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- Consideration of 3E's+S under new energy circumstances in the world -

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IEEJ Outlook Project Team Members

Research Advisor Kokichi ITO

Energy Data and Modelling Center (EDMC)

Director	Yukari YAMASHITA
Group Manager	Shigeru SUEHIRO
Group Manager	Akira YANAGISAWA
Senior Economist	Momoko AOSHIMA
Senior Economist	Koichi UENO
Senior Economist	LU Zheng
Economist	Ryo ETO
Economist	Toshiya KATO
Economist	Yasuaki KAWAKAMI
Economist	Miyuki TSUNODA
Economist	Yasuo YORITA

Global Environment and Sustainable Development Unit

Managing Director	Akihiro KUROKI
Group Manager	Takahiko TAGAMI
Researcher	Shumpei WATANABE

New and Renewable Energy and International Cooperation Unit

Senior Economist	Yoshiaki SHIBATA
Researcher	KAN Sichao

Strategy Research Unit

Managing Director and Chief Economist	Ken KOYAMA
Assistant Director	Ichiro KUTANI
Group Manager	Tomoko MURAKAMI
Senior Researcher	Takashi MATSUMOTO
Researcher	Koshi TAGUCHI
Researcher	Kei SHIMOGORI
Researcher	Atsuhiko SUZUKI

Fossil Fuels and Electric Power Industry Unit

Group Manager	Yoshikazu KOBAYASHI
Group Manager	Tetsuo MORIKAWA
Group Manager	Atsuo SAGAWA
Senior Researcher	Yu NAGATOMI

Senior Economist	Yuji MATSUO
Councillor	Rejean CASAUBON
Editorial Assistant	Chiyoko ONDA

Foreword

Until recently China had been driving the global energy consumption growth. As China's structural economic and industrial changes have started, the global energy consumption has moderated its expansion. Nonetheless, as a consequence of the lower oil prices, global oil consumption has continued to increase by more than 1 million barrels per day annually. European natural gas consumption is indicating a recovery from the bottom reached after the global financial crisis. Overall, the world energy demand is likely to expand over the medium to long term primarily due to strong growth in emerging economies. Following China in contributing to the global growth may include countries such as India and the member countries of the Association of Southeast Asian Nations (ASEAN) that will celebrate its 50th anniversary in 2017.

ASEAN, with its population of 600 million, larger than the European Union, includes countries with great economic development potential and may post strong growth in the future. Given that ASEAN members are in various economic development stages, ASEAN growth could be even firmer if the ASEAN Economic Community, inaugurated in late 2015, enhances its effectiveness to repeal tariffs between ASEAN members. Focusing on the promising regional association, "Asia/World Energy Outlook 2016" reviews its latest situation and analyses its energy and economy.

It may be needless to say that stable energy supply is indispensable to support the development of not only ASEAN but also of any other region. At present, fossil fuels meet more than 80% of global energy demand. Among problems regarding stable fossil fuel supply, economic problems accompanying price hikes have eased on crude oil price plunges from the second half of 2014. The risks of physical supply constraint have not declined. For example, the situation in the Middle East, the largest oil exporter in the world, is likely to remain unstable due to historical problems. After the defeat of the Ottoman Empire, Great Britain and France signed the Sykes-Picot Agreement in 1916, just a century ago. The agreement proposed European spheres of influence and control over the Arab region. It caused artificial and unnatural borderlines between Arab countries that later became independent, creating the root of many problems. Even now, the Islamic State terrorist organisation seeks to tear down the Sykes-Picot Agreement while aggravating the Middle Eastern situation. Given the uneven distribution of oil resources in the world, oil supply disruptions are the first tail risk. "Asia/World Energy Outlook 2016" assesses the economic impacts of crude oil and natural gas supply disruptions and spells out risk reduction measures.

One of the measures to reduce vulnerability to fossil fuel supply disruptions is the utilisation of alternative energy sources. In fact, earlier oil crises stimulated the introduction of renewables and nuclear. Nuclear energy policies have begun to differ from country to country ever since the Three Mile Island, Chernobyl and the Fukushima Daiichi Nuclear Power Station accidents. In the year that followed the Fukushima accident (2011), the number of operational nuclear reactors in the world declined from 441 to 435. Five years later, the number increased to 450. On the premise of everlasting efforts to enhance safety measures, nuclear are required as an electricity source to meet robust electricity demand economically and stably. "Asia/World Energy Outlook 2016" provides a quantitative assessment of different nuclear utilisation scenarios' impacts on the 3E's – energy security, economic growth and environmental conservation – and compiles measures to secure safety, the premise for the 3E's.

While nuclear and renewables are major energy sources to combat climate change, hydrogen can also be expected to become such an energy source over the long term. Hydrogen utilisation, however, is still in the initial phase and various conditions must be met for hydrogen to take a key position, mainly in the power generation sector as an energy source emitting no carbon dioxide during use. "Asia/World Energy Outlook 2016" integrally analyses hydrogen production, international trade and utilisation and depicts a hydrogen society with consideration given to hydrogen's competition with other energy sources or technologies.

The year 2017 corresponds to the 25th anniversary of the United Nations Framework Convention on Climate Change. Although numerous studies have been made on climate mechanisms during the last quarter century, various points are still left unknown. There remains a great amount of knowledge still to be understood about climate change. When assessing a future response under insufficient information, most people pay too much attention to greenhouse gas emission reduction and temperature rises that are both easy to understand. Of the two temperature rise targets cited at the 21st Conference of Parties to the UNFCCC, not a small number of people might have immediately concluded that the 1.5°C target would be unconditionally better than the 2°C target. "Asia/World Energy Outlook 2016" recognises climate change as a long-term challenge that would affect a wide range of areas and many generations to come. As such, the outlook considers sustainability from various facets and prudently proposes an approach to balance between mitigation, adaptation and residual damage, providing norms.

Fortunately, the growth of energy-related CO_2 emissions has decelerated on a coal consumption slowdown in China and expansion in renewable energy. However, views are divided over whether the deceleration should be taken as a temporary phenomenon or as a clear sign of decoupling between the economy and CO_2 emissions. A development that could be understood easily in retrospect may be difficult to be recognised or found while it is occurring. Refraining from becoming shortsighted is the best way to maintain an overall understanding. "The farther backward you can look, the farther forward you are likely to see," said Sir Winston Churchill.

"Asia/World Energy Outlook 2016" represents an attempt to depict future world energy supply and demand based on long-term data, latest information and careful analyses by experts. It also represents an attempt to indicate a prescription for resolving some of the great challenges facing society. We are confident that the Institute of Energy Economics, Japan, will play a role as a skilled Sherpa with its latest outlook in its 50th year, as readers analyse the future energy situation.

Tokyo, October 2016

THE INSTITUTE OF ENERGY ECONOMICS, JAPAN

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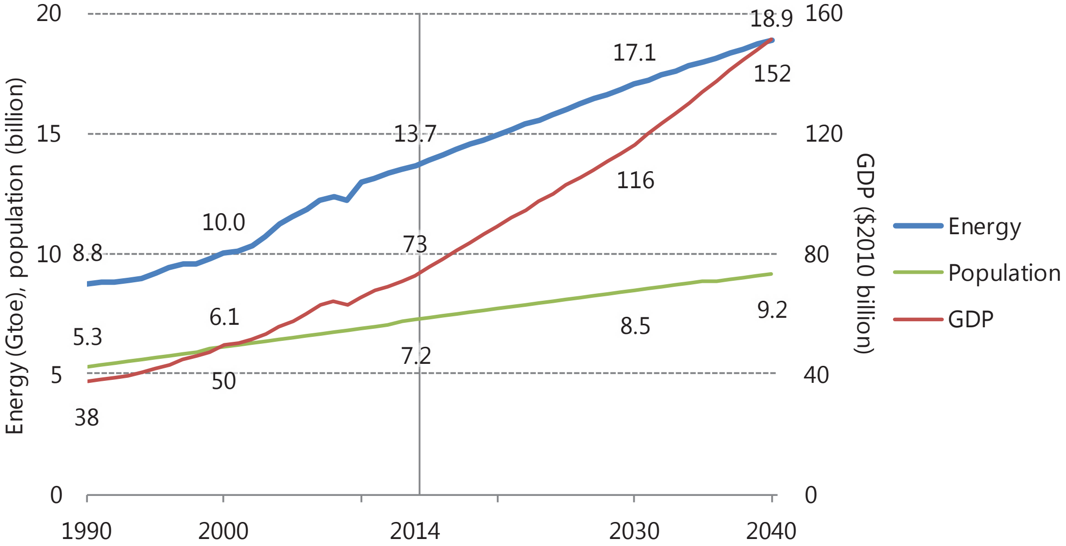
Executive summary

World energy supply and demand outlook

Demand

- Over the next 26 years through 2040, the world's population will increase by 1.9 billion, with the world economy growing 2.1-fold. Energy consumption will expand from 13,699 million tonnes of oil equivalent (Mtoe) to 18,904 Mtoe (in the *Reference Scenario*). Energy consumed for generating $1,000 in gross domestic product (GDP) will decline by one-third from 2014 to 2040, posting some progress in energy conservation. Nevertheless, the world's energy consumption growth during the period will be 5,205 Mtoe, equivalent to the combined current consumption of the United States and China, the two largest energy consuming countries. In the 50 years from 1990 through 2040, energy consumption will more than double.

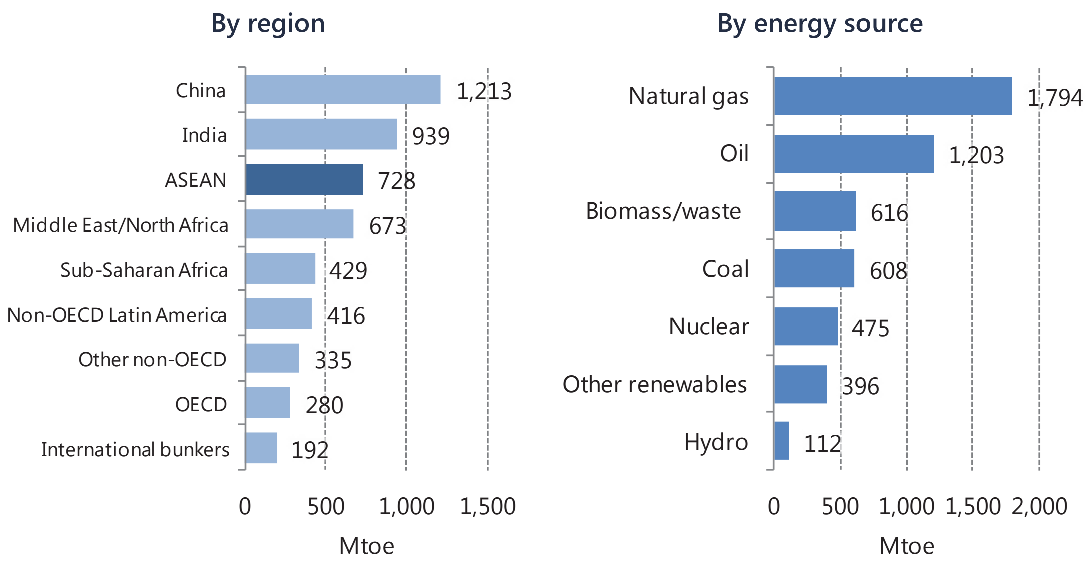
Figure 1 | Global real GDP, population and primary energy consumption



- Energy consumption growth will mostly come from countries other than the members of the Organisation for Economic Cooperation and Development (OECD), which will account for only 5% of global growth. Among non-OECD countries, China, India and the members of the Association of Southeast Asian Nations (ASEAN) will post particularly great growth. Their combined energy consumption growth of 2,879 Mtoe would amount to Japan's present energy consumption for six years.

- Fossil fuels, especially natural gas and oil, will be the primary energy sources satisfying the massive energy consumption growth. Although great hopes are placed on non-fossil energy, fossil fuel consumption will increase by 2.3 toe as non-fossil energy consumption grows by 1 toe during the outlook period. Fossil fuels, though reducing their present share of energy consumption from 81%, will still cover 78% of energy consumption in 2040.

Figure 2 | Global primary energy consumption growth [2014-2040]



- Although oil consumption growth will slip below natural gas consumption growth, it will still be the largest energy source in 2040. Current oil consumption increased by about 1.5 million barrels per day (Mb/d) from a year earlier, partly due to lower oil prices. Oil consumption will grow steadily in the future, exceeding 100 Mb/d in the middle of the 2020s before reaching 114 Mb/d in 2040. Driving oil consumption growth will be non-OECD countries. China will replace the United States as the world's largest oil consumer in the early 2030s. India will surpass Japan in oil consumption this year and outdo the European Union around the middle of the 2030s, reaching 10 Mb/d in 2040.

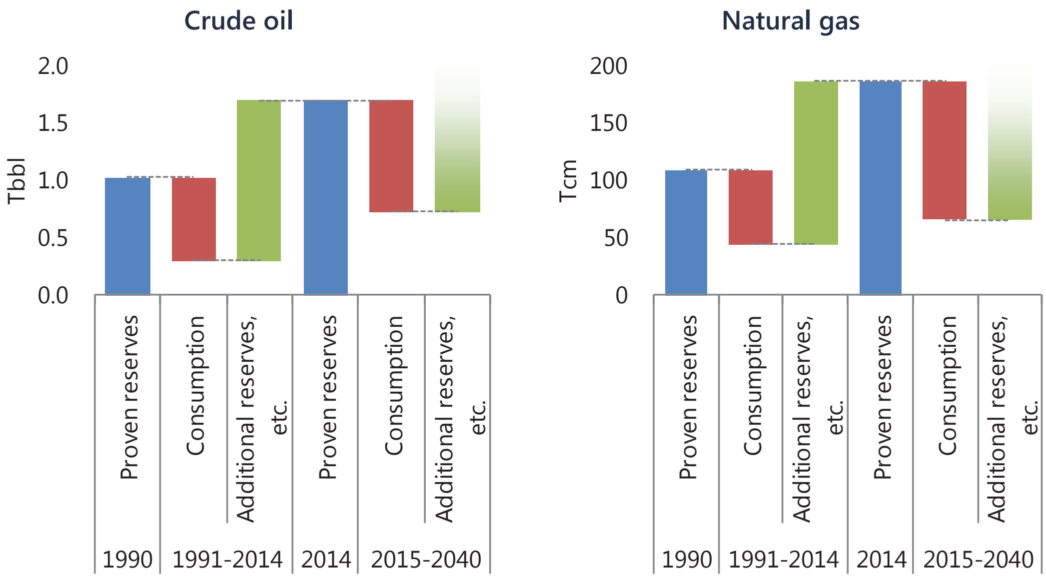
- Natural gas will post faster consumption growth than any other energy source. It will be used more widely in the world replacing coal as the second largest energy source by 2040. In the United States, natural gas will replace oil as the largest energy source by 2030 and the same will happen in the European Union in some five years after 2040. Although the United States, Europe and the former Soviet Union currently account for 53% of global natural gas consumption, the others will capture 62% of global consumption in 2040.

- Coal consumption grew rapidly in the first decade of this century, covering half of global energy consumption growth. Coal consumption growth is currently decelerating rapidly and this trend will generally continue in the future. However, coal consumption conditions will differ from region to region. While coal consumption will decline in Europe and the United States, it will continue to satisfy more than 50% of the robust energy demand in China and more than 40% of demand in India. ASEAN will grow more dependent on coal, which will account for a quarter of its energy consumption.

Coal will be so indispensable in Asia that cleaner ways to use it will be required to realistically address the climate change issue.

- Proven recoverable reserves for oil and natural gas (at present technologies and economic efficiency), as well as abundant coal available for production will be sufficient to cover consumption for the next quarter century (Figure 3). Given growth in reserves through technological development and unproven reserves, the world as a whole is unlikely to experience energy supply constraints attributable to the depletion of resources. A matter of concern is that wild fluctuations of crude oil and natural gas prices over the recent years could impede adequate supply investment.

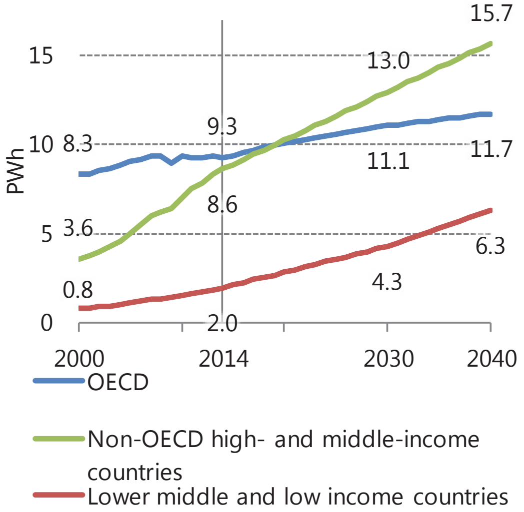
Figure 3 | Proven reserves and fixed-term consumption



- Final electricity consumption will continue growing irrespective of the economic development phases of any country or region (Figure 4). Particularly remarkable growth will be observed in non-OECD countries. Over the next 26 years, China will post the largest final electricity consumption growth, being followed by India, the United States, the European Union and Indonesia, in that order. China will remain the world's largest electricity consumer after becoming so in 2011. India will surpass the European Union and Japan to become the third largest electricity consumer after the United States.

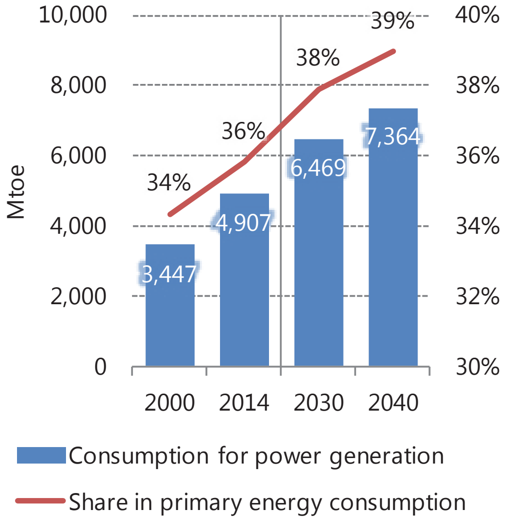
- As electricity consumption grows, global electricity supply (generation) will increase rapidly (Figure 5). Although energy consumption for power generation accounted for a little more than one-third of total primary energy consumption in 2000, the share will expand to about 40% in 2040 despite continuous growth in power generation efficiency. Coal consumption for power generation will capture 62% of total coal consumption.

Figure 4 | Final electricity consumption



Note: Lower middle and low income countries here are defined as countries or regions where real GDP per capita is $4,000 or less.

Figure 5 | Global energy consumption for power generation



Supply

- The Middle Eastern members of the Organization of the Petroleum Exporting Countries (OPEC) and North America will account for 90% of the global crude oil production growth through 2020 (Figure 6). Driving OPEC production growth will be Saudi Arabia with the largest production capacity, Iran on which Western economic sanctions have been lifted and Iraq that has great potential to expand production. In North America, shale oil productivity has continued to improve and as crude oil prices rise moderately, unconventional oil will drive overall crude oil production growth. Crude oil production will peak out in North America, Europe and Eurasia around 2030, leading non-OPEC oil's share of global oil supply to decrease from 60% in 2014 to 54% in 2040.
- Crude oil trade between major regions will increase from 38 Mb/d in 2015 to 48 Mb/d in 2040. While OECD oil imports will decline on a demand fall and a production increase in North America, imports to cover growing demand in China, India, ASEAN and other emerging economies will drive up total crude oil trade. Asia will diversify its oil supply sources to some extent by expanding imports from North America, non-OECD Europe and Central Asia. Still, however, supply from the Middle East and Africa will capture 80% of total oil supply for Asia in 2040 (Figure 7).

Figure 6 | Crude oil production in major regions

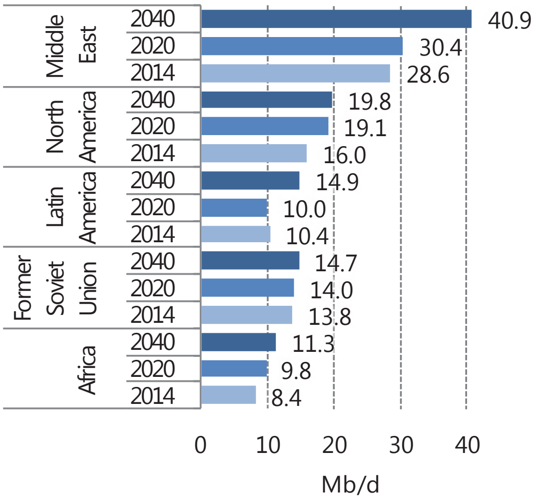
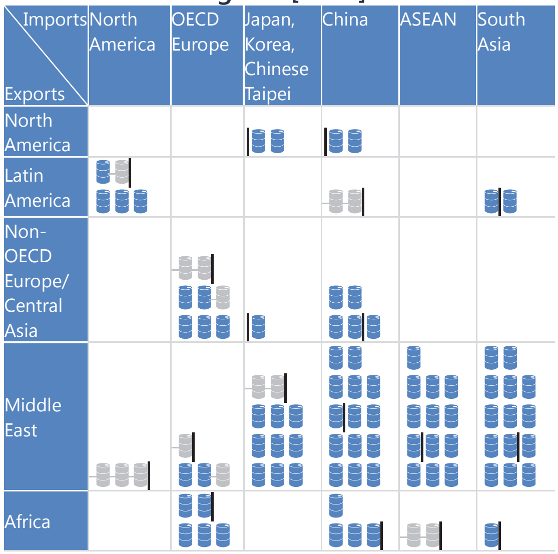


Figure 7 | Crude oil trade between major regions [2040]



Note: = 0.5 Mb/d, | = 2015

Natural gas production will increase by 63% from 2015 to 2040 (Figure 8). Although upstream investment has globally decreased on crude oil price plunges, North American natural gas production will grow steadily due to gas output associated with shale oil production and Russia will develop new gas fields to meet growing exports. In the Middle East, Iran and Saudi Arabia with growing domestic demand will drive the growth in natural gas production. In Asia, China and India will promote gas field development. Particularly, China will further increase natural gas production if shale gas development investment expands from 2025. In Africa, the emergence of new liquefied natural gas (LNG) suppliers such as Mozambique and Tanzania will drive production.

Natural gas trade between major regions will increase from 511 billion cubic metres (Bcm) in 2015 to 887 Bcm in 2040. Trade growth will thus exceed production growth for natural gas, unlike crude oil. Posting the largest growth in natural gas exports through 2030 will be Oceania and North America where many LNG projects are planned to launch production in the first half of the 2020s. After 2030, natural gas trade growth will decelerate slightly because OECD demand growth will slow down while China and Latin America will expand their shale gas production. North America's LNG exports, which started in 2016, will become one of the major suppliers in the world by 2040 (Figure 9). As for trade via pipelines, Russia will remarkably expand natural gas exports to China.

Figure 8 | Natural gas production in major regions

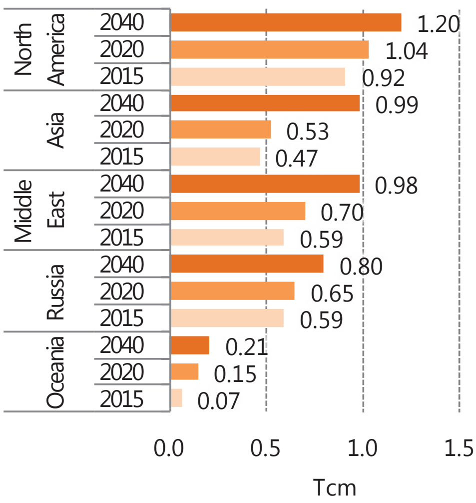
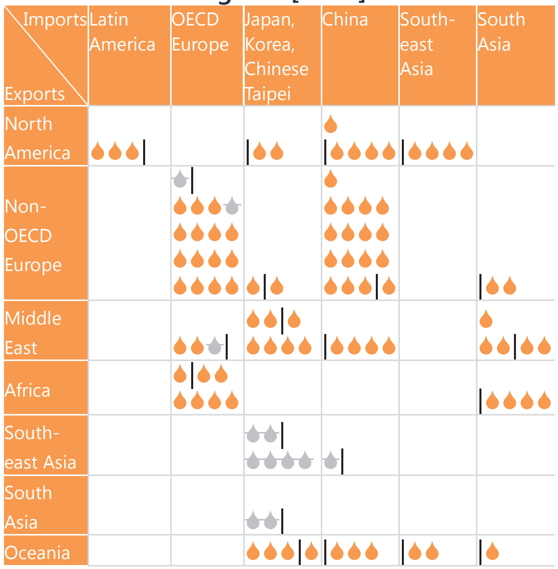


Figure 9 | Natural gas trade between major regions [2040]



Note: ● = 10 Bcm, | = 2015

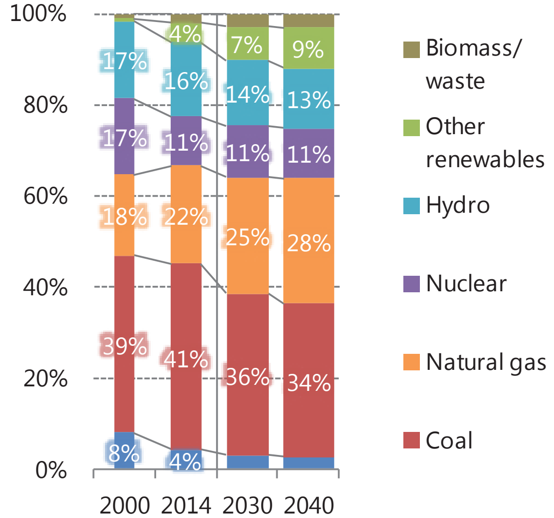
▌ Coal production will expand from 7,937 million tonnes (Mt) in 2014 to 9,286 Mt in 2040 as coal demand grows in non-OECD regions including Asia, Latin America, Africa and the Middle East. Steam coal production will increase by 25% from 6,004 Mt in 2014 to 7,522 Mt in 2040 in line with rising demand for steam coal for power generation. Meanwhile, production for coking coal will decrease from 1,116 Mt in 2014 to 988 Mt in 2040 and lignite will decrease from 817 Mt to 776 Mt.

▌ The power generation mix where fossil fuels command the largest share at around two-thirds will be maintained (Figure 10). Although coal will reduce its share of total power generation by 7 percentage points to 34% due to falls in Europe and the United States, it will remain the largest electricity source. Natural gas-fired power generation will increase in all regions other than the United Kingdom and Italy. Among electricity sources, natural gas will score the largest growth, expanding its share of total power generation by 6 points to 28%.

▌ Nuclear power generation will rise from 2,535 terawatt-hours (TWh) in 2014 to 4,357 TWh in 2040, maintaining its share of global power generation in 2040 unchanged from the present level of 11%. Nuclear power generation capacity will decrease in eight countries and regions, including Germany planning to terminate nuclear power generation in the 2020s and Japan cutting capacity by 20 gigawatts (GW) by 2040. Global nuclear power generation capacity will expand from 399 GW in 2015 to 612 GW in 2040 as 14 countries will launch nuclear power generation for the first time, and 18 other countries will increase their capacity.

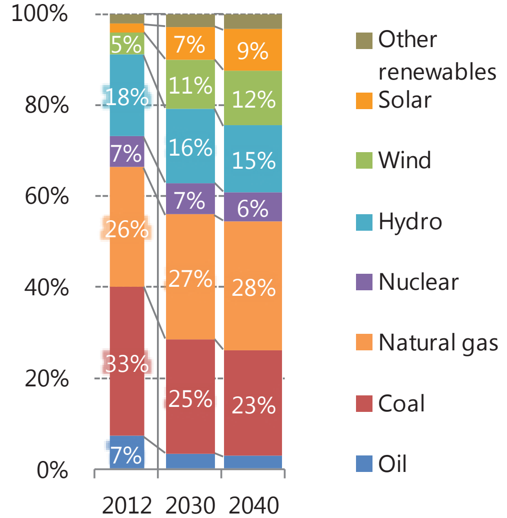
▌ Among renewable energy sources, hydro will be developed mainly in China, India and Brazil. However, due to a moderate growth in hydro power generation that will fail to increase as fast as total generation, its share of the power generation mix will decrease by 3 points. Wind and solar photovoltaics power generation will post a rapid increase of 3.6-fold from 1,005 TWh in 2014 to 3,573 TWh in 2040, accounting for 9% of total power generation. Power generation capacity will expand 3.2-fold from the present level to 1,170 GW for wind and 4.9-fold to 857 GW for solar PV. Wind and solar PV will thus capture 21% of total power generation (Figure 11).

Figure 10 | Global power generation mix



Note: Bar sizes are proportionate to power generation.

Figure 11 | Global power generation capacity mix

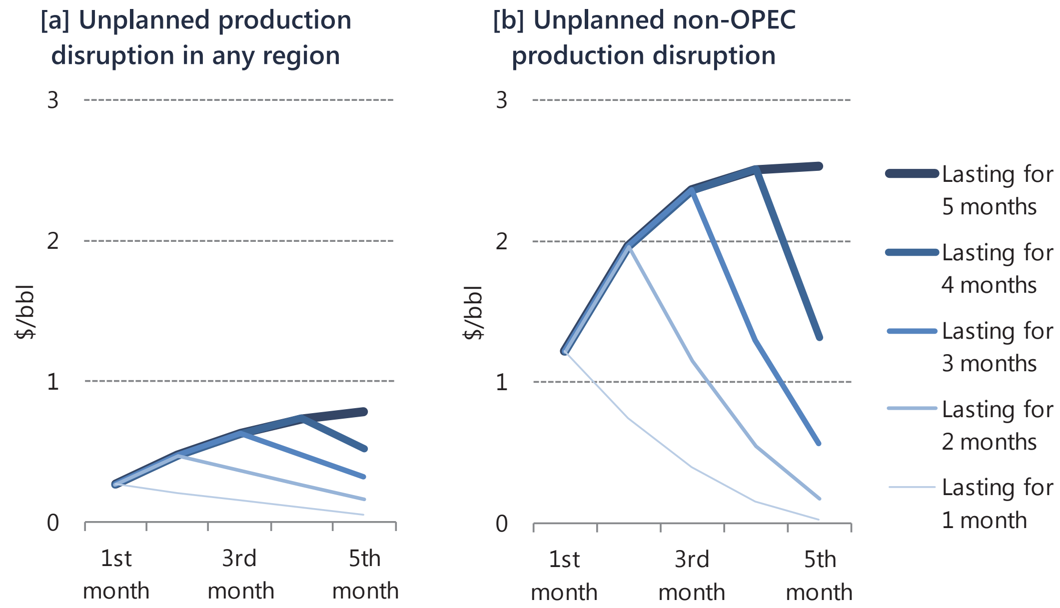


Note: Bar sizes are proportionate to power generation capacity.

Oil supply disruptions

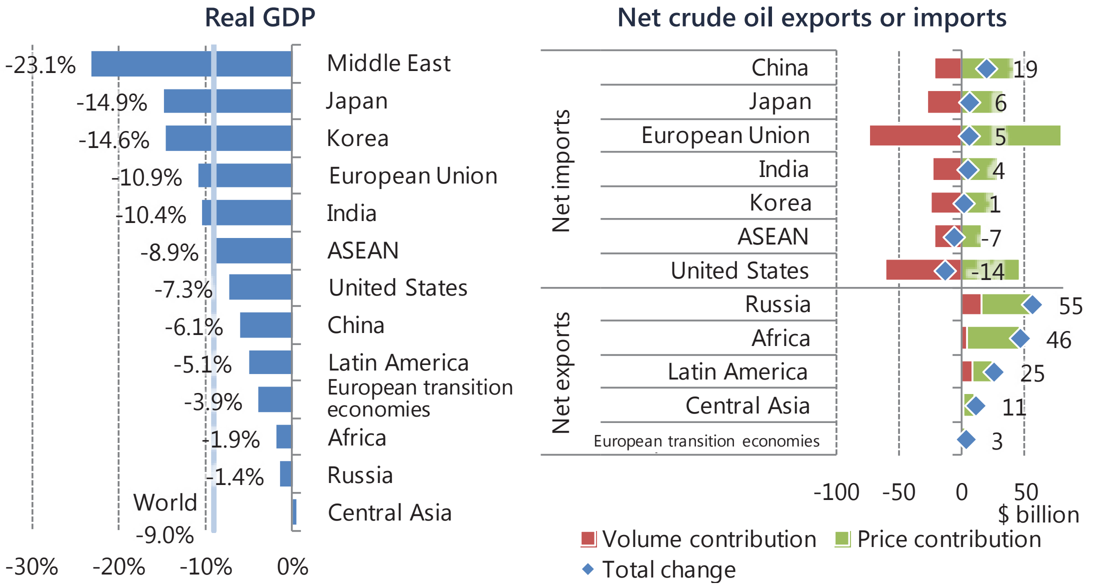
- Fossil fuels including oil and natural gas are key energies supporting the foundation of the modern society, covering more than 80% of the daily human energy demand. Crude oil production disruptions could easily be caused by disasters, accidents, conflicts, terrorist attacks or strikes though no major fossil fuel supply disruptions have occurred in recent years.
- A 100 kb/d unplanned oil production disruption can boost the average crude oil prices in a particular month by $0.3/bbl (Figure 12) and if the disruption continues for five months, the price hike may inflate to $0.8/bbl. If the disruption is limited to non-OPEC production of which an disruption usually leads to a production cut, the impact on prices may be far greater.
- As for price impacts, supply constraints under which energy cannot be procured as required are a major risk factor. If Middle Eastern crude oil production declines unintentionally by as much as 10 Mb/d, with no one making up for the decline, the world economy may contract by 9% (Figure 13).

Figure 12 | Impact of 100 kb/d unplanned crude oil production disruption on oil prices



Note: Average impacts between 2011 and the first half of 2016

Figure 13 | Impact of 10 Mb/d decline in Middle Eastern crude oil production



Note: Net crude oil exports from the Middle East will fall by $139 billion.

Excluding the Middle East, the source of the supply disruption, East Asia other than China may suffer the largest damage from such disruption. Korea and Chinese Taipei would lose GDP as much as their economic growth for some five years. Japan would lose as much as growth for about 20 years. Even the European Union with less dependence on Middle Eastern crude oil may suffer an economic contraction of more than 10%. The U.S. economic contraction may be less than the global average and limited to 7% due to growing domestic crude oil production. However, the United States may not be free from any impact of such great oil supply disruption.

- The shale revolution is expected by some people to allow the United States to become a swing producer. Analogically, the United States could be expected to cover a supply disruption from the Middle East. Even if the United States expands crude oil production by 3.6 Mb/d, the world economy's contraction may be narrowed only by about 2.5 percentage points. Japanese and European Union contraction may be narrowed only by about 2.0 points, covering one-eighth of the damage for Japan and one-sixth for the European Union.

- Energy supply disruptions can bring about great global economic damage that would affect even countries or regions that do not import crude oil or natural gas from countries hit by the disruptions. It may be impossible to completely eliminate risk factors involving energy supply disruptions. Therefore, each country is required to work with the international community to pursue classic, steady efforts to reduce such risks.

ASEAN energy supply/demand outlook

Primary energy consumption

- Reflecting strong economic and population growth, ASEAN primary energy consumption will increase at an annual rate of 3.0% from 624 Mtoe in 2014 to 1,352 Mtoe in 2040 (Figure 14). The growth will exceed the combined Japanese and Korean present consumption, accounting for 14% of the global energy demand growth. ASEAN will post the third largest growth after China and India (Figure 2 above).

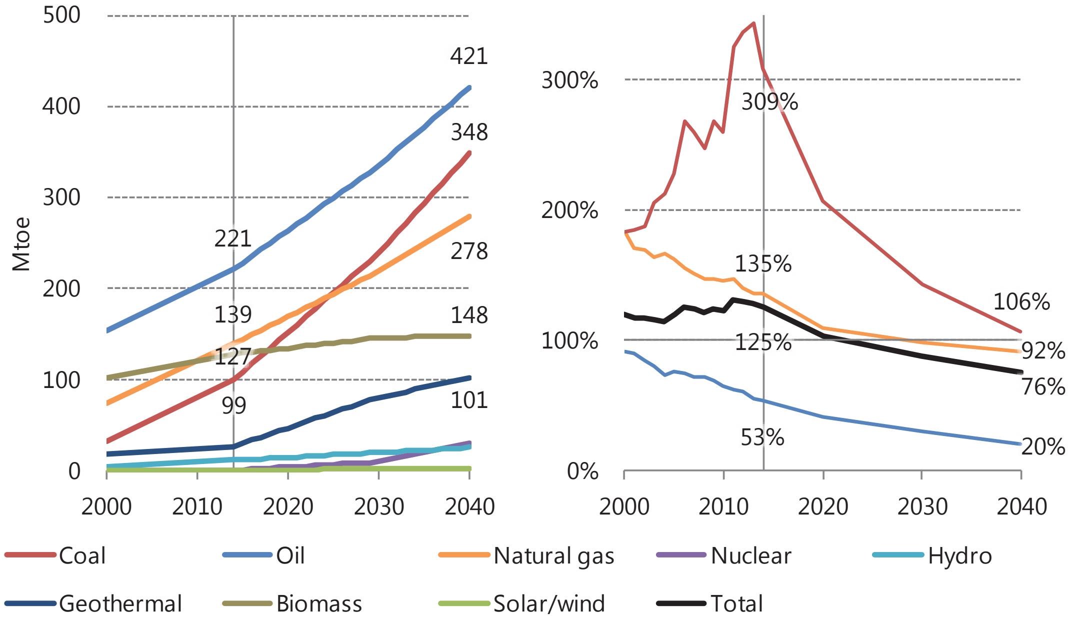
- The ASEAN region, relatively rich with energy resources, is currently a net energy exporter with an energy self-sufficiency rate of 125% (Figure 15). However, as the increase in fossil fuel production will be unable to catch up with the rapid local energy demand growth, the energy self-sufficiency rate will slip below 100% by 2030 and fall to 76% in 2040.

- As fossil fuels cover more than 80% of primary energy consumption growth, ASEAN's rate of dependence on fossil fuels will rise from 74% in 2014 to 77% in 2040. Among energy sources, coal will record the largest growth led by power generation demand, accounting for 34% of overall primary energy consumption growth. The growth totalling 356 million tonnes of coal equivalent (Mtce) will capture about 40% of the global coal consumption growth.

- Oil consumption in 2040 will expand 1.9-fold from 2014, with automobile fuel accounting for half the growth at 4.1 Mb/d. Liquefied petroleum gas (LPG) in the buildings sector and petrochemical feedstocks will also grow significantly. Although oil's share of ASEAN primary energy consumption will fall from 35% to 31%, oil will remain the most important energy source for the region. As ASEAN oil production decreases, the oil self-sufficiency rate will decrease from 53% to 20%.

Figure 14 | ASEAN primary energy consumption

Figure 15 | ASEAN energy self-sufficiency rate



- Natural gas consumption will double by 2040. The majority of the natural gas consumption growth of 170 Bcm will be used for power generation, with most of the remainder being for industrial use (including petrochemical feedstocks). Indonesia and Malaysia, which account for most of the ASEAN natural gas consumption growth, are rich with natural gas resources but will experience a decline in their export capacity. ASEAN now exports 60 Bcm on a net basis but will become a net importer by 2030.

- No nuclear power plants are in operation in the ASEAN region at the moment. From 2025, however, Thailand, Viet Nam, Indonesia and Malaysia will introduce nuclear power generation capacity totalling 16 GW. However, nuclear will account only for 4% of total power generation and 2% of total primary energy consumption.

- ASEAN has great potential to supply renewable energy such as hydro, geothermal and biomass. The Greater Mekong region that spans Cambodia, Thailand, Viet Nam, Laos and Myanmar has a hydro power generation potential at 248 GW, with many hydro development projects being under way. Hydro power generation will expand 2.2-fold by 2040, accounting for about 60% of renewable energy power generation growth in the ASEAN region.

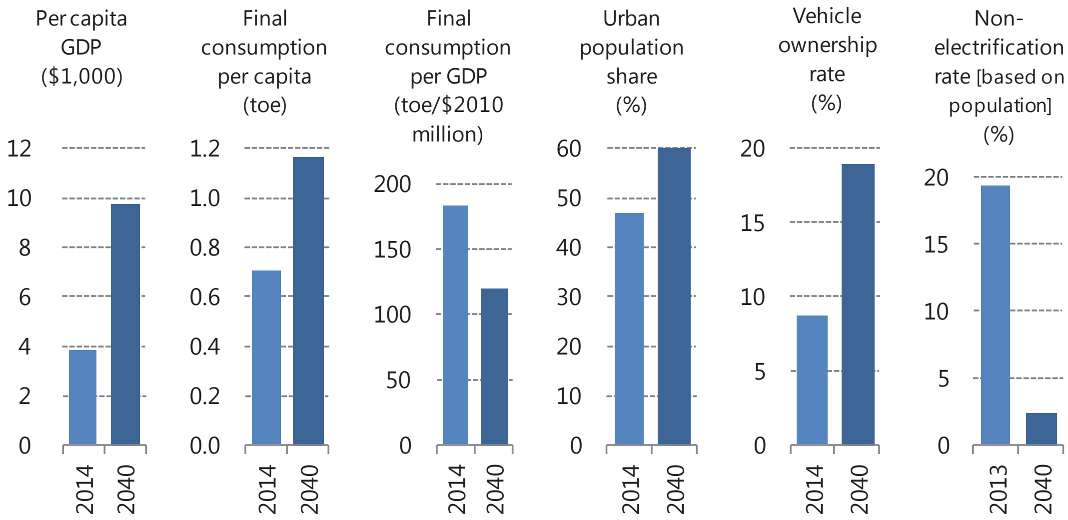
- Indonesia and the Philippines have great geothermal potential. The expansion in geothermal power generation will account for about 20% of renewable energy power generation growth. In terms of primary energy consumption, however, geothermal will increase about five times faster than hydro due to a primary energy conversion efficiency difference[1].

- Consumption of traditional biomass fuels such as firewood and livestock manure, among renewables, will decline on progress in urbanisation and living standards. On the other hand, biomass for power generation and liquid biofuels for automobiles will spread. While biomass consumption will increase by 20% by 2040, its share of the energy mix will halve from 20% to 11%.
- Although wind and solar PV power generation will record the fastest growth, their share of the ASEAN energy mix in 2040 will still be limited to less than 1%.

Final energy consumption

- Final energy consumption will increase at an annual rate of 2.7% from 440 Mtoe in 2014 to 890 Mtoe in 2040 in response to industrialisation, rising living standards and population growth. Final energy consumption per unit of GDP will decline by 35% (Figure 16) due to changes in industrial structure, progress in urbanisation as well as enhancements in energy conservation (including the establishment of energy efficiency standards for automobiles and electrical home appliances and the elimination of fuel subsidies).

Figure 16 | ASEAN economic and energy indicators



- The industry sector will expand final energy consumption at an annual rate of 3.5%, faster than any other sector. Foreign companies have rapidly increased direct investment in Malaysia, Thailand, Indonesia, the Philippines and Viet Nam, placing expectations on abundant, cheap labour. As machinery assembly develops greatly, power demand will grow sharply.

[1] The primary energy conversion efficiency is 100% for hydro against 10% for geothermal.

- The transport sector posts the second fastest energy consumption growth at 2.7%/year. The number of vehicles per 1,000 people will increase from 88 in 2014 to 189 in 2040. The regional vehicle fleet will grow 2.7-fold and the road sector's oil demand will rise by 2.0 Mb/d.
- The buildings and agriculture sectors will register a lower annual energy consumption growth rate of 2.2%, as people switch from traditional biomass fuels to LPG cooking stoves with better energy efficiency. In response to urbanisation, to expanding electrified regions and to raising living standards, the annual modern energy (excluding traditional biomass fuels) demand growth rate in those sectors will exceed the growth of the industry and transport sectors at 4.0%
- The non-electrification rate now stands at 19%, with 120 million people failing to receive electricity supply. ASEAN governments have promoted their respective policies to bring electricity in all regions, as early as possible. Such policies will be combined with economic growth to boost electricity demand 3.2-fold to 2,450 TWh by 2040. Energy consumption for power generation will expand 3.1-fold and fossil fuels will cover some two-thirds of the expansion.

ASEAN energy investment and market integration

- Energy investment between 2015 and 2040 will total $2.3 trillion (Figure 17), amounting to present ASEAN GDP ($2.4 trillion). Investment each in electricity supply and fuel supply will account for $1.0 trillion. Of the electricity supply investment, 55% will be for power generation equipment and the remaining 45% for electricity transmission and distribution equipment. Of the fuel supply investment, gas/oil field and other upstream development will capture about 80%. LNG and other fuel transport facility investment will account for a little less than 10% and oil refinery investment for the remainder. Energy conservation investment in the *Reference Scenario* will be limited to $220 billion.
- As ASEAN as a whole is becoming a net natural gas importer, the legitimacy of pipeline construction within the ASEAN region is losing ground. The only potential pipeline construction project will cover pipelines from the East Natuna gas field to Malaysia and Thailand. If all the production totalling 15 Bcm is provided to Malaysia to replace imported LNG, Malaysia may save $169 billion in payments for LNG imports from outside the ASEAN region by 2040 (Figure 18).
- Wide-area pipeline development can be expected to help ASEAN diversify energy supply sources for the sake of energy security. Pipelines for international supply will allow ASEAN to mitigate adverse effects of unforeseen LNG supply disruptions and rationalise inventories in peacetime in preparation for supply disruptions. While more than 10 LNG receiving terminals have been or are being constructed in the ASEAN region, their adequate distribution may help ASEAN reduce LNG initial costs.
- Hydro resources are abundant in such ASEAN member countries as Laos and Myanmar. ASEAN is seeking to connect these countries with their neighbours for a more effective use of the resources in meeting electricity demand in the region. On Borneo Island rich with hydro resources, efforts are being made to expand local electric grid lines and achieve interconnection with regions such as the Malay Peninsula and Java Island.

Figure 17 | ASEAN energy investment [Cumulative investment through 2040]

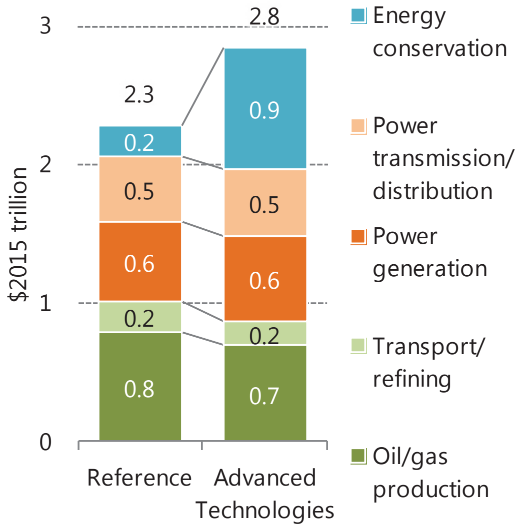
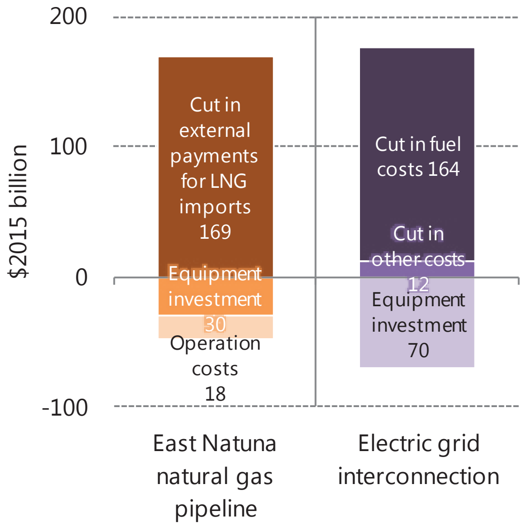


Figure 18 | Effects of ASEAN energy infrastructure development [Cumulative effects through 2040]



- Grid interconnection, though requiring $70 billion in initial investment in interconnection lines and hydro power generation equipment, will stabilise the grid network, reduce the generation reserve margin and limit power outage durations. The expansion of hydro power generation will allow ASEAN to reduce CO_2 emissions by 78 Mt or 5% and fossil fuel costs by $164 billion.

Addressing global environmental problems

Paris Agreement

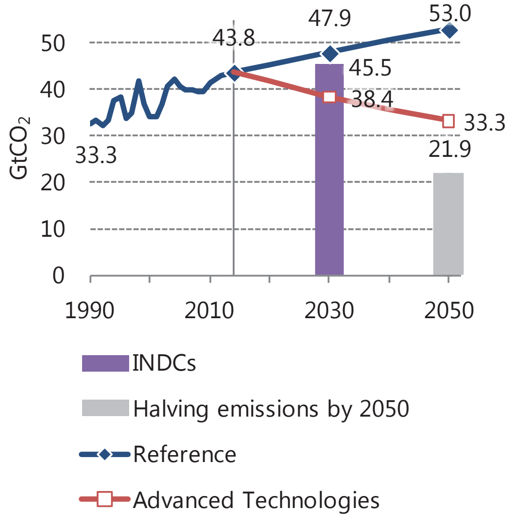
- The 21st Conference of Parties to the United Nations Framework Convention on Climate Change (COP21) in December 2015 adopted the Paris Agreement as a new international framework to reduce greenhouse gas emissions from 2020. Global GHG emissions estimated according to intended nationally determined contributions (INDCs) submitted for the agreement total 45.5 $GtCO_2$, representing an increase from the present level (Figure 19). Although the increase is slower than in the past, the estimated trend deviates far from a target of halving GHG emissions by 2050.

- The assessment of major countries' INDCs indicates that developed countries are close to the *Advanced Technologies Scenario* as explained later (Figure 20). China and India are close to the *Reference Scenario*. Indonesia and Brazil are positioned between the *Advanced Technologies Scenario* and the *Reference Scenario*. Each country will have to make the required efforts as much as for achieving the *Advanced Technologies Scenario* and, as such, low carbon technologies will have to further penetrate in developing countries.

Table 1 | Assessment of Paris Agreement

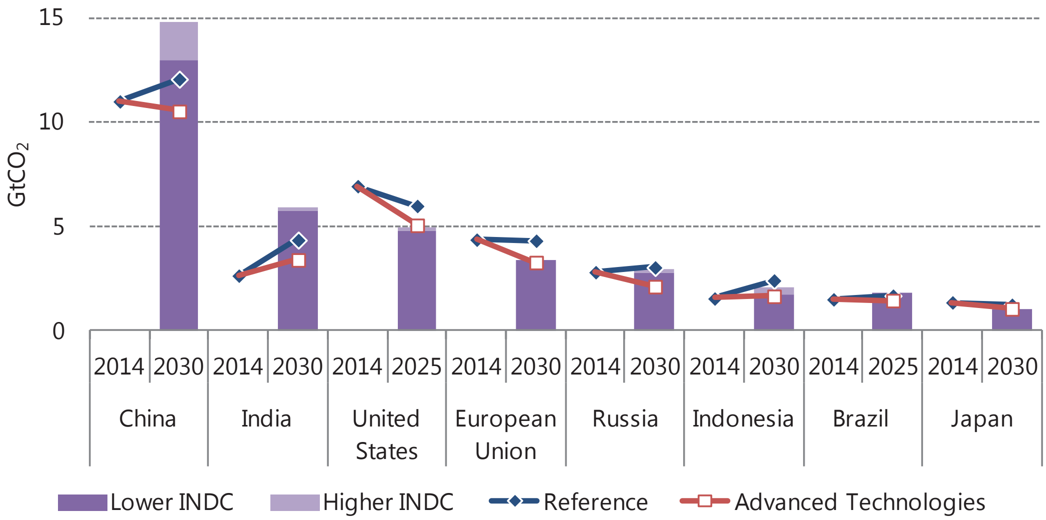
Praiseworthy points
All countries including China, India and other developing countries are required to reduce GHG emissions. More than 180 countries agreed to try to cut GHG emissions. Instead of the top-down approach adopted for the Kyoto Protocol to fix a GHG emission reduction rate before allocating quotas to countries, the Paris Agreement features a bottom-up approach in which countries submit their respective GHG emission reduction targets for accumulation. Every five years, the total of national targets will be assessed to encourage each country to cut emissions further.
Challenge
Global GHG emissions will increase from the present level.

Figure 19 | Global GHG emissions



Note: Estimated according to the Group of 20 major countries' INDCs for the Paris Agreement.

Figure 20 | GHG emissions in major countries and European Union



Note: Estimated according to the INDCs for the Paris Agreement

Nevertheless, we should appreciate the Paris Agreement as making its mark as a global step to addressing climate change. It will be important for all countries to realise their agreed targets and reduce GHG emissions further. To this end, technological innovation must be combined with technology transfers and take advantage of market mechanisms such as the bilateral credit system to support global emission reduction efforts.

Advanced Technologies Scenario

The *Advanced Technologies Scenario* assumes maximum CO_2 emission reduction measures based on their application opportunities and acceptability in society. In that *Scenario*, energy consumption in 2040 will be 2,343 Mtoe or 12% less than in the *Reference Scenario*, with the increase from the present level limited to 55% of the growth in the *Reference Scenario*.

Among energy sources, coal will post the largest consumption decline from the *Reference Scenario* as demand for coal for power generation decreases due to less electricity consumption, power generation efficiency improvement and fuel switching to other energy sources. Natural gas will register the second largest consumption fall. (Figure 21). While coal consumption in 2040 will decrease by 17% from the present level, natural gas consumption will continue to increase for the next quarter century even in the *Advanced Technologies Scenario*. Oil consumption in the *Advanced Technologies Scenario* will be 832 Mtoe less than in the *Reference Scenario*, peaking out around 2040. While fossil fuel consumption in the *Advanced Technologies Scenario* will be 3,196 Mtoe less than in the *Reference Scenario*, nuclear consumption will be 433 Mtoe more and renewable energy, including solar and wind energy, 419 Mtoe more. As a result, fossil fuels' share of total energy consumption will fall from 81% in 2014 to 70% in 2040.

Figure 21 | Global primary energy consumption changes

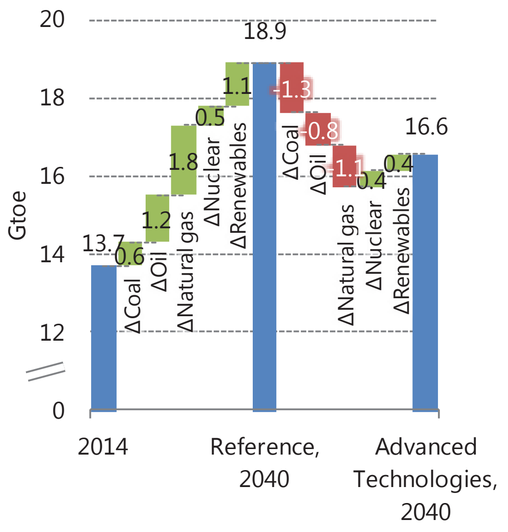
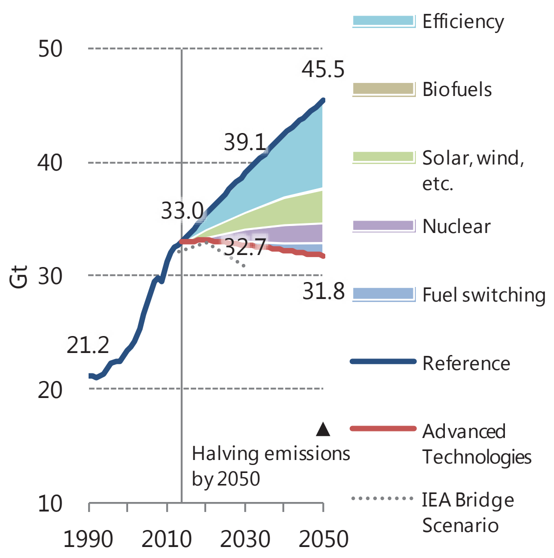


Figure 22 | Global CO_2 emissions and contributions to emission reduction



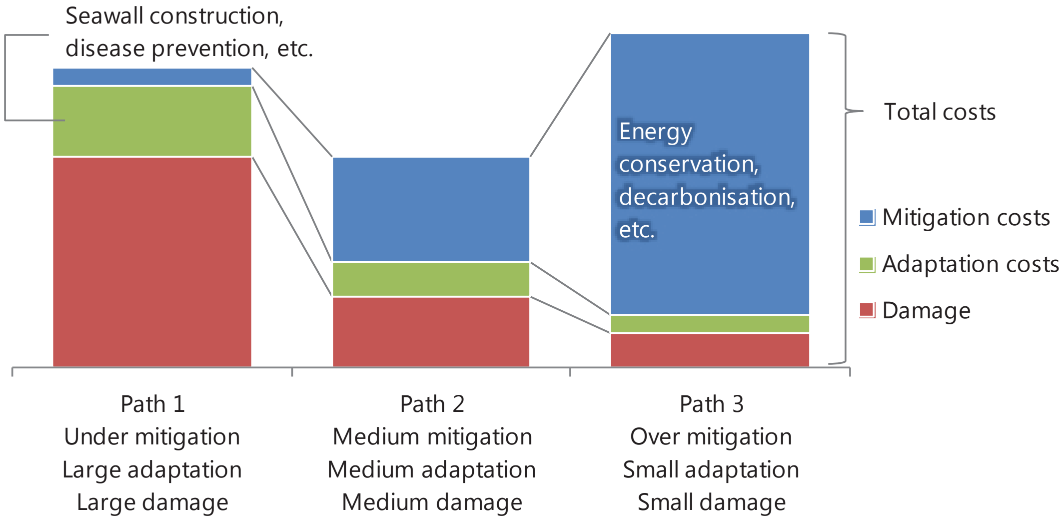
Although China and India will account for 32% of global primary energy consumption in 2040, their share of an energy consumption decline from the *Reference Scenario* to the *Advanced Technologies Scenario* will amount to 36%, indicating the two giant Asian energy consumers' great role. They will account for as much as 61% of a coal consumption fall and for 38% of nuclear and wind/solar energy consumption growth. The presence or absence of proactive energy conservation and carbon emission reduction in non-OECD and other countries, rich with potential, will determine the future picture of the world.

In the *Advanced Technologies Scenario*, global energy-related CO_2 emissions will peak out around 2020 and slowly decline before reaching 31.8 Gt in 2050, down 1.2 Gt or 3.8% from 2014 (Figure 22). A CO_2 emission decline of 13.7 Gt from the *Reference Scenario* will amount to 42% of present global emissions. A cumulative decline of 259 Gt through 2050 will be equivalent to 7.8 years' worth of present global annual emissions.

Super long-term path for climate change measures

The climate change issue is a long-term challenge that will involve a wide range of areas over numerous generations. When and how specific measures should be taken and what measures should be implemented must be considered carefully. From the viewpoint of sustainability, we analysed a combination of measures to minimise the total costs covering mitigation, adaptation and damage (Figure 23). (An attempt to spend $1,000 on cutting emissions and building seawalls to prevent $100 in damage would be very difficult to justify and would risk failure.)

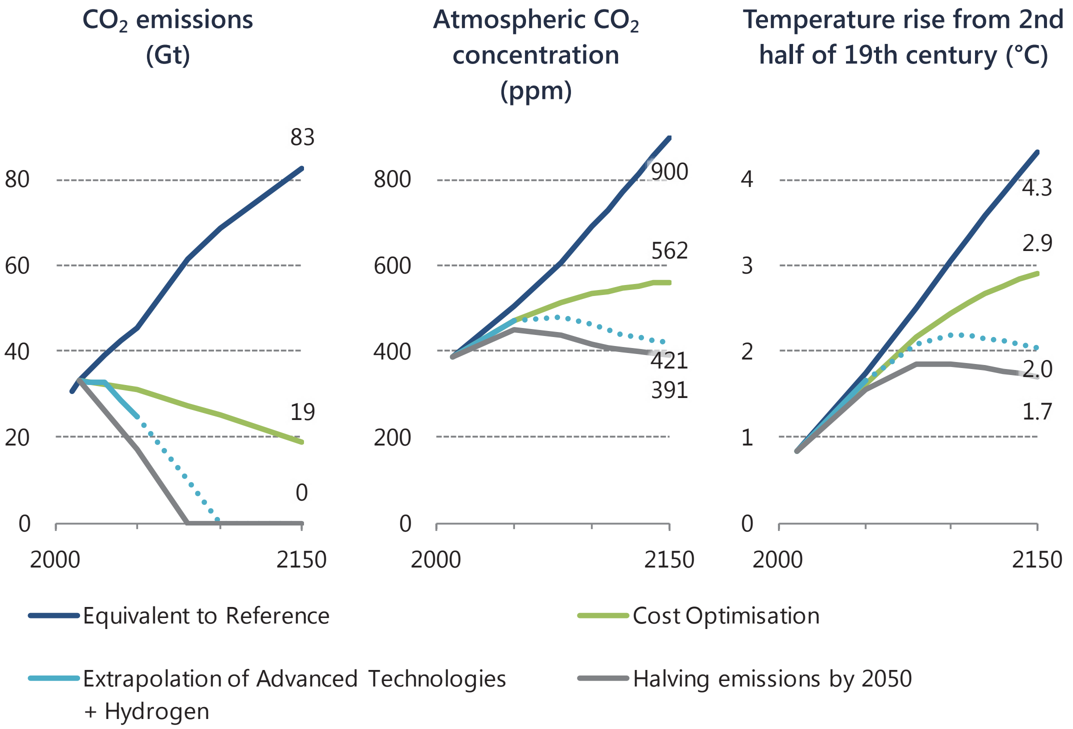
Figure 23 | Image of total mitigation, adaptation and damage costs



CO_2 emissions under the so-called *Cost Optimisation Path* to minimise total cumulative costs will be reduced substantially from the *Reference Scenario*. However, the emissions in 2050 will not have to be halved from the present level (Figure 24). They will continue falling slowly along the *Cost Optimisation Path* even after 2050 and be halved only after 2150. Under the same *Cost Optimisation Path*, the atmospheric CO_2 concentration will continue to increase slowly, reaching 560 ppm in 2150. The average temperature will also continue to rise slowly, posting an increase of almost 3°C from the second half of the 19th century, as of 2150.

The results, however, will change depending on conditions. If marginal costs for the emission reduction after 2050 are lowered due to rapid technological development, or if the climate sensitivity[2] is 2.5°C instead of 3°C, for example, the *Cost Optimisation Path* will differ from what is described above, with the temperature rise limited to a lower level. While humans cannot control the climate sensitivity, mitigation costs can be reduced through low-carbon technology cost cuts and the development of innovative technologies. We are required to cooperate in technological development from the long-term viewpoint while continuing to pursue adequate climate change measures.

Figure 24 | Super long-term path



With more innovative technologies in addition to the carbon free hydrogen (below mentioned) and cost reduction, CO_2 emissions path may become further down to become net zero by 2100. This will reduce the CO_2 concentration down and thus may meet the 2°C target by 2150. Overall total cost will become higher than the optimised total cost of mitigation, damage and adaptation but this result implies that it is possible to return to the 2°C path in the long run.

Hydrogen exploitation scenario

If ambitious global efforts are made to reduce CO_2 emissions over the long term and if some regions such as Japan and China fail to domestically take full advantage of the carbon capture and storage (CCS) technology, power generation using imported hydrogen will play a great role as the fourth zero-emission power source. If coal- and natural gas-fired power plants to be built in regions with limited access to CCS are

[2] The climate sensitivity represents an average temperature rise (°C) for the case in which the atmospheric GHG concentration in terms of CO_2 is doubled.

replaced with hydrogen-fired power plants after 2030, hydrogen will account for 13% of power generation in 2050. If the supply cost is reduced substantially, fuel cell vehicle (FCV) diffusion would accelerate globally[3], with one FCV for every eight passenger cars sold in the world (Figure 25). Global hydrogen consumption will then total 3.2 trillion Nm^3, of which 90% will be used by the power generation sector.

- Major hydrogen producers and exporters will include the Middle East, North Africa, North America, Australia and Europe mainly Russia. Traditional exporters of oil, natural gas and other energy resources will be key hydrogen suppliers.

- Hydrogen lacks expansion because of the high costs for infrastructure development. If no other substitutes are found, however, hydrogen may be adopted as a low-carbon form of energy that is relatively economical. As hydrogen suppliers include North America and Australia as well as the Middle East, the adoption of hydrogen will lead to the diversification of energy supply sources.

Figure 25 | Global power generation mix

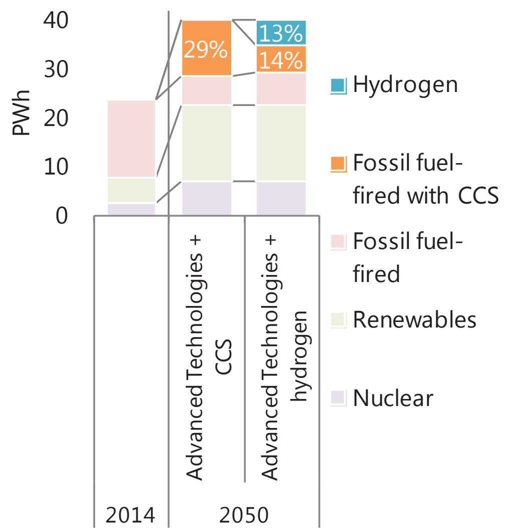
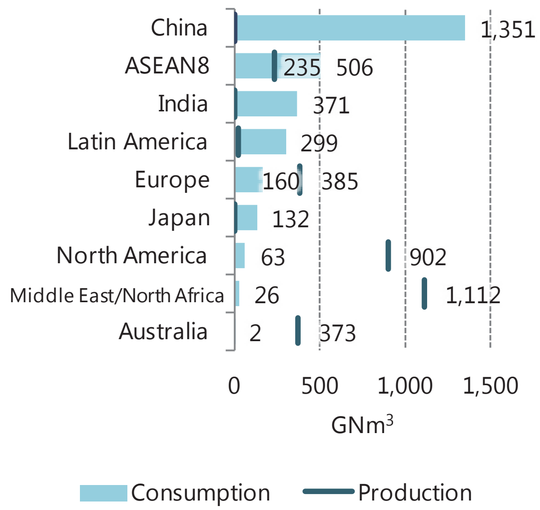


Figure 26 | Hydrogen production and consumption



Importance of nuclear for achieving the 3E's and related challenges

Improvement of safety and independence of regulators

- The Fukushima Daiichi Nuclear Power Station accident triggered by the tsunami accompanying the Great East Japan Earthquake was a common cause failure (CCF) in which an external event devastated multiple safety functions. Given that safety measures for power sources, water supply, containment facilities and other equipment

[3] *"Higher Hydrogen Scenario"* in the body of this outlook

and the preparedness against natural disasters such as tsunamis were insufficient, Japan thoroughly revised its regulatory standards. The basic policy for new regulatory standards calls for (1) spreading the idea of defence in depth, (2) enhancing reliability and (3) enhancing protection measures against CCFs caused by natural disasters. Following the development of safety measures based on the basic policy, some nuclear power plants have been recognised as in compliance with the new standards and allowed to restart.

- Western industrial countries have been enhancing their safety standards since the 1980s. Rather than being satisfied with compliance with the regulatory standards, their industry introduced voluntary efforts to improve safety beyond the standards. Nuclear business operators acknowledged that there can be no zero risk as indicated by the Three Mile Island accident. Consequently, reasonable voluntary safety improvement efforts were a natural option to realistically and rationally continue business operations. The world can learn much from such process when considering regulations.

- Because of their duties, regulators are required to be highly independent from political intentions, economic conditions as well as technical indicators. They must possess high technical capabilities to conduct strict and fair examinations. Recognising that Asian regulatory agencies are less independent than their Western counterparts, Japan and Korea have updated their respective regulatory systems since 2011 to improve the regulators' independence. However, they have a shorter history of enhanced regulations than in Western countries. Regulators' high independence, transparent operations and reliable capabilities are essential conditions for maintaining high safety levels.

- High-level radioactive waste produced through nuclear power generation must be appropriately disposed. Geological disposal to bury such waste into deep underground layers and take advantage of the characteristics of rocks to contain the waste has become a common international method. In Japan, total radioactive waste disposal costs are estimated at about JPY2.8 trillion, contributing JPY40/MWh to the nuclear power generation cost. From an economical viewpoint, waste disposal should not be regarded as a huge problem impeding on nuclear power generation.

- Nevertheless, a radioactive waste disposal plan is occasionally delayed as the selection of a disposal site fails to make progress due to concern about safety among residents near candidate sites. In Sweden, where a disposal site was selected ahead of any other country in the world, negotiations with residents near the site were repeatedly conducted in accordance with the environmental and nuclear operation laws. Sweden then developed the so-called Oskarshamn Model for conducting negotiations among all stakeholders including local governments, regulators, business operators and environmental groups. Such reciprocal dialogues apparently produced successful results.

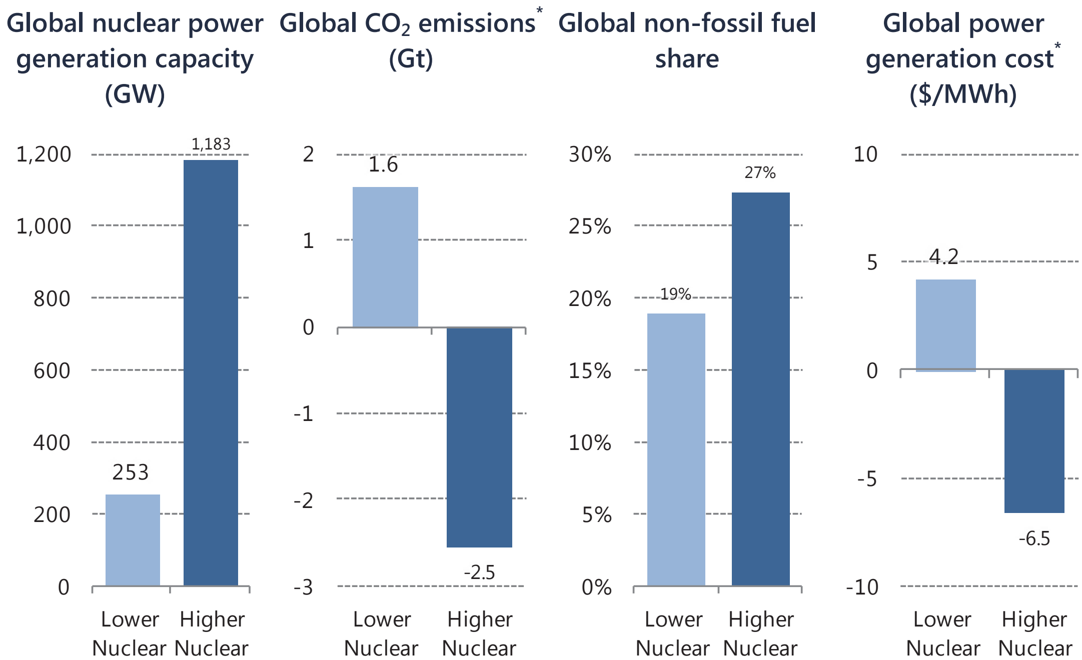
Lower and Higher Nuclear Scenarios

- Paying attention to nuclear development drivers in Asia, we have developed and analysed the implications of two scenarios. In the "*Lower Nuclear Scenario*," the negative drivers for nuclear development are stronger than in the *Reference Scenario*. In the

"*Higher Nuclear Scenario,*" the positive drivers for nuclear development are stronger than in the *Advanced Technologies Scenario*.

In the "*Higher Nuclear Scenario,*" the nuclear power generation capacity in the world in 2040 will be about 1,200 GW (a three-fold increase from 2014) including 700 GW in Asia (a seven-fold increase) and CO_2 emissions will decline by about 6% in the world and by about 9% in Asia. The Asian energy self-sufficiency rate will be about 74%, almost unchanged from 2014 (Figure 27). The unit power generation cost will be more than $9/MWh lower than in the *Reference Scenario*. Generally, this scenario will be favourable for all of the so-called 3E's – energy security, economic growth and environmental protection. A key condition for this scenario will be technology transfer from developed to developing countries. The design of safety regulation systems in emerging countries will be particularly challenging.

Figure 27 | Nuclear Scenarios [2040]



* Compared with the *Reference Scenario*

In the *Lower Nuclear Scenario* in which nuclear power generation capacity in the world in 2040 will be about 250 GW (about 60% of the 2014 level) including 60 GW in Asia (about 60%), CO_2 emissions will increase by about 4% both in the world and Asia. The Asian energy self-sufficiency rate will fall substantially to about 63% and the unit power generation cost will be almost $4/MWh higher than in the *Reference Scenario*. This scenario will thus have negative effects on all the 3E's with challenges regarding upholding safety standards and the maintenance of competent human resources in a declining nuclear industry.

Part I

World and Asia energy supply/demand outlook

1. Major assumptions

1.1 Model and scenarios

We used a quantitative analysis model with an econometric approach adopted as the core to develop an energy supply and demand outlook to quantitatively assess energy supply and demand in the world through 2040. The model, based on the energy balance table of the International Energy Agency (IEA), covers various economic indicators as well as population, vehicle fleet, materials production and other energy-related data collected for modelling. We aggregated the world into 42 regions as indicated in Figure 28, built a detailed supply and demand analysis model for each region and made the projections.

Figure 28 | Geographical coverage

We prepared the following two core scenarios for the projections.

Reference Scenario

This is the core scenario for this Outlook. For this scenario, a future outlook is developed according to the past trends as well as the energy and environment policies that have been in place so far. Only traditional and conventional policies are incorporated into this scenario. We assumed that no aggressive energy conservation or low-carbon policies deviating from the past ones will be adopted in this scenario.

Advanced Technologies Scenario

In this scenario, all countries in the world are assumed to strongly implement energy and environment policies helping to secure stable energy supply and enhancing climate change measures, with these policies' effects being successfully maximised. Specifically, our projection is based on an assumption that advanced technologies for the energy supply and demand sides as given in Figure 29 will be introduced as much as possible, with their application opportunities and acceptability taken into account.

Figure 29 | Assumptions for the Advanced Technologies Scenario

Demand side technologies	Supply side technologies
- Industry Under sectoral and other approaches, best available technologies on industrial processes (for steelmaking, cement and paper-pulp) will be deployed globally. **- Transport** Clean energy vehicles (highly fuel efficient vehicles, hybrid vehicles, plug-in hybrid vehicles, electric vehicles, fuel cell vehicles) will diffuse further. **- Buildings** Efficient electric appliances (refrigerators, TVs, etc.), highly efficient water-heating systems (heat pumps, etc.), efficient air conditioning systems and efficient lighting will diffuse further, with heat insulation enhanced.	**- Renewable energy** Wind power generation, solar photovoltaic power generation, concentrated solar power generation, biomass-fired power generation and bio-fuel will diffuse further. **- Nuclear energy promotion** Nuclear power plant construction will be accelerated with capacity factor improved. **- Highly efficient fossil fuel-fired power generation technology** Coal-fired power plants (USC, IGCC, and IGFC) and natural gas-fired MACC (More Advanced Combined Cycle) plants will diffuse further.

1.2 Major assumptions

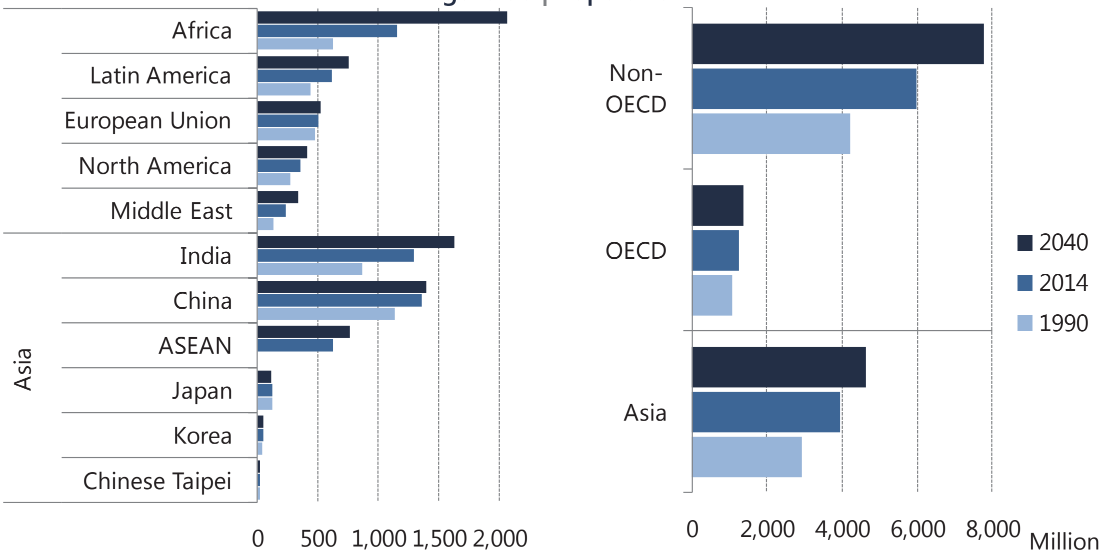
The energy supply and demand structure is subject to population, economic growth and other social and economic factors, as well as energy prices, energy utilisation technologies, and energy and environment policies. The assumptions for population, economic growth and international energy prices among these factors are common to both scenarios.

Population

In assuming population changes, we referred to the United Nations' "World Population Prospects." In many OECD countries where the total fertility rate (TFR), or the average number of children that would be born to a woman during her lifetime, has slipped below 2, downward pressure on population will increase. In non-OECD countries as well, the TFR is trending down in line with income growth and women's increasing social participation. However, their population will continue increasing as the mortality rate is declining due to developing medical technologies and improving food and sanitation conditions. Overall, global population will increase at an annual rate of around 0.9%, expanding to 9.2 billion in 2040 from 5.3 billion in 1990 and 7.2 billion in 2014 (Figure 30, Annex Table 3).

Among OECD countries, North America, particularly the United States, will post a relatively steady but moderate population increase due to a massive population influx from abroad and a high TFR. The United States' share of global population will be falling slightly. In Europe, population will decrease for Germany and Italy while increasing moderately for France and the United Kingdom. The total population of the European Union will increase very moderately. Among Asian countries, Japan has seen a population decline since 2011 and will post the fastest population fall in the world in the future. In 2015, the elderly population more than doubled the young population, indicating a further fall in the birth rate and further population aging in the future. In Korea, population will peak out in the middle of the 2030s.

Figure 30 | Population



As many non-OECD countries will see population continuing to increase, non-OECD will account for most of a global population increase through 2040. Africa is expected to post a rapid annual population increase of 2.3%, still slower than the past population explosion, as many countries in the region see continued high birth rates. Middle Eastern population will expand about 1.6-fold due to governments' financial incentives for increasing population and a growing population influx from other regions. In Asia, India will maintain a high population growth rate, with its population surpassing Chinese population in the middle of the 2020s. In 2040, India will have the world's largest population at about 1.6 billion. Population in the Association of Southeast Asian Nations (ASEAN) has far exceeded European population and will increase at a pace only second to India's. Meanwhile, China's population, now the largest in the world, will peak at 1.41 billion around 2030 and decrease by about 20 million toward 2040. China is the only country with more than 100 million elderly people aged 65 or more and will see further population aging. As the young population concentrates in urban regions, rural population aging will grow more serious. In Europe, Russia, plagued with a population fall since the collapse of the Soviet Union, will see a continuous downward trend. Population in East European countries will decline faster than in Russia.

Asia as a whole will see a continuous population increase. However, its share of global population will slowly decline. The share in 2040 will fall to 50% from 55% in 2014.

Economy

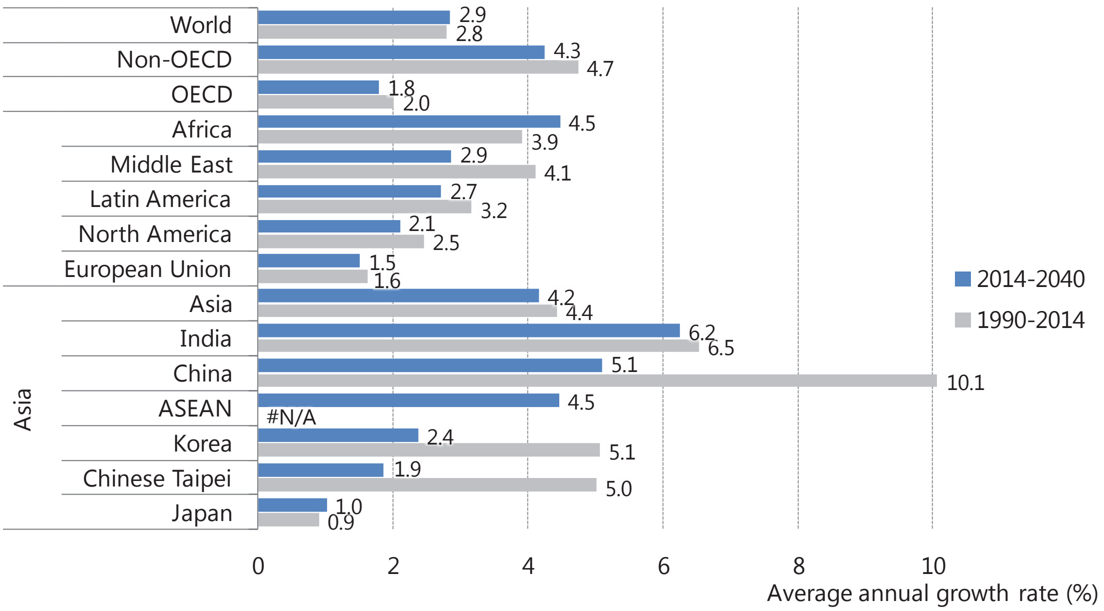
At present, the future course of the world economy is growing uncertain. In the United States, the largest economy in the world, the future is uncertain due to slumping external demand under the dollar's appreciation and presidential election chaos. However, the U.S. economy is expanding moderately thanks to robust private consumption stimulated by low crude oil prices and the falling unemployment rate. In the European economy, second to the U.S. economy, private consumption and the employment outlook have been improving thanks to low oil prices, the euro's depreciation and low interest rates. However, Europe is plagued with destabilising factors including the United Kingdom's plan to exit from the European Union, the Italian bad debt problem, an increasing refugee influx from the Middle East and growing terror threats. The Chinese economy, the third largest after the United States and Europe, has decelerated its growth to around 7% due to slowing exports under economic deterioration in Europe and resource-rich countries and slackening investment. In line with the Chinese economic deceleration, growth has slowed down in other Asian emerging economies that had expanded on the strength of rising exports to China. Particularly, Singapore, Malaysia and Thailand that feature China-bound exports' large shares of their respective total exports have been affected by the Chinese demand deceleration. As the world economy including the U.S. economy rebounds, however, Asian emerging economies will improve. Weak oil prices have exerted downward pressure on oil producing and other resource-rich countries including Russia as well as Middle Eastern and Latin American countries.

However, many economies are likely to rebound through appropriate fiscal and monetary policies and concerted international actions over a medium to long term. Among them, India will increase its presence as a new driver of global economic growth in the future. Over the outlook period, the Indian economy will grow at the world's fastest annual pace of 6.2%. Structural reform, domestic demand expansion and foreign direct investment will become the sources for economic growth. Given that India's exports to China account for only 4% of its total exports and 0.7% of its gross domestic product, India will remain unaffected by the current economic growth deceleration in China. China, even though with the current economic growth slowdown, is expected to maintain an annual economic growth rate of 5.1%. The ASEAN economy will grow at an annual rate of 4.5%.

In this way, Asia is expected to remain the centre of global economic growth. However, rising wages and citizens' growing consciousness of rights will force Asia to switch from export-oriented economic growth that takes advantage of abundant surplus labour and low costs. While the current economic growth deceleration does not necessarily indicate any limit on their growth, the current environment has changed from the past one that supported high economic growth in Asian emerging countries including China. They are required to take precautions against the so-called *middle income country trap*.

In consideration of the above-explained situation, as well as economic outlooks of the Asian Development Bank and other international organisations, and each government's economic development programs, we assumed the world's annual economic growth rate at 2.9% over the outlook period (Figure 31 and Annex Table 4).

Figure 31 | Real GDP growth



International energy prices

From the second half of 2014, economic growth deceleration in Europe and China was combined with crude oil production expansion in the United States and a decision against oil production cuts by the Organization of the Petroleum Exporting Countries (OPEC) to ease the supply-demand balance and cause a glut in the international oil market, resulting in a steep plunge in crude oil prices. In response to a later fall in the number of operating oil-drilling rigs and an oil production growth slowdown in the United States, crude oil prices rallied temporarily. Due to OPEC's decision against oil production cuts and growing expectations of Iranian crude oil export expansion following the termination of Western economic sanctions, however, the Brent crude oil futures price sank to $30.80 per barrel in January 2016. From February 2016, crude oil prices turned upward on some oil producing countries' agreement to freeze any increase in oil production. As OPEC at its extraordinary meeting in September 2016 agreed on a production cut, the price rose back to a one-year high above $53/bbl. Given scepticism about the implementation of the production cut, however, the future course of crude oil prices is uncertain.

Over a medium to long term, oil demand will continue increasing in line with firm global economic growth. While U.S. and other non-OPEC oil production will continue an upward trend on the supply side, oil importing countries will still be heavily dependent on OPEC and Russia plagued with geopolitical risks. At the same time, marginal oil production costs will rise on a shift to small and medium-sized, polar and ultra-deepwater oil fields where production costs are relatively higher. Any tough restrictions on excessive money inflow into the futures market are unlikely to be introduced, indicating that speculative investment money could push up oil prices. Given these factors, crude oil prices are expected to fluctuate wildly over a short term and gradually rise over a medium to long term. The real crude oil price (in 2015 prices) is assumed to increase to $75/bbl in 2020 and $125/bbl in 2040 (Table 2). Under an assumed annual inflation rate of 2%, the nominal price is projected to reach $83/bbl in 2020 and $205/bbl in 2040.

Table 2 | Primary energy prices

Real prices			2015	2020	2030	2040	CAGR (%) 2015/2020	2020/2030	2030/2040	2015/2040
Crude oil		$2015/bbl	52	75	100	125	7.6	2.9	2.3	3.6
Natural gas	Japan	$2015/MBtu	10.4	10.7	12.8	14.1	0.7	1.8	1.0	1.2
	Europe (UK)	$2015/MBtu	6.5	8.5	9.8	11.7	5.4	1.4	1.8	2.4
	United States	$2015/MBtu	2.6	4.5	5.6	6.3	11.4	2.2	1.2	3.6
Steam coal		$2015/t	80	89	106	132	2.2	1.8	2.3	2.1

Nominal prices			2015	2020	2030	2040	CAGR (%) 2015/2020	2020/2030	2030/2040	2015/2040
Crude oil		$/bbl	52	83	135	205	9.8	5.0	4.3	5.6
Natural gas	Japan	$/MBtu	10.4	11.8	17.2	23.1	2.7	3.8	3.0	3.3
	Europe (UK)	$/MBtu	6.5	9.4	13.2	19.2	7.5	3.5	3.8	4.4
	United States	$/MBtu	2.6	5.0	7.5	10.3	13.6	4.3	3.2	5.6
Steam coal		$/t	80	98	142	217	4.3	3.8	4.3	4.1

Note: An annual inflation rate is assumed at 2%.

Natural gas prices will remain low in the United States. In line with development and production cost hikes, however, they will rise from the current record-low levels. Japan's real natural gas price is assumed to rise from $10.4 per million British thermal units in 2015 to $14.1/MBtu toward 2040. Incoming liquefied natural gas exports from the United States will contribute to eliminating or easing the problem of the so-called Asian premium on LNG prices. Given low oil and LNG prices at present, however, the impact of the contributions may be limited. The price in Japan will still be higher than in Western countries due to certain limits on liquefaction and maritime transportation cost cuts.

Coal prices have so far been low, reflecting the loose supply-demand balance. Despite less resource constraints for coal, however, coal prices will rise due to growing Asian demand for coal for power generation and a rebound from the current low levels. Nevertheless, prices per thermal unit for coal will still be lower than those for crude oil or natural gas.

2. Energy demand

2.1 Primary energy consumption

World

Global primary energy consumption growth has decelerated in response to a slowdown in the world economy. In the *Reference Scenario* where social, economic, policy and technology introduction trends involving energy supply and demand are assumed to continue, however, global primary energy consumption will increase by 5,205 million tonnes of oil equivalent (Mtoe) from 13,699 Mtoe in 2014 to 18,904 Mtoe in 2040. The increase equals the combined current consumption of the two world's largest energy consumers, the United States and China. In the outlook period, the world economy will grow 2.1-fold with energy consumption increasing 1.4-fold, meaning that energy conservation will restrict energy consumption to a lower level than indicated by economic growth (Figure 32). This also indicates how difficult it would be to limit energy consumption while promoting economic growth even if presently anticipated national energy policies and energy-saving technologies are taken into account.

Asia, including China as well as India and the Association of Southeast Asian Nations (ASEAN), is expected to experience high economic growth and will greatly contribute to the global energy consumption increase (Figure 33). However, China that has so far driven global consumption growth will keep its share of global energy consumption unchanged from 2014. In contrast, the United States and the European Union (EU) will continue to reduce their respective shares.

Figure 32 | Global primary energy consumption and GDP energy intensity [Reference Scenario]

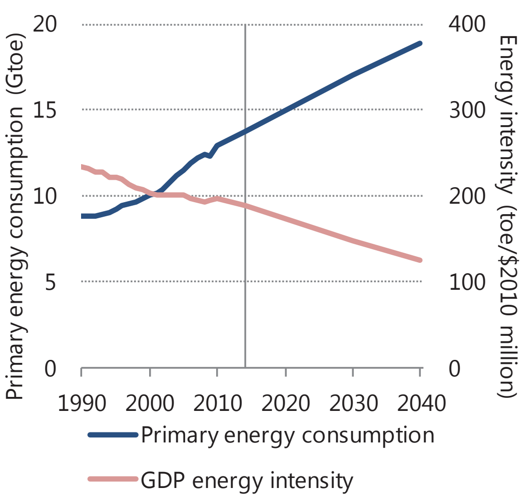
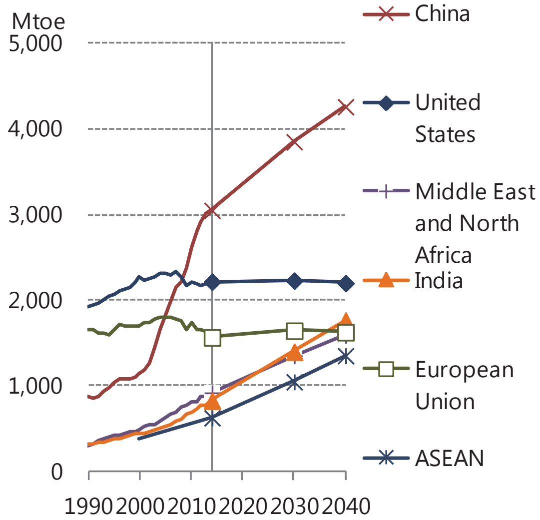


Figure 33 | Primary energy consumption for selected countries/regions [Reference Scenario]



Fossil fuels (oil, coal and natural gas) currently account for 81% of primary energy consumption and will capture about 70% of future consumption growth (Figure 34). In recent years, an increasing number of countries and regions have been introducing the development of a carbon-free society that would reduce dependence on fossil fuels to address climate change. However, even the European Union that is proactively cutting greenhouse gas emissions will depend on fossil fuels for nearly 70% of its energy requirements in 2040 (Figure 35). India and ASEAN posting remarkable economic growth will steadily increase their dependence on fossil fuels.

Figure 34 | Global primary energy consumption [Reference Scenario]

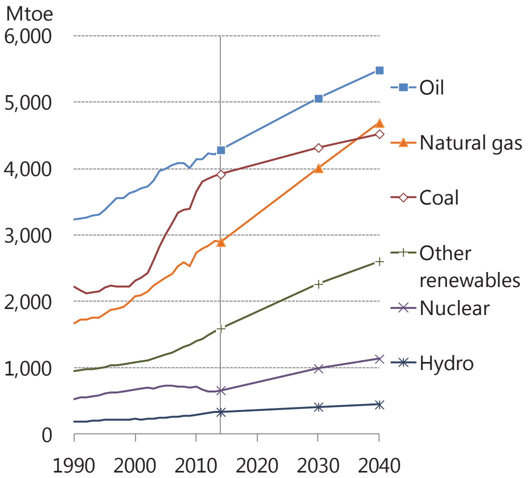
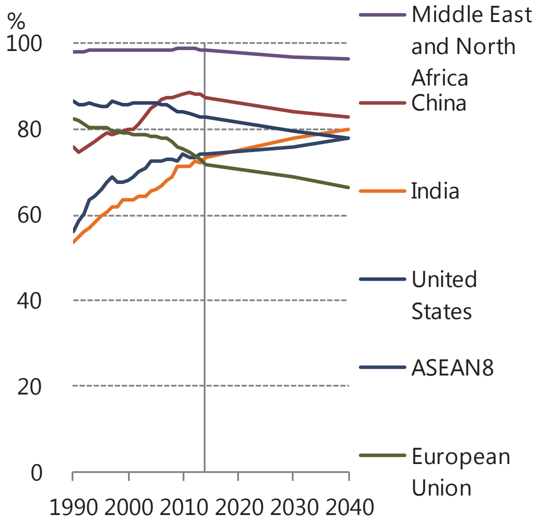
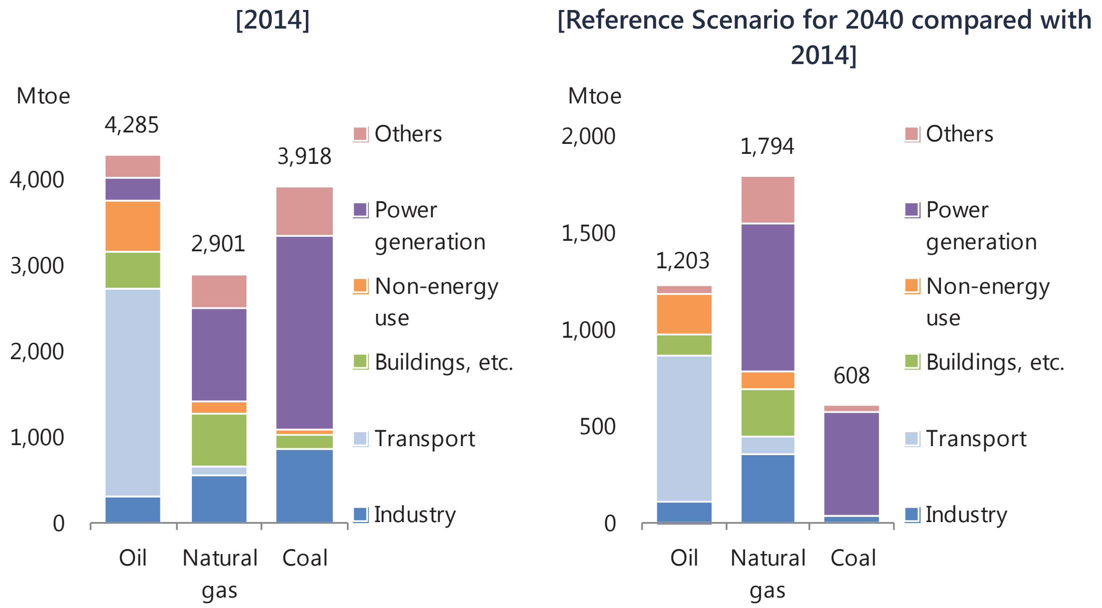


Figure 35 | Dependence on fossil fuels in selected countries/regions [Reference Scenario]



Fossil fuel consumption purposes differ from fuel to fuel (Figure 36). Particularly, oil is used differently from natural gas and coal that are used mainly for industrial and power generation purposes. Accounting for more than a half of oil consumption is the transport sector. Over the next 26 years, the transport sector will capture about two-thirds of the oil consumption increase totalling 1,203 Mtoe. It is important to consider an energy mix for the transport sector to promote oil consumption conservation.

