.

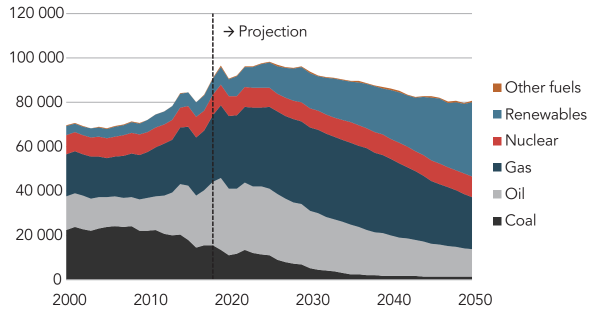
Energy supply in the Carbon Neutrality scenario

Figure 20-20. Total energy supply in CN, 2000-2050 (PJ)



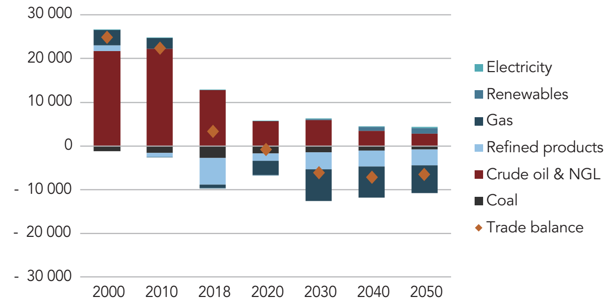
Sources: EGEDA, APERC analysis.

Figure 20-21. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-22. Net energy trade in CN, 2000-2050 (PJ)

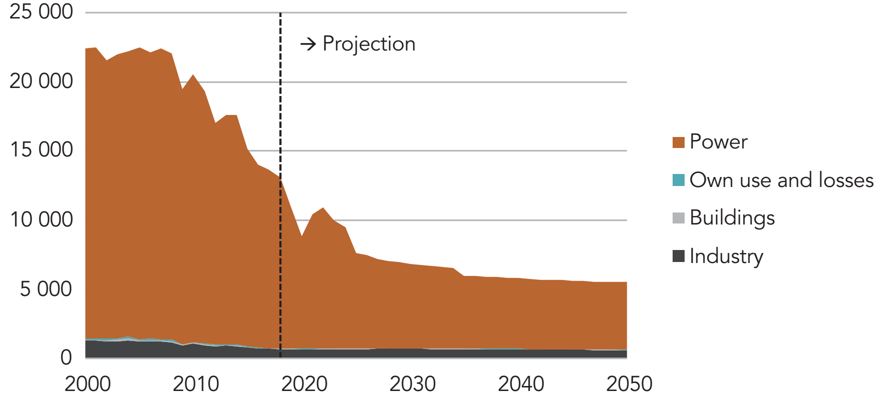


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Energy supply in CN transitions to being more focused on renewables. Coal almost completely exits the supply mix due to consumption reductions in the power and other sectors. Lower demand for refined products leads to lower oil supply.
- Production levels follow domestic and global consumption trends. Coal production drops substantially through the 2020s and 2030s while global export demand drops. Oil consumption, in the United States and globally, declines leading to lower production and exports.
- Natural gas supply remains more resilient but still declines through 2050. Pipeline exports to Mexico are half of REF levels in 2050 due to declining consumption (and imports).
- LNG exports continue to grow into the 2030s to nearly the same levels seen in REF, given that natural gas factors into many carbon neutral plans in APEC and globally. However, LNG exports in CN are 25% lower than REF in 2050.
- Net exports are lower than REF due to a smaller global market for fossil fuels. This is not a reflection on energy security, but a reflection on the challenges for producer-exporter economies like the United States.

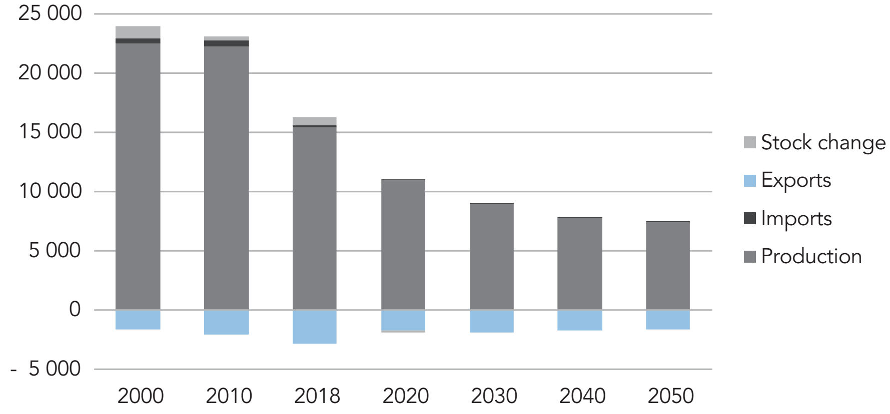
Coal in the Reference scenario

Figure 20-23. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-24. Coal production, imports, and exports in REF, 2000-2050 (PJ)

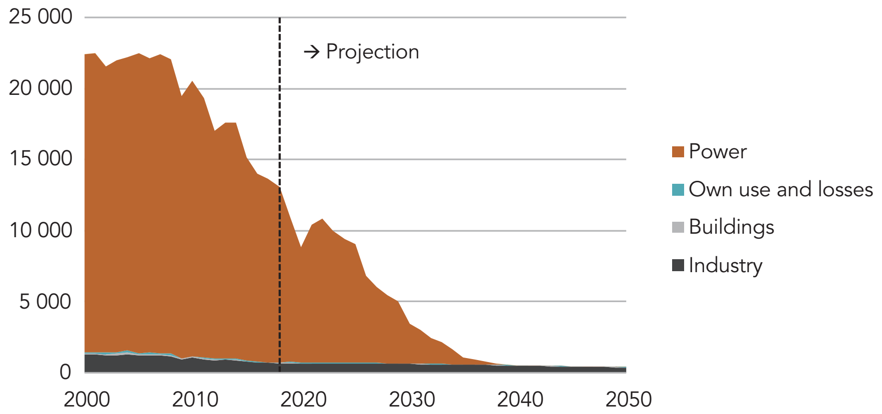


Sources: EGEDA, APERC analysis.

- Coal consumption in the United States has fallen by over 50% since 2000.
- Nearly all coal consumption occurs in the power sector. Fuel switching from coal to natural gas has been the biggest driver of declining coal consumption in the US. The rate of decline slows in the mid-2020s as natural gas plant conversions and new builds slow, reducing fuel switching.
- By 2050, power sector coal consumption is almost one-fifth of the level observed in 2000.
- Metallurgical coal is used for iron and steel production. This consumption is expected to remain steady through 2050.
- Coal production follows the decline in consumption.
- Coal exports decline through 2050. There are no coal export terminals on the US west coast. Instead, thermal and metallurgical coal is exported via a terminal in Vancouver, Canada. However, US coal exports are limited by a ban on thermal coal exports by Canada. Metallurgical coal can still be exported. Without a coal export terminal in the western United States, exports will be limited.

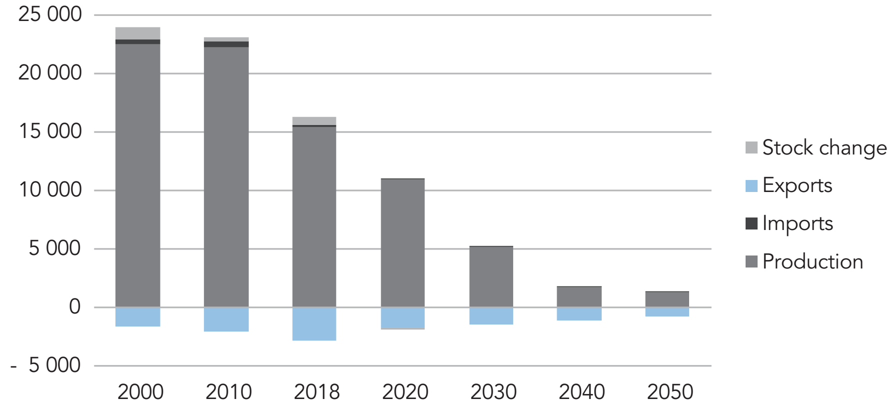
Coal in the Carbon Neutrality scenario

Figure 20-25. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-26. Coal production, imports, and exports in CN, 2000-2050 (PJ)

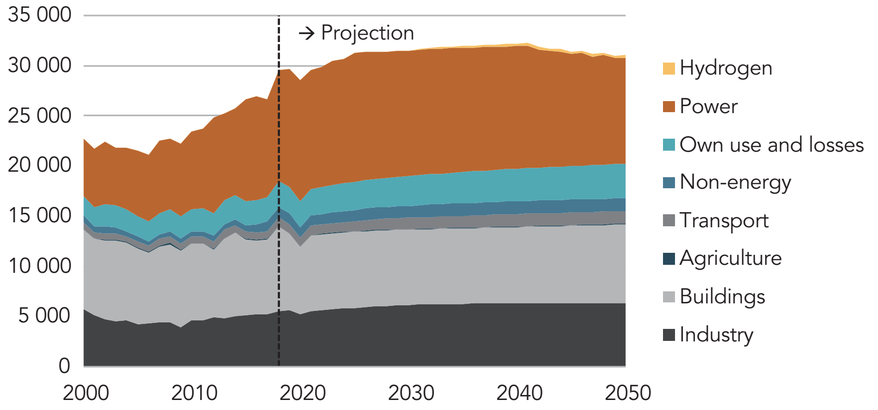


Sources: EGEDA, APERC analysis.

- A phaseout of coal plants in the power sector is complete by the 2040s. In the interim, coal consumption declines at the same rate as the last 15 years.
- Metallurgical coal and coal products consumption remains in the industry sector, but at a lower level than REF.
- Coal supply mirrors the demand side. Global demand for coal is expected to decline as other APEC members and the rest of the world reduce coal consumption.
- Coal exports are limited by the Canadian ban on thermal coal exports. The difficulty reaching export markets leads to a decline in production, especially in the western United States.
- There are uncertainties around policy frameworks that support coal phaseouts in the power sector, and in turn, production. Thus, coal consumption (and supply) could be higher if coal phase-outs are less pervasive than CN assumes.

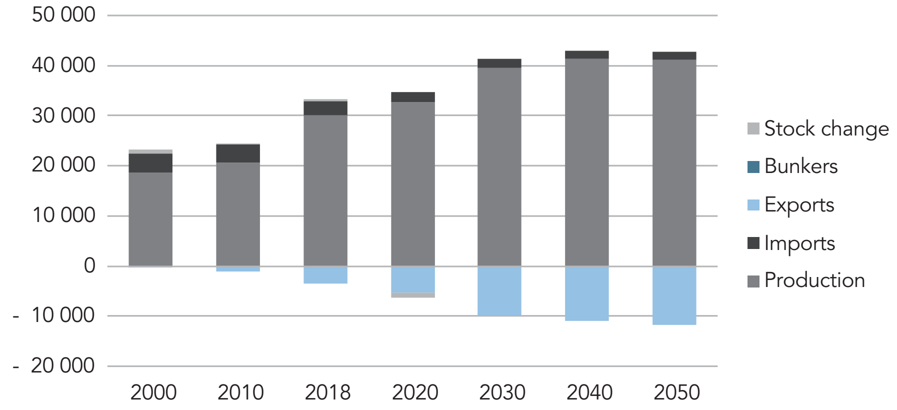
Natural gas in the Reference scenario

Figure 20-27. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-28. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

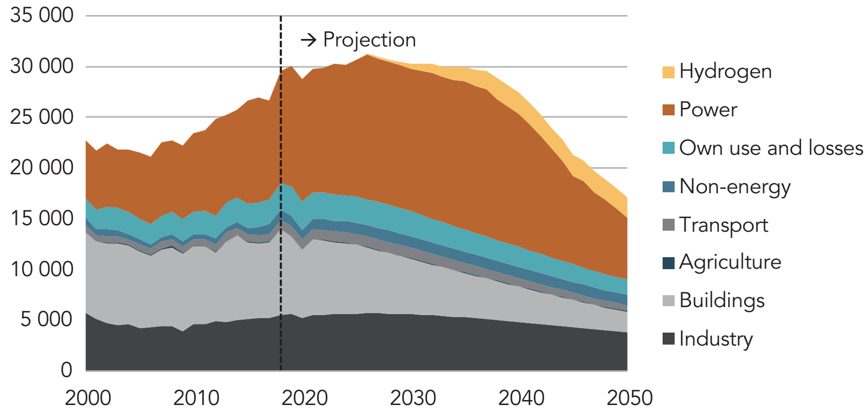


Sources: EGEDA, APERC analysis.

- Natural gas demand (and supply) has increased substantially in the past two decades. Horizontal drilling coupled with hydraulic fracturing across the United States in areas like the Bakken and Marcellus shale plays added a low-cost, domestic source of natural gas.
- Natural gas consumption is distributed across many sectors, illustrating its utility as a combustion input (e.g. power sector) and feedstock (e.g. non-energy sector).
- Consumption is expected to peak around 2040 as new natural gas power plant investments slow down. In other sectors, consumption generally increases through 2050.
- Natural gas for hydrogen production, via steam methane reforming with CCS, becomes a small consumer starting in the mid-2030s.
- The United States has the second largest natural gas reserves in APEC. This resource satisfies domestic consumption and serves export markets. Exports via LNG are expected to increase nearly six-fold by the late 2020s.
- Efficiency gains from increasing throughput of LNG trains help support natural gas exports. Additional efficiency gains could continue in the future, providing upside to the gas export trends shown here.
- Net pipeline trade with Canada falls around 40% as lower cost US natural gas supplants Canada's traditional export market.
- Pipeline exports to Mexico are expected to double by 2050, but there is substantial uncertainty given recent announcements by Mexico to stop importing natural gas from the United States by the mid-2020s.

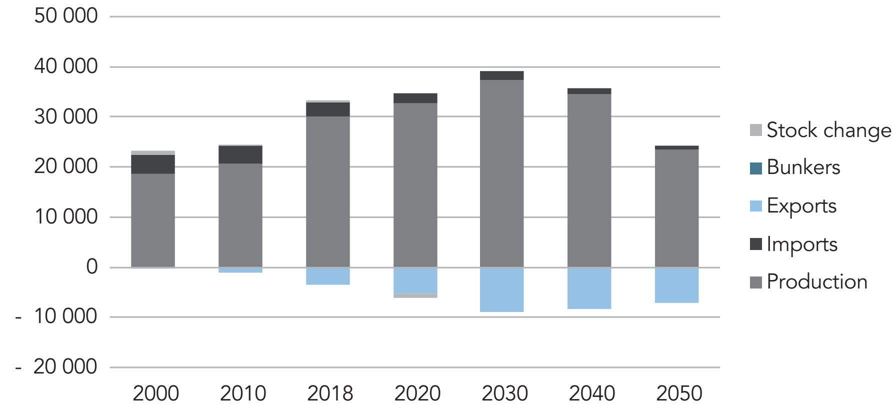
Natural gas in the Carbon Neutrality scenario

Figure 20-29. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-30. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

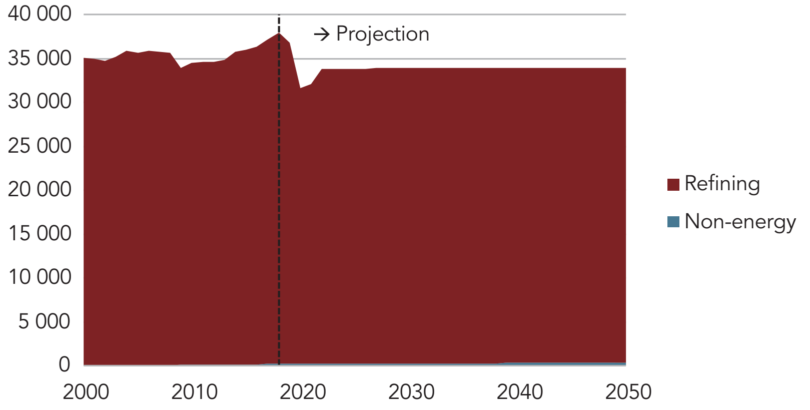


Sources: EGEDA, APERC analysis.

- Natural gas consumption is 45% lower than REF in 2050.
- Natural gas remains an important fuel in the power sector, supported by CCS. Similarly, the buildings and industry sectors continue to consume natural gas for heating and industrial processes.
- Natural gas supply declines through 2050. Pipeline exports to Mexico are half of REF levels in 2050 due to declining consumption (and imports). However, the same uncertainty around natural gas exports to Mexico remain.
- LNG exports peak in 2030 given that natural gas factors into many carbon neutral plans in APEC (e.g. southeast Asia and China) and globally. However, LNG exports in CN are 25% lower than REF in 2050.
- Additional uncertainty exists with respect to actual demand for natural gas in some APEC economies. Natural gas demand could increase if plans include natural gas, especially with CCS, or could decrease if fuel switching from natural gas increases.
- While not explicitly analysed, methane leakages are an important risk associated with natural gas production, transportation, and consumption. The United States is a key producer and supplier of natural gas, and an initiator of the Global Methane Pledge.
- There is uncertainty around efforts to limit methane leakage and its impact on natural gas consumption and supply in the future.
- Consumption of natural gas to produce hydrogen via the steam methane reforming with CCS helps offset a decline in natural gas consumption starting in the mid-2020s.

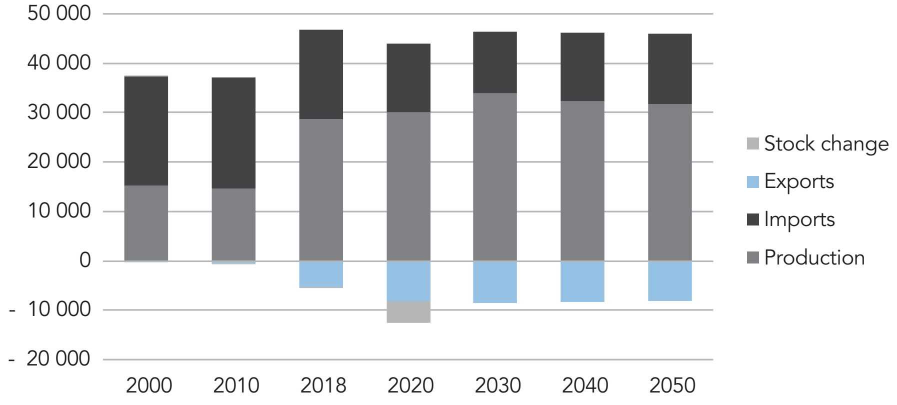
Crude oil and NGLs in the Reference scenario

Figure 20-31. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-32. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)



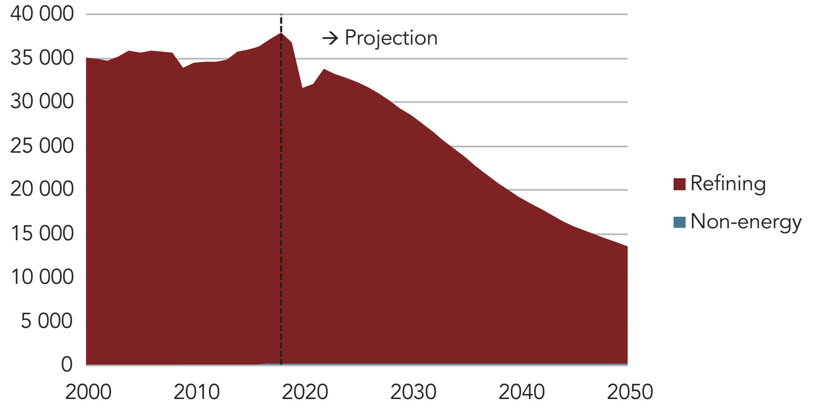
Sources: EGEDA, APERC analysis.

- Nearly all crude oil and NGLs are consumed by the refinery sector. Some crude oil and NGLs are inputs for non-energy products.
- Consumption, production, imports, and exports reflect crude oil and NGLs and do not include petroleum products.
- Production nearly doubled in the last two decades. Production is expected to peak in the mid-2030s then decline slightly through 2050. Horizontal drilling coupled with hydraulic fracturing in shale plays across the United States are responsible for a lot of the increase. Offshore production, while important, is flat throughout the projection.
- Import levels slightly decrease over time, mostly due to lower refinery runs.
- Exports increased substantially following the 2015 legislation authorising exports without a license (aside from sanctions). Exports peak in the 2020s but remain steady through 2050 due to consistent demand and competitiveness of US oil.
- There is uncertainty around federal leasing of exploration and production. Most of the growth is on non-federal lands. In the absence of leases, production on existing leases would be expected to decline.
- The ability for shale oil to sustain production growth is uncertain. Existing resources might not be able to grow production while keeping prices competitive, and to maintain necessary investment in the medium to long-term.
- Shifting investor preferences to cash generation instead of production growth could limit production growth in shale and thus US production.
- The ability of the shale sector to continue to produce at elevated levels is uncertain. If productivity of shale is overestimated, the production and export trends illustrated here are likely not to occur.

Note: Some NGLs are defined by the U.S. Energy Information Administration as petroleum products, so values may differ.

