IEEJ Outlook 2018

– Prospects and challenges until 2050 –

Energy, Environment and Economy

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Foreword

Global energy consumption growth remains slow. This does not imply, however, that energy consumption has become irrelevant to the global economy but it simply means that the growth is slowing down reflecting a more conservative pace of economic expansion. Over the medium to long term, more energy will be required mainly in emerging economies. Contributing to the energy demand growth will be Asian countries including India, the members of the Association of Southeast Asian Nations as well as China, which has so far greatly contributed to the global demand growth. Asia can dramatically change the world energy picture in the future.

Asia, as well as other regions, has been heavily dependent on fossil fuels and such market structure cannot be expected to change rapidly. It is noteworthy, however, that China grew to be a larger renewable energy market than Europe (which was known as proactively using renewable energy), that India is introducing an ambitious plan to more than triple its renewable energy power generation by 2022, and that Indonesia and the Philippines account for 36% of global geothermal energy consumption. Behind these developments, new views on oil, the most significant among fossil fuels, begin attracting people's attention.

A review of the history of oil demand indicates that the decline for lighting requirements, resulting from the commercialisation of the lightbulbs, coincided with an increase to fuel vehicles. In the year prior to the discovery of oil in Spindletop, Texas, in 1901, symbolising the advent of an oil boom, vehicle production was limited to about 10,000 units. Currently, global vehicle fleet has expanded to close to 1.3 billion units, which mostly run on oil. For more than a century, oil and vehicles have been inseparably linked with currently more than 40% of the global oil consumption poured into vehicle fuel tanks. Due to demand-side factors mainly related to climate change countermeasures, however, oil consumption is rumoured by some to peak and turn downward in a not-too-distant future. As climate change countermeasures are combined with the promotion of vehicle electrification for preventing air pollution, interests are growing in peak oil demand. The "IEEJ Outlook 2018" analyses a peak oil demand case from a wide perspective.

Compared to the long oil history which spans over two centuries, the United Nations Framework Convention on Climate Change was adopted only a quarter of a century ago. While a global carbon reduction trend has been gradually realised since its adoption, proposals to further enhance the challenging carbon reduction targets continue to increase and be the subject of international negotiations and politics. The gap between realities and ideals is becoming wider and wider. Climate change influences a wide range of areas and is a long-term challenge covering many generations. The realities of emission cuts, adaptation and residual damage must be carefully balanced within a pluralistic interpretation of sustainability. The IEEJ Outlook 2018 tackles this difficult challenge with more fine-tuned methods.

We are convinced that this newly organised outlook will make great social contributions to the accumulation of knowledge.

Tokyo, October 2017

THE INSTITUTE OF ENERGY ECONOMICS, JAPAN

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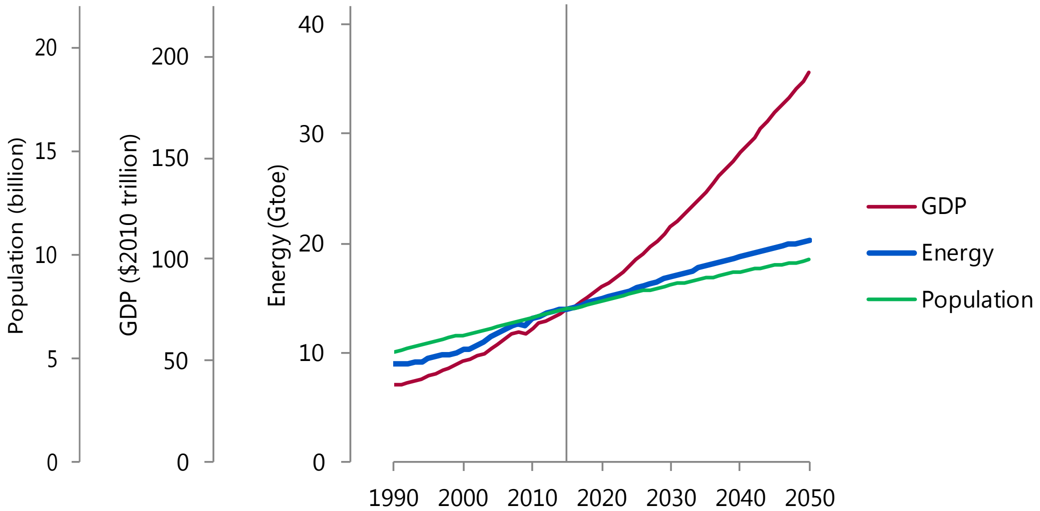
Demand

In the "Reference Scenario" which assumes that energy, environmental policies, etc. follow past trends, the world's population will be 1.3 times larger, the economy 2.5 times larger and energy consumption 1.5 times greater in 2050 than today (Figure 1). The energy needed to generate a single unit of gross domestic product (GDP) will decline at an annual rate of 1.6% due to energy efficiency improvements and will be a little more than half the current level in 2050. Although the increase in energy consumption continues as the economy grows, there is a significant difference in their pace of expansion. Nevertheless, the increase in energy consumption during the period – 6,142 Mtoe – is not a small amount, as the annual increase in demand is equivalent to the United Kingdom's consumption.

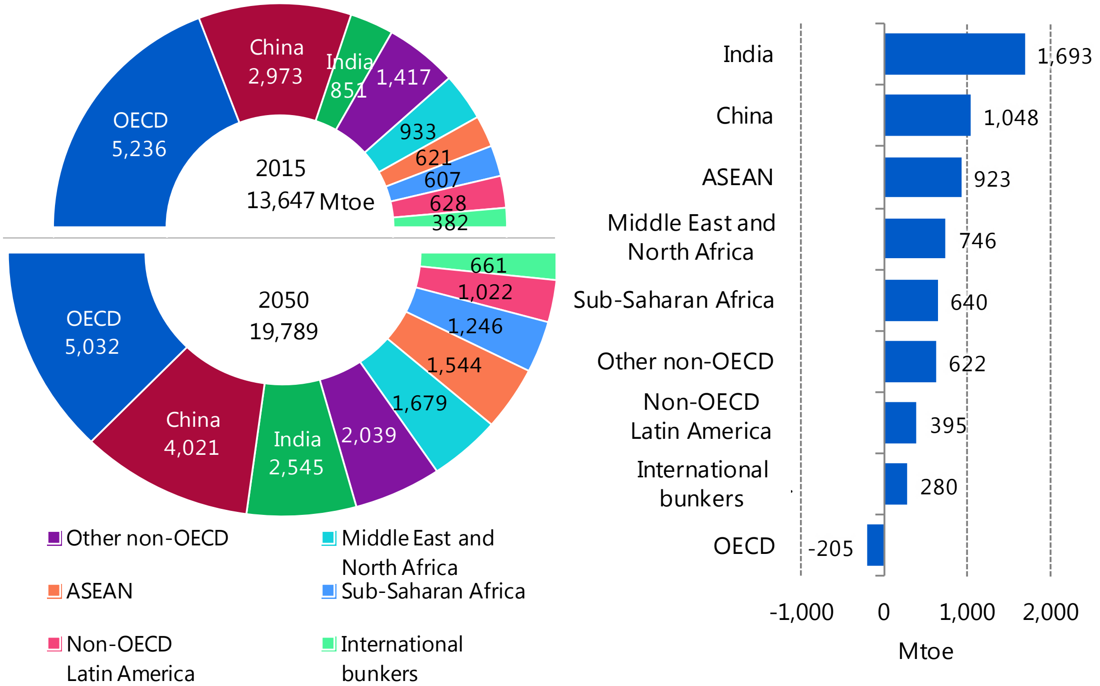
Figure 1 | World population, real GDP, primary energy consumption



The relationship between economic growth and energy consumption is not necessarily the same everywhere in the world. Despite economic growth, the energy consumption of the Organisation for Economic Co-operation and Development (OECD) member states combined will be less in 2050 than today (Figure 2). In other words, the future world increase in energy consumption will all occur outside the OECD. Among non-OECD countries, the significant increase in Asia – India, China and the Association of Southeast Asian Nations (ASEAN) – continues, and the Middle East, North Africa and Sub-Saharan Africa will also increase consumption largely due to rapid population and economic growth. Non-OECD's energy consumption that exceeded OECD in 2005, has since grown to 59% of the world today and will reach 71% in 2050. In other words, if non-OECD, including Asia, slows the increase in energy consumption due to more control or adjustment to their socioeconomic situation, the global energy supply and demand image can be greatly different.

Figure 2 | Primary energy consumption and changes (by region)

[2015 and 2050] **Changes [2015-2050]**

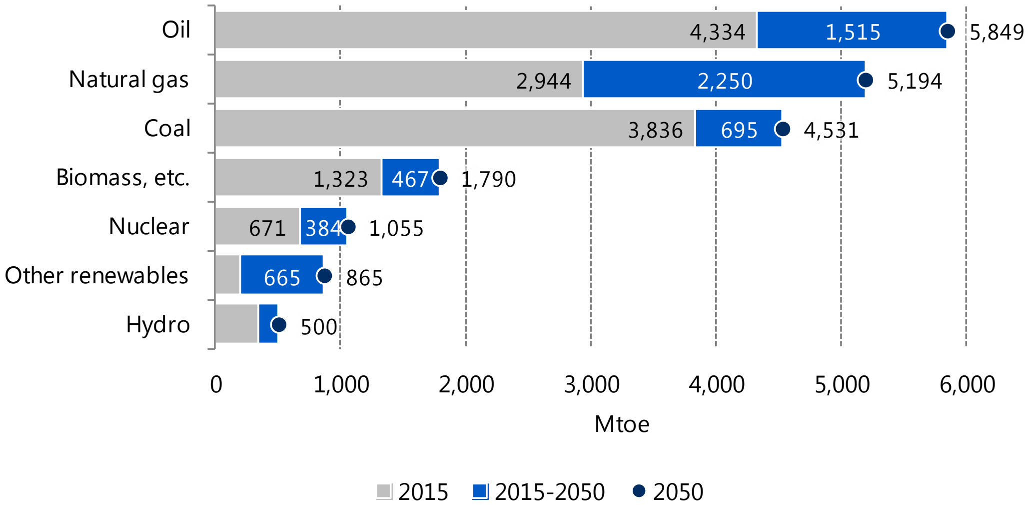


- Despite huge expectations from non-fossil energy, fossil fuels will meet most of the massive new demand (Figure 3). During the projection period, for each 1 toe of non-fossil energy increase, the fossil fuels will increase by 2.7 toes. The sum of all non-fossil fuels has yet to reach the total for coal, the least fossil fuel in 2050. Although non-fossil energy is expanding from 19%, its share is only 21% by the middle of this century.
- Oil remains the largest energy source, even in 2050, supporting 30% of global energy demand. Oil consumption peaked in OECD countries 10 years ago, and it continues to decline at an annual rate of 0.7%. The increase in global oil consumption from 90 million barrels per day (Mb/d) to 122 Mb/d is led by a vigorous consumption in non-OECD and international bunkers. China will be the world's largest oil consumer ahead of the United States in about 10 years. Its consumption will peak by the mid-2040s and decrease thereafter. India will become the second largest consumer prior to 2050, replacing the United States. India, the most populous country by 2022, is expected to become the largest consumer surpassing China in the mid-2050s.
- Natural gas shows increases larger than any other source of energy and overtakes coal as the second energy source by 2040. Both power generation and other uses contribute to an increase of more than 1,000 Mtoe. Of the 42 countries and regions that are listed in

IEEJ Outlook, only four countries, Japan, the United Kingdom, Italy and Germany, consume less natural gas in 2050 than today. Natural gas, the newest of the fossil fuels, exceeds oil and becomes the largest energy source in the United States around 2030 and in the European Union (EU) by 2040. Natural gas is currently the predominant energy source in 10 regions (13% of world energy coverage) but will be the leading fuel in 21 regions (36%) in 2050.

Coal has grown significantly to cover half the world's energy consumption increase over the first 10 years of this century. However, the momentum has slowed down substantially, and this new trend continues in the future. Individual aspects, however, vary considerably from region to region. OECD continues to reduce its consumption and China, which tripled its coal consumption from 2000 to 2015, will turn down its needs after a slight increase by 2040. On the other hand, India and ASEAN provide much of the energy demand for coal, and the dependence on coal in 2050 will be as much as or more than today. As coal continues to be indispensable, it is strongly recommended to develop highly efficient and clean technology for its use.

Figure 3 | World primary energy consumption (by energy source)



Final energy consumption, which represents the actual consumption by end-users, increases in all sectors (buildings, transport, industry, non-energy use, etc.) reaching 13,675 Mtoe in 2050, 46% more than today (Figure 4). As for primary energy consumption, the increase is attributable to non-OECD and international bunkers.

Electricity consumption increases regardless of the economic development stage of each country and region (Figure 5). The share of electricity in the total final energy consumption will rise from 19% today to 24% in 2050. A particularly notable increase in electricity consumption comes from the non-OECD upper-middle-income economies. As non-OECD's lower-middle and low-income economies also increase their electricity consumption by more than four times, total non-OECD's demand increases by 15.7 PWh, well above the current and projected OECD consumption of 9.3 PWh and 12.1 PWh.

Figure 4 | Changes in final energy consumption [2015 – 2050]

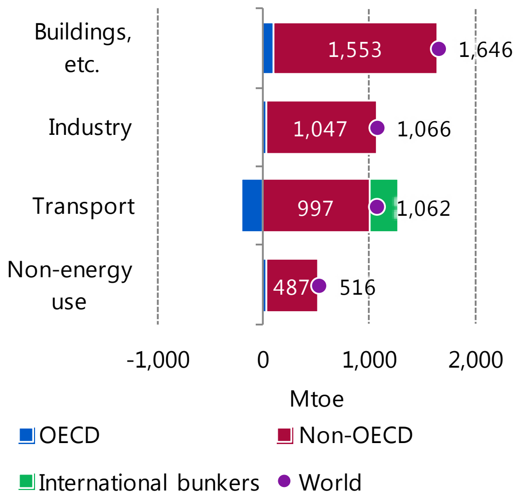
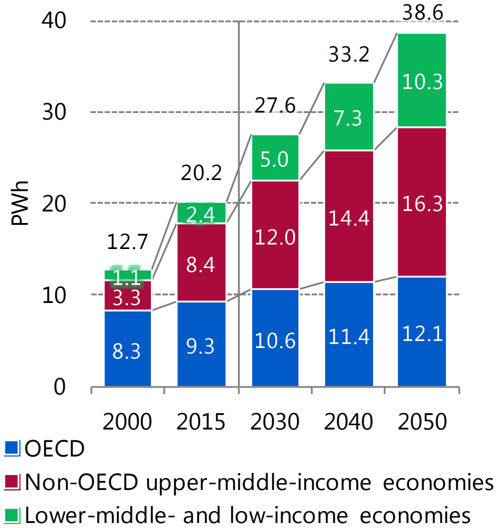


Figure 5 | Final electricity consumption



Note: Lower-middle- and low-income economies are countries and regions with nominal GDP per capita of $4,000 or less as of 2015.

The world electricity supply (electricity generation) is also increasing to meet the rapid growth pace in consumption. Energy used for power generation was 34% of the total primary energy consumption in 2000; it will represent 41% in 2050. The ratio will be 44% in OECD, where electrification is more advanced.

Supply

As a result of higher oil products demand, the supply of oil from both OPEC and non-OPEC will increase (Figure 6). Over 80% of the production increase until 2050 comes from Middle East OPEC, and North and Latin Americas. In North America, investments in exploration and development sectors will improve, backed by a moderate oil price recovery – $95/bbl and $125/bbl (real in $2016) in 2030 and in 2050, respectively. Unconventional oil, such as shale oil and oil sands, will steer the production increase. Production in Latin America, mainly driven by the Brazilian pre-salt development, will also play an important part of the increase in non-OPEC supplies. Non-OPEC production shares, however, will decline gradually from 58% in 2015 to 53% in 2050, due to the production decline in Asia and the peak of Europe and Eurasia around 2030.

Although demand for oil is increasing, the supply until the middle of the century can be met from already proven reserves, which are resources that can be produced in the current technology and economy (Figure 7). As such, the possibility of a supply constraint due to early depletion of resources is small because technological advances will also lead to the discovery of reserves and unconfirmed resources. The concern is that excessive risk avoidance, which is due to the volatility of oil prices and environmental constraints, will hinder adequate supply investment.

Figure 6 | Crude oil production in selected regions

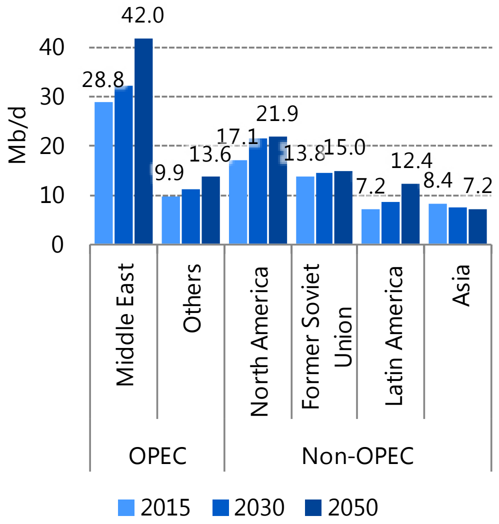
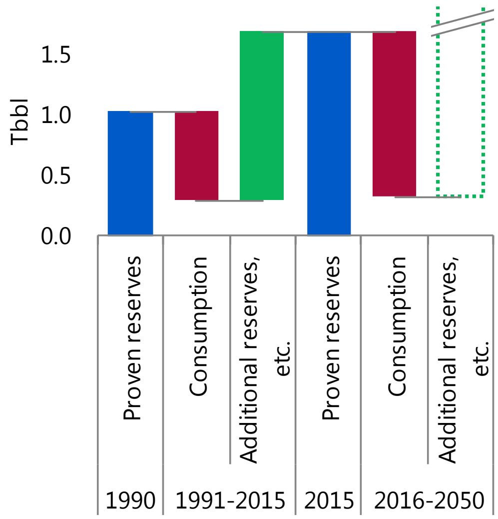
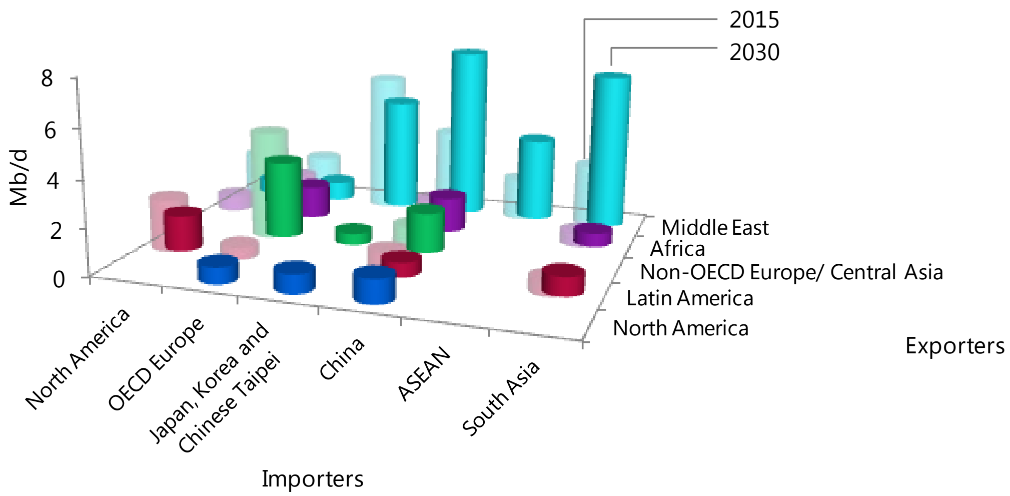


Figure 7 | World crude oil reserves and cumulative consumption



Crude oil trade between the selected regions increases to 43 Mb/d in 2030 (Figure 8). There will be fewer imports in the OECD, as demand declines and production increases in North America, but imports in emerging Asian economies will increase overall trade volume. In Asia, despite some diversification, oil supply from the Middle East and Africa accounts for 80% as of 2030. North American imports from Latin America and the Middle East will remain, but decline substantially. Non-OECD Europe / Central Asia, Africa, and the Middle East will compete in Europe as the region's imports decline. Non-OECD Europe / Central Asia and the Middle East will intensify their exports to Asia where demand increases, deepening the interdependence in crude oil trade between the Middle East and Asia.

Figure 8 | Crude oil trade between selected regions [2015 and 2030]



- The volume of natural gas production in the world increases by 80% from 2015 to 2050 (Figure 9). The largest increase in production comes from the Middle East with the annual addition of 589 billion m³ (Bcm). Iran, which has the largest proven reserves in the world, will continue to maintain its position as the largest producer in the region meeting demand for petrochemical feedstocks and pipeline gas to neighbouring countries after 2030. The United States will continue to increase production using its accumulated knowledge on development and will expand exports of liquefied natural gas (LNG) from the Gulf Coast. The former Soviet Union follows these two regions. In Russia, East Siberia and Sakhalin will contribute to production increases after 2030, adding to the Yamal Peninsula, which is currently under development.
- The amount of natural gas trade between the selected regions of the world as of 2016 was 544 Bcm. Most of it was pipeline trade, especially from Russia to Europe. Trade will continue to expand to 825 Bcm in 2030, increasing Asia's LNG imports and North America's exports. Oceania and North America are the largest growing export regions, in which many LNG projects are planned to start operation between 2020 and 2025. On the other hand, the largest importer is China, importing 108 Bcm by pipeline and vessels (LNG) from Russia and Central Asia.
- Demand for LNG increases faster than the market for natural gas due to the quantitative and regional expansion of the use of natural gas. The balance of supply and demand is now relaxed. It, however, will reach a balance of about 400 million tonnes (Mt) in the mid-2020s if the additional supply capacity is limited to projects with final investment decision (FID) or under construction (Figure 10). On the other hand, about 370 Mt of projects are currently under plan, and there will be no shortage of supply if (part of) these stand up. It is important to develop a favourable environment to attract sufficient investment.

Figure 9 | Natural gas production in selected regions

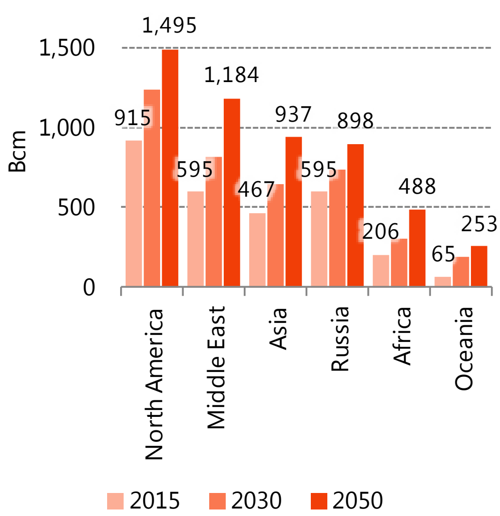
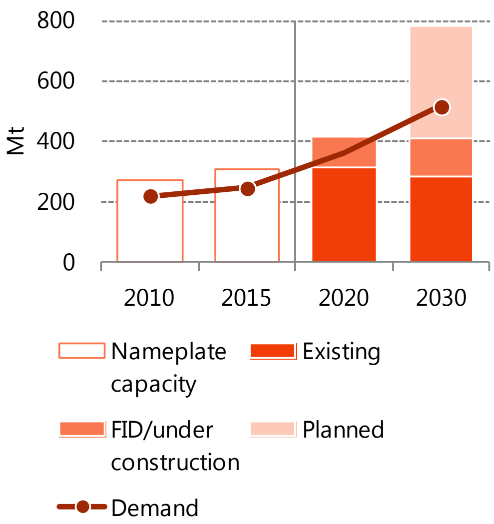
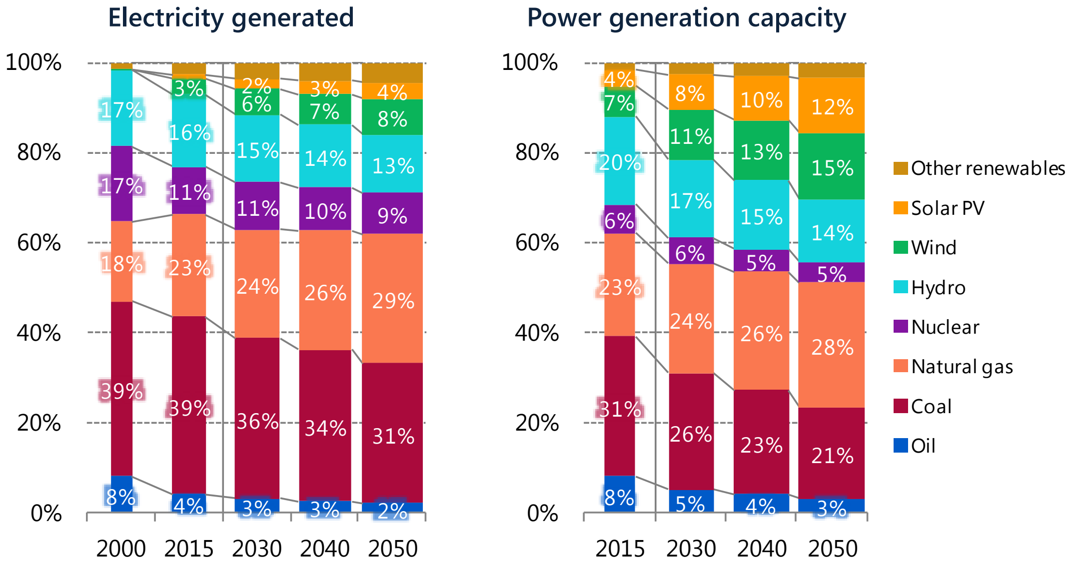


Figure 10 | World LNG supply capacity and demand



- Coal production will increase from 7,727 Mt in 2015 to 9,283 Mt in 2050, with increasing demand for non-OECD countries, mainly in Asia and others such as Latin America and Africa. Steam coal increases from 5,835 Mt in 2015 to 7,710 Mt in 2050, 1.32 times, to largely meet increasing demand for power generation. Coking coal decreases from 1,081 Mt in 2015 to 1,004 Mt in 2050 due to shrinking crude steel production, and lignite decreases from 811 Mt in 2015 to 570 Mt in 2050 due to a decline in demand for this type of coal in power generation.
- Although renewable energy is attracting attention in power generation, thermal power will remain dominant in the electricity generation sector (Figure 11). However, only natural gas-fired with high efficiency, with low carbon dioxide (CO_2) emissions and with excellent load-following will increase its share as thermal power generation. While coal continues to be the largest power source, its share will drop by 8% points to 31%, due to a decline in Europe and America.

Figure 11 | World power generation



Note: Bar width is proportional to total electricity generated

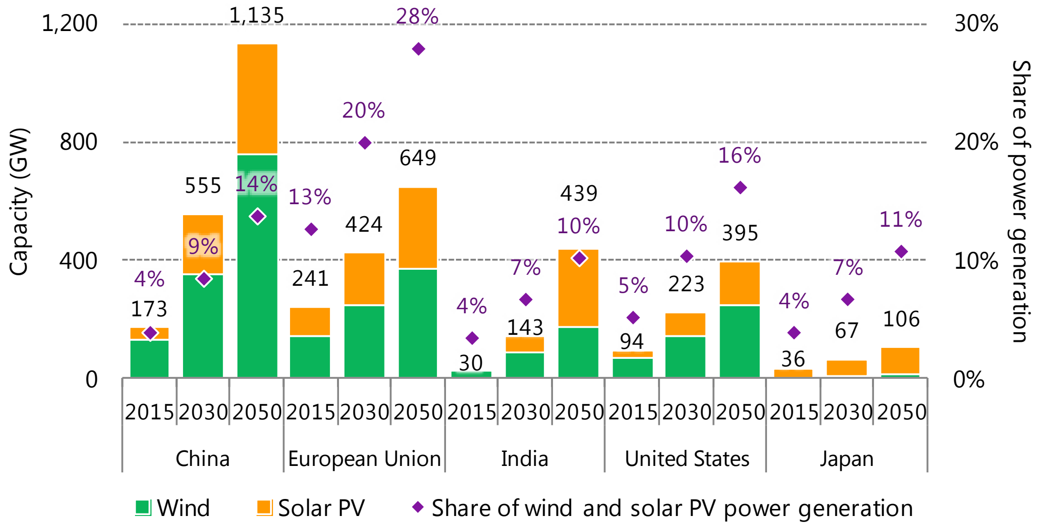
Note: Bar width is proportional to total power generation capacity

- Nuclear power generation increases from 2,571 TWh in 2015 to 4,047 TWh in 2050. It, however, does not grow as rapidly as the total power generation, and its share will shrink by 2% points. The capacity will decrease in nine countries and regions, including Japan and Germany, which will stop in the 2020s. On the other hand, 12 countries will introduce new plants and 20 countries will increase capacities. The global capacity will increase from 406 GW in 2016 to 577 GW in 2050.
- Electricity generated by wind and solar photovoltaic (PV), etc. increases 2.5 times from 1,111 TWh in 2015 to 2,778 TWh in 2030, and will double to 5,637 TWh in the following two decades. It accounts for 13% of total power generation in 2050. The required capacity for such generation is 1,865 GW of wind (4.5 times the current capacity) and

1,519 GW of solar PV, (6.8 times the current capacity) accounting for 27% – more than double the share of electricity generated – of total capacity of 12,547 GW.

The major introduction areas of wind and solar PV are now China, Europe and the United States, but India will be joining in the future (Figure 12). The introduction will expand as a region where those power generation costs decline. Behind the cost reduction, there are various factors, such as the low system price and cost of construction, the blessed solar radiation conditions, wind conditions, land acquisition, and the low barriers related to environmental assessment. Efforts to resolve problems are required in countries where system prices and construction costs are high.

Figure 12 | Capacity and power generation ratio of wind and solar PV in selected regions



Oil Demand Peak Case

Demand

Oil consumption continues to increase for automobiles until 2050 (Figure 13). However, the current movement to shift from conventional gasoline- or diesel oil-fuelled vehicles to electric vehicles has been particularly active in the context of air pollution countermeasures (Table 1). Some predict that oil consumption will peak in the not too distant future from the demand side as a response to climate change issues and not resource constraints.

Figure 13 | World oil consumption

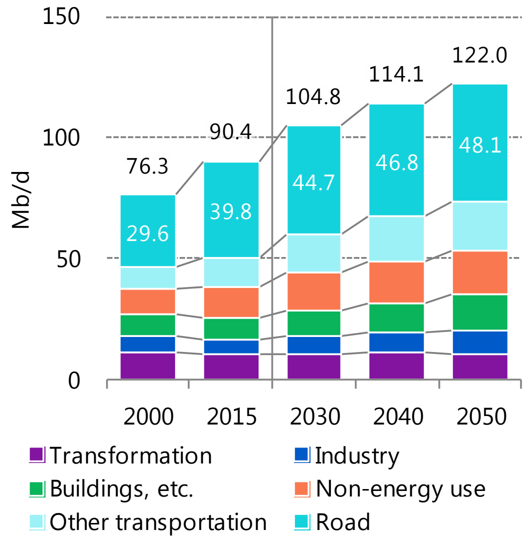


Table 1 | Major movement toward vehicle electrification

Germany	A resolution to ban conventional car sales in the European Union by 2030 was passed by the Bundesrat of Germany (2016)
Norway	The ruling and opposition parties proposed the abolition of conventional vehicles by 2025 (2016)
France	The Government announced that it would ban conventional car sales by 2040 (2017)
United Kingdom	The Government announced that it would ban conventional car sales by 2040 (2017)
India	Minister said that all new car sales after 2030 would be electric vehicles (2017)
China	Deputy Minister mentioned that the ban on the sale of conventional vehicles was under investigation (2017)

Future images are different from the Reference Scenario if all new vehicle (passenger and freight) sales in the world become zero emission vehicles (ZEV)[1] in 2050. In this "Peak Oil Demand Case," oil consumption turns to a decline after peaking at 98 Mb/d; the vertex occurs around 2030 (Figure 14). The reduction from the Reference Scenario widens to 7 Mb/d in 2030 and 33 Mb/d in 2050.

The impact of the increase in electricity demand by ZEVs is not small (Figure 15). Electricity consumption for automobiles increased by 409 Mtoe in 2050 from the Reference Scenario, raising the final consumption of electricity by 12%. If the increased demand is met by thermal power generation, the primary consumption of natural gas and coal is increased by 572 Mtoe and 432 Mtoe, respectively. As a result, natural gas and coal exceed oil by the end of the 2030s, and then natural gas becomes the largest energy source. Biofuels for automobiles decrease with the reduction of vehicles with an internal combustion engine.

Total CO_2 emissions are reduced by 1.8 Gt in 2050 from the Reference Scenario, or 5.9% reduction from 2010. The highest reduction rates are seen in the countries and regions that have low carbon intensity of electricity with a large amount of hydro, including New Zealand, Canada and Latin America. In contrast, Iraq's CO_2 emissions will rather increase by 7%.

[1] In this Outlook, plug-in hybrid vehicles, electric vehicles, and fuel cell vehicles

Figure 14 | World oil consumption and changes

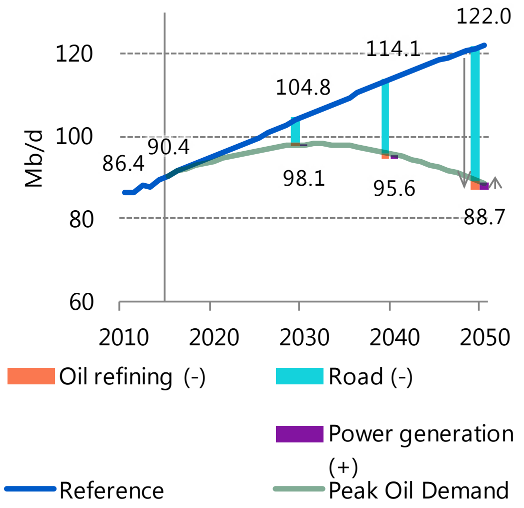
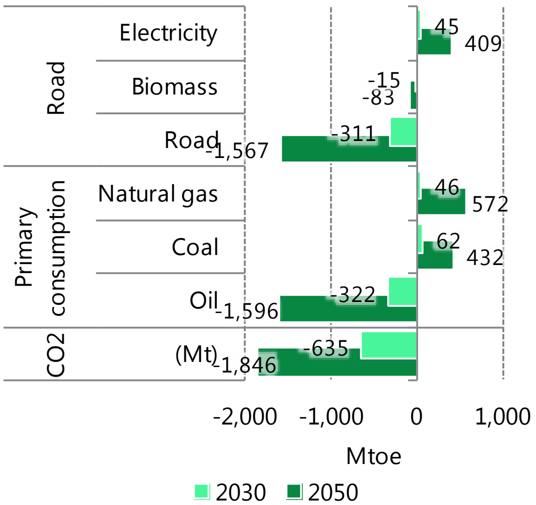


Figure 15 | Changes in world energy consumption (from the Reference Scenario) [Peak Oil Demand Case]

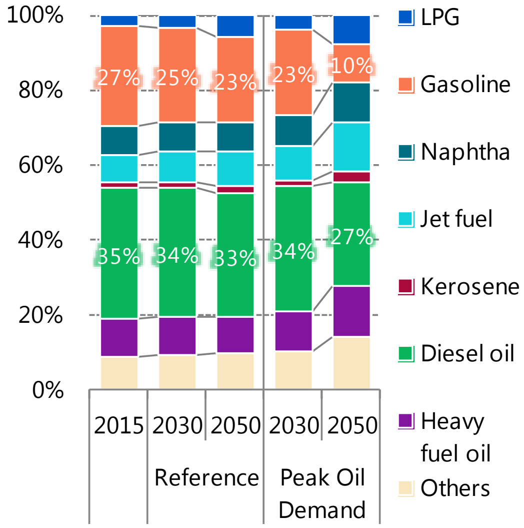


Supply

- These changes also spread to supply and demand by petroleum products (Figure 16). Gasoline's share of petroleum product consumption falls to just 10% in 2050. Since diesel oil is used in industry and other sectors, its share is not as small as gasoline, but it is reduced by 6% points from the Reference Scenario. The oil refining industry facing this situation needs to change drastically its operations. This could have implications for competitiveness due to the difference in secondary refining facilities and the difference in crude oil prices.

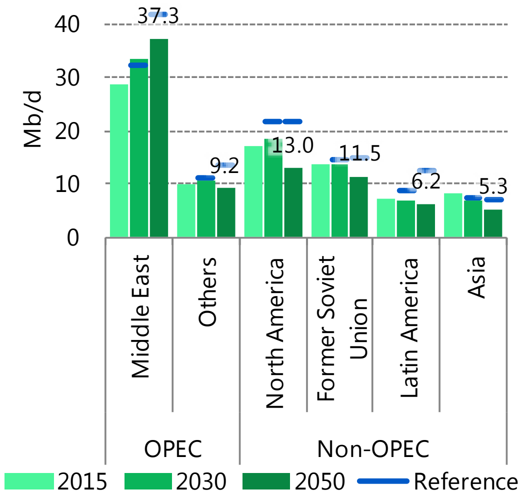
- The decline in oil consumption will have significant impacts on crude oil production (Figure 17). In view of the fact that oil demand in the world continues to increase in the future due to the conventional oil price assumption, the peaking of oil demand in the world becomes a kind of game changer, and oil prices may fall due to the relaxation of the supply and demand pressure and change in the market sentiment. Prices are assumed in this Case at $65/bbl in 2030 and $50/bbl in 2050 while $95/bbl in 2030 and $125/bbl in 2050 were assumed in the Reference Scenario (in 2016 prices). Assuming this significant price decline, regions with lower production costs should have an advantage and, as such, the Middle East is the only region to produce more in 2050 than today. OPEC's production share rose from 42% in 2015 to 46% in 2030 and continues to expand. In contrast, North American production is 13 Mb/d in 2050, 40% less than the Reference Scenario.

Figure 16 | World petroleum product consumption structure



Note: Excluding own use

Figure 17 | Crude oil production in selected regions [Peak Oil Demand Case]

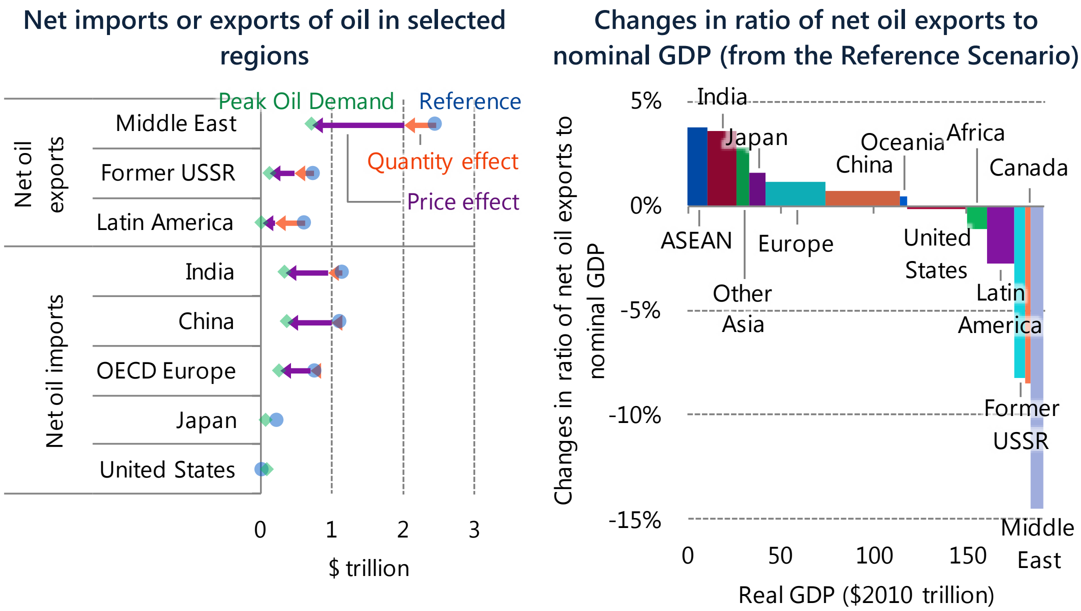


Impact on economic, environment and energy security

- The resulting economic downturn, however, works not only in regions with lower crude oil production share but also in Middle East oil-producing countries (Figure 18). The decrease in net oil exports from the Middle East reaches $1.6 trillion in 2050, equivalent to 13% of its nominal GDP. In oil-producing countries, preparations for economic diversification that do not rely solely on oil are urgently required, and such "buds" are seen in the drawing of the "Saudi Vision 2030" by Saudi Arabia. On the other hand, the country most benefiting from the reduction of net oil imports is India, which will become the second largest oil consumer and poor in domestic reserve. India will be followed by China, which has the world's largest automobile fleet.

- The decline in oil demand may result in a decrease in tax revenues in developed countries where an excise tax is imposed on gasoline and diesel oil for automobiles. The amount of the tax is estimated at about $370 billion today, but it will drop to about $80 billion or one fifth of today in 2050 in the Peak Oil Demand Case if the tax regime is unchanged. On the other hand, in the current system, it is almost impossible to separate the amount of electricity used for automobiles from other uses and tax. It is possible that financial resources will be a major issue in combination with subsidies during the promotion of ZEVs.

Figure 18 | Net imports and exports of oil [Peak Oil Demand Case, 2050]

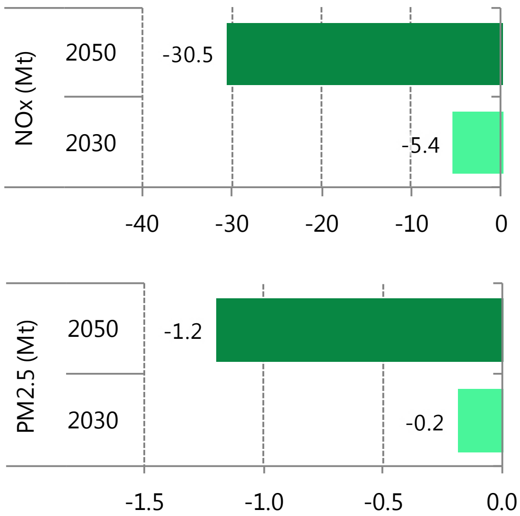


Note: Europe excludes the former Soviet Union

- The emissions of air pollutants, one of the main drivers for the promotion of the ZEVs, are reduced by 30 Mt for nitrogen oxides (NO_x) and 1.2 Mt for particulate matter ($PM_{2.5}$) from the Reference Scenario, or 27% and 3% of total emissions in 2010, respectively (Figure 19). These reductions exclude future improvements in emission control performance of conventional vehicles[2]. Contributions are expected to improve air quality in urban areas.
- The oil self-sufficiency rate of oil importing regions may deteriorate from the Reference Scenario despite the decrease in consumption (Figure 20). This is because oil price fall becomes a headwind against oil production in these high-cost areas as abovementioned.

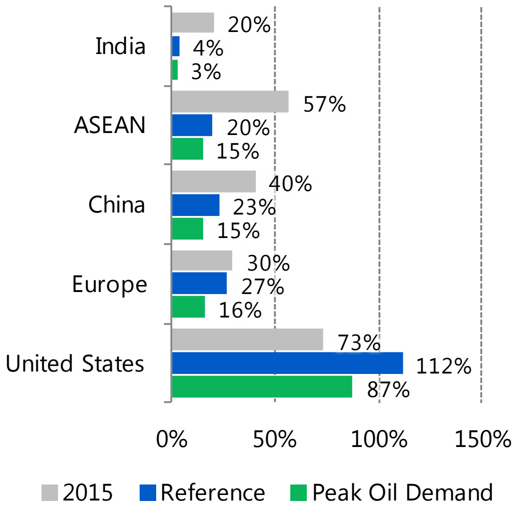
[2] Electricity demand for ZEVs can increase air pollutants from power generation. However, emission measures at power plants are easier to introduce than those for automobiles. Appropriate management is important to avoid increasing emissions.

Figure 19 | Changes in world NO_x and $PM_{2.5}$ emissions (from the Reference Scenario) [Peak Oil Demand Case]



Note: Excluding future improvements in emission control.

Figure 20 | Oil self-sufficiency ratio in selected regions [2050]



Note: Europe excludes the former Soviet Union

How do we recognise the rapid de-oiling?

- The Peak Oil Demand Case has shown that oil consumption can turn into a decline in the not too distant future under some circumstances. However, the feasibility of this Case can be said to be extremely challenging because the penetration of ZEVs is far greater than that in the "Advanced Technologies Scenario," in which a bottom-up approach to the maximum implementation of advanced technologies is adopted (described later). Rather, it can be interpreted that oil consumption may not be easily reduced. Also, it should not be overlooked that oil is required even in 2050 in the Peak Oil Demand Case on a scale that does not differ from today. It is natural for suppliers to worry about and necessary to prepare for demand peaks. However, if the supply investment is neglected, due to excessive pessimism in the future, it can trigger the switching from oil to other energy sources threatening energy security.

- The rising dependence on Middle East crude oil will increase geopolitical risk for stable supply. With the discord between Saudi Arabia and Iran, the rupture of diplomatic relations with Qatar, and the possibility of the proliferation of terrorist attacks while capture of "Islamic State" progresses, the situation in the Middle East is volatile with no sign of stability in the short term. In the Middle East oil-producing countries, the fiscal balance will be difficult to achieve given the low oil prices assumed in this Case. Although it is reasonable to cut public investment and subsidies to reduce budget deficits, it is difficult to deny the possibility of increasing social anxiety and worsening situation not only in oil-producing countries in the Middle East but also in the whole of the region.

Addressing climate change issues

Advanced Technologies Scenario

- In the Advanced Technologies Scenario, it is expected that the use of energy conservation and low-carbon technologies will be maximised in all countries of the world, based on applicable opportunities and acceptability by society to ensure stable energy supply and climate change objectives. In this Scenario, energy consumption in 2050 is reduced by 2,570 Mtoe or 13% from the Reference Scenario and the future increment is suppressed by 42% (Figure 21).
- In 2050, 23% of the energy savings required for the transition from the Reference Scenario to the Advanced Technologies Scenario is from 35 OECD countries; China and India are showing contributions of 24% and 15%, respectively (Figure 22). The world in the future depends on the success of a wide range of energy conservation and low carbonisation in developing countries offering plenty of potential for technological advances.

Figure 21 | World primary energy consumption

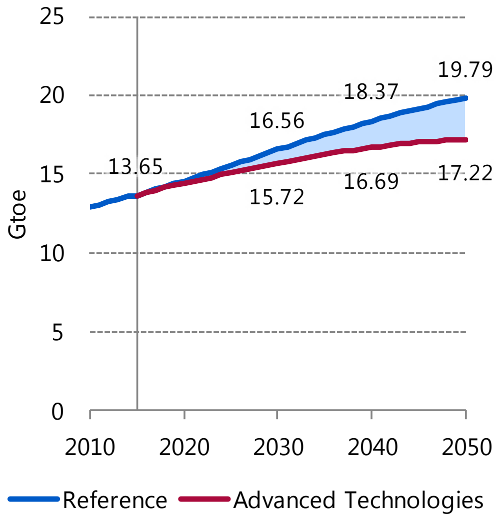
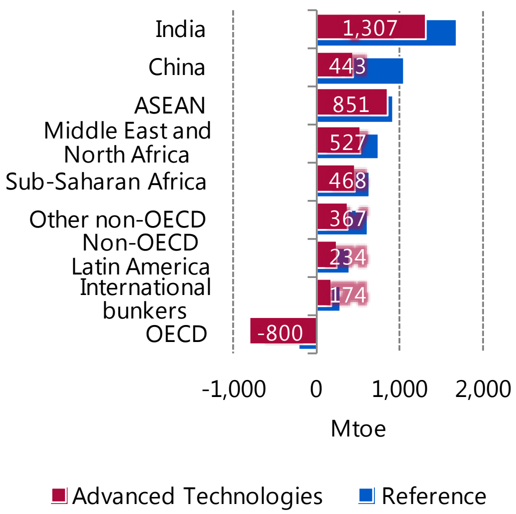
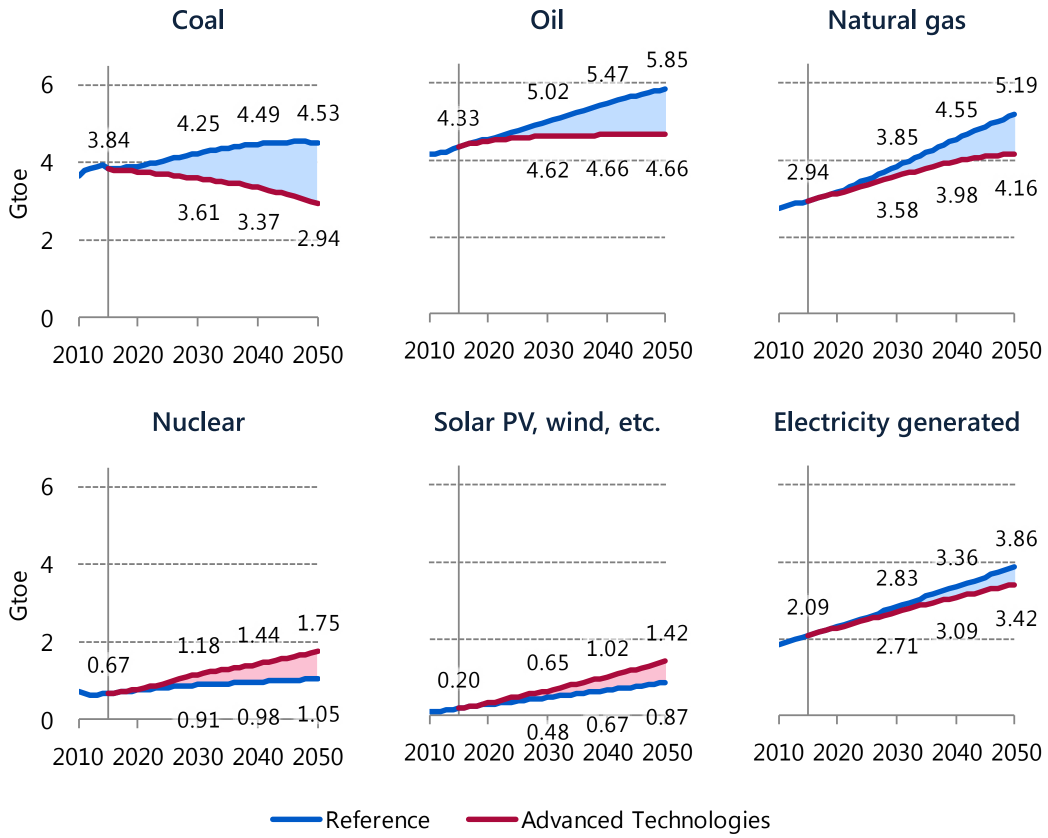


Figure 22 | Changes in primary energy consumption [2015-2050]



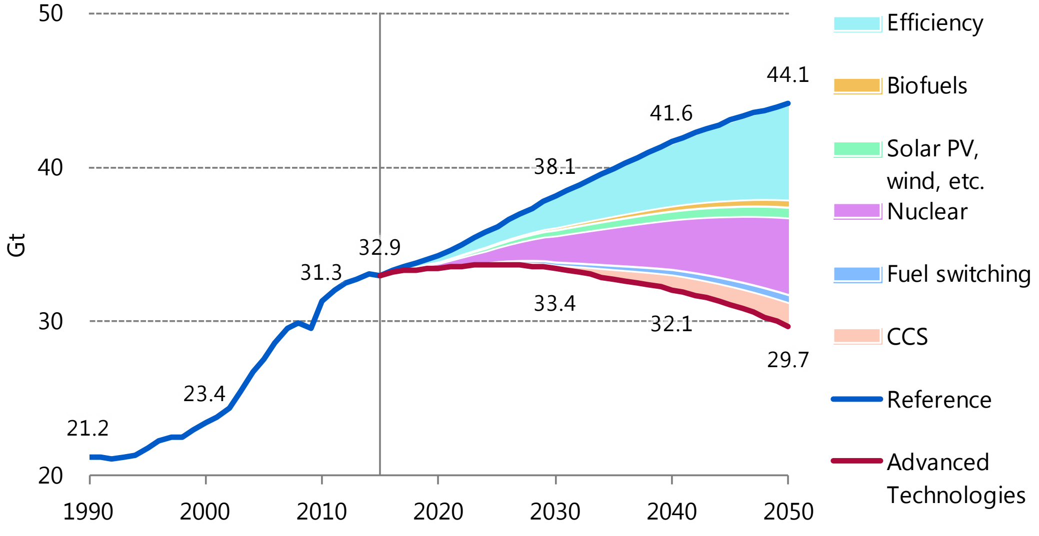
- The most significant change in the energy sources is seen in coal, which is mainly reduced for power generation, the result of lower electricity consumption, improved power generation efficiency, and switching to other energies (Figure 23). Oil reached a peak around 2040 and is 1,193 Mtoe below the Reference Scenario in 2050. Unlike coal and oil, natural gas will continue to increase for the next 35 years. While fossil fuels are reduced by 3,825 Mtoe from the Reference Scenario, nuclear is 699 Mtoe more and renewables are increased by 555 Mtoe, mainly wind and solar PV. As a result, the share of fossil fuels falls from 81% in 2015 to 68% in 2050.

Figure 23 | World primary energy consumption and power generation



Energy-related CO_2 emissions of the world begin to decline gradually in around 2025, and reach 29.7 Gt in 2050, 1.6 Gt or 5% less than in 2010 (Figure 24). It is far from the "sharing with all parties to the UNFCCC the upper end of the latest IPCC recommendation of 40 to 70% reductions (of greenhouse gases [GHGs]) by 2050 compared to 2010" supported at the 2015 G7 Summit 2015 in Schloss Elmau. Nevertheless, the reduction of 14.4 Gt from the Reference Scenario is equivalent to 46% of the world's emissions in 2010, and the cumulative reduction of 227 Gt by 2050 is equivalent to 7.2 years of the world's current emissions. By region, OECD will be halved in 2050 compared to 2010. Although non-OECD emissions will peak in 2040, the overall increase by 2050 will be 23% compared to 2010.

Figure 24 | World energy-related CO_2 emissions and reduction contribution

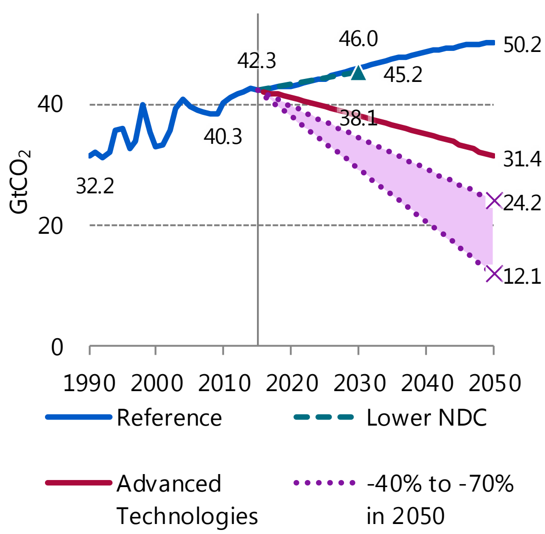


Nationally Determined Contributions under the Paris Agreement

World GHG emissions estimated based on Nationally Determined Contributions[3] (NDC) of the Paris Agreement are 45.2 $GtCO_2$ in 2030, an increase from today (Figure 25). They are lower compared to past trends and the differences from the Reference Scenario are not significant since the emissions of the past few years have been restrained. It is far from the abovementioned 40% to 70% reduction in 2050, or from the long-term goals of the Paris Agreement – peaking of greenhouse gas emissions as soon as possible, and making it virtually zero in the second half of this century. In order to approach the long-term goals, it is desirable for each country to reduce emissions to the extent of the Advanced Technologies Scenario. The penetration of low-carbon technologies in developing countries is particularly important.

[3] On 4 August 2017, the United States submitted a notice to the United Nations that it will withdraw from the Paris Agreement, but it is included in analysis for as the country can withdraw from the Paris Agreement on 4 November 2020 as earliest.