Figure 36 | Global fossil fuel consumption

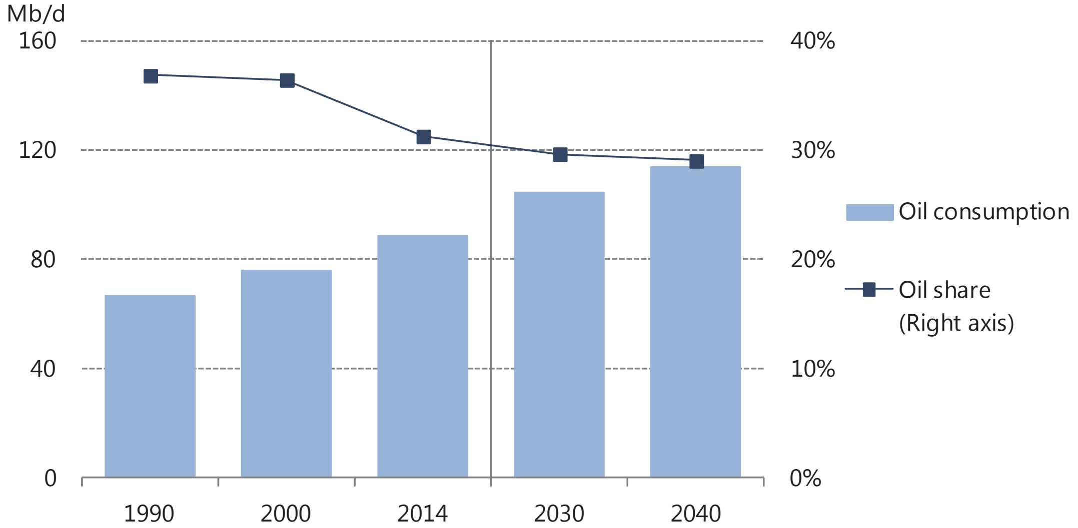


Natural gas will feature the largest consumption growth among fossil fuels over the outlook period through 2040 as consumption increases primarily in the power generation and industry sectors. Natural gas consumption will expand 1.6-fold from 2,901 Mtoe in 2014 to 4,695 Mtoe in 2040. Natural gas will increase its share of primary energy consumption from 21% in 2014 to 25% in 2040, becoming the second largest energy source after oil. Coal consumption will increase primarily in the power generation sector. As coal conservation policies make progress globally to address air pollution and climate change problems, however, coal consumption growth will be slower than the consumption growth for oil or natural gas. Coal consumption in 2040 will be limited to 4,527 Mtoe, up 1.2-fold from 3,918 Mtoe in 2014. Coal's share of primary energy supply will shrink from 29% in 2014 to 24% in 2040.

Oil

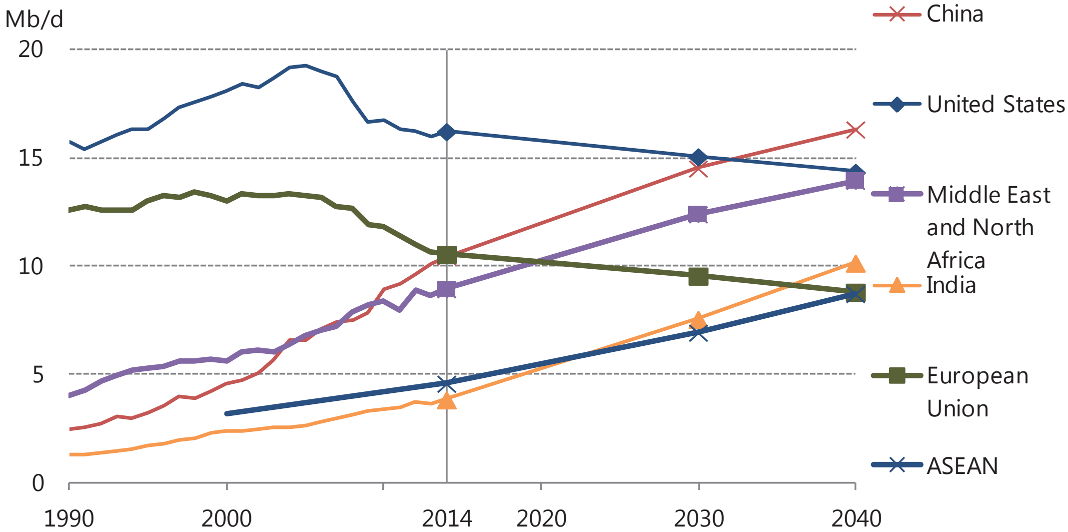
A breakdown by source of the global primary energy consumption indicates that although oil will remain the most heavily consumed energy source, its share of primary energy consumption will fall from 31% in 2014 to 29% in 2040. Oil consumption, which stood at 88.9 million barrels per day (Mb/d) in 2014, will top 100 Mb/d in some 10 years and reach 113.5 Mb/d in 2040, growing at an average annual rate of 1.0% (Figure 37). The increase of 25.0 Mb/d from 2014 to 2040 exceeds two-thirds of the current 36.7 Mb/d crude oil production from the Middle Eastern and North African OPEC members. Two-thirds of the increase (15.9 Mb/d) will be for the transport sector, which, by 2040, will account for 58% of oil consumption; petrochemical feedstocks and other non-energy use will account for 15%. Oil consumption will thus be increasingly concentrated in transport and non-energy use sectors.

Figure 37 | Global oil consumption and its share of primary energy consumption [Reference Scenario]



Non-OECD (Organisation for Economic Cooperation and Development) consumption will grow at an average annual rate of 1.8% during the outlook period through 2040 (Figure 38). Meanwhile, OECD oil consumption will decrease at an average annual rate of 0.4%. The OECD's share of oil consumption will therefore decline from 44% in 2014 to 31% in 2040.

Figure 38 | Oil consumption in selected countries/regions [Reference Scenario]



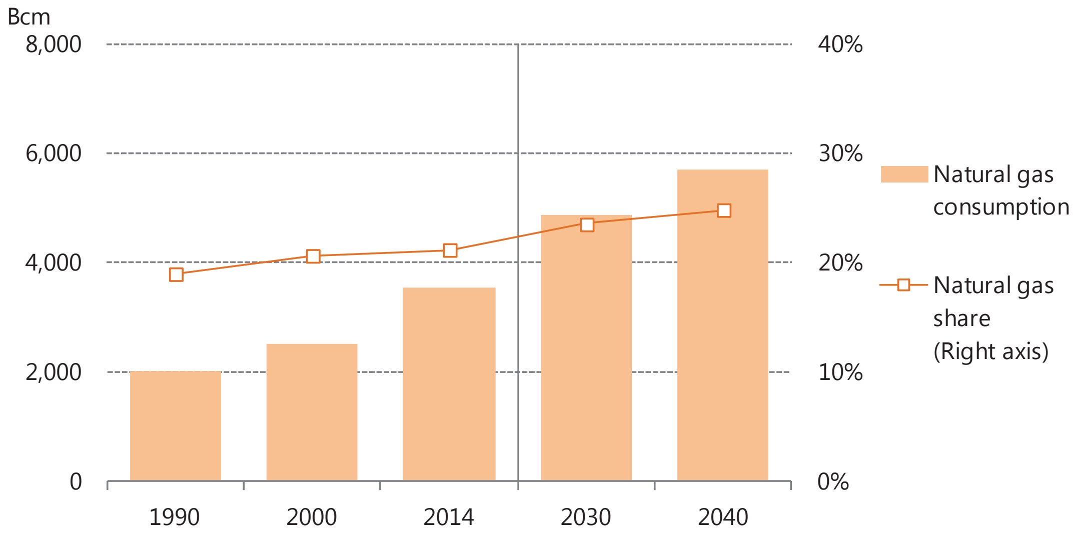
China will replace the United States as the world's largest oil consumer in the first half of the 2030s. Indian and ASEAN oil consumption will almost double from 2014 to 2040. China, India and ASEAN will expand crude oil imports in response to their domestic consumption growth (and China will soon replace the United States as the world's largest oil importer). Japan and Korea, both poor in domestic energy resources, will continue to depend on imports for energy supply. As Asia heavily depends on the Middle East for energy supply, energy security will grow even more important for Asia.

Given climate change and air pollution problems, the transport sector will need to restrict growth in oil consumption. While PM2.5 and other air pollution are growing serious in China, in some other countries such as India and Viet Nam, air pollution from automobiles and motorcycles has already become serious. The Chinese government amended the Air Pollution Control Law in January 2016 to provide for quality standards for gasoline and other fuels and require oil refiners to meet the standards. The amendment also toughened penalties on enterprises causing grave air pollution. Indonesia has enhanced regulations on exhaust gas from motorcycles. Not only fuel quality standards and exhaust gas regulations but also energy conservation in the transport sector can make great contributions to control air pollution. Energy conservation efforts in the sector may include the development of railways and other mass transit systems and the spread of next-generation automobiles. Energy conservation as well as air quality and other regulations are required to solve air pollution problems.

Natural gas

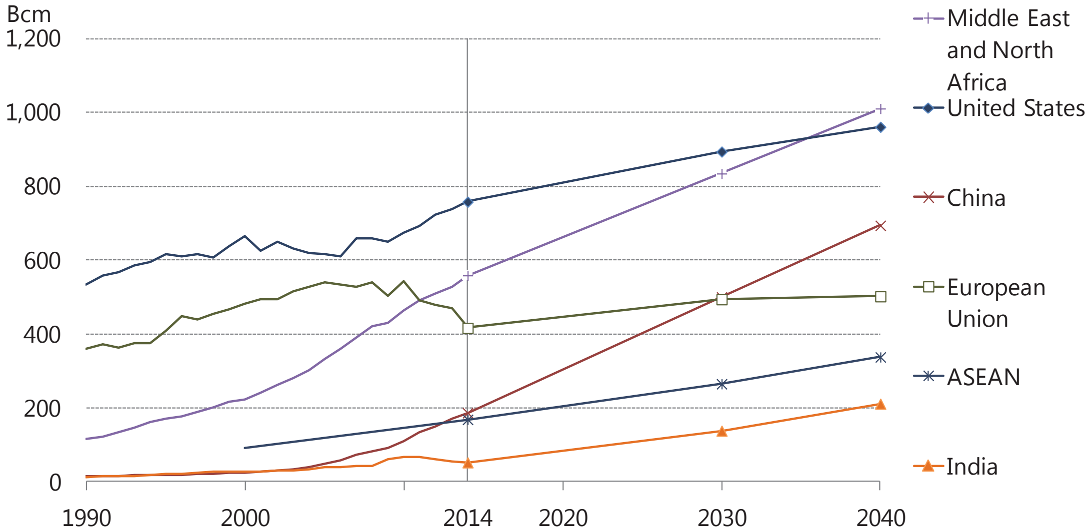
Natural gas will see the fastest expansion among energy sources through 2040 thanks mainly to the power generation sector's fuel switching to natural gas and final consumption growth. It will be increasing 1.6-fold from 3,524 billion cubic metres (Bcm) in 2014 to 5,704 Bcm in 2040 (Figure 39). Natural gas will expand its share of primary energy consumption from 21% in 2014 to 25% in 2040, becoming the second most consumed energy source after oil.

Figure 39 | Global natural gas consumption and its share of primary energy consumption [Reference Scenario]



OECD will account for only 18% of the consumption growth, while non-OECD will account for most of the rest (Figure 40). The non-OECD share of global natural gas consumption will expand from a little more than 50% to 60%.

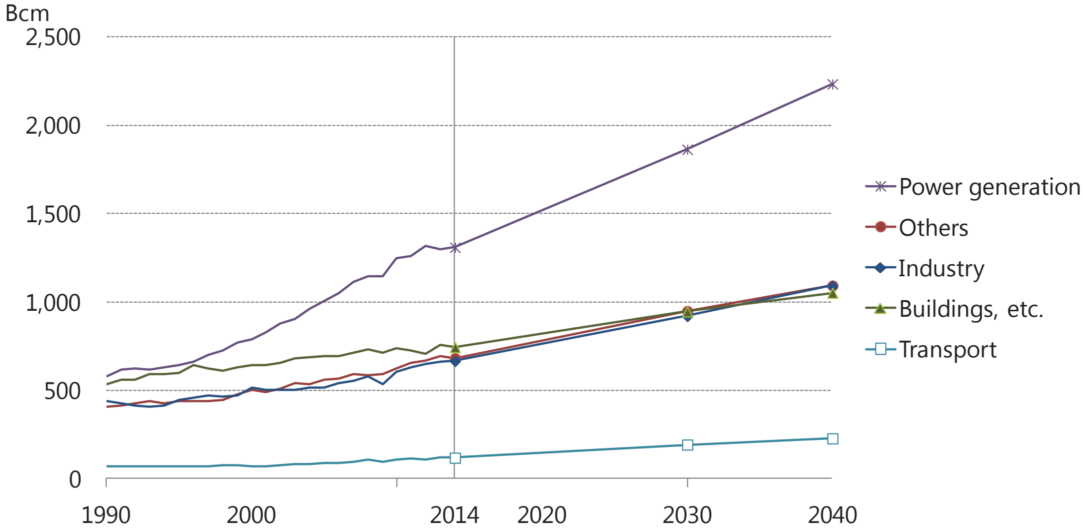
Figure 40 | Natural gas consumption by region [Reference Scenario]



Among OECD countries, the United States will significantly increase natural gas consumption. In the United States, natural gas will surpass oil consumption by the mid-2030s, making natural gas the most consumed energy source. The U.S. natural gas consumption increase in the coming 26 years will total 203 Bcm. Among non-OECD, China, India, and the Middle East and North Africa will remarkably expand natural gas consumption. China's natural gas demand will swell by 507 Bcm in the next 26 years and India's natural gas consumption will increase by 159 Bcm. The Middle East and North Africa will become the world's largest natural gas consuming region by 2040, surpassing the United States.

Among natural gas use modes, natural gas-fired combined cycle power plants will steadily increase due to technological progress, economic efficiency and environmental considerations. As a result, the power generation sector will account for half of the natural gas consumption growth. Natural gas will be growingly used for power generation as oil-fired power generation costs more and because coal poses environmental problems. Natural gas will expand its share of global power generation to 28% in 2040, becoming the second most important electricity source after coal. Natural gas consumption in the industry sector will grow faster than in the buildings sector. The buildings sector will also increase natural gas consumption as emerging countries promote urbanisation in line with high economic growth.

Figure 41 | Natural gas consumption [Reference Scenario]



Coal

Coal's consumption trend will differ from those for other fossil fuels such as oil and natural gas. As coal consumption reduction policies make further progress due to air pollution, climate change and other coal-related issues, coal will post more moderate growth than oil and natural gas. Coal's share of primary energy consumption will narrow from 29% in 2014 to 24% in 2040. Global coal consumption will increase moderately from 5,598 million tonnes of coal equivalent (Mtce[4]) in 2014 to 6,467 Mtce in 2040, with growth being limited to 20% (Figure 42). Most of the increase will be for power generation.

In OECD countries including the United States and European nations, increasing taxes on coal power plants and enhanced regulations on carbon dioxide (CO_2) and mercury emissions will force coal-fired power plants to shut down. Non-OECD will account for all of the coal consumption growth in the next 26 years, with Asia commanding 94% of the growth. India will replace the United States as the world's second largest coal consumer after China by 2020 (Figure 43).

[4] 1 Mtce = 0.7 Mtoe

Figure 42 | Global coal consumption and its share of primary energy consumption [Reference Scenario]

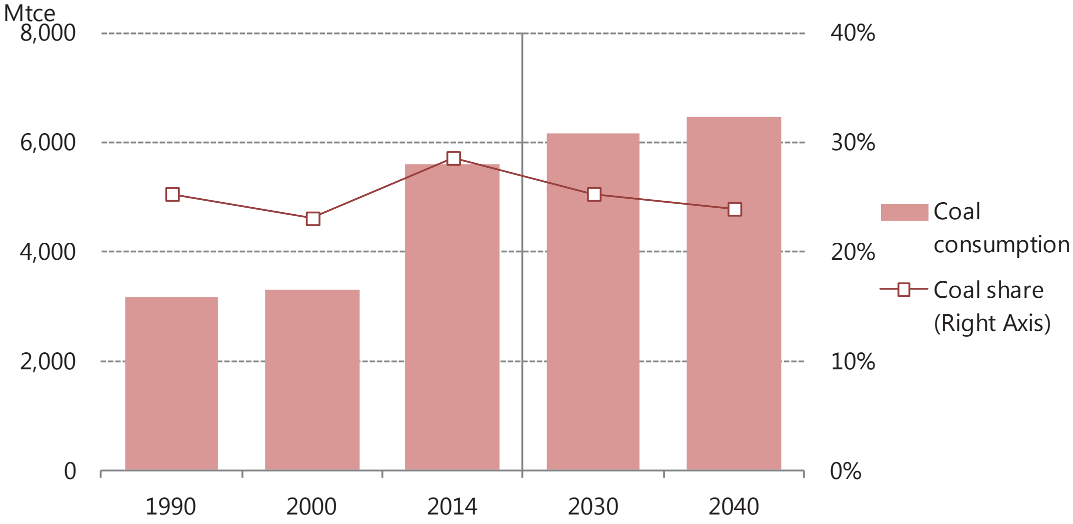
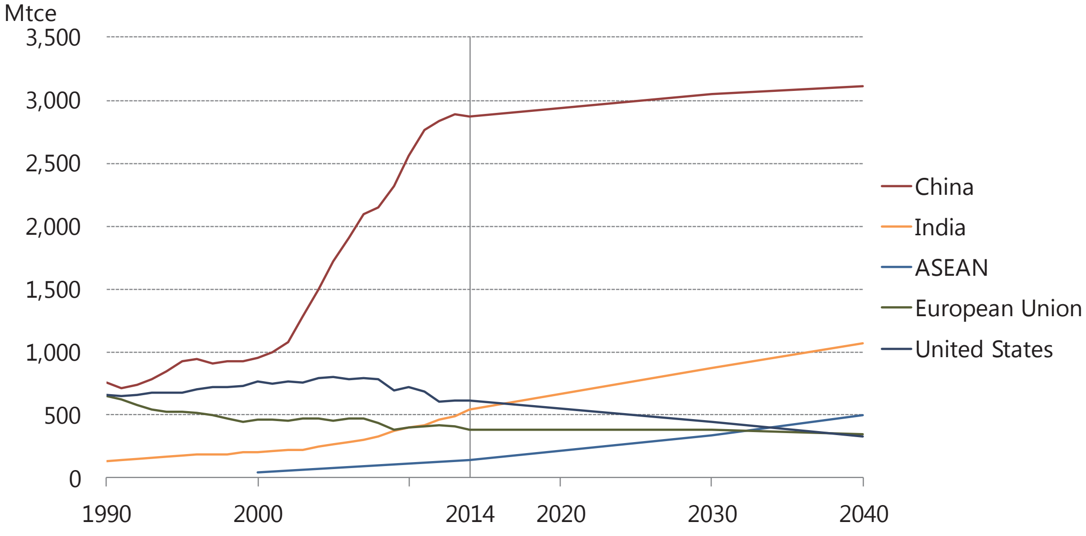
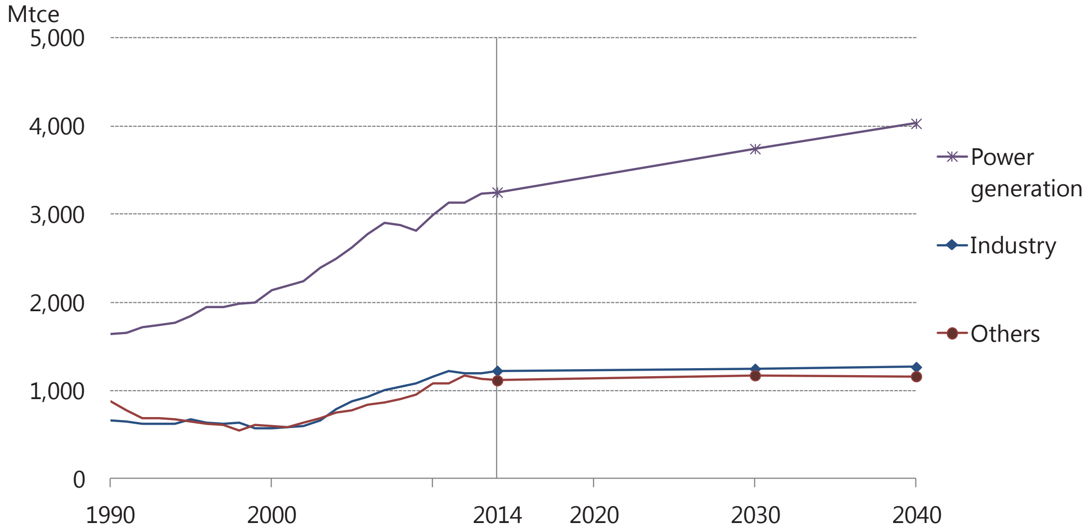


Figure 43 | Coal consumption by region [Reference Scenario]



Many areas in the world are endowed with coal resources so that coal has less supply risk than oil or natural gas resources found in a limited range of regions. Due to lower prices for coal, consumption will increase mainly in the power generation sector where fuel costs are significant for economic efficiency (Figure 44). Coal consumption for power generation will increase at an annual rate of 0.8% through 2040, posting a total rise of 1.2-fold from the present level.

Figure 44 | Global coal consumption by sector [Reference Scenario]



Non-fossil energy

Hydro, geothermal, solar, wind, biomass and other renewable energies will expand their share of primary energy consumption from 14% in 2014 to 16% in 2040. Their consumption growth through 2040 will total 1,124 Mtoe, the third largest after natural gas and oil consumption growth. While solar photovoltaics (PV) and wind power generation will diffuse further, low-cost biomass and waste consumption including fuel wood and livestock manure in developing countries will account for a large share of the total growth.

Nuclear will increase primarily in emerging countries where large amounts of electricity will be required to support economic growth. The number of countries with nuclear power generation will expand from 31 in 2014 to 41 in 2040. Nuclear's share of primary energy consumption will rise from 4.8% in 2014 to 6.0% in 2040. While some OECD countries will make progress in phasing out or reducing nuclear, nuclear's share of total OECD primary energy consumption in 2040 will stand at 10%, almost unchanged from 2014.

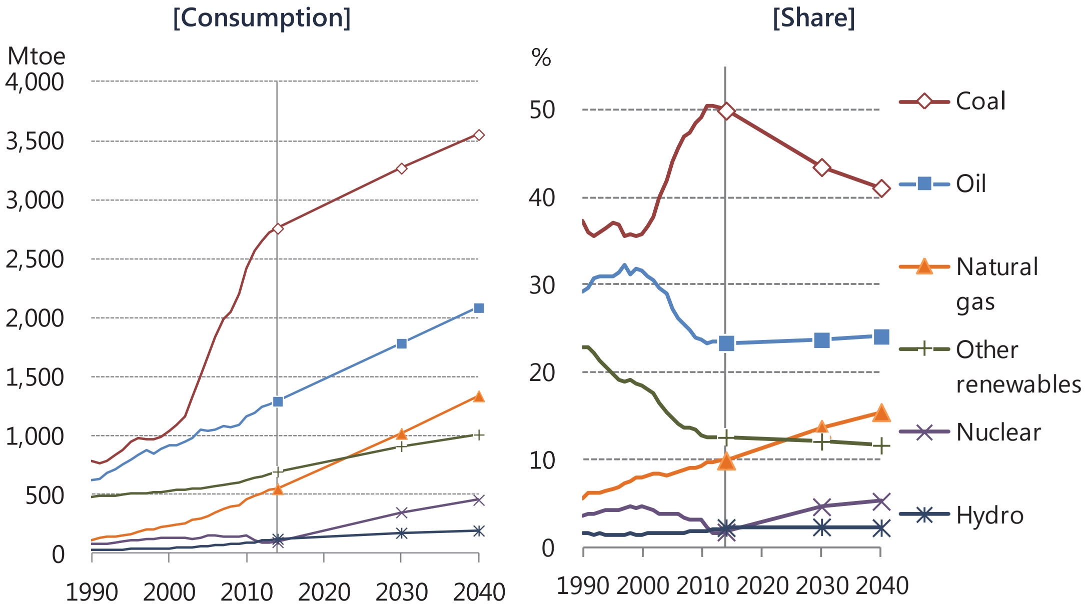
Asia

Asian primary energy consumption will grow at an annual rate of 1.7% from 5,517 Mtoe in 2014 to 8,635 Mtoe in 2040 in line with robust economic growth (Figure 45). The total growth of 3,118 Mtoe, which is equivalent to current consumption in China, will account for 60% of global energy consumption growth. Asia's share of global primary energy consumption will increase from 40% in 2014 to 46% in 2040.

Among Asian countries, China, India and ASEAN, expected to achieve high economic growth, will continue to substantially increase primary energy consumption, accounting for 92% of total Asian energy consumption growth. As a result, their combined share of Asian energy consumption will widen from 81% at present to 84% in 2040. Meanwhile, energy consumption will level off in mature Asian economies such as Japan, Korea and Chinese Taipei.

Fossil fuels account for 84% of Asian primary energy consumption at present and will cover 76% of the consumption growth during the next 26 years. Asia's share of global fossil fuel consumption will rise from 43% in 2014 to 49% in 2040.

Figure 45 | Asian primary energy consumption [Reference Scenario]



Asian oil consumption will expand from 26.8 Mb/d in 2014 to 43.3 Mb/d in 2040. The average annual growth will be 1.9%, 0.9 percentage points higher than the global growth (Figure 46). Asia will further increase its presence in the international oil market, accounting for more than 60% of global oil demand growth and expanding its share of the global market from 30% to 38%.

Asian natural gas consumption will increase 2.4-fold from 667 Bcm in 2014 to 1,625 Bcm in 2040, much faster than the global growth of 1.6-fold (Figure 47). Asia's share of global natural gas consumption will expand from 19% in 2014 to 28% in 2040 and the increase will be faster than in any other region. Many Asian countries will boost consumption, including China that alone will consume in 2040 more natural gas than the current total Asian consumption. Indian natural gas consumption, though declining after peaking in 2011, will increase mainly for power generation and fertilisers in the future. To help ease air pollution, India has been promoting natural gas for mass transit systems. Meanwhile, Japan and Korea, now major LNG importers, will limit natural gas consumption growth to low levels due to economic maturation and the promotion of non-fossil fuels.

Global LNG trade will expand from 245 Mt in 2015 to 547 Mt in 2040, of which exports to Asia will account for more than 70%. In the future, sales promotion in the Asian natural gas market will grow more active. Russia and many other countries rich with natural gas resources are paying special attention to Asia. Asian countries will have to further step up resources diplomacy and market development to prevent LNG contracts that are disadvantageous for them in pricing. They will also have to enhance emergency response arrangements including natural gas stockpiling and the installation of pipelines for inter-regional distribution or supply in emergency.

Figure 46 | Asian oil consumption [Reference Scenario]

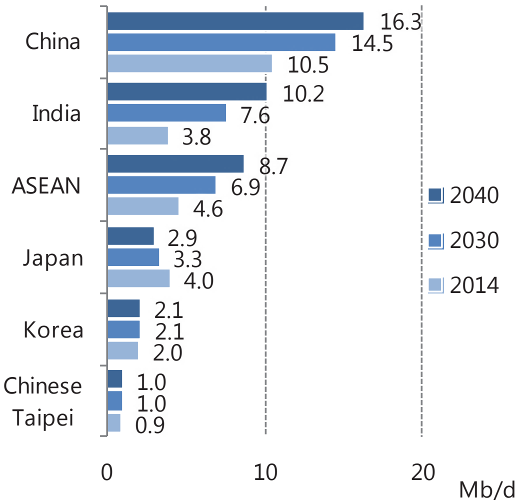
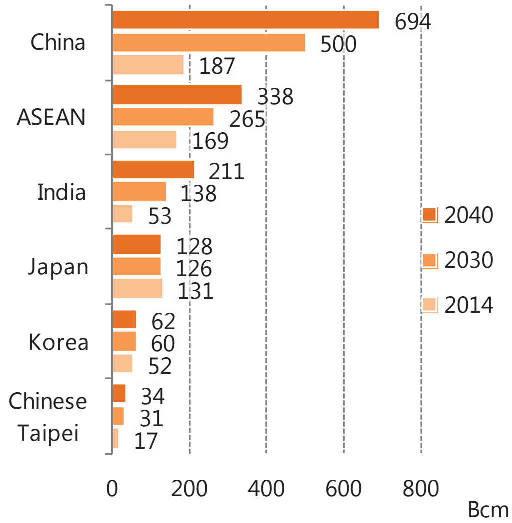


Figure 47 | Asian natural gas consumption [Reference Scenario]



Coal consumption in Asia will rise from 3,940 Mtce in 2014 to 5,075 Mtce in 2040 in contrast to a decline in the rest of the world. Although coal's share of primary energy consumption will shrink from 50% in 2014 to 41% in 2040, coal will remain the largest energy source in Asia. While China will decelerate its coal consumption growth, India and ASEAN will boost coal consumption primarily in the power generation sector. China, India and ASEAN will maintain their combined share of Asian coal consumption at 90% through 2040.

In the future, Asia will need to give more consideration to environmental protection and air pollution in constructing and expanding coal-fired power plants. In an initial effort to do so, China has shut down many of the less efficient small coal-fired power plants. India established emission standards for sulphur dioxide (SO_2), nitrogen oxide (NO_x) and some other pollutants in addition to smoke dust, in December 2015. It is enhancing regulations on emissions from coal-fired power plants.

Asian renewable energy consumption will increase from 897 Mtoe in 2014 to 1,203 Mtoe in 2040. Asia, which has great potential to expand renewable energy consumption, will raise its share of global renewable energy consumption including hydro, geothermal, solar, wind and other energy, excluding biomass and waste, from 40% in 2014 to 48% in 2040. China will capture more than half of the Asian renewable energy consumption.

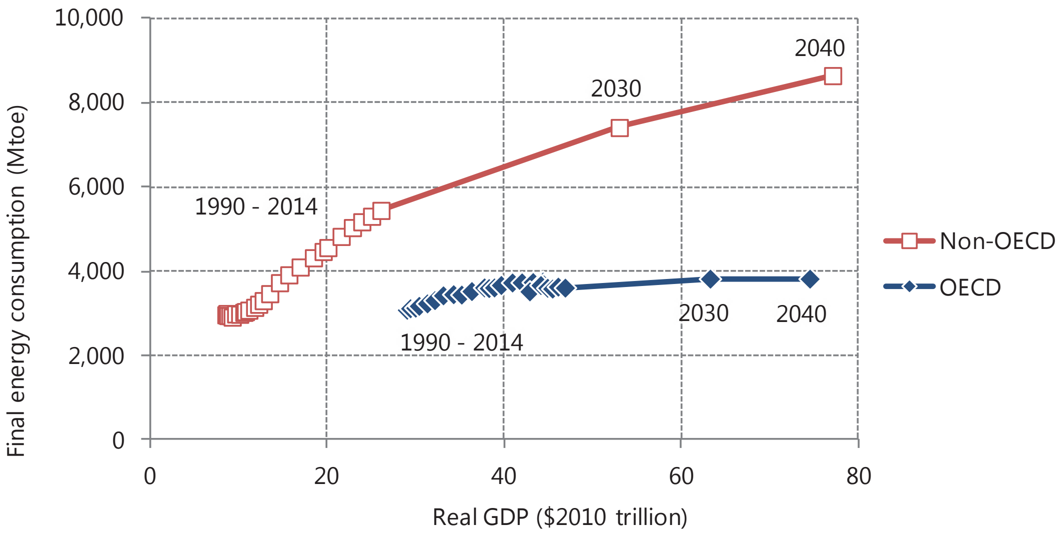
Asian nuclear power generation will increase from 373 TWh in 2014 to 1,748 TWh in 2040 raising its share of primary energy consumption from 1.8% in 2014 to 5.3% in 2040. Asia, including China and India where nuclear power generation will expand remarkably in line with sharp expansion in electricity demand, will account for 75% of global nuclear power generation growth. Asia's share of global nuclear power generation will increase from 15% in 2014 to 40% in 2040.

2.2 Final energy consumption

World

Final energy consumption in the world has grown at a slower pace than the world economy. Between 1990 and 2014, annual growth in final energy consumption came to 1.7% against the annual real GDP growth rate of 2.9%. In OECD where energy conservation has made progress, annual final energy consumption growth was limited to 0.7% against the annual real GDP growth rate of 2.0%. In non-OECD, final energy consumption growth was also slower than economic growth, but was faster than in OECD at 2.6% due mainly to the high economic growth of 4.7%, production growth in energy-intensive industries and increasing population. Final energy consumption will remain bipolarised between OECD and non-OECD. OECD final energy consumption will rise from 3,614 Mtoe in 2014 to 3,827 Mtoe in 2040 with the annual growth limited to 0.2%, while non-OECD consumption will increase at an annual rate of 1.8% from 5,447 Mtoe in 2014 to 8,645 Mtoe in 2040 (Figure 48).

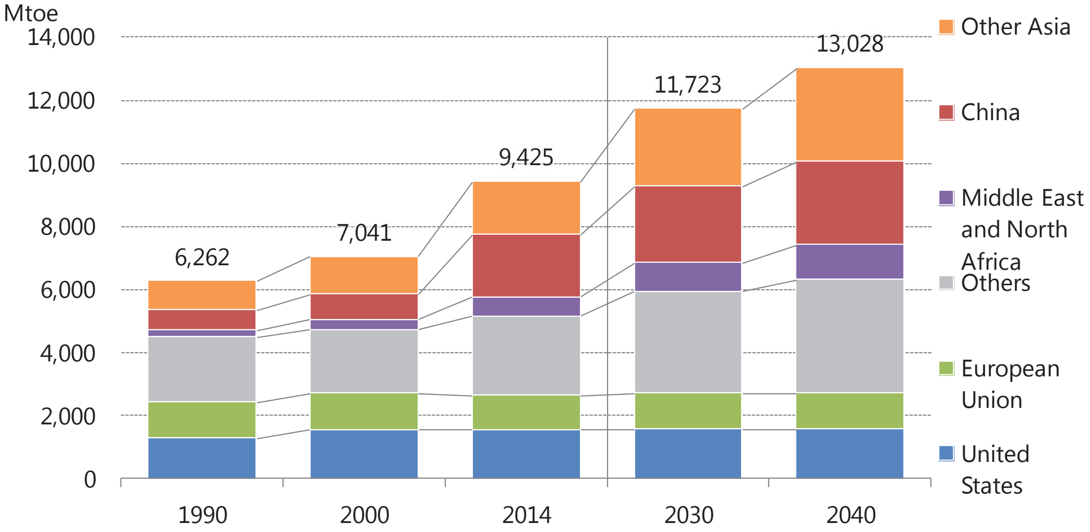
Figure 48 | GDP and final energy consumption [1990-2014, Reference Scenario for 2030 and 2040]



By region

Of the 3,603 Mtoe in global final energy consumption growth through 2040, Asia will account for 1,948 Mtoe or 54% (Figure 49). In Asia where high economic growth will continue, final energy consumption will increase at an annual rate of 1.6% from 3,677 Mtoe in 2014 to 5,625 Mtoe in 2040 due to the development of steel, chemical and other energy intensive materials industries, motorisation, progress in urbanisation and improvements in living standards. Among Asian countries, China, India and ASEAN alone will account for half of the global final energy consumption growth through 2040. Between 2014 and 2040, final energy consumption will grow by 1.1% per year or a total of 679 Mtoe in China, by 3.0% per year or a total of 654 Mtoe in India and by 2.7% per year or a total of 451 Mtoe in ASEAN.

Figure 49 | Final energy consumption by region [Reference Scenario]



In the Middle East and North Africa, final energy consumption will grow from 609 Mtoe in 2014 to 1,103 Mtoe in 2040. The annual growth rate will stand at 2.3% exceeding the Chinese rate. The region's final energy consumption growth will account for 14% of global growth. In the United States and European Union where society has matured, final energy consumption will almost level off from 1,538 Mtoe in 2014 to 1,550 Mtoe in 2040 and from 1,095 Mtoe to 1,148 Mtoe, respectively.

By sector

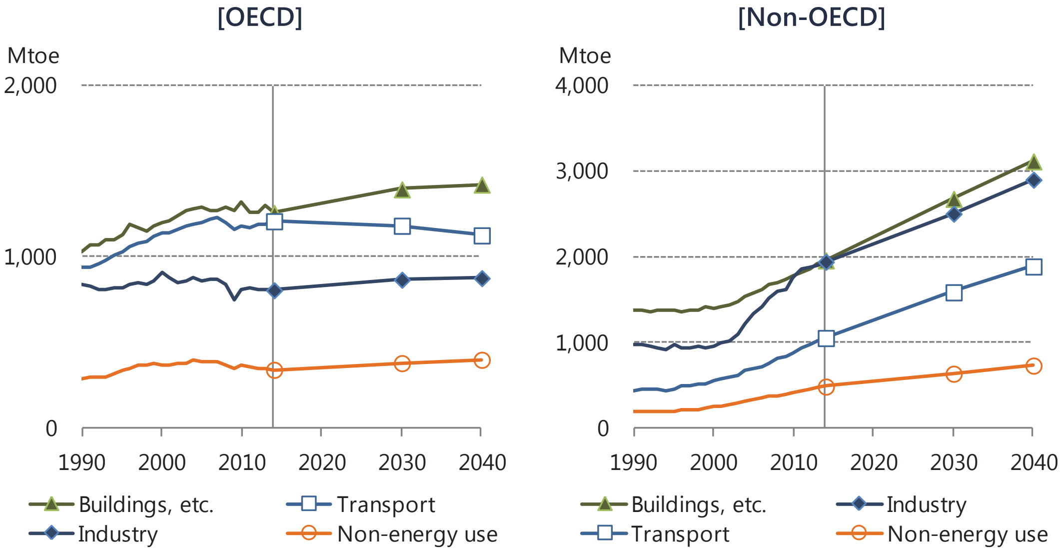
The buildings (residential and commercial) sector will account for 1,324 Mtoe or about one-third of the final energy consumption growth of 3,603 Mtoe between 2014 and 2040, followed by the industry sector with an increase of 1,030 Mtoe, the transport sector with 946 Mtoe and the non-energy use sector with 304 Mtoe. The annual growth rate will be 1.2% - 1.3% for those sectors. From 2014 to 2040, final energy consumption will level off in OECD as a slight increase in the buildings sector is offset by a fall accompanying vehicle fuel efficiency improvements in the transport sector (Figure 50). In non-OECD, final energy consumption will increase rapidly in each of the buildings, industry and transport sectors.

In the buildings sector, non-OECD Asia will post an annual final energy consumption growth rate of 1.9%, higher than in any other countries or regions, as China, India and ASEAN improve their living environments and spread electrical home appliances in line with income growth. Particularly, China will record a remarkable consumption increase of 315 Mtoe between 2014 and 2040, exceeding Japan's annual final energy consumption.

In the industry sector, energy consumption will increase from 2,751 Mtoe in 2014 to 3,781 Mtoe in 2040 as mainly non-OECD shifts from agriculture and other primary industries to manufacturing industries in line with high economic growth. Of the increase of 1,030 Mtoe, non-OECD Asia will account for 50%.

The transport sector will increase its global energy consumption at an annual rate of 1.2% as progress in motorisation in non-OECD drives the consumption growth. The global vehicle fleet will expand from 1,240 million in 2014 to 2,170 million in 2040. Non-OECD Asia will account for 54% of the global vehicle fleet expansion. The transport sector's energy consumption will decline at an annual rate of 0.3% in OECD due to vehicle fuel efficiency improvements, while increasing at an annual rate of 2.3% in non-OECD as the effects of the vehicle fleet expansion outdo fuel efficiency improvements.

Figure 50 | OECD and non-OECD final energy consumption [Reference Scenario]



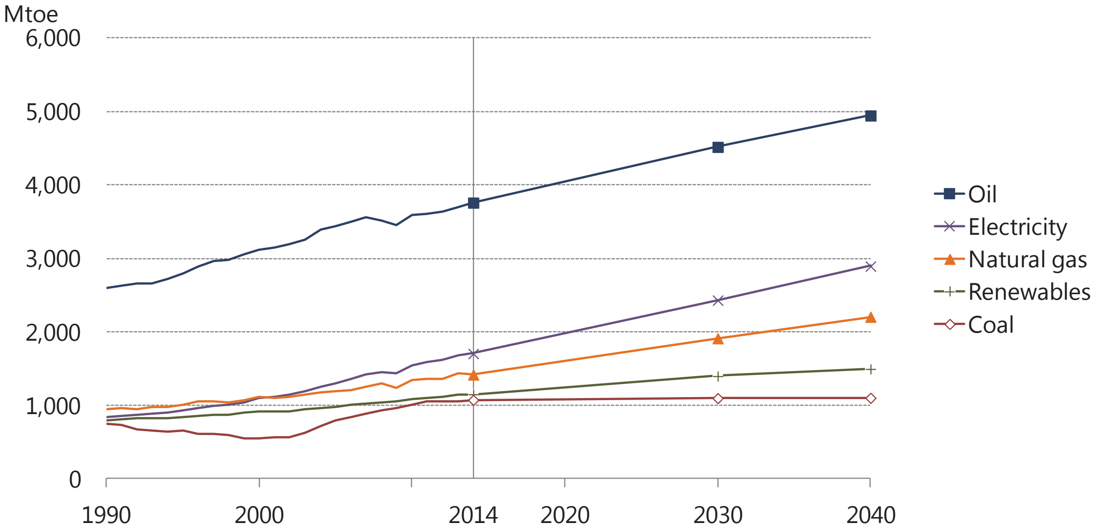
By energy source

A breakdown of final energy consumption by energy source shows that oil will score the largest consumption growth among energy sources, accounting for 33% of the final energy consumption growth. Natural gas consumption will increase both in power generation and in final energy consumption. Electricity will post the highest growth rate among major energy sources both in OECD and in non-OECD (Figure 51). Between 2014 and 2040, consumption will increase at an annual rate of 2.1% for electricity, at 1.7% for natural gas and at 1.1% for oil. Meanwhile, the annual growth rate for coal will be limited to 0.1%. The order of energy sources' shares of total energy consumption will remain unchanged in the outlook period. The share will fall slightly from 40% to 38% for oil and rise from 18% to 22% for electricity and from 15% to 17% for natural gas. Coal's share will shrink from 11% to 8%.

A major driver of oil consumption growth will be the transport sector in Asia. Mainly in China, India and other non-OECD Asia, the vehicle fleet will rapidly expand as motorisation makes progress in line with income growth. Asia will account for 66% of global oil consumption growth and increase its share of global oil consumption from 30% in 2014 to 38% in 2040. As gasoline and diesel oil consumption in the transport sector increases, oil consumption will shift to lighter petroleum products.

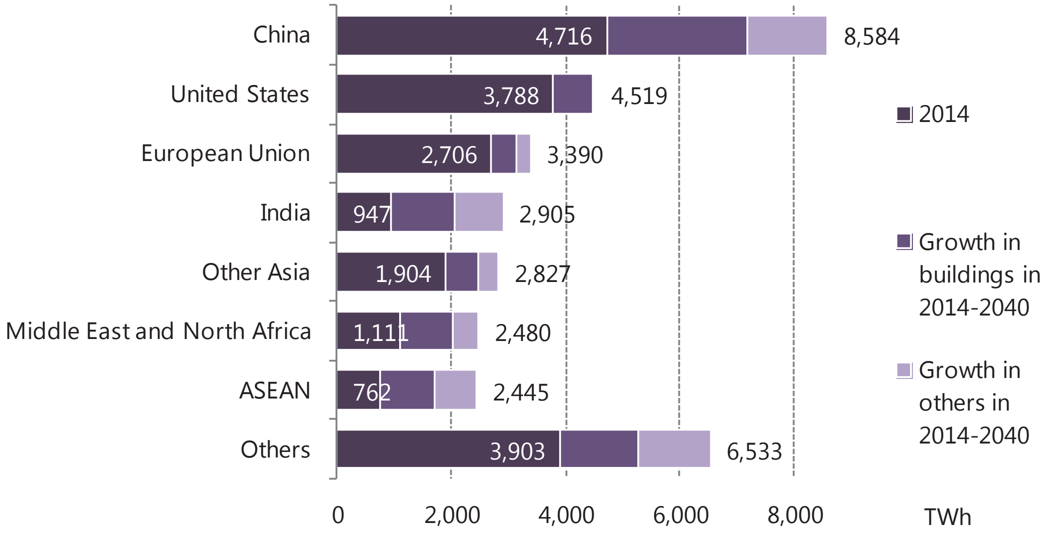
The major drivers of growth in natural gas consumption will be China's residential sector, the Latin American and the Middle Eastern industry sector. The Chinese residential sector still uses coal and biomass including firewood and will shift to city gas in consideration of health and sanitation problems. In Latin America, Brazilian and Mexican basic materials industries such as steel, chemicals and cement will switch fuels from coal and oil to natural gas. The Middle East will promote domestic natural gas utilisation while giving priority to oil exports to earn foreign currencies. They will also increase petrochemical plants using natural gas for job creation purposes.

Figure 51 | Global final energy consumption by source [Reference Scenario]



Generally, people favour more convenient electricity, in line with income growth and this trend will remain unchanged. Electricity will score the highest consumption growth rate among major energy sources both in OECD and in non-OECD. Driving electricity consumption growth will be Asia including China, India and ASEAN, as well as the Middle East and emerging economies like Brazil (Figure 52). The electricity infrastructure development in rural and urban areas and the penetration of electrical home appliances like air conditioners and televisions under growing income will induce electricity consumption growth.

Figure 52 | Final electricity consumption [Reference Scenario]



At the moment, OECD captures 47% of final electricity consumption. However, China, the world's largest electricity consumer, will expand electricity consumption by 3,868 TWh, an amount that exceeds the present consumption of the United States, the second largest electricity consumer. India's electricity consumption will rise at an annual rate of 4.4%, reaching 2,905 TWh in 2040. Non-OECD will thus expand electricity consumption rapidly and substantially. As about 80% of global electricity consumption growth is generated in non-OECD, OECD's share of global consumption will decline to 35% in 2040.

3. Energy supply

3.1 Crude Oil

Supply

Table 3 shows the crude oil supply outlook for the *Reference Scenario*. In response to global oil demand growth, both OPEC and non-OPEC will expand crude oil supply. As production in North America, Europe and Eurasia peaks out around 2030, non-OPEC's share of global crude oil supply will fall from 60% in 2014 to 52% in 2040.

Through 2020, production growth in Middle Eastern OPEC members and North America will account for 90% of global production growth. Driving OPEC production growth will be Saudi Arabia boasting the largest production capacity, Iran expanding production following the termination of Western sanctions and Iraq, which has great production potential while being plagued with security issues. In North America where shale oil productivity has been improving, oil exploration and development investment will recover in line with modest crude oil price hikes. The production growth will be mainly driven by unconventional oil including shale oil and oil sand.

Table 3 | Crude oil supply [Reference Scenario]

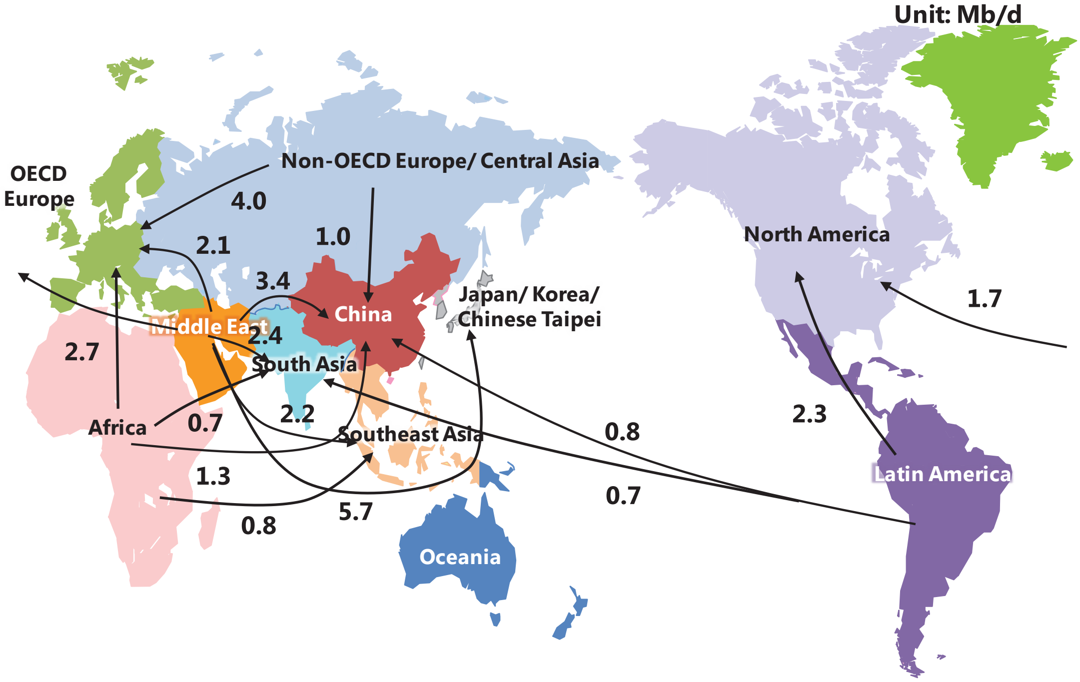
(Mb/d)

	2014	2020	2030	2040	2014-2040	
					Changes	CAGR
Total	91.04	96.34	105.17	114.03	23.00	0.9%
OPEC	36.65	39.40	45.35	51.92	15.27	1.3%
Middle East	27.22	29.00	33.51	39.15	11.92	1.4%
Others	9.43	10.40	11.84	12.77	3.34	1.2%
Non-OPEC	52.18	54.59	57.26	59.33	7.15	0.5%
North America	16.00	19.09	20.15	19.78	3.78	0.8%
Latin America	7.15	7.03	8.44	10.68	3.54	1.6%
Europe and Eurasia	17.21	17.31	17.35	17.21	0.00	0.0%
Middle East	1.33	1.44	1.57	1.71	0.37	1.0%
Africa	2.18	2.37	2.58	2.80	0.61	1.0%
Asia	8.31	7.34	7.17	7.16	-1.15	-0.6%
China	4.25	3.51	3.14	3.09	-1.16	-1.2%
Indonesia	0.85	0.81	0.76	0.66	-0.19	-1.0%
India	0.89	0.72	0.59	0.56	-0.33	-1.8%
Processing gains	2.20	2.35	2.57	2.78	0.58	0.9%

Trade

Global crude oil trade totalled 38 Mb/d in 2015 and Figure 53 indicates major crude oil trade flows for that year. Major importers are in Asia (Japan, Korea, Chinese Taipei, China, Southeast Asia and South Asia), in OECD Europe and in North America. Major suppliers are the Middle East and Africa for Asia, non-OECD Europe and Central Asia for OECD Europe, and Latin America and the Middle East for North America.

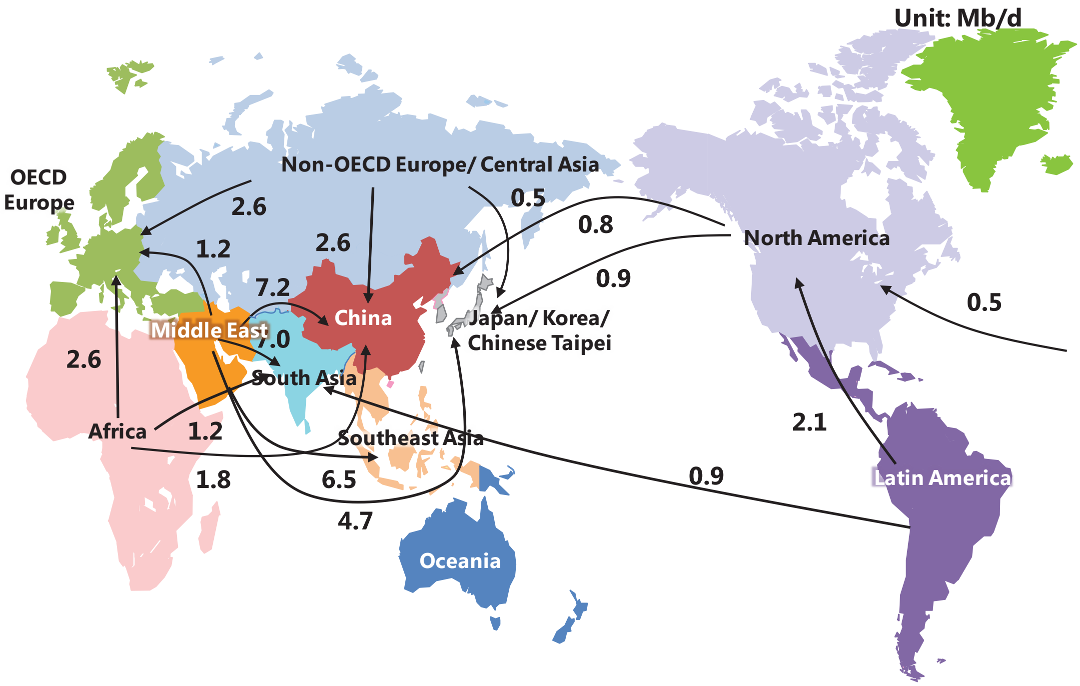
Figure 53 | Major crude oil trade flows [2015]



Crude oil trade will increase to 48 Mb/d in 2040. While OECD will reduce imports due to a demand decline and a production increase in North America, imports to meet growing demand in emerging countries such as China, India and ASEAN members will drive the growth in global trade. Figure 54 indicates major crude oil trade flows in 2040.

Asia will diversify its crude oil supply sources by importing more from North America, non-OECD Europe and Central Asia, but the Middle East and Africa will still supply 80% of the Asian crude oil requirements. Non-OECD Europe, Central Asia, Africa and the Middle East will compete for exports to Europe that will reduce imports, and will shift towards Asia with its growing demand. As North America will also reduce overall imports but maintain imports from Latin America even in 2040, the Middle East will be substantially decreasing its supply to North America.

Figure 54 | Major crude oil trade flows [Reference Scenario, 2040]



3.2 Natural gas

Production

In the *Reference Scenario*, natural gas production will grow by 63% from 2015 to 2040.

Table 4 | Natural gas production [Reference Scenario]

(Bcm)

	2015	2020	2030	2040	2015-2040	
					Changes	CAGR
World	3,497	4,039	4,875	5,700	2,202	2.0%
North America	915	1,035	1,132	1,199	284	1.1%
Latin America	205	251	375	485	280	3.5%
OECD Europe	235	227	211	203	-32	-0.6%
Non-OECD Europe/ Central Asia	809	902	1,044	1,205	396	1.6%
Russia	595	651	707	800	205	1.2%
Middle East	595	702	858	982	387	2.0%
Africa	206	247	343	444	238	3.1%
Asia	467	525	723	985	518	3.0%
China	131	180	295	412	282	4.7%
India	32	33	71	134	102	5.9%
ASEAN	217	221	260	310	93	1.4%
Oceania	65	150	189	210	145	4.8%

Although upstream oil and natural gas investment has globally declined in line with weak crude oil prices since 2014, natural gas production in North America will robustly increase thanks to production in the Marcellus Shale of the U.S. Northeast and associated gas accompanying shale oil production in Permian of the South. Canada will also expand natural gas production toward 2030, given that an LNG project on its West Coast is expected to start operation in or after 2020. In non-OECD Europe, Russia and Turkmenistan, rich with natural gas resources, are expected to expand production. Particularly, Russia will develop new gas fields in line with growing pipeline gas and LNG exports. Natural gas production in the Middle East will continue to expand, driven by the two big gas producers. Iran is expected to increase gas production following the termination of Western economic sanctions over the nuclear development problem and if new LNG projects are launched toward 2030, its natural gas production will expand even further. Saudi Arabia will give priority to domestic gas development to meet growing domestic demand. In Asia, China and India will promote domestic gas field development to meet their respective domestic energy demand growth. Particularly, China will further increase natural gas production depending on investment in shale gas development in or after 2025. In Africa, new LNG producers including Mozambique and Tanzania will drive the growth in natural gas production. Meanwhile, OECD Europe will gradually reduce domestic natural gas production due to geological limits.

Trade

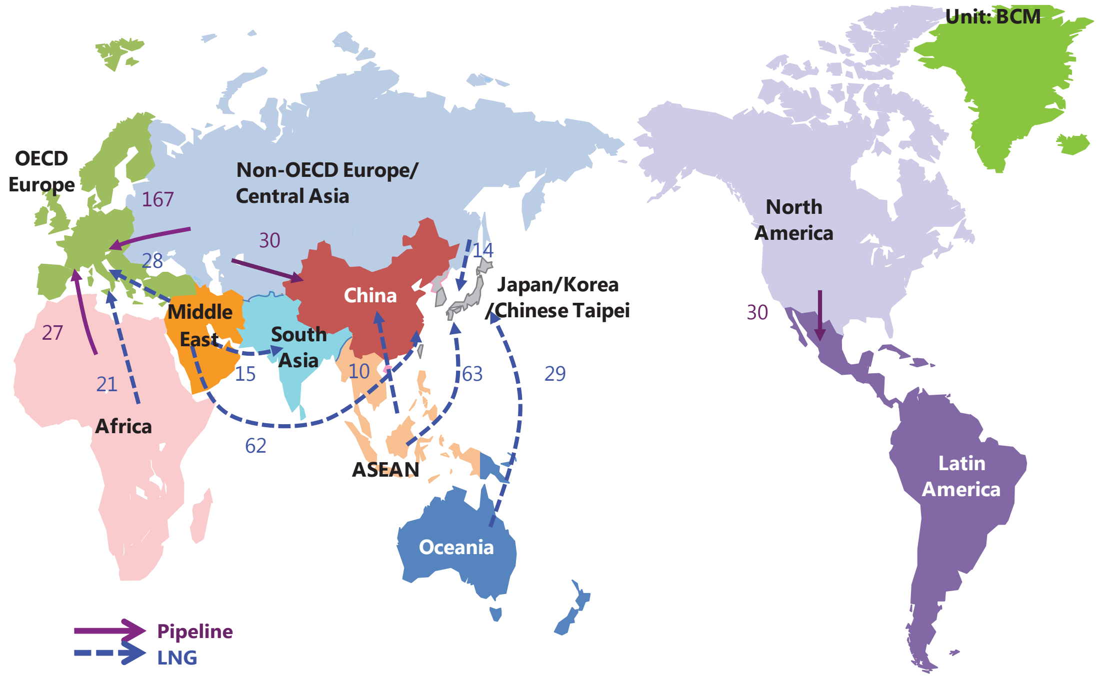
Natural gas trade between major regions in the world totalled 511 Bcm in 2015. Pipeline gas trade accounted for a half of the total, including Russian pipeline gas exports to Europe. LNG trade had been almost limited to exports from Southeast Asia to Northeast Asia including Japan and Korea. In the future, however, natural gas trade flows will be diversified and complicated due to new LNG projects in Qatar, Australia and other countries. In 2016, LNG from shale gas in the U.S. mainland began to be exported in February. LNG importers have also increased, including Jordan and Pakistan as new importers.

Natural gas trade between major regions will expand to 887 Bcm by 2040.

Through 2030, Oceania and North America will post the largest gas export growth with plans to launch many LNG projects between 2020 and 2025. Non-OECD Europe including Russia and Central Asia will remain the world’s largest exporter, expanding pipeline gas exports to China and Europe and LNG exports under Yamal and other new LNG export projects.

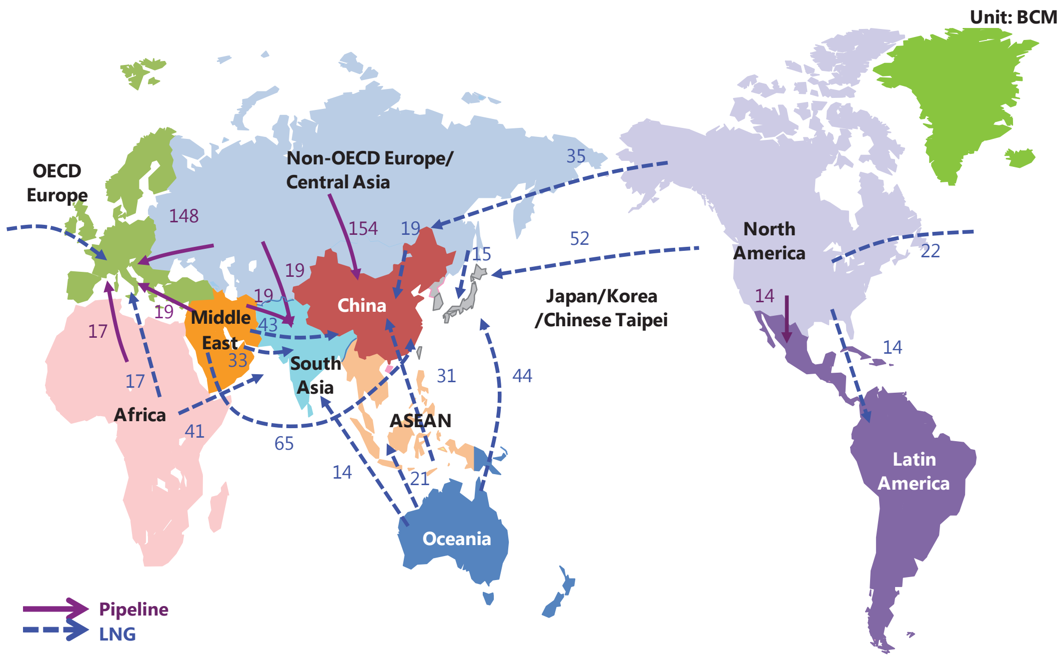
After 2030, natural gas trade growth will decelerate slightly. This is because OECD will slow down natural gas demand growth, with China and Latin America decelerating import growth by expanding domestic production of shale and other natural gas. North America, which started LNG exports in 2016, will become one of the major LNG supply sources in 2040, expanding exports to Japan, Korea, Chinese Taipei and China to 87 Bcm. As for pipeline gas trade, Russian exports to Europe will stagnate due to demand deceleration but Russian exports to China will increase robustly. By 2040, pipeline gas exports from Central Asia to South Asia and from the Middle East to South Asia now under planning could be realised.

Figure 55 | Major natural gas trade flows [2015]



Source: BP, "BP Statistical Review of World Energy"

Figure 56 | Major natural gas trade flow [Reference Scenario, 2040]

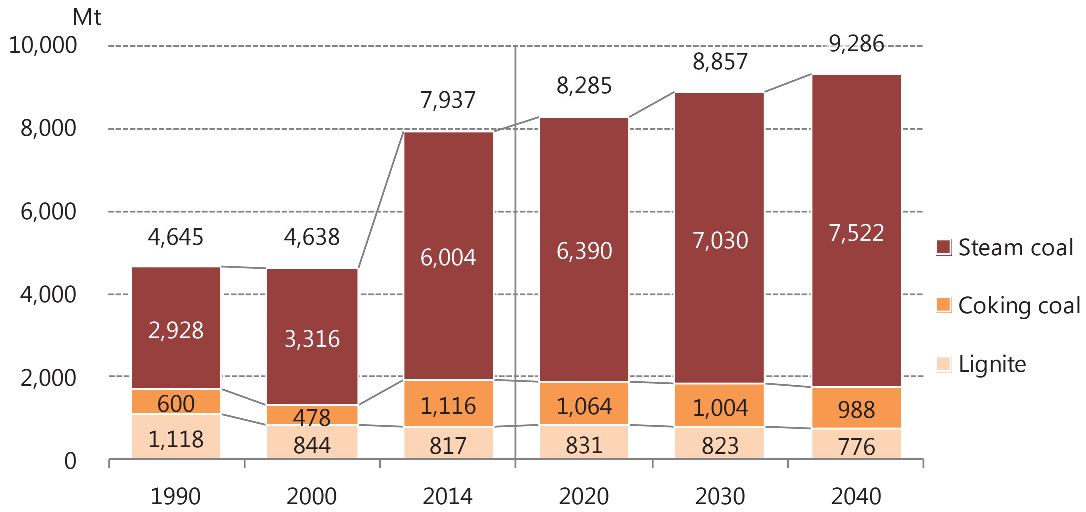


3.3 Coal

Production

Global coal production will increase from 7,937 Mt in 2014 to 9,286 Mt in 2040 as coal demand expands in non-OECD countries in Asia, Latin America, Africa and the Middle East (Figure 57). Steam coal production will rise 1.25-fold from 6,004 Mt in 2014 to 7,522 Mt in 2040 due to growing demand for power generation, while coking coal production will decrease from 1,116 Mt in 2014 to 988 Mt in 2040 and lignite production from 817 Mt in 2013 to 776 Mt in 2040.

Figure 57 | Coal production by type [Reference Scenario]

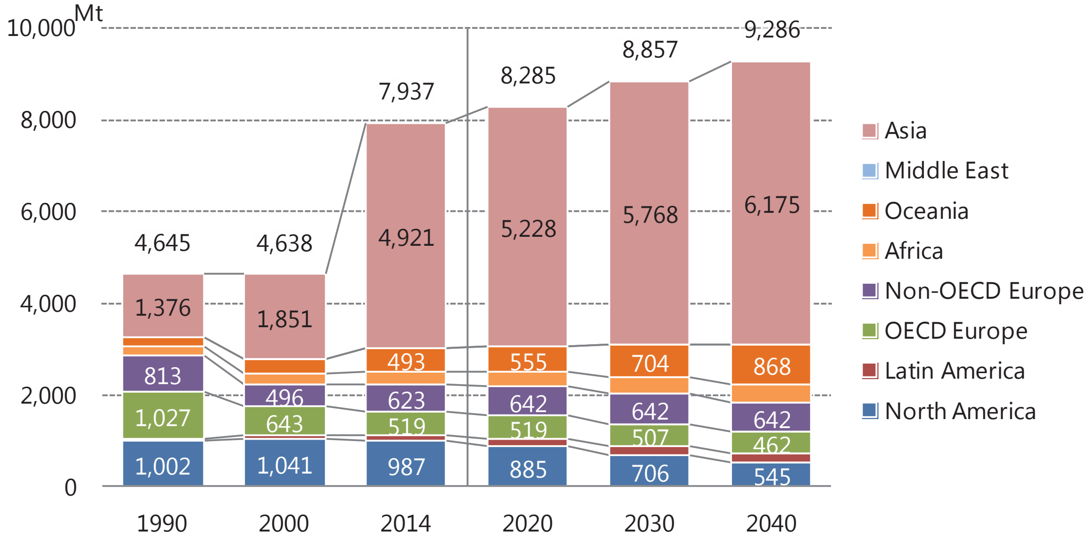


By region, coal production will increase in Asia to meet its growing coal demand and will increase in Oceania, Africa and Latin America among the major coal exporting countries. Production will decrease in North America and OECD Europe where coal demand will decline (Figure 58). Table 5 indicates steam coal production by region and Table 6 coking coal production by region.

Asian coal production will grow by 1,254 Mt from 4,921 Mt in 2014 to 6,175 Mt in 2040. In China, the world's largest coal consumer and producer, coal production has stagnated after expanding rapidly to meet fast domestic demand growth from the early 2000s. As steam coal demand increases in line with electricity demand growth, coal production will rise moderately. The growth in coal production will decelerate gradually. Meanwhile, coking coal production will trend down as demand falls in line with a decline in pig iron production. Indian steam and coking coal production will increase in conjunction with demand growth. India has abundant coal resources and has striven to expand domestic production. Given that Indian coal is high in ash content and that coal mine development and transport infrastructure construction have failed to catch up with demand growth, however, India may fail to cover all its growing demand with domestic production. Indonesia, which had substantially increased steam coal production in line with the expansion of the Asian market, is now decreasing production due to a fall in Chinese imports and slack coal prices. The

Indonesian government plans to adjust coal production to protect its resources and use them sustainably and efficiently. In the future, Indonesia's production growth will be limited to a moderate pace in line with its demand growth.

Figure 58 | Coal production by region [Reference Scenario]



North American coal production will decrease sharply from 987 Mt in 2014 to 545 Mt in 2040. U.S. production will decline substantially due to a domestic demand fall and environmental regulations on coal mining, despite demand from Latin America, Africa and Asia for steam coal exports. In Canada as well, steam coal production will drop in line with a domestic demand decline. Coking coal production has considerably decreased due to slack international prices and a fall in demand for exports. In the future, coking coal production will slightly fall, with no recovery expected in demand for exports.

In OECD Europe, both steam and coking coal production will fall due to a domestic demand decline, production cost hikes and the elimination of subsidies for the coal industry in some countries. In non-OECD Europe, coal production will almost level off as demand for exports increases despite a decline in regional demand. Russia will increase both steam and coking coal production as the Asian market expands.

In Africa, coal production will rise from 275 Mt in 2014 to 411 Mt in 2040 in line with growth in regional steam coal demand and in export demand (including Asian steam coal demand and Indian coking coal demand). In South Africa, steam coal production will increase while Mozambique will expand both coking and steam coal production.

Latin America will increase coal production due to expanding regional and export demand. Major steam coal exporter Colombia will increase production on the expansion of the Asian market as well as imports in Africa, South America and the Middle East, while its current key export destination, the European market, is shrinking.

In Oceania, Australia will substantially raise coal production in line with the expansion of the coal market, including Asia. Australian steam coal production will increase sharply from 248 Mt in 2014 to 598 Mt in 2040 to meet the expansion of the Asian market and make up for a decline in steam coal exports from Indonesia. Coking coal production will also rise in response to the expansion of imports into India.

Table 5 | Steam coal production [Reference Scenario]

(Mt)

	2014	2020	2030	2040	2014-2040	
					Changes	CAGR
World	6,004	6,390	7,030	7,522	1,518	0.9%
North America	802	723	563	420	-382	-2.5%
United States	773	700	548	410	-363	-2.4%
Latin America	107	132	152	169	62	1.8%
Colombia	84	105	120	132	49	1.8%
OECD Europe	88	92	81	73	-15	-0.7%
Non-OECD Europe/ Central Asia	328	361	370	383	56	0.6%
Russia	188	214	225	235	47	0.9%
Middle East	0	0	0	0	0	0.0%
Africa	267	300	342	378	111	1.3%
South Africa	257	288	319	341	84	1.1%
Asia	4,161	4,477	5,076	5,498	1,337	1.1%
China	3,020	3,158	3,448	3,572	551	0.6%
India	559	726	963	1,186	627	2.9%
Indonesia	484	489	542	604	120	0.9%
Oceania	250	305	445	600	350	3.4%
Australia	248	304	443	598	350	3.4%

Table 6 | Coking coal production [Reference Scenario]

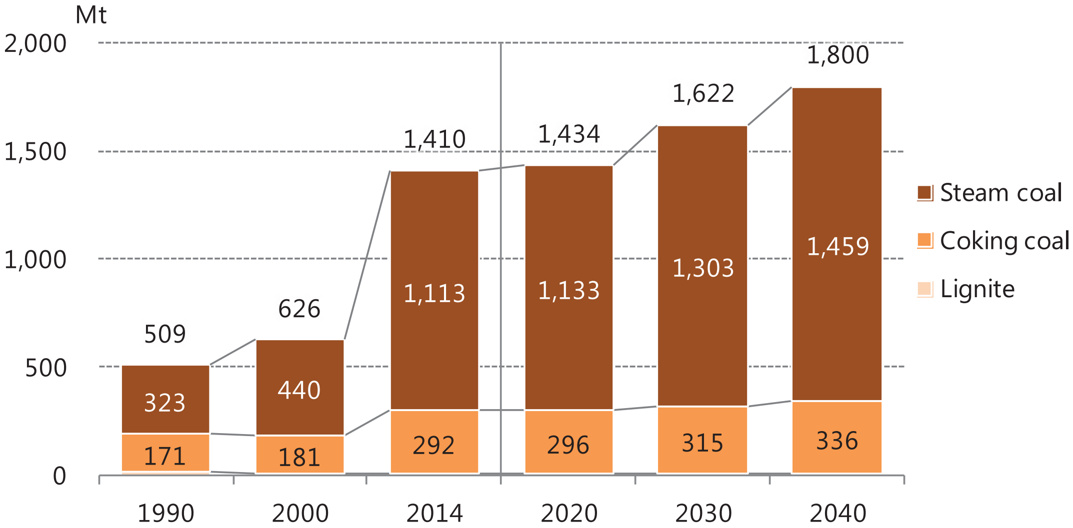
(Mt)

	2014	2020	2030	2040	2014-2040	
					Changes	CAGR
World	1,116	1,064	1,004	988	-128	-0.5%
North America	105	83	80	77	-27	-1.2%
United States	73	55	53	52	-21	-1.3%
Latin America	7	6	6	6	-1	-0.5%
Colombia	5	4	4	4	0	-0.2%
OECD Europe	23	20	17	14	-8	-1.8%
Non-OECD Europe/ Central Asia	106	96	104	107	1	0.0%
Russia	76	69	74	79	3	0.1%
Middle East	1	1	1	1	0	1.2%
Africa	8	14	24	33	25	5.8%
Mozambique	4	10	19	28	24	7.9%
Asia	686	663	581	545	-141	-0.9%
China	620	583	488	441	-179	-1.3%
India	51	64	78	87	36	2.1%
Mongolia	14	13	13	13	-3	-0.5%
Oceania	182	182	192	205	23	0.5%
Australia	180	180	190	203	23	0.5%

Trade

Coal trade (imports) will expand from 1,410 Mt in 2014 to 1,800 Mt in 2040 in line with demand growth (Figure 59). Steam coal trade will increase from 1,113 Mt in 2014 to 1,459 Mt in 2040 in response to demand growth in India and Southeast Asia. Coking coal trade will grow from 292 Mt in 2014 to 336 Mt in 2040 on increasing Indian demand.

Figure 59 | Coal trade [Reference Scenario]



Steam coal imports in Asia will increase from 791 Mt in 2014 to 1,079 Mt in 2040 in response to growing demand for coal for power generation. India and four major ASEAN countries (Malaysia, Thailand, the Philippines and Viet Nam) will substantially expand imports. Of the 287 Mt increase in Asian steam coal imports, India will account for 94 Mt and the four major ASEAN countries for 189 Mt. Steam coal imports will expand by 58 Mt from 2014 to 2040 in Latin America, by 21 Mt in the Middle East and by 11 Mt in Africa. However, OECD Europe and China will reduce imports. OECD Europe's imports fall from 220 Mt in 2014 to 196 Mt in 2040 due to a demand drop. Chinese imports, though expected to increase in conjunction with domestic demand growth, decreased substantially in 2015, resulting in the decline from 2014 to 2040.

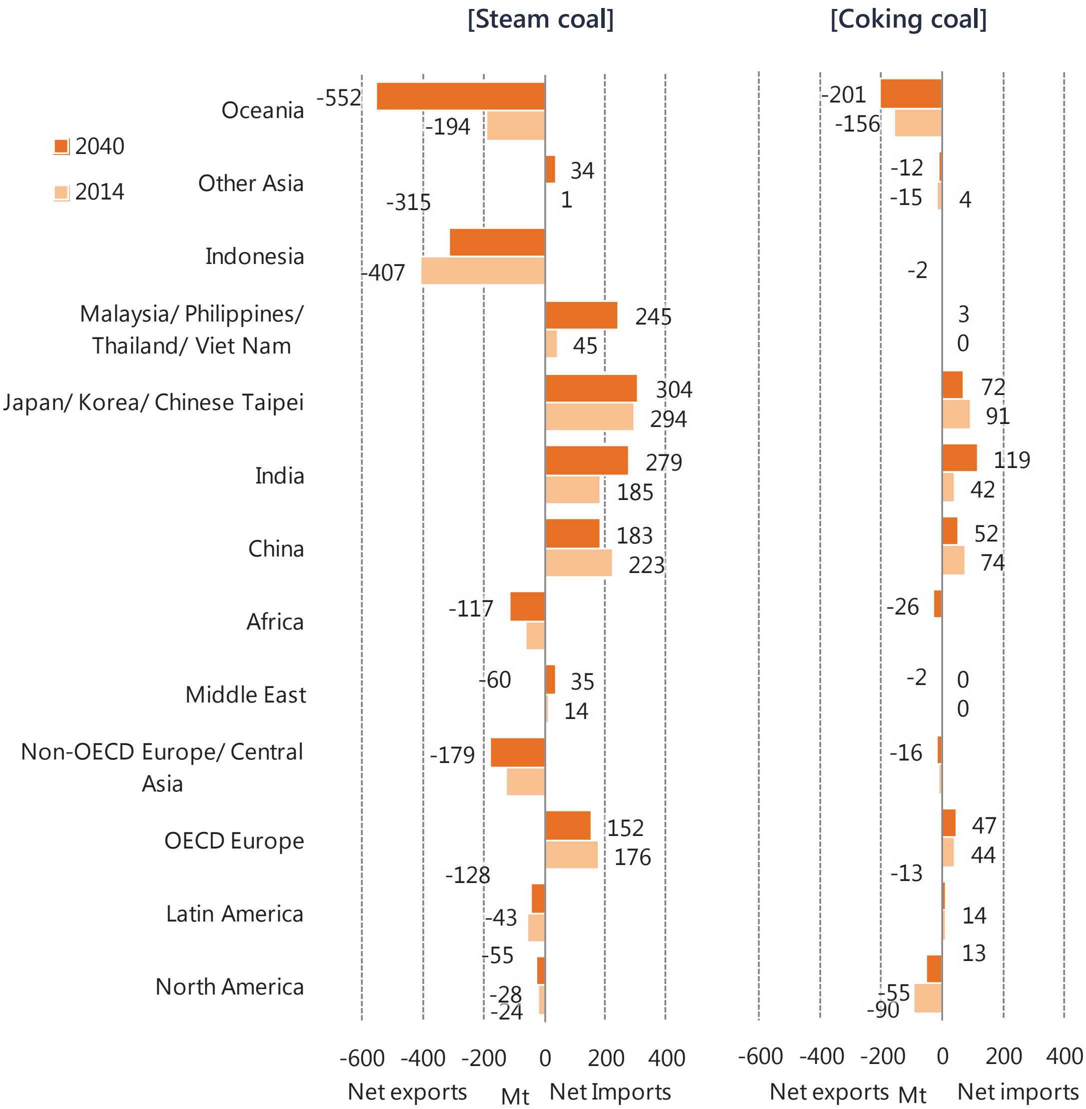
Steam coal exports will increase from Australia, South Africa, Russia and Colombia. On the other hand, Indonesia will reduce exports as production is restricted despite domestic demand growth. Australia will expand steam coal exports by as much as 358 Mt from 195 Mt in 2014 to 552 Mt in 2040 to meet the expansion of the Asian market and make up for a decline in Indonesian exports. South Africa will boost exports from 68 Mt in 2014 to 123 Mt in 2040, Russia from 132 Mt to 180 Mt and Colombia from 80 Mt to 125 Mt.

Coking coal imports will increase from 52 Mt in 2014 to 119 Mt in 2040 for India, while falling in China (down 24 Mt), Japan (down 13 Mt) and Korea (down 7 Mt) where demand will decline. Imports into OECD Europe will almost remain unchanged as the decline in demand coincides with the decrease in domestic production.

Coking coal exports will increase from Australia as well as Mozambique, a new coking coal supplier. Exports from Canada and the United States will decline as China, Japan and Korea reduce imports. Australian exports will rise from 180 Mt in 2014 to 200 Mt in 2040 and Mozambique exports from 4 Mt to 27 Mt. In contrast, U.S. exports will fall from 54 Mt in 2014 to 35 Mt in 2040 and Canadian exports from 31 Mt to 25 Mt. Russia will increase exports slightly from 21 Mt in 2014 to 24 Mt in 2040.

Figure 60 indicates net steam and coking coal exports and imports by region (by country in Asia).

Figure 60 | Net coal exports and imports [Reference Scenario]

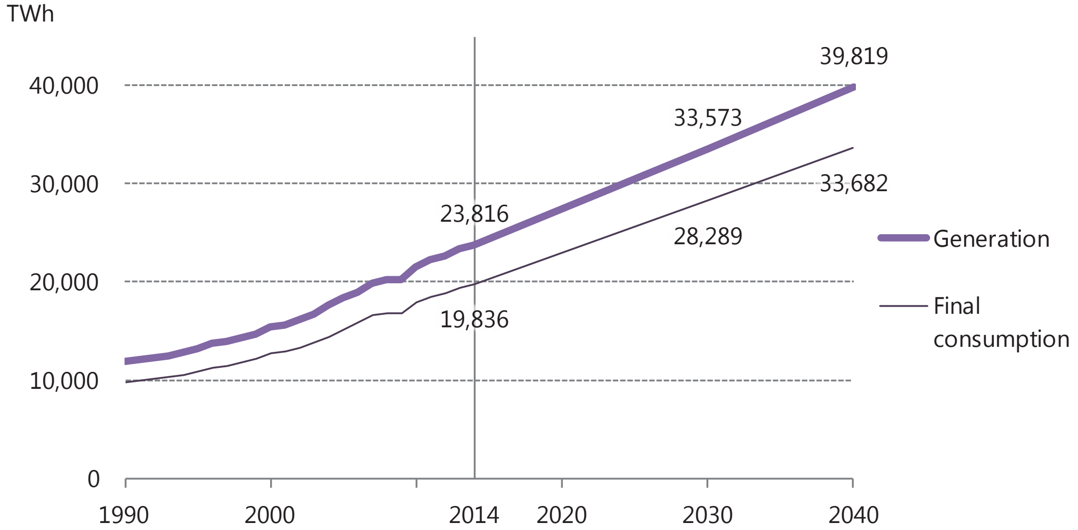


3.4 Electricity generation

Electricity generation and its mix

In line with electricity demand growth, global electricity generation will increase 1.7-fold from 23,816 terawatt-hours (TWh) in 2014 to 39,819 TWh in 2040, growing at an annual rate of 2.0% (Figure 61). The increase of 16,003 TWh is three times as large as present electricity generation in China known as the world's largest electricity generator and 15 times as large as that in Japan.

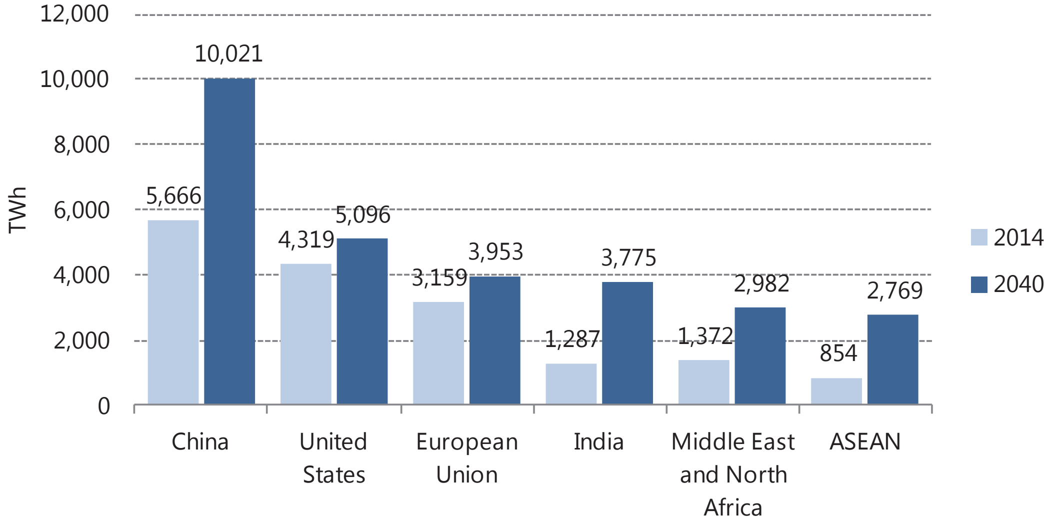
Figure 61 | Global electricity generation and final consumption [Reference Scenario]



Non-OECD will account for about 80% of the electricity generation growth through 2040 (Figure 62). Asian electricity generation will increase at an annual rate of 2.7% from 9,895 TWh in 2014 to 19,627 TWh in 2040. Driving Asian electricity generation growth will be China, India and ASEAN.

Coal accounted for the largest share of global electricity generation in 2014 at 41%, followed by 22% for natural gas, 16% for hydro and 11% for nuclear (Figure 63). Through 2040, coal's share, though declining, will remain the largest, with coal continuing to serve as a mainstay electricity source. As technological development allows combined cycle gas turbines (CCGTs) to diffuse, with gas turbines used to adjust for variable renewables power generation, a shift to natural gas for power generation will make progress. The share for natural gas will thus expand from 22% in 2014 to 28% in 2040. The share for oil will trend down in OECD as well as in the oil-rich Middle East. Nuclear power plant construction will make progress mainly in Asia as a measure to ensure energy security and mitigate climate change. However, nuclear power generation growth will fail to exceed electricity demand growth through 2040. Nuclear's share of electricity generation will thus level off from 2014 to 2040 at 11%. Wind, solar photovoltaic and other renewables power generation, excluding hydro, will expand at an unrivalled annual rate of 5.0% on the strength of policy support and cost reduction. However, renewable energy's share of electricity generation will still be limited to less than 10% in 2040.

Figure 62 | Electricity generation in selected countries/regions [Reference Scenario]



Natural gas will gradually increase its share of total power generation capacity and replace the coal share as the largest one. Renewable energy, though accounting for less than 10% of electricity generation, will expand its share of total capacity beyond 20% (Figure 64).

Figure 63 | Global electricity generation mix [Reference Scenario]

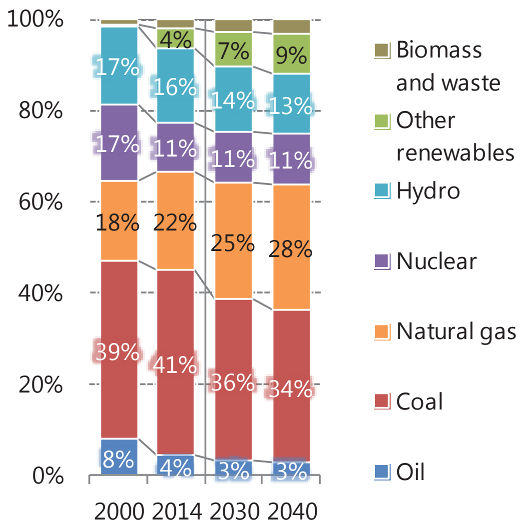
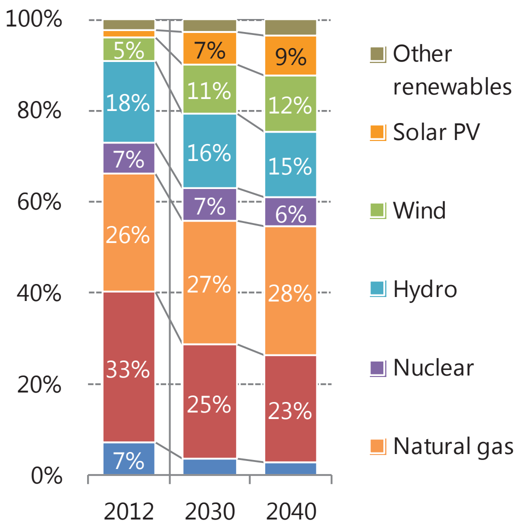
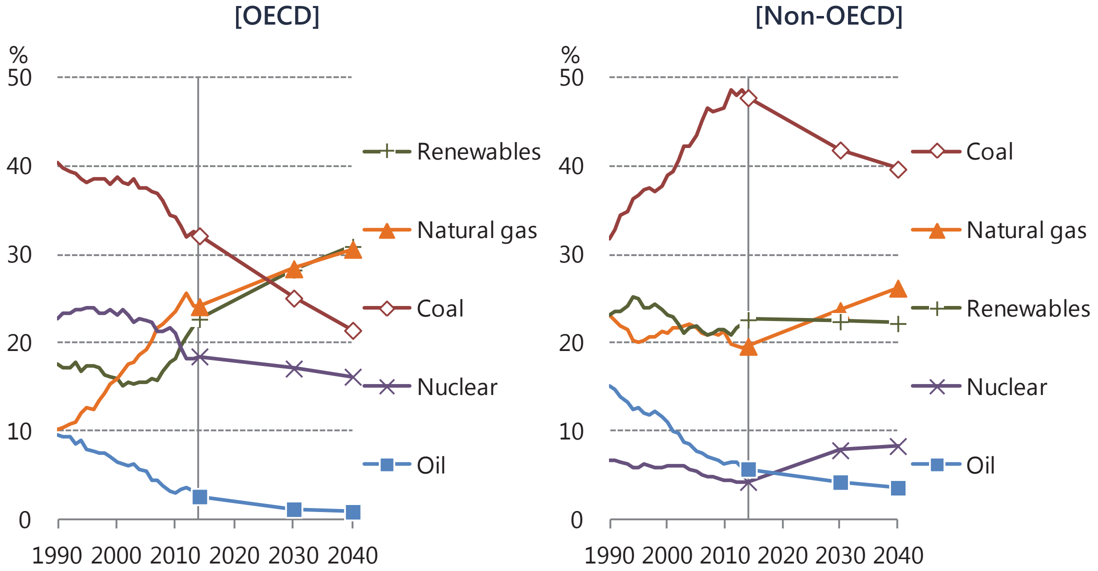


Figure 64 | Global electricity generation capacity mix [Reference Scenario]



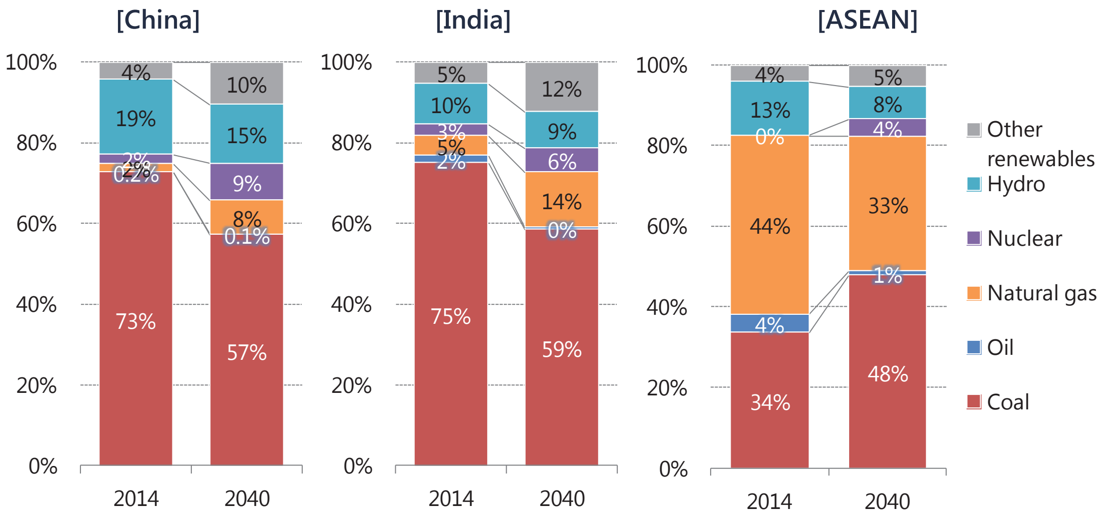
In OECD, renewable energy's share of total electricity generation in 2040 will top 30%, replacing the natural gas share as the largest one. In non-OECD, coal will retain a high share. Natural gas will expand its share to the second largest level after the coal share (Figure 65).

Figure 65 | OECD and non-OECD electricity generation mix [Reference Scenario]



Coal will remain a mainstay electricity source in Asia, including China and India despite its share trending down. In China and India, coal's share of electricity generation will gradually decline, while natural gas's share will increase (Figure 66). Meanwhile, ASEAN has made a great shift from oil to natural gas as electricity generation fuel since the 1990s due to natural gas development in the Bay of Thailand and other locations. Since natural gas production peaked out and natural gas demand emerged in other sectors than electricity generation in the 2000s, however, natural gas supply capacity for electricity generation has become short. Although ASEAN is going ahead with plans to import natural gas after being a net natural gas exporter, natural gas's share of electricity generation in ASEAN countries will decrease with the coal share expanding on the contrary to the Chinese or Indian case.

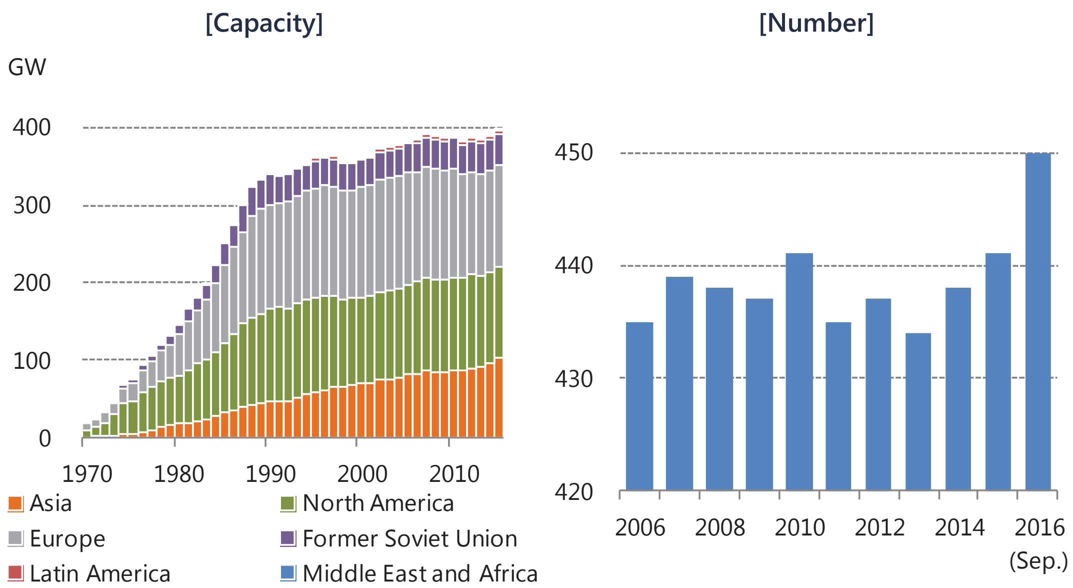
Figure 66 | Chinese, Indian and ASEAN electricity generation mix [Reference Scenario]



Nuclear

Global nuclear power generation capacity rapidly expanded mainly in Europe and the United States in the 1970s and 1980s before slowing down or levelling off in the 1990s. In the second half of the 1990s, the capacity decreased as reactors with poor performance were decommissioned in Europe and the United States. Since the 2000s, however, the capacity has steadily expanded mainly in Asia, though more slowly than in the 1970s. (Figure 67 left side).

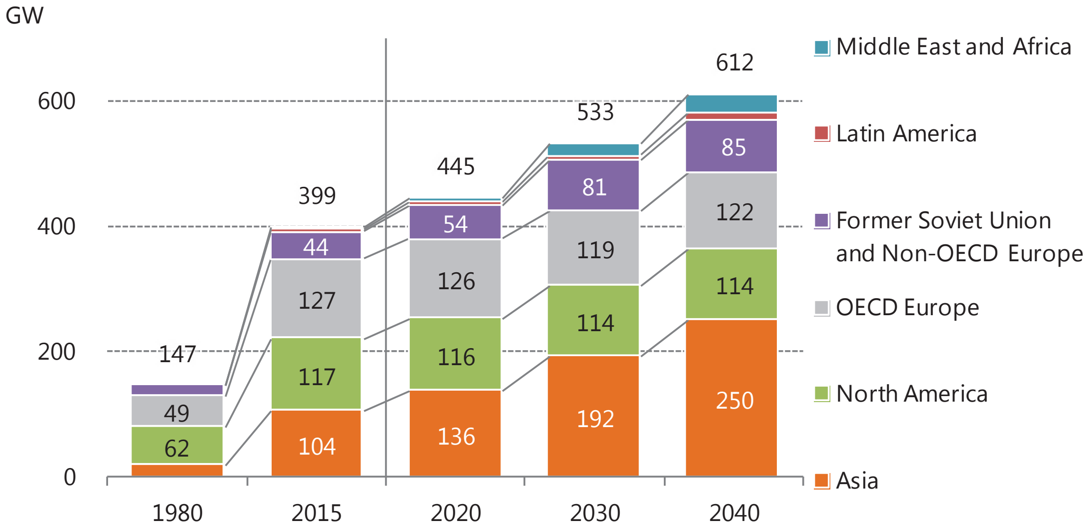
Figure 67 | Capacity and number of nuclear reactors



After the Fukushima Daiichi Nuclear Power Station accident in 2011, the number of nuclear reactors in operation in the world declined due to the temporary shutdown of reactors for the implementation of safety measures under new regulatory standards in Japan, due to the decommissioning of reactors based on a nuclear policy change in Germany and due to economic reasons in the United States. Thanks to new nuclear reactor construction mainly in Asia, however, the number of operating nuclear reactors at the end of 2015 rose back to the level before the Fukushima accident. As new reactors started operation in 2016, the number of operating reactors as of September in the world exceeded the level before the Fukushima accident to 450 (Figure 67 right side).

In the United States, the world's largest nuclear power generating country with 99 nuclear reactors, new nuclear power plant construction has slowed down as the economic advantages of natural gas-fired power generation have increased thanks to shale gas development. The country is in fact shutting down some existing reactors for economic reasons. Given fuel price fluctuation risks accompanying a shift from nuclear to natural gas, as well as climate change implications, however, the United States will retain the policy of maintaining nuclear power plants. U.S. installed capacity for nuclear power generation at 103 GW in 2014 will remain unchanged through 2040 as new reactors are constructed to offset capacity losses on the decommissioning of existing reactors (Figure 68).

