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Economic Cooperation

APEC Energy Demand and Supply Outlook
8th Edition 2022

Volume 1

APERC
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 Mr. Glen Sweetnam and Dr. David Wogan, 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

Acknowledgements

The development of the *APEC Energy Demand and Supply Outlook 8th Edition* would not have been possible without the contributions of many individuals and organisations within APEC's 21 economies and globally. We would like to thank those whose support made this edition possible, particularly those who participated in the APERC Annual Conference and those individuals and organisations below.

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

We would also like to express our appreciation to members of the APEC Secretariat, APEC Energy Working Group (EWG), APEC Expert Group on Energy Data and Analysis (EGEDA), APERC Advisory Board, along with numerous government officials for their helpful information and comments throughout the development process of this report.

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Highlights

Macro

- APEC population is expected to peak in the 2030s, before declining to be only 2.0% higher in 2050.
- Economic output (real GDP) more than doubles out to 2050, with assumed increases largely due to productivity gains.

Demand

- Even with much higher economic output, end-use energy demand only grows by a modest amount (14%) from 2018 to 2050 in REF.
- In CN, demand peaks in the mid-2020s, before declining to a level 11% lower in 2050 relative to 2018.
- Fossil fuels fall from almost 70% of end-use energy demand to just over 60% in REF in 2050. The fall is more prominent in CN, with fossil fuels falling to a 45% share in 2050.
- Electrification of end-use sectors gathers pace, reaching 29% of energy demand in REF and 40% in CN.
- The transport sector undergoes the most substantial transition as EV adoption accelerates.

Power

- To 2050, electricity generation increases by 45% in REF, and by 60% in CN (exclusive of hydrogen electrolysis).
- Coal-fired generation declines in both scenarios, with a near complete phase-out in CN.
- Gas-fired generation expands in both scenarios, with CCS technology enabling a substantial amount of gas to remain in CN, while meeting emissions abatement goals.
- Solar and wind generation expands to a 27% share in REF and 45% share in CN. The absolute increases in both solar and wind generation from 2018 to 2050 rank number one and two in both scenarios.

Supply

- APEC energy supply grows by 16% in REF and falls by 10% in CN, with demand trends driving these results (2018–2050).
- Southeast Asia is the only region to have a higher level of energy supply in CN in 2050, attributable to the rapid economic growth of the region.
- Fossil fuels maintain a large portion of energy supply in both scenarios. However, coal declines even in REF.
- Crude oil continues to dominate net energy imports, but production growth, mainly from the United States and Canada, reduces net crude imports by 20% in REF.
- APEC becomes a net refined products exporter in CN, as refineries strive to capture global market share in the face of declining global demand.

APEC energy goals

- APEC has a shared goal to improve energy intensity by at least 45% by 2035 relative to 2005.
- The goal is expected to be reached one year ahead of schedule (2034) in REF and four years ahead of schedule (2031) in CN.
- By 2050, energy intensity is estimated to be 60% below 2005 levels in REF and almost 70% lower in CN.
- The second shared APEC energy goal is to double the share of modern renewables in the energy mix by 2030, relative to 2010.
- APEC is expected to meet the aspirational goal of doubling renewables by 2026 in REF, and by 2025 in CN.

CO_2 emissions

- Despite growing economic activity, APEC-wide CO_2 emissions are anticipated to decline from 21 000 million tonnes (2018) to 18 000 million tonnes in REF (2050).
- In CN, emissions decline to 7 000 million tonnes (2050) due to a large-scale reduction of coal consumption, primarily in the power sector; electrification of transport; and CCS deployment.
- Energy intensity and emissions intensity more than offset emissions increases that would otherwise occur from increasing standards of living (GDP per capita) and population growth.
- Other greenhouse gases, fugitive emissions, such as from flaring and methane leakage, and non-energy sector emissions are not considered in this analysis.
- Additional CO_2 emissions mitigation beyond CN could be supported by removals or by natural or technological methods.

1. 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.

About APEC

- The Asia-Pacific Economic Cooperation (APEC) is a regional economic forum that promotes balanced and sustainable economic growth.
- APEC member economies meet to discuss and cooperate on economic and social issues such as the welfare of its people, finance, health, food, education, and energy.
- APEC has 21 member economies spanning both sides of the Pacific Ocean. It includes Australia; Brunei Darussalam; Canada; Chile; China; Hong Kong, China; Indonesia; Japan; Republic of Korea; Malaysia; Mexico; New Zealand; Papua New Guinea; Peru; the Philippines; Russia; Singapore; Chinese Taipei; Thailand; the United States; and Viet Nam.
- APEC economies represent over 38% of the global population and 56% of global economic activity, with strong economic trade ties throughout the world.
- The role APEC plays in the global energy market is indispensable. It accounts for 56% of world energy demand, 58% of world energy supply, and 68% of world electricity generation. APEC accounts for 60% of global CO_2 emissions.
- APEC economies are home to a significant quantity of known energy reserves. However, for oil and gas, most global reserves are located outside APEC.
- Many APEC economies have participated in the UNFCCC process at the annual Conference of the Parties conventions and have proposed increasingly ambitious decarbonisation targets in the past few years.
- Since the last *Outlook*, published in 2019, population, GDP, energy demand, supply, production, electricity generation, and CO_2 emissions in the APEC region have all grown.

Table 1-1. APEC statistics, 2018

	2018	Share of world
Population	2 902	38%
GDP	70 125	56%
Energy demand	232 425	56%
Energy supply	345 518	58%
Energy production	340 560	54%
Electricity generation	17 244	68%
CO_2 emissions	21 234	60%

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

Table 1-2. APEC energy resources, 2018

	Proved reserves	Share of world
Coal	15 708 717	71%
Natural gas	2 411 439	36%
Oil	2 391 795	23%
Uranium	3 092 500	50%

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

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.

Table 1-2. 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.

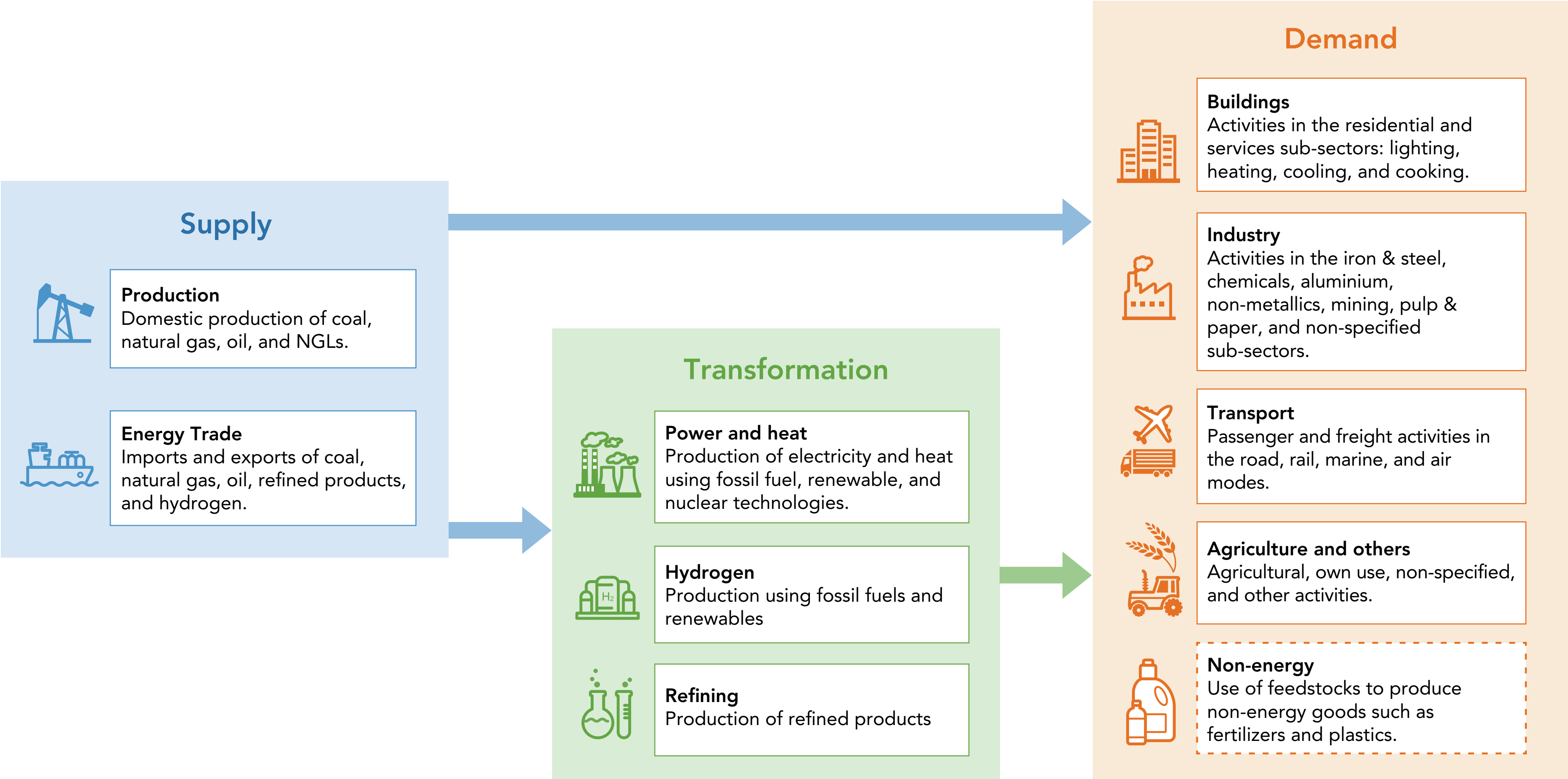
Key assumptions

Table 1-3. Key assumptions for the Reference and Carbon Neutrality scenarios

	Reference	Carbon Neutrality
General	• Historical GDP data from World Bank World Development Indicators • GDP projections from OECD and internal analysis • COVID-19 impact on GDP is incorporated for 2020 to 2025 (IMF). • Population projections are from UN DESA.	• Same as REF
Buildings	• Gradual improvements in energy efficiency • Gradual move away from traditional biomass	• Increased electrification and efficiency measures • Accelerated reduction in traditional biomass
Industry	• Small uptake of CCS for steel, cement, and chemicals subsectors starting in 2040. • Small amount of hydrogen for steel and chemicals subsectors 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 2030. • 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	• Vehicle stock remains mostly ICE. • Fuel efficiency follows recent trends.	• Improved fuel efficiency • 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	• Fuel switching follows recent trends and policy direction. • No CCS	• CCS for gas-fired plants (and some coal-fired plants in select economies) • Near complete coal phase-out by 2050 • Improved competitiveness of utility-scale PV and wind (onshore and offshore)
Supply	• Global market for oil, natural gas, and coal expected to continue to be a prominent market for APEC exports.	• Global export market for oil, natural gas, and coal is lower assuming carbon neutrality measures outside APEC.
Climate	• NDCs and other general targets are considered through 2030, though not strictly adhered to.	• Individual economy targets vary between 2050–2060. • Aggregate APEC emissions observed through 2050. • Fugitive and negative emissions are not considered.

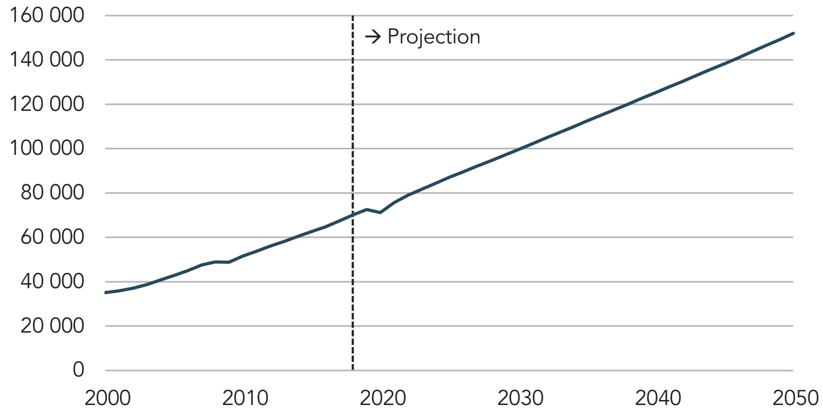
Notes: The base year is 2018. Macro-economic assumptions are constant across scenarios. Historical energy balances are from EGEDA submissions for 2018 (published June 2021).

Components of the APEC energy system



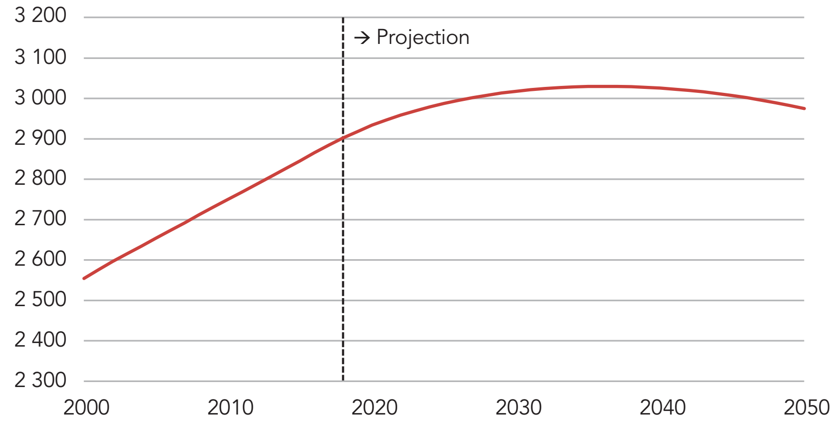
Macroeconomic backdrop

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



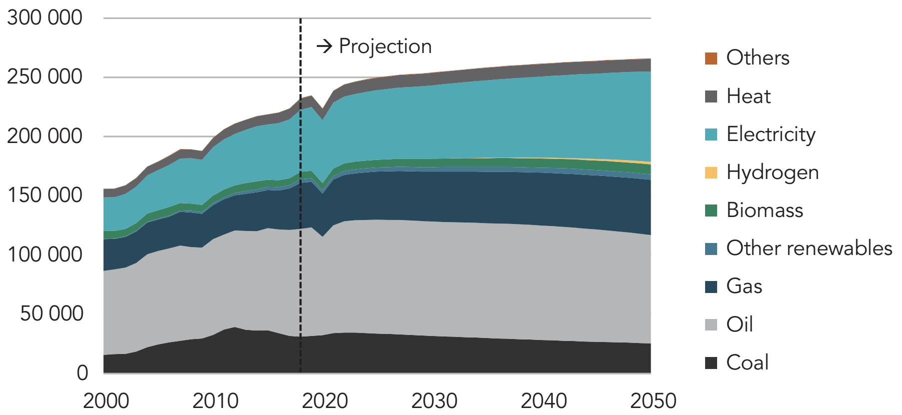
Notes: Historical population data from World Bank WDI. Projections from UN DESA 2019 Population Prospectus.

- APEC population is expected to peak in the 2030s, before declining to be only 2% higher in 2050.
- Economic output (real GDP) more than doubles out to 2050, with assumed increases largely due to productivity gains.
- A population that is only slightly higher in 2050 means that GDP per capita also more than doubles out to 2050. An aging population in many APEC economies implies a declining proportion of working age people, unless retirement ages increase.
- The global financial crisis of 2008 is visible with a slight slowdown in APEC economic output in 2009. The slowdown from the impact of the COVID-19 pandemic is much more prominent, with APEC GDP falling 1.8% in 2020.
- The global recovery from the initial shock of the COVID-19 pandemic has been robust in many APEC economies. However, the recovery is ongoing, and at the time of publication, the short- to long-term outcome of the virus remains uncertain.
- APEC has been an important forum that has facilitated greater levels of trade and globalisation since its foundation in the late 1980s. However, globalisation trends have recently stalled. There is uncertainty about the extent to which global trade, including within APEC, will continue in the coming decades.
- At the time of publication, central bank interest rates are still close to the lowest levels on record. Asset prices have already undergone many years of rapid ascent. Supply chain issues brought about by COVID-19 and other geopolitical issues have brought about the first real bout of consumer inflation in more than a decade in some economies. The extent to which central banks and governments can navigate the inflationary environment will have important implications for continued economic growth.

2. Energy demand

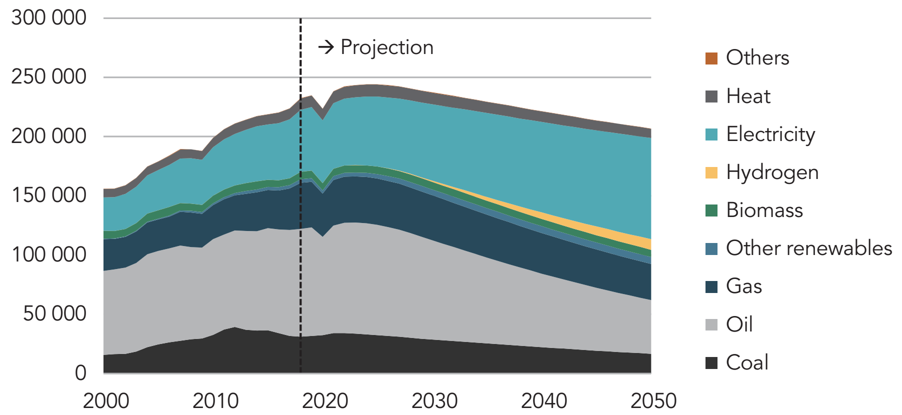
End-use energy demand

Figure 2-1. Energy demand in REF, 2000-2050 (PJ)



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

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

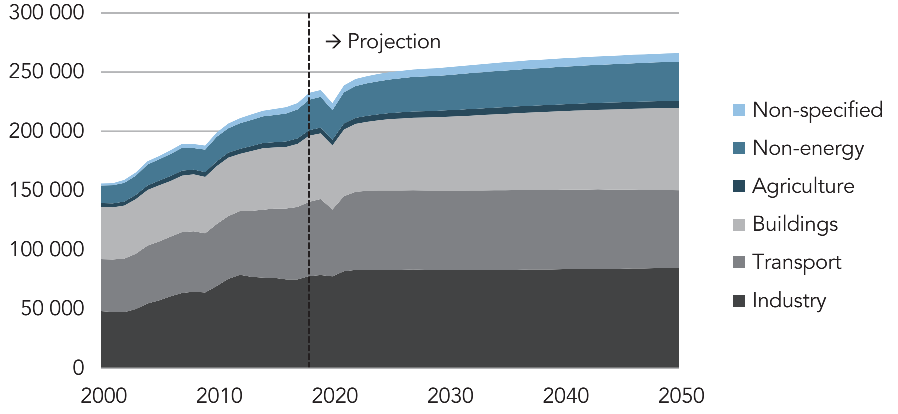


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- End-use energy demand grows by a modest amount in REF (14%). In CN, demand peaks in the mid-2020s, before declining to mid-2010s levels in 2050. While these consumption levels in CN match those of recent years, the composition of energy use is significantly changed and supports much higher levels of economic activity.
- Refined products (oil) currently account for almost two-fifths of APEC final energy demand, with its prominence tied to moving things and people within APEC economies. Transport activity is assumed to continue to increase out to 2050, but fuel efficiency improvements and fuel switching to biofuels and electricity result in refined products consumption remaining relatively flat in REF. In CN, additional fuel efficiency improvements, and higher rates of electrification reduce refined products consumption to just over one-fifth of the energy mix in 2050.
- Electricity in end-use energy applications has increased from 18% in 2000 to 23% just prior to the pandemic. These electrification trends continue and see electricity's end-use share increase to 29% in REF. Greater levels of electrification throughout all energy sectors in CN increase this share to over two-fifths of the energy mix in 2050.
- There is a small amount of growth in hydrogen consumption in REF. Hydrogen is assumed to receive significantly more support in CN, with far greater levels of adoption in end-use applications such as heavy trucking, and steel and chemicals manufacturing. These uses are supported by hydrogen supply infrastructure that spurs end-use development through improved economics. Hydrogen consumption reaches almost 9 000 PJ in CN, or 4% of the end-use energy mix.
- The APEC industrial sector consumes massive amounts of coal in applications such as cement and steel production. In REF, coal remains a foundational input for many industrial enterprises, though natural gas, electricity, and biomass increasingly substitute for its use. In CN, end-use coal consumption falls by almost half, and a significant portion of the remaining consumption is subject to carbon capture.
- Natural gas consumption increases in REF, though its share of the end-use mix is left relatively unchanged. In CN, electricity and hydrogen supplant natural gas in many end-use energy applications, reducing its consumption by more than one-fifth out to 2050. The share of natural gas in CN end-use energy mix also falls.

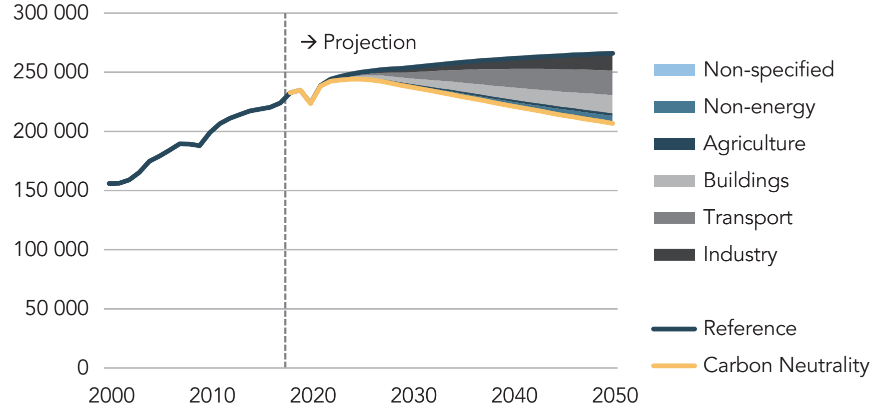
End-use energy demand by sector

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



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

Figure 2-4. Reduction in energy demand by sector between REF and CN, 2000-2050 (PJ)

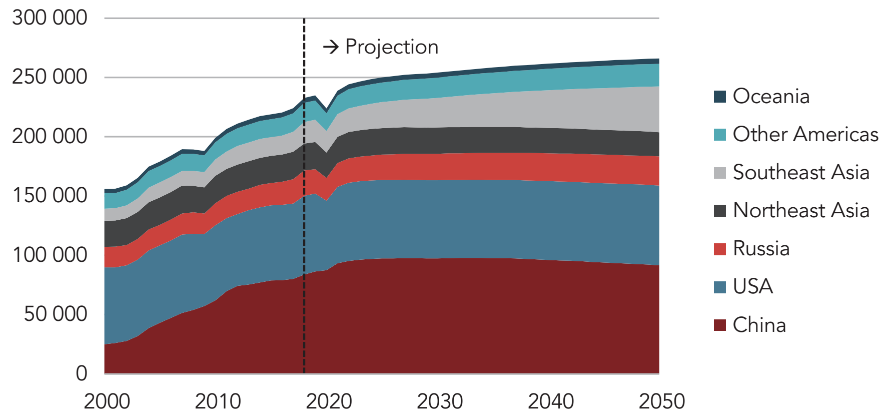


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- The APEC industry sector remains the largest consumer of energy out to 2050 in both scenarios. Industrial energy use grows 14% in REF, and declines by 9% in CN. Greater levels of energy efficiency, material efficiency (achieving the same final output with less inputs), and fuel switching to more efficient fuels contribute to this fall. In both scenarios, there is a projected large decline in output from China's steel and cement sectors due to ongoing structural changes. These declines are offset by the rise in industrial output for many other economies, such as in southeast Asia.
- The transport sector is currently the second-largest energy consuming sector, but it drops to third in both scenarios, as greater levels of energy efficiency in transport, mostly due to widespread electrification, peak demand in both scenarios (earlier in CN). Transport activity increases significantly in most APEC economies, though energy use is only marginally higher in REF. In CN, transport energy use in 2050 is almost 30% lower than current levels.
- Energy consumption by the buildings sector is expected to increase by almost one-quarter in REF, though falls slightly in CN. This large difference between the two scenarios means that the buildings sector accounts for the second-largest drop in energy consumption when comparing the two scenarios (behind transport). A significant increase in space cooling activity from southeast Asia propels buildings to the fastest growing sector in REF. Appliance energy efficiency improvements and implementation of stricter building codes, particularly in CN, mean that living standards increase without a runaway increase in energy consumption.
- The APEC non-energy sector, which mostly relates to chemicals enterprises that use fossil fuels as a feedstock, becomes slightly more prominent in both scenarios, accounting for about one-eighth of the energy mix. In CN, the inputs required by these enterprises decrease due to improved efficiencies.
- Agriculture's share of energy consumption remains relatively low, hovering near 2% in both scenarios. Like other sectors, electrification in CN is significant, with electricity's share increasing from one-fifth to more than half of the end-use agriculture mix by 2050.