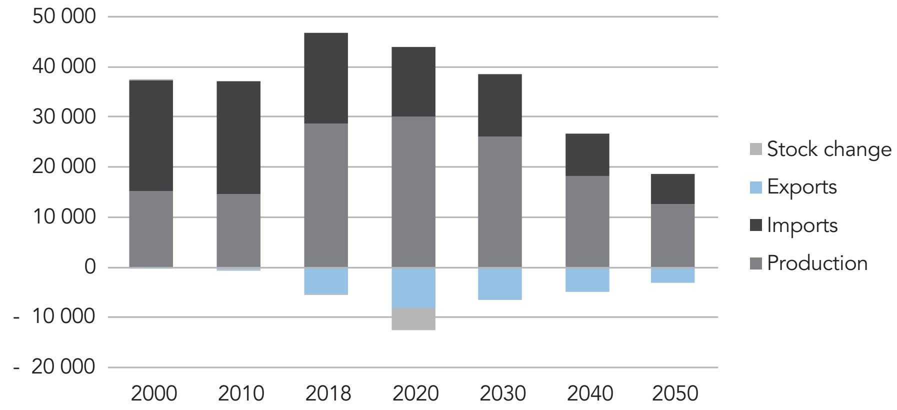
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 20-33. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-34. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)



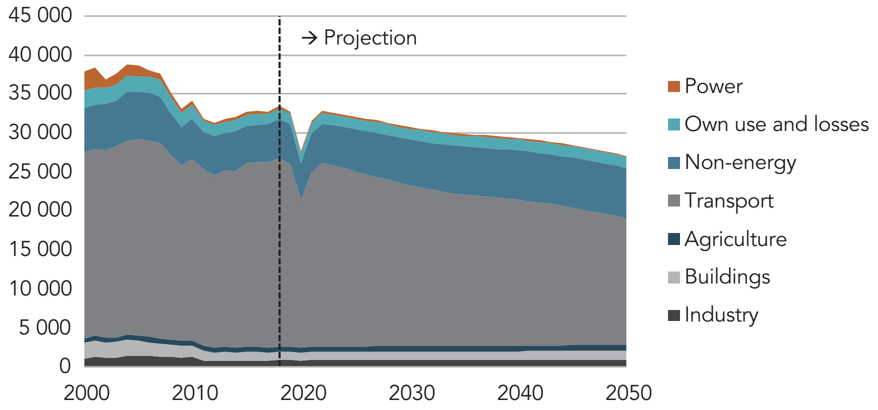
Sources: EGEDA, APERC analysis.

- Crude oil and NGLs in the United States follow a similar trend to other APEC economies in CN. Inside and outside APEC, policy interventions lead to lower demand for crude oil and NGLs by 2050.
- Domestic consumption of refineries falls by around two-thirds between 2018 and 2050 (a 40% reduction compared to REF).
- Crude oil production and imports follow the consumption trend. Lower production would affect shale producers and decisions around future federal offshore leases.
- Risk of stranded assets for shale production might be less due to the shorter payback periods associated with high productivity.
- Agile production, such as from shale, could provide a strategic advantage if production can be ramped up and down in shorter time frames compared to other methods like offshore operations.
- However, there is a risk of stranded refinery assets likely with lower utilisation rates.
- Outside the United States, lower demand for crude oil leads to a fall in exports by 2050.

Note: Some NGLs are defined by the U.S. Energy Information Administration as petroleum products, so values may differ.

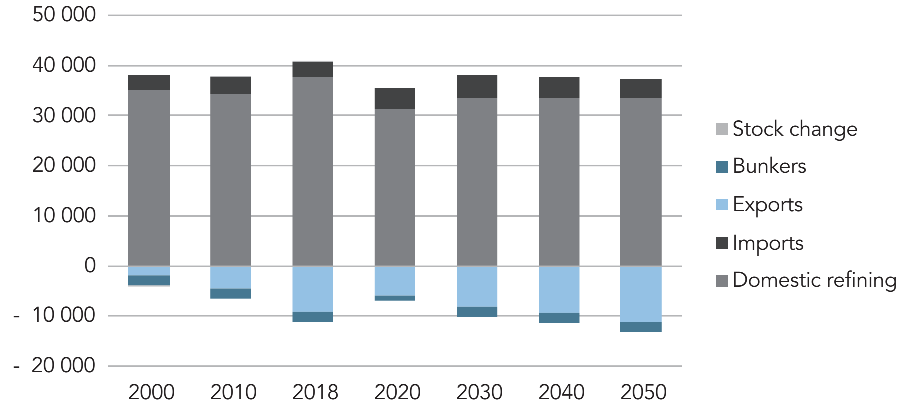
Refined products in the Reference scenario

Figure 20-35. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-36. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

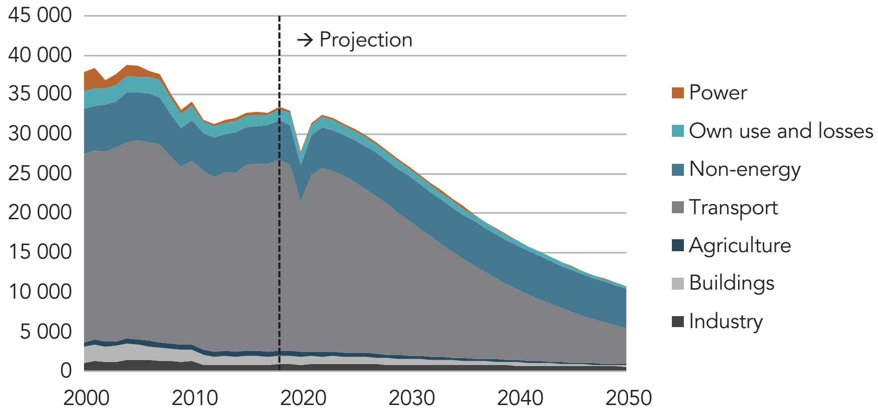


Sources: EGEDA, APERC analysis.

- The transport sector is the largest consuming sector of refined products, which includes gasoline, diesel, and jet fuel.
- The share of consumption between 2000 and 2018 has been consistent, except for a decline in consumption by the power sector.
- Prior to the disruption in transport activities by responses to COVID-19, refined products consumption was increasing slowly.
- The trend reverses in REF following a strong rebound in 2021 and 2022. Behavioral shifts, including remote working, have some effect on refined products, but steadily increasing efficiencies in the transport sector, and gradual electrification lead to lower consumption through 2050.
- On the supply side, domestic refining activities supply both domestic and global markets. While domestic demand decreases, export levels increase slightly based on expectations that demand from other APEC economies and the rest of the world will increase.
- Given the competitiveness of the US refining base, exports are expected to meet some of that demand.
- Import levels remain relatively constant.

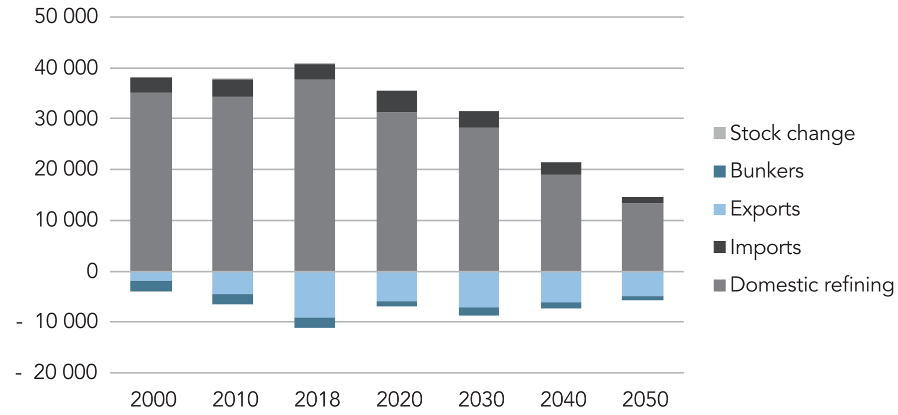
Refined products in the Carbon Neutrality scenario

Figure 20-37. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 20-38. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

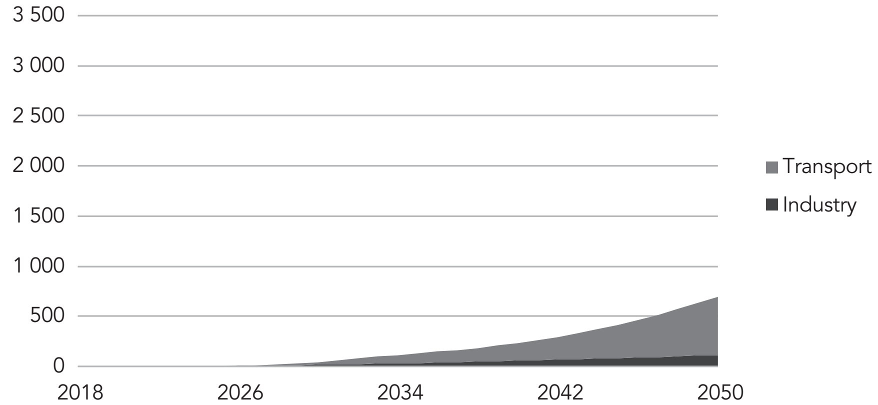


Sources: EGEDA, APERC analysis.

- Consumption of refined products follows a similar trend to other APEC economies in CN. Strong policies that support a reduction in refined products, primarily in the transport sector, begin in the mid-2020s and continue through 2050.
- Domestic consumption of refined products falls by two-thirds between 2018 and 2050. Compared to REF, this is a 40% reduction in 2050.
- Domestic refining activity follows the decline in domestic consumption. Imports of refined products similarly decline.
- The reduced demand for refined products in other APEC economies and the rest of the world leads to a slowdown in exports from the United States. While it remains a competitive refined products exporter, by 2050 exports fall by over one-third.
- There is significant amount of the oil and refinery supply chain that would be at risk of being a stranded asset in a carbon neutral pathway.

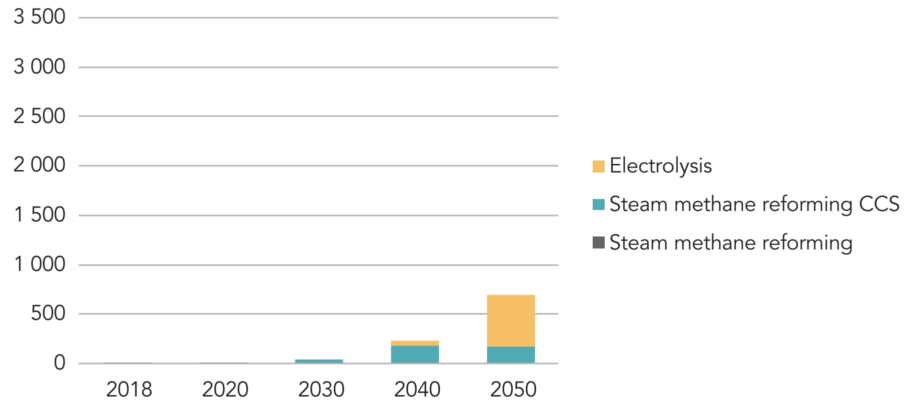
Hydrogen in the Reference scenario

Figure 20-39. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 20-40. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)



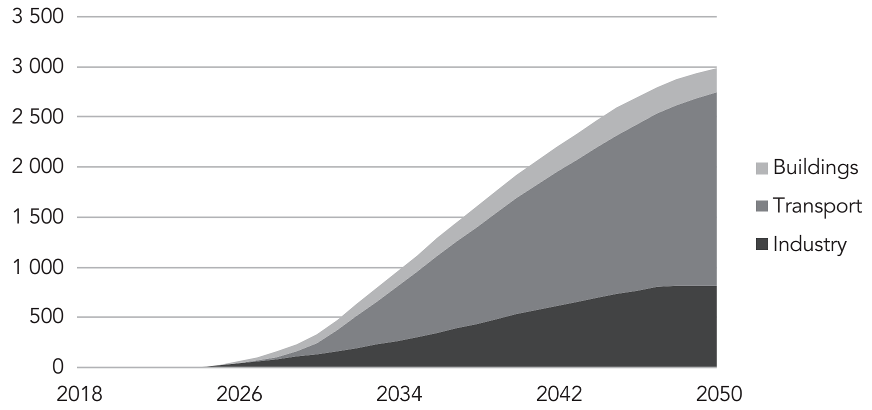
Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- The future of hydrogen remains uncertain, with supply dependent on both domestic and export market prospects. Domestic consumption applications rely on successful development of multiple applications of the technology coupled with an available and ready supply, supported by a functioning supply chain.
- In REF, hydrogen consumption slowly increases but remains a small portion of end-use energy consumption. In the transport sector, some fleets begin to utilise hydrogen for heavy trucking and public transport.
- In the chemicals industry subsector, some use cases that begin to use it as an energy source. This small amount of demand is met by a domestic only hydrogen industry, that is almost exclusively produced by electrolysis.
- Hydrogen supply relies on steam methane reforming through the early 2030s as the process is well developed for applications in industry and refining. Electrolysis becomes more cost competitive in the 2040s, eventually supplying most of the hydrogen.
- In REF, there is no large global demand for hydrogen that would support large-scale hydrogen export activities out of the United States.

Note: Hydrogen is a secondary (conversion) sector.

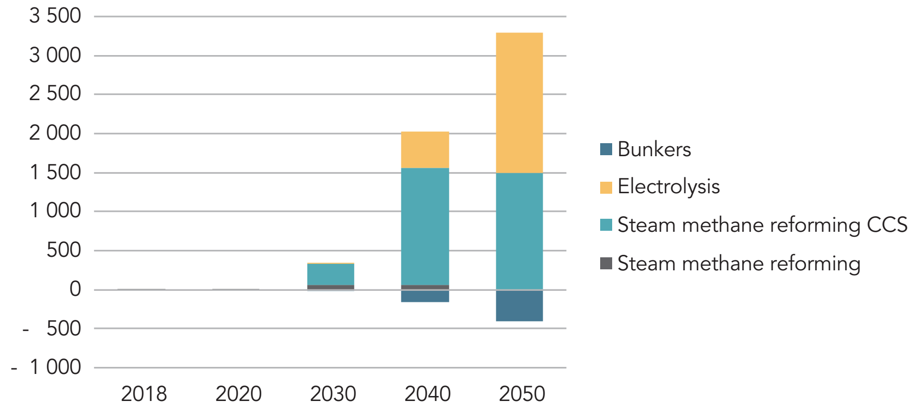
Hydrogen in the Carbon Neutrality scenario

Figure 20-41. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 20-42. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

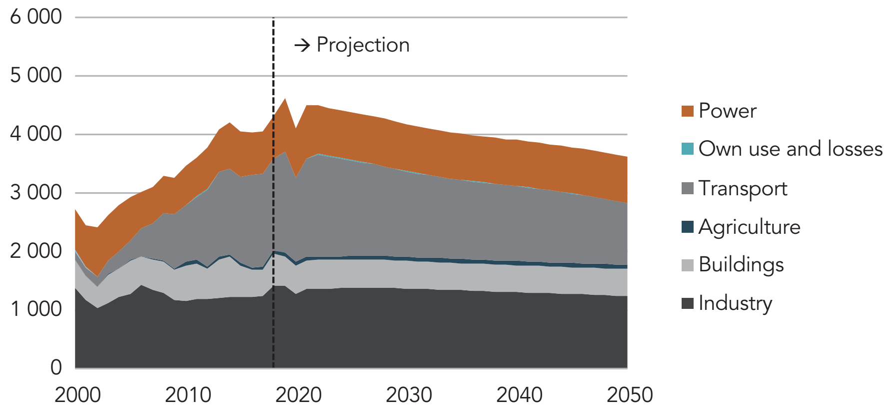


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- In contrast to REF, the domestic market for hydrogen advances rapidly in CN.
- Consumption of hydrogen increases by over 300% in 2050 compared to REF.
- The transport sector consumes the most hydrogen as larger adoption in fleets increases, in addition to passenger light duty vehicles.
- Hydrogen is blended with natural gas to reduce the CO_2 intensity of the buildings sector while utilising existing infrastructure.
- Hydrogen for power generation is not considered in CN. Hydrogen could be blended with natural gas, used as ammonia, or through other methods.
- Hydrogen supply becomes evenly distributed among steam methane reforming with CCS and electrolysis. In CN, CCS is assumed to be more widely available and cost competitive in many sectors, including for hydrogen production. If CCS is not viable, production via electrolysis could increase.
- Hydrogen exports are not considered for the United States in CN given the large uncertainties of a global hydrogen supply chain and market. It is likely US production of hydrogen could increase to serve export markets within APEC and in the rest of the world.

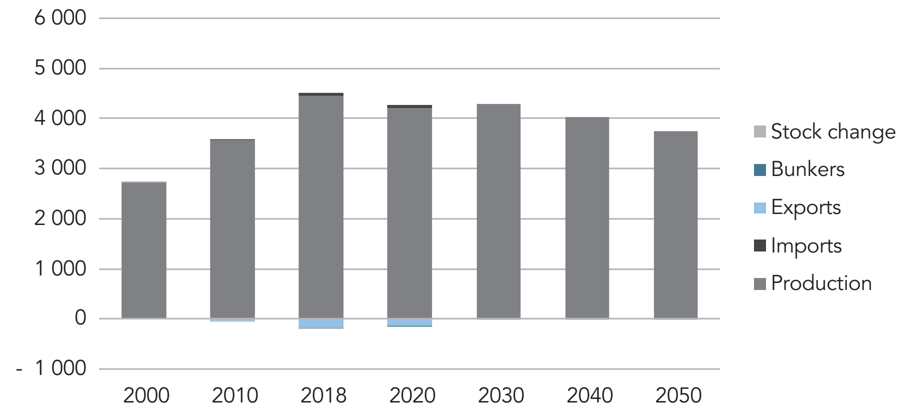
Bioenergy in the Reference scenario

Figure 20-43. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 20-44. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

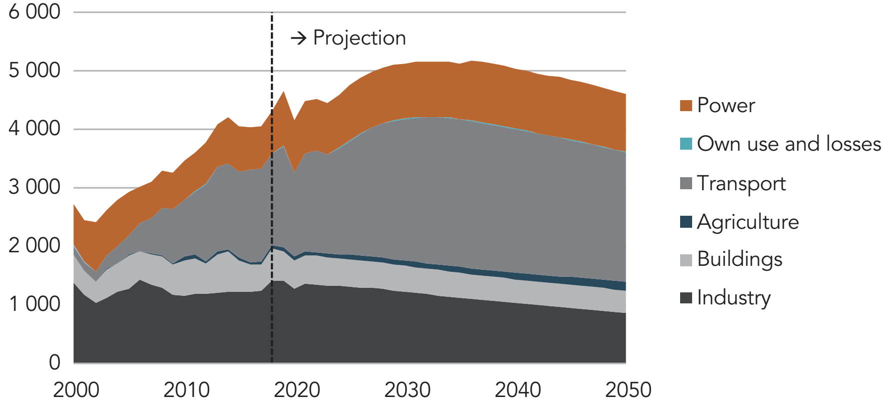


Sources: EGEDA, APERC analysis.

- Consumption of renewables in the transport sector are governed by blending policies. In effect, biofuel consumption is driven by demand for petroleum products.
- The industry sector consumes solid biofuels, such as biomass pellets, as a heat source for some industrial processes. In the buildings sector, solid biomass such as wood pellets, in addition to liquid and gaseous biofuels for some activities, are consumed.
- Solid biomass consumption in the United States is assumed to be modern, rather than traditional biomass.
- The power sector consumes a variety of liquid and solid biofuels such as biomass, and in some cases municipal solid waste.
- Aggregate solid and liquid renewables consumption decreases due to improved efficiency and electrification in end-use sectors.
- The United States satisfies domestic solid and liquid biofuels demand through production. Exports are expected to decline in the 2030s.

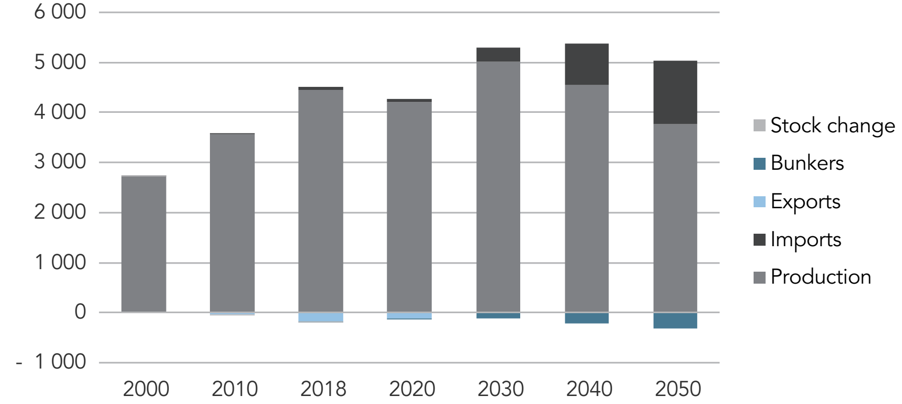
Bioenergy in the Carbon Neutrality scenario

Figure 20-45. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 20-46. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

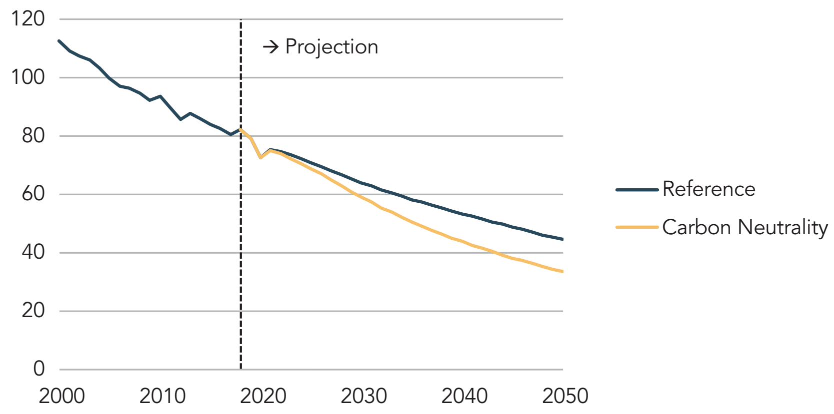


Sources: EGEDA, APERC analysis.

- Additional biofuels consumption in the transport sector is the result of increased blending limits.
- Advanced biofuels, such as cellulosic ethanol and algal biofuels, have received policy and funding support in the past. These fuels are not explicitly considered in CN but could provide additional biofuels supply in the future if the technologies can reach commercial scale.
- Imports of biofuels increase in the 2030s. With declining refinery capacity, there is an opportunity to convert these facilities to biorefineries to satisfy demand. These conversions could reduce the risk of refining assets becoming stranded.