Figure 25 | World GHG emissions



Note: Estimates based on G-20's NDC under the Paris Agreement

Table 2 | Long-term goals of the Paris Agreement

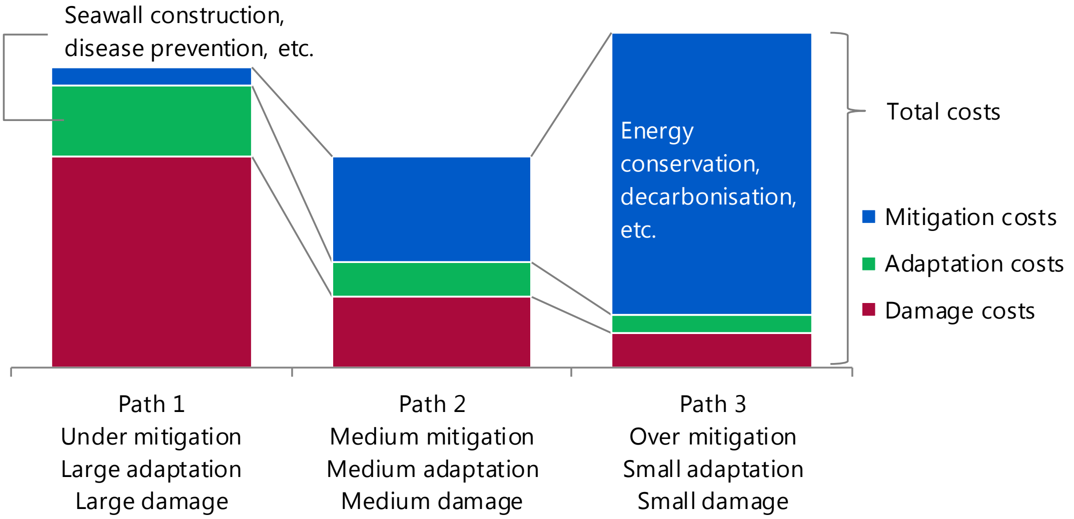
Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change. – Article 2
In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty. – Article 4

Source: United Nations

Ultra long-term climate change paths

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 balance and sustainability, a combination of measures to minimise the total costs covering mitigation, adaptation and damage is evaluated (Figure 26). For example, 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 26 | Illustration of the total costs of mitigation, adaptation and damage



In "Minimising Cost Path" in which cumulative total cost is minimised, energy-related CO_2 emissions in 2050 is reduced to as much as in the Advanced Technologies Scenario. It, however, is not necessary to cut by half the emissions from today (Figure 27). GHG emissions continue to decline moderately after 2050 and fall by 52% from today in 2100. The atmospheric GHG concentration[4] will continue to rise slowly until around 2100 and fall to 550 ppm in 2150. Temperatures increase by 2.4°C and 2.6°C in 2100 and in 2150, respectively, compared to the latter half of the 19th century. That is, the Minimising Cost Path is different from a path of achieving the very ambitious long-term goals of the Paris Agreement.

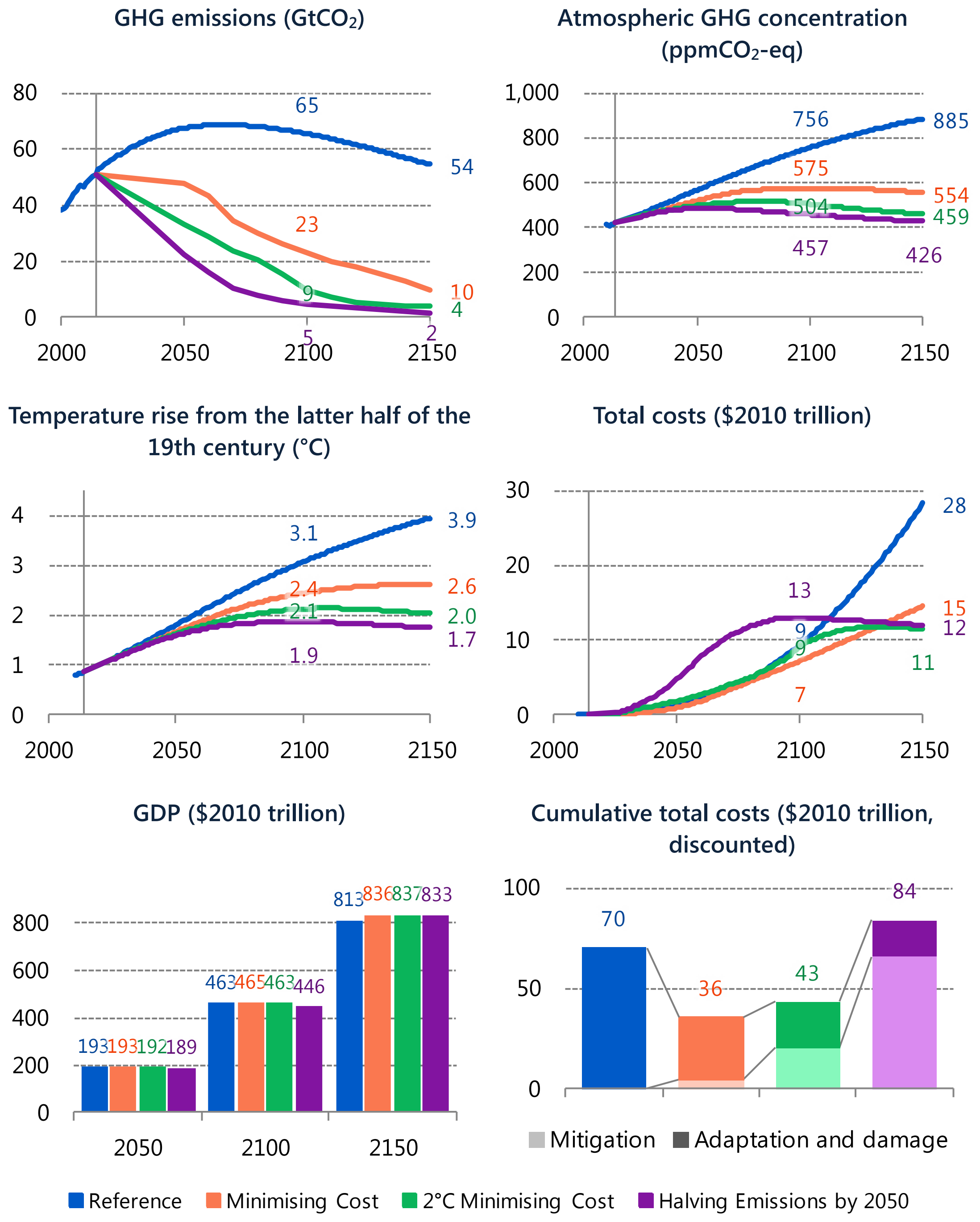
It, however, is dependent on assumptions. For example, although the Minimising Cost Path delays mitigation measures, the temperature rise will still be about 2°C if the climate sensitivity[5] is 1.9°C instead of 3.0°C. A simple calculation results in a difference of about 0.5°C in the temperature of 2200 due to the difference in climate sensitivity of 1°C. In addition, if the average discount rate of the period until 2300 is 1.1%, instead of 2.5%[6], future costs would be higher, so the path for earlier mitigation would be considered as optimal, with a temperature rise of 2°C around 2100 and then decreasing. By simple calculation, a difference of 1% point of the discount rate results in a temperature difference of about 0.5°C in 2200.

[4] CO_2 equivalent. Include aerosols, etc.

[5] Average temperature increase when the atmospheric GHG concentration as CO_2 equivalent concentration is doubled (°C).

[6] The average of 2.5% is equivalent to the pure time preference rate $\delta = 0.5\%$ in the Ramsey rule and the elasticity of the marginal utility of consumption $\eta = 2$. The average of 1.1% is $\delta = 0.1\%$ and $\eta = 1$.

Figure 27 | Ultra long-term paths



Note: Atmospheric GHG concentrations include aerosols, etc. Cumulative total cost is 2015 to 2500.

It is also useful to consider a path that is stronger to curb the temperature rise than the abovementioned Minimising Cost Path, respecting the "2°C Target" in international political and negotiation arenas. For example, in order to keep the cumulative total cost as small as possible and to reduce the temperature rise range in 2150 to 2°C, additional reductions are required to the Minimising Cost Path. GHG emissions under this "2°C Minimising Cost Path" decrease by 31% and by 80% in 2050 and in 2100, respectively, compared to 2010.

- The development and diffusion of innovative technologies is essential for the realisation of the 2°C Minimising Cost Path. The reduction of energy-related CO_2 required for the transition from the Advanced Technologies Scenario to the 2°C Minimising Cost Path is 11.1 Gt in 2050. If this 11.1 Gt is realised by using hydrogen, for example, 3,000 GW of hydrogen-fired power generation and 1 billion fuel cell vehicles are required (Table 3). All innovative technologies, including other options, have challenges in development and social acceptability today. International cooperation is important to overcome these challenges for individual technology development.

- In addition, the costs of technologies must be sufficiently lowered. The highest implicit CO_2 reduction costs (in 2010 prices) for the 2°C Minimising Cost Path are \$85/tCO_2 in 2050 and \$503/tCO_2 in 2100 (Figure 28). The Minimising Cost Path provided by the principle of reducing cumulative total cost will not introduce a technology unless its cost falls below these CO_2 reduction costs. In addition, unless it is cheaper than other competitive technologies, the technology will not be selected economically if the potential for introducing competitive technology is not limited. Innovative technologies also need "innovative" ways to reduce their costs. The target costs for those technologies, such as BECCS, hydrogen-fired power generation, FCV, very-high-temperature reactor, and solar power satellite are almost within the range of the CO_2 reduction costs; the 2°C Target can be achieved with the use of these technologies.

Table 3 | Example of innovative technologies introduced to transition to the 2°C Minimising Cost Path

[1] Zero emission technologies: amount required for CO_2 reduction (10.4 Gt) in the power generation sector

Substitution of approximately 2,800 GW of thermal power generation capacity without CCS in 2050

Thermal power generation with CCS (aquifer storage)	Approximately 2,800 GW (a maximum reduction of 9.4 Gt assuming CO_2 recovery rate of 90%) CO_2 storage potential is estimated at 7,000 Gt or more	Either
Hydrogen-fired power generation (CO_2 free hydrogen)	Approximately 3,000 GW ≈ 1 GW of turbine × approximately 3,000 units Hydrogen required: 650 Mt/year (three times as much as current LNG demand)	
Solar power satellite	Approximately 3,000 GW ≈ 1.3 GW of equipment (2 km × 2 km) × approximately 2,300 units	
Very-high-temperature reactor	Approximately 2,400 GW ≈ 0.275 GW of plant × approximately 8,700 units	
Nuclear fusion	Approximately 2,200 GW ≈ 0.5 GW (ITER equivalent) of plant × approximately 4,500 units	

[2] Zero emission technologies: amount required for CO_2 reduction (remaining 0.7 Gt) outside the power generation sector

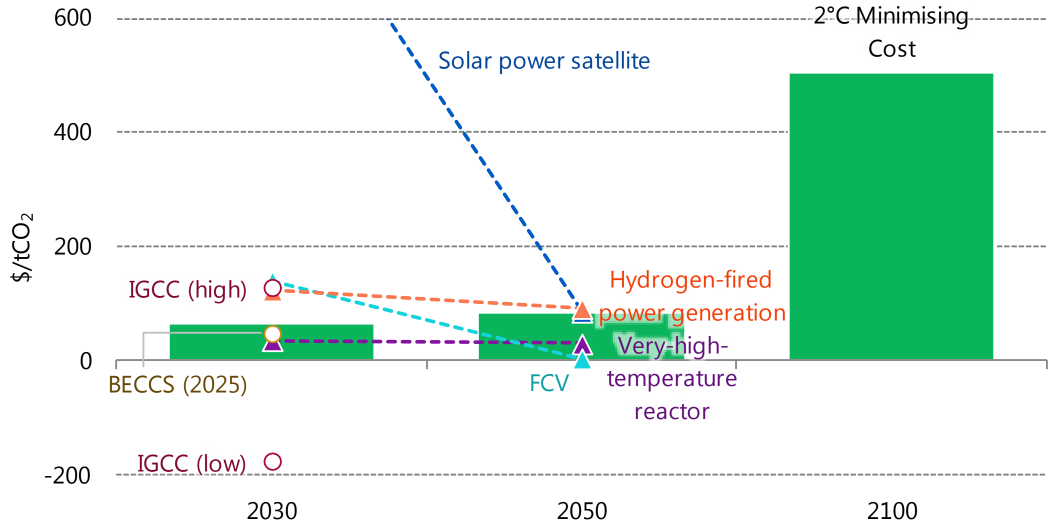
CCS in manufacturing	Laying CCS in 16% of iron and steel, cement, chemical, paper and pulp, petroleum refining, and GTL/CTL production facilities	Either
Fuel cell vehicle (CO_2 free hydrogen)	Approximately 1 billion units (2.6 billion vehicles are on road in 2050) Hydrogen required: 150 Mt/year (equivalent to 60% of current LNG demand)	

[3] Negative emission technologies: amount required for CO_2 reduction in the power generation sector (11.1 Gt)

Biomass-fired power generation with CCS (BECCS)	Approximately 1,400 GW ≈ 0.5 GW turbine × approximately 2,800 units Biomass required: 2,000 Mtoe/year. As much as 2.85 million km^2 of land, larger than Argentina (2.78 million km^2), is required for the supply

Note: Stock volume and usage as of 2050. Addition from the Advanced Technologies Scenario. One from each of [1] and [2], or [3] is equivalent to 11.1 Gt reduction.

Figure 28 | CO_2 reduction costs



Note: The 2°C Minimising Cost Path is the highest CO_2 reduction cost among the technologies adopted at each time of the Path (carbon price) and in 2010 prices. The assumptions and ambition of the goal and estimates are different in each technology.

Key assumptions for calculation:

[Very-high-temperature reactor] With reference to the Nuclear Science and Technology Commission "Development of future research and development related to the very-high-temperature reactor technology (draft)," the construction cost of a 0.3 GW reactor is assumed at about $500 million.

[Integrated coal gasification combined cycle (IGCC)] With reference to OECD/NEA "Projected Costs of Generating Electricity, 2015 Edition," the construction cost is assumed $1,200/kW - $2,900/kW and power generation efficiency is assumed 50% - 52%.

[Fuel cell vehicle (FCV)] With reference to the Hydrogen and Fuel Cell Strategy Council "Hydrogen and Fuel Cell Strategy Roadmap," assumed that vehicle price in 2050 is $25,000 (same as conventional vehicle), fuel economy is 115 km/kg (fuel efficiency of 31 km/Lge) and hydrogen retail price is $0.5/Nm^3$.

[Hydrogen-fired power generation] With reference to the Hydrogen and Fuel Cell Strategy Council "Hydrogen and Fuel Cell Strategy Roadmap" and IEA "Technology Roadmap: Hydrogen and Fuel Cells," assumed that plant delivery price of hydrogen in 2050 is $0.15/Nm^3$, construction cost is $1,200/kW, and power generation efficiency is 57%.

[Solar power satellite] With reference to the Space System Development Promotion Organization "Integrated Space Solar Power Generation System 2006 Model Research and Development Roadmap, Revised version 2016," $100/MWh as the target unit price for power generation in 2050 is used.

[Biomass power generation with CCS (BECCS)] With reference to IRENA "Renewable Power Generation Costs in 2014" and the IPCC "Special Report on CCS," estimated based on power generation cost of $130/MWh and CO_2 recovery and storage cost of $70/tCO_2$.

Part I

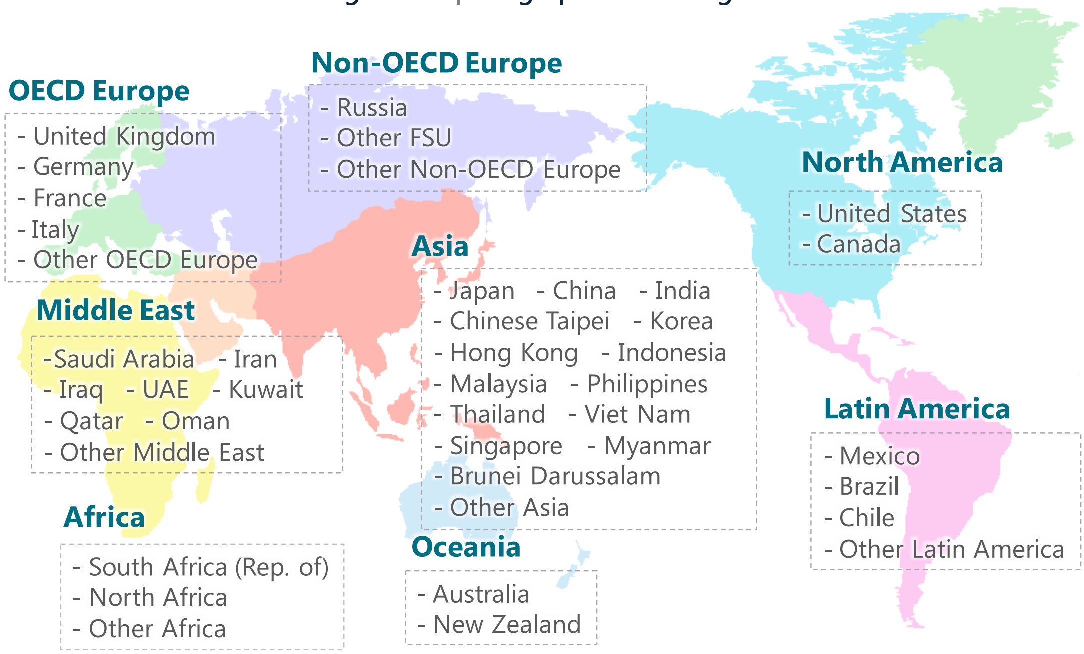
World and Asia energy supply/demand outlook

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 2050. The model, based on the energy balance tables of the International Energy Agency (IEA), covers various economic indicators as well as population, vehicle ownership, basic materials production and other energy-related data collected for modelling. We aggregated the world into 42 regions and international bunkers, as indicated in Figure 1-1, and built a detailed supply and demand analysis model for each.

Figure 1-1 | Geographical coverage



We assumed the following two main scenarios for the projection.

Reference Scenario

This is the core scenario for this Outlook. For this scenario, an outlook is developed according to the past trends as well as the energy and environment policies that have been in place so far. Policies expected through traditional and conventional ways of thinking are incorporated into this scenario. This does not mean that policies or technologies may not be fixed at the present ones. On the other hand, we assume that no aggressive energy conservation or low-carbon policies deviating from past trends will be adopted.

Advanced Technologies Scenario

In this scenario, all countries in the world are assumed to strongly implement energy and environment policies contributing toward a secure and stable energy supply and enhancing climate change countermeasures. The policies' impacts and effects are assumed to be successfully maximised. Specifically, our projection is based on the assumption that advanced technologies for both the energy supply and demand sides, as given in Figure 1-2, will be introduced as much as possible, with their application opportunities and acceptability taken into account.

Figure 1-2 | Technology introduction assumptions for the Advanced Technologies Scenario

Introducing and enhancing environmental regulations and national targets

Environment tax, emissions trading, RPS, subsidy, FIT, efficiency standards, automobile fuel efficiency standard, low carbon fuel standard, energy efficiency labeling, national targets, etc.

Promoting technology development and international technology cooperation

R&D investment expansion, international cooperation on energy efficient technology (steelmaking, cement and other areas), support for establishing energy efficiency standards, etc.

Demand side technologies

■ Industry

Under sectoral and other approaches, best available technologies on industrial processes (for steelmaking, cement, paper-pulp and oil refining) 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 technologies

■ Renewable energies

Wind power generation, photovoltaic power generation, CSP (concentrated solar power) generation, biomass-fired power generation and biofuel will penetrate further.

■ Nuclear

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

■ Highly efficient fossil fuel-fired power generation technologies

Coal-fired power plants (SC,USC, A-USC, IGCC) and natural gas–fired more advanced combined cycle (MACC) plants will penetrate further.

■ Technologies for next-generation transmission and distribution networks

Lower loss type of transformation and voltage regulator will penerate further

■ Carbon capture and storage

Note: SC stands for super critical power generation, USC for ultra super critical power generation, and A-USC for advanced ultra super critical power generation.

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 following assumptions for population, economic growth and international energy prices among these factors are common to the two scenarios.

Population

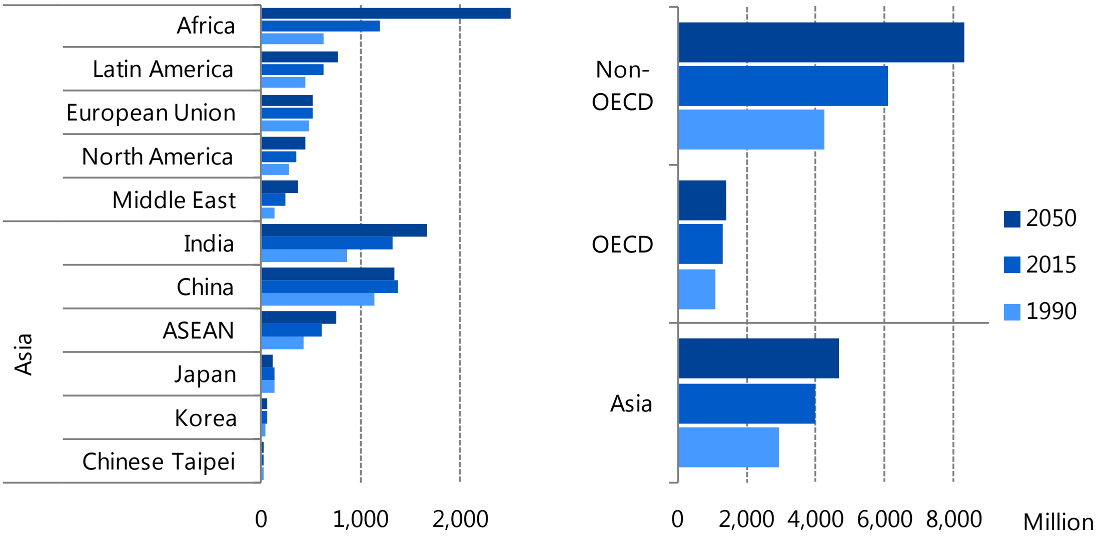
In assuming population changes, we referred to the United Nations' "World Population Prospects." As the total fertility rate (TFR)[7] has slipped below 2 in many of the OECD countries, their population is increasingly facing downward pressure. Reflecting income growth and women's increasing social participation, the TFR is also trending down in non-OECD countries. However, their population will continue increasing because of a declining mortality rate that reflects progress in medical technologies and improvements in food and sanitation conditions. Overall, global population will increase at an annual rate of

[7] TFR; the total fertility rate is the average number of children that would be born to a woman during her lifetime.

around 0.8%, expanding to 9.7 billion in 2050 from 5.3 billion in 1990 and 7.3 billion in 2015 (Figure 1-3, Appendix Table 3).

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

Figure 1-3 | Population in major countries and regions



Most non-OECD countries will see population continuing to increase and non-OECD countries will account for most of a global population increase through 2050. As many countries in Africa will maintain high birth rates, the region is expected to post a rapid annual population increase of 2.2%, slower than the past population explosion. Middle Eastern population will expand about 1.5-fold due to governments' financial incentives for increasing population and a growing population influx from other regions. In non-OECD Europe, Russia which has been plagued with a population decline since the collapse of the Soviet Union will continue to decline. East European countries will expand population moderately. In Asia, India will maintain a high population growth rate, with population surpassing the Chinese population during the first half of the 2020s. In 2050, India will be the world's most populous country at about 1.7 billion. Population in the Association of Southeast Asian Nations (ASEAN) has far exceeded European Union's population and will increase to 760 million in the 2050s. Meanwhile, China's population, currently the largest in the world, will peak at 1.415 billion around 2030 and decrease by about 75 million toward 2050. China is the only country with more than 100 million elderly people (aged 65 or more) and will continue to see more of its population aging. As the young population concentrates in urban regions, the issue of rural population aging will grow more serious.

Asia as a whole will see a continuous population increase, though with its share of global population falling slowly from 54% in 2015 to 48% in 2050.

Economy

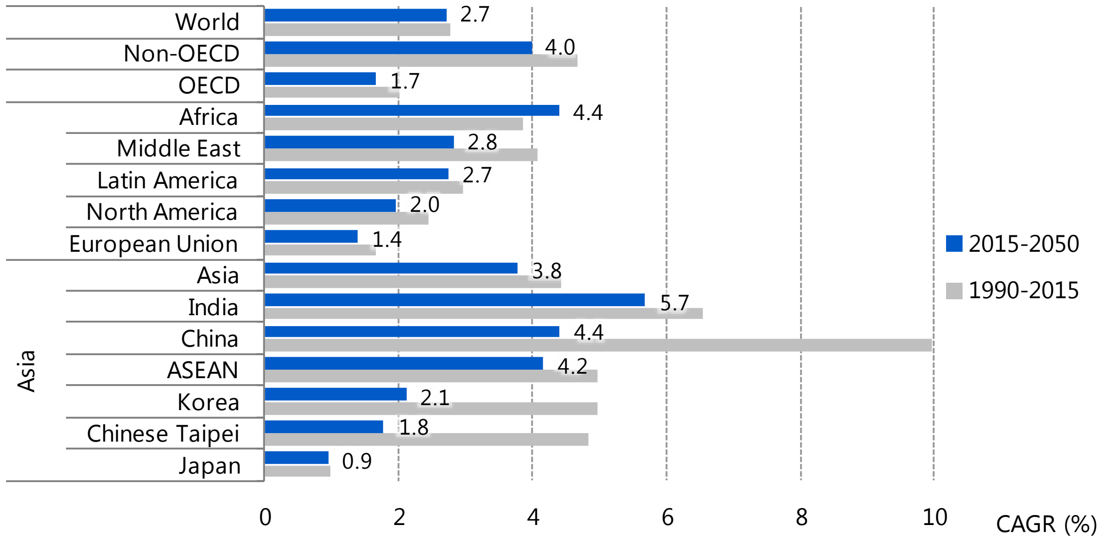
Although being plagued with uncertainties, the world economy will continue to grow. The United States, the largest economy in the world, is moderately recovering thanks to weak oil prices since 2014, the falling unemployment rate and growing private consumption, while concerns exist about certain policies of the Trump administration. Despite the lingering uncertainties surrounding the United Kingdom's exit from the European Union and expectations of negotiations running into rough waters, the European economy, second to the U.S. economy, is supported by employment and income improvements, growing private consumption and expanding investment in plant and equipment. The Chinese economy, the third largest after the United States and Europe, has begun to accelerate its growth leading to a recovery in other Asian emerging economies that took advantage of exports to China for their expansion. Meanwhile, the prolonged weakness of oil prices has exerted downward pressure on oil producing and other resource-rich countries including Russia as well as Middle Eastern and Latin American countries.

Over the medium to long term, many economies are likely to grow through population growth, productivity growth, technological innovation, appropriate fiscal and monetary policies and international collaboration. 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 5.7%. Structural reform, domestic demand expansion and foreign investment will become the sources for Indian economic growth. The ASEAN economy will grow at an annual rate of 4.2%.

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 relies on abundant surplus labour and low costs. In countries that heavily depended on exports, such as China and other Asian emerging countries, the environment that supported their high economic growth is changing requiring them 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 International Monetary Fund, 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 2.7% over the outlook period (Figure 1-4, Appendix Table 4).

Figure 1-4 | Real GDP growth



International energy prices

Oil prices took a steep plunge in the second half of 2014 because of the combined effect of an economic growth deceleration in Europe and China, an expansion in crude oil production in the United States and a decision by OPEC[8] against oil production cuts (to ease the supply-demand balance and cause a glut in the international oil market). The Brent crude oil futures price sank to $30.80 per barrel in January 2016. Later, oil prices seesawed on U.S. crude oil production expansion and OPEC's agreement on a coordinated oil production cut, with the Brent price averaging $56/bbl in September 2017. However, how long OPEC will continue the coordinated production cut is uncertain.

Oil demand will keep on 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 both 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-deep-water oil fields where production costs are relatively higher. No tough restrictions on excessive money inflow into the futures market are likely to be introduced, indicating that speculative investment money could push up oil prices. Given these factors, oil prices are expected to fluctuate wildly over the short term and gradually rise over the medium to long term. The real oil price (in $2016) is assumed to increase to $70/bbl in 2020 and $125/bbl in 2050 (Table 1-1). Under an assumed annual inflation rate of 2%, the nominal price is projected to reach $76/bbl in 2020 and $245/bbl in 2050.

[8] OPEC, the Organization of the Petroleum Exporting Countries

Table 1-1 | Primary energy prices

Real prices		2016	2020	2030	2040	2050	CAGR (%) 2016/ 2020	2020/ 2030	2030/ 2040	2040/ 2050	2016/ 2050
Oil	$2016/bbl	44	70	95	115	125	12.3	3.1	1.9	0.8	3.1
Natural gas											
Japan	$2016/MBtu	6.9	9.0	10.9	12.4	12.6	6.7	2.0	1.3	0.2	1.8
Europe (UK)	$2016/MBtu	4.7	7.1	8.3	9.3	9.5	10.9	1.5	1.2	0.3	2.1
United States	$2016/MBtu	2.5	3.8	4.5	5.5	6.0	11.0	1.7	2.0	0.9	2.6
Steam coal	$2016/t	73	83	100	121	132	3.1	1.9	1.9	0.8	1.7

Nominal prices		2016	2020	2030	2040	2050	CAGR (%) 2016/ 2020	2020/ 2030	2030/ 2040	2040/ 2050	2016/ 2050
Oil	$/bbl	44	76	125	185	245	14.6	5.2	4.0	2.9	5.2
Natural gas											
Japan	$/MBtu	6.9	9.7	14.4	19.9	24.7	8.9	4.0	3.3	2.2	3.8
Europe (UK)	$/MBtu	4.7	7.7	10.9	14.9	18.6	13.1	3.5	3.2	2.3	4.1
United States	$/MBtu	2.5	4.1	5.9	8.8	11.8	13.3	3.7	4.1	2.9	4.7
Steam coal	$/t	73	89	132	195	258	5.2	4.0	4.0	2.9	3.8

Note: The 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 current record-low levels. Japan's real natural gas import price is assumed to rise from $6.9 per million British thermal units in 2015 to $12.6/MBtu in 2050. Liquefied natural gas exports from the United States have started and are expected to contribute to diversifying LNG supply sources for Japan and eliminating or easing the problem of the so-called destination clause for LNG imports. Given low oil and LNG prices at present, however, the price-cutting effect of U.S. LNG exports 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, global primary energy consumption will increase by 6,142 million tonnes of oil equivalent (Mtoe) from 13,647 Mtoe in 2015 to 19,789 Mtoe in 2050 mainly due to global economic and population growth. The increase is more than twice the current annual consumption of China, the world's largest energy consumer. By 2050, global GDP will be about 2.5 times larger, with energy consumption growth limited to only 1.5-fold, meaning that energy efficiency will make some progress. However, this also indicates how difficult it would be to limit energy consumption with the anticipated national energy policies and energy-saving technologies assumed in the Reference Scenario, while promoting economic growth (Figure 1-1).

Asia, including China, India as well as the Association of Southeast Asian Nations (ASEAN), is expected to experience high economic growth and will be responsible for most of the global energy consumption growth (Figure 2-2). Despite expanding energy consumption, however, China that has so far driven the global consumption growth, will slightly reduce its share of global energy consumption from 2015. While the Middle East and Africa will expand their energy demand, the United States and the European Union will continue to reduce their energy requirements.

Figure 2-1 | Global primary energy consumption and GDP energy intensity [Reference Scenario]

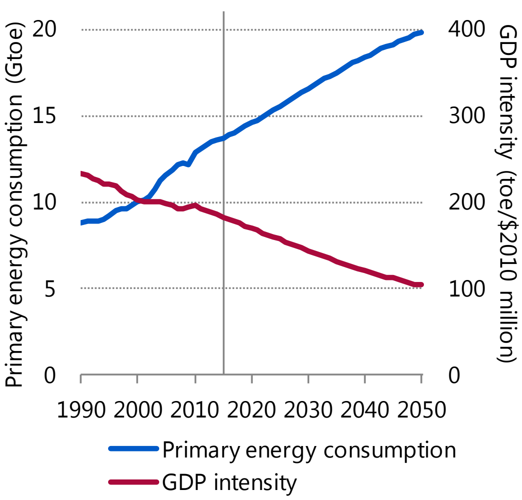
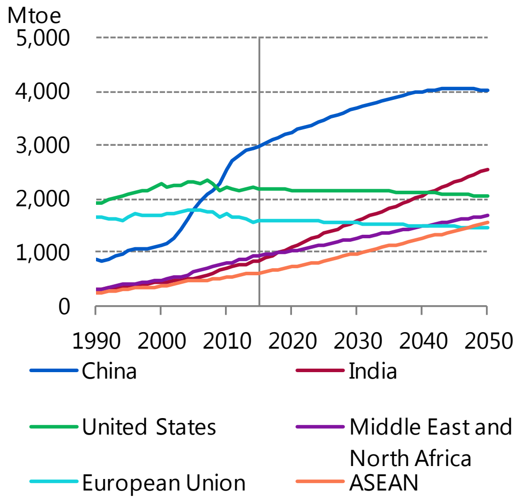


Figure 2-2 | Primary energy consumption in selected countries/regions [Reference Scenario]



As of 2015, fossil fuels (oil, coal and natural gas) accounted for 81% of primary energy consumption. They will still capture about 79% of primary energy consumption even in 2050 (Figure 2-3). In recent years, an increasing number of countries and regions have been trying to reduce their dependence on fossil fuels to address climate change. However, even the European Union that has come up with ambitious climate change countermeasures will depend on fossil fuels for about 60% of its energy needs in 2050 (Figure 2-4). India and ASEAN, posting remarkable economic growth, will increasingly raise their dependence on fossil fuels.

Figure 2-3 | Global primary energy consumption [Reference Scenario]

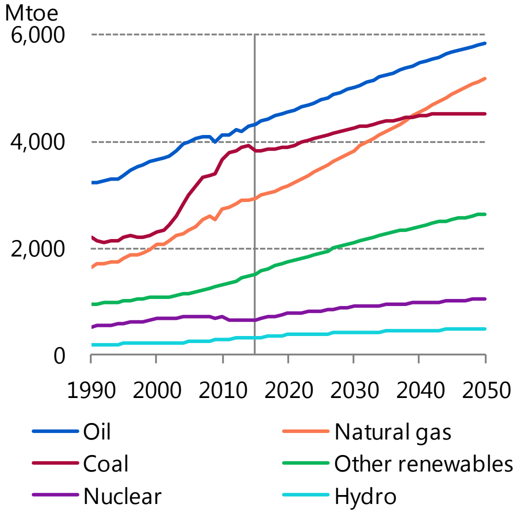
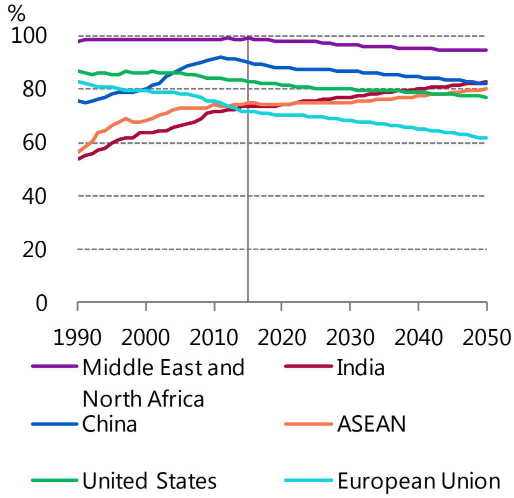


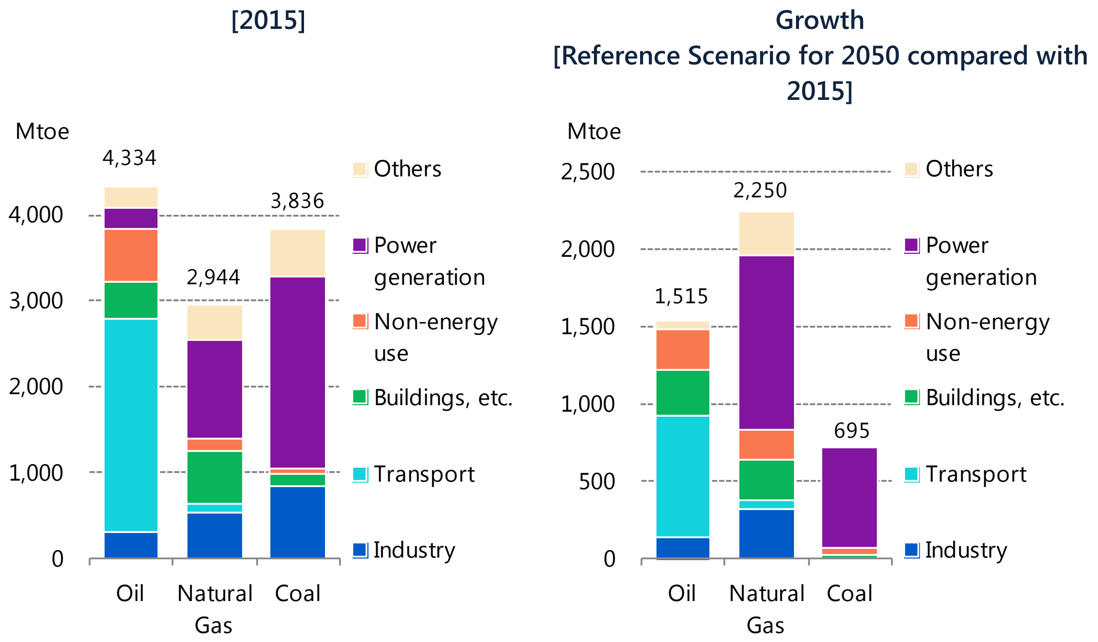
Figure 2-4 | Dependence on fossil fuels in selected countries/regions [Reference Scenario]



Fossil fuel consumption purposes differ from fuel to fuel. Particularly, the needs for oil differ from those of natural gas and coal (Figure 2-5). The transport sector accounted for about 57% of oil consumption in 2015 and this share will remain almost unchanged, even in 2050. To promote reductions in oil consumption, the transport sector must either step up energy efficiency or encourage fuel switching.

Natural gas will feature the largest growth among fossil fuels through 2050 as consumption increases primarily in the power generation sector. Natural gas consumption will expand 1.8-fold from 2,944 Mtoe in 2015 to 5,194 Mtoe in 2050 and will increase its share of primary energy consumption from 22% to 26%, becoming the second largest energy source after oil in 2050. Coal consumption will also increase primarily in the power generation sector. As coal conservation policies make progress globally to address air pollution and climate change issues, coal consumption growth will be slower than that for oil or natural gas. Coal consumption in 2050 will increase to 4,527 Mtoe from 3,836 Mtoe in 2015, limiting its growth to around 1.2-fold. Coal's share of primary energy consumption will fall from 28% in 2015 to 23% in 2050.

Figure 2-5 | Global fossil fuel consumption



Oil

A global primary energy consumption breakdown by source indicates that oil will remain the most heavily consumed energy source although its share of primary energy consumption will fall from 32% in 2015 to 30% in 2050 due to fuel switching to natural gas and progress in energy efficiency in the transport sector. Oil consumption, which stood at 90.4 million barrels per day (Mb/d) in 2015, will be 100 Mb/d around 2025 and reach 122.0 Mb/d in 2050, growing at an average annual rate of 0.9% (Figure 2-6). The increase of 31.6 Mb/d from 2015 to 2050 amounts to present crude oil production in the Middle Eastern and North African OPEC member countries. The transport sector including fuels for vehicles will account for more than half of the increase while oil consumption for power generation will gradually reduce its share of the total. In 2050, 56% of the oil consumption will be accounted for by the transport sector, 15% will be used for petrochemical feedstocks and other non-energy uses and 13% consumed in buildings and other sectors.

Non-OECD (Organisation for Economic Cooperation and Development) oil consumption will experience a robust growth, increasing at an average annual rate of 1.7% during the outlook period through 2050 (Figure 2-7). Meanwhile, OECD oil consumption will decrease at an average annual rate of 0.7%. The OECD's share of oil consumption will decline from 43% in 2015 to 25% in 2050.

Figure 2-6 | Global oil consumption and its share of primary energy consumption [Reference Scenario]

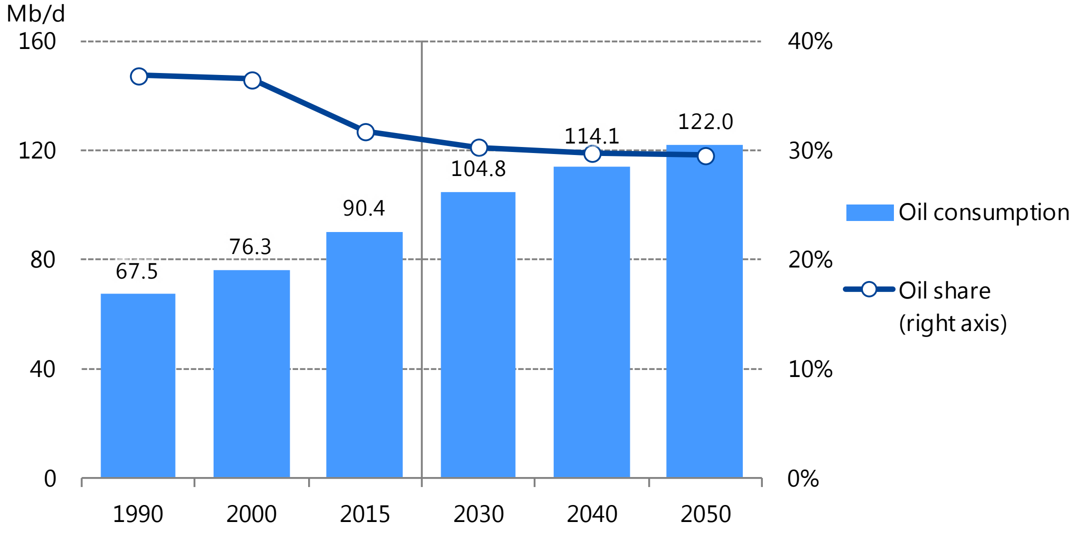
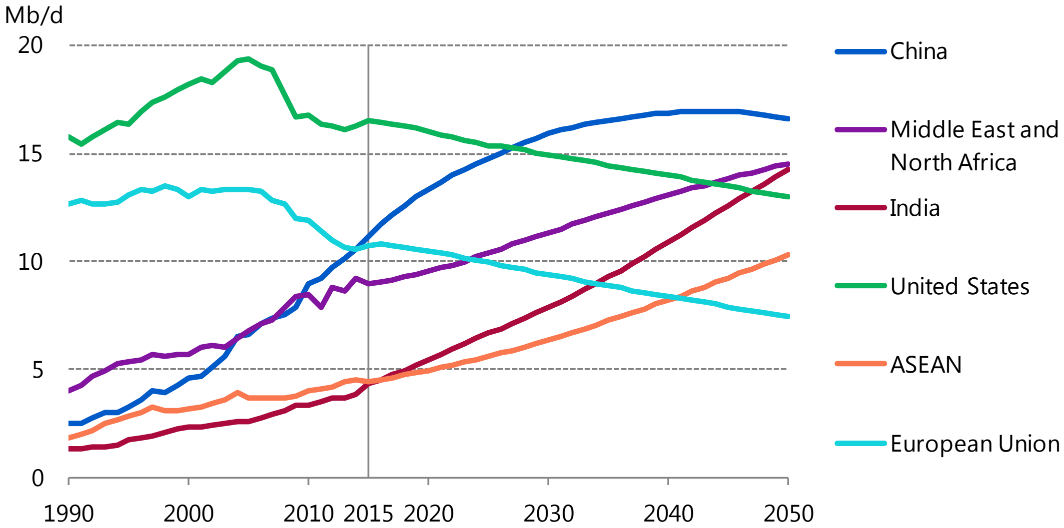


Figure 2-7 | Oil consumption in selected countries/regions [Reference Scenario]



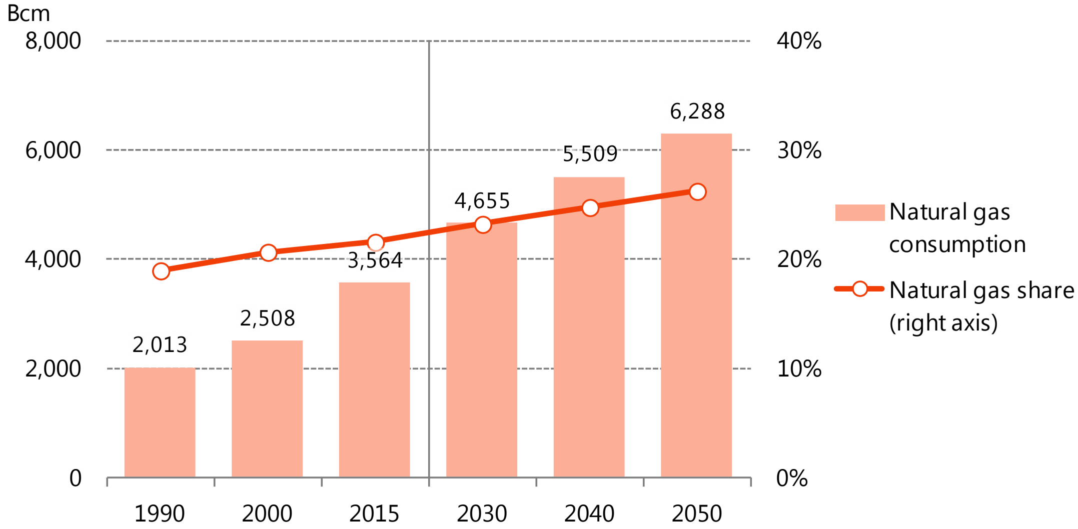
China will replace the United States as the world's largest oil consumer in the second half of the 2020s and its oil consumption will peak and turn downward in the mid-2040s. Indian and ASEAN oil consumption will increase about 3.3-fold and 2.3-fold, respectively, from 2015 to 2050. China, India and ASEAN will need to expand their crude oil imports in response to the domestic consumption growth. As Asia includes many resource-poor countries and will heavily depend on oil imports, energy security will become an important challenge for Asia.

Given anticipated climate change and air pollution countermeasures, growth in oil consumption within the transport sector will increasingly become subject to restrictions. In China, $PM_{2.5}$ and other air pollutants are growing serious. The Chinese government amended its Air Pollution Control Law in August 2015 to provide for quality standards for gasoline and other fuels and oblige refiners to meet those standards while refining crude oil to produce petroleum products. The amendment also toughened penalties on enterprises causing severe air pollution. Indonesia, where air pollution becomes a problem as in China, enhanced regulations on exhaust gas from motorcycles in 2012. Not only fuel quality standards and exhaust gases regulations but also energy efficiency in the transport sector can make great contributions to controlling air pollution. Efficiency improvement efforts in the sector may include the development of railways and other mass transit systems as well as the spread of next-generation automobiles. In July 2017, French Ecology Minister Nicolas Hulot and British Environment, Food and Rural Affairs Secretary Michael Gove indicated their respective plans to ban sales of gasoline- and diesel-fuelled vehicles from 2040. Other countries are considering similar regulations.

Natural gas

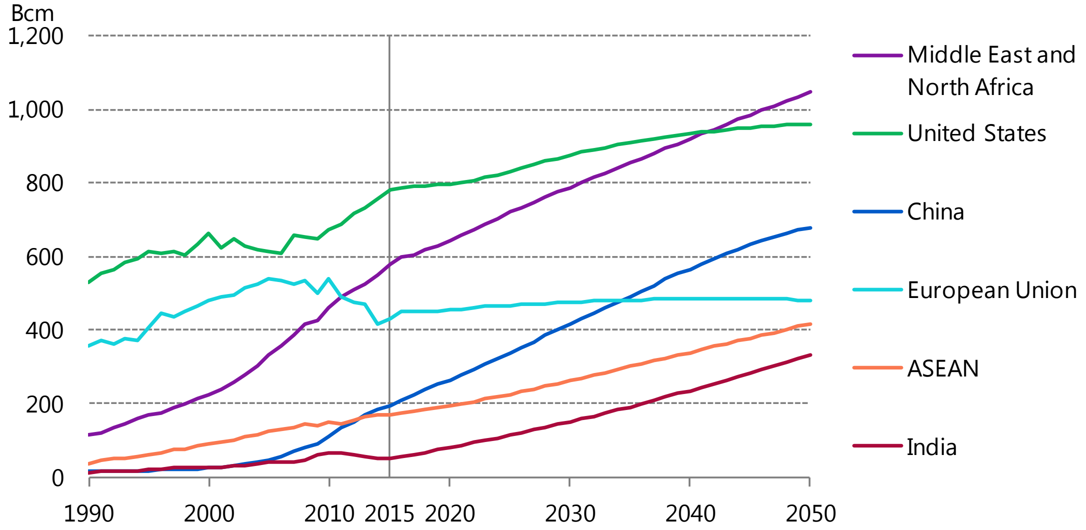
Natural gas will post the largest consumption growth among all energy sources because of additional requirements for the power generation sector, including fuel switching from coal to natural gas, and additional demand from most other sectors. Natural gas consumption will expand 1.8-fold from 3,564 billion cubic metres (Bcm) in 2015 to 6,288 Bcm in 2050 (Figure 2-8). Natural gas will increase its share of primary energy consumption from 22% in 2015 to 26% in 2050, becoming the second largest energy source after oil.

Figure 2-8 | Global natural gas consumption and natural gas's share of primary energy consumption [Reference Scenario]



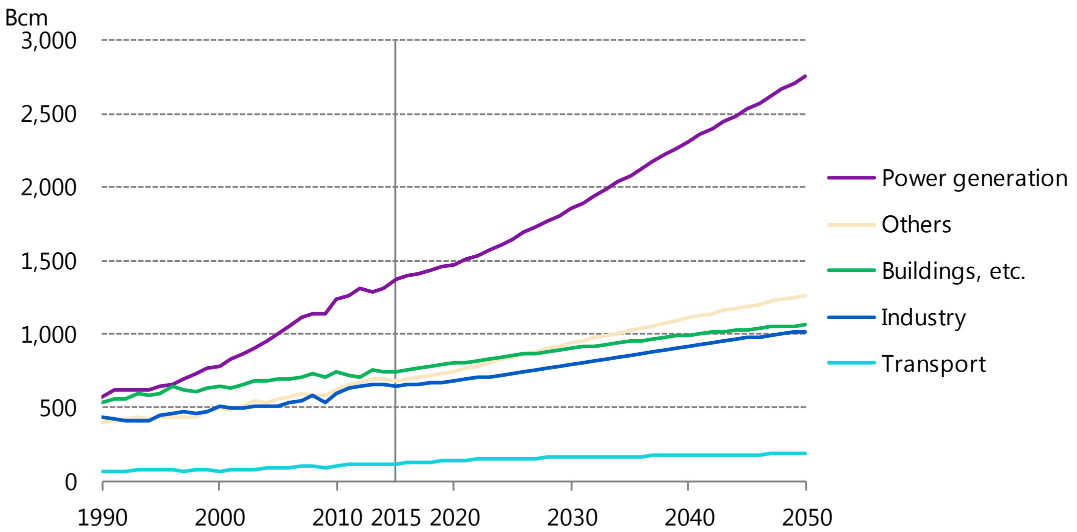
Non-OECD will account for 85% of the natural gas consumption growth of about 2,724 Bcm from 2015 to 2050 (Figure 2-9). Non-OECD's share of global natural gas consumption will expand from 54% to 67%.

Figure 2-9 | Natural gas consumption in selected countries/regions [Reference Scenario]



Among OECD countries, Japan will reduce natural gas consumption from 121 Bcm in 2015 to 118 Bcm in 2050. In contrast, the European Union members will expand natural gas consumption moderately from 433 Bcm to 481 Bcm while the United States will increase from 783 Bcm in 2015 to 961 Bcm in 2050. OECD as a whole will remarkably boost natural gas consumption primarily because natural gas in the United States will replace oil as the largest energy source around 2030. Non-OECD countries expected to log remarkable growth in natural gas consumption include China, India, and the Middle East and North Africa. In the next 35 years, natural gas demand will increase by 487 Bcm in China and by 280 Bcm in India. Natural gas consumption in the Middle East and North Africa will top U.S. consumption around 2040.

Figure 2-10 | Natural gas consumption [Reference Scenario]

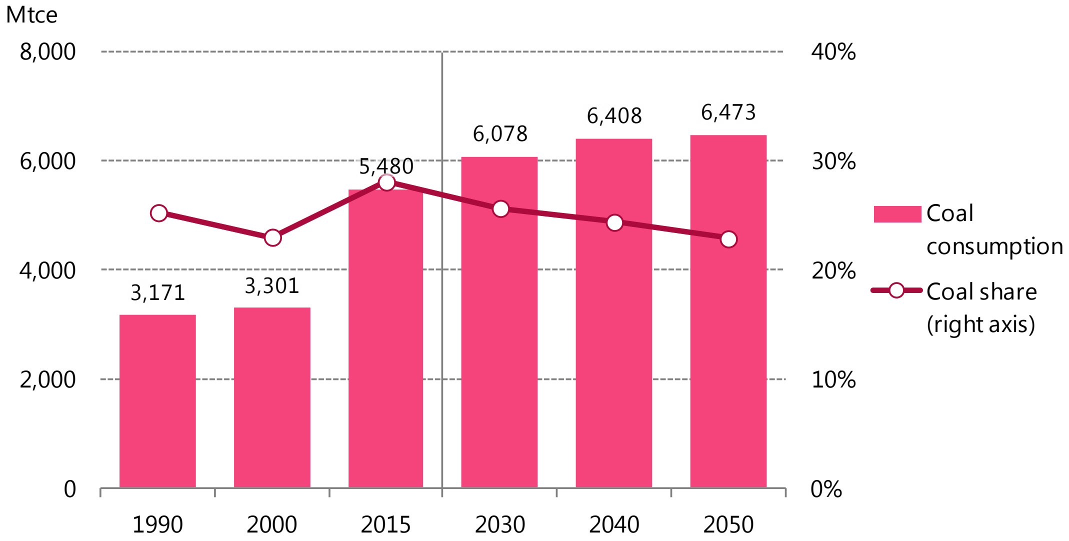


Natural gas consumption for power generation, compared to other uses, will increase substantially due to technological progress, economic efficiency and environmental considerations. As a result, the power generation sector will account for half of the natural gas consumption growth (Figure 2-10). Natural gas will be growingly used for power generation as oil-fired power generation costs more and coal faces environmental issues. Natural gas will expand its share of global power generation to 29% in 2050, narrowing its share gap with coal to 3 percentage points. 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.

Coal

Coal consumption presents a different trend than those for oil and natural gas. As air pollution, climate change and other coal-related problems encourage developed countries to switch from coal to other energy sources, coal will post a more moderate consumption growth than oil and natural gas. Global coal consumption growth will be limited to about 20%, increasing from 5,480 million tonnes of coal equivalent (Mtce[9]) in 2015 to 6,473 Mtce in 2050 (Figure 2-11). Most of the increase will be for power generation. Coal's share of primary energy consumption will narrow from 28% in 2015 to 23% in 2050.

Figure 2-11 | Global coal consumption and its share of primary energy consumption [Reference Scenario]

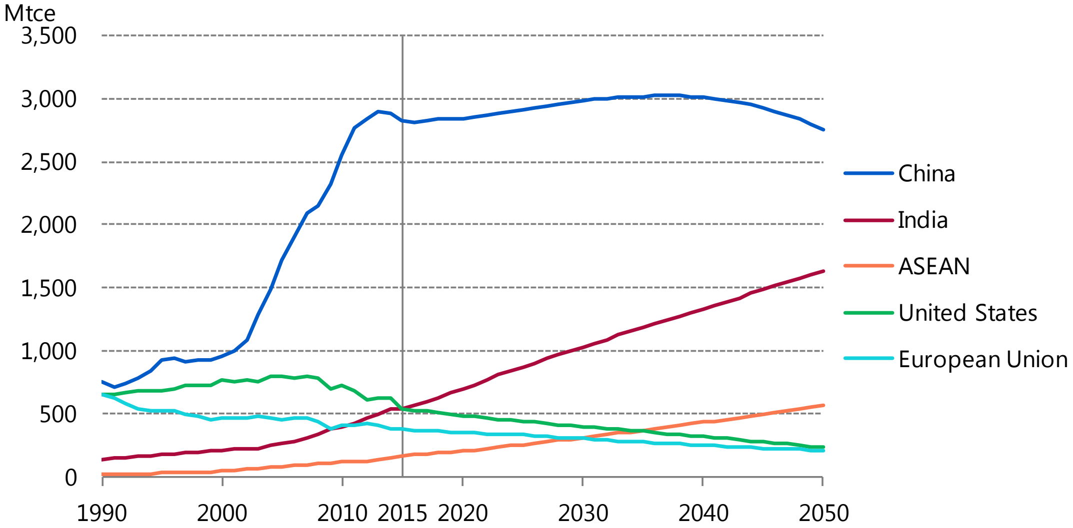


In OECD including the United States and European Union members, increasing taxes on coal-fired power plants and enhanced regulations on CO_2 and mercury emissions will force coal-fired power generation to decline. Non-OECD will account for all of the coal consumption growth in the next 35 years, with Asia commanding 95% of the growth. After replacing the United States as the world's second largest coal consumer after China in 2015,

[9] 1 Mtce = 0.7 Mtoe

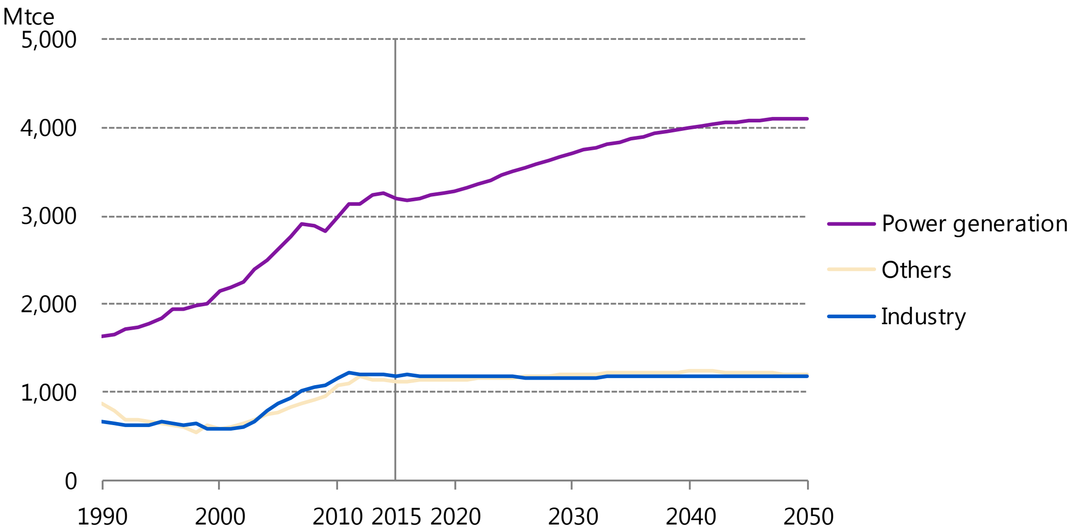
India will post the world's largest coal consumption growth (Figure 2-12). Although China will remain the world's largest coal consumer, it will slowly increase consumption before reducing it in the 2030s.