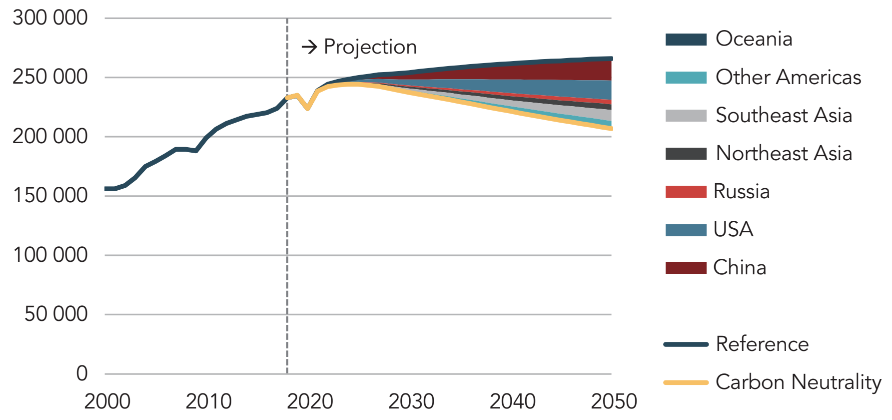
End-use energy demand by APEC region

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



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

Figure 2-6. Reduction in energy demand by region between REF and CN, 2000-2050 (PJ)

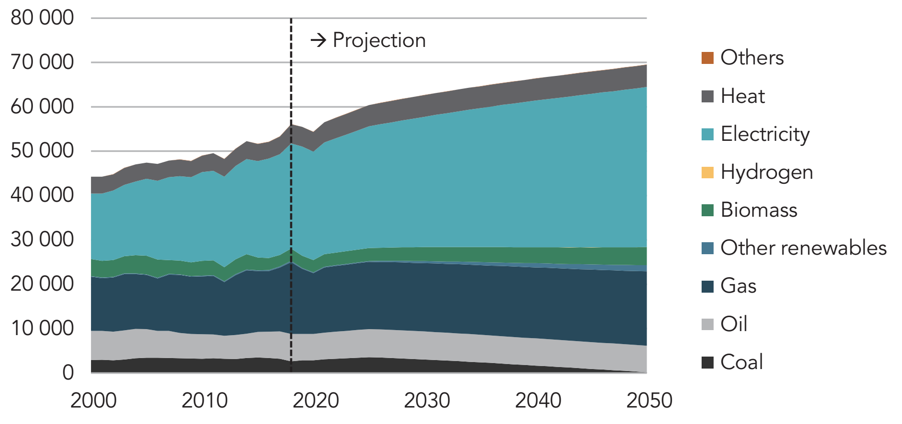


Sources: EGEDA, APERC analysis. Note: Includes non-energy.

- The APEC region consumed over 230 000 PJ of energy in 2018, which represents an increase of more than half since the beginning of the millennium. China accounts for more than 80% of this increase, with the increase in energy consumption fundamental to its growth story.
- China and the US account for almost two-thirds of APEC consumption, with this dominance falling slightly to 2050.
- With the onset of the COVID-19 pandemic, the United States saw the largest decrease in its energy consumption, which fell 11% in 2020. Most other regions saw declines between 4% and 8%. However, a hard lockdown in Wuhan, and successful suppression of the virus, meant that China was able to avoid the disruptions that many other APEC economies endured. China's importance in global manufacturing supply chains, combined with a surge in global goods demand, led to China increasing both its output and energy consumption in 2020.
- China's economic growth has been reliant on construction, manufacturing, and large-scale infrastructure projects. Future economic growth will favour services; however, the shift will be gradual. The transition will see China's energy consumption plateau in REF in the 2020s to 2030s, before slowly declining. In CN, peak energy demand occurs slightly earlier, and energy consumption is one-fifth lower than in REF in 2050.
- Strong macroeconomic fundamentals drive growth in southeast Asia, where energy demand more than doubles in REF and increases by more than three-fifths in CN. This region will more than double their relative share of end-use energy demand in the APEC energy mix. Southeast Asia is also the only region to increase its energy consumption in CN, albeit by a lower amount than in REF.
- In contrast to the growth of southeast Asia, northeast Asia posts a decline in energy demand of 11% in REF, and an even larger decline of almost one-third in CN.
- The largest contributions to reduced energy demand in CN relative to REF are from China and the United States, with declines of more than 18 500 PJ and 16 000 PJ, respectively. Southeast Asia posts the next largest decline of over 9 000 PJ, with assumed market and policy interventions facilitating the same level of economic growth, but with greater levels of energy efficiency.

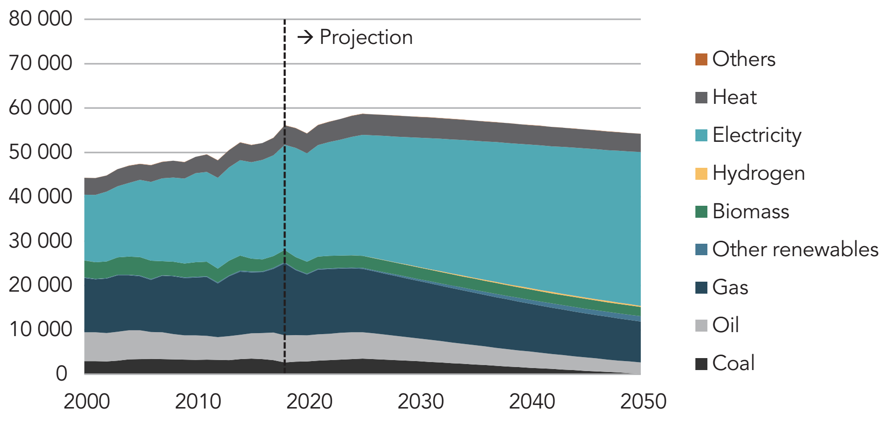
Buildings energy demand

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)



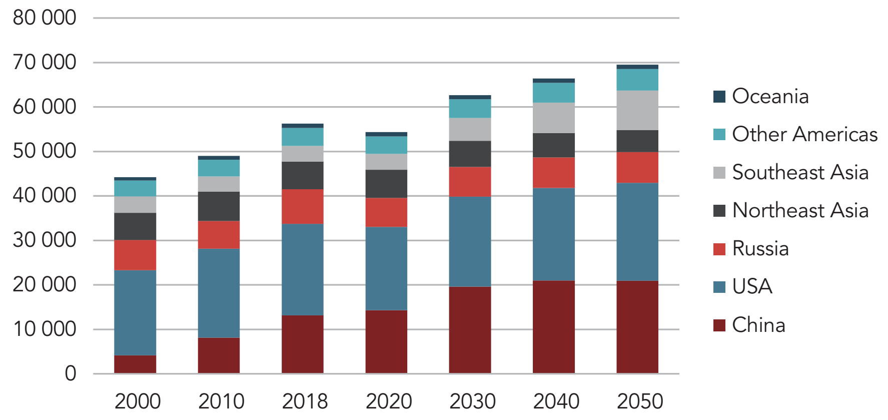
Sources: EGEDA, APERC analysis.

- Buildings energy demand grows a quarter in REF because increasing standards of living allow people to access more services. In contrast, demand peaks in 2025 in CN, and then falls 8% by 2050, as ambitious improvements in energy efficiency and fuel switching curb energy demand.
- Space heating and cooking are the main end-uses consuming fossil fuels, and space cooling, lighting and appliances are the main consumers of electricity. Electricity has the largest fuel share, accounting for 43% of buildings demand in 2018. Electricity grows by half in REF, representing 52% of energy demand in 2050. In CN, electricity demand grows 45% to represent 64% of energy demand in 2050.
- Energy efficiency in buildings curbs electricity demand. Electricity grows in REF due to a rapid rise in space cooling and appliance usage, and moderate electrification of space heating and cooking. In CN, there is higher electrification of the demand than in REF and an increase in the efficiency of building envelopes and appliances that restrict the electricity demand growth.
- Natural gas plays a large role fuelling water heating and cooking in buildings across APEC. The use of natural gas in space heating is important in areas with low winter temperatures, such as in northeast Asia. Natural gas demand increases 3% in REF, as efficiency gains outweigh growth from policies encouraging a fuel-switch from LPG and biomass to gas. In CN, the electrification of space heating and cooking reduces natural gas demand by almost half from today's levels.
- In REF, refined products use (mainly LPG) peaks in 2025, then falls to almost current levels. In contrast, demand falls 60% in CN, displaced by electricity and natural gas. In economies where there are energy infrastructure gaps, infrastructure to improve electricity and natural gas accessibility is required.
- From 2000 to 2018, biomass fell 27%. In REF, biomass continues to meet energy demand requirements, especially in rural areas. Biomass demand grows 46%, which is contrary to initiatives that attempt to reduce its use. In CN, biomass demand falls 26% due to more efficient technologies and through the replacement of biomass with other fuels such as electricity.
- Hydrogen plays a marginal role in both scenarios. Japan uses residential fuel cells to provide electricity and heat. In CN, a blend of hydrogen and natural gas is used by city gas networks in some APEC economies.

Notes: Biomass in buildings is assumed to be traditional biomass. Traditional biomass, mainly fuelwood and crop residues, is an important component of the energy mix in buildings in the rural areas of China, southeast Asia, and other Americas. Policies that support clean stove cooking (Indonesia) or improved cookstoves (Peru) promote the retirement of traditional fuelwood stoves.

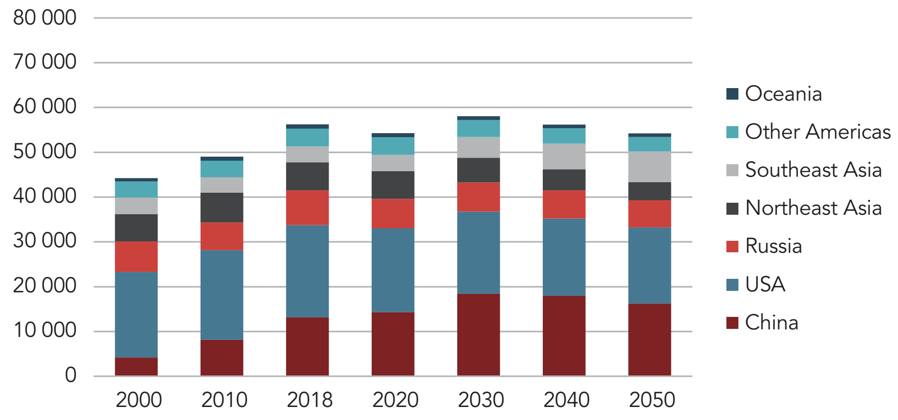
Buildings energy demand by APEC region

Figure 2-9. Buildings energy demand by region in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: APEC region groupings are defined in the Appendix.

Figure 2-10. Buildings energy demand by region in CN, 2000-2050 (PJ)

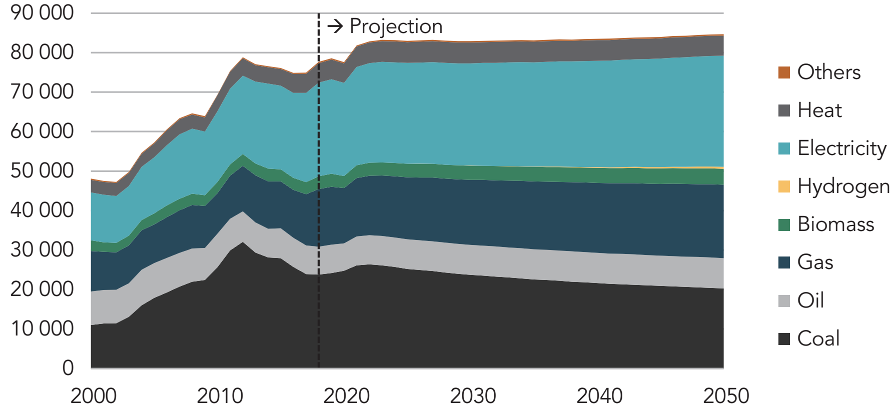


Sources: EGEDA, APERC analysis. Note: APEC region groupings are defined in the Appendix.

- The residential subsector accounts for 65% of energy use in the APEC buildings sector. The share of residential and services varies by APEC economy and region due to economic characteristics and climatic factors. For example, residential is the largest subsector in other Americas, and services is the largest subsector in northeast Asia. The share of services increases from 2018 to 2050 in both scenarios.
- Southeast Asia buildings energy demand grows fastest, increasing 150% in REF and 95% in CN. This increase is due to accelerating urbanisation and improvements in living standards.
- China's buildings energy demand grows the second fastest, increasing by 60% in REF and 23% in CN. China's consumption is roughly the same level as the United States by 2030 in both scenarios. China comprises almost all (95%) of APEC coal use in the buildings sector. However, its residential coal-switching policy is expected to decrease coal consumption over time.
- In aggregate, APEC natural gas consumption in buildings increases via fuel switching away from LPG and coal. In REF, most growth occurs in China with an increase of 1 700 PJ, followed by other Americas (250 PJ), and southeast Asia (200 PJ). Other regions maintain or slightly lower their gas use, highlighting that natural gas development differs from economy to economy. In CN, natural gas growth is curbed in China and southeast Asia, while demand in the other APEC regions declines due to electrification of heating and greater improvements in energy efficiency.
- Electricity demand by buildings grows in all APEC regions in REF. Southeast Asia sees almost as much growth as in China (around 4 800 PJ), with the growth emblematic of accelerating urbanisation and living standards in the region.
- In CN, electricity consumed by the buildings sector is lower than REF in most economies, with notable exceptions being the United States and Russia. The reason for lower electricity consumption in CN is that efficiency gains accompany electrification. Another reason is that universal electricity access will remain elusive for certain difficult-to-access regions in developing APEC economies. For other APEC economies, electricity already accounts for a very large share of buildings energy demand, and the potential to switch to an even greater share of electricity is limited.

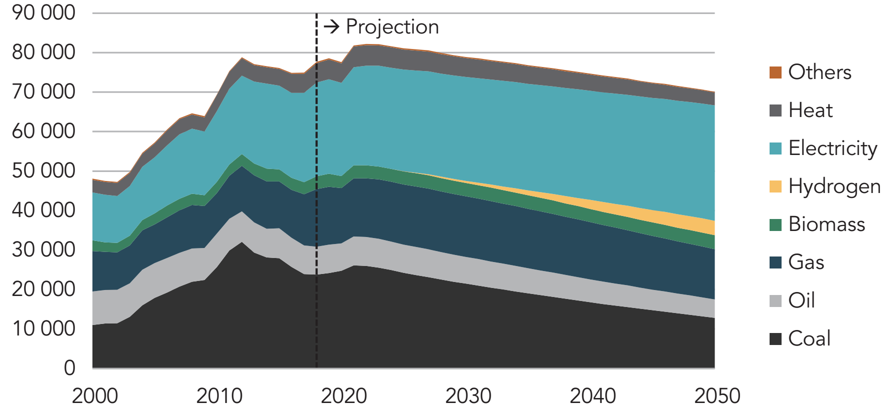
Industry energy demand

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



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

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



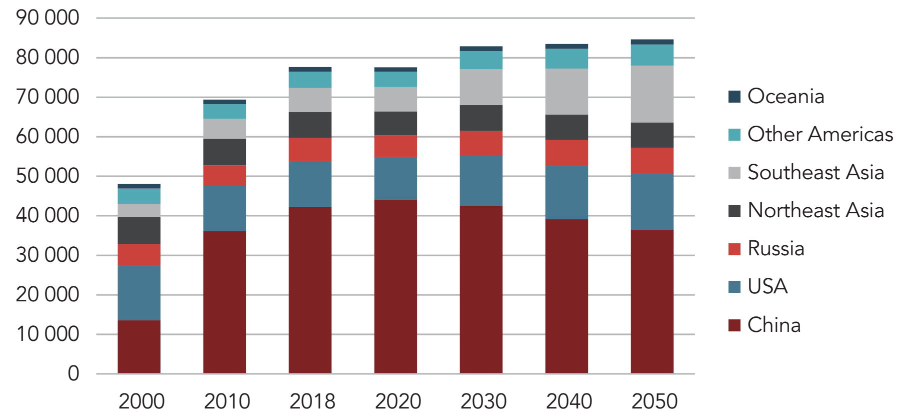
Sources: EGEDA, APERC analysis. Note: Non-energy is not shown.

- Industrial energy demand reached a prior peak in 2012, driven by a large build out in coal-intensive heavy industry in China. Since then, China has enacted policies to consolidate and downsize certain industries such as cement production, which led to a retracement in industry demand growth in the mid-2010s. Industrial output is both a foundation and driver of economic output. Estimating industrial output to 2050 relies on GDP projections in the context of trade and structural composition of economies.
- Many industries in APEC economies were able to continue operating through COVID-19 lockdowns, with only a small pull-back in industrial output and industrial energy use. The recovery in 2021 has seen a rapid increase in industrial output, fueled by large quantities of fiscal and monetary stimulus, and elevated levels of demands for goods rather than services.
- Post-pandemic industrial energy use maintains a high plateau for the remainder of the projection period in REF. Industrial output from APEC is assumed to continue increasing in many subsectors, though gains in energy efficiency, and modest levels of electrification, will temper energy demand needed to deliver this output.
- In REF, coal demand falls from over 30% of the energy mix to under one-quarter. Part of this fall is counteracted by gas, which increases from 19% to 22% of the industrial energy mix. Electricity also increases in share from 30% to 33%, while biomass and hydrogen also see increases out to 2050.
- Industrial energy demand is 17% lower in CN, and there is fuel switching away from fossil fuels to electricity, hydrogen, and biomass. Electricity's share of industrial energy demand increases to 42%, while hydrogen increases from nothing to over 3 500 PJ in 2050, or 5% of industry's end-use energy mix.
- A small amount of CCS technology is employed by heavy industry subsectors in REF. This role increases significantly in CN. Almost one-third of fossil fuels used by heavy industry (steel, chemicals, and non-metallic minerals) are subject to some form of carbon capture process in 2050.[1]
- Non-fossil fuel alternatives are often limited, or yet to exist at scale (such as for certain applications in steel making).[2] The difficult to decarbonise nature of certain subsectors underlines the importance of CCS.

Notes: [1] Emissions capture rates average 80% and vary depending on whether the CCS units are retrofits or constructed as an integrated component of new facilities.
[2] See technical appendix for how hydrogen is modelled in the steel sector.

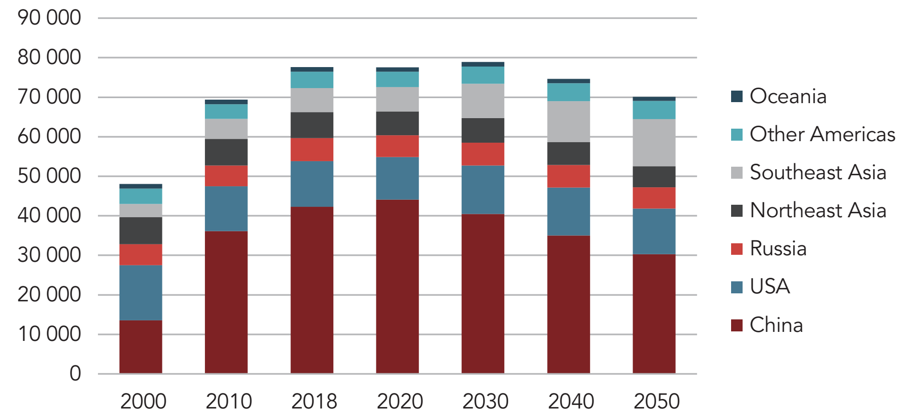
Industry energy demand by APEC region

Figure 2-13. Industry energy demand by region in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Notes: Excludes non-energy. APEC region groupings are defined in the Appendix.

Figure 2-14. Industry energy demand by region in CN, 2000-2050 (PJ)

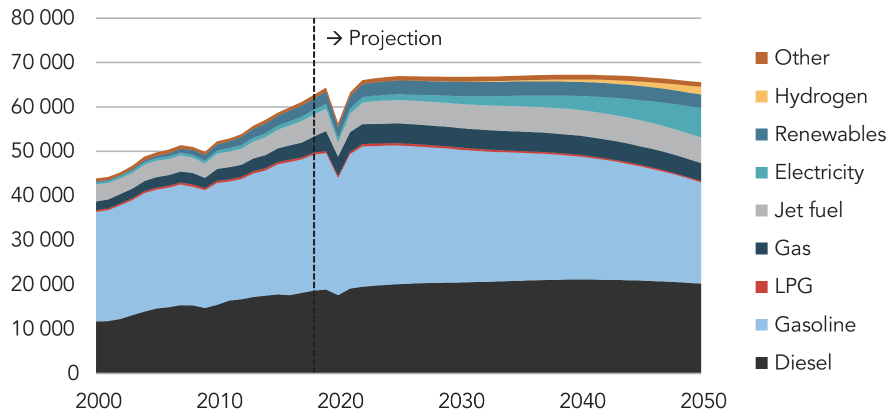


Sources: EGEDA, APERC analysis. Notes: Excludes non-energy. APEC region groupings are defined in the Appendix.

- China accounts for 54% of industrial energy use in 2018, with this large share of energy use due to significant property and infrastructure build-out in recent decades, and the rise of China as the dominant global manufacturing source. As China transitions to a more service-based economy, its industrial energy use share moderates to 43% for both scenarios out to 2050. There is anticipated to be a particularly large decline in China's steel and cement subsectors out to 2050.
- In contrast to China, southeast Asia industrial energy use more than doubles, and its share of APEC industrial energy use increases from 8% in 2018 to 17% in 2050. For the same period, southeast Asia GDP triples, which highlights that industrial energy use increases at a lower rate than output for all economies.
- Energy efficiency improvements are the main reason why industrial energy use increases at a slower rate than output. In addition to energy efficiency, material efficiency in CN is assumed to lead to roughly 10% less required output in steel, chemicals, and non-metallic minerals subsectors for all APEC economies. This material efficiency is achieved via higher rates of technological innovation. The same end good, such as a constructed building, requires less materials, or more recycled materials, to build it.
- Most industrial subsectors throughout APEC are anticipated to deliver increasing levels of output, with notable exceptions being the steel and cement sectors in China. In CN, greater levels of energy efficiency improvements are assumed to be supported by economy level policy interventions. These policy interventions will support the economics of the most energy efficient technologies in all industrial subsectors.
- In Australia, Canada, Chile, China, Mexico, Russia, and Viet Nam, critical minerals mining output is assumed to increase in CN due to greater levels of demand for batteries and other low-carbon technologies. This increased level of mining output requires additional energy consumption. For certain economies, such as Australia and China, the decline in coal production (accounted for in own use consumption) offsets the rise in critical minerals mining (captured in industry).