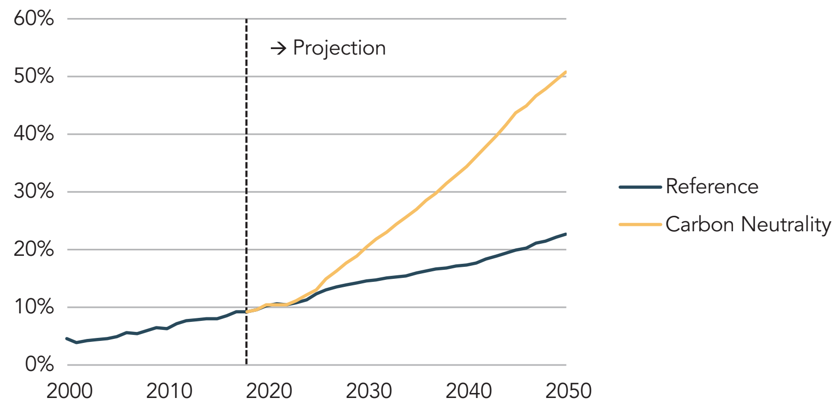
Energy intensity and modern renewables share

Figure 20-47. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 20-48. Modern renewables share in REF and CN, 2000-2050



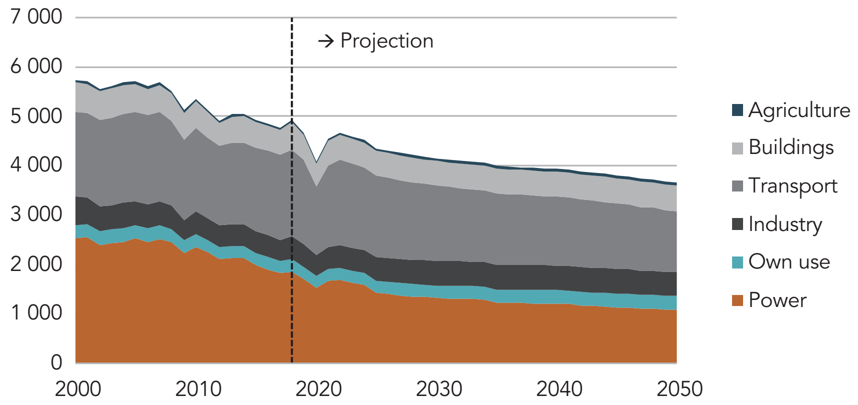
Sources: EGEDA, APERC analysis.

- Final energy intensity in the United States has declined by 30% since 2000, supported by strong GDP growth and steady improvement in energy efficiency across all sectors.
- Final energy intensity is expected to continue declining by 55% for the period 2005 to 2050 in REF, and by over 65% in CN.
- In REF, the share of modern renewables recently surpassed 10% as utility scale renewable generation continues to accelerate.
- Modern renewables growth is expected to continue along recent historic trends. The growth is supported by continued fuel switching from coal and natural gas generation to wind and solar.
- In CN, modern renewables rise to over 50% in 2050. This rise is facilitated by rapid electrification of the transport sector, with electrification in all other sectors playing a role as well.
- Renewable generation accounts for half of all generation in REF, and over 70% of generation in CN.
- The increase in liquid biofuels consumption plays a role in displacing fossil fuels in multiple sectors to improve the share of modern renewables in the energy mix.

Notes: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources. Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

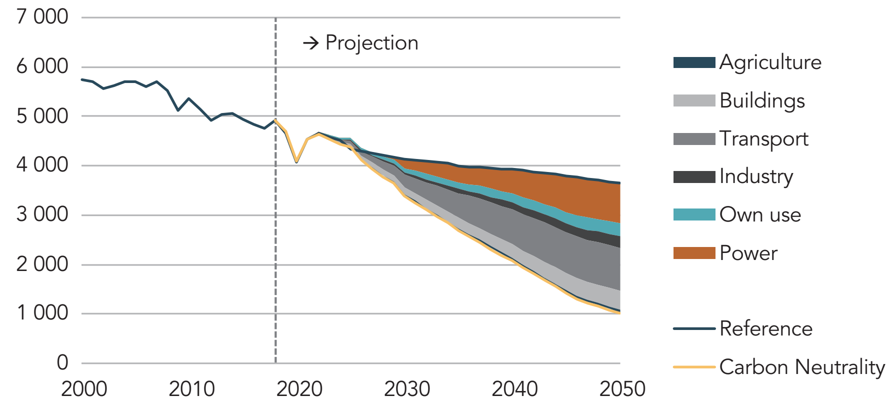
Gross CO_2 emissions

Figure 20-49. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 20-50. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

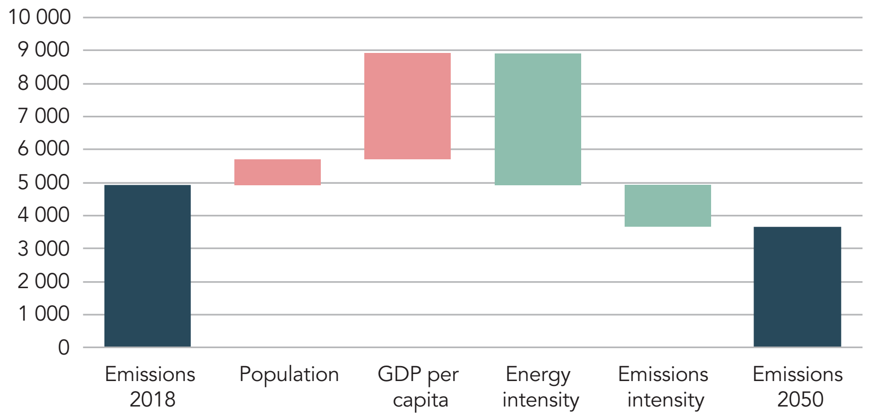


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Gross energy-related CO_2 emissions in the United States have declined 14% between 2000 and 2018. The decline accelerated around the late 2000s due to increased fuel switching from coal to natural gas in the power sector.
- This trend continues through 2050 in REF. The power sector sees the largest reduction in CO_2 emissions (over 760 million tonnes) as coal and natural gas generation falls to around one-third of total generation by 2050.
- The transport sector shows notable reductions as fuel efficiency standards, turnover of older vehicle stock, and electrification add up to lower CO_2 emissions per passenger-km and tonne-km of transport service demand.
- The largest incremental emissions reductions between REF and CN are achieved in the transport sector, primarily from the displacement of gasoline and diesel by electricity. Continued efficiency improvements, biofuels, and hydrogen in heavy-duty fleets further support transport sector CO_2 reductions.
- In CN, the reengineering of the electricity system through deployment of wind and solar generation, a phase-out of coal, and the addition of CCS-equipped gas units lead to the second largest incremental sectoral reductions. By 2050, only 4% of electricity generation is unabated.
- The NDC target of a 50-52% net GHG reduction between 2005 and 2030 is not directly comparable to CN because the scenario only considers CO_2. In CN, energy sector CO_2 emissions decline by 40% between 2005 and 2030.
- Gross energy sector CO_2 emissions of around 1 000 million tonnes remain in 2050 and would need to be offset via natural or technological means (e.g. direct air capture) to achieve full carbon neutrality. Opportunities may exist for the United States to develop its own CO_2 removal potential or collaborate with other APEC member economies.

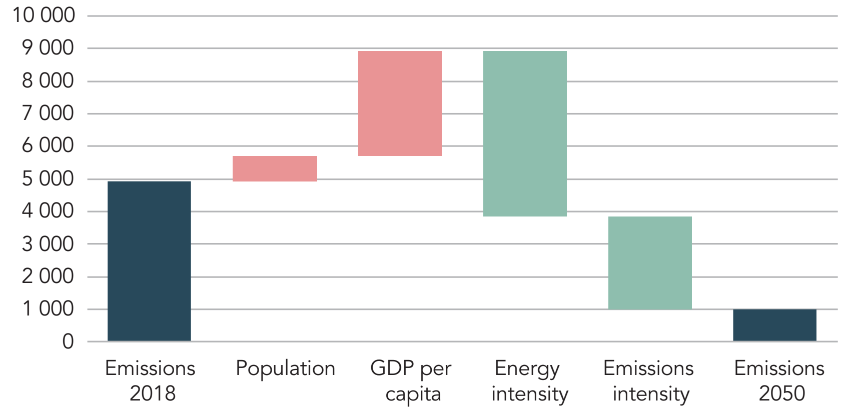
Components of CO_2 emissions

Figure 20-51. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 20-52. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- The United States emitted over 4 900 million tonnes of CO_2 in 2018 (nearly one-quarter of total APEC CO_2 emissions). This amount excludes CO_2 emissions from some industrial processes and the non-energy sector. In the United States, the non-energy sector is a substantial source of CO_2 emissions.
- Given the assumptions about population and GDP growth, CO_2 emissions would nearly double to around 9 000 million tonnes by 2050 in the absence of energy and emissions intensity improvements.
- In REF, improvements in energy intensity and emissions intensity reduce emissions to 3 700 million tonnes. Energy intensity accounts for over 75% of the reduction.
- In CN, energy intensity CO_2 emissions reduction are 27% greater than in REF, while the emissions intensity reduction is around 2.2 times greater. These additional improvements lead to energy sector CO_2 emissions that are 80% lower than 2018.
- Improving energy and emissions intensity beyond levels in CN would require higher levels of fuel switching, CCS, or other measures.
- The remaining energy sector CO_2 emissions in CN (1 000 million tonnes) would need to be countered by emissions sinks. The challenge will be even greater when including process emissions and other GHGs.
- CN is only one of many possible pathways for the United States to approach its decarbonisation objectives.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

U.S. White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/

U.S. Energy Information Administration. https://www.eia.gov/

U.S Net-zero 2050. https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf

U.S NDC. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/United%20States%20of%20America%20First/United%20States%20NDC%20April%2021%202021%20Final.pdf

U.S. Environmental Protection Agency. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

21. Viet Nam

Highlights

Demand

- Viet Nam's energy demand rose significantly over the 2000-2018 period due to a rising population and strong GDP growth, and it continues to rise tremendously over the outlook period. In 2050, energy demand triples above 2018 levels, reaching over 7 400 PJ. In CN, energy demand is 20% lower than REF as a result of energy efficiency improvements.
- In 2018, energy demand was led by oil (35%) and followed by electricity (28%), coal (21.6%) and biomass (13%). In REF, electricity takes over oil, becoming the most-used energy carrier after 2038. In CN, oil demands decline dramatically due to the widespread adoption of zero-emission vehicles. Electricity demand rises significantly relative to REF, surpassing oil in 2029.

Supply

- Viet Nam's energy supply has increased continuously to meet the high energy demand for socio-economic development. Energy supply grows more than three-fold in REF, reaching approximately 11 000 PJ in 2050. Fossil fuels continue to dominate the energy mix, accounting for 78% of the total energy supply in 2050. In CN, supply increases over two-fold but declines by approximately 22% compared with REF in 2050.
- Once a net energy exporter, Viet Nam has been a net energy importer since 2015 due to the depletion of natural resources and high-energy demand for socio-economic development. As energy production increases slightly in both scenarios, imported energy increases to meet demand. Fossil fuel imports rise considerably, led by coal, and followed by oil and gas over the projection period. In REF, Viet Nam's primary energy self-sufficiency falls to 36% by 2050, down from 72% in 2018.
- In CN, energy supply falls by 17%, led by oil (-10%), gas (-4.1%) and coal (-4.0%), while renewables grow by 1.3%. Nevertheless, fossil fuels still account for three-quarters of the total energy supply in 2050.
- Fuel switching in the power sector increases in both scenarios. Viet Nam plans to use a vast amount of LNG imports to fuel LNG-fired power plants, particularly after 2035.

Power

- In REF, electricity generation almost quadruples from 220 TWh in 2018 to 861 TWh in 2050. Gas and renewable generations rise dramatically, while hydropower generation grows 40%. Coal-fired capacity increases gradually, albeit at a slower rate than the Power Development Plan. While there is significant growth in renewables, particularly wind, fossil fuels dominate the power mix throughout REF.
- In CN, electricity generation remains at REF levels and the power mix becomes lower-emitting, with wind and solar accounting for nearly 39% of the total generation mix by 2050, while fossil fuels continue to make up 45%.
- Power capacity increases 5.5 times from 46 GW to 253 GW over the outlook period, with renewables dominating the capacity mix in 2050. In CN, carbon capture and storage (CCS)-equipped coal and gas power plants start operating in 2035 and 2038, respectively. CCS reduces CO_2 emissions from the power sector and allows Viet Nam to leverage much of its fossil fuel fleet within its lifetime.

CO_2 emissions

- In REF, CO_2 emissions from the energy sector rise sharply due to the high consumption of fossil fuels over the projection period. By 2050, nearly two-thirds of CO_2 emissions come from coal combustion, 23% from oil combustion and 14% from gas combustion.
- In CN, CO_2 emissions decline by a third of REF levels, as energy efficiency in the end-use sectors and higher deployment of renewables in the power sector help stabilise emissions in the 2040s.
- The CO_2 reduction in CN by 2030 comes close to Viet Nam's commitment in its 2020 updated Viet Nam Nationally Determined Contribution (NDC). Further reductions will need to be done to achieve this commitment.

About Viet Nam

- Viet Nam is a southeast Asian economy situated with China to the north, Laos and Cambodia to the west, and the East Sea and Pacific Ocean to the east and south, respectively. Viet Nam is one of the fastest-growing economies in Asia. GDP reached USD 742 billion (2018 USD PPP) in 2018. Viet Nam's economic structure has gradually shifted away from agriculture in recent decades. According to the General Statistics Office of Viet Nam (GSO), the industry and service sectors have grown from 62% in the early 1990s to 75% in 2020.
- Viet Nam's natural resources are diverse, including coal, oil, and gas, which can be mined for at least a half-century (Table 21-2). Coal is mined mainly in the Quang Ninh prefecture at a rate of about 40 million tonnes per year. Crude oil and natural gas are mainly exploited in the south, with prioritisation for domestic usage. Viet Nam has exported anthracite coal and crude oil for decades. However, rising demand turned Viet Nam into a net energy importer in 2015.
- Electricity demand is increasingly rising along with GDP, income growth, and population. Viet Nam generated 217 TWh of electricity in 2018, ranking 11th in the APEC region. Coal power dominates the power mix, followed by hydropower and gas power. Solar and wind accounted for less than 10% of Viet Nam's generation mix.
- Energy-related CO_2 emissions were 233 million tonnes in 2018. Viet Nam updated its NDC in July 2020 with a voluntary reduction target of 9% compared to the BAU scenario. However, while implementing the updated NDC, adjustments will be made to align with actual emissions. The reduction target relative to a BAU scenario could increase up to 27% with international support received through bilateral and multilateral cooperation and the implementation of new mechanisms under the Paris Agreement.
- Viet Nam committed to phasing out coal and achieving carbon neutrality by 2050 in the 2021 United Nations Climate Change Conference (COP26).

Table 21-1. Economy statistics, 2018

	2018	APEC share	APEC ranking
Population	96	3.3%	8
GDP	742	1.1%	14
TPES	3 636	1.1%	13
Production	2 624	0.8%	10
Imports	1 330	1.1%	15
Exports	361	0.3%	16
Electricity generation	217	1.3%	11
CO_2 emissions	233	1.1%	12

Notes: Population (millions), GDP (billion 2018 USD PPP), energy (PJ), electricity (TWh), CO_2 (million tonnes).

Table 21-2. Energy resources

	Proved reserves	Years of production	Share of world reserves	APEC ranking (reserves)
Coal	80 468	69	0.3%	8
Natural gas	23 253	74	0.3%	8
Oil	26 919	58	0.3%	6

Notes: Coal, natural gas, and oil (PJ) in 2020 from BP. See Appendix for conversion to other units.

Energy policy context and recent developments

- The Ministry of Industry and Trade (MOIT) is responsible for managing Viet Nam's energy sector. Three bodies in charge of formulating policy and guidance for each energy industry fall under its remit: the Authority of Electricity and Renewable Energy; the Department of Energy Efficiency and Sustainable Development; and the Department of Oil, Gas and Coal. The other two subsidiary agencies of MOIT include the Electricity Regulatory Authority of Viet Nam (ERAV) and the Institute of Energy (IE). While ERAV manages regulatory activities for electricity, IE is responsible for energy research, forecasting activities, and energy development plans.
- The *Politburo's Resolution No. 55 on the orientation of Viet Nam National Energy Development Strategy to 2030 with the vision to 2045* (Resolution No. 55) is a crucial policy guiding Viet Nam's energy future. This resolution prioritises sustainable energy development while fostering favourable conditions for all economic sectors, particularly the private sector, to participate in energy development.
- Two vital, new policies are in the final draft, including the *National Energy Development Strategy for the 2021-2030 period with the vision to 2050* (NEDS) and the *Power Development Plan for the 2021–2030 period with the vision to 2045* (PDP8). These two policies are tailoring a Viet Nam energy system that is considerably different from the current energy system. They are not yet released at the time of this publication.
- A five-year, socio-economic development plan for the 2021-2025 period sets a GDP growth target of around 6.5% to 7.0% per year. However, the GDP growth rate fell to 2.9% in 2020 due to the COVID-19 outbreak. It is expected to rebound slightly in 2021.
- In the *revised PDP7* published in 2016, coal maintains a significant role in the power sector, accounting for 43% of capacity and a 53% share of power generation in 2030. Nevertheless, the government will carefully examine the fossil fuel proportion of the generation mix in the coming *PDP8*. Gas-fired power capacity is expected to gain at the expense of coal power due to environmental and greenhouse gas (GHG) emissions issues.
- Renewable energy is a top priority of Viet Nam's energy policy framework. The Prime Minister approved the *Renewable Energy Development Strategy* (REDS) in November 2015 to accelerate renewables projects, such as solar and wind energy, and reduce fossil fuel use. This policy targets a renewables share of 44% of the total energy mix by 2050. In the power sector, the share of electricity generation from renewable energy (including small and large hydro) should reach about 32% in 2030 and 43% in 2050.
- The *Viet Nam National Energy Efficiency Programme for the 2019–2030 period* (VNEEP) was enacted by the Prime Minister in 2019. This program aims to promote the economical and efficient use of energy through state management, technical assistance, scientific and technological research, product development, market transformation, human resource training and development.
- Viet Nam's NDC was updated in September 2020, providing information on implementation impacts and progress. Viet Nam plans to reduce its GHG emissions by 9% compared to the BAU scenario by 2030. Specifically, the GHG reduction volume increases by 21 million tonnes of carbon dioxide equivalent ($MtCO_2eq$), from 63 $MtCO_2eq$ to 84 $MtCO_2eq$ in the current updated NDC. International support could increase this contribution to 27% by 2030, equivalent to 251 $MtCO_2eq$.
- At COP26 in Glasgow, Prime Minister Pham Minh Chinh affirmed Viet Nam's commitment to net-zero emissions by 2050. To further reduce emissions, Viet Nam is looking to leverage its abilities, international support in finance and technology transfer. In line with COP26, Viet Nam committed to stop deforestation by 2030 and phase-out coal-fired power by the 2040s. Viet Nam will review and adjust the current energy policies, aligning with high-level leaders' commitments at COP26.
- Viet Nam will continue to develop domestic fossil fuel resources to meet the energy demand requirements to grow its economy. As fossil fuel production continues to decline, domestic demand remains a priority. Viet Nam is speeding up infrastructure constructions to import more coal and, for the first time, LNG, in the coming years.

Note: Policy context and notable developments are current as of October 2021.

Scenarios in the 8th Edition

- This edition of the *Outlook* considers two scenarios, both of which will provide a reference for Viet Nam in navigating uncertain energy system landscape.
- **The Reference scenario (REF)** reflects recent trends and current policies in place, or planned to be in place, and seeks to capture the evolving nature of the energy system. Resolution No. 55 is a crucial driving policy. Based on this strategy, two significant policies (NEDS and PDP8) will be revised and updated in the coming months. These updates could result in a Viet Nam energy future that differs than those shown here.
- Assumptions of energy efficiency in the buildings, industry, power and transport sectors in REF are in line with the VNEEP. REF assumes gradual efficiency improvement in the transport sector, with some fuel switching and shifting of modes from road to rail. Efficiency improvements and fuel switching occurs gradually in the industry and power sectors.
- **The Carbon Neutrality scenario (CN)** investigates a hypothetical emissions-reduction pathway through 2050. Unlike its COP26 announcement, this scenario does not trace a clear path for Viet Nam to become a net-zero economy, nor does it phase-out coal-fired power generation in the 2040s. Hence, Viet Nam should review all current energy policies and update them if it is necessary to align with recent high-level leaders' commitments.
- Electrification in the transport sector is expected to accelerate moderately in CN, driven by supporting policies, such as tax subsidies, investments in recharging infrastructure and biofuel utilisation.
- Assumptions in CN are more aspirational than REF, such as coal-to-gas power switching, equipping CCS on gas- and coal-fired power plants, deploying more large-scale solar and wind projects and adopting hydrogen in both the industry and transport sectors. While technically possible, the co-firing of hydrogen in coal power units is not considered in this *Outlook*.