Figure 2-12 | Coal consumption in selected countries/regions [Reference Scenario]



As many areas in the world are endowed with coal resources, coal presents less of a supply risk than oil or natural gas, which, resources found in a limited range of regions. Due to lower prices for coal, consumption will increase mainly in the power generation sector (Figure 2-13). Coal consumption for power generation will increase at an annual rate of 0.7% through 2050, posting a total rise of 1.3-fold from the present level.

Figure 2-13 | Global coal consumption by sector [Reference Scenario]



Non-fossil energy

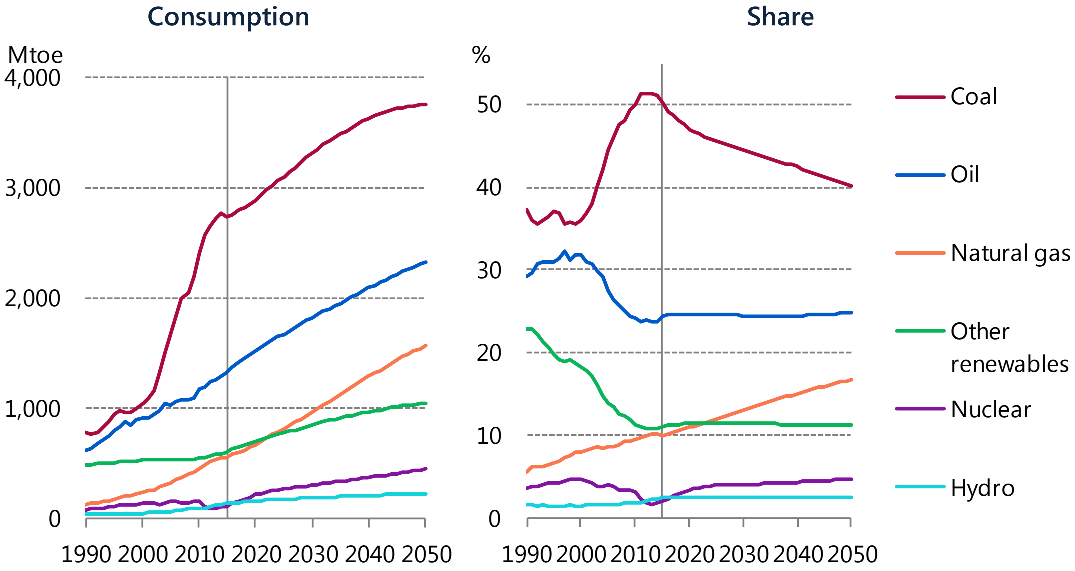
Hydro, geothermal, solar, wind, biomass and other renewable energies will expand their share of primary energy consumption from 14% in 2015 to 16% in 2050. Their consumption growth through 2050 will total 1,298 Mtoe. While solar photovoltaics and wind power generation will diffuse further, insanitary biomass and direct waste consumption including fuel wood and livestock manure in developing countries will account for a large share of the total growth.

Nuclear power generation will grow from 2,571 TWh in 2015 to 4,047 TWh in 2050. Nuclear's share of primary energy consumption will rise from 4.9% in 2015 to 5.3% in 2050. The nuclear power generation growth will centre on emerging countries that require massive amount of electricity to sustain their stable economic growth. Non-OECD nuclear power generation will expand from 601 TWh in 2015 to 2,323 TWh in 2050.

Asia

Asian primary energy consumption will grow at an annual rate of 1.5% from 5,459 Mtoe in 2015 to 9,351 Mtoe in 2040 in line with its robust economic growth (Figure 2-14). The increase of 3,893 Mtoe accounts for about 60% of the global energy consumption growth. Asia's share of global primary energy consumption will increase from 40% in 2015 to 47% in 2050.

Figure 2-14 | Asian primary energy consumption [Reference Scenario]



China, India and ASEAN, expected to achieve high economic growth, will account for 94% of the total Asian primary energy consumption growth. As a result, their combined share of Asian energy consumption will widen from 81% in 2015 to 87% in 2050. Meanwhile, energy consumption will almost level off in mature Asian economies such as Japan, Korea and Chinese Taipei.

Fossil fuels account for 85% of Asian primary energy consumption at present and will cover 78% of the consumption growth during the next 35 years.

Asian oil consumption will expand from 27.7 Mb/d in 2015 to 48.4 Mb/d in 2050 (Figure 2-15). The average annual growth will be 1.6%, remarkably higher than the global growth at 0.9%. The transport and buildings sectors will particularly expand oil consumption. Consumption will increase from 12.4 Mb/d in 2015 to 23.6 Mb/d in 2050 in the transport sector and from 3.6 Mb/d to 8.1 Mb/d in the buildings sector. Asia will account for more than 60% of global oil demand growth, raising its share of global oil demand from 31% to 40%. Through its oil demand growth, Asia will further increase its presence in the international oil market.

Asian natural gas consumption will increase 2.9-fold from 662 Bcm in 2015 to 1,897 Bcm in 2050, with an annual growth averaging 3.1% (Figure 2-16). As is the case with oil, the increase will be faster than the global annual rate of growth of 1.6%. Asia's share of global natural gas consumption will expand from 19% in 2015 to 30% in 2050, faster than in any other region. Particularly, China will make great contributions to Asian natural gas consumption growth, boosting consumption 3.5-fold from 2015 to 679 Bcm in 2050, accounting for 11% of global consumption. Indian natural gas consumption, though declining since 2011, will increase mainly for power generation in the future. India has been promoting natural gas for mass transit systems to help ease air pollution, indicating an increase in its future natural gas demand. Japan, now a major LNG importer, will reduce natural gas consumption due to a peaking of demand in its mature economy and the expansion of non-fossil energy consumption. Korea, another major LNG importer, will experience slow growth in natural gas demand.

Figure 2-15 | Asian oil consumption [Reference Scenario]

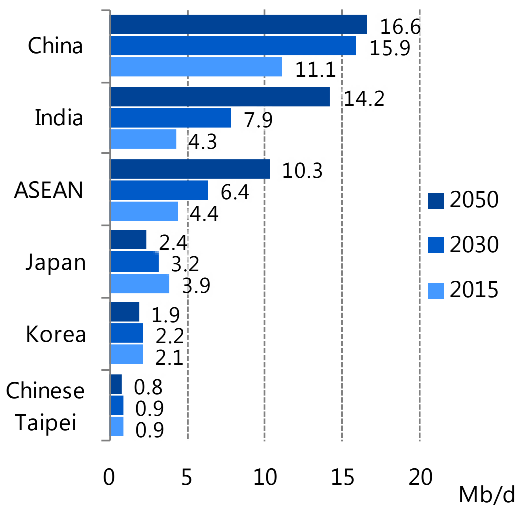
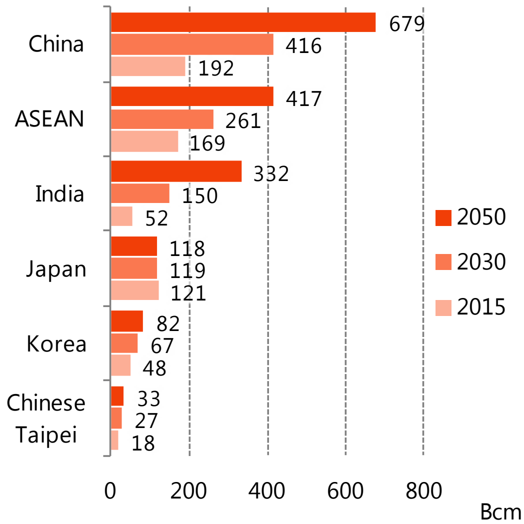


Figure 2-16 | Asian natural gas consumption [Reference Scenario]



In line with Asian natural demand growth, sales promotion in the Asian natural gas market will become more active. Russia and many other countries endowed with natural gas resources are paying attention to Asia as a growing potential market. To achieve stable natural gas supply at low cost, Asian countries should negotiate with resource-rich countries and promote market design and other initiatives. They should also enhance measures against supply disruptions, including natural gas stockpiling and the installation of pipelines for inter-regional distribution or supply. Coal consumption in Asia will rise from 3,913 Mtce in 2015 to 5,363 Mtce in 2050. Although coal's share of primary energy consumption will shrink from 50% in 2015 to 40% in 2050, coal will remain the largest energy source in Asia. While China will decelerate its coal consumption growth, India and ASEAN, with growing economies, will continue to robustly boost coal consumption. Coal for power generation will account for 94% of Asian coal consumption growth at 1,450 Mtce.

In the future, it will increasingly become more difficult to construct or expand coal-fired power plants that do not include considerations to climate change and air pollution. Developing countries have already been implementing relevant initiatives. For example, China has by now shut down its less efficient small coal-fired power plants and India enhanced, in December 2015, its regulations on emissions from coal-fired power plants by establishing emission standards for sulphur dioxide (SO_2), nitrogen oxide (NO_x) and some others, in addition to smoke dust.

Asian renewable energy consumption will increase from 731 Mtoe in 2015 to 1,265 Mtoe in 2050. Asia will raise its share of global renewable energy consumption including hydro, geothermal, solar, wind and other energies, excluding biomass and waste, from 40% in 2015 to 45% in 2050, and China will capture more than half of the Asian renewable energy consumption. As fossil fuel consumption also expands, however, renewable energy's share of primary energy consumption in Asia will remain almost unchanged from 2015.

Asian nuclear power generation will increase from 425 TWh in 2015 to 1,692 TWh in 2050 and will account for 86% of the global nuclear power generation growth through 2050. Nuclear power generation will expand remarkably in China and India, in line with a sharp growth in electricity demand. In Asia, the nuclear's share of primary energy consumption will rise from 2.0% in 2015 to 4.7% in 2050.

2.2 Final energy consumption

World

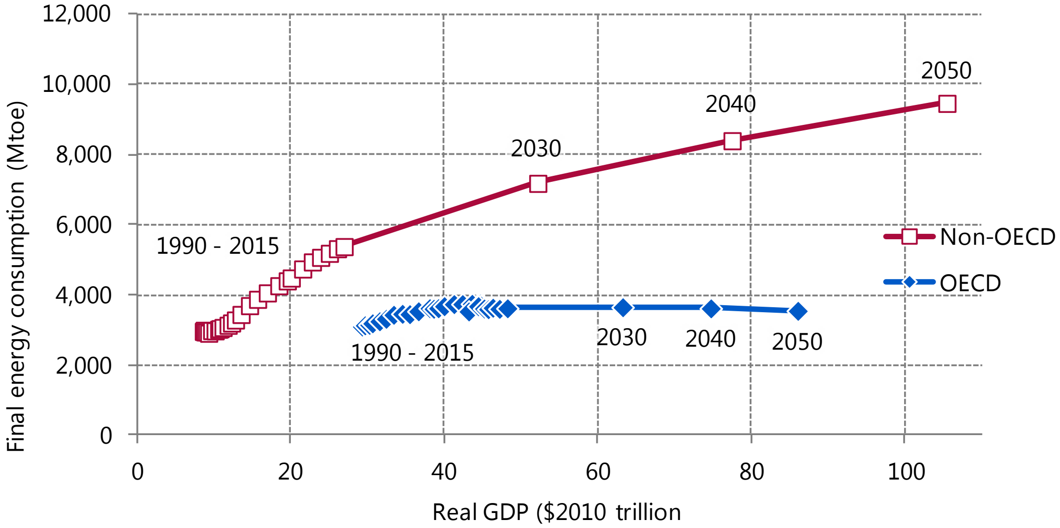
Final energy consumption in the world has grown at a slower pace than the world economy. Between 1990 and 2015, annual growth in final energy consumption came to 1.6% against the annual real GDP growth rate of 2.8%[10]. In OECD where the services sector's expansion and energy efficiency have made progress, the annual final energy consumption growth was limited to 0.6% against the annual real GDP growth rate of 2.0%, with final energy consumption's elasticity to GDP[11] standing at 0.31. In non-OECD, final energy consumption grew at an annual rate of 2.4% due primarily to a higher annual economic growth of 4.7%, increasing production in energy-intensive industries and population growth. The non-OECD final energy consumption's elasticity to GDP stands at 0.52, higher than the elasticity for OECD. As energy consumption and economic growth decouples further, mainly in OECD, annual final energy consumption growth between 2015 and 2050 will decelerate to 1.1% against an annual economic growth of 2.7%, close to growth of the past quarter century.

10 Global total final energy consumption covers international bunkers.

11 Final energy consumption' elasticity to GDP = annual growth rate of final energy consumption / annual growth rate of real GDP

OECD final energy consumption will peak out around 2030 and fall to 3,549 Mtoe, slipping below 3,622 Mtoe in 2015. Non-OECD consumption will increase at an annual rate of 1.6% from 5,380 Mtoe in 2015 to 9,645 Mtoe in 2050, though with final energy consumption's elasticity to GDP falling to 0.41 (Figure 2-17).

Figure 2-17 | GDP and final energy consumption [Reference Scenario]

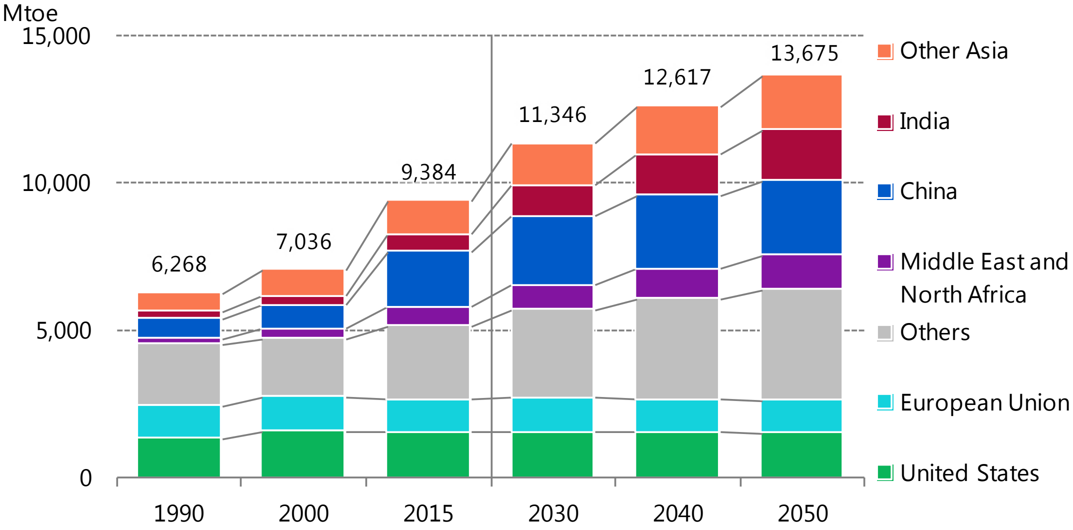


By region

Of the 4,291 Mtoe in global final energy consumption growth through 2050, Asia will account for 2,523 Mtoe or 59% (Figure 2-18). In Asia where high economic growth will continue, final energy consumption will increase at an annual rate of 1.5% from 3,617 Mtoe in 2015 to 6,140 Mtoe in 2050 due mainly to industrial development, motorisation, urbanisation and improvements in living standards.

In the Middle East and North Africa, final energy consumption will grow from 613 Mtoe in 2015 to 1,142 Mtoe in 2050. The growth in volume will top the ASEAN growth, accounting for 12% of global growth. In the United States and European Union where society has matured, final energy consumption will turn downward from the 2020s, falling from 1,520 Mtoe in 2015 to 1,477 Mtoe in 2050 and from 1,114 Mtoe to 1,206 Mtoe, respectively.

Figure 2-18 | Final energy consumption by region [Reference Scenario]



By sector

The buildings (residential and commercial) sector will account for 1,646 Mtoe or 38% of the final energy consumption growth of 4,291 Mtoe between 2015 and 2050. It is followed by the industry sector with an increase of 1,066 Mtoe, the transport sector with 1,062 Mtoe and the non-energy use sector with 516 Mtoe. The annual growth rate will be 1.4% for the non-energy use sector, 1.2% for the buildings sector and 1.0% for the industry and transport sectors.

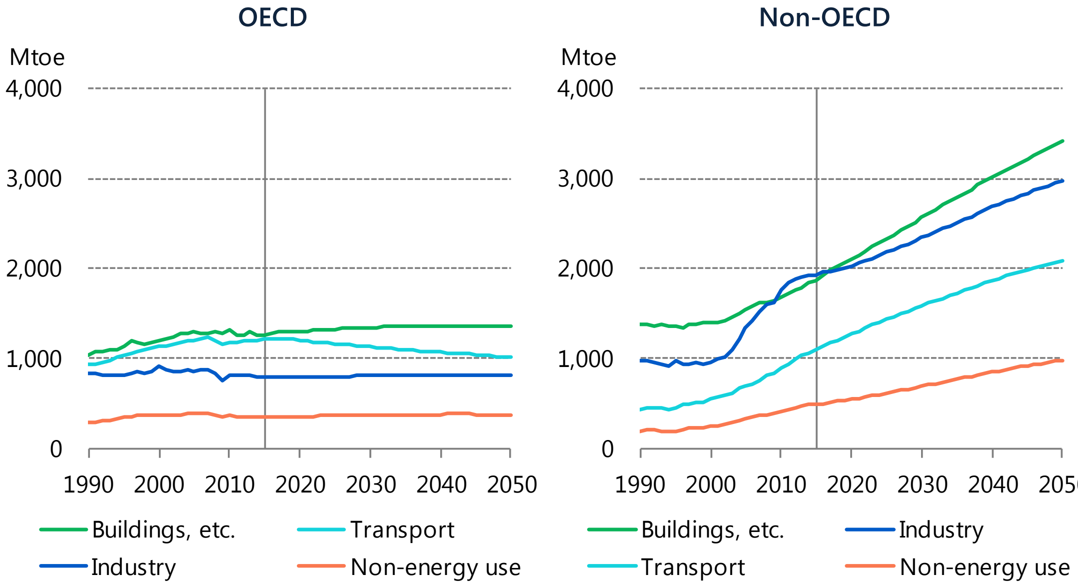
From 2015 to 2050, final energy consumption will follow a downtrend in OECD as a slight increase in the buildings and industry sectors is more than offset by a fall accompanying vehicle fuel efficiency improvements in the transport sector (Figure 2-19). In non-OECD, final energy consumption will increase 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 2.0%, higher than in any other regions. Demand increases due to improved living standards in China, India and ASEAN and spread electrical home appliances in line with income growth. Particularly, China will record a remarkable consumption increase of 331 Mtoe between 2015 and 2050, exceeding Japan's current annual final energy consumption.

In the industry sector, energy consumption will increase from 2,712 Mtoe in 2015 to 3,779 Mtoe in 2050 as many non-OECD countries achieve high economic growth and shift from agriculture and other primary industries to manufacturing industries. Of the increase of 1,066 Mtoe, non-OECD Asia will account for 58%.

The transport sector will increase its global energy consumption at an annual rate of 1.0% as progress in motorisation in non-OECD drives the consumption growth. Global vehicle ownership will double from 1,290 million vehicles in 2015 to 2,560 million vehicles in 2050. Non-OECD Asia will account for 56% of the global vehicle ownership expansion. The transport sector's energy consumption will decline at an annual rate of 0.5% in OECD due to vehicle fuel efficiency improvements, while increasing at an annual rate of 1.9% in non-OECD as the effects of the vehicle ownership expansion outdo fuel efficiency improvements. Consumption by international bunkers will increase at an annual rate of 1.6% from 382 Mtoe in 2015 to 661 Mtoe in 2050 as international travel and trade expand.

Figure 2-19 | OECD and non-OECD final energy consumption [Reference Scenario]



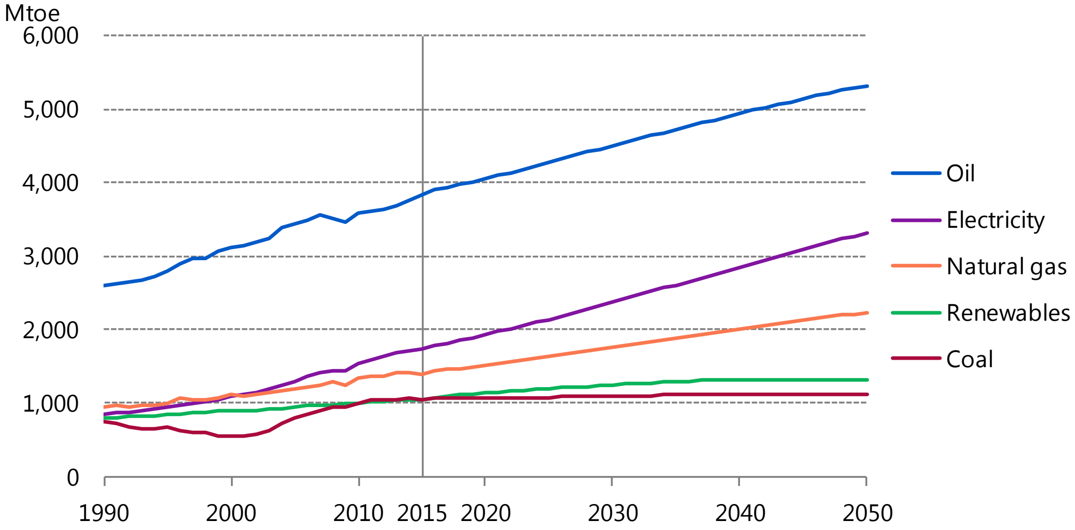
By energy source

A breakdown of final energy consumption by energy source shows that electricity will score the largest consumption growth among energy sources (both in OECD and in non-OECD), accounting for 37% of the total final energy consumption growth (Figure 2-20). Oil consumption will increase as a result of growth in the non-OECD transport and non-energy use sectors. Natural gas consumption will substantially expand in China's buildings sector and the Middle East's industry sector. Between 2015 and 2050, consumption will increase at an annual rate of 1.9% for electricity, at 1.3% for natural gas and at 0.9% for oil. Meanwhile, the annual growth rate for coal will be limited to 0.2%. While the order of energy sources' shares of total energy consumption will remain unchanged in the outlook period, the share will fall from 41% to 39% for oil and rise from 19% to 24% for electricity and from 15% to 16% 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. Vehicle ownership will rapidly expand mainly in China, India and other non-OECD Asian countries, as motorisation makes progress in line with income growth. Asia will account for 65% of global oil consumption growth and increase its share of global oil consumption from 30% in 2015 to 40% in 2050. 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 and the Middle East's industry sector. The Chinese residential sector still uses coal and biomass including firewood and will switch from them to city gas in consideration of air pollution problems. The Middle East will promote domestic natural gas utilisation to earn foreign currencies from oil exports and will expand petrochemical plants using natural gas to generate jobs.

Figure 2-20 | Global final energy consumption by source [Reference Scenario]

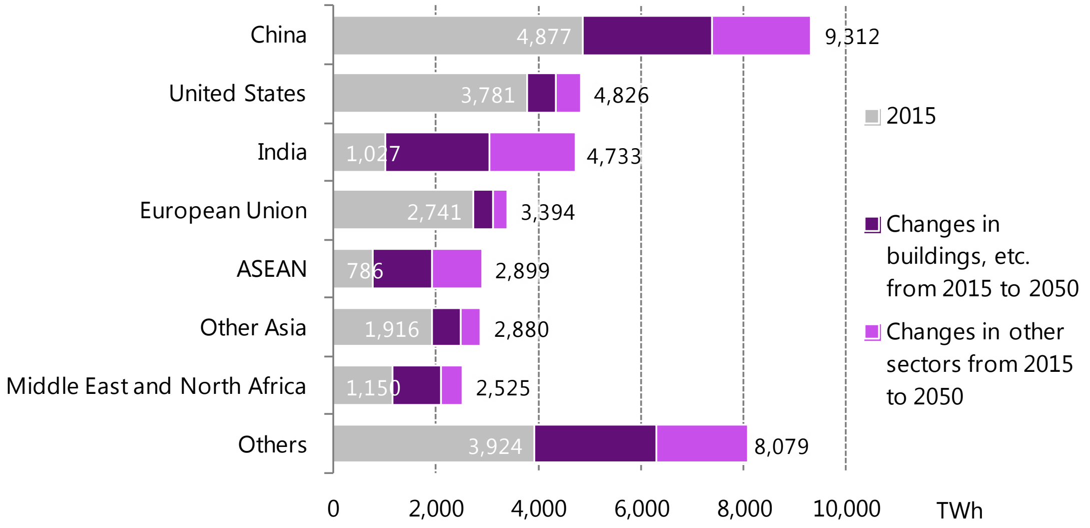


Generally, as income grows, people favour the convenience of electricity and this trend will remain unchanged. Electricity will score the highest consumption growth among major energy sources both in OECD and in non-OECD. The global electrification rate[12] will rise from 19% in 2015 to 24% in 2050. Driving electricity consumption growth will be Asia including China, India and ASEAN, as well as the Middle East and emerging countries like Brazil (Figure 2-21). In any country or region, electricity infrastructure development both in rural and urban areas and in the penetration of electrical home appliances like air conditioners and televisions under growing income will induce electricity consumption growth.

At present, OECD captures 46% of final electricity consumption. However, China, the world's largest electricity consumer, will expand electricity consumption by 4,435 TWh, an amount that exceeds the present consumption level of the second largest electricity consumer, the United States. India's electricity consumption will rise at an annual rate of 4.5%, reaching 4,733 TWh in 2050. Non-OECD will thus expand electricity consumption rapidly and substantially. As more than 80% of global electricity consumption growth is generated in non-OECD, OECD's share of global consumption will decline to 31% in 2050.

[12] The rate is the ratio of electricity consumption to total final energy consumption.

Figure 2-21 | Final electricity consumption [Reference Scenario]



3. Energy supply

3.1 Crude Oil

Supply

Table 1-1 shows the crude oil supply outlook in the Reference Scenario. In response to global oil demand growth, both OPEC and non-OPEC will expand crude oil supply. As production declines in Asia and peaks out in Europe and Eurasia around 2030, the non-OPEC share of global crude oil production will gradually fall from 58% in 2015 to 57% in 2030 and to 53% in 2050.

Through 2050, increased production in OPEC Middle East, North and Latin Americas will account for more than 80% of global production growth. Driving OPEC production growth will be Saudi Arabia with surplus production capacity and Iran and Iraq with potential to expand production. In North America, oil exploration and development investment will recover in line with slow oil price hikes, with production growth driven by unconventional oil including shale oil and oil sands. This will lead to a significant production growth in North America lasting until around 2030. North America with strong growth and Latin America, including Brazil promoting pre-salt oil field development, will play a central role in expanding non-OPEC crude oil supply.

Table 3-1 | Crude oil supply [Reference Scenario]

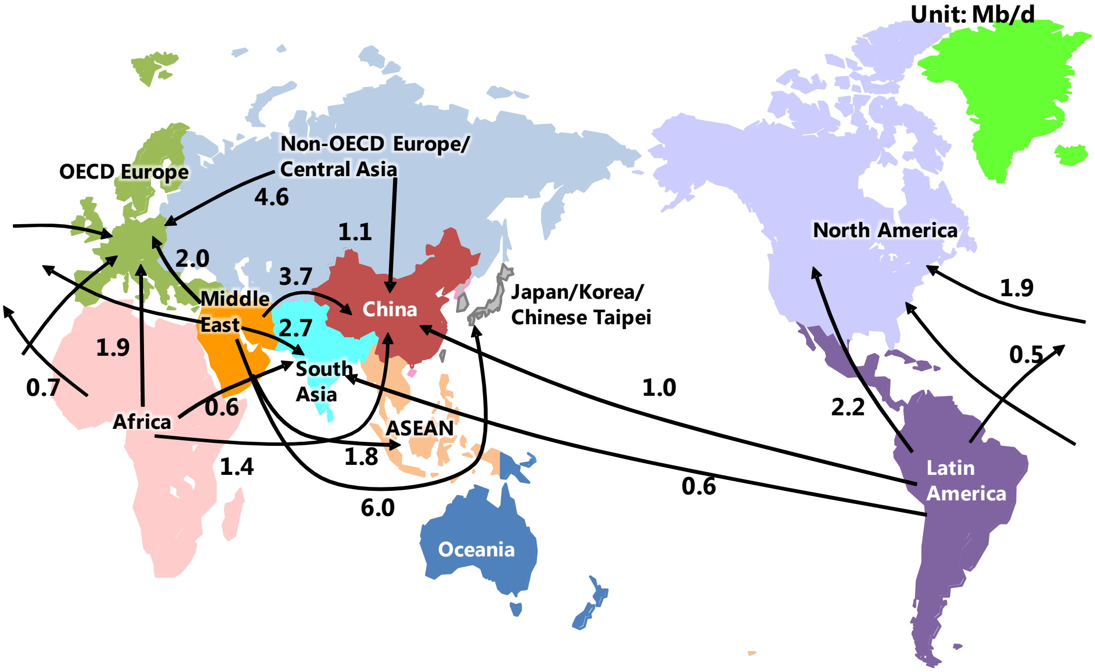
(Mb/d)

	2015	2030	2040	2050	2015-2050	
					Changes	CAGR
Total	93.94	104.90	114.18	121.85	27.91	0.7%
OPEC	38.65	43.61	50.26	55.65	17.00	1.0%
Middle East	28.80	32.36	37.77	42.04	13.24	1.1%
Others	9.85	11.25	12.49	13.60	3.75	0.9%
Non-OPEC	53.05	58.51	60.74	62.66	9.60	0.5%
North America	17.15	21.63	21.89	21.88	4.74	0.7%
Latin America	7.16	8.77	10.75	12.35	5.19	1.6%
Europe/Eurasia	17.48	17.45	17.31	17.29	-0.19	0.0%
Middle East	1.26	1.45	1.58	1.74	0.48	0.9%
Africa	1.63	1.84	1.98	2.18	0.55	0.8%
Asia/Oceania	8.37	7.37	7.24	7.21	-1.16	-0.4%
China	4.31	3.75	3.64	3.63	-0.68	-0.5%
Indonesia	0.84	0.79	0.74	0.71	-0.13	-0.5%
India	0.88	0.61	0.56	0.56	-0.31	-1.3%
Processing gains	2.24	2.78	3.18	3.55	1.31	1.3%

Trade

Global crude oil trade totalled 39 Mb/d in 2016 and Figure 2-5 indicates the oil trade flows for that year. The major importers are Asia (Japan, Korea, Chinese Taipei, China, Southeast Asia and South Asia), OECD Europe and North America. The major suppliers are the Middle East, Africa and Latin America for Asia, non-OECD Europe and Central Asia for OECD Europe, and Latin America and the Middle East for North America.

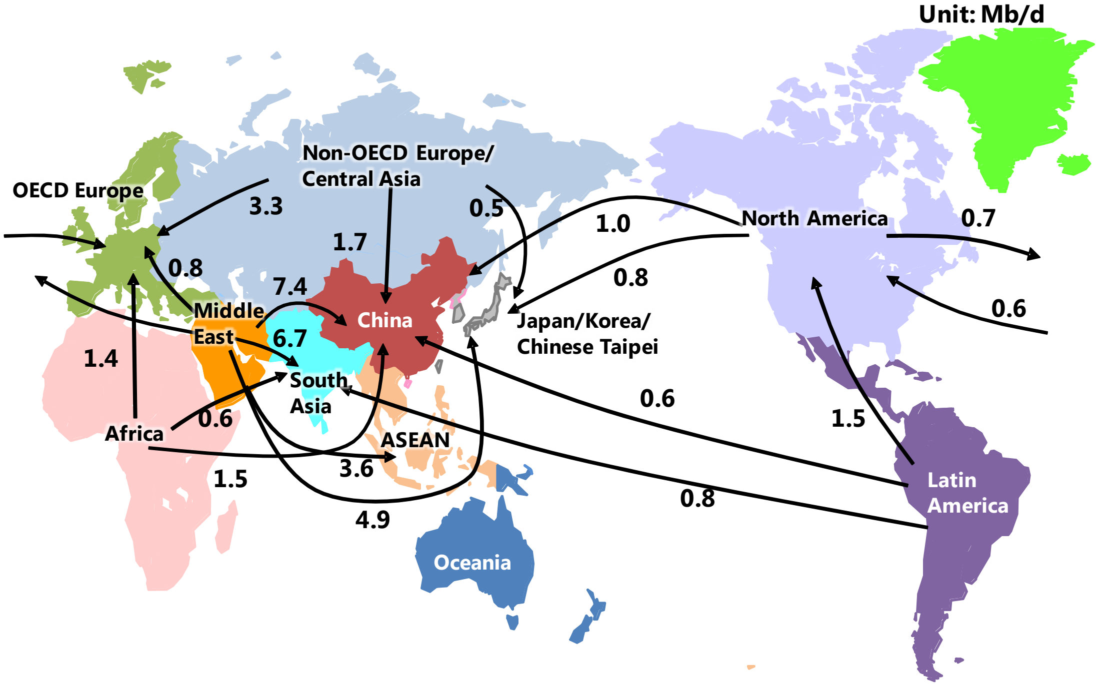
Figure 3-1 | Major crude oil trade flows [2016]



Crude oil trade will increase to 43 Mb/d in 2030. While OECD will reduce imports due to a demand decline and a production increase in North America, imports to meet growing demand in Asian emerging economies such as China, India and ASEAN will drive the global trade growth. Figure 3-2 indicates the trade flows in 2030.

Asia will diversify crude oil supply sources by expanding supply from North America, non-OECD Europe and Central Asia. However, the Middle East and Africa will still account for 80% of Asian crude oil supply in 2030. While continuing to import crude oil from Latin America and the Middle East, North America will substantially reduce imports from 2016 to 2030. Non-OECD Europe, Central Asia, Africa and the Middle East will compete for exports to Europe that will reduce imports. However, non-OECD Europe, Central Asia and the Middle East will enhance their shift to Asia with growing demand, eventually decreasing supply to Europe. Meanwhile, North America will increase crude oil production and exports to Europe.

Figure 3-2 | Major crude oil trade flows [Reference Scenario, 2030]



3.2 Natural gas

Production

In the Reference Scenario, natural gas production will grow by 80% from 2015 to 2050 (Table 3-2).

Among regions, the Middle East will benefit from the largest growth by increasing natural gas production by 589 Bcm from 2015 to 2050. Particularly Iran, with the world's largest proven natural gas reserves will expand production by realising pipeline gas exports to neighbouring countries and LNG projects in or after 2030. Iran will remain the largest gas producer in the Middle East. North America will record the second largest gas production growth. The United States will substantially expand production using its accumulated gas development knowledge and will increase LNG exports from the Gulf of Mexico coast. Canada, endowed with rich shale gas resources as is the case with the United States, will boost production in or after 2030. The former Soviet Union will increase gas production by 503 Bcm between 2015 and 2050. Of particular interest and contributing to the whole of the former Soviet Union are Russia's development of resources on the Yamal Peninsula and the production expansion in Eastern Siberia and Sakhalin.

Table 3-2 | Natural gas production [Reference Scenario]

(Bcm)

	2015	2030	2040	2050	2015-2050	
					Changes	CAGR
World	3,493	4,668	5,521	6,300	2,807	1.7%
North America	915	1,235	1,365	1,495	580	1.4%
Latin America	205	262	381	459	254	2.3%
OECD Europe	248	217	207	190	-58	-0.8%
Non-OECD Europe/Central Asia	792	991	1,153	1,295	503	1.4%
Russia	595	735	809	898	303	1.2%
Middle East	595	820	970	1,184	589	2.0%
Africa	206	301	432	488	283	2.5%
Asia	467	650	793	937	470	2.0%
China	131	260	336	406	276	3.3%
India	32	60	97	129	97	4.1%
ASEAN	215	237	267	310	95	1.1%
Oceania	65	193	221	253	188	4.0%

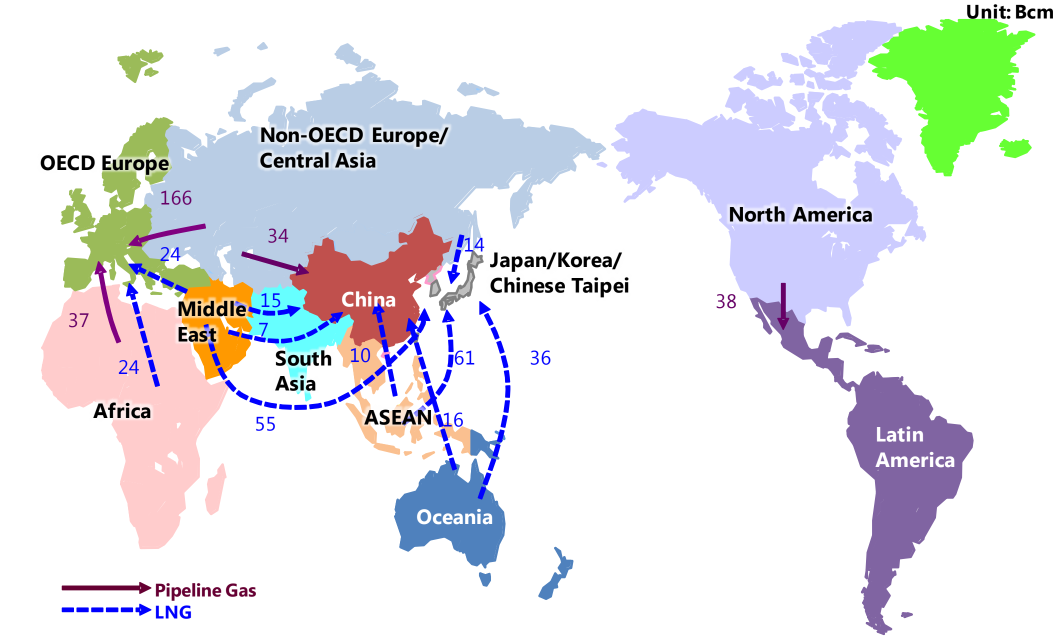
In Asia, China and India will promote domestic gas field developments to meet their respective domestic demand growth. Particularly, China will step up investments to develop domestic shale gas to further promote domestic gas utilisation. In Africa, new LNG producers including Mozambique, Tanzania and Senegal have discovered gas fields one after another and will expand production in or after 2030. Meanwhile, OECD Europe will gradually reduce domestic gas production due to geological limits.

Trade

Natural gas trade between major regions in the world totalled 511 Bcm in 2016. Pipeline gas trade accounted for most 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. Recently, however, global LNG trade flows have diversified as new LNG projects in Qatar, Australia and other countries started operation. On the supply side, LNG exports from the U.S. mainland started in 2016 and on the demand side, Colombia and Jamaica began to import LNG the same year. LNG trade patterns will be further diversified in the future.

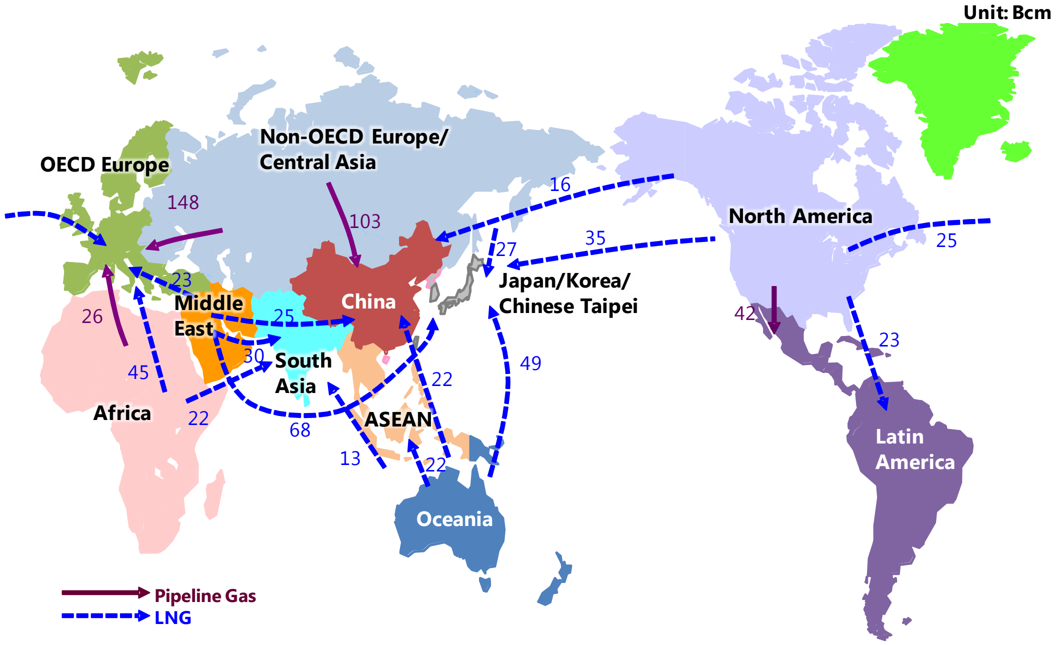
As a result of growth in imports into Asia and growth in exports from North America, natural gas trade between major regions will continue to expand reaching 825 Bcm in 2030. Oceania and North America plan to launch production under many LNG projects between 2020 and 2025, posting the largest gas export growth. China, the largest among natural gas importers, will import 108 Bcm in pipeline gas and LNG from Russia and Central Asia.

Figure 3-3 | Major natural gas trade flows [2016]



Source: BP "BP Statistical Review of World Energy" (2017)

Figure 3-4 | Major natural gas trade flows [Reference Scenario, 2030]



Toward Asian natural gas demand expansion

Natural gas features remarkable growth in reserves through the shale revolution and is the cleanest among fossil fuels. As Asia will drive the growth in future global energy demand, expanding the use of natural gas would contribute greatly to enhancing energy security while limiting the impacts of climate change. As such, Asian emerging economies have unprecedentedly grown interested in using natural gas especially since spot LNG prices have relaxed on the loosening of the supply-demand balance and since LNG supply sources are diversifying through the launch of U.S. LNG with no destination clause constraints.

What would be required to expand the use of natural gas in Asia? The first requirement is the enhancement of flexibility in trade in natural gas, particularly LNG. As Asian emerging economies are comprised of natural gas producers, pipeline gas importers and coal producers, they already have more energy supply options than Japan or Korea. If LNG is considered as only one of the energy supply options, demand for LNG will depend on the options' respective energy supply-demand balances and if it is unstable and uncertain. To encourage these emerging economies to use LNG, long-term LNG trade contracts with destination clause constraints should be transformed into more flexible ones.

A research report on the international LNG market, released in June 2017 by the Japan Fair Trade Commission, is expected to make key contributions for the elimination of destination clause constraints. The report concluded that "long-term FOB contracts that impose these clauses may be in violation of the Antimonopoly Act." According to FTC data, the FOB contracts, which include those requirements for diverting cargoes outside Japan, accounted for 21.8% of long-term contracts. If other Asian competition authorities make the same conclusion, the elimination of destination constraints could become a standard for the Asian LNG market, making great contributions to increasing flexibility in the market.

The next key requirement for expanding the use of natural gas in Asia is financial support for infrastructure development. Due to natural gas's physical characteristics, more investment in supply infrastructure is required for natural gas than for coal or oil. On the other hand, most Asian countries have government regulations on electricity and city gas prices, making natural gas supply less profitable. The private sector alone thus tends to fall short of securing sufficient funding for natural gas infrastructure development. Therefore, financial support by Asian emerging country governments, export credit agencies for companies interested in infrastructure development, and public financial institutions including international development banks such as the World Bank and the Asian Development Bank will play a key role in promoting the use of natural gas in Asian emerging economies. These financial support organisations' advice can be expected to improve the profitability or efficiency of natural gas infrastructure development.

Furthermore, emerging country governments are required to set their medium to long-term policies for the use of natural gas. As noted above, LNG demand in emerging economies is essentially unstable and LNG projects' profitability is uncertain. Governments should make policy commitments to reduce as much as possible the uncertainties concerning new infrastructure investments. Advantages for introducing natural gas include the fact that it burns cleaner than any other fossil fuels and that its diversified supply sources contribute to energy security. However, under market mechanisms these advantages are difficult to reflect in pricing terms, making natural gas less competitive than other fuels such as coal in some cases. In this sense, government policy support can be justified for assessing natural gas's advantages appropriately.

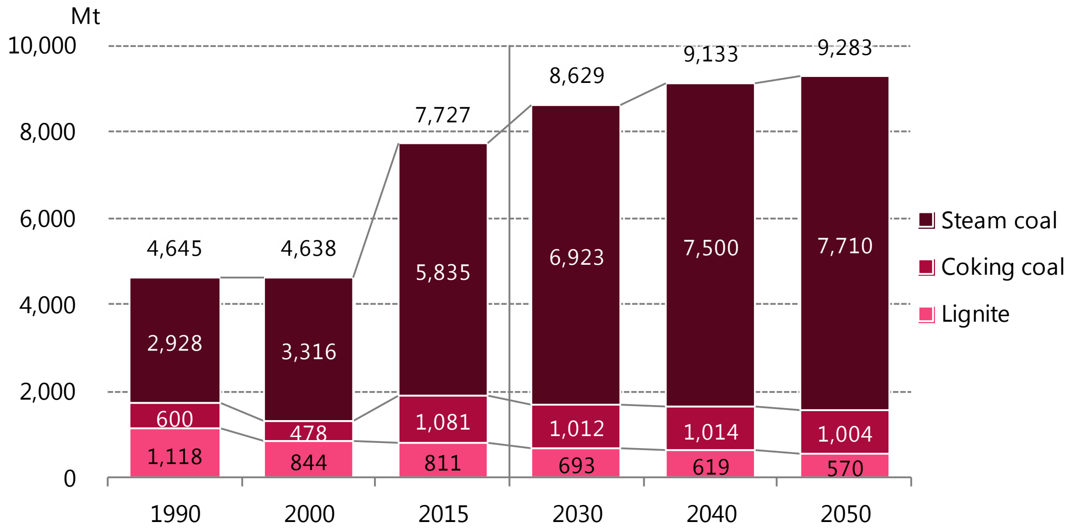
Human resources development is also indispensable for expanding the use of LNG. Given LNG transaction patterns and LNG's physical characteristics (ultra-low temperature liquid), it is a unique energy source. In this sense, special knowledge is required for LNG transactions, safe LNG use and environmental protection. If Japan and other countries that have so far used LNG can play proactive roles in developing relevant human resources, it may contribute much to promoting the use of LNG in Asia. In the administrative area, many Asian emerging economies have yet to develop sufficient regulations for accepting and using LNG, therefore, proactive support should be provided for developing human resources not only in the gas industry but also in the government or administrative sector in these countries.

3.3 Coal

Production

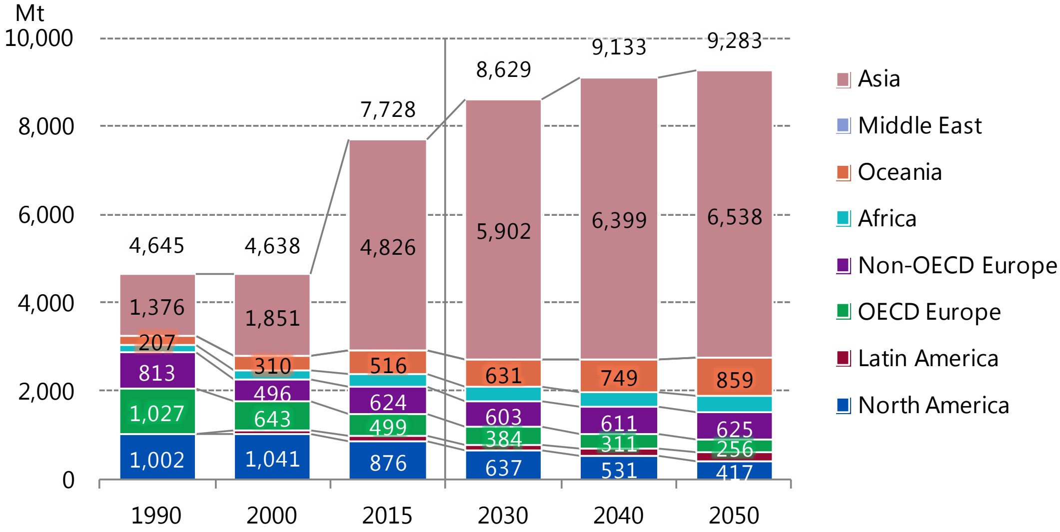
Global coal production will increase from 7,727 Mt in 2015 to 9,283 Mt in 2050 as coal demand expands in non-OECD countries mainly in Asia, Latin America and Africa (Figure 3-5). Steam coal production will rise 1.32-fold from 5,835 Mt in 2015 to 7,710 Mt in 2050 due to growing demand for power generation, while coking coal production will decrease from 1,081 Mt in 2015 to 1,004 Mt in 2050 as crude steel production falls. Lignite production will also decline from 811 Mt in 2015 to 570 Mt in 2050 in line with a fall in demand for power generation.

Figure 3-5 | Coal production by type [Reference Scenario]



By region, coal production will increase in Asia for its growing coal demand and in Oceania, Africa and Latin America that have major coal exporting countries. However, production will decrease in North America and OECD Europe where coal demand will decline (Figure 3-6). Table 3-3 indicates steam and coking coal production by region.

Figure 3-6 | Coal production by region [Reference Scenario]



Asian coal production will grow by 1,712 Mt from 4,826 Mt in 2015 to 6,538 Mt in 2050. In China, steam coal production will rise in line with growth in demand for power generation. However, overall coal production will gradually decelerate its growth before turning downward around 2040. Meanwhile, coking coal production in China will go down as demand for crude steel production falls. Indian steam and coking coal production will increase in conjunction with demand growth. Coal production could level off in Indonesia as a result of the national plan to adjust coal production to protect coal resources and use them sustainably and efficiently.

North American coal production will decrease sharply from 876 Mt in 2015 to 417 Mt in 2050. U.S. production will decline due to a domestic demand fall and the shrinking European market. 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 in Canada will slightly fall, with no recovery expected in demand for exports.

Latin America will increase coal production due to expanding local and export demand. Colombia, a major steam coal exporter, will increase production on the expansion of the Asian market as well as imports in Africa, South America and the Middle East, while its major export destination, the European market, will shrink.

In OECD Europe, both steam and coking coal production will fall due to a decline in domestic demand, hikes in production cost and the elimination of subsidies for the coal industry in some countries.

Table 3-3 | Coal production [Reference Scenario]

Steam coal (Mt)

	2015	2030	2040	2050	2015-2050 Changes	2015-2050 CAGR
World	5,835	6,923	7,500	7,710	1,875	0.8%
North America	718	509	415	318	-400	-2.3%
United States	691	492	401	309	-383	-2.3%
Latin America	101	136	166	192	91	1.8%
Colombia	81	113	140	165	84	2.0%
OECD Europe	81	59	49	41	-40	-1.9%
Non-OECD Europe/Central Asia	312	337	367	393	81	0.7%
Russia	195	221	243	266	71	0.9%
Middle East	0.2	0.2	0.2	0.2	0	0.7%
Africa	264	307	328	352	88	0.8%
South Africa	256	290	302	310	54	0.6%
Asia	4,100	5,193	5,672	5,796	1,696	1.0%
China	2,970	3,335	3,438	3,192	222	0.2%
India	586	1,203	1,572	1,936	1,350	3.5%
Indonesia	453	550	550	550	97	0.6%
Oceania	258	382	502	617	360	2.5%
Australia	256	381	502	616	360	2.5%

Coking coal (Mt)

	2015	2030	2040	2050	2015-2050 Changes	2015-2050 CAGR
World	1,081	1,012	1,014	1,004	-77	-0.2%
North America	84	73	71	67	-17	-0.7%
United States	58	47	46	43	-15	-0.8%
Latin America	8	9	10	10	2	0.8%
Colombia	4	6	6	6	2	1.0%
OECD Europe	22	17	15	14	-8	-1.2%
Non-OECD Europe/Central Asia	106	100	100	100	-6	-0.2%
Russia	83	78	78	79	-4	-0.1%
Middle East	0.9	0.9	0.9	0.9	0	-0.1%
Africa	8	16	23	29	20	3.6%
Mozambique	5	13	19	25	20	4.8%
Asia	660	605	599	589	-72	-0.3%
China	593	466	411	350	-243	-1.5%
India	53	124	174	225	172	4.2%
Mongolia	13	11	10	8	-5	-1.3%
Oceania	192	191	195	195	3	0.0%
Australia	191	190	194	193	2	0.0%

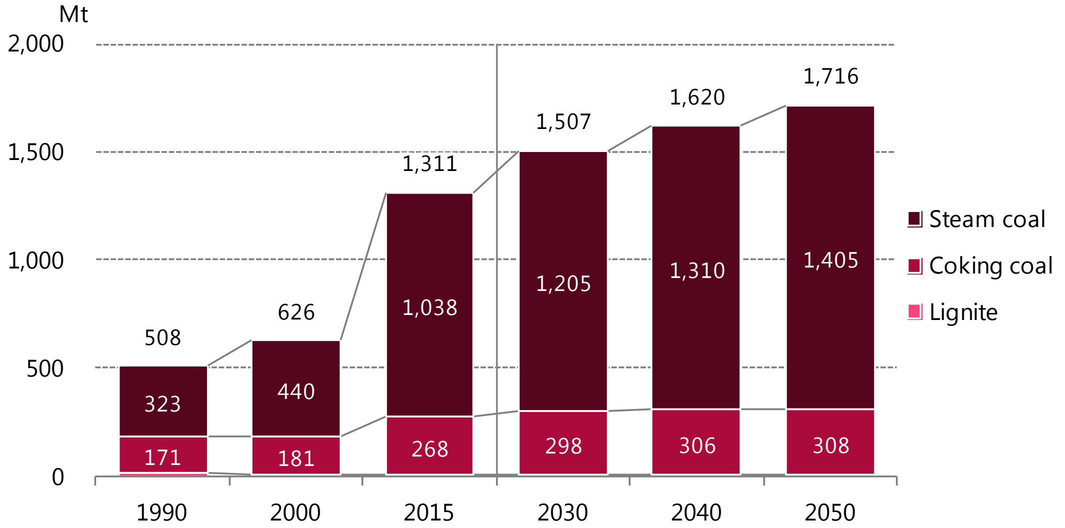
In Africa, coal production will rise from 273 Mt in 2015 to 382 Mt in 2050 in line with growth in regional steam coal demand and in response to export demand (including growing Asian steam coal and Indian coking coal demand). In South Africa, steam coal production will increase. Mozambique will expand both coking and steam coal production.

In Oceania, Australia will raise coal production sharply from 516Mt in 2015 to 859 Mt in 2050 to meet the expansion of the Asian market including India and ASEAN and make up for a decline in steam coal exports from Indonesia.

Trade

Coal trade (imports) will expand from 1,311 Mt in 2015 to 1,716 Mt in 2050 in line with demand growth (Figure 3-7). Steam coal trade will increase from 1,038 Mt in 2015 to 1,405 Mt in 2050 in response to demand growth in India and ASEAN. Coking coal trade will grow from 268 Mt in 2015 to 308 Mt in 2050 due mainly to increasing Indian demand.