Figure 68 | Nuclear electricity generation capacity by region [Reference Scenario]



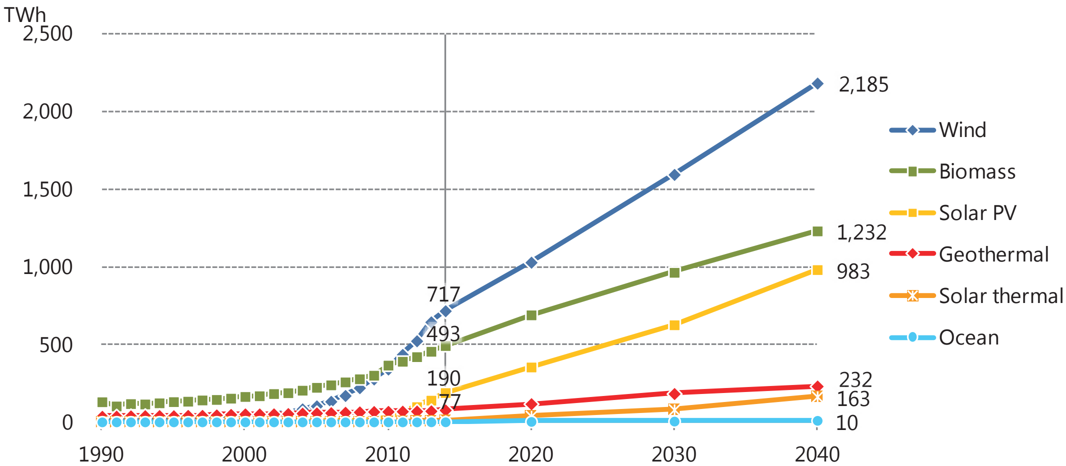
In France, known as the largest nuclear energy promoter in Europe, an energy transition law was enacted in July 2015 to reduce nuclear's share of electricity generation to 50% by 2025 (from 78% in 2015). However, as France has faced electricity rate hikes and employment problems, it released only a plan to shut down the Fessenheim Unit 1 reactor. The present situation, including installed nuclear power generation capacity at 66 GW as of 2015, will be maintained for the immediate future. Germany, Switzerland and Belgium have made clear their nuclear phase-out plans in response to the Fukushima accident and will eliminate nuclear power generation from 2025 to 2035. While outdated nuclear reactors are being decommissioned in European OECD countries, their moves to construct new reactors are also seen. Therefore, Europe's installed nuclear power generation capacity will fall to 114 GW temporarily in 2025 and rise back later. Russia has vowed to proactively use nuclear at home and abroad. Its domestic installed nuclear power generation capacity of 26 GW for 2015 will more than double to 61 GW in 2040.

The presence of Asia including China and India in nuclear power generation will increasingly be recognised. China will boost its installed nuclear power generation capacity from 29 GW in 2015 to 112 GW in 2035, replacing the United States as the largest nuclear power generator in the world. Asian installed nuclear power generation capacity will reach 250 GW in 2040, surpassing the combined OECD Europe and U.S. capacity of 236 GW. From 2030, Middle Eastern, African, Latin American and other countries, which have so far developed little nuclear power generation, will rise as nuclear power generators. The United Arab Emirates and Saudi Arabia will lead the Middle East to raise installed nuclear power generation capacity to 14 GW in 2030. South Africa and Brazil are considering and planning to introduce nuclear power generation to meet domestic electricity demand growth and will steadily construct nuclear power plants.

Renewables

Great expectations are placed on renewable energy including solar and wind energy. Renewables power generation capacity posted strong growth, while being affected by negative factors including the reduction of subsidies mainly in European OECD countries and crude oil price plunges. Despite the growth, non-hydro renewable energy-based electricity generation, which is intermittent dependent on natural conditions, falls short of becoming a mainstay electricity source rivalling fossil fuels on a global scale (Figure 69).

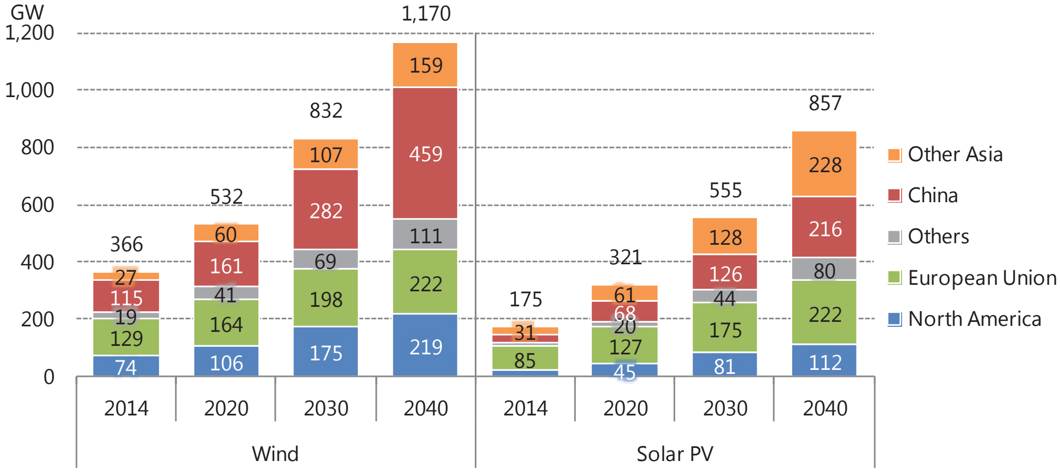
Figure 69 | Global renewables power generation except hydro [Reference Scenario]



Renewable energy penetration contributes to expanding low-carbon electricity sources, reducing dependence on energy imports and potentially holding down fossil fuel prices. Large-scale renewable energy penetration will depend on cost reduction, improved efficiency and harmonisation of renewable energy with energy systems through continuous research and development.

While Europe and North America are currently major wind power generation markets, emerging countries, at the initiative of China and India, will soon expand their capacity very rapidly. Installed wind power generation capacity in the world will more than triple from 366 GW in 2014 to 1,170 GW in 2040 (Figure 70).

Figure 70 | Global wind and solar PV electricity generation capacity [Reference Scenario]



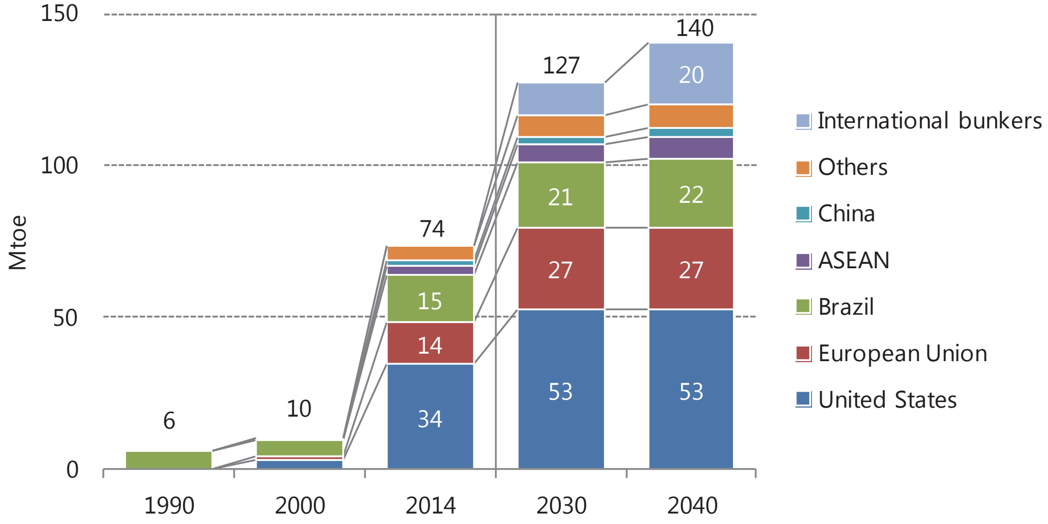
The global solar photovoltaics (PV) market will also continue expanding as the Asia Pacific region including Japan, China and the United States replaces Europe as market leader. For example, China and India have expressed ambitious solar PV power generation targets. High government targets and enhanced relevant incentives will help expand the market and reduce costs, accelerating solar PV penetration. On a global basis, solar PV power generation still costs more than traditional electricity generation technologies. In solar PV auctions in the United Arab Emirates, Chile and other countries rich with solar radiation, however, bid prices as low as less than $30/MWh have been recorded, indicating that solar PV is growing more competitive. In the *Reference Scenario*, installed solar PV power generation capacity in the world will expand some five-fold from 175 GW in 2014 to 857 GW in 2040.

3.5 Biofuels

The penetration of liquid biofuels, including bioethanol and biodiesel, has made progress as part of measures on climate change, energy security and agriculture promotion. However, biofuel consumption for automobiles remains concentrated in the United States, Brazil and the European Union, which accounted for more than 86% of biofuel consumption in 2014.

Global biofuel consumption will increase from 74 Mtoe in 2014 to 140 Mtoe in 2040 (Figure 71). In the future, biofuel consumption will continue to be concentrated in the United States, Brazil and the European Union. In the United States, biofuel consumption will slightly increase on the penetration of vehicles that can run on fuels with high bioethanol contents. In Brazil, biofuel consumption will robustly expand thanks to the spread of flexible fuel vehicles that can use both ethanol and gasoline. In the European Union, biofuel consumption will level off from 2030 as liquid fuel demand growth decelerates and concerns over first-generation biofuels' environmental impact grow. Although ASEAN, China and some other Asian countries will sharply boost biofuel consumption, Asian biofuel consumption will fall short of rivalling European, U.S. or Brazilian levels. Jet biofuel, which is used very little at present, will slowly penetrate as international aviation fuel in 2020 or later.

Figure 71 | Liquid biofuel consumption [Reference Scenario]



4. Energy supply disruption scenario

4.1 Disruption risk

Risk factors

Energy supply disruption risks always exist. The simplest example may be the oil crises in the 1970s. Supply disruptions were then combined with price hikes to inflict great damage particularly to developed economies. Energy supply disruptions still fresh in our minds came with the Great East Japan Earthquake. The earthquake destroyed energy supply infrastructure, exerting serious impacts on industry and daily life, mainly in northeast Japan. Stable supply of gasoline, city gas and electricity, we take for granted, is not necessarily guaranteed.

What factors cause supply disruptions? They are broadly divided into geopolitical risks and natural disasters/accidents/terrorism.

Table 7 | Factors causing supply disruptions

Supply disruption factors	Actual examples
Geopolitical risks	• Oil embargo on the United States and others under the first oil crisis (1973) • Iran's crude oil export ban under the second oil crisis (1978) • Kuwait's crude oil production fall amid the Gulf War (1990) • Crude oil export suspension amid the Iraq War (2003) • Suspension of natural gas supply to Ukraine (multiple times since 2006)
Natural disasters/ accidents/ terrorism	• Suspension of LNG exports from Malaysia's Tiga under fire (2003) • Oil and natural gas production declines in the Gulf of Mexico under hurricane influences (2005) • Coking coal export suspension under flood influences in Australia (2011) • Egypt-Israel natural gas pipeline explosion (2011) • Great East Japan Earthquake (2011)

First oil crisis

The first oil crisis occurred in 1973. It was a dispute over Israel between Middle Eastern countries and the United States. In reaction to the 1973 Arab-Israeli War that broke out between Israel and a coalition of Egypt and Syria, Persian Gulf members of the Organization of the Petroleum Exporting Countries (OPEC) raised crude oil prices. Furthermore, the Organization of Arab Petroleum Exporting Countries (OAPEC) gradually reduced crude oil production and decided of an oil embargo on the United States and other Israel supporters, prompting crude oil prices to quadruple from around \$3/bbl to around \$12/bbl. The price hike directly affected Japan that then depended on oil for 78% of its total primary energy supply. For example, consumers stocked up such daily use goods as toilet paper and detergents, triggering a rapid general price increase. Given the grave effects on the economy, Japan launched long-lasting efforts to reduce its dependence on oil and the Middle East and improved energy efficiency to reform its energy structure.

Suspension of natural gas supply

Natural gas supply to Ukraine was suspended multiple times since 2006, simply indicating energy transportation risks. Causing the suspension were troubles between Russia and Ukraine involving natural gas prices and payments. The suspension of Russian natural gas exports to Ukraine greatly affected not only Ukraine but also European countries located downstream of the Russia-Europe pipeline. Particularly for East European countries that heavily depend on Russian natural gas for heating, the suspension in winter was a life and death issue. The suspension has prompted Europe to revise natural gas security policies.

Terrorist attacks and accidents can also disrupt natural gas supply through international pipelines, including the explosion of the Egypt-Israel natural gas pipeline.

Japan that imports all its energy with ships is not free from risks. Sea lanes for energy transportation to Japan contain choke points such as the Hormuz and Malacca straits and are always exposed to dispute and piracy risks. To secure safety of the sea lanes, Japan maintains government-to-government talks and occasionally sends troops.

Great East Japan Earthquake

Energy supply disruptions mainly in northeast Japan through the Great East Japan Earthquake have led us to focus attention on risks that had attracted little attention in the past. In the cases of the first oil crisis and the suspension of natural gas supply to Ukraine as described above, the source of the risks came from outside the affected countries. However, the Great East Japan Earthquake indicated existing domestic risks.

Just after the earthquake, electricity and city gas supply was disrupted. In addition, road destruction affected oil supply in some regions. The earthquake led us to learn the hard way that energy supply infrastructure seen as stable can be easily threatened by natural disasters beyond human control. The event that significantly affected a number of industries and residents over a period of time has prompted Japan to enhance its domestic energy supply infrastructure.

Past energy supply disruption cases, as described above, must be viewed as nothing more than visible and nominal factors. What would have happened if Japan had imported most of its oil from other regions than the Middle East or used coal, natural gas and other energy sources in a more balanced manner before the first oil crisis? What would have happened if Japan had had sufficient oil reserves then? Probably, the impacts of oil supply disruptions occurring in the Middle East would have been less serious than those Japan actually experienced. We must thus acknowledge that there are potential factors determining the degrees of the impacts of actual events in addition to direct factors affecting energy supply.

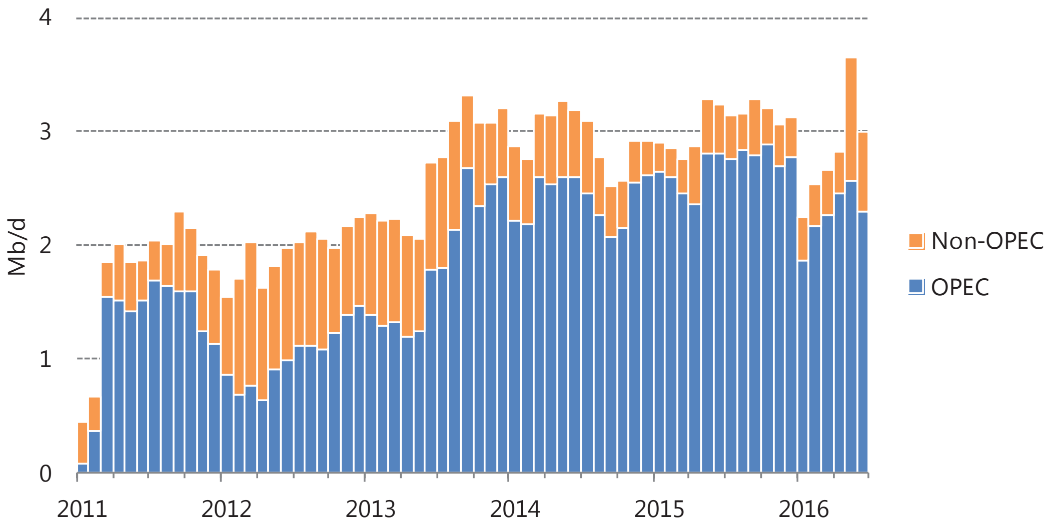
4.2 Economic impacts of supply disruptions

Crude oil supply disruptions and prices

Fortunately, we have seen no large-scale crude oil supply disruptions in recent years. However, unplanned production disruptions have always been caused by disasters, accidents, disputes, terrorist attacks, strikes or other factors at some locations. According to the U.S. Energy Information Administration, between 2011 and the first half of 2016, an average of

2.5 Mb/d of crude oil (1.9 Mb/d for OPEC and 0.6 Mb/d for non-OPEC oil producing countries) has been subjected to unplanned production disruptions (Figure 72).

Figure 72 | Crude oil subjected to unplanned production disruptions

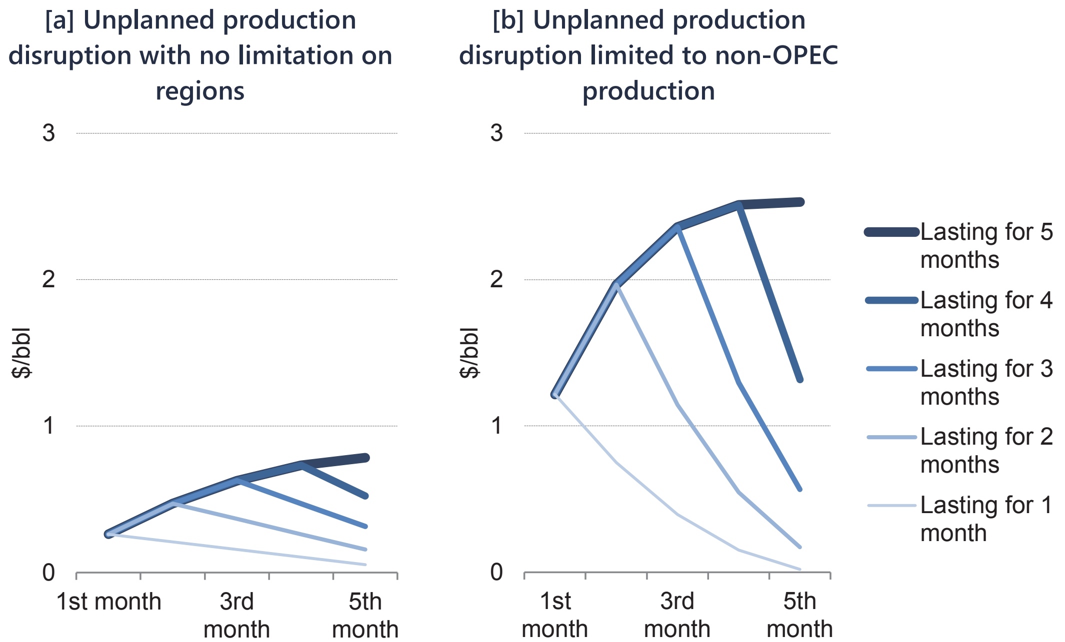


Source: EIA, "Short-Term Energy Outlook"

A simple analysis for the period indicates that a 100 kb/d unplanned oil production disruption can boost crude oil prices of a particular month by $0.30/bbl on average (Figure 73 [a]). If the disruption continues for five months, the price hike may inflate to $0.80/bbl. If the disruption is limited to non-OPEC production of which a disruption usually leads to a production cut, the impact on prices may be far greater (Figure 73 [b]).

If market players are concerned with supply shortages and base their trading on the shortages, speculative influences may increase to push prices up even further. If oversupply dominates market sentiment as seen at present, however, the impact of unplanned oil production disruptions may be more limited.

Figure 73 | Impact of 100 kb/d oil production disruption on crude oil prices



Note: Average impacts between 2011 and the first half of 2016

Analysing economic impacts

The impacts of such price fluctuations are not limited to the oil market but spilled over to the entire economy (see the *Lower Price Scenario* in "Asia/World Energy Outlook 2015"). Similarly, supply constraints under which energy cannot be procured as required are also a major risk factor. Here, we focus on the latter in analysing the economic impacts of crude oil or natural gas supply disruptions.

The analysis uses Version 9[5] of the Global Trade Analysis Project (GTAP) model, one of the representative general equilibrium models. Supply disruptions for any good can not only boost prices by collapsing the supply-demand balance for the good but also affect the behaviours of each economic agent in each region through changes in relative prices for other goods, production fluctuations, income and production factor transfers, and other factors. Here, it is assumed that while a panic just after a supply disruption in a country or region is settled, production increases in other countries or regions and investment in oil conservation have yet to produce any effect. Although International Energy Agency (IEA) members are required to retain oil stocks equivalent to at least 90 days of net oil imports, any effect of stock releases is ignored here for simplification.

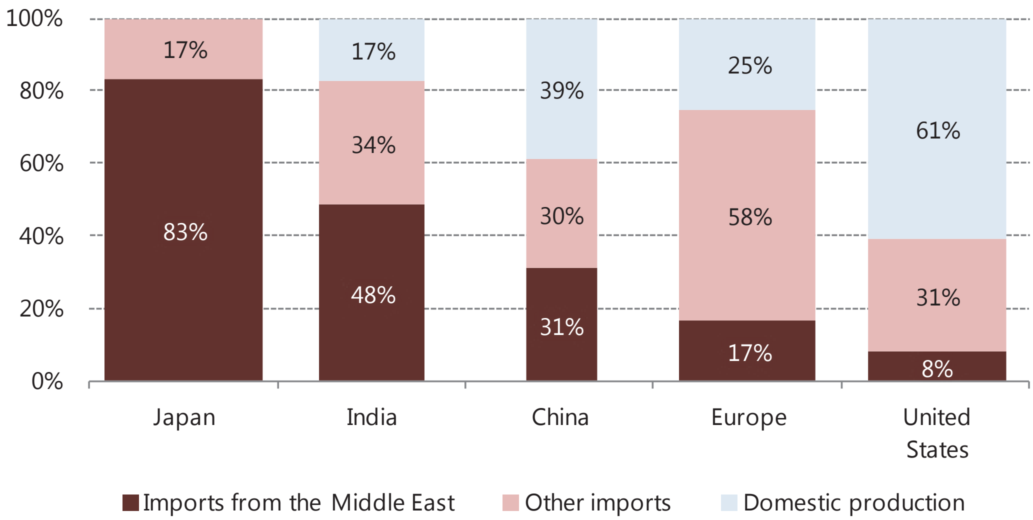
Scenario for 10 Mb/d decline in Middle Eastern crude oil production

The Middle East accounts for about one-third of global crude oil production. However, degrees of oil-consuming countries' dependence on crude oil supply from the Middle East

[5] The base year for this version is 2011 in principle. Given the recent rapid expansion of U.S. crude oil and natural gas production, this analysis simply reflects its production growth through 2015.

differ depending on their resources endowment, the availability of alternative energy sources, economic and industrial structures, geographical and historical factors, and other factors (Figure 74). Asian countries are more dependent on the Middle East than Western countries. Particularly, Japan, Korea and Chinese Taipei depend heavily not only on oil but also on crude oil from the Middle East in overall energy supply. China, though being the second largest oil consumer in the world, depends less on Middle Eastern crude oil because it is the largest oil producer in Asia and the fifth largest in the world, with energy consumption concentrating on coal. In Europe, Middle Eastern crude oil accounts for only one-sixth of total crude oil consumption due to pipeline oil imports from the former Soviet Union and others and North Sea oil production. The degree of U.S. dependence on Middle Eastern crude oil is very low because the United States covers 60% of its requirements with domestic production thanks to crude oil production recovery under the shale revolution, and imports from other countries in the Americas. While consuming nearly five times as much oil as Japan, the United States imports 50% less crude oil from the Middle East than Japan.

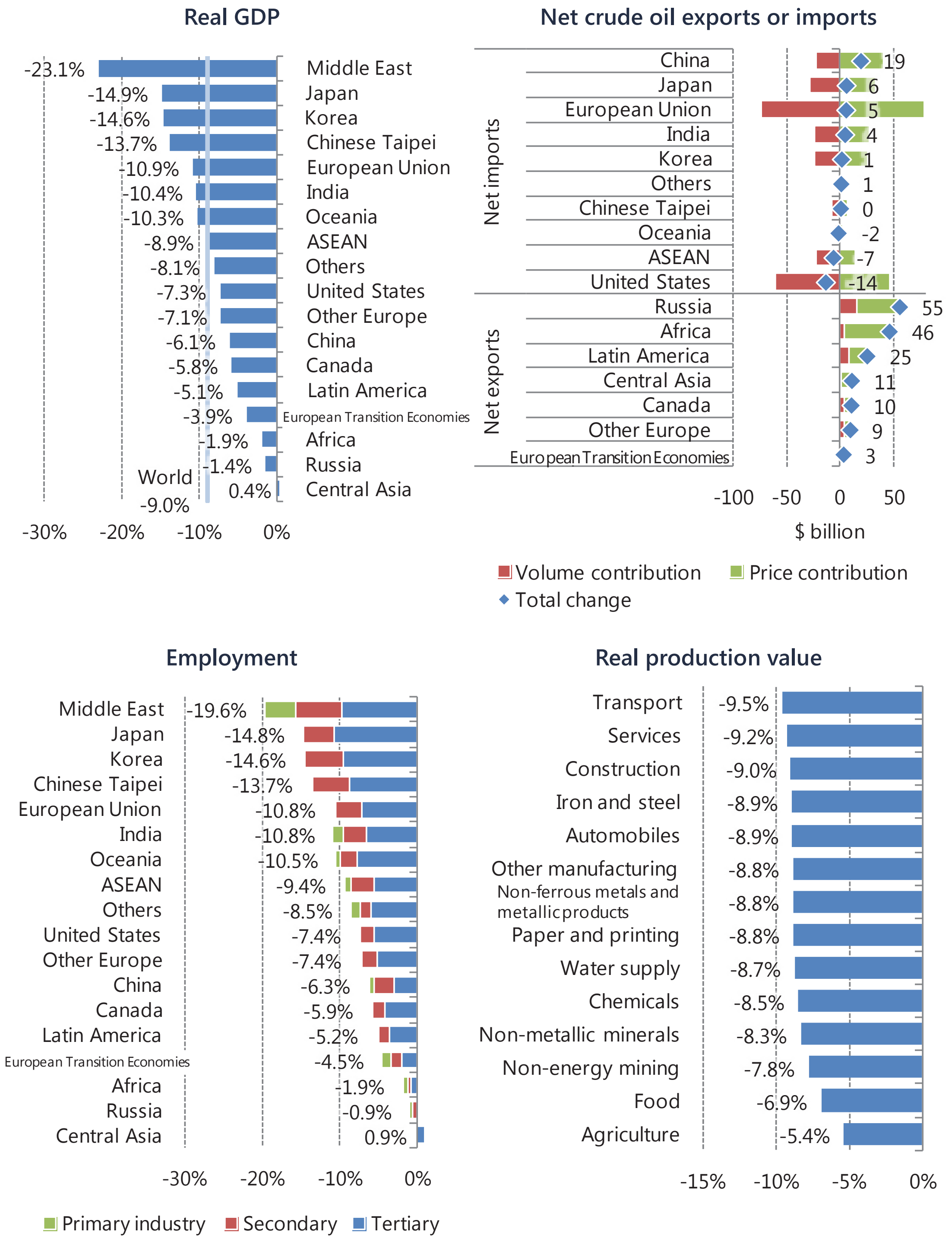
Figure 74 | Crude oil supply mix in selected economies [2015]



Note: The bar width is proportionate to oil's share of primary energy supply.
Source: BP "BP Statistical Review of World Energy"

The different degrees of dependence on Middle Eastern crude oil influence the vulnerability or invulnerability of specific economies to Middle Eastern crude oil supply disruptions. If Middle Eastern crude oil production declines unintentionally by as much as 10 Mb/d, with no one making up for the decline, the world economy may contract by 9%. Excluding the Middle East, the source of the supply disruption, East Asia other than China may suffer the largest damage from such disruption (Figure 75). Korea and Chinese Taipei would lose their economic growth for as much as some five years. Japan would lose growth for about 20 years.

Figure 75 | Impacts of 10 Mb/d decline in Middle Eastern crude oil production



Note: [Net crude oil exports or imports] Net crude oil exports from the Middle East will fall by $139 billion. [Employment] The mining sector is included into the primary industry and the electricity sector into the secondary industry.

India with a higher coal share in the energy mix and the European Union with less dependence on Middle Eastern crude oil, though being less affected than the three East Asian economies, may suffer an economic contraction of more than 10%. The U.S. economic contraction may be less than the global average and limited to 7% due to grown domestic crude oil production. However, the United States may not be free from any impact of such great oil supply disruption. Even China with higher dependence on coal may post a 6% economic contraction.

Net crude oil exporters Russia, Africa, Latin America and Canada may not be free from the impact either. While their crude oil export revenues may increase due to price hikes[6] and export volume growth, their real GDP may contract by 1% - 5% due to the world economy shrinkage. These economies may get relative gains from the Middle Eastern oil production disruption. However, no economies other than Central Asia may get absolute gains.

Employment may post a trend similar to the GDP contraction. Among industrial sectors other than the energy sector, the oil-intensive transport sector may suffer the largest output decline. Production drops may be relatively slower for the agriculture and food sectors of which products are basic goods.

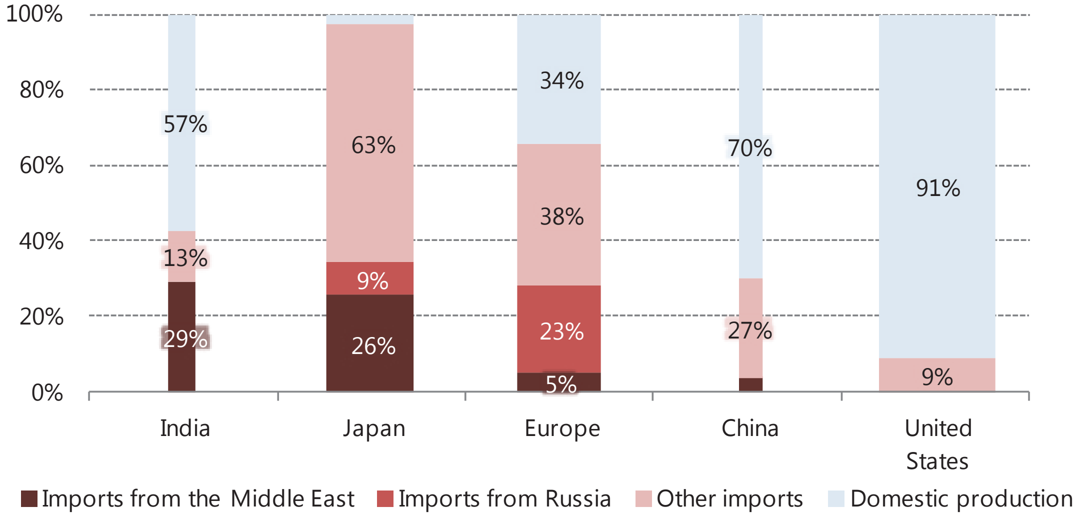
Scenario for 110 Bcm decline in Middle Eastern or Russian natural gas exports

Next, we analysed the impacts of another scenario in which Middle Eastern natural gas exports will decline by 110 Bcm (1 cubic metre = 40 MJ, equivalent to 80 Mt in LNG), with no other country or region increasing production to make up for the decline. For comparison, we also set up a scenario for a 110 Bcm decrease in Russian natural gas exports.

The degree of dependence on the Middle East for natural gas supply is higher for Japan and lower for Western countries, as is the case with crude oil (Figure 76). A major difference between crude oil and natural gas cases is that the degree of Japan's dependence on Middle Eastern natural gas is limited to around 25%. As considerable investment is required in natural gas supply infrastructure, natural gas is less used in non-OECD other than the former Soviet Union and Eastern Europe. This is a characteristic point for natural gas.

[6] Price hikes are limited to those from the supply-demand balance change and exclude those attributable to speculative trading.

Figure 76 | Natural gas supply mix in selected economies [2015]

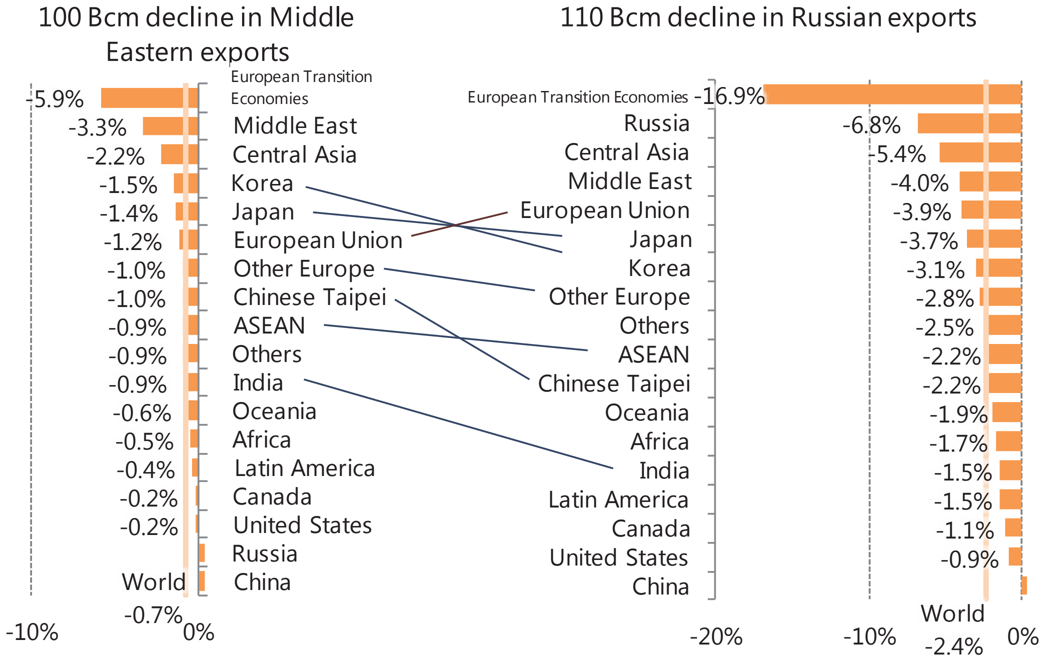


Note: The bar width is proportionate to natural gas's share of primary energy supply.
Source: BP "BP Statistical Review of World Energy," IEA "World Energy Balances"

The impacts of a decline in natural gas exports from the Middle East or Russia will be less than those of the abovementioned 10 Mb/d fall in Middle Eastern crude oil production. This is primarily because the energy amount of 110 Bcm in natural gas is limited to about 100 Mtoe, one-fifth of nearly 500 Mtoe for 10 Mb/d in crude oil.

The adverse impacts of the natural gas export decline will be greater on Japan, Korea and Chinese Taipei, as will be the case with the crude oil production fall (Figure 77). However, the impacts on the European Union will be relatively serious. Particularly, a decline in Russian exports will exert remarkable impacts on the European Union. The impacts on the United States will be very limited because it does not import natural gas from the Middle East or Russia; in fact it recently exported LNG to Kuwait and the United Arab Emirates. China, though being a net natural gas importer, will be an exception. Given China's low dependence on Middle Eastern or Russian natural gas and coal's high share of primary energy supply, price hikes stemming from the natural gas supply disruption in China will be less than in other countries. As a result, China's international competitiveness will increase relatively, with the decline in natural gas exports from the Middle East or Russia falling short of affecting the Chinese economy.

Figure 77 | Impacts of 10 Bcm decline in Middle Eastern or Russian natural gas exports on real GDP



The Middle East or Russia that will reduce natural gas exports will suffer a considerable economic contraction. However, Russia will benefit from the Middle Eastern export fall, while the Middle East will suffer a loss only second to that for Russia on the Russian export fall. The asymmetric result will stem from the different degrees of a contraction in the European economy closely linked to the Middle East.

In each scenario, European transition economies[7] will face the severest adverse impacts. They include countries that feature natural gas's high shares of primary energy supply and poor energy efficiency. When Russian natural gas exports decline, these countries importing natural gas from Russia will see a GDP contraction of as much as 17%. In this scenario, Central Asia exporting natural gas to Russia will suffer a 5% economic contraction. It could be taken as surprising that these countries including inland countries will be the most vulnerable to a plunge of the world economy. Such result could come depending on conditions, as we witnessed at the time of the Lehman Shock in 2008 and the subsequent global financial crisis.

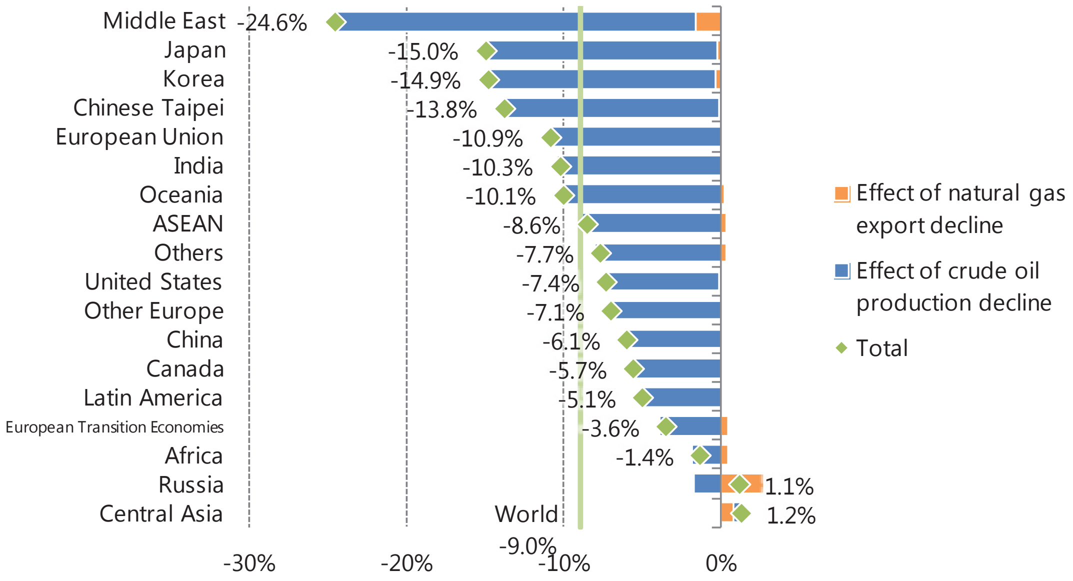
Scenario for a combination of 10 Mb/d decline in Middle Eastern crude oil production and 110 Bcm fall in Middle Eastern natural gas exports

Finally, we take up a scenario in which a 10 Mb/d decline in crude oil production in the Middle East will coincide with a 110 Bcm fall in natural gas exports from the region.

[7] These countries have made a transition from socialism to capitalism and remain outside the European Union, including Ukraine and Albania.

The impacts of the scenario are basically similar to those of the crude oil production decline scenario (Figure 78). This is because the crude oil production decline will cause a world economy contraction of as much as 9% and a substantial energy demand drop, with a natural gas export drop falling short of becoming a severe constraint on energy supply.

Figure 78 | Impacts of 10 Mb/d decline in Middle Eastern crude oil production and 110 Bcm fall in natural gas exports on real GDP



U.S. shale oil's possible moderation of economic contraction

The shale revolution is expected by some to allow the United States to become a swing producer. Analogically, the United States could be expected to cover a supply disruption in the Middle East. Even if the United States expands crude oil production by 3.6 Mb/d[8], the world economy's contraction may be narrowed only by about 2.5 percentage points. Japanese and EU contraction may be narrowed only by about 2.0 points, covering one-eighth of the damage for Japan and one-sixth for the European Union. At present, it is risky to place excess expectations on shale oil in regard to stable oil supply and become complacent.

4.3 Measures to avoid supply disruption risks

Energy supply disruptions in the Middle East will bring about great global damage affecting even economies that do not import crude oil or natural gas from the region. What measures should be taken to mitigate such damage? Regrettably, no magic measure to meet the question can be found. Countries have no choice but to implement classic measures contributing to enhancing energy security.

[8] As of August 2016, there were 5,031 wells that had been drilled and uncompleted. A new well can produce 717 b/d on average (although shale oil wells feature higher decline rates). Potential production estimated from these data amounts to 3.6 Mb/d. This amount may be produced easily if the conditions are right.

Given that supply disruption risks originate from dependence on energy imports, the first measure is to reduce the dependence. In this sense, efforts to reduce energy consumption as much as possible should be made in every area. On the supply side, options are limited for Japan, Korea, Chinese Taipei and other economies that are poor with fossil fuel resources. It is not realistic for Japan to substantially increase fossil fuel production other than methane hydrate now under development. Therefore, it is important to spread renewable energy that has been increasingly used in recent years and posts a remarkable cost drop. However, it is needless to say that measures must be taken to respond to the expansion of intermittent electricity sources including solar photovoltaics and wind. Nuclear power generation that features far less frequent fuel (uranium) imports than fossil fuel-fired power generation and can store the fuel is an effective option.

Despite such efforts to increase energy self-sufficiency, most countries in the world will have to import fossil fuels to some extent in the foreseeable future. Therefore, each country is required to limit any impact of energy supply disruptions by diversifying its energy sources, its energy exporters and the import routes or have measures for offsetting disrupted supply. Of course, holding reserves would be an effective safety net in the event of emergency.

Furthermore, we can find measures to avoid energy supply disruptions through relations with the international community. Most OECD countries including Japan have joined the International Energy Agency (IEA) and are destined to cooperate in addressing any energy supply crisis. Given that the energy market is vast, multilateral cooperation can cope with a crisis more effectively. The IEA is rather seen as a group of oil consuming countries. These countries can achieve more countries' cooperation in stabilising the energy market and reduce energy supply disruption risks by enhancing talks with OPEC and other energy exporters within the framework of the International Energy Forum.

Over a long term, economic support for developing countries will be significant. While Islamic State and other terrorist attacks are a factor to threaten energy supply, poverty is behind terrorism. Energy exporting countries include many of those plagued with economic gaps and poverty. Solutions to these problems may contribute to social and political stabilisation. Support for stabilisation in energy exporting countries, though being circumstantial, can help reduce energy supply disruption risks.

As energy supply has various factors, it may be impossible to completely eliminate risk factors involving energy supply disruptions. Therefore, countries are required to work with the international community to pursue classic, steady efforts to reduce such risks.

Part II

ASEAN energy supply/demand outlook

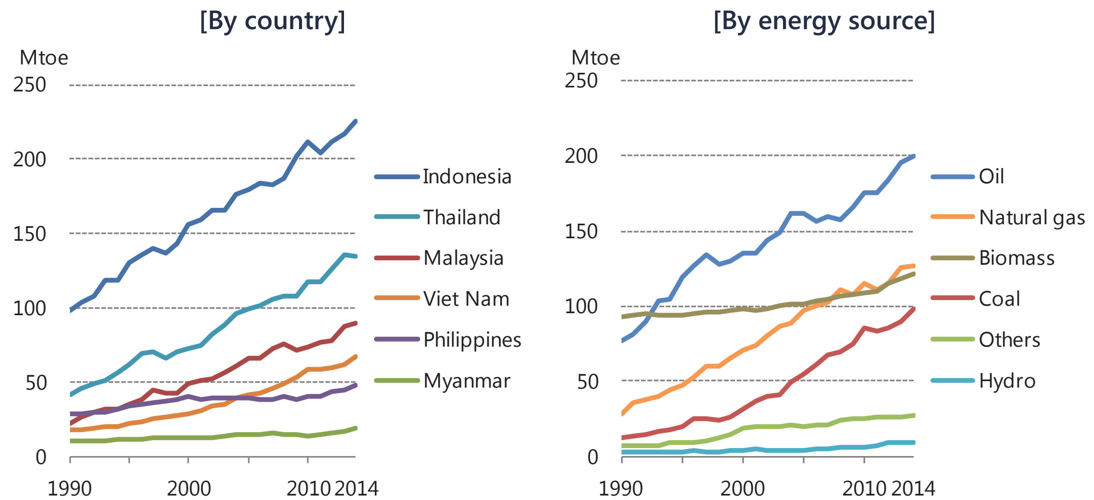
5. ASEAN energy supply/demand outlook

5.1 Supply/demand overview

Supported by past population and economic growth, the Association of Southeast Asian Nations (ASEAN) has sustained a robust increase in energy consumption. As conditions vary among ASEAN countries, however, energy consumption is also growing at various paces. For example, energy consumption has grown substantially in Indonesia, the most populated country among ASEAN, as it achieved growth in the industrial sector in recent years. Consumption increased moderately in Myanmar that just recently opened its market.

Among energy sources, oil used for vehicles and industrial production accounts for the largest share of the ASEAN energy consumption, posting remarkable growth. Natural gas and coal consumption for power generation has also increased rapidly. With regard to biomass, it is important to note that it includes firewood and many other traditional energy sources that will be replaced with electricity, city gas and oil as the economy grows. Consumption of modern biomass energy such as biodiesel and biogas has been increasing and should be assessed separated from traditional ones.

Figure 79 | Primary energy supply in ASEAN



Source: IEA "Energy Balance 2016"

Note: Combining consumption in Indonesia, Thailand, Malaysia, Viet Nam, the Philippines and Myanmar

With energy consumption expanding, growing dependence on energy imports has become a problem. ASEAN, including Indonesia and Malaysia both rich with fossil fuel resources, is still a net energy exporter, however, the supply-demand balance differs from country to country and from energy source to source. For example, when the second oil crisis occurred in 1979, Japan was importing 15% of its crude oil requirements from Indonesia. Since then, however, Indonesia's oil self-sufficiency rate plunged to only 54% in 2014 due to a gradual decline in its domestic production and an increase in domestic demand. Similar trends are seen for oil and natural gas in Malaysia, coal and natural gas in Thailand and, oil and coal in Viet Nam.

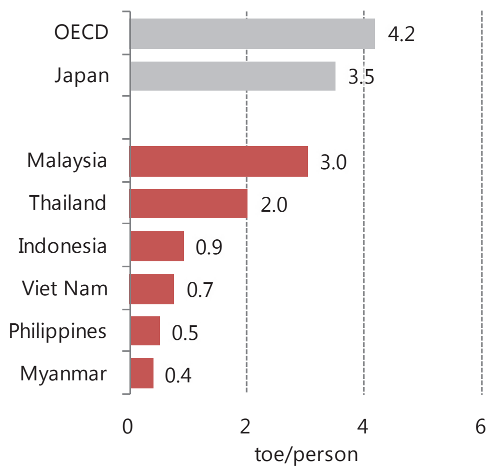
Particularly remarkable in recent years are LNG import plans. Indonesia and Malaysia, though being LNG exporters at present, are steadily developing infrastructure for importing LNG. Thailand is also planning to expand its LNG import capacity, while the Philippines and Viet Nam are considering importing LNG. These plans take into consideration their geographical positions, being surrounded by sea, making LNG transportation more suitable than pipeline gas transportation. ASEAN, which could develop natural gas at such locations as Kalimantan Island, would also depend on LNG.

Figure 80 | ASEAN LNG import infrastructure

Sources: various documents

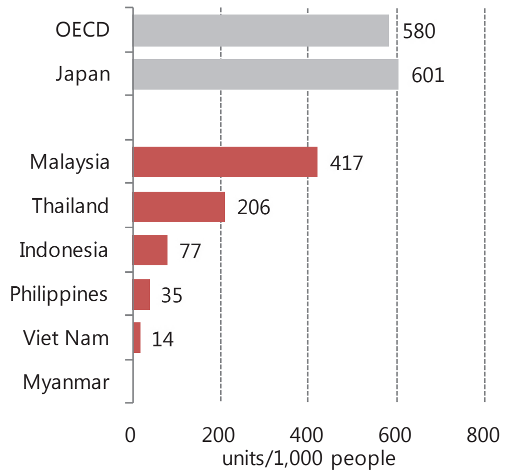
How will ASEAN energy consumption develop in the future? Some factors indicate that regional energy demand is likely to continue expanding despite the uptake of energy conservation measures in the future. For example, energy consumption per capita in ASEAN is still lower than in Japan and other developed countries, implying that energy consumption will further increase in accordance with income growth. Vehicle ownership that greatly influences oil demand will increase further, securing a steady growth for oil consumption. Despite rapid electricity demand growth in recent years, ASEAN must pursue electrification for 120 million people, almost equivalent to the Japanese population, indicating that electricity and power generation energy consumption will increase.

Figure 81 | Primary energy consumption per capita [2014]



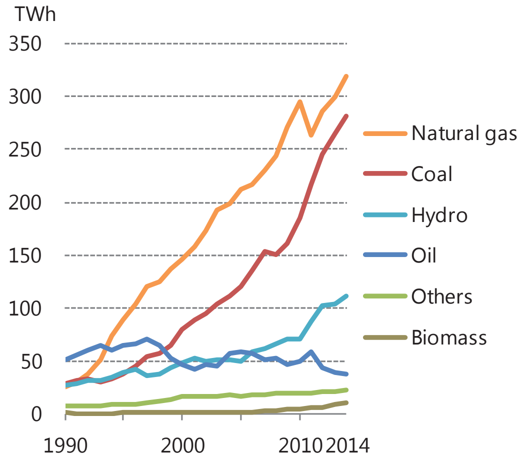
Source: IEA "Energy Balance 2016"

Figure 82 | Vehicle ownership per 1,000 people [2013]



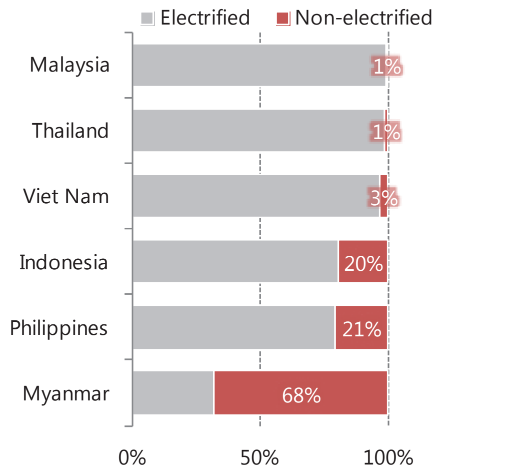
Source: Handbook of Japan's & World Energy & Economic Statistics

Figure 83 | ASEAN electricity generation



Note: Combining generation in Indonesia, Thailand, Malaysia, Viet Nam, the Philippines and Myanmar
Source: IEA "Energy Balance 2016"

Figure 84 | Non-electrified population [at the end of 2013]



Source: IEA "Southeast Asia Energy Outlook 2015"

5.2 Major consumptions

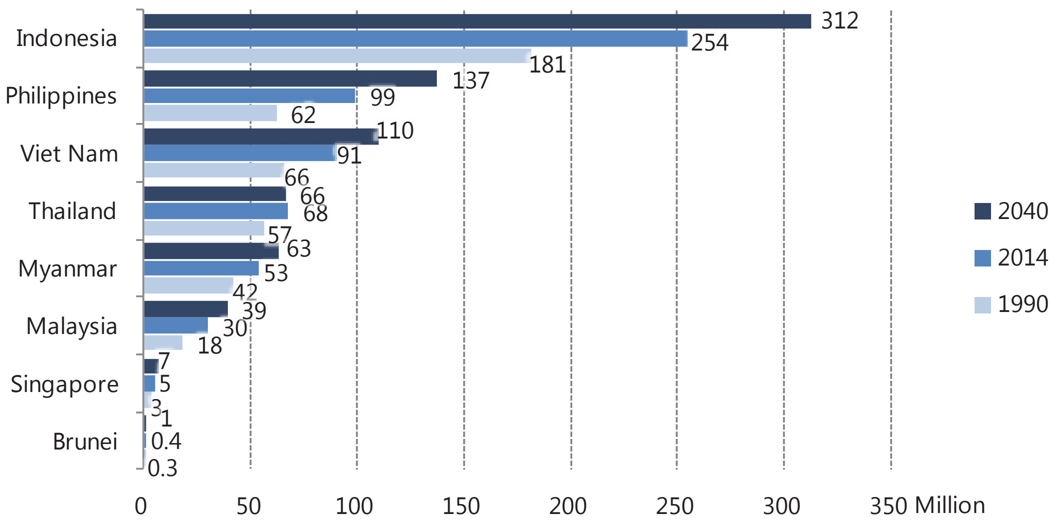
Energy supply and demand are susceptible to demographics, economic growth, the urbanisation rate and other factors.

Population

ASEAN population at present totals 620 million, of which Indonesia accounts for the largest share at about 40%, followed by the Philippines, Viet Nam and Thailand. The four countries capture more than 80% of ASEAN population. ASEAN population is young with an average median age that stands at 29.1, far younger than 46 for Japan or 37 for China[9]. The median age is as young as 21 in Laos, 23 in the Philippines and 24 in Cambodia. Some countries with lower birth rates, however, have more aging population with a median age of 38 in Singapore and 37 in Thailand.

ASEAN population will increase to 760 million by 2040 according to the United Nations World Population Prospects. The average annual growth will decelerate from 1.2% for 2000 - 2014 to 0.8%. Growth rates will be higher for the Philippines, Laos and Cambodia with younger population. Productive population (between 15 and 64) will increase in most ASEAN countries. In Thailand with aging population, however, population will peak in the mid-2020s before turning down (Figure 85).

Figure 85 | Population



Urban and rural energy consumption differs widely. In urban areas, energy consumption per capita is relatively higher thanks to electricity, gas (city gas or LPG) and other energy supply infrastructure. In contrast, rural areas including those that are still non-electrified (19% of ASEAN population) use firewood and livestock manure for cooking and heating (280 million people or 45%[10]).

In the whole of ASEAN, 47% of the total population lives in urban areas. The percentage is as low as 21% in Cambodia, 33% in Viet Nam, 34% in Myanmar and 38% in Laos. In the future, urban population will increase as people will migrate to urban areas, in line with economic development and industrialisation. The urbanisation rate (urban population's share) for

9 PwC Japan "ASEAN Economic Dashboard"

10 IEA "Southeast Asia Outlook 2015"

ASEAN will increase from 47% at present to 60% in 2040 according to the United Nations. While urbanisation will make progress in Viet Nam, Myanmar and Cambodia, their urbanisation rates in 2040 will still be less than 50%. Urbanisation and relevant policy enhancement will greatly reduce the non-electrified population share. While some non-electrified areas will be left in Cambodia and Myanmar, other countries will achieve widespread access to electricity.

Economy

Of the $2.4 trillion in ASEAN's real GDP (2014), Indonesia accounts for about 40%. It and four other major economies – Thailand, Malaysia, Singapore and the Philippines – command 90% of ASEAN GDP. GDP per capita in ASEAN is $3,900, slipping far below the global average of $10,000. However, Singapore and Brunei boast income as high as in developed countries, while GDP per capita stands around $1,000 in Cambodia, Myanmar, Laos and Viet Nam.

ASEAN's average annual economic growth through 2040 will be 4.5%, topping the global average of 2.9%. As productive population increases in many ASEAN countries, people (as workers and consumers) will contribute to economic growth. An abundant labour force and a favourable location neighbouring the giant markets of China and India are attracting foreign direct investment including that from Europe and Japan. In addition, the ASEAN Economic Community (AEC) was established at the end of 2015 to accelerate growth through regional trade liberalisation and market integration. GDP per capita in 2040 will expand 2.5-fold from the present level, though remaining far below $17,000. Such ASEAN countries as Myanmar and Laos will see their GDP per capita still being below $5,000 and will have great economic growth potential after 2040.

Figure 86 | Economic growth

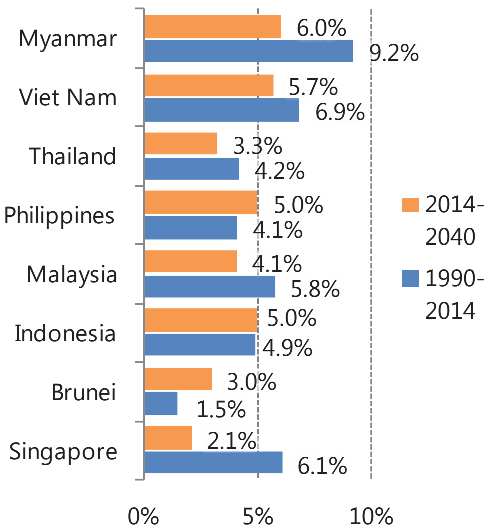
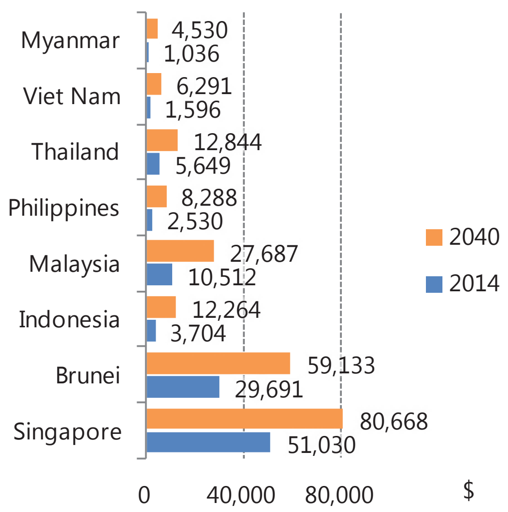


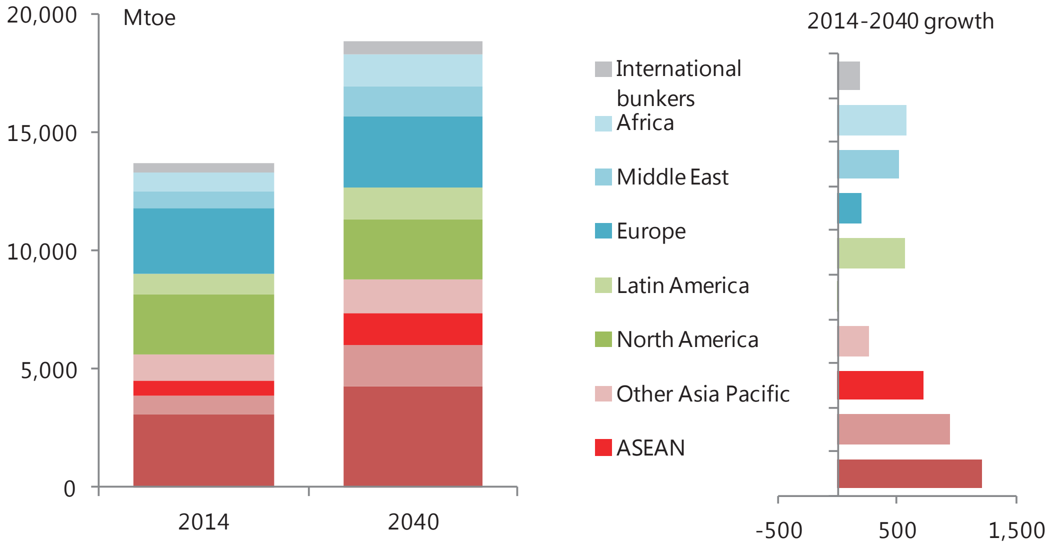
Figure 87 | GDP per capita ($2010)



5.3 Energy demand

ASEAN primary energy consumption expanded 2.6-fold in 24 years from 1990 to 2014. Reflecting economic and population growth in the future, the consumption will increase 2.2-fold from 620 Mtoe in 2014 to 1,350 Mtoe in 2040. The increase will account for 14% of global energy demand growth, being the third largest after Chinese and Indian growth and exceeding the combined present Japanese and Korean consumption. The gravity centre of the energy market will thus shift further to Asia (Figure 88).

Figure 88 | Global primary energy consumption and growth [Reference Scenario]



The average annual growth in ASEAN primary energy consumption during the outlook period will be 3% against the average annual GDP growth of 4.5%. Final energy consumption per GDP, or GDP energy intensity, will improve by 35%. In addition to energy conservation measures, industrial structure changes and urbanisation will contribute to improving the GDP energy intensity. Energy conservation measures will include the establishment of efficiency standards for vehicles and electrical home appliances and the elimination of fuel subsidies.

Energy consumption per capita in 2040 will double to 1.8 toe, still lower than half the OECD average and the global average of 2.1 toe. ASEAN energy consumption can be expected to increase more and more even after the outlook period.

The ASEAN region is relatively rich with energy resources and a net energy exporter with the energy self-sufficiency rate standing at 125% at present. The energy self-sufficiency rate, however, will slip below 100% by 2030 and fall to 76% in 2040 as growth in fossil fuel production fails to catch up with rapid domestic energy demand.

By country

With 40% of the ASEAN population, Indonesia's primary energy consumption will capture 45% of ASEAN primary energy consumption growth while expanding 2.5-fold by 2040,

(Figure 89). Backed by high economic and population growth, Indonesia's share of ASEAN energy consumption will increase from 36% at present to 41%. For Thailand, the only ASEAN member seeing a population decline in the future, its share will fall from 22% to 17%, but will remain the second largest after Indonesia. In Viet Nam that accounts for about 15% of ASEAN population, energy consumption will increase 2.6-fold and will replace Malaysia as the third largest energy market among ASEAN countries. However, energy consumption per capita in Viet Nam will be limited to less than half the Malaysian level (Figure 90).

Figure 89 | ASEAN primary energy consumption and growth by country [Reference Scenario]

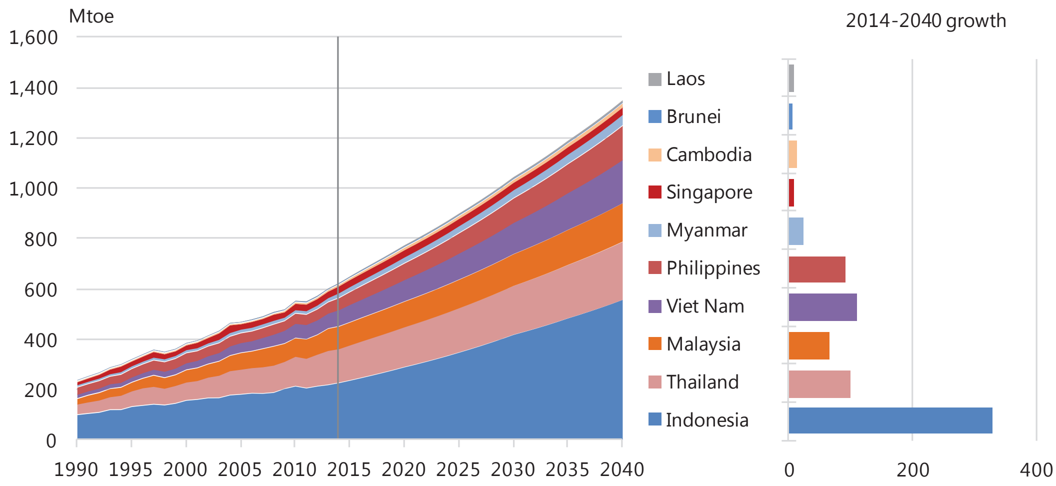
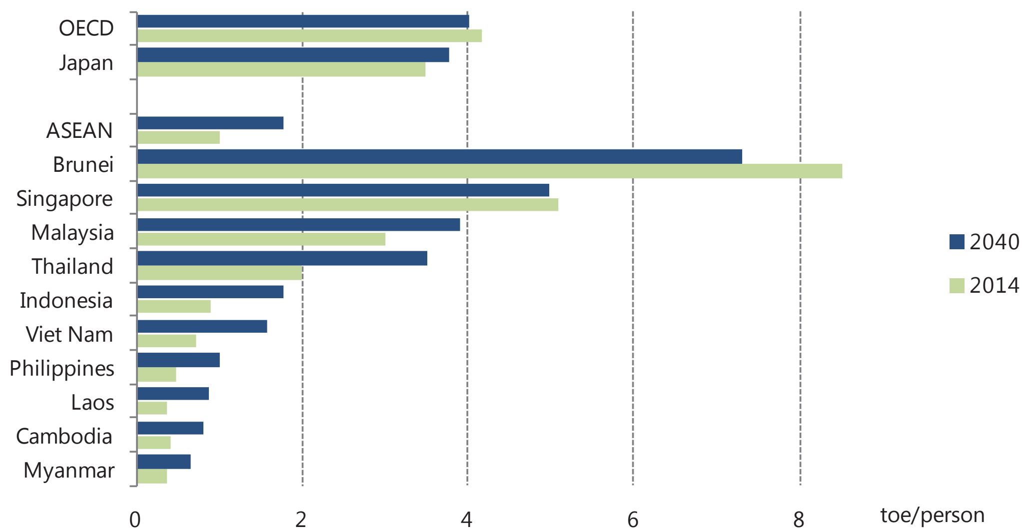


Figure 90 | Energy consumption per capita [Reference Scenario]



In the Philippines, Myanmar, Cambodia and Laos, where urbanisation rates are currently low and many people are still without access to modern energy, energy consumption will grow substantially faster due to industrialisation and improving living standards. However, their energy consumption per capita will remain far below the ASEAN average. In Singapore and Brunei where energy consumption per capita is already higher than in developed countries, energy consumption will increase moderately due to industrial structure changes and energy conservation and consumption per capita will decline.

By sector

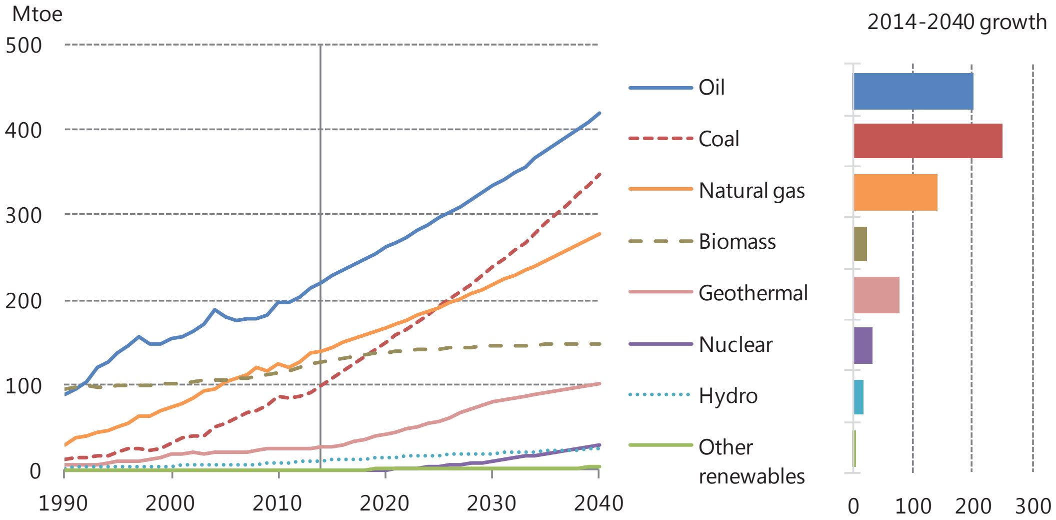
Final energy consumption will increase at an annual rate of 2.7% from 440 Mtoe in 2014 to 890 Mtoe in 2040 in response to industrialisation, rising living standards and population growth. The industry sector will boost energy consumption at an annual rate of 3.5%, faster than any other sectors. Malaysia, Thailand, Indonesia, the Philippines and Viet Nam have made remarkable progress in industrialisation, with foreign direct investment increasing rapidly on expectations of abundant, relatively cheap labour. While the materials industry will grow for expanding domestic infrastructure, the machinery assembling industry will achieve great development, with electricity demand expanding greatly. Following the industry sector, the transport sector will boost energy consumption at an annual rate of 2.7%. The road sector will account for more than 90% of transport sector energy consumption, indicating that energy consumption in the transport sector will depend on vehicle demand. Vehicle ownership will grow from 88 per 1,000 people in 2014 to 189 in 2040 (remaining below the global average of 237). The number of vehicles will increase 2.7-fold, with the road sector's oil demand expanding by 2.0 Mb/d. The buildings (residential and commercial) and agriculture sector will increase energy consumption at a slower annual rate of 2.2% as they switch from traditional biomass (including firewood and livestock manure) to more energy-efficient LPG cooking stoves, etc. Progress in urbanisation (urban population's share rising from 47% to 60%), the expansion of electrified regions (electrified population's share rising from 81% to 98%), rising living standards (GDP per capita growing from $3,900 to $9,800) will lead modern energy demand to grow at an annual rate of 4.0%, faster than industry and transport sector energy consumption. Meanwhile, traditional biomass's share of energy consumption in the buildings and agriculture sector will decline from about 60% to 34%, as there will still be some people having no access to modern cooking tools even in 2040.

The non-electrification rate now stands at 19%, with 120 million people failing to receive electricity. ASEAN governments have promoted their respective electrification policies to eliminate non-electrified regions as early as possible. Such policies will be combined with economic growth to boost electricity demand 3.2-fold to 2,450 TWh by 2040. The growth amounts to the combined present power generation in Africa and the Middle East. Electricity's share of final energy consumption will rise from 15% to 24%. Demand for energy for power generation will increase 3.1-fold to respond to the electricity demand growth (the increase will slip below the electricity demand growth due to the improvement of power generation efficiency and the reduction of power transmission and distribution losses). Fossil fuels will cover some two-thirds of the increase. The power generation sector's fuel input will account for about 60% of primary energy consumption growth.

By energy source

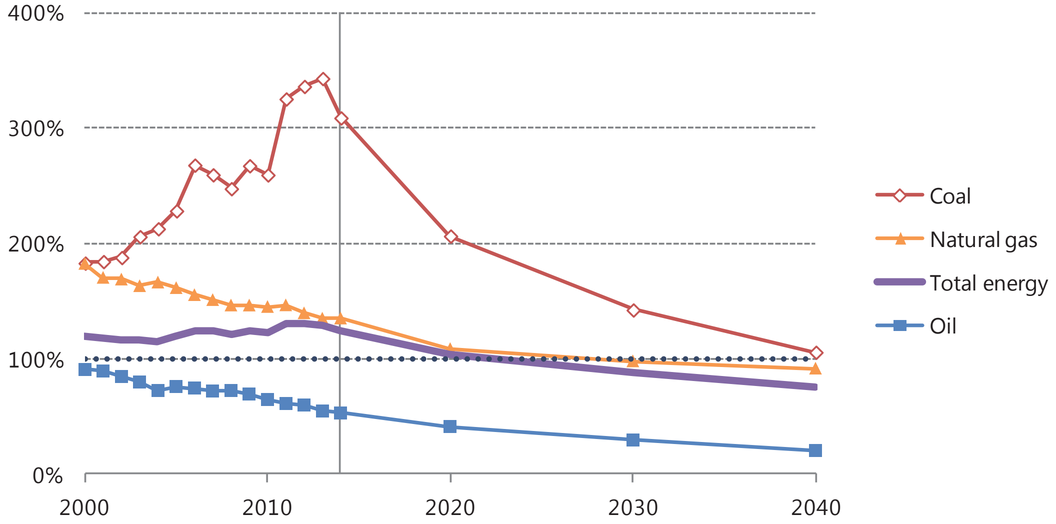
Fossil fuels will cover more than 80% of the energy demand growth (Figure 91). Fossil fuels' share of primary energy consumption will increase from 74% in 2014 to 77% in 2040. Among fossil fuels, coal will post the largest growth at 3.5-fold, accounting for 34% of total energy demand growth. As abundant cheap coal resources in ASEAN are used to cover most of the rapid electricity demand growth, coal demand growth will be primarily for power generation. ASEAN coal demand growth will total 356 million tonnes of coal equivalent (Mtce), capturing about 40% of global coal demand growth.

Figure 91 | ASEAN primary energy consumption and growth by energy source [Reference Scenario]



Oil demand will expand 1.9-fold (4.1 Mb/d) from 2014, with vehicle fuel accounting for half the growth. Demand for oil will also grow sharply including LPG in the buildings sector and oil for petrochemical feedstocks. While oil's share of primary energy consumption will fall from 35% to 31%, oil will remain the most important among energy sources. As regional oil production declines, the degree of dependence on imports for oil will rise from 47% to 80% (Figure 92).

Figure 92 | ASEAN energy self-sufficiency rates [Reference Scenario]



Natural gas demand will increase 2.0-fold (170 Bcm) by 2040. Half the growth will be for power generation and most of the other half for industrial uses (including petrochemical feedstocks). Given the lack of gas distribution infrastructure, growth in the buildings sector will be limited. Demand growth in Indonesia and Malaysia, both rich with natural gas resources, will account for a majority of the ASEAN natural gas demand growth, while their export capacity will decline. The ASEAN region as a whole now exports 60 Bcm in natural gas, but will become a net natural gas importer by 2030.

The ASEAN region has great potential to supply hydro, geothermal, biomass and other renewables. The Greater Mekong Sub-region (GMS), including Cambodia, Thailand, Viet Nam, Laos and Myanmar, has hydro power generation potential as great as 248 GW[11], with many hydro development projects being implemented. Hydro power generation will expand 2.2-fold by 2040, accounting for about 60% of growth in renewables power generation. Geothermal has great potential in Indonesia and the Philippines. Geothermal power generation growth will account for about 20% of total renewable energy generation growth. On a primary energy basis, however, geothermal growth will be five times as much as hydro growth due to a primary conversion factor gap (about 10% for geothermal against 100% for hydro). Wind and solar photovoltaics power generation will post the largest growth rates, but will account for only 1% of the energy mix in 2040. Biomass, including firewood and livestock manure used mainly in rural regions, accounted for about 20% of energy demand in 2014. While such traditional biomass consumption will decline in line with urbanisation and rising living standards, biofuel consumption for power generation and vehicles will expand. Biomass demand will increase by some 20% by 2040, with their share of the energy mix halving to 11%.

Nuclear power generation is not currently present in the ASEAN region. From 2025, however, Thailand, Viet Nam, Indonesia and Malaysia will introduce nuclear power plants with a total

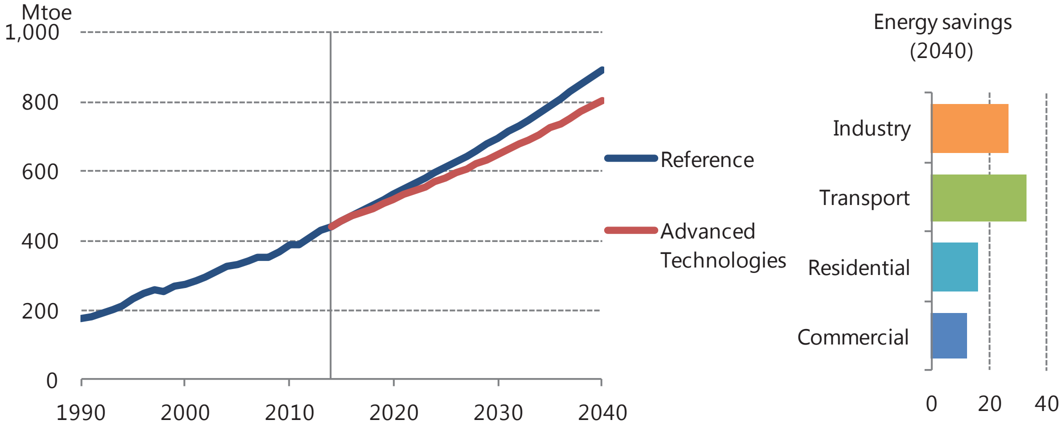
[11] Asian Development Bank "Energy Sector in the Greater Mekong Sub-region" (2008)

capacity of 16 GW. In 2040, nuclear will account for 4% of the electricity mix and 2% of the primary energy mix.

Advanced Technologies Scenario

In the *Advanced Technologies Scenario* with enhanced environmental policies, final energy consumption in the ASEAN region will increase at an annual rate of 2.3% through 2040, while falling by 10% from the *Reference Scenario* (Figure 93). The transport sector will account for about 40% of energy savings, while the industry and buildings sectors each will capture about 30%. Energy conservation progress will improve the energy intensity by 41% (instead of 35% in the *Reference Scenario*). Low-carbon energy consumption, including nuclear, wind and solar PV, will increase 2.6-fold (1.9-fold in the *Reference Scenario*), accounting for 33% of primary energy consumption. Due to such energy savings and the expansion of low-carbon energy, consumption savings in 2040 will total 124 Mtce for coal, 1.1 Mb/d for oil and 66 Bcm for natural gas. The net cumulative saving in fossil fuel imports through 2040, from the *Reference Scenario,* will be $610 billion (equivalent to Indonesia's present GDP). The region's energy self-sufficiency rate that was 125% in 2014 will stand at 83%, rather than the 76% in the *Reference Scenario*. Energy-related CO_2 emissions in 2040 will total 2,493 Mt, 644 Mt (21%) less than in the *Reference Scenario*.

Figure 93 | ASEAN final energy consumption [Advanced Technologies Scenario, compared with Reference Scenario]



5.4 Energy Supply

Coal

The ASEAN region in 2014 produced 556 Mt of coal of which Indonesia accounted for nearly 90% (Table 8). Among other ASEAN countries, Viet Nam, Thailand, the Philippines and Malaysia produce small amounts of coal, but depend on imports to meet increasing steam coal demand. Indonesia is the world's largest steam coal exporter, exporting 84% of its production in 2014. Main export destinations are in Asia, including India, China, Japan, Korea and Chinese Taipei that absorb 80% of Indonesia's total coal exports. Exports to other ASEAN countries are limited to a little more than 10% of the total.

Table 8 | ASEAN coal production [Reference Scenario]

(Mt)

	2014	2020	2030	2040	2014-2040	
					Changes	CAGR
ASEAN	555.5	584.5	647.6	720.8	165.2	1.0%
Indonesia	484.7	490.5	544.5	608.6	123.9	0.9%
Malaysia	2.7	4.6	4.8	4.8	2.2	2.3%
Thailand	18.0	18.5	18.5	18.5	0.4	0.1%
Myanmar	0.7	0.8	1.0	1.4	0.7	2.7%
Viet Nam	41.7	47.7	55.7	63.7	22.0	1.6%
Philippines	7.6	8.9	9.5	10.2	2.6	1.1%
Laos	0.1	13.5	13.5	13.5	13.4	19.5%

Through 2040, mainly Indonesia will expand coal production. Given that the Indonesian Government is planning to adjust coal production from the viewpoint of protecting coal resources, however, Indonesian coal exports will decline due to increasing domestic steam coal demand. ASEAN countries other than Indonesia will attempt to increase coal production in response to their respective demand growth. As production expansion is limited, however, their dependence on imports will rise, and as Indonesian coal exports decline, they will increase imports from non-ASEAN countries. Laos will expand coal production to operate a three-unit lignite-fired power station that started first-phase operation in 2015. About 90% of electricity generated at the station will be exported to Thailand.

Oil

The ASEAN region produced 2.4 Mb/d of crude oil in 2014 (Table 9). The four major crude oil producers are Indonesia, Malaysia, Thailand and Viet Nam; they account for 90% of total ASEAN crude oil production. Brunei, the Philippines and Myanmar produce small amounts of crude oil, while Laos, Cambodia and Singapore do not produce any crude oil. Through 2040, Indonesia, Malaysia, Thailand and Viet Nam will remain the four major crude oil producers in the ASEAN region. Due to the depletion of existing oil wells, however, their production will decline to 1.8 Mb/d in 2040 while ASEAN oil demand in 2040 will increase to 8.7 Mb/d in the *Reference Scenario* and 7.7 Mb/d in the *Advanced Technologies Scenario*, indicating that the ASEAN region will greatly increase dependence on imports.

Table 9 | ASEAN crude oil production [Reference Scenario]

(Mb/d)

	2014	2020	2030	2040	2014-2040	
					Changes	CAGR
ASEAN	2.4	2.2	2.1	1.8	-0.6	-1.1%
Indonesia	0.9	0.8	0.8	0.7	-0.2	-1.0%
Malaysia	0.7	0.6	0.6	0.5	-0.1	-0.8%
Thailand	0.5	0.4	0.4	0.3	-0.1	-1.0%
Viet Nam	0.3	0.3	0.3	0.3	0.0	-0.6%

Natural gas

ASEAN natural gas production totalled 217 Bcm in 2015 and will gradually grow reaching 310 Bcm in 2040. While production in Thailand will decline due to geological constraints, Indonesia and Malaysia will expand production. The whole of ASEAN will thus continue an upward trend in natural gas production if Indonesia's coal bed methane and other unconventional or conventional natural gas developments are kept on track.

Table 10 | ASEAN natural gas production [Reference Scenario]

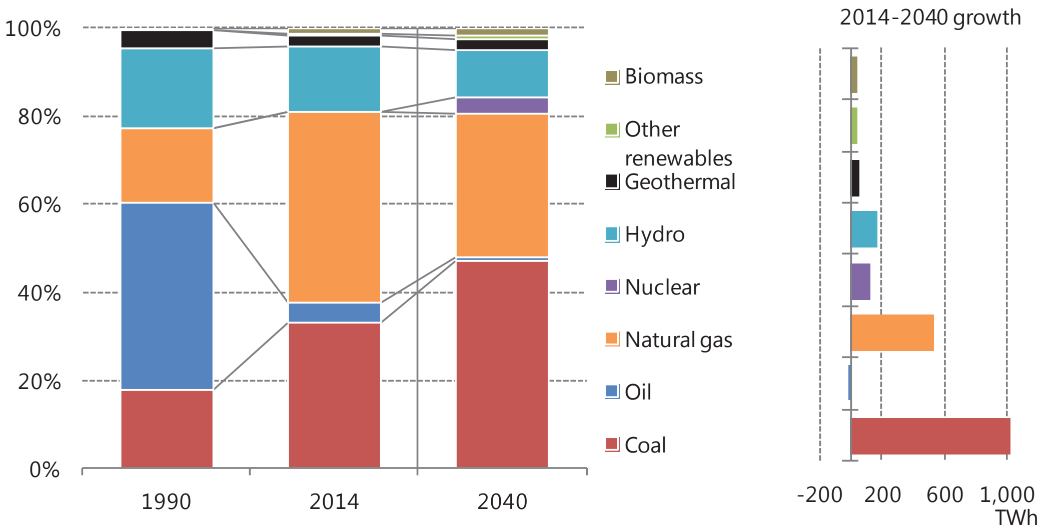
(Bcm)

	2015	2020	2030	2040	2015-2040	
					Changes	CAGR
ASEAN	217	221	260	310	93	1.4%
Indonesia	73	83	111	154	81	3.0%
Malaysia	63	65	71	75	12	0.7%
Thailand	40	29	31	31	-9	-1.0%
Myanmar	18	20	24	28	11	1.9%
Brunei	12	12	11	10	-2	-0.7%
Viet Nam	9	9	9	9	0	0.0%
Philippines	3	3	3	3	0	0.6%

Electricity

Fossil fuel-fired power generation covers about 80% of ASEAN electricity demand that has been increasing rapidly under high economic growth (Figure 94). Electricity demand will more than triple by 2040, with fossil fuel-fired power generation covering about 80% of the growth. Supported by rich coal resources, coal-fired power generation will post the largest growth, boosting its share of total power generation from a little more than 30% at present to nearly 50% in 2040 to hold the largest share of electricity generation. Natural gas-fired power generation now covering more than 40% of total power generation will increase further, but its share of the electricity mix will fall to about 30%. Hydro power generation will more than double mainly in the Mekong region with great hydro potential. Due to delays in international grid development to fill gaps between electricity supply and demand areas, however, hydro's share of the ASEAN electricity mix will decline slightly from the present level to 10%. Power generation with non-hydro renewables (including geothermal, wind, solar PV and biomass) will more than quadruple, though accounting for only 5% of the electricity mix. While renewables have great potential to expand, they face many challenges including financing issues. Nuclear power generation will account for 4% of the 2040 electricity mix with a total capacity of 16 GW introduced after 2025.

Figure 94 | ASEAN power generation mix and changes [Reference Scenario]



Biofuels

ASEAN biofuel consumption is concentrated in Indonesia, Malaysia, the Philippines and Thailand. To develop relevant industries and reduce dependence on oil imports, these countries have established biofuel promotion policies including subsidies, blending requirements and expansion targets. ASEAN biofuel consumption, mainly in those four countries, will reach 8 Mtoe in 2040, up 2.4-fold from 2014. As the promotion is targeting first-generation biofuels, ASEAN governments will need to monitor closely how the expansion of biofuel production will affect land use, tropical rain forests and food supply.

5.5 Assessment of GHG emission reduction targets

In the following, we assess the importance of the ASEAN countries' greenhouse gas (GHG) emission reduction targets as stated in their intended nationally determined contributions (INDCs). Table 11 summarises the INDCs.

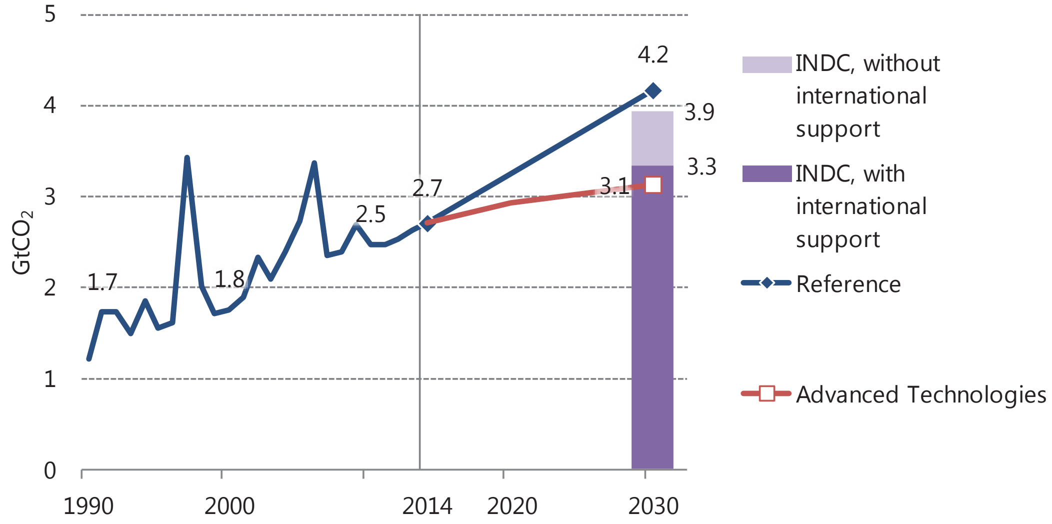
Table 11 | ASEAN INDCs

Country	Base year	Target	Notes
Indonesia	BAU	Cutting GHG emissions by 29% (without international support) or 41% (with international support) from the BAU level by 2030	Limited to CO_2, CH_4 and N_2O
Viet Nam	BAU	Cutting GHG emissions by 8% (without international support) or 25% (with international support) from the BAU level by 2030	Excluding industrial processes
Thailand	BAU	Cutting GHG emissions by 20% (without international support) or 25% (with international support) from the BAU level by 2030	Excluding forestry
Malaysia	2005	Cutting the GHG emission intensity of GDP by 35% (without international support) or 45% (with international support) by 2030	Limited to CO_2, CH_4 and N_2O
Philippines	BAU	Cutting GHG emissions by 70% (with international support) from the BAU level by 2030	
Singapore	2005	Cutting the GHG emission intensity of GDP by 37% (without international support) by 2030	
Myanmar		Increasing hydro power generation by 9.4 GW by 2030, using renewables for 30% of rural electrification, saving electricity consumption by 20% in the manufacturing sector, distributing 260,000 highly efficient cooking stoves, etc.	
Cambodia	BAU	Implementing mitigation actions in energy, manufacturing, transport and other sectors to cut GHG emissions by 3.1 Mt from the BAU level of 11.6 Mt. by 2030	
Laos		Increasing renewables’ share of energy consumption to 30% by 2025, boosting the rural electrification rate to 90% by 2020, increasing capacity of large-scale hydro power stations to 5.5 GW by 2020 for supplying electricity to neighbouring countries and adding 20 GW by 2030	
Brunei		Cutting total energy consumption by 63% from the BAU level by 2035, increasing renewables’ share of power generation to 10% by 2035, cutting the energy intensity of GDP by 45% from 2005, etc.	

The INDC levels of seven ASEAN countries (Indonesia, Viet Nam, Thailand, Malaysia, the Philippines, Singapore and Cambodia) with specific economy-wide targets are compared with GHG emissions[12] in the *Reference Scenario* and the *Advanced Technologies Scenario* in Figure 95. The seven countries cover 97% of total ASEAN GHG emissions[13].

[12] GHG emissions other than energy-related CO_2 were projected as follows:
We used the Emissions Database for Global Atmospheric Research (EDGAR). However, we modified

Figure 95 | Seven ASEAN countries' GHG emissions



The seven ASEAN countries' INDC levels without conditions such as financial aid from developed countries are close to those in the *Reference Scenario* and those with such conditions to those in the *Advanced Technologies Scenario*. These countries will be required to make efforts as assumed in the *Advanced Technologies Scenario*. To this end, technology transfers to developing countries will be important.

these data to reflect latest data written in inventories of national reports or biennial reports submitted by these countries under the United Nations Framework Convention on Climate Change.
Future estimates: For the *Reference Scenario*, we projected future CO_2, CH_4 and N_2O emissions for each emission source (energy, industrial processes, leaks, agriculture, forests, waste, etc.) and future HFC, PFC and SF_6 emissions based on their actual emissions, by conducting a simple regression analysis using GDP, population, material production, energy production and other data. For the *Advanced Technologies Scenario*, we set emission reduction potentials for GHG emissions other than CO_2, based on cuts in 2030 for each emission source given by the U.S. Environmental Protection Agency. CO_2 emissions from forests are assumed to be eliminated by 2040, based on existing assessments.

[13] Based on latest GHG emission data reported by countries under the United Nations Framework Convention on Climate Change when the Paris Agreement was adopted

6. Energy supply and demand in each ASEAN country

6.1 Indonesia

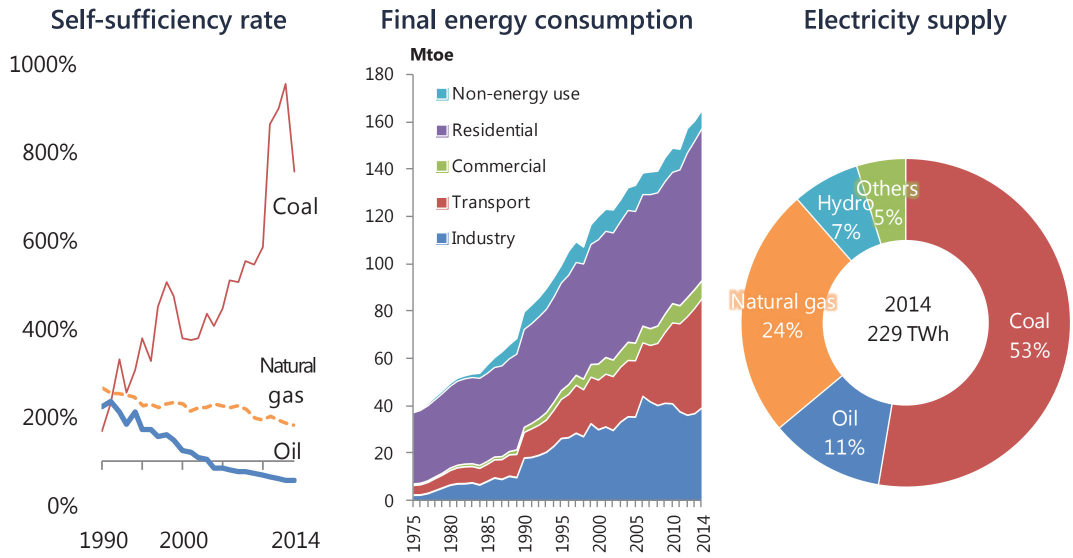
Present situation

Indonesian primary energy consumption has constantly increased since the 1970s, with the average annual growth being 2.6% for the past decade. Indonesia accounts for the largest share of the Association of Southeast Asian Nations (ASEAN), with about 40% of the total economic size and population, outperforming the other ASEAN countries in energy consumption. In 2014, the residential sector accounted for the largest share of the final energy consumption at 39%. In recent years, the transport sector posted large energy consumption growth, with annual growth being 7.8% for the past five years. Among energy sources, oil captured 40% of the final energy consumption in 2014 and traditional biomass, including firewood and livestock manure, represented 35%. As personal income improves and energy supply systems develop, traditional biomass will be gradually replaced with oil and electricity.

For power generation, coal is dominantly used because Indonesia produces large quantities of coal at low cost. Indonesia is the world’s second largest coal exporter after Australia and it has many projects for the construction of large coal-fired power plants. The second most used energy source is natural gas. While natural gas production has been decreasing, demand has been increasing for fertiliser production and other industrial uses as well for power generation. The domestic supply-demand balance for natural gas has therefore been rapidly deteriorating. In response, the Indonesian Government is accelerating domestic natural gas development, restricting exports, requiring some natural gas production to be used domestically and developing LNG import terminals.

As Indonesia consists of thousands of islands, the efficient supply of cleaner energy to these islands is a challenge. The small energy demand of many islands prohibits the use of large equipment for processing and transporting large amounts of energy in order to improve efficiency. For power generation, for example, Indonesia mainly uses diesel oil that features small equipment and simple transportation and storage.

Figure 96 | Indonesia's energy overview



Source: IEA "World Energy Balances 2016"

Outlook

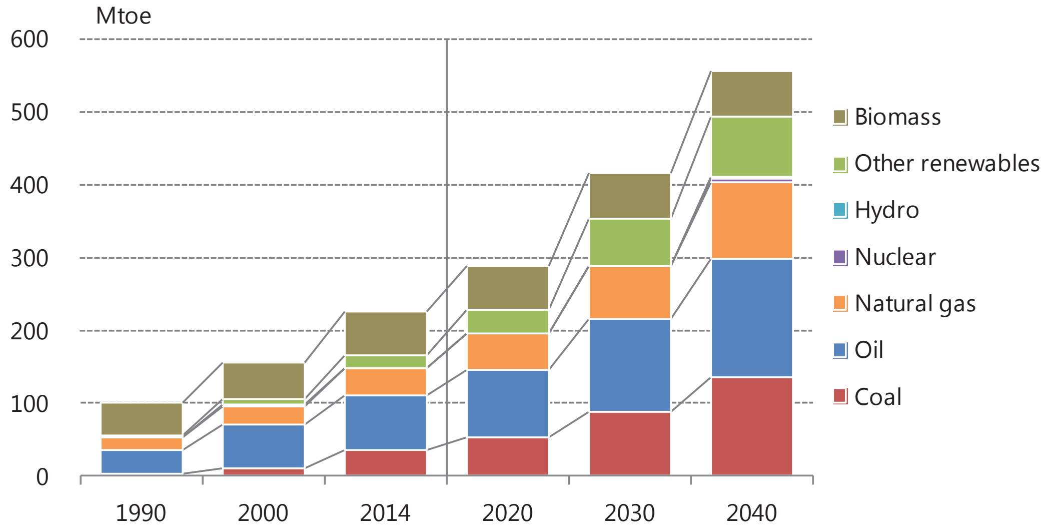
Indonesian GDP will grow at an annual rate of 5.0%, exceeding the ASEAN average. Backed by a high economic growth, primary energy consumption will expand 2.5-fold to 556 Mtoe, while the GDP energy intensity will improve at an annual rate of 1.4%. Energy consumption per capita will double to 1.8 toe, matching the ASEAN average.

Oil consumption that accounts for about one-third of primary energy consumption will grow 2.2-fold mainly due to an increase in vehicle fuel consumption (with vehicle ownership rising from 8% to 22%). Supported by abundant domestic coal resources, coal consumption will expand about four-fold (with coal for power generation accounting for about 80% of demand growth); the coal's share of the energy mix will rise from 16% to 25%. Similarly backed by rich natural gas resources, natural gas consumption will almost triple mainly for industrial production and power generation. Traditional biomass consumption, which accounts for about 70% of buildings sector energy consumption, will increase in line with rural population growth before turning downward around 2030. Non-biomass renewable energy consumption (dominated by geothermal) will expand 4.6-fold, capturing 15% of the energy mix.

Due to industrialisation and improving living standards, electricity demand will almost quadruple, with about two-thirds of the growth covered by domestic coal resources. Coal will account for more than 60% of the power generation mix in 2040 while natural gas will be nearly 30% and renewables, including geothermal, will be 8%. As for nuclear power generation, two reactors will start operation in or after 2030.

Although Indonesia is the only ASEAN country belonging to the Organization of Petroleum Exporting Countries (OPEC), its domestic oil production will fall from 850 kb/d to 660 kb/d due to the depletion of operating wells and delays in new oil well development. During the same period, net oil imports will quadruple. Natural gas production will double to 150 Bcm, of which more than 80% will be used to meet rapidly growing domestic demand. While Indonesia will expand coal production to 570 Mtce, its net coal exports will decline by 25%. Due to such domestic energy production and demand trends, the energy self-sufficiency rate will drop substantially from 203% to 113%.

Figure 97 | Indonesia's primary energy consumption [Reference Scenario]



6.2 Thailand

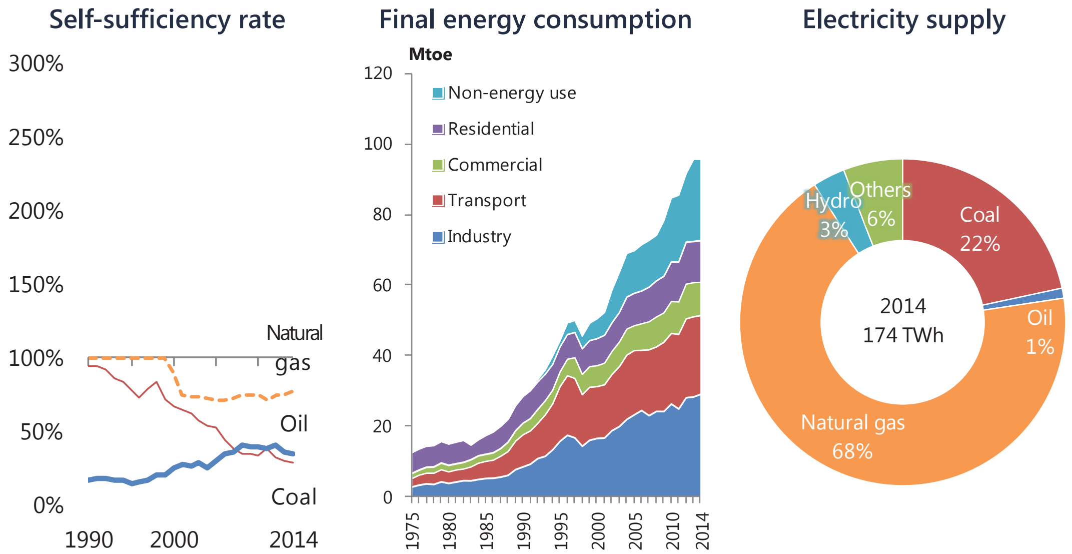
Present situation

With the exception of a temporary decline caused by the 1997 Asian crisis, Thai primary energy consumption has increased at an overall average annual growth of 3.5% for the past decade. In 2014, the industry sector accounted for the largest share of the final energy consumption at 31%. In recent years, the transport sector recorded the highest consumption growth, capturing 23% of the final energy consumption in 2014. Among energy sources, oil is most frequently used, accounting for 54% of the final consumption.