Table 21-3. Scenarios

	Reference (REF)	Carbon Neutrality (CN)
Definition	Recent trends and current policies	Investigates hypothetical decarbonisation pathways for the energy sector of each APEC economy to attain carbon neutrality.
Purpose	Provides a baseline for comparison with the Carbon Neutrality scenario.	Explores additional energy sector transformations that could support decarbonisation objectives.
Key assumptions	Current polices; trends in energy efficiency, and renewable energy deployment; and initial steps towards decarbonisation are included.	Decarbonisation measures and timeframes are based on the unique characteristics, policy objectives, and starting points of each economy. Increased levels of energy efficiency, behavioral changes, fuel switching, and CCUS deployment are implemented. CO_2 removal technologies are not investigated.
Limitations	Assumes that recent trends, including relevant decarbonisation measures, are not altered.	Does not consider non-energy impacts on CO_2 emissions (for example, land-use change, non-combustion of fuels) or CO_2 removal (for example, direct air capture).

Note: Key assumptions are available on the next page.

Key assumptions for Viet Nam

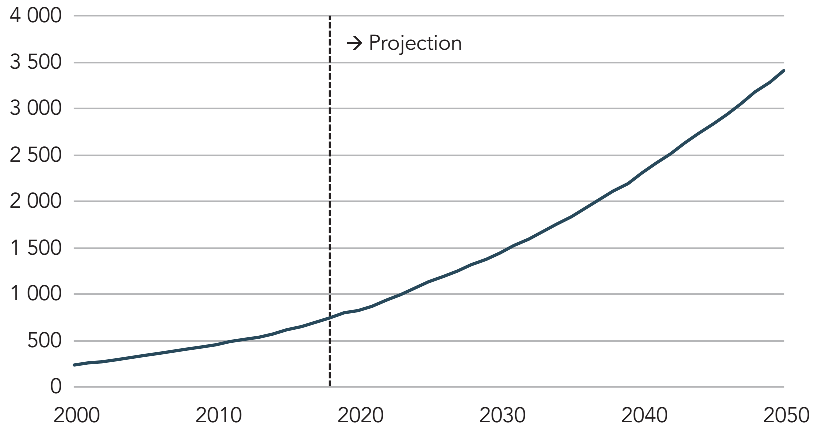
Table 21-4. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Population: (UNDESA) • GDP: World Bank (historical), IMF (COVID-19 impacts), Swan-Solow model (projections 2026 - 2050)	• Same as REF
Buildings	• Carrying out energy saving measures regulated in VNEEP in the 2019-2030 period.	• Additional 20% for energy saving measures by 2050. • Switching from traditional biomass to LPG and electricity. Electrification of heating and cooking.
Industry	• Hydrogen and CCS is not adopted in Viet Nam. • Strong growth in most industry subsectors tied to robust growth estimates out to 2050.	• Hydrogen use in steel and chemical subsectors begins in 2030. • Numerous fuel switching assumptions in different subsectors, typically away from coal and refined products to gas (as a transition fuel), biomass, electricity and/or hydrogen.
Transport	• Reduce fuel consumption by at least 5% by 2030. • Fuel efficiency follows current standards and recent trends.	• 40% of new light passenger vehicle, 10% heavy trucks sales are electric by 2035, growing to 100% and 70%, respectively, by 2050. • Greater utilisation of public transport modes.
Power	• The draft of PDP8 is used as a guideline. • Coal and gas-fired units are used to meet rapidly increasing electricity demand. • Moderate scale adoption of wind and solar projects.	• CCUS-equipped gas and coal adoption from 2035 • Moderate scale adoption of solar and wind projects. • No hydrogen consumption or co-firing coal units due to other technologies being more cost competitive.
Supply	• Gas production falls short of targets, peaking 16% above current levels in 2029, declining thereafter. • LNG imports start in 2022, are held under 2 Mtpa until 2036, and then surge to 9 Mtpa in 2040 and 30 Mtpa by 2050 in line with demand and power requirements. • Coal production consistent with draft Energy Master Plan, hitting targets of 49 Mt in 2030, 47 Mt in 2040 and 48 Mt in 2050. • Oil discovery in 2025 lifts output to 10 Mt peak in 2030; declines to 6 Mt by 2050.	• Gas production is the same as REF. • LNG terminal capacity requirements are 22 Mtpa by 2050. • Coal mining reduced by demand trends, smaller export market in a net-zero world. • Oil peaks at lower levels, declines faster due to a smaller export market in a world pursuing carbon neutrality.
Climate	• Guided by NDC	• Guided by 2050 net-zero carbon emission target.

Notes: The base year is 2018. Projections begin in 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

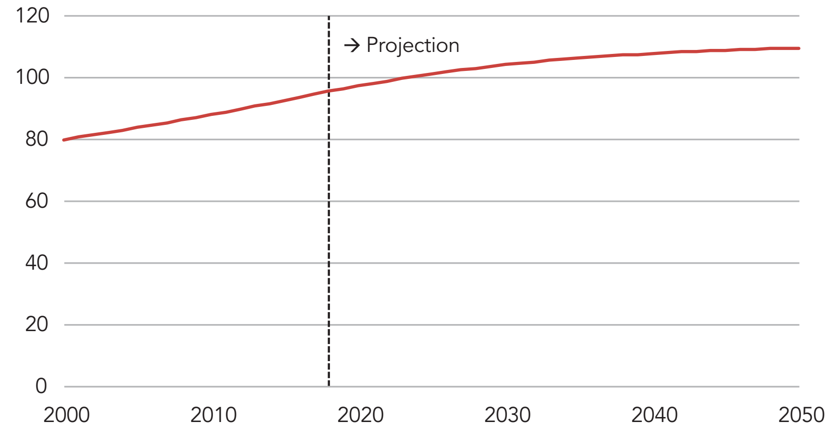
Macroeconomic backdrop

Figure 21-1. GDP in billion 2018 USD PPP, 2000-2050



Notes: Historical GDP data from World Bank WDI. GDP projections from internal analysis. COVID-19 impact on GDP is incorporated in the 2020-2025 timeframe based on IMF projections (May 2021).

Figure 21-2. Population in millions, 2000-2050



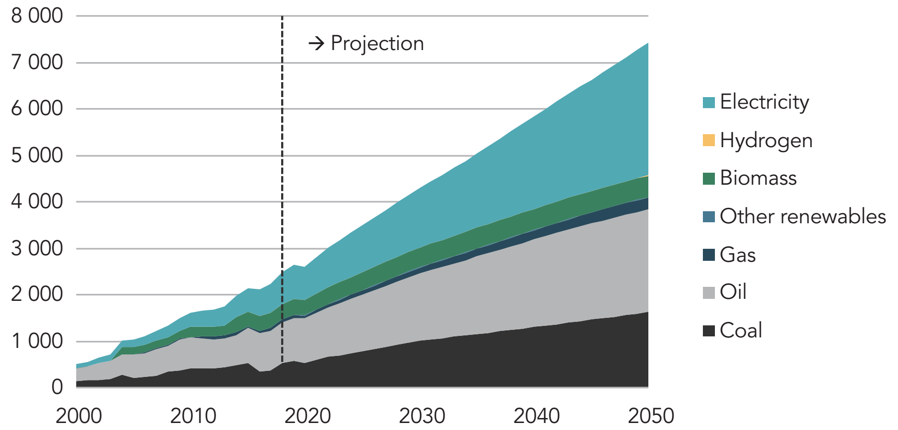
Notes: Historical population data from World Bank WDI. Projections from UNDESA 2019 Population Prospectus.

- Viet Nam's GDP rises approximately five-fold over the projection period. Annual GDP growth is between 6-7% up to 2026, and slightly decreases thereafter.
- COVID-19 has impacted Viet Nam's economic activities, particularly in the middle of 2021. The government has applied lockdown measures to prevent the spread of the virus, which has disrupted the manufacturing sector and many supply chains. Nevertheless, Viet Nam's GDP is expected to rebound in the coming years. The *Outlook* utilises an IMF projection from April 2021 to account for the negative impacts of the ongoing COVID-19 pandemic on economic activity. Actual GDP rates in the 2020 to 2025 period could differ from these estimates.
- Viet Nam's annual population growth rate was approximately 1% over the last two decades, one of the fastest rates worldwide. The young labour force has assisted Viet Nam in carrying out its industrialisation and modernisation strategy. However, low fertility rates could result in a quickly aging population, straining social welfare systems, including pensions, health insurance and social security. Viet Nam's population is projected to grow at an annual rate of 0.4% in the next three decades.
- The economy's structure has gradually shifted away from agriculture in recent decades. The industry and service sectors expanded from 62% in the early 1990s to 75% in 2020.
- Electrification in rural areas and remote islands is 99%. The government has promoted a "green growth" strategy since 2012 for Viet Nam's ongoing industrialisation and modernisation.

Note: For more information on structural changes to Viet Nam's economy and its energy strategy, please see the General Statistics Office and the National Green Growth Strategy.

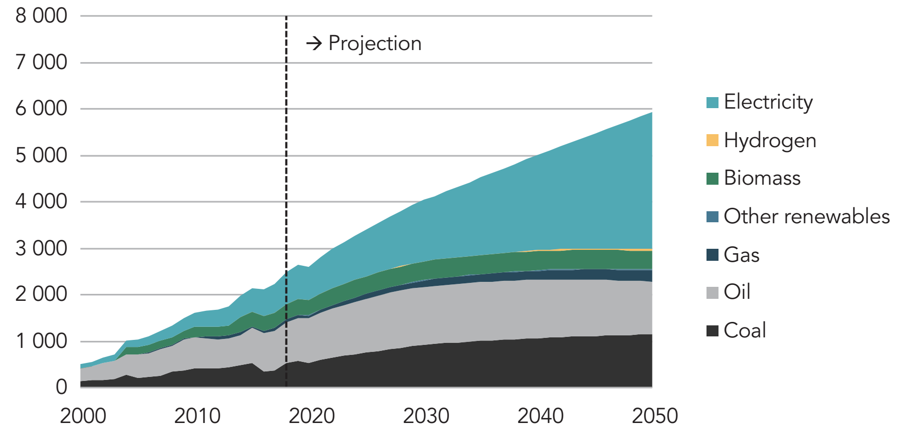
End-use energy demand

Figure 21-3. Energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 21-4. Energy demand in CN, 2000-2050 (PJ)

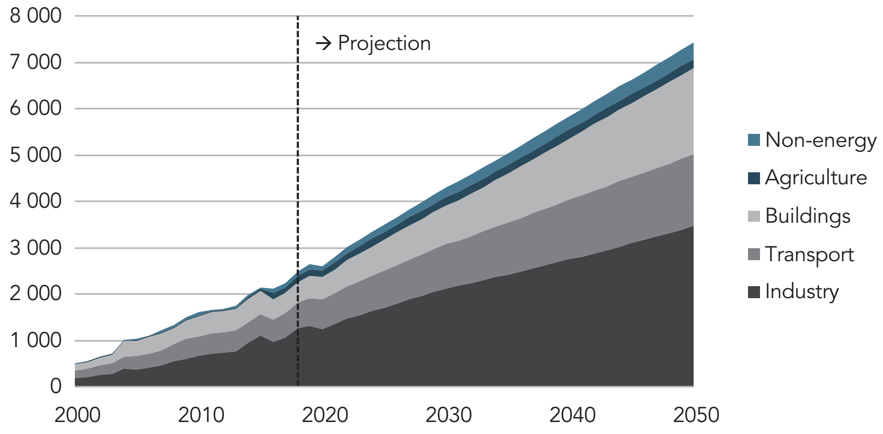


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- As economic activity and population have grown over the last decades, Viet Nam has experienced industrial development, urbanisation, increased transport activity, and improved energy access. These are key drivers for growing energy consumption.
- During the 2010-2018 period, Viet Nam's energy demand has risen at a rapid annual growth rate of 5.7%. Fossil fuel dominates the total energy mix, accounting for 59% in 2018. Oil experienced the highest growth at 4.7% per annum, followed by coal at 2.8%.
- Viet Nam will require more energy in the coming decades as it seeks to further advance the industrialisation and modernisation of its economy. REF projects that energy demand will triple over 2018 levels, reaching over 7 400 PJ. This is within the range of Resolution No. 55, which lays out 160 Mtoe to 190 Mtoe (from 6 690 PJ to 7 954PJ) of energy demand in 2045 as an oriented target for other policies such as the Energy Development Strategy and Power Development Plan.
- Electricity use grows four-fold in REF and makes up over a third of the demand mix by 2050. The rapid growth of electricity is the result of a high electrification rate in most sectors.
- End-use coal demand rises by three-fold over the 2018-2050 period as use in industrial processes (cement, chemicals, iron & steel) increases due to the affordable cost of coal and the lack of cheap alternatives.
- Oil consumption, mostly used in the transportation sector, will increase by 2.5 times by 2050. Although electric vehicles are being used in Viet Nam, policy support is needed to compete with gasoline and diesel vehicles.
- In CN, energy demand falls about 20% below REF levels, as assumed energy efficiency improvements result in energy savings. Electricity demand increases considerably over the 2030-2050 period, rising to half of the fuel mix by 2050. Fossil fuels remain relatively stable, accounting for 42% of the total energy mix by 2050.

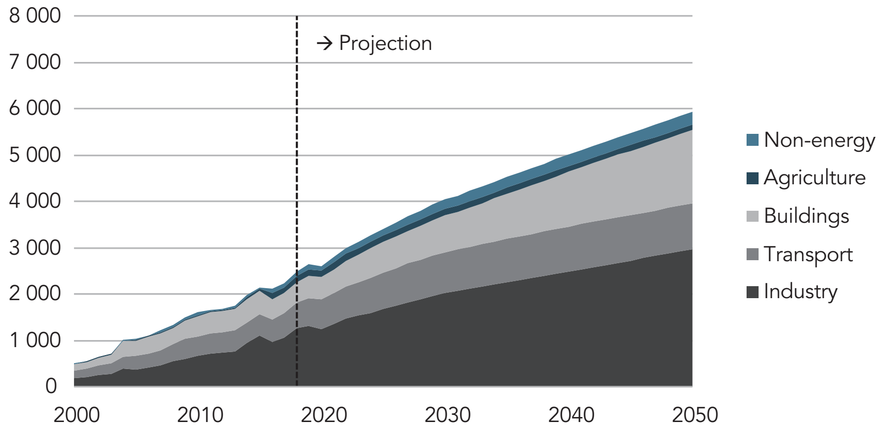
End-use energy demand by sector

Figure 21-5. Energy demand by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Includes non-energy.

Figure 21-6. Energy demand by sector in CN, 2000-2050 (PJ)

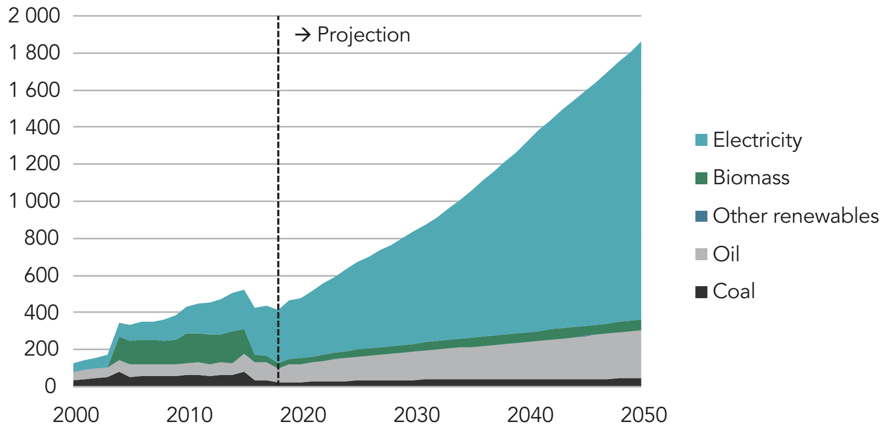


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- As a consequence of the COVID-19 pandemic, end-use energy consumption in all sectors fell in 2020. Declines in industry drove much of this fall.
- Industry is the backbone of the economy and the dominant end-use sector, accounting for just above half of the total end-use energy demand in 2018. Demand in REF rises roughly three-fold over the outlook period. This growth comes mainly from rising activity in the iron, steel, and cement subsectors.
- The transport sector is the second-largest energy consumer, accounting for 23% of total end-use energy demand in 2018. In REF, energy demand increases sharply, almost tripling by 2050. Diesel is currently the main fuel used in long-distance rail transport, but the introduction of electric trains in urban settings, such as Ha Noi and Ho Chi Minh City, should limit its growth going forward.
- Buildings ranked the third-largest energy-consuming sector, accounting for 17% of total end-use energy demand in 2018. However, its proportion will increase up to a quarter of the total energy demand in REF, overtaking the transport sector's energy consumption by 2050. Rising cooling requirements and incomes contribute to the significant increase in buildings demand. As Viet Nam continues to develop, the wide range of electric appliances in buildings continue to grow in quantity and consume increasing amounts of energy.
- Energy demand in agriculture and non-energy sectors is relatively modest over the outlook period and accounts for less than 5% of the total end-use energy demand in 2050.
- In CN, total energy demand is reduced by 20% below REF levels. Transport declines are the main driver, with electrification and a modal shift to public transport reducing demand a third. Improving thermal efficiency in industry reduces energy demand by a seventh. Efficiency improvements in buildings also reduce demand by a seventh.

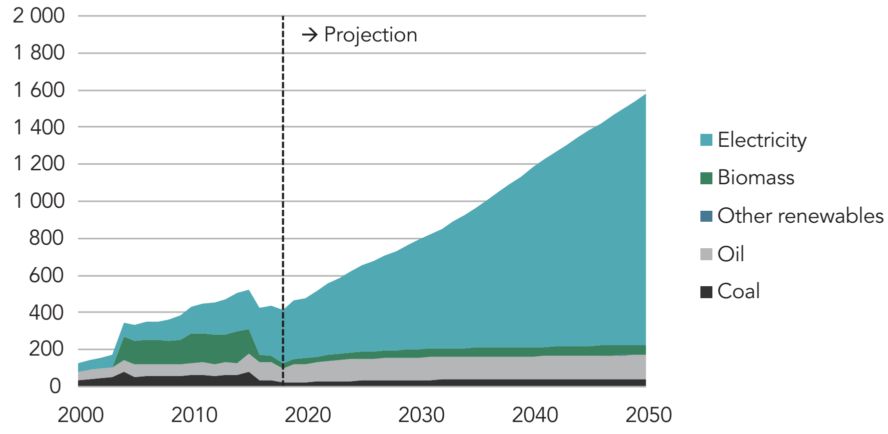
Buildings energy demand

Figure 21-7. Buildings energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-8. Buildings energy demand in CN, 2000-2050 (PJ)

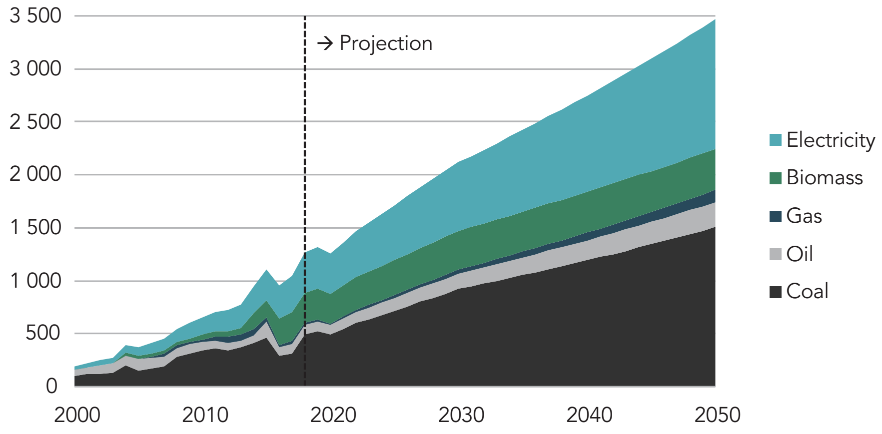


Sources: EGEDA, APERC analysis.

- Energy demand in Viet Nam's buildings sector has increased rapidly over the past decade, in line with rising incomes. Electricity dominates in the buildings sector demand currently and in both scenarios. The rural electrification program was successful at pushing the electrification rate from 96% in 2009 to 99.5% in 2019, providing electricity for over 17 million households.
- Buildings energy demand in REF rises over four-fold to above 1 800 PJ in 2050. Most (86%) of this increase comes from electricity, which grows over five-fold. A large driver of this trend is the popularisation of home electric appliances. Energy consumption for space cooling is growing with an increase in commercial spaces.
- The use of biomass, mainly for households in rural and remote areas, dropped dramatically in recent years due to rising electrification. Traditionally, Vietnamese farmers burnt biomass such as wood, straw, husks and bagasse for heating and cooking. However, with an increase in income in the rural areas, people are switching to electricity and gas.
- Coal is used by buildings for cooking and heating in remote or rural residential areas. Furthermore, some commercial buildings continue to use coal boilers to provide heat. However, coal consumption accounts for a minor share in the buildings fuel mix in both REF and CN, remaining stable over the projection outlook.
- LPG is used widely in buildings for cooking and water heating, while diesel oil is mostly used for backup generators. Oil demand will increase moderately in REF, while it will be most stable in CN over the projection period.
- Despite higher electrification of cooking and heating in CN, improvements in energy efficiency will reduce buildings energy demand by 15% below REF levels.