Figure 3-7 | Coal trade [Reference Scenario]



Note: Figures indicate imports

Steam coal imports in Asia will increase from 320 Mt in 2015 to 917 Mt in 2050. India and four major ASEAN countries (Malaysia, Thailand, the Philippines and Viet Nam) will substantially expand their imports. Of the 597 Mt increase in Asian steam coal imports, India will account for 127 Mt and the four major ASEAN countries for 200 Mt. Steam coal imports in the Middle East will expand by 3.7 Mt from 2015 to 2050. Meanwhile, OECD Europe will reduce net imports by 78 Mt from 170 Mt in 2015 to 92 Mt in 2050 due to a demand drop.

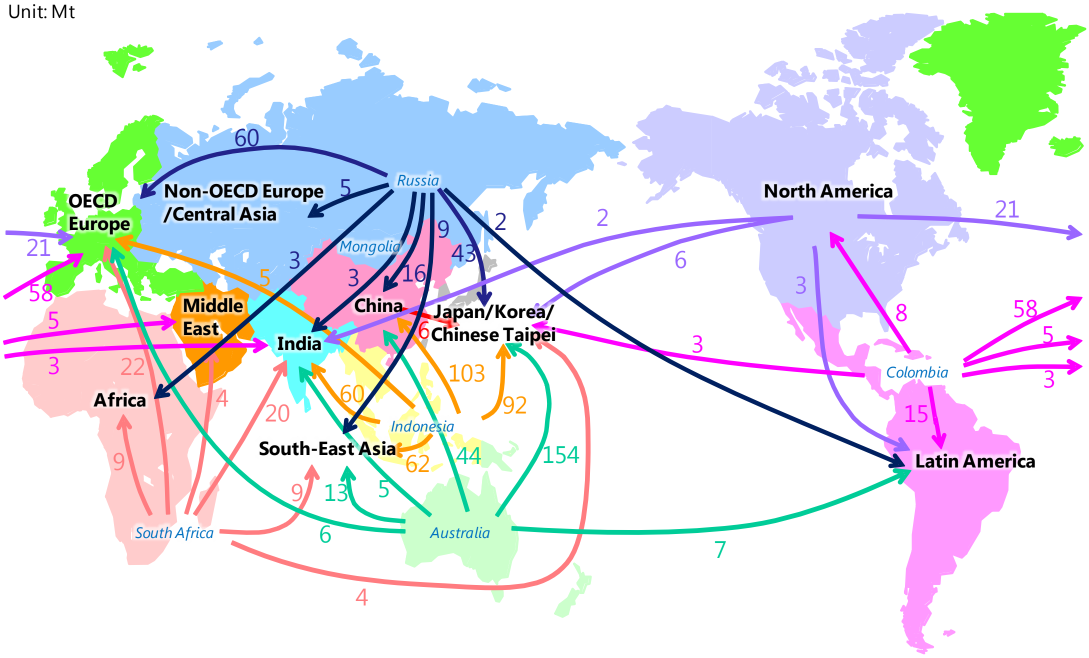
Net steam coal exports will increase from Australia, Russia, Colombia and South Africa. On the other hand, Indonesia, which announced a plan to adjust coal production, will reduce exports in line with domestic demand growth. Australia will expand net steam coal exports by as much as 378 Mt from 205 Mt in 2015 to 583 Mt in 2050 to meet the expansion of the Asian market and make up for a decline in Indonesian exports. Russia will expand net steam coal exports from 112 Mt in 2015 to 201 Mt in 2050 and Colombia will increase exports from 77 Mt to 158 Mt. South Africa will develop new coal mines on a depletion of reserves at major coal mines but face a limit on its production expansion. As its domestic demand increases, South Africa will limit annual exports to 90 Mt.

Net coking coal imports will increase from 49 Mt in 2015 to 109 Mt in 2050 for India, while falling by 12 Mt for China, by 13 Mt for Japan, by 7 Mt for Korea and by 9 Mt for OECD Europe due to their decreasing demand.

While net coking coal exports from Mozambique, a new supply source, will increase, those from the Canada and the United States will decline on falls in imports into China, Japan, Korea and OECD Europe. Mozambique exports will expand from 4 Mt in 2015 to 27 Mt in 2050. Net exports from the United States will decline from 40 Mt in 2015 to 31 Mt in 2050 and those from Canada from 27 Mt to 21 Mt. Net exports from existing coking coal exporters Russia and Australia will level off or increase slightly.

Figure 3-8 | Major steam coal trade flows [2016]

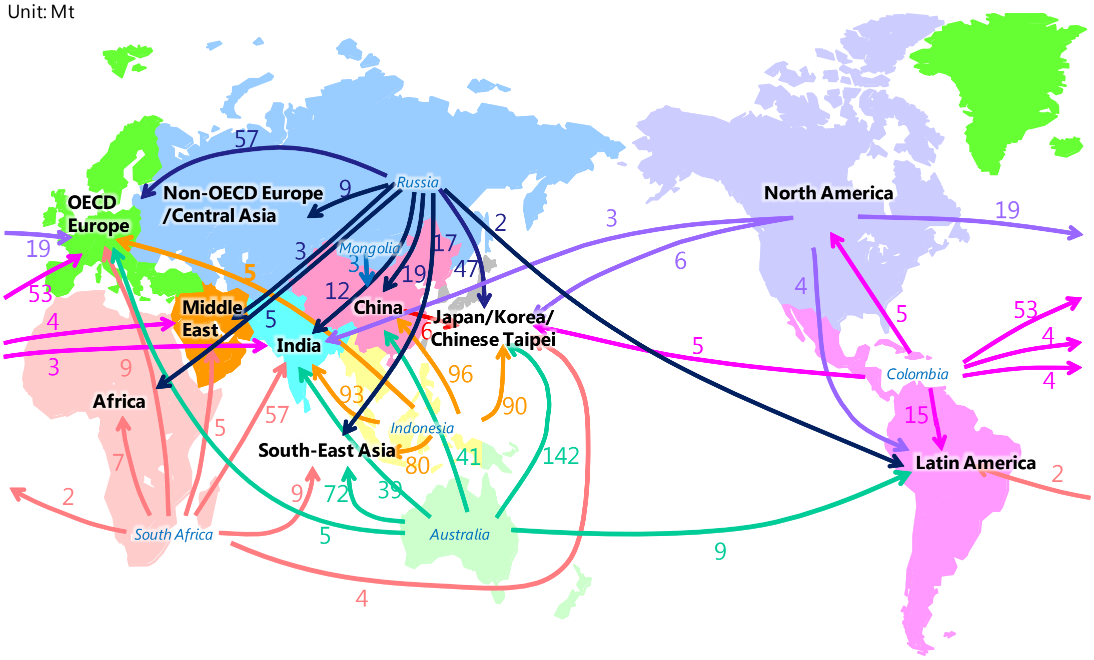
Unit: Mt



Note: Estimated net imports totalling 2 Mt or more are specified. Exports from South Africa include those from Mozambique.
Source: IEA "Coal Information 2017"

Figure 3-9 | Major steam coal trade flows [Reference Scenario, 2030]

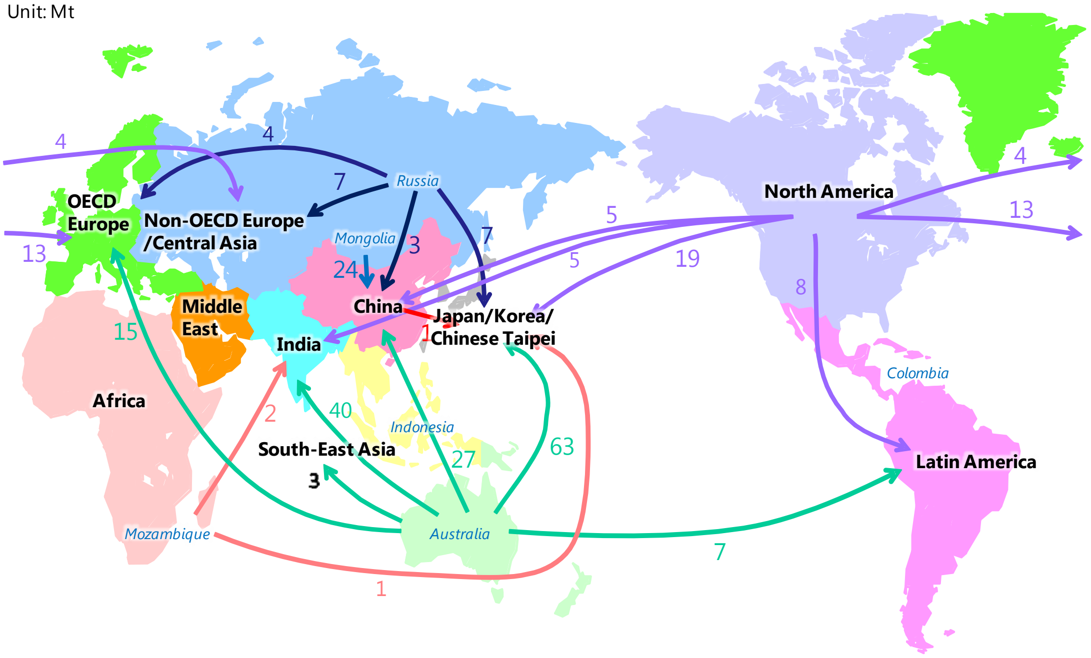
Unit: Mt



Note: Net imports totalling 2 Mt or more are specified. Exports from South Africa include those from Mozambique.

Figure 3-10 | Major coking coal trade flows [2016]

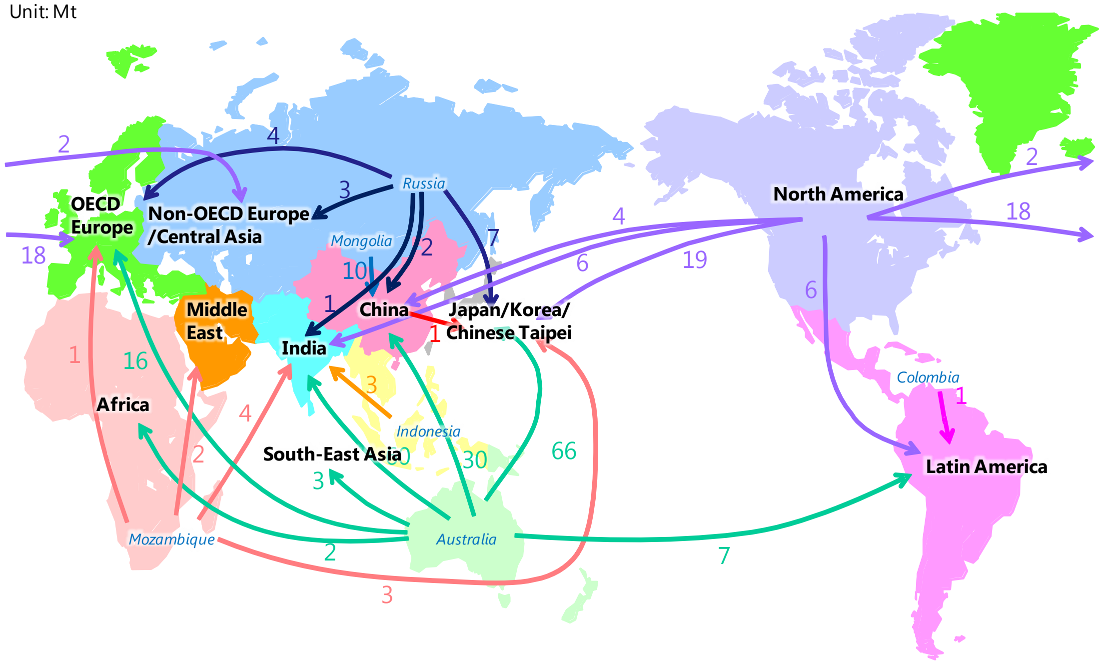
Unit: Mt



Note: Estimated net imports totalling 1 Mt or more are specified.
Source: IEA "Coal Information 2017"

Figure 3-11 | Major coking coal trade flows [Reference Scenario, 2030]

Unit: Mt



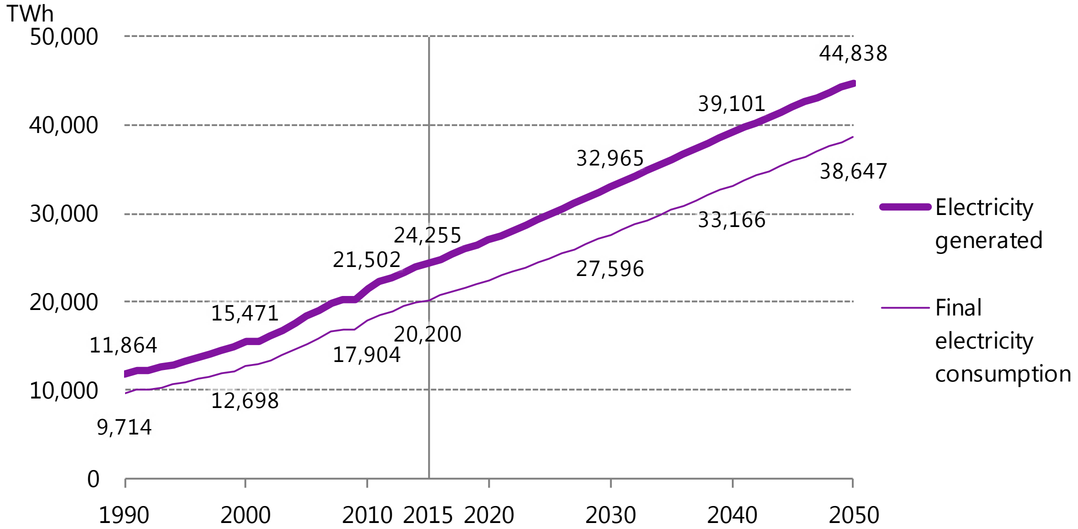
Note: Net imports totalling 1 Mt or more are specified.

3.4 Power generation

Electricity generation and its mix

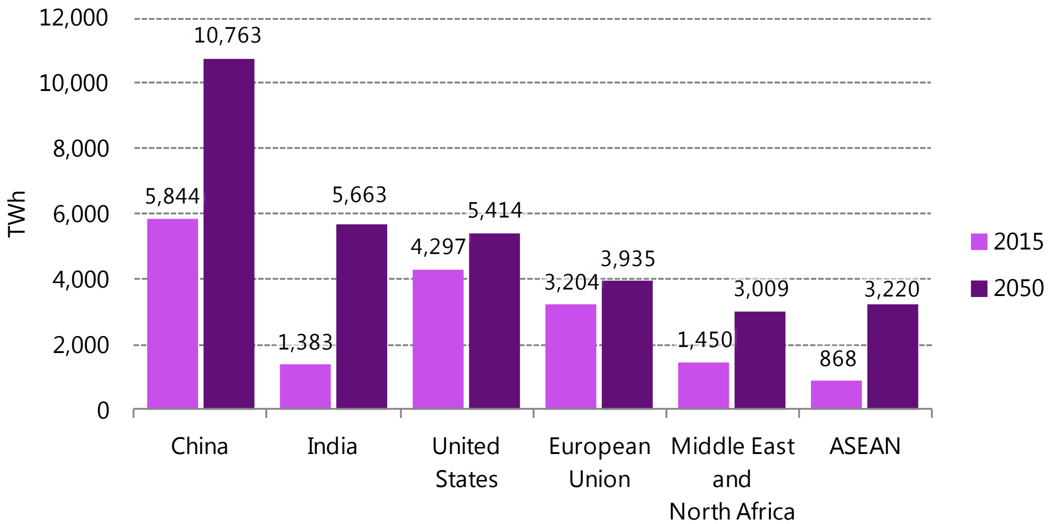
In line with electricity demand growth, global electricity generation will increase 1.8-fold from 24,255 terawatt-hours (TWh) in 2015 to 44,838 TWh in 2040, growing at an annual rate of 1.8% (Figure 3-12). The increase of 20,583 TWh is 3.5 times as large as the present electricity generation in China known as the world’s largest electricity generator and 20 times as large as that in Japan.

Figure 3-12 | Global electricity generated and final electricity consumption [Reference Scenario]



Non-OECD will account for about 90% of the electricity generation growth through 2050 (Figure 3-13). Asian electricity generation will increase at an annual rate of 2.3% from 10,204 TWh in 2015 to 22,874 TWh in 2050. Driving Asian electricity generation growth will be China, India and ASEAN.

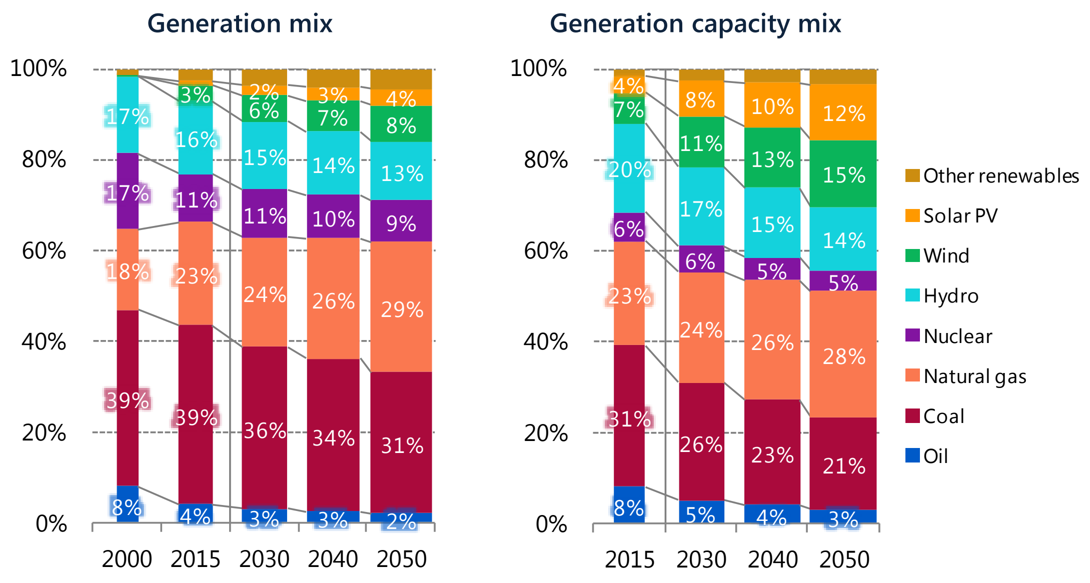
Figure 3-13 | Electricity generated in selected countries/regions [Reference Scenario]



Coal accounted for the largest share of global power generation in 2015 at 39%, followed by 23% for natural gas, 16% for hydro and 11% for nuclear (Figure 3-14). Through 2050, coal's share, though declining, will remain the largest, with coal continuing to serve as a baseload electricity source. As technological development allows combined cycle gas turbines (CCGTs) to diffuse, with gas turbines used to adjust for variable renewable power generation, a shift to natural gas for power generation will make progress. The share for natural gas will thus expand from 23% in 2015 to 29% in 2050. The share for oil will trend down in developed countries 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 2050. The nuclear share of power generation will thus fall to 9% in 2050. Wind, solar photovoltaics and other renewable power generation, excluding hydropower generation, will expand at an unrivalled annual rate of 4.7% on the strength of policy support and cost reduction. However, Wind, solar PVs' share of power generation will still be limited to a little more than 10% in 2050.

Natural gas will gradually increase its share of total power generation capacity and replace the coal share as the largest one. Wind and solar PVs, though accounting for 13% of electricity generation, will expand their share of total capacity to 27%, more than two times as large as the electricity generation share.

Figure 3-14 | Global electricity generation mix [Reference Scenario]



Note: Bar widths are proportionate to total electricity generated.

Note: Bar widths are proportionate to total power generation capacity.

In OECD, renewable energy's share of total electricity generation in 2030 will top 30%, replacing the natural gas share as the largest one. In non-OECD, coal's share of total electricity generation will remain the largest while falling. Natural gas will expand its share to the second largest level after the coal share (Figure 3-15).

In Asia including China and India, coal will remain a mainstay electricity source in response to the rapid electricity demand growth. However, its high share of the power generation mix will fall gradually, while natural gas's share will expand (Figure 3-16). Meanwhile, ASEAN has made a great shift from oil to natural gas as power 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 gas demand emerged in other sectors than power generation in the 2000s, however, natural gas supply capacity for power generation has become short. ASEAN is going ahead with plans to import natural gas after being a net natural gas exporter. Contrarily to the Chinese or Indian case, natural gas's share of power generation in ASEAN will decrease with the coal share expanding.

Figure 3-15 | OECD and non-OECD electricity generation mix [Reference Scenario]

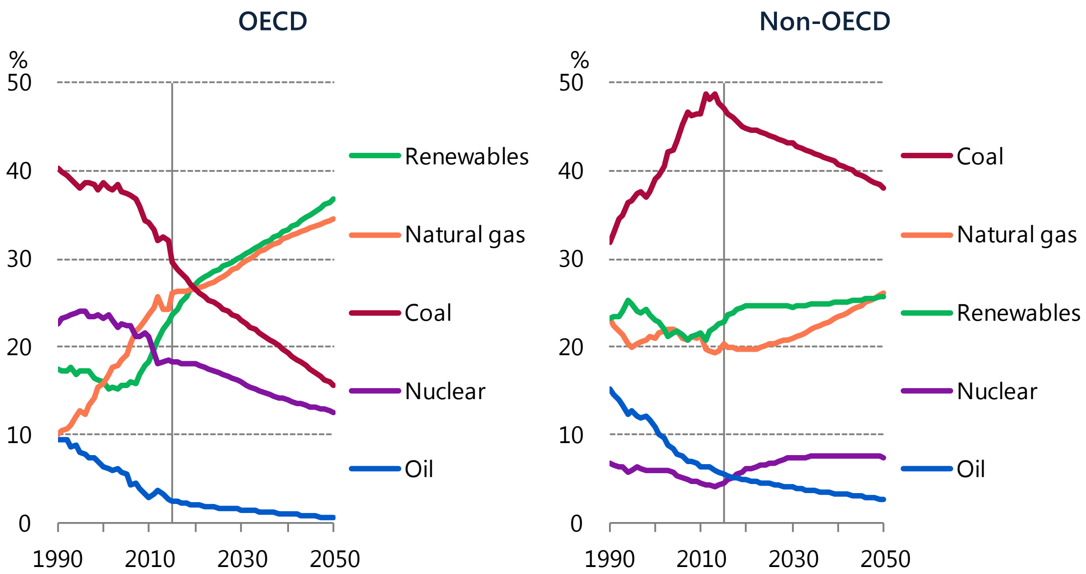
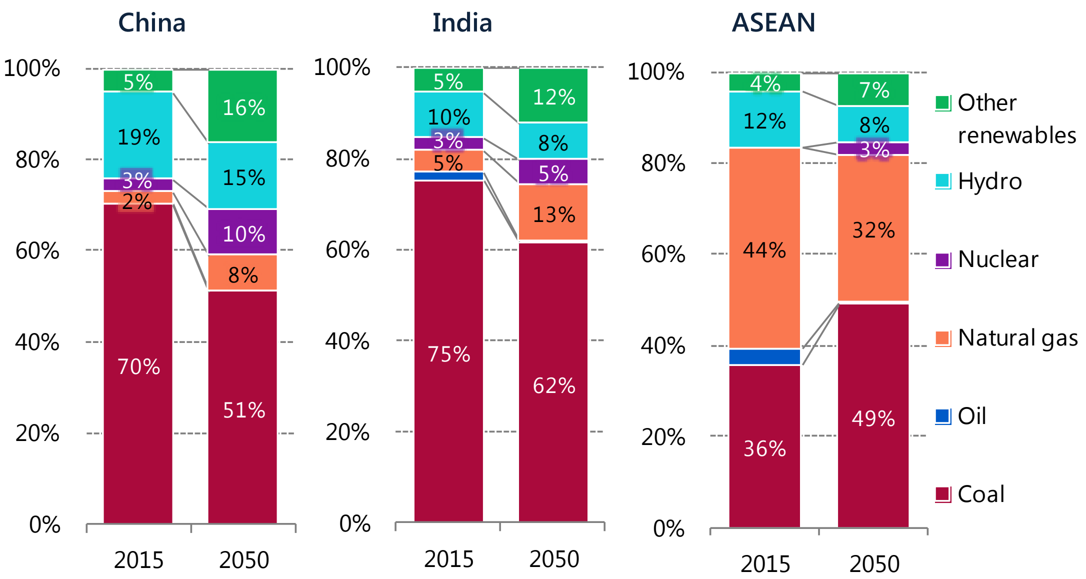


Figure 3-16 | Chinese, Indian and ASEAN electricity generation mix [Reference Scenario]

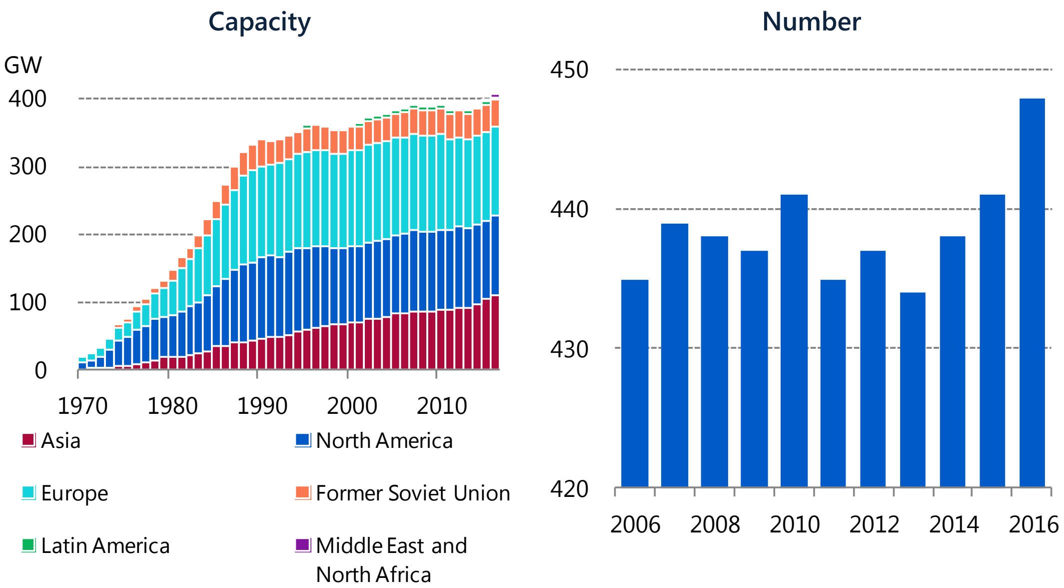


Nuclear

Global nuclear power generation capacity rapidly expanded mainly in Europe and the United States in the 1970s and 1980s before slowing down its growth or levelling off in the 1990s. In the second half of the 1990s, the capacity decreased with some reactors with poor performance decommissioned in Europe and the United States. Since the 2000s, however, the capacity has been steadily expanding mainly in Asia, though more slowly than in the 1970s. (Figure 3-17 left side).

After the Fukushima Daiichi nuclear power plant accident in 2011, the number of nuclear reactors in operation in the world declined temporarily due to the shutdown of reactors for the implementation of safety measures under new regulatory standards in Japan and the decommissioning of reactors based on a nuclear policy change in Germany and on 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 2016 rose back to the level before the Fukushima accident (Figure 3-17 right side).

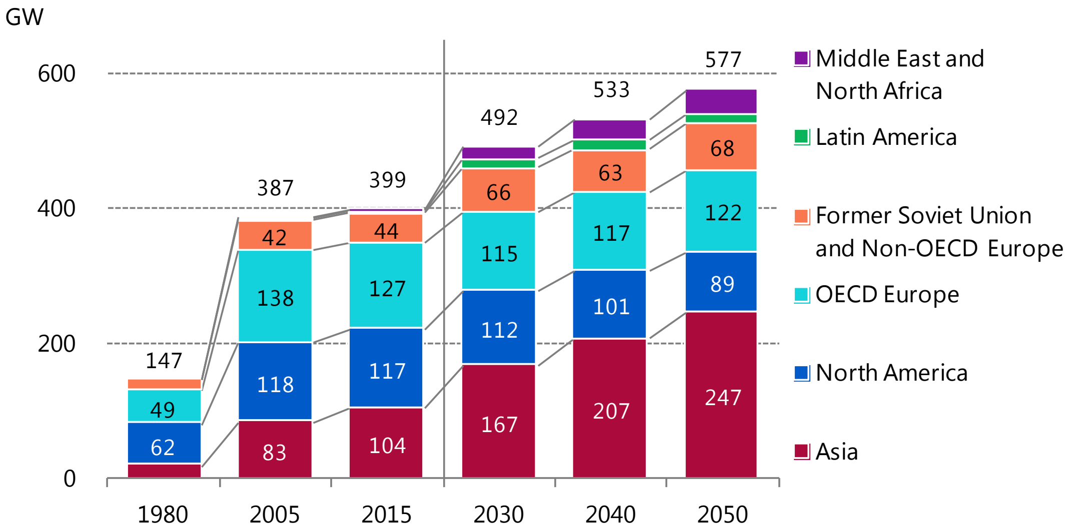
Figure 3-17 | Capacity and number of nuclear reactors



The Fukushima accident has directly affected nuclear energy policies in Japan and some European countries. Meanwhile, the United States, France, Russia and Korea known as traditionally proactive promoters of nuclear power generation, as well as emerging economies like China, have made no major change to their respective nuclear promotion policies aimed at securing stable energy supply, at mitigating climate change, or at maintaining and enhancing international competitiveness through their nuclear industry development. As explained later, France passed an energy transition law to limit nuclear power generation capacity to the present level of 66 GW (63.2 GW in net electricity output) while making no change to its policy of maintaining nuclear power generation as a baseload electricity source.

In the United States, the world's largest nuclear 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 shutting down some existing reactors for economic reasons. U.S. installed capacity for nuclear power generation at 103 GW in 2015 will remain almost unchanged through 2040 as existing plans to build new reactors are implemented, with the lifespan of existing reactors being extended to 60 years. From 2040, however, U.S. installed capacity for nuclear power generation will decline on the decommissioning of existing reactors reaching the 60-year lifespan (Figure 3-18).

Figure 3-18 | Nuclear power generation capacity by region [Reference Scenario]



In France known as the largest nuclear promoter in Europe, an energy transition law was enacted in July 2015 to reduce the nuclear share of electricity generation to 50% by 2025 (from 78% in 2015). In the face of electricity rate hikes and employment problems, however, France has released no plan to close reactors other than 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 under government plans. While outdated nuclear reactors are being decommissioned in OECD Europe, their moves to construct new reactors are also seen. Therefore, Europe's installed nuclear power generation capacity will fall to 115 GW temporarily between 2025 and 2035 and rise back later. Russia has vowed to proactively use nuclear at home and abroad. Its domestic installed nuclear power generation capacity in 2030 will expand about 15-fold from 26 GW in 2015 to 38 GW.

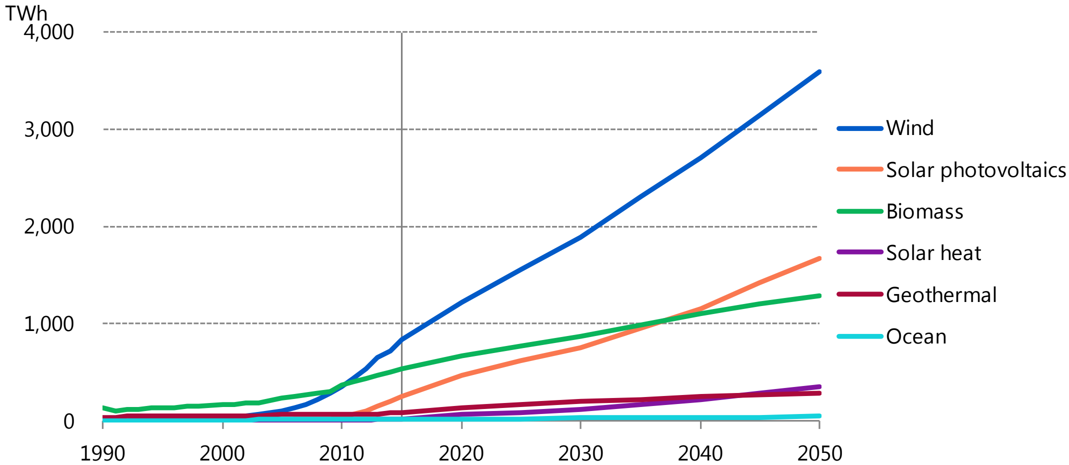
From 2030, Middle Eastern, African, Latin American and other countries, which have so far developed little nuclear power generation, will rise as nuclear power generators. The United Arab Emirates, Saudi Arabia and Iran will lead the Middle East to raise installed nuclear power generation capacity to 13 GW in 2030. South Africa and Brazil in Latin America have adopted the initiative in their respective regions to plan the introduction of nuclear power generation to meet domestic electricity demand growth and will steadily construct nuclear power plants.

The presence of Asia including China and India will increase more and more in nuclear power generation. China will boost its installed nuclear power generation capacity from 29 GW in 2015 to 106 GW in 2035, replacing the United States as the largest nuclear power generator in the world. Asian installed nuclear power generation capacity will reach 247 GW in 2050, surpassing the combined OECD Europe and North American capacity of 211 GW.

Renewables

Great expectations are placed on renewable energy. Renewable power generation capacity including solar PVs and wind power generators has posted smooth growth, while being affected by negative factors including the reduction of subsidies mainly in European developed countries and crude oil price plunges. Despite the growth, non-hydro renewable power generation, which is intermittent depending on natural conditions, falls short of becoming a baseload electricity source rivalling fossil resources on a global scale (Figure 3-19).

Figure 3-19 | Global renewable 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 renewables with energy systems through continuous research and development.

Europe, China and North America are major wind power generation markets at present and will drive wind power generation expansion. Meanwhile, India, Brazil, Mexico and other emerging economies will also expand their wind power generation capacity. Installed wind power generation capacity in the world will more than quadruple from 415 GW in 2015 to 1,865 GW in 2050 (Figure 3-20 and Figure 3-21).

Figure 3-20 | Global wind power generation capacity [Reference Scenario]

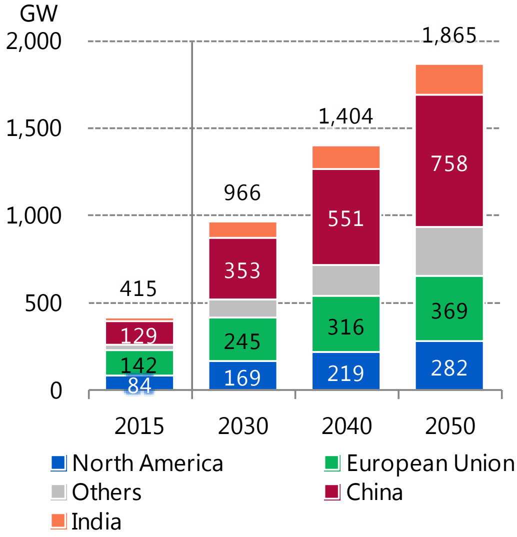
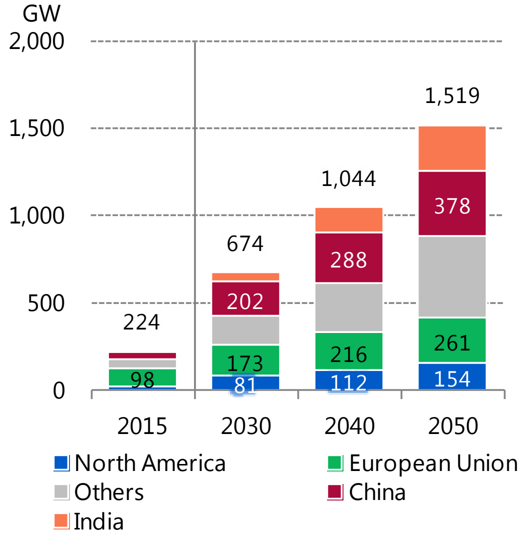


Figure 3-21 | Global solar PV power generation capacity [Reference Scenario]



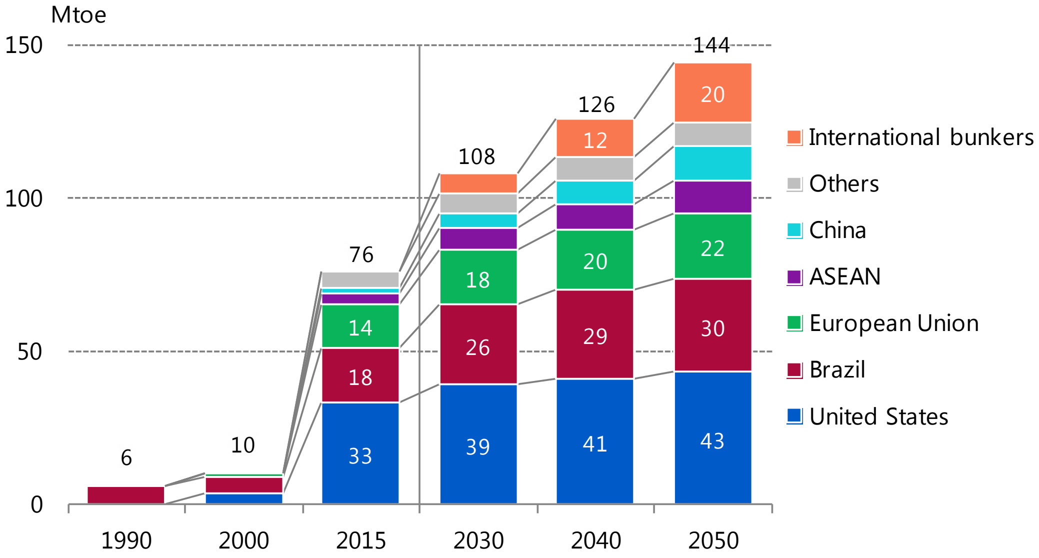
The global solar photovoltaics (PV) market will continue expanding as the Asia Pacific region including Japan, China and the United States replaces Europe as a market leader. For example, China and India have come up with ambitious solar PV power generation targets with high government targets and enhanced relevant incentives to 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 power generation will grow more competitive. In the Reference Scenario, installed solar PV power generation capacity in the world will expand some seven-fold from 224 GW in 2015 to 1,519 GW in 2050.

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 2015.

Global biofuel consumption will increase from 75 Mtoe in 2015 to 125 Mtoe in 2050 (Figure 3-22). 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 content. 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 growth will decelerate from 2030 as liquid fuel demand growth slows down 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. Bio jet fuel, which is used little at present, will begin to be used for international aviation in 2020 or later.

Figure 3-22 | Liquid biofuel consumption [Reference Scenario]



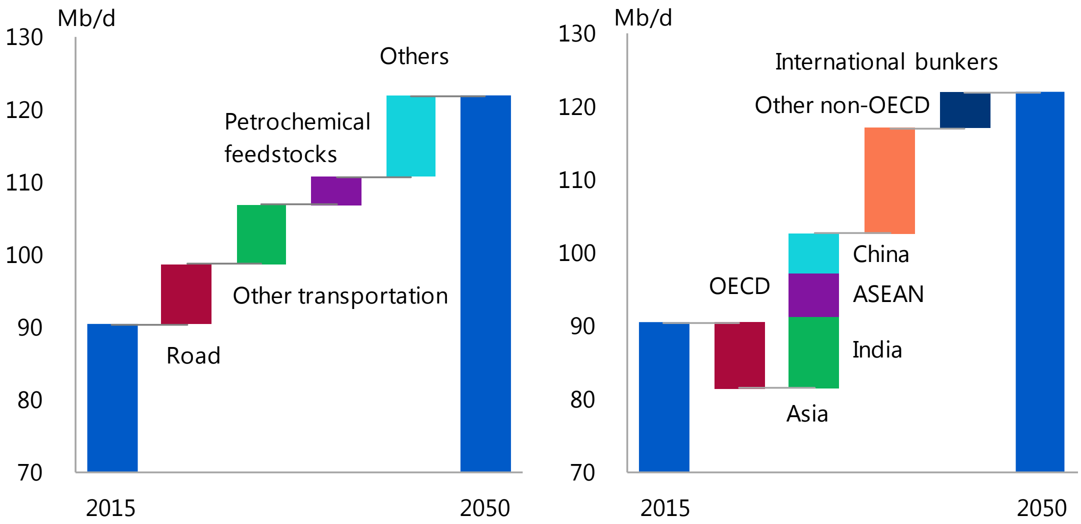
4. Peak Oil Demand Case

4.1 Peak oil theory

From peak supply to peak demand

In the Reference Scenario, oil demand will increase from 90.4 Mb/d in 2015 to 122.0 Mb/d in 2050. As part of the growth of 31.6 Mb/d, road transportation will account for 8.6 Mb/d, other transportation (such as, aviation and shipping) will account for 8.2 Mb/d and petrochemical feedstocks will account for 3.8 Mb/d. The three sectors will thus capture about 70% of the total growth. By region, oil demand will decrease by 9.0 Mb/d in OECD while increasing by 9.9 Mb/d in India, by 5.9 Mb/d in ASEAN and by 5.5 Mb/d in China. Asia will thus post a steep increase in oil demand.

Figure 4-1 | Global oil demand [Reference Scenario]



Primarily due to China's explosive robust demand, global oil demand grew at an annual average pace of 1.3 Mb/d during the period 2000-2007, and the peak oil theory (peak oil supply theory) began attracting people's attention[13]. The tight supply-demand balance, coupled with excessive liquidity in the global financial market, boost oil prices (the front-month WTI futures contract) to $147/bbl in July 2008. Later under the shale revolution, however, unconventional oil supply increased leading the peak oil supply theory to fade away and the "peak oil demand theory" emerged instead. According to the new theory, progress in energy efficiency and conservation combined with a shift to renewable energy

[13] The peak oil theory originally attracted attention as M. King Hubbert forecast that U.S. oil production would begin to decline by 1970 became reality. Peak oil theories in the early 2000s were assumed as accepted. In 2005, Colin Campbell, a peak oil theory advocate, forecast that conventional oil production would peak by 2010.

through the enhancement of climate change countermeasures will lead oil demand to peak before reaching the resource limitations.

However, as 57% of total oil demand is concentrated in transportation fuels (for road transportation, aviation, shipping, etc.) and 10% in petrochemical feedstocks, substitution with non-oil fuels or feedstocks in those sectors is difficult. A mainstream view is that while energy efficiency will make progress on policy enhancement and technological development, oil demand will continue to expand, as indicated in the Reference Scenario. For example, despite substantial improvements in vehicle fuel efficiency, the doubling of vehicle ownership to about 2.6 billion in 2050, will greatly contribute to growth in oil demand in the road transportation sector, as indicated in the Reference Scenario.

Moves to promote zero emission vehicles

Amid remarkable vehicle technology development in recent years, however, the penetration of electric vehicles or zero emission vehicles (ZEVs) is accelerating[14], although their market is still small. Furthermore, ZEV promotion policies, including a ban on conventional engine vehicles from 2030, have been announced one after another in various countries (Table 1-1). Factors behind the ZEV promotion include urban air pollution as well as climate change countermeasures.

Table 4-1 | Recent ZEV promotion policies (in order of announcement)

Country	Announced policy
California, United States	In ZEV regulations requiring ZEVs to account for a certain share of vehicle sales, ZEVs will be redefined as excluding HEVs and being limited to EVs, PHEVs and FCVs from 2018.
Netherlands	A bill was submitted to the parliament to ban gasoline and diesel vehicle sales from 2025 (April 2016).
Norway	The Norwegian parliament would set a target of increasing zero emission vehicles' share of vehicle sales to 100% by 2025 (June 2016).
China	A plan was announced to introduce new energy vehicle regulations to require automakers to raise EV, PHEV and FCV vehicles' share of total production to 8% by 2018 and by 2 percentage points annually later (September 2016).
Germany	The German Bundesrat (upper house) passed a resolution calling for banning new internal-combustion engine vehicle sales by 2030 (October 2016).
India	A policy was announced to limit new vehicle sales in India to electric vehicles by 2030 (June 2017).
France	The environment minister clarified a policy of banning domestic gasoline and diesel vehicle sales by 2040 (July 2017).
United Kingdom	The environment secretary officially announced a plan to ban gasoline and diesel vehicle sales from 2040 (July 2017).

[14] ZEVs in this outlook include electric vehicles (EVs), plug-in hybrid electric vehicle (PHEVs) and fuel cell vehicles (FCVs) while excluding hybrid electric vehicles (HEVs). As of 2015, ZEVs accounted for less than 1% of global vehicle sales.

Country	Announced policy
Indonesia	The energy and mineral resources minister announced a plan to ban new fossil fuel vehicle and motorcycle sales from 2040 (August 2017).
China	The vice minister of industry and information technology stated that a survey was launched on a ban on conventional vehicle sales (September 2017).

Sources: Various media reports, etc.

While European countries have taken the assumed initiative to ban conventional engine vehicle sales, we must pay special attention to similar moves in China and India as they will account for some 30% of the global vehicle sales market in 2040 (Figure 4-2). Reflecting such policy trend, automakers are moving to vehicle electrification particularly for the giant markets (Table 4-2).

Figure 4-2 | Vehicle sales [2040]

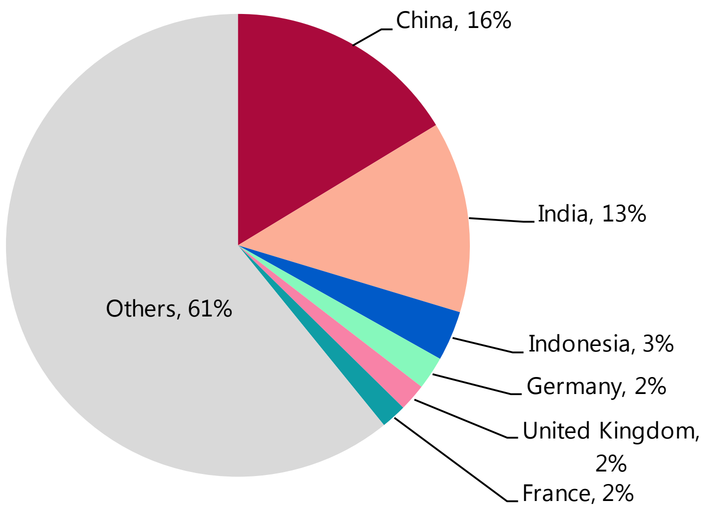


Table 4-2 | Major automakers' recent vehicle electrification strategies (in order of announcement)

Automaker	Announced strategy
Hyundai	Electric vehicles will be ready for all models by 2020 (12 HEV models, six PHEV models, two EV models and two FCV models) (May 2015).
Toyota	Toyota raised its annual FCV sales target to 30,000 units for 2020 (October 2015). Media reports said that Toyota would fully launch EVs in 2020 (November 2016).
PSA	PSA announced that seven PHEV and four EV models will be launched by 2021 (April 2016).
Daimler	Daimler announced a plan to launch 10 or more EV models and raise EVs' share of total sales to 15-25% by 2025 (September 2016).

Automaker	Announced strategy
Ford	Ford announced a plan to increase eco car (EV and HEV) sales to 70% of total sales in China by 2025 (April 2017).
Volkswagen	Volkswagen announced a plan to launch 30 or more EV models and increase EV sales to up to 3 million units or 25% of total sales by 2025 (June 2017).
Honda	Honda announced plans to electrify two-thirds of four-wheel vehicle sales by 2030, launch EVs in China in 2018 and introduce electric scooters (June 2017).
Volvo	Volvo announced a plan to adopt EVs, PHEVs or HEVs for all models to be launched in or after 2019 (July 2017).
BMW	BMW announced a plan to ready EV and PHEV models for all brands and increase sales of electrified models to 15-25% of total annual sales by 2025 (July 2017).
Jaguar Land Rover	Jaguar Land Rover announced a plan to sell only EVs, PHEVs and HEVs from 2020 (September 2017).
Renault/Nissan	The Renault-Nissan alliance announced a plan to launch 12 EV models and increase electrified vehicles' share of total sales to 30% by 2022 (September 2017).

Sources: Various media reports, etc.

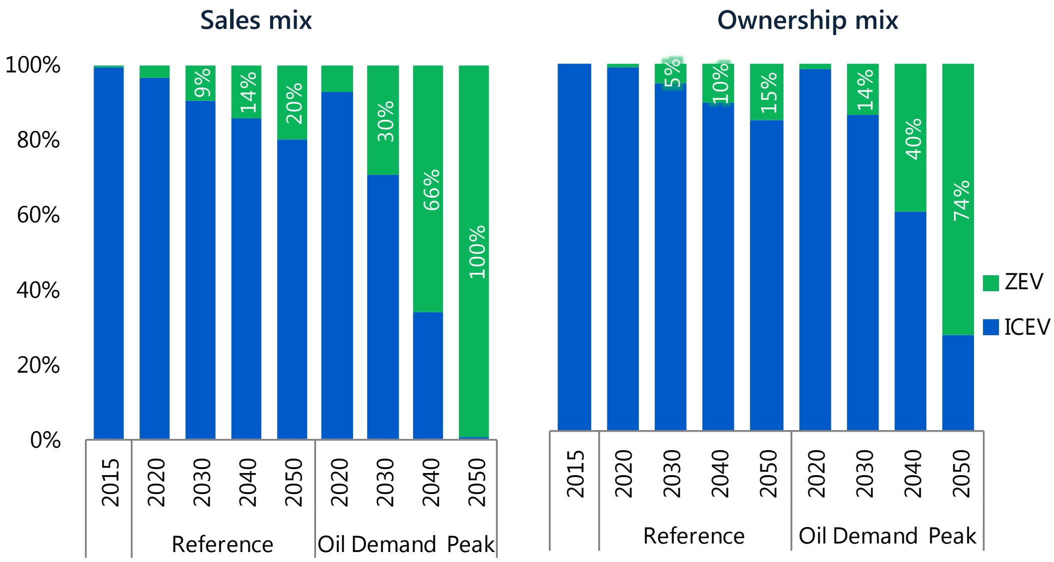
4.2 Peak Oil Demand Case

Oil demand

If the increase in vehicle ownership is progressively limited to ZEVs, oil demand in the road transportation sector will not increase. If existing gasoline and diesel vehicles are replaced with ZEVs, oil demand will decline. We assume in the virtual Peak Oil Demand Case that ZEVs will cover 30% of global vehicle sales in 2030 and 100% by 2050 (Figure 4-3). At such penetration pace, the EV30@30 campaign[15] target of the clean energy ministerial meeting covering major countries will be attained on a global scale. The case also represents an assumption that British, French and other plans to ban combustion-engine vehicle sales by 2040 will be introduced globally by 2050. Under the assumption, ZEVs' share of total vehicle ownership will increase to 14% in 2030 and to 74% in 2050.

[15] The campaign aims to increase share of EV, PHEV and FCV of new vehicles sales to 30% by 2030 in the countries participating in the clean energy ministerial meeting.

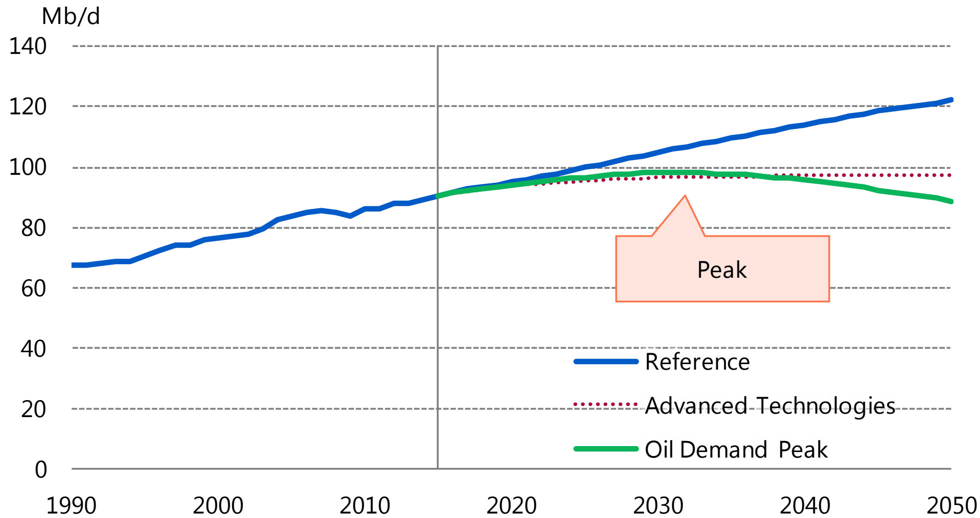
Figure 4-3 | Global vehicle sales and ownership mix



Note: ZEVs (zero emission vehicles): Electric vehicles, plug-in hybrid vehicles, fuel cell vehicles. ICEVs: Internal combustion engine vehicles (including hybrid vehicles)

In the Peak Oil Demand Case, oil demand from the road transportation sector will fall to about one-third of the present level by 2050. Total oil demand will increase from 90.4 Mb/d in 2015 to a peak of 98.2 Mb/d around 2030 before falling to 88.7 Mb/d below the 2015 level in 2050 (Figure 4-4). If the ZEV penetration is far greater than assumed in the Reference or Advanced Technologies Scenario, a peak oil demand may emerge.

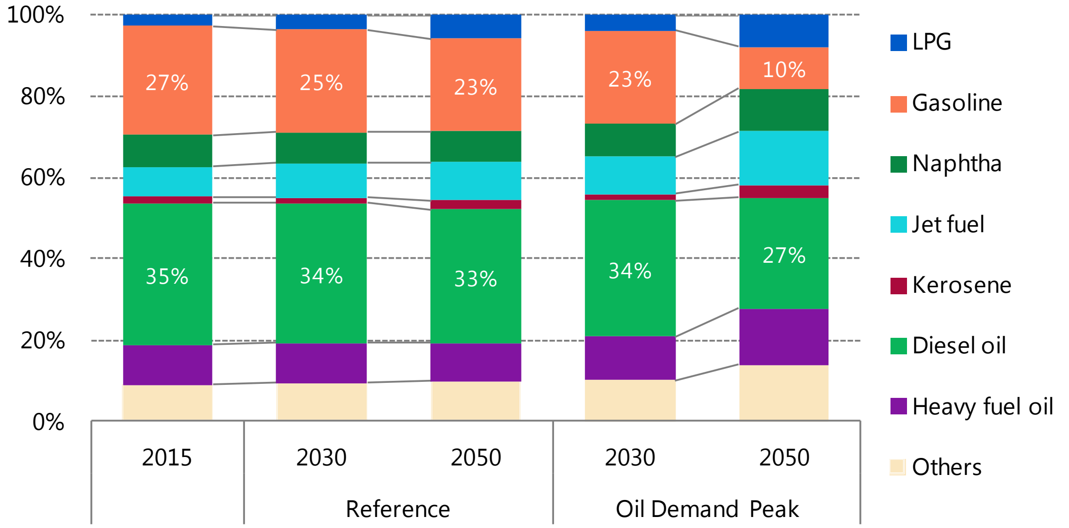
Figure 4-4 | Global oil demand



A shift to ZEVs will affect the petroleum product demand mix. Gasoline's share of petroleum product consumption will decline from a little less than 30% at present to only 10% in 2050

(Figure 4-5). Diesel oil's share, though being higher than the gasoline share thanks to industrial demand, will shrink by 8 percentage points to 27%. In the face of such changes, oil refiners will have to dramatically change production yields. Competitiveness depending on secondary refining equipment differences and gaps between heavy and light crude oil prices will also change.

Figure 4-5 | Global petroleum product consumption mix



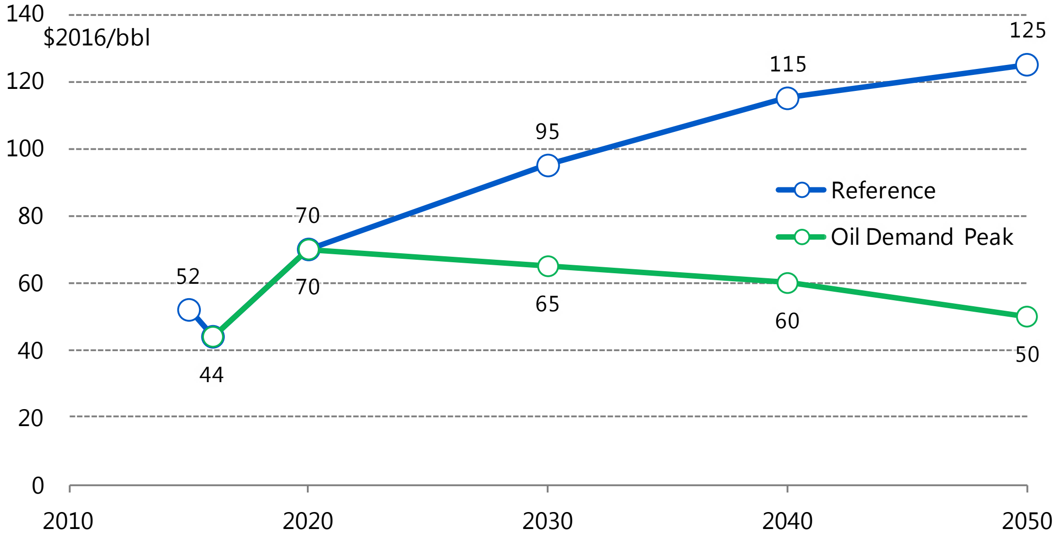
Note: excluding refiners' own consumption

It is worth noting that only a small number of countries have announced policies to ban conventional engine vehicles in or after 2030. Furthermore, how such policies would be implemented or whether they would be feasible is still uncertain. If such policies expand globally, however, it will exert great impacts on the oil industry and the international oil market.

