ENERGY DEMAND AND SUPPLY OUTLOOK BY SOURCE

- *Total primary energy demand in APEC is expected to grow from 5,939 Mtoe in 2002 to 10,332 Mtoe in 2030, at an annual growth rate of 2.0 percent, which is much lower than GDP growth of 4.1 percent per year.*
- *Energy intensity in the APEC region is expected to drop by 40 percent over the outlook period.*
- *Energy diversity is expected to improve for all but four APEC economies: Canada, China, Hong Kong, China, and New Zealand.*
- *The net import of primary energy will grow at an annual rate of 4.7 percent – compared with 0.3 percent annual growth over the past two decades – led by oil in Asia and natural gas in Asia and Americas.*

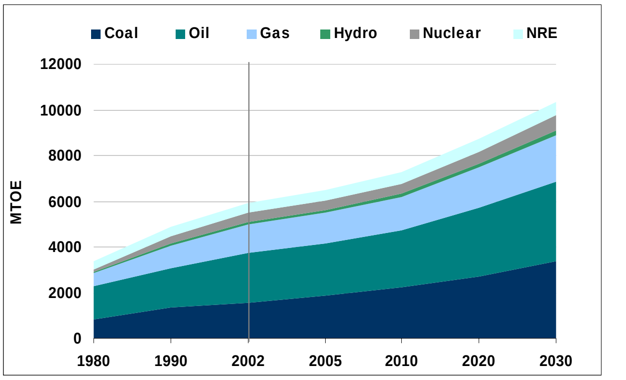
The demand and supply balance in the APEC region will **became tighter** over outlook period, as the region's annual primary energy production is expected to grow at 1.5 percent, which is significantly lower compared with the total primary energy demand growth of 2.0 percent per year. By 2030 the APEC region will swiftly move from a net exporter of natural gas and coal to a net importer, while net oil imports will increase from 36 percent of oil demand in 2002 to 52 percent in 2030. The **energy import dependency** of the APEC region as a whole is expected **to increase** in the future. **Energy intensity** in the APEC region is expected **to drop** by 40 percent through to 2030, following the overall global trend and reflecting high rates of improvement for Russia, China, and the US. **Energy diversity** is expected **to improve** for all but four economies: Canada, China, Hong Kong, China, and New Zealand, while decreasing slightly for APEC as a whole, reflecting China's share in total primary energy demand.

PRIMARY ENERGY DEMAND AND SUPPLY BY FUEL TYPE

Total primary energy demand (TPED) in the APEC region is expected to grow from 5,939 Mtoe in 2002 to 10,332 Mtoe in 2030, at an annual growth rate of 2.0 percent, which is lower than the rate of 2.6 percent per year over the previous two decades (Figure 1, Table 1).

Over the outlook period, **oil** demand is projected to grow at an annual growth rate of 1.7 percent from 2,165 Mtoe in 2002 to 3,488 Mtoe in 2030, and is expected to maintain the largest share of TPED in the APEC region in 2030 at 34 percent. Oil demand for the transport sector will dominate and contribute 68 percent of incremental oil demand growth through 2030. Oil production growth over the outlook period will be lead by Canada (prevailed with non-conventional oil from Alberta's tar sands), accounting for 37 percent of the incremental production in the APEC region, followed by the US at 25 percent and Russia at 21 percent. However, by 2030 some 52 percent of APEC's oil supply will be met by imports predominantly sourced from the Middle East.

Figure 1 Primary Energy Demand (1980-2030)



Source: APERC Analysis (2006)

Given the cost competitiveness relative to other fossil fuels, and the relative abundance in the APEC region **coal** demand is projected to grow the fastest over the outlook period at an annual rate of 2.8 percent from 1,570 Mtoe to 3,366 Mtoe, and account for the second largest share of TPED in 2030 at 33 percent. Approximately 87 percent of incremental coal demand is expected to be derived from the electricity sector, with China projected to be the major coal consumer in the APEC region accounting for 54 percent of TPED for coal in 2030. Coal production in the APEC region is concentrated in the six economies with the largest reserves: Australia, Canada, China, Indonesia, Russia, and the US. These six economies are expected to account for almost 99 percent of APEC's incremental production over the projected period; however, APEC is expected to become a marginal net coal importer of 2.8 Mtoe in 2030.

Table 1 Primary Energy Demand and Supply by Source for APEC (1980-2030)

Energy		1980	2002	2030	1980-2002	2002-2030
		Mtoe	*Mtoe*	*Mtoe*	*AAGR,%*	*AAGR,%*
Coal	Net import	-33	-78	3	4.0	-
	Production	860	1 644	3 364	3.0	2.6
	Demand	822	1 570	3 367	3.0	2.8
Oil	Net import	565	773	1 805	1.4	3.1
	Production	947	1 399	1 683	1.8	0.7
	Demand	1 445	2 165	3 488	1.9	1.7
Natural gas	Net import	4	-113	284		
	Production	591	1 383	1 766	3.9	0.9
	Demand	595	1 255	2 050	3.5	1.8
NRE	Demand	332	460	588	1.5	0.9
Nuclear	Demand	104	382	643	6.1	1.9
Hydro	Demand	65	114	167	2.6	1.4
Total primary energy	**Net import**	**536**	**577**	**2093**	**0.3**	**4.7**
	Demand	**3 363**	**5 939**	**10 332**	**2.6**	**2.0**

Source: APERC Analysis (2006)

Natural gas is projected to account for 20 percent of TPED in 2030. Through to 2020 natural gas is expected to experience fast growth of 2.0 percent per annum, followed by more moderate annual growth of 1.4 percent between 2020 and 2030. Incremental natural gas demand growth will be driven primarily by the electricity sector at 42 percent, followed by industry and residential/commercial on 28 percent each respectively. To meet demand within the APEC region production is expected to increase rapidly – especially in Australia, China, and the US. However, the region is expected to become a net natural gas importer over the outlook period.

The share of **nuclear** in TPED is expected to remain stable at 6 percent through 2030, growing at an annual rate of 1.9 percent from 382 Mtoe in 2002 to 643 Mtoe in 2030. China is expected to exhibit the highest growth over the outlook period rising at 10.5 percent per year. Viet Nam seems to be the first Southeast Asian economy to utilise nuclear power starting from the second decade of this century.

Hydroelectricity is expected to grow at 2.0 percent per year – the second fastest after coal – although the share will remain low at 2 percent in 2030. China, endowed with the largest hydroelectricity potential will see the fastest annual growth in the APEC region at 4.8 percent, and account for 78 percent of total incremental hydroelectricity growth through 2030.

New and renewable energy (**NRE**) which includes biomass, solar, wind, tidal and wave energy is expected to grow at 0.9 percent per year. The share of NRE is expected to fall from 8 percent in 2002 to 6 percent in 2030 due in part to a shift to commercial fuel sources in rural areas of less-developed regions that rely heavily on biomass for cooking and heating, as socio-economic conditions will improve.

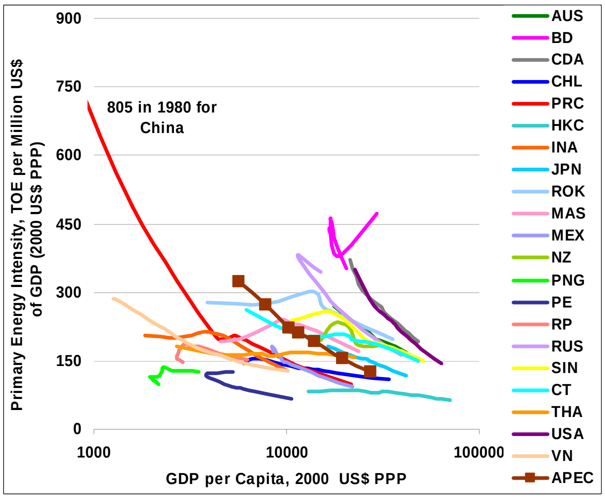
ENERGY INTENSITY AND PER CAPITA PRIMARY ENERGY DEMAND

Energy intensity (toe per GDP US$ million in constant 2000 dollars) for the APEC region is expected to decline significantly over the outlook period, indicating a less energy-intensive future (Figure 2).

Factors affecting the level of energy intensity include income level, industry structure, technology, energy prices and climatic conditions. There are wide disparities in energy intensity between economies in addition to changes in the trends historically. While energy intensity generally declines over time, this was not the case for seven APEC economies over the period 1980 to 2002. The energy intensity of these seven economies' – Indonesia, Malaysia, Papua-New Guinea, Philippines, Korea, New Zealand and Russia – has increased mainly due to the development of heavy industry, and partly, by ineffective management of existing industrial capacities and their underperformance. However, all APEC member economies are projected to improve their energy intensity over the outlook period.

Russia and China are expected to show the highest rate of energy intensity improvement at 3.0 and 2.5 percent per year respectively. Overall improvement in these economies will be largely driven by high economic growth, industrial retrofitting and introduction of advanced energy-efficient technologies. The US, Japan and Korea are also expected to exhibit annual energy intensity improvement of between one and three percent, and combined with China and Russia these five economies will account for more then 80 percent of APEC's industrial value added in 2030. As a result, energy intensity improvement in the whole APEC region will decline at 2.0 percent per year over the outlook period, compared with the 1.7 percent per year rate observed from 1980 to 2002.