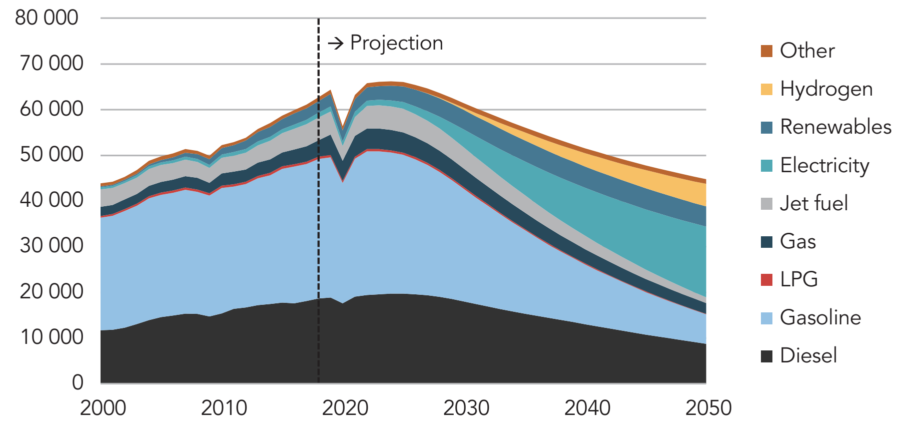
Transport energy demand

Figure 2-15. Transport energy demand in REF, 2000-2050 (PJ)



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

Figure 2-16. Transport energy demand in CN, 2000-2050 (PJ)



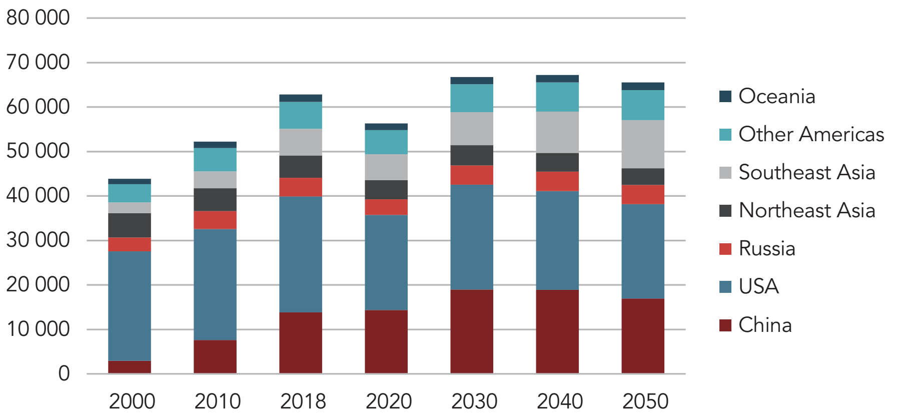
Sources: EGEDA, APERC analysis. Note: Excludes international transport demand.

- Energy consumption in the transport sector fell 12% in 2020 due to the onset of COVID-19. Passenger activity, and therefore gasoline and domestic jet fuel use, fell to very low levels for a significant portion of the year. Freight activity only dropped 5% for the year, leaving diesel less impacted.
- In REF, total energy use increases 4% out to 2050. In CN, total energy use begins falling quickly from the mid-2020s, to about a third less than REF in 2050. The main downward pressure on energy demand is the adoption of EVs, which are currently three-times as efficient as ICE alternatives.
- Diesel and gasoline currently account for almost four-fifths of transport energy demand. An increased uptake of EVs in CN will cause diesel and gasoline prominence to decrease to one-third of total use by 2050. This illustrates how EV adoption can provide co-benefits like reducing emissions and improving oil security.
- EV adoption drives the share of electricity up from 1.7% in 2018 to over 10% in REF and almost 35% in CN.
- Hydrogen and biofuel blending for aviation and heavy trucking is currently a more viable decarbonisation route than electrification. This is because battery technologies are not expected to reach an energy-to-weight ratio high enough to also carry the high weight of trucks and airplanes over long distances. However, the challenges in introducing these new technologies mean that in REF, hydrogen and biofuels integrate slowly. In CN, an accelerated rate of this fuel-switching and some efficiency improvements cause diesel use to decrease by half, and jet fuel declines by three-quarters.
- Transport activity, mostly driven by macro forces, continues to grow but at a slowly decreasing rate. In CN, there is 5% less activity in 2050 compared with REF. Switching to public transport or improving the optimisation of freight is expected to cause a decrease in energy use, as a result of a decrease in activity requirements. This will be more pronounced in CN.
- These transformations in the transport sector need a lot of planning. For example, the success of EVs relies on robust distribution networks, and battery technology investment.

Notes: The projections assume that activity returns to pre-pandemic levels in the short term. Although teleworking and videoconferencing could result in lower demand than shown here.

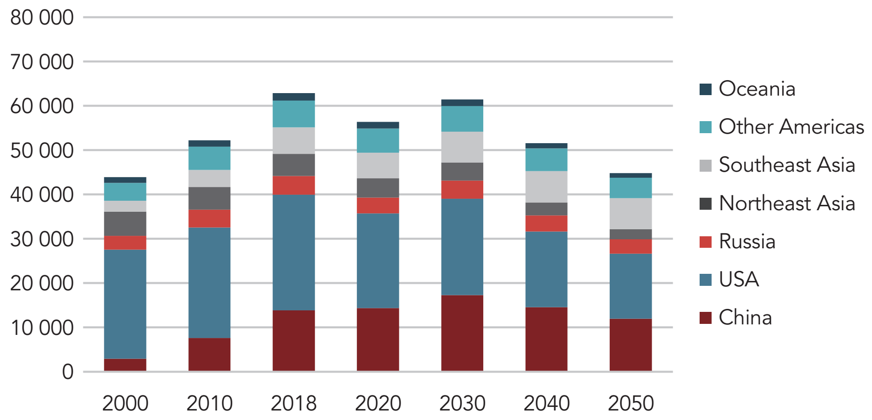
Transport energy demand by APEC region

Figure 2-17. Transport energy demand by region in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis. Note: APEC region groupings are defined in the Appendix.

Figure 2-18. Transport energy demand by region in CN, 2000-2050 (PJ)



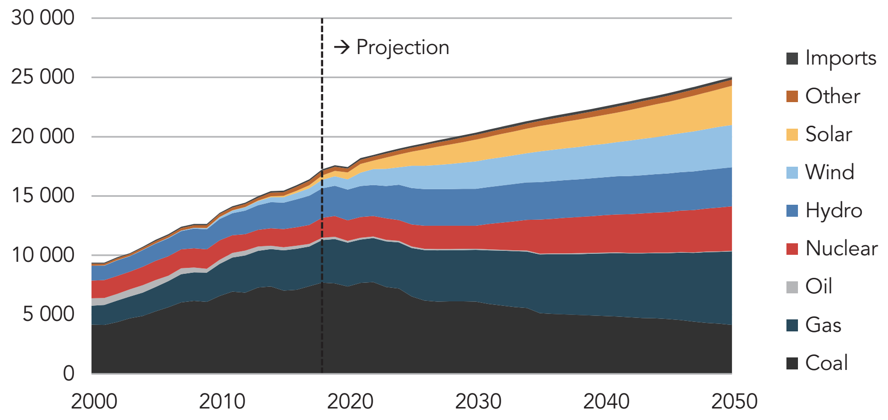
Sources: EGEDA, APERC analysis. Note: APEC region groupings are defined in the Appendix.

- China has accounted for most of the increase in APEC transport energy demand since 2000. For the projection period, the US is expected to have the highest energy use, but China is expected to have the highest activity in both passenger and freight transport. This is a result of higher transport efficiency in China.
- Government action in response to COVID-19 has curbed transport activity throughout APEC, but policy variance in mobility restrictions led some regions to see lower activity and demand than others. While APEC transport energy demand fell an eighth in 2020, containment during the early onset of the virus allowed China and some southeast Asia economies to relax mobility restrictions enough to limit the demand drop to about 4%.
- Energy efficiency of transport is expected to improve gradually for all regions. The driving force of this are improvements in fuel economy in ICE vehicles and the increasing stocks of EVs. Freight transport will improve in efficiency at a slower rate than passenger transport.
- While activity increases for all vehicle types, modal switching from light passenger vehicles to public transport is expected to occur in all regions. This causes the share of passenger activity in personal light-duty cars and trucks to decrease a small amount. Meanwhile, the share of activity for buses and rail for both freight and passenger services will increase.
- In both scenarios, southeast Asia experiences the largest regional growth in energy and activity which is connected to their high growth in population and income. While passenger activity grows 2.6-fold, and freight 3.5-fold, energy use in the region only grows 1.8 times in REF. This is because of improvements in energy intensity. In CN, even greater levels of energy efficiency improvements mean that southeast Asia transport energy demand plateaus at 7 000 PJ from 2030 onwards, only 1.15 times today's levels.
- The largest proportional decline in energy use is from northeast Asia, which falls over a quarter in REF and a half in CN. The US sees the largest absolute decline, of almost 5 000 PJ in REF and 10 000 PJ in CN. Whereas all other regions increase transport energy use in REF. In CN, China's transport energy demand declines 7%, Oceania falls over a third, Russia falls almost a quarter, and other Americas falls by a fifth.

3. Power

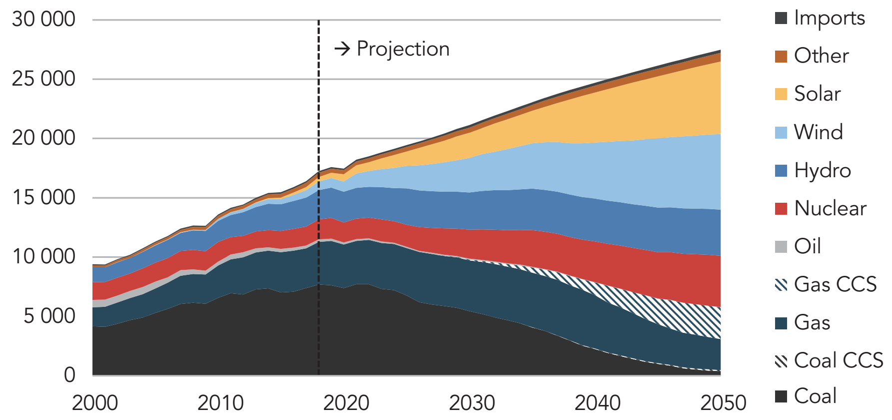
Electricity generation

Figure 3-1. Electricity generation in REF, 2000-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 3-2. Electricity generation in CN, 2000-2050 (TWh)

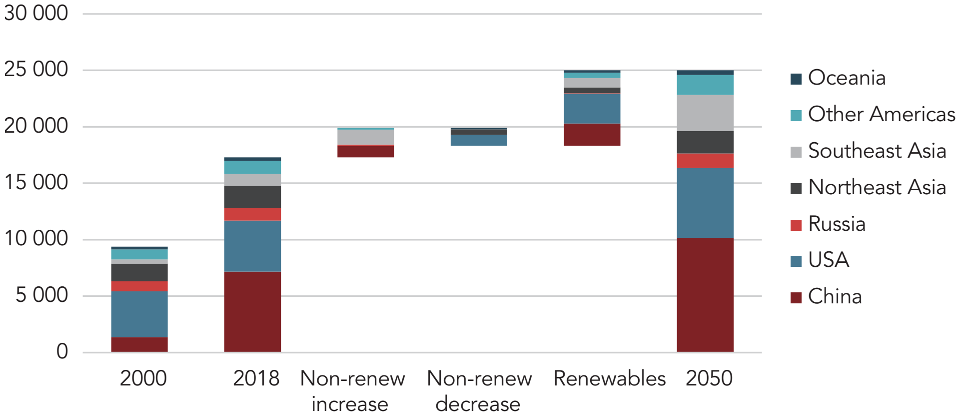


Sources: EGEDA, APERC analysis.

- Electricity generation nearly doubled between 2000 and 2018. Two-thirds of the increase came from coal- and gas-fired power plants.
- In REF, increasing standards of living and the general electrification trend in all demand sectors lead to generation increasing by 45% through to 2050. Within this increase, the share of thermal power plant generation declines by 25%.
- Coal-fired generation declines by half in REF, though this decline is partially offset by gas-fired generation increasing by almost three-quarters. The decline in coal is part of a concerted effort by most APEC economies to move to cleaner generation technologies.
- Three quarters of the increased generation in REF is provided by solar and wind, and 20% will be from increased generation from nuclear power plants. The share of nuclear generation grows from 10% in 2018 to 15% in 2050, with much of the increase occurring in China.
- In REF, the reduction in share of thermal power plant generation is almost equal to the increase in share from solar and wind, which increases from 8% in 2018 to nearly 30% in 2050.
- In CN, greater levels of electrification lead to 10% more electricity generation than in REF by 2050. The absolute increase would be larger were it not for the greater levels of end-use energy efficiency in CN.
- There are three significant changes in the generation mix in CN compared to REF: the almost complete displacement of coal; moderate growth of gas-fired generation (though with much of this generation is supported by CCS technologies); and accelerated growth of generation by solar and wind. By 2050, power plants with CCS technologies account for 20% of coal-fired generation (all these CCS units are in southeast Asia) and more than half of gas-fired generation.
- In CN, wind and solar generation is more than 80% greater than in REF, and accounts for a 45% share of total generation by 2050. The combined share of hydro and nuclear generation increases from one-quarter to three-tenths, whereas the share of thermal power falls from two-thirds to 21%.

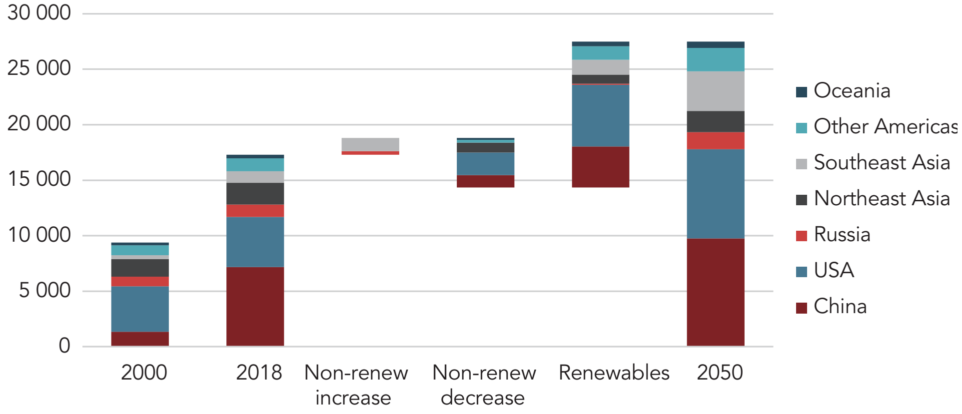
Electricity generation by APEC region

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



Sources: EGEDA, APERC analysis.

Figure 3-4. Electricity generation in CN, 2000-2050 (TWh)

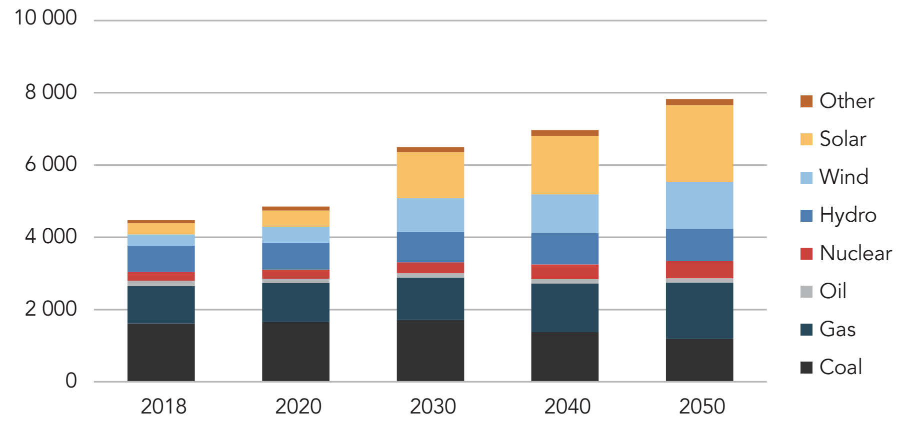


Sources: EGEDA, APERC analysis.

- China has accounted for almost three-quarters of the increase in APEC electricity generation from 2000 to 2018, having increased more than five-fold. For the same period, southeast Asia's electricity generation almost tripled. Two-thirds of the additional generation has been from fossil fuels plants, 16% is from hydro, and 14% is from solar and wind. Nuclear generation increased by 12%, accounting for 2% of the increase.
- In REF, electricity generation in APEC grows by 45%. China and southeast Asia continue to increase non-renewable generation, while the United States and northeast Asia see a decrease out to 2050. The increase in APEC renewables generation is 87% of the total increase in APEC generation.
- Southeast Asia's generation more than triples in REF, with non-renewables accounting for three-fifths of this growth, and renewables accounting for the remaining two-fifths. In CN, southeast Asia generation is more than 10% greater than in REF, and renewables account for more than half of the total increase.
- In CN, all regions see a decline in non-renewable generation except for southeast Asia and Russia. Within non-renewables, nuclear generation increases 2.6 times, meaning that fossil combustible fuel generation declines significantly. This means that renewable generation will provide not only a net increase in total generation, but also compensate for the decrease in fossil combustible fuel generation.
- In CN, the United States accounts for 42% of the increase in renewable generation, followed by China, accounting for 28%.
- Wind and solar generation in APEC increase more than 11-fold by 2050 and is 85% of the increase in renewables.

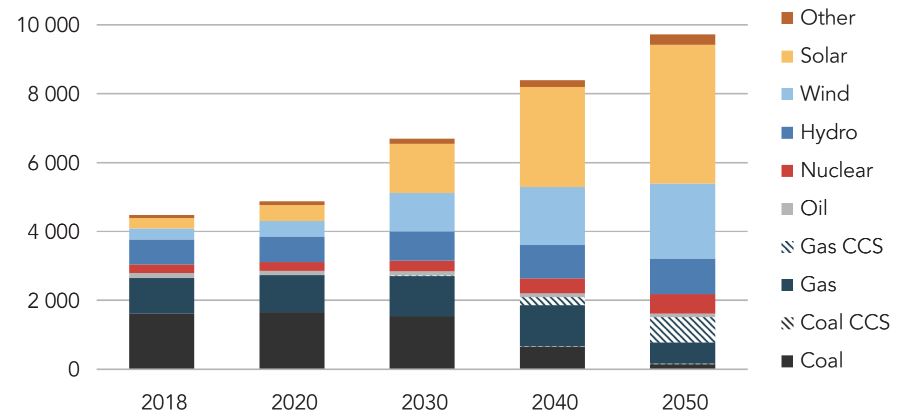
Generation capacity

Figure 3-5. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 3-6. Generation capacity in CN, 2018-2050 (GW)

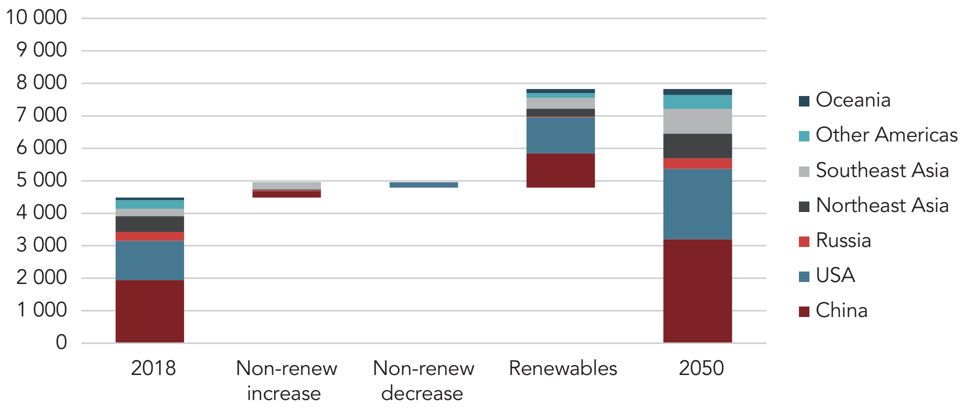


Sources: EGEDA, APERC analysis.

- Over half of the 4 500 GW capacity in 2018 are fossil fuel plants. The share of renewables in installed capacity in 2018 was 15%.
- In REF, installed capacity increases by 75%, with the structure of installed capacity undergoing significant change through to 2050. The share of thermal power plants falls by about 25%, which is largely due to the very large increase in solar and wind capacity. More than 430 GW of net coal-fired power plants retirements occur, but this is more than offset by a 520 GW increase in gas-fired plants. Hydro capacity increases, though its share declines from 16% in 2018 to 11% in 2050. Nuclear capacity almost doubles, and its share increases slightly to 6%.
- In REF, the installed capacity of wind increases more than four-fold while solar increases almost seven-fold. Solar increases more than wind due to easier deployment, especially as compared with offshore wind. The share of wind and solar in total installed capacity more than triples to almost 44%.
- In CN, additional capacity is required to meet the increased demand for electricity. Installed capacity more than doubles out to 2050 and is one quarter higher than in REF. The increase in installed capacity is greater than the increase in generation because the capacity is constituted by a larger proportion of variable generation rather than dispatchable or baseload capacity.
- In CN, the share of thermal power plants almost halves, falling to 20%. There is an almost complete decommissioning of coal-fired plants, which peak in 2024. In contrast to this declining trend, gas-fired capacity increases by 30% through to 2050. Almost 55% of gas capacity incorporates CCS technologies, which begin to be deployed from the late 2020s. Gas-fired power with CCS will be an important low-emitting complement to the high levels of variable renewable capacity.
- Solar and wind are poised to dominate renewable power capacity in CN. However, their non-dispatchable nature means that improving grid flexibility by the deployment of storage, among other measures, is necessary to facilitate the modelled level of penetration to the APEC power grid.
- Solar and wind's almost two-thirds share of APEC capacity in CN will be reliant on critical minerals mining. These minerals are used in the construction of solar and wind capacity and for the accompanying battery storage capacity.