Thai energy supply features the power generation sector's high dependence on natural gas. In 2014, natural gas accounted for about 70% of electricity supply. While Thailand produces natural gas, production fails to meet domestic demand, with resources declining. Therefore, its natural gas imports have continued increasing since they started in 1998, creating a matter of concern regarding energy security. Given the situation, the Thai Government is seeking to restrict natural gas consumption for power generation and expand coal consumption for that purpose, while constructing LNG receiving facilities to meet a future increase in imports. Due to air pollution problems (to which a response has been made) caused by a lignite-fired power plant in central Thailand, citizens have raised strong opposition to coal-fired power generation, making it difficult to build new coal-fired power plants. The Government has cited nuclear power generation as a long-term option, while no specific progress has been made for introducing nuclear power plants. As a result, Thailand has remained highly dependent on natural gas, irrespective of policy intentions.

In response, Thailand is attempting to build power plants in neighbouring countries such as Laos and Myanmar and import electricity generated there (possibly hydro power generation in Laos and coal-fired power generation in Myanmar). Concerned that excessive electricity imports could further cause security problems, however, Thailand has set up a ceiling on imports' share of electricity supply. In this way, the diversification of electricity and other energy supply has become a major challenge.

Figure 98 | Thailand's energy overview



Source: IEA "World Energy Balances 2016"

Outlook

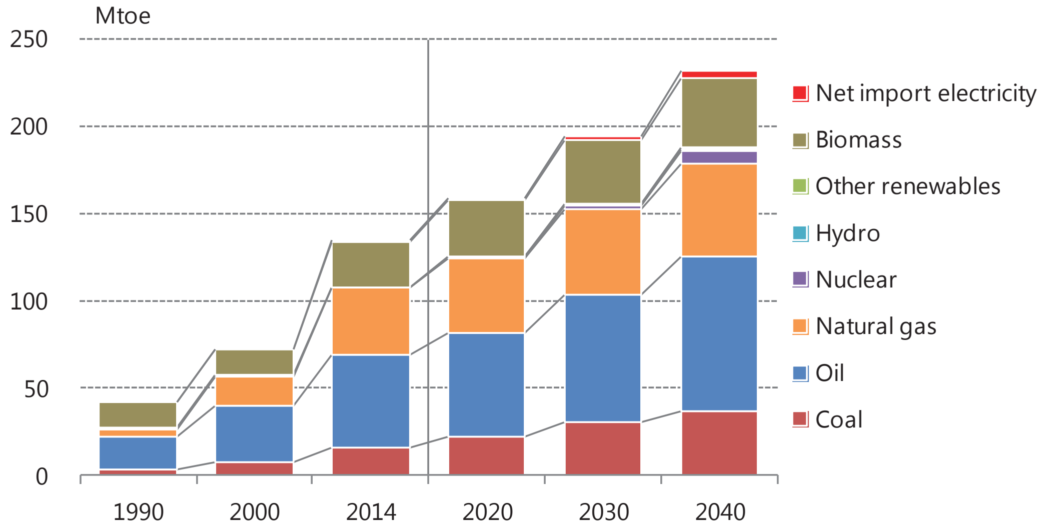
In Thailand, the only ASEAN country with a population decline, the average annual economic growth through 2040 will be 3.3%, slipping below the ASEAN average. While primary energy consumption will expand 1.7-fold to 232 Mtoe, the GDP energy intensity will improve at an annual rate of 1.1%. Energy consumption per capita will be 3.5 toe, double the ASEAN average.

Oil consumption, accounting for about 40% of primary energy demand, will increase 1.7-fold. While most other ASEAN countries will expand oil demand due primarily to growing vehicle fuel consumption, about 70% of the Thai oil demand growth will be for the industry sector including the petrochemical industry. Coal demand will almost double for power generation and industrial production such as steel and non-metallic minerals, with its share of the energy mix rising from 12% to 16%. Demand for natural gas mainly for industrial production and power generation will increase about 1.4-fold. While traditional biomass demand in rural regions will decline in line with urbanisation, the whole of biomass demand will expand 1.6-fold due to rising demand for power generation and vehicle fuels. Demand for renewables other than biomass will increase 3.3-fold, while non-biomass renewables' share of the energy mix will be limited to less than 1%.

Electricity demand will double, with coal-fired power plants covering more than one-third of the growth. Despite citizens' opposition to coal consumption given air pollution problems, demand for cheap coal will increase. Meanwhile, natural gas's share of the power generation mix will fall from about 70% to less than 50%, indicating the diversification of electricity sources. As for nuclear power generation, three reactors will be introduced from 2025. Electricity imports from neighbouring countries such as Myanmar and Laos will increase, with a dependence rate on imports for electricity supply rising from 6% to 11%.

Domestic oil production will decline from 450 kb/d to 350 kb/d while net oil imports will double. Natural gas production will also fall slowly but net natural gas imports will more than triple. Due to the domestic fossil fuel production decline, rising domestic energy demand and growing electricity imports, the energy self-sufficiency rate will drop from 58% at present to 42%.

Figure 99 | Thailand's primary energy consumption [Reference Scenario]



6.3 Malaysia

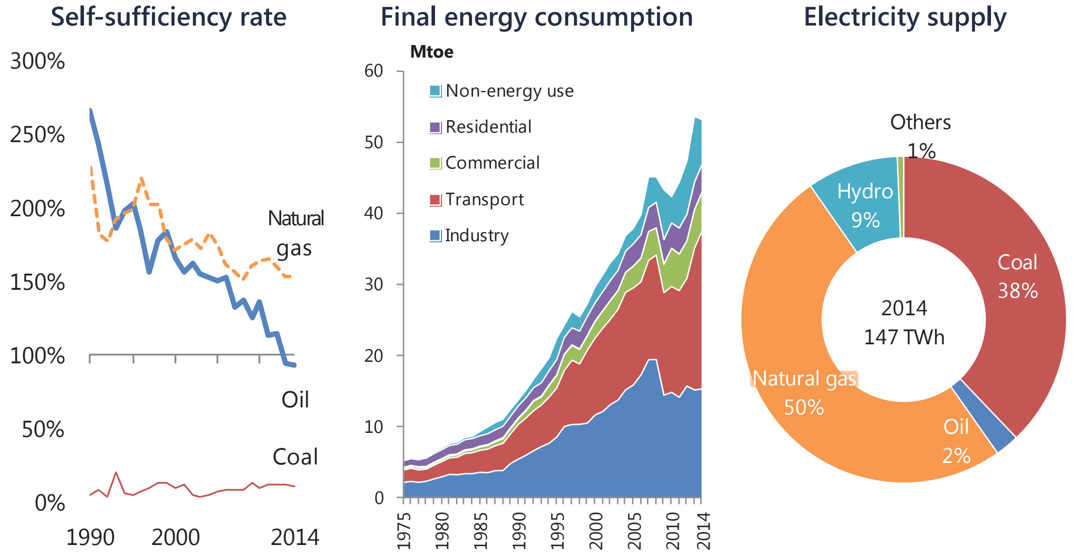
Present situation

Despite a temporary fall in 2009, Malaysian primary energy consumption has mostly continued growing robustly. The average annual growth for the past decade was 3.5%. During the same period, the transport sector posted the largest annual growth in final energy consumption at 5.6% representing the largest share of the consumption at 42% in 2014. While energy demand in the commercial and residential sectors has increased, demand in the industry sector failed to recover after a substantial decline in 2009. Among energy sources, oil is the most used, accounting for 55% of final consumption in 2014.

Malaysia, though exporting oil and natural gas, has seen its energy self-sufficiency rate trending down for more than two decades. The downward trend is so significant for oil that Malaysia became a net oil importer in 2013. As for natural gas, a mismatch between consumption and production locations has become a problem. While natural gas demand is concentrated in the Malay Peninsula including the capital city of Kuala Lumpur, most Malaysian natural gas resources are located on the Borneo Island, across the sea. Therefore, Malaysia completed an LNG terminal in the western part of the Malay Peninsula and is proceeding with new LNG terminal construction projects to secure natural gas supply for the peninsula. It has also introduced initiatives to restrict natural gas consumption.

Natural gas's share of the power generation mix has been declining gradually on progress in the construction of coal-fired power plants. With concerns emerging about natural gas supply on the Malay Peninsula limits have been introduced on domestic natural gas resources. Natural gas's share of the electricity supply peaked at 74% in 2000 and currently accounts for about half.

Figure 100 | Malaysia's energy overview



Source: IEA "World Energy Balances 2016"

Outlook

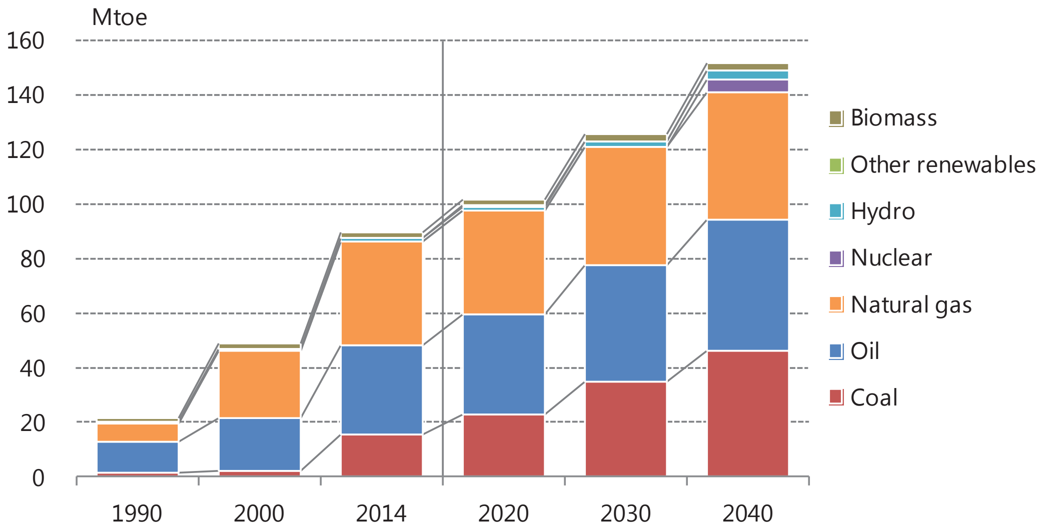
Malaysia, which is relatively wealthy in the ASEAN region with income per capita exceeding $10,000, will see population increasing at an average annual rate of 1.0% per year and GDP growing annually at 4.1% through 2040. Primary energy consumption will expand 1.7-fold to 152 Mtoe, posting an average annual increase of 2.0%, slipping far below the economic growth. The GDP energy intensity will therefore improve by about 40%.

Due to limited access to traditional biomass and relatively poor hydro resources on the Malay Peninsula, fossil fuels cover 97% of primary energy consumption. Natural gas, used mainly for petrochemical and other industrial production, will increase by about 20% through 2040 while its share of the energy mix will fall from 43% to 31%. Although oil consumption will increase by about 50%, mainly for vehicles, its energy mix share will also decline. Meanwhile, coal will post a three-fold consumption increase (of which more than 90% will be for power generation), raising its energy mix share to 31% rivalling oil and natural gas shares. Although non-fossil energy consumption including nuclear and hydro will also increase sharply, Malaysia will continue to depend on fossil fuels for more than 90% of primary energy supply.

Electricity demand will grow 2.5-fold in line with industrialisation and improvements in living standards, with coal-fired power plants covering about two-thirds of the growth. Coal's share of the power generation mix in 2040 will exceed 50%. Meanwhile, natural gas's share will decline from 50% at present to less than 30%. Hydro's share will remain unchanged at around 9%. Other renewable energy power generation will increase seven-fold, though with its share being limited to 2%. As for nuclear power generation, two reactors will launch operation in or after 2030.

Domestic oil production will decrease from 310 kb/d to 250 kb/d, with the rate of dependence on oil imports rising to some 50%. Natural gas production will expand by 5% to 75 Bcm of which 75% will be used to meet rapidly increasing domestic demand. Due to such domestic production and demand trends, the energy self-sufficiency rate will fall from 106% to 67%, slipping far below 100%.

Figure 101 | Malaysia's primary energy consumption [Reference Scenario]



6.4 Viet Nam

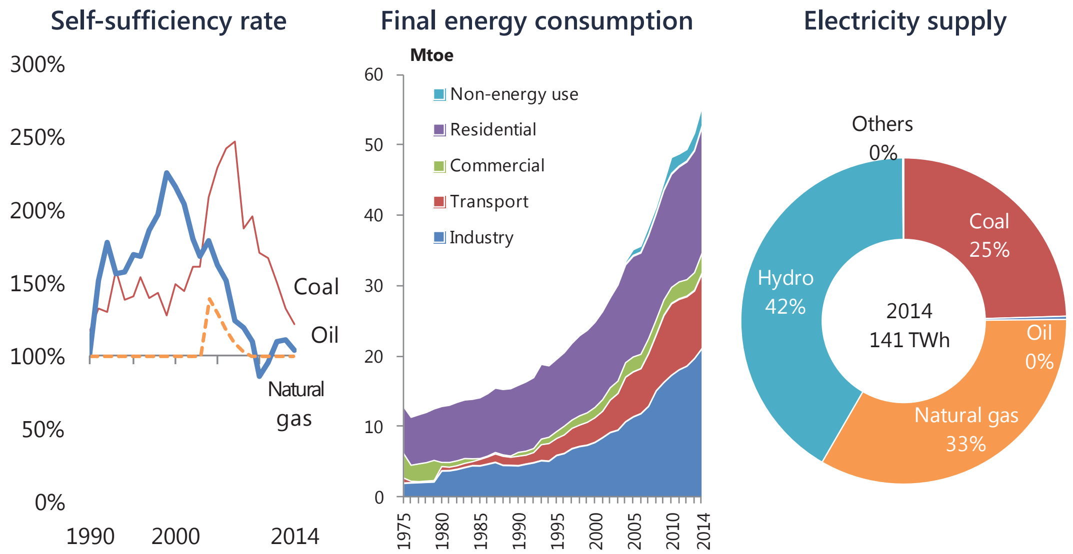
Present situation

Viet Nam's primary energy consumption has been rising since the 1970s, with the growth accelerating since the 2000s. The average annual growth was 5.5% for the past decade. Among sectors, industry recorded the largest annual consumption growth of 17.1% for the past decade and the largest consumption share of 38% in 2014. The transport sector's share of final energy consumption in 2014 was 19%, not as large as the other sectors. However, its final energy consumption's average annual growth for the past decade was as high as 5.8%. No particular energy source seems to present remarkable trends as each sources (coal, oil, electricity and traditional biomass) accounts for a quarter of the final energy consumption. Viet Nam had traditionally depended on imports for most of its petroleum products supply before its first oil refinery went on stream in 2009, allowing the country to refine domestically produced crude oil on its own. A second oil refinery is now under construction.

Hydro is the most used electricity source in Viet Nam. Coal-fired power plants are mainly used in the North (near Hanoi) and natural gas-fired power plants are mainly in the South including Ho Chi Minh City. The energy bias is attributable to abundant coal resources in the North and abundant natural gas resources in the South. As electricity demand is growing very rapidly, domestic coal and natural gas production is feared to fail to meet the growth. Therefore, Viet Nam has enhanced domestic coal resources development, reduced exports and started imports. In preparation for future natural gas shortages, the country is proceeding with an LNG terminal construction project.

While taking these measures, Viet Nam will become the first ASEAN country to use nuclear power generation. It has adopted the Russian technology for its first nuclear reactor that is expected to come on stream around 2030, slightly later than planned.

Figure 102 | Viet Nam's energy overview



Source: IEA "World Energy Balances 2016"

Outlook

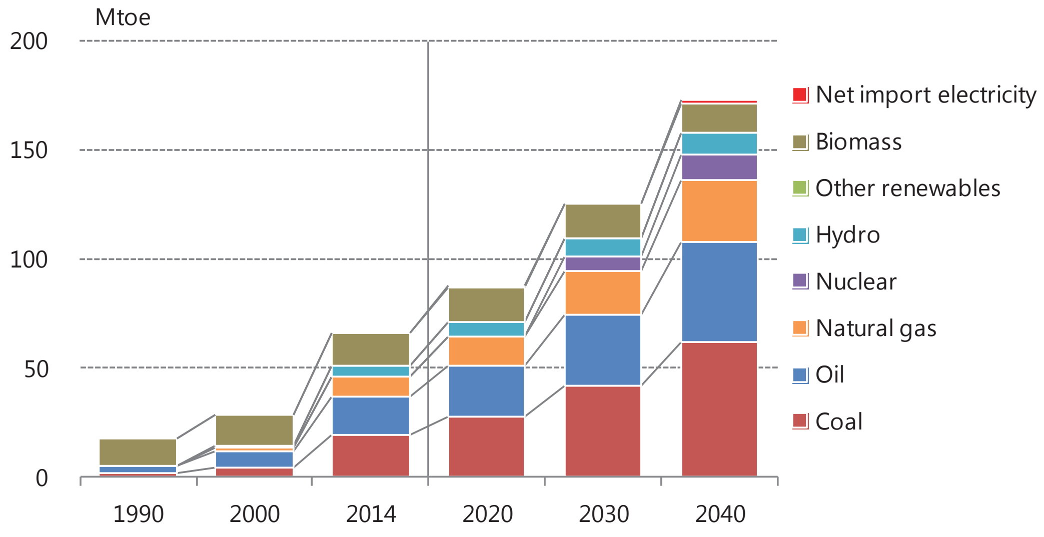
Viet Nam, which is poor with income per capita limited to half of the ASEAN average at about $1,600, will post a high average annual economic growth rate of 5.7%. Backed by the high economic growth and a population accounting for 15% of the ASEAN region, Viet Nam will boost primary energy consumption 2.6-fold to 173 Mtoe, replacing Malaysia as the third largest ASEAN energy market. Consumption per capita will double to 1.6 toe, while the GDP energy intensity will improve at an annual rate of 1.8%.

Coal consumption, currently accounting for about 30% of primary energy consumption, will increase 3.2-fold mainly for power generation in line with rapidly growing electricity demand; the coal's share of the energy mix will rise to 36%. Natural gas consumption will expand 3.1-fold with power generation accounting for 85% of the growth. Oil consumption will grow 2.6-fold mainly in the road sector (with motorcycle fuel accounting for about 70% of demand). The rate of dependence on fossil fuels will rise from 69% to 79%. Meanwhile, traditional biomass, which currently accounts for more than 20% of the energy mix and about 60% of residential sector energy consumption, will decline in response to urbanisation, with its energy mix share falling to 8%.

In line with industrialisation and improvements in living standards, electricity demand will expand 3.6-fold, with coal covering more than 40% of the growth and natural gas a little less than 30%. Nuclear power generation, for which plant construction has been delayed, will start from the 2020s toward a total capacity of 6.4 GW and account for 9% of the electricity mix. Hydro power generation, which is the largest electricity source accounting for more than 40% of total power generation now, will double, but its share will fall to 23%.

Domestic oil production will decline slowly from 290 kb/d to 250 kb/d, while domestic oil demand will rapidly increase. The oil self-sufficiency rate will slip below 30%. Viet Nam rich with coal resources will boost coal production 1.5-fold. However, domestic coal production will fail to meet rapidly increasing domestic demand, resulting in a substantial increase in coal imports. Due to such domestic energy production and demand trends, the energy self-sufficiency rate will decrease from 107% at present to 53%.

Figure 103 | Viet Nam's primary energy consumption [Reference Scenario]



6.5 Philippines

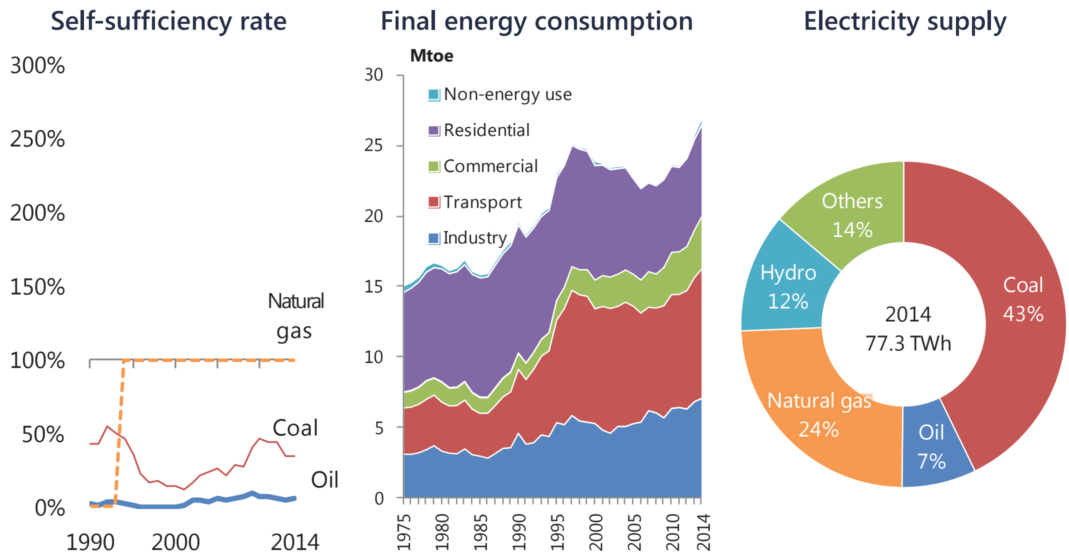
Present situation

Philippines primary energy supply rapidly increased before turning down in the wake of the Asian currency crisis. It has picked up in recent years, reflecting one of the highest economic growths in the ASEAN region. As such, the average annual energy supply growth for the past decade was 2.3%, lower than in other ASEAN countries. However, the average growth for the past five years was faster at 4.5%. Among sectors, transport captured the largest share of final energy consumption at 34%, while industry posted the highest annual average growth of 3.3% for the past decade. Among energy sources, oil accounted for the largest share of final energy consumption at 48%. This may be because oil is the most convenient or the only available energy source for many islands making up the Philippines, as is the case with Indonesia.

Coal is the most used energy source for power generation in the Philippines, followed by natural gas. In the Philippines where the electricity market has been deregulated, energy sources are selected from the viewpoint of economic efficiency and coal is cheaper. While natural gas accounts for about a quarter of electricity supply, the Philippines depend on limited domestic resources for natural gas supply, resulting in some constraints on natural gas supply expansion. The Philippines Government pursues a low-carbon electricity supply for which natural gas is a promising option. However, natural gas supply expansion cannot be realised without an import infrastructure development. The natural gas self-sufficiency rate now stands at 100% because consumption is limited to domestic gas production capacity.

The Philippines is separated by the sea from other ASEAN countries, making it difficult to increase and stabilise electricity supply by connecting either gas pipelines or transmission lines. The presence of many remote islands also makes it difficult for the existing system to improve energy supply efficiency. Therefore, the Philippines pays attention to the expansion of hydro, biomass and other renewables and distributed energy supply systems.

Figure 104 | Philippines' energy overview



Source: IEA "World Energy Balances 2016"

Outlook

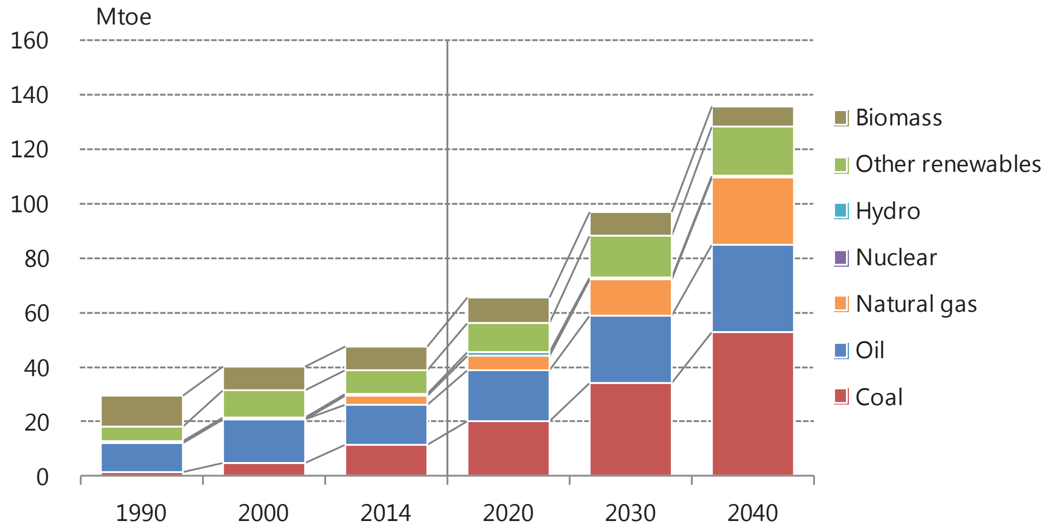
Philippines population will increase at an annual rate of 1.3% (the second fastest after Laos in the ASEAN region) from 100 million at present through 2040, accounting for 18% of ASEAN population. As GDP grows at an annual rate of 5.0%, primary energy consumption will expand 2.9-fold to 136 Mtoe. Energy consumption per capita will double to 1.0 toe, still equivalent to some 60% of the ASEAN average in 2040.

Oil consumption, now accounting for about 30% of primary energy consumption, will expand 2.2-fold mainly for vehicle fuels (the vehicle ownership now stands at 10%, a half of the ASEAN average). Coal and natural gas consumption will increase about five-fold and eight-fold, respectively, to meet rapidly increasing electricity demand, with the two energy sources' combined share of the energy mix doubling from 31% to 57%. The rate of dependence on fossil fuels will expand to 81%. Meanwhile, traditional biomass, which now accounts for nearly 20% of the energy mix and more than 40% of the buildings sector's energy consumption, will decline in consumption as urbanisation increases, with its energy share falling to 6%. Other renewables (dominated by geothermal) will expand about two-fold in consumption while their energy mix share will decrease.

In line with urbanisation, rising living standards and industrialisation, electricity demand will increase more than five-fold. Coal- and natural gas-fired power plants will cover nearly 60% and more than 40% of the growth, respectively. Geothermal power generation now accounts for 13% of electricity supply. Although generation will double, its share will decline to 5% due to far faster growth in electricity demand. Solar PV and wind power generation will expand more than 20-fold, with their share of the power generation mix still limited to around 1%.

The Philippines, rather poor with fossil resources, will reduce domestic oil production and maintain natural gas and coal production at present levels, depending on imports to meet domestic demand growth. The energy self-sufficiency rate will drop from 54% to 25%.

Figure 105 | Philippines' primary energy consumption [Reference Scenario]



6.6 Myanmar

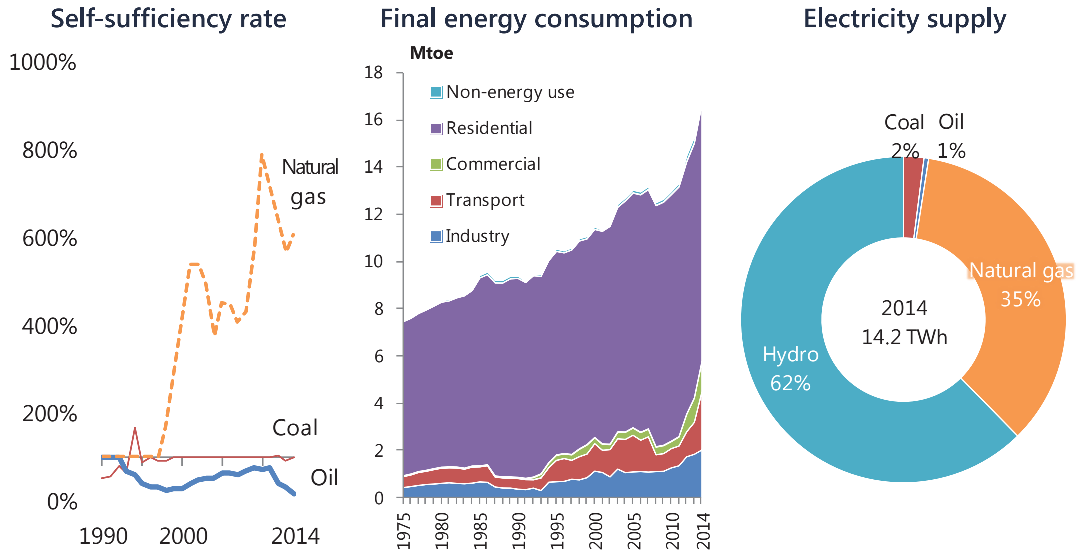
Present situation

Myanmar's primary energy consumption has increased steadily since the 1970s. The average annual growth rate for the past decade was 2.9%, a standard level for ASEAN countries. For the past five years, however, the average growth rate reached as high as 6.2%. The residential sector accounts for as much as 64% of final energy consumption, indicating that Myanmar is in the initial industrialisation and motorisation phase. In the past five years, however, the transport and industry sectors posted respective explosive average annual consumption growth rates of 32% and 12%. The international community has promoted assistance to Myanmar since its democratisation in 2015, with many international enterprises expanding into that country. Therefore, energy consumption will continue growing mainly in those two sectors. Among energy sources, traditional biomass accounted for as much as 64% of final energy consumption in 2014.

Hydro accounts for 60% of the power generation and natural gas for most of the remainder. Myanmar has one of the largest hydro power generation potentials in the ASEAN region, indicating future expansions in hydro power generation. Myanmar, rich with natural gas among fossil fuels, uses natural gas for power generation.

Myanmar's energy supply challenges are electrification and future natural gas supply. Its electrification rate was as low as 32% in 2015 (IEA), showing that the country must construct large power plants and develop grid networks. Current natural gas production is sufficient to cover domestic demand as well as exports to China and Thailand. Over a medium to long term, however, domestic supply is feared to become short. Therefore, Myanmar is now accelerating natural gas development in offshore concessions where resources are expected to exist.

Figure 106 | Myanmar's energy overview



Source: IEA "World Energy Balances 2016"

Outlook

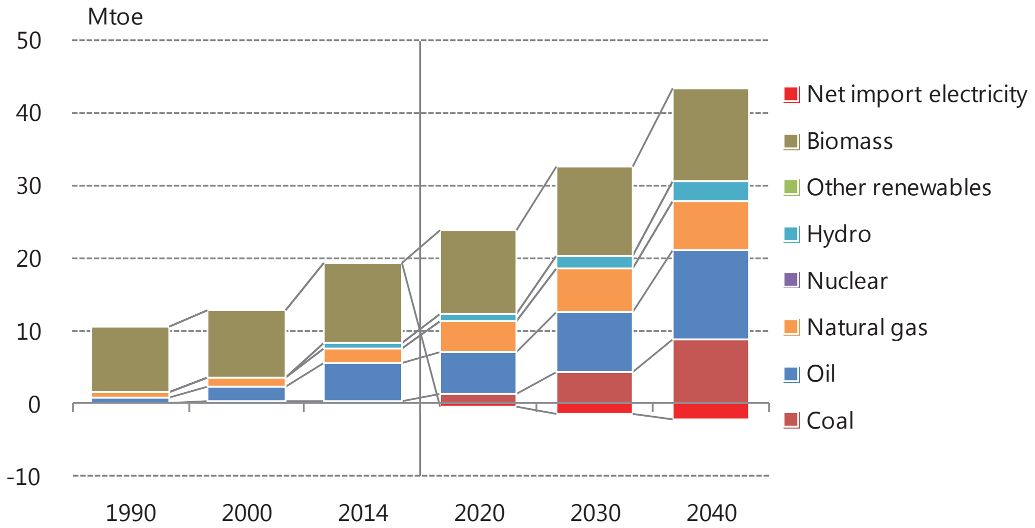
With income per capita being as low as $1,000, Myanmar is one of the poorest countries in the ASEAN region. Given progress in democratisation and economic opening, however, Myanmar is seen as one of the attention-attracting countries in Asia. In the outlook period, its annual average economic growth is expected to be as high as 6.0%. Supported by high economic growth, primary energy consumption will expand 2.1-fold to 41 Mtoe. Consumption per capita will double to 0.7 toe, still less than 40% of the ASEAN average.

Traditional biomass accounts for about 60% of primary energy consumption and for about 90% of the buildings sector's consumption (mainly for cooking). With urbanisation, fossil fuel demand will be expanding rapidly and the traditional biomass demand growth will decelerate to a point where its share of primary energy consumption will fall to 30%. Oil consumption will more than double due to growth in vehicle fuel consumption and industrial production. Natural gas consumption covered by domestic resources will almost triple mainly for industry and power generation sectors and coal consumption will expand about 22-fold to meet a rapidly growing electricity demand. Given high economic growth, the rate of dependence on fossil fuels will rise from 39% to 68%.

Electricity demand will expand about six-fold due to industrialisation and rising living standards. Cheap coal-fired power generation will cover nearly 50% of the growth, while natural gas-fired and hydro power generation will equally share the remainder. The domestic resources of hydro and natural gas cover more than 60% and nearly 40% of electricity demand at present. In 2040, however, coal will become the largest electricity source, with its share of the power generation mix coming to 40%. Shares for hydro and natural gas will fall to around 30%. Backed by abundant hydro resources, Myanmar will export a quarter of its total electricity generation to such countries as Thailand.

Limited domestic oil production will decline further, leading Myanmar to depend on imports for almost all its oil supply. With abundant natural gas resources compared to domestic demand, Myanmar will expand natural gas production by about 80% from the present level, becoming the only ASEAN country to expand natural gas exports. The energy self-sufficiency rate covering electricity exports as well will fall from 133% at present to 101%, managing to remain above 100%.

Figure 107 | Myanmar's primary energy consumption [Reference Scenario]



6.7 Other ASEAN countries

Singapore

In Singapore, the wealthiest ASEAN country with income per capita topping $50,000, final energy consumption totalled 17.4 Mtoe in 2014. Due to the small country size, final consumption is similar to the level in Myanmar. However, Singapore's consumption per capita is 10 times as much as the Myanmar level. Energy demand has come close to saturation and will limit growth through 2040 to some 20%. Primary energy consumption per capita will fall slightly to 5.0 toe, while the GDP energy intensity will improve by about 30%. Serving as the centre of Asian oil trade, Singapore has a larger oil and petrochemical industry than indicated by its country size. Therefore, energy consumption for the industry sector and petrochemical feedstocks accounts for more than 70% of final consumption. Due to such industrial structure, oil captures more than 60% of primary energy consumption. Although Singapore depends on imports for all of its natural gas supply, natural gas accounts for 95% of the power generation. Electricity demand will increase by 40% mainly in the buildings sector, with more than 80% of the growth being covered by natural gas-fired power generation and the remainder by biomass-fired and other renewable energy generation. As natural gas consumption for power generation expands, oil's share of the energy mix will gradually decline. In Singapore, limited in natural resources, the current energy self-sufficiency rate of 2% will rise to around 5% in 2040, thanks to renewable energy expansion.

Brunei

Brunei, an oil and natural gas producer, accounts for only 0.1% of ASEAN population. However, GDP per capita is about eight times higher than the ASEAN average and energy consumption per capita about nine times higher. Final energy consumption in 2014 stood at 1.4 Mtoe. Among sectors, transport captures the largest share of final energy consumption at

30% as the country features a small population size and the absence of significant industries other than the oil and natural gas export industry. Energy demand is close to saturation and will increase by only 10% through 2040, with demand per capita falling. Oil consumption will expand 1.4-fold, mainly for industrial production and vehicle fuels and the oil's share of primary energy consumption will rise to around 30%. Natural gas consumption, now accounting for about 80% of total primary energy consumption, will increase for petrochemical and other industrial production while decreasing for power generation, eventually remaining unchanged. Natural gas covers almost all power generation in Brunei. In 2040, however, solar PV and wind power generation under development will increase to 7% of total generation. Given a downtrend in resources, the conservation of natural gas resources and the medium to long-term diversification of the economy have become challenges. Brunei will become a net oil importer as oil resources deplete, but will remain a net natural gas exporter, even with a 20% decline in production.

Cambodia

With income per capita limited to as low as $1,000 and the electrification rate at only 34%, Cambodia and Myanmar are the poorest countries in the ASEAN region. Primary energy consumption has expanded robustly in recent years, reaching 6.4 Mtoe in 2014. Among sectors, the residential sector captures a large share of primary energy consumption, indicating that industrialisation and motorisation are starting. GDP will grow by an average 6.1% per year through 2040, with primary energy consumption expanding 2.6-fold to 16.8 Mtoe. Consumption per capita will double to 0.8 toe, still lower than a half of the ASEAN average. As about 80% of the population lives in rural areas, traditional biomass accounts for two-thirds of primary energy consumption and as rural population continues to increase, despite progress in urbanisation, biomass consumption will increase 1.4-fold. Oil consumption will quadruple mainly in the transport and buildings sectors. In line with high economic growth, Cambodia's rate of dependence on fossil fuels will rise from 31% to 53%. The power generation sector has been dependent on oil for the majority of its total power generation, leading to the problem of high power generation costs. The electricity supply mix has dramatically changed in the past decade and in recent years, coal-fired and hydro power generation has made progress, resulting in a rapid fall in oil's share of power generation. Electricity demand will expand more than six-fold, with some 20% of the growth covered by coal-fired power generation and the remainder by hydro power generation. Poor in domestic resources, other than hydro, Cambodia's energy self-sufficiency rate will fall from 67% at present to 46% in 2040.

Laos

Laos has attracted attention in recent years under the Japanese companies' Thailand Plus One strategy. As industrialisation is making progress, GDP is expected to grow at an annual rate of 5.2% through 2040. Primary energy consumption will expand 3.3-fold from an estimated 2.4 Mtoe in 2014, representing the highest growth in the ASEAN region. Consumption per capita will increase 2.4-fold to 0.9 toe, still limited to less than a half of the ASEAN average. Supported by the abundant hydro resources of the Mekong River, hydro accounts for the majority of its primary energy consumption. Most hydro power generation is exported to such countries as Thailand. Laos's hydro power generation potential is greater than indicated by domestic demand, leading the country to take maximum advantage of the potential for exporting electricity. However, there had been the problem of seasonal fluctuations in hydro power generation. Since 2015, coal-fired power plants have been operating as stable electricity sources unaffected by weather conditions. Domestic electricity demand will quintuple by 2040, with 30% of the growth covered by coal-fired power generation and the remainder by hydro power generation (exports' share of power generation will be kept at 70%). Oil consumption mainly for the transportation sector and coal consumption for the power generation sector will increase more than seven-fold, raising Laos's rate of dependence on fossil fuels from 33% to 72%. Laos depends on imports for almost all oil supply and on domestic production for coal supply. The energy self-sufficiency rate covering electricity exports will stand at 153% in 2040, maintaining the current level of 147%.

7. Influences of ASEAN market integration on energy

7.1 Oil and natural gas

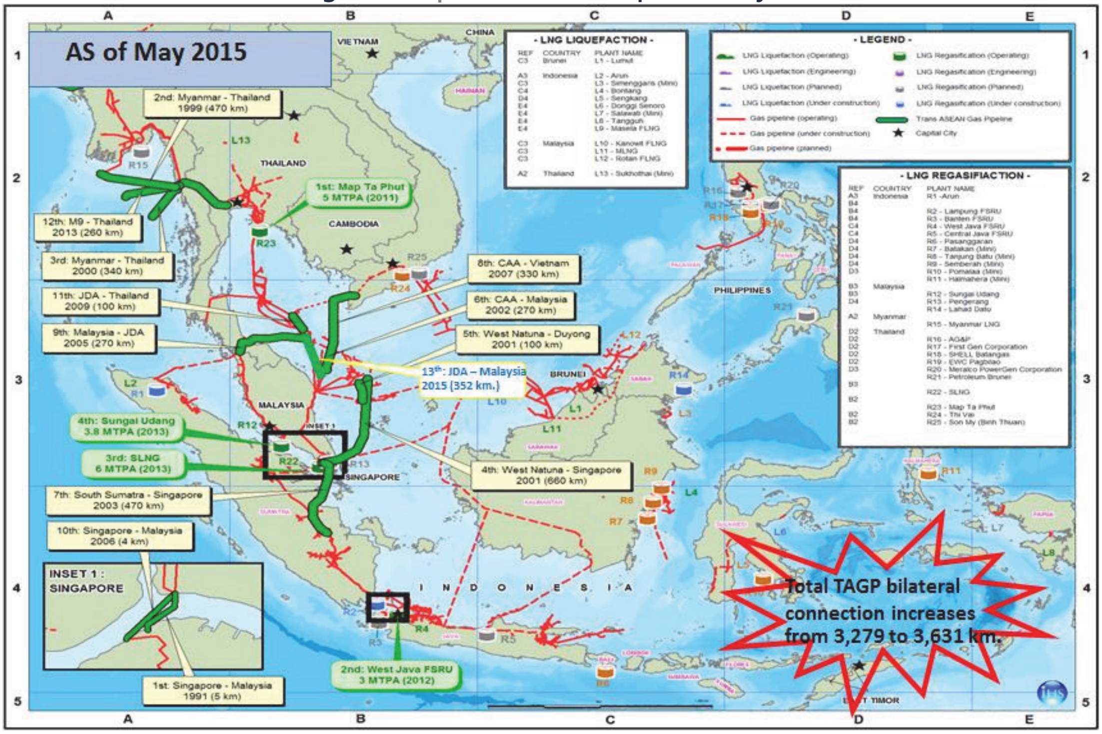
The ASEAN Economic Community (AEC) was established at the end of 2015 after preparations under the 2003 Declaration of ASEAN Concord II to deepen ASEAN. Regarding energy, the AEC gives priority to supply security. As for oil and natural gas, an official document[14] cites the ASEAN Petroleum Security Agreement to provide for a framework for mutual oil supply between ASEAN members in an emergency and the Trans ASEAN Gas Pipeline Project to cover the whole of ASEAN. These schemes focus on oil and natural gas supply security rather than market integration.

Market integration would undoubtedly contribute to improving energy security and lowering energy prices. Toward market integration, ASEAN is repealing tariffs on goods and services under the ASEAN Trade in Goods Agreement (ATIGA). Oil and natural gas as well as other goods are subject to ATIGA. Tariffs on oil and natural gas transactions between ASEAN members are left only in Cambodia, Viet Nam, Myanmar and Laos. Given that the four countries account for only 5% of ASEAN oil and natural gas imports and import oil and natural gas from non-ASEAN countries as well ASEAN members, the complete repeal of intraregional tariffs will have only limited market integration effects. ASEAN must go ahead with the repeal of restrictions on new entries into domestic energy markets, energy subsidies and other non-tariff trade barriers. It should complete the elimination of intraregional tariffs and pursue the connection of infrastructure.

The Trans ASEAN Gas Pipeline Project was originally proposed as one of the ASEAN integration measures at an ASEAN summit in Kuala Lumpur in 1997. The ASEAN Council on Petroleum, which consists of state-run oil companies in the region, has been commissioned to serve as the secretariat for promoting the project. Since the preparation of a master plan for pipeline construction, pipelines connecting 13 locations in the region have been opened, including those from Myanmar to Thailand and from Indonesia (West Natuna) to Singapore and Malaysia. However, the existing pipeline network has yet to link all ASEAN countries. Behind such situation are the problem of how to share pipeline construction costs and a decline in the natural gas export potential of Indonesia and Malaysia that were assumed as exporters but now see growing domestic demand.

[14] ASEAN Economic Community Blueprint 2025, November 2015
http://www.asean.org/storage/images/2015/November/aec-page/AEC-Blueprint-2025-FINAL.pdf

Figure 108 | Trans ASEAN Pipeline Project



Source: ASCOPE, http://www.ascope.org/Projects/Detail/1060

At a time when ASEAN as a whole is becoming a net natural gas importer, the legitimacy of the ASEAN pipeline network is being lost. A seemingly feasible plan at present is to construct pipelines from Indonesia's East Natuna gas field to Malaysia and Thailand.

East Natuna is an offshore gas field located in waters off northern Sumatra of Indonesia, with reserves proven at 46 Tcf. A consortium comprising ExxonMobil, Pertamina (Indonesia), Total and PTT (Thailand) is planned to develop the gas field. Given that the consortium members have not signed any production sharing agreement and that development is difficult due to high carbon dioxide content (at 71%), however, development has been delayed. Development costs are estimated at $20 – 40 billion[15], with production projected at about 20 Bcm. We here estimate a simple economic effect under an assumption that natural gas production will be exported to Malaysia to reduce its LNG imports.

Wellhead development costs at the East Natuna gas field are assumed at $30 billion, with operation costs at 3% of the initial investment amount and annual production at 20 Bcm. All production is assumed to be exported to the Malay Peninsula. Construction of a pipeline (about 150 km) to the Malay Peninsula is estimated at $450 million, with operation costs at 2% of the initial investment. The LNG import cost is presumed to gradually rise from $10.7/MBtu in 2020 to $14.1/MBtu in 2040, as described in Chapter 1. If natural gas produced

[15] Jakarta Post, January 6, 2016
http://www.thejakartapost.com/news/2016/01/07/joint-operation-natuna-block-proposed.html

at East Natuna is transported via pipeline to Malaysia to replace imported LNG, external LNG import payments will be reduced by a total of $169 billion through 2040.

Other advantages accompanying the pipeline construction include the diversification of supply sources for energy security. International pipelines in the ASEAN region for international natural gas provision could minimise adverse effects of unexpected LNG supply disruptions. Such international provision arrangements may also allow inventories for supply disruptions to be reduced.

A wide pipeline network will also allow multiple LNG terminals to be integrated. At present, more than 10 LNG terminals are being constructed in the ASEAN region. The wide pipeline network will enable the integration of these terminals to reduce initial LNG introduction costs. The integration will allow stakeholders to benefit from economies of scale at LNG terminals. International LNG provision via the pipeline network will enable Laos, an inland country without coasts for LNG terminals, to introduce LNG.

Furthermore, pipeline network development will also contribute to expanding natural gas's share of the energy mix. As a matter of course, policy authorities in each country will have to make clear commitments to expand the share for natural gas that is inferior to coal in economic efficiency. Wide pipeline network development will promote a shift to natural gas in locations along pipelines, contributing to preventing air pollution resulting from excessive coal consumption and to cutting greenhouse gas emissions.

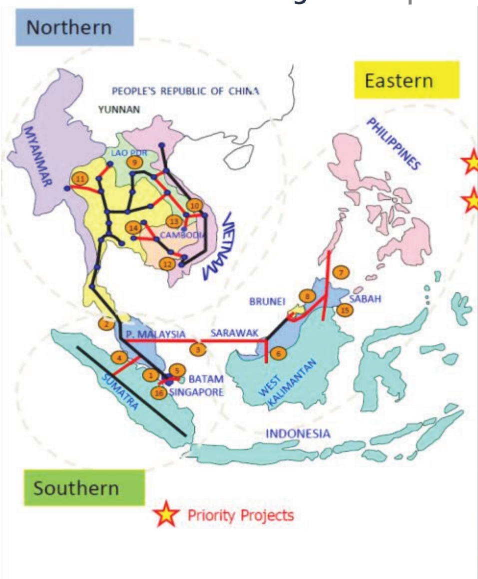
7.2 Electricity

Greater expectations are placed on market integration of the electricity sector over a long run. As indicated by Figure 109, for example, the ASEAN Power Grid (APG) initiative is planned to internationally connect transmission lines of ASEAN countries. The initiative aims to improve the reliability of electricity systems and respond to growing electricity demand by connecting present separated electricity systems to use regional energy resources effectively and enhance electricity trading.

Behind the initiative is the uneven distribution of ASEAN energy resources including hydro resources. As indicated by Figure 110, ASEAN hydro resources are concentrated in Laos and Myanmar. The initiative seeks to link these hydro-rich countries to energy demand areas such as southern China (Yunnan Province), northeast India, Thailand, the Malay Peninsula and Java Island to induce the effective use of hydro resources.

Southern ASEAN countries feature island-by-island or area-by-area electricity systems. For example, Borneo consisting of Brunei, Malaysian and Indonesian territories is known for rich hydro resources. Of particular interest, a large-scale hydro development is going on in Malaysia's Sarawak State. Many countries plan to enhance the connection of state-by-state electricity systems on Borneo and link them via submarine cables to demand locations such as the Malay Peninsula and Java Island for the effective use of hydro resources.

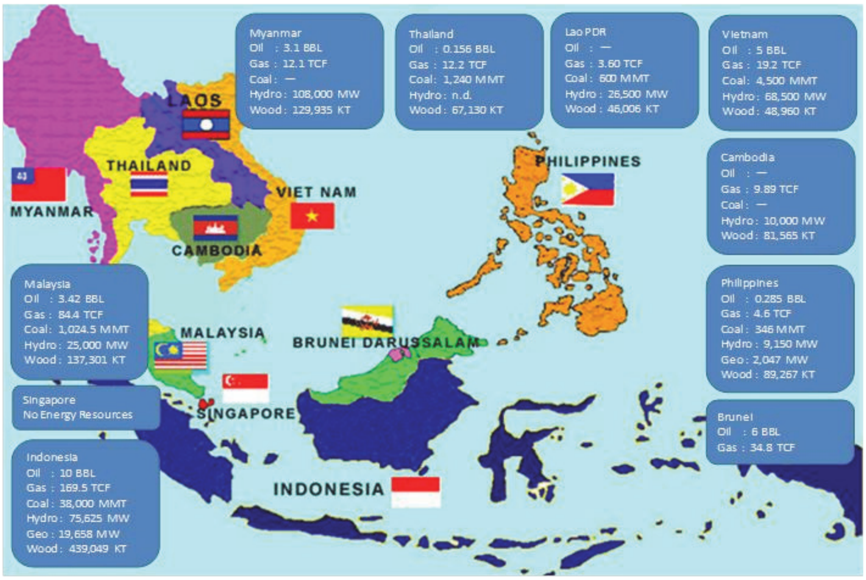
Figure 109 | ASEAN Power Grid



		Earliest COD
1)	P.Malaysia - Singapore (New)	Post 2020
2)	Thailand - P.Malaysia	
•	Sadao - Bukit Keteri	Existing
•	Khlong Ngae - Gurun	Existing
•	Su Ngai Kolok - Rantau Panjang	2016
•	Khlong Ngae – Gurun (2nd Phase, 300MW)	2016
3)	Sarawak - P. Malaysia	2025
☆4)	P.Malaysia - Sumatra	2019
5)	Batam - Singapore	2020
☆6)	Sarawak - West Kalimantan	2015
7)	Philippines - Sabah	2020
8)	Sarawak - Sabah – Brunei	
•	Sarawak –Sabah	2020
•	Sabah – Brunei	Not Selected
•	Sarawak – Brunei	2016
9)	Thailand - Lao PDR	
•	Roi Et 2 - Nam Theun 2	Existing
•	Sakon Nakhon 2 – Thakhek – Then Hinboun (Exp.)	Existing
•	Mae Moh 3 - Nan - Hong Sa	2015
•	Udon Thani 3- Nabong (converted to 500KV)	2019
•	Ubon Ratchathani 3 – Pakse – Xe Pian Xe Namnoy	2018
•	Khon Kaen 4 – Loei 2 – Xayaburi	2019
•	Thailand – Lao PDR (New)	2015-2023
10)	Lao PDR - Vietnam	2016-2020
11)	Thailand - Myanmar	2018-2026
12)	Vietnam - Cambodia (New)	2020
13)	Lao PDR - Cambodia	2016
14)	Thailand - Cambodia (New)	Post 2020
15)	East Sabah - East Kalimantan	Post 2020
16)	Singapore – Sumatra	Post 2020

Source: HAPUA

Figure 110 | ASEAN hydro potential



Source: EGAT

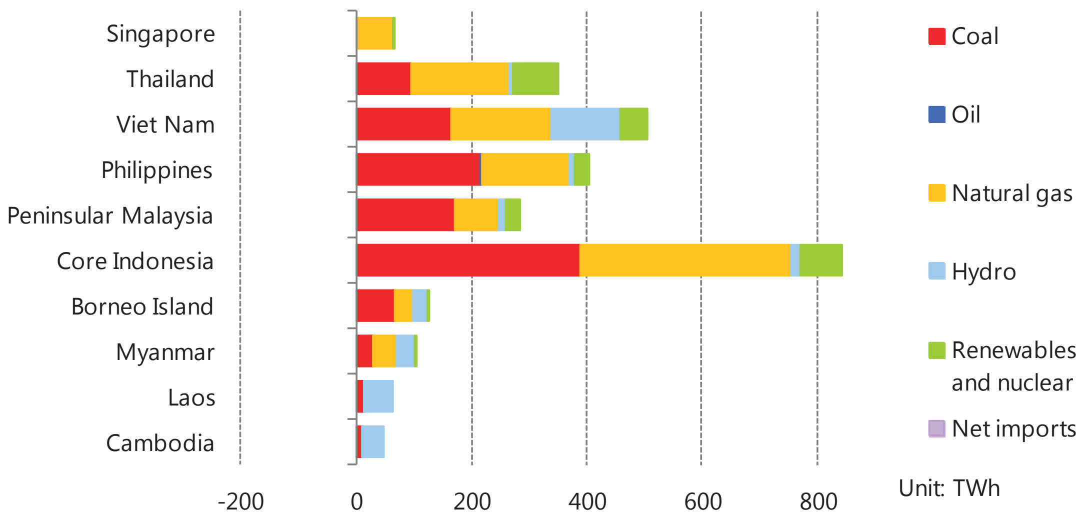
In the following analysis, we assess the economic effect of the international grid connection[16]. The assessment covers three cases: (1) No-connection Case[17] in which there will be no additional grid connection through 2040; (2) Planned Connection Case in which existing grid

[16] This chapter's assessment follows an approach in Kutani, I and Y. Li, "Investing in Power Grid Interconnection in East Asia," ERIA Research Project Report 2013-23, (2014).
[17] This is equivalent to the *Reference Scenario*.

connection plans will be implemented; and (3) Unlimited Connection Case in which maximum grid connection will be implemented beyond the existing plans by 2030.

Figure 111 | ASEAN power generation mix [2040]

[No-connection Case]



[Planned Connection Case]

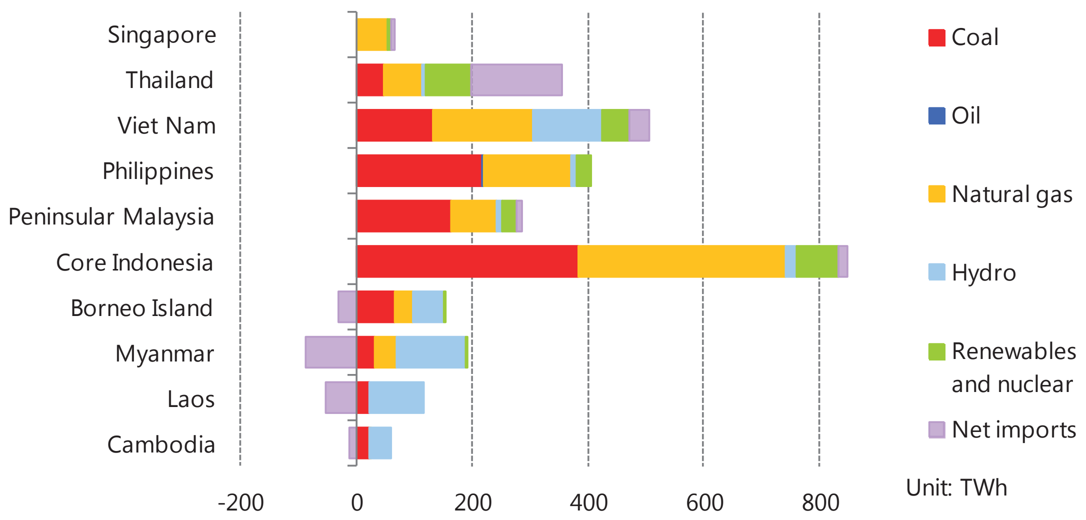
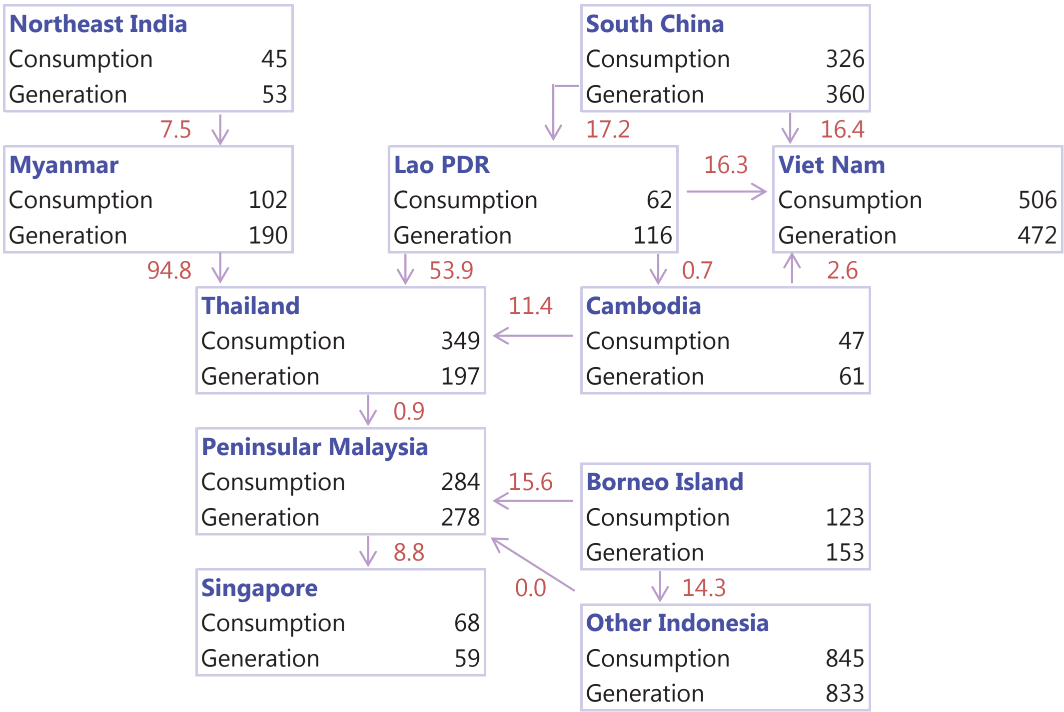


Figure 111 indicates each country's power generation mix for 2040. In the No-connection Case, ASEAN countries will conduct their respective independent electricity supply without international supply. In the Planned Connection Case, Borneo Island, Myanmar, Laos and Cambodia will develop hydro resources and export electricity, while Thailand, Viet Nam, Peninsular Malaysia and core Indonesia will import electricity. Particularly, the connection will have a great effect on Thailand neighbouring Laos and Myanmar.

Figure 112 indicates electricity trade flows for 2040 in the Planned Connection Case. Viet Nam anticipating rapid growth in electricity demand will import electricity from Laos, Cambodia and outside the ASEAN region (southern China: Yunnan Province). On the other hand, electricity will be supplied from northern ASEAN to southern ASEAN to meet electricity demand in areas such as Thailand, Peninsular Malaysia and Java Island.

Figure 112 | Electricity trade flows [Planned Connection Case for 2040]

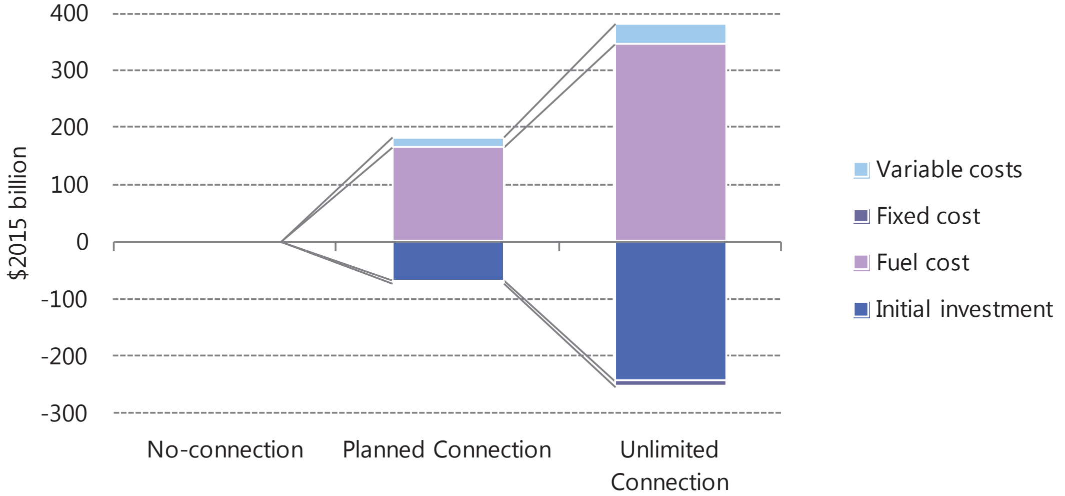


Unit: TWh
Note: "Consumption" includes plant and transmission losses.

Figure 113 indicates the accumulated costs and benefits accompanying grid connection through 2040 as gaps with the No-connection Case. While grid connection will require initial investment in cables and hydro power generation facilities as additional costs, grid stabilisation through the connection will allow the generation reserve margin for the same loss of load expectation (assumed at around 24 hours per year here) to be reduced with relevant investment saved. The expansion of hydro power generation will work to reduce CO_2 emissions in the Planned Connection Case by 5% from 1,465 Mt in the No-connection Case to 1,387 Mt and those in the Unlimited Connection Case by 19% to 1,190 Mt. Furthermore, fossil fuel purchase costs will be reduced substantially.

In this way, ASEAN countries will greatly benefit from grid connection in the electricity sector. The effect will remarkably increase beyond 2040. Therefore, connection plans will have to be steadily implemented based on a long-term outlook. In fact, however, international grid connection will have many political challenges. Particularly, the enhancement of grid connection will lead one country to depend more on others for energy security and occasionally face opposition. To maximise benefits from grid connection, all relevant countries will have to share a common determination to do so.

Figure 113 | Accumulated costs and benefits accompanying grid connection through 2040



Note: Gaps with the no-connection case, including costs for connection cables between countries or areas and on Borneo Island while excluding those for other regional cables.

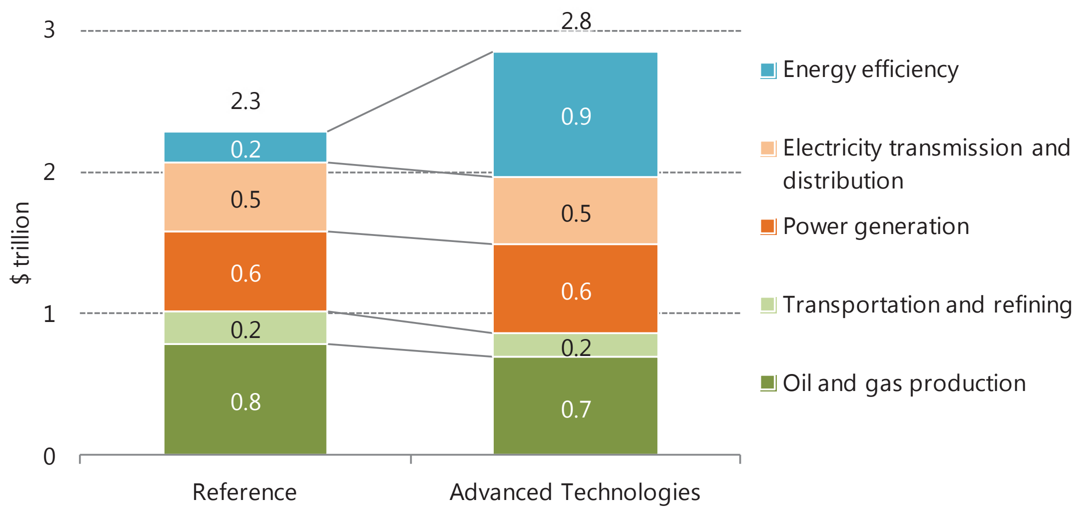
8. ASEAN energy investment outlook

8.1 Energy investment

ASEAN energy demand will more than double from 620 Mtoe in 2014 to 1,350 Mtoe in 2040. Massive investment in energy production (power generation) and transportation (power transmission and distribution) will be required to meet the rapidly growing demand. As each country has enhanced energy conservation policies, costlier production and equipment must be introduced. This chapter projects investment required in energy facilities, equipment and products through 2040.

Cumulative energy investment between 2015 and 2040 will reach about $2.3 trillion, rivalling the present ASEAN GDP at $2.4 trillion. The total includes $1.0 trillion each for the power and fuel supply sectors. About 55% of the investment in the power supply sector will be for generation equipment and the remaining 45% for transmission and distribution equipment. Of the fuel supply sector investment, gas and oil upstream development will account for about 80%, LNG and other fuel transportation facilities for nearly 10% and oil refineries for the remainder. Energy conservation investment will be limited to about $220 billion in the *Reference Scenario*.

Figure 114 | ASEAN energy investments [cumulative total for 2015-2040]



Total energy investments in the *Advanced Technologies Scenario* will be about $2.8 trillion, up $560 billion from the *Reference Scenario*. Energy conservation investment will increase by $880 billion, particularly in the transport sector. Power supply sector investment will slightly rise to $1.1 trillion. While fossil fuel-fired power generation investment will decline by $110 billion, renewable and nuclear power generation investment will increase by $160 billion. Fuel supply investment will decrease by $150 billion to $870 billion as regional and export demand is held down. Energy conservation and low-carbon energy expansion will reduce coal consumption in 2040 by 124 Mtoe from the *Reference Scenario*, oil consumption by 1.1 Mb/d and natural gas consumption by 66 Bcm. Net fossil fuel imports into the ASEAN region will be cut by a total of $610 billion, surpassing an investment increase of $560 billion.

Total energy investment at $2.3 trillion in the *Reference Scenario* is translated into an annual average of $88 billion. Private sector energy investment in the past five years averaged $10 billion. The limited private sector investment is understandable as the ASEAN energy sector has been almost monopolized by state-run oil and power companies. However, controlled energy prices failing to fully cover supply costs and international oil and natural gas price falls affecting resource-rich countries indicate that state-run companies or the government sector do not necessarily have financial leeway[18]. Therefore, private sector funds must be mobilised for investment. Many ASEAN countries impose restrictions on foreign investment in the energy sector and are urgently required to repeal or ease them. These countries are also required to repeal fossil fuel subsidies (eliminate price control or raise controlled prices) for introducing private sector funds because private companies do not participate in a market where supply costs cannot be covered. They must secure policy transparency and stability. Most ASEAN countries have introduced democracy but have vulnerable political or administrative arrangements. Although there are many challenges to be resolved for attracting private sector funds into the energy sector, ASEAN governments should give top priority to energy that is the foundation for economic development.

8.2 Oil and natural gas sector investment

Many energy development projects are going on in the ASEAN region to meet energy demand growth. Major investment targets regarding oil and natural gas include field exploration and development, oil refineries, LNG production and import terminals, and pipelines.

In the *Reference Scenario*, ASEAN crude oil production will decrease from 2.4 Mb/d in 2014 to 1.8 Mb/d in 2040, while natural gas production will increase from 217 Bcm in 2015 to 310 Bcm in 2040. Although investment may change depending on depletion rates for operating oil and gas fields, productivity of new oil and gas fields, technological development and investment conditions, ASEAN will be required to invest a cumulative total of $790 billion in the oil and gas sector through 2040.

Indonesia, Malaysia, the Philippines, Viet Nam and Myanmar have projects to build new oil refineries or expand existing ones. The total capacity of these projects exceeds 2.0 Mb/d requiring investments ranging between $60 – 80 billion; the investment amounts for many of these projects have not yet been made available. Given ASEAN crude oil imports and petroleum product demand in 2040, refinery investments will need to be far larger, depending on petroleum products imports. They are projected to total $140 billion through 2040.

[18] ASEAN public investment in 2014 totalled $170 billion. The required energy investment amounts to a half of the public investment. As public investment is required for various fields such as transport infrastructure (roads, bridges, railways, ports, etc.), education, health care and information network development, balanced investment is important.

Table 12 | Major ASEAN oil refinery construction/expansion projects

Country	Project	Participants	Capacity (kb/d)	Completion schedule
Indonesia	Cilacap expansion	Pertamina, Saudi Aramco	348 → 370	2022
	Balikpapan expansion	Pertamina	220 → 360	2019
	Pare	Pare	300	n.a.
	Tanjung Sauh	Gulf	200	n.a.
	Situbondo	Prima, Indo Refinery DEX	150	n.a.
	West Java	Kreasindo, Nakhle Barani Pardis	150	n.a.
	Tuban	Pertamina, Rosneft	300	n.a.
Malaysia	RAPID	Petronas	300	2019
Philippines	Bataan	Petron	180	n.a.
Viet Nam	Van Phong	Petrolimex, JX	200	n.a.
	Nhon Hoi	PTT, Saudi Aramco, Viet Nam Goverment	400	n.a.
Myanmar	Dawei	Zhuhai Zhenrong, UMEHL,Yangon Engineering	100	2019

Table 13 shows natural gas liquefaction projects planned in the ASEAN region for total investment of nearly $50 billion, as massive as oil refinery investment. Given regional natural gas supply and export potential, a medium-term LNG supply-demand balance and other factors, however, it is unlikely that new LNG projects will be implemented through 2040 in addition to the planned ones. Given the possible expansion of existing facilities and other factors, investment in natural gas liquefaction facilities is projected to total $60 – 70 billion.

Table 13 | ASEAN LNG production capacity construction projects

Country	Plant	Liquefaction equipment		Production launch	Companies and participants (equity stake)	Investment ($ billion)
		Train	Capacity (Mt/year)			
Indonesia	Tangguh (Train 3)	1	3.80	2019-2020 (under planning)	BP 37.16%, MI Berau B.V. (Mitsubishi Corp. 56%, INPEX 44%) 16.3%, CNOOC 13.9%, Nippon Oil Exploration (Berau) 12.23%, KG Berau Petroleum 8.56%, KG Wiriagar 1.44%, LNG Japan 7.35%, Talisman 3.06%	12.0
	Sengkang (Train 1-4)	4	2.00	2016 (under construction)	Energy Equity Epic Sengkang (put under control of Energy World Corporation)	0.352
		6	3.00	Under planning		n.a.
	Abadi (Floating)	n.a.	2.50	Under planning	INPEX 65%, Shell 35%	15.0
Malaysia	Petronas LNG 9 (Train 9)	1	3.60	2016 (under construction)	Petronas 90%, JX 10%	2.0
	Petronas FLNG 1 (Floating)	1	1.20	2016 (under construction)	Petronas	10.0
	Petronas FLNG 2 (Floating)	1	1.50	2018 (under construction)	Petronas	10.0

Note: Investment amounts are estimated.
Sources: GIIGNL "The LNG industry," company websites

Investment in new LNG terminal construction is expected to grow robust due to regional demand growth. Table 14 shows present LNG terminal construction projects. Many of them are still under planning or drafting, with total costs remaining unknown. If these projects are implemented, total investment will be at least $20 billion.

Table 14 | ASEAN LNG terminal construction projects

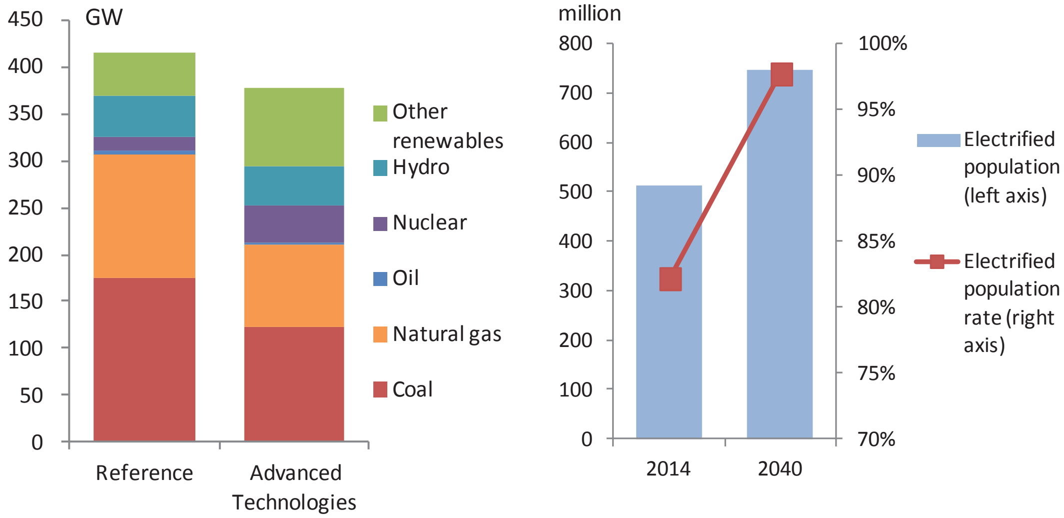
Country	Plant	Capacity (Mt)	Storage capacity (ML)	Acceptance launch	Companies and participants (equity stake)	Investment ($ billion unless otherwise specified)
Thailand	Map Ta Phut, Rayong, Phase 2	5.00	320	2017 (under planning)	PTT, EGAT, EGCO	n.a.
Malaysia	Pengerang, Johor	3.50	400	2018 (under planning)	Petronas 65%, Dialog LNG 25%, Johor State Government 10%	RM2.7 billion
	Lumut, Perak	n.a.	n.a.	Under planning	Petronas	n.a.
	Lahad Datu, Sabah	1.00	n.a.	Under planning	Tenaga Nasional Bhd (TNB), Petronas	0.66
Indonesia	Central Java, Semarang/ Offshore (FSRU)	3.00	n.a.	Under planning	Pertamina	0.4
	Banten, Bojonegara	4.00	n.a.	2019 (under planning)	Pertamina, Bumi Sarana Migas	n.a.
	Central Java, Cilacap/ Offshore (FSRU)	1.60	n.a.	2017 (under planning)	Pertamina	n.a.
	West Java, Cilamaya/ Offshore (FSRU)	3.80	n.a.	2017-2018 (under planning)	Pertamina	n.a.
	North Java	n.a.	n.a.	Under planning	Perusahaan Gas Negara, ENGIE	n.a.
	East Java, Lamongan	3.00	n.a.	Under planning	Energy World Corporation	n.a.
Singapore	Jurong Island Phase 3	5.00	260	2018 (under planning)	Singapore LNG	S$700 million
Philippines	Pagbilao LNG	3.00	130	2016 (under construction)	Inter Oil, Pacific Energy, Energy World Corporation	0.21
	Batangas (FSRU)	4.00	170	2016-2017 (under planning)	Shell	1.6
	(Undecided)	n.a.	n.a.	Under planning	First Gen	1.0
Viet Nam	Thi Vai	1.00	100	2017 (under planning)	PetroVietnam Gas	n.a.
	Son My, Binh Thuan	1.80 (→ 9.60)	320	2019-2020 (under planning)	PetroVietnam Gas, Shell	n.a.

Sources: GIIGNL "The LNG industry," company websites

8.3 Power generation sector investment

ASEAN electricity demand will triple by 2040, requiring about 420 GW in new power generation capacity. Investment in the new capacity will total $570 billion, most of which will be in fossil fuel-fired power generation capacity. While responding to rapidly growing electricity demand, ASEAN countries will have to expand power transmission and distribution networks at a cost of $480 billion to reduce non-electrified areas. Electricity demand in 2040 in the *Advanced Technologies Scenario* will be 13% less than in the *Reference Scenario*, with required fossil fuel-fired power generation capacity being about 100 GW less. Meanwhile, nuclear and renewable power generation capacity in the *Advanced Technologies Scenario* will be about 60 GW more than in the *Reference Scenario*, raising required power generation capacity investment by $50 billion from the *Reference Scenario* to $620 billion.

Figure 115 | New power generation capacity [2015-2040] and electrified population



8.4 Energy conservation investment

In the *Reference Scenario*, the GDP final energy consumption intensity will decline by 35% from the present level by 2040. Although industrial structure changes will contribute to reducing the GDP energy intensity, traditional energy conservation efforts will need to continue for the reduction. Relevant investment through 2040 in the ASEAN region will total $220 billion[19]. Nearly 60% of the energy conservation investment will be additional costs particularly for fuel efficient vehicles (hybrid and other electric vehicles) in the transport sector. The buildings sector will account for nearly 30% of the energy conservation

[19] The investment represents final users' energy conservation investment (additional costs for purchasing more efficient products or equipment, or price gaps between conventional and more efficient products or equipment), rather than investment for developing energy conservation technologies. If technology development costs are all passed on to final prices, however, the investment may be taken as similar to technology development costs.

investment, improving mainly air conditioners and insulation performance. The remaining 15% will be in the industry sector.

To achieve the *Advanced Technologies Scenario*, ASEAN will have to invest a total of $880 billion in energy conservation in the final consumption sectors. Of the total, transport will account for $490 billion on nearly 60%, buildings will account for $320 billion and industry for $60 billion. In addition to energy conservation investment in the *Reference Scenario,* about $660 billion will have to be invested in the *Advanced Technologies Scenario*. Meanwhile, energy savings as of 2040 will be 85 Mtoe. The average unit cost for energy conservation, or energy savings divided by additional investment, will come to $7,800/toe. The unit cost will exceed $10,000/toe in the transport and residential sectors while being limited to $1,000/toe in the industry sector. Energy savings through 2040 in the *Advanced Technologies Scenario* can be converted into about $850 billion in retail prices[20]. This means that final energy users' payment cut through energy conservation will surpass the additional investment at $660 billion.

[20] Final prices of electricity and petroleum products in ASEAN countries vary depending on subsidisation and other policies. In our estimation here, we tentatively used present retail prices in Indonesia.

Part III

Nuclear technology challenges and outlook

9. Nuclear technology challenges and outlook

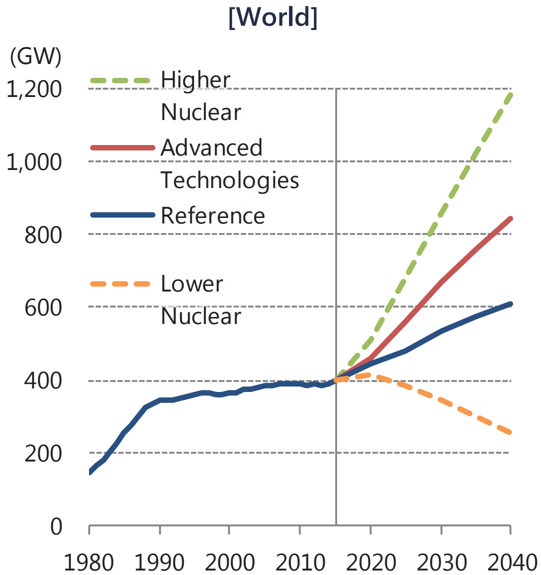
9.1 Nuclear scenarios

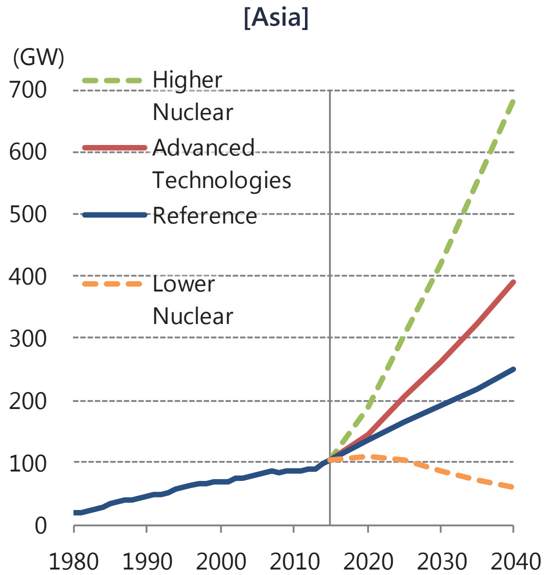
How installed nuclear power generation capacity in a country or region would increase or decrease in the future depends not only on local energy conditions, economic conditions and social infrastructure maturity but also on international relations. It is always uncertain and difficult to predict. Paying attention to nuclear development drivers in Asia, this sub-chapter develops and analyses the implications of two scenarios. In the "*Lower Nuclear Scenario,*" negative drivers for nuclear development are stronger than in the *Reference Scenario*. In the "*Higher Nuclear Scenario,*" positive drivers for nuclear development are stronger than in the *Advanced Technologies Scenario*.

Scenario assumptions

In the *Lower Nuclear Scenario,* any nuclear reactors still under planning as of 1 January 2016, will not be constructed. Those that were under construction with a specified year for launching commercial operations in the "World Nuclear Plants 2016" are included; those under construction but without a specified date will not. The maximum service life for nuclear reactors will be 60 years in North America and OECD Europe and 40 years in Latin America, Asia, the Middle East and Africa. As for Germany, Switzerland (the maximum service life at 50 years), Belgium (40 years, with Tihange-1 planned to remain in operation until 2025) and the United Kingdom, their respective schedules for decommissioning nuclear reactors are taken into account. Installed nuclear power generation capacity in 2040 will total about 250 GW in the world (about 60% of the 2014 level) and about 60 GW in Asia (also about 60% of the 2014 level).

Figure 116 | Installed nuclear power generation capacity





In the *Higher Nuclear Scenario*, installed nuclear power generation capacity growth in the Middle East, Asia (excluding Japan and Chinese Taipei) and Africa from 2020 will be twice as large as in the *Advanced Technologies Scenario*. Installed nuclear power generation capacity in 2040 will total about 1,200 GW in the world (a three-fold increase from 2014) and about 700 GW in Asia (a seven-fold increase).

Results

The analysis provides for changes in CO_2 emissions and in the unit power generation cost for the world and Asia, relative to the *Reference Scenario*. It also estimates the resulting energy self-sufficiency rates.

In the *Higher Nuclear Scenario*, CO_2 emissions will decline by about 6% in the world and by about 9% in Asia relative to the *Reference Scenario*. The Asian energy self-sufficiency rate will be about 74%, almost unchanged from 2014 while the unit power generation cost will be about $9/MWh lower than in the *Reference Scenario*. In the *Lower Nuclear Scenario*, however, CO_2 emissions will increase by about 4% both in the world and in Asia. The Asian energy self-sufficiency rate will fall substantially to about 63%. The unit power generation cost will be about $4/MWh higher than in the *Reference Scenario*.

Figure 117 | CO_2 emissions compared with Reference Scenario [2040]

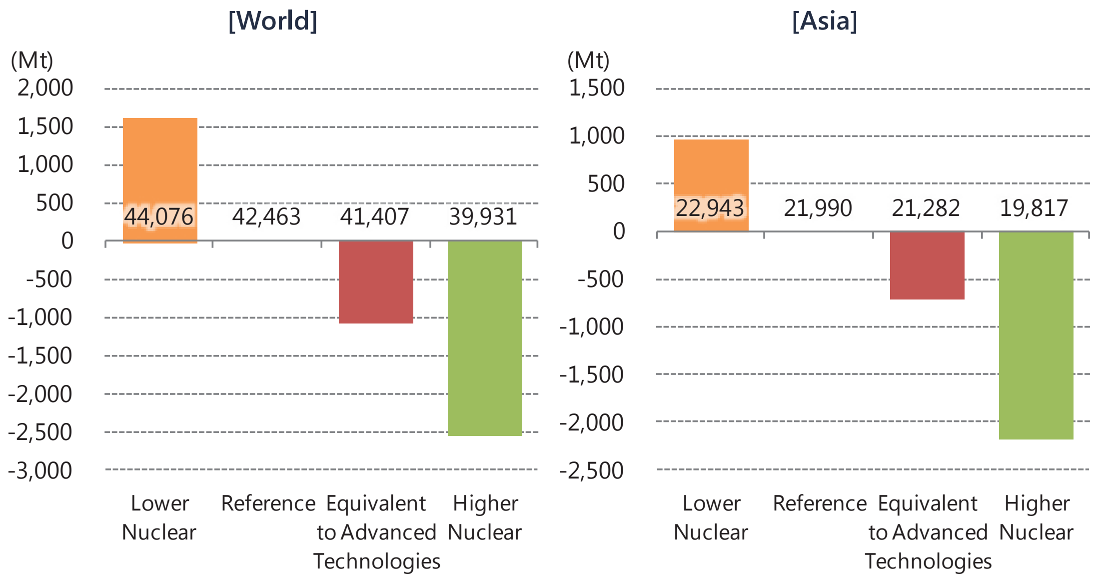


Figure 118 | World non-fossil fuel share

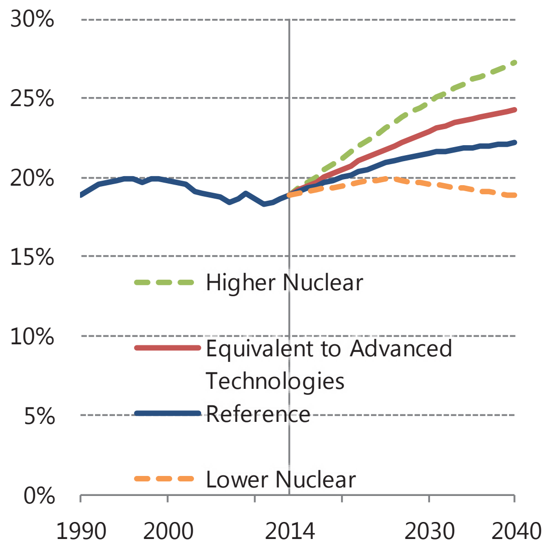


Figure 119 | Asian energy self-sufficiency rate

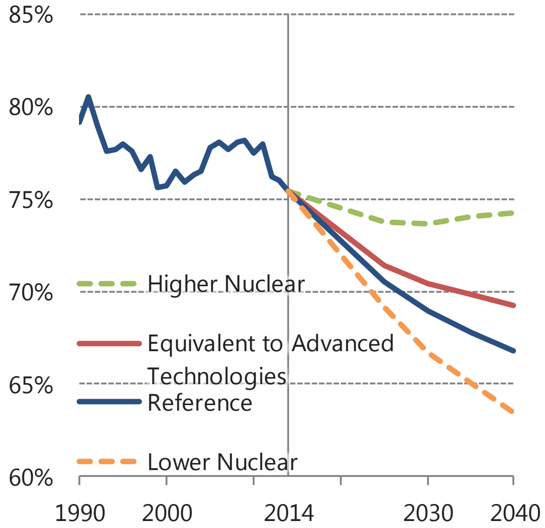
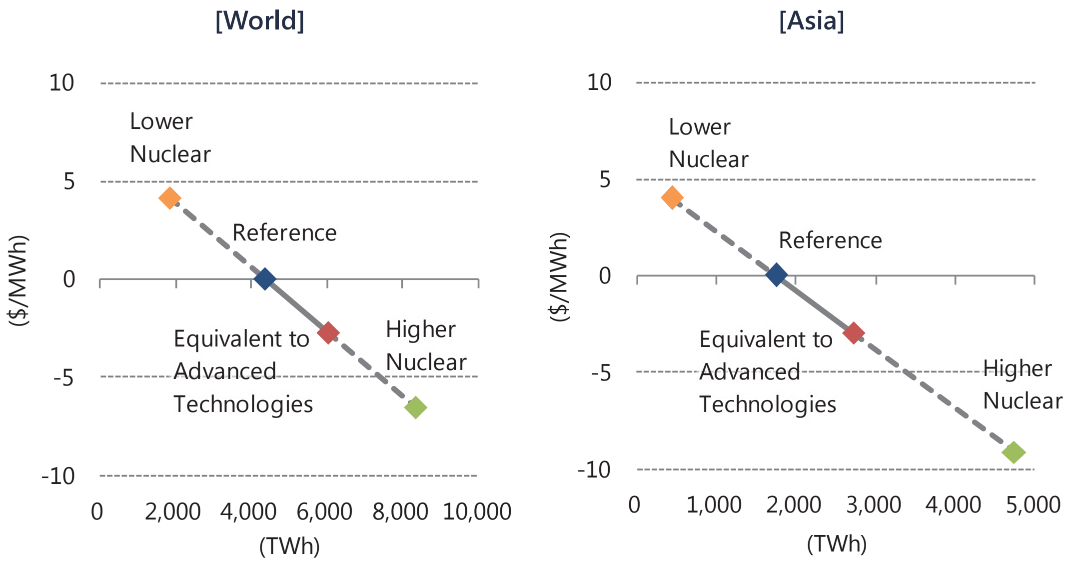


Figure 120 | Unit power generation cost compare with Reference Scenario [2040]



Prerequisites for and implications of Lower Nuclear Scenario

In the *Lower Nuclear Scenario*, all nuclear reactor projects at the planning stage will be suspended regardless of country. Only reactors under construction will be operated for 40 to 60 years before being decommissioned. A prerequisite for this scenario will be the preparation of stable baseload electricity sources replacing nuclear in China, India and all other emerging countries where electricity demand will be increasing. Even if the prerequisite is met, energy security or the energy self-sufficiency rate will substantially decline for Asia that heavily depends on fossil fuel imports. As costlier electricity sources than nuclear increase their share of the power generation mix, electricity costs will increase. As low-carbon electricity sources to replace nuclear are insufficient, CO_2 emissions will increase. All of the 3E's will thus deteriorate.

Even if the whole world commits to a nuclear phase-out, nuclear-related problems will remain in addition to energy security and environmental issues. As seen in Italy, Germany and Japan, a nuclear phase-out policy will weaken the nuclear industry infrastructure with technologies failing to be passed on to next generations. For as long as nuclear reactors and nuclear fuel cycle facilities exist, their safety will have to be secured, with spent nuclear fuels being disposed safely. Countries with a declining nuclear industry infrastructure will face far more difficulties than those with a growing nuclear industry. Japan and other nuclear technology holders must recognise that such risk would accompany the reduction of dependence on nuclear.

Prerequisites for and implications of Higher Nuclear Scenario

In the *Higher Nuclear Scenario*, nuclear reactors will increase even faster than in the *Advanced Technologies Scenario* in Middle Eastern, Asian and other emerging countries that have weaker electricity and social infrastructure than Western developed countries. Therefore, key prerequisites for this scenario will include the maintenance of nuclear power generation's cost competitiveness and appropriate technology transfers from the United States, France and Japan to emerging countries. This means that a nuclear industry with the same technological level as the present Western industry will have to be developed in China, India, the United Arab Emirates, Iran and other emerging countries.

If this scenario is established, considerable improvements will be made in energy security, environmental protection and electricity costs. However, there will be matters of concern. One of them is whether safety standards and regulations would be developed in line with the expansion of industrial infrastructure. Given that Japan and Korea lagged behind Western industrial countries in securing the independence of regulatory agencies, the development of regulatory institutions is feared to fail to catch up with the rapid nuclear expansion. The already existing deviation between developed and emerging countries regarding the maturity of safety regulations and the idea of a safety culture – or the north-south nuclear safety culture gap – could widen further. Given that stable electricity supply is a driver of nuclear expansion acceleration for emerging countries, a race to secure cheap, stably available uranium fuels may intensify. As the disposal of spent fuels and radioactive waste is given less priority, the safeguards of the International Atomic Energy Agency (IAEA) may be disregarded. As a result, threats to nuclear security could increase.

All major nuclear accidents in the past – the 1979 Three Mile Island, 1986 Chernobyl and 2011 Fukushima accidents – occurred in countries that had introduced commercial nuclear reactors more than 30 years ago and had sufficient engineering and manufacturing infrastructure. Accident risks are not limited to countries with weak infrastructure but present in all countries using nuclear. All nuclear-using countries are required to continue voluntary safety enhancement efforts under the principle that "safety is never perfect," without being complacent with the presence of strict safety standards.

9.2 Safety standards

The major accident at the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Co. (hereinafter referred to as the Fukushima accident) was caused by a tsunami accompanying the Great East Japan Earthquake in March 2011, representing a typical common cause failure (CCF) in which a single external event devastatingly damaged multiple safety functions. Although the then regulatory requirements had taken the CCF into account to some extent, safety measures had been insufficient for electricity sources, water supply sources and reactor containment vessels indispensable for nuclear reactor safety. Preparations for natural disasters such as tsunamis had also been insufficient. Given these insufficient safety measures, the Fukushima accident led Japan to fully revise the regulatory requirements.

Following are the basic policies for new regulatory requirements enforced in July 2013:

1/ Spreading the concept of defence in depth

Multi-layered protective measures effective for achieving specific objectives must be prepared. Upper layers above one layer must be assumed to fail (denying former clauses). Expectations must not be placed on lower layers below one layer (denying latter clauses).

2/ Enhancing reliability

Enhancing and spreading fire protection, introducing measures against internal flooding, enhancing particularly important systems for safety

3/ Assuming CCF resulting from natural disasters and upgrading protection measures

Enhancing assessment of earthquakes and tsunamis, and introduction, diversification and independence of measures against tsunami flooding to reduce possible CCF

Cited as a particularly regrettable problem was the “overconfidence in the so-called safety myth,” which alleged that the possibility of any massive radioactive material release through core damage or containment failure was sufficiently low and described post-accident damage mitigation measures as unnecessary. The belief that core damage could practically be eliminated to make successive efforts unnecessary for preventing the dispersion of radioactive materials or leading local residents to evacuate meant that the concept of defence in depth had not been understood, the new requirements pointed out. The Fukushima accident thus led Japan to thoroughly spread the concept of defence in depth in each stage.

Measures against severe accidents and external threats such as terrorism, which had been treated as voluntary measures by reactor operators under the previous requirements, have become requirements as follows:

1/ Adopting multi-layered protection including core damage prevention, containment function maintenance and reduction of radioactive material dispersion

2/ Responding to emergencies basically with transportable equipment that may be combined with fixed equipment to further improve reliability

3/ Enhancing protection of spent fuel pools

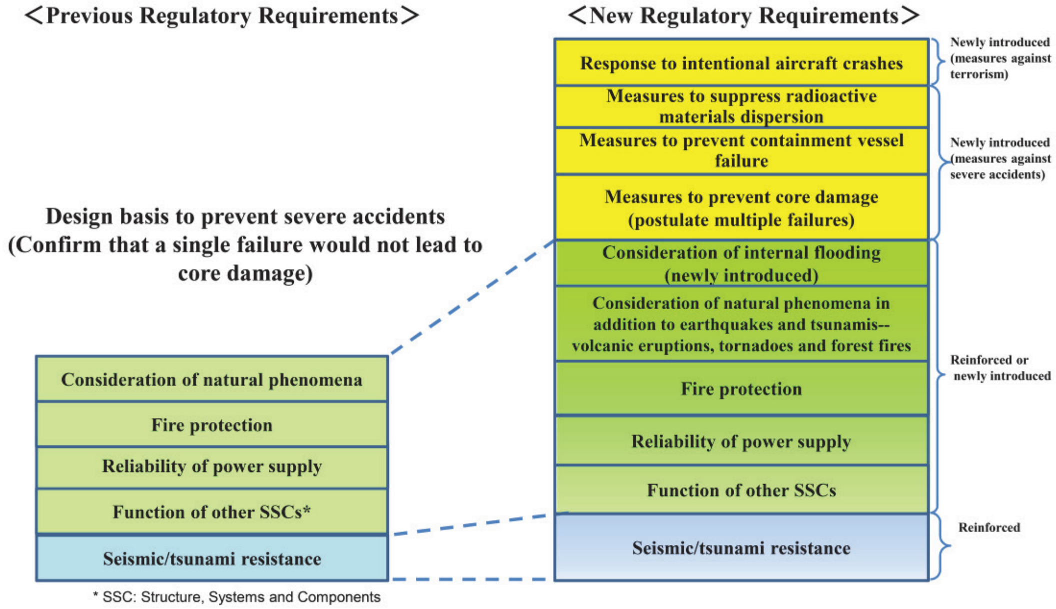
4/ Enhancing tolerance of emergency response facilities

5/ Introducing severe accident response facilities to prepare for airplane crashes

Based on the new regulatory standards, nuclear power plant operators from 2013 applied for assessment of their reactors' conformity with the new requirements as soon as preparations were made. By October 2016, five reactors passed the assessment.

Figure 121 indicates a comparison between the previous and new regulatory requirements.

Figure 121 | Comparison between previous and new regulatory requirements



* SSC: Structures, Systems and Components
Source: Nuclear Regulation Authority

The toughening of regulatory requirements, implemented in Japan after the Fukushima accident, had been done since the 1980s in Western industrial countries that learned lessons from the 1979 Three Mile Island Unit 2 accident and the 1986 Chernobyl Unit 4 accident. For example, the enhancement of buildings' tolerance and the distribution of power sources in anticipation of airplane crashes have been requirements in the United States since before the September 2001 terrorist attacks on that country. In European countries, filtered venting system have been installed as standard for containment vessels to prevent pressure damage.

In addition to the toughening of regulatory requirements and the enhancement of equipment, major Western countries have led the industry sector to voluntarily improve nuclear safety beyond its compliance with regulatory requirements. As a result, the average capacity factor for nuclear power plants improved substantially from the 1980s to the 1990s particularly in the United States.