Figure 2 Primary Energy Intensity (1980-2030)

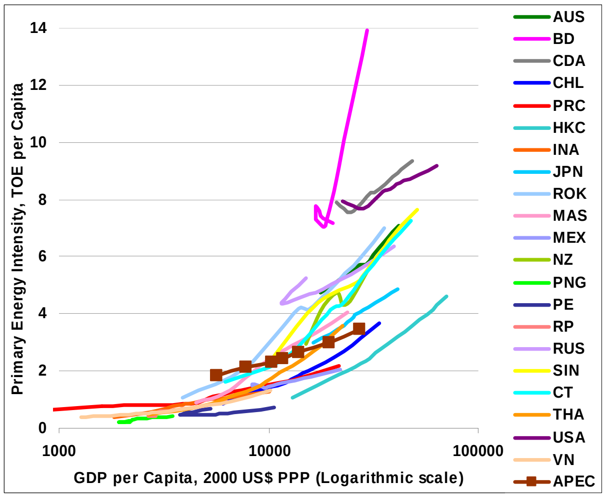


Source: APERC Analysis (2006)

Per capita primary energy demand in the APEC region is expected to increase from 2.3 toe in 2002 to 3.4 toe in 2030, equivalent to an annual rate of 1.5 percent. However, despite this robust growth there will be a wide range in demand among individual member economies in 2030 from 0.4 toe in Papua New Guinea to 9.4 toe in Canada (Figure 3). On the other hand, the per capita energy consumption of Brunei Darussalam has almost halved since 1980 as population has grown significantly while industrial activity has not shown much change. In 2030, Papua New Guinea, Peru, Philippines, Indonesia and Viet Nam are projected to have energy demand of less then one toe per capita, while Canada, the US, Singapore, Taiwan, Brunei Darussalam, Australia and Korea are expected to encompass demand of more then seven toe per capita.

The general trend observed is that economy's with higher per capita energy demand tend to exhibit slower growth over the long-term. The exemptions to this observation are Chinese Taipei and Korea which already had per capita consumption levels compatible to Japan (4 toe) in 2002, and are projected to increase to 7 toe (compatible to Australia) in 2030 at annual growth rate 2.0 percent and 1.9 percent, respectively. Singapore is very close to Australia in terms of per capita energy consumption, however it is going to over pace it at 1.5 percent annual growth rate comparative to Australia's 0.8 percent. In comparison, for the US and Japan per capita energy demand is expected to grow at 0.4 percent, and 0.8 percent, respectively.

Figure 3 APEC Primary Energy Demand per Capita vs. GDP per Capita (1980-2030)



Source: APERC Analysis (2006)

ENERGY DIVERSITY

The energy diversity indicator (that assesses the distribution of energy sources in the primary energy mix for each economy in range from 1 to 100 points) for the APEC region as a whole will change slightly from 89 to 87 during the outlook period (Table 2). The least diversified economies are Papua New-Guinea, Brunei Darussalam and Singapore with energy diversity indicators of at 44, 45 and 47 points respectively in 2030. Historically, Hong Kong, China has improved it's energy diversity since 1980 from almost full dependency on oil (resulted in just one point's value for this indicator) to high diversity at 70 points in 2002, by introducing coal and natural gas to the primary energy's mix. For three of the four economies noted above high dependency on one energy type – greater than 80 percents – was observed, with this phenomena being primarily explained by the small geographical scale of the economy, low domestic crude oil prices and therefore low petroleum product prices. For example, in case of Brunei Darussalam low energy diversity is explained by huge domestic natural gas resources that can be cheaply utilised within the economy.

While APEC has a high level of energy diversity (89 points in 2002), the net energy import ratio of the region was 10 percent, with the net oil import dependency of 36 percent in 2002. Securing future oil and natural gas supply through enhanced exploration and development activities within the region and enhancing external co-operation is of great importance.

Table 2 Energy Diversity Indicator, (points 1-100)

Economy	1980	2002	2030
Australia	73	76	81
BD	14	33	45
Canada	81	89	83
Chile	69	78	81
China	68	68	65
HKC	1	70	67
Indonesia	62	84	86
Japan	53	78	86
Korea	50	74	89
Malaysia	50	63	77
Mexico	51	65	70
NZ	74	82	74
PNG	7	30	44
Peru	55	58	75
Philippines	55	74	82
Russia	78	71	77
Singapore	1	28	47
CT	47	75	80
Thailand	56	78	83
USA	80	84	84
Viet Nam	36	64	92
APEC	**83**	**89**	**87**

Source: APERC Analysis (2006)

Canada, China, Hong Kong, China and New Zealand are the only economies expected to reduce their energy diversification over the outlook period. The underlying reasons for this occurrence are:

a) rising share of natural gas and oil at the expense of coal and nuclear in Canada;

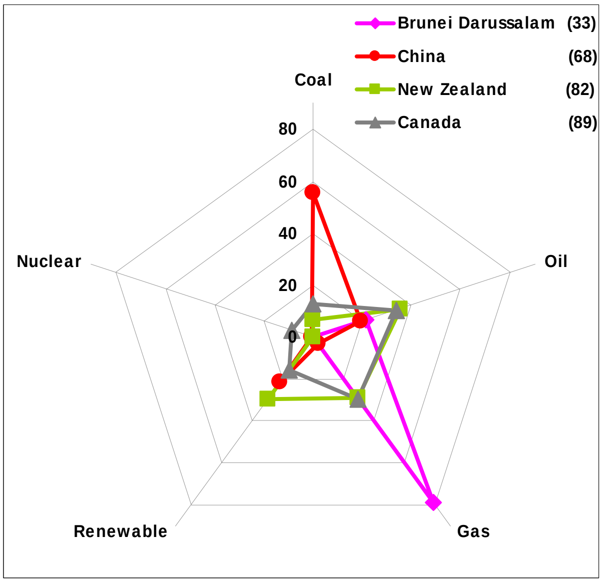
b) shrinking share of renewable energy in China and coal in Hong Kong, China;

c) rising share of renewable energy at the expense of natural gas in New Zealand.

More then half of all APEC economies will have in 2030 energy diversity indicators higher then 80 points. Viet Nam, Korea, Japan and Indonesia will head list with 92, 89, 86 and 86 points respectively.

The energy diversity indicator pattern by fuel for four selected APEC economies in 2002 is presented in Figure 4. Interpretation of this Figure shows a high dependency on natural gas for Brunei Darussalam and coal for China, which results in the lower energy diversity indicator for these economies. Whereas a more balanced energy supply as shown for New Zealand and Canada leads to much higher values for the energy diversity indicator.

Figure 4 Energy Diversity Indicator for Selected APEC Economies in 2002

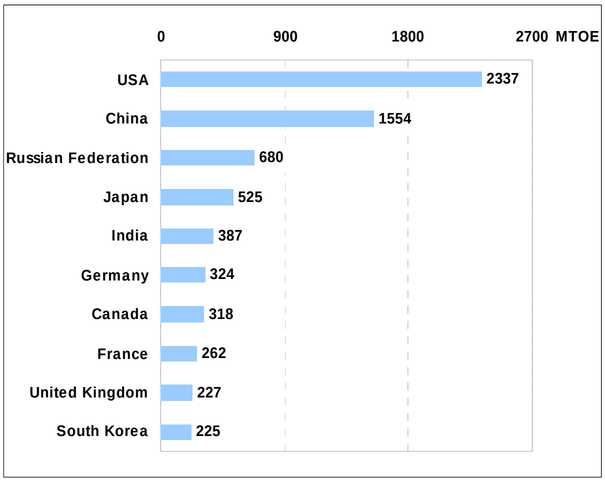


Source: APERC Analysis (2006)

ENERGY IMPORT DEPENDENCY

The APEC region is host to the top four energy consumers in the world, namely the US, China, Russia and Japan, which together account for about 48 percent of the world's primary energy demand (Figure 5).

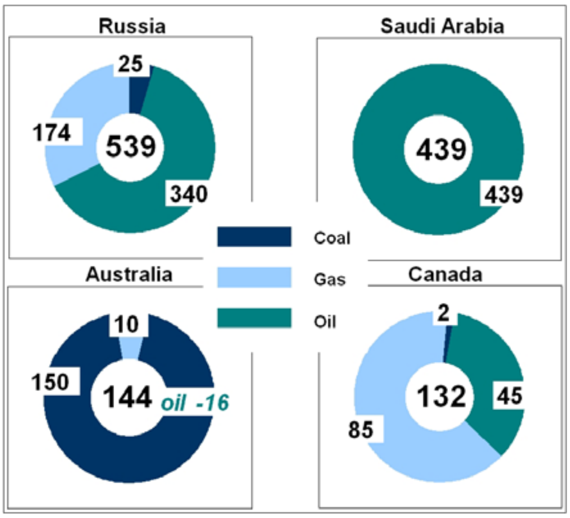
Figure 5 World's Top Ten Energy Consumers in 2005 (Mtoe)



Source: BP (2006)

APEC is also host to three of the world's four largest energy exporters – Russia, Australia and Canada, – and currently is a net exporter of natural gas and coal.

Figure 6 World's Four Largest Energy Exporters in 2005 (Mtoe)



Source: BP (2006)

Over the outlook period the energy **import dependence** of most APEC member economies is expected to increase. The only economies which are expected to increase their net energy ***export*** ratios are Australia, Papua New Guinea, and Brunei Darussalam. Current energy exporters Russia, Canada, Mexico and especially Indonesia are projected to decrease their export to domestic energy demand ratio, with Mexico and Indonesia approaching a net energy trade balance close to zero by 2030. Furthermore, Malaysia and Viet Nam are expected to swing from net energy exporters to importers, while China is expected to become one of the world's major energy importers, increasing from a net energy balance of zero percent in 2002 to an import dependency of 18 percent in 2030.

The status of import dependency (the ratio of net imported primary energy to total primary energy demand, with nuclear considered as a domestic energy source) for all APEC member economies is shown in Table 3. Only seven economies (Australia, Brunei Darussalam, Canada, Indonesia, Mexico, Papua New Guinea and Russia) will remain net exporters, while China, Malaysia and Viet Nam will switch from a net energy export to net import position over the outlook period.