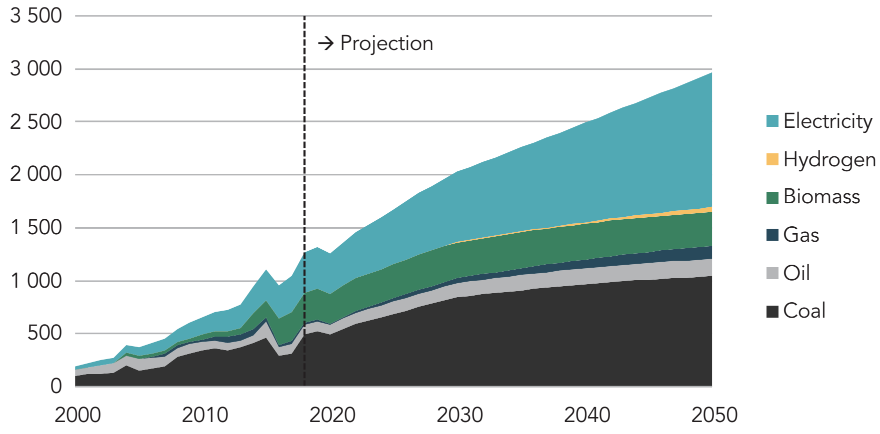
Industry energy demand

Figure 21-9. Industry energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

Figure 21-10. Industry energy demand in CN, 2000-2050 (PJ)

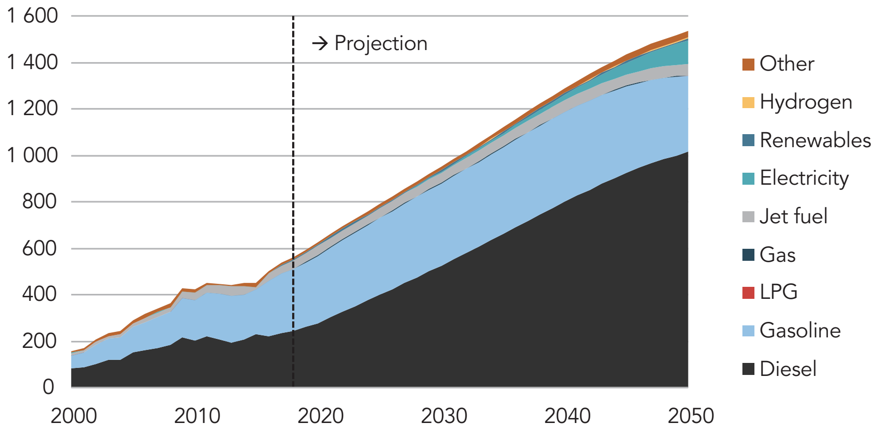


Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Energy demand in industry rose significantly over the last two decades, in tandem with significant industrialisation in Viet Nam. Industry continues to be a key driver of GDP growth in REF, and its energy use nearly triples over 2018 levels by 2050. The Others subsector (representing the manufacturing sector) is the largest energy user now, and continues to be in both scenarios. The second largest is the Non-metallic minerals subsector (including cement).
- Coal is the most-consumed industry fuel, accounting for 39% of the energy demand in 2018. Low prices and its necessary role in various industrial processes propel use three-fold in REF, and it accounts for 43% of the industrial demand in 2050. Available technologies and cost implications constrain Viet Nam's capacity to shift away from coal, making industry difficult to decarbonise.
- Electricity is the second-most used fuel by industry, accounting for 30% of the energy demand in 2018. While used in all subsectors, its mainly used in the non-metallic minerals, iron and steel, and pulp and paper subsectors. Electricity demand triples in REF, accounting for over one-third of the industrial energy demand in 2050.
- Biomass and oil demand account for 23% and 7.3% of the total industrial energy demand in 2018, respectively. Oil use more than doubles, while biomass grows moderately out to 2050. Wood and husks are the main biomass fuels for industry.
- Gas demand in the industry grows tremendously (7.8 fold) in REF, but from a small base.
- In CN, energy and material efficiency helps reduce industrial end use by almost a seventh below REF levels. There is enormous potential for energy saving and energy-efficient improvements in Viet Nam. The VNEEP sets out the target to reduce energy consumption by 10% in the 2019-2030 period.
- In CN, a small amount of hydrogen is used for the heat-producing processes after 2030. Fuel switching from coal to gas and hydrogen increases after 2030. Furthermore, electricity will substitute partly for firing in iron and steel manufacturing.

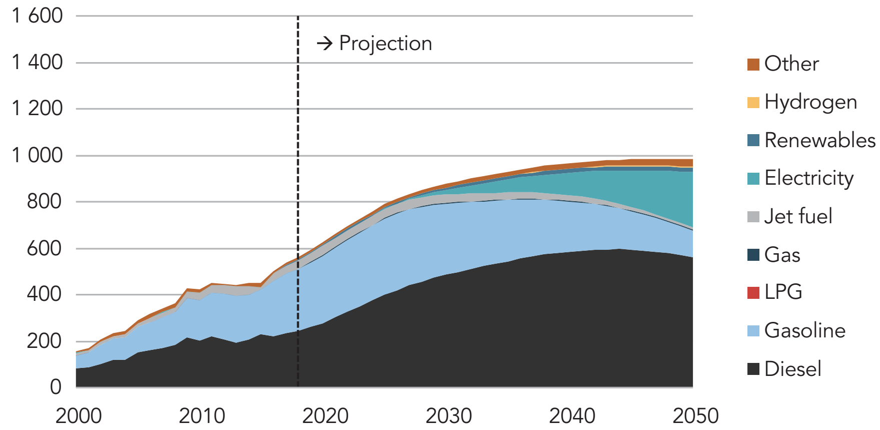
Transport energy demand

Figure 21-11. Transport energy demand in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

Figure 21-12. Transport energy demand in CN, 2000-2050 (PJ)

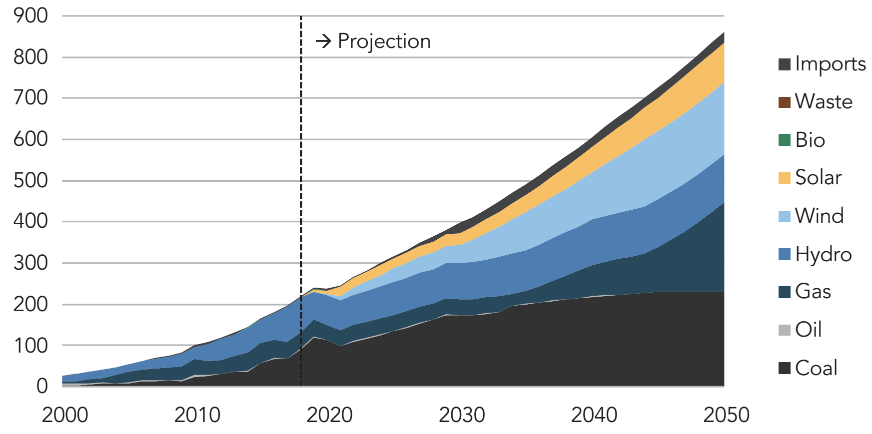


Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Transport demand is influenced by population growth in the city centres and surrounding urban environments. Energy demand in the transport sector grew substantially during the 2000-2010 period, before stabilising in the 2010-2015 period. Transport demand increases 2.7 times in REF, as both private passenger vehicle use grows and freight transport takes off.
- The dominant energy source for transport is oil products (diesel and gasoline), which account for 91% of the demand in 2018. Oil grows 2.6-fold in REF, accounting for 87% of the transport energy demand in 2050.
- Gradual uptake of electric vehicles leads electricity demand to rise dramatically in the last decade of the projection period. Electricity accounts for approximately 6.7% of transport energy demand in 2050.
- Road transport is the most extensive transport mode currently and this continues in both scenarios. Energy demand in road transport increases 2.8 times in REF due to rapid increases in domestic freight transportation and widespread use of private motorcycles and cars.
- Motorcycles and tricycles (three wheelers) are currently the most widely used vehicle by domestic road transport (91% of all vehicles). Roughly one in two people currently own a motorcycle, which contributes to heavy traffic, a high risk of accidents and high levels of air pollution in the major Viet Nam cities. Energy inefficiency and pollution are further exacerbated by an unreported number of outdated engines that do not comply with government standards.
- In CN, transport demand falls over a third from REF levels by higher electric vehicle adoption and the introduction of biofuels and hydrogen. Sales of light passenger electric vehicles rise more rapidly, reaching 40% sales by 2035 and 100% by 2050. Around 10% and 70% of heavy truck sales will be electric by 2035 and 2050, respectively. There is also a 30% reduction in private passenger vehicle use compared to REF due to policy supporting active modes of transport, use of public transit, and work from home policies.

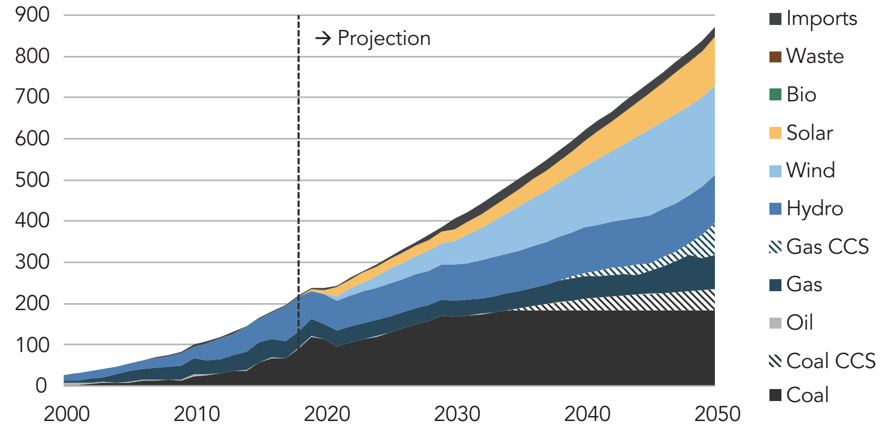
Electricity generation

Figure 21-13. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 21-14. Electricity generation in CN, 2000-2050 (TWh)

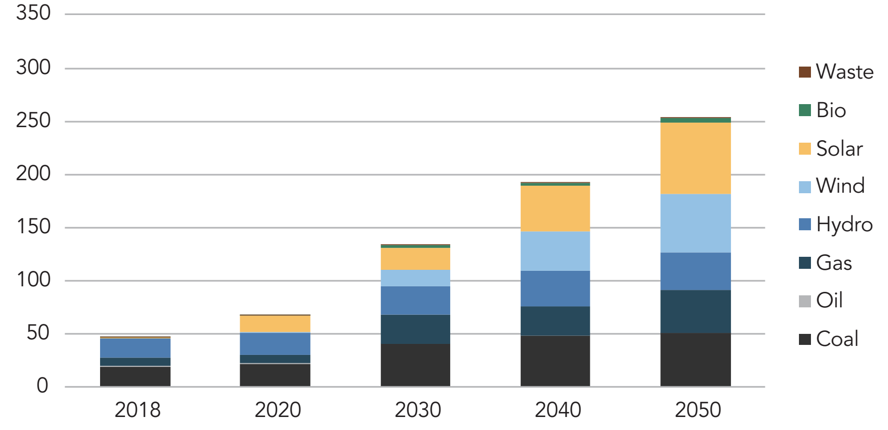


Sources: EGEDA, APERC analysis.

- Viet Nam's power sector is one of the highest growing electricity grids in the world. Although the electricity grid is interconnected across the whole economy, electricity sources are unbalanced across the economy. Coal-fired power plants are mainly located in the north, while gas-fired power plants are located in the south.
- Electricity generation follows the trends of electricity demand in REF, quadrupling from 220 TWh in 2018 to 861 TWh in 2050.
- While hydropower grows 40% above 2018 levels in both scenarios, a high utilisation rate of existing dams at their technical limits dampens growth over the projection period.
- Coal power will increase 2.5 times in the next three decades to serve as a baseload to the generation mix. However, the role of coal in the overall generation mix falls from 42% in 2019 to 27% in 2050, even though it is reduced from 42% of the total generation mix in 2018.
- Gas-fired power generation rises dramatically after 2030 to the end of the projection period. The increase of gas-fired power plants is in line with Resolution No. 55 and the draft PDP8. The electricity generation from natural gas is projected to rise 5.4 times over the outlook period. Among these, almost a fifth of natural gas comes from domestic production, with the rest, 83%, coming from LNG imports.
- Electricity generation from wind and solar will contribute considerably to the generation mix in REF, accounting for approximately 32% of the total generation outputs in 2050. This is much greater than its proportion in 2018 of less than 0.3%.
- In CN, CCS-equipped coal and gas are expected to be available from 2035 and 2038, respectively. While fossil fuels continue to make up a large share of 2050 generation, a third of their use is partially abated with CCS. The share of renewable generation makes up 39% of the total generation in 2050.

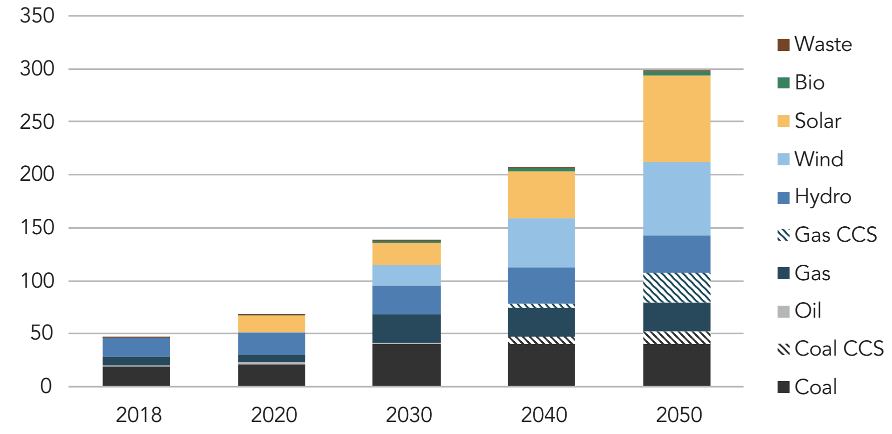
Generation capacity

Figure 21-15. Generation capacity in REF, 2017-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 21-16. Generation capacity in CN, 2017-2050 (GW)

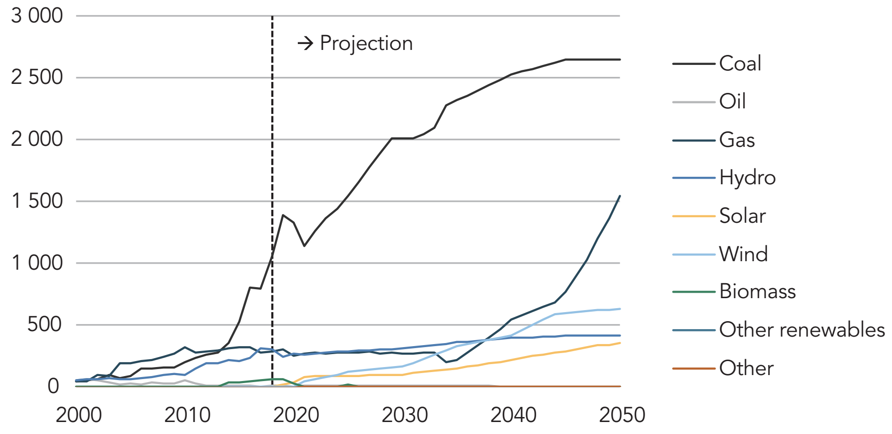


Sources: EGEDA, APERC analysis.

- Power capacity increases over five-fold in REF, from 46 GW in 2018 to 253 GW in 2050. While fossil fuels dominate current capacity, renewables contribute to most of the capacity additions over the projection period. CN capacity is even higher, reaching nearly 300 GW, to support higher electricity demand and higher renewable capacity. Wind and solar are the main drivers of this increase, but CCS-equipped coal and gas are also contributors.
- Despite its recent commitment to phase-out coal at COP26, coal continues to play an important role in powering Viet Nam's economy in both scenarios. Coal capacity rises nearly 2.7-fold in REF, from 19 GW in 2018 to approximately 51 GW in 2050. This is slightly lower than the figure planned in the revised PDP7.
- Gas power rises remarkably from 7.5 GW in 2018 to 40 GW in 2050. With domestic natural gas production insufficient to supply this capacity, LNG imports will grow to satisfy this rising demand.
- Hydropower capacity doubles over the projection period, growing from 18 GW in 2018 to over 35 GW in both scenarios. Most hydropower additions are medium and small stations.
- Renewable capacity increases tremendously over the projection period, reaching 48% of the total generation capacity by 2050. Solar and wind both contribute, with solar growing to 67 GW and wind to 56 GW.
- Variable renewable capacity grows even higher in CN to two-thirds of the capacity mix, with solar reaching 81 GW and wind 69 GW. Further expansions of variable renewables than illustrated here are required for Viet Nam to achieve a net-zero economy by 2050.
- In both scenarios, biomass power capacity increases 12-fold to 4.3 GW, while oil capacity declines from 250 MW in 2024 to 66 MW in 2050.
- In CN, CCS-equipped coal and gas power plants are assumed to start operating from 2035 and 2038, respectively. CCS technology will help reduce emissions while allowing the economy to leverage existing coal and gas-fired power plants within their lifetimes.

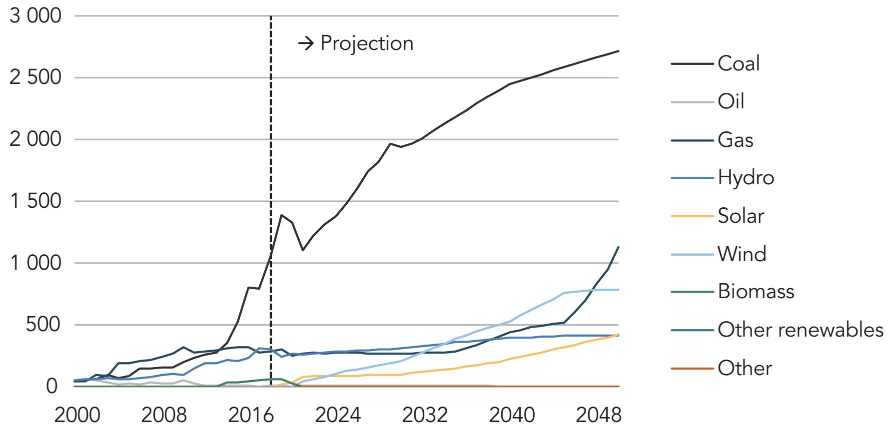
Fuel consumption by power sector

Figure 21-17. Fuel consumption by the power sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

Figure 21-18. Fuel consumption by the power sector in CN, 2000-2050 (PJ)

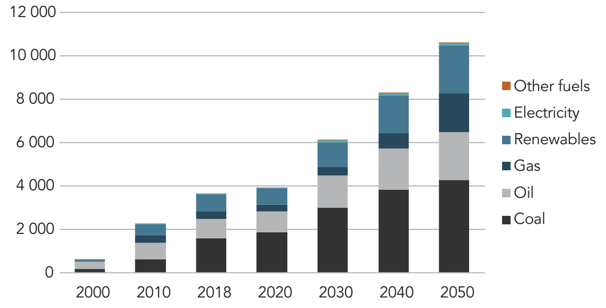


Sources: EGEDA, APERC analysis. Note: Non-fossil fuels are estimated using conversion factors from primary electricity.

- Coal use in the power sector surged in recent years to meet rising electricity demand, rising from 356 PJ in 2014 to 1 060 PJ in 2018. This continues in REF, as rising electricity demand lifts coal use to 2 647 PJ in 2050. Coal accounted for 62% of the total input fuel for the power sector in 2018 and its share declines gradually to half over the outlook period.
- Gas use in the power sector accelerates in the coming decades. However, the complicated nature of LNG-to-power projects could challenge development. Furthermore, becoming reliant on gas imports will make Viet Nam vulnerable to gas supply disruptions. Still, the share of gas increases from 17% in 2018 to 28% in REF and 21% in CN.
- The large increase in renewables consumption after 2030 follows a higher deployment in solar and wind capacity. However, grid system improvements also play a factor, as the transmission and distribution system improves to receive more electricity outputs from renewables in a stable and efficient manner. Renewable fuel use accounts for approximately 17% of total input fuel consumption by 2050 in REF.
- The hydro share accounted for 17% of total input fuel in 2018, and this declines to less than 10% by 2050. This occurs despite a modest increase in hydrogeneration, as other forms of capacity outpace hydro growth.
- By 2050, wind and solar shares of input fuel consumption in CN reaches 22%, which is 5% higher than the figure in REF. In contrast, declining gas consumption reduces its share form 28% in REF to 20% in CN. Although electricity generation in CN is higher, fuel consumption is lower due to the higher utilisation rate of renewables (solar and wind), which do not lose energy inputs in the combustion process.

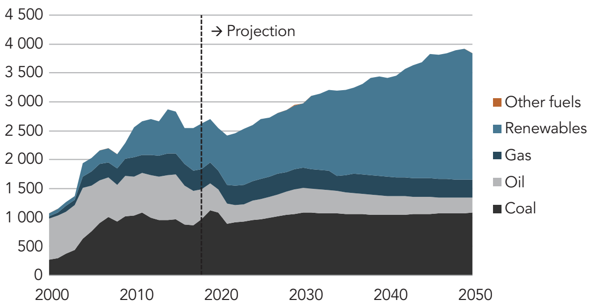
Energy supply in the Reference scenario

Figure 21-19. Total energy supply in REF, 2000-2050 (PJ)



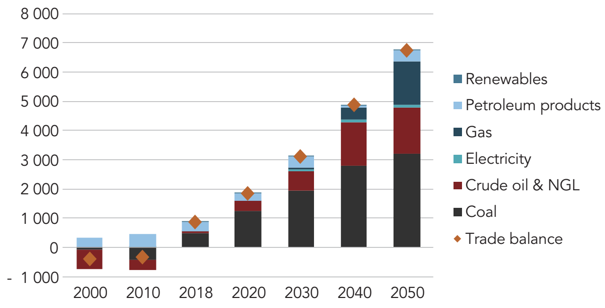
Sources: EGEDA, APERC analysis.