Oil supply

If oil demand peaks around 2030 as mentioned above, international oil prices will decline due to the easing supply-demand balance. While the oil prices were to rise to $125/bbl (in 2016 prices) in 2050 in the Reference Scenario, they will turn down in or after the 2020s and fall to $50/bbl in 2050 in the Peak Oil Demand Case (Figure 4-6).

Figure 4-6 | Real oil prices



While total crude oil production would hit a ceiling around 2030 to meet the peak demand, situations would differ from region to region. Production in the Middle Eastern OPEC countries, though being less than in the Reference Scenario, will continue to increase (Figure 4-7, Table 4-3). In other oil producing countries, however, production will drop from 2030. This is mainly because Middle Eastern crude oil, including output from onshore oil fields, feature lower production costs and greater resistance to low oil prices than crude oil produced in other regions. Among higher production cost regions, the Americas have great potential in U.S. shale oil and Brazilian pre-salt oil and will see oil production failing to secure profitability under prolonged oil price weakness and declining substantially. As a result, OPEC's share of global oil production will rise from 42% in 2015 to 49% in 2040 and to 54% in 2050.

Figure 4-7 | Crude oil production

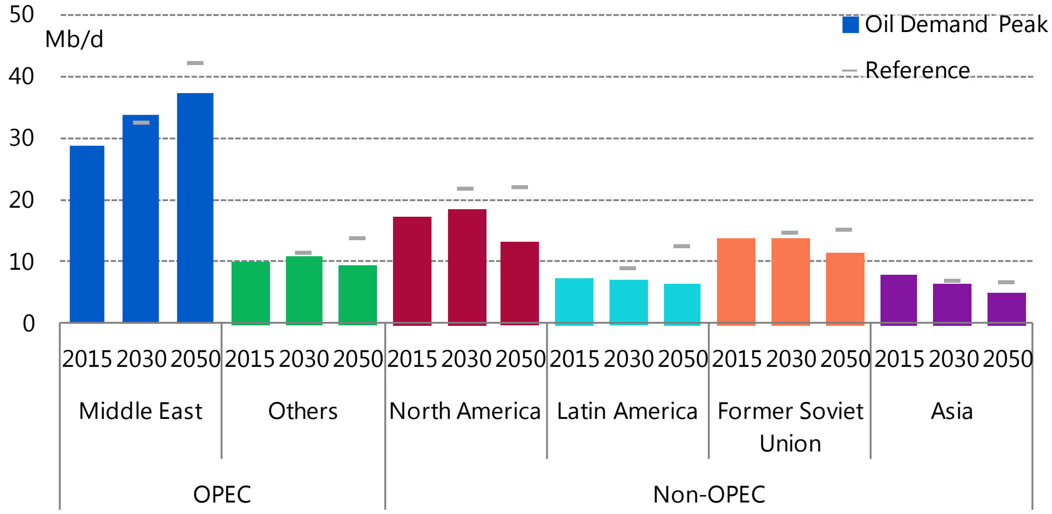


Table 4-3 | Crude oil supply [Peak Oil Demand Case]

(Mb/d)

	2015	2030	2040	2050	2015-2050 Changes	2015-2050 CAGR
Total	93.94	98.35	95.58	88.71	-5.24	-0.2%
OPEC	38.65	44.35	45.97	46.47	7.82	0.5%
Middle East	28.80	33.69	35.86	37.30	8.50	0.7%
Others	9.85	10.66	10.11	9.17	-0.68	-0.2%
Non-OPEC	53.05	51.39	46.95	39.65	-13.40	-0.8%
North America	17.15	18.36	16.53	12.99	-4.15	-0.8%
Latin America	7.16	6.95	6.89	6.23	-0.93	-0.4%
Europe and Eurasia	17.48	16.46	14.84	12.81	-4.67	-0.9%
Middle East	1.26	1.34	1.36	1.37	0.10	0.2%
Africa	1.63	1.39	1.20	0.96	-0.67	-1.5%
Asia and Oceania	8.37	6.90	6.12	5.29	-3.07	-1.3%
China	4.31	3.51	3.08	2.67	-1.64	-1.4%
Indonesia	0.84	0.73	0.62	0.52	-0.32	-1.4%
India	0.88	0.57	0.48	0.41	-0.46	-2.1%
Processing gains	2.24	2.61	2.66	2.58	0.34	0.4%

4.3 Implications of Peak Oil Demand Case

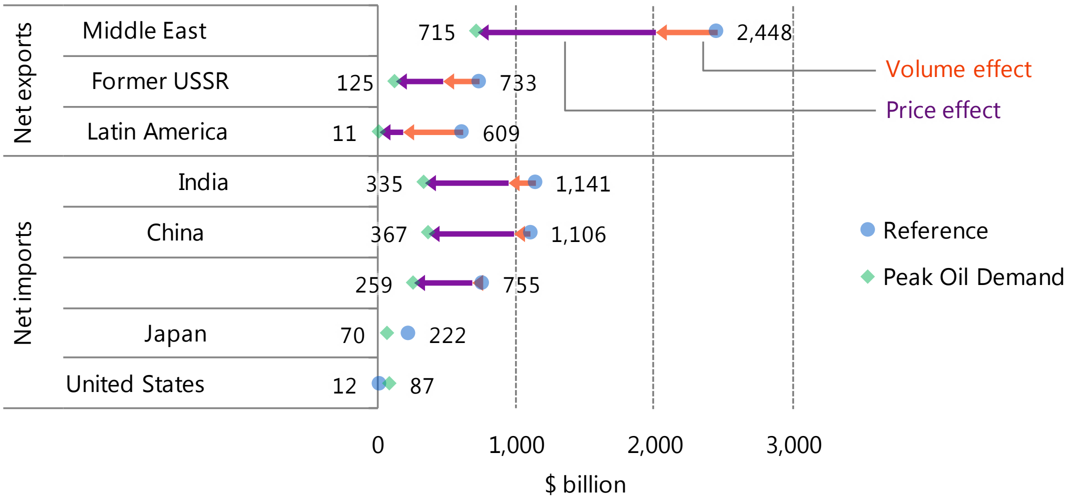
Low oil prices' effects on oil supply

While the substantial easing of the oil supply-demand balance is good news for oil importing countries, weak oil prices present risks in securing medium to long-term oil supply. According to the International Energy Agency, global oil and gas field development investment plunged by 50% from 2014 to 2016. Usually, a conventional oil field development project takes seven to 15 years to start production after an investment decision. The slack upstream development investment since 2015 could lead to oil supply shortages in the 2020s, risking destabilising oil supplies. If oil demand peaks out around 2030, the oil supply-demand balance may have fewer chances to tighten. If the upstream investment decline is substantial enough to lead production to fall short of meeting even a weaker demand, however, the stability of oil supplies would be at risks. Not only oil producing countries' efforts but also oil consuming countries' financial support will remain important for securing a stream of continuous upstream investment.

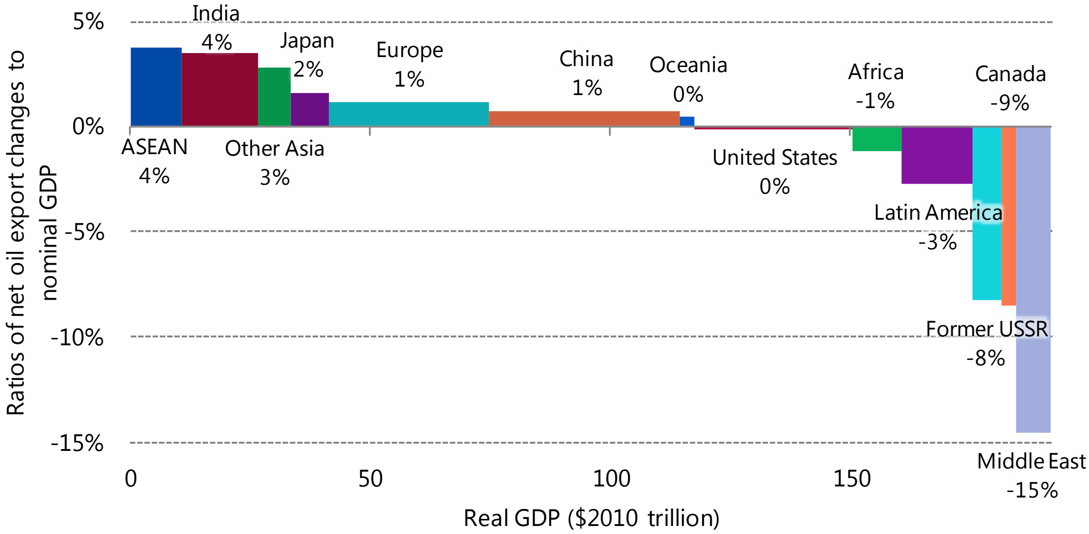
Economic effects

A drop in oil prices will reduce the production shares of high cost oil producing countries or regions, bringing about relative benefits to Middle East oil producing countries. Nevertheless, weak oil prices will exert downward pressures on Middle Eastern economies. The decline in the Middle East's net oil exports will reach $1.6 trillion, equivalent to 13% of those countries nominal GDP (Figure 4-8). Gaining most from net oil import drops will be India, which will become the world's second largest oil consumer while being poor in domestic resources. China, with the world's largest vehicle fleet, will be the next economy to benefit most. Such relative gains will be greater for oil consuming countries that feature less energy efficiency, larger oil share in their energy mix and greater dependence on oil imports. As the United States becomes self-sufficient in oil, economic effects on the country will be less than indicated by its massive oil consumption.

Figure 4-8 | Net oil imports or exports on selected countries and regions [Peak Oil Demand Case, 2050]



Ratios of net oil export changes to nominal GDP (compared with Reference Scenario)

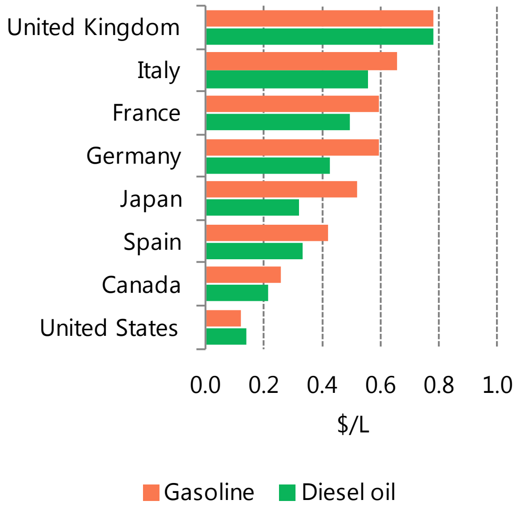


Note: Europe excludes the former Soviet Union.

Economic effects will influence not only international trade but also affect the financing of central and local government in developed countries. Most developed countries impose commodity tax on gasoline and diesel oil for vehicles (Figure 4-9). If vehicles are electrified rapidly, gasoline and diesel tax revenues in OECD countries will decrease remarkably from the present level estimated at about $370 billion to about $270 billion in 2030 and to about $80 billion in 2050 (Figure 4-10). Under the present system, electricity consumed by vehicles cannot be taxed separately from that of other uses. The tax revenue plunge and subsidies for

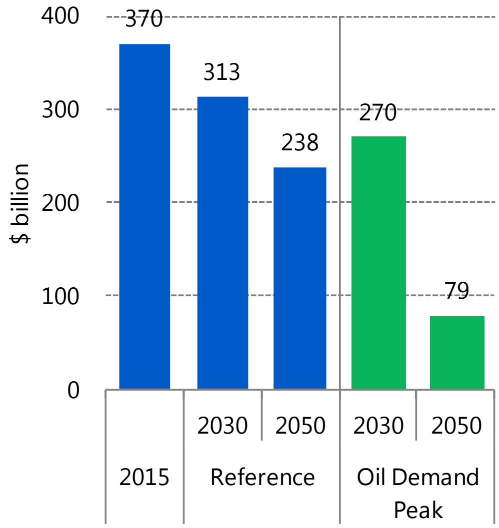
ZEV promotion could develop into major fiscal problems. On the other hand, developing countries would have more room to reduce fuel subsidies.

Figure 4-9 | OECD commodity tax rates on gasoline and diesel oil for vehicles [2016]



Sources: IEA "Monthly oil price statistics," IMF "International Financial Statistics"

Figure 4-10 | OECD revenues from commodity tax on gasoline and diesel oil for vehicles

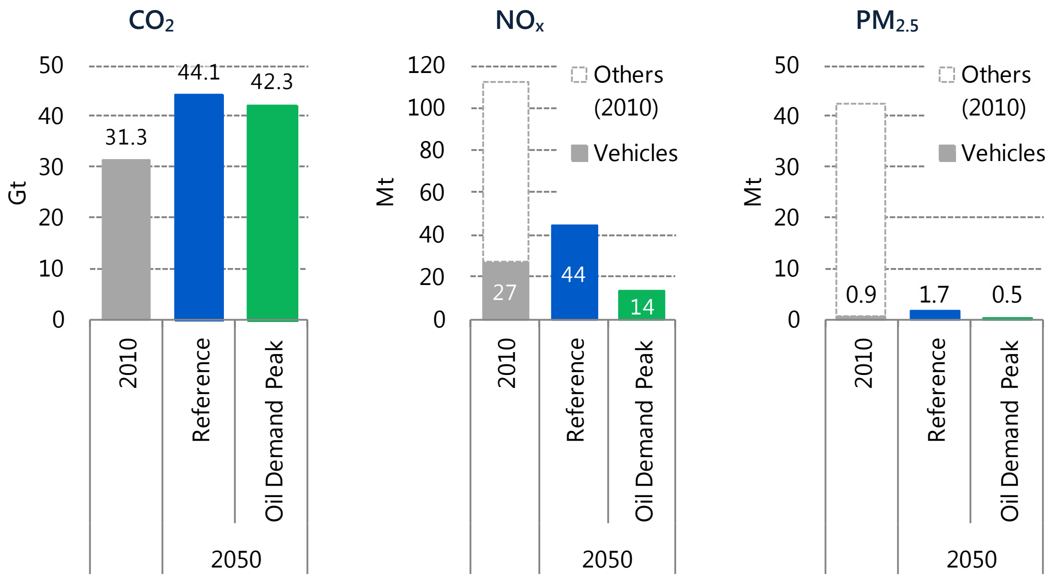


Environmental effects

CO_2 emissions in 2050 in the Peak Oil Demand Case will be 1.8 Gt less than in the Reference Scenario, falling by 5.9% from the 2010 level (Figure 4-11). Posting the largest CO_2 emission cuts will be New Zealand, Canada, South America and others that boast lower carbon intensity of electricity on the strength of rich hydro resources. In contrast, Iraqi CO_2 emissions will increase by 7%. Among air pollutant emissions that have driven countries to promote ZEVs, nitrogen oxide (NO_x) and fine particulate matters ($PM_{2.5}$) emissions in 2050 will be 30 Mt and 1.2 Mt less than in the Reference Scenario, declining by 27% and 3%, respectively, from 2010[16]. The decline does not include any effect of improvements in emission-reducing performance for conventional vehicles. As massive $PM_{2.5}$ emissions come from residential firewood, charcoal consumption and agricultural waste burning in developing countries, ZEVs' contribution to reducing $PM_{2.5}$ emissions will be limited. Nevertheless, ZEVs will make some contributions to urban air quality.

[16] Growing demand for electricity for ZEVs can lead to an increase in air pollutant emissions from power plants. However, emission prevention measures for power plants are easier to implement than for vehicles. Power plants must be appropriately controlled to prevent any increase in emissions.

Figure 4-11 | Global environmental pollutant emissions

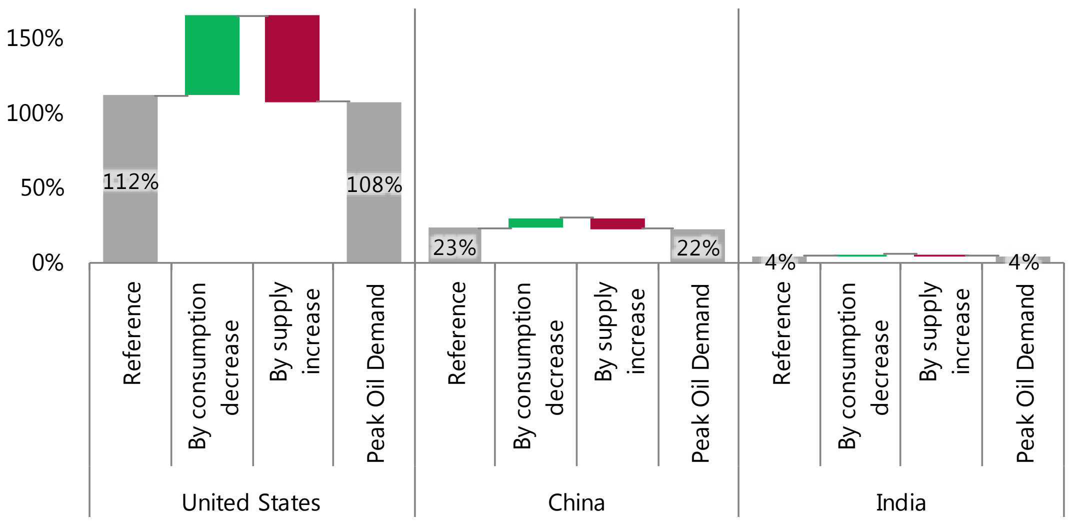


Note: CO_2 emissions represent total emissions. NO_x and $PM_{2.5}$ emissions represent those from vehicles and do not reflect effects of improvements in emission-reducing performance for conventional vehicles.

Impacts on energy security

Net oil importers' oil self-sufficiency rates in the Peak Oil Demand Case could be lower than in the Reference Scenario despite less consumption (Figure 4-12). This is because oil price declines could affect crude oil production in high cost oil producing countries, as noted above.

Figure 4-12 | Oil self-sufficiency rates in three largest oil consuming countries [2050]



Growing dependence on Middle Eastern crude oil may increase geopolitical risks involving the stability of oil supplies. As indicated by the Saudi Arabia-Iran confrontation, Qatar's severance of diplomatic ties with other Persian Gulf countries and the possible spread of terrorism amid the ongoing fall of the Islamic State terrorist group, the Middle Eastern situation remains fragile and is unlikely to stabilise in the immediate future. As Middle Eastern oil producing countries generally feature high macroeconomic dependence on oil exports, the Peak Oil Demand Case will be difficult for them to achieve any balanced budget. Public investment restrictions and subsidy cuts to lower budget deficits would be reasonable, but could add fuel to social instability and deteriorate the situation not only in oil producing countries but also in the entire Middle East. If oil demand peaks out, oil importing countries must enhance their support to the "Saudi Vision 2030" and other initiatives in oil producing countries.

Part II

Addressing global environmental problems

5. Advanced Technologies Scenario

5.1 Major measures

In the Advanced Technologies Scenario, maximum CO_2 emission reduction measures will be implemented after considerations of their application opportunities and acceptability to society. Each country will strongly implement aggressive energy conservation and decarbonisation policies contributing to enhancing climate change measures while securing stable energy supply and further 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 efficient equipment and the supply side will further promote renewables and nuclear (Figure 2-5).

Figure 5-1 | Assumptions for Advanced Technologies Scenario

Introducing and enhancing environmental regulations and national targets

Environment tax, emissions trading, RPS, subsidy, FIT, efficiency standards, automobile fuel efficiency standard, low carbon fuel standard, energy efficiency labeling, national targets, etc.

Promoting technology development and international technology cooperation

R&D investment expansion, international cooperation on energy efficient technology (steelmaking, cement and other areas), support for establishing energy efficiency standards, etc.

Demand side technologies

■ Industry

Under sectoral and other approaches, best available technologies on industrial processes (for steelmaking, cement, paper-pulp and oil refining) 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 technologies

■ Renewable energies

Wind power generation, photovoltaic power generation, CSP (concentrated solar power) generation, biomass-fired power generation and biofuel will penetrate further.

■ Nuclear

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

■ Highly efficient fossil fuel-fired power generation technologies

Coal-fired power plants (SC,USC, A-USC, IGCC) and natural gas–fired more advanced combined cycle (MACC) plants will penetrate further.

■ Technologies for next-generation transmission and distribution networks

Lower loss type of transformation and voltage regulator will penerate further

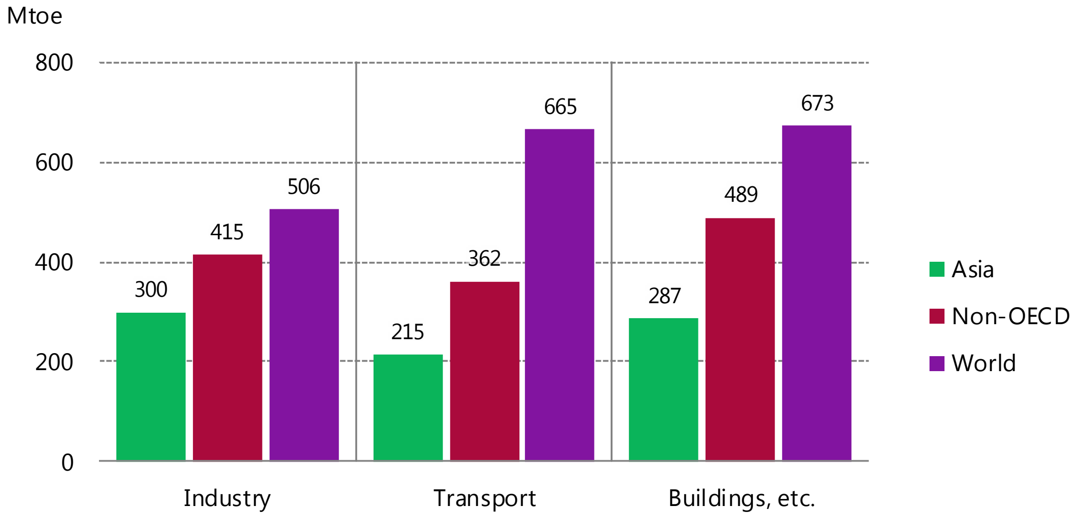
■ Carbon capture and storage

Note: SC stands for super critical power generation, USC for ultra-super critical power generation, and A-USC for advanced ultra-super critical power generation.

Energy efficiency

Final energy consumption in 2050 in the Advanced Technologies Scenario will be 1,844 Mtoe less than in the Reference Scenario. The energy savings amount to 20% of global final energy consumption. Of the energy savings, the buildings sector will account for 673 Mtoe, the transport sector for 665 Mtoe and the industry sector for 506 Mtoe (Figure 5-2). Non-OECD will capture more than 50% of energy savings in all sectors, including the industry sector where non-OECD will account for 82% of energy savings. Whether or not non-OECD would realise their potential energy conservation is key to global energy conservation progress. In the following, we explain the characteristics of energy conservation on a sector-by-sector basis in the Advanced Technologies Scenario.

Figure 5-2 | Energy saving from the Reference Scenario [Advanced Technologies Scenario, 2050]



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 2015. While non-OECD energy efficiency has been improving due to the introduction of new and efficient 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, each of these industries could improve their energy intensity in 2050 by some 12% from the Reference Scenario (Table 1-1). Through the energy intensity improvement, the non-OECD industry sector will reduce energy consumption by 415 Mtoe from the Reference Scenario. Asia, where the production of basic industrial materials (such as steel, aluminium, paper, petrochemical products and cement) command 59% of the energy savings. OECD's transfer of highly efficient technologies to non-OECD will make great contributions to improving energy efficiency. OECD is expected to implement energy conservation technology research programs and positive cooperation with developing countries.

In the transport sector, fuel efficiency and vehicle fleet mix improvements will make further progress. Hybrid vehicles and ZEVs, including electric, plug-in hybrid and fuel cell vehicles, will expand their share of vehicle sales in 2050 by 23 percentage points from the Reference Scenario. Thanks to the fuel efficiency and vehicle fleet mix improvements, the global average new vehicle fuel efficiency in 2050 will improve by 9.7 km/L from the Reference Scenario to 32.0 km/L (3.1 L/100 km). As ZEVs' share of the vehicle fleet mix in developed countries increases faster, the transport sector will post the largest energy savings among sectors in OECD. International bunkers will make progress in energy conservation through technological innovation and operational improvements. Given their great potential to switch fuels, natural gas will account for 25% of international marine bunkers and biofuels for 20% of international aviation bunkers.

The buildings sector differs from the industry sector which is highly conscious of energy conservation for economic reasons. So far, energy conservation incentives in the buildings sector failed to work smoothly. Therefore, both OECD and non-OECD have great potential to save energy consumption in the buildings sector. The overall global residential and commercial energy efficiency will improve by more than 20%. Energy efficiency improvements for space and water heating systems in cold regions and insulation improvements in non-OECD countries 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 for water and space heating will be greatly reduced. Given that electrification in the Advanced Technologies Scenario will make faster progress than in the Reference Scenario and that electricity is used for a wide range of equipment from air-conditioners to power sources and lamps, electricity conservation will account for more than half of the energy savings in the buildings sector.

Table 5-1 | Energy indicators

		2015	2050 Reference	2050 Advanced Technologies
Industry	Intensities (2015=100)			
	Steel	100	73.2	64.3
	Non-metallic minerals	100	80.6	71.2
	Chemical	100	75.6	66.5
	Paper and pulp	100	80.1	70.9
	Other industries	100	68.7	60.6
Transport	New passenger vehicle fuel efficiency (km/L)	13.6	22.3	32.0
	ZEVs' share of vehicle sales	0.5%	20%	43%
	Natural gas's share of international marine bunkers	0.0%	8.0%	25%
	Biofuel's share of international aviation bunkers	0.0%	5.0%	20%
Buildings	Overall energy efficiency (2015=100)			
	Residential	100	77.0	61.1
	Commercial	100	50.2	40.0
	Residential sector electrification rate	23%	32%	32%
	Commercial sector electrification rate	51%	56%	55%

Note: Energy intensity is energy consumption per production and overall energy efficiency is energy consumption per energy service.

Renewables

In the Advanced Technologies Scenario, renewables (including hydro) will increase their share of primary energy consumption from 14% in 2015 to 22% in 2050, 6 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 together with concentrated solar and marine power generation will rise from 0.9% in 2015 to 5.8% in 2050.

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 either already developed or under development. Offshore wind power generation will expand mainly in Europe as construction, operation and management, and grid connection costs will be further reduced (Figure 5-3). Global installed wind power generation capacity in 2050 in the Advanced Technologies Scenario will reach 3,002 GW, about 1.6 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 (Figure 5-4). 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 2050 will be 2,497 GW, 1.6 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's 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 and information technologies.

Figure 5-3 | Global installed wind power generation capacity [Advanced Technologies Scenario]

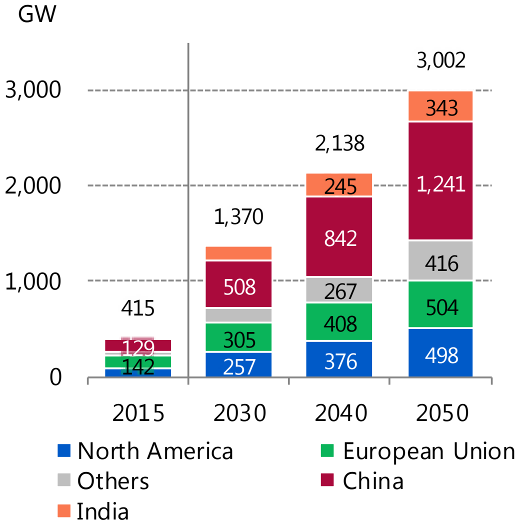
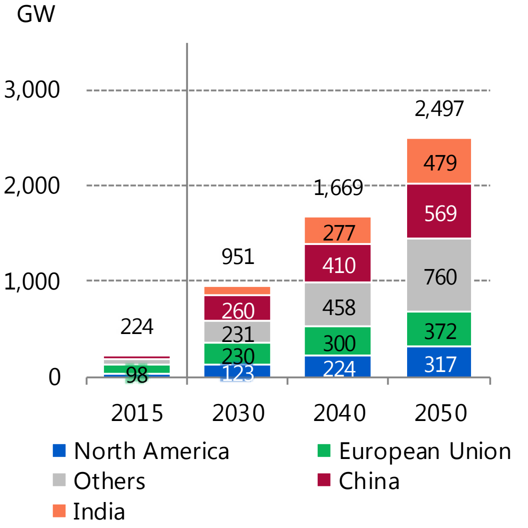


Figure 5-4 | Global installed solar PV power generation capacity [Advanced Technologies Scenario]



Nuclear

Great expectations are placed on the introduction of nuclear power generation as a decarbonisation measure. Emerging economies 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 will maintain their capacity at the 2015 level while the United Kingdom and Russia will build new nuclear power plants to increase their capacity. Switzerland and Belgium clarified their nuclear phase-out policy in response to the Fukushima nuclear power station accident but could change that policy to put off their nuclear power plant shutdown and replace decommissioned capacity to promote decarbonisation and maintain their industrial competitiveness.

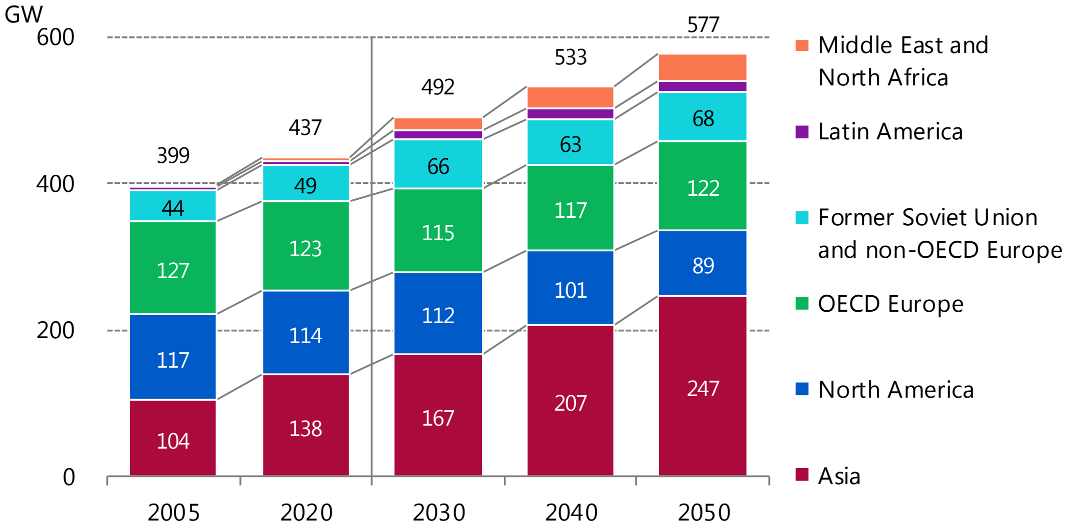
In the Advanced Technologies Scenario, nuclear's share of primary energy consumption will rise from 4.9% in 2015 to 10.2% in 2050, 4.9 percentage points higher than in the Reference Scenario. Installed nuclear power generation capacity will increase from 399 GW in 2015 to 956 GW in 2050 (Figure 5-5), some 1.7 times as much as the 577 GW anticipated in the Reference Scenario.

North America will expand installed nuclear power generation capacity to 125 GW in 2050 due primarily to an increase in the United States. The United States will reduce its capacity to 95 GW in 2035 by shutting down some of the existing capacity while seeking capacity construction projects that were stalled under slack electricity demand and cheap natural gas prices. Given that the United States is considering extending the service life of nuclear power plants to 80 years and is expected to build new nuclear power plants to counter fuel price fluctuation risks accompanying natural gas expansion and climate change, U.S. installed nuclear power generation capacity will expand to 114 GW in 2050.

OECD Europe will decommission outdated reactors and construct replacements, eventually increasing installed nuclear power generation capacity in 2050 to 146 GW from 127 GW in 2015. In the United Kingdom, for example, installed capacity will increase to 15 GW in 2050 as new plants are built, with some outdated reactors being decommissioned. Russia will accelerate the construction of new nuclear power plants, sharply expanding installed nuclear power generation capacity from 26 GW in 2015 to 40 GW in 2050. East Europe will steadily implement their nuclear introduction.

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 238 GW) in 2030 and reach 508 GW in 2050. China will boost its capacity beyond the U.S. level of 101 GW and replace the United States as the world's largest nuclear power generator in 2025. Later, China's capacity will increase to 150 GW in 2030 and to 300 GW in 2050. India, with installed nuclear power generation capacity limited to 6 GW in 2015, has put forward a proactive nuclear power generation capacity expansion target and will boost its capacity to 45 GW in 2030 and 90 GW in 2050. 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 38 GW in 2050.

Figure 5-5 | Installed nuclear power generation capacity



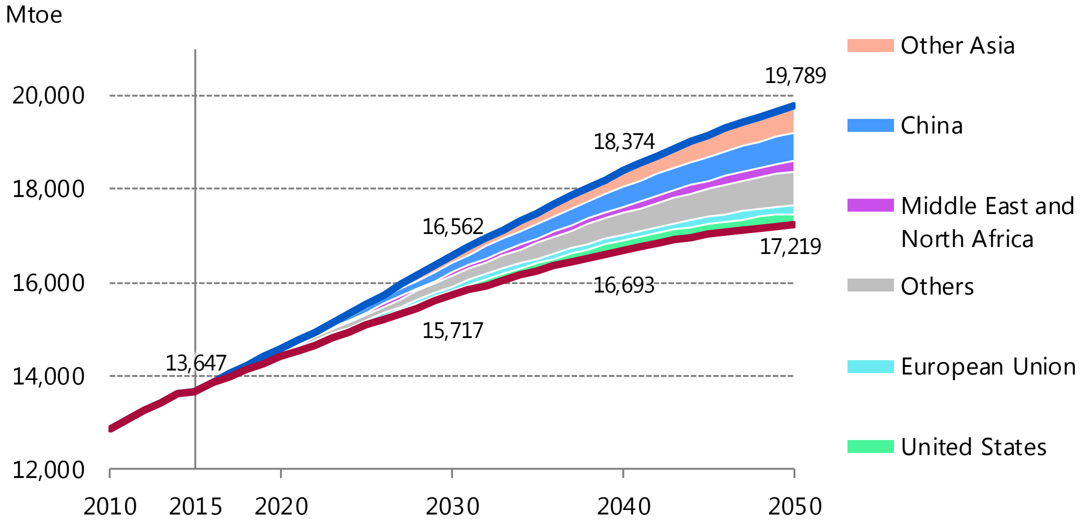
5.2 Energy supply and demand

Primary energy consumption

The strong implementation of the abovementioned energy conservation and climate change measures will substantially reduce primary energy consumption (Figure 5-6). Primary energy consumption in 2050 in the Advanced Technologies Scenario will total 17,219 Mtoe, down 2,570 Mtoe from the Reference Scenario. The gap corresponds to some 20% of global primary energy consumption in 2015. Accumulated energy savings through 2050 will total about 40 Gtoe, three times as much as global primary energy consumption in 2015.

In transition to the Advanced Technologies Scenario, non-OECD and Asia, projected to expand energy demand while offering great energy conservation potential, will play a great role. Non-OECD will account for 73% of global energy conservation in 2050 and Asia for 46%. Non-OECD and Asia hold the key to reforming the broadly defined global energy system and influencing the global environment. They can change the patterns of consumption and production for energy required by the world.

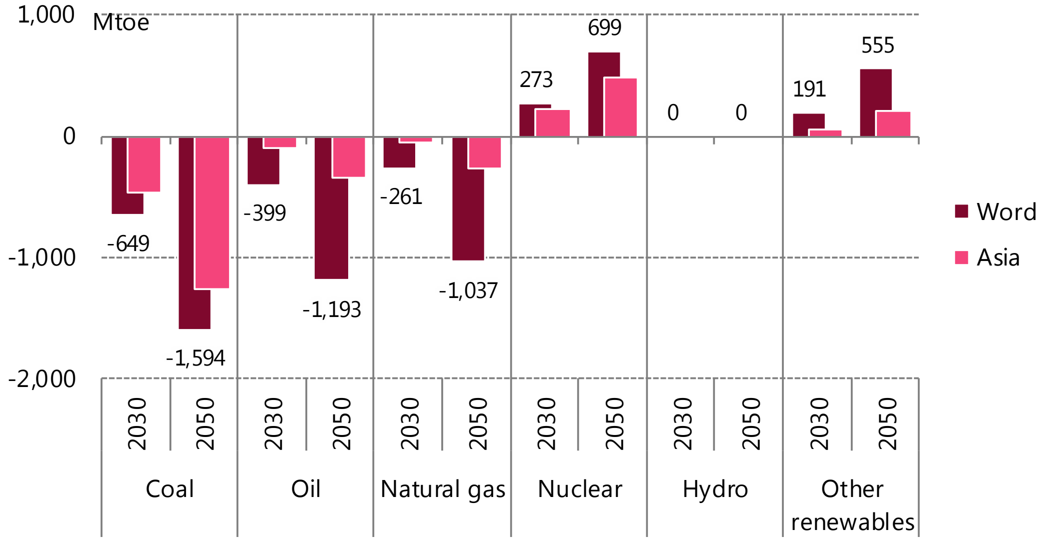
Figure 5-6 | Global primary energy consumption and savings by region



Among energy sources, fossil fuels will post great primary energy consumption savings (Figure 5-7). Of the 2,570 Mtoe decline in primary energy consumption from the Reference Scenario in 2050, coal will account for 1,594 Mtoe, oil for 1,193 Mtoe and natural gas for 1,037 Mtoe. Meanwhile, nuclear and renewable energy will accelerate their spread. Nuclear consumption in the Advanced Technologies Scenario will be 699 Mtoe (including 477 Mtoe in Asia) more than in the Reference Scenario. Renewables excluding hydro consumption will be 555 Mtoe (including 205 Mtoe in Asia) more. As a result, fossil fuels' share of primary energy consumption in the Advanced Technologies Scenario will fall from 82% in 2015 to 68% in 2050.

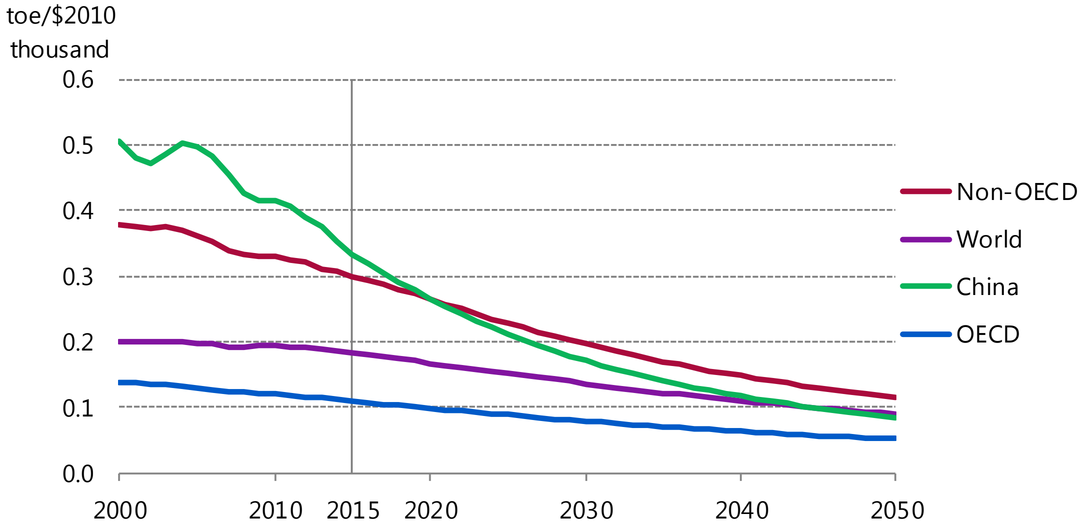
Asia, including China and India, will account for 49% of the fossil fuel consumption savings, and Asia will capture as much as 79% of the coal consumption savings. Asia will also account for more than 50% of nuclear consumption growth, while its share of renewable energy consumption growth will be limited to 37%.

Figure 5-7 | Global primary energy consumption changes from the Reference Scenario [Advanced Technologies Scenario]



The world's GDP energy intensity, or primary energy consumption per unit of GDP, an indicator of macro energy efficiency, will plunge by 51% from 2015 to 2050. OECD will post a moderate decline of 53% against 61% for non-OECD, which have greater potential to improve energy efficiency and will narrow the gap with OECD. 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 around 2020, and catch up with the global average (Figure 5-8). Asia's GDP energy intensity will drop by 59% by 2050.

Figure 5-8 | GDP energy intensity [Advanced Technologies Scenario]



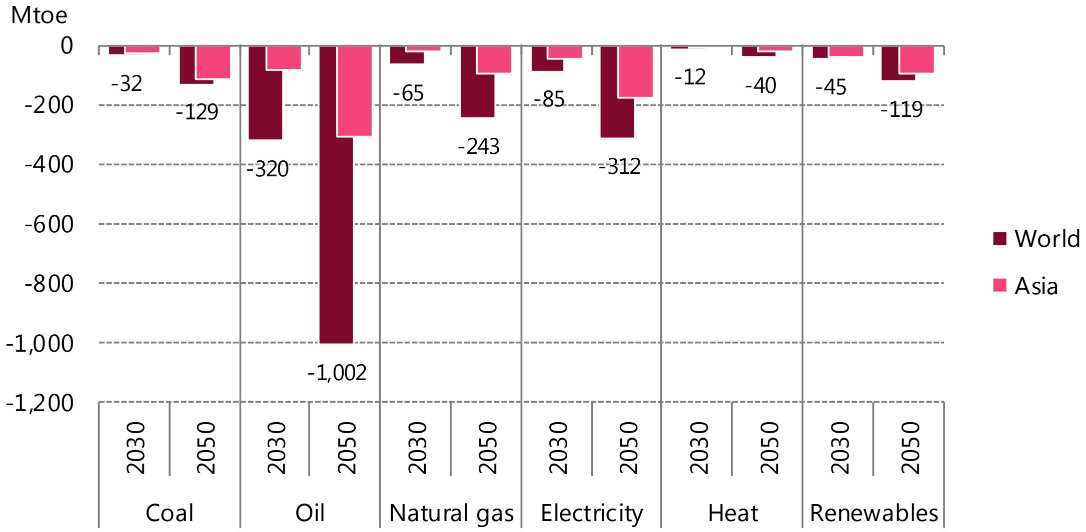
Asia will play a very important role in realising the global energy system depicted in the Advanced Technologies Scenario. Asia must eliminate energy conservation barriers including the lack of fundraising capacity and consciousness that blocks the penetration of technologies.

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. 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 2050 will decrease by 1,844 Mtoe, of which oil will account for 1,002 Mtoe or 54% (Figure 5-9).

Figure 5-9 | Final energy consumption changes from the Reference Scenario [Advanced Technologies Scenario]



Energy conservation progress mainly in the transport sector will make great contributions to oil consumption savings. In the Advanced Technologies Scenario, oil's share of energy consumption in the road transportation sector will decline from 94% in 2015 to 77% in 2050 (Figure 5-10). As ZEVs spread, non-oil energy sources' share of energy consumption in the road transportation sector will reach 23% in 2050. From the Reference Scenario, electricity will post the largest increase in the sector's energy consumption (Figure 5-11). In the Advanced Technologies Scenario, information technologies for traffic demand management including traffic congestion mitigation and distribution efficiency improvement will diffuse faster along with electric vehicles.

Figure 5-10 | Road transportation sector energy consumption mix in world

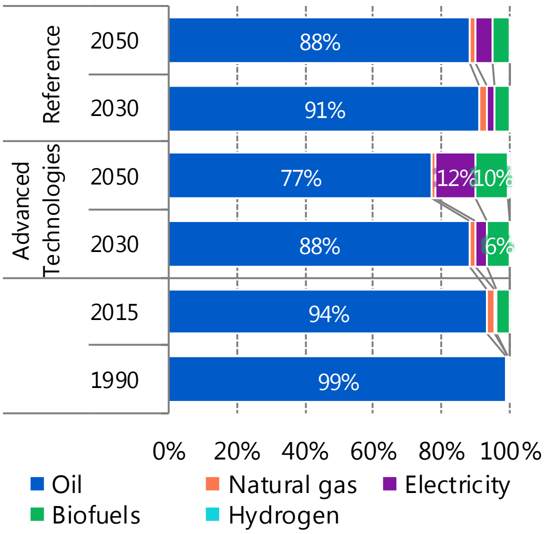
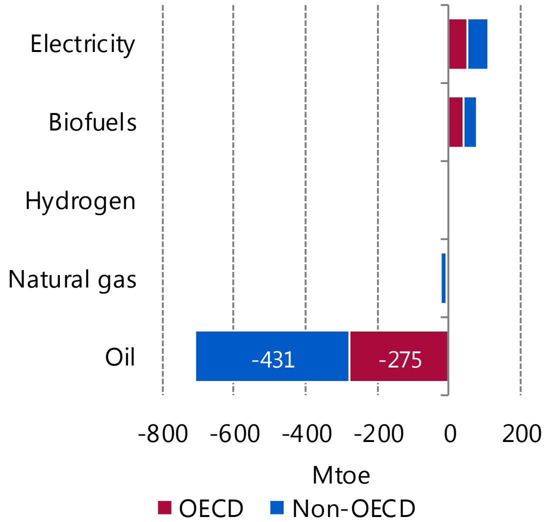
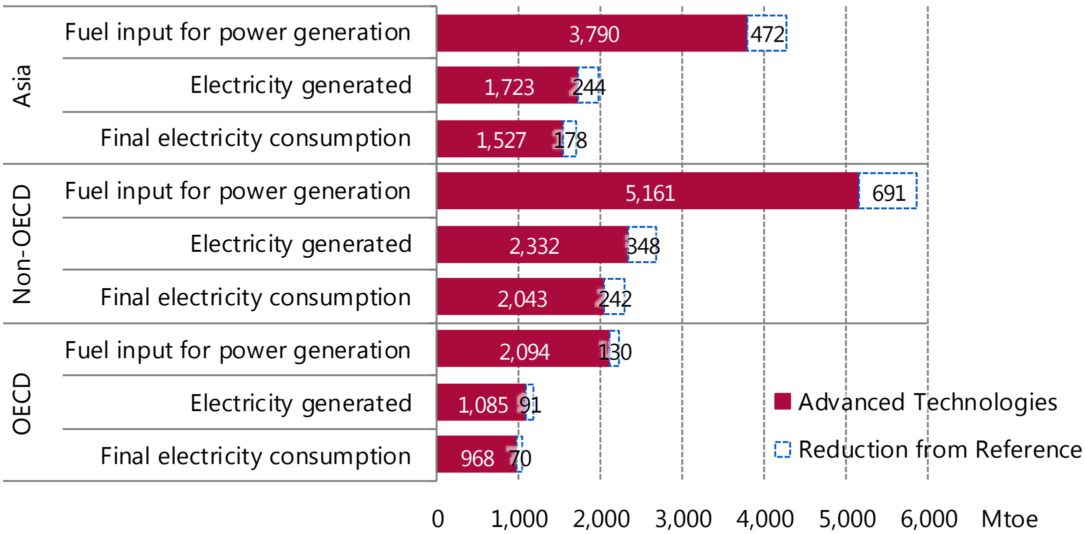


Figure 5-11 | Road transportation sector energy consumption changes from the Reference Scenario [Advanced Technologies Scenario, 2050]



Final electricity consumption will be reduced by 312 Mtoe, lowering required power generation by 439 Mtoe. The electricity savings will be coupled with power generation efficiency improvement to save primary energy consumption by 822 Mtoe (Figure 5-12). The savings are equivalent to 32% of total primary energy consumption savings.

Figure 5-12 | Primary energy consumption reduction through final electricity consumption savings [Advanced Technologies Scenario in 2050]



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 2050.

Developed countries should cooperate with emerging countries in improving power generation efficiency globally. Emerging economies frequently give top priority to high economic growth while failing to equally consider environmental concerns. For example, there are hesitations to address air pollution from fossil fuel-fired power generation, as such efforts are likely to reduce economic efficiency. Therefore, it will become more important that developed countries take advantage of their past overcoming of environmental problems to cooperate with emerging economies.

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.

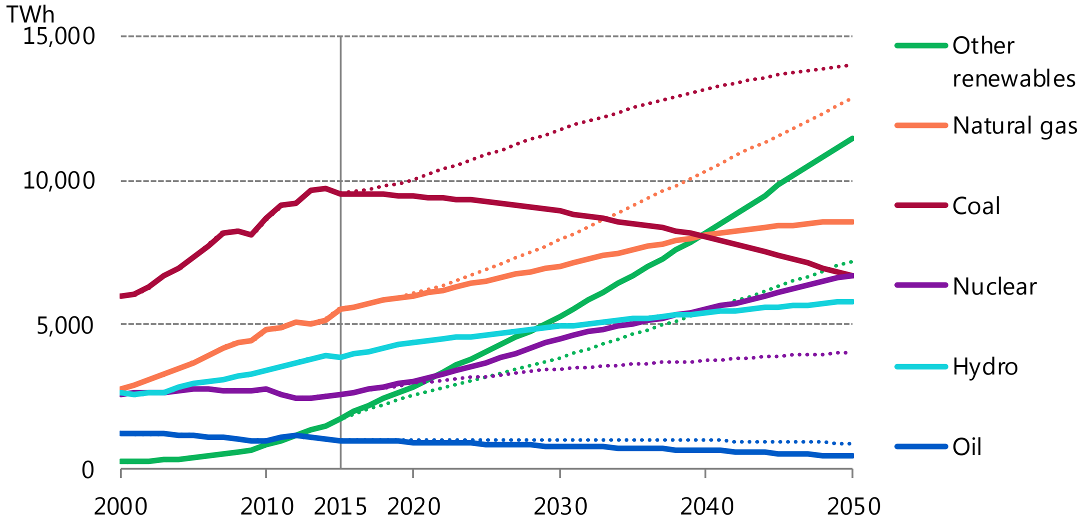
Asia will account for 85% of global coal consumption reduction totaling 129 Mtoe in 2050. In this respect, steelmakers' energy conservation will be important in India and other countries where crude steel production will expand rapidly. Japan's energy consumption per unit of steel production is one of 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 5,105 TWh, equivalent to combined present generation in the United States and Japan. The integrated gasification combined cycle (IGCC) for coal power generation and the development of technology for mixing coal with biomass energy will contribute to cutting coal consumption for power generation substantially. In contrast to coal, non-hydro renewables including solar PV, wind and biomass will become the largest electricity source and nuclear power generation will increase its presence (Figure 5-13).

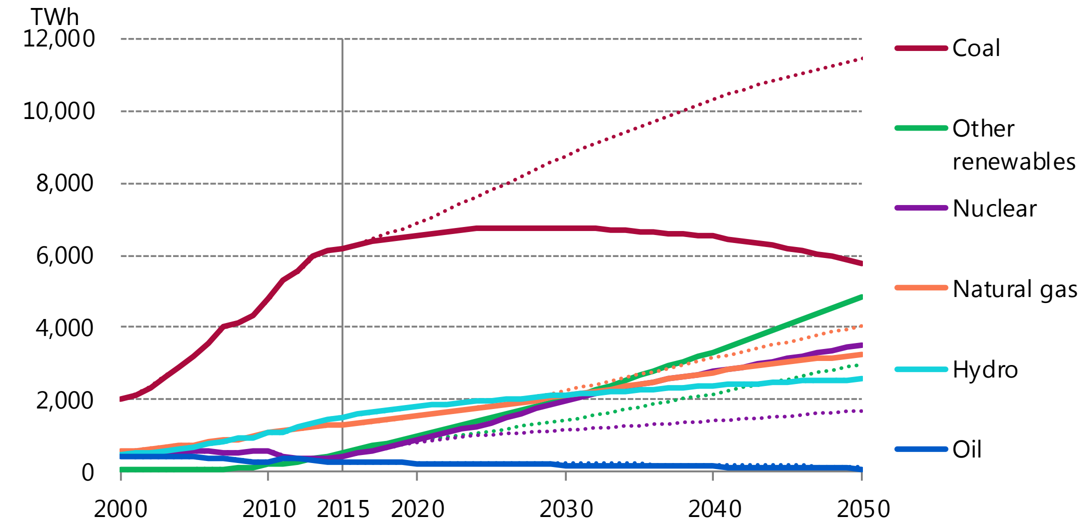
In Asia as well, coal-fired power generation will be reduced substantially. Nevertheless, coal's share of power generation in 2050 in Asia will still be larger than in any other region (Figure 5-14). China and other Asian countries have promoted the introduction of renewable energy technology as it is important for them to reduce coal consumption while expanding renewable energy generation.

Figure 5-13 | Global power generation mix [Advanced Technologies Scenario]



Note: Dashed lines represent the Reference Scenario.

Figure 5-14 | Asian power generation mix [Advanced Technologies Scenario]



Note: Dashed lines represent the Reference Scenario.

Crude oil supply

Table 5-2 shows crude oil supply in the Advanced Technologies Scenario. Demand in 2030 and 2050 will be 8% and 20% less than in the Reference Scenario, respectively. In line with demand growth's substantial deceleration, production in each country will decline. However, Asian and other net oil importers will limit their own production cuts from the viewpoint of supply security, posting higher oil self-sufficiency rates than in the Reference Scenario.

Table 5-2 | Crude oil supply [Advanced Technologies Scenario]

(Mb/d)

	2015	2030	2040	2050	2015-2050	
					Changes	CAGR
Total	93.94	96.60	97.27	97.28	3.34	0.1%
OPEC	38.65	40.03	42.56	44.01	5.36	0.4%
Middle East	28.80	29.70	31.99	33.26	4.46	0.4%
Others	9.85	10.33	10.58	10.76	0.91	0.3%
Non-OPEC	53.05	54.00	52.00	50.43	-2.62	-0.1%
North America	17.15	19.86	18.53	17.31	0.16	0.0%
Latin America	7.16	8.13	9.34	10.16	3.00	1.0%
Europe and Eurasia	17.48	16.02	14.66	13.68	-3.80	-0.7%
Middle East	1.26	1.33	1.34	1.38	0.11	0.2%
Africa	1.63	1.69	1.68	1.72	0.09	0.2%
Asia and Oceania	8.37	6.98	6.46	6.18	-2.19	-0.9%
China	4.31	3.55	3.27	3.15	-1.16	-0.9%
Indonesia	0.84	0.74	0.66	0.62	-0.22	-0.9%
India	0.88	0.59	0.51	0.49	-0.39	-1.7%
Processing gains	2.24	2.56	2.71	2.83	0.59	0.7%

Natural gas supply

As progress in energy utilisation technologies, including energy conservation technologies, suppresses natural gas consumption in the Advanced Technologies Scenario, natural gas production will be 7% less than in the Reference Scenario in 2030 and 20% less in 2050 (Table 5-3).

As natural gas is the cleanest among fossil fuels, its production fall will be slower than a coal or oil production drop. A wide gap between the Reference and Advanced Technologies Scenarios will be seen in OECD Europe where natural gas development costs are relatively higher. The region's natural gas production in 2050 in the Advanced Technologies Scenario will be 42% less than in the Reference Scenario. In contrast, North America will post the smallest fall of 12% from the Reference Scenario in 2050.