Table 3 Net Energy Import Dependency of the APEC economies (%)

Economy	1980	2002	2030
Australia	-25	-121	-193
BD	-630	-668	-688
Canada	-6	-48	-33
Chile	41	63	84
China	-3	0	18
HKC	99	100	100
Indonesia	-120	-55	*negl.*
Japan	88	82	78
Korea	77	84	77
Malaysia	-44	-57	32
Mexico	-50	-59	-9
NZ	43	19	27
PNG	96	-100	-120
Peru	-25	27	18
Philippines	54	51	68
Russia	-42	-72	-67
Singapore	100	97	99
CT	81	87	89
Thailand	52	53	81
USA	17	30	36
Viet Nam	8	-26	15

Note: negative values mean net export to domestic consumption rate

Source: APERC Analysis (2006)

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OIL

- *The share of transportation in total oil demand is projected to increase from 50 percent in 2002 to 57 percent in 2030 making transportation the leading sector for oil demand growth*
- *APEC oil import dependency is expected to rise from 36 percent in 2002 to 52 percent in 2030, with the increase in the Asian and Oceania sub region's projected to be even higher, increasing from 59 percent in 2002 to 75 percent in 2030.*
- *The share of non-conventional oil will increase over the outlook period as price signals and technological advances are increasingly tapped to utilise these huge resources.*

Security of oil supply is directly related to society's mobility and its ability to provide energy service even to the very remote and small consumers. **Transportation, agriculture, construction and military almost completely rely on petroleum products** supply, while the most convenient way to produce latter is crude oil refining and treating. More expensive **unconventional technologies** - oil sands, oil shale, and enhanced oil recovery **will account larger share** in oil supply in the future, as technology development and strong prices eventually will encourage tapping of this resource in tight competition environment for international oil companies.

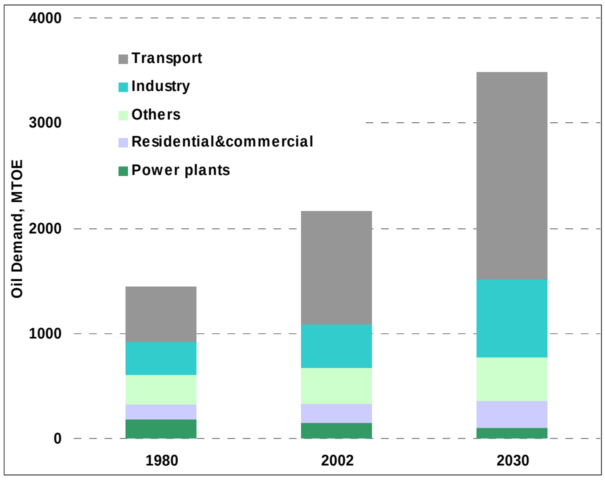
TRANSPORTATION TO LEAD OIL DEMAND GROWTH

Oil demand in APEC region is expected to increase from 2,165 Mtoe in 2002 to 3,488 Mtoe in 2030, at 1.7 percent annually. Oil demand patterns in the APEC region are shown on Figure 7, and transportation sector is expected to maintain principal position at 57 percent (1,973 Mtoe) in 2030, compared with 50 percent (1,077 Mtoe) in 2002 and 47 percent (591.2 Mtoe) in 1980. On the other hand oil shares almost 99 percent of the total fuel used for transport, and this share will not change radically up to the year 2030. Oil consumption in the industrial sector is projected to grow at an average annual rate of 2.1 percent and will maintain the second largest share of total oil demand at 25 percent. The share of the residential and commercial sectors in total oil demand will show a slight decrease over the outlook period – from 11 percent in 2002 to 8 percent in 2030 – as other energy sources are utilised in these sectors.

As mobility of society is expected to increase steadily in the future, and economic development will encourage global freight movement, transportation sector will grow robustly. Spurring demand for oil is the sharp increase in the number of the cargo ships, road vehicles and, more recently, the air transport. In APEC, the essential growth in road transport demand is to be expected over the outlook period, with the emergence of economies like China and Viet Nam. Some 4 million passenger vehicles are added every year in China and seven-fold increase of passenger vehicles in Viet Nam projected during the outlook period, show that a soaring in oil demand is foreseeable.

During the outlook period the APEC region is also expected to experience continuous growth in the air transport sub-sector. Greater global economic integration is likely to spur the growth in air passenger travel and cargo freight deliveries, which will translate into robust growth in aviation jet kerosene demand.

Figure 7 Oil demand patterns in APEC region (Mtoe)



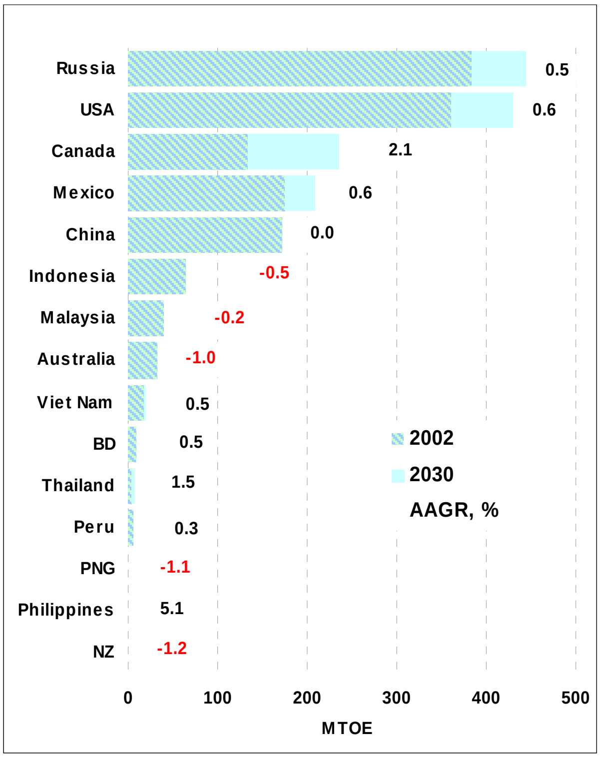
Source: APERC Analysis (2006)

OIL SUPPLY

The APEC region has five of the 10 largest crude oil producers in the world. However, the region also has five of the 10 largest crude oil consuming economies. Thus, while APEC produces around 42 percent of the world's oil supply, it also accounts for some 62 percent of world oil demand. In 2002, this imbalance resulted in the APEC region having an **oil import dependency of 36 percent, which is expected to rise to 52 percent by 2030**. Furthermore, while APEC oil demand is projected to increase by 61 percent between 2002 and 2030 at 1.7 percent annually, production over the same period is only expected to increase by 20 percent at an annual growth rate of 0.7 percent, further contributing to the expanding trade imbalance.

For the fifteen APEC economies in Asia and Oceania this supply and demand imbalance is even greater. Demand in this region is projected to increase by 60 percent between 2002 and 2030, while conversely production is expected to decrease by 5 percent, resulting in an overall **increase in the net import dependency of this sub-region from 59 percent in 2002 to 75 percent in 2030**.

Figure 8 Crude oil production in the APEC region (Mtoe)



Source: APERC Analysis (2006)

Three of the major APEC producers – Canada, the US and Russia – are projected to increase their crude oil production the most, while Australia, China, Indonesia, Malaysia, New Zealand and Papua-New Guinea may face oil production decline (Figure 8). Four APEC economies that are currently net oil exporters − Indonesia, Malaysia, Papua New Guinea and Viet Nam − may become net importers over the period 2020 to 2030. Already high reliance on imports is likely to increase substantially. Net imports of crude oil and oil products are projected to increase from 773 million tonnes in 2002 to 1,805 million tonnes in 2030, at growth rate of 3.1 percent per annum. At the end of the outlook period only four net oil exporters will remain in the APEC region, namely Brunei Darussalam, Canada, Mexico and Russia (Table 4).

The **structure of the resource base** (i.e., geological information of oil-bearing deposits quality and stratification) has a significant impact on oil supply patterns. Exploration and technological development (enhanced oil recovery, synthetic crude production from bitumen and oil shale's, oceanic deep water and Arctic oil fields, *etc.*) are increasing oil reserves greatly. In addition high oil prices will encourage exploration of undiscovered resources and their transition to proved reserves for hard-to-develop and non-conventional oil deposits.