Figure 21-20. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-21. Net energy trade in REF, 2000-2050 (PJ)

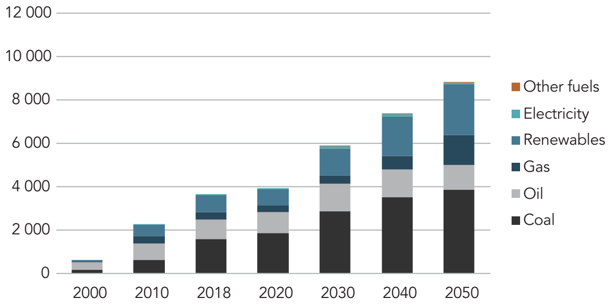


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Viet Nam's energy supply increases continuously in REF to fuel its socio-economic development, growing more than three-fold to reach over 10 500 PJ in 2050.
- Fossil fuels continue to dominant the energy mix, accounting for 78% of the total energy supply in 2050, a similar proportion to 2018 levels. Coal has the largest share, accounting for 40%, decreasing by 3.6% compared with 2018 levels. The gas supply share nearly doubles, to 17%, due to rising demand for power generation. Oil supply falls slightly to 21%, down from a quarter in 2018.
- Total energy production increases by 1.5 times from 2 600 PJ in 2018 to over 3 800 PJ in 2050. Renewable production triples from 2018 through to 2050, while fossil fuel production declines by 10% following a slight increase out to 2030.
- While Viet Nam continues to export a small amount of anthracite coal and crude oil, energy imports rise dramatically to meet its rising supply requirements. Energy imports increases six-fold in REF, and by 2050, net energy imports account for two-thirds of energy supply, up from a quarter today. Accordingly, fossil fuel's net trade accounts for 93% of Viet Nam's net energy imports. Coal accounts for 47% of the total trade balance, followed by crude oil and oil products (23%) and gas (22%).
- Relying on higher amounts of imports to sustain Viet Nam's economy will make it vulnerable to coal, gas and oil supply disruptions. Viet Nam must strive to maintain energy security throughout its energy future due to the rising vulnerabilities illustrated here.

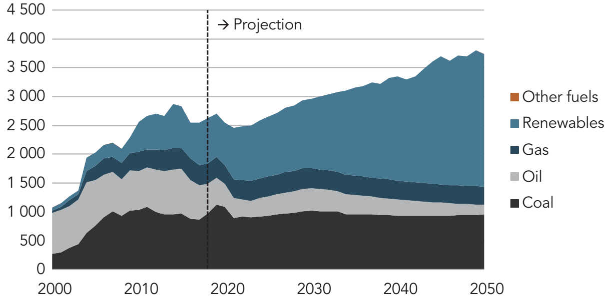
Energy supply in the Carbon Neutrality scenario

Figure 21-22. Total energy supply in CN, 2000-2050 (PJ)



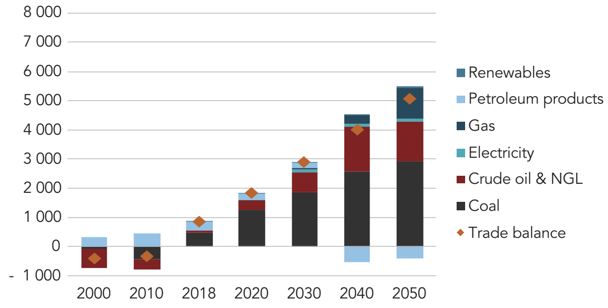
Sources: EGEDA, APERC analysis.

Figure 21-23. Energy production in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-24. Net energy trade in CN, 2000-2050 (PJ)

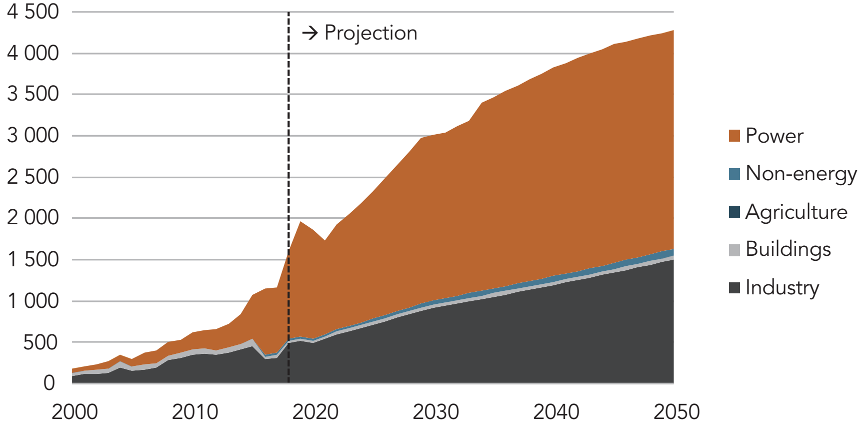


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- Viet Nam's energy supply continues to grow in CN, but energy efficiency gains help limit it to just under 9 000 PJ, a fifth below REF levels. Lower supply requirements and the higher deployment of solar and wind resources allow renewables to grow their share of supply to 27%, moderately higher than REF.
- Fossil fuel supply continues to grow and meets almost three-quarters of energy requirements. However, 2050 fossil fuel supply falls by almost a quarter below REF levels, as the adoption of electric and fuel-cell vehicles reduces oil supply by a half, and fuel switching in both the industry and the power sectors reduce coal supply by a tenth and gas supply by a quarter.
- While total energy production grows similarly to REF, falling 2.8% beneath REF levels in 2050, there is some variation amongst the components. Higher deployment of solar and wind lifts renewables production up by 5.2% over REF, while lower domestic and global demand for fossil fuels reduces their production by almost an eighth, with most of this decline occurring in coal and oil.
- Net energy trade falls a quarter below REF levels, but import requirements grow five-fold. This highlights how Viet Nam will remain vulnerable to supply disruptions in CN. Viet Nam becomes a net petroleum products exporter after 2040 in CN. This assumes that it can find a market for its excess product and that refineries are not retired due to low utilisation rates.
- Viet Nam's current policies enable the development of renewable energy and reduce fossil fuel use. However, it faces several challenges that will hinder renewable adoption, such as the insufficiency of smart grid technologies, storage systems and transmission lines. Consequently, in the transitional period to a carbon neutral society, Viet Nam will continue to require fossil fuel-based power plants for baseload generation. Further development in smart grids, storage systems and transmission lines than shown here is required to achieve more ambitious emission reductions.

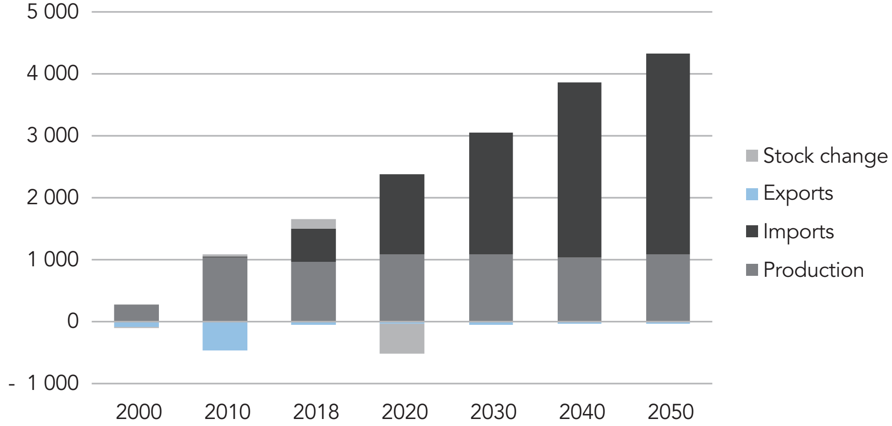
Coal in the Reference scenario

Figure 21-25. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-26. Coal production, imports, and exports in REF, 2000-2050 (PJ)

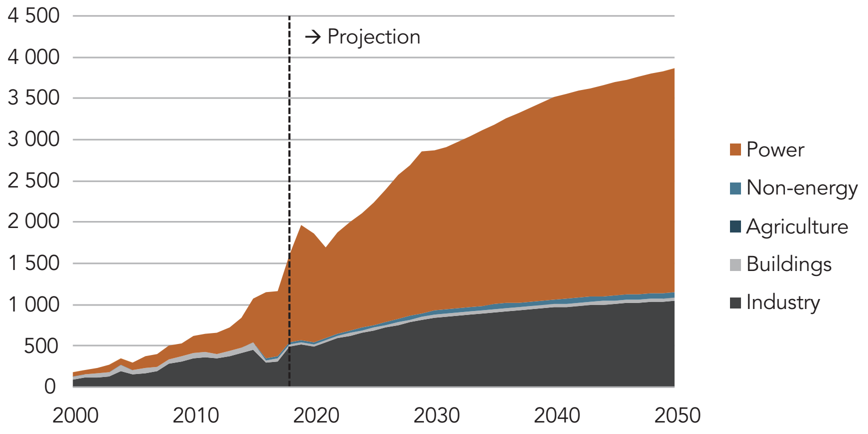


Sources: EGEDA, APERC analysis.

- Coal is used mainly in the power and industry sectors, but is also a feedstock in the non-energy sector and combusted for heating and cooking in buildings. Coal consumption grows steeply, rising 2.7 times over the outlook period, as demand from the power and industry sectors surges.
- The low cost and availability of coal over the last decade prompted Viet Nam to significantly invest in coal-fired generation capacity. Power now makes up 70% of coal supply requirements in the economy. A continuation of lower-costs and availability will continue to drive coal supply trends, despite echoing calls to phase-out coal-fired power generation. Rising coal capacity continues throughout the outlook period, and coal-fired generation lifts coal supply to 2 700 PJ in 2050.
- The industrial subsectors continue to rely on both thermal and metallurgical coal for processes that require consistent calorific heat. Industry use of coal triples over the outlook period, accounting for 28% of coal consumption by 2050.
- Coal production regains some of its recent losses following the pandemic, rising over 1 000 PJ in the 2020s, before declining slightly below it for the remainder of the projection. Further production increases are challenged due to the unfavourable conditions of mining geology in Quang Ninh, a traditional anthracite coalfield in Viet Nam. Although the potential to raise capacity exists at the Red Delta River, any increase will be minor relative to Viet Nam's total demand after 2035. With coal production constrained, coal imports will rise substantially to meet the coal demand increases to 2050.
- Viet Nam has started to import a large amount of coal since 2014 to supplement its domestic production. This trend continues, with imports rising over six times in REF. By 2050, three-quarters of Viet Nam's coal supply comes from imports. Because metallurgical coal production is in short supply, most metallurgical coal for iron and steel manufacturers continues to be imported.

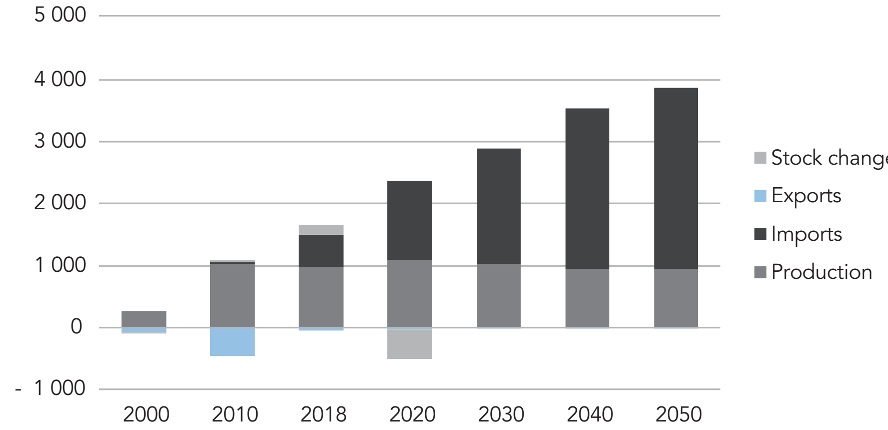
Coal in the Carbon Neutrality scenario

Figure 21-27. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-28. Coal production, imports, and exports in CN, 2000-2050 (PJ)

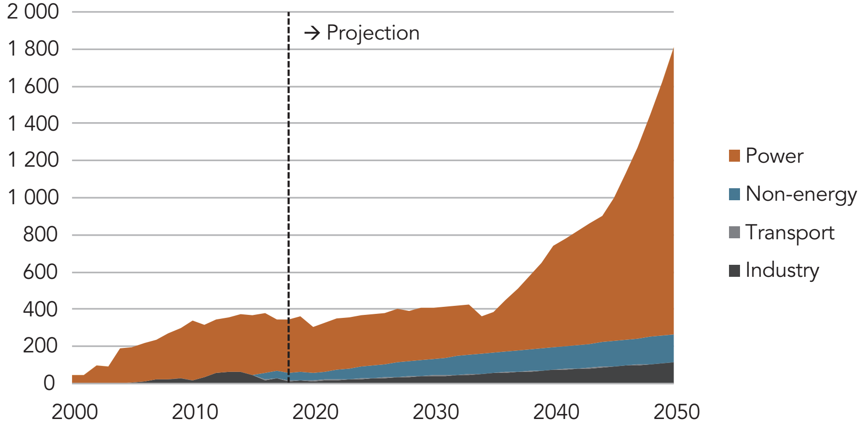


Sources: EGEDA, APERC analysis.

- Coal use continues to grow significantly in CN, more than doubling over current levels. Relative to REF, use falls a tenth, as energy efficiency and fuel switching in the end-use sector reduce demand.
- The low price and availability of coal continue to trump phase-out desires in CN, as coal-fired generation increases slightly over REF levels. Part of this is driven by rising electricity demand and the adoption of CCS to abate some of the emissions associated with coal use.
- Coal consumption by industry increases considerably before shifting to a slower pace in the 2040s. In 2050 industrial coal use is nearly a third below REF and fuel switching reduces use in industrial subsectors. For example, a higher adoption of electric arc furnaces allow the iron and steel subsectors to reduce their metallurgical coal usage.
- By 2050, lower domestic demand for coal drives both coal production and imports down by 12% and 10% below REF levels, respectively.
- At COP26 Viet Nam pledged to phase out coal by the 2040s. This includes ending the construction and investment into coal-fired power generation and new coal plants. This *Outlook* is not consistent with that commitment and highlights the significant work that Viet Nam's power and industry sectors will need to do to reduce their future emission profile. Viet Nam still consumes approximately 3 900 PJ of coal by 2050.

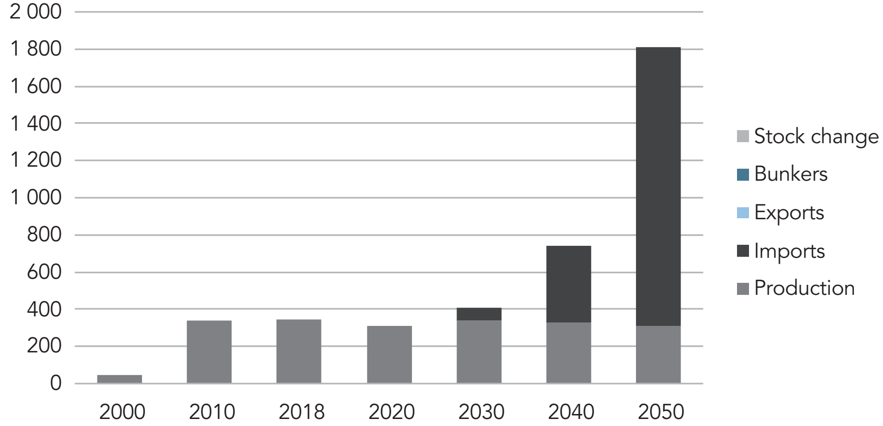
Natural gas in the Reference scenario

Figure 21-29. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-30. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

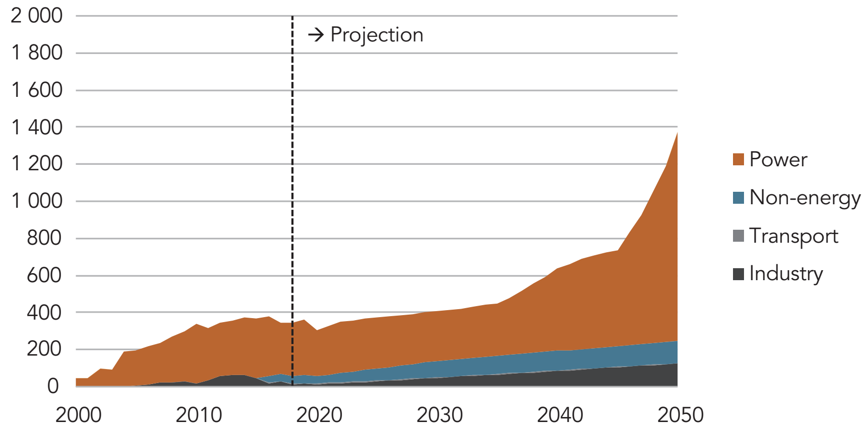


Sources: EGEDA, APERC analysis.

- Natural gas use grows five-fold in REF, with a notable increase occurring after 2035 in the power sector. This results from the government's fuel-switching policies that encourage the use of lower-emitting fuels in the power sector. Gas demand also grows almost eight times in industry and four times in non-energy, albeit from smaller bases.
- According to the new draft of the NEDS and PDP8, gas supply is expected to spike after 2030 to fuel new LNG-fired power plants. However, before 2035, gas supply in REF grows at a slower pace than the trajectories shown in the two draft policies, because the *Outlook* projects lower gas use in the power sector.
- Natural gas production increases slightly during this decade to around its pre-pandemic high of 350 PJ, then declines gradually through to the end of the projection period to around 300 PJ.
- Historically, domestic production met all of Viet Nam's gas consumption, but in the 2020s, the economy will begin importing LNG to fuel LNG-to-power plants. After 2035, rising power demand lifts supply requirements well above domestic production, and resulting in a significant build-out of LNG terminal capacity to meet it.
- The commissioning of Viet Nam's first LNG import terminal is assumed to occur in late 2022, but power demand keeps LNG imports at or below 100 PJ until 2035. This changes soon after, as rising power demand lifts LNG imports to 411 PJ in 2040 and approximately 1 500 PJ in 2050. LNG capacity rises from about 23 Mtpa in 2035 to almost 30 Mtpa in 2050 to meet these requirements, with the terminal utilisation rate increasing from 10% to 100% over the same period.
- Viet Nam's vulnerability to gas security disruptions increases in REF, with LNG imports increasing gas import dependence from zero to over 80%. Securing gas supply becomes an essential condition of Viet Nam's economic prosperity in this scenario.

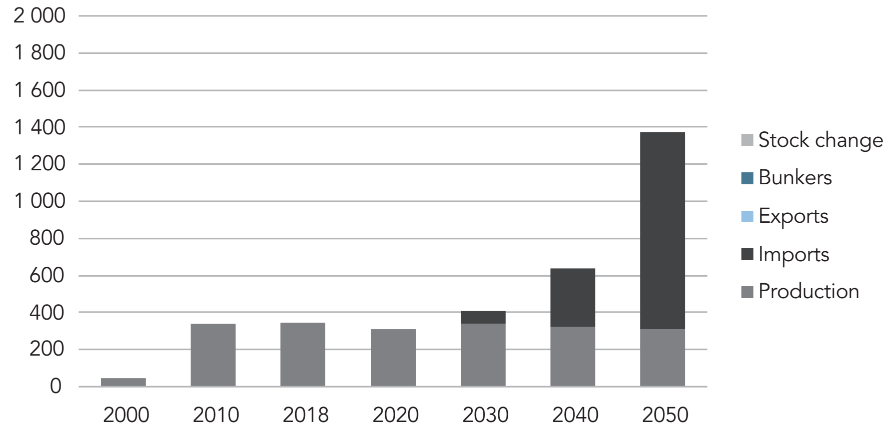
Natural gas in the Carbon Neutrality scenario

Figure 21-31. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-32. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

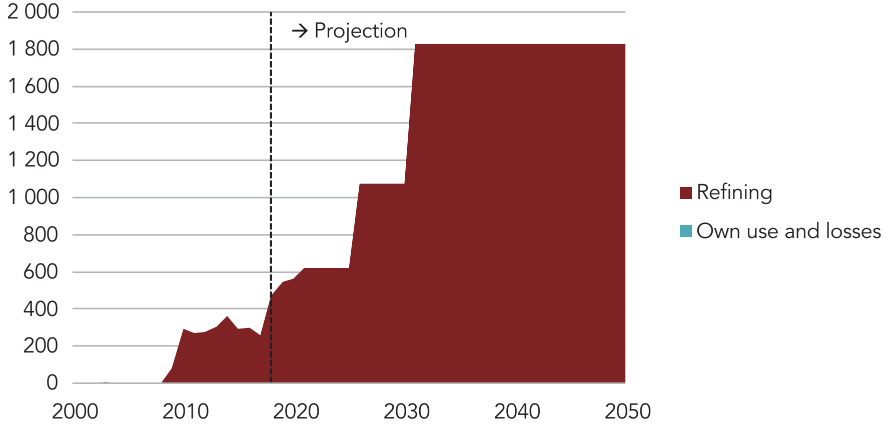


Sources: EGEDA, APERC analysis.

- Natural gas use continues to surge in CN, quadrupling over current levels on the back of significant power growth in the back half of the *Outlook*. However, natural gas consumption is lower than REF for almost all energy sectors in CN except industry, and by 2050, the total natural gas consumption will fall a quarter below REF levels.
- Gas continues to play a role in fueling the power sector in CN, quadrupling over the outlook period. However, higher renewable penetration reduces the role of gas, and the adoption of CCS helps abate some of its remaining energy-related emissions.
- Natural gas makes gains in industry as a result of the government's fuel-switching policy to reduce coal use. Reductions in transport and non-energy is due to energy efficiency improvements and fuel switching from natural gas to electricity.
- Natural gas production in CN is about the same as REF, peaking near 350 PJ by 2030, and declining gradually over the projection period.
- LNG imports grows significantly to almost 1 100 PJ, about a third below REF levels, and regasification capacity rises to 23 Mtpa to process the imports. This capacity is a third below REF levels. Utilisation rates rise throughout the outlook period, hitting a high of 95% in 2050.
- Imported LNG accounts for 78% of the total gas supply in 2050, 5.2% lower than in REF. Viet Nam's vulnerability to gas security disruptions still rises in this scenario and securing gas supply becomes an essential condition of economic prosperity.