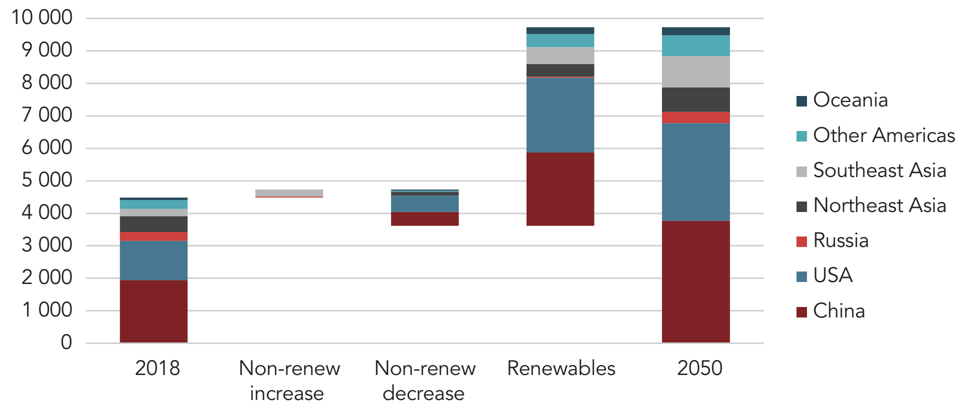
Generation capacity by APEC region

Figure 3-7. Generation capacity in REF, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

Figure 3-8. Generation capacity in CN, 2018-2050 (GW)



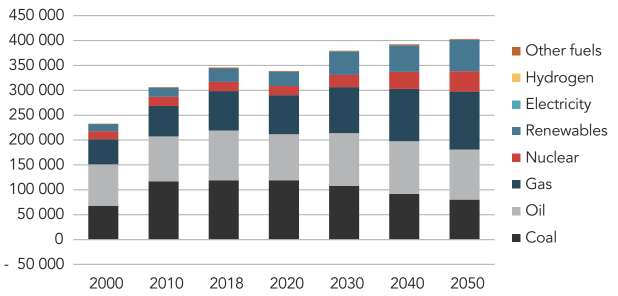
Sources: EGEDA, APERC analysis.

- To meet the modelled increase in electricity demand, wind and solar capacity increases more than five-fold in REF and almost 10-fold in CN. Wind and solar have a significantly lower capacity factor than most other types of power plants. The high penetration of these renewables causes the average APEC capacity factor to drop from 44% currently to 36% in 2050 of REF and to 32% in 2050 of CN.
- In REF, two-thirds of the new wind and solar capacity comes from the two largest electricity producers, China and the United States, in roughly equal shares. More than 10% of the increase is installed in southeast Asia economies and 8% is installed in northeast Asia economies.
- In CN, the United States and China account for an even higher share of installed renewable capacity. All other regions account for a smaller share than in REF, except for other Americas, which accounts for almost 7% of the increase in renewable capacity, up from less than 5% in REF.
- For non-renewables, most regions record a small net capacity addition out to 2050. Southeast Asia records the largest relative increase, with a net non-renewable capacity addition equal to 28% of its 2050 capacity. At the opposite end of the scale, Oceania shows a net retirement equal to 12% of its total capacity in 2050, and the United States records a net retirement of 7% of its total capacity in 2050.
- In REF, a much greater proportion of wind and solar capacity is installed towards the end of the projection. Renewable capacity additions occur at a more uniform rate through to 2050 in CN, which is supported by a policy and economic environment that is more favourable for renewables.
- In CN, the share of renewables (including large hydro) in the capacity mix reaches more than 80% by 2050. More than 90% of the capacity in CN is low or non-emitting, with this high level achieved through CCS technologies for gas generation across the APEC region and some coal-fired power plants in southeast Asia. The more than doubling in nuclear capacity, which is 15% greater in 2050 than in REF, is also influential in reducing emissions from the APEC power system.

4. Energy supply

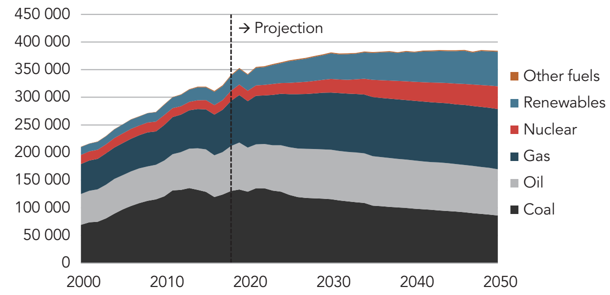
Energy supply in the Reference scenario

Figure 4-1. Total energy supply in REF, 2000-2050 (PJ)



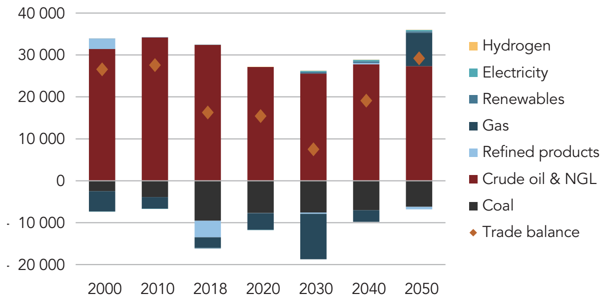
Sources: EGEDA, APERC analysis.

Figure 4-2. Energy production in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-3. Net energy trade in REF, 2000-2050 (PJ)

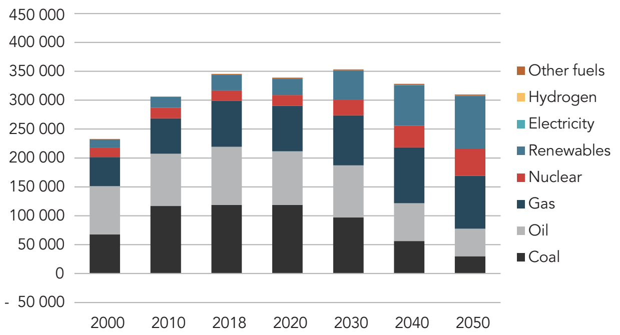


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- APEC energy supply grows a sixth to meet the rising energy demand and power requirements for a region that has GDP double over the projection period. China and southeast Asia account for almost all supply growth, while energy efficiency results in declines in the US, Oceania, and northeast Asia.
- Fossil fuels play a lower, but still dominant, role in the APEC energy mix. Declining use in power drives coal down to a fifth of the supply mix, while transport electrification is instrumental in reducing oil to a quarter. The share of gas rises to 29%, mostly on higher use in China and southeast Asia.
- Lower-emitting fuels play a larger role in APEC's energy system. Increases in hydroelectric and variable renewable capacity, particularly in China, southeast Asia, and the United States, more than double renewable supply in terms of absolute value and share. Despite the retirement of several reactors in APEC, the share of nuclear doubles to 10%, mostly due to growth in China, which surpasses the United States as the top nuclear user in the late 2020s.
- Energy production grows an eighth. Natural gas production rises a third, while coal production falls a third. Oil production peaks in the mid-2030s and is 3% higher than 2018 production in 2050.
- Expansions in production and export capacity, particularly in the form of LNG from the United States, and both LNG and pipelines from Russia, play an instrumental role in reducing APEC's energy trade deficit by two-thirds in the 2020s. However, soaring gas use in southeast Asia during the 2030s and 2040s turns APEC into a net gas importer by the mid-2040s, and increases net energy imports to their highest levels since 2007. Security of gas supply will be a chief concern amongst APEC importers in the latter half of this projection.
- Crude oil continues to dominate net energy imports, but production growth, mainly from the United States and Canada, reduces net crude imports by a fifth. Net refined product exports decrease as demand in China and southeast Asia outpaces refinery output, prompting an increase in gross imports.
- Electricity trade increases by almost a third, as imports into Thailand and Viet Nam from non-APEC economies help fuel surging electricity demand.

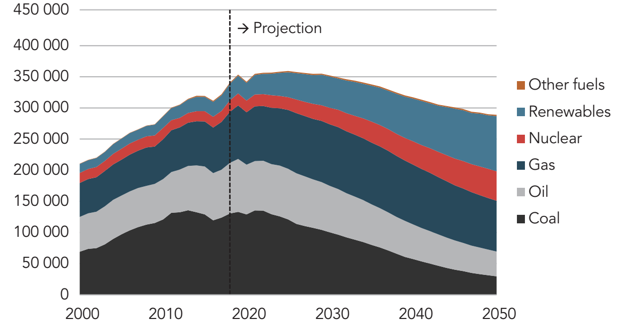
Energy supply in the Carbon Neutrality scenario

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



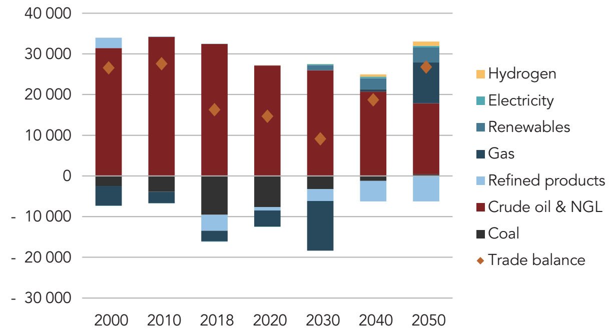
Sources: EGEDA, APERC analysis.

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



Sources: EGEDA, APERC analysis.

Figure 4-6. Net energy trade in CN, 2000-2050 (PJ)

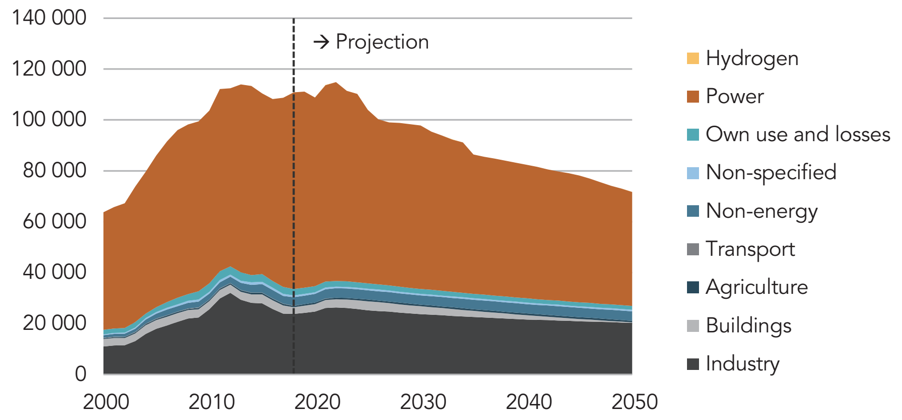


Sources: EGEDA, APERC analysis. Note: Exports appear as negative.

- APEC energy supply falls a tenth out to 2050 in CN, with China and the United States accounting for most of the reduction, falling a seventh and a fifth, respectively. Supply also falls over a third in northeast Asia, a fifth in other Americas, and a third in Oceania. Supply is flat in Russia and grows by three-quarters in southeast Asia.
- The role of fossil fuels is diminished, but they still account for more than half of APEC supply in 2050. Declining coal-fired generation drives coal to a tenth of the supply mix, while transport electrification and modal shifting reduce oil to a sixth. The share of gas rises to 30%, mostly on higher use in China and southeast Asia.
- Lower-emitting fuels play a larger role in APEC's energy system. Higher variable renewable deployment increases renewable supply by over three-times in terms of both value and share, and nuclear triples to 15%.
- Lower domestic supply requirements and a declining global market for fossil fuels drive energy production down a sixth. Natural gas production grows to meet rising demand but peaks in 2032 and falls to 2018 levels by 2050. Coal and oil production begin to decline in 2023, with coal falling three-quarters and oil by almost half.
- A declining global market for fossil fuels reduces APEC's role as a producer-exporter, but robust demand in southeast Asia for coal and natural gas buoys import requirements. Whereas APEC net coal imports approach zero by 2050, APEC net gas imports increase as producer-exporters lose market share to non-APEC suppliers. Security of gas supply remains a concern in CN.
- Crude oil continues to dominate net energy imports, but lower refinery runs reduce crude oil imports by over a half. APEC becomes a net refinery products exporter, as refineries strive to capture global market share while oil demand falls within the APEC region.
- Electricity trade increases by over half, while net hydrogen imports rise 22-fold over REF levels, as both energy carriers provide lower-emitting solutions to multiple APEC economies. Further trade of both carriers could reduce the role of fossil fuels in APEC even further than shown here.

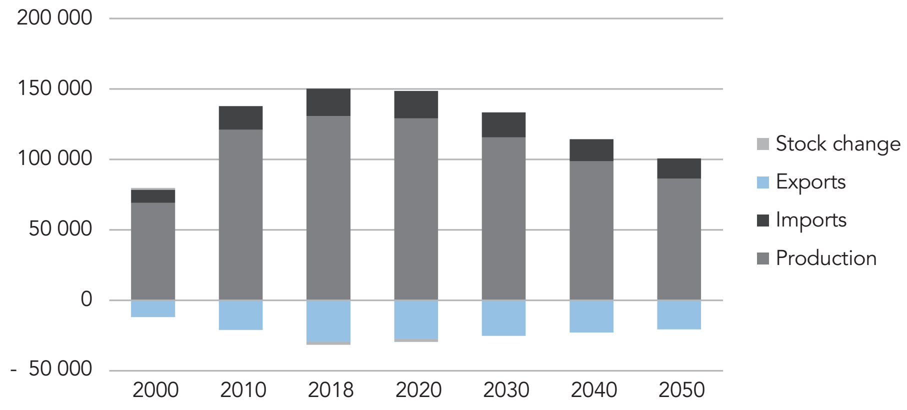
Coal in the Reference scenario

Figure 4-7. Coal consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-8. Coal production, imports, and exports in REF, 2000-2050 (PJ)

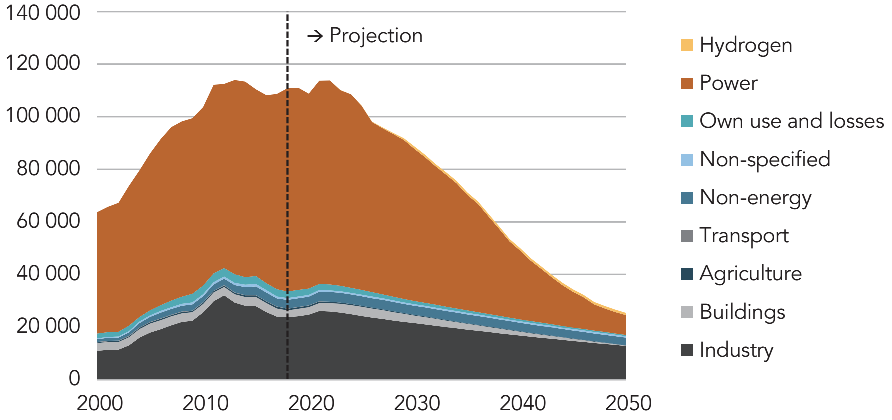


Sources: EGEDA, APERC analysis.

- APEC-wide coal consumption nearly doubled between 2000 and the early 2010s, though consumption levels have since plateaued. Coal is mainly consumed to provide electricity, with the power sector accounting for 70% of APEC coal consumption in 2018. The industry sector is also a large coal consumer. Industry consumption almost tripled from 2000 to 2012, mostly due to China's demand for steel and cement that was required to build out its economy. APEC industry consumption has since fallen by one-quarter to nearly 24 000 PJ but remains important due to its role in energy-intensive processes and its relatively affordable cost.
- APEC coal consumption is anticipated to decline by one-third through the projection period, though consumption has rebounded significantly in the aftermath of the COVID-19 pandemic. The power sector accounts for most of the projected fall, with multiple coal phase-out policies leading to a 42% decline in power sector coal consumption out to 2050. Industry sector consumption remains more robust, declining by 15% to 2050. Part of this robust industrial demand is due to the indispensable role of metallurgical coal in providing coke for steel making.
- Buildings sector coal consumption is already relatively low, though it will become even less prominent, falling by 94% out to 2050. The large decline is due to both electrification and fuel switching to less carbon-intensive fuels.
- APEC coal production closely tracked APEC consumption trends between 2000 and 2018. The relationship is expected to remain in place, with production falling from 131 000 PJ in 2018 to 86 000 PJ in 2050.
- APEC economies imported 9 300 PJ of coal in 2000, with this more than doubling to 19 500 PJ in 2018. Coal imports are expected to fall by roughly one-quarter to 14 400 PJ in 2050. While all economies, except Papua New Guinea, will import some coal by 2050, China, Japan, the Philippines, Korea, and Chinese Taipei will together make up three-quarters of APEC imports.
- APEC is home of the largest coal producers in the world. While production is expected to fall out to 2050, exports as a proportion of production increase from 22% in 2018 to 24% by the end of the projection period. APEC remains a major coal supplier by 2050, exporting more than 20 000 PJ.

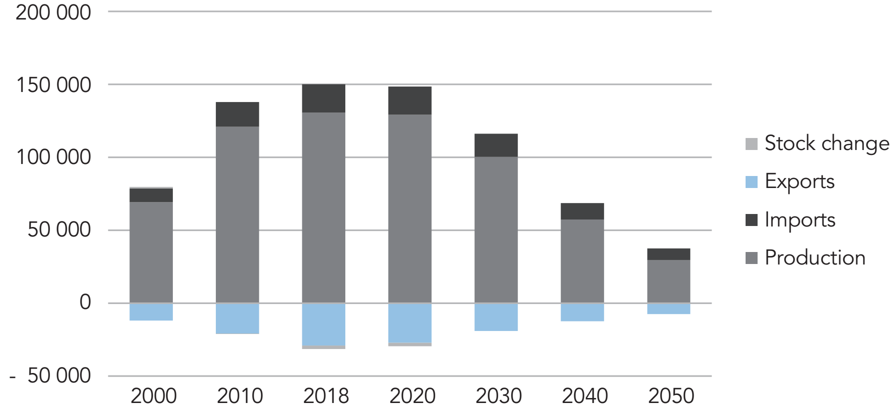
Coal in the Carbon Neutrality scenario

Figure 4-9. Coal consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-10. Coal production, imports, and exports in CN, 2000-2050 (PJ)

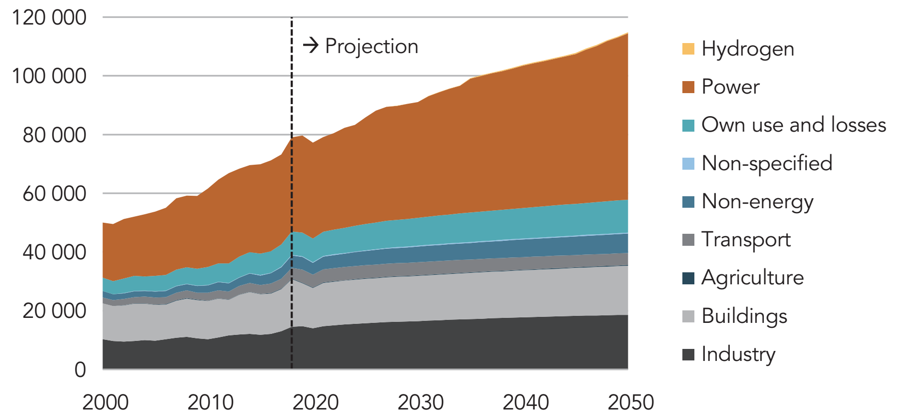


Sources: EGEDA, APERC analysis.

- APEC-wide coal consumption is expected to fall by almost 80% in CN, with a more than 90% fall from the power sector. Higher rates of fuel switching away from coal and more stringent coal phase-out policies contribute to this decline. However, coal consumption by the hydrogen sector is higher in CN than in REF.
- At COP26, nine APEC economies signed the Global Coal to Clean Power Transition Statement, with economies committing to no new coal-fired power plants from the 2030s or 2040s, depending on their development level. CN assumptions lead to an even lower level of consumption than these commitments imply. However, coal generation still increases in southeast Asia, albeit by a lower level than in REF.
- Coal consumption in the industry sector declines by almost half in CN. Electrification and other fuel-switching are the main drivers of this reduction. Greater prominence of electric arc furnaces and hydrogen-based technologies begin to displace metallurgical coal in steel making towards the end of the projection period. However, approximately 13 000 PJ of coal consumption in 2050 underlines the challenge of eliminating coal from industry.
- China's share of APEC coal consumption decreases from 68% to 58% by the end of the CN projection. This declining share is contrasted by southeast Asia increasing its share of APEC coal consumption from 6% to 34%, as coal use continues to grow in industry and power, albeit at lower levels than in REF.
- Rapidly increasing hydrogen demand supports additional coal use for hydrogen production in CN. However, coal consumption by the hydrogen sector remains relatively low in the context of total APEC coal consumption. China and Australia are two pioneering economies in producing hydrogen from coal, reflecting domestic resources and policies supporting the nascent industry.
- Coal production falls by 77% in 2050 in CN and is 66% lower than in REF. The reduction is due to declining coal demand in APEC and the world, which sees coal trade (imports and exports) fall by two-thirds through to 2050.

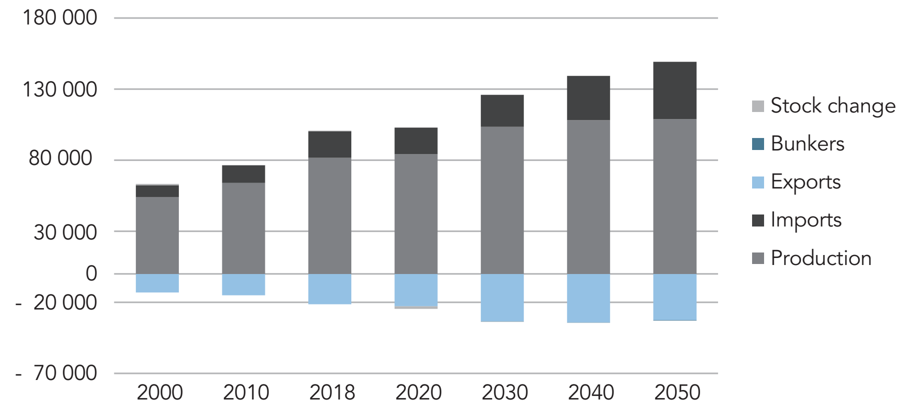
Natural gas in the Reference scenario

Figure 4-11. Natural gas consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-12. Natural gas production, imports, and exports in REF, 2000-2050 (PJ)

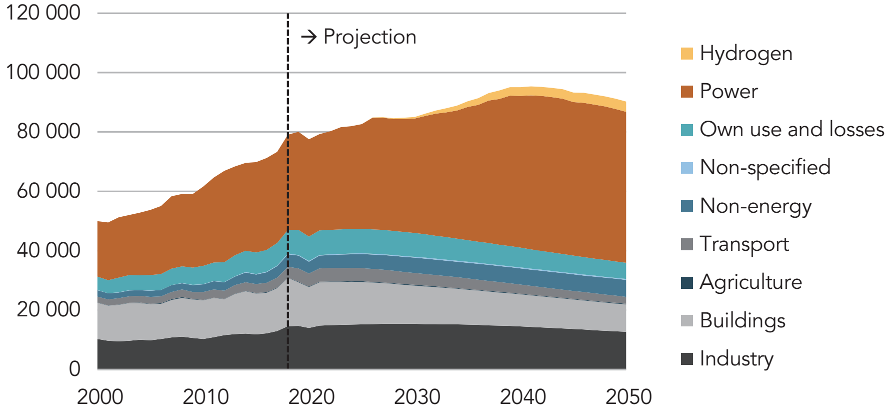


Sources: EGEDA, APERC analysis.