Table 4 Net Oil Trade Position for the APEC Economies, Mtoe

Economy	2002	2030	AAGR, %
Australia	8.6	34.6	5.1%
BD	-9.2	-10.1	0.3%
Canada	-45.1	-111.2	3.3%
Chile	10.4	33.1	4.2%
China	48.6	470.1	8.4%
HKC	8.1	19.7	3.2%
Indonesia	-1.5	81.3	
Japan	254.4	247.7	-0.1%
Korea	106.4	135.6	0.9%
Malaysia	-14.1	17.6	
Mexico	-92.0	-70.9	-0.9%
NZ	5.3	9.3	2.0%
PNG	-1.4	0.9	
Peru	2.8	7.6	3.6%
Philippines	16.2	44.5	3.7%
Russia	-263.7	-294.0	0.4%
Singapore	17.7	31.3	2.1%
CT	42.4	69.5	1.8%
Thailand	31.4	96.6	4.1%
USA	655.6	965.1	1.4%
Viet Nam	-7.6	26.6	
APEC	**773**	**1 805**	**3.1%**

Note: (Net) Oil Imports (>0) and (Net) Exports (<0)

Source: APERC Analysis (2006)

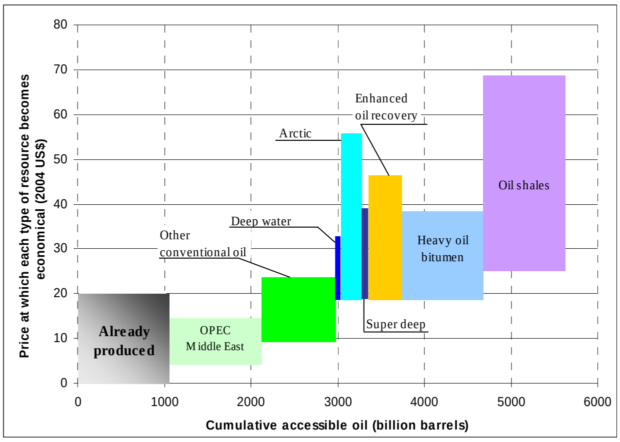
There are different assessments for global oil resources due to uncertainty, classification and accounting problems. The latest USGS Survey 2000[1] stated that **total remaining world conventional oil resources are more then 2.1 trillion barrels.**[2] It is assumed that unexplored petroleum provinces, such as East Siberia and Antarctica could still contain huge and yet undiscovered oil resources. In addition, the World Energy Congress estimates there are **2.6 trillion barrels of natural bitumen, 3.3 trillion barrels of oil shale, and 2.1 trillion barrels of extra-heavy oil** worldwide. "Clearly, many more deposits for natural bitumen and shale oil are

[1] USGS (2000)

[2] This is a low estimate, as this survey did not consider all terrestrial land mass, ocean deepwater, or unconventional heavy oil, tar accumulations, and oil shale.

identified but no resource estimate is possible." [3] While oil shale resources have been reported in some economies, they along with many other types of unconventional resources remain unreported in other economies. Therefore in most instances only conservative estimations for non-conventional oil reserves have been made due to insufficient data availability. It is important to note that non-conventional oil resources as a rule are more expensive to develop than conventional ones, as shown in Figure 9 prepared by International Energy Agency in 2004 for the supply potential as a function of the economic cost of extraction.

Figure 9 Availability of Oil Resources as a Function of Economic Price, 2004



Source: IEA (2005)

While a time lag exists between global oil market signals and supply response, the dynamic equilibrium between supply and demand also gives rise to substitution of other materials when scarcity looms (or the price is artificially elevated). For example, in 1973 as a result of the sudden four-fold increase in the price of oil, followed by a four month long oil embargo, several things happened at both the producer and consumer levels. The producers increased their exploration efforts, and implemented new techniques to boost oil recovery from previously "exhausted" or uneconomic wells and fields, which resulted in a dramatic increase in oil resources. Similar techniques have been used by North Sea producers in 1995, when fields that had originally been deemed too small to be produced economically, but due to a combination of ongoing infrastructure development (easier pipeline access) and improvements in technology (sub sea templates), have become viable. [4] Thus it follows that technological advances in extracting non-conventional oil combined with high oil prices will significantly enhance the share of synthetic crude produced in Canada's Alberta province. More expensive enhanced oil recovery and production of unconventional resources – oil sands, and oil shale – are thus expected to garner a greater share of future oil supply. **Increasing supply from non-conventional oil** resources will greatly affect the upstream and downstream oil industries because the new technologies implemented will influence the quality of oil produced, which in turn will have an impact on the configuration of oil refineries.

Oil Refining Capacity Growth Requirement

The refining capacity of the APEC region was 43.75 million B/D in 2002, which is approximately 50 percent of the world refining capacity. However, for APEC to meet the demand for oil products over the outlook period, an **additional 26.6 million B/D of capacity will need to be constructed**. In some economies "grassroots" refinery construction is seldom approved due to intense public opposition and therefore capacity addition is most likely to occur through expansion of existing facilities. In addition, for many economies, it is more economic to import a portion of petroleum products from the international market rather than construct additional refining capacity within the economy.

In addition to distillation capacity increases, there must be a **considerable increase in the upgrading capacity** to enhance the production of gasoline and middle distillates to meet demand in the transportation sector. At present Asian refineries are relatively poorly equipped in terms of upgrading capacity. In 2003, the cracking to distillation capacity ratio for the major Asian economies was 11 percent for Korea, 13 percent for Singapore, and 22 percent for both Japan and China, which is quite low in contrast to the 43 percent for the US. The decline in light sweet crude oil production in China and Southeast Asian economies and the resulting increase in dependence on heavy sour crude oils from the Middle East has motivated the refiners in these economies (except Singapore) to expand/ construct upgrading facilities to take advantage of the widening price spread between light and heavy crude oils.

The **introduction of stricter environmental regulations and fuel standards** in most APEC economies over the outlook period is likely to **precipitate expansion of hydro-treatment capacity** For example, in Japan with the introduction of "zero sulphur" (less than 10 ppm) gasoline from 2005, the hydro-treating to distillation ratio of the economy topped 92 percent.

[3] WEC (2004)

[4] Lynch (1997, 2005)

IMPLICATIONS

Lower rates of the region's oil production to demand lead to accelerated rate of oil import in the APEC region. High exposure of transportation energy demand to oil supply security and price volatility combined with high import ratio will facilitate introduction of improved efficiency standards for mobile vehicles, stimulate exploration and development for both conventional and non-conventional oil, alternative motor fuels production, and encourage government's efforts to secure oil supply.

Refining industry will become more complicated to process heavier oil and produce higher yield of environmentally friendly motor fuels.

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COAL

- *APEC's coal demand is expected to more than double from 1,570 Mtoe in 2002 to 3,366 Mtoe in 2030, growing at an annual rate of 2.8 percent – the fastest annual growth rate among fossil fuels.*
- *Coal is about to tread a stellar path as the fuel for the 21st century mainly due to its price advantage.*
- *Coal resources are also under pressure from depletion, thus production and transportation costs have been steadily increasing.*
- *A regional temporary coal supply shortage is not unforeseeable in particular in Northeast Asia as Indonesia and China's coal export capacities are starting to decline.*

Historically coal has been known to cause lots of problems. It was not until the 1970's that public sentiment turned against the large scale use of coal on a global scale and coal was denounced as the "dirty energy". Serious environmental problems associated with its extensive use were brought to the attention of the international community for the first time. The UN Framework Convention on Climate Change and the subsequent Kyoto Protocol were the culmination of numerous international meetings of policymakers on energy induced global warming from fossil fuel use in general, steering the world clear of coal burning as much as financially possible. It was seen that the Protocol and coal were as compatible as are good and the evil.

The social and environmental stigma attached to coal was created and sustained throughout the last three decades of the 20th century in spite of the advent of clean coal technology (CCT), which was still regarded unclean.

It may be serendipitous that world oil prices hovered around historically low levels at the time that these treaties were signed, adopted, ratified, and finally entered into force. During this period between 1986 and 2003 it was obvious that the world had grown blatantly complacent about the long-term availability of cheap energy sources including oil and natural gas. Added to this complacency was the overblown confidence in the role of new technologies and alternative energy sources overlaid the world energy future with a seemingly unrealistic CO_2 constrained one, whereby a lot less carbon intensive energy, ie coal, would be consumed.

Coal is now at the critical juncture for its future expansion. Provided the inherently "unclean" nature of coal is technologically resolved, coal could enter a new period of glory.

RENEWED INTEREST IN COAL

Coal consumption is for either coking or thermal use. The share of thermal coal is roughly 66 percent, almost twice as much as that of coking coal. Facing escalating oil and gas prices, the electricity sector, the major consumer of thermal coal is diligently looking for a feedstock fuel with a certain degree of long-term stability in both price and volume. Electricity generators now find coal more attractive than ever because of the widening price gap between coal and its alternatives, i.e., natural gas and residual oil.

Unlike oil or natural gas, coal can be found almost everywhere in the world, in other words supply sources are evenly distributed, preventing the formation of collective action/oligopolies by the producers. Besides coal resources are a lot larger in volume than oil and natural gas such that the resource/production ratio is currently estimated at around 200 years according to BP statistics. As a matter of fact, coal has been the major fuel for the world so far and is likely to be so for a long time yet to come.

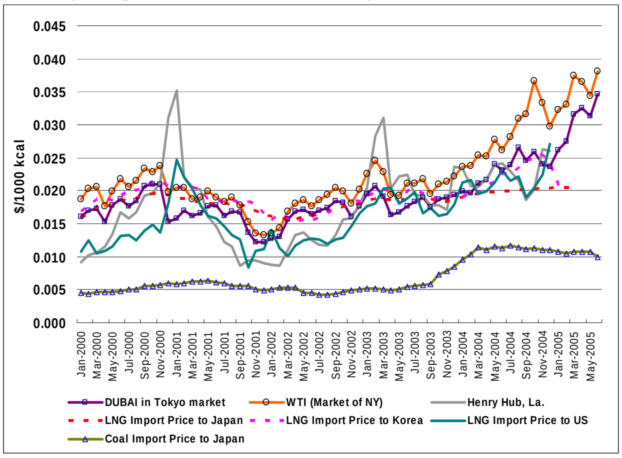
It was, however, in the 1970's when environmental awareness triggered a rather long-term shift away from coal and towards oil and natural gas. With the technological progress in LNG a number of economies implemented energy policies aimed at gradually displacing coal with natural gas and to a limited extent with new and renewables such as solar and wind. Switching to LNG turned out to be very successful and natural gas made major inroads into the electricity markets in many economies taking up a sizable share of primary energy supply. Even through to the beginning of 2005, this trend seems to be advancing robustly.

Faced with the surge in the short-term cargo price and the perceived supply shortage for the next several years LNG markets are expected to run out of steam. A couple of major LNG importing economies including the US have revised their outlook for LNG downwards reflecting the present market perception.