Main drivers that led business operators to adopt rational voluntary requirements in Western countries in the 1980s and 1990s apparently included not only lessons from the Three Mile Island and Chernobyl accidents but also a competitive environment under electricity market deregulation.

Business operators cannot afford to spend too much on safety in a business environment where costs cannot be recovered and are required to achieve good performance and economically rational power plant management. However, those who acknowledged that zero-risk plant management cannot be guaranteed, as indicated by the Three Mile Island accident, also acknowledged that rational voluntary efforts to improve safety were required for continuing business realistically and rationally. In considering regulatory requirements, Japan can learn much from the process.

9.3 Regulatory arrangements

Nuclear regulatory agencies enforce regulatory requirements, screen nuclear facilities' conformity with the requirements and approve business operators' operation of these facilities. They are called the Nuclear Regulatory Commission (NRC) in the United States, the French Nuclear Safety Authority (ASN) in France, the Office of Nuclear Regulation (ONR) in the United Kingdom, the Nuclear Safety and Security Commission (NSSC) in Korea, the Swedish Radiation Safety Authority (SSM) in Sweden, the Radiation and Nuclear Safety Authority (STUK) in Finland, the Swiss Federal Nuclear Safety Inspectorate (ENSI) in Switzerland and the Nuclear Regulation Authority (NRA) in Japan. While their names differ somewhat from country to country, their roles are the same.

Given their roles, regulatory agencies are required to be highly independent from political intentions, economic trends and others, excluding technological indicators, and have high technological capabilities for strict, fair examinations. Regulatory agencies in Western industrial countries have mostly maintained their high independence and staff levels since before 2011. The IAEA has the Integrated Regulatory Review Service (IRRS) to review the adequacy of regulatory activities and requirements in member countries. While undergoing the regular IRRS review, regulatory agencies have continued to improve organisations and regulatory activities to contribute to securing safety.

Table 15 shows a comparison of decision-making and control systems and sizes of nuclear regulatory agencies in major Western countries. Table 16 indicates a comparison of those in Asian countries. Assessment comments by the IRRS are given for Asian agencies.

Table 15 | Regulatory agencies in major Western countries

	United States	France	United Kingdom	Sweden	Finland
Regulatory agency	NRC	ASN	ONR	SSM	STUK
Position	Federal independent agency	Independent agency	Public corporation	Independent agency under Ministry of the Environment and Energy	Independent agency under Ministry of Social Affairs and Health
Legal base	1974 Energy Reorganization Act	2006 Act on Transparency and Security in the Nuclear Field	2013 Energy Act[*1]	2008 Act on Nuclear Activities	2015 Nuclear Act[*2]
Management and decision-making	Commission (Voting by 5 commissioners)	Committee (Consensual decision-making by 5 committee members)	Board[*3]	Nuclear facility safety and other divisions under Director General	Nuclear reactor regulation and other divisions under Director General
(Reference) Staff size	About 4,000 employees	About 470 employees	About 500 employees	About 300 employees	About 320 employees

*1 In 2008, voluntary regulatory reorganisation was launched. The ONR was created in 2014, based on the 2013 Energy Act.
*2 The STUK has served as an independent regulatory agency since before 2015 and was given the legal base in 2015 in line with recommendations by the IRRS in 2012.
*3 Regulatory decisions are made by employees with sufficient expertise and experiences under the leadership by the chief inspector appointed by the Board, which is not responsible for decision-making.
Sources: IAEA, websites of regulatory agencies

Table 16 | Regulatory agencies in Asian countries

	Japan	Korea	China	India	Viet Nam
Regulatory agency	NRA	NSSC	NNSA	AERB	VARANS
Position	Independent agency under Ministry of the Environment	Independent agency under Prime Minister	Agency under Ministry of Environmental Protection	Independent agency	Agency under Ministry of Science and Technology
Legal base	2012 Act for Establishment of the Nuclear Regulation Authority	2013 Act on the Establishment and Operation of Nuclear Safety and Security Commission	Preparing for enacting Nuclear Safety Act	1983 Nuclear Act	2008 Nuclear Act
Management and decision-making	Commission (Consensual decision-making by 5 commissioners)	Commission (Voting by commissioners)	Nuclear facility safety and other divisions under Chairman	Board (Consensual decision-making by chairman and 5 members)	Inspection and other divisions under Director
Latest IRRS recommenda-tions (concerning independence)	-	-	Secure independence and transparency in enacting Nuclear Safety Act (2016)	Secure independence under law (2015)	Secure independence from Ministry of Industry and Trade and Ministry of Natural Resources and Environment (2014)

Sources: IAEA, websites of regulatory agencies

Compared with Western regulatory agencies, Asian agencies may face issues concerning independence. Since 2011, Japan and Korea have reformed regulatory systems to enhance the independence of their nuclear regulatory agencies, but have shorter histories regarding independence than Western countries. High independence and transparency of regulatory activities and high levels worthy of trust are indispensable for maintaining safety levels. In Asia where nuclear will expand, regulatory requirements and activities will have to be improved qualitatively.

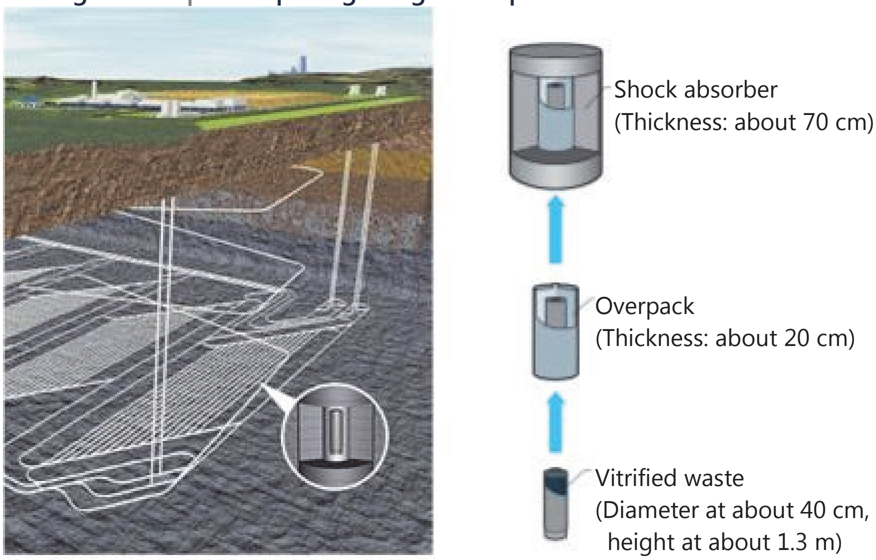
9.4 High-level radioactive waste disposal problem

Overview, super-long-term safety and economy of high-level radioactive waste disposal

Spent nuclear fuel generated through nuclear power generation is reprocessed or directly disposed. Whether reprocessing or direct disposal is adopted in accordance with national policies, high-level radioactive waste must be disposed of adequately.

While various methods are conceivable for disposing of high-level radioactive waste, oceanic and ice sheet disposal is made impossible under international law. Outer space disposal has problems with safety during transportation to the outer atmosphere. Therefore, geological disposal to bury and contain waste in deep layers by taking advantage of the bedrock's characteristics has become an internationally common approach. Geological disposal is defined as isolating radioactive waste from the ground with artificial and natural barriers by covering vitrified waste, or waste dispersed in glass, with a metal overpack and clay layers (shock absorber) for burial into rocks at least 300 metres underground (Figure 122).

Figure 122 | Concept of geological disposal



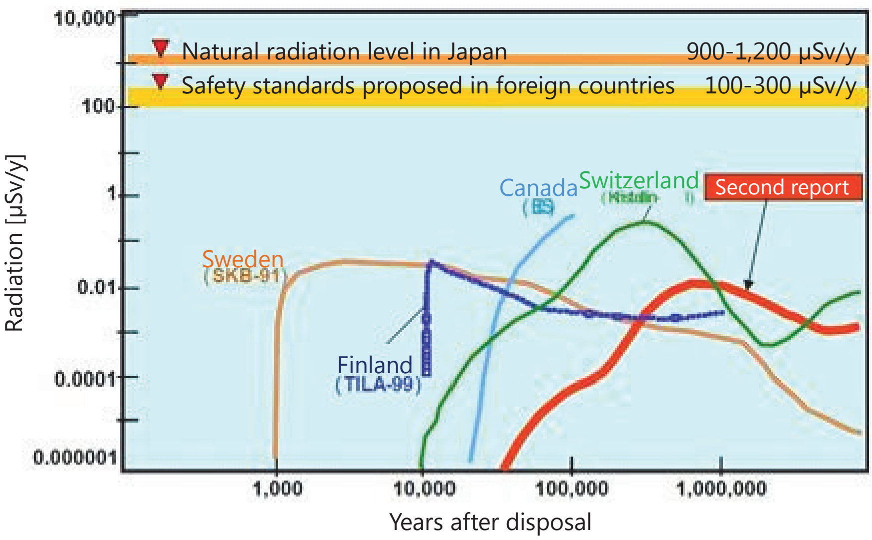
Source: Nuclear Waste Management Organization of Japan (NUMO)

An important problem here is whether waste could be safely isolated over hundreds of thousands of years until the radioactivity depletes sufficiently after being buried at a disposal site. No one can predict how society will be managed tens of thousands of years later. In order to prevent burdens from being left for future generations, stakeholders are trying to locate, design and construct disposal sites in a manner to secure safety without long-term human management after the burial.

A great number of studies have been done on long-term safety. In Japan known as a volcanic country, for example, any disposal site located close to an active volcano can easily be expected to lose safety over a long term. However, a detailed study on geological layers and structures has found that volcanic locations in Japan have changed little over millions of years and that fault activities have been repeated at the same locations over hundreds of thousands of years. If the geological environment is sufficiently screened for selecting a disposal site, therefore, the site may be expected to remain unaffected by any active volcano or fault over hundreds of thousands of years.

On super-long-term safety, the Japan Nuclear Cycle Development Institute (JNC), now called the Japan Atomic Energy Agency (JAEA), released a detailed study in 1999[21]. Figure 123 indicates the assessment of super-long-term safety in the study. In a standard conservative underground water scenario in which vitrified waste will contact underground water and elute with the overpack function lost and be carried to the surface of the earth 1,000 years after the disposal site shutdown, its impact on humans will peak 800,000 years after the disposal, with radiation limited to 0.005 μSv/y, according to the study (Second report in Figure 123). Assessment under geological environment assumptions unique to foreign countries produced roughly similar results.

Figure 123 | Assessment of super-long-term safety



Sources: JNC, NUMO

Total costs required for high-level radioactive waste disposal are estimated at JPY2.8 trillion, adding JPY40/MWh to the unit nuclear power generation cost[22]. This means that the waste disposal does not account for any large share of nuclear power generation problems as far as economic efficiency alone is concerned. The total costs at JPY2.8 trillion cover disposal site operations that are not assumed to be managed by humans over hundreds of thousands of year as noted above[23]. Therefore, a key point in the radioactive waste disposal is not

21 Japan Nuclear Cycle Development Institute, "Technological Reliability of Geological Disposal of High-level Radioactive Waste in Japan -- Second Report on Geological Disposal Research and Development" https://www.jaea.go.jp/04/tisou/houkokusyo/dai2jitoimatome.html

22 Power Generation Cost Verification Working Group, "Report on Verification of Power Generation Costs to Long-term Energy Supply and Demand Outlook Subcommittee" http://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/mitoshi/cost_wg/pdf/cost_wg_01.pdf

23 Even if annual operation costs worth JPY1 billion are required over one million years, however, cumulative costs (after conversion into current prices with the effective discount rate assumed at 3%) come to JPY33 billion, in addition to the sum of JPY2.8 trillion. This means that if a certain amount is invested in the initial phase, investment returns may be estimated to cover costs permanently.

economic efficiency but how or whether super-long-term safety could be secured. This point should be considered further with new scientific knowledge collected.

Progresses in nuclear waste disposal plans in relevant countries

As shown in Table 17, progresses in geological disposal plans differ from country to country. Factors behind delays in geological disposal plans include the failure to select disposal sites amid concerns over safety among residents near candidate sites.

In Japan, no local government has offered to conduct literature research in the initial phase of the disposal site selection process. The Government plans to select and propose scientifically suitable sites (scientifically promising sites) and work with relevant local governments. The United States and the United Kingdom have made no smooth progress in selecting disposal sites. The United States is still in the selection process, while a local government for a candidate site has withdrawn the candidacy just before the final selection in the United Kingdom.

Meanwhile, Finland and Sweden have selected their respective disposal sites and are preparing for implementing disposal. The two countries are not necessarily exceptional. Among other countries, France and Switzerland have made relatively smooth progress in selecting disposal sites. Given that the disposal of high-level radioactive waste represents a very long process, not only central and local governments but also all other stakeholders including business operators, local residents and environmental groups are required to have sufficient talks to make steady progress.

Table 17 | Progress in geological disposal plans in relevant countries

Country	Site selection status	Disposal site operation plan
Japan	Preparing for proposing “scientifically promising sites”	2028-2032
China	Conducting surveys at multiple candidate sites	—
Korea	Considering how to select a disposal site	—
United States	The selection has been suspended after Yucca Mountain in Nevada had been planned as a candidate	Around 2048
United Kingdom	Selecting new candidates after a local government in western Cumbria withdrew its candidacy	2050s
France	Selecting a site near the Bure underground laboratory	Around 2025
Switzerland	Two candidate sites have been selected, with the final selection phase planned to start in 2017	Around 2060
Sweden	Forsmarks in Osthammar has been selected	Around 2029
Finland	Olkiluoto in Eurajoki has been selected	Around 2022

Source: Radioactive Waste Management Funding and Research Centre

In Sweden between 2002 and the final site selection in 2010, the Government repeated talks with local stakeholders for a candidate site based on the Environmental Code and the Act on Nuclear Activities. In this process, the so-called Oskarshamn model was developed for coordination involving all stakeholders including the local government, regulators, business operators and environmental groups. In the model, civic and environmental groups took leadership in talks, with all stakeholders making independent decisions. Local residents were given the right to reject the disposal at any time and negotiated with the government and business operators on an equal footing. Financial assistance from a nuclear waste management fund contributed by electric utilities was provided not only to the local government but also to environmental non-government organisations. Such interactive dialogue differing from the government's or business operators' unilateral engagement with local stakeholders might have enabled Sweden to take the initiative in selecting a nuclear waste disposal site.

9.5 Generation-IV reactors

Generation-IV reactors are defined as[24]:

"Innovative reactors that are being developed for commercialisation in the 2030s to achieve a sustainable energy source through efficient fuel consumption, minimised nuclear waste and non-proliferation security, to improve safety and reliability through the substantial reduction of core damage incidence and the practical elimination of the off-site emergency response and to attain economic efficiency allowing nuclear to compete with other energy sources."

Of about 400 reactors in operation in the world as of 2016, most are generation II light water reactors. Of about 70 reactors under construction, a half are generation III or generation III+ light water reactors.

Generation IV reactors, excluding some, are not light water reactors. They are innovative reactors that adopt coolants other than light water to meet the abovementioned development objectives and include fast reactors using no moderators.

Issue 1: Why are light water reactors dominant in the world at present?

Issue 2: Why are generation IV reactors planned to adopt coolants other than light water?

This section looks into the two issues

Since Western countries and Russia started commercial nuclear power generation in the 1950s, nuclear reactor technologies have made progress through the accumulation of improvements. When we review the history of nuclear reactor development, we must take note of the fact that light water has not been the optimum material from the viewpoint of making maximum use of nuclear fuel.

The idea of using nuclear energy emerged from fast neutron criticality core systems that do not use thermal neutrons. The first nuclear reactor was a graphite-moderated, air-cooled reactor[25], followed by the first commercial nuclear reactor that was a graphite-moderated, gas-cooled reactor (GCR) [26]. The GCR age lasted long. Japan first introduced the GCR. This is because graphite was considered the most effective for moderating to sustain nuclear reaction. Then (and at present), water was considered a problematic coolant oxidising metals.

[24] Generation IV International Forum

[25] Chicago Pile 1

[26] Calder Hall 1

Although water is more effective for cooling than gas, it was believed that water had bad chemistry with structural materials.

From the 1960s when a light water reactor concept was completed with a prototype operated and with uranium enrichment commercialised, however, light water reactors fast spread to several tens of countries. Since the 1980s, generation II, generation III and generation III+ light water reactors have been smoothly developed, with Japan and Korea promoting their own improvements. In contrast, integrated fast reactor (IFR) and other reactor concepts proposed almost along with light water reactors have remained in the design stage.

Light water reactors are made of water and stainless steel that are available at any location in the world. Therefore, materials have been improved for immediate input into reactors in response to material troubles including stress corrosion cracks[27]. Improvements have been accumulated based on the actual use of improved materials, taking advantage of knowledge about high temperature and pressure, corrosion-resistance and other materials used for fossil fuel-fired power generation and other industries. While problems have existed with light water reactors as noted above, various improvements have been put into reactors and shared.

For other reactor concepts requiring non-water coolants and suitable materials, meanwhile, technological demonstration opportunities have been available at a limited range of test facilities due to their characteristics. For example, large thermal-hydraulic test facilities for sodium-cooled fast reactors in Japan are very limited, including a JAEA facility in Oarai, Ibaraki Prefecture. As there have been only several sodium-cooled fast reactors in the world, peer review of troubles and feedback, which have been frequent for light water reactors, has not been implemented for sodium-cooled fast reactors. Knowledge from other fields and information exchange in the industrial world has been very limited. Engineering and operation locations have been abundant for light water reactors while being very limited for other innovative reactor concepts. The broad technology base attributable to the universality of materials might have made a difference for light water reactors.

The above is a response to Issue 1: Why are light water reactors dominant in the world at present?

Why are generation IV reactors under research and development different from light water reactors that have widely spread and boast cost competitiveness against other electricity sources?

A simple answer is that attempts to solve light water reactors' weaknesses and problems with some other materials have continued since the second generation age. As noted above, light water is not necessarily ideal for making maximum use of nuclear fuel. Natural uranium must be enriched (enrichment costs have been considerably reduced and have potential to be further reduced through technological innovation) for light water reactors. While light water reactors can consume plutonium from uranium, it is very difficult for them to serve as fast breeder reactors that can produce more plutonium than they consume. Some other coolants than light water are desirable for making effective use of limited resources including various substances in spent nuclear fuel. This had been already known since nuclear power

27 Stress corrosion cracks in materials occur in a stress environment.

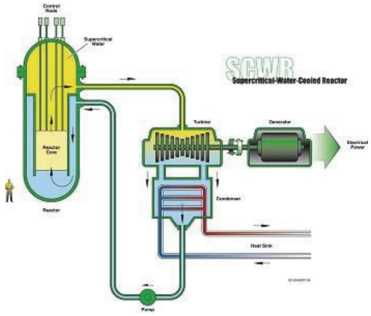
generation was initiated. Nevertheless, a broad technology base attributable to the universality of materials has not been realised for coolants other than light water.

Innovative reactors have various patterns for combining coolants with fuel types and structural materials. Until the 1990s, various reactor concepts in the development phase existed, ranging from paper reactors to large reactors such as sodium-cooled fast reactors that were constructed and operated. Researchers in the world were competing to develop new nuclear reactors. Competition, though being favourable in the research phase for inducing various ideas, may not be so in the development phase put under budget constraints.

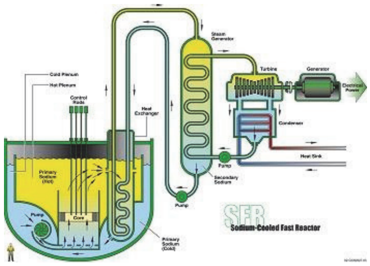
In 1999, the U.S. Department of Energy advocated the Generation IV International Forum (GIF) as an international joint development program in which reactor concepts available for commercialisation around 2030 would be proposed by countries and narrowed down for joint development. In response, countries began to make proposals in April 2001. In July 2001, Argentina, the United Kingdom, Canada, Korea, Japan, Brazil, France, the United States and South Africa created a charter providing for GIF ideas. After country-by-country proposals were considered by the Technical Working Group for a review by the Roadmap Integration Team, six concepts were selected in July 2002. The GIF member countries created research and development programs for these systems, their safety and anti-proliferation characteristics. As of October 2016, the GIF members were 13 countries and the European Union. They are now participating in specific research and development projects after signing the GIF charter and a framework agreement and preparing system and business arrangements.

The six concepts are given in Figure 124.

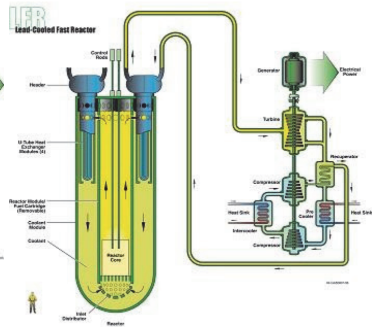
Figure 124 | Overview of fourth-generation nuclear reactor concepts



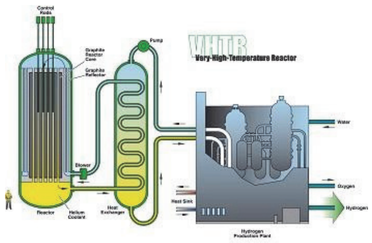
Supercritical-Water-Cooled Reactor (SCWR)
The SCWR features a compact device using supercritical water (220 atmospheres, more than 374°C) and improved thermal efficiency



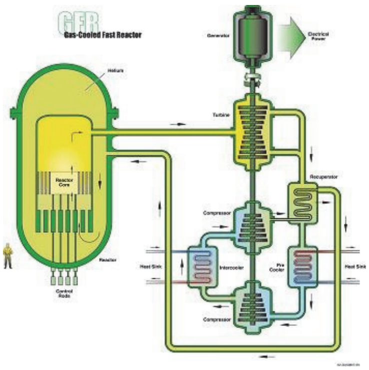
Sodium-Cooled Fast Reactor (SFR)
The SFR is the most technologically mature, introducing innovative technology to improve safety and economic efficiency.



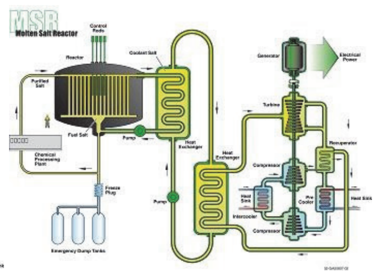
Lead-Cooled Fast Reactor (LFR)
Adopting lead instead of chemically active sodium



Very-High-Temperature Reactor (VHTR)
Industrial use of high-temperature gas (950°C or higher)



Gas-Cooled Fast Reactor (GFR)
Adopting helium gas instead of chemically active sodium



Molten Salt Reactor (MSR)
The figure shows a concept of a thermal neutron reactor using thorium fuel (liquid). The GIF is studying a molten salt reactor (using liquid fuel) and a high temperature reactor with molten salt-cooled materials (using solid fuel).

Source: GIF website

Table 18 shows participating countries in GIF concept projects.

Table 18 | Participating countries in GIF concept projects [January 2014]

System	CA	CN	EU	FR	JP	KR	RU	CH	US	ZA
SFR		✓	✓	✓	✓	✓	✓		✓	
VHTR		✓	✓	✓	✓	✓		✓	✓	
SCWR	✓		✓		✓		✓			
GFR			✓	✓	✓			✓		
LFR			P		P		P			
MSR			P	P			P			

✓= Signatory to the System Arrangement; P = signatory to the Memorandum of Understanding; Argentina, Brazil, and the United Kingdom are inactive.

Source: Technology Roadmap Update for Generation IV Nuclear Energy Systems, GIF website, January 2014

Among the GIF member countries, Japan participates in the largest number of GIF concepts, followed by France and Russia. Korea and China, which joined the GIF later, have taken part in the SFR and VHTR core GIF concepts, indicating that their technological levels may rival French, Japanese and U.S. levels. Among developed countries, however, the United Kingdom and Canada have made little contribution to the GIF. Nuclear technology levels may not necessarily be linked to contribution to the GIF.

Generation IV nuclear reactors, as described above, will take advantage of innovative materials and technologies to reach challenging objectives that are difficult for light water reactors to achieve. The GIF was advocated by the United States and formed at the initiative of France and Japan. However, whether the three countries could retain leadership in the GIF is uncertain. France decommissioned the Super Phoenix demonstration fast breeder reactor in the 1990s and shut down the Phoenix prototype in 2010. Japan has effectively decided to decommission the Monju prototype fast breeder reactor. In contrast, China is developing high-temperature gas reactors and Korea is giving massive funding for research and development of next-generation nuclear reactors and advanced nuclear fuel recycling. Leadership in the GIF may be transferred from France and Japan to China and Korea.

Part IV

Addressing global environmental problems

10. Advanced Technologies Scenario

10.1 Major measures

In the *Advanced Technologies Scenario*, maximum CO_2 emission reduction measures will be implemented with their application opportunities and acceptability to society taken into account. Each country will strongly implement aggressive energy conservation and decarbonisation policies contributing to securing stable energy supply and to enhancing climate change measures further while accelerating the development and introduction of innovative technologies globally. Against the backdrop of the introduction of environmental regulations and national targets, the enhancement of technological development and the promotion of international technological cooperation, the demand side will strongly spread energy conservation equipment and the supply side will further promote renewables and nuclear (Figure 125).

Figure 125 | Assumptions for Advanced Technologies Scenario

Introducing and enhancing environmental regulations and national targets
National strategies and targets, energy conservation standards, automobile fuel efficiency standards, low carbon fuel standards, energy conservation and environmental labelling, renewable energy introduction standards, feed-in tariff system, subsidies, environment tax, emissions trading, etc.

Promoting technology development and international technology cooperation
R&D investment expansion, international energy conservation technology cooperation (steelmaking, cement and other areas), support for establishing energy conservation standards, etc

Demand side technology

- Industry
Under sectoral and other approaches, best available technologies on industrial processes (steelmaking, cement, paper-pulp, etc.) will be deployed globally.

- Transport
Clean energy vehicles (highly fuel efficient vehicles, hybrid vehicles, plug-in hybrid vehicles, electric vehicles, fuel cell vehicles) will diffuse further.

- Buildings
Efficient electric appliances (refrigerators, TVs, etc.), highly efficient water-heating systems (heat pumps, etc.) efficient air conditioning systems and efficient lighting will diffuse further, with heat insulation enhanced

Supply side technology

- Renewable energy
Wind power generation, solar PV power generation, concentrated solar power generation, biomass-fired power generation, marine power generation and bio-fuel will diffuse further.

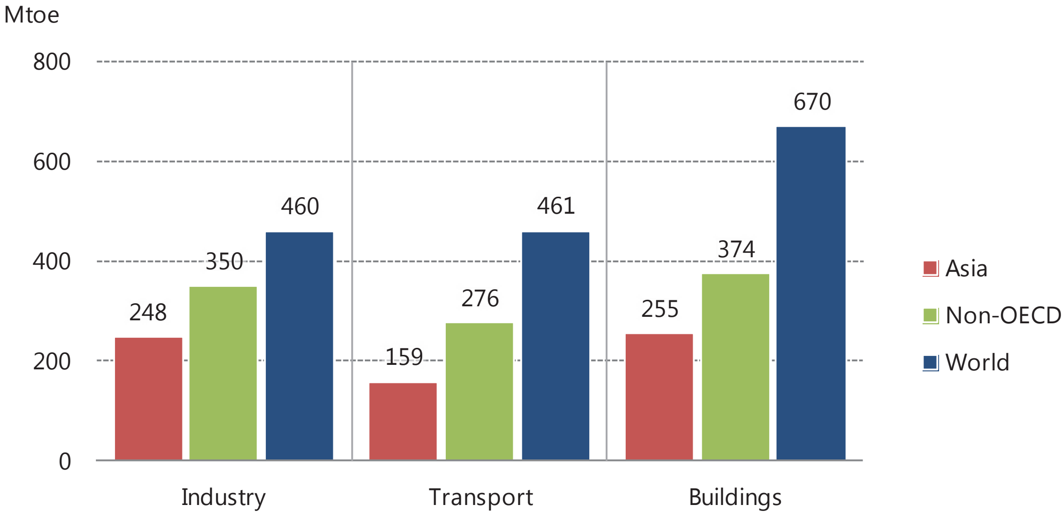
- Nuclear promotion
Nuclear power plant construction will be accelerated with capacity factor improved.

- Highly efficient fossil fuel-fired power generation technology
Coal-fired power plants (USC, IGCC, and IGFC) and natural gas MACC (More Advanced Combined Cycle) plants will diffuse further.

Energy conservation

Final energy consumption in the *Advanced Technologies Scenario* will be 1,590 Mtoe less than in the *Reference Scenario*. The energy savings exceed the total of present final energy consumption in OECD Europe and Japan. Of the energy savings, the buildings sector will account for 670 Mtoe, the transport sector for 461 Mtoe and the industry sector for 460 Mtoe (Figure 126). Non-OECD will capture more than 50% of energy savings in all sectors. Whether or not non-OECD would realise their potential energy conservation is key to global energy conservation progress. In the industry sector, particularly, non-OECD will account for as much as 76% of energy savings. In the following, we explain the characteristics of energy conservation on a sector-by-sector basis in the *Advanced Technologies Scenario.*

Figure 126 | Energy savings from Reference Scenario [Advanced Technologies Scenario, 2040]

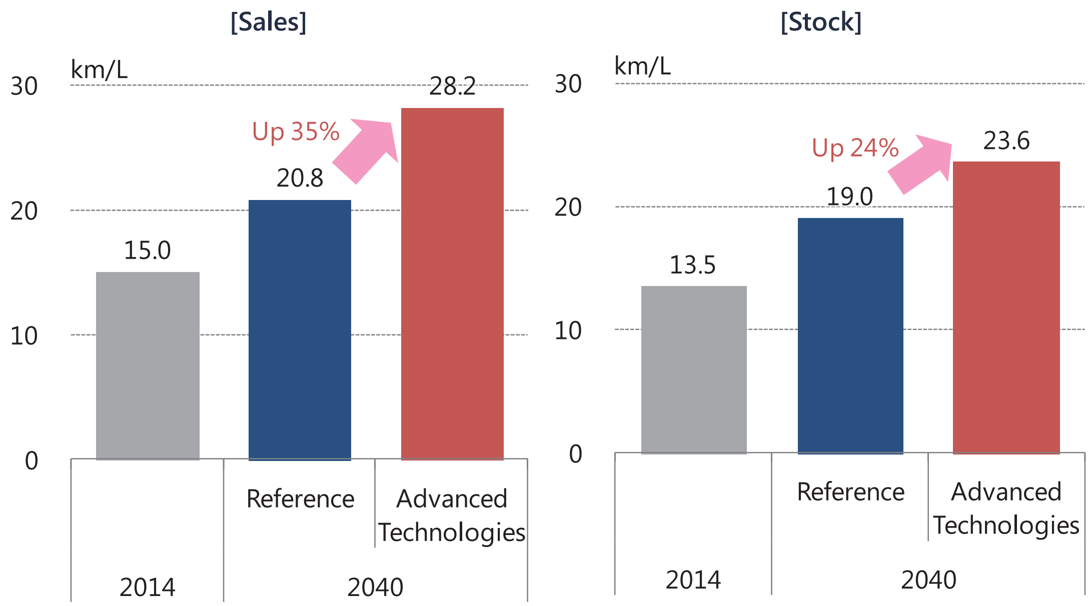


The buildings sector differs from the industry sector, which is highly conscious of energy conservation for economic reasons, in that energy conservation incentives fail to work smoothly. Therefore, both OECD and non-OECD have great potential to save energy consumption in the buildings sector. Particularly, energy efficiency improvements for water heating systems in cold regions and insulation improvements in non-OECD will make great contributions to saving energy. Since kerosene, liquefied petroleum gas, city gas and other fuels are used for water and space heating in various ways depending on national conditions, fuel consumption will be greatly reduced. However, electricity conservation through power and lighting savings will account for more than half of the savings in the whole of the buildings sector.

In the transport sector, fuel efficiency and vehicle fleet mix improvements will make further progress. The global average new vehicle fuel efficiency in 2040 will improve by 7.4 km/L from the *Reference Scenario* to 28.2 km/L (3.5 L/100 km) and the average stock mileage by 4.5 km/L to 23.6 km/L (4.2 L/100 km) (Figure 127). In the vehicle fleet mix, hybrid and electric vehicles will spread on a worldwide basis. Developed countries are expected to introduce and spread next-generation vehicles including plug-in hybrid and fuel cell vehicles. As next-generation vehicles' auto fleet share increases faster in developed countries, OECD's share of energy savings in the transport sector from the *Reference Scenario* will be 40%, larger than in the industry sector.

In the industry sector, non-OECD has particularly great potential to improve energy efficiency. Non-OECD energy consumption in this sector has remarkably expanded, boosting its share of global energy consumption from 51% in 2000 to 71% in 2014. While non-OECD energy efficiency has been improving due to the introduction of new equipment, energy consumption has been growing because of production growth in energy-intensive industries. By applying presently available high-efficiency technologies for steel, chemical, pulp and paper, and other energy-intensive industries, the non-OECD industry sector will reduce energy consumption by 350 Mtoe from the *Reference Scenario*. Asia, where those industries are expected to remarkably expand production, will account for 54% of the energy savings. OECD, with less room to improve energy efficiency than non-OECD, will cut industry sector energy consumption by 109 Mtoe. OECD's transfer of highly efficient technologies to non-OECD will make great contributions to energy conservation. OECD is expected to positively implement such technology transfer programs including energy conservation technology research projects and their joint forums with developing countries.

Figure 127 | Automobile fuel efficiency



Renewable energy

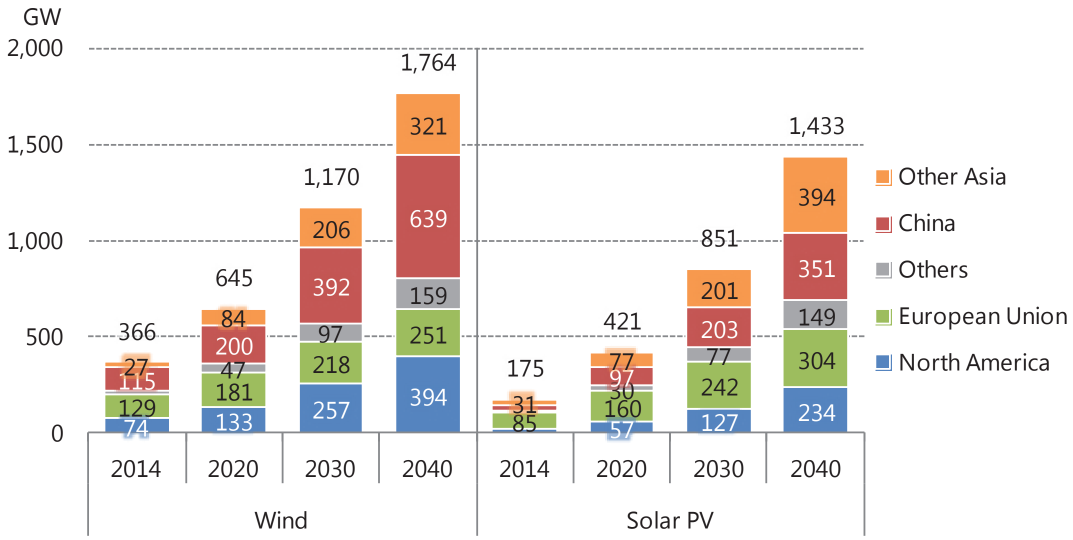
In the *Advanced Technologies Scenario*, renewables (including hydro) will increase their share of primary energy consumption from 14% in 2014 to 21% in 2040, 5 percentage points higher than in the *Reference Scenario*. Driving the renewable energy share expansion will be wind and solar photovoltaics. The share for wind and solar PV power generation (including concentrated solar and marine power generation) will rise from 0.8% in 2014 to 3.2% in 2040.

The spread of wind power generation will accelerate mainly in emerging and developing countries and the United States as onshore wind power plant costs are further reduced and electricity transmission and distribution infrastructure is developed. Offshore wind power generation will expand mainly in Europe as construction, operation and management, and grid connection costs are reduced (Figure 128). Global installed wind power generation capacity in 2040 in the *Advanced Technologies Scenario* will reach 1,764 GW, about 1.5 times as much as in the *Reference Scenario*.

Solar PV power generation will spread further in emerging and developing countries thanks to system cost cuts. Solar PV power generation will significantly grow in the Sun Belt (rich with sunlight resources) including China, India, the Middle East, North Africa and Latin America. In developed countries, storage cell price cuts will accelerate the spread of solar PV power generation. Global installed solar PV power generation capacity in 2040 will be 1,433 GW, 1.7 times as large as in the *Reference Scenario*.

Factors for accelerating the spread of wind, solar PV and other intermittent electricity sources include the reduction of construction and system costs. In developing countries, low-cost loans are a major factor. Also playing major roles in spreading these intermittent electricity sources will be power generation prediction, output control, storage technologies, transmission and distribution network expansion and the enhancement of grid stabilisation through smart grid systems combining these technologies.

Figure 128 | Wind and solar PV power generation capacity [Advanced Technologies Scenario]



Nuclear

Great expectations are placed on the introduction of nuclear power generation as a decarbonisation measure. Emerging countries are considering introducing nuclear power generation to meet the rapid growth in their electricity demand and promote decarbonisation. Among countries that have traditionally and proactively promoted nuclear power generation, the United States and France maintain their capacity for 2015. Russia and Korea will build new nuclear power plants to increase their capacity. Germany, Switzerland and Belgium clarified their nuclear phase-out policies in response to the Fukushima Daiichi Nuclear Power Station accident but could change those policies to put off their nuclear power plant shutdown and replace decommissioned capacity to promote decarbonisation and maintain their industrial competitiveness.

In the *Advanced Technologies Scenario*, nuclear's share of primary energy consumption will rise from 4.8% in 2014 to 9.8% in 2040, 3.6 percentage points higher than in the *Reference Scenario*.

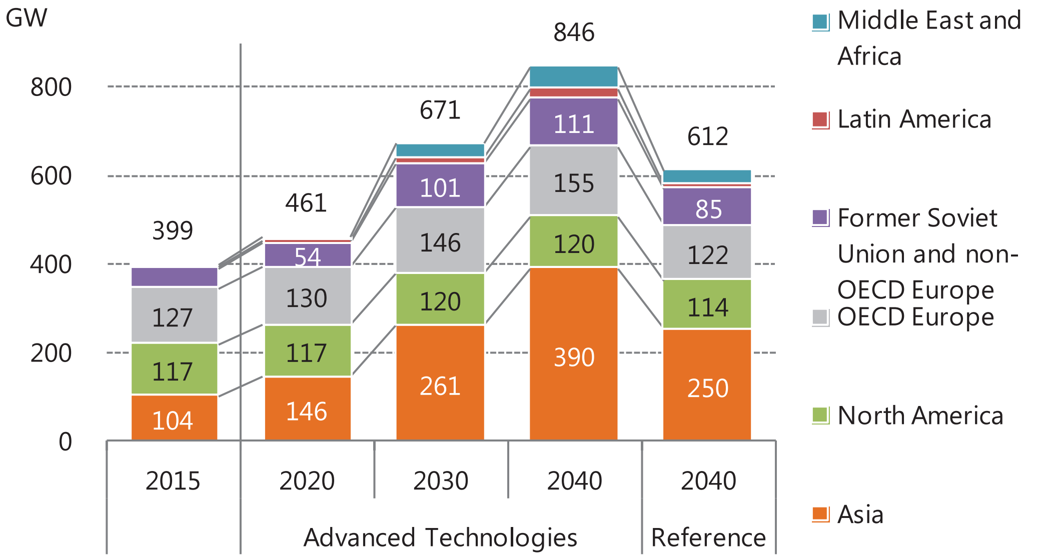
Installed nuclear power generation capacity will increase from 399 GW in 2015 to 847 GW in 2040 (Figure 129), some 1.4 times as much as 612 GW in the *Reference Scenario*.

North America will expand installed nuclear power generation capacity to 120 GW in 2040 due primarily to an increase in Canada. Canada will reduce its capacity to 11 GW in 2025 by shutting down some of the existing capacity, before expanding it to 17 GW in 2030 by building new capacity. The United States has approved up to 60 years of operation for more than 80% of existing nuclear reactors and is considering extending the service life to 80 years. Given that new reactor construction projects are expected to remain in a slump due to recently stagnant electricity demand and cheap natural gas prices, however, U.S. installed nuclear power generation capacity in 2040 will remain unchanged from the present 103 GW.

OECD Europe will decommission outdated reactors and construct replacements, eventually increasing installed nuclear power generation capacity in 2040 to 155 GW from 127 GW in 2015. In the United Kingdom, for example, installed capacity will fall to 8 GW in 2025 on decommissioning of existing reactors and will rise back to 12 GW in 2040. Germany, Switzerland, Belgium and Italy switched to a nuclear phase-out policy after the Chernobyl Nuclear Power Station accident and later restored their policy of using nuclear. Another policy switch after the Fukushima accident could be revised depending on the international situation. Russia will accelerate the construction of new nuclear power plants, sharply expanding installed nuclear power generation capacity from 26 GW in 2015 to 76 GW in 2040. East European countries are steadily implementing their nuclear introduction targets.

In Asia, China and India, as well as Southeast Asian countries, will make progress in the construction of new nuclear power plants. Asia’s installed nuclear power generation capacity will surpass the combined capacity of OECD Europe and North America (at 269 GW) in 2035 and reach 390 GW in 2040. China will increase its installed nuclear power generation capacity by some 34 GW every five years from 2020, replacing the United States (with capacity at 103 GW) as the world’s largest nuclear power generating country in 2030. In 2040, the Chinese capacity will expand to 194 GW. India, with installed nuclear power generation capacity limited to 6 GW in 2015, has put forward a proactive nuclear power generation capacity expansion target, boosting its capacity to 33 GW in 2030 and 62 GW in 2040. The Middle East, Africa and Latin America, known as emerging nuclear energy markets, will launch the operation of new reactors around 2025 and steadily expand installed nuclear power generation capacity thereafter. In the Middle East where mainly the United Arab Emirates and Saudi Arabia are planning to build nuclear power plants, installed nuclear power generation capacity will reach 20 GW in 2030 and 29 GW in 2040.

Figure 129 | Nuclear power generation capacity



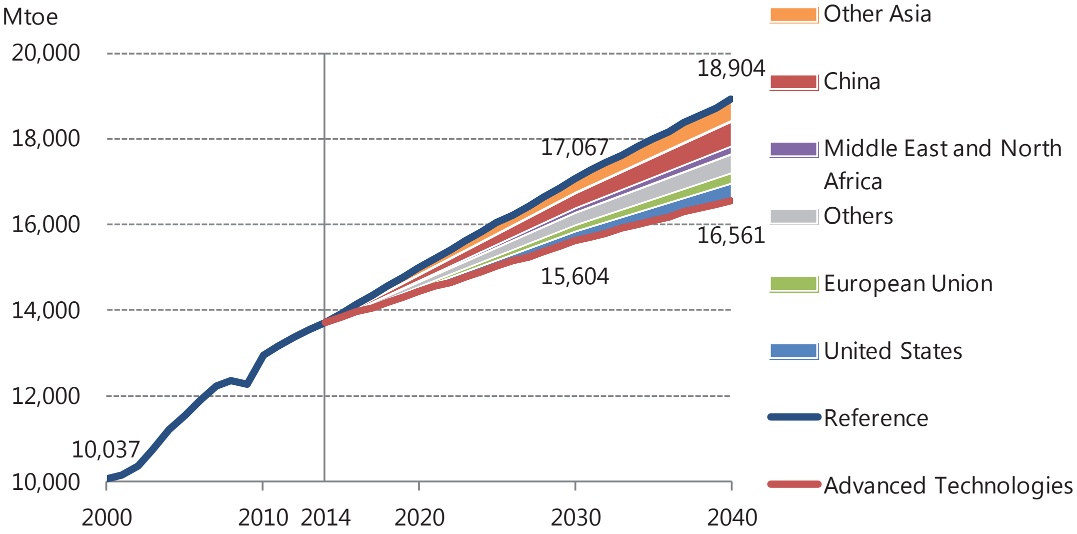
10.2 Energy supply and demand

Primary energy consumption

The strong implementation of the abovementioned energy conservation and climate change measures will substantially reduce primary energy consumption (Figure 130). Primary energy consumption in 2040 in the *Advanced Technologies Scenario* will total 16,561 Mtoe, down 2,343 Mtoe from the *Reference Scenario*. The gap corresponds to the present primary energy consumption in North America. Accumulated energy savings through 2040 will total about 32 Gtoe, 2.3 times as much as global primary energy consumption in 2014.

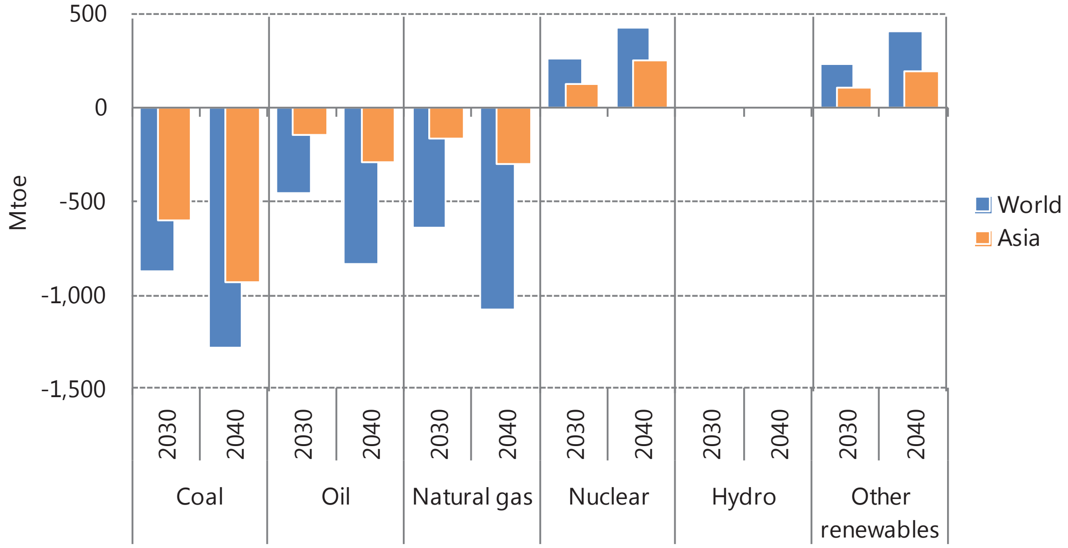
In transition to the *Advanced Technologies Scenario*, non-OECD and Asia, projected to expand energy demand while offering energy conservation potential, will play a great role. Non-OECD will account for 65% of global energy conservation in 2040 and Asia for 45%. Non-OECD and Asia hold the key to reforming the broadly defined global energy system, including consumption and production ways for energy sources required by the world and influences on the global environment.

Figure 130 | Global primary energy consumption and savings by region



Among energy sources, fossil fuels will post great primary energy consumption savings (Figure 131). Of the 2,343 Mtoe decline in primary energy consumption from the *Reference Scenario* in 2040, coal will account for 1,286 Mtoe, natural gas for 1,078 Mtoe and oil for 832 Mtoe. Meanwhile, nuclear and renewable energy will accelerate their spread. Nuclear in the *Advanced Technologies Scenario* will be 433 Mtoe (including 254 Mtoe in Asia) more than in the *Reference Scenario*. Renewables excluding hydro will be 408 Mtoe (including 198 Mtoe in Asia) more. As a result, fossil fuels' share of primary energy consumption in the *Advanced Technologies Scenario* will fall from 81% in 2014 to 70% in 2040.

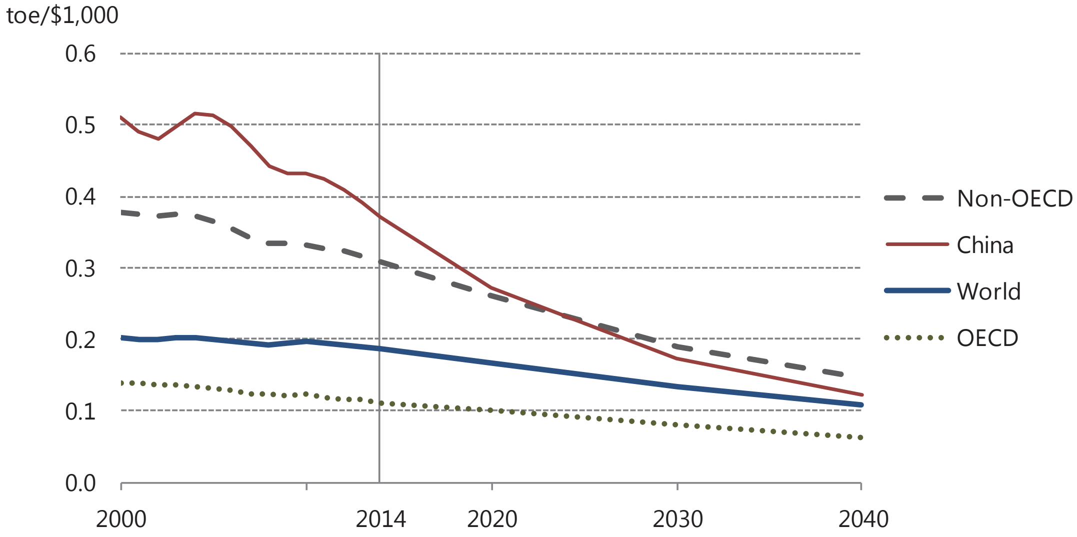
Figure 131 | Global primary energy consumption changes from Reference Scenario [Advanced Technologies Scenario]



Of fossil fuel savings, Asia, including China and India, will account for 48%. Particularly, Asia will capture as much as 73% of coal savings. Asia will also account for more than 50% of nuclear and renewable energy growth.

The world's GDP energy intensity, or primary energy consumption per GDP, an indicator of macro energy efficiency, will plunge by 42% from 2014 to 2040. OECD will post a moderate decline of 44% against 53% for non-OECD. The gap between OECD and non-OECD will narrow. China's energy consumption per GDP, which has been rapidly declining due to industrial structure changes, will continue declining and slip below the non-OECD average by 2030 (Figure 132). China will later drive non-OECD energy conservation. Asia's GDP energy intensity will drop by 52% by 2040.

Figure 132 | GDP energy intensity [Advanced Technologies Scenario]

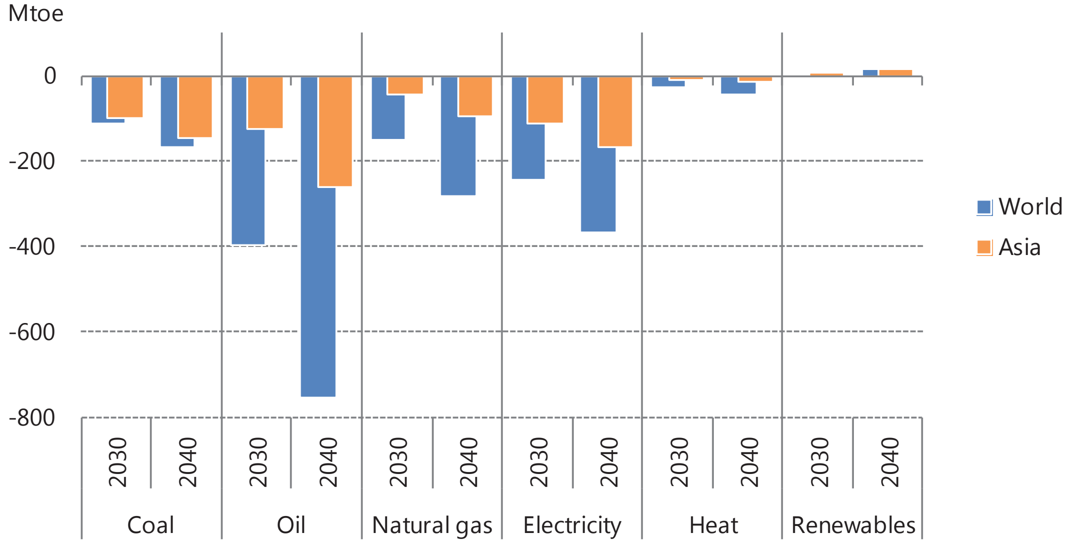


Asia will play a very important role in realising the global energy system depicted in the *Advanced Technologies Scenario*. Asia must eliminate energy conservation barriers including the lack of fundraising capacity and consciousness that blocks the penetration of technologies. The region must spread energy-saving equipment by offering them at reasonable prices to low-income people and provide energy-saving technologies that take into consideration differences between urban and suburban lifestyles. Each country must implement education programs to enhance energy conservation consciousness on a nationwide basis. Joint forums and other bilateral cooperation schemes, as well as multilateral frameworks such as the ASEAN+3 and Asia Pacific Economic Cooperation forums, will help promote such education.

Final energy consumption

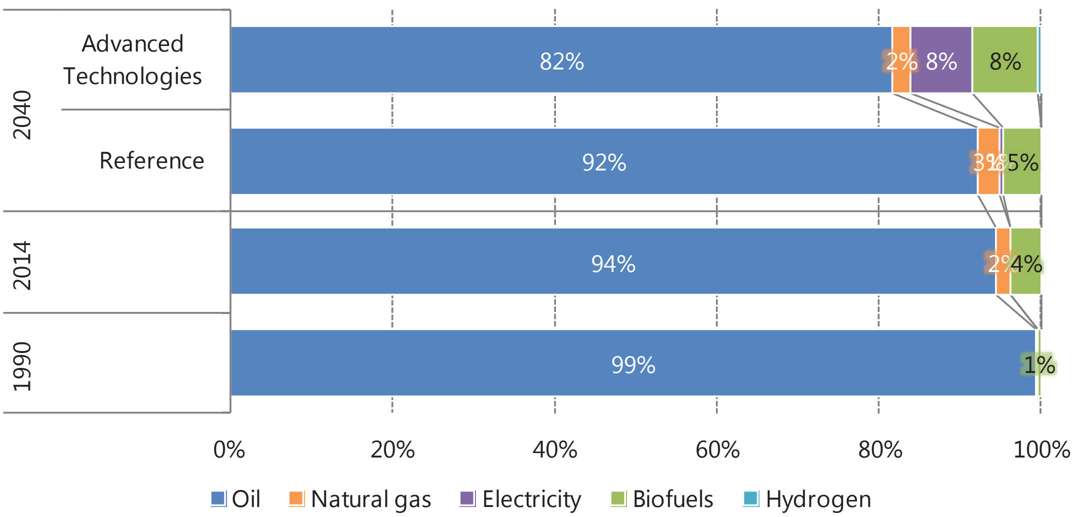
Final energy consumption in 2040 will be lowered by 1,590 Mtoe, of which oil will account for 753 Mtoe and electricity for 368 Mtoe. Oil and electricity will thus cover 70% of energy conservation (Figure 133).

Figure 133 | Final energy consumption changes from Reference Scenario [Advanced Technologies Scenario]



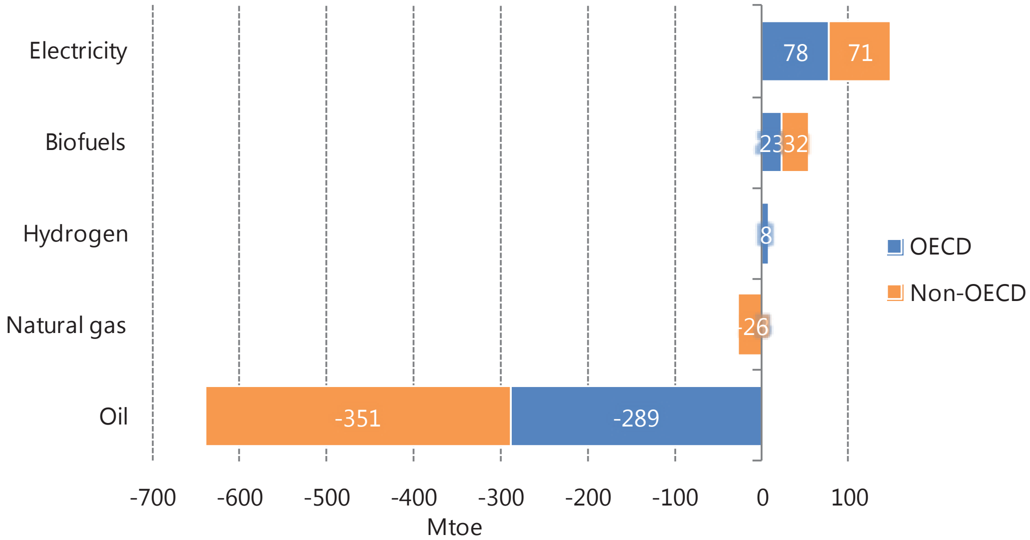
Energy conservation progress mainly in the transport sector will make great contributions to oil savings. In the *Advanced Technologies Scenario*, oil's share of energy consumption in the road sector will decline from 94% in 2014 to 82% in 2040 (Figure 134). As natural gas, electric, fuel cell and other next-generation vehicles spread further, the share for non-oil energy sources will reach 18% in 2040.

Figure 134 | Road sector energy consumption mix in world



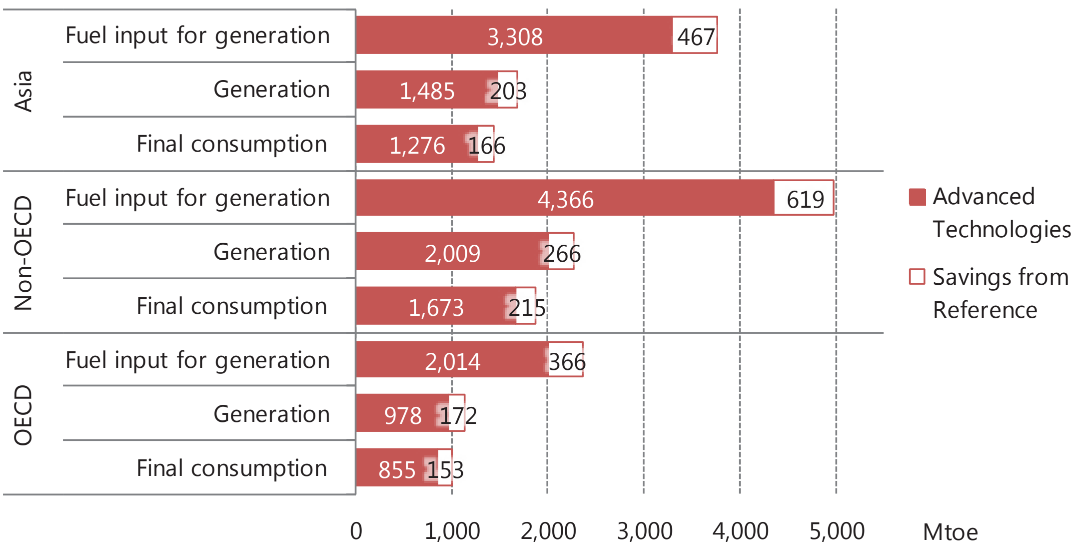
Electricity demand growth will capture the greatest share of energy consumption changes from the *Reference Scenario* in the road sector (Figure 135). In the *Advanced Technologies Scenario*, electric vehicles will spread along with information technologies for traffic demand management to ease congestion and increase distribution efficiency.

Figure 135 | Road sector energy consumption changes from Reference Scenario [Advanced Technologies Scenario, 2040]



Final electricity consumption will be reduced by 368 Mtoe, lowering required power generation by 438 Mtoe. The electricity savings will be coupled with power generation efficiency improvement to save primary energy consumption by 985 Mtoe (Figure 136). The savings are equivalent to 42% of total primary energy consumption savings. Making great contributions to the savings will be Asia. Through the introduction of new power generation equipment and the replacement of outdated equipment accompanying electricity demand growth, Asian emerging countries' power generation efficiency will improve to almost the same levels as in developed countries by 2040.

Figure 136 | Primary energy consumption reduction through final electricity consumption savings [Advanced Technologies Scenario in 2040]



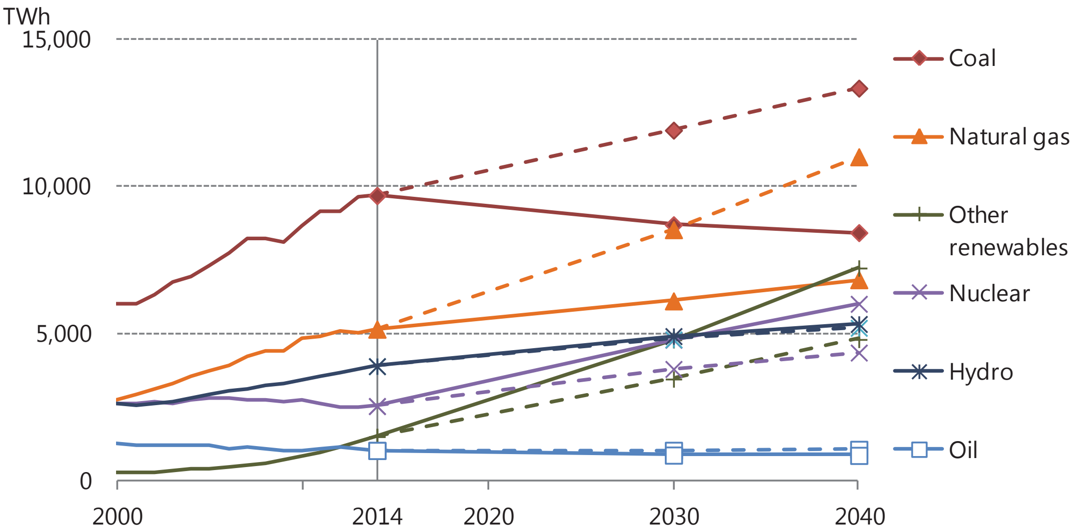
Developed countries should cooperate with emerging countries in improving power generation efficiency globally. Emerging countries frequently fail to take into account environmental conservation while giving top priority to high economic growth. For example, they hesitate to address air pollution by the industry sector as efforts to solve air pollution problems are likely to suppress economic growth. Therefore, it will become more important that developed countries take advantage of their past overcoming of environmental problems to cooperate with emerging countries.

Asia will make great contributions to reducing final coal consumption, accounting for 85% of the global coal consumption reduction in 2040. In this respect, steelmakers' energy conservation will be important in India and other countries where crude steel production will expand rapidly. Japan's energy consumption per unit of steel production is at one of the lowest levels in the world, standing at less than one-third of India's. If highly efficient technologies are transferred from Japan and other developed countries to India and other Asian emerging countries, relevant sectors' energy consumption savings will become more feasible. Developed countries will contribute to energy savings not only in energy-saving equipment and other hardware but also in software including equipment operations.

Power generation mix

In the *Advanced Technologies Scenario,* final energy consumption savings will work to cut electricity generation by about 5,839 TWh, equivalent to combined present generation in China, the world's largest electricity generation, and Japan. The integrated gasification combined cycle (IGCC) for coal-fired power generation and the development of technology for mixing coal with biomass energy will contribute to cutting coal consumption for power generation. In contrast to coal, natural gas, nuclear and renewables will increase their presence in power generation (Figure 137).

Figure 137 | Global power generation by source [Advanced Technologies Scenario]

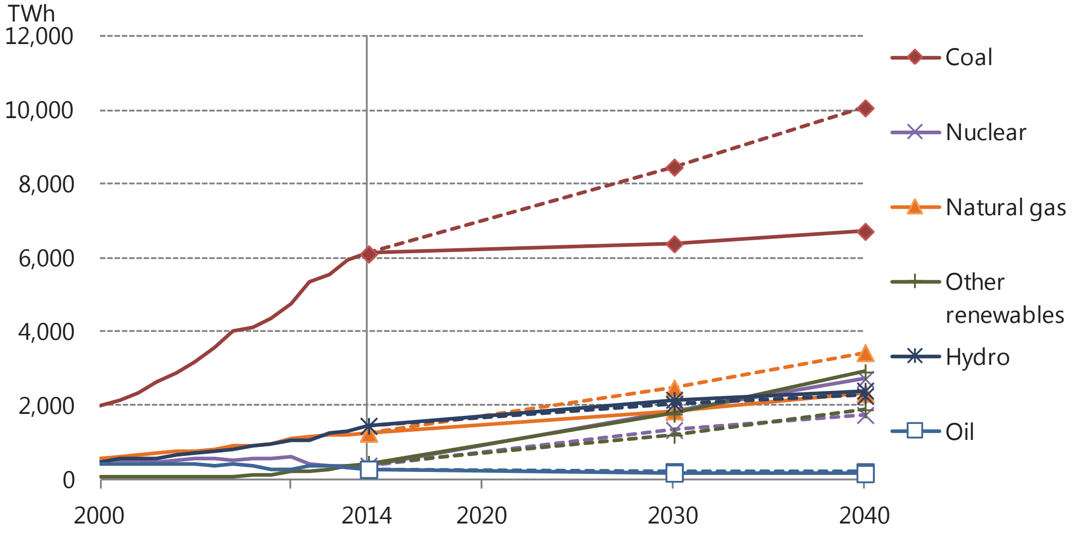


Note: Dashed lines represent the Reference Scenario

In Asia as well, coal-fired power generation will be reduced substantially. Nevertheless, coal's share of electricity generation in 2040 in Asia will still be larger than in any other region (Figure 138). China and other Asian countries have promoted the introduction of renewable energy technology. It is important for them to reduce coal while continuing to expand renewable energy.

In addition to technologies for improving power generation efficiency to reduce primary energy consumption, those for limiting electricity consumption itself are important. A particularly key challenge in developed countries as well as others is how to restrict electricity consumption in the buildings sector that increases consumption in line with living standard improvements. Home energy management systems (HEMS) including smart metres, building energy management systems (BEMS) and other technologies to control energy consumption are expected to spread in developed countries and be transferred to emerging countries.

Figure 138 | Asian power generation by source [Advanced Technologies Scenario]



Note: Dashed lines represent the Reference Scenario

Crude oil supply

Table 19 shows crude oil supply in the *Advanced Technologies Scenario*. Demand in 2040 will be 15% less than in the *Reference Scenario*. As competition between oil suppliers intensifies on sharp demand growth deceleration, relatively cost-competitive OPEC will expand its share of global oil supply from 40% in 2014 to 44% in 2040. Meanwhile, production will decline in North America where demand will decrease and in Europe and Eurasia including Russia, which provides crude oil mainly to Europe with shrinking demand.

Table 19 | Crude oil supply [Advanced Technologies Scenario]

(Mb/d)

	2014	2020	2030	2040	2014-2040	
					Changes	CAGR
Total	91.04	94.03	95.63	96.64	5.60	0.2%
OPEC	36.65	38.43	40.69	41.70	5.05	0.5%
Middle East	27.22	28.28	30.51	32.19	4.97	0.6%
Others	9.43	10.15	10.18	9.51	0.08	0.0%
Non-OPEC	52.18	53.31	52.61	52.58	0.40	0.0%
North America	16.00	17.82	16.84	16.07	0.07	0.0%
Latin America	7.15	7.38	7.68	9.06	1.92	0.9%
Europe and Eurasia	17.21	17.18	16.93	16.10	-1.11	-0.3%
Middle East	1.33	1.41	1.45	1.48	0.15	0.4%
Africa	2.18	2.37	2.58	2.80	0.61	1.0%
Asia	8.31	7.16	7.13	7.07	-1.24	-0.6%
China	4.25	3.43	3.12	3.05	-1.20	-1.3%
Indonesia	0.85	0.79	0.76	0.65	-0.20	-1.0%
India	0.89	0.70	0.59	0.55	-0.34	-1.8%
Processing gains	2.20	2.29	2.33	2.36	0.16	0.3%

Natural gas supply

As natural gas consumption is suppressed in the *Advanced Technologies Scenario*, production will be 16% less than in the *Reference Scenario* in 2030 and 23% less in 2040. A wide production gap between the two scenarios will be seen in OECD Europe where development costs are higher. In 2040, the region's production will be 40% less than in the *Reference Scenario*. In North America, production will peak in 2030 and fall back close to the 2015 level in 2040.

Table 20 | Natural gas production [Advanced Technologies Scenario]

(Bcm)

	2015	2020	2030	2040	2015-2040	
					Changes	CAGR
World	3,602	3,775	4,100	4,394	792	0.8%
North America	915	975	982	935	20	0.1%
Latin America	205	211	305	364	159	2.3%
OECD Europe	235	202	161	122	-114	-2.6%
Non-OECD Europe/ Central Asia	809	882	894	960	151	0.7%
Russia	595	631	642	656	61	0.4%
Middle East	595	662	688	737	142	0.9%
Africa	206	207	283	345	139	2.1%
Asia	467	505	653	767	300	2.0%
China	131	170	275	357	226	4.1%
India	32	33	61	105	72	4.8%
ASEAN	217	221	221	216	-1	0.0%
Oceania	65	130	149	168	103	3.9%

Coal supply

In the *Advanced Technologies Scenario,* global coal demand will decline due to coal consumption efficiency improvements and a fall in coal's share of the power generation mix. As a result, global coal production will decrease from 7,937 Mt in 2014 to 6,565 Mt in 2040

(Figure 139). Steam coal production will decline from 6,004 Mt in 2014 to 5,291 Mt in 2040. Coking coal production will fall from 1,116 Mt in 2014 to 872 Mt in 2040. Lignite production will drop from 817 Mt in 2014 to 402 Mt in 2040. Coal production in 2040 in the *Advanced Technologies Scenario* will be 2,721 Mt less than in the *Reference Scenario*. Production will be 2,231 Mt less for steam coal, 117 Mt less for coking coal and 374 Mt less for lignite.

Figure 139 | Coal production [Advanced Technologies Scenario]

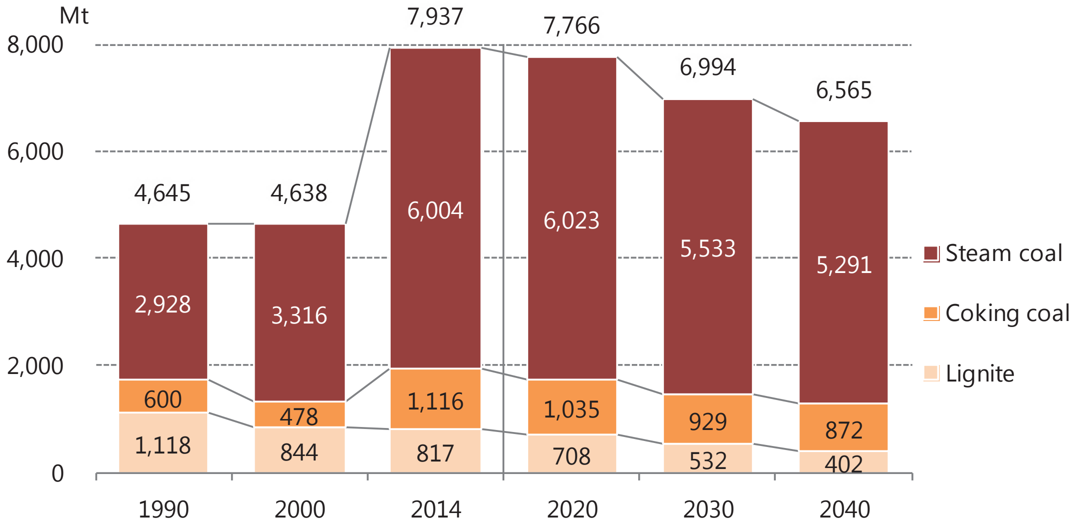


Table 21 and Table 22 indicate steam coal and coking coal production by region, respectively. Coal production will decline substantially in North America, OECD Europe and China where demand will plunge. In India and Indonesia, however, production will increase in line with demand growth. As coal trade decreases due to a global demand drop, coal exporting countries' production will level off or decline depending on regional conditions.

Table 21 | Steam coal production [Advanced Technologies Scenario]

(Mt)

	2014	2020	2030	2040	2014-2040	
					Changes	CAGR
World	6,004	6,023	5,533	5,291	-713	-0.5%
North America	802	631	413	234	-568	-4.6%
United States	773	614	406	230	-544	-4.6%
Latin America	107	105	104	110	4	0.1%
Colombia	84	79	75	79	-5	-0.2%
OECD Europe	88	80	54	34	-54	-3.5%
Non-OECD Europe/ Central Asia	328	325	293	281	-47	-0.6%
Russia	188	187	177	176	-12	-0.3%
Middle East	0	0	0	0	0	0.0%
Africa	267	281	288	306	38	0.5%
South Africa	257	270	272	280	23	0.3%
Asia	4,161	4,347	4,139	4,080	-81	-0.1%
China	3,020	3,158	2,838	2,644	-377	-0.5%
India	559	605	658	732	173	1.0%
Indonesia	484	486	531	586	103	0.7%
Oceania	250	254	242	245	-5	-0.1%
Australia	248	252	241	243	-5	-0.1%

Table 22 | Coking coal production [Advanced Technologies Scenario]

(Mt)

	2014	2020	2030	2040	2014-2040	
					Changes	CAGR
World	1,116	1,035	929	872	-244	-0.9%
North America	105	86	82	79	-25	-1.1%
United States	73	58	56	55	-17	-1.0%
Latin America	7	5	5	5	-2	-1.1%
Colombia	5	4	4	4	-1	-0.8%
OECD Europe	23	20	17	14	-9	-1.8%
Non-OECD Europe/ Central Asia	106	95	97	97	-10	-0.4%
Russia	76	69	70	73	-4	-0.2%
Middle East	1	1	1	1	0	1.2%
Africa	8	10	14	18	11	3.4%
South Africa	4	6	10	14	10	5.1%
Asia	686	647	547	494	-192	-1.3%
China	620	574	471	414	-206	-1.5%
India	51	59	63	68	17	1.1%
Indonesia	14	13	10	9	-6	-1.8%
Oceania	182	171	166	164	-19	-0.4%
Australia	180	170	164	162	-18	-0.4%

11. Addressing global environmental problems

11.1 CO_2/GHG emissions

Paris Agreement and GHG emission reduction targets

The 21st Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015 adopted the Paris Agreement, a new international framework to reduce greenhouse gas (GHG) emissions from 2020. Learning lessons from the Kyoto Protocol, the Paris Agreement became a bottom-up framework in which all countries participate and submit Intended Nationally Determined Contributions (INDCs) (Table 23 and Table 24). Major parties to the UNFCCC are required to update their INDCs every five years. New INDCs will have to be tougher than previous ones. In this way, progress toward long-term targets will be assessed every five years in the so-called global stocktake. Assessment results will have to be taken into account when the next INDCs are submitted. The Paris Agreement also includes a peer review for UNFCCC parties to assess progress toward the achievement of targets and seek further GHG reduction efforts every two years in principle.

The Paris Agreement includes independent provisions not only about mitigation (reduction) but also about adaptation, and loss and damage from climate change. By 5 October 2016, more than 55 countries accounting for more than 55% of global GHG emissions ratified the agreement, allowing it to take effect on 4 November, within one year from its signing.

Table 23 | Overview of Paris Agreement

Item	Contents
Aim	The Paris Agreement's aim is to strengthen the global response to the threat of climate change by keeping the global temperature rise this century well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 °C.
Joint long-term goals on mitigation (reduction)	Parties to the agreement aim to reach global peaking of GHG emissions as soon as possible and undertake rapid reductions thereafter in accordance with the best available science, so as to achieve a balance between anthropogenic emissions by source and removals by sinks of GHG in the second half of the 21st century,
Process for setting targets	The meeting of the parties to the Paris Agreement shall periodically take stock of the implementation of this agreement to assess the collective progress towards achieving the purpose of this agreement and its long-term goals (referred to as the "global stocktake"). Each party shall take the global stocktake results into account when communicating a nationally determined contribution (reduction targets, etc.) every five years.
Review of target achievements	Information on mitigation and support submitted by each party to the agreement shall undergo a technical expert review. Each party shall participate in a facilitative, multilateral consideration of progress with respect to support efforts and its respective implementation and achievement of its nationally determined contribution.
Finance	Developed countries shall communicate information on financial support and the mobilisation of climate finance biennially.
Adaptation	Parties establish the global goal on adaptation including the reduction of vulnerability to climate change. Developing countries' adaptation efforts must be recognised. Each party should, as appropriate, submit and periodically update reports on adaptation.
Loss and damage	The Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts, established at the COP19 meeting, shall be subject to the authority and guidance of the meeting of the parties to this agreement.

Table 24 | G20 countries' INDCs

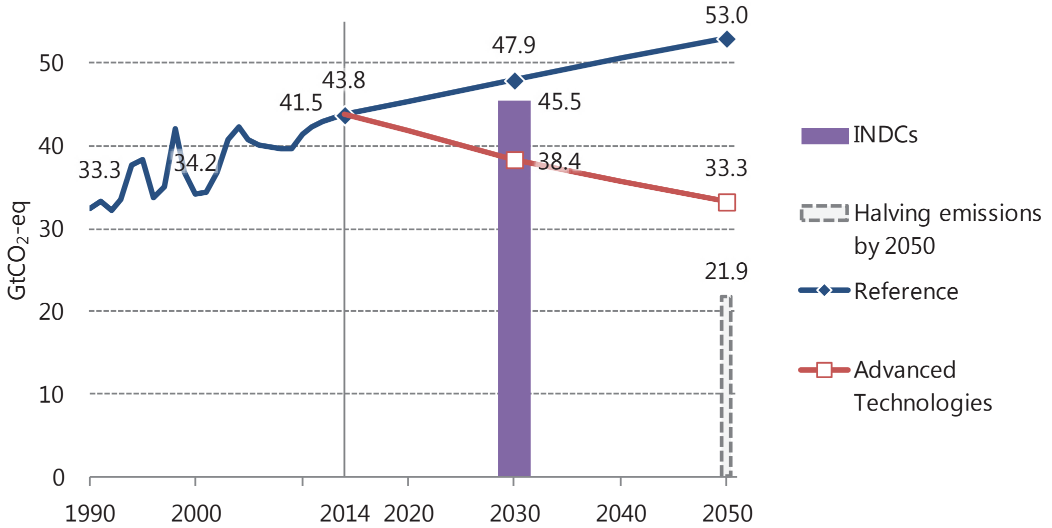
	Target type	Reduction level (%)	Reference point	Target year	Target sector or gas
China	GDP emission intensity reduction from the reference year	60-65	2005	2030	CO_2 emissions
United States	Emission reduction from the reference year	26-28	2005	2025	GHG emissions*
European Union	Emission reduction from the reference year	40	1990	2030	GHG emissions
Russia	Emission reduction from the reference year	25-30	1990	2030	GHG emissions
India	GDP emission intensity reduction from the reference year	33-35	2005	2030	GHG emissions
Japan	Emission reduction from the reference year	26	2013	2030	GHG emissions
Brazil	Emission reduction from the reference year	37 (43 in 2030)	2005	2025	GHG emissions
Canada	Emission reduction from the reference year	30	2005	2030	GHG emissions*
Korea	Emission reduction from BAU	37	BAU	2030	GHG emissions (Excluding forest sinks for the immediate future)
Mexico	Emission reduction from BAU	22 (Unconditional), 40 (Conditional)	BAU	2030	GHG emissions*
Indonesia	Emission reduction from BAU	29	BAU	2030	GHG emissions
South Africa	Emissions	Emissions: 398-614 million tonnes	-	2025, 2030	GHG emissions
Australia	Emission reduction from the reference year	26-28	2005	2030	GHG emissions*
Turkey	Emission reduction from BAU	21	BAU	2030	GHG emissions
Argentina	Emission reduction from BAU	15 (Unconditional), 30 (Conditional)	BAU	2030	GHG emissions
Saudi Arabia	Emission reduction from BAU	130 million tonnes cut	BAU	2030	GHG emissions

Note: Excluding Germany, the United Kingdom, France and Italy belonging to the European Union.
* Emissions in the reference year include those absorbed by forest sinks.

The Paris Agreement has the following praiseworthy points: First, all countries including such developing countries as China and India are required to cut GHG emissions. More than 180 countries agreed to make emission reduction efforts. Under the Kyoto Protocol, only 37 countries were required to reduce emissions. As the United States failed to ratify the Kyoto Protocol, it effectively became an EU-Japan agreement. Second, the Paris Agreement negotiators adopted a bottom-up approach in which countries submitted their respective emission reduction targets for accumulation, instead of the top-down approach for the Kyoto Protocol in which a target reduction was set before being allocated to countries. Unlike under the Kyoto Protocol, targets themselves are not binding. Every five years, the total of all countries' targets is assessed, with countries urged to make more emission reduction efforts.

However, there are some problems with the Paris Agreement. Global GHG emissions[28], estimated according to the Group of 20 members' INDCs, total 45.5 $GtCO_2$ for 2030, posting an increase from the present level (Figure 140). Although the increase is slower than in the past, the estimated trend deviates far from a target of halving GHG emissions in 2050.

Figure 140 | Global GHG emissions

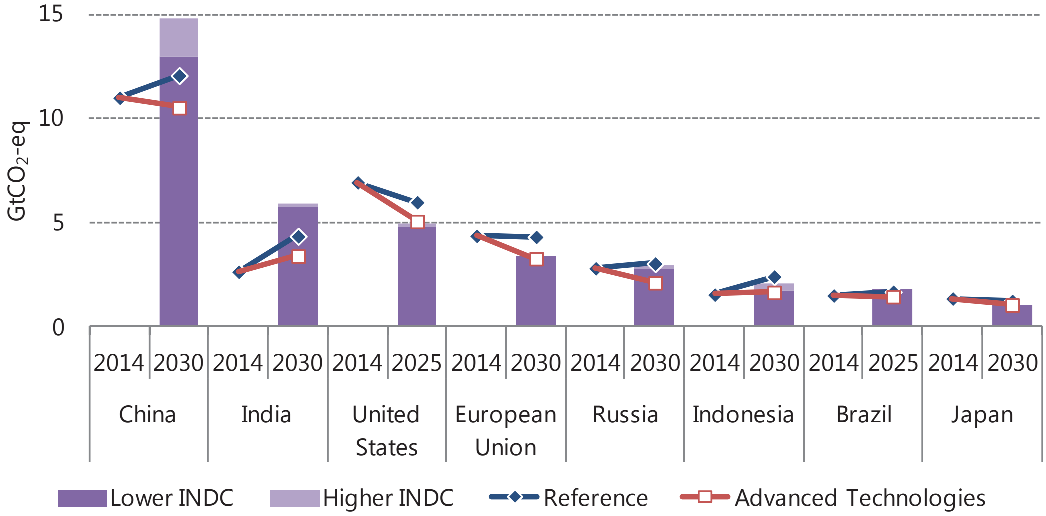


Note: Estimated according to the Group of 20 major countries' INDCs for the Paris Agreement.

Figure 141 compares major countries' INDC-based GHG emissions and those in the *Reference* and *Advanced Technologies Scenarios* to be explained later.

[28] Energy-related CO_2 emissions in 2010 totalled 30.2 $GtCO_2$ (excluding bunker emissions) for the world and 25.5 $GtCO_2$ for the G20. G20 GHG emissions in 2030 were multiplied by their ratio to project global emissions.

Figure 141 | GHG emissions in major countries and European Union



Note: Estimated according to the INDCs for the Paris Agreement

The assessment of major countries' INDCs indicates that developed countries are close to the *Advanced Technologies Scenario* as explained later. China and India are close to the *Reference Scenario*. Indonesia and Brazil are positioned between the *Advanced Technologies Scenario* and the *Reference Scenario*. Each country will have to make efforts required for the *Advanced Technologies Scenario*. To this end, low carbon technologies will have to penetrate in developing countries.

Nevertheless, we should appreciate the Paris Agreement as making its mark as a global step to addressing climate change. It will be important for all countries to realise their agreed targets and reduce GHG emissions further. To this end, objective assessment of targets will be required. In addition, technological innovation must be combined with technology transfers and financial support using the joint crediting mechanism (JCM) to support global emission reduction efforts.

Advanced Technologies Scenario

In the *Advanced Technologies Scenario* in which energy conservation and low-carbon technologies will be further advanced, global energy-related CO_2 emissions will peak out around 2020 and slowly decline before reaching 31.8 Gt in 2050, down 1.2 Gt or 3.8% from 2014. A CO_2 emission decline of 13.7 Gt from the *Reference Scenario* will amount to 42% of present global emissions (Figure 142). A cumulative decline of 259 Gt through 2050 will be equivalent to 7.8 years' worth of present global annual emissions.

Figure 142 | Global energy-related CO_2 emissions

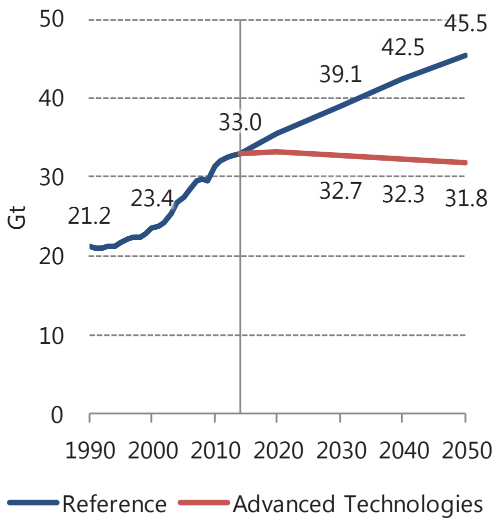
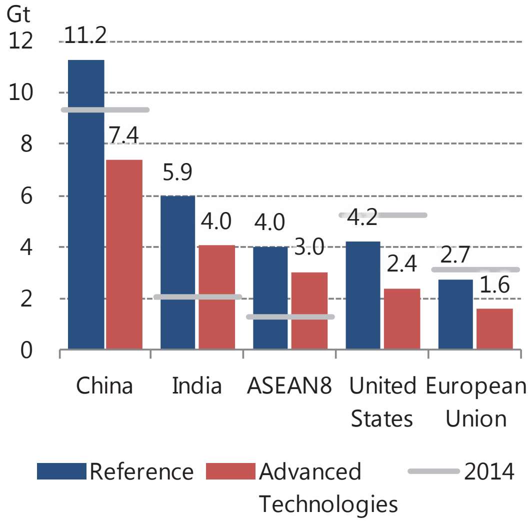


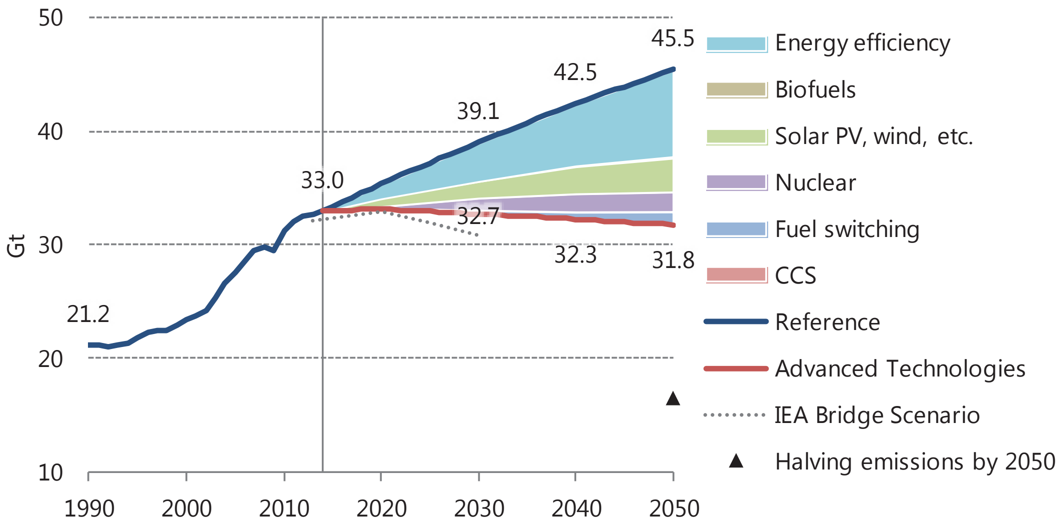
Figure 143 | CO_2 emissions in major countries/regions [2050]



Non-OECD will account for about 70% of the emission decline from the *Reference Scenario* in 2050. A decline in China, the largest CO_2 emitter in the world, will come to 3.8 Gt, far exceeding the present emission level of 3.1 Gt for the European Union (Figure 143). India, which will replace the United States as the second largest CO_2 emitter in the world by 2040, will reduce emissions by 1.9 Gt, equivalent to 90% of its present emissions. ASEAN8, which will emit more CO_2 than the United States in the *Advanced Technologies Scenario*, will account for 7% of the global emission decline from the *Reference Scenario*. The reduction of CO_2 emissions in Asian and other developing countries will be indispensable as an effective climate change measure. In this sense, developing countries' emission reduction efforts and developing countries' technology transfers to and institution-building support for developing countries to spread low-carbon technologies will be very significant.

Of the emission decline from the *Reference Scenario* in 2050, energy efficiency will account for 7.6 Gt, the largest share, followed by 3.2 Gt for renewable energy, 1.7 Gt for nuclear and 1.2 Gt for fuel switching (Figure 144). Each technology is imperfect, having both advantages and disadvantages. It is important to appropriately use various options without depending heavily on certain technologies or measures.

Figure 144 | Global CO_2 emissions reduction by technology



11.2 Super long-term emission reduction path

Super long-term norm

In the *Advanced Technologies Scenario*, maximum CO_2 emission reduction measures will be implemented with their application opportunities and acceptability to society taken into account. GHG emissions in this ambitious scenario could be adopted as a target. However, the climate change issue is a long-term challenge that will involve a wide range of areas over numerous generations. When and how specific measures should be taken and what measures should be implemented must be considered carefully. The selection of the key path should not depend on simple comparison of emission cuts at a specific point in time. Given various aspects of sustainability, we believe that it is desirable to appropriately balance GHG emission reduction (mitigation), adaptation and residual damage.

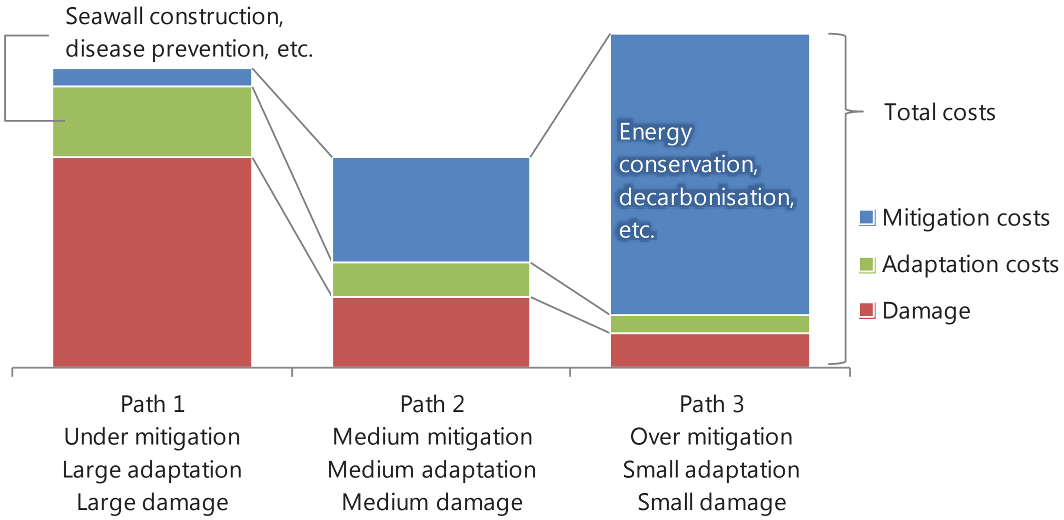
Table 25 | Mitigation, adaptation and damage

Mitigation	Adaptation	Damage
Representative among mitigation measures is GHG emission reduction, including carbon capture and storage (CCS) to prevent GHG from being released into the atmosphere. Mitigation measures are designed to mitigate climate change.	A temperature rise could cause sea surface elevation, droughts, new disease epidemics, etc. Seawall and reservoir construction, agricultural research, and disease prevention and treatment to respond to these problems are “adaptation” measures.	When mitigation and adaptation fail to sufficiently reduce the effects of climate change, damage may emerge, including sea surface elevation, drought and new disease epidemics.

If no measure is taken in response to climate change, adaptation costs and damage may be enormous, though with mitigation costs limited to zero. Mitigation measures may reduce adaptation costs and damage. Mitigation to a certain degree may not cost so much[29]. In order to substantially reduce GHG emissions to mitigate climate change, however, high-cost energy conservation equipment may have to spread, expanding mitigation costs remarkably. Mitigation thus trades off with adaptation and damage.

There could be various views about how to balance mitigation, adaptation and damage. From the viewpoint of long-term sustainability, we consider as desirable a combination to limit the total of mitigation, adaptation and damage costs. In Figure 145, Path 2 rather than Path 1 or 3 should be recommended. A bold conclusion is that an attempt to spend $500 or $1,000 on cutting emissions and building seawalls to prevent $100 in damage would be very difficult to implement and would risk failure.

Figure 145 | Image of total mitigation, adaptation and damage costs



Cost optimisation path

For projecting the total costs, this outlook uses marginal emission reduction costs projected with our accumulation model as mitigation (emission reduction) costs through 2050 (Figure 146). The model calculates technology introduction costs' changes responding to CO_2 emission reduction rates by taking into account the stock and flow of energy conservation and low-carbon technologies through 2050. While the spread of sophisticated technologies could substantially reduce CO_2 emissions, the existing stock alone could not. Energy efficiency improvements could reduce emissions but could not eliminate them. For these reasons, costs will rise rapidly if an emission cut from the *Reference Scenario* exceeds 60%. In the *Standard Scenario*, technological advancement is assumed to allow mitigation costs to fall at an annual rate of 0.5% from 2050.

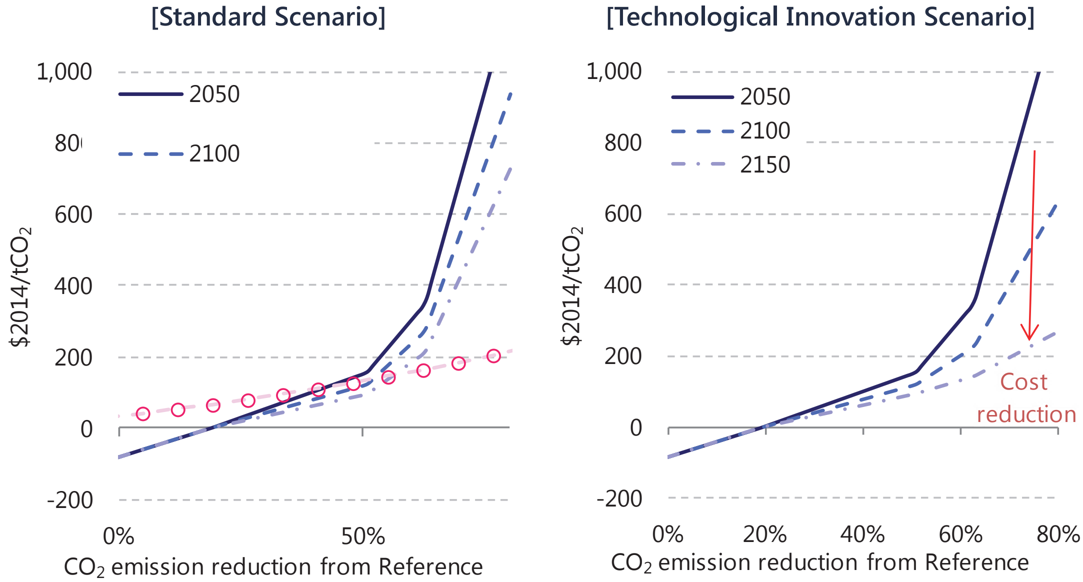
In the far future from 2050, innovative technologies surpassing existing sophisticated ones could be introduced to further reduce mitigation costs. In order to reduce CO_2 emissions close to zero over the super long term in the world, the anticipated rapid rise in costs for

[29] Energy conservation to reduce energy costs could bring about benefits.

when the emission cut exceeds 60% for the years 2100 and 2150 will need to be curbed down.. To this end, the introduction of innovative technologies accompanied by structural changes in energy use will be required along with the promotion of energy conservation. In the "*Technological Innovation Scenario*," marginal emission reduction costs are assumed to decline from 2050, as shown in the right part of Figure 146.

As for "damage and adaptation costs," we used a projection formula in the DICE-2013R model[30]. Damage (and adaptation costs replacing damage partially) at each time point in the future is approximately indicated by the quadratic function of a temperature rise from the second half of the 19th century.

Figure 146 | Marginal abatement costs



Based on these projected costs, we derived the "*Cost Optimisation Path*" to minimise cumulative total costs each in the *Standard* and *Technological Innovation Scenarios*[31]. CO_2 emissions through 2050 in the *Cost Optimisation Path* will be reduced substantially from the *Reference Scenario*. However, the emissions in 2050 will not have to be halved from the present level. The reduction is close to that in the *Advanced Technologies Scenario* (Figure 147).