Table 5-3 | Natural gas production [Advanced Technologies Scenario]

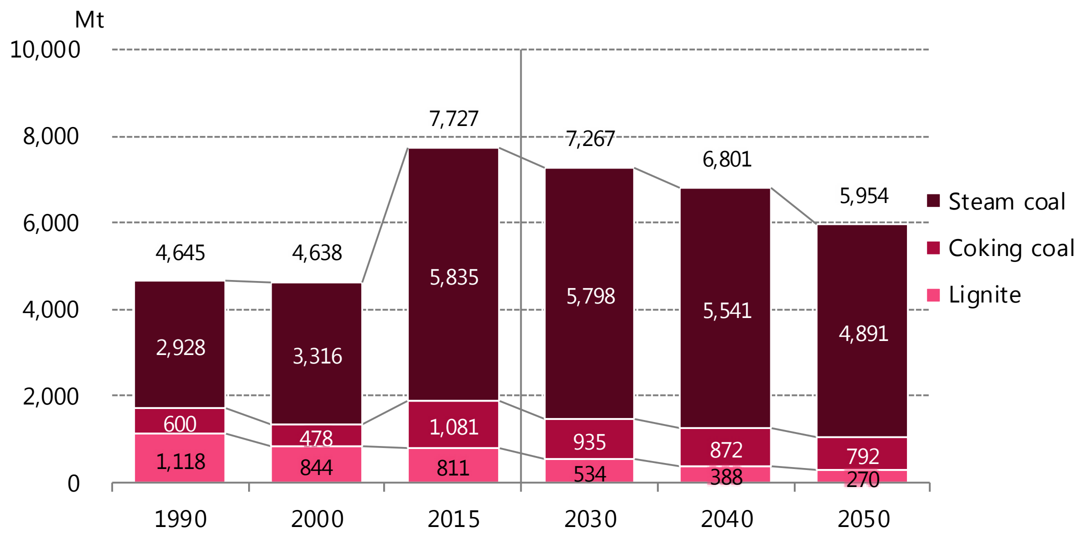
(Bcm)

	2015	2030	2040	2050	2015-2050	
					Changes	CAGR
World	3,493	4,352	4,825	5,039	1,546	1.1%
North America	915	1,155	1,230	1,332	417	1.1%
Latin America	205	242	312	331	126	1.4%
OECD Europe	248	190	162	110	-138	-2.3%
Non-OECD Europe/Central Asia	792	937	1,011	1,040	248	0.8%
Russia	595	701	752	768	173	0.7%
Middle East	595	745	832	869	274	1.1%
Africa	206	283	344	353	148	1.6%
Asia	467	638	764	817	350	1.6%
China	131	260	328	356	226	2.9%
India	32	60	95	114	82	3.7%
ASEAN	215	230	254	265	50	0.6%
Oceania	65	163	171	188	123	3.1%

Coal supply

In the Advanced Technologies Scenario, coal demand will decline due to improvement in coal utilisation efficiency and a fall in coal's share of the power generation mix. Consequently, coal production will decrease from 7,935 Mt in 2015 to 5,954 Mt in 2050 (Figure 5-15).

Figure 5-15 | Coal production [Advanced Technologies Scenario]



Steam coal production will decline from 5,835 Mt in 2015 to 4,891 Mt in 2050, coking coal production from 1,081 Mt to 792 Mt and lignite production from 811 Mt to 270 Mt. From the Reference Scenario, coal production in 2050 will decrease by 3,329 Mt including 2,818 Mt for steam coal, 212 Mt for coking coal and 299 Mt for lignite. Coal production will decline substantially in North America, OECD Europe and China where demand will plunge (Table 5-4). Meanwhile, coal production will increase in line with demand growth in India and

Indonesia. As coal international trade decreases due to a global demand drop, coal exporting countries' production will level off or decline depending on regional conditions.

Coal's role in Asia and efficient coal utilisation

In the Reference Scenario, coal-fired power generation will increase mainly in Asia including China and India, with coal accounting for 50% of Asia's total power generation in 2050. In the Advanced Technologies Scenario, coal-fired power generation will decline substantially due to a power demand fall amid energy conservation progress and fuel switching, with the share falling to 29%. India and ASEAN, where power demand will increase, will proceed with coal-fired power plant construction in consideration of energy security and cheap coal prices and expand coal-fired power generation from 2015 even in the Advanced Technologies Scenario.

Energy conditions in Asia differ from those in Western Europe where coal phaseout moves are invigorated. As countries must pursue power generation mixes meeting their respective conditions, coal will play some role in stable energy supply.

As a matter of course, each country must give considerations to coal consumption's environmental effects (including air pollution and climate change). In this respect, clean coal technologies will grow more important. Desulfurisation, denitrification, dust collection and other technologies to counter air pollution have been established and will have to be used for new and existing coal-fired power plants.

To counter climate change, meanwhile, highly efficient coal-fired power generation technologies are being developed and introduced to cut CO_2 emissions as much as possible. Super critical (SC) and ultra-super critical (USC) coal-fired power plants have been commercialised, with integrated gasification combined cycle (IGCC) plants left for future commercialisation. Advanced ultra-super critical (A-USC), integrated coal gasification fuel cell combined cycle (IGFC) and other more efficient coal-fired power plants are left for future development commercialisation.

SC coal-fired power plants can reduce CO_2 emissions per kWh to 90% of the level for subcritical coal-fired power plants, USC plants to 86% and IGCC plants to 79%. However, SC plants cost 1.2-fold more than subcritical plants, USC plants 1.3-fold more and IGCC plants 1.5-fold more.

Highly efficient coal-fired power plants will be able to recover higher initial investment over a long term as greater efficiency reduces fuel costs. Nevertheless, higher initial investment may impede the introduction of highly efficient plants. While European and U.S. financial institutions and investors are moving to discontinue investment and loans for coal-fired power plants, financing will grow more important for countries where coal-fired power generation will be required.

Table 5-4 | Coal production [Advanced Technologies Scenario]

Steam coal (Mt)

	2015	2030	2040	2050	2015-2050 Changes	2015-2050 CAGR
World	5,835	5,798	5,541	4,891	-943	-0.5%
North America	718	394	255	133	-585	-4.7%
United States	691	391	253	131	-560	-4.6%
Latin America	101	87	84	79	-23	-0.7%
Colombia	81	67	64	59	-22	-0.9%
OECD Europe	81	39	23	12	-69	-5.2%
Non-OECD Europe/Central Asia	312	265	250	225	-88	-0.9%
Russia	195	170	164	154	-41	-0.7%
Middle East	0.2	0.2	0.2	0.2	0	-0.4%
Africa	264	272	285	254	-11	-0.1%
South Africa	256	262	270	232	-23	-0.3%
Asia	4,100	4,467	4,358	3,905	-196	-0.1%
China	2,970	2,819	2,542	1,953	-1,017	-1.2%
India	586	1,004	1,160	1,293	707	2.3%
Indonesia	453	550	550	550	97	0.6%
Oceania	258	273	285	284	27	0.3%
Australia	256	272	284	284	28	0.3%

Coking coal (Mt)

	2015	2030	2040	2050	2015-2050 Changes	2015-2050 CAGR
World	1,081	935	872	792	-289	-0.9%
North America	84	63	57	48	-36	-1.6%
United States	58	40	36	31	-27	-1.8%
Latin America	8	9	9	9	1	0.4%
Colombia	4	6	6	5	1	0.6%
OECD Europe	22	14	12	11	-11	-2.0%
Non-OECD Europe/Central Asia	106	93	87	81	-25	-0.8%
Russia	83	72	69	65	-18	-0.7%
Middle East	0.9	0.9	0.9	0.9	0	-0.1%
Africa	8	15	20	25	17	3.2%
Mozambique	5	12	18	22	18	4.5%
Asia	660	572	527	473	-187	-0.9%
China	593	446	370	288	-305	-2.0%
India	53	113	147	177	124	3.5%
Mongolia	13	9	7	5	-9	-3.0%
Oceania	192	168	158	144	-49	-0.8%
Australia	191	166	156	142	-49	-0.8%

6. Addressing global environmental problems

6.1 CO_2/GHG emissions

Paris Agreement and GHG emission reduction targets

The 21st session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) 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 their Nationally Determined Contributions (NDCs) (Table 1-1 and Table 6-2). The parties to the United Nations Framework Convention on Climate Change (UNFCCC) are required to update their NDCs every five years and each successive NDCs will represent a progression beyond the Party's then current NDC. In this way, progress toward long-term targets will be assessed every five years in the so-called global stocktake. An assessment of the results must accompany the newly submitted NDCs.

Table 6-1 | Overview of Paris Agreement

Item	Contents
Purpose	The Paris Agreement's aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase even further to 1.5°C.
Collective long-term goals on mitigation (reduction)	Parties to the agreement aim to reach global peaking of GHG emissions as soon as possible and to undertake rapid reductions thereafter in accordance with the best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of the 21st century,
Process for setting targets	The Conference of the Parties serving as 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.

The Paris Agreement also includes a peer review for UNFCCC parties to assess progress made toward the achievement of targets and seek further GHG reduction efforts every two years in principle. Within one year from its signing, more than 55 countries accounting for more than 55% of global GHG emissions ratified the agreement; it therefore took effect on 4 November 2016.

Table 6-2 | Major countries' NDCs

	Target type	Reduction level (%)	Reference year	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
Indonesia	Emission reduction from BAU	29	BAU	2030	GHG emissions

Note: *Emissions in the reference year include those absorbed by forest sinks.

The Ad Hoc Working Group on the Paris Agreement is considering (1) a global stocktake to review progress toward the achievement of long-term targets every five years regarding the setting of emission reduction targets and (2) procedures and guidelines for a framework to secure transparency of mitigation actions and support regarding the achievement of targets, as well as a mechanism for implementation and compliance. In November 2016, the COP22 in Morocco's Marrakesh decided to complete preparations for implementing the Paris Agreement by COP24 in 2018.

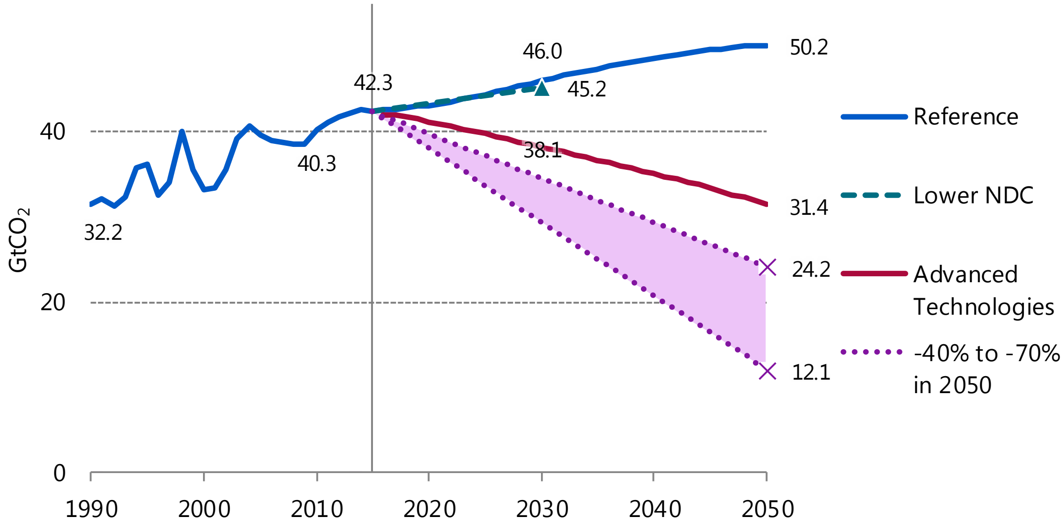
On 1 June 2017, meanwhile, U.S. President Donald Trump issued a statement vowing to withdraw the United States from the Paris Agreement. We must pay attention to how the United States exit from the Paris Agreement would affect international climate change negotiations.

Global GHG emissions[17], estimated according to the Group of 20 members' NDCs, total 45.5 $GtCO_2$ for 2030, posting an increase from the present level (Figure 2-5). Although the

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

increase is slower than indicated by the past trend, the estimated trend deviates substantially from the target of halving GHG emissions in 2050.

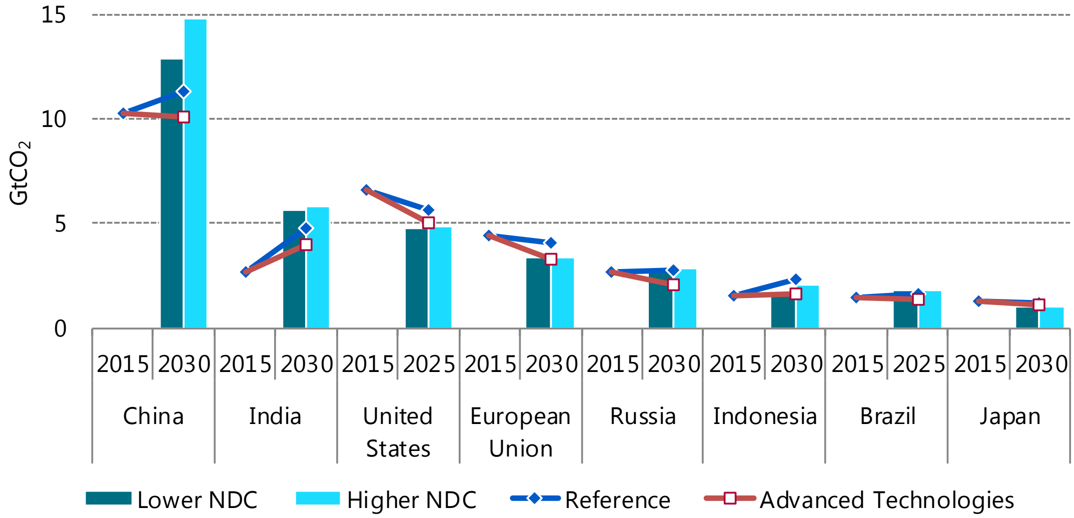
Figure 6-1 | Global GHG emissions



Note: Estimated according to the Group of 20 major countries' NDCs for the Paris Agreement. This analysis still covers the United States which notified the United Nations of its decision to withdraw from the Paris Agreement on 4 August 2017, because the withdrawal is set to come on 4 November 2020, at the earliest.

Figure 6-2 compares major countries' NDC-based GHG emissions and those in the Reference and Advanced Technologies Scenarios to be explained later.

Figure 6-2 | GHG emissions in selected countries and European Union



Note: Estimated according to the NDCs for the Paris Agreement. This study only covers GDP emission intensity reduction targets from reference years for Chinese and Indian NDCs.

The assessment of major countries' NDCs indicates that developed countries are generally close to the Advanced Technologies Scenario. China, India and Brazil are close to the Reference Scenario. Indonesia is 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.

Before the 2023 global stocktake, the Paris Agreement parties will convene a facilitative dialogue in 2018 to assess their efforts for progress toward the achievement of their long-term targets under the agreement and will notify the United Nations of their 2030 targets in early 2020 anew in response to the assessment. An objective assessment of emission reduction contributions will be required to steadily evaluate the targets under the agreement and lead to further emission cuts. In addition, global technology transfers and financial support as well as technological innovation will have to be promoted.

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 around 2025 and slowly decline (Figure 6-3) before reaching 29.7 Gt in 2050, down 9.8% from 2015. A CO_2 emission decline of 14.4 Gt or 33% from the Reference Scenario will surpass present OECD emissions at 11.9 Gt. A cumulative decline of 227 Gt through 2050 will be equivalent to 6.9 years' worth of present global annual emissions.

Figure 6-3 | Global energy-related CO_2 emissions

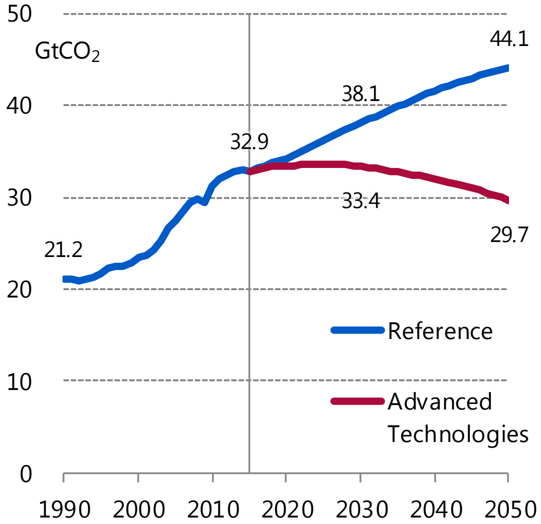
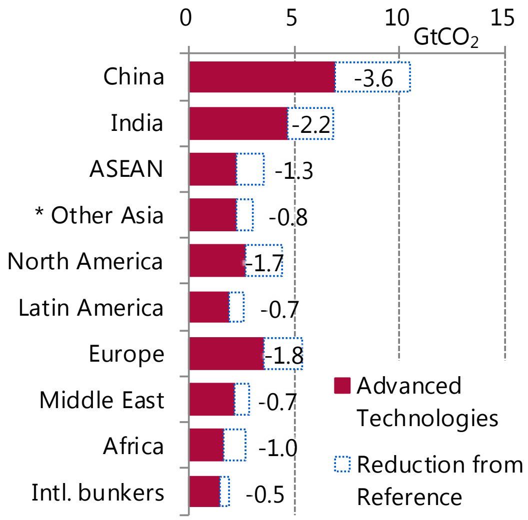


Figure 6-4 | CO_2 emissions [Advanced Technologies Scenario, 2050]



Note: Other Asia includes Oceania.

Non-OECD will account for about three quarters of the emission decline from the Reference Scenario in 2050, indicating developing countries' great potential to reduce emissions. The decline in China, the largest CO_2 emitter in the world, will come to 3.6 Gt, far exceeding the present emission level of 3.2 Gt for the European Union (Figure 6-4). Coal-fired power generation accounts for 70% of the present total Chinese power generation and will represent more than 50% even in 2050 in the Reference Scenario. About 70% of the decline will be attributable to cuts in coal consumption in that sector. In order for China to cut CO_2 emissions, the country will need to heavily rely on factors such as power demand reduction, power generation efficiency improvements as well as switching to non-fossil power sources. India, which will replace the United States as the second largest CO_2 emitter in the world by 2035 in the Reference Scenario, will reduce its emissions by 2.2 Gt by 2050, equivalent to more than its current emissions. Like China, India will heavily depend on coal-fired power generation and about 60% of the emission reduction will be attributable to a coal consumption cut in the power generation sector.

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 developed countries' relevant 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 improvement will represent the largest share accounting for 6.2 Gt; it is followed by 4.0 Gt for the expansion of renewable energy, 2.2 Gt for the expansion of nuclear and 1.5 Gt for carbon capture and storage (CCS) (Figure 6-5, Table 6-3). A little more than 30% of the energy efficiency contribution (about 2 Gt) will be attributable to power-related measures (including generation efficiency improvements, demand reductions and lower transmission and distribution losses). Nearly 30% of the energy efficiency contribution will be attributable to transport sector measures (such as improvements in vehicle fuel efficiency and international bunkers' operational efficiency). A little more than 40% of the overall emission decline will arise from the expansion of non-fossil power generation including renewable energy and nuclear power generation. CCS technologies are assumed to be introduced for all new fossil fuel-fired power plants to be built from 2030 in regions with potential for storing CO_2. Power-related technologies, the combination of fossil-fuel fired power plant CCS, non-fossil power generation and energy conservation technologies, will reduce about two-thirds of the total emission decline.

Each chosen technology is imperfect, presenting both advantages and disadvantages; on a country by country or region by region, they can either be easy or difficult to introduce. It is important to properly assess the various options without depending too heavily on certain technologies or measures.

Figure 6-5 | Global CO_2 emissions reduction by measure

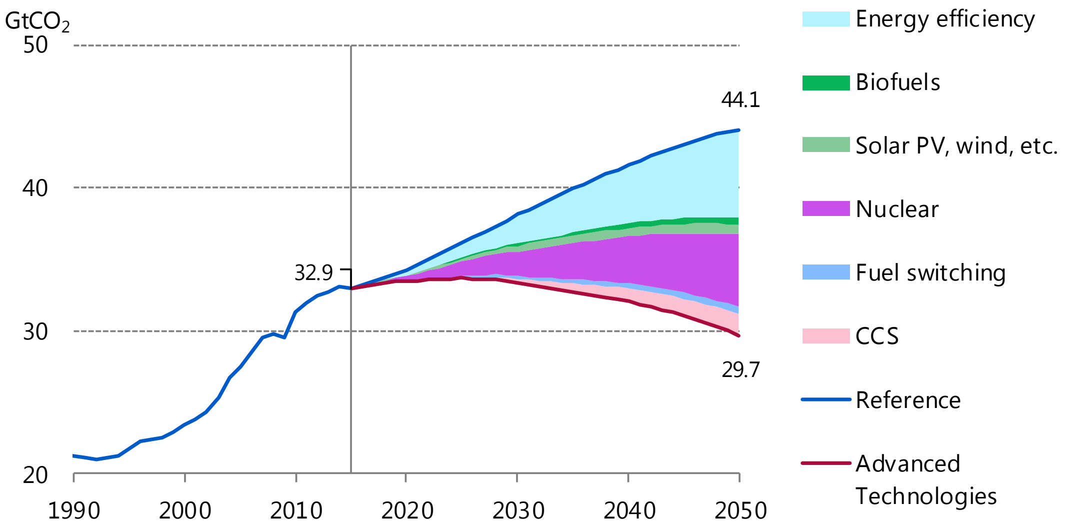


Table 6-3 | CO_2 emissions reduction from the Reference Scenario [Advanced Technologies Scenario]

($GtCO_2$)

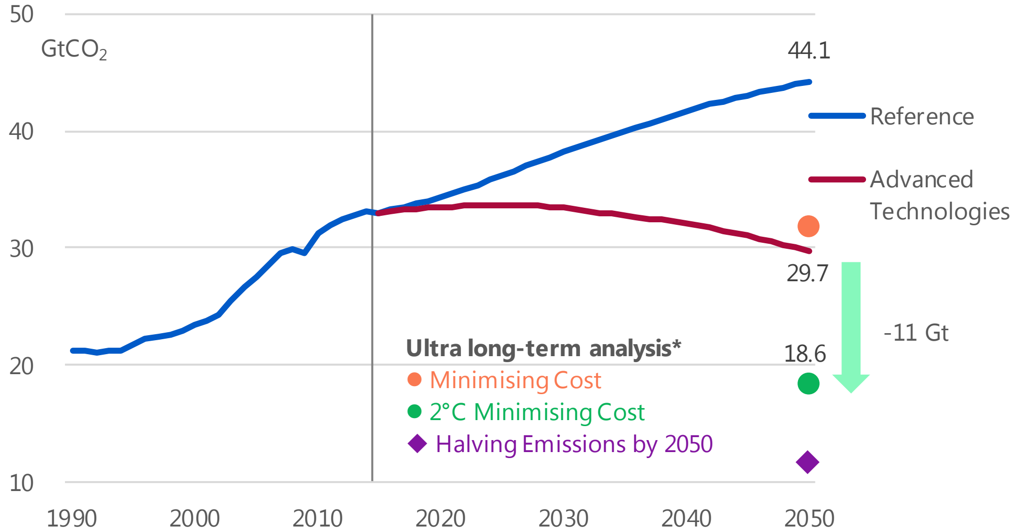
	2050		Cumulative reduction, 2016-2050	
	Reduction	Share	Reduction	Share
Energy efficiency	6.2	43%	97.0	43%
Biofuels	0.4	3%	6.5	3%
Solar PV, wind, etc.	3.6	25%	58.1	26%
Nuclear	2.2	16%	37.0	16%
Fuel switching	0.5	4%	8.5	4%
CCS	1.5	10%	19.8	9%
Total	14.4	100%	226.6	100%

Cutting CO_2 emissions further

Energy-related CO_2 emissions in 2050 in the Advanced Technologies Scenario will fall by 5.1% from 2010, deviating far from the target of halving emissions in 2050. The CO_2 emission path in the Advanced Technologies Scenario is almost consistent with the "Minimising Cost Path" to be described in the next section. In the Minimising Cost Path, however, the temperature in 2150 would increase by 2.6°C from the second half of the 19th century. The Minimising Cost Path is not consistent with the ambitious long-term Paris Agreement target of keeping a global temperature rise this century well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase even further to 1.5°C. If the temperature increase from the second half of the 19th century is to be limited to 2°C in 2150 (see the "2°C Minimising Cost Path" in the next section), CO_2 emissions will have to be reduced by a further 11.1 Gt from the Advanced Technologies Scenario in 2050.

To reduce CO_2 emissions by an additional 11.1 Gt in 2050, a massive introduction of innovative technologies will be required (Table 6-4). Zero-emission power sources such as CCS-equipped fossil fuel-fired power plants and carbon-free hydrogen[18]-fired power plants will need to be introduced. In the Advanced Technologies Scenario, zero-emission power sources (non-fossil and CCS-equipped fossil fuel-fired power plants) already account for two-thirds of all power sources. If the remaining fossil fuel-fired power plants were replaced with zero-emission power sources, the additional reduction would reach 10.4 Gt. If they are instead equipped with CCS, with the carbon capture rate limited to 90%, the additional CO_2 reduction will be limited to up to 9.4 Gt. CCS storage potential, including water-bearing layers, totals more than 7,000 Gt[19], indicating that the additional reduction using CCS could physically be feasible.

Figure 6-6 | Global energy-related CO_2 emissions (comparison with ultra long-term analysis)



Note: The ultra long-term analysis represents results gained with an integrated assessment model (see the next section).

[18] Carbon-free hydrogen may be produced through electrolysis using renewable energy-generated electricity or from fossil fuels through CCS-equipped facilities, emitting no CO_2 during production and consumption. See "Asia/World Energy Outlook 2016" by the Institute of Energy Economics, Japan.

[19] Global CCS Institute "Global Storage Portfolio", 2016

Table 6-4 | Example of innovative technologies introduced to transition to the 2°C Minimising Cost Path

[1] Zero emission technologies: amount required for CO_2 reduction (10.4 Gt) in the power generation sector Substitution of approximately 2,800 GW of thermal power generation capacity without CCS in 2050		
Thermal power generation with CCS (aquifer storage)	Approximately 2,800 GW (a maximum reduction of 9.4 Gt assuming CO_2 recovery rate of 90%) CO_2 storage potential is estimated at 7,000 Gt or more	Either
Hydrogen-fired power generation (CO_2 free hydrogen)	Approximately 3,000 GW ≈ 1 GW of turbine × approximately 3,000 units Hydrogen required: 650 Mt/year (three times as much as current LNG demand)	
Solar power satellite	Approximately 3,000 GW ≈ 1.3 GW of equipment (2 km × 2 km) × approximately 2,300 units	
Very-high-temperature reactor	Approximately 2,400 GW ≈ 0.275 GW of plant × approximately 8,700 units	
Nuclear fusion	Approximately 2,200 GW ≈ 0.5 GW (ITER equivalent) of plant × approximately 4,500 units	
[2] Zero emission technologies: amount required for CO_2 reduction (remaining 0.7 Gt) outside the power generation sector		
CCS in manufacturing	Laying CCS in 16% of iron and steel, cement, chemical, paper and pulp, petroleum refining, and GTL/CTL production facilities	Either
Fuel cell vehicle (CO_2 free hydrogen)	Approximately 1 billion units (2.6 billion vehicles are on road in 2050) Hydrogen required: 150 Mt/year (equivalent to 60% of current LNG demand)	
[3] Negative emission technologies: amount required for CO_2 reduction in the power generation sector (11.1 Gt)		
Biomass-fired power generation with CCS (BECCS)	Approximately 1,400 GW ≈ 0.5 GW turbine × approximately 2,800 units Biomass required: 2,000 Mtoe/year. As much as 2.85 million km^2 of land, larger than Argentina (2.78 million km^2), is required for the supply	

Non-CCS-equipped fossil fuel-fired power generation capacity in the Advanced Technologies Scenario in 2050 will total about 2,800 GW. If the capacity is substituted for by hydrogen-fired power generation capacity, 3,000 hydrogen-fired power plants will be required in the world. The annual carbon-free hydrogen demand would total 650 Mt and would be available through international trade primarily for countries without access to CCS storage potential. International trade of hydrogen could be three times as much as the present LNG market. The non-CCS-equipped fossil fuel-fired power generation capacity could also be substituted for by 2,300 solar power satellite plants, 8,700 high temperature gas reactors or 4,500 nuclear fusion reactors.

The remaining 0.7 Gt that the power generation sector will not be able to cover could be covered by CCS expansion in the manufacturing sector. If all plants for steel, cement, chemicals, paper and pulp, petroleum products, and gas-to-liquid and coal-to-liquid fuels are equipped with CCS, CO_2 emissions would be reduced by 4.4 Gt. To cover the remaining 0.7 Gt, 16% of these plants will have to be equipped with CCS. If fuel cell vehicles (FCVs) powered by carbon-free hydrogen are used to cover the remaining 0.7 Gt, about one billion FCVs would be required in the world, accounting for nearly 40% of global vehicle fleet of about 2.6 billion units in 2050. In addition, hydrogen supply infrastructure will have to be developed.

Negative emission technologies including bioenergy and carbon capture and storage (BECCS) could reduce CO_2 emissions by 11.1 Gt. About 2,800 CCS-equipped biomass-fired power plants will be required for the reduction. Their annual biomass fuel consumption will total 2,000 Mtoe. If short rotation coppices (including willows and poplars) are used to meet the biomass consumption, lands totalling 2.85 million square kilometres, larger than Argentina, will be required for growing them.

As a matter of course, any single technology alone may not have to be adopted for cutting CO_2 emissions further. These innovative technologies may be introduced compositely according to local conditions. If these technologies are to be spread massively by 2050, they may have to be commercialised by around 2030 before sufficient cost cuts over 20 years.

6.2 Ultra long-term GHG emission reduction path

Ultra 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 considered. GHG emissions in this ambitious scenario could be adopted as a target. However, the climate change issue is a long-term challenge involving 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 and the selection of a specific path should not simply depend on a 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.

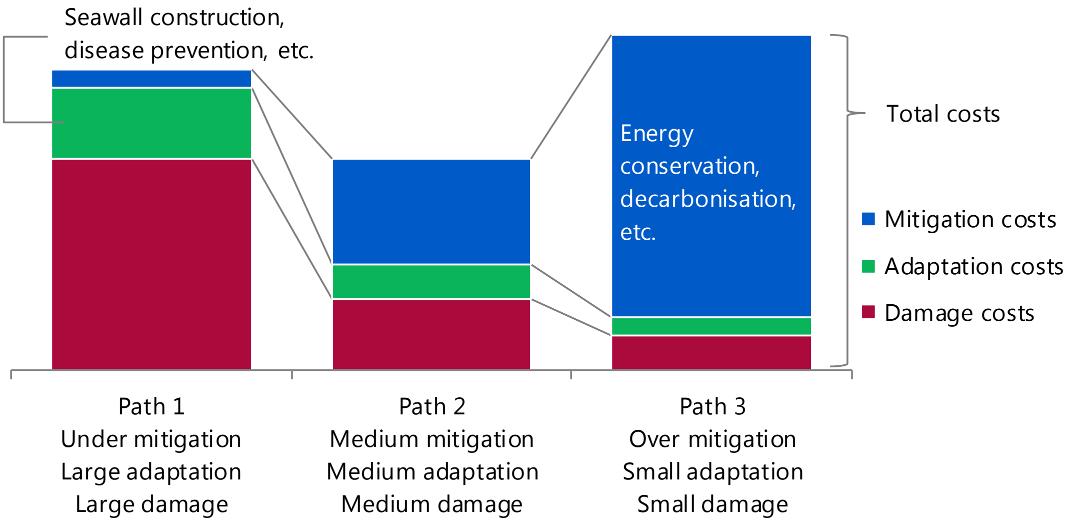
Table 6-5 | Mitigation, adaptation and damage

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.	An increase in temperature could cause a sea level rise, droughts, new disease epidemics, etc. Seawalls 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, damages from sea level rise, droughts or new disease epidemics may emerge

If no measures are taken to prevent climate change, the mitigation costs would be near zero while the adaptation and damage costs would be enormous. In other words, mitigation measures reduce adaptation and damage costs. Mitigation to some extent may not cost so much[20]. In order to substantially reduce GHG emissions to mitigate the impacts of climate change, however, high-cost energy conservation equipment would be required, expanding the mitigation costs remarkably. Mitigation thus trades off with adaptation and damages.

There could be various views about how to balance mitigation, adaptation and damages. From the viewpoint of long-term sustainability, we consider desirable to minimise the combined total cost of mitigation, adaptation and damages. In Figure 6-7, Path 2 rather than Path 1 or 3 should be recommended. An attempt to spend $500 or $1,000 on cutting emissions and building seawalls to prevent $100 in damages would be very difficult to justify and risks failure.

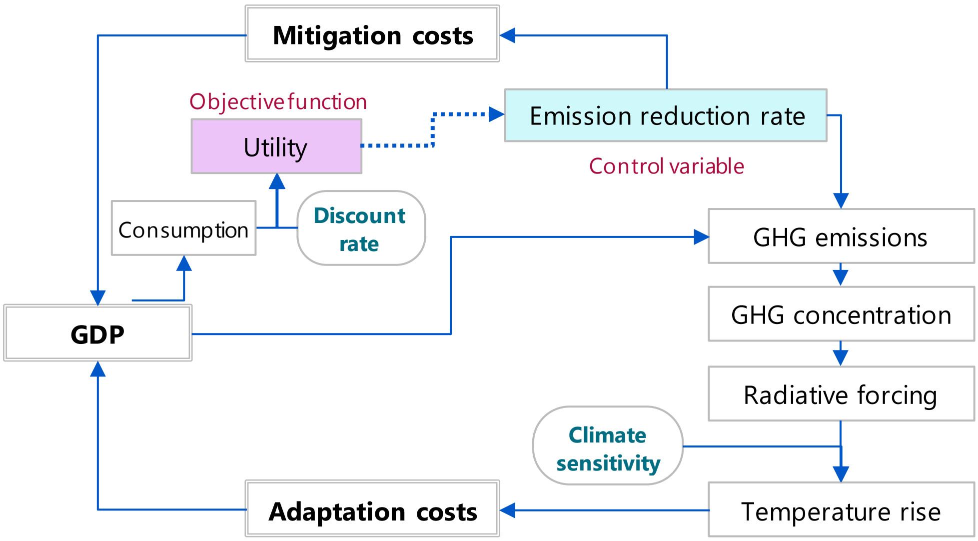
Figure 6-7 | Illustration of total mitigation, adaptation and damage costs



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

An integrated assessment model (IAM) is a tool developed for the analysis of an economically optimum in an ultra long-term path. The IAM integrates different models that comprehensively cover and assess macroeconomic data, GHG emissions, climate change and subsequent damages. The IEEJ's IAM is comprised of (1) a macroeconomic module, (2) a GHG emission module and (3) a climate change module and is designed to maximise utility by controlling the GHG emission reduction rate. If the GHG emission reduction rate is raised, the cost of mitigation soars while the costs of adaptation and damages decline. Mitigation, adaptation and damage costs influence utility (consumption function) through GDP. Each year's GHG emission reduction rate (GHG emission reduction path) is set to maximise the total utility (discounted) through 2500. In this model, the utility maximisation amounts to the total cost minimisation.

Figure 6-8 | Model diagram



Minimising Cost Path

IEEJ's IAM begins by setting the Reference Pathway irrespective of the cost minimisation (utility maximisation). While referring to the CO_2 emission path through 2050 in Chapter 2 of this outlook, the IAM extends the trend way beyond 2050. GHG emissions are projected to peak around 2080 and decrease later due to energy intensity improvements and slower growths in GDP and population. However, the atmospheric GHG concentration (including aerosols) and the temperature are projected to continue rising until 2150.

Based on the Reference Pathway, a path minimising total costs (Minimising Cost Path) is projected. In the Minimising Cost Path, the 2010 GHG emissions will decline by 1% in 2050, by 52% in 2100 and by 79% in 2150. However, the atmospheric GHG concentration will continue rising slowly until around 2100, peak in 2100 and fall to 550 ppm of CO_2 equivalent in 2150. The temperature will continue rising more moderately until 2150, posting an increase of 2.6°C from the second half of the 19th century. Total costs (cumulative costs through 2500 on a discount cash flow basis) in the Minimising Cost Path will be half the Reference Path level.

Figure 6-9 | GHG emissions

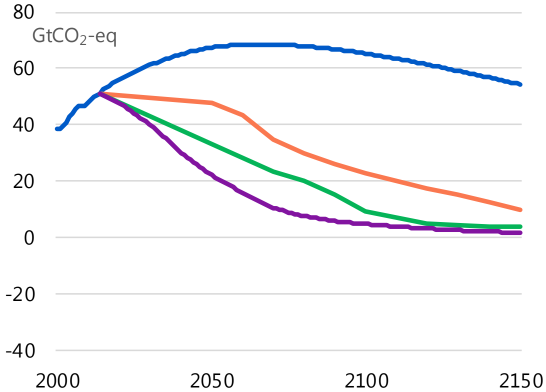


Figure 6-10 | Atmospheric GHG concentration

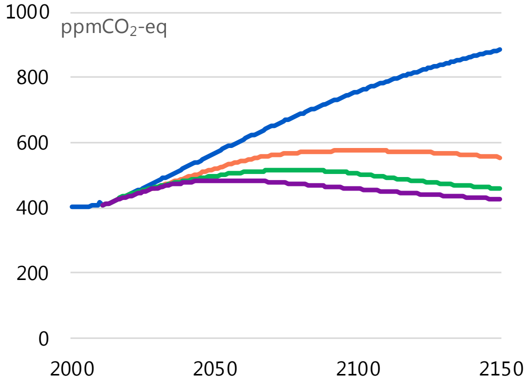


Figure 6-11 | Temperature increase from second half of 19th century

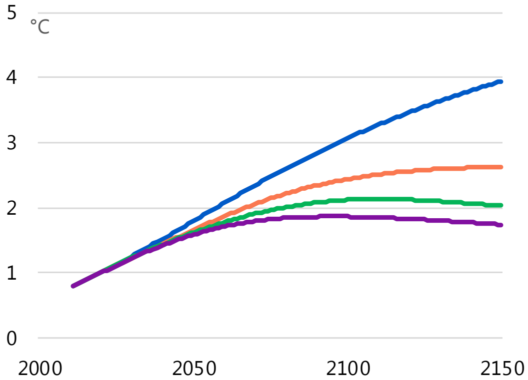
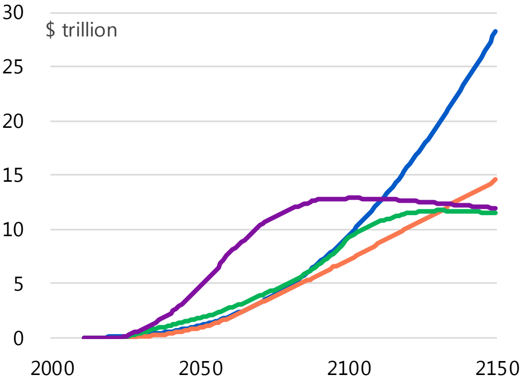


Figure 6-12 | Total costs



Reference Minimising Cost 2°C Minimising Cost Halving Emissions by 2050

Figure 6-13 | Real GDP

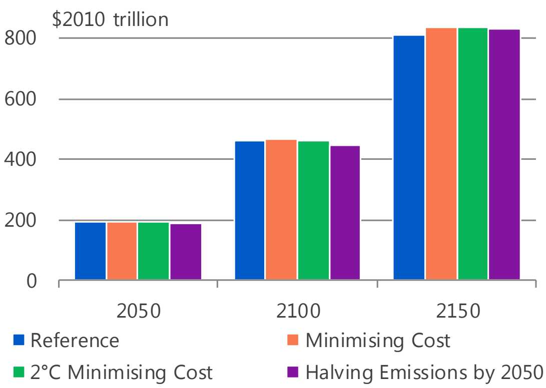
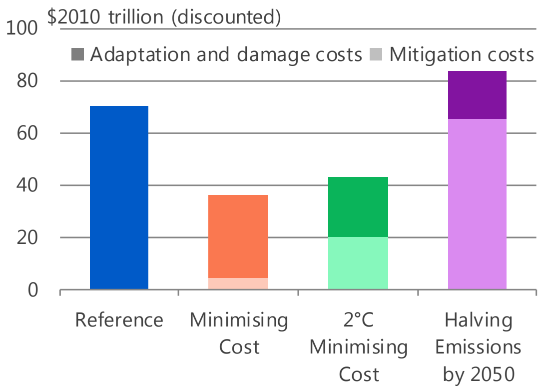


Figure 6-14 | Cumulative total costs (in present value)



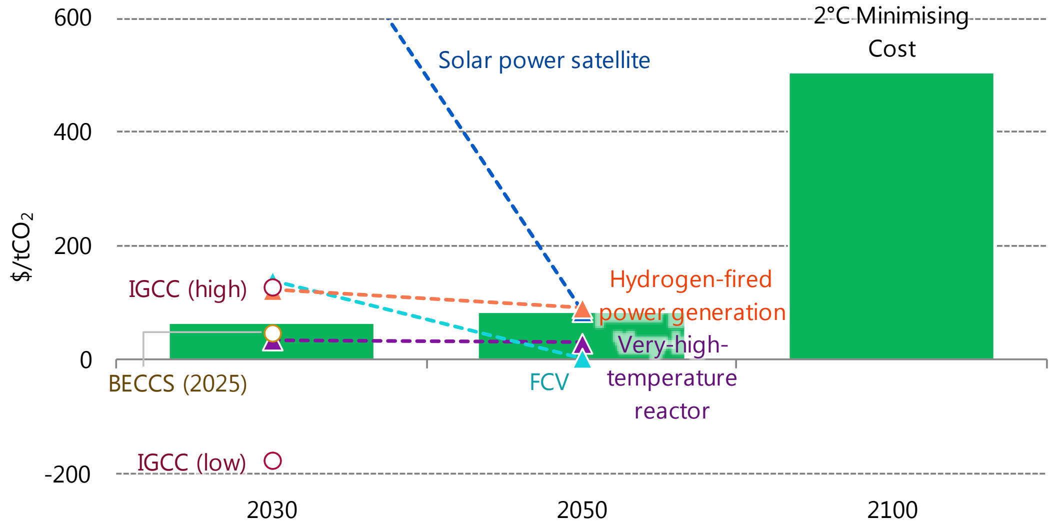
Note: The atmospheric GHG concentration is in terms of CO_2 including aerosol.

In the "Halving Emissions by 2050 Path[21]" in which GHG emissions would be cut by 50% from 2010 in 2050, however, the atmospheric GHG concentration will peak at near 480 ppm of CO_2 equivalent around 2050 and fall to 430 ppm in 2150, with the temperature increase limited to 2°C or less. While adaptation and damage costs will be held down considerably, mitigation costs will become enormous, exceeding by far the Reference Path level. As the enormous mitigation costs affect economic conditions, real GDP through 2100 in the Halving Emissions by 2050 Path will be smaller than in the Reference Path or the Minimising Cost Path.

In the Minimising Cost Path, as mentioned above, the temperature in 2150 will increase by 2.6°C from the second half of the 19th century. This path will not enforce the achievement of the ambitious long-term Paris Agreement target of keeping a global temperature rise this century well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase even further to 1.5°C. Given that the 2°C target is well accepted in international politics and negotiations, however, it is useful to consider a GHG emission path in which powerful measures will be taken to hold down the temperature increase. For example, the 2°C Minimising Cost Path is a path projected to minimise total costs on condition that the temperature increase in 2150 be limited to 2°C. Total costs for such path are some 20% higher than in the Minimising Cost Path (free of a temperature rise condition), but about 50% less than in the Halving Emissions by 2050 Path. Unlike the Minimising Cost Path (heavily dependent on adaptation and damage costs) and the Halving Emissions by 2050 Path (heavily dependent on mitigation costs), the 2°C Minimising Cost Path features a form of balance between mitigation, adaptation and damage costs. In the 2°C Minimising Cost Path, the 2010 GHG emissions will be down 31% in 2050, down 80% in 2100, and then cut to almost zero. The temperature increase from the second half of the 19th century will reach 2.1°C in 2100 before falling back to 2°C in 2150 and continue decreasing later. Real GDP in the 2°C Minimising Cost Path would be almost the same as in the Minimising Cost Path free of a temperature rise condition.As a matter of course, efforts are required to reduce mitigation costs and it is desirable to reduce total costs to the level of the Minimising Cost Path that was free of a temperature rise constraint. There is great potential for hydrogen-fired power generation and other innovative technologies to substantially reduce mitigation costs. In the 2°C Minimising Cost Path projected in the model, the implicit carbon price (in 2010 dollars) will be \$85/tCO_2 in 2050 and \$503/tCO_2 in 2100. Target costs for innovative technologies, including BECCS, hydrogen-fired power generation, fuel cell vehicles and high temperature gas reactors, fall in the carbon price range (Figure 6-15). These technologies are sufficient to achieve the 2°C Minimising Cost Path. If technology development makes progress toward the target, with costs reduced to levels below the carbon price projected in the model, the true Minimising Cost Path free from any temperature condition will become feasible.

[21] This path represents an emission path in the RCP2.6 scenario summarised in the fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC).

Figure 6-15 | CO_2 emission reduction costs



Note: In the 2°C Minimising Cost Path, costs represent those (in 2010 dollars) for the costliest ones among technologies adopted at each time point. Preconditions and ambitiousness for targets or projections differ from technology to technology.
Major assumptions for calculation
[High temperature gas reactor] Construction costs for a 300,000-kW power generation reactor are assumed at about $500 million, based on "Future Research and Development of High Temperature Gas Reactors (draft)" by the Nuclear Science and Technology Committee.
[Integrated gasification combined cycle (IGCC) power generation] Construction costs are assumed at between $1,200/kW and $2,900/kW and the power generation efficiency at between 50% and 52%, based on OECD/NEA "Projected Costs of Generating Electricity 2015 Edition."
[Fuel cell vehicle (FCV)] For 2050, the FCV price is assumed at $25,000 (equivalent to a conventional vehicle price), the fuel efficiency at 115 km/kg (31 km/L in gasoline terms) and the retail hydrogen price at $0.5/Nm^3, based on "Roadmap for Strategy for Hydrogen and Fuel Cells" by the Council for a Strategy for Hydrogen and Fuel Cells.
[Hydrogen-fired power generation] For 2050, the hydrogen plant delivery price is assumed at $0.15/Nm^3, construction costs at $1,200/kW and power generation efficiency at 57%, based on "Roadmap for Strategy for Hydrogen and Fuel Cells" by the Council for a Strategy for Hydrogen and Fuel Cells and "Technology Roadmap: Hydrogen and Fuel Cells" by the IEA.
[Solar power satellite] The 2050 unit power generation cost target of $100/MWh is used, based on "Research and Development Roadmap for 2006 Model Integrated Space Solar PV Power Generation and Transmission System – 2016 Revision" by the Japan Space Systems.
[BECCS] The biomass-fired power generation unit cost is assumed at $130/MWh in line with IRENA "Renewable Power Generation Costs in 2014" and the carbon capture and storage cost at $70/t$CO_2$ in line with IPCC "Special Report on CCS."

Although the cost of the Minimising Cost Path is some 50% less than in the Reference Path, the temperature rise by 2150 will be 2.6°C from the second half of the 19th century. The total costs in the 2°C Minimising Cost Path (2°C by 2150) is higher than in the Minimising Cost Path but 50% lower than the Halving Emissions by 2050 Path. However, in order for the 2°C Minimising Cost Path to materialise, GHG emissions will need to be cut to zero by 2100 and, therefore, it will be indispensable to introduce negative emission technologies such as, carbon capture and utilisation (CCU) and bioenergy and CCS (BECCS) technologies.

Fortunately, these technologies may not be necessary for the immediate future. Several decades are left for their development and commercialisation. If technology costs are rapidly lowered by 2050, the temperature increase may be limited to 2°C or less even from 2150. It is important to enhance innovative technology research and development from the long-term viewpoint to realise the overshoot path. Governments, enterprises and academic organisations will have to share wisdom and closely cooperate with each other. The Innovation for Cool Earth Forum (ICEF) and other international cooperation forums will be required to discuss what innovative technologies should be developed, how innovation should be promoted and how stakeholders should enhance their cooperation. Future technology development and cost reduction will be very significant for the long term sustainable development of humanity.

6.3 Uncertainties of ultra long-term analysis

The previous section's analysis represents assessment based on various parameters. As much as possible, objective and average data from various documents have been adopted for parameter assumptions. As any ultra long-term analysis involves various levels of uncertainties, parameters widely differ from document to document. Particularly, the discount rate[22] and the equilibrium climate sensitivity are frequently cited as issues. We here fully recognise the uncertainties associated with those two parameters before reassessing the ultra long-term Minimising Cost Path.

Discount rate

When a long-term economic problem is considered, the gap between time points at which costs are generated must be prudently accounted for. Costs at different points of time are of different values. Even if the effect of price fluctuations is removed, the future value of money may be generally lower than the present value. If a higher discount rate is used for assessing mitigation, adaptation and damage costs (or the far future value is estimated at a lower level), climate change damage costs are relatively lower, with a path free from mitigation measures becoming close to the optimum path. If a lower discount rate is used, future damage costs are estimated at a higher level, with a path including immediate mitigation measures assessed as close to the optimum one. When ultra long-term problems such as climate change are considered, discount rate levels become controversial.

The discount rate (social discount rate) is generally described by the following equation called the "Ramsey rule:"

$$\rho = \delta + \eta g$$

In the equation, δ stands for the pure time preference rate. If the pure time preference rate is higher, people think that the future value should be assessed as lower than the present value. g represents the consumption growth rate. Generally, consumption grows along with the economic size. η represents the elasticity of marginal utility of consumption, indicating what

[22] See Column in Chapter 9 of IEEJ "Asia/World Energy Outlook 2015."

percentage decline the value of a good of the same monetary value would post when consumption (per capita consumption) expands 1%.

The pure time preference rate and the elasticity of marginal utility of consumption are put at various levels by various analysts. Table 6-6 indicates various levels of the pure time preference rate and the elasticity of marginal utility of consumption adopted in major academic papers, as compiled by the Fifth Assessment Report (AR5) by the Intergovernmental Panel on Climate Change (IPCC). The pure time preference rate ranges from 0% to 2% and the elasticity of marginal utility of consumption from 1 to 4.

Table 6-6 | Discount rate examples

	Pure time preference rate	Elasticity of marginal utility of consumption
Cline (1992)	0%	1.5
IPCC (1996)	0%	1.5 – 2
Arrow (1999)	0%	2
United Kingdom: Green Book (HM Treasury, 2003)	1.5%	1
France: Rapport Lebègue (2005)	0%	2
Stern (2007)	0.1%	1
Dasgupta (2007)	0.1%	2 – 4
Weitzman (2007a)	2%	2
Nordhaus (2008)	1%	2

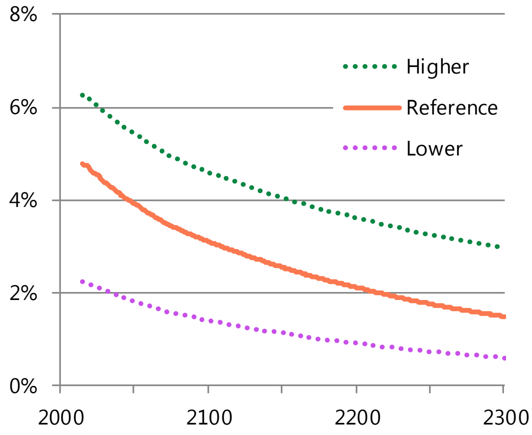
Source: Table 3.2, Chapter 3, IPCC AR5

We here analyse how discount rate differences influence the Minimising Cost Path. In the previous section's analysis, the two parameters were put at average levels in Table 6-6 (0.5% for the δ pure time preference rate and 2 for the η elasticity of marginal utility of consumption), resulting in the average discount rate of 2.5% through 2300. The highest average discount rate resulting from the combination of 2.0% for δ and 2 for η in the table comes to 4.1% and is set as the higher discount rate. The lowest average discount rate resulting from the combination of 0.1% for δ and 1 for η in the table comes to 1.1% and is set as the lower discount rate.

Table 6-7 | Discount rate assumptions

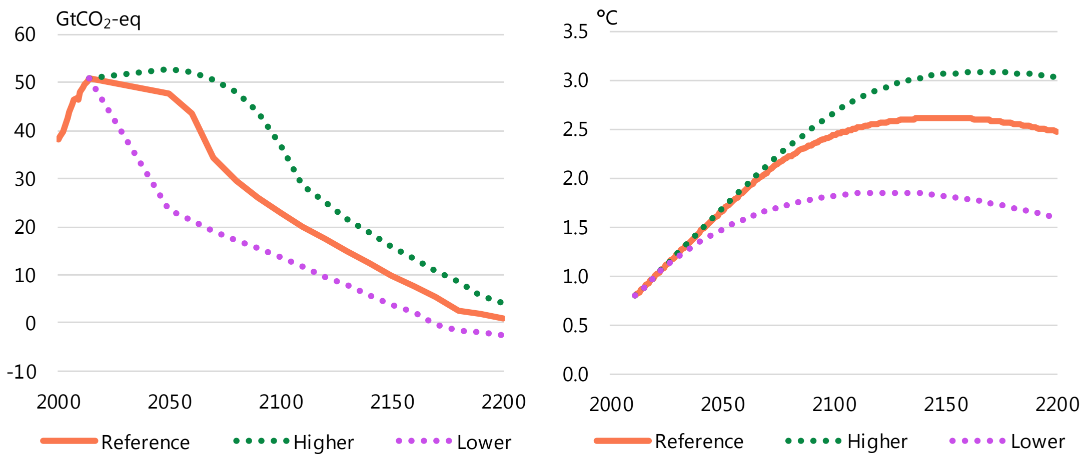
	Pure time preference rate (δ)	Elasticity of marginal utility of consumption (η)	Average discount rate (2015-2300)
Higher discount rate	2.0%	2.0	4.1%
Reference	0.5%	2.0	2.5%
Lower discount rate	0.1%	1.0	1.1%

Figure 6-16 | Discount rate trends through 2300



If damage is assessed as relatively low with a higher discount rate (averaging of 4.1% through 2300), mitigation measures would tend to be delayed until mitigation costs decline. As of 2200, the temperature increase from the second half of the 19th century will be 3.0°C. With a lower discount rate (averaging 1.1% through 2300), a path for the immediate implementation of mitigation measures would be assessed as optimum. The temperature increase would rise close to 2.0°C around 2100 and fall later. The temperature gap between the higher and lower discount rate cases, as of 2200, would be 1.4°C, indicating that a discount rate gap of 1 percentage point would lead to a temperature gap of about 0.5°C. Consequently, analysis results may differ widely depending on discount rate assumptions.

Figure 6-17 | Ultra long-term GHG emission and temperature increase paths by discount rates



Equilibrium climate sensitivity

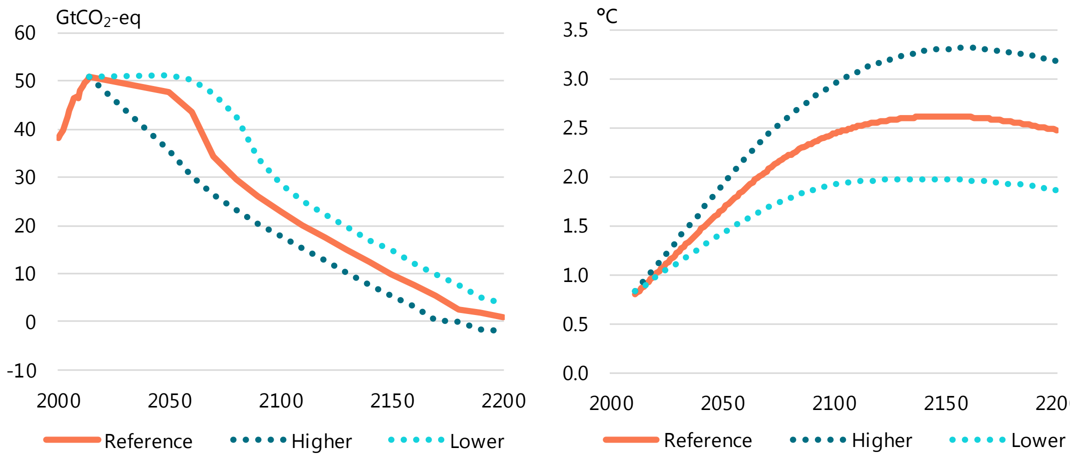
Equilibrium climate(ECS) sensitivity is a parameter indicating how much the temperature will increase when the atmospheric GHG concentration (expressed in CO_2 equivalent) doubles. It is a very important parameter for analysing how much human economic activities would influence the temperature increase. As scientific understanding about cloud radiative forcing has fallen short of making smooth progress, however, ECS widely differs from climate model to climate model. The IPCC assessment reports have described ECS as ranging widely from 1.5°C to 4.5°C. The best estimate was changed to 3.0°C in the fourth IPCC assessment report from 2.5°C in the first three reports. However, the fifth or latest report gives no best estimate. Climatologists have thus not yet reached consensus on ECS. Although scientific advancement may lead to a unique sensitivity level, ECS is one of the most uncertain parameters at present. Our analysis adopts the ECS of 3.0°C by reference to the MAGICC Model used in IPCC assessment reports.