Once viewed as the "black sheep" of the energy family, coal is about to tread a stellar path as the fuel of choice for the 21st century mainly due to its price advantage. There are a few reasons that could well account for the recent reposition of energy policies towards coal, among which are the low relative price, the long-term price stability, the availability of supply infrastructure, and advance in clean coal technology and CO_2 capture and storage technologies.

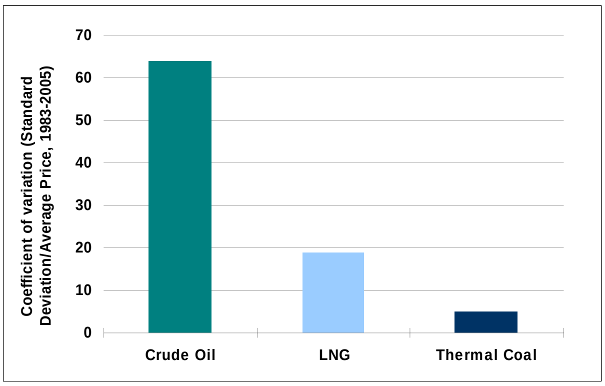
The coal price has been low relative to oil and natural gas for the last four decades because the coal price does not move in parallel with oil prices even at the time of the previous oil crises. Eventually the coal price was decoupled from oil prices around the end of the 1970's and stayed relatively low until 2004, when unexpectedly high oil prices prompted inter-fuel substitution in electricity generation sparked Australian coal prices to reach record high levels of $60/ton. While oil prices are still around $70/bbl, coal price have came down to $45/ton in recent months. It seems that the spikes in the price of coal between the last quarter of 2003 and the first quarter of 2006 were a temporary market response to higher demand rather than a fundamental shift in the market as they were relatively short-lived (Figure 10).

Figure 10 Monthly Trends in Coal, Oil and Natural Gas Prices (US$ per 1,000 kcal, 2000-2005)



Source: APERC Analysis (2006)

Figure 11 Comparison of coefficient of variation



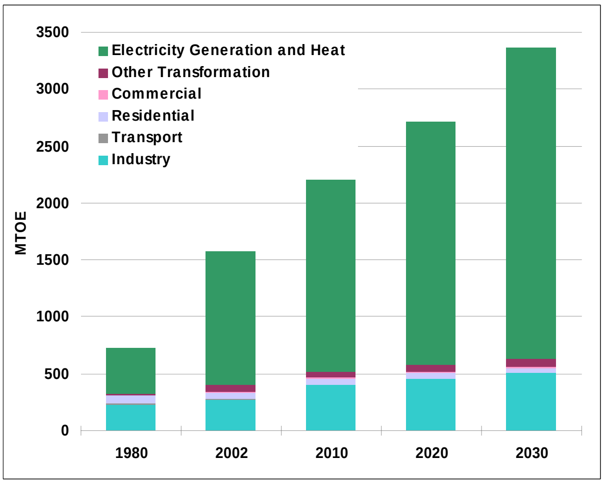
Source: Mimuroto (2006)

The low price volatility measured as the standard deviation from the historical mean for coal has also been low. Between 1983 and 2005, the coefficients of variation for crude oil, LNG and thermal coal were 64, 19, and 5 (Figure 11). From the pure economical point of view, it is not difficult to pick coal as the winner.

COAL DEMAND OUTLOOK

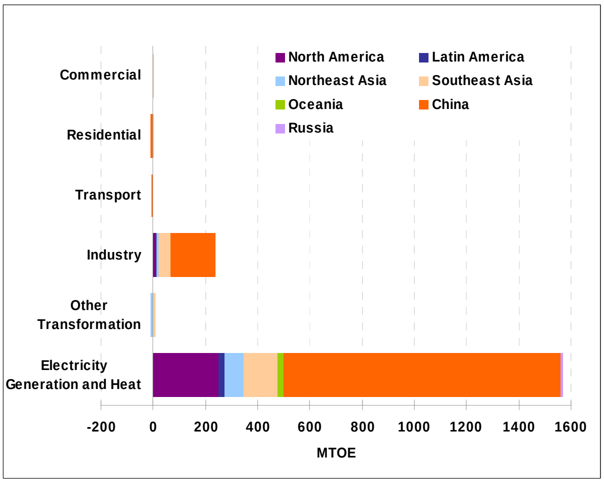
APEC's coal demand is expected to more than double from 1,570 Mtoe in 2002 to 3,366 Mtoe in 2030, growing at an annual rate of 2.8 percent. The projected growth rate of coal demand through 2030 is the fastest among the fossil fuels. In the near-term, stable supply as well as low prices are the key factors likely to attribute to the faster coal demand growth. In the long-term, technological development to minimise the impact on both the local and global environment will boost the demand for coal in electricity generation.

Figure 12 Coal Demand by Sector (1980 – 2030)



Source: APERC Analysis (2006)

Figure 13 Incremental Growth in Coal by Region (2002 – 2030)



Source: APERC Analysis (2006)

By sector, the electricity sector is projected to continue to lead coal demand growth. Over the outlook period, coal demand in the electricity sector is projected to grow at an annual rate of 3.1 percent, followed by the industry sector at 2.3 percent. With this robust growth, the share of coal in the electricity sector as a percentage of total coal demand is projected to increase from 74 percent in 2002 to 81 percent in 2030.

Near-term growth in coal demand is projected to be faster than that of the long-term. By 2010, coal demand is expected to grow at a robust pace of 4.4 percent pear year driven mainly by China's rapid economic development. China's projected GDP growth rate of 7.7 percent per year between 2002 and 2010, will translate into massive coal requirements to generate electricity, operate industrial facilities and produce cement and steel. In fact it is expected that China will account for about 80 percent of APEC's coal demand growth between 2002 and 2010.

Table 5 Coal Demand by Economy (Mtoe)

Economy	1980	2002	2030	1980-2002 (%)	2002-2030 (%)
Australia	27.3	46.9	66.2	2.5	1.2
BD					
Canada	21.2	33.8	24.3	2.1	-1.2
Chile	1.2	2.8	11.9	3.9	5.3
China	312.6	618.7	1833.9	3.2	4.0
HKC		4.8	7.7		1.7
Indonesia	0.2	18.7	68.3	22.9	4.7
Japan	59.6	95.4	107.6	2.2	0.4
Korea	13.5	34.5	62.8	4.4	2.2
Malaysia	0.04	2.5	33.7	20.7	9.7
Mexico	2.4	7.9	25.0	5.6	4.2
NZ	1.0	1.2	2.7	0.8	2.9
PNG					
Peru	0.1	0.6	2.1	8.5	4.6
Philippines	0.4	7.1	30.0	14.0	5.3
Russia		106.1	117.4		0.4
Singapore					
CT	3.9	32.4	65.0	10.1	2.5
Thailand	0.5	9.8	64.6	14.5	7.0
USA	376.2	541.2	807.9	1.7	1.4
Viet Nam	2.3	5.5	35.1	4.0	6.8
APEC	**822.3**	**1,570**	**3,366**	**3.0**	**2.8**

Source: APERC Analysis (2006)

Aside from China, economies like Thailand and Malaysia are projected to increase their demand for coal to diversify feedstock fuels for electricity generation. With further technological innovation in sequestration of CO_2 emissions from electricity generation and expected increase in production, the US coal demand is projected to increase faster in the long-term than in the near-term. Between 2002 and 2015, US coal demand is projected to grow at 0.9 percent per year, while between 2015 and 2030 growth is expected to be faster at a rate of 1.9 percent per year.

COAL SUPPLY ISSUES

The investment requirements for infrastructure expansion of coal are generally the lowest of conventional energy types, such that switching to coal can be done without much financial difficulty. As opposed to liquid fuels like oil and natural gas, coal can be transported by using existing railroads, roads, ports, and maritime bulk carriers. Similarly the distribution and storage of coal does not require sophisticated and expensive technologies. Therefore the scale of investment necessary for coal is a lot lower than that of oil or natural gas and coal supply could be expanded with little financial burden in comparison to coal's main rival LNG that requires a substantial amount of initial investment in liquefaction, re-gasification, and storage facilities.

The combination of various negative externalities from coal burning, which ranges from haze, detrimental health effects to worries over the possible consequences of global climate change from CO_2 emissions led to the Kyoto Protocol in 1997, which was expected to place limitations on the amount of future coal consumption for many economies

In recent years technological advance in CCT demonstrates that major environmental problems that arise from coal burning can be effectively dealt with. According to a JPOWER report (2004), current CCT technology can reduce emissions of SO_X, NO_X, and soot particulates by 90% compared to CCT technology utilised in the early 1980's. It is a remarkable achievement that some heavy users of coal including the US have announced plans to adopt advanced CCT in the near future. To illustrate, the US president's 2005 Clean Skies legislation called for a 90% reduction in power plant emissions of SO_X, NO_X and mercury in the next 15 years. In addition, the US announced a $1 billion, 10-year demonstration project to create the world's first coal-based, zero-emissions electricity and hydrogen power plant under the FutureGen Initiative.[5]

With the pace of technological progress in CCT and FutureGen, coal could easily pass the public acceptance test before long. We should not be surprised to witness a major comeback of coal as the reliable and sustainable fuel for the 21st century especially in Northeast Asia, where coal endowments are relatively large.

[5] Korea expressed its intention to join the projects at the informal US-Korea energy dialogue in April 2006

IMPLICATIONS

Coal has huge a potential to provide energy in the future, but this is not without challenges.

Coal resources are also under pressure from depletion and production and transportation costs have been steadily increasing. A temporary regional coal supply shortage is foreseeable, in particular in Northeast Asia as Indonesia and China's coal export capacities are starting to decline. Although coal consumption is expected to rise, it should be noted that while coal is one of the solutions, coal is not "the" solution to our energy and environment problems.