In the *Standard Scenario*, CO_2 emissions under the *Cost Optimisation Path* will continue falling slowly even after 2050 and be halved from the present level after 2150 (Figure 148). In this scenario where marginal emission reduction costs emerge in areas with greater CO_2 emission reduction rates, it will be difficult to realise emissions close to zero even in the far future

[30] W. Nordhaus and P. Sztorc, "DICE 2013R: Introduction and User's Manual," http://www.econ.yale.edu/~nordhaus/homepage/documents/DICE_Manual_103113r2.pdf

[31] Specifically, a path has been pursued to maximise cumulative utility corresponding to consumption under these costs. As for parameters for the effective discount rate, we used "standard discount rates," or the pure time preference rate at 1.5% and the elasticity of marginal utility of consumption at 1.45, in "Asia/World Energy Outlook 2015." The climate sensitivity (equilibrium climate sensitivity) is tentatively put at 3°C.

beyond 2100. In the *Technological Innovation Scenario*, CO_2 emissions under the *Cost Optimisation Path* will decline rapidly from 2100 and near zero around 2150. The development and diffusion of innovative technologies surpassing existing ones will be indispensable for achieving the ambitious target of reducing global CO_2 emissions close to zero.

Figure 147 | CO_2 emissions in super long-term path

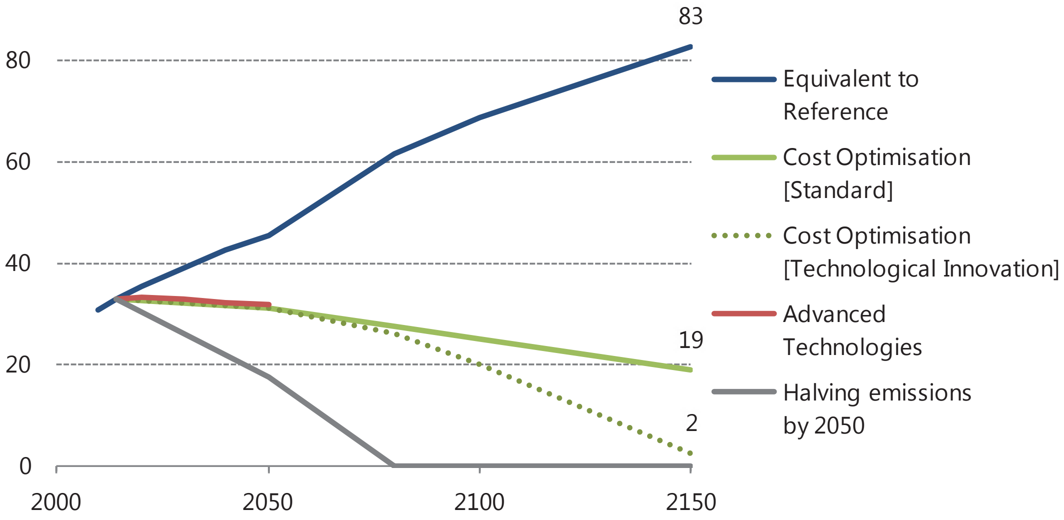
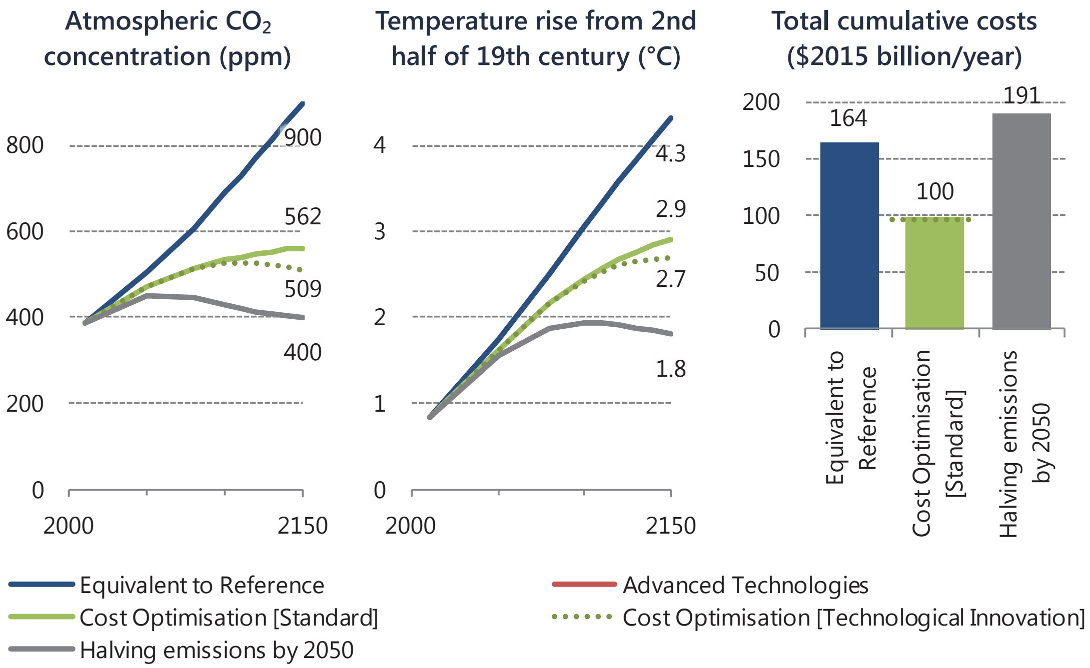


Figure 148 | Super long-term path

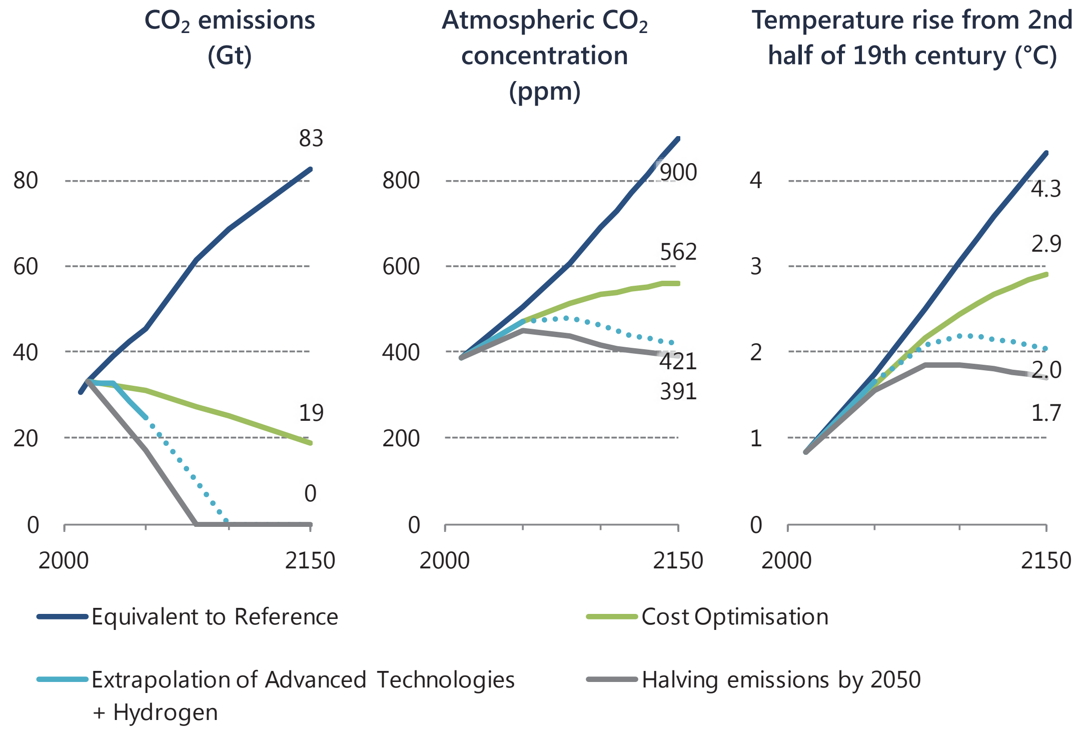


Under the *Cost Optimisation Path* in the *Standard Scenario*, the average temperature will rise by 2.9°C from the second half of the 19th century by 2150 and continue rising later over a long time. Nevertheless, total costs will be limited to an annual average of $100 billion, slipping far below levels for a scenario equivalent to the *Reference Scenario* and the *Halving Emissions by 2050 Path*. Under the *Cost Optimisation Path* in the *Technological Innovation Scenario*, the average temperature will rise by 2.4°C from the second half of the 19th century in 2100 and by 2.7°C in 2150 before turning down, with the rise being stabilised in a 2.0 – 2.5°C range (If negative emissions are assumed for 2150, the temperature rise may become smaller). The reduction of mitigation costs accompanying future technological development will be very important for the long term sustainable development of the human race.

Giving priority to total costs as a super long-term norm does not necessarily fix any optimum emission path. While the world has reached a scientific consensus that human effects have been a dominant factor behind global warming observed since the middle of the 20th century, many factors involving future climate change are uncertain. As noted in "Asia/World Energy Outlook 2015," these uncertain factors (including the climate sensitivity and an effective discount rate as well as mitigation, adaptation and damage cost projections) could exert great influences on the cost optimisation path.

However, humans cannot control the climate sensitivity. On the other hand, mitigation costs can be cut through the reduction of costs for existing low-carbon technologies and the development of innovative technologies. We are required to cooperate in technological development from the long-term viewpoint while continuing to pursue adequate climate change measures. For example, with more innovative technologies in addition to the carbon free hydrogen (see Chapter 12) and cost reduction, CO_2 emissions path may become further down to become net zero by 2100. This will reduce the CO_2 concentration down and thus may meet the 2°C target by 2150. Overall total cost will become higher than the optimised total cost of mitigation, damage and adaptation but this result implies that it is possible to return to the 2°C path in the long run (Figure 149).

Figure 149 | Innovative technologies and super long-term path



11.3 Innovative technology development over super long time

It is idealistic to limit the temperature rise to 2°C over time. Therefore, it is important to develop innovative technologies while promoting technology transfers over the next 50 years. One of such technologies is next-generation nuclear power generation. The others include hydrogen plus carbon capture and storage (CCS) technologies, carbon capture and utilisation (CCU) technologies, nuclear fusion and space solar PV.

Table 26 | Innovative technologies that should be developed over a medium to long time horizon

Technologies to reduce CO_2 emissions

Next-generation nuclear reactors	
Present technology development situation	Concepts are under consideration for next-generation (fourth-generation) nuclear reactors that satisfy such requirements as efficient fuel consumption, minimised nuclear waste and anti-proliferation security and ensure safety and economic efficiency. Small and medium-sized reactors are also being developed internationally. Fourth-generation nuclear reactors include very high temperature reactors, supercritical water-cooled reactors, fused-salt reactors, gas-cooled fast reactors, sodium-cooled fast reactors and lead-cooled fast reactors. Particularly, very high temperature reactors can be used for mass production of hydrogen and have been adopted for construction or under planning in some countries.

Next-generation nuclear reactors	
	Among new-type reactors, Russia has launched operation of a fast reactor and China plans to operate a high temperature reactor.
Future challenges	A future challenge is to expand support for research and development of next-generation reactors.

Nuclear fusion	
Present technology development situation	Nuclear fusion of hydrogen and other elements with smaller nuclear numbers can produce energy as the sun does. The deuterium fuel for nuclear fusion is abundantly and universally present. Nuclear fusion does not generate spent fuel as high-level radioactive waste. Tokamak, helical, field-reversed configuration, laser nuclear fusion and other types have been proposed for confining plasma. An international consortium of 35 countries, including Japan, the United States, Russia, European countries and China, is constructing the tokamak-type international thermonuclear experimental reactor (ITER) under a plan to achieve burning plasma (steady-state fusion) conditions. In addition, various countries are proceeding with research on nuclear fusion reactors. • Germany's Max Planck Institute launched the Wendelstein 7-X superconducting helical advanced stellarator in 2015. • In the United States, multiple federal research organisations under the Department of Energy are studying elemental technologies. Ambitious venture firms, including Tri-Alpha Energy cited below, are developing small nuclear fusion reactors for earlier commercialisation. • Tokamak Energy in the United Kingdom focuses on a spherical tokamak reactor. • Tri Alpha Energy in the United States is engaging in research and development of a field-reversed configuration reactor under funding by Goldman Sachs and other private sector firms.
Future challenges	Technological challenges include the following: • Technology to continuously induce nuclear fusion and confine it in a given space • Development of materials that are stable under high temperatures, high pressures, high magnetic fields and high neutron radiation • Establishment of safe tritium treatment technology • Reduction of energy balance and costs Following measures are required for long-term research and development: • Raising funds and building international cooperation arrangements for large-scale technology development • Encouraging private sector companies to participate in technology development projects for commercialisation

Space solar PV	
Present technology development situation	Solar PV power generation will be implemented in outer space where there is more solar energy available to be collected than on the Earth. Electricity will be wirelessly transmitted to the Earth with microwaves for ground utilisation. Solar PV power generation in outer space will be invulnerable to weather conditions or night and day changes in output and qualified as a baseload electricity source. Space solar PV is under research and development, with elemental technologies being tested on

Space solar PV	
	the Earth. Mainly Japan and the United States have so far considered various space solar PV schemes. In Japan, the Japan Aerospace Exploration Agency (JAXA) is testing electricity transmission with microwaves.
Future challenges	Key technological challenges include the establishment of wireless energy transmission technology, the improvement of the efficiency for converting microwaves into electricity and satellite attitude control. Costs must be reduced for transporting materials for constructing a solar PV plant in outer space. Mainly venture firms for recyclable rockets have been undertaking relevant research in recent years. As any achievement is difficult to make in a short time, research and development funds must be ready. In this respect, consideration should be given to spinoffs during research and development that could make social contributions. Human resources development is indispensable for super long-term technology development.

Technologies to capture CO_2 and remove CO_2 from atmosphere

Hydrogen production and utilisation	
Present technology development situation	Hydrogen is produced by steam reforming of fossil fuels, biomass through gasification or fermentation, and electrolysation of water. While hydrogen consumption itself is free from carbon, steam reforming of natural gas and coal to produce hydrogen generates CO_2, which could be subjected to CCS. In the future, hydrogen could be produced in a carbon-free manner using renewable and nuclear energy. Hydrogen is now transported as compressed hydrogen through pipelines linking factories. Liquefied hydrogen, organic hydride and ammonia are under consideration for future hydrogen transportation. Hydrogen could be used for fuel cells, fuel like natural gas for combined cycle power generation and combustion in the industry sector.
Future challenges	Technological challenges include cost cuts and efficiency improvements in all of hydrogen production, storage, transportation and utilisation stages. Social challenges include relevant infrastructure development in which the entire energy supply system must be reformed.

CO_2 capture and utilisation	
Present technology development situation	CO_2 capture and utilisation (CCU) technologies include artificial photosynthesis for producing carbon compounds as chemical materials from CO_2, and conversion of biomass into hydrocarbon fuel, chemical materials and other valuable goods for utilisation. There are electrochemical, photochemical, biochemical and thermochemical methods to produce hydrocarbon from CO_2. The CCU can remove CO_2 from the atmosphere. The CCU is particularly important for areas where CO_2 storage sites are limited. The present artificial photosynthesis consists of three chemical reaction processes – (1) separation of hydrogen and oxygen in water through photocatalysts, (2) separation of hydrogen from oxygen and (3) reaction between hydrogen and CO_2 to produce organic matters. Energy conversion efficiency has continued to be improved.

CO_2 capture and utilisation	
	The reaction between hydrogen and CO_2 produces methane, carbon monoxide and formic acid.
Future challenges	A challenge is to substantially increase CO_2 available for CCU and improve CCU efficiency. Challenges regarding artificial photosynthesis include the development of catalysts and the improvement of technology to safely separate combustible hydrogen from oxygen. The Innovation for Cool Earth Forum plans to release a CCU technology roadmap in 2017.

International cooperation is required for developing innovative technologies. In this respect, hopes are placed on the Innovation for Cool Earth Forum (ICEF).

12. CCS and hydrogen exploitation scenarios

12.1 CCS potential and costs

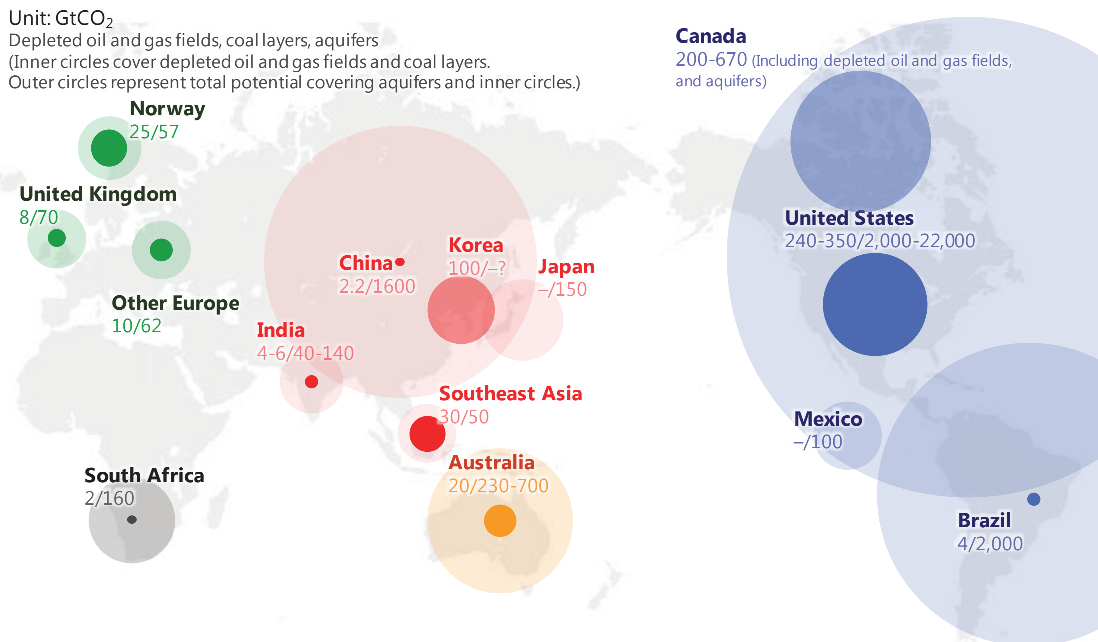
Present situation

Carbon capture and storage (CCS) technology is being studied and developed as an indispensable tool for the substantial reduction of CO_2 emissions over a long time. Particularly, the technology is expected to diffuse in the power generation and industry sectors that are large CO_2 emitters. At present, 40 large-scale CCS projects are underway mainly in North America, China and the United Kingdom, according to the Global CCS Institute. Japan is conducting a large-scale CCS demonstration test for a CO_2-emitting oil refinery in Tomakomai. Since April 2016, more than 100,000 tonnes of CO_2 have been injected into a test storage. Japan's Strategic Energy Plan calls for research and development to commercialise the CCS technology around 2020.

Storage

Conceivable CO_2 storage sites include depleted oil and gas fields, unused coal layers and aquifers. Ongoing CCS projects are mostly related to enhanced oil recovery (EOR) and other technologies for operating into depleted oil and gas fields. Further technological and economic consideration will be required for using aquifers as stable CO_2 storage sites.

Figure 150 | World CCS potential



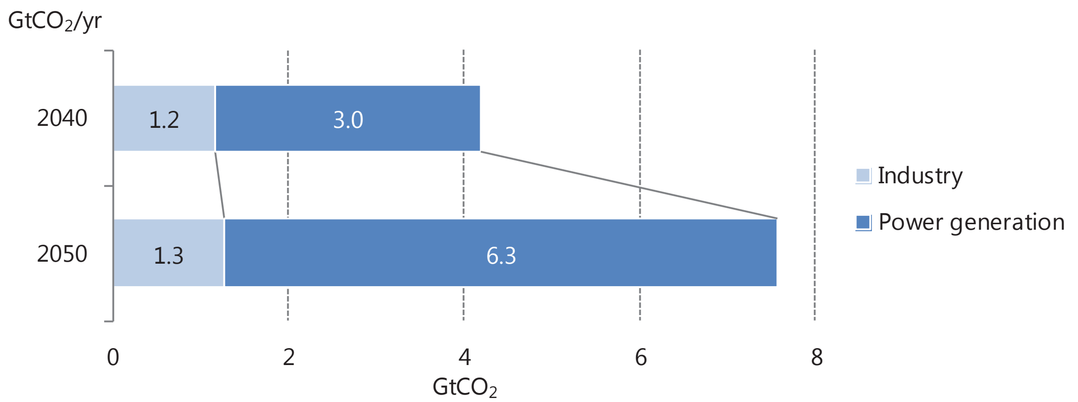
Sources: Global CCS Institute (2016), "Global Storage Portfolio", Global CCS Institute, Melbourne. p. 93, U.S. DOE/NETL (2015), "Carbon Storage Atlas 5th ed.", Carbon Storage Taskforce (2009), "National Carbon Mapping and Infrastructure Plan – Australia"

CCS potential has been surveyed in many countries. Present potential assessments cannot be compared simply as survey accuracy or progress differs from country to country. Relatively great potential has been reported for North America, Australia and Europe where surveys have made more progress than in other regions. Potential in the Middle East, Africa and Southeast Asia could increase depending on future progress in surveys. If storage in aquifers is economically and socially feasible, CCS may be implemented in many countries in the world. If realistic potential is limited to depleted oil and gas fields and the EOR, however, CCS diffusion may be confined to some regions.

Emission reductions

If storing CO_2 into aquifers is economically feasible on a widespread basis, many countries including Japan may make progress in expanding CCS. If CCS is introduced for all coal- and natural gas-fired power plants launching operation in or after 2030 and for the industry sector, including steel and cement producers, to the maximum degree, the CO_2 emission reduction through CCS will reach 4.2 Gt in 2040 and 7.6 Gt in 2050, as shown in Figure 151. Particularly, the power generation sector will account for a large share of the reduction.

Figure 151 | CO_2 emission reductions through CCS



Costs

There are some studies on CCS costs as well. Table 27 shows avoided costs for CCS for new fossil fuel-fired power plants. The estimated costs range wide from \$30/tCO_2 to \$140/tCO_2 because of differences in power generation technologies and in fuel price and thermal efficiency assumptions.

Table 27 | CCS costs for new fossil fuel-fired power plants

	IPCC (2005)*1 ($2013/t$CO_2$)	E.S. Rubin et al. (2015) ($2013/t$CO_2$)	GCCSI (2015)*2 ($2014/t$CO_2$)
Natural gas combined cycle (NGCC)	64-136	59-143	74-114
Supercritical pulverised coal (SCPC)	45-114	46-99	48-109
Integrated gasification combined cycle (IGCC)	25-85	38-84	

*1: Value after unit conversion by authors of the sources

*2: Assessments for United States

Sources: Edward S. Rubin, John E. Davison and Howard J. Herzog, "The cost of CO_2 capture and storage", International Journal of Greenhouse Gas Control 40 (2015) pp.378-400; Global CCS Institute (GCCSI) "The Costs of CCS and Other Low-Carbon Technologies in the United States - 2015 Update", (2015)

Only if carbon prices exceed the estimated costs in the future, economic rationale will justify CCS introduction. For example, the International Energy Agency's "Energy Technology Perspectives 2015" points out that the carbon price will have to be raised to $100/t$CO_2$ in 2030 and to $170/t$CO_2$ in 2050 to realise the 2DS Scenario for limiting the global average temperature rise to 2°C. If based on these carbon prices, low-cost CCS projects will be introduced in 2030 and abundant CCS projects, including higher-cost ones, in 2050.

12.2 Using hydrogen as energy

Characteristics of hydrogen

Hydrogen is an energy source that features a high calorific value per unit of weight, emits no CO_2 in the exploitation stage and can be made from multiple energy sources and stored relatively easily. It thus has various advantages. However, hydrogen's uses and consumption have been limited, despite a long history of utilising hydrogen for energy. Another problem is that social costs are high for developing infrastructure for introducing hydrogen energy. Hydrogen is a secondary energy, resulting in lower energy system efficiency (or higher costs). Greater handling care is required for hydrogen than for natural gas or LNG. Massive investment is required for developing infrastructure for handling hydrogen. Investment in hydrogen would be difficult in developing countries required to take electrification measures and enhance oil refining capacity to meet rapid energy demand growth. Future technological development to substantially reduce costs is indispensable for realising the large-scale exploitation of hydrogen for energy.

Hydrogen does not exist abundantly in nature. Therefore, hydrogen must be produced from feedstocks. Hydrogen production methods include steam reforming of fossil fuels, electrolysation of water, utilisation of nuclear and industrial processes.

Hydrogen applications

Conceivable hydrogen applications include fuel cells and power generation. Fuel cells can directly convert chemical energy into electricity without producing thermal or mechanical energy before generating electricity. Therefore, fuel cells feature high power generation efficiency irrespective of power generation amounts, allowing specific amounts to be chosen freely. Fuel cells can be widely used for large power plants, household electricity supply and vehicles. Particularly, fuel cell vehicle (FCV) research and development has made rapid progress in recent years. The transport sector depends on oil far more heavily than other energy consumption sectors. Therefore, the full-fledged penetration of FCVs using hydrogen made from various energy sources could structurally change energy supply and demand.

Hydrogen-fired power generation uses gas turbines or boilers for burning hydrogen. Basically, gas turbines similar to those for natural gas can be used for hydrogen-fired power generation. The turbine entrance temperature for hydrogen-fired power generation is 1,700°C, higher than for natural gas-fired power generation, allowing gross thermal efficiency to rise to more than 60%. Another advantage is that rapid hydrogen gas flow through power plant components allows those components to treat more gas than indicated by their sizes and weights. This means that weight and inner volume per output can be reduced for these components.

Transportation

Hydrogen may be transported in the forms of compressed hydrogen, liquefied hydrogen, organic hydride and ammonia. Hydrogen can be compressed into cylinders for transportation. The pressure for charging hydrogen for present industrial uses is between 15 MPa and 20 MPa. The hydrogen charging pressure for fuel cell vehicles is set at 70 MPa. Hydrogen may be liquefied at the very low temperature of minus 253°C for transportation. Liquefied hydrogen's cubic measure is one-12th of compressed hydrogen's and suitable for massive transportation.

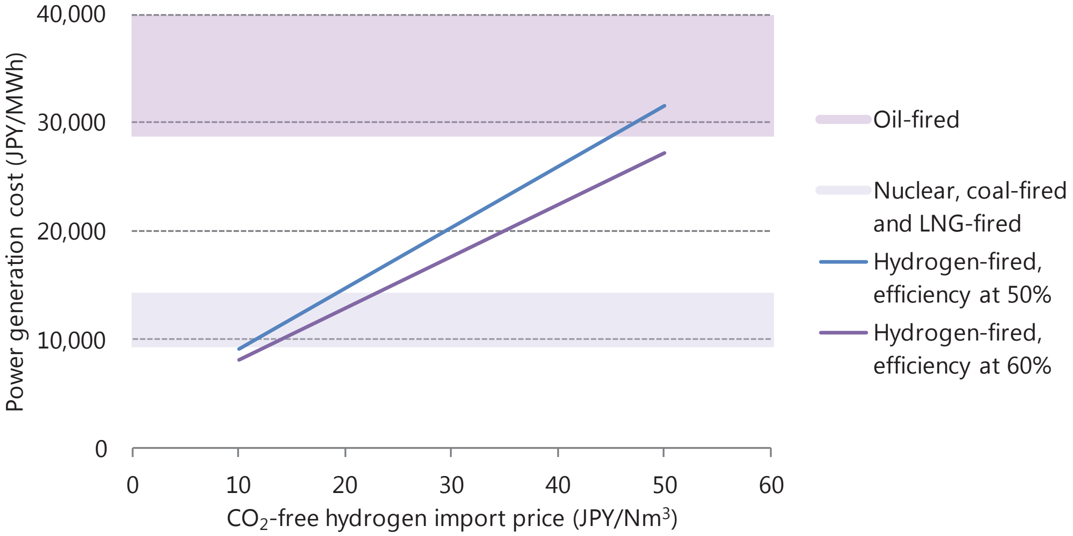
Organic hydride is hydrogen combined with aromatic compounds such as methylcyclohexane and decalin. It can be repeatedly used through hydrogenation and dehydrogenation. Organic hydride is liquid at ordinary temperatures and pressures and can be handled in the same way as for petroleum products.

Ammonia has a gravimetric hydrogen capacity of 17.8 wt%, far higher than for other liquid hydrides. Ammonia molecules contain no carbon and emit no CO_2 during combustion. Ammonia can be handled as liquid at temperatures and pressures close to normal levels in the same way as for liquefied petroleum gas. Ammonia can be transported through existing distribution infrastructure, with minimum additional investment. Ammonia gas turbines, if developed, may cost less than direct hydrogen exploitation in developing countries. Given that ammonia reduces system energy efficiency, however, direct hydrogen exploitation could be more advantageous than ammonia in developed countries.

Economic efficiency

Economic efficiency is a great challenge for future hydrogen exploitation. Figure 152 shows the estimated unit cost for hydrogen-fired power generation. When CO_2-free hydrogen from fossil fuels is imported into Japan, the price is estimated to decline to JPY30 per normal cubic metre (Nm^3). In such case, the unit hydrogen-fired power generation cost is a little less than JPY20,000/MWh. If the unit cost were to be equal to that for nuclear or fossil fuel-fired power generation, the import price would have to slip below JPY20/Nm^3. Similarly, hydrogen prices for FCVs are still high. Hydrogen production and distribution costs must be reduced further.

Figure 152 | Estimated unit cost for hydrogen-fired power generation



Note: The capacity factor is assumed at 50% and the unit construction cost at JPY120,000/kW (close to the cost for LNG-fired power plants).

Generally, it is difficult for hydrogen to economically compete with conventional energy sources unless infrastructure and relevant costs are reduced substantially. Therefore, hydrogen should be positioned as a substitute energy source when prices rise sharply for conventional energy sources (including oil and LNG) or a supplementary energy source when constraints emerge on other energy sources due to the need for substantial CO_2 emission reduction.

12.3 Long-term CCS and hydrogen exploitation scenarios

The following assesses how hydrogen exploitation will be positioned if ambitious CO_2 emission reduction efforts are made on a worldwide basis over a long term.

Hydrogen may be used for fuel cells and power generation. In scale, hydrogen-fired power generation has greater potential than fuel cells. If CCS is globally and sufficiently available for fossil fuel-fired power generation, CCS-equipped fossil fuel-fired power plants may be spread as a zero-emission power source along with nuclear and renewables power plants. In this case, the room for introducing hydrogen-fired power generation plants costing more than CCS-equipped fossil fuel-fired power plants will be very limited. If some energy consuming regions such as Japan and China fail to domestically take full advantage of the CCS technology, power generation using imported hydrogen will play a great role as the fourth zero-emission power source.

If steam reforming of natural gas and coal (lignite) is adopted for hydrogen production, CCS will have to be implemented at hydrogen production sites (assumed in North America, the Middle East, Australia, etc.) to make the overall hydrogen flow free from CO_2 emissions. From the viewpoint of CO_2 emission reduction, hydrogen exploitation depends on whether CCS is implemented in energy consuming or producing regions. Hydrogen may thus be used to resolve the imbalance between CCS regions with depleted oil and gas fields and energy consuming regions.

In addition to steam reforming of fossil fuels, electrolysation using electricity generated with renewable energy, and high temperature gas reactors and other nuclear technologies can be used for producing zero-emission hydrogen. Given technological development and cost reduction conditions, however, this chapter assumes that steam reforming of fossil fuels will be adopted before the other hydrogen production technologies are introduced. It is assumed that hydrogen from fossil fuels will be mainly exploited through 2050. For a longer-term hydrogen exploitation scenario, hydrogen energy from non-fossil fuel sources will have to be taken into account.

We developed the following three scenarios for assessment according to the availability of CCS and the technology introduction pace under the assumption that energy conservation and low-carbon technologies will spread as much as in the *Advanced Technologies Scenario.* In the second and third scenarios, CCS will not be globally available. Specifically, we assume that the Middle East and Africa will sufficiently spread CCS at depleted oil and gas fields, while Asian and other countries having little CCS potential in addition to aquifers will fail to do so.

Maximum CCS Scenario

In this scenario, CCS including aquifer CO_2 storage will be made available to the maximum extent in the world. The power generation sector will not exploit hydrogen. As hydrogen exploitation costs fail to decline sufficiently, FCV penetration in the transport sector will be limited.

Lower Hydrogen Scenario

While CCS will fail to become globally available, the world will seek to substantially reduce CO_2 emissions. In regions where CCS is difficult or limited, hydrogen-fired power plants will be substituted for a half of coal- and natural gas-fired power plants for construction from 2035. CCS will fail to expand in the industry sector.

Higher Hydrogen Scenario

In order to assess the maximum hydrogen exploitation potential mainly in the power generation sector, hydrogen-fired power plants are assumed to be substituted for all coal- and natural gas-fired power plants for construction from 2030 in the abovementioned hydrogen-fired power generation regions. Hydrogen supply costs will decline substantially while FCVs will penetrate on a worldwide basis faster than in the *Advanced Technologies Scenario.* FCVs will account for 13% of passenger car sales and 8% of car ownership in 2050.

Cogeneration systems using stationary fuel cells to which hydrogen is provided externally and directly are assumed to fail to diffuse sufficiently due to high infrastructure development costs[32]. However, we should take note of the possibility that the direct use of hydrogen with

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[32] See Matsuo, Kawakami, Eto, Shibata, Suehiro and Yanagisawa, "Positioning Hydrogen Energy for Low-carbon Society in 2050 and Hydrogen Diffusion Outlook," *Energy Economics,* 39 (3), (2013), pp.15-24, http://eneken.ieej.or.jp/data/4854.pdf

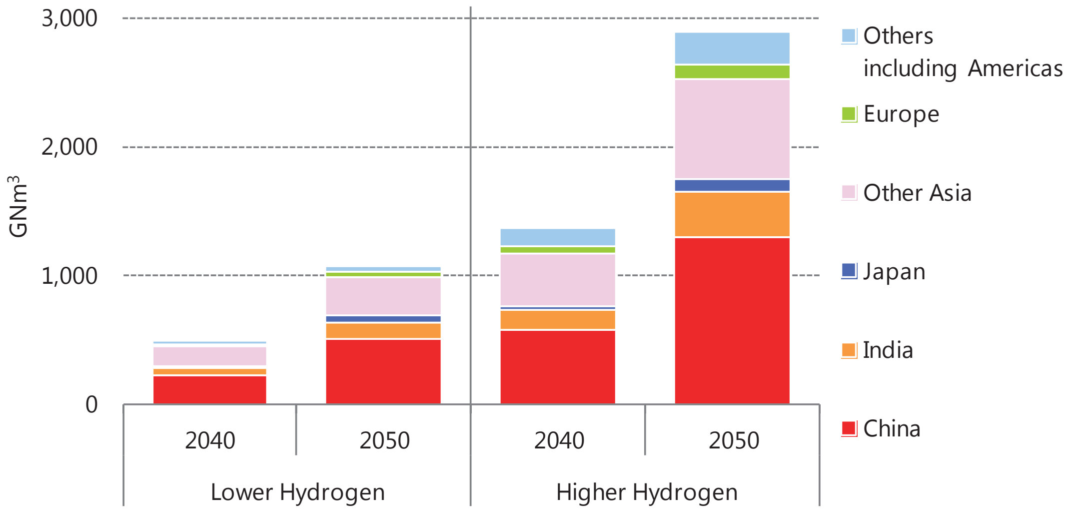
stationary fuel cells could make progress to contribute to improving overall energy utilisation efficiency and expanding distributed power sources if hydrogen supply costs decline with infrastructure developed substantially.

12.4 Hydrogen exploitation scenarios

Hydrogen demand

Global hydrogen demand in 2050 will total 940 billion Nm^3 in the *Lower Hydrogen Scenario* and 3.24 trillion Nm^3 in the *Higher Hydrogen Scenario*. More than 90% of hydrogen demand will be for power generation. Hydrogen will account for 5% of global power generation in the *Lower Hydrogen Scenario* and 13% in the *Higher Hydrogen Scenario*. Hydrogen demand by region is shown in Figure 153. In both scenarios, Asia will account for nearly 90% of hydrogen demand. China alone will capture more than 40% of the total demand.

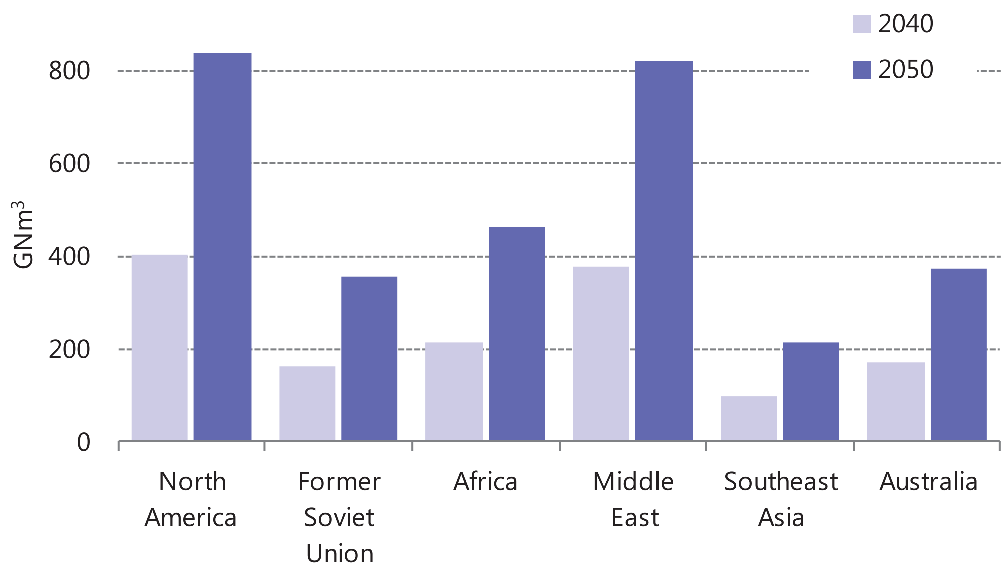
Figure 153 | Hydrogen demand in power generation sector



Hydrogen exports

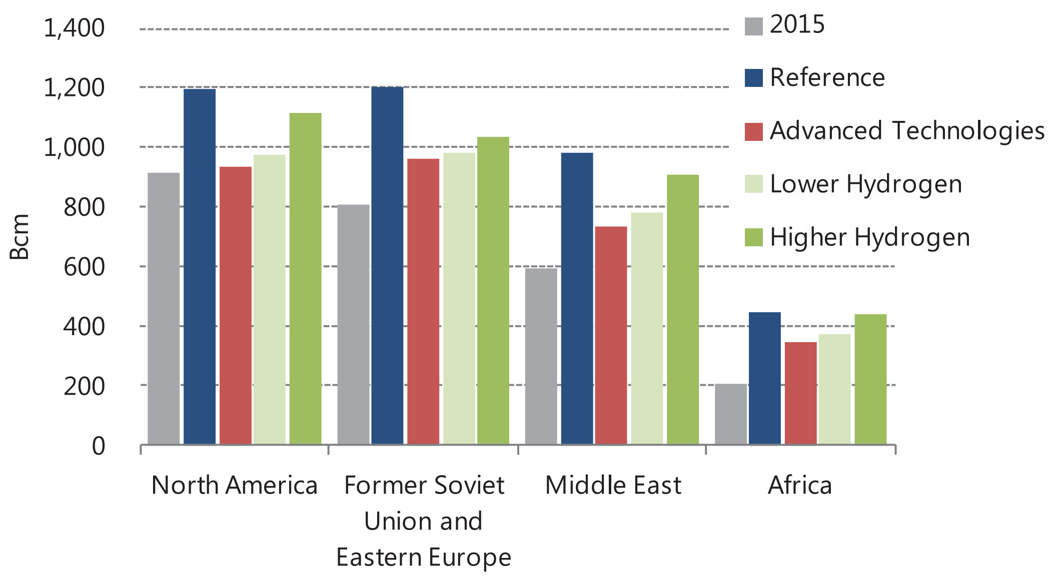
Projected hydrogen exports by region are given in Figure 154. Abundant hydrogen exports will come from North America, the Middle East, Africa and Australia that have massive fossil fuel resources and great CCS potential.

Figure 154 | Hydrogen exports by region [Higher Hydrogen Scenario]



Hydrogen will be produced by steam reforming of lignite in Australia and from natural gas in North America, the Middle East and Africa. Natural gas production in North America in 2040 will increase slightly from 915 Bcm in 2015 to 935 Bcm in the *Advanced Technologies Scenario*. It will considerably expand to 1,006 Bcm in the *Lower Hydrogen Scenario* and 1,115 Bcm in the *Higher Hydrogen Scenario*, though falling short of 1,199 Bcm in the *Reference Scenario* (Figure 155).

Figure 155 | Natural gas production [2040]

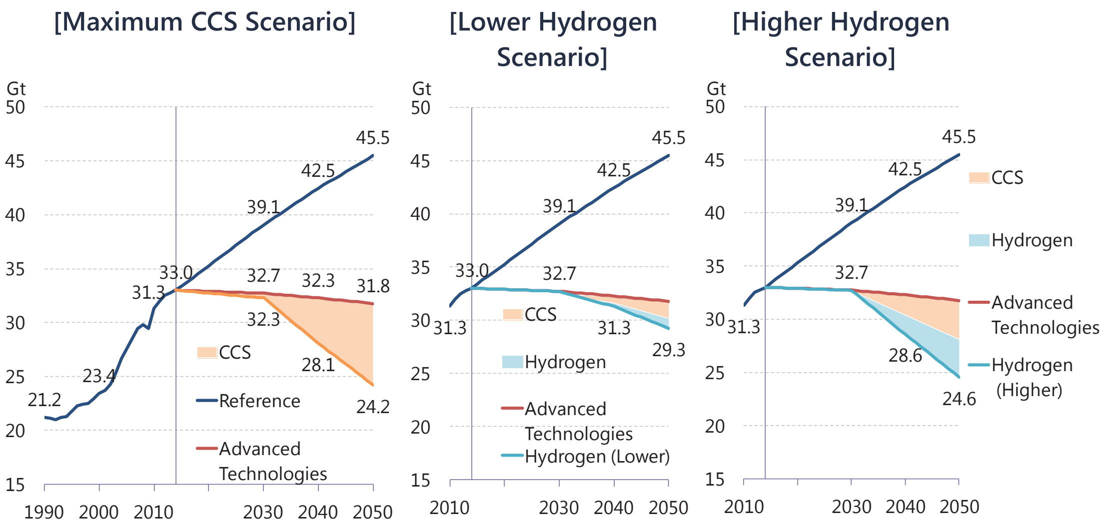


Contributing to resolving global environmental problems

In the *Advanced Technologies Scenario*, global energy-related CO_2 emissions will slowly decrease from 33.0 Gt in 2014 to 31.8 Gt in 2050 (Figure 156). In the *Maximum CCS Scenario*, CCS will reduce CO_2 emissions by 7.6 Gt to 24.2 Gt. In the two hydrogen scenarios, CCS will not be universally available and hydrogen-fired power generation will replace some part rather than all of fossil fuel-fired power generation. Therefore, the CO_2 emission reduction will be relatively small.

In the *Lower Hydrogen Scenario* where CCS-equipped fossil fuel-fired power plants and hydrogen-fired power plants replacing fossil fuel-fired power plants will be limited, CO_2 emissions in 2050 will be reduced by only 2.5 Gt from the *Advanced Technologies Scenario* to 29.3 Gt. In the *Higher Hydrogen Scenario*, all coal- and natural gas-fired power plants for construction from 2030 will reduce CO_2 emissions. CCS will expand in regions rich with depleted oil and gas fields and hydrogen-fired power generation will spread in other regions, contributing to reducing CO_2 emissions. Those emissions in 2050 will be reduced by 3.6 Gt from the *Advanced Technologies Scenario* through CCS and by 3.6 Gt through greater hydrogen exploitation including FCVs' greater penetration to 24.6 Gt.

Figure 156 | Global energy-related CO_2 emissions



Conclusion

A precondition for a hydrogen society is that the world launch an ambitious plan to reduce GHG (or energy-related CO_2) emissions. Hydrogen exploitation can be the last-resort power generation means for a case where limits emerge on the diffusion of other low-carbon technologies such as nuclear and renewables power generation and CCS in the power generation sector. This means that if the other low-carbon technologies spread sufficiently, hydrogen exploitation will be limited. Potential hydrogen demand in the huge power generation sector is far greater than in any other sector. Therefore, the diffusion of hydrogen exploitation will depend on its requirement in the power generation sector.

The transport sector is also a key sector for hydrogen demand. As the power generation sector steps up decarbonisation under the severe constraint of CO_2 emission reduction, however, electric vehicles will compete with hydrogen vehicles in the transport sector. Given that the transport sector depends heavily on fossil fuels, energy switching through the diffusion of FCVs and electric vehicles in the sector will make great contributions to CO_2 emission reduction and energy security.

Production of hydrogen from nuclear or renewable energy will greatly contribute to reducing CO_2 emissions and promoting energy security. In the initial stage of hydrogen exploitation, however, steam reforming of fossil fuels will be adopted for producing hydrogen, with CCS implemented in the vicinity of hydrogen production sites to reduce CO_2 emissions. In this case, hydrogen supply will be available in a wide range of regions including not only the Middle East and the former Soviet Union but also North America and Australia, contributing to improving energy security for energy consuming countries. For energy supplying countries, hydrogen exports may take the place of fossil fuel exports.

High costs could become a barrier to the diffusion of hydrogen. They include not only hydrogen supply costs but also transportation and other infrastructure costs. The diffusion of hydrogen will thus depend on how future technological development would reduce total costs for hydrogen and how reasonable hydrogen costs would be to support the globally required CO_2 emission reduction efforts.

Annex

Table A28 | Regional groupings

Asia	People's Republic of China	
	Hong Kong	
	India	
	Japan	
	Korea	
	Chinese Taipei	
	ASEAN	Brunei Darussalam
		Cambodia
		Indonesia
		Lao P.D.R.
		Malaysia
		Myanmar
		Philippines
		Singapore
		Thailand
		Viet Nam
	Others	Bangladesh, D. P. R. Korea, Mongolia, Nepal, Pakistan, Sri Lanka, and Other Asia excluding Lao P.D.R. in IEA statistics
North America	United States	
	Canada	
Latin America	Brazil	
	Chile	
	Mexico	
	Others	Argentina, Bolivia, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela, and Other Non–OECD Americas in IEA statistics
Europe	OECD Europe	France
		Germany
		Italy
		United Kingdom

		Others	Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and Turkey
	Non-OECD Europe	Russia	
		Other non-OECD former Soviet Union	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan
		Others	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Gibraltar, Kosovo, Former Yugoslav Republic of Macedonia, Malta, Montenegro, Romania, and Serbia
Africa	Republic of South Africa		
	North Africa	Algeria, Egypt, Libya, Morocco, and Tunisia	
	Others	Angola, Benin, Botswana, Cameroon, Democratic Republic of Congo, Congo, Côte d'Ivoire, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Mauritius, Mozambique, Namibia, Niger, Nigeria, Senegal, South Sudan, Sudan, Togo, United Republic of Tanzania, Zambia, Zimbabwe, and Other Africa in IEA statistics	
Middle East	Iran		
	Iraq		
	Kuwait		
	Oman		
	Qatar		
	Saudi Arabia		
	United Arab Emirates		
	Others	Bahrain, Israel, Jordan, Lebanon, Syrian Arab Republic, and Yemen	
Oceania	Australia		

	New Zealand
International bunkers	
European Union	Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, the Slovak Republic, Slovenia, Spain, Sweden, and the United Kingdom
OECD	Australia, Austria, Belgium, Canada, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States

Notes: (1) Other non-OECD former Soviet Union includes energy data of Estonia before 1990, (2) OECD does not include Israel, and (3) ASEAN8 includes Brunei Darussalam, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam.

Table A29 | Major energy and economic indicators

		1990	2014	2040 Reference	2040 Advanced Technologies	CAGR (%) 1990/2014	CAGR (%) 2014/2040 Reference	CAGR (%) 2014/2040 Advanced Technologies
Total primary energy consumption (Mtoe)	**World**	**8,772**	**13,699**	**18,904**	**16,561**	**1.9**	**1.2**	**0.7**
	Asia	2,108	5,517	8,635	7,577	4.1	1.7	1.2
	China	871	3,052	4,264	3,690	5.4	1.3	0.7
	India	306	825	1,763	1,497	4.2	3.0	2.3
	Japan	439	442	429	395	0.0	-0.1	-0.4
Oil consumption (Mtoe)	**World**	**3,233**	**4,285**	**5,488**	**4,656**	**1.2**	**1.0**	**0.3**
	Asia	618	1,291	2,085	1,798	3.1	1.9	1.3
	China	119	504	787	663	6.2	1.7	1.1
	India	61	185	490	424	4.7	3.8	3.2
	Japan	250	192	141	122	-1.1	-1.2	-1.7
Natural gas consumption (Mtoe)	**World**	**1,663**	**2,901**	**4,695**	**3,617**	**2.3**	**1.9**	**0.9**
	Asia	116	549	1,337	1,032	6.7	3.5	2.5
	China	13	154	571	462	10.9	5.2	4.3
	India	11	43	174	124	6.0	5.5	4.1
	Japan	44	108	105	73	3.8	-0.1	-1.5
Coal consumption (Mtoe)	**World**	**2,220**	**3,918**	**4,527**	**3,241**	**2.4**	**0.6**	**-0.7**
	Asia	785	2,758	3,552	2,620	5.4	1.0	-0.2
	China	528	2,012	2,175	1,656	5.7	0.3	-0.7
	India	93	378	747	487	6.0	2.7	1.0
	Japan	76	118	108	92	1.8	-0.4	-0.9
Power generation (TWh)	**World**	**11,864**	**23,816**	**39,819**	**34,730**	**2.9**	**2.0**	**1.5**
	Asia	2,252	9,895	19,627	17,264	6.4	2.7	2.2
	China	621	5,666	10,021	9,136	9.6	2.2	1.9
	India	293	1,287	3,775	3,167	6.4	4.2	3.5
	Japan	873	1,036	1,203	1,059	0.7	0.6	0.1
Energy-related carbon dioxide emissions (Mt)	**World**	**21,202**	**33,009**	**42,463**	**32,285**	**1.9**	**1.0**	**-0.1**
	Asia	4,918	15,067	21,990	16,701	4.8	1.5	0.4
	China	2,339	9,347	11,618	8,922	5.9	0.8	-0.2
	India	542	2,053	4,646	3,296	5.7	3.2	1.8
	Japan	1,071	1,201	1,007	812	0.5	-0.7	-1.5
Primary energy consumption per GDP (toe/$2010 million)	**World**	**233**	**188**	**125**	**109**	**-0.9**	**-1.6**	**-2.1**
	Asia	284	262	142	125	-0.3	-2.3	-2.8
	China	1,056	371	142	123	-4.3	-3.6	-4.2
	India	638	377	167	142	-2.2	-3.1	-3.7
	Japan	96	78	58	54	-0.9	-1.1	-1.4
Primary energy consumption per capita (toe/person)	**World**	**1.66**	**1.89**	**2.06**	**1.81**	**0.5**	**0.3**	**-0.2**
	Asia	0.72	1.39	1.87	1.64	2.8	1.1	0.6
	China	0.77	2.24	3.06	2.65	4.6	1.2	0.6
	India	0.35	0.64	1.08	0.92	2.5	2.1	1.4
	Japan	3.55	3.47	3.77	3.47	-0.1	0.3	0.0
GDP ($2010 billion)	**World**	**37,578**	**72,934**	**151,552**	**151,552**	**2.8**	**2.9**	**2.9**
	Asia	7,433	21,055	60,826	60,826	4.4	4.2	4.2
	China	824	8,230	29,970	29,970	10.1	5.1	5.1
	India	479	2,188	10,573	10,573	6.5	6.2	6.2
	Japan	4,553	5,650	7,354	7,354	0.9	1.0	1.0
Population (Million)	**World**	**5,276**	**7,249**	**9,157**	**9,157**	**1.3**	**0.9**	**0.9**
	Asia	2,932	3,956	4,624	4,624	1.3	0.6	0.6
	China	1,135	1,364	1,395	1,395	0.8	0.1	0.1
	India	871	1,295	1,634	1,634	1.7	0.9	0.9
	Japan	124	127	114	114	0.1	-0.4	-0.4

Table A30 | Population

(Million)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
World	4,434 (100)	5,276 (100)	6,107 (100)	7,249 (100)	8,493 (100)	9,157 (100)	1.5	1.2	1.0	0.8	0.9
Asia	2,440 (55.0)	2,932 (55.6)	3,408 (55.8)	3,956 (54.6)	4,445 (52.3)	4,624 (50.5)	1.5	1.1	0.7	0.4	0.6
China	981 (22.1)	1,135 (21.5)	1,263 (20.7)	1,364 (18.8)	1,414 (16.6)	1,395 (15.2)	1.1	0.6	0.2	-0.1	0.1
India	697 (15.7)	871 (16.5)	1,053 (17.3)	1,295 (17.9)	1,528 (18.0)	1,634 (17.8)	1.9	1.5	1.0	0.7	0.9
Japan	117 (2.6)	124 (2.3)	127 (2.1)	127 (1.8)	120 (1.4)	114 (1.2)	0.3	0.0	-0.3	-0.6	-0.4
Korea	38 (0.9)	43 (0.8)	47 (0.8)	50 (0.7)	53 (0.6)	52 (0.6)	0.9	0.5	0.3	0.0	0.1
Chinese Taipei	18 (0.4)	20 (0.4)	22 (0.4)	23 (0.3)	23 (0.3)	22 (0.2)	0.9	0.4	-0.1	-0.4	-0.2
ASEAN	n.a. (n.a.)	n.a. (n.a.)	523 (8.6)	623 (8.6)	723 (8.5)	765 (8.4)	-	1.3	0.9	0.6	0.8
Indonesia	147 (3.3)	181 (3.4)	212 (3.5)	254 (3.5)	295 (3.5)	312 (3.4)	1.5	1.3	0.9	0.6	0.8
Malaysia	14 (0.3)	18 (0.3)	23 (0.4)	30 (0.4)	36 (0.4)	39 (0.4)	2.5	1.8	1.2	0.7	1.0
Myanmar	34 (0.8)	42 (0.8)	48 (0.8)	53 (0.7)	60 (0.7)	63 (0.7)	1.3	0.8	0.8	0.4	0.6
Philippines	47 (1.1)	62 (1.2)	78 (1.3)	99 (1.4)	124 (1.5)	137 (1.5)	2.3	1.7	1.4	1.0	1.3
Singapore	2 (0.1)	3 (0.1)	4 (0.1)	5 (0.1)	6 (0.1)	7 (0.1)	2.8	2.2	1.0	0.4	0.8
Thailand	47 (1.1)	57 (1.1)	63 (1.0)	68 (0.9)	68 (0.8)	66 (0.7)	1.0	0.6	0.0	-0.3	-0.1
Viet Nam	54 (1.2)	66 (1.3)	78 (1.3)	91 (1.3)	105 (1.2)	110 (1.2)	1.6	1.1	0.9	0.5	0.7
Asia excl. Japan	2,323 (52.4)	2,808 (53.2)	3,281 (53.7)	3,828 (52.8)	4,324 (50.9)	4,510 (49.2)	1.6	1.1	0.8	0.4	0.6
North America	252 (5.7)	277 (5.3)	313 (5.1)	354 (4.9)	396 (4.7)	416 (4.5)	1.2	0.9	0.7	0.5	0.6
United States	227 (5.1)	250 (4.7)	282 (4.6)	319 (4.4)	356 (4.2)	374 (4.1)	1.2	0.9	0.7	0.5	0.6
Latin America	361 (8.1)	442 (8.4)	522 (8.5)	622 (8.6)	719 (8.5)	761 (8.3)	1.7	1.3	0.9	0.6	0.8
OECD Europe	476 (10.7)	499 (9.5)	521 (8.5)	560 (7.7)	579 (6.8)	584 (6.4)	0.4	0.5	0.2	0.1	0.2
European Union	n.a. (n.a.)	478 (9.1)	488 (8.0)	508 (7.0)	521 (6.1)	522 (5.7)	0.2	0.3	0.2	0.0	0.1
Non-OECD Europe	319 (7.2)	344 (6.5)	341 (5.6)	342 (4.7)	341 (4.0)	333 (3.6)	-0.1	0.0	0.0	-0.2	-0.1
Africa	476 (10.7)	629 (11.9)	812 (13.3)	1,155 (15.9)	1,678 (19.8)	2,063 (22.5)	2.6	2.5	2.4	2.1	2.3
Middle East	92 (2.1)	132 (2.5)	168 (2.7)	232 (3.2)	302 (3.6)	340 (3.7)	2.5	2.3	1.7	1.2	1.5
Oceania	18 (0.4)	20 (0.4)	23 (0.4)	28 (0.4)	34 (0.4)	36 (0.4)	1.2	1.4	1.1	0.8	1.0
OECD	981 (22.1)	1,062 (20.1)	1,149 (18.8)	1,263 (17.4)	1,350 (15.9)	1,382 (15.1)	0.8	0.7	0.4	0.2	0.3
Non-OECD	3,453 (77.9)	4,214 (79.9)	4,958 (81.2)	5,986 (82.6)	7,143 (84.1)	7,775 (84.9)	1.6	1.4	1.1	0.9	1.0

Source: United Nations "Population Estimates and Projections: The 2015 Revision", World Bank "World Development Indicators"

Note: Figures in parentheses are global shares (%).

Table A31 | GDP

($2010 billion)

	1980	1990	2000	2014	2030	2040	CAGR (%)				
							1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
World	27,804 (100)	37,578 (100)	49,555 (100)	72,934 (100)	116,213 (100)	151,552 (100)	2.8	2.8	3.0	2.7	2.9
Asia	4,340 (15.6)	7,433 (19.8)	10,786 (21.8)	21,055 (28.9)	42,319 (36.4)	60,826 (40.1)	3.8	4.9	4.5	3.7	4.2
China	338 (1.2)	824 (2.2)	2,224 (4.5)	8,230 (11.3)	20,185 (17.4)	29,970 (19.8)	10.4	9.8	5.8	4.0	5.1
India	279 (1.0)	479 (1.3)	825 (1.7)	2,188 (3.0)	6,281 (5.4)	10,573 (7.0)	5.6	7.2	6.8	5.3	6.2
Japan	2,894 (10.4)	4,553 (12.1)	5,093 (10.3)	5,650 (7.7)	6,582 (5.7)	7,354 (4.9)	1.1	0.7	1.0	1.1	1.0
Korea	149 (0.5)	377 (1.0)	710 (1.4)	1,234 (1.7)	1,878 (1.6)	2,270 (1.5)	6.5	4.0	2.7	1.9	2.4
Chinese Taipei	73 (0.3)	162 (0.4)	309 (0.6)	523 (0.7)	723 (0.6)	845 (0.6)	6.7	3.8	2.1	1.6	1.9
ASEAN	n.a. (n.a.)	n.a. (n.a.)	1,188 (2.4)	2,407 (3.3)	5,071 (4.4)	7,488 (4.9)	-	5.2	4.8	4.0	4.5
Indonesia	162 (0.6)	300 (0.8)	453 (0.9)	943 (1.3)	2,193 (1.9)	3,334 (2.2)	4.2	5.4	5.4	4.3	5.0
Malaysia	46 (0.2)	82 (0.2)	163 (0.3)	314 (0.4)	633 (0.5)	896 (0.6)	7.1	4.8	4.5	3.5	4.1
Myanmar	6 (0.0)	7 (0.0)	13 (0.0)	55 (0.1)	155 (0.1)	255 (0.2)	7.2	10.7	6.6	5.1	6.0
Philippines	80 (0.3)	95 (0.3)	125 (0.3)	251 (0.3)	589 (0.5)	899 (0.6)	2.9	5.1	5.5	4.3	5.0
Singapore	32 (0.1)	68 (0.2)	134 (0.3)	279 (0.4)	405 (0.3)	482 (0.3)	7.1	5.4	2.4	1.8	2.1
Thailand	67 (0.2)	142 (0.4)	218 (0.4)	383 (0.5)	643 (0.6)	881 (0.6)	4.4	4.1	3.3	3.2	3.3
Viet Nam	17 (0.1)	29 (0.1)	61 (0.1)	145 (0.2)	367 (0.3)	609 (0.4)	7.6	6.4	6.0	5.2	5.7
Asia excl. Japan	1,446 (5.2)	2,880 (7.7)	5,693 (11.5)	15,405 (21.1)	35,737 (30.8)	53,472 (35.3)	7.1	7.4	5.4	4.1	4.9
North America	7,305 (26.3)	10,073 (26.8)	14,050 (28.4)	18,052 (24.8)	25,535 (22.0)	31,014 (20.5)	3.4	1.8	2.2	2.0	2.1
United States	6,529 (23.5)	9,064 (24.1)	12,713 (25.7)	16,282 (22.3)	23,132 (19.9)	28,154 (18.6)	3.4	1.8	2.2	2.0	2.1
Latin America	2,410 (8.7)	2,782 (7.4)	3,774 (7.6)	5,881 (8.1)	9,045 (7.8)	11,817 (7.8)	3.1	3.2	2.7	2.7	2.7
OECD Europe	9,882 (35.5)	12,581 (33.5)	15,852 (32.0)	18,996 (26.0)	24,681 (21.2)	28,051 (18.5)	2.3	1.3	1.6	1.3	1.5
European Union	n.a. (n.a.)	11,801 (31.4)	14,729 (29.7)	17,396 (23.9)	22,607 (19.5)	25,741 (17.0)	2.2	1.2	1.7	1.3	1.5
Non-OECD Europe	1,750 (6.3)	2,141 (5.7)	1,494 (3.0)	2,704 (3.7)	3,863 (3.3)	5,043 (3.3)	-3.5	4.3	2.3	2.7	2.4
Africa	715 (2.6)	877 (2.3)	1,145 (2.3)	2,205 (3.0)	4,476 (3.9)	6,882 (4.5)	2.7	4.8	4.5	4.4	4.5
Middle East	875 (3.1)	971 (2.6)	1,461 (2.9)	2,556 (3.5)	4,126 (3.6)	5,331 (3.5)	4.2	4.1	3.0	2.6	2.9
Oceania	525 (1.9)	720 (1.9)	994 (2.0)	1,485 (2.0)	2,170 (1.9)	2,588 (1.7)	3.3	2.9	2.4	1.8	2.2
OECD	21,329 (76.7)	29,003 (77.2)	37,727 (76.1)	46,852 (64.2)	63,227 (54.4)	74,479 (49.1)	2.7	1.6	1.9	1.7	1.8
Non-OECD	6,475 (23.3)	8,575 (22.8)	11,828 (23.9)	26,082 (35.8)	52,987 (45.6)	77,073 (50.9)	3.3	5.8	4.5	3.8	4.3

Source: World Bank "World Development Indicators", etc. (historical)

Note: Figures in parentheses are global shares (%).

Table A32 | GDP per capita

($2010 thousand/person)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
World	6.3	7.1	8.1	10.1	13.7	16.6	1.3	1.5	1.9	1.9	1.9
Asia	1.8	2.5	3.2	5.3	9.5	13.2	2.2	3.8	3.7	3.3	3.5
China	0.3	0.7	1.8	6.0	14.3	21.5	9.3	9.2	5.5	4.2	5.0
India	0.4	0.6	0.8	1.7	4.1	6.5	3.6	5.6	5.7	4.6	5.3
Japan	24.8	36.9	40.2	44.4	54.7	64.6	0.9	0.7	1.3	1.7	1.5
Korea	3.9	8.8	15.1	24.5	35.7	43.3	5.6	3.5	2.4	2.0	2.2
Chinese Taipei	4.1	7.9	13.9	22.3	31.2	37.9	5.8	3.4	2.1	1.9	2.1
ASEAN	n.a.	n.a.	2.3	3.9	7.0	9.8	-	3.9	3.8	3.4	3.6
Indonesia	1.1	1.7	2.1	3.7	7.4	10.7	2.6	4.0	4.4	3.7	4.2
Malaysia	3.3	4.5	6.9	10.5	17.5	23.1	4.4	3.0	3.2	2.8	3.1
Myanmar	0.2	0.2	0.3	1.0	2.6	4.1	5.8	9.8	5.9	4.7	5.4
Philippines	1.7	1.5	1.6	2.5	4.8	6.6	0.5	3.3	4.0	3.2	3.7
Singapore	13.3	22.2	33.4	51.0	63.3	72.5	4.2	3.1	1.4	1.4	1.4
Thailand	1.4	2.5	3.5	5.6	9.4	13.3	3.3	3.5	3.3	3.5	3.4
Viet Nam	0.3	0.4	0.8	1.6	3.5	5.5	5.8	5.2	5.0	4.7	4.9
Asia excl. Japan	0.6	1.0	1.7	4.0	8.3	11.9	5.4	6.2	4.6	3.7	4.2
North America	29.0	36.3	44.9	50.9	64.5	74.5	2.1	0.9	1.5	1.5	1.5
United States	28.7	36.3	45.1	51.1	65.1	75.3	2.2	0.9	1.5	1.5	1.5
Latin America	6.7	6.3	7.2	9.4	12.6	15.5	1.4	1.9	1.8	2.1	1.9
OECD Europe	20.7	25.2	30.4	33.9	42.6	48.0	1.9	0.8	1.4	1.2	1.3
European Union	n.a.	24.7	30.2	34.2	43.4	49.3	2.0	0.9	1.5	1.3	1.4
Non-OECD Europe	5.5	6.2	4.4	7.9	11.3	15.1	-3.5	4.3	2.3	2.9	2.5
Africa	1.5	1.4	1.4	1.9	2.7	3.3	0.1	2.2	2.1	2.3	2.2
Middle East	9.5	7.4	8.7	11.0	13.7	15.7	1.7	1.7	1.4	1.4	1.4
Oceania	29.5	35.3	43.2	53.1	64.7	71.0	2.0	1.5	1.2	0.9	1.1
OECD	21.7	27.3	32.8	37.1	46.8	53.9	1.9	0.9	1.5	1.4	1.4
Non-OECD	1.9	2.0	2.4	4.4	7.4	9.9	1.6	4.4	3.4	2.9	3.2

Source: World Bank "World Development Indicators", International Energy Agency "World Energy Balances", etc. (historical)

Table A33 | International energy prices

Real prices			2015	2020	2030	2040	CAGR (%) 2015/2020	2020/2030	2030/2040	2015/2040
Crude oil		$2015/bbl	52	75	100	125	7.6	2.9	2.3	3.6
Natural gas	Japan	$2015/MBtu	10.4	10.7	12.8	14.1	0.7	1.8	1.0	1.2
	Europe (UK)	$2015/MBtu	6.5	8.5	9.8	11.7	5.4	1.4	1.8	2.4
	United States	$2015/MBtu	2.6	4.5	5.6	6.3	11.4	2.2	1.2	3.6
Steam coal		$2015/t	80	89	106	132	2.2	1.8	2.3	2.1

Nominal prices			2015	2020	2030	2040	CAGR (%) 2015/2020	2020/2030	2030/2040	2015/2040
Crude oil		$/bbl	52	83	135	205	9.8	5.0	4.3	5.6
Natural gas	Japan	$/MBtu	10.4	11.8	17.2	23.1	2.7	3.8	3.0	3.3
	Europe (UK)	$/MBtu	6.5	9.4	13.2	19.2	7.5	3.5	3.8	4.4
	United States	$/MBtu	2.6	5.0	7.5	10.3	13.6	4.3	3.2	5.6
Steam coal		$/t	80	98	142	217	4.3	3.8	4.3	4.1

Note: 2% per annum of inflation rates are assumed.

Table A34 | Primary energy consumption [Reference Scenario]

(Mtoe)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
World	7,205 (100)	8,772 (100)	10,037 (100)	13,699 (100)	17,067 (100)	18,904 (100)	1.4	2.2	1.4	1.0	1.2
Asia	1,439 (20.0)	2,108 (24.0)	2,893 (28.8)	5,517 (40.3)	7,506 (44.0)	8,635 (45.7)	3.2	4.7	1.9	1.4	1.7
China	598 (8.3)	871 (9.9)	1,135 (11.3)	3,052 (22.3)	3,854 (22.6)	4,264 (22.6)	2.7	7.3	1.5	1.0	1.3
India	200 (2.8)	306 (3.5)	441 (4.4)	825 (6.0)	1,398 (8.2)	1,763 (9.3)	3.7	4.6	3.4	2.3	3.0
Japan	345 (4.8)	439 (5.0)	518 (5.2)	442 (3.2)	453 (2.7)	429 (2.3)	1.7	-1.1	0.2	-0.5	-0.1
Korea	41 (0.6)	93 (1.1)	188 (1.9)	268 (2.0)	321 (1.9)	318 (1.7)	7.3	2.6	1.1	-0.1	0.7
Chinese Taipei	28 (0.4)	48 (0.5)	85 (0.8)	110 (0.8)	125 (0.7)	127 (0.7)	5.9	1.9	0.8	0.1	0.5
ASEAN	n.a. (n.a.)	n.a. (n.a.)	385 (3.8)	624 (4.6)	1,046 (6.1)	1,352 (7.1)	-	3.5	3.3	2.6	3.0
Indonesia	56 (0.8)	99 (1.1)	156 (1.6)	226 (1.6)	417 (2.4)	556 (2.9)	4.7	2.7	3.9	2.9	3.5
Malaysia	12 (0.2)	22 (0.2)	49 (0.5)	90 (0.7)	126 (0.7)	152 (0.8)	8.4	4.4	2.1	1.9	2.0
Myanmar	9 (0.1)	11 (0.1)	13 (0.1)	19 (0.1)	31 (0.2)	41 (0.2)	1.9	3.0	3.1	2.7	2.9
Philippines	22 (0.3)	29 (0.3)	40 (0.4)	48 (0.3)	97 (0.6)	136 (0.7)	3.4	1.3	4.5	3.4	4.1
Singapore	5 (0.1)	12 (0.1)	19 (0.2)	28 (0.2)	32 (0.2)	33 (0.2)	4.9	2.9	0.8	0.4	0.6
Thailand	22 (0.3)	42 (0.5)	72 (0.7)	135 (1.0)	195 (1.1)	232 (1.2)	5.6	4.5	2.3	1.8	2.1
Viet Nam	14 (0.2)	18 (0.2)	29 (0.3)	67 (0.5)	126 (0.7)	173 (0.9)	4.9	6.2	4.1	3.2	3.7
Asia excl. Japan	1,094 (15.2)	1,669 (19.0)	2,375 (23.7)	5,075 (37.0)	7,054 (41.3)	8,206 (43.4)	3.6	5.6	2.1	1.5	1.9
North America	1,997 (27.7)	2,126 (24.2)	2,527 (25.2)	2,496 (18.2)	2,524 (14.8)	2,499 (13.2)	1.7	-0.1	0.1	-0.1	0.0
United States	1,805 (25.0)	1,915 (21.8)	2,273 (22.6)	2,216 (16.2)	2,230 (13.1)	2,201 (11.6)	1.7	-0.2	0.0	-0.1	0.0
Latin America	382 (5.3)	465 (5.3)	599 (6.0)	863 (6.3)	1,220 (7.1)	1,427 (7.5)	2.6	2.6	2.2	1.6	2.0
OECD Europe	1,494 (20.7)	1,619 (18.5)	1,748 (17.4)	1,674 (12.2)	1,763 (10.3)	1,744 (9.2)	0.8	-0.3	0.3	-0.1	0.2
European Union	n.a. (n.a.)	1,645 (18.8)	1,695 (16.9)	1,565 (11.4)	1,644 (9.6)	1,626 (8.6)	0.3	-0.6	0.3	-0.1	0.1
Non-OECD Europe	1,241 (17.2)	1,537 (17.5)	1,004 (10.0)	1,124 (8.2)	1,212 (7.1)	1,257 (6.6)	-4.2	0.8	0.5	0.4	0.4
Africa	273 (3.8)	393 (4.5)	496 (4.9)	772 (5.6)	1,118 (6.6)	1,357 (7.2)	2.3	3.2	2.3	2.0	2.2
Middle East	121 (1.7)	223 (2.5)	372 (3.7)	744 (5.4)	1,077 (6.3)	1,262 (6.7)	5.3	5.1	2.3	1.6	2.1
Oceania	79 (1.1)	99 (1.1)	125 (1.2)	146 (1.1)	163 (1.0)	168 (0.9)	2.4	1.1	0.7	0.3	0.5
OECD	4,060 (56.3)	4,514 (51.5)	5,282 (52.6)	5,251 (38.3)	5,550 (32.5)	5,531 (29.3)	1.6	0.0	0.3	0.0	0.2
Non-OECD	2,967 (41.2)	4,056 (46.2)	4,482 (44.7)	8,085 (59.0)	11,035 (64.7)	12,818 (67.8)	1.0	4.3	2.0	1.5	1.8

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%). World includes international bunkers.

Table A35 | Primary energy consumption, coal [Reference Scenario]

(Mtoe)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
World	**1,783** (100)	**2,220** (100)	**2,316** (100)	**3,918** (100)	**4,320** (100)	**4,527** (100)	0.4	3.8	0.6	0.5	0.6
Asia	**466** (26.1)	**785** (35.3)	**1,037** (44.8)	**2,758** (70.4)	**3,268** (75.6)	**3,552** (78.5)	2.8	7.2	1.1	0.8	1.0
China	**313** (17.5)	**528** (23.8)	**665** (28.7)	**2,012** (51.3)	**2,134** (49.4)	**2,175** (48.1)	2.3	8.2	0.4	0.2	0.3
India	**44** (2.5)	**93** (4.2)	**146** (6.3)	**378** (9.6)	**613** (14.2)	**747** (16.5)	4.6	7.0	3.1	2.0	2.7
Japan	**60** (3.3)	**76** (3.4)	**97** (4.2)	**118** (3.0)	**114** (2.6)	**108** (2.4)	2.4	1.4	-0.2	-0.6	-0.4
Korea	**14** (0.8)	**25** (1.1)	**42** (1.8)	**82** (2.1)	**84** (2.0)	**83** (1.8)	5.2	4.9	0.2	-0.2	0.0
Chinese Taipei	**4** (0.2)	**11** (0.5)	**30** (1.3)	**41** (1.0)	**41** (1.0)	**40** (0.9)	10.2	2.3	0.0	-0.3	-0.1
ASEAN	**n.a.** (n.a.)	**n.a.** (n.a.)	**32** (1.4)	**99** (2.5)	**239** (5.5)	**348** (7.7)	-	8.4	5.6	3.9	5.0
Indonesia	**0** (0.0)	**4** (0.2)	**12** (0.5)	**36** (0.9)	**88** (2.0)	**136** (3.0)	13.0	8.2	5.7	4.5	5.3
Malaysia	**0** (0.0)	**1** (0.1)	**2** (0.1)	**15** (0.4)	**35** (0.8)	**46** (1.0)	5.5	14.4	5.3	2.9	4.4
Myanmar	**0** (0.0)	**0** (0.0)	**0** (0.0)	**0** (0.0)	**4** (0.1)	**9** (0.2)	17.0	1.8	15.8	7.5	12.5
Philippines	**1** (0.0)	**2** (0.1)	**5** (0.2)	**12** (0.3)	**35** (0.8)	**53** (1.2)	13.0	6.0	7.0	4.3	6.0
Singapore	**0** (0.0)	**0** (0.0)	**-** (-)	**0** (0.0)	**0** (0.0)	**0** (0.0)	-100.0	-	0.3	0.3	0.3
Thailand	**0** (0.0)	**4** (0.2)	**8** (0.3)	**16** (0.4)	**31** (0.7)	**37** (0.8)	7.2	5.3	4.3	1.9	3.3
Viet Nam	**2** (0.1)	**2** (0.1)	**4** (0.2)	**19** (0.5)	**42** (1.0)	**62** (1.4)	7.0	11.1	5.0	4.1	4.6
Asia excl. Japan	**406** (22.8)	**708** (31.9)	**939** (40.6)	**2,639** (67.4)	**3,153** (73.0)	**3,445** (76.1)	2.9	7.7	1.1	0.9	1.0
North America	**397** (22.3)	**485** (21.8)	**565** (24.4)	**451** (11.5)	**320** (7.4)	**239** (5.3)	1.6	-1.6	-2.1	-2.9	-2.4
United States	**376** (21.1)	**460** (20.7)	**534** (23.0)	**432** (11.0)	**309** (7.2)	**231** (5.1)	1.5	-1.5	-2.1	-2.9	-2.4
Latin America	**13** (0.7)	**21** (1.0)	**27** (1.2)	**45** (1.2)	**71** (1.6)	**87** (1.9)	2.6	3.7	2.9	2.0	2.5
OECD Europe	**464** (26.0)	**449** (20.2)	**330** (14.3)	**292** (7.5)	**288** (6.7)	**265** (5.9)	-3.0	-0.9	-0.1	-0.8	-0.4
European Union	**n.a.** (n.a.)	**456** (20.5)	**321** (13.9)	**268** (6.9)	**265** (6.1)	**243** (5.4)	-3.4	-1.3	-0.1	-0.8	-0.4
Non-OECD Europe	**362** (20.3)	**367** (16.5)	**209** (9.0)	**208** (5.3)	**176** (4.1)	**173** (3.8)	-5.5	-0.1	-1.0	-0.1	-0.7
Africa	**52** (2.9)	**74** (3.3)	**90** (3.9)	**112** (2.9)	**135** (3.1)	**146** (3.2)	2.0	1.6	1.2	0.8	1.0
Middle East	**1** (0.1)	**3** (0.1)	**8** (0.3)	**10** (0.2)	**17** (0.4)	**22** (0.5)	10.4	1.2	3.6	2.9	3.3
Oceania	**28** (1.6)	**36** (1.6)	**49** (2.1)	**43** (1.1)	**45** (1.0)	**43** (0.9)	3.1	-1.0	0.3	-0.5	0.0
OECD	**966** (54.2)	**1,079** (48.6)	**1,094** (47.2)	**1,006** (25.7)	**889** (20.6)	**783** (17.3)	0.1	-0.6	-0.8	-1.3	-1.0
Non-OECD	**817** (45.8)	**1,142** (51.4)	**1,222** (52.8)	**2,913** (74.3)	**3,431** (79.4)	**3,743** (82.7)	0.7	6.4	1.0	0.9	1.0

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%). World includes international bunkers.

Table A36 | Primary energy consumption, oil [Reference Scenario]

(Mtoe)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
World	3,102 (100)	3,233 (100)	3,660 (100)	4,285 (100)	5,062 (100)	5,488 (100)	1.2	1.1	1.0	0.8	1.0
Asia	477 (15.4)	618 (19.1)	917 (25.1)	1,291 (30.1)	1,783 (35.2)	2,085 (38.0)	4.0	2.5	2.0	1.6	1.9
China	89 (2.9)	119 (3.7)	221 (6.0)	504 (11.8)	700 (13.8)	787 (14.3)	6.4	6.1	2.1	1.2	1.7
India	33 (1.1)	61 (1.9)	112 (3.1)	185 (4.3)	364 (7.2)	490 (8.9)	6.2	3.6	4.3	3.0	3.8
Japan	234 (7.5)	250 (7.7)	255 (7.0)	192 (4.5)	158 (3.1)	141 (2.6)	0.2	-2.0	-1.2	-1.1	-1.2
Korea	27 (0.9)	50 (1.5)	99 (2.7)	96 (2.2)	103 (2.0)	100 (1.8)	7.1	-0.2	0.4	-0.3	0.2
Chinese Taipei	20 (0.6)	26 (0.8)	38 (1.0)	42 (1.0)	47 (0.9)	47 (0.8)	4.0	0.7	0.6	0.0	0.4
ASEAN	n.a. (n.a.)	n.a. (n.a.)	154 (4.2)	221 (5.2)	334 (6.6)	421 (7.7)	-	2.6	2.6	2.3	2.5
Indonesia	20 (0.7)	33 (1.0)	58 (1.6)	75 (1.8)	128 (2.5)	163 (3.0)	5.7	1.9	3.4	2.5	3.0
Malaysia	8 (0.3)	11 (0.4)	19 (0.5)	33 (0.8)	43 (0.8)	48 (0.9)	5.4	3.9	1.6	1.2	1.5
Myanmar	1 (0.0)	1 (0.0)	2 (0.1)	5 (0.1)	8 (0.2)	12 (0.2)	10.5	7.0	3.1	4.0	3.4
Philippines	10 (0.3)	11 (0.3)	16 (0.4)	15 (0.3)	24 (0.5)	33 (0.6)	4.0	-0.6	3.2	2.9	3.1
Singapore	5 (0.2)	11 (0.4)	17 (0.5)	18 (0.4)	18 (0.4)	19 (0.3)	4.3	0.2	0.3	0.0	0.2
Thailand	11 (0.3)	18 (0.6)	32 (0.9)	54 (1.3)	73 (1.4)	88 (1.6)	5.9	3.8	1.9	2.0	1.9
Viet Nam	2 (0.1)	3 (0.1)	8 (0.2)	18 (0.4)	33 (0.6)	46 (0.8)	11.2	6.1	3.8	3.4	3.7
Asia excl. Japan	244 (7.9)	368 (11.4)	662 (18.1)	1,099 (25.6)	1,625 (32.1)	1,943 (35.4)	6.1	3.7	2.5	1.8	2.2
North America	885 (28.5)	833 (25.8)	958 (26.2)	880 (20.5)	834 (16.5)	801 (14.6)	1.4	-0.6	-0.3	-0.4	-0.4
United States	797 (25.7)	757 (23.4)	871 (23.8)	782 (18.3)	726 (14.3)	692 (12.6)	1.4	-0.8	-0.5	-0.5	-0.5
Latin America	223 (7.2)	238 (7.4)	302 (8.3)	397 (9.3)	478 (9.4)	518 (9.4)	2.4	2.0	1.2	0.8	1.0
OECD Europe	688 (22.2)	606 (18.7)	652 (17.8)	541 (12.6)	487 (9.6)	449 (8.2)	0.7	-1.3	-0.7	-0.8	-0.7
European Union	n.a. (n.a.)	605 (18.7)	625 (17.1)	509 (11.9)	460 (9.1)	425 (7.7)	0.3	-1.5	-0.6	-0.8	-0.7
Non-OECD Europe	464 (15.0)	468 (14.5)	203 (5.5)	245 (5.7)	253 (5.0)	255 (4.7)	-8.0	1.4	0.2	0.1	0.2
Africa	61 (2.0)	86 (2.7)	97 (2.7)	165 (3.8)	243 (4.8)	285 (5.2)	1.2	3.8	2.5	1.6	2.1
Middle East	90 (2.9)	146 (4.5)	217 (5.9)	353 (8.2)	473 (9.4)	533 (9.7)	4.0	3.5	1.9	1.2	1.6
Oceania	34 (1.1)	35 (1.1)	40 (1.1)	50 (1.2)	58 (1.1)	60 (1.1)	1.4	1.7	0.9	0.4	0.7
OECD	1,938 (62.5)	1,861 (57.6)	2,103 (57.5)	1,872 (43.7)	1,778 (35.1)	1,697 (30.9)	1.2	-0.8	-0.3	-0.5	-0.4
Non-OECD	986 (31.8)	1,169 (36.2)	1,283 (35.1)	2,050 (47.8)	2,832 (56.0)	3,290 (59.9)	0.9	3.4	2.0	1.5	1.8

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%). World includes international bunkers.

Table A37 | Primary energy consumption, natural gas [Reference Scenario]

(Mtoe)

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
World	**1,232** (100)	**1,663** (100)	**2,071** (100)	**2,901** (100)	**4,014** (100)	**4,695** (100)	2.2	2.4	2.1	1.6	1.9
Asia	**51** (4.1)	**116** (7.0)	**232** (11.2)	**549** (18.9)	**1,018** (25.4)	**1,337** (28.5)	7.2	6.3	3.9	2.8	3.5
China	**12** (1.0)	**13** (0.8)	**21** (1.0)	**154** (5.3)	**412** (10.3)	**571** (12.2)	4.9	15.4	6.4	3.3	5.2
India	**1** (0.1)	**11** (0.6)	**23** (1.1)	**43** (1.5)	**114** (2.8)	**174** (3.7)	8.1	4.6	6.2	4.3	5.5
Japan	**21** (1.7)	**44** (2.7)	**66** (3.2)	**108** (3.7)	**104** (2.6)	**105** (2.2)	4.0	3.6	-0.2	0.1	-0.1
Korea	**-** (-)	**3** (0.2)	**17** (0.8)	**43** (1.5)	**50** (1.2)	**51** (1.1)	20.1	6.9	0.9	0.2	0.6
Chinese Taipei	**2** (0.1)	**1** (0.1)	**6** (0.3)	**14** (0.5)	**26** (0.6)	**28** (0.6)	14.8	6.6	4.0	0.8	2.8
ASEAN	**n.a.** (n.a.)	**n.a.** (n.a.)	**74** (3.6)	**139** (4.8)	**218** (5.4)	**278** (5.9)	-	4.6	2.9	2.4	2.7
Indonesia	**5** (0.4)	**16** (1.0)	**27** (1.3)	**37** (1.3)	**73** (1.8)	**104** (2.2)	5.3	2.3	4.4	3.7	4.1
Malaysia	**2** (0.2)	**7** (0.4)	**25** (1.2)	**38** (1.3)	**43** (1.1)	**46** (1.0)	13.8	3.2	0.7	0.7	0.7
Myanmar	**0** (0.0)	**1** (0.0)	**1** (0.1)	**2** (0.1)	**6** (0.2)	**7** (0.1)	4.6	4.1	7.0	0.9	4.6
Philippines	**-** (-)	**-** (-)	**0** (0.0)	**3** (0.1)	**13** (0.3)	**25** (0.5)	-	51.9	9.5	6.5	8.3
Singapore	**-** (-)	**-** (-)	**1** (0.1)	**9** (0.3)	**11** (0.3)	**12** (0.3)	-	16.2	1.3	0.8	1.1
Thailand	**-** (-)	**5** (0.3)	**17** (0.8)	**38** (1.3)	**49** (1.2)	**53** (1.1)	13.3	5.7	1.6	0.8	1.3
Viet Nam	**-** (-)	**0** (0.0)	**1** (0.1)	**9** (0.3)	**20** (0.5)	**28** (0.6)	82.6	16.0	5.1	3.5	4.5
Asia excl. Japan	**30** (2.4)	**72** (4.3)	**167** (8.0)	**441** (15.2)	**915** (22.8)	**1,232** (26.2)	8.8	7.2	4.7	3.0	4.0
North America	**522** (42.4)	**493** (29.6)	**622** (30.0)	**713** (24.6)	**836** (20.8)	**893** (19.0)	2.3	1.0	1.0	0.7	0.9
United States	**477** (38.7)	**438** (26.3)	**548** (26.4)	**624** (21.5)	**736** (18.3)	**791** (16.8)	2.3	0.9	1.0	0.7	0.9
Latin America	**48** (3.9)	**72** (4.3)	**119** (5.7)	**203** (7.0)	**352** (8.8)	**440** (9.4)	5.1	3.9	3.5	2.3	3.0
OECD Europe	**206** (16.7)	**260** (15.6)	**393** (19.0)	**374** (12.9)	**445** (11.1)	**452** (9.6)	4.2	-0.4	1.1	0.2	0.7
European Union	**n.a.** (n.a.)	**297** (17.9)	**396** (19.1)	**343** (11.8)	**407** (10.1)	**413** (8.8)	2.9	-1.0	1.1	0.2	0.7
Non-OECD Europe	**355** (28.8)	**603** (36.2)	**489** (23.6)	**541** (18.7)	**565** (14.1)	**583** (12.4)	-2.1	0.7	0.3	0.3	0.3
Africa	**12** (1.0)	**30** (1.8)	**47** (2.3)	**108** (3.7)	**184** (4.6)	**250** (5.3)	4.8	6.1	3.4	3.1	3.3
Middle East	**29** (2.4)	**72** (4.3)	**145** (7.0)	**376** (13.0)	**556** (13.8)	**668** (14.2)	7.3	7.0	2.5	1.9	2.2
Oceania	**8** (0.7)	**19** (1.1)	**24** (1.2)	**36** (1.2)	**37** (0.9)	**38** (0.8)	2.7	2.9	0.2	0.1	0.2
OECD	**778** (63.2)	**843** (50.7)	**1,163** (56.1)	**1,338** (46.1)	**1,574** (39.2)	**1,657** (35.3)	3.3	1.0	1.0	0.5	0.8
Non-OECD	**454** (36.8)	**820** (49.3)	**909** (43.9)	**1,563** (53.9)	**2,419** (60.3)	**3,004** (64.0)	1.0	4.0	2.8	2.2	2.5

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%). World includes international bunkers.

Table A38 | Final energy consumption [Reference Scenario]

(Mtoe)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
World	5,368 (100)	6,262 (100)	7,041 (100)	9,425 (100)	11,723 (100)	13,028 (100)	1.2	2.1	1.4	1.1	1.3
Asia	1,129 (21.0)	1,551 (24.8)	1,995 (28.3)	3,677 (39.0)	4,893 (41.7)	5,625 (43.2)	2.5	4.5	1.8	1.4	1.6
China	487 (9.1)	654 (10.4)	786 (11.2)	1,988 (21.1)	2,433 (20.8)	2,667 (20.5)	1.9	6.9	1.3	0.9	1.1
India	174 (3.2)	243 (3.9)	315 (4.5)	556 (5.9)	952 (8.1)	1,210 (9.3)	2.6	4.1	3.4	2.4	3.0
Japan	232 (4.3)	287 (4.6)	328 (4.7)	296 (3.1)	294 (2.5)	279 (2.1)	1.4	-0.7	0.0	-0.5	-0.2
Korea	31 (0.6)	65 (1.0)	127 (1.8)	170 (1.8)	197 (1.7)	196 (1.5)	7.0	2.1	0.9	-0.1	0.5
Chinese Taipei	19 (0.3)	29 (0.5)	49 (0.7)	68 (0.7)	79 (0.7)	81 (0.6)	5.2	2.4	1.0	0.2	0.7
ASEAN	n.a. (n.a.)	n.a. (n.a.)	274 (3.9)	441 (4.7)	695 (5.9)	892 (6.8)	-	3.4	2.9	2.5	2.7
Indonesia	50 (0.9)	80 (1.3)	120 (1.7)	165 (1.8)	274 (2.3)	360 (2.8)	4.2	2.3	3.2	2.8	3.0
Malaysia	7 (0.1)	14 (0.2)	30 (0.4)	53 (0.6)	78 (0.7)	96 (0.7)	7.9	4.2	2.4	2.1	2.3
Myanmar	8 (0.2)	9 (0.2)	11 (0.2)	17 (0.2)	24 (0.2)	32 (0.2)	2.0	2.8	2.3	2.6	2.4
Philippines	17 (0.3)	20 (0.3)	24 (0.3)	27 (0.3)	52 (0.4)	73 (0.6)	2.0	0.9	4.1	3.6	3.9
Singapore	2 (0.0)	5 (0.1)	8 (0.1)	17 (0.2)	20 (0.2)	21 (0.2)	5.2	5.4	0.9	0.5	0.8
Thailand	15 (0.3)	29 (0.5)	51 (0.7)	96 (1.0)	135 (1.2)	161 (1.2)	5.8	4.7	2.2	1.8	2.0
Viet Nam	13 (0.2)	16 (0.3)	25 (0.4)	56 (0.6)	95 (0.8)	125 (1.0)	4.6	5.8	3.4	2.8	3.2
Asia excl. Japan	897 (16.7)	1,264 (20.2)	1,667 (23.7)	3,381 (35.9)	4,600 (39.2)	5,346 (41.0)	2.8	5.2	1.9	1.5	1.8
North America	1,466 (27.3)	1,455 (23.2)	1,738 (24.7)	1,738 (18.4)	1,782 (15.2)	1,783 (13.7)	1.8	0.0	0.2	0.0	0.1
United States	1,311 (24.4)	1,294 (20.7)	1,546 (22.0)	1,538 (16.3)	1,553 (13.3)	1,550 (11.9)	1.8	0.0	0.1	0.0	0.0
Latin America	288 (5.4)	343 (5.5)	447 (6.3)	617 (6.5)	855 (7.3)	995 (7.6)	2.7	2.3	2.1	1.5	1.9
OECD Europe	1,081 (20.1)	1,122 (17.9)	1,229 (17.5)	1,172 (12.4)	1,242 (10.6)	1,226 (9.4)	0.9	-0.3	0.4	-0.1	0.2
European Union	n.a. (n.a.)	1,130 (18.0)	1,180 (16.8)	1,095 (11.6)	1,161 (9.9)	1,148 (8.8)	0.4	-0.5	0.4	-0.1	0.2
Non-OECD Europe	869 (16.2)	1,073 (17.1)	654 (9.3)	713 (7.6)	797 (6.8)	836 (6.4)	-4.8	0.6	0.7	0.5	0.6
Africa	218 (4.1)	292 (4.7)	369 (5.2)	559 (5.9)	838 (7.1)	1,024 (7.9)	2.4	3.0	2.6	2.0	2.4
Middle East	84 (1.6)	157 (2.5)	253 (3.6)	491 (5.2)	724 (6.2)	868 (6.7)	4.9	4.9	2.5	1.8	2.2
Oceania	54 (1.0)	66 (1.1)	83 (1.2)	95 (1.0)	110 (0.9)	116 (0.9)	2.2	1.0	0.9	0.6	0.8
OECD	2,937 (54.7)	3,090 (49.3)	3,621 (51.4)	3,614 (38.4)	3,827 (32.6)	3,827 (29.4)	1.6	0.0	0.4	0.0	0.2
Non-OECD	2,252 (42.0)	2,970 (47.4)	3,147 (44.7)	5,447 (57.8)	7,413 (63.2)	8,645 (66.4)	0.6	4.0	1.9	1.5	1.8

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%). World includes international bunkers.

Table A39 | Final energy consumption, industry [Reference Scenario]

(Mtoe)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
World	1,766 (100)	1,805 (100)	1,868 (100)	2,751 (100)	3,375 (100)	3,781 (100)	0.3	2.8	1.3	1.1	1.2
Asia	383 (21.7)	517 (28.6)	645 (34.6)	1,494 (54.3)	1,811 (53.7)	2,027 (53.6)	2.2	6.2	1.2	1.1	1.2
China	181 (10.3)	234 (13.0)	299 (16.0)	983 (35.7)	995 (29.5)	1,007 (26.6)	2.5	8.9	0.1	0.1	0.1
India	41 (2.3)	67 (3.7)	83 (4.5)	191 (6.9)	347 (10.3)	463 (12.3)	2.3	6.1	3.8	2.9	3.5
Japan	91 (5.2)	110 (6.1)	100 (5.3)	88 (3.2)	95 (2.8)	93 (2.5)	-0.9	-0.9	0.5	-0.2	0.2
Korea	10 (0.6)	19 (1.1)	38 (2.1)	49 (1.8)	58 (1.7)	57 (1.5)	7.2	1.8	1.0	-0.2	0.6
Chinese Taipei	10 (0.6)	12 (0.7)	19 (1.0)	23 (0.8)	27 (0.8)	27 (0.7)	4.5	1.2	1.1	0.1	0.7
ASEAN	n.a. (n.a.)	n.a. (n.a.)	76 (4.1)	121 (4.4)	221 (6.5)	296 (7.8)	-	3.4	3.8	3.0	3.5
Indonesia	7 (0.4)	18 (1.0)	30 (1.6)	39 (1.4)	81 (2.4)	116 (3.1)	5.2	1.9	4.6	3.7	4.2
Malaysia	3 (0.2)	6 (0.3)	12 (0.6)	15 (0.6)	24 (0.7)	31 (0.8)	7.8	2.0	2.8	2.6	2.7
Myanmar	1 (0.0)	0 (0.0)	1 (0.1)	2 (0.1)	5 (0.1)	7 (0.2)	11.3	4.2	5.2	4.0	4.7
Philippines	3 (0.2)	5 (0.3)	5 (0.3)	7 (0.3)	15 (0.5)	23 (0.6)	1.4	2.1	4.8	4.0	4.5
Singapore	0 (0.0)	1 (0.0)	2 (0.1)	6 (0.2)	7 (0.2)	8 (0.2)	13.7	7.2	1.3	1.1	1.2
Thailand	4 (0.2)	9 (0.5)	17 (0.9)	29 (1.1)	47 (1.4)	57 (1.5)	6.8	4.1	3.0	1.9	2.6
Viet Nam	4 (0.2)	5 (0.3)	8 (0.4)	21 (0.8)	40 (1.2)	52 (1.4)	5.7	7.4	4.0	2.6	3.5
Asia excl. Japan	292 (16.5)	407 (22.6)	546 (29.2)	1,406 (51.1)	1,716 (50.9)	1,934 (51.1)	3.0	7.0	1.3	1.2	1.2
North America	437 (24.8)	331 (18.3)	388 (20.7)	317 (11.5)	325 (9.6)	327 (8.6)	1.6	-1.4	0.2	0.0	0.1
United States	387 (21.9)	284 (15.7)	332 (17.8)	269 (9.8)	271 (8.0)	269 (7.1)	1.6	-1.5	0.0	-0.1	0.0
Latin America	98 (5.6)	114 (6.3)	148 (7.9)	196 (7.1)	286 (8.5)	345 (9.1)	2.7	2.0	2.4	1.9	2.2
OECD Europe	356 (20.2)	323 (17.9)	325 (17.4)	280 (10.2)	289 (8.6)	286 (7.6)	0.1	-1.1	0.2	-0.1	0.1
European Union	n.a. (n.a.)	343 (19.0)	310 (16.6)	255 (9.3)	267 (7.9)	266 (7.0)	-1.0	-1.4	0.3	0.0	0.2
Non-OECD Europe	394 (22.3)	396 (21.9)	206 (11.0)	195 (7.1)	243 (7.2)	269 (7.1)	-6.3	-0.4	1.4	1.0	1.2
Africa	46 (2.6)	55 (3.0)	58 (3.1)	86 (3.1)	140 (4.2)	183 (4.8)	0.5	2.9	3.1	2.7	3.0
Middle East	30 (1.7)	47 (2.6)	71 (3.8)	156 (5.7)	250 (7.4)	314 (8.3)	4.2	5.8	3.0	2.3	2.7
Oceania	20 (1.1)	23 (1.3)	28 (1.5)	29 (1.1)	30 (0.9)	31 (0.8)	2.0	0.2	0.2	0.4	0.3
OECD	940 (53.3)	835 (46.2)	913 (48.9)	806 (29.3)	868 (25.7)	877 (23.2)	0.9	-0.9	0.5	0.1	0.3
Non-OECD	825 (46.7)	970 (53.8)	954 (51.1)	1,945 (70.7)	2,507 (74.3)	2,904 (76.8)	-0.2	5.2	1.6	1.5	1.6

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%).