- In 2018, APEC accounted for 58% of global natural gas consumption. APEC consumption is expected to grow by 45% through to 2050 in REF. The US is the largest natural gas consumer in APEC and maintains the leading position to 2050. China and southeast Asia contribute three-quarters of the total consumption increase in REF.
- Natural gas consumption in power sector increases by three-quarters to 2050 and accounts for 69% of total growth. Natural gas becomes the most prominent fuel for APEC electricity generation in the mid-2040s. Dispatchable natural gas units become an important counterpart to higher levels of renewable capacity, specifically for intermittent electricity from solar and wind.
- Natural gas consumption increases in almost all sectors, though at a slower rate than in the power sector.
- Natural gas production grows a third to 2040 and then stabilises through to 2050. In order of absolute increases, the US, China, Russia and Canada account for over 99% of production growth. The US surpassed Russia as the largest producer in 2009 and remains the top producer, largely due to shale gas production.
- Production in China increases by 135% to 2050, supported by investment and financial incentives to explore oil and gas fields and develop unconventional gas resources. Natural gas production in southeast Asia is expected to moderate and decline after 2030 due to depleting reserves. Northeast Asia production remains negligible with supply almost completely reliant on imports.
- Trade volume has increased 88% since 2000 and continues to grow at a similar rate to 2050. There is a disparity in the growth, with imports increasing 115% and exports increasing by half.
- APEC becomes a net natural gas importer in the mid-2040s. Import dependency in APEC grows and reaches 35% by 2050 (compared with 24% in 2018). China becomes the largest importer of natural gas in APEC, with imports more than tripling by 2050. Russia remains the largest exporter.

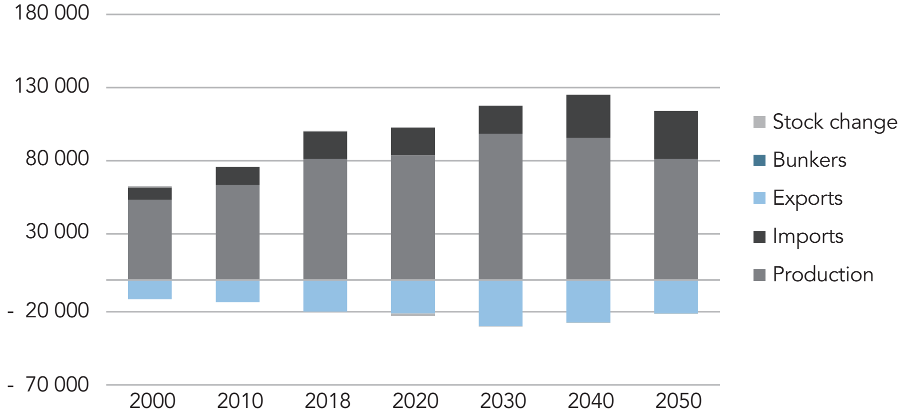
Natural gas in the Carbon Neutrality scenario

Figure 4-13. Natural gas consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-14. Natural gas production, imports, and exports in CN, 2000-2050 (PJ)

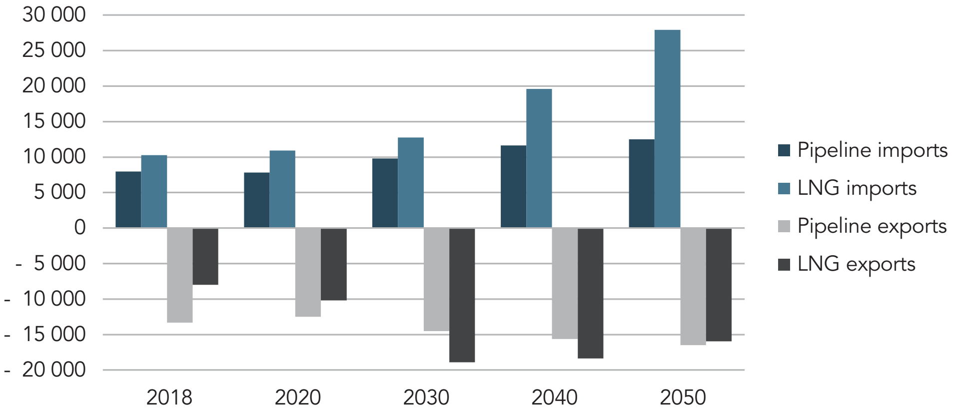


Sources: EGEDA, APERC analysis.

- APEC natural gas consumption grows at a slower rate in CN, peaking in the early 2040s and falling 14% below REF levels in 2050. The US, other Americas, northeast Asia, and Oceania all reduce gas consumption in this scenario. In contrast, China, southeast Asia, and Russia consume greater levels of natural gas to replace coal in the power sector, and China and Russia both surpass the US to become APEC's largest natural gas consumers in the 2040s.
- The power sector remains the largest natural gas consuming sector in CN, but its consumption peaks by the early 2040s and is almost 25% lower than REF levels by 2050. Natural gas remains important for providing peaking and ancillary services, as coal phase-outs and renewable deployments accelerate. There is uncertainty about the increased role of gas in the power sector depending on penetration of storage technologies.
- In the early 2030s, all APEC economies except Chile, New Zealand, Papua New Guinea, and Peru begin to equip gas-fired power plants with CCS technology to reduce CO_2 emissions from the power sector. This provides additional support for natural gas as a transitional fuel.
- Outside of power, hydrogen, and the non-energy sectors, natural gas consumption declines in CN due to more stringent efficiency policies, improvements in technology, and electrification.
- APEC production follows a similar trajectory to consumption, declining during the last decade of the projection after a peak in the 2040s. Production from large APEC natural gas exporting economies (the US, Russia, other Americas, and Oceania) declines in response to falling demand.
- APEC natural gas trade volumes are 25% lower in CN than REF by 2050, with exports declining from the early 2030s. In contrast to exports, APEC natural gas imports continue to grow, with volumes almost 75% larger than 2018 levels by 2050. APEC becomes a net natural gas importer in 2040, which is four years earlier than in REF.

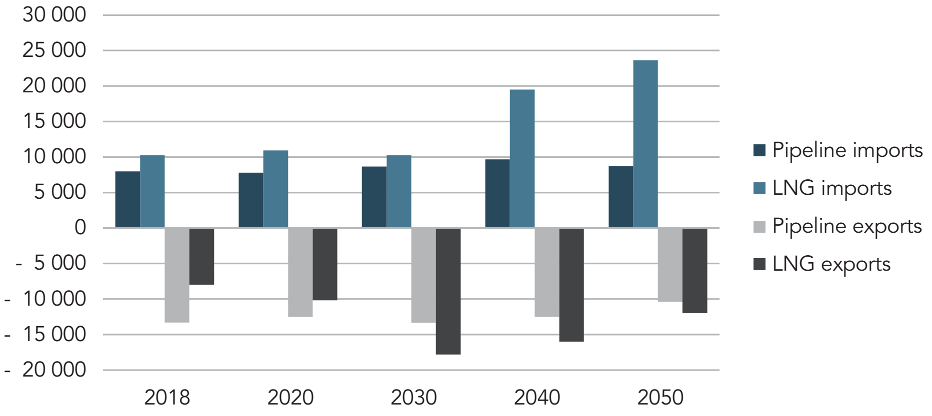
Gross natural gas trade

Figure 4-15. Pipeline and LNG imports and exports in REF, 2018-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-16. Pipeline and LNG imports and exports in CN, 2018-2050 (PJ)

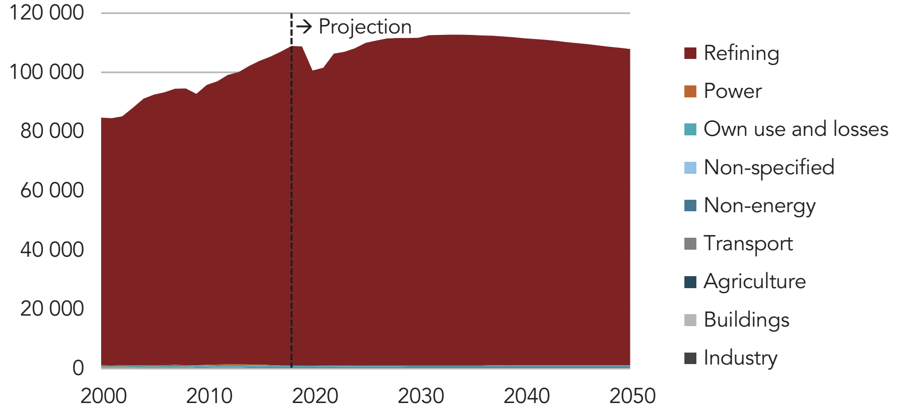


Sources: EGEDA, APERC analysis.

- APEC natural gas imports more than double by 2050 in REF, with 80% of the growth attributable to LNG (172% growth). LNG imports account for 70% of all natural gas imports in 2050, which is up from 56% in 2018. In CN, there is a similar level of reliance on LNG and pipeline infrastructure, though trade levels are all lower in 2050 relative to REF due to lower APEC natural gas demand.
- Growth in LNG imports is mainly from China, northeast Asia, and southeast Asia, with growth in southeast Asia increasing six-fold through the projection period in REF. The increase in LNG imports will require regasification capacity additions of roughly 60%, or 367 Mtpa of additions. Four-fifths of the additions are built in China and southeast Asia. There is less of a need for capacity expansion in northeast Asia due to its high levels of capacity from existing infrastructure.
- In CN, lower gas demand in both APEC and the world leads to a lower requirement for LNG capacity. Regasification capacity is 949 Mtpa in 2050, 2% lower than REF, and liquefaction capacity is 447 Mtpa in 2050, also 2% lower than REF.
- Pipeline imports do not grow as quickly as LNG imports in REF and only grow by a small amount by 2050, compared with 2018 in CN. The completion of the southern leg of the Power of Siberia line from Russia to China supports higher trade from 2025 and results in China becoming the largest gas pipeline importer in APEC in both scenarios.
- APEC LNG exports rise to about 19 500 PJ in 2030 in REF due to rising volumes from the US, Russia, and other Americas. Although LNG exports decline in southeast Asia, APEC LNG exports are 150% higher at the end of the projection, compared with 2018. Liquefaction capacity reaches 455 Mtpa, with about three-quarters of the capacity located in the US, Russia, and Australia.
- In REF, APEC pipeline exports grow steadily and reach almost 16 500 PJ in 2050. Increasing flows come from the expansion of existing pipeline export capacity, as well as the completion of the Power of Siberia pipeline project in 2025.

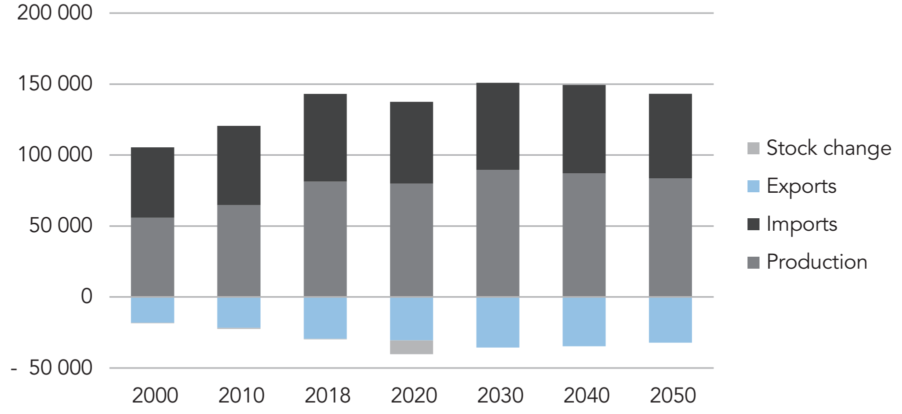
Crude oil and NGLs in the Reference scenario

Figure 4-17. Crude oil and NGLs consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-18. Crude oil and NGLs production, imports, and exports in REF, 2000-2050 (PJ)

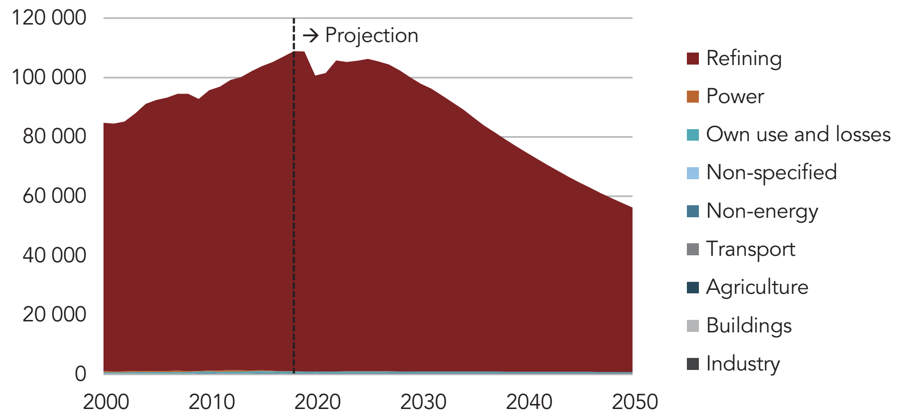


Sources: EGEDA, APERC analysis.

- Refineries are the overwhelming consumers of crude oil and NGLs, with production determined by refinery capacity and global demand for the different types of refined products.
- Refinery runs fall 7.5% in 2020, recover above pre-pandemic levels by the mid-2020s and peak in the 2030s. Utilisation rates hover around 84% for most of the projection, recovering from a low of 80% during the onset of COVID-19 but falling short of the 2018 level of 88%.
- Refinery capacity increases 3% to 2050 in REF, with increases in southeast Asia, China, and other Americas more than offsetting declines in northeast Asia and Oceania. Following the decommissioning of the Marsden Point refinery in 2022, New Zealand joins Hong Kong, China in the short list of APEC members without a refinery.
- Oil production fell 6% in 2020. Production rebounds in the United States and Russia, and with growing output in Canada, APEC oil production surpasses pre-pandemic levels in 2025. Production begins to fall in the 2030s due to declines in the United States, Russia, and southeast Asia. Production grows 11% in China and falls 11% in Mexico.
- Higher production from Canada and the US, alongside lower refinery runs in the United States and northeast Asia, reduce import requirements slightly in REF.
- Exports mirror production trends, peaking in the 2030s but falling thereafter due to declines in both Russia and the United States. Canada surpasses Russia to become the largest crude oil exporter in the 2020s.
- The persistence of investors in oil and gas producing assets to prefer income remuneration rather than growth could limit supply growth from both the United States and Canada. OPEC+ constraints on Russian production, plus Russia's ability to increase output from new resources, are key uncertainties in this projection. Production from economies in southeast Asia and China will be subject to the success of future exploration and could be different than shown here.

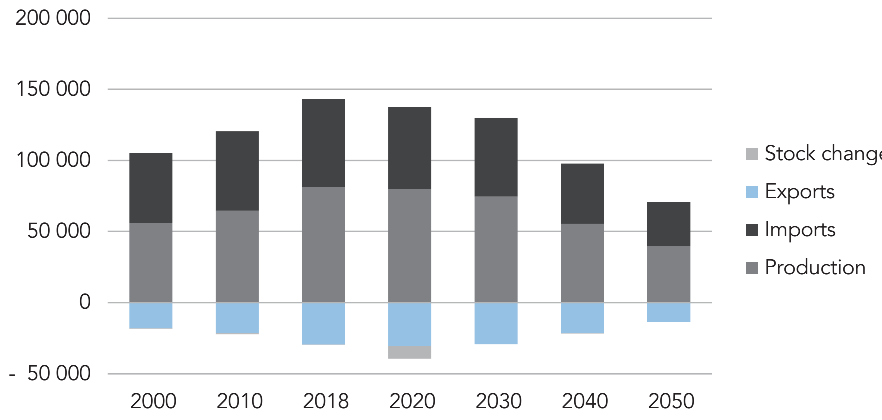
Crude oil and NGLs in the Carbon Neutrality scenario

Figure 4-19. Crude oil and NGLs consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-20. Crude oil and NGLs production, imports, and exports in CN, 2000-2050 (PJ)

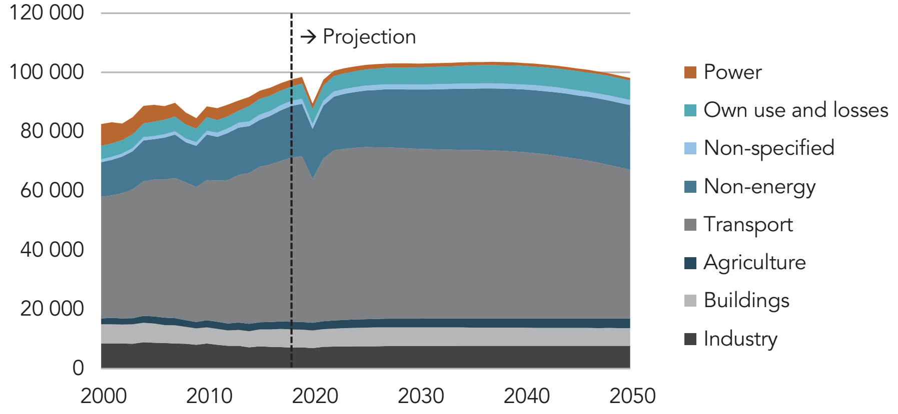


Sources: EGEDA, APERC analysis.

- Declining demand in CN sees crude oil consumption peak prior to the COVID-19 pandemic. A more than halving of global demand for refined products leads to a halving of crude oil and NGLs use through to 2050.
- While refinery runs never reach pre-pandemic highs, refinery consumption partially recovers to a lower high in 2025. Refinery capacity falls a third through the projection, as lower oil demand reduces utilisation rates, and in turn, the profitability of the existing refinery fleet. Even with greater retirements, the utilisation rates still fall under 64% by 2050, indicating that further decommissioning is possible. There is risk of these refinery investments becoming stranded assets.
- Like consumption, APEC oil production in CN never reaches its pre-pandemic peak and halves over the projection period due to lower global demand for oil. Both imports and exports fall by about half as well. These trends are observed across all APEC regions in CN.
- While macroeconomic fundamentals are shared by both scenarios, the declining revenues from a declining oil market could impact the economies of large-scale producer-exporters such as Brunei Darussalam, Russia, and Canada. APEC members should investigate the implications that these trends, particularly on the GDP, employment and incomes of their respective economy.
- Declines in oil supply requirements in CN highlights how investments in oil demand reduction is a longer-term strategy for alleviating energy security concerns in the APEC region.
- This projection highlights the increased risk of investments in oil infrastructure 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 levels of stranded asset risk in CN.

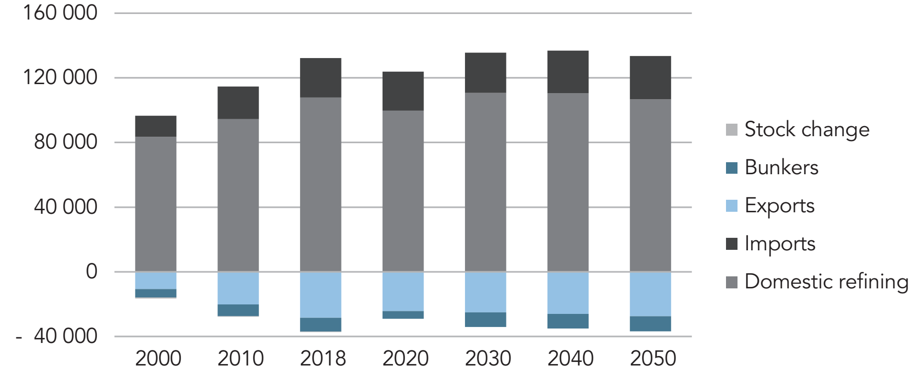
Refined products in the Reference scenario

Figure 4-21. Refined products consumption by sector in REF, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-22. Refined products production, imports, and exports in REF, 2000-2050 (PJ)

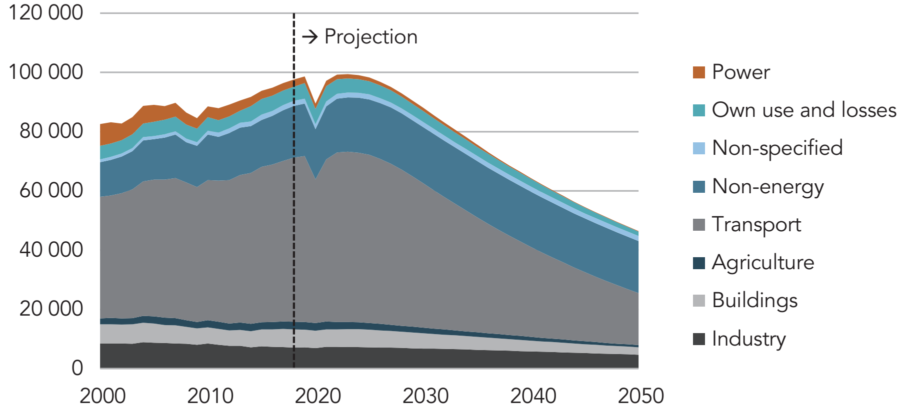


Sources: EGEDA, APERC analysis.

- Refined product use fell 9% in 2020 and after recovering from its pandemic drop in 2022, it slowly increases into the mid-2030s despite declines in transport consumption. Thereafter, declines in all sectors begin to compound, causing consumption to fall in the 2040s. Refined products consumption is 0.5% higher in 2050 than in 2018.
- Transport demand for refined products peaks in 2025 as higher efficiency vehicles and EV adoption leads to declining use in the United States, Oceania, other Americas, and northeast Asia. However, growing demand in Russia, China, and southeast Asia buoys consumption. By 2050, transport sector demand for refined products falls by almost a tenth through the projection period in REF.
- Non-energy use of refined products as feedstocks in petrochemical applications continues to grow throughout APEC, increasing by a quarter to 2050. Industrial combustion of refined products grows by 7.9% through the projection period.
- Refined products are an important fuel source for peaking power plants and remote generation across APEC. The historical decline in usage reflects grid expansion and the adoption of alternatives as peaking fuels. This decline continues, with refined product consumption by the power sector falling two-thirds by 2050.
- Refined products are integral to powering modern drilling rigs and coal mining equipment. High oil, gas, and coal production in REF lifts own use demand by 40%.
- Refinery production remains relatively stable over the outlook period after recovering from the drop during the onset of COVID-19. Output peaks in the 2030s and lower domestic demand in APEC thereafter reduces utilisation rates, bringing output down slightly by 2050.
- Refined products trade rises slightly, with imports increasing slightly more than exports. Withdrawals to bunkers, fuelling international maritime and aviation, increases 10% through the projection.

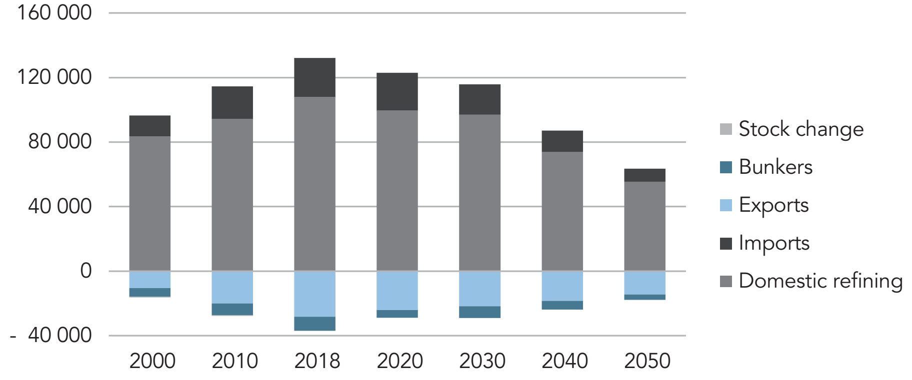
Refined products in the Carbon Neutrality scenario

Figure 4-23. Refined products consumption by sector in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

Figure 4-24. Refined products production, imports, and exports in CN, 2000-2050 (PJ)

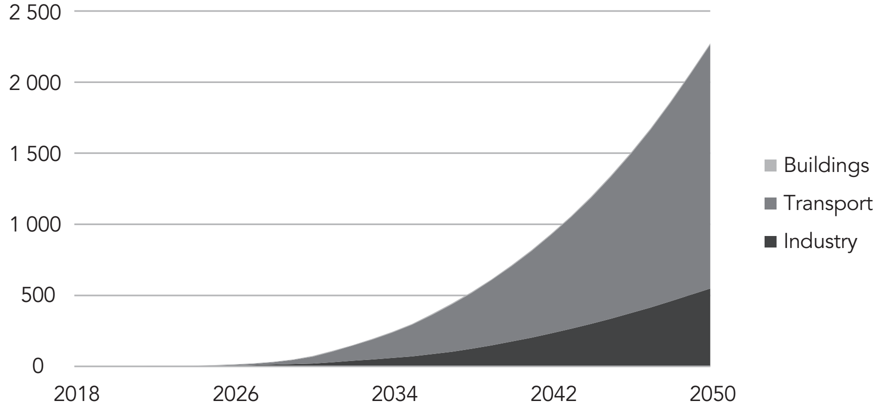


Sources: EGEDA, APERC analysis.