As for Northeast Asian economies, their coal consumption levels are already high, such that large scale investment in upstream exploration and development to ensure stable supply, as well as the introduction of CCT and perhaps FutureGen technologies to limit coal induced environmental problems seems inevitable, in the face of rising demand. In 2000, Japan and Korea collectively accounted for 55.2% of total world coal imports.

The new coal question is how we can ensure that coal provides energy security and sustainable development in the future until a set of technological breakthroughs that takes mankind away from depleting fossils fuels and opens the page to a new energy future. Until this time the rapid globalisation of coal trade has to be encouraged rather than banned.

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NATURAL GAS

- *APEC's natural gas demand is projected to grow at 1.8 percent per year – a slower rate than history. Despite the relative slow growth, natural gas will play an important role to meet the rising demand of APEC with the environmental advantages.*
- *With the slow growth in natural gas production relative to demand growth, APEC as a whole will become a net importer of natural gas by 2015.*
- *LNG import in APEC is expected to increase from 101 million tonnes in 2004 to 389 million tonnes in 2030.*

With the ease-of-use factor and environmental advantages, natural gas consumption in the APEC region has been growing robustly. From 1980 to 2002, natural gas consumption grew at an annual rate of 3.4 percent – a faster rate than the average annual growth rate of primary energy consumption at 2.6 percent. Cost reduction in natural gas supply – from production to end-user – has further spurred growth in the use of natural gas. Concerns with respect to the global environment and worsening local air quality have prompted energy industries to increase natural gas consumption.

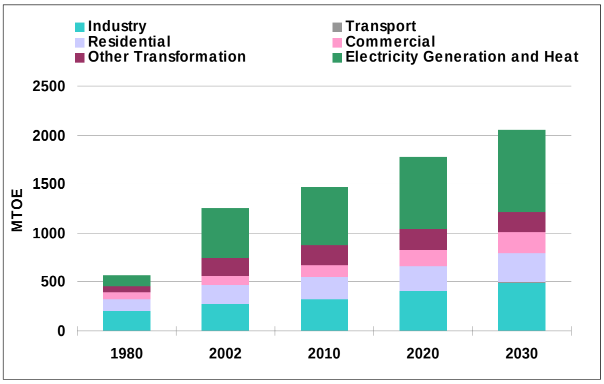
There is no doubt that natural gas has the potential to play a vital role in meeting APEC's rising energy demand. Nevertheless a number of challenges have to be overcome before we see further penetration of natural gas in the market. In electricity generation – the largest natural gas consumer – natural gas has to compete with coal, nuclear, and new and renewables, in terms of cost and stability of supply, especially in deregulated markets. In addition, an increasing amount of natural gas demand in APEC would have to be met by imports from both within and outside of the region. This means that APEC economies will face challenges on where to and how to secure long-term natural gas supply amid a rapidly changing as well as competitive market environment.

NATURAL GAS DEMAND OUTLOOK

Over the outlook period, natural gas demand is expected to increase from 1,255 Mtoe in 2002 to 2,050 Mtoe in 2030, growing at an annual rate of 1.8 percent. The projected growth rate is slower than that of the past two decades at 3.4 percent, reflecting some economies' shift in the choice of fuel for electricity generation. Due to the rise in natural gas prices and decline in domestic production, the power generators of several APEC member economies are projected to increase the use coal rather than natural gas. For example, Thailand and Malaysia have both been relying on natural gas for more than 70 percent of total electricity generation in the early 2000s; however the share of natural gas in electricity generation is expected to decline to 45 percent and 57 percent respectively in 2030. Similarly, in the US the share of natural gas in electricity generation is expected to decline from 18 percent in 2002 to 14 percent in 2030, in contrast, the share of coal in the generation mix is expected to increase from 50 percent in 2002 to 58 percent in 2030.

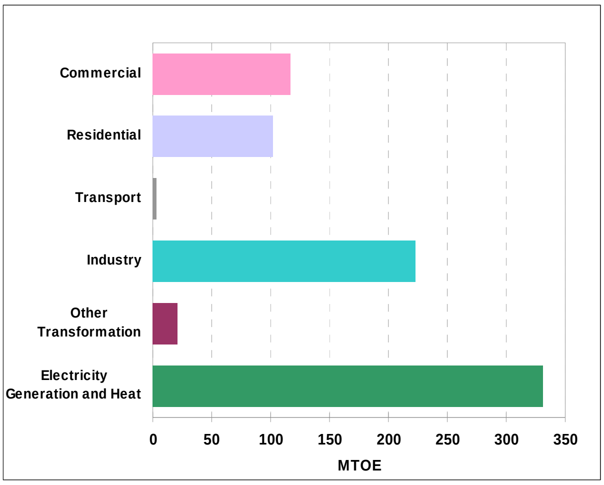
Despite a slower projected growth rate than historically, the electricity sector is expected to continue to be leading sector for natural gas demand growth. The electricity sector will account for 42 percent of total natural gas demand growth between 2002 and 2030, followed by the industry sector (28 percent), the commercial sector (15 percent), the residential sector (13 percent) and others.

Figure 14 Natural Gas Demand by Sector (1980 – 2030)



Source: APERC Analysis (2006)

Figure 15 Incremental Growth in Natural Gas (2002 – 2030)



Source: APERC Analysis (2006)

By economy, the projected growth rate of natural gas demand varies considerably (Table 4). In rapidly growing/developing economies such as China, Peru and Viet Nam, natural gas demand is expected to grow robustly at an annual rate in excess of 7.0 percent per year. For those economies at an early stage of development, natural gas has been a "premium fuel" compared with coal, hydro and biomass, that is, more expensive than other fuels; therefore the share of natural gas in total energy consumption remained low at around 3-5 percent in 2002. In addition, the large-scale capital investment requirements from upstream, midstream to the downstream have been a bottleneck to the market penetration of natural gas. Over the outlook period, driven by the steady economic development, these economies will strengthen their infrastructure to deliver natural gas to end users, thereby widening the customer base across all sectors.

Table 6 Natural Gas Demand by Economy (Mtoe)

Economy	1980	2002	2030	1980-2002 (%)	2002-2030 (%)
Australia	7.5	18.2	40.1	4.1	2.9
BD	2.46	2.02	2.23	-0.9	0.3
Canada	45.6	77.7	124.8	2.5	1.7
Chile	0.7	3.8	18.8	7.8	5.9
China	12.0	33.0	240.8	4.7	7.4
HKC		2.5	8.0		4.3
Indonesia	4.9	39.7	86.7	9.9	2.8
Japan	21.4	69.5	100.9	5.5	1.3
Korea		27.4	72.9		3.6
Malaysia	2.0	24.7	54.4	12.1	2.9
Mexico	19.1	35.7	89.5	2.9	3.3
NZ	0.8	5.4	3.3	9.2	-1.8
PNG		0.1	0.4		5.0
Peru	0.4	0.5	6.8	0.5	9.8
Philippines		1.8	11.8		7.0
Russia		364	386		0.4
Singapore		3.1	14.7		5.8
CT	1.6	7.4	25.2	7.2	4.5
Thailand		18.8	65.0		4.5
USA	477	535	681	0.5	0.9
Viet Nam		2.3	16.7		7.3
APEC	**595**	**1255**	**2050**	**3.4**	**1.8**

Source: APERC Analysis (2006)

By contrast, the demand for natural gas is not expected to grow rapidly in those economies that already have high consumption levels. For example, US natural gas demand is expected to grow at an annual rate of 0.9 percent due to the slow demand growth for electricity generation resulting from sustained high gas prices. Likewise, Russia's natural gas demand is expected to grow slowly at an annual rate of 0.4 percent reflecting the efficiency improvement and efforts to diversify energy sources away from natural gas across all sectors.

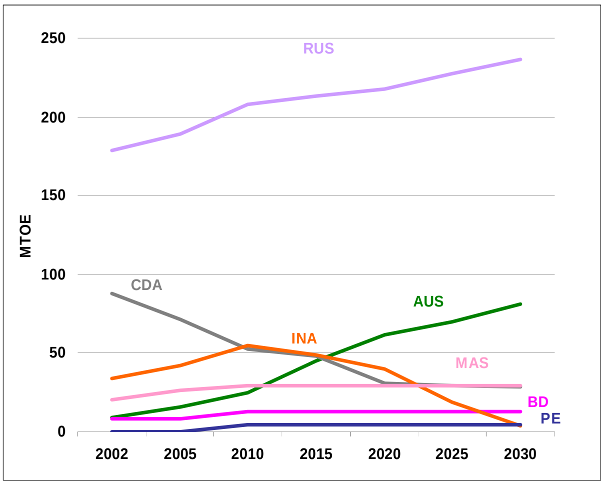
NATURAL GAS SUPPLY

Increased demand for natural gas is not likely to be met by increased production within APEC economies. Demand for natural gas is projected to grow at 1.8 percent per year, while the production of natural gas is projected to grow at 0.7 percent per year through 2030. With slow production growth relative to demand growth, APEC as a whole will become a net importer of natural gas by 2015 from the current net export position of –8 percent.

Several factors can explain why APEC will become a net exporter of natural gas. Currently APEC contains 6 net natural gas exporters including Australia, Brunei Darussalam, Canada, Indonesia, Malaysia, and Russia. Altogether these economies represented around 51 percent of global natural gas export volumes and 60 percent of the global LNG export volumes in 2003. With the exception of Australia and Russia, the other four net exporting natural gas economies will exhibit either a substantial decline or grow only modestly over the outlook period.