Table A40 | Final energy consumption, transport [Reference Scenario]

(Mtoe)

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
World	1,248 (100)	1,573 (100)	1,961 (100)	2,627 (100)	3,255 (100)	3,573 (100)	2.2	2.1	1.3	0.9	1.2
Asia	126 (10.1)	186 (11.9)	321 (16.3)	612 (23.3)	963 (29.6)	1,171 (32.8)	5.6	4.7	2.9	2.0	2.5
China	24 (1.9)	33 (2.1)	87 (4.5)	268 (10.2)	426 (13.1)	501 (14.0)	10.1	8.4	2.9	1.6	2.4
India	17 (1.3)	21 (1.3)	32 (1.6)	78 (3.0)	190 (5.8)	258 (7.2)	4.4	6.6	5.7	3.1	4.7
Japan	54 (4.3)	68 (4.3)	84 (4.3)	72 (2.7)	62 (1.9)	56 (1.6)	2.2	-1.2	-0.9	-1.1	-1.0
Korea	5 (0.4)	15 (0.9)	26 (1.3)	32 (1.2)	34 (1.0)	32 (0.9)	6.1	1.4	0.3	-0.6	0.0
Chinese Taipei	3 (0.2)	7 (0.4)	12 (0.6)	12 (0.5)	13 (0.4)	13 (0.4)	5.7	0.4	0.4	-0.2	0.2
ASEAN	n.a. (n.a.)	n.a. (n.a.)	62 (3.1)	118 (4.5)	186 (5.7)	237 (6.6)	-	4.7	2.9	2.4	2.7
Indonesia	6 (0.5)	11 (0.7)	21 (1.1)	46 (1.8)	84 (2.6)	110 (3.1)	6.9	5.8	3.8	2.8	3.4
Malaysia	2 (0.2)	5 (0.3)	11 (0.6)	22 (0.8)	29 (0.9)	33 (0.9)	8.3	5.3	1.7	1.1	1.5
Myanmar	1 (0.1)	0 (0.0)	1 (0.1)	2 (0.1)	4 (0.1)	7 (0.2)	10.0	5.6	3.3	5.3	4.1
Philippines	3 (0.3)	5 (0.3)	8 (0.4)	9 (0.3)	17 (0.5)	25 (0.7)	6.0	0.9	4.1	3.7	3.9
Singapore	1 (0.1)	1 (0.1)	2 (0.1)	2 (0.1)	3 (0.1)	3 (0.1)	2.6	2.5	0.6	0.0	0.4
Thailand	3 (0.3)	9 (0.6)	15 (0.7)	22 (0.8)	23 (0.7)	24 (0.7)	5.0	3.0	0.3	0.1	0.3
Viet Nam	1 (0.1)	1 (0.1)	3 (0.2)	11 (0.4)	20 (0.6)	28 (0.8)	9.7	8.3	4.1	3.5	3.8
Asia excl. Japan	72 (5.8)	118 (7.5)	236 (12.0)	540 (20.6)	901 (27.7)	1,115 (31.2)	7.1	6.1	3.3	2.2	2.8
North America	470 (37.6)	531 (33.7)	640 (32.7)	685 (26.1)	655 (20.1)	620 (17.3)	1.9	0.5	-0.3	-0.6	-0.4
United States	425 (34.1)	488 (31.0)	588 (30.0)	623 (23.7)	588 (18.1)	556 (15.6)	1.9	0.4	-0.4	-0.6	-0.4
Latin America	85 (6.8)	103 (6.5)	141 (7.2)	223 (8.5)	309 (9.5)	349 (9.8)	3.2	3.3	2.1	1.2	1.7
OECD Europe	209 (16.7)	266 (16.9)	316 (16.1)	325 (12.4)	304 (9.3)	281 (7.9)	1.8	0.2	-0.4	-0.8	-0.6
European Union	n.a. (n.a.)	259 (16.5)	304 (15.5)	307 (11.7)	288 (8.9)	267 (7.5)	1.6	0.1	-0.4	-0.8	-0.5
Non-OECD Europe	107 (8.6)	173 (11.0)	111 (5.6)	144 (5.5)	167 (5.1)	172 (4.8)	-4.3	1.9	0.9	0.3	0.7
Africa	27 (2.2)	38 (2.4)	54 (2.8)	96 (3.6)	143 (4.4)	161 (4.5)	3.7	4.2	2.5	1.2	2.0
Middle East	26 (2.1)	51 (3.2)	75 (3.8)	142 (5.4)	190 (5.8)	220 (6.2)	4.0	4.7	1.8	1.5	1.7
Oceania	19 (1.5)	24 (1.5)	30 (1.5)	36 (1.4)	42 (1.3)	44 (1.2)	2.1	1.5	0.9	0.5	0.7
OECD	781 (62.6)	934 (59.4)	1,139 (58.1)	1,210 (46.0)	1,183 (36.4)	1,127 (31.5)	2.0	0.4	-0.1	-0.5	-0.3
Non-OECD	289 (23.1)	436 (27.7)	549 (28.0)	1,054 (40.1)	1,589 (48.8)	1,890 (52.9)	2.3	4.8	2.6	1.8	2.3

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%). World includes international bunkers.

Table A41 | Final energy consumption, buildings, etc. [Reference Scenario]

(Mtoe)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
World	2,000 (100)	2,408 (100)	2,596 (100)	3,219 (100)	4,076 (100)	4,543 (100)	0.8	1.5	1.5	1.1	1.3
Asia	567 (28.3)	733 (30.4)	842 (32.4)	1,215 (37.7)	1,650 (40.5)	1,891 (41.6)	1.4	2.7	1.9	1.4	1.7
China	272 (13.6)	344 (14.3)	340 (13.1)	577 (17.9)	800 (19.6)	918 (20.2)	-0.1	3.9	2.1	1.4	1.8
India	110 (5.5)	142 (5.9)	173 (6.7)	246 (7.6)	351 (8.6)	408 (9.0)	2.0	2.5	2.3	1.5	2.0
Japan	58 (2.9)	76 (3.1)	103 (4.0)	100 (3.1)	102 (2.5)	97 (2.1)	3.1	-0.2	0.1	-0.5	-0.1
Korea	13 (0.7)	24 (1.0)	37 (1.4)	43 (1.3)	51 (1.2)	51 (1.1)	4.4	1.0	1.1	0.1	0.7
Chinese Taipei	4 (0.2)	7 (0.3)	10 (0.4)	12 (0.4)	13 (0.3)	14 (0.3)	4.6	1.1	0.6	0.4	0.5
ASEAN	n.a. (n.a.)	n.a. (n.a.)	116 (4.5)	154 (4.8)	216 (5.3)	268 (5.9)	-	2.0	2.2	2.2	2.2
Indonesia	36 (1.8)	44 (1.8)	59 (2.3)	72 (2.2)	97 (2.4)	117 (2.6)	3.1	1.4	1.8	2.0	1.9
Malaysia	2 (0.1)	3 (0.1)	5 (0.2)	9 (0.3)	15 (0.4)	20 (0.4)	6.6	4.6	3.2	2.7	3.0
Myanmar	7 (0.4)	8 (0.4)	9 (0.3)	12 (0.4)	15 (0.4)	17 (0.4)	0.7	2.1	1.4	1.3	1.3
Philippines	9 (0.5)	10 (0.4)	10 (0.4)	10 (0.3)	19 (0.5)	25 (0.5)	-0.1	0.1	3.7	3.0	3.5
Singapore	0 (0.0)	1 (0.0)	2 (0.1)	2 (0.1)	3 (0.1)	3 (0.1)	3.8	2.8	1.4	1.2	1.3
Thailand	8 (0.4)	11 (0.4)	14 (0.5)	21 (0.7)	29 (0.7)	36 (0.8)	2.4	3.3	2.0	2.0	2.0
Viet Nam	9 (0.4)	10 (0.4)	14 (0.5)	21 (0.6)	29 (0.7)	36 (0.8)	3.0	3.1	2.1	2.2	2.2
Asia excl. Japan	508 (25.4)	657 (27.3)	739 (28.5)	1,115 (34.6)	1,548 (38.0)	1,794 (39.5)	1.2	3.0	2.1	1.5	1.8
North America	446 (22.3)	460 (19.1)	537 (20.7)	595 (18.5)	642 (15.7)	659 (14.5)	1.6	0.7	0.5	0.3	0.4
United States	397 (19.8)	403 (16.7)	473 (18.2)	526 (16.4)	568 (13.9)	584 (12.9)	1.6	0.8	0.5	0.3	0.4
Latin America	89 (4.4)	101 (4.2)	120 (4.6)	159 (4.9)	210 (5.1)	245 (5.4)	1.8	2.0	1.8	1.6	1.7
OECD Europe	425 (21.3)	433 (18.0)	473 (18.2)	463 (14.4)	531 (13.0)	537 (11.8)	0.9	-0.1	0.9	0.1	0.6
European Union	n.a. (n.a.)	429 (17.8)	454 (17.5)	433 (13.5)	494 (12.1)	501 (11.0)	0.6	-0.3	0.8	0.1	0.6
Non-OECD Europe	301 (15.1)	439 (18.2)	289 (11.1)	282 (8.8)	302 (7.4)	310 (6.8)	-4.1	-0.2	0.4	0.3	0.4
Africa	139 (7.0)	188 (7.8)	242 (9.3)	357 (11.1)	523 (12.8)	638 (14.1)	2.6	2.8	2.4	2.0	2.3
Middle East	22 (1.1)	40 (1.7)	75 (2.9)	125 (3.9)	190 (4.7)	229 (5.0)	6.5	3.7	2.7	1.9	2.4
Oceania	11 (0.6)	15 (0.6)	19 (0.7)	23 (0.7)	30 (0.7)	33 (0.7)	2.3	1.6	1.5	1.0	1.3
OECD	972 (48.6)	1,032 (42.8)	1,198 (46.2)	1,258 (39.1)	1,396 (34.2)	1,424 (31.3)	1.5	0.3	0.7	0.2	0.5
Non-OECD	1,027 (51.4)	1,376 (57.2)	1,397 (53.8)	1,961 (60.9)	2,681 (65.8)	3,119 (68.7)	0.2	2.5	2.0	1.5	1.8

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%).

Table A42 | Final energy consumption, electricity [Reference Scenario]

(TWh)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
World	6,816 (100)	9,716 (100)	12,699 (100)	19,836 (100)	28,289 (100)	33,682 (100)	2.7	3.2	2.2	1.8	2.1
Asia	1,025 (15.0)	1,834 (18.9)	3,254 (25.6)	8,328 (42.0)	13,406 (47.4)	16,761 (49.8)	5.9	6.9	3.0	2.3	2.7
China	248 (3.6)	454 (4.7)	1,037 (8.2)	4,716 (23.8)	7,193 (25.4)	8,584 (25.5)	8.6	11.4	2.7	1.8	2.3
India	91 (1.3)	215 (2.2)	376 (3.0)	947 (4.8)	2,037 (7.2)	2,905 (8.6)	5.8	6.8	4.9	3.6	4.4
Japan	513 (7.5)	771 (7.9)	969 (7.6)	951 (4.8)	1,087 (3.8)	1,117 (3.3)	2.3	-0.1	0.8	0.3	0.6
Korea	33 (0.5)	94 (1.0)	263 (2.1)	487 (2.5)	688 (2.4)	727 (2.2)	10.8	4.5	2.2	0.5	1.6
Chinese Taipei	37 (0.5)	77 (0.8)	160 (1.3)	232 (1.2)	281 (1.0)	294 (0.9)	7.6	2.7	1.2	0.4	0.9
ASEAN	n.a. (n.a.)	n.a. (n.a.)	321 (2.5)	762 (3.8)	1,641 (5.8)	2,445 (7.3)	-	6.4	4.9	4.1	4.6
Indonesia	7 (0.1)	28 (0.3)	79 (0.6)	199 (1.0)	482 (1.7)	781 (2.3)	10.8	6.8	5.7	4.9	5.4
Malaysia	9 (0.1)	20 (0.2)	61 (0.5)	133 (0.7)	241 (0.9)	327 (1.0)	11.9	5.7	3.8	3.1	3.5
Myanmar	1 (0.0)	2 (0.0)	3 (0.0)	10 (0.1)	33 (0.1)	57 (0.2)	6.5	8.3	7.8	5.5	6.9
Philippines	17 (0.2)	21 (0.2)	37 (0.3)	63 (0.3)	198 (0.7)	333 (1.0)	5.6	4.0	7.4	5.4	6.6
Singapore	6 (0.1)	13 (0.1)	27 (0.2)	46 (0.2)	58 (0.2)	64 (0.2)	7.7	3.9	1.4	1.0	1.2
Thailand	13 (0.2)	38 (0.4)	88 (0.7)	169 (0.9)	275 (1.0)	361 (1.1)	8.7	4.8	3.1	2.8	3.0
Viet Nam	3 (0.0)	6 (0.1)	22 (0.2)	131 (0.7)	325 (1.1)	476 (1.4)	13.7	13.4	5.9	3.9	5.1
Asia excl. Japan	512 (7.5)	1,063 (10.9)	2,285 (18.0)	7,376 (37.2)	12,318 (43.5)	15,644 (46.4)	8.0	8.7	3.3	2.4	2.9
North America	2,329 (34.2)	3,052 (31.4)	3,981 (31.3)	4,277 (21.6)	4,900 (17.3)	5,135 (15.2)	2.7	0.5	0.9	0.5	0.7
United States	2,026 (29.7)	2,634 (27.1)	3,499 (27.6)	3,788 (19.1)	4,318 (15.3)	4,519 (13.4)	2.9	0.6	0.8	0.5	0.7
Latin America	317 (4.7)	517 (5.3)	798 (6.3)	1,282 (6.5)	2,057 (7.3)	2,613 (7.8)	4.4	3.4	3.0	2.4	2.8
OECD Europe	1,709 (25.1)	2,230 (22.9)	2,708 (21.3)	2,988 (15.1)	3,546 (12.5)	3,729 (11.1)	2.0	0.7	1.1	0.5	0.9
European Union	n.a. (n.a.)	2,163 (22.3)	2,529 (19.9)	2,706 (13.6)	3,209 (11.3)	3,390 (10.1)	1.6	0.5	1.1	0.5	0.9
Non-OECD Europe	1,100 (16.1)	1,471 (15.1)	1,011 (8.0)	1,246 (6.3)	1,561 (5.5)	1,773 (5.3)	-3.7	1.5	1.4	1.3	1.4
Africa	162 (2.4)	257 (2.6)	361 (2.8)	605 (3.0)	1,021 (3.6)	1,381 (4.1)	3.4	3.8	3.3	3.1	3.2
Middle East	75 (1.1)	199 (2.0)	379 (3.0)	864 (4.4)	1,479 (5.2)	1,934 (5.7)	6.7	6.1	3.4	2.7	3.1
Oceania	99 (1.4)	157 (1.6)	207 (1.6)	247 (1.2)	319 (1.1)	356 (1.1)	2.8	1.3	1.6	1.1	1.4
OECD	4,749 (69.7)	6,420 (66.1)	8,310 (65.4)	9,269 (46.7)	11,061 (39.1)	11,724 (34.8)	2.6	0.8	1.1	0.6	0.9
Non-OECD	2,067 (30.3)	3,296 (33.9)	4,389 (34.6)	10,567 (53.3)	17,228 (60.9)	21,958 (65.2)	2.9	6.5	3.1	2.5	2.9

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%).

Table A43 | Electricity generation [Reference Scenario]

(TWh)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
World	8,283 (100)	11,864 (100)	15,471 (100)	23,816 (100)	33,573 (100)	39,819 (100)	2.7	3.1	2.2	1.7	2.0
Asia	1,196 (14.4)	2,252 (19.0)	4,013 (25.9)	9,895 (41.5)	15,749 (46.9)	19,627 (49.3)	5.9	6.7	2.9	2.2	2.7
China	301 (3.6)	621 (5.2)	1,356 (8.8)	5,666 (23.8)	8,455 (25.2)	10,021 (25.2)	8.1	10.8	2.5	1.7	2.2
India	120 (1.5)	293 (2.5)	570 (3.7)	1,287 (5.4)	2,687 (8.0)	3,775 (9.5)	6.9	6.0	4.7	3.5	4.2
Japan	573 (6.9)	873 (7.4)	1,088 (7.0)	1,036 (4.3)	1,177 (3.5)	1,203 (3.0)	2.2	-0.4	0.8	0.2	0.6
Korea	37 (0.4)	105 (0.9)	289 (1.9)	546 (2.3)	747 (2.2)	788 (2.0)	10.6	4.7	2.0	0.5	1.4
Chinese Taipei	43 (0.5)	88 (0.7)	181 (1.2)	257 (1.1)	307 (0.9)	320 (0.8)	7.4	2.6	1.1	0.4	0.8
ASEAN	n.a. (n.a.)	n.a. (n.a.)	374 (2.4)	854 (3.6)	1,864 (5.6)	2,769 (7.0)	-	6.1	5.0	4.0	4.6
Indonesia	8 (0.1)	33 (0.3)	93 (0.6)	229 (1.0)	553 (1.6)	890 (2.2)	11.1	6.6	5.7	4.9	5.4
Malaysia	10 (0.1)	23 (0.2)	69 (0.4)	147 (0.6)	262 (0.8)	355 (0.9)	11.6	5.5	3.6	3.1	3.4
Myanmar	1 (0.0)	2 (0.0)	5 (0.0)	14 (0.1)	60 (0.2)	102 (0.3)	7.5	7.5	9.5	5.3	7.9
Philippines	18 (0.2)	26 (0.2)	45 (0.3)	77 (0.3)	241 (0.7)	406 (1.0)	5.6	3.9	7.4	5.3	6.6
Singapore	7 (0.1)	16 (0.1)	32 (0.2)	49 (0.2)	61 (0.2)	68 (0.2)	7.3	3.2	1.4	1.0	1.2
Thailand	14 (0.2)	44 (0.4)	96 (0.6)	174 (0.7)	273 (0.8)	349 (0.9)	8.1	4.3	2.9	2.5	2.7
Viet Nam	4 (0.0)	9 (0.1)	27 (0.2)	141 (0.6)	347 (1.0)	506 (1.3)	11.8	12.7	5.8	3.8	5.0
Asia excl. Japan	623 (7.5)	1,380 (11.6)	2,925 (18.9)	8,860 (37.2)	14,571 (43.4)	18,425 (46.3)	7.8	8.2	3.2	2.4	2.9
North America	2,801 (33.8)	3,685 (31.1)	4,631 (29.9)	4,975 (20.9)	5,630 (16.8)	5,884 (14.8)	2.3	0.5	0.8	0.4	0.6
United States	2,427 (29.3)	3,203 (27.0)	4,026 (26.0)	4,319 (18.1)	4,878 (14.5)	5,096 (12.8)	2.3	0.5	0.8	0.4	0.6
Latin America	380 (4.6)	623 (5.3)	1,009 (6.5)	1,592 (6.7)	2,484 (7.4)	3,116 (7.8)	4.9	3.3	2.8	2.3	2.6
OECD Europe	2,049 (24.7)	2,662 (22.4)	3,223 (20.8)	3,500 (14.7)	4,121 (12.3)	4,325 (10.9)	1.9	0.6	1.0	0.5	0.8
European Union	n.a. (n.a.)	2,577 (21.7)	3,006 (19.4)	3,159 (13.3)	3,729 (11.1)	3,953 (9.9)	1.6	0.4	1.0	0.6	0.9
Non-OECD Europe	1,461 (17.6)	1,894 (16.0)	1,432 (9.3)	1,749 (7.3)	2,173 (6.5)	2,457 (6.2)	-2.8	1.4	1.4	1.2	1.3
Africa	184 (2.2)	316 (2.7)	442 (2.9)	762 (3.2)	1,272 (3.8)	1,712 (4.3)	3.4	4.0	3.3	3.0	3.2
Middle East	95 (1.1)	244 (2.1)	472 (3.1)	1,051 (4.4)	1,771 (5.3)	2,280 (5.7)	6.8	5.9	3.3	2.6	3.0
Oceania	118 (1.4)	187 (1.6)	249 (1.6)	292 (1.2)	374 (1.1)	416 (1.0)	2.9	1.1	1.6	1.1	1.4
OECD	5,656 (68.3)	7,645 (64.4)	9,726 (62.9)	10,724 (45.0)	12,650 (37.7)	13,367 (33.6)	2.4	0.7	1.0	0.6	0.9
Non-OECD	2,628 (31.7)	4,218 (35.6)	5,745 (37.1)	13,092 (55.0)	20,923 (62.3)	26,451 (66.4)	3.1	6.1	3.0	2.4	2.7

Source: International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%).

Table A44 | Primary energy consumption per capita [Reference Scenario]

(toe/person)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
World	1.62	1.66	1.64	1.89	2.01	2.06	-0.1	1.0	0.4	0.3	0.3
Asia	0.59	0.72	0.85	1.39	1.69	1.87	1.7	3.6	1.2	1.0	1.1
China	0.61	0.77	0.90	2.24	2.73	3.06	1.6	6.7	1.2	1.2	1.2
India	0.29	0.35	0.42	0.64	0.92	1.08	1.8	3.0	2.3	1.7	2.1
Japan	2.95	3.55	4.08	3.47	3.77	3.77	1.4	-1.1	0.5	0.0	0.3
Korea	1.08	2.17	4.00	5.32	6.09	6.08	6.3	2.1	0.8	0.0	0.5
Chinese Taipei	1.56	2.34	3.81	4.70	5.41	5.68	5.0	1.5	0.9	0.5	0.7
ASEAN	n.a.	n.a.	0.74	1.00	1.45	1.77	-	2.2	2.3	2.0	2.2
Indonesia	0.38	0.54	0.74	0.89	1.41	1.78	3.1	1.3	2.9	2.3	2.7
Malaysia	0.86	1.20	2.09	3.00	3.48	3.91	5.7	2.6	0.9	1.2	1.0
Myanmar	0.27	0.25	0.27	0.36	0.52	0.65	0.6	2.1	2.3	2.3	2.3
Philippines	0.47	0.46	0.51	0.48	0.79	0.99	1.0	-0.5	3.1	2.4	2.8
Singapore	2.13	3.78	4.63	5.12	4.95	4.97	2.1	0.7	-0.2	0.0	-0.1
Thailand	0.46	0.74	1.15	1.99	2.85	3.50	4.5	4.0	2.3	2.1	2.2
Viet Nam	0.27	0.27	0.37	0.73	1.20	1.57	3.2	5.0	3.1	2.7	3.0
Asia excl. Japan	0.47	0.59	0.72	1.33	1.63	1.82	2.0	4.4	1.3	1.1	1.2
North America	7.93	7.66	8.08	7.04	6.38	6.00	0.5	-1.0	-0.6	-0.6	-0.6
United States	7.94	7.67	8.06	6.95	6.27	5.89	0.5	-1.0	-0.6	-0.6	-0.6
Latin America	1.06	1.05	1.15	1.39	1.70	1.88	0.9	1.4	1.3	1.0	1.2
OECD Europe	3.14	3.25	3.36	2.99	3.04	2.99	0.3	-0.8	0.1	-0.2	0.0
European Union	n.a.	3.44	3.47	3.08	3.16	3.11	0.1	-0.9	0.2	-0.1	0.0
Non-OECD Europe	3.89	4.47	2.94	3.28	3.56	3.77	-4.1	0.8	0.5	0.6	0.5
Africa	0.57	0.62	0.61	0.67	0.67	0.66	-0.2	0.7	0.0	-0.1	-0.1
Middle East	1.32	1.69	2.22	3.20	3.57	3.71	2.7	2.7	0.7	0.4	0.6
Oceania	4.41	4.86	5.44	5.21	4.87	4.61	1.1	-0.3	-0.4	-0.5	-0.5
OECD	4.14	4.25	4.60	4.16	4.11	4.00	0.8	-0.7	-0.1	-0.3	-0.1
Non-OECD	0.86	0.96	0.90	1.35	1.54	1.65	-0.6	2.9	0.8	0.7	0.8

Source: World Bank "World Development Indicators", International Energy Agency "World Energy Balances", etc. (historical)

Note: World includes international bunkers.

Table A45 | Primary energy consumption per GDP [Reference Scenario]

(toe/$2010 million)

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
World	259	233	203	188	147	125	-1.4	-0.5	-1.5	-1.6	-1.6
Asia	332	284	268	262	177	142	-0.6	-0.2	-2.4	-2.2	-2.3
China	1,768	1,056	510	371	191	142	-7.0	-2.3	-4.1	-2.9	-3.6
India	716	638	534	377	223	167	-1.8	-2.5	-3.2	-2.8	-3.1
Japan	119	96	102	78	69	58	0.5	-1.9	-0.8	-1.6	-1.1
Korea	277	246	265	218	171	140	0.7	-1.4	-1.5	-1.9	-1.7
Chinese Taipei	380	295	274	211	173	150	-0.7	-1.9	-1.2	-1.4	-1.3
ASEAN	n.a.	n.a.	324	259	206	181	-	-1.6	-1.4	-1.3	-1.4
Indonesia	345	329	343	239	190	167	0.4	-2.5	-1.4	-1.3	-1.4
Malaysia	260	267	301	285	198	170	1.2	-0.4	-2.2	-1.6	-2.0
Myanmar	1,606	1,602	966	349	202	161	-4.9	-7.0	-3.3	-2.2	-2.9
Philippines	280	304	319	190	165	151	0.5	-3.6	-0.9	-0.9	-0.9
Singapore	160	171	139	100	78	69	-2.0	-2.3	-1.5	-1.3	-1.5
Thailand	331	296	332	352	303	263	1.1	0.4	-0.9	-1.4	-1.1
Viet Nam	851	606	470	460	343	284	-2.5	-0.2	-1.8	-1.9	-1.8
Asia excl. Japan	757	579	417	329	197	153	-3.2	-1.7	-3.2	-2.5	-2.9
North America	273	211	180	138	99	81	-1.6	-1.9	-2.1	-2.0	-2.1
United States	276	211	179	136	96	78	-1.7	-1.9	-2.1	-2.1	-2.1
Latin America	159	167	159	147	135	121	-0.5	-0.6	-0.5	-1.1	-0.7
OECD Europe	151	129	110	88	71	62	-1.5	-1.6	-1.3	-1.4	-1.3
European Union	n.a.	139	115	90	73	63	-1.9	-1.7	-1.3	-1.4	-1.4
Non-OECD Europe	709	718	672	416	314	249	-0.7	-3.4	-1.7	-2.3	-1.9
Africa	382	448	433	350	250	197	-0.3	-1.5	-2.1	-2.3	-2.2
Middle East	139	229	254	291	261	237	1.1	1.0	-0.7	-1.0	-0.8
Oceania	150	138	126	98	75	65	-0.9	-1.8	-1.6	-1.5	-1.6
OECD	190	156	140	112	88	74	-1.1	-1.6	-1.5	-1.7	-1.6
Non-OECD	458	473	379	310	208	166	-2.2	-1.4	-2.5	-2.2	-2.4

Source: World Bank "World Development Indicators", International Energy Agency "World Energy Balances", etc. (historical)

Note: World includes international bunkers.

Table A46 | Energy-related carbon dioxide emissions [Reference Scenario]

(Mt)

	1980	1990	2000	2014	2030	2040	CAGR (%) 1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
World	18,409 (100)	21,202 (100)	23,433 (100)	33,009 (100)	39,062 (100)	42,463 (100)	1.0	2.5	1.1	0.8	1.0
Asia	3,267 (17.7)	4,918 (23.2)	6,893 (29.4)	15,067 (45.6)	19,379 (49.6)	21,990 (51.8)	3.4	5.7	1.6	1.3	1.5
China	1,505 (8.2)	2,339 (11.0)	3,164 (13.5)	9,347 (28.3)	10,894 (27.9)	11,618 (27.4)	3.1	8.0	1.0	0.6	0.8
India	263 (1.4)	542 (2.6)	899 (3.8)	2,053 (6.2)	3,638 (9.3)	4,646 (10.9)	5.2	6.1	3.6	2.5	3.2
Japan	916 (5.0)	1,071 (5.1)	1,195 (5.1)	1,201 (3.6)	1,075 (2.8)	1,007 (2.4)	1.1	0.0	-0.7	-0.6	-0.7
Korea	126 (0.7)	239 (1.1)	433 (1.8)	578 (1.8)	599 (1.5)	582 (1.4)	6.1	2.1	0.2	-0.3	0.0
Chinese Taipei	74 (0.4)	115 (0.5)	225 (1.0)	259 (0.8)	286 (0.7)	282 (0.7)	6.9	1.0	0.6	-0.1	0.3
ASEAN	n.a. (n.a.)	n.a. (n.a.)	713 (3.0)	1,258 (3.8)	2,328 (6.0)	3,137 (7.4)	-	4.1	3.9	3.0	3.6
Indonesia	71 (0.4)	134 (0.6)	262 (1.1)	439 (1.3)	878 (2.2)	1,244 (2.9)	6.9	3.8	4.4	3.5	4.1
Malaysia	29 (0.2)	54 (0.3)	121 (0.5)	236 (0.7)	347 (0.9)	410 (1.0)	8.3	4.9	2.4	1.7	2.1
Myanmar	5 (0.0)	4 (0.0)	10 (0.0)	21 (0.1)	56 (0.1)	87 (0.2)	9.3	5.7	6.1	4.6	5.5
Philippines	33 (0.2)	39 (0.2)	69 (0.3)	98 (0.3)	241 (0.6)	364 (0.9)	6.0	2.5	5.8	4.2	5.2
Singapore	15 (0.1)	29 (0.1)	48 (0.2)	57 (0.2)	63 (0.2)	66 (0.2)	4.9	1.3	0.6	0.5	0.5
Thailand	34 (0.2)	81 (0.4)	152 (0.6)	248 (0.8)	354 (0.9)	407 (1.0)	6.5	3.6	2.2	1.4	1.9
Viet Nam	15 (0.1)	17 (0.1)	43 (0.2)	143 (0.4)	294 (0.8)	426 (1.0)	9.8	8.9	4.6	3.8	4.3
Asia excl. Japan	2,351 (12.8)	3,847 (18.1)	5,698 (24.3)	13,866 (42.0)	18,304 (46.9)	20,983 (49.4)	4.0	6.6	1.8	1.4	1.6
North America	5,169 (28.1)	5,236 (24.7)	6,125 (26.1)	5,739 (17.4)	5,316 (13.6)	4,972 (11.7)	1.6	-0.5	-0.5	-0.7	-0.5
United States	4,743 (25.8)	4,820 (22.7)	5,617 (24.0)	5,221 (15.8)	4,805 (12.3)	4,476 (10.5)	1.5	-0.5	-0.5	-0.7	-0.6
Latin America	801 (4.4)	909 (4.3)	1,204 (5.1)	1,760 (5.3)	2,432 (6.2)	2,810 (6.6)	2.9	2.8	2.0	1.5	1.8
OECD Europe	4,164 (22.6)	3,951 (18.6)	3,891 (16.6)	3,385 (10.3)	3,328 (8.5)	3,129 (7.4)	-0.2	-1.0	-0.1	-0.6	-0.3
European Union	n.a. (n.a.)	4,067 (19.2)	3,783 (16.1)	3,134 (9.5)	3,085 (7.9)	2,898 (6.8)	-0.7	-1.3	-0.1	-0.6	-0.3
Non-OECD Europe	3,497 (19.0)	4,123 (19.4)	2,462 (10.5)	2,596 (7.9)	2,569 (6.6)	2,607 (6.1)	-5.0	0.4	-0.1	0.1	0.0
Africa	403 (2.2)	593 (2.8)	718 (3.1)	1,148 (3.5)	1,626 (4.2)	1,929 (4.5)	1.9	3.4	2.2	1.7	2.0
Middle East	332 (1.8)	572 (2.7)	945 (4.0)	1,810 (5.5)	2,560 (6.6)	2,991 (7.0)	5.1	4.7	2.2	1.6	2.0
Oceania	227 (1.2)	281 (1.3)	357 (1.5)	390 (1.2)	418 (1.1)	417 (1.0)	2.4	0.6	0.4	0.0	0.3
OECD	10,863 (59.0)	11,100 (52.4)	12,412 (53.0)	11,846 (35.9)	11,530 (29.5)	11,002 (25.9)	1.1	-0.3	-0.2	-0.5	-0.3
Non-OECD	6,998 (38.0)	9,482 (44.7)	10,181 (43.4)	20,049 (60.7)	26,098 (66.8)	29,842 (70.3)	0.7	5.0	1.7	1.3	1.5

Source: Compiled from International Energy Agency "World Energy Balances" (historical)

Note: Figures in parentheses are global shares (%). Excludes emission reduction by CCS. World includes international bunkers.

Table A47 | World [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	7,205	8,772	10,037	13,699	17,067	18,904	100	100	100	1.4	2.2	1.4	1.0	1.2
Coal	1,783	2,220	2,316	3,918	4,320	4,527	25	29	24	0.4	3.8	0.6	0.5	0.6
Oil	3,102	3,233	3,660	4,285	5,062	5,488	37	31	29	1.2	1.1	1.0	0.8	1.0
Natural gas	1,232	1,663	2,071	2,901	4,014	4,695	19	21	25	2.2	2.4	2.1	1.6	1.9
Nuclear	186	526	676	661	991	1,136	6.0	4.8	6.0	2.5	-0.2	2.6	1.4	2.1
Hydro	148	184	225	335	413	447	2.1	2.4	2.4	2.0	2.9	1.3	0.8	1.1
Geothermal	12	34	52	71	182	229	0.4	0.5	1.2	4.3	2.3	6.0	2.3	4.6
Solar, wind, etc.	0.1	2.6	8.0	110	247	348	0.0	0.8	1.8	11.9	20.5	5.2	3.5	4.5
Biomass and waste	741	909	1,028	1,413	1,834	2,028	10	10	11	1.2	2.3	1.6	1.0	1.4

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	5,368	6,262	7,041	9,425	11,723	13,028	100	100	100	1.2	2.1	1.4	1.1	1.3
Industry	1,766	1,805	1,868	2,751	3,375	3,781	29	29	29	0.3	2.8	1.3	1.1	1.2
Transport	1,248	1,573	1,961	2,627	3,255	3,573	25	28	27	2.2	2.1	1.3	0.9	1.2
Buildings, etc.	2,000	2,408	2,596	3,219	4,076	4,543	38	34	35	0.8	1.5	1.5	1.1	1.3
Non-energy use	354	476	617	828	1,017	1,132	7.6	8.8	8.7	2.6	2.1	1.3	1.1	1.2
Coal	703	754	548	1,075	1,098	1,102	12	11	8.5	-3.1	4.9	0.1	0.0	0.1
Oil	2,446	2,595	3,115	3,761	4,520	4,948	41	40	38	1.8	1.4	1.2	0.9	1.1
Natural gas	814	944	1,117	1,420	1,914	2,206	15	15	17	1.7	1.7	1.9	1.4	1.7
Electricity	586	836	1,092	1,706	2,433	2,897	13	18	22	2.7	3.2	2.2	1.8	2.1
Heat	121	335	248	274	298	303	5.4	2.9	2.3	-3.0	0.7	0.5	0.2	0.4
Hydrogen	-	-	-	-	0.3	0.6	-	-	0.0	n.a.	n.a.	n.a.	5.8	n.a.
Renewables	698	799	921	1,188	1,460	1,571	13	13	12	1.4	1.8	1.3	0.7	1.1

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	8,283	11,864	15,471	23,816	33,573	39,819	100	100	100	2.7	3.1	2.2	1.7	2.0
Coal	3,137	4,425	6,005	9,707	11,934	13,365	37	41	34	3.1	3.5	1.3	1.1	1.2
Oil	1,659	1,358	1,251	1,023	1,027	1,060	11	4.3	2.7	-0.8	-1.4	0.0	0.3	0.1
Natural gas	999	1,753	2,753	5,155	8,545	11,028	15	22	28	4.6	4.6	3.2	2.6	3.0
Nuclear	713	2,013	2,591	2,535	3,800	4,357	17	11	11	2.6	-0.2	2.6	1.4	2.1
Hydro	1,717	2,143	2,619	3,895	4,807	5,201	18	16	13	2.0	2.9	1.3	0.8	1.1
Geothermal	14	36	52	77	183	232	0.3	0.3	0.6	3.6	2.9	5.5	2.4	4.3
Solar, wind, etc.	0.5	5.2	35	928	2,309	3,342	0.0	3.9	8.4	20.8	26.5	5.9	3.8	5.1
Biomass and waste	44	131	164	493	965	1,232	1.1	2.1	3.1	2.3	8.2	4.3	2.5	3.6
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	27,804	37,578	49,555	72,934	116,213	151,552	2.8	2.8	3.0	2.7	2.9
Population (million)	4,434	5,276	6,107	7,249	8,493	9,157	1.5	1.2	1.0	0.8	0.9
CO_2 emissions[*2] (Mt)	18,409	21,202	23,433	33,009	39,062	42,463	1.0	2.5	1.1	0.8	1.0
GDP per capita ($2010 thousand)	6.3	7.1	8.1	10	14	17	1.3	1.5	1.9	1.9	1.9
Primary energy consump. per capita (toe)	1.6	1.7	1.6	1.9	2.0	2.1	-0.1	1.0	0.4	0.3	0.3
Primary energy consumption per GDP[*3]	259	233	203	188	147	125	-1.4	-0.5	-1.5	-1.6	-1.6
CO_2 emissions per GDP[*2, *4]	662	564	473	453	336	280	-1.8	-0.3	-1.8	-1.8	-1.8
CO_2 per primary energy consumption[*2, *5]	2.6	2.4	2.3	2.4	2.3	2.2	-0.3	0.2	-0.3	-0.2	-0.3
Automobile ownership (million)	416	577	767	1,243	1,853	2,171	2.9	3.5	2.5	1.6	2.2
Automobile ownership rates[*6]	94	109	126	171	218	237	1.4	2.3	1.5	0.8	1.3

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A48 | Asia [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
Total[*1]	1,439	2,108	2,893	5,517	7,506	8,635	100	100	100	3.2	4.7	1.9	1.4	1.7
Coal	466	785	1,037	2,758	3,268	3,552	37	50	41	2.8	7.2	1.1	0.8	1.0
Oil	477	618	917	1,291	1,783	2,085	29	23	24	4.0	2.5	2.0	1.6	1.9
Natural gas	51	116	232	549	1,018	1,337	5.5	10.0	15	7.2	6.3	3.9	2.8	3.5
Nuclear	25	77	132	97	349	455	3.6	1.8	5.3	5.5	-2.2	8.3	2.7	6.1
Hydro	20	32	41	125	176	195	1.5	2.3	2.3	2.7	8.3	2.2	1.0	1.7
Geothermal	2.6	8.2	23	33	99	122	0.4	0.6	1.4	10.9	2.7	7.0	2.2	5.1
Solar, wind, etc.	-	1.5	2.2	44	110	169	0.1	0.8	2.0	4.4	23.7	5.9	4.3	5.3
Biomass and waste	397	471	508	617	701	718	22	11	8.3	0.8	1.4	0.8	0.2	0.6

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
Total	1,129	1,551	1,995	3,677	4,893	5,625	100	100	100	2.5	4.5	1.8	1.4	1.6
Industry	383	517	645	1,494	1,811	2,027	33	41	36	2.2	6.2	1.2	1.1	1.2
Transport	126	186	321	612	963	1,171	12	17	21	5.6	4.7	2.9	2.0	2.5
Buildings, etc.	567	733	842	1,215	1,650	1,891	47	33	34	1.4	2.7	1.9	1.4	1.7
Non-energy use	54	115	188	356	469	536	7.4	9.7	9.5	5.0	4.7	1.7	1.3	1.6
Coal	301	424	378	926	931	932	27	25	17	-1.1	6.6	0.0	0.0	0.0
Oil	327	453	727	1,120	1,616	1,909	29	30	34	4.9	3.1	2.3	1.7	2.1
Natural gas	21	47	88	255	463	614	3.0	6.9	11	6.4	7.9	3.8	2.9	3.4
Electricity	88	158	280	716	1,153	1,441	10	19	26	5.9	6.9	3.0	2.3	2.7
Heat	7.5	14	30	84	110	119	0.9	2.3	2.1	7.7	7.7	1.7	0.8	1.3
Hydrogen	-	-	-	-	0.0	0.0	-	-	0.0	n.a.	n.a.	n.a.	7.1	n.a.
Renewables	386	456	493	575	621	609	29	16	11	0.8	1.1	0.5	-0.2	0.2

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
Total	1,196	2,252	4,013	9,895	15,749	19,627	100	100	100	5.9	6.7	2.9	2.2	2.7
Coal	298	863	1,994	6,116	8,472	10,079	38	62	51	8.7	8.3	2.1	1.8	1.9
Oil	476	469	430	275	208	206	21	2.8	1.1	-0.9	-3.2	-1.7	-0.1	-1.1
Natural gas	90	240	565	1,252	2,481	3,441	11	13	18	9.0	5.9	4.4	3.3	4.0
Nuclear	97	294	505	373	1,340	1,748	13	3.8	8.9	5.5	-2.2	8.3	2.7	6.1
Hydro	232	367	479	1,453	2,045	2,263	16	15	12	2.7	8.3	2.2	1.0	1.7
Geothermal	3.0	8.4	20	23	65	80	0.4	0.2	0.4	9.0	1.0	6.7	2.0	4.9
Solar, wind, etc.	-	0.0	3.0	268	863	1,430	0.0	2.7	7.3	52.3	37.8	7.6	5.2	6.7
Biomass and waste	0.0	10	17	136	274	380	0.5	1.4	1.9	5.1	16.2	4.5	3.3	4.0
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/2000	2000/2014	2014/2030	2030/2040	2014/2040
GDP ($2010 billion)	4,340	7,433	10,786	21,055	42,319	60,826	3.8	4.9	4.5	3.7	4.2
Population (million)	2,440	2,932	3,408	3,956	4,445	4,624	1.5	1.1	0.7	0.4	0.6
CO_2 emissions[*2] (Mt)	3,267	4,918	6,893	15,067	19,379	21,990	3.4	5.7	1.6	1.3	1.5
GDP per capita ($2010 thousand)	1.8	2.5	3.2	5.3	9.5	13	2.2	3.8	3.7	3.3	3.5
Primary energy consump. per capita (toe)	0.6	0.7	0.8	1.4	1.7	1.9	1.7	3.6	1.2	1.0	1.1
Primary energy consumption per GDP[*3]	332	284	268	262	177	142	-0.6	-0.2	-2.4	-2.2	-2.3
CO_2 emissions per GDP[*2, *4]	753	662	639	716	458	362	-0.3	0.8	-2.8	-2.3	-2.6
CO_2 per primary energy consumption[*2, *5]	2.3	2.3	2.4	2.7	2.6	2.5	0.2	1.0	-0.4	-0.1	-0.3
Automobile ownership (million)	48	86	139	351	709	900	5.0	6.8	4.5	2.4	3.7
Automobile ownership rates[*6]	20	29	41	89	160	195	3.4	5.7	3.7	2.0	3.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A49 | China [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	598	871	1,135	3,052	3,854	4,264	100	100	100	2.7	7.3	1.5	1.0	1.3
Coal	313	528	665	2,012	2,134	2,175	61	66	51	2.3	8.2	0.4	0.2	0.3
Oil	89	119	221	504	700	787	14	17	18	6.4	6.1	2.1	1.2	1.7
Natural gas	12	13	21	154	412	571	1.5	5.0	13	4.9	15.4	6.4	3.3	5.2
Nuclear	-	-	4.4	35	172	240	-	1.1	5.6	n.a.	15.9	10.6	3.4	7.7
Hydro	5.0	11	19	90	121	126	1.3	3.0	2.9	5.8	11.7	1.8	0.4	1.3
Geothermal	-	-	1.7	4.8	10	12	-	0.2	0.3	n.a.	7.9	4.8	1.8	3.6
Solar, wind, etc.	-	0.0	1.0	36	79	118	0.0	1.2	2.8	40.4	29.3	5.1	4.0	4.7
Biomass and waste	180	200	203	217	226	236	23	7.1	5.5	0.1	0.5	0.3	0.4	0.3

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	487	654	786	1,988	2,433	2,667	100	100	100	1.9	6.9	1.3	0.9	1.1
Industry	181	234	299	983	995	1,007	36	49	38	2.5	8.9	0.1	0.1	0.1
Transport	24	33	87	268	426	501	5.1	13	19	10.1	8.4	2.9	1.6	2.4
Buildings, etc.	272	344	340	577	800	918	53	29	34	-0.1	3.9	2.1	1.4	1.8
Non-energy use	10	43	60	160	212	240	6.6	8.0	9.0	3.4	7.2	1.8	1.3	1.6
Coal	214	308	274	726	616	554	47	37	21	-1.2	7.2	-1.0	-1.0	-1.0
Oil	59	85	180	451	643	725	13	23	27	7.8	6.8	2.2	1.2	1.8
Natural gas	6.4	8.9	12	106	230	320	1.4	5.3	12	3.4	16.6	5.0	3.4	4.3
Electricity	21	39	89	406	619	738	6.0	20	28	8.6	11.4	2.7	1.8	2.3
Heat	7.4	13	25	78	100	107	2.0	3.9	4.0	6.8	8.3	1.5	0.7	1.2
Hydrogen	-	-	-	-	0.0	0.0	-	-	0.0	n.a.	n.a.	n.a.	7.4	n.a.
Renewables	180	200	205	221	225	223	31	11	8.3	0.2	0.5	0.1	-0.1	0.0

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	301	621	1,356	5,666	8,455	10,021	100	100	100	8.1	10.8	2.5	1.7	2.2
Coal	159	441	1,060	4,115	5,147	5,739	71	73	57	9.2	10.2	1.4	1.1	1.3
Oil	82	50	47	9.5	9.2	9.1	8.1	0.2	0.1	-0.6	-10.8	-0.2	-0.2	-0.2
Natural gas	0.7	2.8	5.8	115	589	840	0.4	2.0	8.4	7.6	23.8	10.8	3.6	8.0
Nuclear	-	-	17	133	660	920	-	2.3	9.2	n.a.	15.9	10.6	3.4	7.7
Hydro	58	127	222	1,051	1,405	1,460	20	19	15	5.8	11.7	1.8	0.4	1.3
Geothermal	-	0.1	0.1	0.1	0.4	0.4	0.0	0.0	0.0	6.7	1.0	7.1	1.4	4.9
Solar, wind, etc.	-	0.0	0.6	185	518	856	0.0	3.3	8.5	50.2	49.8	6.6	5.1	6.1
Biomass and waste	-	-	2.4	57	126	195	-	1.0	2.0	n.a.	25.4	5.0	4.5	4.8
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	338	824	2,224	8,230	20,185	29,970	10.4	9.8	5.8	4.0	5.1
Population (million)	981	1,135	1,263	1,364	1,414	1,395	1.1	0.6	0.2	-0.1	0.1
CO_2 emissions[*2] (Mt)	1,505	2,339	3,164	9,347	10,894	11,618	3.1	8.0	1.0	0.6	0.8
GDP per capita ($2010 thousand)	0.3	0.7	1.8	6.0	14	21	9.3	9.2	5.5	4.2	5.0
Primary energy consump. per capita (toe)	0.6	0.8	0.9	2.2	2.7	3.1	1.6	6.7	1.2	1.2	1.2
Primary energy consumption per GDP[*3]	1,768	1,056	510	371	191	142	-7.0	-2.3	-4.1	-2.9	-3.6
CO_2 emissions per GDP[*2, *4]	4,452	2,838	1,423	1,136	540	388	-6.7	-1.6	-4.5	-3.3	-4.0
CO_2 per primary energy consumption[*2, *5]	2.5	2.7	2.8	3.1	2.8	2.7	0.4	0.7	-0.5	-0.4	-0.4
Automobile ownership (million)	1.2	5.3	16	146	353	417	11.5	17.3	5.7	1.7	4.1
Automobile ownership rates[*6]	1.2	4.7	12	107	250	299	10.3	16.6	5.4	1.8	4.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A50 | India [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	200	306	441	825	1,398	1,763	100	100	100	3.7	4.6	3.4	2.3	3.0
Coal	44	93	146	378	613	747	30	46	42	4.6	7.0	3.1	2.0	2.7
Oil	33	61	112	185	364	490	20	22	28	6.2	3.6	4.3	3.0	3.8
Natural gas	1.3	11	23	43	114	174	3.5	5.2	9.9	8.1	4.6	6.2	4.3	5.5
Nuclear	0.8	1.6	4.4	9.4	34	59	0.5	1.1	3.3	10.7	5.6	8.4	5.5	7.3
Hydro	4.0	6.2	6.4	11	21	29	2.0	1.4	1.6	0.4	4.2	3.8	3.4	3.6
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	0.2	4.2	20	35	0.0	0.5	2.0	33.0	25.2	10.5	5.4	8.5
Biomass and waste	116	133	149	194	231	230	44	23	13	1.1	1.9	1.1	0.0	0.7

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	174	243	315	556	952	1,210	100	100	100	2.6	4.1	3.4	2.4	3.0
Industry	41	67	83	191	347	463	27	34	38	2.3	6.1	3.8	2.9	3.5
Transport	17	21	32	78	190	258	8.6	14	21	4.4	6.6	5.7	3.1	4.7
Buildings, etc.	110	142	173	246	351	408	59	44	34	2.0	2.5	2.3	1.5	2.0
Non-energy use	5.7	13	27	41	63	81	5.5	7.4	6.7	7.3	3.1	2.7	2.5	2.6
Coal	25	39	35	114	194	244	16	20	20	-1.1	8.9	3.4	2.3	3.0
Oil	27	50	94	156	336	460	21	28	38	6.5	3.7	4.9	3.2	4.2
Natural gas	0.7	5.6	9.7	29	52	73	2.3	5.2	6.0	5.5	8.1	3.8	3.4	3.6
Electricity	7.8	18	32	81	175	250	7.6	15	21	5.8	6.8	4.9	3.6	4.4
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	114	130	144	176	195	183	54	32	15	1.0	1.4	0.6	-0.6	0.2

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	120	293	570	1,287	2,687	3,775	100	100	100	6.9	6.0	4.7	3.5	4.2
Coal	61	192	390	967	1,728	2,211	65	75	59	7.4	6.7	3.7	2.5	3.2
Oil	8.8	13	29	23	19	16	4.5	1.8	0.4	8.2	-1.8	-1.0	-2.1	-1.4
Natural gas	0.6	10.0	56	63	284	522	3.4	4.9	14	18.8	0.8	9.9	6.3	8.5
Nuclear	3.0	6.1	17	36	131	225	2.1	2.8	6.0	10.7	5.6	8.4	5.5	7.3
Hydro	47	72	74	132	239	334	24	10	8.8	0.4	4.2	3.8	3.4	3.6
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	1.7	42	227	390	0.0	3.3	10	48.7	25.8	11.1	5.5	8.9
Biomass and waste	-	-	1.3	25	59	78	-	2.0	2.1	n.a.	23.8	5.4	2.9	4.4
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	279	479	825	2,188	6,281	10,573	5.6	7.2	6.8	5.3	6.2
Population (million)	697	871	1,053	1,295	1,528	1,634	1.9	1.5	1.0	0.7	0.9
CO_2 emissions[*2] (Mt)	263	542	899	2,053	3,638	4,646	5.2	6.1	3.6	2.5	3.2
GDP per capita ($2010 thousand)	0.4	0.6	0.8	1.7	4.1	6.5	3.6	5.6	5.7	4.6	5.3
Primary energy consump. per capita (toe)	0.3	0.4	0.4	0.6	0.9	1.1	1.8	3.0	2.3	1.7	2.1
Primary energy consumption per GDP[*3]	716	638	534	377	223	167	-1.8	-2.5	-3.2	-2.8	-3.1
CO_2 emissions per GDP[*2, *4]	943	1,131	1,090	938	579	439	-0.4	-1.1	-3.0	-2.7	-2.9
CO_2 per primary energy consumption[*2, *5]	1.3	1.8	2.0	2.5	2.6	2.6	1.4	1.4	0.3	0.1	0.2
Automobile ownership (million)	1.7	4.3	9.4	38	126	207	8.1	10.5	7.8	5.1	6.7
Automobile ownership rates[*6]	2.4	5.0	8.9	29	83	127	6.1	8.9	6.7	4.4	5.8

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million, *4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A51 | Japan [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	345	439	518	442	453	429	100	100	100	1.7	-1.1	0.2	-0.5	-0.1
Coal	60	76	97	118	114	108	17	27	25	2.4	1.4	-0.2	-0.6	-0.4
Oil	234	250	255	192	158	141	57	43	33	0.2	-2.0	-1.2	-1.1	-1.2
Natural gas	21	44	66	108	104	105	10	24	25	4.0	3.6	-0.2	0.1	-0.1
Nuclear	22	53	84	-	41	34	12	-	8.0	4.8	-100	n.a.	-1.7	n.a.
Hydro	7.6	7.5	7.3	7.0	8.1	8.1	1.7	1.6	1.9	-0.2	-0.3	0.9	0.0	0.6
Geothermal	0.8	1.6	3.1	2.4	7.7	8.9	0.4	0.5	2.1	7.0	-1.8	7.5	1.6	5.2
Solar, wind, etc.	-	1.4	0.9	2.9	6.8	8.9	0.3	0.7	2.1	-3.7	8.4	5.5	2.7	4.4
Biomass and waste	-	4.5	4.7	11	13	14	1.0	2.5	3.3	0.4	6.3	1.1	0.6	0.9

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	232	287	328	296	294	279	100	100	100	1.4	-0.7	0.0	-0.5	-0.2
Industry	91	110	100	88	95	93	38	30	33	-0.9	-0.9	0.5	-0.2	0.2
Transport	54	68	84	72	62	56	24	24	20	2.2	-1.2	-0.9	-1.1	-1.0
Buildings, etc.	58	76	103	100	102	97	26	34	35	3.1	-0.2	0.1	-0.5	-0.1
Non-energy use	28	34	41	36	35	33	12	12	12	2.1	-1.0	-0.2	-0.6	-0.3
Coal	25	30	24	24	25	22	11	8.0	8.1	-2.2	-0.2	0.4	-1.1	-0.2
Oil	157	171	194	156	133	116	59	53	42	1.3	-1.6	-1.0	-1.4	-1.1
Natural gas	5.8	15	22	30	34	34	5.3	10	12	3.6	2.3	0.8	0.0	0.5
Electricity	44	66	83	82	94	96	23	28	34	2.3	-0.1	0.8	0.3	0.6
Heat	0.1	0.2	0.5	0.5	4.7	6.5	0.1	0.2	2.3	10.5	0.1	14.3	3.4	10.0
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	-	4.1	3.8	3.9	4.0	4.0	1.4	1.3	1.4	-0.7	0.1	0.3	0.0	0.2

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	573	873	1,088	1,036	1,177	1,203	100	100	100	2.2	-0.4	0.8	0.2	0.6
Coal	55	118	234	349	325	308	13	34	26	7.1	2.9	-0.4	-0.5	-0.5
Oil	265	284	179	116	60	59	33	11	4.9	-4.5	-3.0	-4.1	-0.1	-2.6
Natural gas	81	171	254	421	411	446	20	41	37	4.0	3.7	-0.1	0.8	0.2
Nuclear	83	202	322	-	156	132	23	-	11	4.8	-100	n.a.	-1.7	n.a.
Hydro	88	87	85	82	94	94	10.0	7.9	7.9	-0.2	-0.3	0.9	0.0	0.6
Geothermal	0.9	1.7	3.3	2.6	8.7	10	0.2	0.2	0.8	6.8	-1.9	7.9	1.6	5.4
Solar, wind, etc.	-	0.0	0.5	30	76	100	0.0	2.9	8.3	84.4	34.7	6.0	2.8	4.8
Biomass and waste	-	9.6	10	36	46	52	1.1	3.4	4.4	0.7	9.3	1.7	1.2	1.5
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	2,894	4,553	5,093	5,650	6,582	7,354	1.1	0.7	1.0	1.1	1.0
Population (million)	117	124	127	127	120	114	0.3	0.0	-0.3	-0.6	-0.4
CO_2 emissions[*2] (Mt)	916	1,071	1,195	1,201	1,075	1,007	1.1	0.0	-0.7	-0.6	-0.7
GDP per capita ($2010 thousand)	25	37	40	44	55	65	0.9	0.7	1.3	1.7	1.5
Primary energy consump. per capita (toe)	3.0	3.6	4.1	3.5	3.8	3.8	1.4	-1.1	0.5	0.0	0.3
Primary energy consumption per GDP[*3]	119	96	102	78	69	58	0.5	-1.9	-0.8	-1.6	-1.1
CO_2 emissions per GDP[*2, *4]	317	235	235	213	163	137	0.0	-0.7	-1.6	-1.7	-1.7
CO_2 per primary energy consumption[*2, *5]	2.7	2.4	2.3	2.7	2.4	2.3	-0.6	1.2	-0.8	-0.1	-0.6
Automobile ownership (million)	38	58	72	77	74	71	2.3	0.4	-0.2	-0.4	-0.3
Automobile ownership rates[*6]	325	467	571	604	615	626	2.0	0.4	0.1	0.2	0.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A52 | Korea [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	41	93	188	268	321	318	100	100	100	7.3	2.6	1.1	-0.1	0.7
Coal	14	25	42	82	84	83	27	30	26	5.2	4.9	0.2	-0.2	0.0
Oil	27	50	99	96	103	100	54	36	31	7.1	-0.2	0.4	-0.3	0.2
Natural gas	-	2.7	17	43	50	51	2.9	16	16	20.1	6.9	0.9	0.2	0.6
Nuclear	0.9	14	28	41	76	76	15	15	24	7.5	2.6	4.0	0.0	2.4
Hydro	0.2	0.5	0.3	0.2	0.2	0.2	0.6	0.1	0.1	-4.5	-2.7	0.0	0.0	0.0
Geothermal	-	-	-	0.1	0.1	0.1	-	0.0	0.0	n.a.	n.a.	1.4	1.1	1.2
Solar, wind, etc.	-	0.0	0.0	0.5	1.5	2.6	0.0	0.2	0.8	15.8	18.5	7.6	5.5	6.8
Biomass and waste	-	0.7	1.4	5.6	5.8	5.8	0.8	2.1	1.8	6.6	10.5	0.3	-0.1	0.1

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	31	65	127	170	197	196	100	100	100	7.0	2.1	0.9	-0.1	0.5
Industry	10	19	38	49	58	57	30	29	29	7.2	1.8	1.0	-0.2	0.6
Transport	4.8	15	26	32	34	32	22	19	16	6.1	1.4	0.3	-0.6	0.0
Buildings, etc.	13	24	37	43	51	51	38	25	26	4.4	1.0	1.1	0.1	0.7
Non-energy use	3.1	6.7	25	46	54	56	10	27	29	14.0	4.5	1.0	0.3	0.7
Coal	9.7	12	9.1	11	10	8.5	18	6.4	4.3	-2.5	1.3	-0.4	-1.7	-0.9
Oil	19	44	80	87	94	92	67	51	47	6.2	0.6	0.5	-0.2	0.2
Natural gas	-	0.7	11	22	26	25	1.0	13	13	32.1	5.2	0.9	-0.1	0.5
Electricity	2.8	8.1	23	42	59	62	13	25	32	10.8	4.5	2.2	0.5	1.6
Heat	-	-	3.3	4.6	4.1	3.9	-	2.7	2.0	n.a.	2.4	-0.7	-0.4	-0.6
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	-	0.7	1.3	4.2	4.1	4.0	1.1	2.5	2.0	5.9	8.7	-0.2	-0.3	-0.2

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	37	105	289	546	747	788	100	100	100	10.6	4.7	2.0	0.5	1.4
Coal	2.5	18	111	232	267	285	17	42	36	20.2	5.4	0.9	0.7	0.8
Oil	29	19	35	17	7.7	6.1	18	3.2	0.8	6.3	-4.8	-4.9	-2.4	-4.0
Natural gas	-	9.6	29	130	157	169	9.1	24	21	11.9	11.2	1.2	0.7	1.0
Nuclear	3.5	53	109	156	291	291	50	29	37	7.5	2.6	4.0	0.0	2.4
Hydro	2.0	6.4	4.0	2.8	2.8	2.8	6.0	0.5	0.3	-4.5	-2.7	0.0	0.0	0.0
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	0.0	5.1	17	30	0.0	0.9	3.8	36.2	47.6	7.8	5.6	7.0
Biomass and waste	-	-	0.1	2.2	3.2	3.7	-	0.4	0.5	n.a.	25.2	2.5	1.5	2.1
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	149	377	710	1,234	1,878	2,270	6.5	4.0	2.7	1.9	2.4
Population (million)	38	43	47	50	53	52	0.9	0.5	0.3	0.0	0.1
CO_2 emissions[*2] (Mt)	126	239	433	578	599	582	6.1	2.1	0.2	-0.3	0.0
GDP per capita ($2010 thousand)	3.9	8.8	15	24	36	43	5.6	3.5	2.4	2.0	2.2
Primary energy consump. per capita (toe)	1.1	2.2	4.0	5.3	6.1	6.1	6.3	2.1	0.8	0.0	0.5
Primary energy consumption per GDP[*3]	277	246	265	218	171	140	0.7	-1.4	-1.5	-1.9	-1.7
CO_2 emissions per GDP[*2, *4]	845	634	610	469	319	256	-0.4	-1.9	-2.4	-2.2	-2.3
CO_2 per primary energy consumption[*2, *5]	3.1	2.6	2.3	2.2	1.9	1.8	-1.1	-0.5	-0.9	-0.2	-0.6
Automobile ownership (million)	0.5	3.4	12	20	25	28	13.5	3.7	1.5	1.0	1.3
Automobile ownership rates[*6]	14	79	257	399	483	535	12.5	3.2	1.2	1.0	1.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A53 | Chinese Taipei [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	28	48	85	110	125	127	100	100	100	5.9	1.9	0.8	0.1	0.5
Coal	3.9	11	30	41	41	40	24	37	31	10.2	2.3	0.0	-0.3	-0.1
Oil	20	26	38	42	47	47	54	38	37	4.0	0.7	0.6	0.0	0.4
Natural gas	1.6	1.4	5.6	14	26	28	2.9	12	22	14.8	6.6	4.0	0.8	2.8
Nuclear	2.1	8.6	10	11	8.0	8.0	18	10	6.3	1.6	0.7	-2.0	0.0	-1.2
Hydro	0.3	0.5	0.4	0.4	0.4	0.4	1.1	0.3	0.3	-3.3	-0.4	0.0	0.0	0.0
Geothermal	-	0.0	-	-	-	-	0.0	-	-	-100	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	0.1	0.3	0.8	1.2	0.0	0.3	0.9	14.7	10.3	6.7	4.0	5.7
Biomass and waste	-	-	0.6	1.7	2.7	3.1	-	1.5	2.4	n.a.	7.4	3.1	1.2	2.4

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	19	29	49	68	79	81	100	100	100	5.2	2.4	1.0	0.2	0.7
Industry	10	12	19	23	27	27	42	34	34	4.5	1.2	1.1	0.1	0.7
Transport	2.9	6.6	12	12	13	13	22	18	16	5.7	0.4	0.4	-0.2	0.2
Buildings, etc.	3.6	6.5	10	12	13	14	22	17	17	4.6	1.1	0.6	0.4	0.5
Non-energy use	2.0	4.0	7.8	21	26	27	14	31	34	7.0	7.4	1.3	0.4	1.0
Coal	2.2	3.6	5.0	7.6	9.2	9.5	12	11	12	3.3	3.1	1.2	0.3	0.9
Oil	12	18	28	37	42	42	62	55	52	4.4	2.0	0.8	0.0	0.5
Natural gas	1.4	0.9	1.6	2.7	3.2	3.5	3.0	4.0	4.4	5.9	4.1	1.1	0.9	1.0
Electricity	3.2	6.6	14	20	24	25	22	29	31	7.6	2.7	1.2	0.4	0.9
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	-	0.0	0.1	0.3	0.4	0.4	0.1	0.5	0.5	18.7	8.5	1.2	0.3	0.8

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	43	88	181	257	307	320	100	100	100	7.4	2.6	1.1	0.4	0.8
Coal	6.0	24	88	125	118	113	28	49	35	13.7	2.5	-0.4	-0.4	-0.4
Oil	26	23	30	8.6	5.8	5.4	26	3.3	1.7	2.5	-8.6	-2.4	-0.8	-1.7
Natural gas	-	1.2	17	70	134	146	1.4	27	46	30.3	10.5	4.1	0.9	2.9
Nuclear	8.2	33	39	42	31	31	37	16	9.6	1.6	0.7	-2.0	0.0	-1.2
Hydro	2.9	6.4	4.6	4.3	4.3	4.3	7.2	1.7	1.3	-3.3	-0.4	0.0	0.0	0.0
Geothermal	-	0.0	-	-	-	-	0.0	-	-	-100	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	0.0	2.1	7.7	12	-	0.8	3.7	n.a.	72.4	8.6	4.6	7.0
Biomass and waste	-	-	1.7	3.7	7.2	8.2	-	1.4	2.6	n.a.	5.7	4.2	1.3	3.1
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	73	162	309	523	723	845	6.7	3.8	2.1	1.6	1.9
Population (million)	18	20	22	23	23	22	0.9	0.4	-0.1	-0.4	-0.2
CO_2 emissions[*2] (Mt)	74	115	225	259	286	282	6.9	1.0	0.6	-0.1	0.3
GDP per capita ($2010 thousand)	4.1	7.9	14	22	31	38	5.8	3.4	2.1	1.9	2.1
Primary energy consump. per capita (toe)	1.6	2.3	3.8	4.7	5.4	5.7	5.0	1.5	0.9	0.5	0.7
Primary energy consumption per GDP[*3]	380	295	274	211	173	150	-0.7	-1.9	-1.2	-1.4	-1.3
CO_2 emissions per GDP[*2, *4]	1,015	714	727	495	395	334	0.2	-2.7	-1.4	-1.7	-1.5
CO_2 per primary energy consumption[*2, *5]	2.7	2.4	2.6	2.3	2.3	2.2	0.9	-0.9	-0.2	-0.3	-0.2
Automobile ownership (million)	0.5	2.9	5.5	7.5	8.6	9.0	6.7	2.2	0.9	0.5	0.7
Automobile ownership rates[*6]	27	141	249	320	373	405	5.8	1.8	1.0	0.8	0.9

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A54 | ASEAN [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	n.a.	n.a.	385	624	1,046	1,352	n.a.	100	100	n.a.	3.5	3.3	2.6	3.0
Coal	n.a.	n.a.	32	99	239	348	n.a.	16	26	n.a.	8.4	5.6	3.9	5.0
Oil	n.a.	n.a.	154	221	334	421	n.a.	35	31	n.a.	2.6	2.6	2.3	2.5
Natural gas	n.a.	n.a.	74	139	218	278	n.a.	22	21	n.a.	4.6	2.9	2.4	2.7
Nuclear	n.a.	n.a.	-	-	9.1	30	n.a.	-	2.2	n.a.	n.a.	n.a.	12.5	n.a.
Hydro	n.a.	n.a.	4.4	11	19	25	n.a.	1.8	1.8	n.a.	6.8	3.6	2.5	3.2
Geothermal	n.a.	n.a.	18	26	80	101	n.a.	4.2	7.4	n.a.	2.5	7.3	2.3	5.3
Solar, wind, etc.	n.a.	n.a.	0.0	0.2	1.1	2.7	n.a.	0.0	0.2	n.a.	72.9	11.7	9.3	10.7
Biomass and waste	n.a.	n.a.	102	127	145	148	n.a.	20	11	n.a.	1.6	0.8	0.2	0.6

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	n.a.	n.a.	274	441	695	892	n.a.	100	100	n.a.	3.4	2.9	2.5	2.7
Industry	n.a.	n.a.	76	121	221	296	n.a.	28	33	n.a.	3.4	3.8	3.0	3.5
Transport	n.a.	n.a.	62	118	186	237	n.a.	27	27	n.a.	4.7	2.9	2.4	2.7
Buildings, etc.	n.a.	n.a.	116	154	216	268	n.a.	35	30	n.a.	2.0	2.2	2.2	2.2
Non-energy use	n.a.	n.a.	21	48	72	91	n.a.	11	10	n.a.	6.0	2.6	2.4	2.5
Coal	n.a.	n.a.	13	29	54	68	n.a.	6.6	7.6	n.a.	5.7	3.9	2.3	3.3
Oil	n.a.	n.a.	123	197	309	395	n.a.	45	44	n.a.	3.4	2.9	2.5	2.7
Natural gas	n.a.	n.a.	17	38	73	102	n.a.	8.5	11	n.a.	5.9	4.2	3.5	3.9
Electricity	n.a.	n.a.	28	65	141	210	n.a.	15	24	n.a.	6.4	4.9	4.1	4.6
Heat	n.a.	n.a.	-	-	-	-	n.a.	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	n.a.	n.a.	-	-	0.0	0.0	n.a.	-	0.0	n.a.	n.a.	n.a.	6.9	n.a.
Renewables	n.a.	n.a.	93	112	119	117	n.a.	25	13	n.a.	1.3	0.4	-0.2	0.2

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	n.a.	n.a.	374	854	1,864	2,769	n.a.	100	100	n.a.	6.1	5.0	4.0	4.6
Coal	n.a.	n.a.	79	283	813	1,303	n.a.	33	47	n.a.	9.5	6.8	4.8	6.0
Oil	n.a.	n.a.	72	38	30	26	n.a.	4.4	0.9	n.a.	-4.5	-1.5	-1.4	-1.5
Natural gas	n.a.	n.a.	154	371	662	898	n.a.	43	32	n.a.	6.5	3.7	3.1	3.5
Nuclear	n.a.	n.a.	-	-	35	114	n.a.	-	4.1	n.a.	n.a.	n.a.	12.5	n.a.
Hydro	n.a.	n.a.	51	128	224	288	n.a.	15	10	n.a.	6.8	3.6	2.5	3.2
Geothermal	n.a.	n.a.	16	20	56	69	n.a.	2.4	2.5	n.a.	1.5	6.5	2.1	4.8
Solar, wind, etc.	n.a.	n.a.	0.0	2.2	13	32	n.a.	0.3	1.1	n.a.	73.4	11.7	9.3	10.7
Biomass and waste	n.a.	n.a.	1.0	12	32	42	n.a.	1.4	1.5	n.a.	19.3	6.4	2.8	5.0
Hydrogen	n.a.	n.a.	-	-	-	-	n.a.	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	422	735	1,188	2,407	5,071	7,488	4.9	5.2	4.8	4.0	4.5
Population (million)	357	443	523	623	723	765	1.7	1.3	0.9	0.6	0.8
CO_2 emissions[*2] (Mt)	n.a.	n.a.	713	1,258	2,328	3,137	n.a.	4.1	3.9	3.0	3.6
GDP per capita ($2010 thousand)	1.2	1.7	2.3	3.9	7.0	9.8	3.2	3.9	3.8	3.4	3.6
Primary energy consump. per capita (toe)	n.a.	n.a.	0.7	1.0	1.4	1.8	n.a.	2.2	2.3	2.0	2.2
Primary energy consumption per GDP[*3]	n.a.	n.a.	324	259	206	181	n.a.	-1.6	-1.4	-1.3	-1.4
CO_2 emissions per GDP[*2, *4]	n.a.	n.a.	601	523	459	419	n.a.	-1.0	-0.8	-0.9	-0.8
CO_2 per primary energy consumption[*2, *5]	n.a.	n.a.	1.9	2.0	2.2	2.3	n.a.	0.6	0.6	0.4	0.5
Automobile ownership (million)	n.a.	n.a.	21	55	106	145	n.a.	7.2	4.3	3.1	3.8
Automobile ownership rates[*6]	n.a.	n.a.	40	88	147	189	n.a.	5.8	3.3	2.5	3.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A55 | Indonesia [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	56	99	156	226	417	556	100	100	100	4.7	2.7	3.9	2.9	3.5
Coal	0.2	3.5	12	36	88	136	3.6	16	25	13.0	8.2	5.7	4.5	5.3
Oil	20	33	58	75	128	163	34	33	29	5.7	1.9	3.4	2.5	3.0
Natural gas	4.9	16	27	37	73	104	16	16	19	5.3	2.3	4.4	3.7	4.1
Nuclear	-	-	-	-	-	5.1	-	-	0.9	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.5	0.9	1.3	1.6	1.7	0.5	0.6	0.3	5.8	3.0	1.4	0.7	1.1
Geothermal	-	1.9	8.4	17	65	83	2.0	7.7	15	15.8	5.3	8.6	2.5	6.2
Solar, wind, etc.	-	-	-	0.0	0.0	0.1	-	0.0	0.0	n.a.	n.a.	22.9	11.8	18.5
Biomass and waste	30	44	50	59	62	62	44	26	11	1.4	1.2	0.3	0.0	0.2

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	50	80	120	165	274	360	100	100	100	4.2	2.3	3.2	2.8	3.0
Industry	6.7	18	30	39	81	116	23	24	32	5.2	1.9	4.6	3.7	4.2
Transport	6.0	11	21	46	84	110	13	28	31	6.9	5.8	3.8	2.8	3.4
Buildings, etc.	36	44	59	72	97	117	55	44	33	3.1	1.4	1.8	2.0	1.9
Non-energy use	1.2	7.4	9.8	7.7	12	16	9.2	4.7	4.4	2.9	-1.7	2.9	2.6	2.8
Coal	0.1	2.2	4.7	6.6	15	20	2.7	4.0	5.6	7.8	2.5	5.4	2.8	4.4
Oil	17	27	48	67	118	153	34	40	43	5.8	2.4	3.7	2.6	3.3
Natural gas	2.4	6.0	12	17	39	59	7.5	10	16	6.7	2.8	5.3	4.3	4.9
Electricity	0.6	2.4	6.8	17	41	67	3.0	10	19	10.8	6.8	5.7	4.9	5.4
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	29	42	49	58	60	60	53	35	17	1.6	1.2	0.3	-0.1	0.1

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	7.5	33	93	229	553	890	100	100	100	11.1	6.6	5.7	4.9	5.4
Coal	-	9.8	34	120	322	545	30	53	61	13.3	9.4	6.4	5.4	6.0
Oil	6.2	15	18	26	22	21	47	11	2.3	1.8	2.5	-0.9	-0.9	-0.9
Natural gas	-	0.7	26	56	148	232	2.2	25	26	42.9	5.6	6.2	4.6	5.6
Nuclear	-	-	-	-	-	20	-	-	2.2	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	1.3	5.7	10	15	19	20	17	6.6	2.3	5.8	3.0	1.4	0.7	1.1
Geothermal	-	1.1	4.9	10	38	48	3.4	4.4	5.4	15.8	5.3	8.6	2.5	6.2
Solar, wind, etc.	-	-	-	0.0	0.3	0.9	-	0.0	0.1	n.a.	n.a.	22.9	11.8	18.5
Biomass and waste	-	-	0.0	1.0	2.6	3.5	-	0.4	0.4	n.a.	43.7	6.5	2.9	5.1
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	162	300	453	943	2,193	3,334	4.2	5.4	5.4	4.3	5.0
Population (million)	147	181	212	254	295	312	1.5	1.3	0.9	0.6	0.8
CO_2 emissions[*2] (Mt)	71	134	262	439	878	1,244	6.9	3.8	4.4	3.5	4.1
GDP per capita ($2010 thousand)	1.1	1.7	2.1	3.7	7.4	11	2.6	4.0	4.4	3.7	4.2
Primary energy consump. per capita (toe)	0.4	0.5	0.7	0.9	1.4	1.8	3.1	1.3	2.9	2.3	2.7
Primary energy consumption per GDP[*3]	345	329	343	239	190	167	0.4	-2.5	-1.4	-1.3	-1.4
CO_2 emissions per GDP[*2, *4]	442	447	578	466	400	373	2.6	-1.5	-0.9	-0.7	-0.8
CO_2 per primary energy consumption[*2, *5]	1.3	1.4	1.7	1.9	2.1	2.2	2.2	1.0	0.5	0.6	0.5
Automobile ownership (million)	1.3	2.8	5.4	20	48	69	6.8	9.7	5.8	3.7	4.9
Automobile ownership rates[*6]	8.8	15	26	78	164	222	5.2	8.3	4.8	3.1	4.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A56 | Malaysia [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	12	22	49	90	126	152	100	100	100	8.4	4.4	2.1	1.9	2.0
Coal	0.1	1.4	2.3	15	35	46	6.2	17	31	5.5	14.4	5.3	2.9	4.4
Oil	7.9	11	19	33	43	48	53	37	32	5.4	3.9	1.6	1.2	1.5
Natural gas	2.2	6.8	25	38	43	46	31	43	31	13.8	3.2	0.7	0.7	0.7
Nuclear	-	-	-	-	-	5.1	-	-	3.4	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.3	0.6	1.2	2.0	2.8	1.6	1.3	1.8	5.7	4.8	3.6	3.1	3.4
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.0	0.1	0.3	-	0.0	0.2	n.a.	n.a.	12.4	8.8	11.0
Biomass and waste	1.6	1.9	1.9	1.9	2.5	2.8	8.5	2.1	1.9	0.0	0.0	1.8	1.3	1.6

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	7.2	14	30	53	78	96	100	100	100	7.9	4.2	2.4	2.1	2.3
Industry	3.1	5.6	12	15	24	31	40	29	32	7.8	2.0	2.8	2.6	2.7
Transport	2.1	4.9	11	22	29	33	35	42	34	8.3	5.3	1.7	1.1	1.5
Buildings, etc.	1.7	2.6	5.0	9.4	15	20	19	18	21	6.6	4.6	3.2	2.7	3.0
Non-energy use	0.3	0.8	2.2	6.2	9.6	12	6.0	12	13	10.4	7.5	2.8	2.3	2.6
Coal	0.1	0.5	1.0	1.7	2.7	4.1	3.7	3.2	4.2	6.8	4.0	2.9	4.1	3.4
Oil	5.3	9.3	18	29	39	44	67	55	46	7.0	3.4	1.8	1.2	1.6
Natural gas	0.0	1.1	3.9	9.6	15	18	7.9	18	19	13.5	6.7	2.6	2.3	2.5
Electricity	0.7	1.7	5.3	11	21	28	12	21	29	11.9	5.7	3.8	3.1	3.5
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	-	-	0.0	n.a.	n.a.	n.a.	6.7	n.a.
Renewables	1.0	1.3	1.3	1.1	1.4	1.5	9.1	2.1	1.6	0.4	-1.1	1.2	1.0	1.1

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	10	23	69	147	262	355	100	100	100	11.6	5.5	3.6	3.1	3.4
Coal	-	2.9	7.7	56	141	192	13	38	54	10.1	15.2	6.0	3.1	4.9
Oil	8.5	11	3.6	3.5	0.7	0.3	46	2.4	0.1	-10.2	-0.2	-9.6	-9.1	-9.4
Natural gas	0.1	5.5	51	74	93	104	24	50	29	24.9	2.7	1.4	1.2	1.3
Nuclear	-	-	-	-	-	20	-	-	5.5	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	1.4	4.0	7.0	13	24	32	17	9.1	9.1	5.7	4.8	3.6	3.1	3.4
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.2	1.5	3.5	-	0.2	1.0	n.a.	n.a.	12.4	8.8	11.0
Biomass and waste	-	-	-	0.7	1.8	2.5	-	0.5	0.7	n.a.	n.a.	6.2	2.9	4.9
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	46	82	163	314	633	896	7.1	4.8	4.5	3.5	4.1
Population (million)	14	18	23	30	36	39	2.5	1.8	1.2	0.7	1.0
CO_2 emissions[*2] (Mt)	29	54	121	236	347	410	8.3	4.9	2.4	1.7	2.1
GDP per capita ($2010 thousand)	3.3	4.5	6.9	11	18	23	4.4	3.0	3.2	2.8	3.1
Primary energy consump. per capita (toe)	0.9	1.2	2.1	3.0	3.5	3.9	5.7	2.6	0.9	1.2	1.0
Primary energy consumption per GDP[*3]	260	267	301	285	198	170	1.2	-0.4	-2.2	-1.6	-2.0
CO_2 emissions per GDP[*2, *4]	630	665	744	751	548	457	1.1	0.1	-2.0	-1.8	-1.9
CO_2 per primary energy consumption[*2, *5]	2.4	2.5	2.5	2.6	2.8	2.7	-0.1	0.4	0.3	-0.2	0.1
Automobile ownership (million)	0.9	2.4	5.2	12	18	21	8.0	6.3	2.3	1.5	2.0
Automobile ownership rates[*6]	65	133	224	414	492	532	5.3	4.5	1.1	0.8	1.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million, *4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A57 | Myanmar [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	9.4	11	13	19	31	41	100	100	100	1.9	3.0	3.1	2.7	2.9
Coal	0.2	0.1	0.3	0.4	4.3	8.9	0.6	2.1	22	17.0	1.8	15.8	7.5	12.5
Oil	1.3	0.7	2.0	5.1	8.3	12	6.8	26	30	10.5	7.0	3.1	4.0	3.4
Natural gas	0.3	0.8	1.2	2.1	6.2	6.7	7.1	11	16	4.6	4.1	7.0	0.9	4.6
Nuclear	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.1	0.2	0.8	1.7	2.8	1.0	3.9	6.7	4.7	11.6	5.1	5.1	5.1
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	-	0.0	0.0	-	-	0.1	n.a.	n.a.	n.a.	3.2	n.a.
Biomass and waste	7.6	9.0	9.2	11	12	13	84	57	31	0.2	1.3	0.7	0.4	0.6

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	8.4	9.4	11	17	24	32	100	100	100	2.0	2.8	2.3	2.6	2.4
Industry	0.6	0.4	1.2	2.0	4.6	6.8	4.2	12	22	11.3	4.2	5.2	4.0	4.7
Transport	0.6	0.4	1.2	2.5	4.1	7.0	4.7	15	22	10.0	5.6	3.3	5.3	4.1
Buildings, etc.	7.0	8.5	9.1	12	15	17	90	72	55	0.7	2.1	1.4	1.3	1.3
Non-energy use	0.1	0.1	0.1	0.3	0.4	0.5	1.0	1.5	1.6	-0.1	7.5	3.3	1.9	2.8
Coal	0.1	0.1	0.3	0.3	0.4	0.5	0.5	2.0	1.5	20.1	0.4	1.2	1.1	1.2
Oil	1.2	0.6	1.5	4.2	7.4	11	6.2	24	36	10.0	7.4	3.6	4.4	3.9
Natural gas	0.1	0.2	0.3	0.7	1.5	2.2	2.4	4.1	6.9	3.7	5.6	4.9	3.8	4.5
Electricity	0.1	0.1	0.3	0.9	2.9	4.9	1.6	5.1	16	6.5	8.3	7.8	5.5	6.9
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	-	-	0.0	n.a.	n.a.	n.a.	8.0	n.a.
Renewables	6.9	8.4	9.0	11	12	13	89	64	40	0.7	1.4	0.7	0.4	0.6

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	1.5	2.5	5.1	14	60	102	100	100	100	7.5	7.5	9.5	5.3	7.9
Coal	0.0	0.0	-	0.3	18	40	1.6	2.0	40	-100	n.a.	29.3	8.7	21.0
Oil	0.5	0.3	0.7	0.1	0.1	0.1	11	0.5	0.1	9.8	-15.5	0.0	0.0	0.0
Natural gas	0.2	1.0	2.5	5.0	23	28	39	35	28	10.0	4.9	10.0	2.2	6.9
Nuclear	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	0.8	1.2	1.9	8.8	20	32	48	62	32	4.7	11.6	5.1	5.1	5.1
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	-	0.4	0.5	-	-	0.5	n.a.	n.a.	n.a.	3.2	n.a.
Biomass and waste	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	5.9	6.7	13	55	155	255	7.2	10.7	6.6	5.1	6.0
Population (million)	34	42	48	53	60	63	1.3	0.8	0.8	0.4	0.6
CO_2 emissions[*2] (Mt)	5.2	4.1	9.9	21	56	87	9.3	5.7	6.1	4.6	5.5
GDP per capita ($2010 thousand)	0.2	0.2	0.3	1.0	2.6	4.1	5.8	9.8	5.9	4.7	5.4
Primary energy consump. per capita (toe)	0.3	0.3	0.3	0.4	0.5	0.7	0.6	2.1	2.3	2.3	2.3
Primary energy consumption per GDP[*3]	1,606	1,602	966	349	202	161	-4.9	-7.0	-3.3	-2.2	-2.9
CO_2 emissions per GDP[*2, *4]	893	609	745	388	360	342	2.0	-4.6	-0.5	-0.5	-0.5
CO_2 per primary energy consumption[*2, *5]	0.6	0.4	0.8	1.1	1.8	2.1	7.3	2.6	3.0	1.8	2.5
Automobile ownership (million)	0.1	0.1	0.3	0.7	2.2	4.8	13.9	7.7	7.3	8.1	7.6
Automobile ownership rates[*6]	2.2	1.6	5.3	13	37	77	12.5	6.8	6.5	7.7	7.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A58 | Philippines [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	22	29	40	48	97	136	100	100	100	3.4	1.3	4.5	3.4	4.1
Coal	0.5	1.5	5.2	12	35	53	5.3	24	39	13.0	6.0	7.0	4.3	6.0
Oil	10	11	16	15	24	33	38	31	24	4.0	-0.6	3.2	2.9	3.1
Natural gas	-	-	0.0	3.1	13	25	-	6.4	18	n.a.	51.9	9.5	6.5	8.3
Nuclear	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	0.3	0.5	0.7	0.8	0.8	0.8	1.8	1.6	0.6	2.6	1.1	0.0	0.0	0.0
Geothermal	1.8	4.7	10.0	8.9	15	17	16	19	13	7.8	-0.9	3.5	1.2	2.6
Solar, wind, etc.	-	-	-	0.0	0.2	0.4	-	0.0	0.3	n.a.	n.a.	16.7	8.3	13.4
Biomass and waste	9.4	11	8.1	8.5	8.7	7.6	39	18	5.6	-3.1	0.3	0.1	-1.3	-0.4

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	17	20	24	27	52	73	100	100	100	2.0	0.9	4.1	3.6	3.9
Industry	3.4	4.7	5.3	7.1	15	23	24	26	31	1.4	2.1	4.8	4.0	4.5
Transport	3.5	4.5	8.1	9.2	17	25	23	34	34	6.0	0.9	4.1	3.7	3.9
Buildings, etc.	9.4	10	10	10	19	25	52	38	34	-0.1	0.1	3.7	3.0	3.5
Non-energy use	0.3	0.2	0.3	0.5	0.6	0.7	1.2	1.7	1.0	1.8	3.6	1.9	1.9	1.9
Coal	0.2	0.6	0.8	2.3	4.3	5.8	3.1	8.7	7.9	2.3	8.2	3.9	3.0	3.5
Oil	7.0	8.1	13	13	23	32	41	48	43	4.9	-0.1	3.7	3.2	3.5
Natural gas	-	-	-	0.1	0.7	1.3	-	0.3	1.7	n.a.	n.a.	14.6	6.2	11.3
Electricity	1.5	1.8	3.1	5.4	17	29	9.3	20	39	5.6	4.0	7.4	5.4	6.6
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	-	-	0.0	n.a.	n.a.	n.a.	9.2	n.a.
Renewables	7.8	9.1	6.9	6.2	6.5	5.9	46	23	8.1	-2.7	-0.7	0.3	-1.0	-0.2

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	18	26	45	77	241	406	100	100	100	5.6	3.9	7.4	5.3	6.6
Coal	0.2	1.9	17	33	127	217	7.3	43	53	24.0	5.0	8.8	5.5	7.5
Oil	12	12	9.2	5.7	3.9	2.4	47	7.4	0.6	-3.0	-3.3	-2.4	-4.8	-3.3
Natural gas	-	-	0.0	19	80	152	-	24	37	n.a.	64.9	9.5	6.6	8.4
Nuclear	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	3.5	6.1	7.8	9.1	9.1	9.1	23	12	2.3	2.6	1.1	0.0	0.0	0.0
Geothermal	2.1	5.5	12	10	18	20	21	13	5.0	7.8	-0.9	3.5	1.2	2.6
Solar, wind, etc.	-	-	-	0.2	2.0	4.5	-	0.2	1.1	n.a.	n.a.	16.7	8.3	13.4
Biomass and waste	-	0.4	-	0.2	0.5	0.7	1.6	0.3	0.2	-100	n.a.	6.6	2.9	5.1
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	80	95	125	251	589	899	2.9	5.1	5.5	4.3	5.0
Population (million)	47	62	78	99	124	137	2.3	1.7	1.4	1.0	1.3
CO_2 emissions[*2] (Mt)	33	39	69	98	241	364	6.0	2.5	5.8	4.2	5.2
GDP per capita ($2010 thousand)	1.7	1.5	1.6	2.5	4.8	6.6	0.5	3.3	4.0	3.2	3.7
Primary energy consump. per capita (toe)	0.5	0.5	0.5	0.5	0.8	1.0	1.0	-0.5	3.1	2.4	2.8
Primary energy consumption per GDP[*3]	280	304	319	190	165	151	0.5	-3.6	-0.9	-0.9	-0.9
CO_2 emissions per GDP[*2, *4]	414	409	550	389	409	405	3.0	-2.4	0.3	-0.1	0.2
CO_2 per primary energy consumption[*2, *5]	1.5	1.3	1.7	2.0	2.5	2.7	2.5	1.2	1.2	0.8	1.0
Automobile ownership (million)	0.9	1.2	2.4	3.5	8.1	13	7.2	2.6	5.4	5.1	5.3
Automobile ownership rates[*6]	18	20	31	35	66	97	4.7	0.8	4.0	4.0	4.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A59 | Thailand [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	22	42	72	135	195	232	100	100	100	5.6	4.5	2.3	1.8	2.1
Coal	0.5	3.8	7.7	16	31	37	9.1	12	16	7.2	5.3	4.3	1.9	3.3
Oil	11	18	32	54	73	88	43	40	38	5.9	3.8	1.9	2.0	1.9
Natural gas	-	5.0	17	38	49	53	12	28	23	13.3	5.7	1.6	0.8	1.3
Nuclear	-	-	-	-	2.6	7.7	-	-	3.3	n.a.	n.a.	n.a.	11.6	n.a.
Hydro	0.1	0.4	0.5	0.5	0.5	0.5	1.0	0.4	0.2	1.9	-0.6	0.5	0.5	0.5
Geothermal	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	-4.8	9.6	1.2	6.3
Solar, wind, etc.	-	-	-	0.1	0.6	1.5	-	0.1	0.6	n.a.	n.a.	9.3	9.5	9.4
Biomass and waste	11	15	15	26	37	40	35	19	17	-0.1	4.1	2.2	0.9	1.7

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	15	29	51	96	135	161	100	100	100	5.8	4.7	2.2	1.8	2.0
Industry	4.0	8.7	17	29	47	57	30	31	35	6.8	4.1	3.0	1.9	2.6
Transport	3.2	9.0	15	22	23	24	31	23	15	5.0	3.0	0.3	0.1	0.3
Buildings, etc.	7.8	11	14	21	29	36	37	22	22	2.4	3.3	2.0	2.0	2.0
Non-energy use	0.2	0.4	5.6	23	35	46	1.5	24	28	29.4	10.6	2.7	2.5	2.7
Coal	0.1	1.3	3.5	6.4	13	15	4.5	6.7	9.2	10.5	4.3	4.4	1.5	3.3
Oil	7.3	15	29	52	69	85	52	54	52	6.9	4.2	1.9	2.0	1.9
Natural gas	-	0.1	1.1	7.4	12	14	0.5	7.8	8.7	23.1	14.6	2.8	1.9	2.5
Electricity	1.1	3.3	7.6	15	24	31	11	15	19	8.7	4.8	3.1	2.8	3.0
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	6.7	9.2	9.4	16	18	17	32	17	10	0.2	3.8	0.6	-0.4	0.2

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	14	44	96	174	273	349	100	100	100	8.1	4.3	2.9	2.5	2.7
Coal	1.4	11	18	38	77	101	25	22	29	4.9	5.5	4.6	2.8	3.9
Oil	12	10	10	1.7	1.6	1.5	23	1.0	0.4	-0.3	-12.0	-0.4	-0.5	-0.5
Natural gas	-	18	62	119	148	163	40	68	47	13.2	4.8	1.4	0.9	1.2
Nuclear	-	-	-	-	9.8	29	-	-	8.4	n.a.	n.a.	n.a.	11.6	n.a.
Hydro	1.3	5.0	6.0	5.5	6.0	6.3	11	3.2	1.8	1.9	-0.6	0.5	0.5	0.5
Geothermal	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.2	-4.8	9.6	1.2	6.3
Solar, wind, etc.	-	-	-	1.7	7.0	17	-	1.0	5.0	n.a.	n.a.	9.3	9.5	9.4
Biomass and waste	-	-	0.5	8.5	24	31	-	4.9	9.0	n.a.	22.3	6.6	2.9	5.1
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	67	142	218	383	643	881	4.4	4.1	3.3	3.2	3.3
Population (million)	47	57	63	68	68	66	1.0	0.6	0.0	-0.3	-0.1
CO_2 emissions[*2] (Mt)	34	81	152	248	354	407	6.5	3.6	2.2	1.4	1.9
GDP per capita ($2010 thousand)	1.4	2.5	3.5	5.6	9.4	13	3.3	3.5	3.3	3.5	3.4
Primary energy consump. per capita (toe)	0.5	0.7	1.2	2.0	2.9	3.5	4.5	4.0	2.3	2.1	2.2
Primary energy consumption per GDP[*3]	331	296	332	352	303	263	1.1	0.4	-0.9	-1.4	-1.1
CO_2 emissions per GDP[*2, *4]	512	570	697	648	550	462	2.0	-0.5	-1.0	-1.7	-1.3
CO_2 per primary energy consumption[*2, *5]	1.5	1.9	2.1	1.8	1.8	1.8	0.9	-0.9	-0.1	-0.3	-0.2
Automobile ownership (million)	0.9	2.8	6.1	16	23	25	8.1	6.9	2.4	0.9	1.8
Automobile ownership rates[*6]	19	50	98	230	333	377	7.0	6.3	2.3	1.2	1.9

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A60 | Viet Nam [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	14	18	29	67	126	173	100	100	100	4.9	6.2	4.1	3.2	3.7
Coal	2.3	2.2	4.4	19	42	62	12	29	36	7.0	11.1	5.0	4.1	4.6
Oil	1.8	2.7	7.8	18	33	46	15	27	27	11.2	6.1	3.8	3.4	3.7
Natural gas	-	0.0	1.1	8.9	20	28	0.0	13	16	82.6	16.0	5.1	3.5	4.5
Nuclear	-	-	-	-	6.6	12	-	-	6.8	n.a.	n.a.	n.a.	5.9	n.a.
Hydro	0.1	0.5	1.3	5.0	9.0	10	2.6	7.6	5.8	10.5	10.5	3.7	1.2	2.7
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.0	0.1	0.3	-	0.0	0.2	n.a.	n.a.	19.1	10.0	15.5
Biomass and waste	10	12	14	15	15	14	70	23	7.9	1.3	0.6	-0.1	-1.1	-0.5