- Consumption of refined products halves in CN. The main driver of this fall is the transport sector, which accounts for well over half of current consumption. Transport sector refined products use peaks in 2023 due to a rapid roll-out of low and zero emission vehicles, efficiency improvements, and modal switching.
- Fuel-switching in other sectors also contributes to the decline. Consumption in the power sector falls 95%, industry a third, buildings more than half, agriculture three-quarters, and own use two-thirds.
- Non-energy consumption of refined products is more robust than other sectors, increasing by a quarter through the projection. This growth is tied to the strong growth for petro-chemical products, such as plastics.
- Reductions in refined product use across APEC regions generally reflects current consumption shares, with slightly higher reductions coming from the United States, northeast Asia, other Americas, and Oceania, and slightly lower reductions from China, Russia, and south-east Asia.
- Refinery production halves in CN as lower domestic and global demand for refined products is met by a reduction in output from APEC refineries. Refined product trade falls almost three-fifths, with imports taking a larger hit than exports as member economies opt to protect domestic market share. Bunkers, too, fall two-fifths, as international marine and aviation switch to lower-emitting fuels.
- This projection highlights the elevated risk of investment in oil product infrastructure as the world strives to achieve carbon neutrality. Current investments in product pipelines, refinery hubs, storage, bunker services, and import and export terminals, which are meeting current demand requirements, all face a higher likelihood of becoming stranded assets in CN.

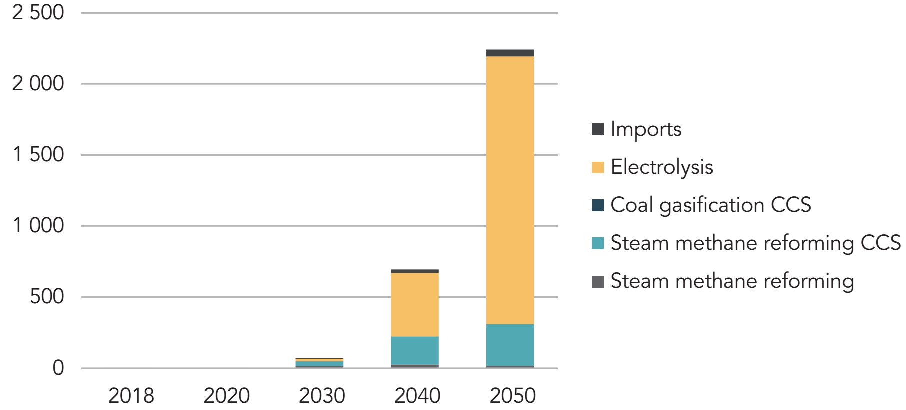
Hydrogen in the Reference scenario

Figure 4-25. Hydrogen consumption by sector in REF, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered as an energy carrier.

Figure 4-26. Hydrogen production and imports in REF, 2000-2050 (PJ)

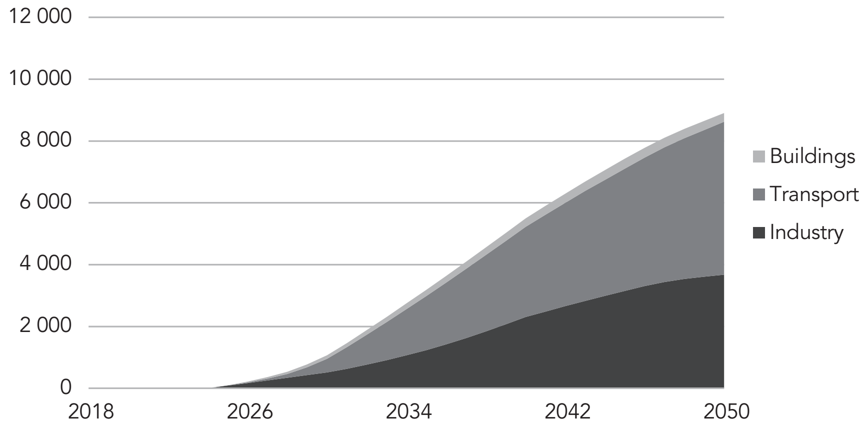


Note: Hydrogen as an industrial feedstock is not considered.

- Although Australia, Canada, Chile, China, Japan, Korea, New Zealand, and the United States have all developed hydrogen strategies that identify priorities and convey recommendations, the future for hydrogen remains uncertain because its deployment requires substantial investments and the creation of a new supply chain.
- In REF, hydrogen grows to account for 1% of APEC's final energy demand in 2050. This requires exponential hydrogen demand growth from a very low base. Transport is the largest consuming sector, responsible for three-quarters of hydrogen demand in 2050. Heavy-duty freight and passenger transport are the main transport applications for hydrogen.
- Industry accounts for the remaining quarter of hydrogen demand in 2050. This consumption accounts for energy use only and does not include current demand for hydrogen as a feedstock for refining or ammonia production. Hydrogen is mainly used in the iron and steel and chemicals subsectors.
- There is also a very small use of hydrogen in the buildings sector. In Japan, residential fuel cells are used to provide electricity and heat.
- Hydrogen demand is initially led by Japan, the United States, and Korea, but by 2030, China and the United States are the main hydrogen consumers in APEC. China consumes more than half of the hydrogen in APEC, while the United States accounts for almost a third.
- Blue, grey, and brown hydrogen account for more than 70% of hydrogen production in 2030. Later, green hydrogen becomes the dominant production process, supplying 64% in 2040 and almost 85% in 2050. The increase in green hydrogen requires a very large increase in electrolyser capacity. In 2017, electrolysis accounted for 2.2 PJ of hydrogen production. In REF, hydrogen production by electrolysis grows by almost 1000-times those levels.

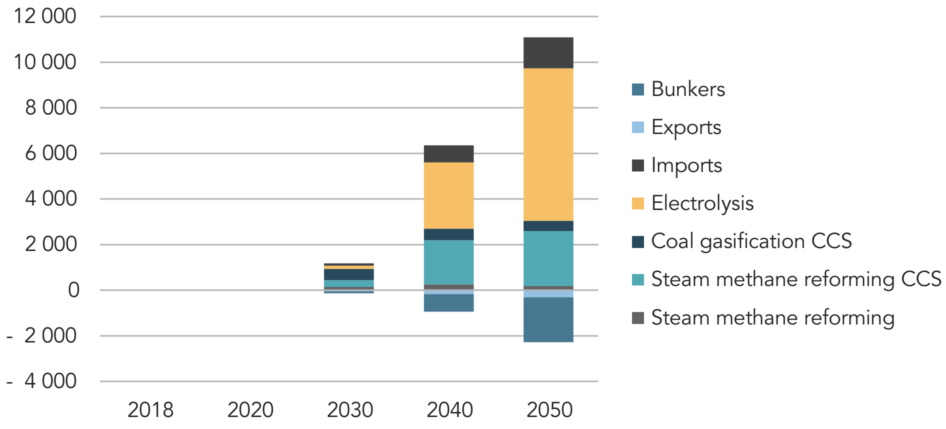
Hydrogen in the Carbon Neutrality scenario

Figure 4-27. Hydrogen consumption by sector in CN, 2000-2050 (PJ)



Note: Hydrogen as an industrial feedstock is not considered as an energy carrier.

Figure 4-28. Hydrogen production, imports, and exports in CN, 2000-2050 (PJ)

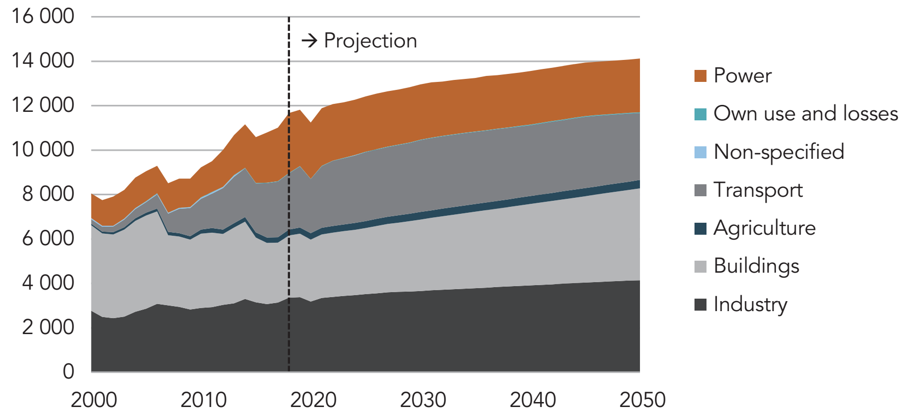


Note: Hydrogen as an industrial feedstock is not considered.

- Hydrogen demand is projected to be higher in CN. Hydrogen accounts for 4.3% (almost 9 000 PJ) of the APEC end-use energy mix in 2050. The increase in hydrogen consumption is driven by higher sales of fuel-cell vehicles for long-distance heavy-duty transport. By 2050, the level of consumption is 6.5 times greater than in REF.
- Hydrogen use rapidly advances in the chemicals and iron and steel industry subsectors. By 2050, hydrogen accounts for 5.2% of industry energy demand, and within the chemicals subsector, hydrogen's share of end-use is more than 13%.
- Almost a quarter of APEC hydrogen production is exported or used by international marine and aviation bunkers. Imports satisfy almost 15% of APEC hydrogen demand, and a quarter of these imports are satisfied by other APEC members.
- While hydrogen production becomes dominant after 2030, hydrogen production that uses CCS also plays an important role in meeting APEC hydrogen demand while limiting emissions. CCS in natural gas-based hydrogen production captures CO_2 emissions of about 200 million tonnes by 2050, almost 3% of emissions in that year.
- Supply chains are nascent and depend on the growth of global hydrogen markets and technological advancements. Hydrogen production in large-scale plants might require a mature hydrogen market supported by high demand, while small-scale and even pilot level generation are required at the earliest stages to create demand. Several hydrogen transportation pathways are promising, such as pipelines, liquefying hydrogen, ammonia, or liquid organic hydrogen carriers. The extent to which hydrogen take-up occurs will rely on the success of supply-side and demand-side technological advancement.
- The structure of regional or global hydrogen markets may develop in a similar manner as other commodities such as LNG and coal but could prove to be unique. Exports of green hydrogen may represent an opportunity for economies with large renewable energy potential, such as Australia and Chile.

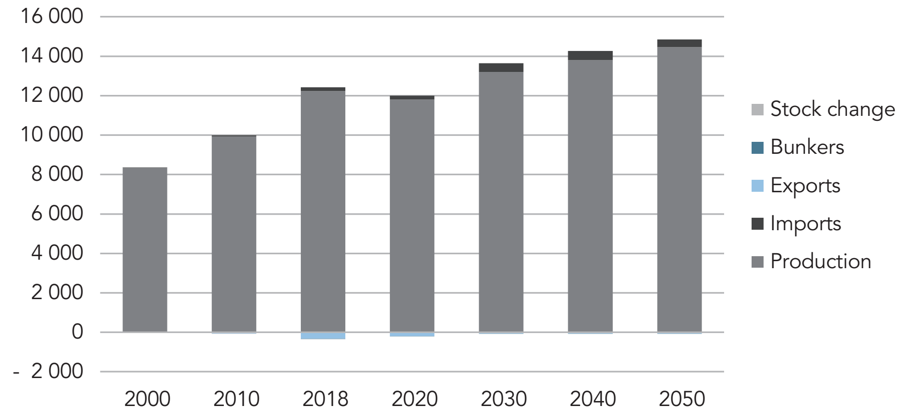
Bioenergy in the Reference scenario

Figure 4-29. Bioenergy consumption by sector in REF, 2000-2050 (PJ)



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

Figure 4-30. Bioenergy production, imports, and exports in REF, 2000-2050 (PJ)



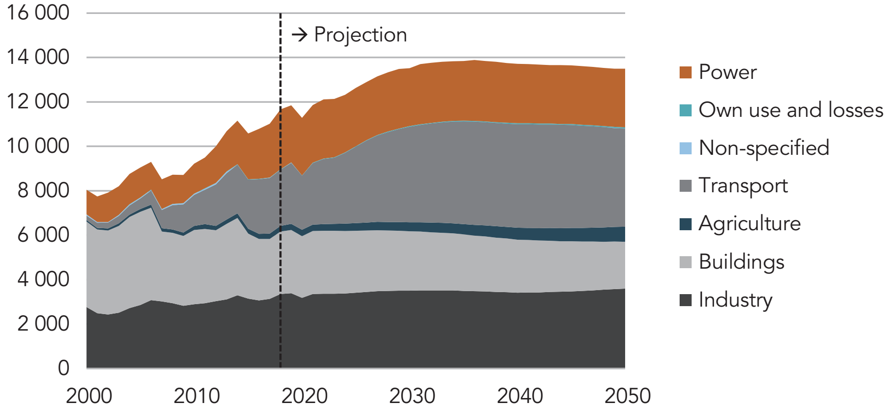
Sources: EGEDA, APERC analysis.

- Demand for solid and liquid renewables in APEC increased by almost half from 2000 to 2018. This increasing consumption trend continues in REF, with more than three-quarters of demand coming from the US, southeast Asia, and China.
- The industry sector is the largest consumer of biomass (solid renewables). Industrial consumption grows in most APEC economies, except in the United States and northeast Asia, which show a slight decrease. The increase in demand is primarily from the pulp and paper industry and through the implementation of coal-to-biomass fuel switching.
- Buildings' biomass consumption is mainly used for cooking and heating. Many economies are enacting measures (such as fuel switching, electrification, and fuel stove upgrades) to reduce consumption due to the negative health effects associated with combusting biomass. However, a projected tripling of consumption in China leads to an increase in APEC consumption out to 2050.
- COVID-19 led to an 12% fall in biofuel consumption by the APEC transport sector. The US is expected to remain the largest biofuels consumer in APEC due to its large transportation sector. Other regions in APEC, like southeast Asia and other Americas, see substantial increases in biofuels consumption due to fuel blending policies and high blending requirements.
- Agriculture and forestry waste by-products from several APEC members support the power sector by the consumption of these renewables in northeast and southeast Asia.
- APEC produces nearly all the solid and liquid biofuels it consumes. Notable exceptions are ethanol imports in the US from non-APEC member economies.
- Consumption for international transportation (bunkers) increases through the projection but is small compared with total supply.

Note: The *Outlook* does not model trade for several solid and liquid renewable commodities, which leads to discontinuities in the trade of solid and liquid renewables over the outlook period.

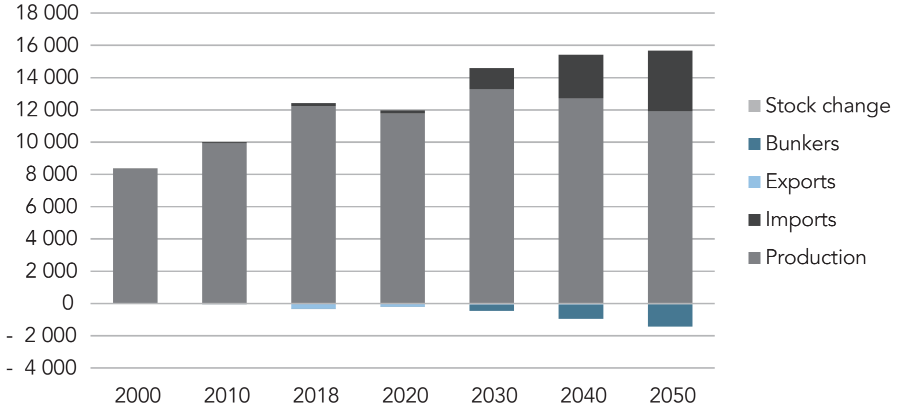
Bioenergy in the Carbon Neutrality scenario

Figure 4-31. Bioenergy consumption by sector in CN, 2000-2050 (PJ)



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

Figure 4-32. Bioenergy production, imports, and exports in CN, 2000-2050 (PJ)



Sources: EGEDA, APERC analysis.

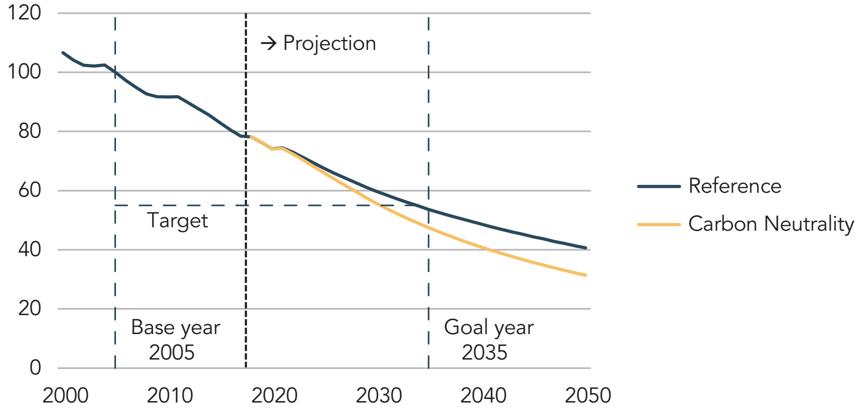
- Demand for solid and liquid renewables in CN is slightly lower than in REF due to greater energy efficiency measures and greater levels of fuel switching to electricity and hydrogen, rather than to renewables.
- The transport sector becomes the largest consumer, via liquid biofuels consumption. This increase is primarily driven by the US, where higher blending requirements are implemented. Advanced engine designs enable blending rates for ethanol and biodiesel that are higher than current limits.
- Renewables consumption by the industry sector continues to increase through the projection period, though at a lower rate than in REF. Lower consumption is due to improved energy efficiency and material efficiencies (achieving the same final output with less inputs), as well as more fuel switching to electricity and hydrogen. Contrary to APEC-wide trends, China's industrial demand for renewable fuels will be slightly higher in CN than in REF driven by stronger fuel switching in the industry from fossil fuel, especially from coal, to renewables fuel.
- Demand for traditional biomass for cooking and heating in the buildings sector decreases throughout APEC. APEC demand in buildings is about half of REF in 2050. This decline is driven by increased policy ambitions that improve health outcomes and lead to reductions in China, southeast Asia, and other Americas.
- APEC has high production potential for biomass, as indicated in REF. However, CN relies more on imports to satisfy incremental demand for liquid biofuels. Increasing investment in bio-refining capacity could see APEC meet the additional demand internally, rather than relying on imports.

Note: The *Outlook* does not model trade for several solid and liquid renewable commodities, which leads to discontinuities in the trade of solid and liquid renewables over the outlook period.

5. APEC energy goals

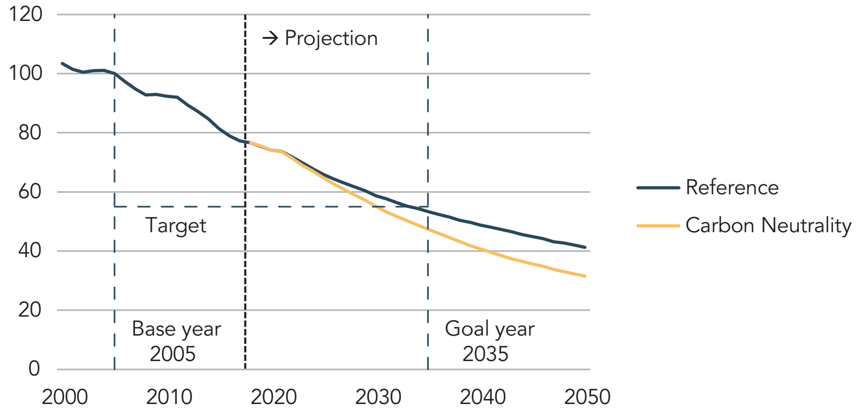
Energy intensity

Figure 5-1. Final energy intensity in REF and CN (2005=100)



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

Figure 5-2. Energy supply intensity in REF and CN (2005=100)



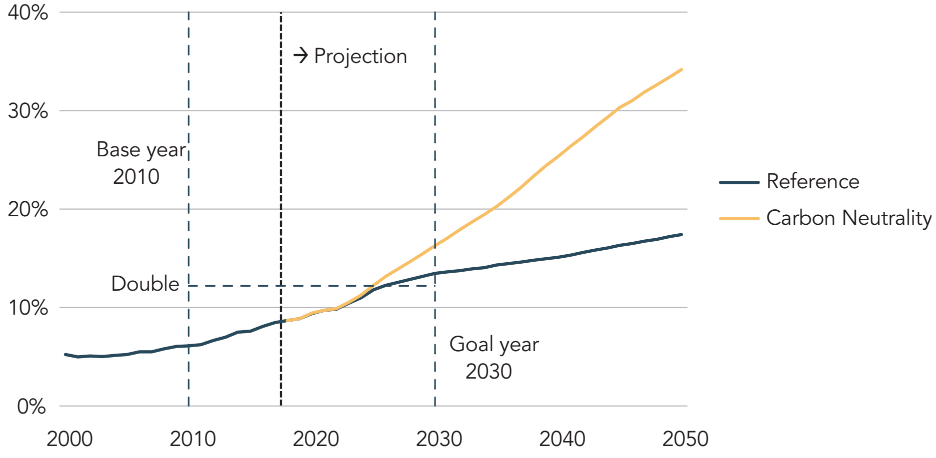
Sources: EGEDA, APERC analysis.

- APEC Leaders agreed on a target to reduce energy intensity by at least 25% by 2030 relative to 2005 levels during the APEC Leaders meeting in Sydney, Australia in 2007.
- The target was subsequently raised to 45% by 2035 at the Honolulu Declaration in 2011, following recommendations from the APEC Energy Working Group (EWG) members.
- Agreement was reached at EWG53 to analyse final energy consumption intensity (excluding non-energy), using APEC data.
- The energy intensity target is APEC-wide and not set at the economy level.
- Final energy intensity has been improving at an average annual rate of 1.9% since 2005 (energy intensity improved 22% from 2005 to 2018).
- APEC reaches the aspirational goal one year ahead of schedule (2034) in REF, suggesting that current policies, measures, and trends are sufficient for the goal to be achieved.
- Final energy intensity will continue to improve beyond 2035, projected to improve 60% by 2050 relative to 2005 in REF.
- In CN, the energy intensity goal is reached four years early (2031), as APEC economies enact more stringent and robust interventions that positively impact energy intensity. By 2050, APEC's energy intensity is estimated to have improved by almost 70% relative to 2005 levels.
- At aggregate levels over long periods of time, energy supply trends mirror energy demand trends. Projected energy supply intensity improvements are very close to projected final energy intensity improvements for both scenarios.