Table 6-8 | Equilibrium Climate sensitivity in IPCC reports

IPCC reports	Climate sensitivity (°C)	Best estimate (°C)
First (1990)	1.5-4.5	2.5
Second (1995)	1.5-4.5	2.5
Third (2001)	1.5-4.5	2.5
Fourth (2007)	2.0-4.5	3.0
Fifth (2014)	1.5-4.5	n.a.

A simple average of ECS levels in climate models adopted in the IPCC AR5 report comes to 3.2°C, while the report estimates that sensitivity has a 90% chance to fall within a range of plus or minus 1.3°C. We set the higher ECS at 4.5°C and the lower one at 1.9°C to analyse how a difference in climate sensitivity would influence the Minimising Cost Path.

Figure 6-18 | Ultra long-term GHG emission and temperature increase paths by equilibrium climate sensitivity level



As the implications of economic activities on the temperature rise are greater at the higher ECS level of 4.5°C, a path for the early implementation of mitigation measures is assessed as optimum. Even in the path, however, the temperature increase will come to 3.2°C in 2200. At the lower ECS level of 1.9°C, the temperature increase will be limited to around 2°C, even with mitigation measures being delayed. The temperature gap between the two cases in 2200 comes to 1.3°C, indicating that an ECS change of 1°C could result in a temperature change of 0.5°C. Equilibrium climate sensitivity differences could greatly influence not only the temperature increase but also mitigation measures.

Although humans cannot control the sensitivity, they can reduce the mitigation costs by lowering the costs of existing low-carbon technologies and by developing innovative technologies. We are required to cooperate in technology development from a long-term perspective while continuing to implement appropriate climate change countermeasures. For example, the development of the following innovative technologies will have to be promoted for a path to limit the temperature increase to about 2°C around 2150.

6.4 Innovative technology development over the ultra long term

Various technologies to hold down the temperature increase

In addition to energy conservation, renewable energy and nuclear technologies, there are various technologies to hold down the temperature increase.

Table 6-9 | Various technologies to hold down the temperature increase

	Technologies
Energy conservation technologies	Energy conservation
Clean energy technologies	Renewable energy Nuclear Clean fossil fuels
Zero carbon technologies	Next-generation nuclear reactors Nuclear fusion Solar power satellite Hydrogen utilisation
Negative carbon technologies	Carbon capture and utilisation (CCU) Bioenergy with CCS (BECCS)

It would be ideal to limit the temperature rise to 2°C over the long term. Therefore, it is important to develop innovative technologies over the next half century while promoting technology transfers. Innovative technologies include next-generation nuclear power generation, nuclear fusion, solar power satellite, hydrogen utilisation, carbon capture and storage (CCS), carbon capture and utilisation (CCU), and bioenergy with CCS (BECCS) (Table 6-10).

Table 6-10 | Innovative technologies that should be developed over a medium to long-term 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.

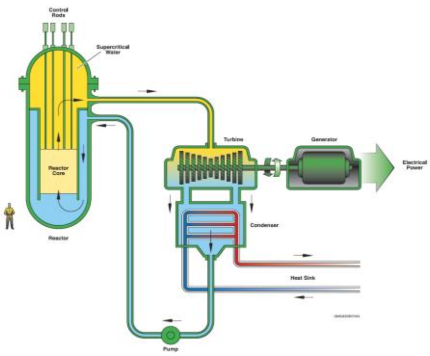
Fourth-generation nuclear reactors include very high temperature gas reactors, supercritical water-cooled reactors, molten salt reactors, gas-cooled fast reactors, sodium-cooled fast reactors and lead-cooled fast reactors.

Russia already operates the BN800 sodium-cooled fast reactor, while China and India are constructing sodium-cooled fast reactors.

The following are six candidate concepts for fourth-generation nuclear reactors.

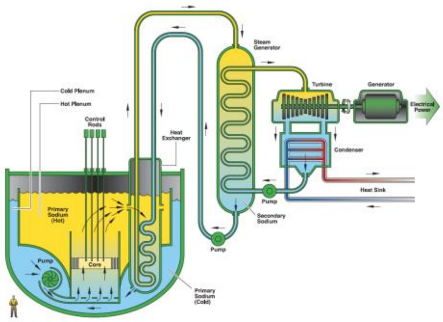
Supercritical-Water-Cooled Reactor

Compacting systems using supercritical water (220 atmospheres, 374°C or more) and thermal efficiency



Sodium-Cooled Fast Reactor

This reactor is the most technologically mature among next-generation nuclear reactors, using innovative technologies to improve safety and efficiency.



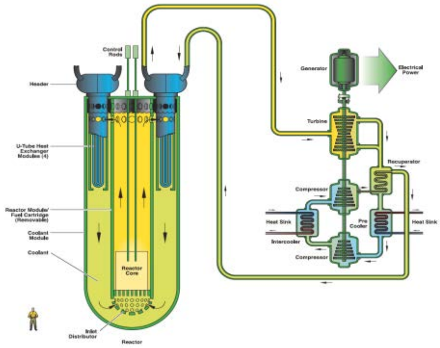
Lead-Cooled Fast Reactor

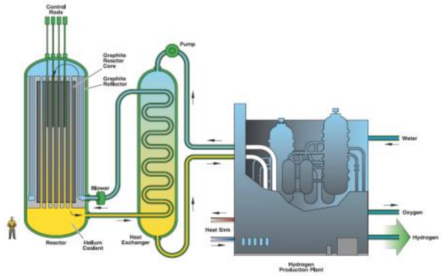
Lead is used in place of chemically active sodium.

Very-High-Temperature Reactor

Industrial use of high temperature (950°C or hotter) gas

Next-generation nuclear reactors



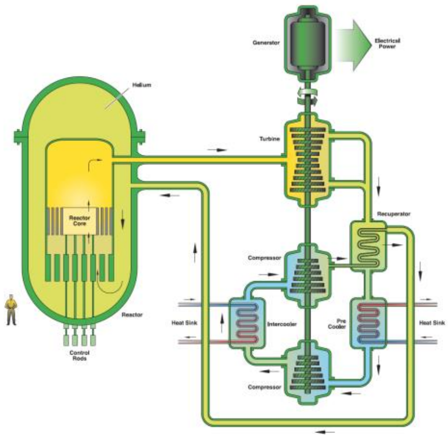


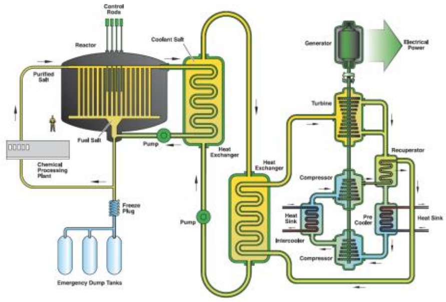
Gas-Cooled Fast Reactor

Helium gas is used in place of chemically active sodium.

Molten Salt Reactor

Using thorium fuel (liquid fuel)



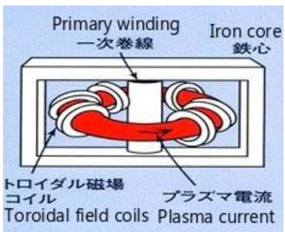


Source: http://www.enecho.meti.go.jp/committee/council/basic_policy_subcommittee/008/pdf/008_003.pdf, U.S. DOE "A Technology Roadmap for Generation IV Nuclear Energy Systems"

Costs	All projects seek to develop new reactors that can achieve the same efficiency as or greater efficiency than existing light-water reactors. Estimated by the European Sustainable Nuclear Industrial Initiative (ESNII) Sodium-cooled fast reactor: Prototype (600 MWe) design/construction costs at €4,000 million Lead-cooled fast reactor: Prototype (100 MWe) design/construction costs at €1,000 million Gas-cooled fast reactor: Prototype (70-100 MWe) design/construction costs at €700 million - €800 million GIF: Generation-IV International Forum

Next-generation nuclear reactors	
	Pursuing the same lifecycle costs and financial risks as other energy sources Commercial high temperature gas reactor system (Japan) estimated at about JPY4.2/kWh Capital costs estimated at JPY200,000/kW for the Fast Reactor Cycle Technology Development Project (FaCT) (Japan)
Potential	A reactor's power generation capacity is assumed at 70-600 MWe.
Future challenges	Expansion of support for research and development of next-generation nuclear reactors, etc.

Nuclear fusion	
Present technology development situation	Nuclear fusion of hydrogen and other elements with smaller nuclear numbers can produce energy the same way the sun does. The deuterium fuel for nuclear fusion is abundant 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 engages in research and development of a field-reversed configuration reactor under funding by Goldman Sachs and other private sector firms. Tokamak type • A doughnut-shaped magnetic basket is made to confine plasma. • The tokamak type was devised by the former Soviet Union and adopted by other countries. → The most advanced nuclear fusion reactor at present • Electric current is passed through plasma to form a twisted magnetic field.



Nuclear fusion

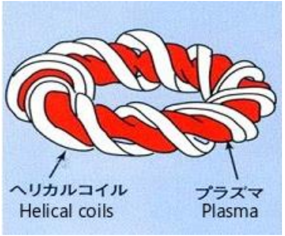
• Japan has achieved the world record ion temperature of 520 million degrees in its JT-60, boasting the world-leading fusion technology level.

ITER (International Thermonuclear Experimental Reactor)

JT-60

National Institutes for Quantum and Radiological Science and Technology

Helical type



• A doughnut-shaped basket is made, as is the case with the tokamak type, while twisted coils are used.

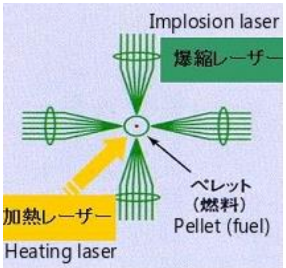
• As a magnetic field is formed with external coils, electric current does not have to be passed through plasma.
→ Economical, long operation

• The LHD has achieved the world record steady operation of about one hour.

Large helical device (LHD)

National Institute for Fusion Science

Laser type



Unlike the two above types to confine plasma, the laser type uses a high-power laser to explosively compress and heat fuel to generate pressure for confining plasma.

• The laser type essentially differs from the left types for confining plasma in a magnetic field and has potential to substitute for them from a different angle.

• U.S. and French defence-related agencies promote this type.

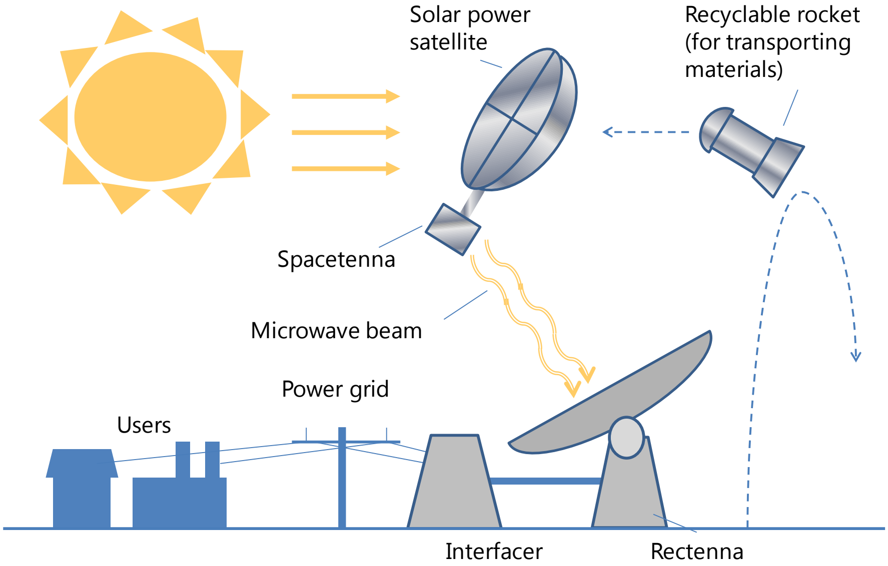
Gekko-XII, LFEX (Laser for Fast Ignition Experiments)

Osaka University

Source: http://www.mext.go.jp/a_menu/shinkou/iter/019.htm

Costs	While it is too early to discuss the economic efficiency of nuclear fusion reactors at the commercialisation stage, the following estimates have been given: ITER reactor (tokamak) under construction in France’s Cadarache: 500 MW Construction cost: €13 billion Operation cost: €320 million/year Decontamination cost: €280 million Decommissioning cost: €5.3 billion
Potential	One nuclear fusion reactor’s power generation capacity is assumed at 700 MW.

Nuclear fusion	
Future challenges	Major challenges include the following: Technology to continuously induce nuclear fusion and confine it to a specific 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 The 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

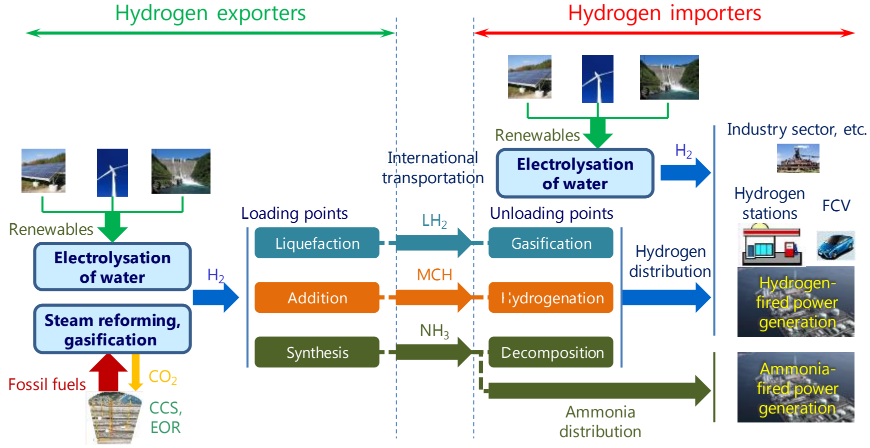
Solar power satellite	
Present technology development situation	Solar PV power generation will be implemented in outer space where there is more solar energy available to be collected than on the Earth. Electricity will be wirelessly transmitted to the Earth by microwaves, for ground utilisation. Solar PV power generation in outer space will be unaffected by weather conditions or night and day changes in output and be qualified as a baseload electricity source. Solar power satellite is under research and development, with elemental technologies being tested on Earth. Mainly Japan and the United States have so far considered various solar power satellite schemes. In Japan, the Japan Aerospace Exploration Agency (JAXA) is testing electricity transmission by microwaves. 
Costs	Construction cost: JPY1,271.6 billion

Solar power satellite	
	Annual maintenance and operation cost: JPY33.6 billion (if the unit cost is limited to JPY10/kWh or less)
Potential	Power generation capacity per system: 1.3 GW (assumption for the above cost estimation)
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 ultra long-term technology development.

Note: See the following for costs and potential: "Research and Development Roadmap for 2006 Model Integrated Space Solar PV Power Generation and Transmission System – 2016 Revision" by the Japan Space Systems (March 2017)

Hydrogen utilisation	
Present technology development situation	Hydrogen is currently produced by steam reforming of natural gas, gasification of coal or electrolysation of water. While hydrogen consumption itself is free from carbon, the production of hydrogen from fossil fuels generates CO_2, which should be subjected to CCS. In the future, hydrogen could be produced with nuclear energy (high temperature gas nuclear reactors). Hydrogen is now transported over short distances as compressed hydrogen or through pipelines linking factories. Japan is considering liquefied hydrogen and organic hydride (methylcyclohexane) for long-distance international maritime transportation. Japan is planning to operate a demonstration ship from 2020. Ammonia, a fertiliser material for which supply chains have been developed, is also considered as a hydrogen carrier. Hydrogen could be used for fuel cells, fuel like natural gas for combined cycle power generation, combustion in the industry sector, desulfurisation in oil refining, hydrogen reduction steelmaking and injection into natural gas networks. Ammonia is also considered as fuel for direct burning for power generation.

Hydrogen utilisation



Costs	While hydrogen production costs widely differ from process to process and from region to region, the IEA's "Technology Roadmap, Hydrogen and Fuel Cells" estimates hydrogen production costs at $0.1/Nm^3 - $0.3/Nm^3 for steam reforming of natural gas and at $0.5/Nm^3 - $0.6/Nm^3 for electrolysation of water. However, CCS costs must be added to the natural gas reforming. The import CIF price for Japan of CO_2-free hydrogen made from lignite in Australia is estimated at JPY30/Nm^3.
Potential	Hydrogen can be produced from various resources, boasting of great potential. However, hydrogen production from fossil fuels is vulnerable to CCS potential or availability. Production of CO_2-free hydrogen from lignite in Australia reportedly has potential to cover Japan's total power generation over 240 years. Associated gas from oil fields also has great potential. Promising renewable energy for hydrogen production includes wind power in Argentina's Patagonia, hydro energy in Canada and Far Eastern Russia and solar energy in the Middle East. Regarding grid stabilisation required for massive renewable energy power generation, the power-to-gas technology for hydrogen production is considered.
Future challenges	While steam reforming of natural gas, electrolysis of water and other hydrogen production technologies are mature, production costs must be reduced. As for hydrogen transportation and storage, efficiency must be improved through technological verification. Hydrogen utilisation technologies must be demonstrated with costs reduced. A challenge that must also be considered is the development of institutions for the promotion of carbon free hydrogen utilisation.

Technologies to capture CO_2 or remove CO_2 from atmosphere

Carbon capture and utilisation

Present technology development situation	Carbon 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. CO_2 conversion processes include catalytic conversion, mineralisation, electrochemical

Carbon capture and utilisation

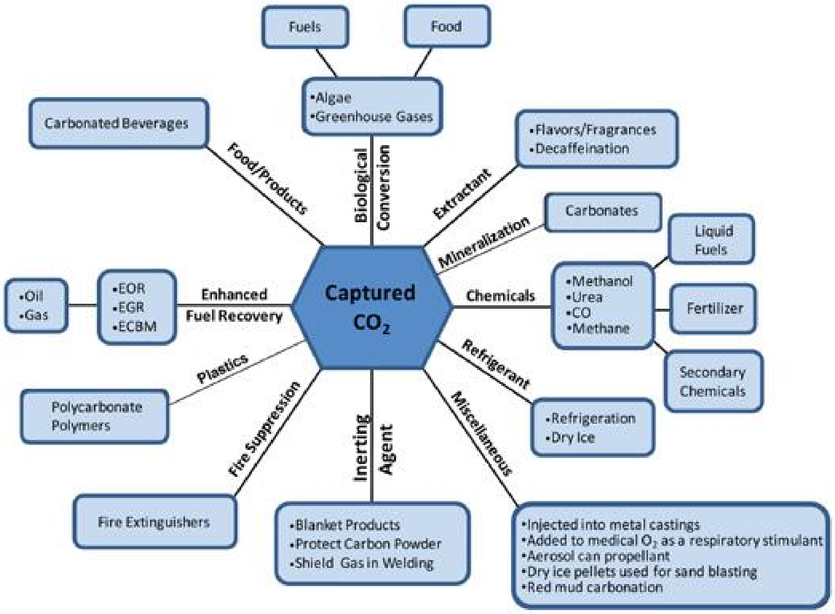
conversion, photocatalytic conversion and fermentation.

CCU products include chemical intermediates, fuels, building materials and polymers.

CCU technologies can capture CO_2 and are important particularly for regions where CO_2 storage sites are limited.

The present artificial photosynthesis consists of three chemical reaction processes – (1) conversion of water into hydrogen and oxygen through photocatalysts, (2) separation of hydrogen from oxygen through membrane and (3) reaction between hydrogen and CO_2 to produce organic matter. Energy conversion efficiency has continued to be improved.

The reaction between hydrogen and CO_2 produces methane, carbon monoxide and formic acid.



Source: http://www.netl.doe.gov/research/coal/carbon-storage/research-and-development/co2-utilisation

Costs

Building materials and polymers are close to commercialisation.

Potential

CCU products including concrete, aggregates, polymers and ethanol have potential to utilise 1 billion t/y to 7 billion t/y in CO_2 in 2030. Maximum CO_2 utilisation potential as of 2030 is estimated at 3.6 billion t/y for aggregate, 2.1 billion t/y for fuels and 1.4 billion t/y for concrete.

Source: ICEF, Carbon Dioxide Utilization (CO2U) – ICEF Roadmap 1.0, 2016

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 and oxygen.

The Innovation for Cool Earth Forum published a CCU technology roadmap in 2016 and

Carbon capture and utilisation

plans to release its second version in 2017.

Bioenergy and CCS (BECCS)

Present technology development situation

BECCS uses CCS technologies for a bioenergy conversion process, having potential to absorb CO_2 from the atmosphere.

BECCS takes advantage of biological photosynthesis and CCS to absorb carbon from the atmosphere.

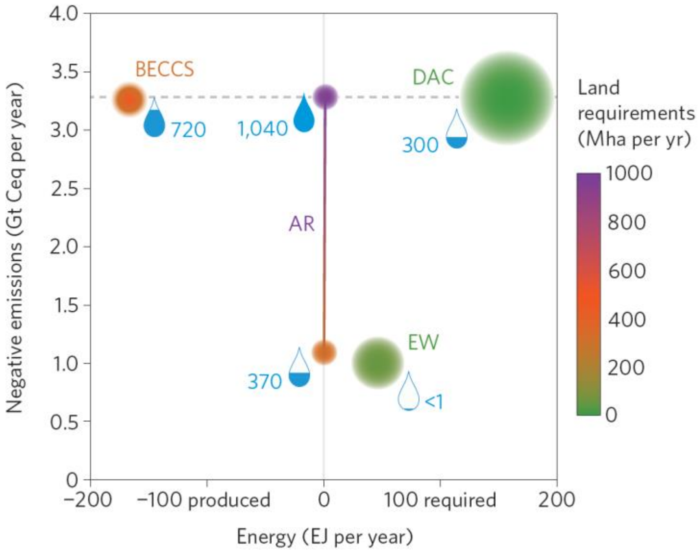
Energy crop productivity is estimated at 4.7-8.6 tC/ha/y for short rotation coppices (including willows and poplars) and *Miscunthas*.

Costs

\$40/tCO_2 - \$100/tCO_2 (Model median price in 2100 at \$36/tCO_2)

Potential

BECCS has potential to absorb 12.1 GtCO_2/y in 2100 in a scenario to limit the CO_2 concentration to a 430-480 ppm range.



Effects of negative emission technology

Source: Smith et al., 2015

Future challenges

BECCS, which could produce negative emissions totalling 12.1 GtCO_2/y, will require lands totalling 380-700 million ha in 2100, depending on productivity.

Lands for BECCS (280-700 million ha) will account for 7-25% of agricultural land (including permanent pastures) totalling 4.96 billion ha in 2000 and 25-46% of arable plus permanent crop (including fruit trees) area totalling 1.52 billion ha. BECCS land demand will be two to four times as much as abandoned or marginal lands. Massive land utilisation for BECCS will affect food production, creating constraints on BECCS.

Source: Smith et al., 2015

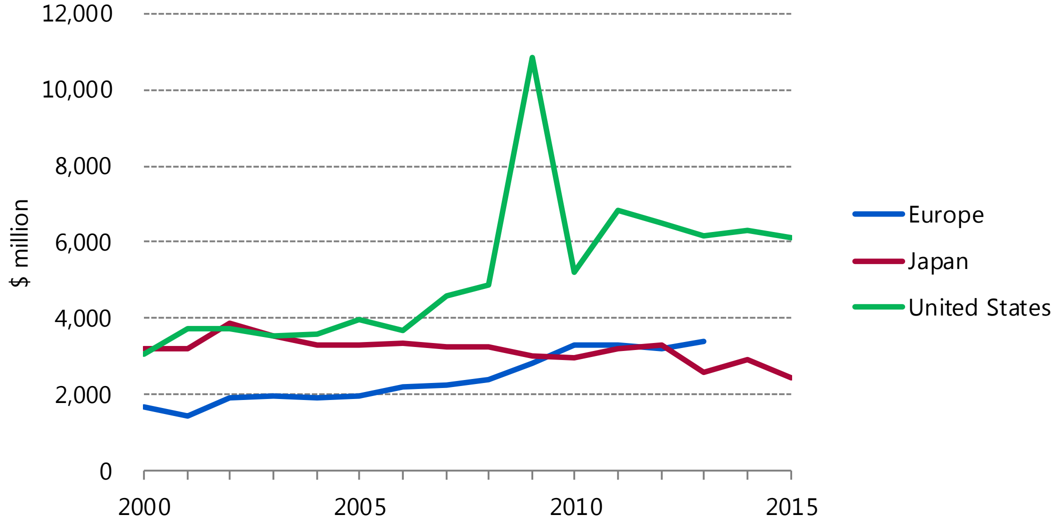
(Reference)

Geoengineering	
Present technology development situation	Geoengineering represents approaches or technologies to intervene in the earth's climate system to mitigate climate change. The approaches or technologies are grouped into two categories – solar radiation management to reduce solar energy absorbed into the climate system and carbon dioxide removal to increase net carbon removal from the atmosphere in a scale large enough to change the climate system. Solar radiation management intentionally changes shortwave radiation to the earth to mitigate climate change. It includes the injection of aerosols into the stratosphere. Geoengineering technologies are hypothetical at present. It is uncertain whether these technologies could contribute to avoiding future climate change effects.
Costs	Some studies indicate that some solar radiation management technologies feature low costs.
Potential	As geoengineering technologies' effects or risks are still unknown, it is uncertain whether geoengineering technologies such as carbon dioxide removal and solar radiation management could play any useful role in changing the GHG emission path.
Future challenges	Geoengineering is feared to utilise or affect the climate system and exert unintended cross-border effects. Solar radiation management has the following challenges: ● Solar radiation management may have to be continued to avoid global warming as far as the GHG concentration remains high. ● Solar radiation management may fall short of reversing all climate change caused by a GHG concentration rise, having different effects from region to region. ● Solar radiation management may have spinoff effects in addition to a climate change avoidance. For example, the introduction of sulphuric acid aerosol could reduce the ozone level.

Trends of research and development budgets and desirable direction

How are the budgets for energy technology development described above? Figure 6-19 shows the trends of energy technology research, development and demonstration budgets in Japan, the United States and Europe as seen from the IEA's energy technology research, development and demonstration data.

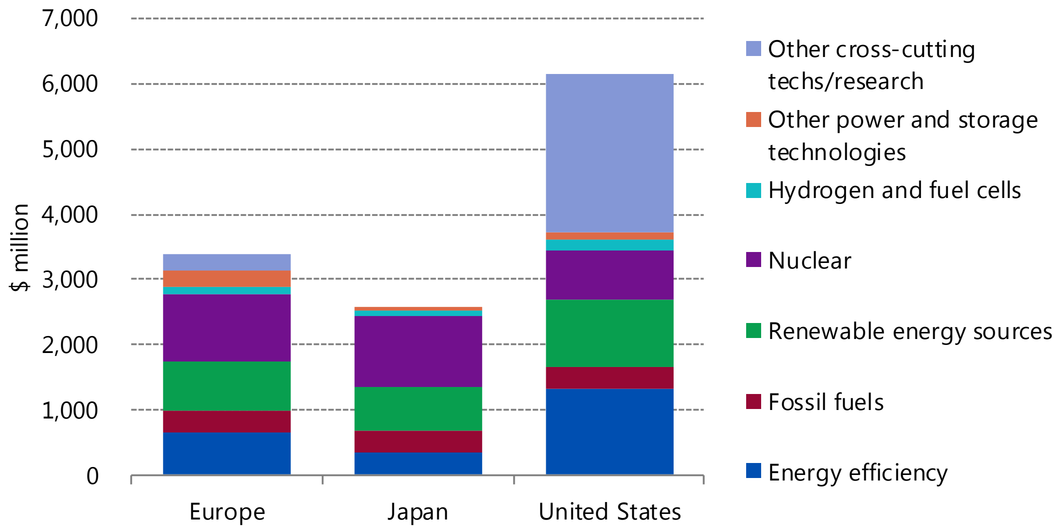
Figure 6-19 | Trends of Japanese, U.S. and European budgets for energy technology research, development and demonstration



Note: Europe is represented by four major countries – France, Germany, Italy and the United Kingdom. The peak in 2009 in the United States represents spending under the American Recovery and Reinvestment Act of 2009.
Source: IEA energy technology RD&D database

The energy technology research, development and demonstration budget in 2013 totalled $6.1 billion in the United States, $3.4 billion in the four European countries and $2.6 billion in Japan. U.S. and European budgets doubled from 2000 to 2013 while Japanese budgets decreased by 20%.

Figure 6-20 | Japanese, U.S. and European budgets by technology category (2013)



Note: Europe is represented by four countries – France, Germany, Italy and the United Kingdom.
Source: IEA energy technology RD&D database.

Spending priority is given in the order of nuclear, renewable energy and energy efficiency in Japan and Europe. In contrast, the United States gives spending priority in the order of cross-cutting technologies and research (basic research), energy efficiency and renewable energy, featuring more spending on basic research. From 2000 to 2013, the United States and Europe expanded budgets for renewable energy and energy efficiency. The United States also increased budgets for cross-cutting technologies and research. Japan reduced budgets for nuclear.

Energy technology research, development demonstration budgets centre on existing energy sources such as nuclear, energy efficiency, renewable energy and fossil fuels. Long-term technology research and development should be given greater priority.

Annex

Table A1 | Regional groupings

Asia	People's Republic of China	
	Hong Kong	
	India	
	Japan	
	Korea	
	Chinese Taipei	
	ASEAN	Brunei Darussalam
		Indonesia
		Malaysia
		Myanmar
		Philippines
		Singapore
		Thailand
		Viet Nam
	Others	Bangladesh, D. P. R. Korea, Mongolia, Nepal, Pakistan, Sri Lanka, and Other Asia 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, Latvia, 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, 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 and Latvia before 1990, and (2) OECD does not include Israel.

Table A2 | Major energy and economic indicators

				Reference		Advanced Technologies		CAGR (%)		
								1990/	2015/2050	
		1990	2015	2030	2050	2030	2050	2015	Reference	Adv. Tech.
Total primary energy consumption (Mtoe)	World	8,774	13,647	16,562	19,789	15,717	17,219	1.8	1.1	0.7
	Asia	2,108	5,459	7,434	9,351	7,078	8,156	3.9	1.5	1.2
	China	871	2,973	3,695	4,021	3,485	3,416	5.0	0.9	0.4
	India	306	851	1,585	2,545	1,492	2,158	4.2	3.2	2.7
	Japan	439	430	433	391	425	369	-0.1	-0.3	-0.4
Oil consumption (Mtoe)	World	3,235	4,334	5,024	5,849	4,625	4,656	1.2	0.9	0.2
	Asia	618	1,330	1,820	2,323	1,720	1,974	3.1	1.6	1.1
	China	119	534	763	795	722	673	6.2	1.1	0.7
	India	61	206	377	683	358	582	5.0	3.5	3.0
	Japan	250	185	151	115	141	100	-1.2	-1.4	-1.7
Natural gas consumption (Mtoe)	World	1,663	2,944	3,845	5,194	3,584	4,157	2.3	1.6	1.0
	Asia	116	547	965	1,567	906	1,294	6.4	3.1	2.5
	China	13	159	343	561	333	448	10.6	3.7	3.0
	India	11	43	124	274	122	235	5.8	5.4	5.0
	Japan	44	100	98	98	86	82	3.3	-0.1	-0.6
Coal consumption (Mtoe)	World	2,220	3,836	4,254	4,531	3,606	2,937	2.2	0.5	-0.8
	Asia	785	2,739	3,320	3,754	2,848	2,499	5.1	0.9	-0.3
	China	528	1,982	2,096	1,935	1,806	1,219	5.4	-0.1	-1.4
	India	93	379	720	1,143	606	775	5.8	3.2	2.1
	Japan	76	117	112	104	103	76	1.7	-0.3	-1.2
Power generation (TWh)	World	11,864	24,255	32,965	44,838	31,482	39,733	2.9	1.8	1.4
	Asia	2,252	10,204	15,895	22,874	15,136	20,032	6.2	2.3	1.9
	China	621	5,844	8,441	10,763	8,036	9,298	9.4	1.8	1.3
	India	293	1,383	3,106	5,663	2,904	4,845	6.4	4.1	3.6
	Japan	873	1,035	1,136	1,150	1,109	1,091	0.7	0.3	0.1
Energy-related carbon dioxide emissions (Mt)	World	21,205	32,910	38,142	44,107	33,377	29,699	1.8	0.8	-0.3
	Asia	4,918	15,076	19,461	23,706	17,007	15,977	4.6	1.3	0.2
	China	2,339	9,333	10,721	10,517	9,399	6,939	5.7	0.3	-0.8
	India	542	2,107	4,040	6,850	3,491	4,699	5.6	3.4	2.3
	Japan	1,071	1,147	1,023	884	925	691	0.3	-0.7	-1.4
Primary energy consumption per GDP (toe/$2010 million)	World	232	182	144	103	136	90	-1.0	-1.6	-2.0
	Asia	278	244	174	114	166	100	-0.5	-2.2	-2.5
	China	1,050	334	182	100	172	85	-4.5	-3.4	-3.8
	India	651	372	258	160	243	136	-2.2	-2.4	-2.8
	Japan	94	72	62	47	61	44	-1.1	-1.2	-1.4
Primary energy consumption per capita (toe/person)	World	1.66	1.86	1.95	2.04	1.85	1.77	0.5	0.3	-0.1
	Asia	0.72	1.37	1.68	2.01	1.60	1.75	2.6	1.1	0.7
	China	0.77	2.17	2.61	3.00	2.46	2.55	4.2	0.9	0.5
	India	0.35	0.65	1.05	1.53	0.98	1.30	2.5	2.5	2.0
	Japan	3.55	3.39	3.59	3.62	3.52	3.42	-0.2	0.2	0.0
GDP ($2010 billion)	World	37,797	75,059	115,303	191,400	115,303	191,400	2.8	2.7	2.7
	Asia	7,586	22,344	42,637	81,910	42,637	81,910	4.4	3.8	3.8
	China	830	8,910	20,311	40,328	20,311	40,328	10.0	4.4	4.4
	India	470	2,288	6,133	15,857	6,133	15,857	6.5	5.7	5.7
	Japan	4,683	5,986	6,948	8,329	6,948	8,329	1.0	0.9	0.9
Population (Million)	World	5,277	7,336	8,497	9,710	8,497	9,710	1.3	0.8	0.8
	Asia	2,932	3,993	4,433	4,658	4,433	4,658	1.2	0.4	0.4
	China	1,135	1,371	1,415	1,340	1,415	1,340	0.8	-0.1	-0.1
	India	871	1,311	1,515	1,662	1,515	1,662	1.7	0.7	0.7
	Japan	124	127	121	108	121	108	0.1	-0.5	-0.5

Table A3 | Population

(Million)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	5,277 (100)	6,108 (100)	7,336 (100)	8,497 (100)	9,152 (100)	9,710 (100)	1.3	1.0	0.7	0.6	0.8
Asia	2,932 (55.6)	3,407 (55.8)	3,993 (54.4)	4,433 (52.2)	4,595 (50.2)	4,658 (48.0)	1.2	0.7	0.4	0.1	0.4
China	1,135 (21.5)	1,263 (20.7)	1,371 (18.7)	1,415 (16.6)	1,391 (15.2)	1,340 (13.8)	0.8	0.2	-0.2	-0.4	-0.1
India	871 (16.5)	1,053 (17.2)	1,311 (17.9)	1,515 (17.8)	1,608 (17.6)	1,662 (17.1)	1.7	1.0	0.6	0.3	0.7
Japan	124 (2.3)	127 (2.1)	127 (1.7)	121 (1.4)	114 (1.2)	108 (1.1)	0.1	-0.3	-0.5	-0.6	-0.5
Korea	43 (0.8)	47 (0.8)	51 (0.7)	53 (0.6)	52 (0.6)	50 (0.5)	0.7	0.3	-0.1	-0.4	0.0
Chinese Taipei	20 (0.4)	22 (0.4)	23 (0.3)	24 (0.3)	24 (0.3)	23 (0.2)	0.6	0.2	-0.1	-0.5	-0.1
ASEAN	430 (8.1)	505 (8.3)	608 (8.3)	696 (8.2)	736 (8.0)	761 (7.8)	1.4	0.9	0.6	0.3	0.6
Indonesia	181 (3.4)	212 (3.5)	258 (3.5)	295 (3.5)	312 (3.4)	322 (3.3)	1.4	0.9	0.6	0.3	0.6
Malaysia	18 (0.3)	23 (0.4)	30 (0.4)	36 (0.4)	39 (0.4)	41 (0.4)	2.1	1.2	0.7	0.5	0.9
Myanmar	42 (0.8)	48 (0.8)	54 (0.7)	61 (0.7)	63 (0.7)	64 (0.7)	1.0	0.8	0.4	0.1	0.5
Philippines	62 (1.2)	78 (1.3)	101 (1.4)	124 (1.5)	138 (1.5)	150 (1.5)	2.0	1.4	1.1	0.8	1.1
Singapore	3 (0.1)	4 (0.1)	6 (0.1)	6 (0.1)	7 (0.1)	7 (0.1)	2.4	0.9	0.3	0.0	0.5
Thailand	57 (1.1)	63 (1.0)	68 (0.9)	69 (0.8)	68 (0.7)	65 (0.7)	0.7	0.1	-0.2	-0.4	-0.1
Viet Nam	66 (1.3)	78 (1.3)	92 (1.3)	104 (1.2)	109 (1.2)	112 (1.2)	1.3	0.9	0.5	0.3	0.6
Asia excl. Japan	2,809 (53.2)	3,281 (53.7)	3,866 (52.7)	4,313 (50.8)	4,481 (49.0)	4,551 (46.9)	1.3	0.7	0.4	0.2	0.5
North America	277 (5.3)	313 (5.1)	357 (4.9)	397 (4.7)	419 (4.6)	436 (4.5)	1.0	0.7	0.5	0.4	0.6
United States	250 (4.7)	282 (4.6)	321 (4.4)	356 (4.2)	376 (4.1)	391 (4.0)	1.0	0.7	0.5	0.4	0.6
Latin America	442 (8.4)	522 (8.5)	629 (8.6)	715 (8.4)	754 (8.2)	777 (8.0)	1.4	0.9	0.5	0.3	0.6
OECD Europe	502 (9.5)	524 (8.6)	566 (7.7)	586 (6.9)	591 (6.5)	589 (6.1)	0.5	0.2	0.1	0.0	0.1
European Union	478 (9.1)	488 (8.0)	510 (6.9)	524 (6.2)	526 (5.7)	523 (5.4)	0.3	0.2	0.0	-0.1	0.1
Non-OECD Europe	341 (6.5)	339 (5.5)	341 (4.7)	344 (4.1)	341 (3.7)	337 (3.5)	0.0	0.1	-0.1	-0.1	0.0
Africa	631 (12.0)	813 (13.3)	1,185 (16.2)	1,691 (19.9)	2,085 (22.8)	2,509 (25.8)	2.6	2.4	2.1	1.9	2.2
Middle East	132 (2.5)	168 (2.7)	235 (3.2)	297 (3.5)	332 (3.6)	364 (3.7)	2.3	1.6	1.1	0.9	1.3
Oceania	20 (0.4)	23 (0.4)	28 (0.4)	33 (0.4)	36 (0.4)	39 (0.4)	1.3	1.1	0.8	0.7	0.9
OECD	1,065 (20.2)	1,151 (18.8)	1,275 (17.4)	1,358 (16.0)	1,392 (15.2)	1,409 (14.5)	0.7	0.4	0.2	0.1	0.3
Non-OECD	4,213 (79.8)	4,957 (81.2)	6,062 (82.6)	7,139 (84.0)	7,760 (84.8)	8,301 (85.5)	1.5	1.1	0.8	0.7	0.9

Source: United Nations "Population Estimates and Projections: The 2017 Revision", World Bank "World Development Indicators"

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

Table A4 | GDP

($2010 billion)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	37,797 (100)	49,825 (100)	75,059 (100)	115,303 (100)	152,089 (100)	191,400 (100)	2.8	2.9	2.8	2.3	2.7
Asia	7,586 (20.1)	11,047 (22.2)	22,344 (29.8)	42,637 (37.0)	61,674 (40.6)	81,910 (42.8)	4.4	4.4	3.8	2.9	3.8
China	830 (2.2)	2,237 (4.5)	8,910 (11.9)	20,311 (17.6)	30,759 (20.2)	40,328 (21.1)	10.0	5.6	4.2	2.7	4.4
India	470 (1.2)	809 (1.6)	2,288 (3.0)	6,133 (5.3)	10,236 (6.7)	15,857 (8.3)	6.5	6.8	5.3	4.5	5.7
Japan	4,683 (12.4)	5,349 (10.7)	5,986 (8.0)	6,948 (6.0)	7,705 (5.1)	8,329 (4.4)	1.0	1.0	1.0	0.8	0.9
Korea	377 (1.0)	710 (1.4)	1,267 (1.7)	1,877 (1.6)	2,284 (1.5)	2,633 (1.4)	5.0	2.7	2.0	1.4	2.1
Chinese Taipei	162 (0.4)	309 (0.6)	527 (0.7)	715 (0.6)	851 (0.6)	975 (0.5)	4.8	2.1	1.8	1.4	1.8
ASEAN	741 (2.0)	1,180 (2.4)	2,490 (3.3)	4,955 (4.3)	7,383 (4.9)	10,390 (5.4)	5.0	4.7	4.1	3.5	4.2
Indonesia	310 (0.8)	453 (0.9)	988 (1.3)	2,124 (1.8)	3,329 (2.2)	4,819 (2.5)	4.7	5.2	4.6	3.8	4.6
Malaysia	82 (0.2)	163 (0.3)	330 (0.4)	629 (0.5)	895 (0.6)	1,205 (0.6)	5.7	4.4	3.6	3.0	3.8
Myanmar	7 (0.0)	13 (0.0)	59 (0.1)	153 (0.1)	252 (0.2)	384 (0.2)	9.1	6.5	5.1	4.3	5.5
Philippines	95 (0.3)	125 (0.3)	266 (0.4)	609 (0.5)	901 (0.6)	1,286 (0.7)	4.2	5.7	4.0	3.6	4.6
Singapore	68 (0.2)	134 (0.3)	287 (0.4)	407 (0.4)	487 (0.3)	547 (0.3)	6.0	2.4	1.8	1.2	1.9
Thailand	142 (0.4)	218 (0.4)	392 (0.5)	642 (0.6)	884 (0.6)	1,157 (0.6)	4.2	3.3	3.2	2.7	3.1
Viet Nam	29 (0.1)	61 (0.1)	155 (0.2)	367 (0.3)	607 (0.4)	957 (0.5)	6.9	5.9	5.2	4.7	5.3
Asia excl. Japan	2,903 (7.7)	5,698 (11.4)	16,358 (21.8)	35,689 (31.0)	53,969 (35.5)	73,581 (38.4)	7.2	5.3	4.2	3.1	4.4
North America	10,078 (26.7)	14,056 (28.2)	18,394 (24.5)	25,027 (21.7)	30,559 (20.1)	36,274 (19.0)	2.4	2.1	2.0	1.7	2.0
United States	9,064 (24.0)	12,713 (25.5)	16,597 (22.1)	22,629 (19.6)	27,677 (18.2)	32,902 (17.2)	2.4	2.1	2.0	1.7	2.0
Latin America	2,779 (7.4)	3,767 (7.6)	5,779 (7.7)	8,545 (7.4)	11,704 (7.7)	14,903 (7.8)	3.0	2.6	3.2	2.4	2.7
OECD Europe	12,666 (33.5)	15,889 (31.9)	19,517 (26.0)	24,815 (21.5)	28,286 (18.6)	31,565 (16.5)	1.7	1.6	1.3	1.1	1.4
European Union	11,888 (31.5)	14,768 (29.6)	17,885 (23.8)	22,762 (19.7)	26,005 (17.1)	29,079 (15.2)	1.6	1.6	1.3	1.1	1.4
Non-OECD Europe	2,142 (5.7)	1,496 (3.0)	2,658 (3.5)	3,862 (3.3)	5,106 (3.4)	6,671 (3.5)	0.9	2.5	2.8	2.7	2.7
Africa	876 (2.3)	1,145 (2.3)	2,261 (3.0)	4,224 (3.7)	6,841 (4.5)	10,197 (5.3)	3.9	4.3	4.9	4.1	4.4
Middle East	949 (2.5)	1,430 (2.9)	2,582 (3.4)	4,001 (3.5)	5,302 (3.5)	6,834 (3.6)	4.1	3.0	2.9	2.6	2.8
Oceania	721 (1.9)	995 (2.0)	1,524 (2.0)	2,192 (1.9)	2,619 (1.7)	3,045 (1.6)	3.0	2.5	1.8	1.5	2.0
OECD	29,226 (77.3)	38,029 (76.3)	48,159 (64.2)	63,177 (54.8)	74,658 (49.1)	85,986 (44.9)	2.0	1.8	1.7	1.4	1.7
Non-OECD	8,572 (22.7)	11,796 (23.7)	26,900 (35.8)	52,126 (45.2)	77,431 (50.9)	105,413 (55.1)	4.7	4.5	4.0	3.1	4.0

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

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

Table A5 | GDP per capita

($2010 thousand/person)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/ 2015	2015/ 2030	2030/ 2040	2040/ 2050	2015/ 2050
World	7.2	8.2	10.2	13.6	16.6	19.7	1.4	1.9	2.0	1.7	1.9
Asia	2.6	3.2	5.6	9.6	13.4	17.6	3.1	3.7	3.4	2.7	3.3
China	0.7	1.8	6.5	14.4	22.1	30.1	9.1	5.4	4.4	3.1	4.5
India	0.5	0.8	1.7	4.0	6.4	9.5	4.8	5.8	4.6	4.1	5.0
Japan	37.9	42.2	47.2	57.6	67.4	77.2	0.9	1.3	1.6	1.4	1.4
Korea	8.8	15.1	25.0	35.6	43.6	52.2	4.3	2.4	2.0	1.8	2.1
Chinese Taipei	7.9	13.9	22.4	29.6	35.7	42.8	4.2	1.9	1.9	1.8	1.9
ASEAN	1.7	2.3	4.1	7.1	10.0	13.7	3.5	3.8	3.5	3.1	3.5
Indonesia	1.7	2.1	3.8	7.2	10.7	15.0	3.3	4.3	4.0	3.5	4.0
Malaysia	4.5	6.9	10.9	17.3	22.8	29.3	3.6	3.1	2.8	2.5	2.9
Myanmar	0.2	0.3	1.1	2.5	4.0	6.0	8.0	5.7	4.7	4.2	5.0
Philippines	1.5	1.6	2.6	4.9	6.5	8.6	2.2	4.2	2.9	2.8	3.4
Singapore	22.2	33.4	51.9	64.1	74.2	83.3	3.5	1.4	1.5	1.2	1.4
Thailand	2.5	3.5	5.8	9.3	13.1	17.9	3.4	3.2	3.4	3.2	3.3
Viet Nam	0.4	0.8	1.7	3.5	5.6	8.5	5.5	5.0	4.7	4.3	4.7
Asia excl. Japan	1.0	1.7	4.2	8.3	12.0	16.2	5.8	4.6	3.8	3.0	3.9
North America	36.3	44.9	51.5	63.1	73.0	83.2	1.4	1.4	1.5	1.3	1.4
United States	36.3	45.1	51.6	63.5	73.6	84.1	1.4	1.4	1.5	1.3	1.4
Latin America	6.3	7.2	9.2	11.9	15.5	19.2	1.5	1.8	2.7	2.1	2.1
OECD Europe	25.2	30.4	34.5	42.3	47.9	53.6	1.3	1.4	1.2	1.1	1.3
European Union	24.9	30.3	35.1	43.5	49.4	55.6	1.4	1.4	1.3	1.2	1.3
Non-OECD Europe	6.3	4.4	7.8	11.2	15.0	19.8	0.9	2.5	2.9	2.8	2.7
Africa	1.4	1.4	1.9	2.5	3.3	4.1	1.3	1.8	2.8	2.2	2.2
Middle East	7.2	8.5	11.0	13.5	16.0	18.8	1.7	1.4	1.7	1.6	1.5
Oceania	35.4	43.3	53.7	65.6	72.3	78.4	1.7	1.3	1.0	0.8	1.1
OECD	27.5	33.0	37.8	46.5	53.6	61.0	1.3	1.4	1.4	1.3	1.4
Non-OECD	2.0	2.4	4.4	7.3	10.0	12.7	3.2	3.4	3.2	2.4	3.0

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

Table A6 | International energy prices

Real prices		2016	2020	2030	2040	2050	CAGR (%) 2016/2020	2020/2030	2030/2040	2040/2050	2016/2050
Oil	$2016/bbl	44	70	95	115	125	12.3	3.1	1.9	0.8	3.1
Natural gas											
Japan	$2016/MBtu	6.9	9.0	10.9	12.4	12.6	6.7	2.0	1.3	0.2	1.8
Europe (UK)	$2016/MBtu	4.7	7.1	8.3	9.3	9.5	10.9	1.5	1.2	0.3	2.1
United States	$2016/MBtu	2.5	3.8	4.5	5.5	6.0	11.0	1.7	2.0	0.9	2.6
Steam coal	$2016/t	73	83	100	121	132	3.1	1.9	1.9	0.8	1.7

Nominal prices		2016	2020	2030	2040	2050	CAGR (%) 2016/2020	2020/2030	2030/2040	2040/2050	2016/2050
Oil	$/bbl	44	76	125	185	245	14.6	5.2	4.0	2.9	5.2
Natural gas											
Japan	$/MBtu	6.9	9.7	14.4	19.9	24.7	8.9	4.0	3.3	2.2	3.8
Europe (UK)	$/MBtu	4.7	7.7	10.9	14.9	18.6	13.1	3.5	3.2	2.3	4.1
United States	$/MBtu	2.5	4.1	5.9	8.8	11.8	13.3	3.7	4.1	2.9	4.7
Steam coal	$/t	73	89	132	195	258	5.2	4.0	4.0	2.9	3.8

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

Table A7 | Primary energy consumption [Reference Scenario]

(Mtoe)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	8,774 (100)	10,028 (100)	13,647 (100)	16,562 (100)	18,374 (100)	19,789 (100)	1.8	1.3	1.0	0.7	1.1
Asia	2,108 (24.0)	2,887 (28.8)	5,459 (40.0)	7,434 (44.9)	8,548 (46.5)	9,351 (47.3)	3.9	2.1	1.4	0.9	1.5
China	871 (9.9)	1,130 (11.3)	2,973 (21.8)	3,695 (22.3)	4,005 (21.8)	4,021 (20.3)	5.0	1.5	0.8	0.0	0.9
India	306 (3.5)	441 (4.4)	851 (6.2)	1,585 (9.6)	2,061 (11.2)	2,545 (12.9)	4.2	4.2	2.7	2.1	3.2
Japan	439 (5.0)	518 (5.2)	430 (3.1)	433 (2.6)	414 (2.3)	391 (2.0)	-0.1	0.0	-0.4	-0.6	-0.3
Korea	93 (1.1)	188 (1.9)	273 (2.0)	292 (1.8)	283 (1.5)	263 (1.3)	4.4	0.5	-0.3	-0.7	-0.1
Chinese Taipei	48 (0.5)	85 (0.8)	109 (0.8)	110 (0.7)	109 (0.6)	103 (0.5)	3.3	0.1	-0.2	-0.5	-0.1
ASEAN	233 (2.7)	379 (3.8)	621 (4.5)	982 (5.9)	1,259 (6.9)	1,544 (7.8)	4.0	3.1	2.5	2.1	2.6
Indonesia	99 (1.1)	156 (1.6)	225 (1.7)	394 (2.4)	511 (2.8)	619 (3.1)	3.4	3.8	2.7	1.9	2.9
Malaysia	22 (0.2)	49 (0.5)	86 (0.6)	120 (0.7)	142 (0.8)	158 (0.8)	5.6	2.3	1.7	1.1	1.8
Myanmar	11 (0.1)	13 (0.1)	20 (0.1)	35 (0.2)	50 (0.3)	69 (0.3)	2.5	3.9	3.6	3.3	3.6
Philippines	29 (0.3)	40 (0.4)	52 (0.4)	97 (0.6)	132 (0.7)	175 (0.9)	2.4	4.3	3.0	2.9	3.5
Singapore	12 (0.1)	19 (0.2)	26 (0.2)	30 (0.2)	33 (0.2)	34 (0.2)	3.2	1.2	0.8	0.4	0.8
Thailand	42 (0.5)	72 (0.7)	135 (1.0)	174 (1.1)	210 (1.1)	245 (1.2)	4.8	1.7	1.9	1.6	1.7
Viet Nam	18 (0.2)	29 (0.3)	74 (0.5)	128 (0.8)	178 (1.0)	240 (1.2)	5.8	3.7	3.3	3.0	3.4
Asia excl. Japan	1,669 (19.0)	2,369 (23.6)	5,029 (36.8)	7,001 (42.3)	8,134 (44.3)	8,960 (45.3)	4.5	2.2	1.5	1.0	1.7
North America	2,126 (24.2)	2,527 (25.2)	2,458 (18.0)	2,420 (14.6)	2,382 (13.0)	2,312 (11.7)	0.6	-0.1	-0.2	-0.3	-0.2
United States	1,915 (21.8)	2,273 (22.7)	2,188 (16.0)	2,154 (13.0)	2,116 (11.5)	2,049 (10.4)	0.5	-0.1	-0.2	-0.3	-0.2
Latin America	465 (5.3)	600 (6.0)	851 (6.2)	1,092 (6.6)	1,264 (6.9)	1,378 (7.0)	2.5	1.7	1.5	0.9	1.4
OECD Europe	1,629 (18.6)	1,752 (17.5)	1,706 (12.5)	1,658 (10.0)	1,606 (8.7)	1,561 (7.9)	0.2	-0.2	-0.3	-0.3	-0.3
European Union	1,647 (18.8)	1,695 (16.9)	1,586 (11.6)	1,545 (9.3)	1,499 (8.2)	1,458 (7.4)	-0.1	-0.2	-0.3	-0.3	-0.2
Non-OECD Europe	1,530 (17.4)	1,000 (10.0)	1,106 (8.1)	1,216 (7.3)	1,322 (7.2)	1,451 (7.3)	-1.3	0.6	0.8	0.9	0.8
Africa	393 (4.5)	496 (4.9)	788 (5.8)	1,086 (6.6)	1,349 (7.3)	1,635 (8.3)	2.8	2.2	2.2	1.9	2.1
Middle East	223 (2.5)	372 (3.7)	752 (5.5)	993 (6.0)	1,153 (6.3)	1,291 (6.5)	5.0	1.9	1.5	1.1	1.6
Oceania	99 (1.1)	120 (1.2)	146 (1.1)	153 (0.9)	152 (0.8)	150 (0.8)	1.6	0.3	-0.1	-0.1	0.1
OECD	4,524 (51.6)	5,281 (52.7)	5,236 (38.4)	5,240 (31.6)	5,162 (28.1)	5,032 (25.4)	0.6	0.0	-0.1	-0.3	-0.1
Non-OECD	4,048 (46.1)	4,472 (44.6)	8,029 (58.8)	10,812 (65.3)	12,613 (68.6)	14,096 (71.2)	2.8	2.0	1.6	1.1	1.6

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

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

Table A8 | Primary energy consumption, coal [Reference Scenario]