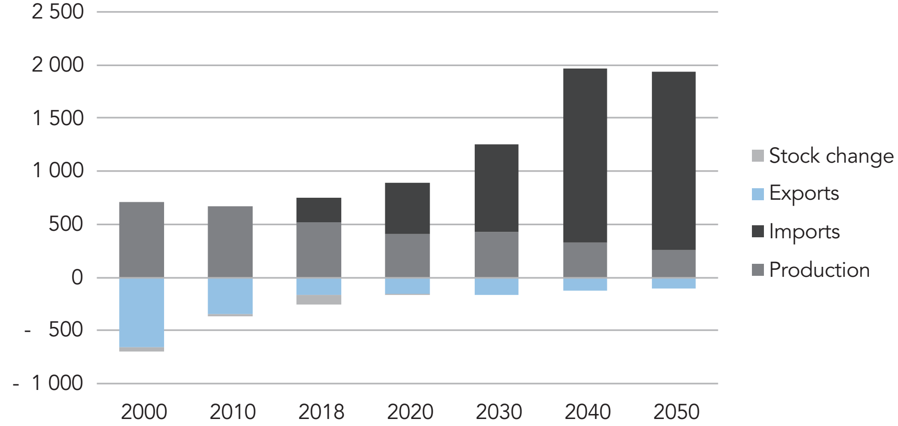
Crude oil and NGLs in the Reference scenario

Figure 21-33. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-34. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

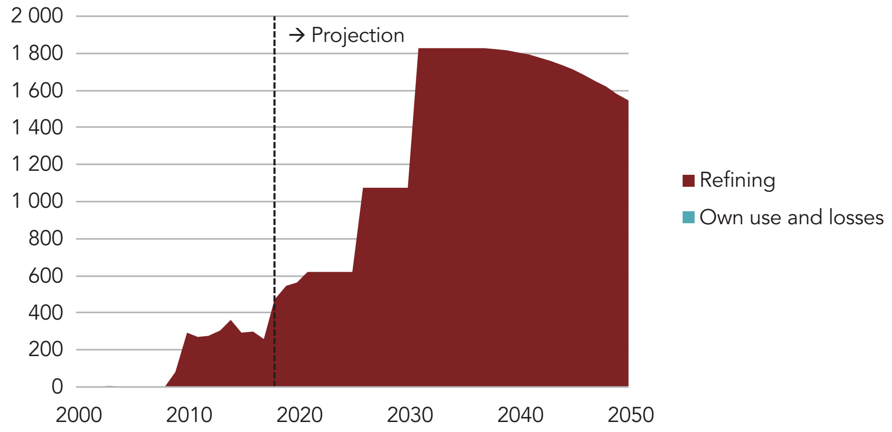


Sources: EGEDA, APERC analysis.

- Crude oil use in Viet Nam occurs completely at its refineries, although there is historically some personal-use consumption of crude oil that receded in 2004. In recent years, processing has increased following the commissioning of another refinery.
- Refinery capacity is set to nearly triple over the outlook period, as new refineries come online in both the 2020s and 2030s. Crude oil consumption by refineries quadruples between 2018 and 2050.
- Viet Nam's crude oil is historically a major energy export and contributor to GDP for the economy. However, revenue from crude oil exports is declining, falling from 12% of GDP in 2014 to 7.1% in 2015, and less than 1% in 2018, as production fell by half due to both lower global oil prices and the maturation of the Cuu Long Basin.
- In REF, some exploration allows crude oil production to partially reverse its decline, increasing to around 10 Mtoe. However, resource depletion continues thereafter, and by 2050 production falls to about half of 2018 levels, under 6 Mtoe. Current high prices could incentivise Viet Nam to explore and develop further domestic crude oil supplies than illustrated here.
- Imported crude oil rises dramatically over the projection period to supply rising refinery capacity, reaching approximately 1 700 PJ by 2050, an increase of over seven times. Crude oil exports track production, falling over a third. A reliance on imports to feed refineries exposes Viet Nam to oil supply disruptions. Policies to maintain oil supply security will become important in this scenario.

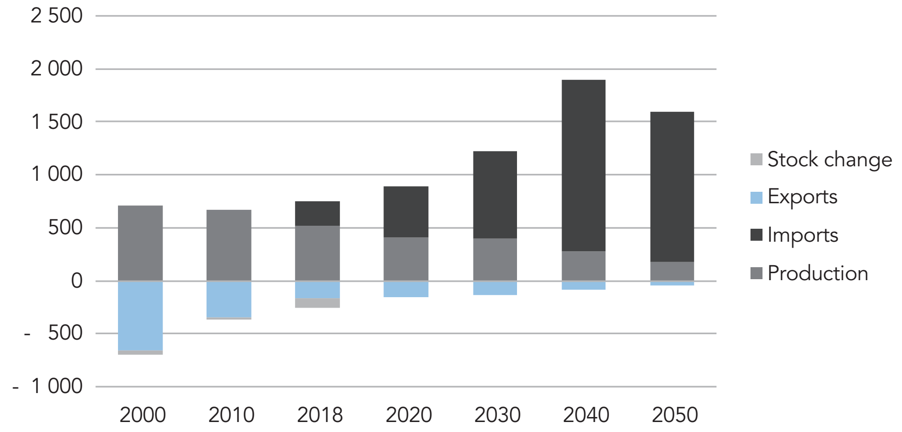
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 21-35. Crude oil and NGL consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-36. Crude oil and NGL production, imports, and exports in CN, 2000-2050 (PJ)

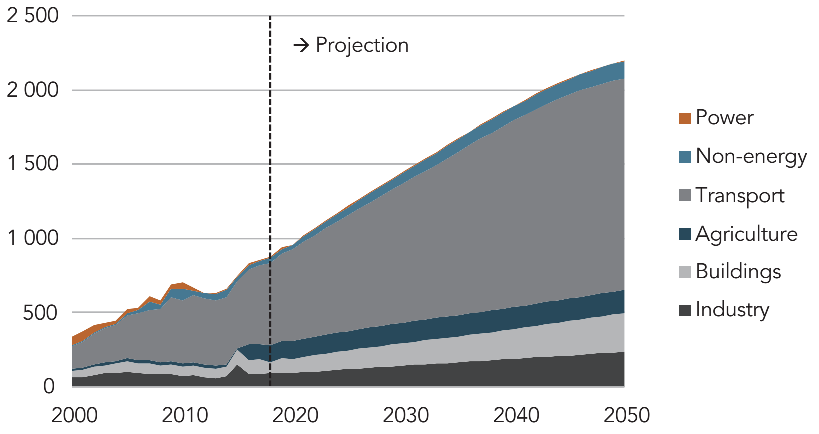


Sources: EGEDA, APERC analysis.

- Into the 2030s, refinery capacity in CN mimics REF, tripling over current levels. However, as the world embraces carbon neutrality, global demand for refined product falls, and lowers demand for Viet Nam output. To maintain a high utilisation rate of 90%, Viet Nam will retire 16% of its refinery capacity by 2050.
- Refinery runs continue to grow but trail off into the 2040s to match this lower capacity, falling 16% below REF levels.
- There is risk that as the world embraces carbon neutrality, the global and domestic market for refined products could shrink and result in higher competition across the remaining global refiners. Any refinery addition after the 2030s, such as the planned Dong Nam Bo expansion, carries significant stranded asset risk in this scenario. Viet Nam must carefully analyse the economics of refinery expansions in the future.
- Lower global demand for oil in this scenario drags down crude oil exports to about half of REF levels. This results in lower oil production, which is about a third below REF levels.
- Crude oil imports mimic the refinery runs, climbing significantly until reaching a peak of over 1 600 PJ in 2040. However, a declining global market for refined products reduces refinery runs, and in turn oil import requirements, by 16% below REF levels.

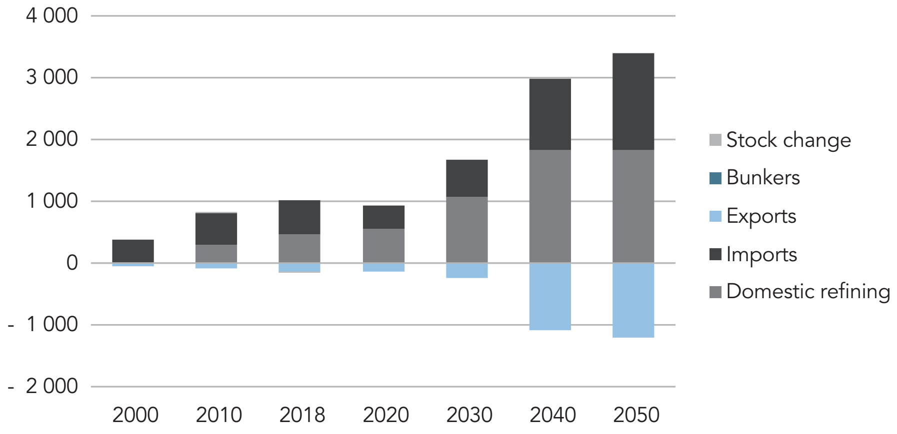
Refined products in the Reference scenario

Figure 21-37. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-38. Refined products production, imports, and exports in REF, 2000-2050 (PJ)



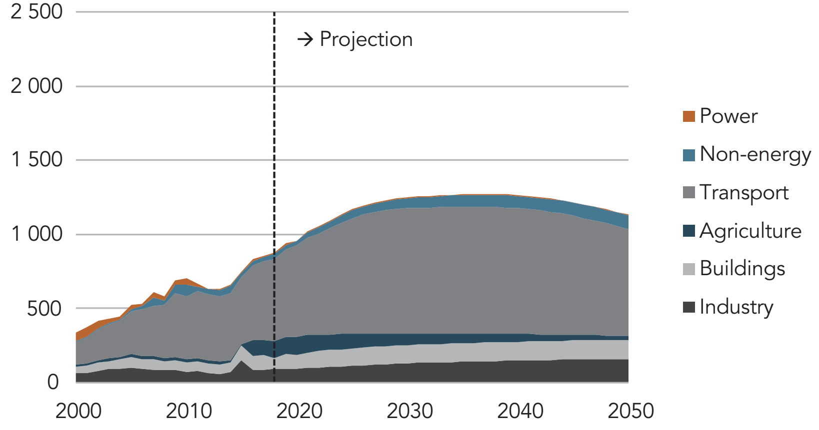
Sources: EGEDA, APERC analysis.

- Currently, Viet Nam has two refining plants (Dung Quat and Nghi Son) with 17 Mtpa, meeting 70% of its oil product demand. Viet Nam planned a schedule of expansions and new refineries to help meet rising refined product demand over the coming decades. According to the draft of NEDS, Viet Nam plans to expand refining capacity to 39 Mtpa in 2031-36 and 49 Mtpa in 2040-50. The results of REF mirror this plan, with capacity nearly tripling by 2050.
- Refined products are consumed throughout Viet Nam's sectors. Transport consumes mainly gasoline and diesel, and the mining subsector consumes diesel to operate heavy machinery, like trucks and hydraulic excavators. Buildings use refined products for cooking and heating purposes, agriculture is a large user of diesel, and the non-energy sector consumes petroleum products as feedstocks.
- Demand for petroleum products rises significantly in most sectors, lifting total consumption 2.5 times over the outlook period, as the industrialisation and modernisation of Viet Nam continues, and population and incomes continue to grow. Transport and industry more than doubles, buildings and non-energy more than triple, and agriculture grows by about a third.
- Imports of petroleum products have grown significantly since 2000 due to rapid growth in consumption and limited domestic refinery capacity. Imports continue to grow in the projection period, tripling by 2050, as much of the domestic production of refined products is exported to global markets. Exports grow over 10-fold by 2050.
- There may be an opportunity to reduce the vulnerability of Viet Nam to refined product imports by diverting some of its export volumes for domestic use.

Note: NEDS - the National Energy Development Strategy for the 2021-2030 period with the vision to 2050

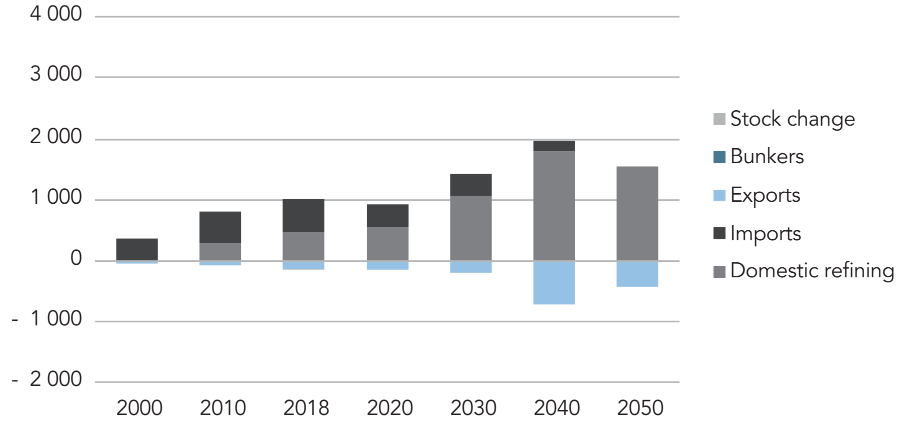
Refined products in the Carbon Neutrality scenario

Figure 21-39. Refined product consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 21-40. Refined product production, imports, and exports in CN, 2000-2050 (PJ)

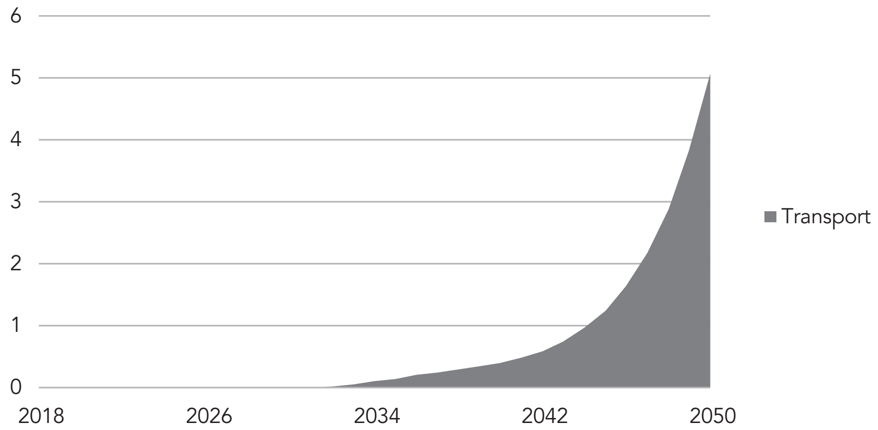


Sources: EGEDA, APERC analysis.

- Refined product use grows in CN but is curbed significantly due to fuel switching and energy efficiency improvements. Use peaks in the 2030s, falling thereafter to about half of REF levels by 2050. Much of this is driven by the transport sector, where consumption is also halved, as hydrogen and electricity begin to increasingly displace oil products.
- In buildings and industry, petroleum product consumption falls by almost half and one-third below REF levels, respectively. Electrification and switching away from both LPG and diesel are significant drivers of this trend. A rural electrification program helps agriculture reduce its refined product consumption by over three-quarters below current and REF levels.
- With a lower and more competitive market for refined products in CN, it is assumed that Viet Nam buoys its refinery sector by diverting more product output to the domestic market. As a result, imports decline significantly compared to REF, being nearly eliminated in 2050, and exports fall to about a third of REF levels.
- Viet Nam's refining capacity declines 16% below both its peak in the 2030s and REF levels due to the lower oil products demand in both Viet Nam and the world. This retirement illustrates the stranded asset risk facing refinery investments over the next few decades.

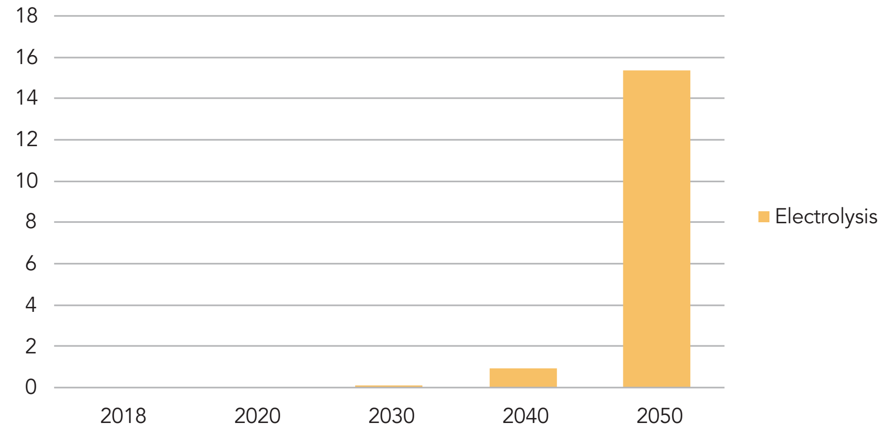
Hydrogen in the Reference scenario

Figure 21-41. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 21-42. Hydrogen production, imports, and exports in REF, 2000-2050 (PJ)

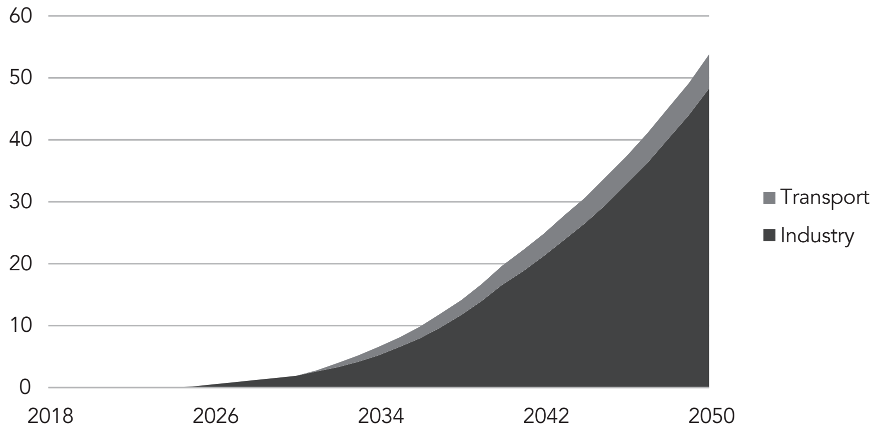


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- A small amount of hydrogen starts to be used in the transport sector from 2031. Hydrogen utilisation in transport is expected to rise dramatically in the last decade of the projection period due government support. However, it grows from a low base, and only makes up a third of a percent of transport demand by 2050.
- Resolution No. 55 states Viet Nam's intent to foster the use of hydrogen in its energy sector. This includes technological research, the development of production pilot projects and encouraging utilisation in line with global trends. In December 2020, Prime Minister's decision No 38/2020/QD-TTg mentions hydrogen development as a high priority project, particularly green hydrogen.
- This small amount of demand in REF is met exclusively with domestic production via electrolysis. Viet Nam has a large potential for offshore wind, which will be fundamental to developing green hydrogen at an affordable cost. Viet Nam's Oil and Gas Group is a likely candidate to produce green hydrogen based on its experience and ability to leverage existing infrastructure.

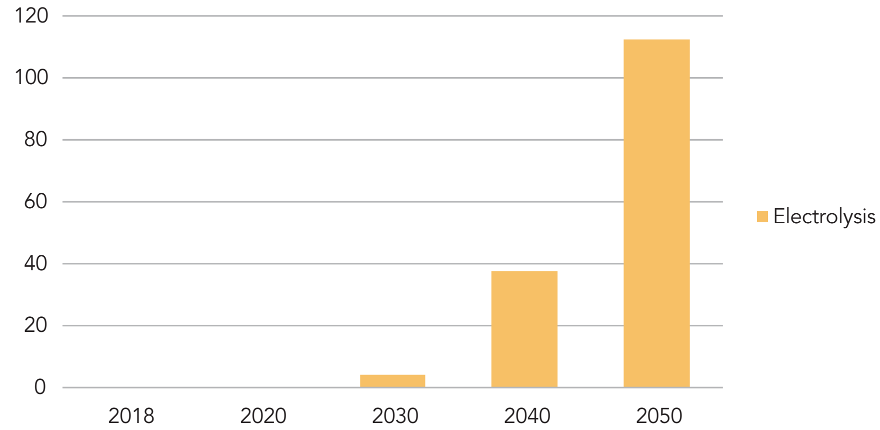
Hydrogen in the Carbon Neutrality scenario

Figure 21-43. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered.

Figure 21-44. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

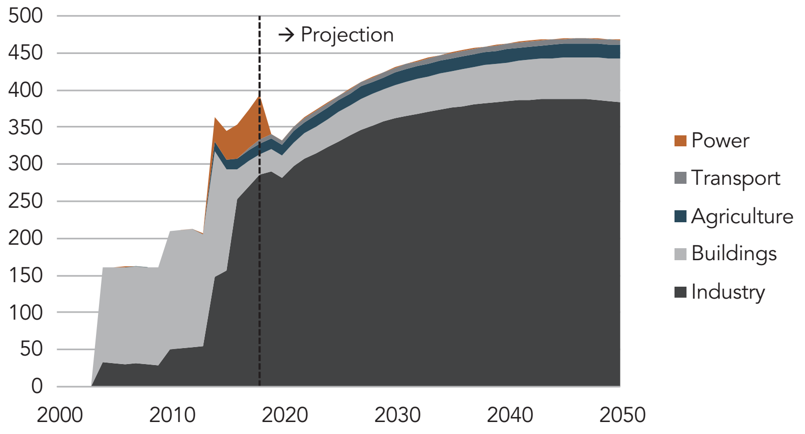


Notes: Hydrogen as an industrial feedstock is not considered. Exports are produced from steam methane reformation with CCUS (blue) or electrolyser processes (green).