Note: Additional calculations for final energy intensity are available in the supporting dataset.

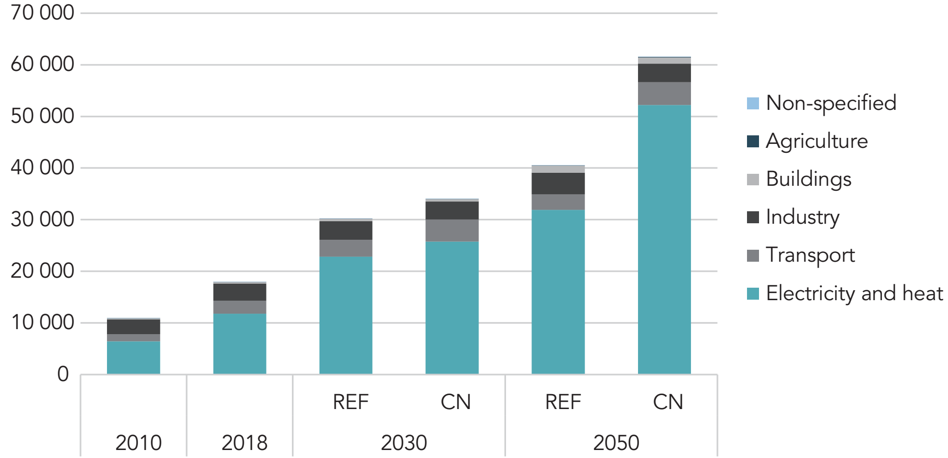
Modern renewables energy share

Figure 5-3. Modern renewable energy share in REF and CN, 2000-2050



Sources: EGEDA, APERC analysis.

Figure 5-4. Modern renewable energy demand by sector in REF and CN, 2010-2050 (PJ)



Sources: EGEDA, APERC analysis.

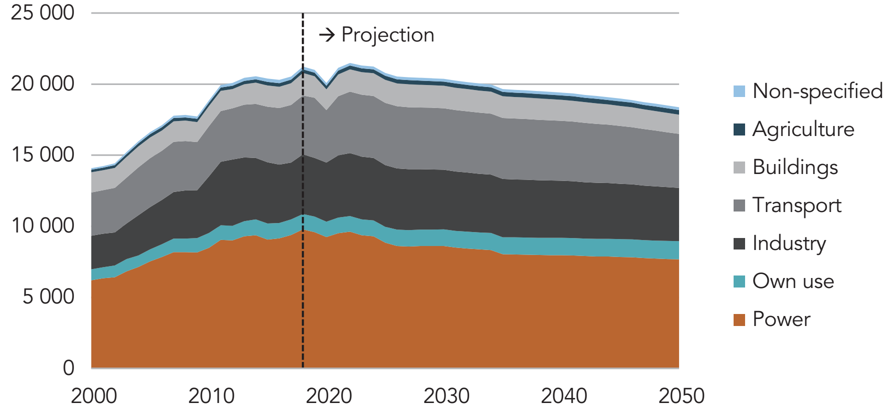
- The second APEC energy goal is to double the share of modern renewables by 2030 relative to 2010 levels, as announced at the APEC Energy Ministers Meeting in 2014.
- Modern renewable energy demand is defined as the consumption of renewables in end-use sectors (excluding traditional biomass) and includes the proportion of electricity and heat consumption that is attributable to renewable sources.
- The modern renewables share increased from 6.1% in 2010 to 8.7% in 2018, which represents a 42% increase in share. Renewable electricity and heat consumption accounted for the largest share of modern renewables, followed by direct use of modern renewables in the industry and transport sectors.
- APEC is expected to meet the aspirational goal of doubling renewables by 2026 in REF, four years ahead of schedule. This suggests that APEC economies are well on their way to significantly accelerating the deployment of renewables. In CN, the goal is achieved five years ahead of schedule in 2025.
- Renewable electricity and heat grow to account for a higher share of modern renewable energy demand than is currently the case. In 2030, renewable electricity and heat accounts for three-quarters of modern renewable energy demand in both scenarios, up from two-thirds in 2018. In 2050, renewable electricity and heat will account for 79% (REF) and 85% (CN) of modern renewable energy demand.
- Direct use of modern renewable in other sectors increases, too. Direct use includes the greater adoption of biofuels in the transport sector as well as increased demand for biomass in the industry sector.

Notes: Additional calculations for modern renewables share are available in the supporting dataset. Biomass consumption in the buildings and agricultural sectors is assumed to be traditional biomass.

6. CO_2 emissions

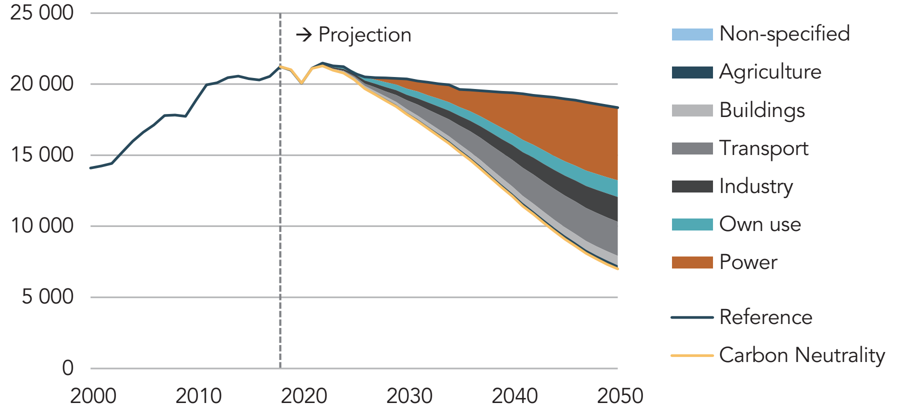
Gross CO_2 emissions

Figure 6-1. Gross CO_2 emissions in REF, 2000-2050 (million tonnes)



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

Figure 6-2. Change in gross CO_2 emissions, 2000-2050 (million tonnes)



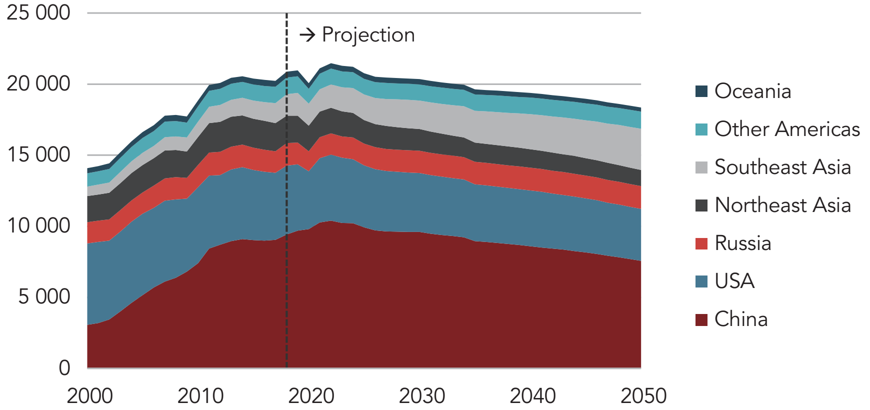
Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy and methane emissions.

- The power sector has been the largest source of energy-related CO_2 emissions in the APEC region (46% in 2018). The industry and transport sectors accounted for about 20%, while buildings accounted for 8%. Coal contributed more than half of the emissions in 2018, with oil and gas contributing 27% and 20%, respectively.
- In REF, the APEC region is expected to reduce its overall CO_2 emissions from 21 000 million tonnes in 2018 to 18 000 million tonnes in 2050. The largest CO_2 emissions reduction is by the power sector (20%), due mostly to a reduction in coal-fired generation. Buildings sector's CO_2 emissions fall by 14%, driven by a decline of coal use in boilers for heating. The transport and industry sectors each contribute to an 8% emissions reduction, due to electrification, other fuel switching, and energy efficiency improvements.
- In CN, CO_2 emissions decline to 7 000 million tonnes in 2050, which is half of total emissions in 2000. All sectors make significant reductions in their CO_2 emissions between 2018 and 2050. Key drivers include the phase-out of coal in the power sector; widespread electrification, particularly in the transport sector; successful development of hydrogen applications in the transport and industry sectors; and extensive CCS deployment in power (mostly gas-fired units), own use, and industry sectors.
- By 2050, CO_2 emissions in CN are 62% below REF levels, with power and transport sectors contributing to most of the reduction.
- These estimates consider only CO_2 emissions from the combustion of fossil fuels in the energy sector. Fugitive emissions, such as flaring and methane leakage, and non-energy sectors, are not considered.
- Mitigating the remaining 7 000 million tonnes of CO_2 emissions in 2050 in CN could require natural removals (for example, forest rehabilitation and preservation) and/or technological initiatives (for example, direct air capture). There may be an opportunity for future collaboration between APEC economies.

Note: Non-energy sectors include those defined by the IPCC (IPPU - Industrial Processes and Product Use; AFOLU – Agriculture, Forestry and Land Use; and waste)

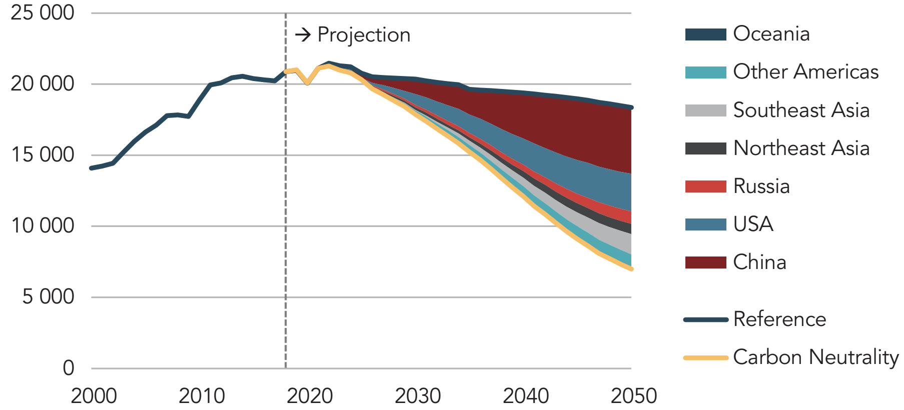
Gross CO_2 emissions by APEC region

Figure 6-3. 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 6-4. Change in gross CO_2 emissions, 2000-2050 (million tonnes)

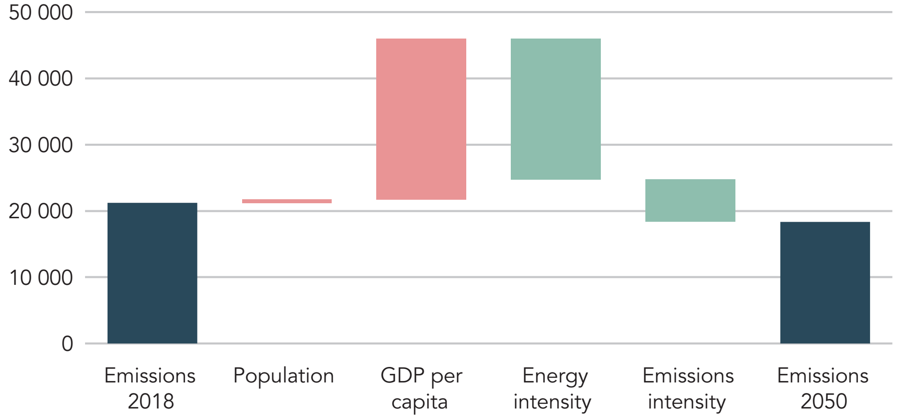


Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- CO_2 emissions grew by 48% between 2000-2018, driven by rapid economic growth, which relied heavily upon coal, oil, and natural gas.
- China and the United States are the largest CO_2 emitters in APEC and the world, contributing 45% and 23% of APEC-wide CO_2 emissions in 2018. China's emissions tripled from 2000 to 2018, with a very large increase in industrial output.
- CO_2 emissions in southeast Asia doubled between 2000–2018, due to rapid economic development and increasing energy demand that has been reliant on fossil fuels.
- In REF, CO_2 emissions decline for all regions except southeast Asia and other Americas between 2018 and 2050. Many of the economies see an increase in the use of natural gas, but this increase is more than offset by a decline in coal and oil (refined products).
- Southeast Asia and other Americas CO_2 emissions expand by 92% and 4% between 2018 and 2050 in REF. Reliance on fossil fuels is expected to continue in these regions to meet their sectoral energy demands.
- In CN, every region achieves substantial emissions reductions over the course of the projection period relative to REF, and every region achieves substantial reductions relative to current emissions except southeast Asia. These emissions reductions occur in the context of significant growth in GDP, implying that economic prosperity is compatible with declining emissions.
- Given accelerated regional climate ambitions in CN, measures to reduce CO_2 emissions from REF levels in 2050 are expected to avoid over 11 000 million tonnes in CN. China and the United States contribute over 60% of the CO_2 reduction in CN relative to REF. Southeast Asia is expected to contribute a further 13%, driven by the region's transition away from coal, and the influence of electrification and energy efficiency, amongst other reasons.

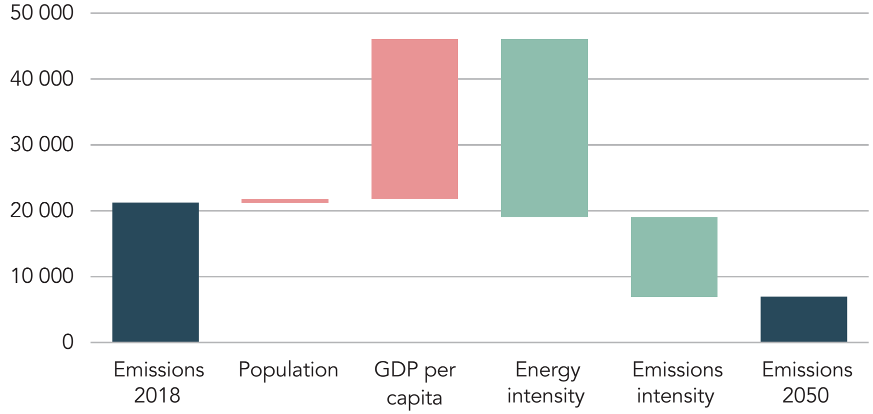
Components of CO_2 emissions

Figure 6-5. CO_2 emissions components in REF, 2018 and 2050 (million tonnes)



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

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



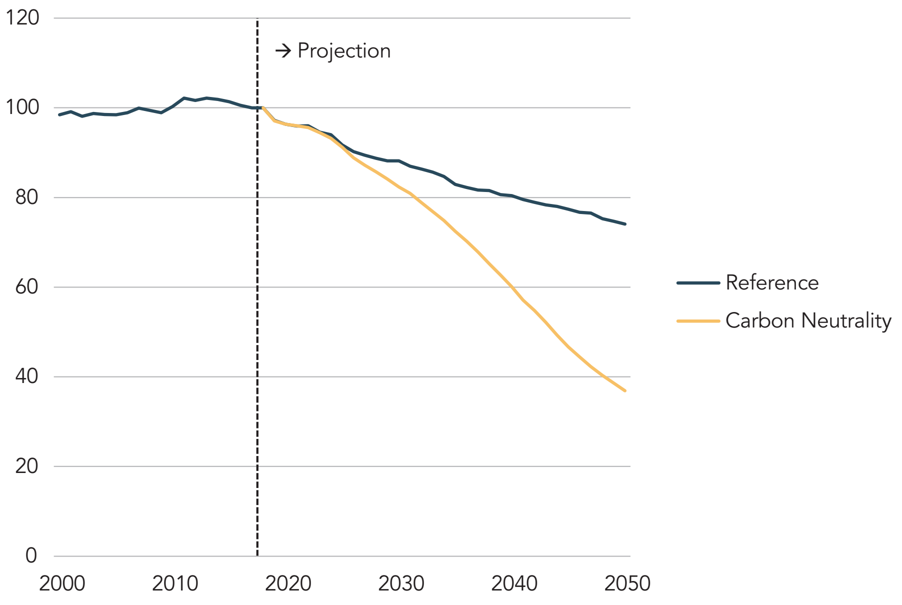
Sources: UNFCCC, EGEDA, APERC analysis. Note: Excludes non-energy, land-use, and methane emissions.

- APEC population is expected to grow by 2% to 2050, despite significant population declines in China and northeast Asia. Population puts a small amount of pressure on CO_2 emissions growth.
- Living standards (GDP per capita) would lead to a doubling in CO_2 emissions were it not for energy intensity and emissions intensity improvements.
- In REF, increases in population and economic output are more than offset by improvements in energy intensity and emissions intensity. By 2050, these improvements lead to CO_2 emissions being 2 500 million tonnes lower than in 2018.
- In CN, energy intensity improvements more than offset CO_2 emission increases from population and economic activity. The additional emissions intensity improvements reduce CO_2 emissions to one-third of 2018 levels.
- Taken together, energy intensity and emissions intensity illustrate the magnitude of CO_2 emissions reductions from technological and behavioral changes, driven and supported by economics and policies.
- Energy policies, particularly those related to energy efficiency, and market trends, such as electrification of many end-use demand applications, are more impactful in CN, and lead to greater reductions in energy demand per unit of economic activity.
- Emissions intensity improvements are due to a reduction in carbon-intensive fuels, like coal, in the supply mix, an expansion of renewables, and the deployment of CCS.
- Additional energy-related CO_2 emissions mitigation beyond levels observed in CN will require additional improvements in energy intensity and emissions intensity.

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

Emissions intensity

Figure 6-7. Emissions intensity, 2000-2050 (2018=100)



- Emissions intensity slightly increased from 2000 to 2018, mainly due to emission increase in the industry and in the power sectors.
- In REF, emissions intensity will drop significantly between 2018 and 2050. This reduction is mainly led by the power sector. Decrease in coal utilization will contribute to the emissions intensity reduction most.
- In CN, there will be more substantial decline in emissions intensity than in REF. All sectors excluding the non-specified will have greater contributions to this decline.

Note: Emissions intensity = CO_2 emission ÷ total primary energy supply

Figure 6-8. Contribution to change in emissions intensity by sector (2000 to 2050)

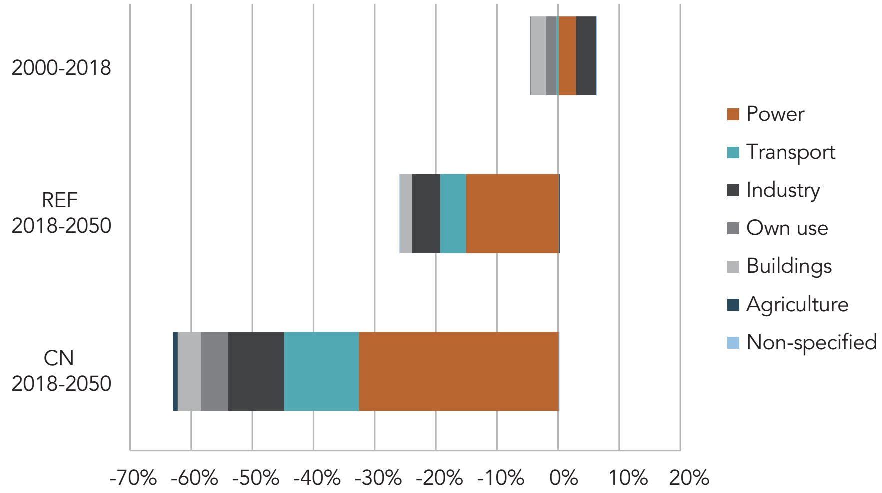
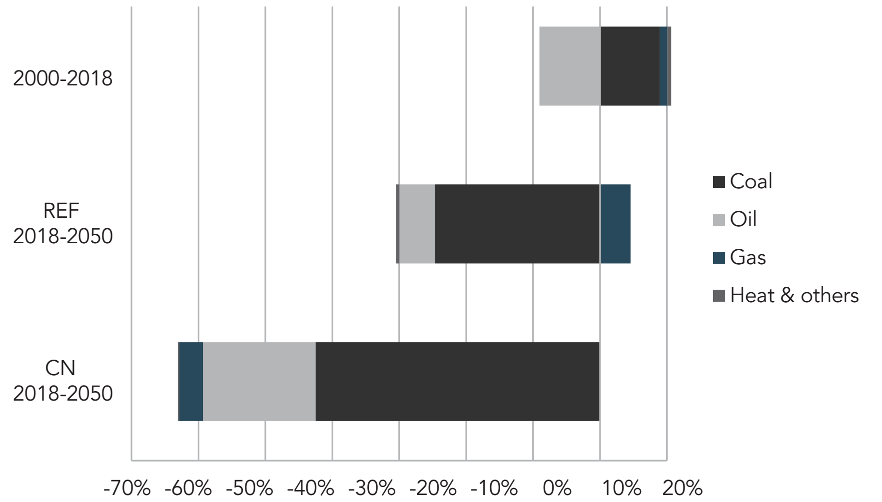


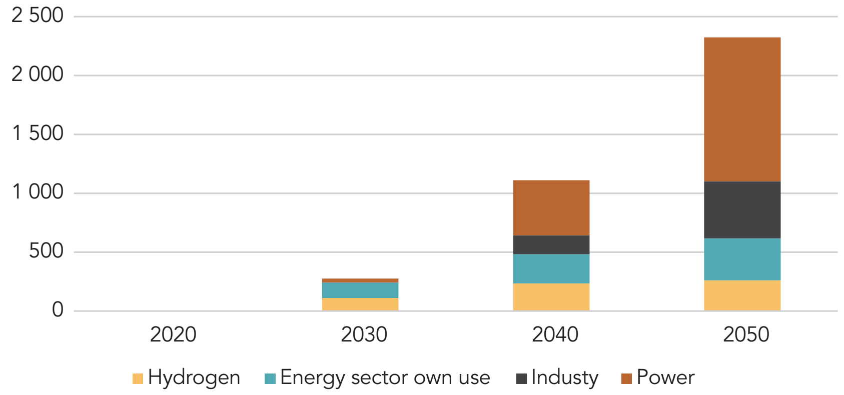
Figure 6-9. Contribution to change in emissions intensity by fuel (2000 to 2050)



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

Carbon capture technologies

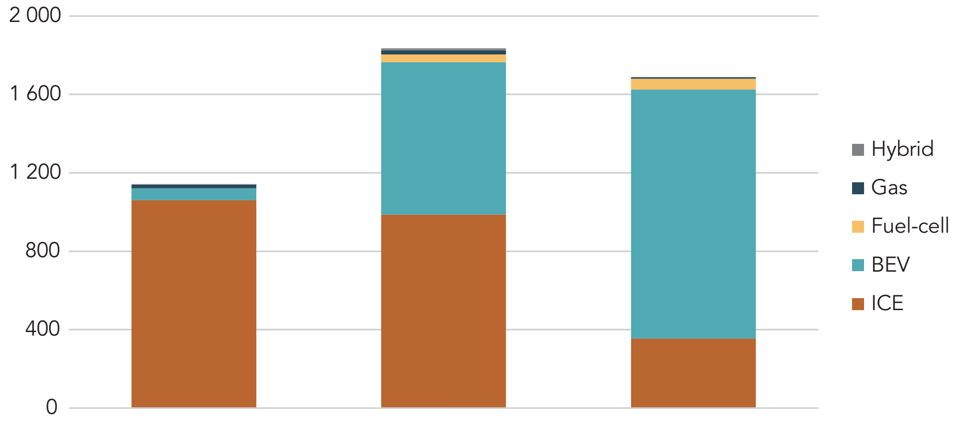
Figure 6-10. CO_2 captured by CCS facilities in CN, by sector (million tonnes)



- Carbon capture technologies that permanently store CO_2 in geologic formations or use CO_2 for purposes are not yet widely deployed across the world. Cost is the main limiting factor, as facilities without carbon capture capability are more competitive in the absence of policy interventions that place an implicit or explicit price on emissions.
- In APEC, the two coal-fired power plants equipped with carbon capture capability have been unable to operate at their sequestration potential (Boundary Dam in Canada) or at a financial profit (Petra Nova in the US). However, learnings at both facilities could improve the viability of future projects.
- In the US, the 45Q tax credit is providing support via up to USD 50 per tonne of captured CO_2. US Congress proposals to increase the tax credit would lead to significant growth in carbon capture facilities once a threshold of economic viability is achieved. Estimates for the cost of carbon storage are closer to USD 100 per tonne, though depend on many factors.
- In REF, a relatively small amount of carbon capture technologies are deployed by heavy industries and the hydrogen production sector towards the end of the projection period. Captured emissions increase to just over 150 million tonnes of CO_2 in 2050. The relatively low take-up in REF is mostly due to an assumed lack of policy support, including a low market price on GHG emissions.
- Policy support for decarbonisation is much higher in CN. Carbon capture technologies benefit via direct support for facilities, support for pipeline infrastructure to move CO_2, and support for development of viable storage sites. Markets for CO_2 become integrated in the global economy, which assists enterprises to develop CCS technologies at a rapid rate. In addition to the industry and hydrogen sectors, CCS technologies are widely adopted by the power sector, and by oil and gas producers in own use applications. These efforts combine to achieve more than 2.3 billion tonnes of CO_2 captured per year in 2050, which is almost 15 times higher than in REF.
- Gas-fired power plants with CCS begin to be deployed from the late 2020s in 17 out of the 21 APEC economies in CN. This widespread deployment allows gas to act as even more of a transitional fuel than would otherwise be the case. On-demand reliability is maintained, with emissions levels kept in check.
- In addition to gas-fired CCS units, Indonesia and Viet Nam are assumed to invest in CCS for a portion of their coal-fired capacity. There is uncertainty about the inclusion of these units in the results, but it is a recognition that coal is not necessarily incompatible with carbon neutrality. Nevertheless, for the APEC power sector, 92% of the captured emissions are from gas-fired CCS units.
- Hydrogen production from fossil fuels with CCS technologies increases significantly from the early 2020s in CN. However, electrolysis-based production of hydrogen becomes the dominant method of hydrogen production in the latter part of the projection period, which limits CO_2 capture growth by the hydrogen sector out to 2050.
- CCS technologies begin to be adopted by heavy industry (steel, cement, and chemicals) from 2030, which is imperative for emissions reductions given the difficulty in switching away many industrial processes from fossil fuels. By 2050, almost one-third of fossil fuels used by heavy industry are subject to some carbon capture process, with an average capture rate of 80%.