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	13	16	25	56	95	125	100	100	100	4.6	5.8	3.4	2.8	3.2
Industry	3.8	4.5	7.9	21	40	52	28	38	41	5.7	7.4	4.0	2.6	3.5
Transport	0.6	1.4	3.5	11	20	28	8.6	19	23	9.7	8.3	4.1	3.5	3.8
Buildings, etc.	8.6	10	14	21	29	36	63	38	29	3.0	3.1	2.1	2.2	2.2
Non-energy use	0.0	0.0	0.1	2.8	5.8	8.7	0.2	5.0	7.0	16.9	24.3	4.8	4.2	4.5
Coal	1.5	1.3	3.2	12	18	22	8.3	21	18	9.3	9.6	2.9	2.1	2.6
Oil	1.7	2.3	6.5	17	32	45	15	31	36	10.8	7.2	4.0	3.5	3.8
Natural gas	-	-	0.0	1.0	2.6	3.9	-	1.8	3.1	n.a.	33.1	6.1	4.2	5.4
Electricity	0.2	0.5	1.9	11	28	41	3.3	20	33	13.7	13.4	5.9	3.9	5.1
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	9.7	12	13	14	14	13	74	26	10	1.2	0.5	-0.1	-1.1	-0.5

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	3.6	8.7	27	141	347	506	100	100	100	11.8	12.7	5.8	3.8	5.0
Coal	1.4	2.0	3.1	35	110	189	23	25	37	4.6	18.7	7.5	5.6	6.8
Oil	0.7	1.3	4.5	0.4	0.4	0.4	15	0.3	0.1	13.2	-15.2	0.0	0.0	0.0
Natural gas	-	0.0	4.4	47	106	150	0.1	34	30	93.2	18.6	5.2	3.5	4.6
Nuclear	-	-	-	-	25	45	-	-	8.9	n.a.	n.a.	n.a.	5.9	n.a.
Hydro	1.5	5.4	15	59	104	117	62	42	23	10.5	10.5	3.7	1.2	2.7
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.1	1.4	3.7	-	0.1	0.7	n.a.	n.a.	19.1	10.0	15.5
Biomass and waste	-	-	-	0.1	0.2	0.2	-	0.0	0.0	n.a.	n.a.	6.2	2.9	4.9
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	17	29	61	145	367	609	7.6	6.4	6.0	5.2	5.7
Population (million)	54	66	78	91	105	110	1.6	1.1	0.9	0.5	0.7
CO_2 emissions[*2] (Mt)	15	17	43	143	294	426	9.8	8.9	4.6	3.8	4.3
GDP per capita ($2010 thousand)	0.3	0.4	0.8	1.6	3.5	5.5	5.8	5.2	5.0	4.7	4.9
Primary energy consump. per capita (toe)	0.3	0.3	0.4	0.7	1.2	1.6	3.2	5.0	3.1	2.7	3.0
Primary energy consumption per GDP[*3]	851	606	470	460	343	284	-2.5	-0.2	-1.8	-1.9	-1.8
CO_2 emissions per GDP[*2, *4]	860	579	711	990	802	700	2.1	2.4	-1.3	-1.4	-1.3
CO_2 per primary energy consumption[*2, *5]	1.0	1.0	1.5	2.2	2.3	2.5	4.7	2.5	0.5	0.5	0.5
Automobile ownership (million)	0.1	0.2	0.4	1.3	5.4	9.5	9.2	9.5	9.1	5.9	7.9
Automobile ownership rates[*6]	2.6	2.3	4.8	15	51	87	7.5	8.3	8.2	5.4	7.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A61 | North America [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	1,997	2,126	2,527	2,496	2,524	2,499	100	100	100	1.7	-0.1	0.1	-0.1	0.0
Coal	397	485	565	451	320	239	23	18	9.5	1.6	-1.6	-2.1	-2.9	-2.4
Oil	885	833	958	880	834	801	39	35	32	1.4	-0.6	-0.3	-0.4	-0.4
Natural gas	522	493	622	713	836	893	23	29	36	2.3	1.0	1.0	0.7	0.9
Nuclear	80	179	227	245	234	234	8.4	9.8	9.4	2.4	0.5	-0.3	0.0	-0.2
Hydro	46	49	53	55	60	62	2.3	2.2	2.5	0.7	0.4	0.5	0.3	0.5
Geothermal	4.6	14	13	9.0	21	27	0.7	0.4	1.1	-0.7	-2.7	5.5	2.3	4.3
Solar, wind, etc.	-	0.3	2.1	23	57	74	0.0	0.9	3.0	20.6	18.5	6.0	2.7	4.7
Biomass and waste	62	73	87	121	161	169	3.4	4.8	6.8	1.8	2.3	1.8	0.5	1.3

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	1,466	1,455	1,738	1,738	1,782	1,783	100	100	100	1.8	0.0	0.2	0.0	0.1
Industry	437	331	388	317	325	327	23	18	18	1.6	-1.4	0.2	0.0	0.1
Transport	470	531	640	685	655	620	36	39	35	1.9	0.5	-0.3	-0.6	-0.4
Buildings, etc.	446	460	537	595	642	659	32	34	37	1.6	0.7	0.5	0.3	0.4
Non-energy use	114	134	173	142	159	178	9.2	8.1	10.0	2.6	-1.4	0.7	1.1	0.9
Coal	60	59	36	26	24	22	4.0	1.5	1.2	-4.8	-2.4	-0.3	-1.0	-0.6
Oil	769	752	874	835	782	753	52	48	42	1.5	-0.3	-0.4	-0.4	-0.4
Natural gas	374	346	413	405	422	433	24	23	24	1.8	-0.1	0.3	0.3	0.3
Electricity	200	262	342	368	421	442	18	21	25	2.7	0.5	0.9	0.5	0.7
Heat	1.0	2.8	6.1	6.5	6.9	6.7	0.2	0.4	0.4	8.1	0.5	0.3	-0.2	0.1
Hydrogen	-	-	-	-	0.2	0.4	-	-	0.0	n.a.	n.a.	n.a.	5.9	n.a.
Renewables	62	33	66	98	125	126	2.3	5.7	7.1	7.2	2.9	1.5	0.1	1.0

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	2,801	3,685	4,631	4,975	5,630	5,884	100	100	100	2.3	0.5	0.8	0.4	0.6
Coal	1,303	1,782	2,247	1,777	1,311	983	48	36	17	2.3	-1.7	-1.9	-2.8	-2.3
Oil	277	147	133	48	35	25	4.0	1.0	0.4	-1.0	-7.1	-2.0	-3.3	-2.5
Natural gas	380	391	668	1,223	1,865	2,199	11	25	37	5.5	4.4	2.7	1.7	2.3
Nuclear	304	685	871	938	897	897	19	19	15	2.4	0.5	-0.3	0.0	-0.2
Hydro	530	570	612	644	703	724	15	13	12	0.7	0.4	0.5	0.3	0.5
Geothermal	5.4	16	15	19	45	56	0.4	0.4	1.0	-0.9	1.8	5.6	2.4	4.3
Solar, wind, etc.	-	3.8	6.7	239	623	817	0.1	4.8	14	5.9	29.1	6.2	2.7	4.8
Biomass and waste	1.8	90	80	87	152	184	2.5	1.8	3.1	-1.2	0.6	3.5	1.9	2.9
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	7,305	10,073	14,050	18,052	25,535	31,014	3.4	1.8	2.2	2.0	2.1
Population (million)	252	277	313	354	396	416	1.2	0.9	0.7	0.5	0.6
CO_2 emissions[*2] (Mt)	5,169	5,236	6,125	5,739	5,316	4,972	1.6	-0.5	-0.5	-0.7	-0.5
GDP per capita ($2010 thousand)	29	36	45	51	64	75	2.1	0.9	1.5	1.5	1.5
Primary energy consump. per capita (toe)	7.9	7.7	8.1	7.0	6.4	6.0	0.5	-1.0	-0.6	-0.6	-0.6
Primary energy consumption per GDP[*3]	273	211	180	138	99	81	-1.6	-1.9	-2.1	-2.0	-2.1
CO_2 emissions per GDP[*2, *4]	708	520	436	318	208	160	-1.7	-2.2	-2.6	-2.6	-2.6
CO_2 per primary energy consumption[*2, *5]	2.6	2.5	2.4	2.3	2.1	2.0	-0.2	-0.4	-0.5	-0.6	-0.6
Automobile ownership (million)	169	205	239	275	327	352	1.5	1.0	1.1	0.8	1.0
Automobile ownership rates[*6]	671	740	764	775	825	846	0.3	0.1	0.4	0.3	0.3

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A62 | United States [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	1,805	1,915	2,273	2,216	2,230	2,201	100	100	100	1.7	-0.2	0.0	-0.1	0.0
Coal	376	460	534	432	309	231	24	19	10	1.5	-1.5	-2.1	-2.9	-2.4
Oil	797	757	871	782	726	692	40	35	31	1.4	-0.8	-0.5	-0.5	-0.5
Natural gas	477	438	548	624	736	791	23	28	36	2.3	0.9	1.0	0.7	0.9
Nuclear	69	159	208	216	212	212	8.3	9.8	9.6	2.7	0.3	-0.1	0.0	-0.1
Hydro	24	23	22	22	24	24	1.2	1.0	1.1	-0.8	0.2	0.4	0.1	0.3
Geothermal	4.6	14	13	9.0	21	27	0.7	0.4	1.2	-0.7	-2.7	5.5	2.3	4.3
Solar, wind, etc.	-	0.3	2.1	20	52	68	0.0	0.9	3.1	20.5	17.8	6.0	2.7	4.7
Biomass and waste	54	62	73	105	145	152	3.3	4.7	6.9	1.6	2.6	2.0	0.5	1.4

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	1,311	1,294	1,546	1,538	1,553	1,550	100	100	100	1.8	0.0	0.1	0.0	0.0
Industry	387	284	332	269	271	269	22	17	17	1.6	-1.5	0.0	-0.1	0.0
Transport	425	488	588	623	588	556	38	41	36	1.9	0.4	-0.4	-0.6	-0.4
Buildings, etc.	397	403	473	526	568	584	31	34	38	1.6	0.8	0.5	0.3	0.4
Non-energy use	102	119	153	119	127	141	9.2	7.8	9.1	2.5	-1.8	0.4	1.0	0.6
Coal	56	56	33	22	20	18	4.3	1.4	1.2	-5.2	-2.7	-0.5	-1.2	-0.8
Oil	689	683	793	744	677	646	53	48	42	1.5	-0.5	-0.6	-0.5	-0.5
Natural gas	337	303	360	355	368	378	23	23	24	1.7	-0.1	0.2	0.3	0.2
Electricity	174	226	301	326	371	389	18	21	25	2.9	0.6	0.8	0.5	0.7
Heat	-	2.2	5.3	5.6	5.9	5.7	0.2	0.4	0.4	9.4	0.4	0.3	-0.3	0.1
Hydrogen	-	-	-	-	0.2	0.3	-	-	0.0	n.a.	n.a.	n.a.	5.6	n.a.
Renewables	54	23	54	84	111	112	1.8	5.5	7.3	9.0	3.2	1.7	0.2	1.1

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	2,427	3,203	4,026	4,319	4,878	5,096	100	100	100	2.3	0.5	0.8	0.4	0.6
Coal	1,243	1,700	2,129	1,713	1,284	969	53	40	19	2.3	-1.5	-1.8	-2.8	-2.2
Oil	263	131	118	40	27	18	4.1	0.9	0.3	-1.0	-7.5	-2.4	-4.1	-3.0
Natural gas	370	382	634	1,161	1,724	2,042	12	27	40	5.2	4.4	2.5	1.7	2.2
Nuclear	266	612	798	831	812	812	19	19	16	2.7	0.3	-0.1	0.0	-0.1
Hydro	279	273	253	261	278	281	8.5	6.1	5.5	-0.8	0.2	0.4	0.1	0.3
Geothermal	5.4	16	15	19	45	56	0.5	0.4	1.1	-0.9	1.8	5.6	2.4	4.3
Solar, wind, etc.	-	3.7	6.4	213	565	745	0.1	4.9	15	5.5	28.5	6.3	2.8	4.9
Biomass and waste	0.5	86	72	82	143	173	2.7	1.9	3.4	-1.8	0.9	3.5	1.9	2.9
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	6,529	9,064	12,713	16,282	23,132	28,154	3.4	1.8	2.2	2.0	2.1
Population (million)	227	250	282	319	356	374	1.2	0.9	0.7	0.5	0.6
CO_2 emissions[*2] (Mt)	4,743	4,820	5,617	5,221	4,805	4,476	1.5	-0.5	-0.5	-0.7	-0.6
GDP per capita ($2010 thousand)	29	36	45	51	65	75	2.2	0.9	1.5	1.5	1.5
Primary energy consump. per capita (toe)	7.9	7.7	8.1	7.0	6.3	5.9	0.5	-1.0	-0.6	-0.6	-0.6
Primary energy consumption per GDP[*3]	276	211	179	136	96	78	-1.7	-1.9	-2.1	-2.1	-2.1
CO_2 emissions per GDP[*2, *4]	726	532	442	321	208	159	-1.8	-2.3	-2.7	-2.6	-2.7
CO_2 per primary energy consumption[*2, *5]	2.6	2.5	2.5	2.4	2.2	2.0	-0.2	-0.3	-0.6	-0.6	-0.6
Automobile ownership (million)	156	189	221	252	300	323	1.6	0.9	1.1	0.7	1.0
Automobile ownership rates[*6]	686	756	785	790	843	863	0.4	0.0	0.4	0.2	0.3

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A63 | Latin America [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	382	465	599	863	1,220	1,427	100	100	100	2.6	2.6	2.2	1.6	2.0
Coal	13	21	27	45	71	87	4.5	5.2	6.1	2.6	3.7	2.9	2.0	2.5
Oil	223	238	302	397	478	518	51	46	36	2.4	2.0	1.2	0.8	1.0
Natural gas	48	72	119	203	352	440	16	24	31	5.1	3.9	3.5	2.3	3.0
Nuclear	0.6	3.2	5.3	8.0	16	21	0.7	0.9	1.5	5.1	3.0	4.3	2.8	3.7
Hydro	19	33	50	64	76	85	7.2	7.4	5.9	4.2	1.7	1.2	1.0	1.1
Geothermal	1.2	5.1	6.3	6.4	26	40	1.1	0.7	2.8	2.2	0.0	9.2	4.2	7.3
Solar, wind, etc.	-	0.0	0.2	3.1	8.1	13	0.0	0.4	0.9	24.4	23.8	6.2	4.8	5.6
Biomass and waste	78	92	89	136	192	224	20	16	16	-0.3	3.1	2.2	1.5	1.9

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	288	343	447	617	855	995	100	100	100	2.7	2.3	2.1	1.5	1.9
Industry	98	114	148	196	286	345	33	32	35	2.7	2.0	2.4	1.9	2.2
Transport	85	103	141	223	309	349	30	36	35	3.2	3.3	2.1	1.2	1.7
Buildings, etc.	89	101	120	159	210	245	29	26	25	1.8	2.0	1.8	1.6	1.7
Non-energy use	16	26	38	40	51	56	7.5	6.5	5.7	4.0	0.4	1.5	1.0	1.3
Coal	6.1	7.8	11	14	19	20	2.3	2.3	2.0	3.1	2.0	1.8	0.5	1.3
Oil	159	179	240	316	412	458	52	51	46	3.0	2.0	1.7	1.1	1.4
Natural gas	27	38	53	77	119	143	11	12	14	3.6	2.6	2.8	1.9	2.4
Electricity	27	44	69	110	177	225	13	18	23	4.4	3.4	3.0	2.4	2.8
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	69	74	74	99	129	149	22	16	15	0.0	2.1	1.6	1.5	1.6

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	380	623	1,009	1,592	2,484	3,116	100	100	100	4.9	3.3	2.8	2.3	2.6
Coal	7.8	23	43	103	236	322	3.8	6.5	10	6.3	6.4	5.3	3.2	4.5
Oil	111	128	197	200	147	121	21	13	3.9	4.4	0.1	-1.9	-1.9	-1.9
Natural gas	35	60	141	416	900	1,263	9.6	26	41	9.0	8.1	4.9	3.4	4.4
Nuclear	2.3	12	20	31	61	80	2.0	1.9	2.6	5.1	3.0	4.3	2.8	3.7
Hydro	218	386	584	740	888	985	62	46	32	4.2	1.7	1.2	1.0	1.1
Geothermal	1.4	5.9	7.8	10	31	47	1.0	0.6	1.5	2.8	1.8	7.3	4.2	6.1
Solar, wind, etc.	-	0.0	0.3	26	78	121	0.0	1.6	3.9	66.8	36.6	7.0	4.5	6.0
Biomass and waste	3.9	7.6	14	66	143	178	1.2	4.1	5.7	6.3	11.7	5.0	2.2	3.9
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	2,410	2,782	3,774	5,881	9,045	11,817	3.1	3.2	2.7	2.7	2.7
Population (million)	361	442	522	622	719	761	1.7	1.3	0.9	0.6	0.8
CO_2 emissions[*2] (Mt)	801	909	1,204	1,760	2,432	2,810	2.9	2.8	2.0	1.5	1.8
GDP per capita ($2010 thousand)	6.7	6.3	7.2	9.4	13	16	1.4	1.9	1.8	2.1	1.9
Primary energy consump. per capita (toe)	1.1	1.1	1.1	1.4	1.7	1.9	0.9	1.4	1.3	1.0	1.2
Primary energy consumption per GDP[*3]	159	167	159	147	135	121	-0.5	-0.6	-0.5	-1.1	-0.7
CO_2 emissions per GDP[*2, *4]	332	327	319	299	269	238	-0.2	-0.5	-0.7	-1.2	-0.9
CO_2 per primary energy consumption[*2, *5]	2.1	2.0	2.0	2.0	2.0	2.0	0.3	0.1	-0.1	-0.1	-0.1
Automobile ownership (million)	28	38	55	120	182	218	3.6	5.8	2.6	1.8	2.3
Automobile ownership rates[*6]	79	87	105	193	254	286	1.9	4.5	1.7	1.2	1.5

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A64 | OECD Europe [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	1,494	1,619	1,748	1,674	1,763	1,744	100	100	100	0.8	-0.3	0.3	-0.1	0.2
Coal	464	449	330	292	288	265	28	17	15	-3.0	-0.9	-0.1	-0.8	-0.4
Oil	688	606	652	541	487	449	37	32	26	0.7	-1.3	-0.7	-0.8	-0.7
Natural gas	206	260	393	374	445	452	16	22	26	4.2	-0.4	1.1	0.2	0.7
Nuclear	60	205	245	228	210	216	13	14	12	1.8	-0.5	-0.5	0.3	-0.2
Hydro	36	38	47	49	51	51	2.4	2.9	2.9	2.0	0.3	0.2	0.0	0.2
Geothermal	3.0	4.9	7.2	14	20	24	0.3	0.8	1.4	3.9	4.9	2.3	1.6	2.0
Solar, wind, etc.	0.1	0.3	2.7	35	56	66	0.0	2.1	3.8	25.1	20.1	3.0	1.6	2.5
Biomass and waste	36	54	70	140	204	219	3.4	8.4	13	2.6	5.1	2.4	0.7	1.7

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	1,081	1,122	1,229	1,172	1,242	1,226	100	100	100	0.9	-0.3	0.4	-0.1	0.2
Industry	356	323	325	280	289	286	29	24	23	0.1	-1.1	0.2	-0.1	0.1
Transport	209	266	316	325	304	281	24	28	23	1.8	0.2	-0.4	-0.8	-0.6
Buildings, etc.	425	433	473	463	531	537	39	40	44	0.9	-0.1	0.9	0.1	0.6
Non-energy use	90	100	115	104	118	121	8.9	8.9	9.9	1.4	-0.7	0.8	0.2	0.6
Coal	156	124	63	47	46	42	11	4.0	3.4	-6.6	-2.1	-0.1	-1.0	-0.4
Oil	551	518	571	491	450	417	46	42	34	1.0	-1.1	-0.5	-0.8	-0.6
Natural gas	161	201	268	247	286	291	18	21	24	2.9	-0.6	0.9	0.2	0.6
Electricity	147	192	233	257	305	321	17	22	26	2.0	0.7	1.1	0.5	0.9
Heat	35	40	41	45	48	48	3.6	3.9	3.9	0.1	0.8	0.4	-0.1	0.2
Hydrogen	-	-	-	-	0.1	0.1	-	-	0.0	n.a.	n.a.	n.a.	5.2	n.a.
Renewables	31	47	54	85	106	107	4.2	7.2	8.7	1.4	3.3	1.4	0.1	0.9

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	2,049	2,662	3,223	3,500	4,121	4,325	100	100	100	1.9	0.6	1.0	0.5	0.8
Coal	887	1,030	968	876	947	906	39	25	21	-0.6	-0.7	0.5	-0.4	0.1
Oil	364	206	179	52	24	16	7.7	1.5	0.4	-1.4	-8.4	-4.7	-4.1	-4.5
Natural gas	138	168	512	566	775	816	6.3	16	19	11.8	0.7	2.0	0.5	1.4
Nuclear	230	787	939	876	807	831	30	25	19	1.8	-0.5	-0.5	0.3	-0.2
Hydro	416	446	546	568	591	593	17	16	14	2.0	0.3	0.2	0.0	0.2
Geothermal	2.7	3.6	6.2	14	22	26	0.1	0.4	0.6	5.5	5.9	2.8	2.0	2.5
Solar, wind, etc.	0.5	1.4	24	355	596	711	0.1	10	16	33.3	21.2	3.3	1.8	2.7
Biomass and waste	11	21	48	192	358	426	0.8	5.5	9.8	8.9	10.3	4.0	1.7	3.1
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	9,882	12,581	15,852	18,996	24,681	28,051	2.3	1.3	1.6	1.3	1.5
Population (million)	476	499	521	560	579	584	0.4	0.5	0.2	0.1	0.2
CO_2 emissions[*2] (Mt)	4,164	3,951	3,891	3,385	3,328	3,129	-0.2	-1.0	-0.1	-0.6	-0.3
GDP per capita ($2010 thousand)	21	25	30	34	43	48	1.9	0.8	1.4	1.2	1.3
Primary energy consump. per capita (toe)	3.1	3.2	3.4	3.0	3.0	3.0	0.3	-0.8	0.1	-0.2	0.0
Primary energy consumption per GDP[*3]	151	129	110	88	71	62	-1.5	-1.6	-1.3	-1.4	-1.3
CO_2 emissions per GDP[*2, *4]	421	314	245	178	135	112	-2.4	-2.3	-1.7	-1.9	-1.8
CO_2 per primary energy consumption[*2, *5]	2.8	2.4	2.2	2.0	1.9	1.8	-0.9	-0.7	-0.4	-0.5	-0.5
Automobile ownership (million)	124	179	238	304	356	370	2.9	1.8	1.0	0.4	0.8
Automobile ownership rates[*6]	261	359	457	543	615	634	2.4	1.2	0.8	0.3	0.6

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A65 | Non-OECD Europe [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	1,241	1,537	1,004	1,124	1,212	1,257	100	100	100	-4.2	0.8	0.5	0.4	0.4
Coal	362	367	209	208	176	173	24	18	14	-5.5	-0.1	-1.0	-0.1	-0.7
Oil	464	468	203	245	253	255	30	22	20	-8.0	1.4	0.2	0.1	0.2
Natural gas	355	603	489	541	565	583	39	48	46	-2.1	0.7	0.3	0.3	0.3
Nuclear	21	59	64	78	147	157	3.9	7.0	12	0.7	1.5	4.0	0.6	2.7
Hydro	20	23	24	26	28	29	1.5	2.3	2.3	0.3	0.7	0.4	0.3	0.4
Geothermal	-	0.0	0.1	0.2	1.4	1.6	0.0	0.0	0.1	12.5	7.6	12.3	1.5	8.0
Solar, wind, etc.	-	-	0.0	1.3	4.7	8.5	-	0.1	0.7	n.a.	28.8	8.2	6.0	7.3
Biomass and waste	21	18	17	24	37	51	1.2	2.1	4.0	-0.7	2.6	2.8	3.2	3.0

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	869	1,073	654	713	797	836	100	100	100	-4.8	0.6	0.7	0.5	0.6
Industry	394	396	206	195	243	269	37	27	32	-6.3	-0.4	1.4	1.0	1.2
Transport	107	173	111	144	167	172	16	20	21	-4.3	1.9	0.9	0.3	0.7
Buildings, etc.	301	439	289	282	302	310	41	40	37	-4.1	-0.2	0.4	0.3	0.4
Non-energy use	67	66	49	91	85	85	6.2	13	10	-2.9	4.5	-0.4	0.0	-0.2
Coal	152	114	37	36	39	40	11	5.1	4.8	-10.7	-0.1	0.5	0.2	0.4
Oil	310	280	146	203	210	213	26	28	26	-6.3	2.4	0.2	0.2	0.2
Natural gas	215	261	201	212	265	284	24	30	34	-2.6	0.4	1.4	0.7	1.1
Electricity	95	126	87	107	134	153	12	15	18	-3.7	1.5	1.4	1.3	1.4
Heat	78	278	172	138	133	130	26	19	16	-4.7	-1.6	-0.2	-0.2	-0.2
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	21	14	12	17	16	16	1.3	2.3	2.0	-1.0	2.1	-0.1	0.1	0.0

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	1,461	1,894	1,432	1,749	2,173	2,457	100	100	100	-2.8	1.4	1.4	1.2	1.3
Coal	471	429	338	392	379	411	23	22	17	-2.4	1.1	-0.2	0.8	0.2
Oil	357	256	70	20	19	18	14	1.2	0.7	-12.2	-8.5	-0.5	-0.5	-0.5
Natural gas	295	715	504	712	806	945	38	41	38	-3.4	2.5	0.8	1.6	1.1
Nuclear	79	226	242	299	561	599	12	17	24	0.7	1.5	4.0	0.6	2.7
Hydro	232	267	275	305	324	334	14	17	14	0.3	0.7	0.4	0.3	0.4
Geothermal	-	0.0	0.1	0.5	1.5	1.7	0.0	0.0	0.1	7.6	15.9	7.5	1.5	5.2
Solar, wind, etc.	-	-	0.0	14	53	97	-	0.8	4.0	n.a.	65.8	8.6	6.2	7.6
Biomass and waste	27	0.0	2.6	5.6	29	52	0.0	0.3	2.1	48.8	5.8	10.7	6.2	8.9
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	1,750	2,141	1,494	2,704	3,863	5,043	-3.5	4.3	2.3	2.7	2.4
Population (million)	319	344	341	342	341	333	-0.1	0.0	0.0	-0.2	-0.1
CO_2 emissions[*2] (Mt)	3,497	4,123	2,462	2,596	2,569	2,607	-5.0	0.4	-0.1	0.1	0.0
GDP per capita ($2010 thousand)	5.5	6.2	4.4	7.9	11	15	-3.5	4.3	2.3	2.9	2.5
Primary energy consump. per capita (toe)	3.9	4.5	2.9	3.3	3.6	3.8	-4.1	0.8	0.5	0.6	0.5
Primary energy consumption per GDP[*3]	709	718	672	416	314	249	-0.7	-3.4	-1.7	-2.3	-1.9
CO_2 emissions per GDP[*2, *4]	1,998	1,926	1,648	960	665	517	-1.5	-3.8	-2.3	-2.5	-2.4
CO_2 per primary energy consumption[*2, *5]	2.8	2.7	2.5	2.3	2.1	2.1	-0.9	-0.4	-0.5	-0.2	-0.4
Automobile ownership (million)	22	32	47	96	118	126	3.9	5.3	1.3	0.6	1.0
Automobile ownership rates[*6]	69	93	137	281	347	378	4.0	5.3	1.3	0.9	1.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A66 | European Union [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	n.a.	1,645	1,695	1,565	1,644	1,626	100	100	100	0.3	-0.6	0.3	-0.1	0.1
Coal	n.a.	456	321	268	265	243	28	17	15	-3.4	-1.3	-0.1	-0.8	-0.4
Oil	n.a.	605	625	509	460	425	37	33	26	0.3	-1.5	-0.6	-0.8	-0.7
Natural gas	n.a.	297	396	343	407	413	18	22	25	2.9	-1.0	1.1	0.2	0.7
Nuclear	n.a.	207	246	228	209	215	13	15	13	1.7	-0.5	-0.5	0.3	-0.2
Hydro	n.a.	25	31	32	33	33	1.5	2.1	2.0	2.1	0.4	0.2	0.0	0.1
Geothermal	n.a.	3.2	4.6	6.2	8.0	8.9	0.2	0.4	0.6	3.7	2.2	1.6	1.1	1.4
Solar, wind, etc.	n.a.	0.3	2.4	34	56	68	0.0	2.2	4.2	25.3	20.8	3.2	1.9	2.7
Biomass and waste	n.a.	47	67	142	203	219	2.9	9.1	13	3.5	5.5	2.3	0.8	1.7

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	n.a.	1,130	1,180	1,095	1,161	1,148	100	100	100	0.4	-0.5	0.4	-0.1	0.2
Industry	n.a.	343	310	255	267	266	30	23	23	-1.0	-1.4	0.3	0.0	0.2
Transport	n.a.	259	304	307	288	267	23	28	23	1.6	0.1	-0.4	-0.8	-0.5
Buildings, etc.	n.a.	429	454	433	494	501	38	40	44	0.6	-0.3	0.8	0.1	0.6
Non-energy use	n.a.	99	113	100	111	114	8.7	9.1	9.9	1.4	-0.9	0.7	0.2	0.5
Coal	n.a.	122	53	37	36	33	11	3.4	2.9	-8.1	-2.5	-0.1	-1.0	-0.4
Oil	n.a.	503	543	460	424	392	44	42	34	0.8	-1.2	-0.5	-0.8	-0.6
Natural gas	n.a.	226	272	235	272	277	20	21	24	1.9	-1.0	0.9	0.2	0.6
Electricity	n.a.	186	217	233	276	292	16	21	25	1.6	0.5	1.1	0.5	0.9
Heat	n.a.	54	45	46	49	49	4.8	4.2	4.3	-1.8	0.0	0.5	-0.1	0.3
Hydrogen	n.a.	-	-	-	0.1	0.1	-	-	0.0	n.a.	n.a.	n.a.	5.2	n.a.
Renewables	n.a.	40	50	85	104	105	3.5	7.7	9.1	2.3	3.8	1.3	0.1	0.8

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	n.a.	2,577	3,006	3,159	3,729	3,953	100	100	100	1.6	0.4	1.0	0.6	0.9
Coal	n.a.	1,050	968	841	911	870	41	27	22	-0.8	-1.0	0.5	-0.5	0.1
Oil	n.a.	224	181	57	30	22	8.7	1.8	0.5	-2.1	-7.9	-4.0	-3.2	-3.7
Natural gas	n.a.	193	480	457	618	661	7.5	14	17	9.5	-0.3	1.9	0.7	1.4
Nuclear	n.a.	795	945	876	804	825	31	28	21	1.7	-0.5	-0.5	0.3	-0.2
Hydro	n.a.	290	357	375	385	385	11	12	9.7	2.1	0.4	0.2	0.0	0.1
Geothermal	n.a.	3.2	4.8	6.2	8.1	9.1	0.1	0.2	0.2	4.0	1.9	1.7	1.1	1.5
Solar, wind, etc.	n.a.	1.3	24	355	616	752	0.1	11	19	33.9	21.2	3.5	2.0	2.9
Biomass and waste	n.a.	20	46	189	357	430	0.8	6.0	11	8.9	10.6	4.0	1.9	3.2
Hydrogen	n.a.	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	n.a.	11,801	14,729	17,396	22,607	25,741	2.2	1.2	1.7	1.3	1.5
Population (million)	n.a.	478	488	508	521	522	0.2	0.3	0.2	0.0	0.1
CO_2 emissions[*2] (Mt)	n.a.	4,067	3,783	3,134	3,085	2,898	-0.7	-1.3	-0.1	-0.6	-0.3
GDP per capita ($2010 thousand)	n.a.	25	30	34	43	49	2.0	0.9	1.5	1.3	1.4
Primary energy consump. per capita (toe)	n.a.	3.4	3.5	3.1	3.2	3.1	0.1	-0.9	0.2	-0.1	0.0
Primary energy consumption per GDP[*3]	n.a.	139	115	90	73	63	-1.9	-1.7	-1.3	-1.4	-1.4
CO_2 emissions per GDP[*2, *4]	n.a.	345	257	180	136	113	-2.9	-2.5	-1.7	-1.9	-1.8
CO_2 per primary energy consumption[*2, *5]	n.a.	2.5	2.2	2.0	1.9	1.8	-1.0	-0.8	-0.4	-0.5	-0.4
Automobile ownership (million)	n.a.	177	235	298	346	359	2.9	1.7	0.9	0.4	0.7
Automobile ownership rates[*6]	n.a.	371	482	587	665	687	2.7	1.4	0.8	0.3	0.6

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million, *4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A67 | Africa [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	273	393	496	772	1,118	1,357	100	100	100	2.3	3.2	2.3	2.0	2.2
Coal	52	74	90	112	135	146	19	15	11	2.0	1.6	1.2	0.8	1.0
Oil	61	86	97	165	243	285	22	21	21	1.2	3.8	2.5	1.6	2.1
Natural gas	12	30	47	108	184	250	7.5	14	18	4.8	6.1	3.4	3.1	3.3
Nuclear	-	2.2	3.4	3.6	10	23	0.6	0.5	1.7	4.4	0.4	6.6	8.7	7.4
Hydro	4.1	4.8	6.4	11	16	20	1.2	1.4	1.5	2.9	3.6	2.7	2.0	2.4
Geothermal	-	0.3	0.4	3.5	6.4	7.2	0.1	0.5	0.5	2.9	17.4	3.9	1.1	2.8
Solar, wind, etc.	-	0.0	0.0	0.7	2.3	4.8	0.0	0.1	0.4	45.1	29.0	7.3	7.7	7.5
Biomass and waste	143	196	250	368	520	619	50	48	46	2.5	2.8	2.2	1.8	2.0

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	218	292	369	559	838	1,024	100	100	100	2.4	3.0	2.6	2.0	2.4
Industry	46	55	58	86	140	183	19	15	18	0.5	2.9	3.1	2.7	3.0
Transport	27	38	54	96	143	161	13	17	16	3.7	4.2	2.5	1.2	2.0
Buildings, etc.	139	188	242	357	523	638	64	64	62	2.6	2.8	2.4	2.0	2.3
Non-energy use	5.4	11	15	20	32	41	3.8	3.5	4.0	3.2	1.9	3.0	2.5	2.8
Coal	22	20	19	21	31	38	6.7	3.8	3.7	-0.5	0.9	2.4	2.0	2.2
Oil	54	71	89	145	222	263	24	26	26	2.4	3.5	2.7	1.7	2.3
Natural gas	2.8	8.6	14	34	54	72	2.9	6.1	7.1	5.0	6.5	3.0	2.9	2.9
Electricity	14	22	31	52	88	119	7.6	9.3	12	3.4	3.8	3.3	3.1	3.2
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	126	171	216	306	443	532	59	55	52	2.4	2.5	2.3	1.9	2.2

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	184	316	442	762	1,272	1,712	100	100	100	3.4	4.0	3.3	3.0	3.2
Coal	100	165	209	258	358	411	52	34	24	2.4	1.5	2.1	1.4	1.8
Oil	22	41	51	72	86	94	13	9.4	5.5	2.4	2.4	1.1	0.9	1.0
Natural gas	14	45	92	282	564	821	14	37	48	7.3	8.4	4.4	3.8	4.2
Nuclear	-	8.4	13	14	38	89	2.7	1.8	5.2	4.4	0.4	6.6	8.7	7.4
Hydro	47	56	75	123	189	230	18	16	13	2.9	3.6	2.7	2.0	2.4
Geothermal	-	0.3	0.4	4.1	7.5	8.4	0.1	0.5	0.5	2.9	17.4	3.9	1.1	2.8
Solar, wind, etc.	-	-	0.2	6.8	25	54	-	0.9	3.1	n.a.	27.2	8.4	8.0	8.3
Biomass and waste	0.2	0.5	1.1	1.8	3.7	4.9	0.1	0.2	0.3	8.9	3.9	4.5	2.8	3.8
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	715	877	1,145	2,205	4,476	6,882	2.7	4.8	4.5	4.4	4.5
Population (million)	476	629	812	1,155	1,678	2,063	2.6	2.5	2.4	2.1	2.3
CO_2 emissions[*2] (Mt)	403	593	718	1,148	1,626	1,929	1.9	3.4	2.2	1.7	2.0
GDP per capita ($2010 thousand)	1.5	1.4	1.4	1.9	2.7	3.3	0.1	2.2	2.1	2.3	2.2
Primary energy consump. per capita (toe)	0.6	0.6	0.6	0.7	0.7	0.7	-0.2	0.7	0.0	-0.1	-0.1
Primary energy consumption per GDP[*3]	382	448	433	350	250	197	-0.3	-1.5	-2.1	-2.3	-2.2
CO_2 emissions per GDP[*2, *4]	564	676	627	521	363	280	-0.8	-1.3	-2.2	-2.6	-2.4
CO_2 per primary energy consumption[*2, *5]	1.5	1.5	1.4	1.5	1.5	1.4	-0.4	0.2	-0.1	-0.2	-0.2
Automobile ownership (million)	9.8	14	20	37	70	95	3.1	4.6	4.1	3.1	3.7
Automobile ownership rates[*6]	21	23	24	32	42	46	0.5	2.0	1.7	1.0	1.4

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A68 | Middle East [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	121	223	372	744	1,077	1,262	100	100	100	5.3	5.1	2.3	1.6	2.1
Coal	1.2	3.0	8.1	9.5	17	22	1.3	1.3	1.8	10.4	1.2	3.6	2.9	3.3
Oil	90	146	217	353	473	533	66	47	42	4.0	3.5	1.9	1.2	1.6
Natural gas	29	72	145	376	556	668	32	51	53	7.3	7.0	2.5	1.9	2.2
Nuclear	-	-	-	1.2	25	30	-	0.2	2.4	n.a.	n.a.	21.1	1.9	13.3
Hydro	0.8	1.0	0.7	1.7	1.7	1.7	0.5	0.2	0.1	-3.9	6.8	0.0	0.0	0.0
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.4	0.7	1.4	3.5	5.4	0.2	0.2	0.4	4.8	5.7	5.7	4.4	5.2
Biomass and waste	0.3	0.4	0.4	0.9	1.1	1.2	0.2	0.1	0.1	-0.4	5.4	1.3	0.9	1.1

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	84	157	253	491	724	868	100	100	100	4.9	4.9	2.5	1.8	2.2
Industry	30	47	71	156	250	314	30	32	36	4.2	5.8	3.0	2.3	2.7
Transport	26	51	75	142	190	220	32	29	25	4.0	4.7	1.8	1.5	1.7
Buildings, etc.	22	40	75	125	190	229	25	25	26	6.5	3.7	2.7	1.9	2.4
Non-energy use	5.6	20	32	68	94	106	12	14	12	5.2	5.4	2.0	1.2	1.7
Coal	0.3	0.2	0.5	2.5	4.3	5.3	0.1	0.5	0.6	9.9	12.5	3.4	2.2	2.9
Oil	67	108	153	239	322	374	69	49	43	3.6	3.2	1.9	1.5	1.7
Natural gas	9.8	31	65	173	267	318	20	35	37	7.6	7.2	2.7	1.8	2.4
Electricity	6.5	17	33	74	127	166	11	15	19	6.7	6.1	3.4	2.7	3.1
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Renewables	0.2	0.7	1.0	2.1	3.3	4.3	0.5	0.4	0.5	3.1	5.2	2.9	2.8	2.9

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	95	244	472	1,051	1,771	2,280	100	100	100	6.8	5.9	3.3	2.6	3.0
Coal	0.1	11	30	31	58	81	4.3	2.9	3.5	11.0	0.2	4.1	3.3	3.8
Oil	47	108	188	351	505	578	44	33	25	5.7	4.6	2.3	1.4	1.9
Natural gas	39	114	246	642	1,077	1,461	47	61	64	8.0	7.1	3.3	3.1	3.2
Nuclear	-	-	-	4.5	95	115	-	0.4	5.0	n.a.	n.a.	21.1	1.9	13.3
Hydro	9.7	12	8.0	20	20	20	4.9	1.9	0.9	-3.9	6.8	0.0	0.0	0.0
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	0.0	1.5	14	25	0.0	0.1	1.1	44.6	29.6	14.8	6.0	11.3
Biomass and waste	-	-	-	0.1	0.3	0.4	-	0.0	0.0	n.a.	n.a.	6.0	2.6	4.6
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	875	971	1,461	2,556	4,126	5,331	4.2	4.1	3.0	2.6	2.9
Population (million)	92	132	168	232	302	340	2.5	2.3	1.7	1.2	1.5
CO_2 emissions[*2] (Mt)	332	572	945	1,810	2,560	2,991	5.1	4.7	2.2	1.6	2.0
GDP per capita ($2010 thousand)	9.5	7.4	8.7	11	14	16	1.7	1.7	1.4	1.4	1.4
Primary energy consump. per capita (toe)	1.3	1.7	2.2	3.2	3.6	3.7	2.7	2.7	0.7	0.4	0.6
Primary energy consumption per GDP[*3]	139	229	254	291	261	237	1.1	1.0	-0.7	-1.0	-0.8
CO_2 emissions per GDP[*2, *4]	380	589	647	708	621	561	0.9	0.6	-0.8	-1.0	-0.9
CO_2 per primary energy consumption[*2, *5]	2.7	2.6	2.5	2.4	2.4	2.4	-0.1	-0.3	-0.1	0.0	-0.1
Automobile ownership (million)	5.8	10	14	40	65	83	3.2	7.7	3.1	2.4	2.9
Automobile ownership rates[*6]	63	78	84	171	215	243	0.8	5.2	1.5	1.2	1.4

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A69 | Oceania [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	79	99	125	146	163	168	100	100	100	2.4	1.1	0.7	0.3	0.5
Coal	28	36	49	43	45	43	37	29	25	3.1	-1.0	0.3	-0.5	0.0
Oil	34	35	40	50	58	60	35	34	36	1.4	1.7	0.9	0.4	0.7
Natural gas	8.3	19	24	36	37	38	19	25	22	2.7	2.9	0.2	0.1	0.2
Nuclear	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	2.7	3.2	3.5	3.7	4.0	4.4	3.2	2.5	2.6	0.9	0.3	0.6	1.0	0.7
Geothermal	1.0	1.5	1.9	4.8	7.5	7.9	1.5	3.3	4.7	2.8	6.6	2.9	0.5	2.0
Solar, wind, etc.	0.0	0.1	0.1	1.8	5.3	7.9	0.1	1.3	4.7	1.4	19.9	6.8	4.2	5.8
Biomass and waste	4.1	4.7	6.1	6.2	7.0	7.5	4.8	4.3	4.5	2.7	0.1	0.7	0.7	0.7

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	54	66	83	95	110	116	100	100	100	2.2	1.0	0.9	0.6	0.8
Industry	20	23	28	29	30	31	35	30	27	2.0	0.2	0.2	0.4	0.3
Transport	19	24	30	36	42	44	36	38	38	2.1	1.5	0.9	0.5	0.7
Buildings, etc.	11	15	19	23	30	33	22	24	28	2.3	1.6	1.5	1.0	1.3
Non-energy use	3.1	4.6	6.1	6.6	8.2	8.5	6.9	6.9	7.3	2.9	0.6	1.3	0.4	1.0
Coal	5.3	5.2	4.7	3.1	3.6	3.8	7.9	3.2	3.2	-1.0	-3.0	1.0	0.4	0.8
Oil	31	33	40	49	56	58	50	51	50	1.9	1.4	0.8	0.5	0.7
Natural gas	5.4	10	14	16	17	17	16	17	15	3.3	1.0	0.0	0.3	0.1
Electricity	8.5	14	18	21	27	31	20	22	26	2.8	1.3	1.6	1.1	1.4
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	-	-	0.0	n.a.	n.a.	n.a.	7.1	n.a.
Renewables	4.0	4.1	5.6	5.9	6.3	6.5	6.2	6.2	5.6	3.1	0.5	0.4	0.3	0.4

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	118	187	249	292	374	416	100	100	100	2.9	1.1	1.6	1.1	1.4
Coal	70	122	176	154	174	173	65	53	42	3.7	-0.9	0.8	0.0	0.5
Oil	5.2	3.6	1.8	5.0	3.7	2.2	1.9	1.7	0.5	-6.7	7.7	-1.9	-5.0	-3.1
Natural gas	8.7	20	26	61	75	82	11	21	20	2.6	6.4	1.3	0.8	1.1
Nuclear	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydro	32	37	41	43	47	52	20	15	12	0.9	0.3	0.6	1.0	0.7
Geothermal	1.2	2.1	2.9	7.3	12	12	1.1	2.5	3.0	3.2	6.7	3.0	0.5	2.0
Solar, wind, etc.	-	0.1	0.3	17	57	88	0.0	6.0	21	15.5	34.2	7.7	4.4	6.4
Biomass and waste	0.7	1.3	1.7	4.1	6.2	7.6	0.7	1.4	1.8	3.2	6.5	2.5	2.1	2.4
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	525	720	994	1,485	2,170	2,588	3.3	2.9	2.4	1.8	2.2
Population (million)	18	20	23	28	34	36	1.2	1.4	1.1	0.8	1.0
CO_2 emissions[*2] (Mt)	227	281	357	390	418	417	2.4	0.6	0.4	0.0	0.3
GDP per capita ($2010 thousand)	30	35	43	53	65	71	2.0	1.5	1.2	0.9	1.1
Primary energy consump. per capita (toe)	4.4	4.9	5.4	5.2	4.9	4.6	1.1	-0.3	-0.4	-0.5	-0.5
Primary energy consumption per GDP[*3]	150	138	126	98	75	65	-0.9	-1.8	-1.6	-1.5	-1.6
CO_2 emissions per GDP[*2, *4]	432	390	359	263	193	161	-0.8	-2.2	-1.9	-1.8	-1.9
CO_2 per primary energy consumption[*2, *5]	2.9	2.8	2.9	2.7	2.6	2.5	0.1	-0.5	-0.3	-0.3	-0.3
Automobile ownership (million)	8.8	12	15	20	25	27	2.6	2.2	1.3	0.9	1.2
Automobile ownership rates[*6]	495	567	648	725	750	754	1.3	0.8	0.2	0.1	0.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A70 | OECD [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	4,060	4,514	5,282	5,251	5,550	5,531	100	100	100	1.6	0.0	0.3	0.0	0.2
Coal	966	1,079	1,094	1,006	889	783	24	19	14	0.1	-0.6	-0.8	-1.3	-1.0
Oil	1,938	1,861	2,103	1,872	1,778	1,697	41	36	31	1.2	-0.8	-0.3	-0.5	-0.4
Natural gas	778	843	1,163	1,338	1,574	1,657	19	25	30	3.3	1.0	1.0	0.5	0.8
Nuclear	162	451	586	516	564	563	10	9.8	10	2.7	-0.9	0.5	0.0	0.3
Hydro	94	101	115	120	129	131	2.2	2.3	2.4	1.3	0.3	0.4	0.2	0.3
Geothermal	10	27	30	33	73	95	0.6	0.6	1.7	1.4	0.7	5.0	2.6	4.1
Solar, wind, etc.	0.1	2.1	5.9	63	130	165	0.0	1.2	3.0	10.7	18.4	4.6	2.4	3.7
Biomass and waste	111	149	183	300	412	438	3.3	5.7	7.9	2.1	3.6	2.0	0.6	1.5

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	2,937	3,090	3,621	3,614	3,827	3,827	100	100	100	1.6	0.0	0.4	0.0	0.2
Industry	940	835	913	806	868	877	27	22	23	0.9	-0.9	0.5	0.1	0.3
Transport	781	934	1,139	1,210	1,183	1,127	30	33	29	2.0	0.4	-0.1	-0.5	-0.3
Buildings, etc.	972	1,032	1,198	1,258	1,396	1,424	33	35	37	1.5	0.3	0.7	0.2	0.5
Non-energy use	243	289	370	341	380	400	9.4	9.4	10	2.5	-0.6	0.7	0.5	0.6
Coal	259	232	139	113	113	101	7.5	3.1	2.6	-5.0	-1.5	0.0	-1.0	-0.4
Oil	1,570	1,574	1,830	1,703	1,633	1,564	51	47	41	1.5	-0.5	-0.3	-0.4	-0.3
Natural gas	559	589	744	736	807	826	19	20	22	2.4	-0.1	0.6	0.2	0.4
Electricity	408	552	715	797	951	1,008	18	22	26	2.6	0.8	1.1	0.6	0.9
Heat	36	43	50	57	64	65	1.4	1.6	1.7	1.6	0.8	0.8	0.1	0.5
Hydrogen	-	-	-	-	0.3	0.5	-	-	0.0	n.a.	n.a.	n.a.	5.8	n.a.
Renewables	105	100	143	208	259	262	3.2	5.8	6.9	3.7	2.7	1.4	0.1	0.9

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	5,656	7,645	9,726	10,724	12,650	13,367	100	100	100	2.4	0.7	1.0	0.6	0.9
Coal	2,319	3,083	3,763	3,448	3,172	2,864	40	32	21	2.0	-0.6	-0.5	-1.0	-0.7
Oil	980	723	623	277	145	114	9.5	2.6	0.9	-1.5	-5.6	-4.0	-2.4	-3.4
Natural gas	618	774	1,543	2,586	3,594	4,093	10	24	31	7.1	3.8	2.1	1.3	1.8
Nuclear	621	1,729	2,249	1,981	2,162	2,161	23	18	16	2.7	-0.9	0.5	0.0	0.3
Hydro	1,093	1,179	1,339	1,401	1,495	1,527	15	13	11	1.3	0.3	0.4	0.2	0.3
Geothermal	11	29	33	48	106	137	0.4	0.5	1.0	1.4	2.8	5.0	2.6	4.1
Solar, wind, etc.	0.5	5.2	31	655	1,396	1,780	0.1	6.1	13	19.8	24.2	4.8	2.5	3.9
Biomass and waste	13	123	143	328	578	689	1.6	3.1	5.2	1.5	6.1	3.6	1.8	2.9
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	21,329	29,003	37,727	46,852	63,227	74,479	2.7	1.6	1.9	1.7	1.8
Population (million)	981	1,062	1,149	1,263	1,350	1,382	0.8	0.7	0.4	0.2	0.3
CO_2 emissions[*2] (Mt)	10,863	11,100	12,412	11,846	11,530	11,002	1.1	-0.3	-0.2	-0.5	-0.3
GDP per capita ($2010 thousand)	22	27	33	37	47	54	1.9	0.9	1.5	1.4	1.4
Primary energy consump. per capita (toe)	4.1	4.3	4.6	4.2	4.1	4.0	0.8	-0.7	-0.1	-0.3	-0.1
Primary energy consumption per GDP[*3]	190	156	140	112	88	74	-1.1	-1.6	-1.5	-1.7	-1.6
CO_2 emissions per GDP[*2, *4]	509	383	329	253	182	148	-1.5	-1.9	-2.0	-2.1	-2.0
CO_2 per primary energy consumption[*2, *5]	2.7	2.5	2.4	2.3	2.1	2.0	-0.5	-0.3	-0.5	-0.4	-0.5
Automobile ownership (million)	347	468	593	736	873	927	2.4	1.6	1.1	0.6	0.9
Automobile ownership rates[*6]	353	441	517	583	647	671	1.6	0.9	0.7	0.4	0.5

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A71 | Non-OECD [Reference Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	2,967	4,056	4,482	8,085	11,035	12,818	100	100	100	1.0	4.3	2.0	1.5	1.8
Coal	817	1,142	1,222	2,913	3,431	3,743	28	36	29	0.7	6.4	1.0	0.9	1.0
Oil	986	1,169	1,283	2,050	2,832	3,290	29	25	26	0.9	3.4	2.0	1.5	1.8
Natural gas	454	820	909	1,563	2,419	3,004	20	19	23	1.0	4.0	2.8	2.2	2.5
Nuclear	24	74	89	145	427	573	1.8	1.8	4.5	1.9	3.5	7.0	3.0	5.4
Hydro	54	83	110	214	285	316	2.0	2.7	2.5	2.9	4.9	1.8	1.0	1.5
Geothermal	2.2	7.6	22	38	108	134	0.2	0.5	1.0	11.0	4.0	6.8	2.2	5.0
Solar, wind, etc.	-	0.5	2.1	46	118	184	0.0	0.6	1.4	15.9	24.8	6.0	4.6	5.4
Biomass and waste	631	760	844	1,113	1,411	1,570	19	14	12	1.1	2.0	1.5	1.1	1.3

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	2,252	2,970	3,147	5,447	7,413	8,645	100	100	100	0.6	4.0	1.9	1.5	1.8
Industry	825	970	954	1,945	2,507	2,904	33	36	34	-0.2	5.2	1.6	1.5	1.6
Transport	289	436	549	1,054	1,589	1,890	15	19	22	2.3	4.8	2.6	1.8	2.3
Buildings, etc.	1,027	1,376	1,397	1,961	2,681	3,119	46	36	36	0.2	2.5	2.0	1.5	1.8
Non-energy use	111	187	247	486	637	732	6.3	8.9	8.5	2.8	5.0	1.7	1.4	1.6
Coal	444	521	409	963	986	1,001	18	18	12	-2.4	6.3	0.1	0.2	0.2
Oil	697	819	1,012	1,695	2,436	2,882	28	31	33	2.1	3.8	2.3	1.7	2.1
Natural gas	256	355	373	684	1,086	1,347	12	13	16	0.5	4.4	2.9	2.2	2.6
Electricity	178	283	377	909	1,482	1,888	9.5	17	22	2.9	6.5	3.1	2.5	2.9
Heat	85	292	198	217	234	238	9.8	4.0	2.8	-3.8	0.7	0.5	0.2	0.4
Hydrogen	-	-	-	-	0.0	0.0	-	-	0.0	n.a.	n.a.	n.a.	7.1	n.a.
Renewables	592	699	779	980	1,190	1,289	24	18	15	1.1	1.7	1.2	0.8	1.1

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	2,628	4,218	5,745	13,092	20,923	26,451	100	100	100	3.1	6.1	3.0	2.4	2.7
Coal	817	1,342	2,242	6,260	8,762	10,502	32	48	40	5.3	7.6	2.1	1.8	2.0
Oil	678	636	628	746	883	946	15	5.7	3.6	-0.1	1.2	1.1	0.7	0.9
Natural gas	381	979	1,210	2,569	4,952	6,934	23	20	26	2.1	5.5	4.2	3.4	3.9
Nuclear	93	283	341	555	1,637	2,196	6.7	4.2	8.3	1.9	3.5	7.0	3.0	5.4
Hydro	624	963	1,280	2,494	3,312	3,674	23	19	14	2.9	4.9	1.8	1.0	1.5
Geothermal	2.6	7.8	19	29	77	94	0.2	0.2	0.4	9.3	3.1	6.3	2.0	4.6
Solar, wind, etc.	-	0.0	3.1	273	913	1,561	0.0	2.1	5.9	53.2	37.6	7.8	5.5	6.9
Biomass and waste	31	7.7	21	165	387	543	0.2	1.3	2.1	10.7	15.7	5.5	3.4	4.7
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	6,475	8,575	11,828	26,082	52,987	77,073	3.3	5.8	4.5	3.8	4.3
Population (million)	3,453	4,214	4,958	5,986	7,143	7,775	1.6	1.4	1.1	0.9	1.0
CO_2 emissions[*2] (Mt)	6,998	9,482	10,181	20,049	26,098	29,842	0.7	5.0	1.7	1.3	1.5
GDP per capita ($2010 thousand)	1.9	2.0	2.4	4.4	7.4	9.9	1.6	4.4	3.4	2.9	3.2
Primary energy consump. per capita (toe)	0.9	1.0	0.9	1.4	1.5	1.6	-0.6	2.9	0.8	0.7	0.8
Primary energy consumption per GDP[*3]	458	473	379	310	208	166	-2.2	-1.4	-2.5	-2.2	-2.4
CO_2 emissions per GDP[*2, *4]	1,081	1,106	861	769	493	387	-2.5	-0.8	-2.7	-2.4	-2.6
CO_2 per primary energy consumption[*2, *5]	2.4	2.3	2.3	2.5	2.4	2.3	-0.3	0.6	-0.3	-0.2	-0.2
Automobile ownership (million)	69	109	173	507	980	1,245	4.8	8.0	4.2	2.4	3.5
Automobile ownership rates[*6]	20	26	35	85	137	160	3.1	6.5	3.1	1.6	2.5

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A72 | World [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	7,205	8,772	10,037	13,699	15,604	16,561	100	100	100	1.4	2.2	0.8	0.6	0.7
Coal	1,783	2,220	2,316	3,918	3,450	3,241	25	29	20	0.4	3.8	-0.8	-0.6	-0.7
Oil	3,102	3,233	3,660	4,285	4,609	4,656	37	31	28	1.2	1.1	0.5	0.1	0.3
Natural gas	1,232	1,663	2,071	2,901	3,374	3,617	19	21	22	2.2	2.4	0.9	0.7	0.9
Nuclear	186	526	676	661	1,250	1,569	6.0	4.8	9.5	2.5	-0.2	4.1	2.3	3.4
Hydro	148	184	225	335	423	459	2.1	2.4	2.8	2.0	2.9	1.5	0.8	1.2
Geothermal	12	34	52	71	269	382	0.4	0.5	2.3	4.3	2.3	8.7	3.6	6.7
Solar, wind, etc.	0.1	2.6	8.0	110	339	528	0.0	0.8	3.2	11.9	20.5	7.3	4.5	6.2
Biomass and waste	741	909	1,028	1,413	1,885	2,103	10	10	13	1.2	2.3	1.8	1.1	1.5

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	5,368	6,262	7,041	9,425	10,794	11,438	100	100	100	1.2	2.1	0.9	0.6	0.7
Industry	1,766	1,805	1,868	2,751	3,095	3,321	29	29	29	0.3	2.8	0.7	0.7	0.7
Transport	1,248	1,573	1,961	2,627	3,022	3,112	25	28	27	2.2	2.1	0.9	0.3	0.7
Buildings, etc.	2,000	2,408	2,596	3,219	3,660	3,873	38	34	34	0.8	1.5	0.8	0.6	0.7
Non-energy use	354	476	617	828	1,017	1,132	7.6	8.8	9.9	2.6	2.1	1.3	1.1	1.2
Coal	703	754	548	1,075	986	935	12	11	8.2	-3.1	4.9	-0.5	-0.5	-0.5
Oil	2,446	2,595	3,115	3,761	4,122	4,195	41	40	37	1.8	1.4	0.6	0.2	0.4
Natural gas	814	944	1,117	1,420	1,764	1,925	15	15	17	1.7	1.7	1.4	0.9	1.2
Electricity	586	836	1,092	1,706	2,188	2,529	13	18	22	2.7	3.2	1.6	1.5	1.5
Heat	121	335	248	274	270	259	5.4	2.9	2.3	-3.0	0.7	-0.1	-0.4	-0.2
Hydrogen	-	-	-	-	4.7	8.6	-	-	0.1	n.a.	n.a.	n.a.	6.2	n.a.
Renewables	698	799	921	1,188	1,459	1,587	13	13	14	1.4	1.8	1.3	0.8	1.1

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	8,283	11,864	15,471	23,816	30,201	34,730	100	100	100	2.7	3.1	1.5	1.4	1.5
Coal	3,137	4,425	6,005	9,707	8,712	8,444	37	41	24	3.1	3.5	-0.7	-0.3	-0.5
Oil	1,659	1,358	1,251	1,023	865	855	11	4.3	2.5	-0.8	-1.4	-1.0	-0.1	-0.7
Natural gas	999	1,753	2,753	5,155	6,118	6,840	15	22	20	4.6	4.6	1.1	1.1	1.1
Nuclear	713	2,013	2,591	2,535	4,793	6,018	17	11	17	2.6	-0.2	4.1	2.3	3.4
Hydro	1,717	2,143	2,619	3,895	4,919	5,332	18	16	15	2.0	2.9	1.5	0.8	1.2
Geothermal	14	36	52	77	287	398	0.3	0.3	1.1	3.6	2.9	8.5	3.3	6.5
Solar, wind, etc.	0.5	5.2	35	928	3,393	5,456	0.0	3.9	16	20.8	26.5	8.4	4.9	7.1
Biomass and waste	44	131	164	493	1,111	1,385	1.1	2.1	4.0	2.3	8.2	5.2	2.2	4.1
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	27,804	37,578	49,555	72,934	116,213	151,552	2.8	2.8	3.0	2.7	2.9
Population (million)	4,434	5,276	6,107	7,249	8,493	9,157	1.5	1.2	1.0	0.8	0.9
CO_2 emissions[*2] (Mt)	18,409	21,202	23,433	33,009	32,724	32,285	1.0	2.5	-0.1	-0.1	-0.1
GDP per capita ($2010 thousand)	6.3	7.1	8.1	10	14	17	1.3	1.5	1.9	1.9	1.9
Primary energy consump. per capita (toe)	1.6	1.7	1.6	1.9	1.8	1.8	-0.1	1.0	-0.2	-0.2	-0.2
Primary energy consumption per GDP[*3]	259	233	203	188	134	109	-1.4	-0.5	-2.1	-2.0	-2.1
CO_2 emissions per GDP[*2, *4]	662	564	473	453	282	213	-1.8	-0.3	-2.9	-2.8	-2.9
CO_2 per primary energy consumption[*2, *5]	2.6	2.4	2.3	2.4	2.1	1.9	-0.3	0.2	-0.9	-0.7	-0.8
Automobile ownership (million)	416	577	767	1,243	1,853	2,172	2.9	3.5	2.5	1.6	2.2
Automobile ownership rates[*6]	94	109	126	171	218	237	1.4	2.3	1.5	0.8	1.3

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A73 | Asia [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	1,439	2,108	2,893	5,517	6,840	7,577	100	100	100	3.2	4.7	1.4	1.0	1.2
Coal	466	785	1,037	2,758	2,665	2,620	37	50	35	2.8	7.2	-0.2	-0.2	-0.2
Oil	477	618	917	1,291	1,643	1,798	29	23	24	4.0	2.5	1.5	0.9	1.3
Natural gas	51	116	232	549	854	1,032	5.5	10.0	14	7.2	6.3	2.8	1.9	2.5
Nuclear	25	77	132	97	476	710	3.6	1.8	9.4	5.5	-2.2	10.4	4.1	8.0
Hydro	20	32	41	125	186	207	1.5	2.3	2.7	2.7	8.3	2.5	1.1	2.0
Geothermal	2.6	8.2	23	33	131	194	0.4	0.6	2.6	10.9	2.7	8.9	4.0	7.0
Solar, wind, etc.	-	1.5	2.2	44	152	245	0.1	0.8	3.2	4.4	23.7	8.1	4.9	6.8
Biomass and waste	397	471	508	617	730	767	22	11	10	0.8	1.4	1.1	0.5	0.8

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	1,129	1,551	1,995	3,677	4,519	4,963	100	100	100	2.5	4.5	1.3	0.9	1.2
Industry	383	517	645	1,494	1,661	1,779	33	41	36	2.2	6.2	0.7	0.7	0.7
Transport	126	186	321	612	899	1,012	12	17	20	5.6	4.7	2.4	1.2	2.0
Buildings, etc.	567	733	842	1,215	1,489	1,636	47	33	33	1.4	2.7	1.3	0.9	1.2
Non-energy use	54	115	188	356	469	536	7.4	9.7	11	5.0	4.7	1.7	1.3	1.6
Coal	301	424	378	926	835	789	27	25	16	-1.1	6.6	-0.6	-0.6	-0.6
Oil	327	453	727	1,120	1,491	1,648	29	30	33	4.9	3.1	1.8	1.0	1.5
Natural gas	21	47	88	255	422	520	3.0	6.9	10	6.4	7.9	3.2	2.1	2.8
Electricity	88	158	280	716	1,042	1,276	10	19	26	5.9	6.9	2.4	2.0	2.2
Heat	7.5	14	30	84	102	105	0.9	2.3	2.1	7.7	7.7	1.2	0.3	0.9
Hydrogen	-	-	-	-	0.4	0.5	-	-	0.0	n.a.	n.a.	n.a.	2.5	n.a.
Renewables	386	456	493	575	627	626	29	16	13	0.8	1.1	0.5	0.0	0.3

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	1,196	2,252	4,013	9,895	14,184	17,264	100	100	100	5.9	6.7	2.3	2.0	2.2
Coal	298	863	1,994	6,116	6,393	6,729	38	62	39	8.7	8.3	0.3	0.5	0.4
Oil	476	469	430	275	171	157	21	2.8	0.9	-0.9	-3.2	-2.9	-0.8	-2.1
Natural gas	90	240	565	1,252	1,861	2,332	11	13	14	9.0	5.9	2.5	2.3	2.4
Nuclear	97	294	505	373	1,825	2,724	13	3.8	16	5.5	-2.2	10.4	4.1	8.0
Hydro	232	367	479	1,453	2,161	2,408	16	15	14	2.7	8.3	2.5	1.1	2.0
Geothermal	3.0	8.4	20	23	87	127	0.4	0.2	0.7	9.0	1.0	8.6	3.9	6.8
Solar, wind, etc.	-	0.0	3.0	268	1,350	2,320	0.0	2.7	13	52.3	37.8	10.6	5.6	8.7
Biomass and waste	0.0	10	17	136	337	467	0.5	1.4	2.7	5.1	16.2	5.8	3.3	4.8
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	4,340	7,433	10,786	21,055	42,319	60,826	3.8	4.9	4.5	3.7	4.2
Population (million)	2,440	2,932	3,408	3,956	4,445	4,624	1.5	1.1	0.7	0.4	0.6
CO_2 emissions[*2] (Mt)	3,267	4,918	6,893	15,067	16,176	16,701	3.4	5.7	0.4	0.3	0.4
GDP per capita ($2010 thousand)	1.8	2.5	3.2	5.3	9.5	13	2.2	3.8	3.7	3.3	3.5
Primary energy consump. per capita (toe)	0.6	0.7	0.8	1.4	1.5	1.6	1.7	3.6	0.6	0.6	0.6
Primary energy consumption per GDP[*3]	332	284	268	262	162	125	-0.6	-0.2	-3.0	-2.6	-2.8
CO_2 emissions per GDP[*2, *4]	753	662	639	716	382	275	-0.3	0.8	-3.8	-3.3	-3.6
CO_2 per primary energy consumption[*2, *5]	2.3	2.3	2.4	2.7	2.4	2.2	0.2	1.0	-0.9	-0.7	-0.8
Automobile ownership (million)	48	86	139	351	709	900	5.0	6.8	4.5	2.4	3.7
Automobile ownership rates[*6]	20	29	41	89	160	195	3.4	5.7	3.7	2.0	3.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A74 | China [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	598	871	1,135	3,052	3,508	3,690	100	100	100	2.7	7.3	0.9	0.5	0.7
Coal	313	528	665	2,012	1,793	1,656	61	66	45	2.3	8.2	-0.7	-0.8	-0.7
Oil	89	119	221	504	643	663	14	17	18	6.4	6.1	1.5	0.3	1.1
Natural gas	12	13	21	154	364	462	1.5	5.0	13	4.9	15.4	5.5	2.4	4.3
Nuclear	-	-	4.4	35	229	355	-	1.1	9.6	n.a.	15.9	12.6	4.5	9.4
Hydro	5.0	11	19	90	131	138	1.3	3.0	3.7	5.8	11.7	2.3	0.6	1.6
Geothermal	-	-	1.7	4.8	10	12	-	0.2	0.3	n.a.	7.9	4.8	1.9	3.7
Solar, wind, etc.	-	0.0	1.0	36	99	152	0.0	1.2	4.1	40.4	29.3	6.6	4.3	5.7
Biomass and waste	180	200	203	217	239	254	23	7.1	6.9	0.1	0.5	0.6	0.6	0.6

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	487	654	786	1,988	2,245	2,333	100	100	100	1.9	6.9	0.8	0.4	0.6
Industry	181	234	299	983	915	878	36	49	38	2.5	8.9	-0.4	-0.4	-0.4
Transport	24	33	87	268	402	434	5.1	13	19	10.1	8.4	2.6	0.8	1.9
Buildings, etc.	272	344	340	577	716	781	53	29	33	-0.1	3.9	1.4	0.9	1.2
Non-energy use	10	43	60	160	212	240	6.6	8.0	10	3.4	7.2	1.8	1.3	1.6
Coal	214	308	274	726	551	463	47	37	20	-1.2	7.2	-1.7	-1.7	-1.7
Oil	59	85	180	451	590	611	13	23	26	7.8	6.8	1.7	0.3	1.2
Natural gas	6.4	8.9	12	106	205	258	1.4	5.3	11	3.4	16.6	4.2	2.3	3.5
Electricity	21	39	89	406	578	679	6.0	20	29	8.6	11.4	2.2	1.6	2.0
Heat	7.4	13	25	78	92	93	2.0	3.9	4.0	6.8	8.3	1.0	0.2	0.7
Hydrogen	-	-	-	-	0.1	0.1	-	-	0.0	n.a.	n.a.	n.a.	7.2	n.a.
Renewables	180	200	205	221	228	229	31	11	9.8	0.2	0.5	0.2	0.0	0.1

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	301	621	1,356	5,666	7,876	9,136	100	100	100	8.1	10.8	2.1	1.5	1.9
Coal	159	441	1,060	4,115	4,054	4,016	71	73	44	9.2	10.2	-0.1	-0.1	-0.1
Oil	82	50	47	9.5	9.2	9.1	8.1	0.2	0.1	-0.6	-10.8	-0.2	-0.2	-0.2
Natural gas	0.7	2.8	5.8	115	505	658	0.4	2.0	7.2	7.6	23.8	9.7	2.7	7.0
Nuclear	-	-	17	133	880	1,361	-	2.3	15	n.a.	15.9	12.6	4.5	9.4
Hydro	58	127	222	1,051	1,521	1,607	20	19	18	5.8	11.7	2.3	0.6	1.6
Geothermal	-	0.1	0.1	0.1	0.5	0.6	0.0	0.0	0.0	6.7	1.0	8.8	2.6	6.3
Solar, wind, etc.	-	0.0	0.6	185	754	1,259	0.0	3.3	14	50.2	49.8	9.2	5.3	7.6
Biomass and waste	-	-	2.4	57	152	225	-	1.0	2.5	n.a.	25.4	6.3	4.0	5.4
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	338	824	2,224	8,230	20,185	29,970	10.4	9.8	5.8	4.0	5.1
Population (million)	981	1,135	1,263	1,364	1,414	1,395	1.1	0.6	0.2	-0.1	0.1
CO_2 emissions[*2] (Mt)	1,505	2,339	3,164	9,347	9,257	8,922	3.1	8.0	-0.1	-0.4	-0.2
GDP per capita ($2010 thousand)	0.3	0.7	1.8	6.0	14	21	9.3	9.2	5.5	4.2	5.0
Primary energy consump. per capita (toe)	0.6	0.8	0.9	2.2	2.5	2.6	1.6	6.7	0.7	0.6	0.6
Primary energy consumption per GDP[*3]	1,768	1,056	510	371	174	123	-7.0	-2.3	-4.6	-3.4	-4.2
CO_2 emissions per GDP[*2, *4]	4,452	2,838	1,423	1,136	459	298	-6.7	-1.6	-5.5	-4.2	-5.0
CO_2 per primary energy consumption[*2, *5]	2.5	2.7	2.8	3.1	2.6	2.4	0.4	0.7	-0.9	-0.9	-0.9
Automobile ownership (million)	1.2	5.3	16	146	353	417	11.5	17.3	5.7	1.7	4.1
Automobile ownership rates[*6]	1.2	4.7	12	107	250	299	10.3	16.6	5.4	1.8	4.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A75 | India [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	200	306	441	825	1,225	1,497	100	100	100	3.7	4.6	2.5	2.0	2.3
Coal	44	93	146	378	440	487	30	46	33	4.6	7.0	1.0	1.0	1.0
Oil	33	61	112	185	335	424	20	22	28	6.2	3.6	3.8	2.4	3.2
Natural gas	1.3	11	23	43	91	124	3.5	5.2	8.3	8.1	4.6	4.7	3.2	4.1
Nuclear	0.8	1.6	4.4	9.4	57	108	0.5	1.1	7.2	10.7	5.6	12.0	6.5	9.8
Hydro	4.0	6.2	6.4	11	21	29	2.0	1.4	1.9	0.4	4.2	3.8	3.4	3.6
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	0.2	4.2	40	69	0.0	0.5	4.6	33.0	25.2	15.1	5.8	11.4
Biomass and waste	116	133	149	194	242	256	44	23	17	1.1	1.9	1.4	0.6	1.1

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	174	243	315	556	873	1,068	100	100	100	2.6	4.1	2.9	2.0	2.5
Industry	41	67	83	191	308	398	27	34	37	2.3	6.1	3.1	2.6	2.9
Transport	17	21	32	78	176	223	8.6	14	21	4.4	6.6	5.2	2.4	4.1
Buildings, etc.	110	142	173	246	325	366	59	44	34	2.0	2.5	1.8	1.2	1.5
Non-energy use	5.7	13	27	41	63	81	5.5	7.4	7.6	7.3	3.1	2.7	2.5	2.6
Coal	25	39	35	114	169	204	16	20	19	-1.1	8.9	2.5	1.9	2.3
Oil	27	50	94	156	310	398	21	28	37	6.5	3.7	4.4	2.5	3.7
Natural gas	0.7	5.6	9.7	29	50	67	2.3	5.2	6.3	5.5	8.1	3.5	2.9	3.3
Electricity	7.8	18	32	81	149	210	7.6	15	20	5.8	6.8	3.8	3.5	3.7
Heat	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	-	-	0.0	n.a.	n.a.	n.a.	8.7	n.a.
Renewables	114	130	144	176	196	190	54	32	18	1.0	1.4	0.7	-0.3	0.3

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	120	293	570	1,287	2,279	3,167	100	100	100	6.9	6.0	3.6	3.3	3.5
Coal	61	192	390	967	1,101	1,218	65	75	38	7.4	6.7	0.8	1.0	0.9
Oil	8.8	13	29	23	12	8.6	4.5	1.8	0.3	8.2	-1.8	-3.8	-3.5	-3.7
Natural gas	0.6	10.0	56	63	181	287	3.4	4.9	9.1	18.8	0.8	6.8	4.7	6.0
Nuclear	3.0	6.1	17	36	220	414	2.1	2.8	13	10.7	5.6	12.0	6.5	9.8
Hydro	47	72	74	132	239	334	24	10	11	0.4	4.2	3.8	3.4	3.6
Geothermal	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	1.7	42	450	793	0.0	3.3	25	48.7	25.8	16.0	5.8	12.0
Biomass and waste	-	-	1.3	25	76	113	-	2.0	3.6	n.a.	23.8	7.1	4.1	5.9
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	279	479	825	2,188	6,281	10,573	5.6	7.2	6.8	5.3	6.2
Population (million)	697	871	1,053	1,295	1,528	1,634	1.9	1.5	1.0	0.7	0.9
CO_2 emissions[*2] (Mt)	263	542	899	2,053	2,808	3,296	5.2	6.1	2.0	1.6	1.8
GDP per capita ($2010 thousand)	0.4	0.6	0.8	1.7	4.1	6.5	3.6	5.6	5.7	4.6	5.3
Primary energy consump. per capita (toe)	0.3	0.4	0.4	0.6	0.8	0.9	1.8	3.0	1.5	1.3	1.4
Primary energy consumption per GDP[*3]	716	638	534	377	195	142	-1.8	-2.5	-4.0	-3.2	-3.7
CO_2 emissions per GDP[*2, *4]	943	1,131	1,090	938	447	312	-0.4	-1.1	-4.5	-3.5	-4.1
CO_2 per primary energy consumption[*2, *5]	1.3	1.8	2.0	2.5	2.3	2.2	1.4	1.4	-0.5	-0.4	-0.5
Automobile ownership (million)	1.7	4.3	9.4	38	126	207	8.1	10.5	7.8	5.1	6.7
Automobile ownership rates[*6]	2.4	5.0	8.9	29	83	127	6.1	8.9	6.7	4.4	5.8

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A76 | Japan [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	345	439	518	442	426	395	100	100	100	1.7	-1.1	-0.2	-0.8	-0.4
Coal	60	76	97	118	102	92	17	27	23	2.4	1.4	-0.9	-1.0	-0.9
Oil	234	250	255	192	145	122	57	43	31	0.2	-2.0	-1.8	-1.7	-1.7
Natural gas	21	44	66	108	77	73	10	24	19	4.0	3.6	-2.0	-0.5	-1.5
Nuclear	22	53	84	-	61	56	12	-	14	4.8	-100	n.a.	-0.7	n.a.
Hydro	7.6	7.5	7.3	7.0	8.3	8.3	1.7	1.6	2.1	-0.2	-0.3	1.0	0.0	0.6
Geothermal	0.8	1.6	3.1	2.4	10	15	0.4	0.5	3.9	7.0	-1.8	9.5	4.1	7.4
Solar, wind, etc.	-	1.4	0.9	2.9	7.4	10	0.3	0.7	2.6	-3.7	8.4	6.0	3.1	4.9
Biomass and waste	-	4.5	4.7	11	16	16	1.0	2.5	4.2	0.4	6.3	2.1	0.6	1.5

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	232	287	328	296	271	248	100	100	100	1.4	-0.7	-0.5	-0.9	-0.7
Industry	91	110	100	88	92	87	38	30	35	-0.9	-0.9	0.3	-0.5	0.0
Transport	54	68	84	72	57	48	24	24	19	2.2	-1.2	-1.4	-1.7	-1.6
Buildings, etc.	58	76	103	100	88	81	26	34	32	3.1	-0.2	-0.8	-0.9	-0.8
Non-energy use	28	34	41	36	35	33	12	12	13	2.1	-1.0	-0.2	-0.6	-0.3
Coal	25	30	24	24	25	23	11	8.0	9.1	-2.2	-0.2	0.3	-1.1	-0.2
Oil	157	171	194	156	120	98	59	53	39	1.3	-1.6	-1.6	-2.0	-1.8
Natural gas	5.8	15	22	30	31	30	5.3	10	12	3.6	2.3	0.2	-0.4	0.0
Electricity	44	66	83	82	85	85	23	28	34	2.3	-0.1	0.2	0.0	0.2
Heat	0.1	0.2	0.5	0.5	5.1	7.2	0.1	0.2	2.9	10.5	0.1	15.0	3.5	10.4
Hydrogen	-	-	-	-	0.4	0.4	-	-	0.2	n.a.	n.a.	n.a.	1.5	n.a.
Renewables	-	4.1	3.8	3.9	4.7	4.9	1.4	1.3	2.0	-0.7	0.1	1.2	0.5	0.9

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	573	873	1,088	1,036	1,064	1,059	100	100	100	2.2	-0.4	0.2	-0.1	0.1
Coal	55	118	234	349	262	236	13	34	22	7.1	2.9	-1.8	-1.1	-1.5
Oil	265	284	179	116	55	51	33	11	4.8	-4.5	-3.0	-4.6	-0.7	-3.1
Natural gas	81	171	254	421	274	273	20	41	26	4.0	3.7	-2.6	0.0	-1.6
Nuclear	83	202	322	-	233	216	23	-	20	4.8	-100	n.a.	-0.7	n.a.
Hydro	88	87	85	82	96	96	10.0	7.9	9.1	-0.2	-0.3	1.0	0.0	0.6
Geothermal	0.9	1.7	3.3	2.6	12	18	0.2	0.2	1.7	6.8	-1.9	9.9	4.2	7.6
Solar, wind, etc.	-	0.0	0.5	30	76	105	0.0	2.9	9.9	84.4	34.7	6.1	3.3	5.0
Biomass and waste	-	9.6	10	36	57	64	1.1	3.4	6.1	0.7	9.3	3.0	1.2	2.3
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	2,894	4,553	5,093	5,650	6,582	7,354	1.1	0.7	1.0	1.1	1.0
Population (million)	117	124	127	127	120	114	0.3	0.0	-0.3	-0.6	-0.4
CO_2 emissions[*2] (Mt)	916	1,071	1,195	1,201	922	812	1.1	0.0	-1.6	-1.3	-1.5
GDP per capita ($2010 thousand)	25	37	40	44	55	65	0.9	0.7	1.3	1.7	1.5
Primary energy consump. per capita (toe)	3.0	3.6	4.1	3.5	3.5	3.5	1.4	-1.1	0.1	-0.2	0.0
Primary energy consumption per GDP[*3]	119	96	102	78	65	54	0.5	-1.9	-1.2	-1.9	-1.4
CO_2 emissions per GDP[*2, *4]	317	235	235	213	140	110	0.0	-0.7	-2.6	-2.4	-2.5
CO_2 per primary energy consumption[*2, *5]	2.7	2.4	2.3	2.7	2.2	2.1	-0.6	1.2	-1.4	-0.5	-1.1
Automobile ownership (million)	38	58	72	77	74	71	2.3	0.4	-0.2	-0.4	-0.3
Automobile ownership rates[*6]	325	467	571	604	615	628	2.0	0.4	0.1	0.2	0.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A77 | ASEAN [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	n.a.	n.a.	385	624	992	1,275	n.a.	100	100	n.a.	3.5	2.9	2.5	2.8
Coal	n.a.	n.a.	32	99	191	262	n.a.	16	21	n.a.	8.4	4.2	3.2	3.8
Oil	n.a.	n.a.	154	221	311	369	n.a.	35	29	n.a.	2.6	2.2	1.7	2.0
Natural gas	n.a.	n.a.	74	139	184	224	n.a.	22	18	n.a.	4.6	1.8	1.9	1.8
Nuclear	n.a.	n.a.	-	-	27	73	n.a.	-	5.7	n.a.	n.a.	n.a.	10.5	n.a.
Hydro	n.a.	n.a.	4.4	11	19	24	n.a.	1.8	1.9	n.a.	6.8	3.5	2.5	3.1
Geothermal	n.a.	n.a.	18	26	110	166	n.a.	4.2	13	n.a.	2.5	9.4	4.2	7.4
Solar, wind, etc.	n.a.	n.a.	0.0	0.2	2.3	5.5	n.a.	0.0	0.4	n.a.	72.9	16.7	9.4	13.8
Biomass and waste	n.a.	n.a.	102	127	149	152	n.a.	20	12	n.a.	1.6	1.0	0.2	0.7

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	n.a.	n.a.	274	441	649	805	n.a.	100	100	n.a.	3.4	2.4	2.2	2.3
Industry	n.a.	n.a.	76	121	205	269	n.a.	28	33	n.a.	3.4	3.3	2.8	3.1
Transport	n.a.	n.a.	62	118	172	204	n.a.	27	25	n.a.	4.7	2.4	1.7	2.1
Buildings, etc.	n.a.	n.a.	116	154	199	240	n.a.	35	30	n.a.	2.0	1.6	1.9	1.7
Non-energy use	n.a.	n.a.	21	48	72	91	n.a.	11	11	n.a.	6.0	2.6	2.4	2.5
Coal	n.a.	n.a.	13	29	50	61	n.a.	6.6	7.6	n.a.	5.7	3.4	2.0	2.9
Oil	n.a.	n.a.	123	197	286	345	n.a.	45	43	n.a.	3.4	2.4	1.9	2.2
Natural gas	n.a.	n.a.	17	38	69	94	n.a.	8.5	12	n.a.	5.9	3.8	3.3	3.6
Electricity	n.a.	n.a.	28	65	124	184	n.a.	15	23	n.a.	6.4	4.1	4.0	4.0
Heat	n.a.	n.a.	-	-	-	-	n.a.	-	-	n.a.	n.a.	n.a.	n.a.	n.a.
Hydrogen	n.a.	n.a.	-	-	0.0	0.0	n.a.	-	0.0	n.a.	n.a.	n.a.	6.0	n.a.
Renewables	n.a.	n.a.	93	112	120	121	n.a.	25	15	n.a.	1.3	0.5	0.0	0.3

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	n.a.	n.a.	374	854	1,632	2,412	n.a.	100	100	n.a.	6.1	4.1	4.0	4.1
Coal	n.a.	n.a.	79	283	628	954	n.a.	33	40	n.a.	9.5	5.1	4.3	4.8
Oil	n.a.	n.a.	72	38	29	25	n.a.	4.4	1.0	n.a.	-4.5	-1.7	-1.3	-1.6
Natural gas	n.a.	n.a.	154	371	512	648	n.a.	43	27	n.a.	6.5	2.0	2.4	2.2
Nuclear	n.a.	n.a.	-	-	104	280	n.a.	-	12	n.a.	n.a.	n.a.	10.5	n.a.
Hydro	n.a.	n.a.	51	128	222	284	n.a.	15	12	n.a.	6.8	3.5	2.5	3.1
Geothermal	n.a.	n.a.	16	20	74	107	n.a.	2.4	4.5	n.a.	1.5	8.4	3.8	6.6
Solar, wind, etc.	n.a.	n.a.	0.0	2.2	26	64	n.a.	0.3	2.7	n.a.	73.4	16.7	9.4	13.8
Biomass and waste	n.a.	n.a.	1.0	12	38	48	n.a.	1.4	2.0	n.a.	19.3	7.6	2.3	5.5
Hydrogen	n.a.	n.a.	-	-	-	-	n.a.	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	n.a.	n.a.	1,188	2,407	5,071	7,488	n.a.	5.2	4.8	4.0	4.5
Population (million)	n.a.	n.a.	523	623	723	765	n.a.	1.3	0.9	0.6	0.8
CO_2 emissions[*2] (Mt)	n.a.	n.a.	713	1,258	1,979	2,493	n.a.	4.1	2.9	2.3	2.7
GDP per capita ($2010 thousand)	n.a.	n.a.	2.3	3.9	7.0	9.8	n.a.	3.9	3.8	3.4	3.6
Primary energy consump. per capita (toe)	n.a.	n.a.	0.7	1.0	1.4	1.7	n.a.	2.2	2.0	2.0	2.0
Primary energy consumption per GDP[*3]	n.a.	n.a.	324	259	196	170	n.a.	-1.6	-1.7	-1.4	-1.6
CO_2 emissions per GDP[*2, *4]	n.a.	n.a.	601	523	390	333	n.a.	-1.0	-1.8	-1.6	-1.7
CO_2 per primary energy consumption[*2, *5]	n.a.	n.a.	1.9	2.0	2.0	2.0	n.a.	0.6	-0.1	-0.2	-0.1
Automobile ownership (million)	n.a.	n.a.	21	55	106	145	n.a.	7.2	4.3	3.1	3.8
Automobile ownership rates[*6]	n.a.	n.a.	40	88	147	189	n.a.	5.8	3.3	2.5	3.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A78 | United States [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	1,805	1,915	2,273	2,216	2,001	1,812	100	100	100	1.7	-0.2	-0.6	-1.0	-0.8
Coal	376	460	534	432	231	131	24	19	7.2	1.5	-1.5	-3.8	-5.6	-4.5
Oil	797	757	871	782	631	514	40	35	28	1.4	-0.8	-1.3	-2.0	-1.6
Natural gas	477	438	548	624	624	573	23	28	32	2.3	0.9	0.0	-0.8	-0.3
Nuclear	69	159	208	216	214	214	8.3	9.8	12	2.7	0.3	-0.1	0.0	-0.1
Hydro	24	23	22	22	24	24	1.2	1.0	1.3	-0.8	0.2	0.4	0.1	0.3
Geothermal	4.6	14	13	9.0	39	50	0.7	0.4	2.7	-0.7	-2.7	9.6	2.4	6.8
Solar, wind, etc.	-	0.3	2.1	20	81	133	0.0	0.9	7.3	20.5	17.8	8.9	5.1	7.5
Biomass and waste	54	62	73	105	153	169	3.3	4.7	9.3	1.6	2.6	2.4	1.0	1.8

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	1,311	1,294	1,546	1,538	1,403	1,295	100	100	100	1.8	0.0	-0.6	-0.8	-0.7
Industry	387	284	332	269	249	233	22	17	18	1.6	-1.5	-0.5	-0.6	-0.5
Transport	425	488	588	623	532	455	38	41	35	1.9	0.4	-1.0	-1.5	-1.2
Buildings, etc.	397	403	473	526	495	465	31	34	36	1.6	0.8	-0.4	-0.6	-0.5
Non-energy use	102	119	153	119	127	141	9.2	7.8	11	2.5	-1.8	0.4	1.0	0.6
Coal	56	56	33	22	19	16	4.3	1.4	1.2	-5.2	-2.7	-0.9	-1.7	-1.2
Oil	689	683	793	744	589	481	53	48	37	1.5	-0.5	-1.5	-2.0	-1.7
Natural gas	337	303	360	355	338	326	23	23	25	1.7	-0.1	-0.3	-0.3	-0.3
Electricity	174	226	301	326	336	335	18	21	26	2.9	0.6	0.2	0.0	0.1
Heat	-	2.2	5.3	5.6	5.5	5.1	0.2	0.4	0.4	9.4	0.4	0.0	-0.8	-0.3
Hydrogen	-	-	-	-	3.4	6.4	-	-	0.5	n.a.	n.a.	n.a.	6.5	n.a.
Renewables	54	23	54	84	112	124	1.8	5.5	9.6	9.0	3.2	1.8	1.0	1.5

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	2,427	3,203	4,026	4,319	4,429	4,422	100	100	100	2.3	0.5	0.2	0.0	0.1
Coal	1,243	1,700	2,129	1,713	923	488	53	40	11	2.3	-1.5	-3.8	-6.2	-4.7
Oil	263	131	118	40	19	9.0	4.1	0.9	0.2	-1.0	-7.5	-4.4	-7.4	-5.6
Natural gas	370	382	634	1,161	1,240	1,029	12	27	23	5.2	4.4	0.4	-1.8	-0.5
Nuclear	266	612	798	831	820	820	19	19	19	2.7	0.3	-0.1	0.0	-0.1
Hydro	279	273	253	261	278	281	8.5	6.1	6.4	-0.8	0.2	0.4	0.1	0.3
Geothermal	5.4	16	15	19	84	106	0.5	0.4	2.4	-0.9	1.8	9.8	2.4	6.9
Solar, wind, etc.	-	3.7	6.4	213	900	1,499	0.1	4.9	34	5.5	28.5	9.4	5.2	7.8
Biomass and waste	0.5	86	72	82	165	190	2.7	1.9	4.3	-1.8	0.9	4.5	1.4	3.3
Hydrogen	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	6,529	9,064	12,713	16,282	23,132	28,154	3.4	1.8	2.2	2.0	2.1
Population (million)	227	250	282	319	356	374	1.2	0.9	0.7	0.5	0.6
CO_2 emissions[*2] (Mt)	4,743	4,820	5,617	5,221	3,940	3,024	1.5	-0.5	-1.7	-2.6	-2.1
GDP per capita ($2010 thousand)	29	36	45	51	65	75	2.2	0.9	1.5	1.5	1.5
Primary energy consump. per capita (toe)	7.9	7.7	8.1	7.0	5.6	4.8	0.5	-1.0	-1.3	-1.5	-1.4
Primary energy consumption per GDP[*3]	276	211	179	136	86	64	-1.7	-1.9	-2.8	-2.9	-2.8
CO_2 emissions per GDP[*2, *4]	726	532	442	321	170	107	-1.8	-2.3	-3.9	-4.5	-4.1
CO_2 per primary energy consumption[*2, *5]	2.6	2.5	2.5	2.4	2.0	1.7	-0.2	-0.3	-1.1	-1.6	-1.3
Automobile ownership (million)	156	189	221	252	300	323	1.6	0.9	1.1	0.7	1.0
Automobile ownership rates[*6]	686	756	785	790	843	863	0.4	0.0	0.4	0.2	0.3

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people

Table A79 | European Union [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total[*1]	n.a.	1,645	1,695	1,565	1,486	1,372	100	100	100	0.3	-0.6	-0.3	-0.8	-0.5
Coal	n.a.	456	321	268	169	119	28	17	8.6	-3.4	-1.3	-2.9	-3.5	-3.1
Oil	n.a.	605	625	509	412	341	37	33	25	0.3	-1.5	-1.3	-1.9	-1.5
Natural gas	n.a.	297	396	343	327	290	18	22	21	2.9	-1.0	-0.3	-1.2	-0.6
Nuclear	n.a.	207	246	228	264	280	13	15	20	1.7	-0.5	0.9	0.6	0.8
Hydro	n.a.	25	31	32	33	33	1.5	2.1	2.4	2.1	0.4	0.2	0.0	0.1
Geothermal	n.a.	3.2	4.6	6.2	10	12	0.2	0.4	0.8	3.7	2.2	3.1	1.4	2.4
Solar, wind, etc.	n.a.	0.3	2.4	34	66	82	0.0	2.2	5.9	25.3	20.8	4.3	2.1	3.4
Biomass and waste	n.a.	47	67	142	203	214	2.9	9.1	16	3.5	5.5	2.3	0.5	1.6

Final energy consumption

	Mtoe						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	n.a.	1,130	1,180	1,095	1,051	966	100	100	100	0.4	-0.5	-0.3	-0.8	-0.5
Industry	n.a.	343	310	255	246	231	30	23	24	-1.0	-1.4	-0.2	-0.6	-0.4
Transport	n.a.	259	304	307	264	225	23	28	23	1.6	0.1	-0.9	-1.6	-1.2
Buildings, etc.	n.a.	429	454	433	430	397	38	40	41	0.6	-0.3	-0.1	-0.8	-0.3
Non-energy use	n.a.	99	113	100	111	114	8.7	9.1	12	1.4	-0.9	0.7	0.2	0.5
Coal	n.a.	122	53	37	33	28	11	3.4	2.9	-8.1	-2.5	-0.7	-1.6	-1.1
Oil	n.a.	503	543	460	380	318	44	42	33	0.8	-1.2	-1.2	-1.8	-1.4
Natural gas	n.a.	226	272	235	250	240	20	21	25	1.9	-1.0	0.4	-0.4	0.1
Electricity	n.a.	186	217	233	241	236	16	21	24	1.6	0.5	0.2	-0.2	0.1
Heat	n.a.	54	45	46	46	43	4.8	4.2	4.5	-1.8	0.0	0.0	-0.6	-0.2
Hydrogen	n.a.	-	-	-	0.5	0.9	-	-	0.1	n.a.	n.a.	n.a.	6.2	n.a.
Renewables	n.a.	40	50	85	101	100	3.5	7.7	10	2.3	3.8	1.1	0.0	0.7

Electricity generation

	(TWh)						Shares (%)			CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990	2014	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
Total	n.a.	2,577	3,006	3,159	3,323	3,299	100	100	100	1.6	0.4	0.3	-0.1	0.2
Coal	n.a.	1,050	968	841	474	277	41	27	8.4	-0.8	-1.0	-3.5	-5.2	-4.2
Oil	n.a.	224	181	57	21	14	8.7	1.8	0.4	-2.1	-7.9	-6.0	-3.9	-5.2
Natural gas	n.a.	193	480	457	313	189	7.5	14	5.7	9.5	-0.3	-2.3	-4.9	-3.3
Nuclear	n.a.	795	945	876	1,012	1,074	31	28	33	1.7	-0.5	0.9	0.6	0.8
Hydro	n.a.	290	357	375	385	385	11	12	12	2.1	0.4	0.2	0.0	0.1
Geothermal	n.a.	3.2	4.8	6.2	10	12	0.1	0.2	0.4	4.0	1.9	3.3	1.3	2.5
Solar, wind, etc.	n.a.	1.3	24	355	736	916	0.1	11	28	33.9	21.2	4.7	2.2	3.7
Biomass and waste	n.a.	20	46	189	371	431	0.8	6.0	13	8.9	10.6	4.3	1.5	3.2
Hydrogen	n.a.	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

							CAGR (%)				
	1980	1990	2000	2014	2030	2040	1990/ 2000	2000/ 2014	2014/ 2030	2030/ 2040	2014/ 2040
GDP ($2010 billion)	n.a.	11,801	14,729	17,396	22,607	25,741	2.2	1.2	1.7	1.3	1.5
Population (million)	n.a.	478	488	508	521	522	0.2	0.3	0.2	0.0	0.1
CO_2 emissions[*2] (Mt)	n.a.	4,067	3,783	3,134	2,370	1,860	-0.7	-1.3	-1.7	-2.4	-2.0
GDP per capita ($2010 thousand)	n.a.	25	30	34	43	49	2.0	0.9	1.5	1.3	1.4
Primary energy consump. per capita (toe)	n.a.	3.4	3.5	3.1	2.9	2.6	0.1	-0.9	-0.5	-0.8	-0.6
Primary energy consumption per GDP[*3]	n.a.	139	115	90	66	53	-1.9	-1.7	-1.9	-2.1	-2.0
CO_2 emissions per GDP[*2, *4]	n.a.	345	257	180	105	72	-2.9	-2.5	-3.3	-3.6	-3.5
CO_2 per primary energy consumption[*2, *5]	n.a.	2.5	2.2	2.0	1.6	1.4	-1.0	-0.8	-1.4	-1.6	-1.5
Automobile ownership (million)	n.a.	177	235	298	346	359	2.9	1.7	0.9	0.4	0.7
Automobile ownership rates[*6]	n.a.	371	482	587	665	687	2.7	1.4	0.8	0.3	0.6

*1 Trade of electricity, heat and hydrogen are not shown, *2 Excludes emission reduction by CCS, *3 toe/$2010 million,
*4 t/$2010 million, *5 t/toe, *6 Vehicles per 1,000 people