Natural gas export from Canada and Indonesia is expected to decline considerably. By 2030, Canada's natural gas exports are expected to drop by about 67 percent from the 2002 level as a result of declining domestic production combined with a rise in domestic natural gas demand, mainly for replacing Ontario's coal-fired electricity generation and for fuelling industrial demand. Likewise, Indonesia's natural gas export is expected to fall by 89 percent, due in part to dwindling natural gas reserves and rising domestic demand in the industry sector. Similarly, natural gas exports from Brunei Darussalam and Malaysia will not grow as quickly due mainly to the waning domestic natural gas reserves.

Figure 16 Natural Gas Export from the Major Producers in APEC (2002-2030)



Source: APERC Analysis (2006)

LNG

Over the outlook period, LNG is expected to become an important supply source to meet the demand increase. Given the projected decline in regional production and the only modest increase in natural gas exports, an increasing amount of natural gas in several economies is expected to be supplied from economies both within and outside of the region. Over long-distances exceeding 4,000 km, LNG becomes competitive relative to pipeline transport, therefore LNG has a big potential to fill the gap between increasing demand and declining supply.

Four APEC economies – Japan, Korea, Chinese Taipei and the US – buy natural gas in the form of LNG. In June 2006, China joined them with the economy's first LNG delivery arriving at the Guangdong receiving terminal.

In 2004, total LNG imports to Japan, Korea, Chinese Taipei and the US reached 100.7 million LNG tonnes or 77 percent of global LNG trade volume. Over the outlook period, as a result of expanded imports from existing importers combined with the addition of new importing economies, total LNG imports to APEC are expected to reach 389 million tonnes in 2030.

Table 7 LNG Import (Million Tonnes of LNG)

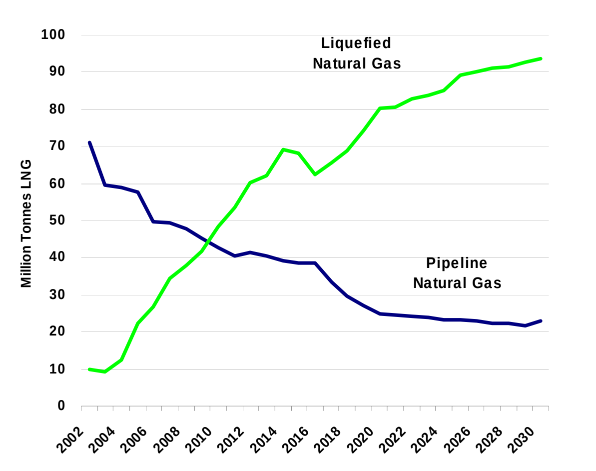
Economy	2004	2010	2020	2030
Northeast Asia				
China		6.6	26.2	52.0
Japan	57.0	60.7	74.1	81.2
Korea	22.3	35	48.4	58.7
CT	6.5	11	14.8	19.7
Southeast Asia				
Singapore		0.309	3.5	6.6
Philippines		0.929	0.929	0.929
North America				
Canada		7.8	25.8	31.8
USA	12.5	45.8	80.2	93.6
Latin America				
Chile		1.06	5.01	11.4
Mexico		14.3	26.2	33.2

Source: APERC Analysis (2006)

The Northeast Asian economies of Japan, Korea and Chinese Taipei are the biggest LNG importers in APEC as well as in the world. Due to the lack of domestic natural gas reserves, most of the economies' natural gas consumption is supplied through LNG. Over the outlook period, Northeast Asia's natural gas growth is expected to vary from economy to economy. It is expected that Japan's LNG imports will grow at a moderate rate of 1.3 percent per year, reflecting declining population and revival of nuclear and coal in electricity generation. Korea's LNG imports are expected to more than double between 2002 and 2030, to fuel the substantial growth in natural gas demand for the electricity and industry sectors.

Over the outlook period, the US is expected to expand LNG imports from 13.5 million tonne in 2004 to 93.6 million tonne in 2030. By sometime around 2015, US LNG imports are expected to surpass that of Japan and the US will become the biggest LNG importer in APEC and the world. In 2002, domestic natural gas production accounted for about 80 percent of total consumption, and pipeline natural gas from Canada accounted for about 90 percent of total imports. However, after 2010, LNG is expected to replace pipeline natural gas to become the primary source of imports, due in part to declining Canadian natural gas production in addition to the need to meet domestic natural gas demand growth.

Figure 17 Natural Gas Import to the US by Mode (Million Tonnes of LNG)



Source: APERC Analysis (2006)

Given the limited availability of natural gas reserves, China needs to rely on imports to meet natural gas demand growth. LNG imports are projected to increase from 3 million tonne in 2006 to 52.0 million tonne in 2030. However, near-term growth in LNG imports is expected to be slower than in the long-term due to the high LNG prices in the global market. By 2015, in addition to the Guangdong receiving terminal that started operation in late 2005, and the Fujiang receiving terminal planned to be operational in 2007, another one or two terminals are expected to start operation, receiving a combined total of around 15 million tonnes. By 2030, China's LNG imports have the potential to reach 52.0 million tonnes, which will account for 27 percent of total natural gas demand or 2 percent of primary energy demand in 2030. There are currently plans to build up to 15 LNG receiving terminals along the east coast under consideration.

To enhance natural gas supply security, Chile and Singapore plan to start importing LNG. In 2004, both economies experienced a loss in supply from their incumbent/neighbouring suppliers. In 2004, Chilean gas-fired power stations and methanol plants had to suspend operations because natural gas supply from Argentina – the exclusive natural gas supplier to Chile – was cut by half on some days. Similarly, Singapore was rattled by a natural gas supply disruption from Indonesia, which resulted in blackouts across the economy. These incidents drove Chile and Singapore to formulate a policy to develop LNG receiving terminals as LNG is considered to provide a strategic back-up in terms of supply diversification to augment existing pipeline gas supply from neighbouring economies.

IMPLICATIONS

Natural gas is expected to play a vital role to meet the APEC's rising energy demand.

To fill the gap between the increase in demand and decline in production, increasing number of APEC economies are expected to rely on natural gas import in a form of LNG. On top of existing major LNG importers, namely Japan, Korea, Chinese Taipei and USA, 6 APEC economies are expected to join them as LNG importers.

APEC economies will face challenges to secure LNG supply due to the distinctive features of the LNG industry. Because of the capital-intensive nature of the LNG project and the need to ensure stable supply, LNG will continue to be traded under long-term contracts. Nevertheless, securing long-term contracts will be an arduous process due to financial and technological challenges.

Recently, LNG supply costs are rising in parallel with the rise in material costs, shortage of engineering, unavailability of procurement and construction companies on large-scale LNG projects.[6] Also, balance between LNG demand and supply is expected to remain tight until 2010 when major supply projects from Australia, Qatar and Nigeria will start-up operations. This indicates that the difference between "proposed sales prices" and "purchase prices" will not narrow significantly in the near future.

Finding and developing natural gas reserves will become more difficult over time. In newly found fields, reserves are getting smaller, deeper, more remote and harder to reach. In other words, the execution out of future natural gas projects poses technological as well as financial challenges for developers.

Rising LNG imports may also increase the inter-dependence of economies both within and outside of APEC. Given the challenging environment for finding and developing natural gas and securing long-term supply, APEC governments have a catalytic role in terms of creating a framework through which upstream investment is ensured, and both suppliers and consumers make commitments for long-term contracts. The concerted efforts of APEC policy makers and energy industries, will lead to the enhancement of natural gas supply security and mutual prosperity.

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NUCLEAR

- *Demand for nuclear energy in electricity generation is expected to grow at 1.9 percent per year from 1,488 TWh in 2002 to 2,526 TWh in 2030; owed mainly to the growing concerns for energy supply security and activity to mitigate negative environmental effects of electricity generation.*
- *Perennial concern over safety and security will remain the major hindrances to public acceptance of nuclear energy.*
- *The development of new technologies will contribute to the expanded use of nuclear energy, and fertilize other hi-tech industries*

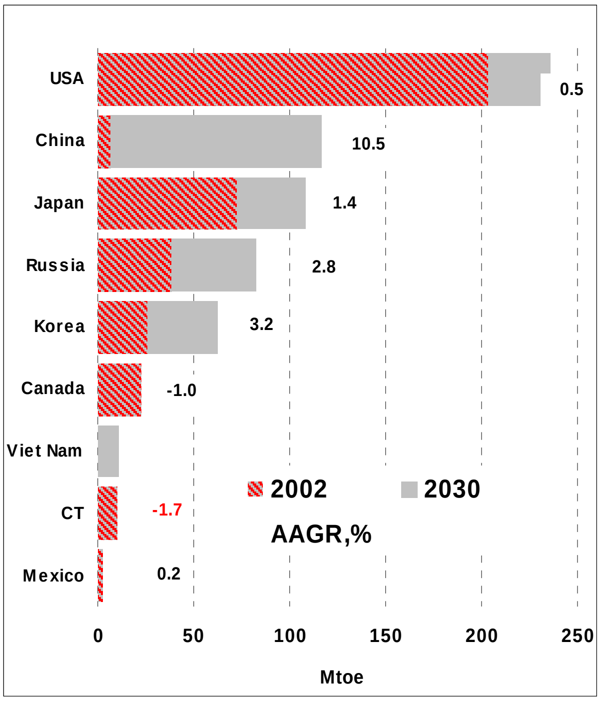
The economic advantages (low generation cost, reduced air pollutions, and low exposure to price volatility from the operation of nuclear energy) are likely to contribute to considerable growth of nuclear energy over the outlook period. This growth is expected to be predominantly centred in the traditional nuclear APEC economies with the addition of Viet Nam from Southeast Asia after 2015. However, the main impediment to nuclear expansion is low public acceptance of nuclear energy due to safety issues arising from the fuel handling and operation of nuclear power assets. To overcome this impediment enormous effort will need to be made by the scientific, business and governmental communities worldwide to develop advanced nuclear technologies that further strengthen operational safety and alleviate the public risk.