Electric vehicles

Figure 6-11. Vehicle stocks, 2018-2050 (millions)

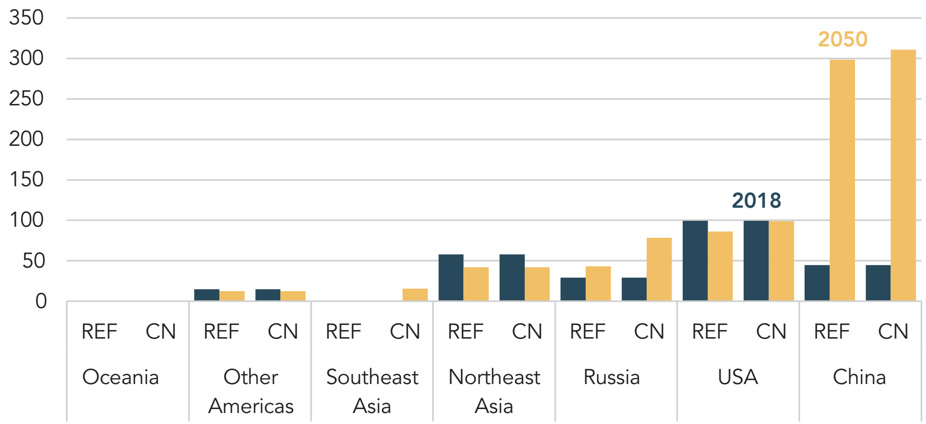


ICE: Internal combustion engine, BEV: Battery powered electric vehicle, Fuel-cell: Hydrogen powered electric vehicle, Gas: CNG or LNG powered ICE, Hybrid: Plug-in electric mixed with diesel or gasoline.

- Accelerated movement away from ICE vehicles to EVs can support APEC members in reducing their emissions. The reduced reliance on refined products can also lower vulnerability to oil supply disruptions.
- In REF, there is little change in total energy used in road transport. However, in CN, a 60% faster growth in EV stocks drives road transport energy use down by more than a third. This is because the fuel economy of EVs is around three-times as efficient as ICE vehicles from the same model years.
- Two/three-wheelers are electrifying at a rapid rate, as their light weight and short driving distances only requires small batteries. These vehicles have the highest electrification proportion of any vehicle type out to 2050. However, their low share of energy use limits their impact on reducing APEC's energy use and emissions.
- Light passenger vehicles make up the largest share of vehicle stocks and transport energy use, thus their electrification causes the largest decline in total energy use in both scenarios.
- The electrification rate of heavy vehicles is the lowest of all vehicle types. This is because the energy-to-weight ratio of batteries is low enough to make it difficult to carry heavy vehicles over long distances. So, to decarbonize regional trucking, either advanced technologies for high-power fast charging or alternative energy sources are needed.
- Some economies plan to use the high energy to weight ratio of hydrogen, used in fuel cells, for decarbonising heavy vehicles. For example, Japan plans to install 320 hydrogen stations by 2025 to help expand hydrogen production and make the fuel more abundant and affordable.
- Battery-powered heavy vehicles will be more common in urban areas, such as delivery and refuse trucks and buses, due to shorter driving distances.
- China leads in the electrification of the transport sector. In 2020, China had electrified over 20% of its vehicle fleet. Most of this is from two/three wheelers, at near 50% electrification. APEC is an important region for EV development. This ranges from the importance of critical minerals in Chile, Peru, and Viet Nam, to the massive battery production capacity in China, where 70% of all batteries in the world are currently produced.
- Batteries are expected to face challenges related to material sourcing, security of supply, and recycling/disposal, which could limit the adoption of EVs across APEC.
- EVs are currently not sold in enough models and price points to suit all consumer needs. Some economies have been using subsidies to encourage uptake, though models sell at a premium to ICE alternatives.
- The network of public chargers for EVs will continue expanding. It is important that economies plan for increases in peak power generation and transmission capacity to meet the demand that EV potential implies. Innovative solutions, like smart charging, will be required to help alleviate heavy load problems and guarantee grid capacity for EV charging.
- Transport electrification reduces emissions in both scenarios. However, decarbonising power grids is important to maximise the benefits.
- The benefits of EVs are not limited to reducing emissions. Reducing exhaust fumes is expected to reduce health costs attached to air pollution. EVs are also less noisy, cheaper to maintain, and will improve energy security by decreasing reliance on fossil fuels.

Nuclear power

Figure 6-12. Installed nuclear capacity in REF and CN, 2018 and 2050 (GW)



Contribution to CN

- Eight APEC economies currently have nuclear power. The government of Chinese Taipei has decided to phase-out nuclear power by 2025, choosing instead to rely on imported LNG, offshore wind and solar. However, Indonesia will deploy nuclear power in the 2040s in CN as part of its decarbonisation strategy, returning APEC to eight nuclear economies.
- Between 2018 and 2050, 313 GW of new nuclear capacity will be added in APEC, mostly in China (266 GW), followed by Russia (49 GW), and Indonesia (16 GW). The 14th Five Year Plan in China announced a goal of 70 GW of total nuclear capacity by the end of 2025. In Russia, the government estimates that 15 units will be completed in or by 2030.

Uncertainty and Risks

- An environment of high risk and uncertainty related to nuclear power is estimated to limit capacity additions in both scenarios.
- **Investment:** Nuclear power projects are characterised by having high upfront capital costs and long construction periods. The duration and costs of construction can also vary considerably, which creates uncertainty for investors. However, once operational, variable fuel and operation costs are typically lower than those for fossil fuel counterparts.
- High investment costs for nuclear power projects increase risks for investors and typically require loan guarantees or support from governments.
- **Regulatory Risks:** There are risks associated with regulatory changes. For example, in Japan, after the Fukushima Daiichi nuclear power plant incident in 2011, new regulatory requirements that include countermeasures for natural disasters were established. These new regulatory requirements mean that there is uncertainty for some reactors to restart operations.
- **Public Acceptance:** There is uncertainty regarding public opposition to nuclear power projects. For example, in Chinese Taipei, a referendum seeking to restart construction of the fourth nuclear power plant failed to pass in 2021.
- **Non-proliferation Risks:** There are potential risks related to non-proliferation of technology and materials that could be used for nuclear weapons.

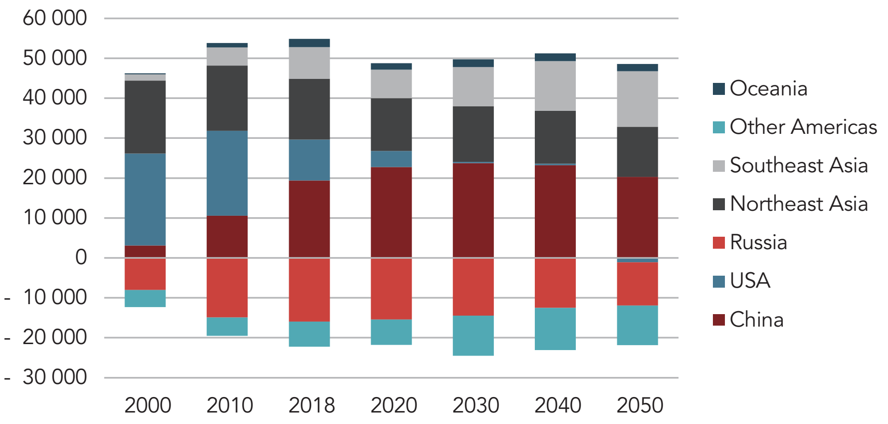
Future technology

- **Small Modular Reactors (SMRs):** SMRs have captured the attention of policymakers as suitable technology options. SMRs offer opportunities to expand the role of nuclear energy. In the US, NuScale Power is building an SMR project that is planned to begin operation in 2029. In Canada, the SMR Action Plan states that the first SMR units should enter operation by the late 2020s.
- **Generation IV reactors:** These are a type of reactor design that are expected to increase design flexibility and improve thermal efficiency. Designs include sodium-cooled fast reactors, very high temperature reactors, gas-cooled fast reactors, molten salt reactors, lead-cooled fast reactors, and supercritical water-cooled reactors. While Generation IV designs are promised to improve sustainability, economics, safety, and reliability, they are subject to some of the same risks as other nuclear technologies.

7. Energy security and grid reliability

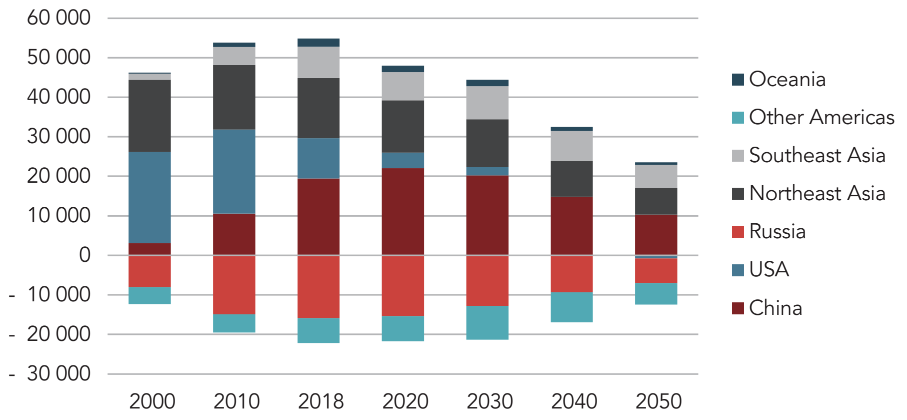
Oil import dependence

Figure 7-1. Net imports of crude oil and petroleum products in REF, 2000-2050 (PJ)



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

Figure 7-2. Net imports of crude oil and petroleum products in CN, 2000-2050 (PJ)



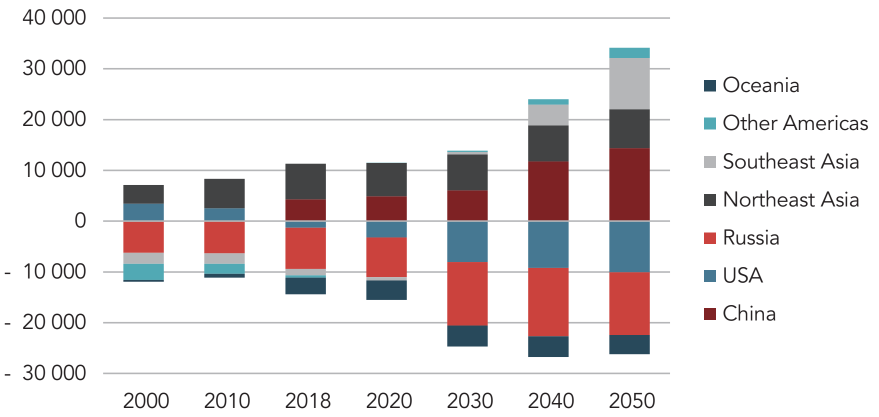
Sources: EGEDA, APERC analysis. Note: Exports appear as negative values.

- APEC oil import dependence was 23% in 2020 and varies both by region and among producing and consuming economies. Northeast Asia was the most dependent region at 100%, followed by China (86%), Oceania (67%), and southeast Asia (58%).
- In 2050 in REF and CN, APEC net oil import dependence is expected to decline to 17% and 16%, respectively. Northeast Asia's dependence remains at 100%.
- Southeast Asia is the only region where import dependence increases: from 58% in 2020 to 74% in REF and 70% in CN. Net oil imports double in southeast Asia (representing half of APEC's net oil imports by 2050) due to rapid economic growth, associated oil consumption, and declining oil production.
- China's import dependence is expected to decline to 69% in both REF and CN, largely due to increased electrification of China's transport sector.
- The US transitions to a net oil exporter in 2026 in REF and in 2031 in CN. Net oil dependence falls from 10% in 2020 to –11% (REF) and –14% (CN), though the volume of US oil production and exports is significantly lower in CN.
- Constraints are currently limiting global oil supply despite high prices. Factors include the OPEC+ agreement, sanctions targeting Russian supply, and investors continuing to demand remuneration over supply growth in Canada and the US. Insufficient investment in new oil and gas upstream and midstream projects could increase import dependence and energy security risks in both scenarios if oil production falls, or oil demand rises, more than projected.
- Mitigation measures will remain important tools to reduce the impact of oil supply disruptions in both scenarios. Tools include collaborative investments in strategic oil stocks across APEC to mitigate supply emergencies, further investments to reduce oil demand (and thus import dependence), and oil demand-reducing technologies, like EVs and fuel efficiency measures.

Notes: Oil import dependence is defined as (net crude oil imports plus net petroleum product imports) divided by oil supply. Bunkers are counted as exports.

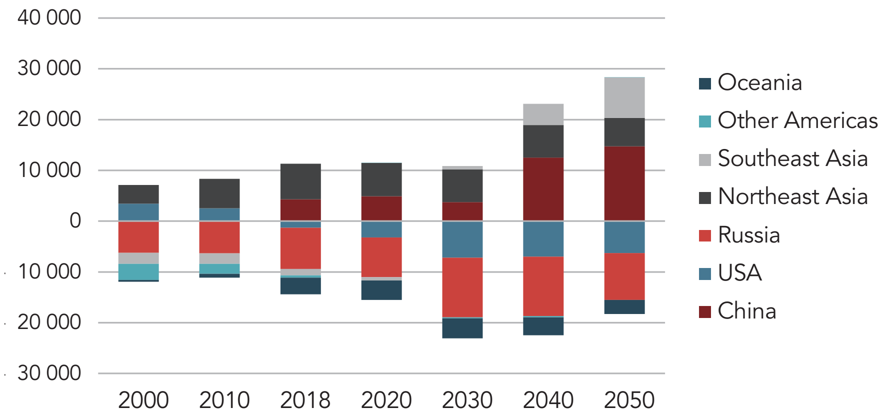
Natural gas import dependence

Figure 7-3. Net natural gas imports in REF, 2000-2050 (PJ)



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

Figure 7-4. Net natural gas imports in CN, 2000-2050 (PJ)



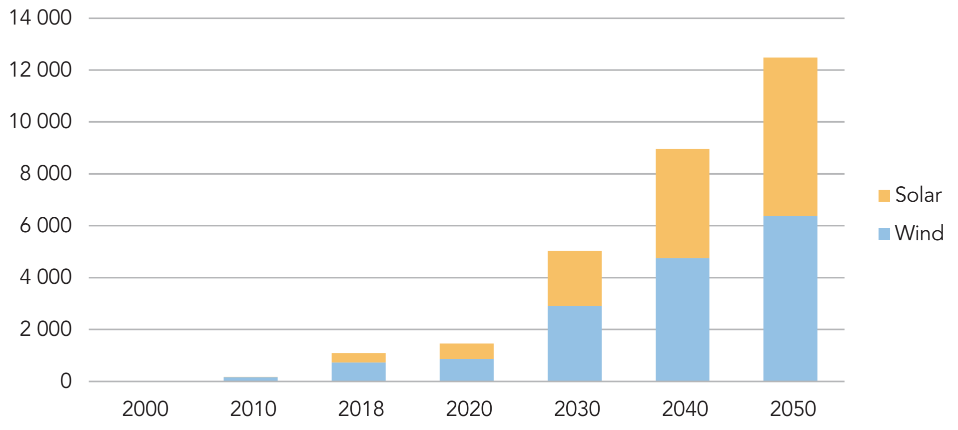
Sources: EGEDA, APERC analysis. Note: Exports appear as negative values.

- In 2020, APEC exported more gas than it imported, resulting in a negative gas dependence ratio. By 2050, APEC gas import dependence increases to 7% in REF and 11% in CN.
- China drives growth through 2050, with gas net imports that almost triple in both scenarios. China's gas production grows more slowly than consumption due to several factors, including complex geology. Import dependence was 38% in 2020, but this increases to 51% in both scenarios by 2050.
- China's import capacity is already growing significantly. In 2021, the economy became the largest LNG importer and the Power of Siberia pipeline from Russia became operational (capacity 38 bcm).
- Northeast Asia is wholly dependent on gas imports. In REF, northeast Asia grows its net gas imports by 15%, reaching a volume of more than 7 600 PJ (about half of China's net imports).
- Southeast Asia accounts for the second-largest increase in gas net imports due to a decline in domestic gas production and fuel switching from coal to gas. The region transitions from a net exporter to a net importer by the mid-2020s in both scenarios. By 2050, net imports are more than 10 000 PJ in REF and almost 8 000 PJ in CN, with import dependence of 61% (REF) and 55% (CN).
- In 2017, the US transitioned from a net gas importer to a net gas exporter. US net gas exports are expected to increase through to 2050 in REF but are expected to peak in 2032 in CN due to declining global gas demand.
- Surging global demand and sanctions on Russian exports are placing the availability and affordability of LNG at risk. Investments to increase liquidity (such as investing in storage), mandating storage level targets for heating and cooling seasons, and ensuring supply through long-term contracts or equity investments throughout the supply chain could enhance gas security. Mandated winterisation of gas production facilities, especially in northern latitudes, could improve supply reliability.

Note: Gas import dependence is defined as net gas imports divided by gas supply.

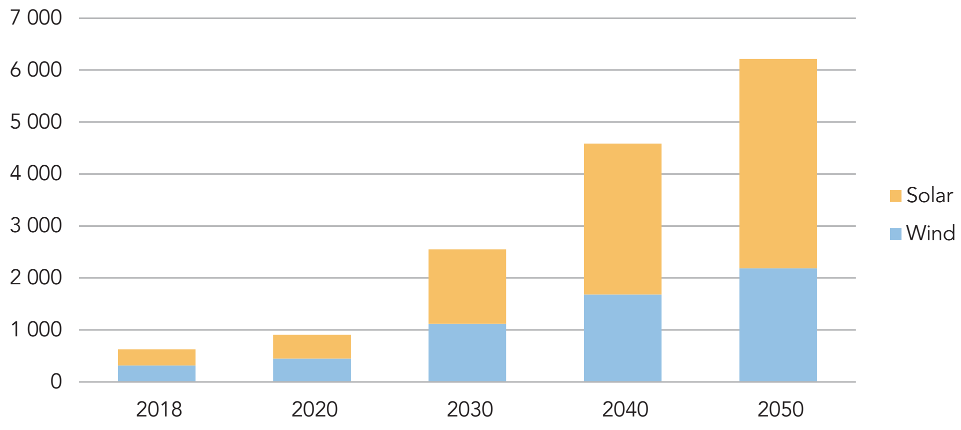
Electric grid reliability

Figure 7-5. Wind and solar PV electricity generation in CN, 2018-2050 (TWh)



Sources: EGEDA, APERC analysis.

Figure 7-6. Wind and solar PV generation capacity in CN, 2018-2050 (GW)



Sources: EGEDA, APERC analysis.

- Maintaining grid reliability requires balancing electricity supply and demand in real time. Balancing can become challenging as the share of non-dispatchable power sources increases, especially when unexpected weather events or supply outages occur.
- APEC has experienced several notable reliability issues such as in Australia (2016), California (2020), and Texas (2021).
- Grid reliability appears to be declining in regions where reliance on non-dispatchable power sources, such as wind and solar, is increasing. APEC members may want to investigate the reasons for this decline in advance of even larger deployment of non-dispatchable resources.
- In 2018, wind and solar accounted for 4% and 2% of total electricity generation in APEC, respectively. In REF, the share of generation increases to 12% for wind and 11% for solar. In CN, the share grows to 19% (wind) and 17% (solar).
- With respect to capacity, the projections show large increases in solar and wind capacities in both REF (44% share) and CN (64% share).
- The non-dispatchable nature of wind and solar means that firm capacity—technologies that are flexible enough to ramp up during shortfalls in generation—is essential. Energy storage and interruptible demand can also enhance reliability.
- Increasing reserve margin to accommodate higher shares of non-dispatchable units can raise costs for consumers. One means of creating reserve margin is to establish robust interconnections with other grids.
- The ERCOT outage in Texas (2021) exposed how vulnerabilities in upstream natural gas infrastructure prevented gas from meeting the residual load that occurred from low wind generation and increased demand due to extreme weather. Strengthening power grids via using weather forecasts to better predict demand and supply from non-dispatchable sources, increasing the ability to rotate rolling blackouts, and increasing back-up infrastructure (stockpiles), will lower the risk of outcomes like in Texas.

Note: Capacity refers to nameplate capacity.

8. 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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