- The market for hydrogen makes significant gains in CN, with multiple global industry and transport use cases fuelling robust development in Viet Nam.
- Hydrogen use begins earlier in CN, as industry starts adopting it in 2025. The scale of hydrogen consumption is far larger in CN, reaching approximately 54 PJ in 2050, 10-fold that of REF.
- Hydrogen demand in the transport sector grows modestly over REF to around 5.4 PJ. This is partly driven by technology advancements and the commercialisation of industrial hydrogen applications, such as the co-firing of hydrogen with other fuels for process heat use by subsectors such as chemicals and steel. Demand rises to almost 50 PJ by 2050.

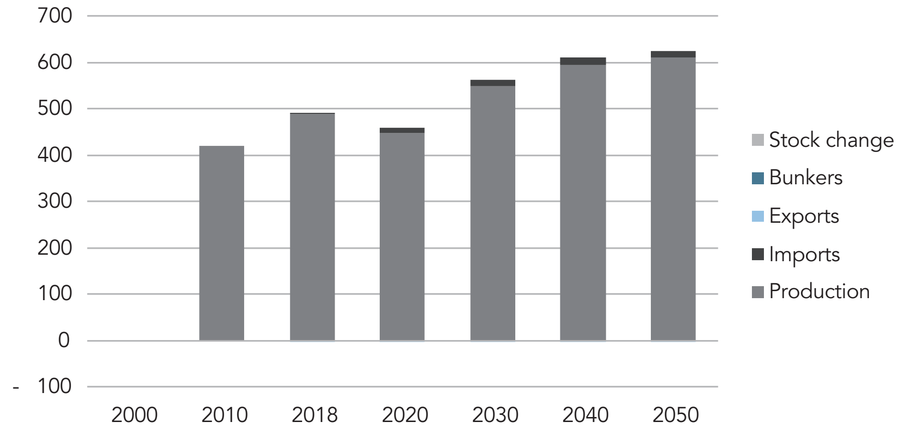
Bioenergy in the Reference scenario

Figure 21-45. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 21-46. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)

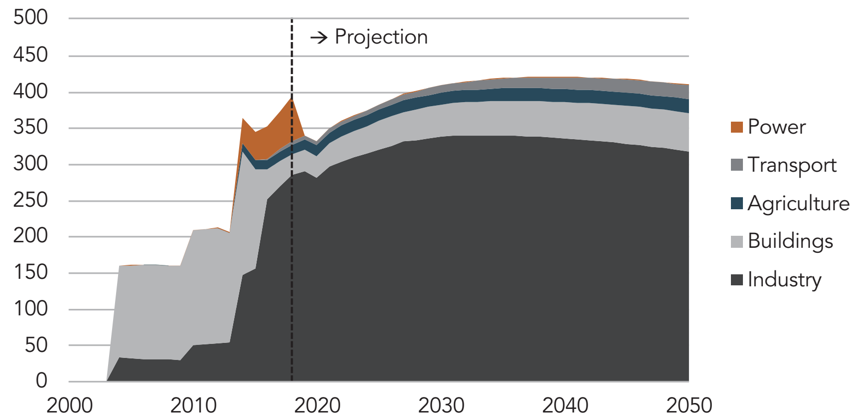


Sources: EGEDA, APERC analysis.

- Consumption of bioenergy increases gradually to the early 2040s, plateauing out to 2050, though the sectoral composition of that consumption shifts significantly. Total renewables consumption rises by 1.4 times over 2018-2050.
- Biomass is used mainly in the industrial sector, rising substantially in the 2020s and continuing to rise slowly through to 2050. Biomass consumption is projected to rise by 1.3 times relative to 2018, accounting for approximately 82% of the total solid and liquid renewable consumption by 2050. Increasing end-use of renewables in the industry sector is driven by replacing coal and coal-based products with advanced biomass at various rates in non-metallic minerals and chemical and petrochemical.
- In the buildings sector, biofuels and biogas are more available in the residential subsector than traditional biomass, increasing gradually over the projection period.
- While solid and liquid renewables used in the agriculture sector increase slightly, biomass in power and transport sectors mostly keep unchanged over the projection period.
- Viet Nam has deployed more biofuels (bioethanol) in the transport sector using E5 and E10 gasoline-bioethanol blend (a fuel mixture of 5% or 10% ethanol and 95% or 90% gasoline, respectively) for many years. However, the consumption of these products is modest due to the quality of the gasoline-bioethanol blend and commuters' awareness.
- The supply of bioenergy is exclusively from domestic production sources.

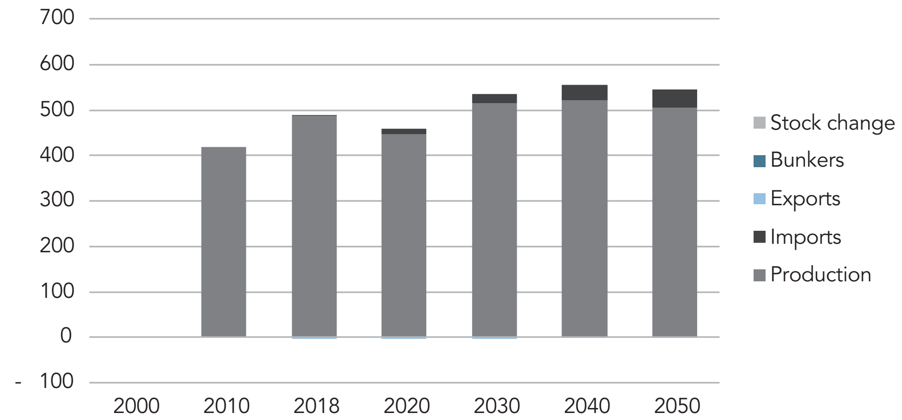
Bioenergy in the Carbon Neutrality scenario

Figure 21-47. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: Solid and liquid renewables includes biomass, biogas, and biofuels.

Figure 21-48. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)

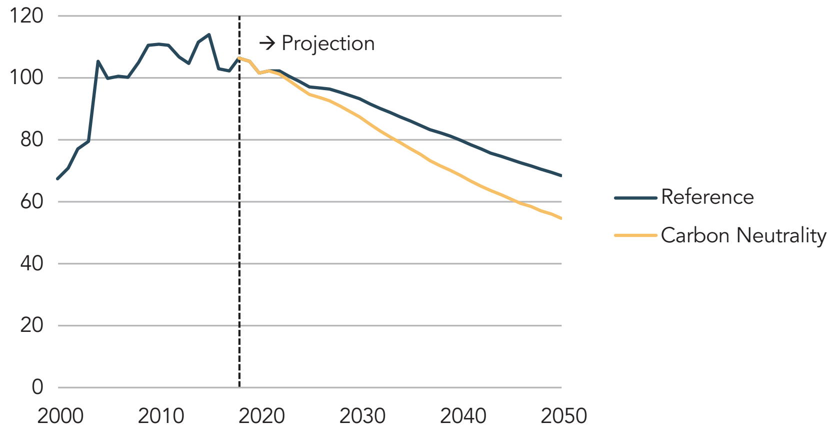


Sources: EGEDA, APERC analysis.

- The total consumption of bioenergy is 12% lower in CN. Biofuel consumption by transport in CN rises by 3.1 times, while biomass consumption by the power sector is similar to REF.
- Biomass consumption in the industrial sector reaches a peak in 2035, declining gradually over the projection period.
- Unlike in REF, imported biofuel will almost rise by three times in CN. This is partially driven by biojet fuel demand being used by the aviation sector.

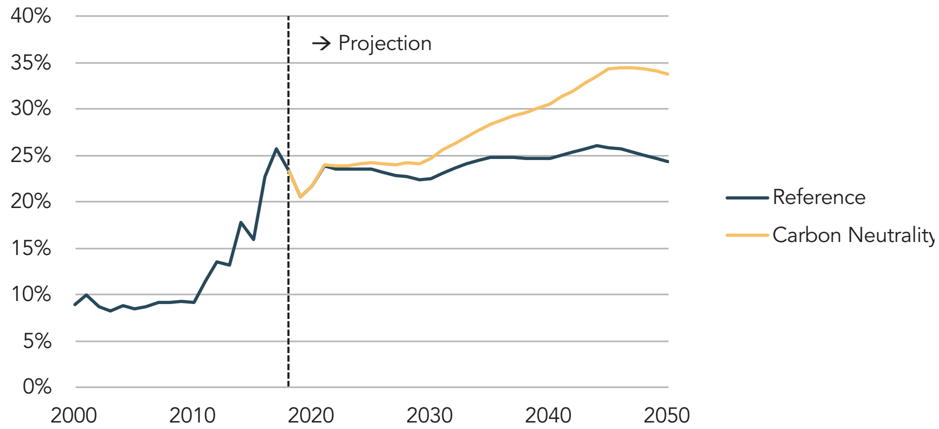
Energy Intensity and Modern Renewable share

Figure 21-49. Final energy intensity in REF and CN (2005=100)



Sources: EGEDA, APERC analysis. Note: Excludes non-energy.

Figure 21-50. Modern renewables share in REF and CN, 2000-2050



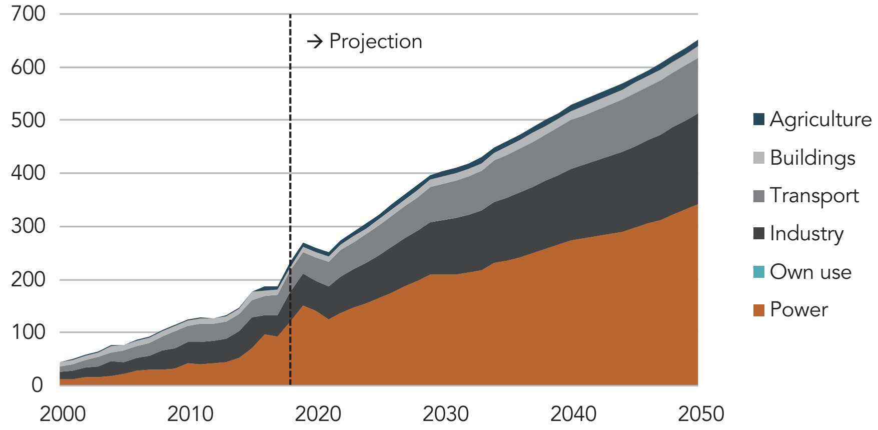
Sources: EGEDA, APERC analysis. Note: Modern renewables include direct consumption of renewables in end-use demand sectors (excluding non-energy and biomass in some sectors) and the share of electricity produced by renewable sources.

- While Viet Nam's final energy intensity improved slightly during the 2010–2017 period, it increased by 4.2% in 2018.
- Viet Nam's VNEEP program targets a saving of 8–10% of total energy consumption and ensuring that electric losses are below 6%. This program helps Viet Nam reduce its energy intensity by almost a third below 2005 levels in REF, and further efficiency enhancements in CN drive further reductions, to about 45% below 2005 levels.
- The VNEEP program helps Viet Nam contribute to APEC achieving its aspirational target of reducing energy intensity by 45% below 2005 levels by 2035. However, Viet Nam itself only achieves intensity reductions in the 2035 target year of 14% in REF and 23% in CN.
- The share of modern renewables in Viet Nam's energy mix remained under 10% until the 2010s, when a tripling of hydrogeneration lifted the share to 26% in 2017. However, this proportion dropped in recent years due to overcapacity on electric transmission lines constraints. For example, almost all solar and wind farms were asked to curtail output to the economy-wide grid in both 2020 and 2021. According to the EVN, about 364 GWh of solar electricity output was diminished in 2020. Similarly, EVN plans to reduce 1.3 TWh of solar and 430 GWh of wind output in 2021.
- Modern renewables growth rises at a modest pace, reaching almost a quarter of Viet Nam's energy mix in 2050 in REF. This growth is supported by growth in hydro capacity and the continued deployment of wind and solar, which partly displaces fossil-based power generation.
- In CN, the share of modern renewables rises to almost 35%, as renewable deployment, the electrification of the industrial and transport sectors, and lower demand allow it to make gains over REF share.

Note: Additional calculations for final energy intensity and modern renewables share are available in the supporting dataset.

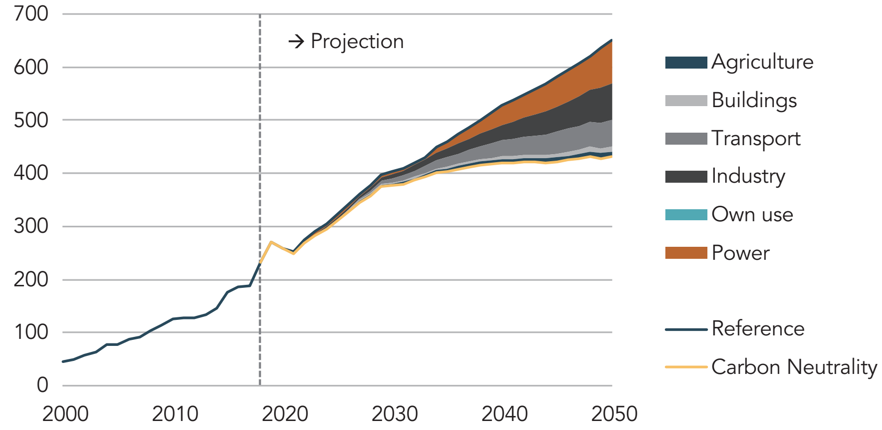
Gross CO_2 emissions

Figure 21-51. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

Figure 21-52. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

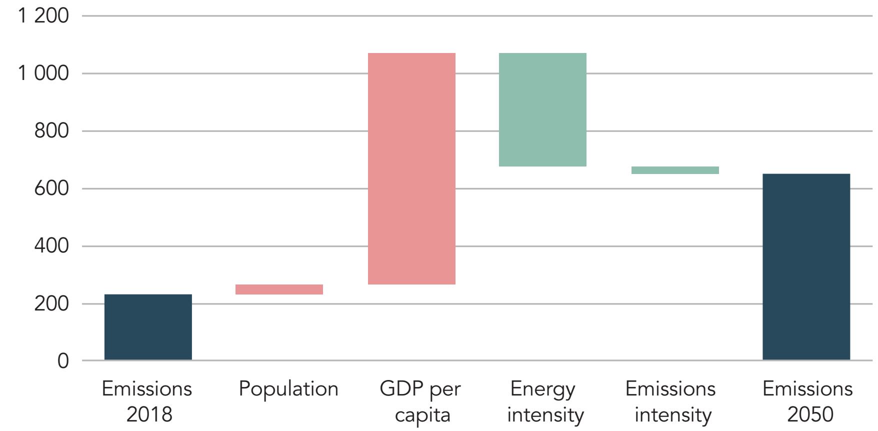


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- Viet Nam's energy-related CO_2 emissions grew a torrid pace of 10% per annum from 2000 to 2018 as the economy underwent significant industrialisation and modernisation. While the onset of the pandemic delivered a 3.9% drop in emissions in 2020, fossil fuels continue to fuel further advances in the economy in both scenarios, driving emissions 2.8 times higher in REF and 1.9 times in CN.
- In REF, increases in fossil fuel-fired generation nearly triples power sector CO_2 emissions by 2050. Power sector emissions maintain a stable emission share, comprising over half of total energy-related CO_2. Unabated coal-fired power plants - the largest single emitter – continue to rise by 2.5-fold. CCS is not deployed on any thermal assets in REF.
- Industry is the second-largest CO_2 emitter and its emissions rise gradually in REF, accounting for over a quarter of Viet Nam's emissions by 2050. Fuel switching in industrial processes, mainly from coal to natural gas, limits increases.
- In REF, the growth of private vehicle use and the freight activity increases transport emissions by 2.6 times. In 2050, transport accounts for 16% of the total energy-related CO_2 emissions.
- In CN, energy-related CO_2 emissions continue to grow but are reduced by one-third compared to REF levels. Fuel switching and CCS reduce power sector emissions by a quarter below REF levels, while electrification and fuel switching reduce emissions in both industry and buildings by over two-fifths and over 80% in agriculture. Modal switching, lower activity levels and electrification help half emissions in the transport sector compared to REF.
- Viet Nam updated its NDC in July 2020 with a voluntary reduction target of 9% compared to the BAU scenario by 2030. It can be increased by up to 27% compared to the BAU scenario with international support. In CN, energy-related CO_2 emissions are expected to decline by 6.7% in 2030 relative to REF, which is close to the energy-related CO_2 emissions target (7.2%) in the updated NDC.

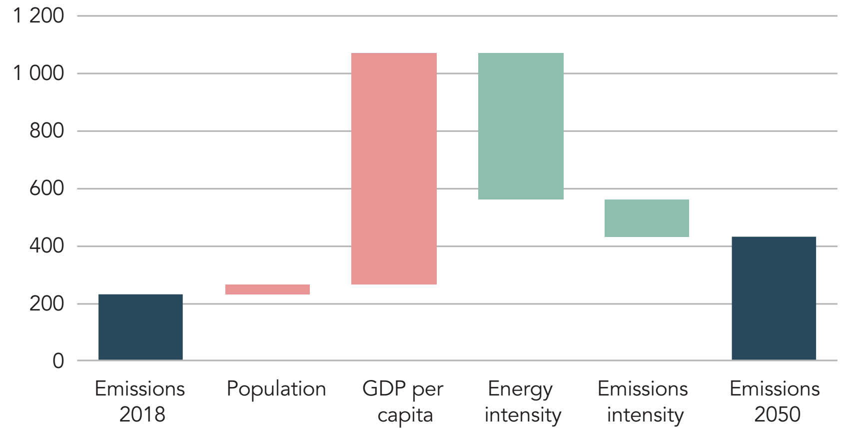
Components of CO_2 emissions

Figure 21-53. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

Figure 21-54. CO_2 emissions components in CN, 2018 and 2050 (million tonnes)



Sources: UNFCCC, EGEDA, APERC analysis.

- These charts show CO_2 emissions as the product of four factors: population, GDP per capita, energy intensity, and emissions intensity. Energy and emissions intensities are calculated using the total primary energy supply, including inputs to the refining and power sectors.
- REF shows a strong correlation between CO_2 emissions and income growth. The modelling results suggest a rise of 0.7% in CO_2 emissions for every 1.0% increase in GDP per capita.
- Viet Nam emitted 233 million tonnes of CO_2 in 2018, accounting for 1.1% of total APEC emissions. Based on Viet Nam's assumed population and GDP growth, emissions would rise 4.6 times in REF without efficiency improvements or carbon abatement. However, both help reduce energy-related CO_2 emissions by 418 million tonnes of CO_2. Energy intensity accounts for 94% of this CO_2 reduction, with emissions intensity accounting for the remainder.
- Advances in energy efficiency in CN increase the energy intensity emission reduction by a third over REF. Fuel-switching and carbon abatement lift the emissions intensity reduction 5.0 times higher than REF levels. These additional improvements mean that the energy-related CO_2 emissions in 2050 are reduced by one-third below REF levels.
- With emissions nearly doubling in CN, Viet Nam will need to deploy extensive negative CO_2 emissions measures, such as CCUS, large-scale carbon dioxide removal offsets or declines in non-combustible emissions to achieve carbon neutrality. Additionally, further action would be required to achieve Viet Nam's 2050 net-zero CO_2 emissions target.

Note: The above charts are a representation of the Kaya identity which is CO_2 emissions = Population * $\frac{\text{GDP}}{\text{Population}} * \frac{\text{Energy supply}}{\text{GDP}} * \frac{CO_2\text{ emissions}}{\text{Energy supply}}$.

Additional information

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Viet Nam Oil and Gas Group (PVN). http://www.pvn.com.vn

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Viet Nam National Coal and Mineral Industries Holding Corporation Ltd (Vinacomin). http://www.vinacomin.vn/

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Annex

Conversion factors

From Petajoule (PJ) to	Multiply by:	
Trillion British thermal units	TBTU	0.948
Million tonnes of oil equivalent	MTOE	0.024
Million barrels of oil equivalent	MMBOE	0.164
Million tonnes of coal equivalent	MTCE	0.04 - 0.093
Million tonnes per annum of LNG	Mtpa	0.020
Billion cubic meters of natural gas	bcm	0.028
Billion cubic feet of natural gas	bcf	0.981
Terawatt-hour	TWh	0.278
Million gigacalorie	Million GCal	0.239
Million tonnes of hydrogen	MM tonne H_2	0.008

Regional groupings

China

Northeast Asia Hong Kong, China; Japan; Korea; Chinese Taipei.

Oceania Australia; New Zealand; Papua New Guinea.

Other Americas Canada; Chile; Mexico; Peru.

Russia

Southeast Asia Brunei Darussalam; Indonesia; Malaysia; the Philippines; Singapore; Thailand; Viet Nam.

United States

Commonly used abbreviations and terms

AFOLU	Agriculture, Forestry, and Other Land Use
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Centre
bcm	Billion cubic metres
BEV	Battery electric vehicle
CCS	Carbon capture and storage
CCUS	Carbon capture, utilisation, and storage
CN	The Carbon Neutrality scenario
CNG	Compressed natural gas
CO_2	Carbon dioxide
COP26	2021 United Nations Climate Change Conference
COVID-19	Coronavirus disease 2019
EGEDA	Expert Group on Energy Data and Analysis
EV	Electric vehicle
EWG	APEC Energy Working Group
GDP	Gross domestic product
GHG	Greenhouse gases
GW	Gigawatt
ICE	Internal combustion engine
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
km^2	Square kilometer
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
Mtpa	Million tonnes per annum
MTOE	Million tonnes of oil equivalent
NDC	Nationally Determined Contribution
NGL	Natural gas liquids
OECD	Organisation for Economic Co-operation and Development
OPEC+	Organisation of the Petroleum Exporting Countries Plus
PJ	Petajoule
PPP	Purchasing power parity
PV	Photovoltaic
REF	The Reference scenario
SMR	Small modular reactor
TWh	Terawatt-hour
UN DESA	United Nations Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
USD	US dollar
WDI	World Development Indicators

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