HISTORICAL TREND AND OUTLOOK PROJECTIONS

There has been renewed interest in nuclear energy worldwide, particularly in the APEC region. Over the past two decades, electricity generation from nuclear in the APEC region has grown at an average annual rate of 6.1 percent. In 2002 Korea and Japan were the leading users of nuclear energy, generating respectively 36 and 29 percent of total electricity from nuclear, followed by Chinese Taipei and the US each with a 20 percent share. However, unresolved issues and the perceived risks have remained a major barrier to the full deployment of nuclear industry within the APEC region. The nuclear industry is still fighting a legacy of fear in relation to radiation as a result of accidents, and the issues of waste disposal. Despite these perceived risks, nuclear is still considered a viable alternative from the viewpoint of supply security and low or near zero air pollutions. Supply security and low generation costs have made nuclear energy attractive in many APEC economies and offer a strong incentive to continue the operation. However, the economics of the nuclear fuel cycle may have negative impact on market competitiveness when all aspects of the nuclear supply chain, including fuel recycling and waste storage, are considered (see Box "Nuclear energy peculiarities").

The share of nuclear energy in total primary energy demand in APEC region is expected to remain stable at 6 percent between 2002 and 2030, while the share in electricity production will decline slightly from 16 percent in 2002 to 12 percent in 2030. In 2002, nuclear power plants accounted for 10 percent (204 GW) of total electricity generation capacity in the APEC region, and 16 percent of the electricity produced. With the exception of petroleum-based generation, nuclear generation capacity is expected to grow the slowest over the outlook period at 1.7 percent per year. Similarly, nuclear electricity generation is projected to grow the slowest at an annual rate of 1.9 percent. Nevertheless, electricity generation from nuclear power will increase from 1,488 in 2002 to reach 2,526 TWh in 2030. In the APEC region, China is expected to lead nuclear growth at 10.5 percent per year, with capacities increasing in Korea, Russia, Japan, and the US over that in 2002, and Viet Nam as new regional nuclear power (Figure 18).

Figure 18 Nuclear Energy Production (Mtoe)



Source: APERC Analysis (2006)

Many important issues currently existing in the APEC region can be addressed by nuclear power: scarcity of local energy resources, the need for energy diversification while meeting electricity demand, and the need to reduce the emission of pollutants and greenhouse gases. Nuclear power is a baseload energy source which significantly reduces dependency on fossil fuels. Nuclear fuel price has a history of stability, and because of the low contribution of the uranium price to total generation costs are much less vulnerable to fuel price volatility. Additionally, besides hydro nuclear power is the only large-scale, baseload energy source that does not create air pollution and emit greenhouse gases, and contrary to hydro did not impact heavy on river's ecosystems.

PUBLIC ACCEPTANCE[7]

There is an overstatement of nuclear energy's drawbacks; especially over issues such as safety, waste, and economics. Fears about nuclear power's safety are not necessarily well justified. Since its beginnings in mid-1950's it has proven to be the safest of all energy sources, even considering the one single accident, Chernobyl. Safety records in the operation of nuclear plants are improving and nuclear reactors in the future can be made even safer as more safety features are being incorporated into new designs.

The public perception of nuclear waste as being an 'unsolvable' problem is unfounded from a technological standpoint. Waste in the nuclear industry is but a small fraction of the burden that industrial waste represents worldwide, with the difference that nuclear waste decays to safe radioactive levels over time. There is no urgent need at present for final disposal of high level radioactive waste given that almost all is currently undergoing the required 40-50 year initial cooling down period. When sufficient volumes of spent fuel assemblies or of high-level waste are ready to be definitively disposed of, the technology for deep underground repositories will have been demonstrated and available. The technology is well advanced today and there is already one repository for military use in operation, while the construction of the first civilian repository is expected sometime after 2010.

For nuclear power to have a prominent position in the electricity generation sector, advances have to be made on the most controversial issues. The industry has to eliminate the public's scepticism concerning nuclear waste handling. On the part of governments, it will entail major responsibilities to ensure the continued safe operation of nuclear facilities, to make the required political decisions to develop and implement national waste management strategies, and to promote international action to strengthen non-proliferation controls. This should be closely coordinated with activities towards processing spent nuclear fuel that can effectively reduce the volume and toxicity while implementing advanced proliferation-resistant treatment and transmutation technologies.

ADVANCED FISSION AND FUSION[8]

In response to the challenges currently facing nuclear power, many countries are working to improve the economics, safety, waste management and proliferation resistance of advanced reactor-fuel cycle systems. For advanced nuclear power plant designs, efforts are focused on making plants simpler to operate, inspect, maintain and repair. In the near term, most new nuclear power plants are likely to be evolutionary designs building on proven systems while incorporating technological advances and often economies of scale. Over the longer term, the focus is on innovative designs, several of which are in the small-to-medium range (up to 700 MW_e). These envision construction with factory-built components, including complete modular units for fast on-site installation, creating possible economies of series production instead of economies of scale. Some are being designed for operation without on-site refuelling. Other advantages foreseen for smaller units are easier financing, greater suitability for small electricity grids or remote locations, and their potential for district heating, seawater desalination and other non-electric applications. Such advances should increase their attractiveness for many developing countries and some industrialised countries.

There are two major international efforts to promote innovation for nuclear energy – the IAEA's **International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)** and **Generation IV International Forum (GIF)**. Canada, Chile, China, Indonesia, Korea, and Russia are the APEC economies participating in INPRO project. INPRO published an initial report in 2003 that outlined the potential of nuclear power and specified guidelines and a methodology for evaluating innovative concepts. The next stage of INPRO is to facilitate assessments of innovative nuclear energy systems (INSs), to define and model INS deployment scenarios taking into account strategies considered by participating economies. Canada, Japan, Korea, and the US are the APEC member economies participating in the GIF project. GIF has reviewed a wide range of innovative concepts and, in 2002, selected six types of reactor systems for future

[7] APERC (2004)

[8] IAEA (2005)

bilateral and multilateral cooperation: gas cooled fast reactors, lead alloy liquid metal cooled reactors, molten salt reactors, sodium liquid metal cooled reactors, supercritical water cooled reactors and very high temperature gas reactors.

Much of the current experimental and theoretical research on nuclear fusion is focused on the **International Thermonuclear Experimental Reactor (ITER)**. ITER's "engineering design activities" stage has been completed, and the realization of ITER came closer with the announcement in June 2005 by Seven Parties to ITER – the European Union, Russia, Japan, China, India, Korea and the United States – that it will be sited at Cadarache in France. The aim of ITER is to demonstrate the scientific and technological feasibility of fusion energy by constructing a functional fusion power plant. ITER would take about 8 years to build and will then operate for a further twenty years. **It will be the first device in the world where a controlled nuclear fusion reaction will generate at least 5 times more power than it consumes**. ITER will open new horizons for nuclear science and technology for energy applications, with expected spin-offs in many other areas.

IMPLICATIONS

High growth rates for nuclear energy development, especially in China, and exhaustion of military stocks for nuclear fuel production renew issues of nuclear industry's safety. That is internal safety of nuclear reactor operations; nuclear fuel cycle safety for environment, human's health, and non-proliferation. Critical decisions for nuclear industry should be made and strong amendments to the international regime for peaceful utilisation of nuclear energy should be implemented in coming decades, based on technological developments and political willingness.

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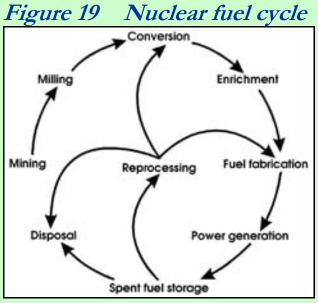
Nuclear Energy Peculiarities [based on WNA (2005)]

The fundamental difference in nuclear energy utilisation is the multi-stage nature: mining or production of fission materials from ore or other natural sources, conversion, enrichment, production of nuclear fuel for certain reactor design, spent fuel processing and disposal (temporary for spent fuel and permanent for wastes), see Figure 19. These fundamentals of the nuclear fuel cycle lead to multiply sources of nuclear energy transformation to more convenient energy carriers: electricity, heat, and, possibly in the future, hydrogen. One source of nuclear fuel is from processing row materials containing uranium (or thorium) in very low concentrations (sometimes less then one part per billion). Processing of waste tales of past nuclear enrichment is close to this process. The other way is to process high enriched nuclear materials from obsolete or terminated nuclear weapons. Or the third source for nuclear fuel production is to process spent nuclear fuel, which is treated as enriched nuclear materials.

Figure 19 Nuclear fuel cycle



Source: WNA (2005)

The physical process of fission requires strictly controlled conditions and a high purity of materials while utilising only a small amount of the energy held in the nuclear fuel. This last characteristic provides a unique opportunity to reuse the residual fissile materials contained in the nuclear fuel after reprocessing, creating the so-called nuclear fuel cycle. In addition, under some conditions even more fissile material can be accounted for in spent nuclear fuel after power generation than it held before power generation. This breeder concept of a self-sufficient and enhanced fuel cycle requires creation of expensive reprocessing and disposal facilities as preliminary conditions.

However, fuel reprocessing does not solve the waste disposal problem and unless it is blended as mixed oxide fuel (MOX) for use in conventionally designed reactors, creates large inventories of plutonium that must be safeguarded against weapons proliferation.[9]

Nuclear energy also seems to be the most likely means of large-scale hydrogen production without the release of greenhouse gases, using very-high temperature reactors coupled with thermo-chemical or high-temperature electrolytic water dissociation processes.

[9] WEA (2004), p 55