(Mtoe)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	2,220 (100)	2,311 (100)	3,836 (100)	4,254 (100)	4,486 (100)	4,531 (100)	2.2	0.7	0.5	0.1	0.5
Asia	785 (35.4)	1,037 (44.9)	2,739 (71.4)	3,320 (78.0)	3,632 (81.0)	3,754 (82.9)	5.1	1.3	0.9	0.3	0.9
China	528 (23.8)	665 (28.8)	1,982 (51.7)	2,096 (49.3)	2,109 (47.0)	1,935 (42.7)	5.4	0.4	0.1	-0.9	-0.1
India	93 (4.2)	146 (6.3)	379 (9.9)	720 (16.9)	932 (20.8)	1,143 (25.2)	5.8	4.4	2.6	2.1	3.2
Japan	76 (3.4)	97 (4.2)	117 (3.1)	112 (2.6)	110 (2.5)	104 (2.3)	1.7	-0.3	-0.1	-0.6	-0.3
Korea	25 (1.1)	42 (1.8)	81 (2.1)	92 (2.2)	91 (2.0)	82 (1.8)	4.7	0.9	-0.1	-1.0	0.0
Chinese Taipei	11 (0.5)	30 (1.3)	40 (1.0)	42 (1.0)	39 (0.9)	33 (0.7)	5.1	0.4	-0.9	-1.5	-0.5
ASEAN	13 (0.6)	32 (1.4)	114 (3.0)	217 (5.1)	300 (6.7)	398 (8.8)	9.2	4.4	3.3	2.9	3.6
Indonesia	4 (0.2)	12 (0.5)	41 (1.1)	87 (2.0)	123 (2.7)	161 (3.6)	10.3	5.1	3.6	2.8	4.0
Malaysia	1 (0.1)	2 (0.1)	18 (0.5)	31 (0.7)	38 (0.8)	47 (1.0)	10.8	4.0	1.9	2.3	2.9
Myanmar	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.1)	5 (0.1)	9 (0.2)	7.9	13.4	6.2	5.3	9.0
Philippines	2 (0.1)	5 (0.2)	13 (0.3)	25 (0.6)	36 (0.8)	49 (1.1)	8.8	4.7	3.4	3.2	3.9
Singapore	0 (0.0)	- (-)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	12.5	0.1	0.0	-0.5	-0.1
Thailand	4 (0.2)	8 (0.3)	17 (0.4)	24 (0.6)	30 (0.7)	34 (0.8)	6.1	2.4	2.2	1.3	2.0
Viet Nam	2 (0.1)	4 (0.2)	25 (0.7)	47 (1.1)	68 (1.5)	97 (2.1)	10.2	4.3	3.9	3.6	4.0
Asia excl. Japan	708 (31.9)	939 (40.7)	2,622 (68.3)	3,208 (75.4)	3,521 (78.5)	3,650 (80.6)	5.4	1.4	0.9	0.4	1.0
North America	485 (21.8)	565 (24.5)	393 (10.2)	289 (6.8)	230 (5.1)	168 (3.7)	-0.8	-2.0	-2.3	-3.1	-2.4
United States	460 (20.7)	534 (23.1)	374 (9.8)	278 (6.5)	221 (4.9)	162 (3.6)	-0.8	-2.0	-2.3	-3.1	-2.4
Latin America	21 (1.0)	27 (1.2)	47 (1.2)	59 (1.4)	68 (1.5)	72 (1.6)	3.3	1.4	1.6	0.6	1.2
OECD Europe	449 (20.2)	331 (14.3)	285 (7.4)	226 (5.3)	186 (4.1)	154 (3.4)	-1.8	-1.5	-1.9	-1.9	-1.7
European Union	455 (20.5)	321 (13.9)	263 (6.9)	210 (4.9)	173 (3.9)	144 (3.2)	-2.2	-1.5	-1.9	-1.8	-1.7
Non-OECD Europe	367 (16.5)	209 (9.0)	211 (5.5)	185 (4.3)	183 (4.1)	183 (4.0)	-2.2	-0.9	-0.1	0.0	-0.4
Africa	74 (3.3)	90 (3.9)	107 (2.8)	122 (2.9)	134 (3.0)	150 (3.3)	1.5	0.8	1.0	1.1	1.0
Middle East	3 (0.1)	8 (0.3)	10 (0.3)	16 (0.4)	18 (0.4)	19 (0.4)	4.9	3.3	1.2	0.8	2.0
Oceania	36 (1.6)	44 (1.9)	44 (1.2)	39 (0.9)	34 (0.8)	31 (0.7)	0.8	-0.9	-1.2	-1.1	-1.0
OECD	1,079 (48.6)	1,089 (47.1)	941 (24.5)	786 (18.5)	685 (15.3)	575 (12.7)	-0.5	-1.2	-1.4	-1.7	-1.4
Non-OECD	1,141 (51.4)	1,222 (52.9)	2,895 (75.5)	3,468 (81.5)	3,801 (84.7)	3,956 (87.3)	3.8	1.2	0.9	0.4	0.9

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

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

Table A9 | Primary energy consumption, oil [Reference Scenario]

(Mtoe)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	3,235 (100)	3,660 (100)	4,334 (100)	5,024 (100)	5,471 (100)	5,849 (100)	1.2	1.0	0.9	0.7	0.9
Asia	618 (19.1)	916 (25.0)	1,330 (30.7)	1,820 (36.2)	2,089 (38.2)	2,323 (39.7)	3.1	2.1	1.4	1.1	1.6
China	119 (3.7)	221 (6.0)	534 (12.3)	763 (15.2)	809 (14.8)	795 (13.6)	6.2	2.4	0.6	-0.2	1.1
India	61 (1.9)	112 (3.1)	206 (4.8)	377 (7.5)	521 (9.5)	683 (11.7)	5.0	4.1	3.3	2.7	3.5
Japan	250 (7.7)	255 (7.0)	185 (4.3)	151 (3.0)	133 (2.4)	115 (2.0)	-1.2	-1.3	-1.3	-1.4	-1.4
Korea	50 (1.5)	99 (2.7)	103 (2.4)	105 (2.1)	99 (1.8)	91 (1.6)	2.9	0.1	-0.5	-0.9	-0.3
Chinese Taipei	26 (0.8)	38 (1.0)	42 (1.0)	42 (0.8)	40 (0.7)	37 (0.6)	2.0	-0.1	-0.4	-0.7	-0.4
ASEAN	89 (2.7)	153 (4.2)	210 (4.9)	305 (6.1)	394 (7.2)	493 (8.4)	3.5	2.5	2.6	2.3	2.5
Indonesia	33 (1.0)	58 (1.6)	71 (1.6)	107 (2.1)	142 (2.6)	176 (3.0)	3.1	2.8	2.8	2.2	2.6
Malaysia	11 (0.4)	19 (0.5)	28 (0.6)	34 (0.7)	37 (0.7)	40 (0.7)	3.6	1.4	1.0	0.7	1.1
Myanmar	1 (0.0)	2 (0.1)	5 (0.1)	15 (0.3)	24 (0.4)	36 (0.6)	8.4	7.1	4.7	4.2	5.6
Philippines	11 (0.3)	16 (0.4)	18 (0.4)	34 (0.7)	49 (0.9)	68 (1.2)	2.0	4.4	3.7	3.4	3.9
Singapore	11 (0.4)	17 (0.5)	15 (0.4)	18 (0.4)	20 (0.4)	21 (0.4)	1.2	1.1	0.9	0.6	0.9
Thailand	18 (0.6)	32 (0.9)	54 (1.2)	64 (1.3)	75 (1.4)	87 (1.5)	4.5	1.1	1.7	1.4	1.4
Viet Nam	3 (0.1)	8 (0.2)	19 (0.4)	32 (0.6)	46 (0.8)	64 (1.1)	8.1	3.6	3.5	3.4	3.5
Asia excl. Japan	368 (11.4)	661 (18.1)	1,145 (26.4)	1,669 (33.2)	1,956 (35.8)	2,208 (37.7)	4.6	2.5	1.6	1.2	1.9
North America	833 (25.8)	958 (26.2)	888 (20.5)	805 (16.0)	751 (13.7)	695 (11.9)	0.3	-0.7	-0.7	-0.8	-0.7
United States	757 (23.4)	871 (23.8)	794 (18.3)	717 (14.3)	670 (12.3)	622 (10.6)	0.2	-0.7	-0.7	-0.8	-0.7
Latin America	238 (7.4)	303 (8.3)	377 (8.7)	449 (8.9)	487 (8.9)	491 (8.4)	1.9	1.2	0.8	0.1	0.8
OECD Europe	611 (18.9)	653 (17.8)	554 (12.8)	484 (9.6)	433 (7.9)	387 (6.6)	-0.4	-0.9	-1.1	-1.1	-1.0
European Union	608 (18.8)	625 (17.1)	516 (11.9)	450 (9.0)	401 (7.3)	357 (6.1)	-0.7	-0.9	-1.1	-1.2	-1.0
Non-OECD Europe	465 (14.4)	201 (5.5)	238 (5.5)	247 (4.9)	271 (5.0)	301 (5.1)	-2.6	0.3	0.9	1.1	0.7
Africa	86 (2.7)	97 (2.7)	176 (4.1)	252 (5.0)	340 (6.2)	458 (7.8)	2.9	2.4	3.1	3.0	2.8
Middle East	146 (4.5)	217 (5.9)	341 (7.9)	422 (8.4)	485 (8.9)	536 (9.2)	3.4	1.4	1.4	1.0	1.3
Oceania	35 (1.1)	40 (1.1)	49 (1.1)	48 (1.0)	46 (0.8)	44 (0.7)	1.4	0.0	-0.5	-0.6	-0.3
OECD	1,867 (57.7)	2,105 (57.5)	1,885 (43.5)	1,714 (34.1)	1,588 (29.0)	1,455 (24.9)	0.0	-0.6	-0.8	-0.9	-0.7
Non-OECD	1,166 (36.0)	1,281 (35.0)	2,068 (47.7)	2,815 (56.0)	3,315 (60.6)	3,780 (64.6)	2.3	2.1	1.6	1.3	1.7

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

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

Table A10 | Primary energy consumption, natural gas [Reference Scenario]

(Mtoe)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	1,663 (100)	2,071 (100)	2,944 (100)	3,845 (100)	4,550 (100)	5,194 (100)	2.3	1.8	1.7	1.3	1.6
Asia	116 (7.0)	232 (11.2)	547 (18.6)	965 (25.1)	1,285 (28.2)	1,567 (30.2)	6.4	3.9	2.9	2.0	3.1
China	13 (0.8)	21 (1.0)	159 (5.4)	343 (8.9)	468 (10.3)	561 (10.8)	10.6	5.3	3.2	1.8	3.7
India	11 (0.6)	23 (1.1)	43 (1.5)	124 (3.2)	195 (4.3)	274 (5.3)	5.8	7.3	4.6	3.5	5.4
Japan	44 (2.7)	66 (3.2)	100 (3.4)	98 (2.6)	100 (2.2)	98 (1.9)	3.3	-0.1	0.2	-0.2	-0.1
Korea	3 (0.2)	17 (0.8)	39 (1.3)	56 (1.4)	64 (1.4)	68 (1.3)	11.3	2.3	1.4	0.6	1.6
Chinese Taipei	1 (0.1)	6 (0.3)	15 (0.5)	22 (0.6)	25 (0.5)	27 (0.5)	9.9	2.7	1.3	0.9	1.7
ASEAN	30 (1.8)	74 (3.6)	140 (4.8)	216 (5.6)	280 (6.2)	344 (6.6)	6.3	2.9	2.7	2.1	2.6
Indonesia	16 (1.0)	27 (1.3)	38 (1.3)	72 (1.9)	101 (2.2)	131 (2.5)	3.6	4.4	3.4	2.6	3.6
Malaysia	7 (0.4)	25 (1.2)	38 (1.3)	50 (1.3)	57 (1.3)	61 (1.2)	7.1	1.9	1.4	0.6	1.4
Myanmar	1 (0.0)	1 (0.1)	3 (0.1)	5 (0.1)	7 (0.2)	10 (0.2)	5.7	3.0	4.4	3.4	3.5
Philippines	- (-)	0 (0.0)	3 (0.1)	9 (0.2)	15 (0.3)	24 (0.5)	-	7.6	5.4	4.8	6.2
Singapore	- (-)	1 (0.1)	9 (0.3)	11 (0.3)	11 (0.2)	11 (0.2)	-	1.0	0.4	0.0	0.6
Thailand	5 (0.3)	17 (0.8)	38 (1.3)	49 (1.3)	59 (1.3)	67 (1.3)	8.4	1.7	1.9	1.3	1.6
Viet Nam	0 (0.0)	1 (0.1)	10 (0.3)	18 (0.5)	27 (0.6)	38 (0.7)	38.6	4.4	4.0	3.3	4.0
Asia excl. Japan	72 (4.3)	167 (8.0)	446 (15.2)	866 (22.5)	1,185 (26.0)	1,469 (28.3)	7.6	4.5	3.2	2.2	3.5
North America	493 (29.6)	622 (30.0)	733 (24.9)	819 (21.3)	877 (19.3)	905 (17.4)	1.6	0.7	0.7	0.3	0.6
United States	438 (26.3)	548 (26.4)	646 (22.0)	724 (18.8)	772 (17.0)	794 (15.3)	1.6	0.8	0.7	0.3	0.6
Latin America	72 (4.3)	119 (5.7)	207 (7.0)	281 (7.3)	364 (8.0)	437 (8.4)	4.3	2.1	2.6	1.8	2.2
OECD Europe	262 (15.8)	394 (19.0)	389 (13.2)	425 (11.0)	431 (9.5)	426 (8.2)	1.6	0.6	0.1	-0.1	0.3
European Union	297 (17.9)	396 (19.1)	358 (12.1)	393 (10.2)	400 (8.8)	397 (7.6)	0.7	0.6	0.2	-0.1	0.3
Non-OECD Europe	600 (36.1)	487 (23.5)	526 (17.9)	598 (15.6)	676 (14.8)	751 (14.5)	-0.5	0.9	1.2	1.1	1.0
Africa	30 (1.8)	47 (2.3)	108 (3.7)	183 (4.8)	253 (5.6)	359 (6.9)	5.3	3.6	3.3	3.5	3.5
Middle East	72 (4.3)	145 (7.0)	397 (13.5)	523 (13.6)	602 (13.2)	677 (13.0)	7.1	1.9	1.4	1.2	1.5
Oceania	19 (1.1)	24 (1.2)	36 (1.2)	42 (1.1)	44 (1.0)	45 (0.9)	2.7	1.0	0.4	0.2	0.6
OECD	845 (50.8)	1,164 (56.2)	1,367 (46.4)	1,531 (39.8)	1,628 (35.8)	1,674 (32.2)	1.9	0.8	0.6	0.3	0.6
Non-OECD	818 (49.2)	908 (43.8)	1,577 (53.6)	2,305 (59.9)	2,905 (63.8)	3,493 (67.2)	2.7	2.6	2.3	1.9	2.3

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

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

Table A11 | Final energy consumption [Reference Scenario]

(Mtoe)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/ 2015	2015/ 2030	2030/ 2040	2040/ 2050	2015/ 2050
World	6,268 (100)	7,036 (100)	9,384 (100)	11,346 (100)	12,617 (100)	13,675 (100)	1.6	1.3	1.1	0.8	1.1
Asia	1,551 (24.7)	1,990 (28.3)	3,617 (38.5)	4,838 (42.6)	5,560 (44.1)	6,140 (44.9)	3.4	2.0	1.4	1.0	1.5
China	654 (10.4)	781 (11.1)	1,906 (20.3)	2,346 (20.7)	2,532 (20.1)	2,555 (18.7)	4.4	1.4	0.8	0.1	0.8
India	243 (3.9)	315 (4.5)	578 (6.2)	1,056 (9.3)	1,383 (11.0)	1,729 (12.6)	3.5	4.1	2.7	2.3	3.2
Japan	287 (4.6)	328 (4.7)	291 (3.1)	279 (2.5)	266 (2.1)	251 (1.8)	0.1	-0.3	-0.5	-0.6	-0.4
Korea	65 (1.0)	127 (1.8)	174 (1.9)	191 (1.7)	189 (1.5)	180 (1.3)	4.0	0.6	-0.1	-0.5	0.1
Chinese Taipei	29 (0.5)	49 (0.7)	69 (0.7)	71 (0.6)	71 (0.6)	70 (0.5)	3.4	0.2	0.0	-0.2	0.0
ASEAN	173 (2.8)	270 (3.8)	436 (4.6)	645 (5.7)	817 (6.5)	1,006 (7.4)	3.8	2.6	2.4	2.1	2.4
Indonesia	80 (1.3)	120 (1.7)	163 (1.7)	245 (2.2)	314 (2.5)	382 (2.8)	2.9	2.8	2.5	2.0	2.5
Malaysia	14 (0.2)	30 (0.4)	52 (0.5)	71 (0.6)	82 (0.7)	92 (0.7)	5.4	2.1	1.5	1.2	1.7
Myanmar	9 (0.1)	11 (0.2)	18 (0.2)	31 (0.3)	43 (0.3)	59 (0.4)	2.6	3.7	3.4	3.2	3.5
Philippines	20 (0.3)	24 (0.3)	30 (0.3)	58 (0.5)	82 (0.6)	114 (0.8)	1.7	4.6	3.5	3.3	3.9
Singapore	5 (0.1)	8 (0.1)	17 (0.2)	20 (0.2)	22 (0.2)	23 (0.2)	5.0	1.2	0.8	0.4	0.8
Thailand	29 (0.5)	51 (0.7)	98 (1.0)	122 (1.1)	144 (1.1)	168 (1.2)	5.0	1.4	1.7	1.5	1.5
Viet Nam	16 (0.3)	25 (0.4)	58 (0.6)	96 (0.8)	128 (1.0)	167 (1.2)	5.3	3.4	2.9	2.7	3.1
Asia excl. Japan	1,264 (20.2)	1,662 (23.6)	3,326 (35.4)	4,559 (40.2)	5,294 (42.0)	5,889 (43.1)	3.9	2.1	1.5	1.1	1.6
North America	1,455 (23.2)	1,738 (24.7)	1,714 (18.3)	1,711 (15.1)	1,701 (13.5)	1,669 (12.2)	0.7	0.0	-0.1	-0.2	-0.1
United States	1,294 (20.6)	1,546 (22.0)	1,520 (16.2)	1,516 (13.4)	1,506 (11.9)	1,477 (10.8)	0.6	0.0	-0.1	-0.2	-0.1
Latin America	343 (5.5)	447 (6.4)	610 (6.5)	773 (6.8)	891 (7.1)	975 (7.1)	2.3	1.6	1.4	0.9	1.3
OECD Europe	1,134 (18.1)	1,233 (17.5)	1,202 (12.8)	1,188 (10.5)	1,157 (9.2)	1,123 (8.2)	0.2	-0.1	-0.3	-0.3	-0.2
European Union	1,136 (18.1)	1,180 (16.8)	1,114 (11.9)	1,168 (10.3)	1,138 (9.0)	1,106 (8.1)	-0.1	0.3	-0.3	-0.3	0.0
Non-OECD Europe	1,067 (17.0)	651 (9.3)	701 (7.5)	768 (6.8)	836 (6.6)	918 (6.7)	-1.7	0.6	0.9	0.9	0.8
Africa	292 (4.7)	369 (5.2)	573 (6.1)	804 (7.1)	1,005 (8.0)	1,216 (8.9)	2.7	2.3	2.3	1.9	2.2
Middle East	157 (2.5)	253 (3.6)	489 (5.2)	652 (5.7)	766 (6.1)	868 (6.3)	4.6	1.9	1.6	1.3	1.7
Oceania	66 (1.1)	83 (1.2)	95 (1.0)	102 (0.9)	104 (0.8)	104 (0.8)	1.5	0.5	0.1	0.0	0.3
OECD	3,102 (49.5)	3,624 (51.5)	3,622 (38.6)	3,652 (32.2)	3,619 (28.7)	3,549 (26.0)	0.6	0.1	-0.1	-0.2	-0.1
Non-OECD	2,964 (47.3)	3,138 (44.6)	5,380 (57.3)	7,184 (63.3)	8,399 (66.6)	9,465 (69.2)	2.4	1.9	1.6	1.2	1.6

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

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

Table A12 | Final energy consumption, industry [Reference Scenario]

(Mtoe)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	1,809 (100)	1,868 (100)	2,712 (100)	3,146 (100)	3,499 (100)	3,779 (100)	1.6	1.0	1.1	0.8	1.0
Asia	517 (28.6)	646 (34.6)	1,481 (54.6)	1,759 (55.9)	1,956 (55.9)	2,097 (55.5)	4.3	1.2	1.1	0.7	1.0
China	234 (12.9)	299 (16.0)	966 (35.6)	965 (30.7)	973 (27.8)	937 (24.8)	5.8	0.0	0.1	-0.4	-0.1
India	67 (3.7)	83 (4.5)	195 (7.2)	376 (12.0)	492 (14.1)	597 (15.8)	4.4	4.5	2.7	2.0	3.2
Japan	110 (6.1)	100 (5.3)	82 (3.0)	81 (2.6)	81 (2.3)	78 (2.1)	-1.1	-0.1	0.0	-0.3	-0.1
Korea	19 (1.1)	38 (2.1)	49 (1.8)	53 (1.7)	53 (1.5)	50 (1.3)	3.8	0.5	-0.1	-0.5	0.1
Chinese Taipei	12 (0.7)	19 (1.0)	23 (0.8)	23 (0.7)	23 (0.7)	23 (0.6)	2.4	0.1	0.0	-0.1	0.0
ASEAN	43 (2.4)	75 (4.0)	125 (4.6)	198 (6.3)	257 (7.3)	318 (8.4)	4.4	3.1	2.6	2.2	2.7
Indonesia	18 (1.0)	30 (1.6)	42 (1.5)	69 (2.2)	92 (2.6)	115 (3.0)	3.4	3.4	3.0	2.3	3.0
Malaysia	6 (0.3)	12 (0.6)	15 (0.6)	24 (0.8)	30 (0.9)	36 (0.9)	4.1	3.1	2.3	1.7	2.5
Myanmar	0 (0.0)	1 (0.1)	2 (0.1)	5 (0.2)	7 (0.2)	10 (0.3)	7.1	5.8	4.0	2.8	4.4
Philippines	5 (0.3)	5 (0.3)	7 (0.3)	13 (0.4)	18 (0.5)	24 (0.6)	1.9	4.0	3.0	3.0	3.4
Singapore	1 (0.0)	2 (0.1)	6 (0.2)	6 (0.2)	7 (0.2)	7 (0.2)	9.3	0.8	0.5	0.1	0.5
Thailand	9 (0.5)	17 (0.9)	31 (1.1)	38 (1.2)	46 (1.3)	53 (1.4)	5.2	1.5	1.7	1.4	1.6
Viet Nam	5 (0.3)	8 (0.4)	23 (0.8)	42 (1.3)	57 (1.6)	73 (1.9)	6.7	4.1	3.1	2.6	3.4
Asia excl. Japan	407 (22.5)	546 (29.2)	1,399 (51.6)	1,678 (53.4)	1,876 (53.6)	2,019 (53.4)	5.1	1.2	1.1	0.7	1.1
North America	331 (18.3)	388 (20.7)	304 (11.2)	305 (9.7)	305 (8.7)	299 (7.9)	-0.3	0.0	0.0	-0.2	-0.1
United States	284 (15.7)	332 (17.8)	262 (9.6)	264 (8.4)	265 (7.6)	259 (6.9)	-0.3	0.1	0.0	-0.2	0.0
Latin America	114 (6.3)	148 (7.9)	191 (7.0)	229 (7.3)	274 (7.8)	310 (8.2)	2.1	1.2	1.8	1.2	1.4
OECD Europe	328 (18.2)	326 (17.4)	280 (10.3)	279 (8.9)	276 (7.9)	271 (7.2)	-0.6	0.0	-0.1	-0.2	-0.1
European Union	347 (19.2)	309 (16.6)	254 (9.4)	279 (8.9)	279 (8.0)	278 (7.4)	-1.2	0.6	0.0	0.0	0.3
Non-OECD Europe	394 (21.8)	205 (11.0)	191 (7.0)	214 (6.8)	243 (6.9)	275 (7.3)	-2.9	0.8	1.3	1.3	1.0
Africa	55 (3.0)	58 (3.1)	87 (3.2)	126 (4.0)	173 (5.0)	222 (5.9)	1.9	2.5	3.2	2.5	2.7
Middle East	47 (2.6)	71 (3.8)	150 (5.5)	203 (6.4)	241 (6.9)	274 (7.3)	4.8	2.0	1.7	1.3	1.7
Oceania	23 (1.3)	28 (1.5)	28 (1.0)	30 (1.0)	30 (0.9)	30 (0.8)	0.9	0.5	0.0	-0.1	0.2
OECD	840 (46.5)	914 (48.9)	789 (29.1)	806 (25.6)	815 (23.3)	808 (21.4)	-0.2	0.1	0.1	-0.1	0.1
Non-OECD	968 (53.5)	954 (51.1)	1,923 (70.9)	2,340 (74.4)	2,684 (76.7)	2,970 (78.6)	2.8	1.3	1.4	1.0	1.3

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

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

Table A13 | Final energy consumption, transport [Reference Scenario]

(Mtoe)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	1,573 (100)	1,961 (100)	2,703 (100)	3,230 (100)	3,528 (100)	3,765 (100)	2.2	1.2	0.9	0.7	1.0
Asia	186 (11.9)	320 (16.3)	648 (24.0)	989 (30.6)	1,149 (32.6)	1,274 (33.8)	5.1	2.9	1.5	1.0	2.0
China	33 (2.1)	87 (4.5)	299 (11.0)	504 (15.6)	541 (15.3)	537 (14.3)	9.2	3.6	0.7	-0.1	1.7
India	21 (1.3)	32 (1.6)	86 (3.2)	163 (5.0)	236 (6.7)	304 (8.1)	5.8	4.3	3.8	2.6	3.7
Japan	68 (4.3)	84 (4.3)	71 (2.6)	57 (1.8)	52 (1.5)	47 (1.2)	0.2	-1.4	-1.0	-1.0	-1.2
Korea	15 (0.9)	26 (1.3)	33 (1.2)	36 (1.1)	34 (0.9)	30 (0.8)	3.4	0.4	-0.6	-1.0	-0.3
Chinese Taipei	7 (0.4)	12 (0.6)	12 (0.5)	12 (0.4)	11 (0.3)	9 (0.2)	2.6	-0.4	-0.9	-1.4	-0.8
ASEAN	32 (2.1)	61 (3.1)	117 (4.3)	170 (5.3)	215 (6.1)	270 (7.2)	5.2	2.5	2.4	2.3	2.4
Indonesia	11 (0.7)	21 (1.1)	44 (1.6)	68 (2.1)	88 (2.5)	110 (2.9)	5.8	2.9	2.6	2.2	2.6
Malaysia	5 (0.3)	11 (0.6)	21 (0.8)	24 (0.7)	25 (0.7)	25 (0.7)	6.0	0.8	0.4	0.2	0.5
Myanmar	0 (0.0)	1 (0.1)	4 (0.1)	10 (0.3)	16 (0.5)	25 (0.7)	8.6	7.2	4.9	4.6	5.8
Philippines	5 (0.3)	8 (0.4)	11 (0.4)	24 (0.7)	35 (1.0)	50 (1.3)	3.5	5.5	4.0	3.6	4.5
Singapore	1 (0.1)	2 (0.1)	2 (0.1)	2 (0.1)	2 (0.1)	2 (0.1)	2.3	-0.1	-0.6	-1.0	-0.5
Thailand	9 (0.6)	15 (0.7)	24 (0.9)	26 (0.8)	28 (0.8)	30 (0.8)	3.9	0.6	0.8	0.6	0.7
Viet Nam	1 (0.1)	3 (0.2)	11 (0.4)	15 (0.5)	20 (0.6)	27 (0.7)	8.5	2.4	2.6	3.2	2.7
Asia excl. Japan	118 (7.5)	236 (12.0)	576 (21.3)	931 (28.8)	1,097 (31.1)	1,227 (32.6)	6.5	3.3	1.7	1.1	2.2
North America	531 (33.7)	640 (32.7)	690 (25.5)	640 (19.8)	609 (17.3)	584 (15.5)	1.1	-0.5	-0.5	-0.4	-0.5
United States	488 (31.0)	588 (30.0)	629 (23.3)	578 (17.9)	550 (15.6)	528 (14.0)	1.0	-0.6	-0.5	-0.4	-0.5
Latin America	103 (6.5)	140 (7.2)	222 (8.2)	284 (8.8)	316 (9.0)	332 (8.8)	3.1	1.7	1.1	0.5	1.2
OECD Europe	267 (17.0)	317 (16.2)	335 (12.4)	293 (9.1)	264 (7.5)	241 (6.4)	0.9	-0.9	-1.0	-0.9	-0.9
European Union	259 (16.5)	303 (15.5)	312 (11.6)	273 (8.4)	245 (6.9)	223 (5.9)	0.8	-0.9	-1.1	-0.9	-1.0
Non-OECD Europe	171 (10.9)	110 (5.6)	143 (5.3)	147 (4.6)	153 (4.3)	162 (4.3)	-0.7	0.2	0.4	0.5	0.3
Africa	38 (2.4)	54 (2.8)	105 (3.9)	149 (4.6)	196 (5.6)	247 (6.5)	4.2	2.4	2.8	2.3	2.5
Middle East	51 (3.2)	75 (3.8)	141 (5.2)	180 (5.6)	206 (5.8)	229 (6.1)	4.2	1.6	1.4	1.0	1.4
Oceania	24 (1.5)	30 (1.5)	37 (1.4)	37 (1.2)	37 (1.0)	36 (1.0)	1.8	0.0	-0.2	-0.2	-0.1
OECD	936 (59.5)	1,139 (58.1)	1,227 (45.4)	1,131 (35.0)	1,067 (30.2)	1,012 (26.9)	1.1	-0.5	-0.6	-0.5	-0.5
Non-OECD	435 (27.7)	547 (27.9)	1,095 (40.5)	1,588 (49.2)	1,862 (52.8)	2,092 (55.6)	3.8	2.5	1.6	1.2	1.9

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

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

Table A14 | Final energy consumption, buildings, etc. [Reference Scenario]

(Mtoe)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	2,409 (100)	2,591 (100)	3,132 (100)	3,911 (100)	4,367 (100)	4,779 (100)	1.1	1.5	1.1	0.9	1.2
Asia	733 (30.4)	836 (32.3)	1,124 (35.9)	1,593 (40.7)	1,872 (42.9)	2,126 (44.5)	1.7	2.4	1.6	1.3	1.8
China	344 (14.3)	335 (12.9)	483 (15.4)	661 (16.9)	767 (17.6)	814 (17.0)	1.4	2.1	1.5	0.6	1.5
India	142 (5.9)	173 (6.7)	250 (8.0)	420 (10.7)	525 (12.0)	671 (14.0)	2.3	3.5	2.3	2.5	2.9
Japan	76 (3.1)	103 (4.0)	99 (3.2)	103 (2.6)	97 (2.2)	90 (1.9)	1.1	0.3	-0.6	-0.7	-0.3
Korea	24 (1.0)	37 (1.4)	44 (1.4)	50 (1.3)	50 (1.1)	48 (1.0)	2.4	0.8	0.0	-0.3	0.2
Chinese Taipei	7 (0.3)	10 (0.4)	12 (0.4)	14 (0.4)	14 (0.3)	14 (0.3)	2.5	1.0	0.3	0.0	0.5
ASEAN	87 (3.6)	113 (4.4)	147 (4.7)	211 (5.4)	262 (6.0)	317 (6.6)	2.1	2.5	2.2	1.9	2.2
Indonesia	44 (1.8)	59 (2.3)	70 (2.2)	97 (2.5)	119 (2.7)	140 (2.9)	1.9	2.2	2.0	1.6	2.0
Malaysia	3 (0.1)	5 (0.2)	9 (0.3)	14 (0.4)	17 (0.4)	20 (0.4)	5.2	2.8	1.9	1.4	2.1
Myanmar	8 (0.4)	9 (0.4)	12 (0.4)	15 (0.4)	19 (0.4)	23 (0.5)	1.3	1.7	2.0	2.0	1.9
Philippines	10 (0.4)	10 (0.4)	11 (0.3)	19 (0.5)	25 (0.6)	34 (0.7)	0.1	4.0	3.0	3.0	3.4
Singapore	1 (0.0)	2 (0.1)	3 (0.1)	3 (0.1)	3 (0.1)	3 (0.1)	3.2	1.3	0.6	0.1	0.8
Thailand	11 (0.4)	14 (0.5)	21 (0.7)	29 (0.7)	35 (0.8)	41 (0.9)	2.7	2.1	2.0	1.6	1.9
Viet Nam	10 (0.4)	14 (0.5)	21 (0.7)	33 (0.8)	43 (1.0)	55 (1.2)	3.0	3.0	2.7	2.6	2.8
Asia excl. Japan	657 (27.3)	734 (28.3)	1,025 (32.7)	1,491 (38.1)	1,775 (40.7)	2,036 (42.6)	1.8	2.5	1.8	1.4	2.0
North America	460 (19.1)	537 (20.7)	574 (18.3)	607 (15.5)	621 (14.2)	623 (13.0)	0.9	0.4	0.2	0.0	0.2
United States	403 (16.7)	473 (18.2)	506 (16.2)	537 (13.7)	549 (12.6)	551 (11.5)	0.9	0.4	0.2	0.0	0.2
Latin America	101 (4.2)	120 (4.6)	160 (5.1)	212 (5.4)	246 (5.6)	272 (5.7)	1.9	1.9	1.5	1.0	1.5
OECD Europe	438 (18.2)	475 (18.3)	485 (15.5)	509 (13.0)	508 (11.6)	501 (10.5)	0.4	0.3	0.0	-0.1	0.1
European Union	430 (17.9)	454 (17.5)	450 (14.4)	515 (13.2)	511 (11.7)	501 (10.5)	0.2	0.9	-0.1	-0.2	0.3
Non-OECD Europe	436 (18.1)	287 (11.1)	274 (8.7)	291 (7.4)	298 (6.8)	307 (6.4)	-1.8	0.4	0.2	0.3	0.3
Africa	188 (7.8)	242 (9.3)	362 (11.6)	499 (12.8)	595 (13.6)	695 (14.5)	2.7	2.2	1.8	1.6	1.9
Middle East	40 (1.7)	75 (2.9)	129 (4.1)	170 (4.4)	197 (4.5)	222 (4.6)	4.8	1.9	1.4	1.2	1.6
Oceania	15 (0.6)	19 (0.7)	24 (0.8)	29 (0.7)	31 (0.7)	33 (0.7)	2.0	1.2	0.7	0.5	0.9
OECD	1,036 (43.0)	1,201 (46.4)	1,260 (40.2)	1,344 (34.4)	1,359 (31.1)	1,353 (28.3)	0.8	0.4	0.1	0.0	0.2
Non-OECD	1,373 (57.0)	1,390 (53.6)	1,872 (59.8)	2,567 (65.6)	3,008 (68.9)	3,425 (71.7)	1.2	2.1	1.6	1.3	1.7

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

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

Table A15 | Final energy consumption, electricity [Reference Scenario]

(TWh)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/ 2015	2015/ 2030	2030/ 2040	2040/ 2050	2015/ 2050
World	9,714 (100)	12,698 (100)	20,200 (100)	27,596 (100)	33,166 (100)	38,647 (100)	3.0	2.1	1.9	1.5	1.9
Asia	1,834 (18.9)	3,254 (25.6)	8,605 (42.6)	13,392 (48.5)	16,753 (50.5)	19,824 (51.3)	6.4	3.0	2.3	1.7	2.4
China	454 (4.7)	1,037 (8.2)	4,877 (24.1)	7,111 (25.8)	8,505 (25.6)	9,312 (24.1)	10.0	2.5	1.8	0.9	1.9
India	215 (2.2)	376 (3.0)	1,027 (5.1)	2,387 (8.7)	3,454 (10.4)	4,733 (12.2)	6.5	5.8	3.8	3.2	4.5
Japan	771 (7.9)	969 (7.6)	949 (4.7)	1,043 (3.8)	1,059 (3.2)	1,059 (2.7)	0.8	0.6	0.2	0.0	0.3
Korea	94 (1.0)	263 (2.1)	495 (2.5)	591 (2.1)	628 (1.9)	641 (1.7)	6.9	1.2	0.6	0.2	0.7
Chinese Taipei	77 (0.8)	160 (1.3)	231 (1.1)	261 (0.9)	275 (0.8)	284 (0.7)	4.5	0.8	0.5	0.3	0.6
ASEAN	130 (1.3)	320 (2.5)	786 (3.9)	1,500 (5.4)	2,132 (6.4)	2,899 (7.5)	7.5	4.4	3.6	3.1	3.8
Indonesia	28 (0.3)	79 (0.6)	203 (1.0)	453 (1.6)	668 (2.0)	913 (2.4)	8.2	5.5	4.0	3.2	4.4
Malaysia	20 (0.2)	61 (0.5)	133 (0.7)	222 (0.8)	286 (0.9)	347 (0.9)	7.9	3.5	2.5	2.0	2.8
Myanmar	2 (0.0)	3 (0.0)	13 (0.1)	38 (0.1)	62 (0.2)	95 (0.2)	8.5	7.2	5.0	4.3	5.7
Philippines	21 (0.2)	37 (0.3)	68 (0.3)	155 (0.6)	242 (0.7)	373 (1.0)	4.8	5.7	4.6	4.4	5.0
Singapore	13 (0.1)	27 (0.2)	48 (0.2)	59 (0.2)	63 (0.2)	65 (0.2)	5.3	1.4	0.8	0.3	0.9
Thailand	38 (0.4)	88 (0.7)	175 (0.9)	272 (1.0)	358 (1.1)	445 (1.2)	6.3	3.0	2.8	2.2	2.7
Viet Nam	6 (0.1)	22 (0.2)	143 (0.7)	297 (1.1)	448 (1.3)	656 (1.7)	13.4	5.0	4.2	3.9	4.4
Asia excl. Japan	1,063 (10.9)	2,285 (18.0)	7,656 (37.9)	12,349 (44.7)	15,694 (47.3)	18,765 (48.6)	8.2	3.2	2.4	1.8	2.6
North America	3,052 (31.4)	3,981 (31.4)	4,284 (21.2)	4,804 (17.4)	5,183 (15.6)	5,482 (14.2)	1.4	0.8	0.8	0.6	0.7
United States	2,634 (27.1)	3,499 (27.6)	3,781 (18.7)	4,249 (15.4)	4,575 (13.8)	4,826 (12.5)	1.5	0.8	0.7	0.5	0.7
Latin America	517 (5.3)	798 (6.3)	1,289 (6.4)	1,898 (6.9)	2,428 (7.3)	2,922 (7.6)	3.7	2.6	2.5	1.9	2.4
OECD Europe	2,236 (23.0)	2,711 (21.4)	3,040 (15.0)	3,362 (12.2)	3,554 (10.7)	3,706 (9.6)	1.2	0.7	0.6	0.4	0.6
European Union	2,161 (22.2)	2,528 (19.9)	2,741 (13.6)	3,055 (11.1)	3,242 (9.8)	3,394 (8.8)	1.0	0.7	0.6	0.5	0.6
Non-OECD Europe	1,463 (15.1)	1,006 (7.9)	1,222 (6.1)	1,524 (5.5)	1,820 (5.5)	2,168 (5.6)	-0.7	1.5	1.8	1.8	1.7
Africa	257 (2.6)	361 (2.8)	620 (3.1)	1,018 (3.7)	1,508 (4.5)	2,296 (5.9)	3.6	3.4	4.0	4.3	3.8
Middle East	199 (2.0)	379 (3.0)	890 (4.4)	1,283 (4.6)	1,569 (4.7)	1,863 (4.8)	6.2	2.5	2.0	1.7	2.1
Oceania	157 (1.6)	207 (1.6)	250 (1.2)	315 (1.1)	352 (1.1)	386 (1.0)	1.9	1.5	1.1	0.9	1.2
OECD	6,426 (66.2)	8,313 (65.5)	9,343 (46.3)	10,603 (38.4)	11,416 (34.4)	12,073 (31.2)	1.5	0.8	0.7	0.6	0.7
Non-OECD	3,288 (33.8)	4,384 (34.5)	10,857 (53.7)	16,992 (61.6)	21,750 (65.6)	26,574 (68.8)	4.9	3.0	2.5	2.0	2.6

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

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

Table A16 | Electricity generation [Reference Scenario]

(TWh)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/2015	2015/2030	2030/2040	2040/2050	2015/2050
World	11,864 (100)	15,471 (100)	24,255 (100)	32,965 (100)	39,101 (100)	44,838 (100)	2.9	2.1	1.7	1.4	1.8
Asia	2,252 (19.0)	4,013 (25.9)	10,204 (42.1)	15,895 (48.2)	19,641 (50.2)	22,874 (51.0)	6.2	3.0	2.1	1.5	2.3
China	621 (5.2)	1,356 (8.8)	5,844 (24.1)	8,441 (25.6)	9,970 (25.5)	10,763 (24.0)	9.4	2.5	1.7	0.8	1.8
India	293 (2.5)	570 (3.7)	1,383 (5.7)	3,106 (9.4)	4,311 (11.0)	5,663 (12.6)	6.4	5.5	3.3	2.8	4.1
Japan	873 (7.4)	1,088 (7.0)	1,035 (4.3)	1,136 (3.4)	1,152 (2.9)	1,150 (2.6)	0.7	0.6	0.1	0.0	0.3
Korea	105 (0.9)	289 (1.9)	549 (2.3)	655 (2.0)	694 (1.8)	707 (1.6)	6.8	1.2	0.6	0.2	0.7
Chinese Taipei	88 (0.7)	181 (1.2)	255 (1.1)	288 (0.9)	303 (0.8)	312 (0.7)	4.3	0.8	0.5	0.3	0.6
ASEAN	154 (1.3)	370 (2.4)	868 (3.6)	1,670 (5.1)	2,374 (6.1)	3,220 (7.2)	7.2	4.5	3.6	3.1	3.8
Indonesia	33 (0.3)	93 (0.6)	234 (1.0)	520 (1.6)	762 (1.9)	1,035 (2.3)	8.2	5.5	3.9	3.1	4.3
Malaysia	23 (0.2)	69 (0.4)	150 (0.6)	250 (0.8)	321 (0.8)	388 (0.9)	7.8	3.5	2.5	1.9	2.8
Myanmar	2 (0.0)	5 (0.0)	16 (0.1)	66 (0.2)	103 (0.3)	149 (0.3)	7.7	9.9	4.6	3.7	6.6
Philippines	26 (0.2)	45 (0.3)	82 (0.3)	186 (0.6)	287 (0.7)	434 (1.0)	4.7	5.6	4.4	4.2	4.9
Singapore	16 (0.1)	32 (0.2)	50 (0.2)	62 (0.2)	67 (0.2)	69 (0.2)	4.8	1.4	0.8	0.3	0.9
Thailand	44 (0.4)	96 (0.6)	178 (0.7)	260 (0.8)	341 (0.9)	422 (0.9)	5.7	2.6	2.8	2.2	2.5
Viet Nam	9 (0.1)	27 (0.2)	153 (0.6)	320 (1.0)	487 (1.2)	716 (1.6)	12.2	5.0	4.3	3.9	4.5
Asia excl. Japan	1,380 (11.6)	2,925 (18.9)	9,169 (37.8)	14,760 (44.8)	18,490 (47.3)	21,724 (48.5)	7.9	3.2	2.3	1.6	2.5
North America	3,685 (31.1)	4,631 (29.9)	4,968 (20.5)	5,538 (16.8)	5,929 (15.2)	6,218 (13.9)	1.2	0.7	0.7	0.5	0.6
United States	3,203 (27.0)	4,026 (26.0)	4,297 (17.7)	4,829 (14.6)	5,169 (13.2)	5,414 (12.1)	1.2	0.8	0.7	0.5	0.7
Latin America	623 (5.3)	1,009 (6.5)	1,598 (6.6)	2,314 (7.0)	2,906 (7.4)	3,426 (7.6)	3.8	2.5	2.3	1.7	2.2
OECD Europe	2,668 (22.5)	3,227 (20.9)	3,559 (14.7)	3,913 (11.9)	4,099 (10.5)	4,231 (9.4)	1.2	0.6	0.5	0.3	0.5
European Union	2,577 (21.7)	3,006 (19.4)	3,204 (13.2)	3,571 (10.8)	3,774 (9.7)	3,935 (8.8)	0.9	0.7	0.6	0.4	0.6
Non-OECD Europe	1,888 (15.9)	1,428 (9.2)	1,738 (7.2)	2,083 (6.3)	2,383 (6.1)	2,713 (6.1)	-0.3	1.2	1.4	1.3	1.3
Africa	316 (2.7)	442 (2.9)	781 (3.2)	1,266 (3.8)	1,832 (4.7)	2,717 (6.1)	3.7	3.3	3.8	4.0	3.6
Middle East	244 (2.1)	472 (3.1)	1,111 (4.6)	1,585 (4.8)	1,902 (4.9)	2,215 (4.9)	6.2	2.4	1.8	1.5	2.0
Oceania	187 (1.6)	249 (1.6)	296 (1.2)	370 (1.1)	409 (1.0)	444 (1.0)	1.9	1.5	1.0	0.8	1.2
OECD	7,652 (64.5)	9,730 (62.9)	10,794 (44.5)	12,189 (37.0)	13,031 (33.3)	13,670 (30.5)	1.4	0.8	0.7	0.5	0.7
Non-OECD	4,212 (35.5)	5,741 (37.1)	13,461 (55.5)	20,776 (63.0)	26,070 (66.7)	31,168 (69.5)	4.8	2.9	2.3	1.8	2.4

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

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

Table A17 | Primary energy consumption per capita [Reference Scenario]

(toe/person)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/ 2015	2015/ 2030	2030/ 2040	2040/ 2050	2015/ 2050
World	1.66	1.64	1.86	1.95	2.01	2.04	0.5	0.3	0.3	0.2	0.3
Asia	0.72	0.85	1.37	1.68	1.86	2.01	2.6	1.4	1.0	0.8	1.1
China	0.77	0.89	2.17	2.61	2.88	3.00	4.2	1.2	1.0	0.4	0.9
India	0.35	0.42	0.65	1.05	1.28	1.53	2.5	3.2	2.1	1.8	2.5
Japan	3.55	4.08	3.39	3.59	3.62	3.62	-0.2	0.4	0.1	0.0	0.2
Korea	2.17	4.00	5.39	5.54	5.39	5.21	3.7	0.2	-0.3	-0.3	-0.1
Chinese Taipei	2.34	3.81	4.63	4.57	4.56	4.54	2.8	-0.1	0.0	0.0	-0.1
ASEAN	0.54	0.75	1.02	1.41	1.71	2.03	2.6	2.2	1.9	1.7	2.0
Indonesia	0.54	0.74	0.87	1.33	1.64	1.92	1.9	2.8	2.1	1.6	2.3
Malaysia	1.20	2.09	2.83	3.31	3.62	3.84	3.5	1.0	0.9	0.6	0.9
Myanmar	0.25	0.27	0.37	0.58	0.79	1.07	1.5	3.1	3.1	3.1	3.1
Philippines	0.46	0.51	0.52	0.78	0.95	1.17	0.4	2.8	2.0	2.1	2.4
Singapore	3.78	4.63	4.63	4.80	5.00	5.19	0.8	0.2	0.4	0.4	0.3
Thailand	0.74	1.15	1.99	2.53	3.10	3.79	4.0	1.6	2.1	2.0	1.9
Viet Nam	0.27	0.37	0.80	1.23	1.63	2.13	4.5	2.9	2.9	2.7	2.8
Asia excl. Japan	0.59	0.72	1.30	1.62	1.82	1.97	3.2	1.5	1.1	0.8	1.2
North America	7.66	8.08	6.88	6.10	5.69	5.30	-0.4	-0.8	-0.7	-0.7	-0.7
United States	7.67	8.06	6.81	6.04	5.63	5.24	-0.5	-0.8	-0.7	-0.7	-0.7
Latin America	1.05	1.15	1.35	1.53	1.68	1.77	1.0	0.8	0.9	0.6	0.8
OECD Europe	3.25	3.35	3.01	2.83	2.72	2.65	-0.3	-0.4	-0.4	-0.3	-0.4
European Union	3.44	3.47	3.11	2.95	2.85	2.79	-0.4	-0.4	-0.4	-0.2	-0.3
Non-OECD Europe	4.48	2.95	3.24	3.53	3.88	4.30	-1.3	0.6	1.0	1.0	0.8
Africa	0.62	0.61	0.66	0.64	0.65	0.65	0.3	-0.2	0.1	0.1	-0.1
Middle East	1.69	2.22	3.19	3.35	3.47	3.54	2.6	0.3	0.4	0.2	0.3
Oceania	4.86	5.22	5.14	4.58	4.19	3.85	0.2	-0.8	-0.9	-0.8	-0.8
OECD	4.25	4.59	4.11	3.86	3.71	3.57	-0.1	-0.4	-0.4	-0.4	-0.4
Non-OECD	0.96	0.90	1.32	1.51	1.63	1.70	1.3	0.9	0.7	0.4	0.7

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

Note: World includes international bunkers.

Table A18 | Primary energy consumption per GDP [Reference Scenario]

(toe/$2010 million)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/ 2015	2015/ 2030	2030/ 2040	2040/ 2050	2015/ 2050
World	232	201	182	144	121	103	-1.0	-1.6	-1.7	-1.5	-1.6
Asia	278	261	244	174	139	114	-0.5	-2.2	-2.3	-1.9	-2.2
China	1,050	505	334	182	130	100	-4.5	-4.0	-3.3	-2.6	-3.4
India	651	545	372	258	201	160	-2.2	-2.4	-2.5	-2.2	-2.4
Japan	94	97	72	62	54	47	-1.1	-0.9	-1.5	-1.3	-1.2
Korea	246	265	215	156	124	100	-0.5	-2.1	-2.3	-2.1	-2.2
Chinese Taipei	295	274	207	154	128	106	-1.4	-1.9	-1.9	-1.8	-1.9
ASEAN	314	322	249	198	171	149	-0.9	-1.5	-1.5	-1.4	-1.5
Indonesia	318	343	228	185	154	128	-1.3	-1.4	-1.9	-1.8	-1.6
Malaysia	267	301	260	191	159	131	-0.1	-2.0	-1.8	-1.9	-1.9
Myanmar	1,593	960	336	230	198	179	-6.0	-2.5	-1.5	-1.0	-1.8
Philippines	304	319	196	160	146	136	-1.7	-1.4	-0.9	-0.7	-1.0
Singapore	171	139	89	75	67	62	-2.6	-1.2	-1.0	-0.8	-1.0
Thailand	296	332	345	271	238	212	0.6	-1.6	-1.3	-1.1	-1.4
Viet Nam	606	470	478	349	293	250	-1.0	-2.1	-1.7	-1.6	-1.8
Asia excl. Japan	575	416	307	196	151	122	-2.5	-3.0	-2.6	-2.1	-2.6
North America	211	180	134	97	78	64	-1.8	-2.1	-2.1	-2.0	-2.1
United States	211	179	132	95	76	62	-1.9	-2.1	-2.2	-2.0	-2.1
Latin America	167	159	147	128	108	92	-0.5	-0.9	-1.7	-1.5	-1.3
OECD Europe	129	110	87	67	57	49	-1.5	-1.8	-1.6	-1.4	-1.6
European Union	139	115	89	68	58	50	-1.8	-1.8	-1.6	-1.4	-1.6
Non-OECD Europe	714	668	416	315	259	217	-2.1	-1.8	-1.9	-1.7	-1.8
Africa	449	433	348	257	197	160	-1.0	-2.0	-2.6	-2.0	-2.2
Middle East	235	260	291	248	217	189	0.9	-1.1	-1.3	-1.4	-1.2
Oceania	138	121	96	70	58	49	-1.4	-2.1	-1.9	-1.6	-1.9
OECD	155	139	109	83	69	59	-1.4	-1.8	-1.8	-1.7	-1.8
Non-OECD	472	379	298	207	163	134	-1.8	-2.4	-2.4	-2.0	-2.3

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

Note: World includes international bunkers.

Table A19 | Energy-related carbon dioxide emissions [Reference Scenario]

(Mt)

	1990	2000	2015	2030	2040	2050	CAGR (%) 1990/ 2015	2015/ 2030	2030/ 2040	2040/ 2050	2015/ 2050
World	21,205 (100)	23,416 (100)	32,910 (100)	38,142 (100)	41,613 (100)	44,107 (100)	1.8	1.0	0.9	0.6	0.8
Asia	4,918 (23.2)	6,891 (29.4)	15,076 (45.8)	19,461 (51.0)	22,011 (52.9)	23,706 (53.7)	4.6	1.7	1.2	0.7	1.3
China	2,339 (11.0)	3,164 (13.5)	9,333 (28.4)	10,721 (28.1)	11,088 (26.6)	10,517 (23.8)	5.7	0.9	0.3	-0.5	0.3
India	542 (2.6)	899 (3.8)	2,107 (6.4)	4,040 (10.6)	5,400 (13.0)	6,850 (15.5)	5.6	4.4	2.9	2.4	3.4
Japan	1,071 (5.1)	1,195 (5.1)	1,147 (3.5)	1,023 (2.7)	966 (2.3)	884 (2.0)	0.3	-0.8	-0.6	-0.9	-0.7
Korea	239 (1.1)	433 (1.9)	582 (1.8)	656 (1.7)	652 (1.6)	603 (1.4)	3.6	0.8	-0.1	-0.8	0.1
Chinese Taipei	115 (0.5)	225 (1.0)	255 (0.8)	277 (0.7)	263 (0.6)	239 (0.5)	3.2	0.6	-0.5	-1.0	-0.2
ASEAN	362 (1.7)	711 (3.0)	1,288 (3.9)	2,111 (5.5)	2,812 (6.8)	3,602 (8.2)	5.2	3.4	2.9	2.5	3.0
Indonesia	134 (0.6)	262 (1.1)	451 (1.4)	811 (2.1)	1,120 (2.7)	1,440 (3.3)	5.0	4.0	3.3	2.5	3.4
Malaysia	54 (0.3)	121 (0.5)	227 (0.7)	323 (0.8)	372 (0.9)	421 (1.0)	5.9	2.4	1.4	1.3	1.8
Myanmar	4 (0.0)	10 (0.0)	25 (0.1)	68 (0.2)	111 (0.3)	169 (0.4)	7.5	6.9	5.0	4.4	5.6
Philippines	39 (0.2)	69 (0.3)	108 (0.3)	218 (0.6)	314 (0.8)	440 (1.0)	4.2	4.8	3.7	3.4	4.1
Singapore	29 (0.1)	48 (0.2)	50 (0.2)	56 (0.1)	59 (0.1)	59 (0.1)	2.2	0.7	0.5	0.1	0.5
Thailand	81 (0.4)	152 (0.6)	252 (0.8)	319 (0.8)	381 (0.9)	428 (1.0)	4.7	1.6	1.8	1.2	1.5
Viet Nam	17 (0.1)	44 (0.2)	168 (0.5)	308 (0.8)	449 (1.1)	635 (1.4)	9.6	4.1	3.8	3.5	3.9
Asia excl. Japan	3,847 (18.1)	5,696 (24.3)	13,928 (42.3)	18,438 (48.3)	21,046 (50.6)	22,821 (51.7)	5.3	1.9	1.3	0.8	1.4
North America	5,236 (24.7)	6,126 (26.2)	5,574 (16.9)	5,066 (13.3)	4,786 (11.5)	4,438 (10.1)	0.3	-0.6	-0.6	-0.8	-0.6
United States	4,820 (22.7)	5,617 (24.0)	5,071 (15.4)	4,598 (12.1)	4,328 (10.4)	4,004 (9.1)	0.2	-0.7	-0.6	-0.8	-0.7
Latin America	909 (4.3)	1,206 (5.2)	1,724 (5.2)	2,137 (5.6)	2,469 (5.9)	2,651 (6.0)	2.6	1.4	1.5	0.7	1.2
OECD Europe	3,971 (18.7)	3,897 (16.6)	3,436 (10.4)	3,057 (8.0)	2,752 (6.6)	2,471 (5.6)	-0.6	-0.8	-1.0	-1.1	-0.9
European Union	4,068 (19.2)	3,783 (16.2)	3,176 (9.6)	2,835 (7.4)	2,552 (6.1)	2,292 (5.2)	-1.0	-0.8	-1.0	-1.1	-0.9
Non-OECD Europe	4,104 (19.4)	2,455 (10.5)	2,543 (7.7)	2,577 (6.8)	2,749 (6.6)	2,928 (6.6)	-1.9	0.1	0.6	0.6	0.4
Africa	593 (2.8)	718 (3.1)	1,168 (3.5)	1,605 (4.2)	2,064 (5.0)	2,705 (6.1)	2.7	2.1	2.5	2.7	2.4
Middle East	573 (2.7)	945 (4.0)	1,822 (5.5)	2,310 (6.1)	2,630 (6.3)	2,910 (6.6)	4.7	1.6	1.3	1.0	1.3
Oceania	281 (1.3)	337 (1.4)	395 (1.2)	385 (1.0)	366 (0.9)	347 (0.8)	1.4	-0.2	-0.5	-0.5	-0.4
OECD	11,120 (52.4)	12,402 (53.0)	11,687 (35.5)	10,860 (28.5)	10,277 (24.7)	9,551 (21.7)	0.2	-0.5	-0.6	-0.7	-0.6
Non-OECD	9,464 (44.6)	10,174 (43.4)	20,051 (60.9)	25,738 (67.5)	29,551 (71.0)	32,605 (73.9)	3.0	1.7	1.4	1.0	1.4

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

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

Table A20 | World [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	7,205	8,774	10,028	13,647	16,562	18,374	19,789	100	100	100	1.8	1.3	0.9	1.1
Coal	1,783	2,220	2,311	3,836	4,254	4,486	4,531	25	28	23	2.2	0.7	0.3	0.5
Oil	3,102	3,235	3,660	4,334	5,024	5,471	5,849	37	32	30	1.2	1.0	0.8	0.9
Natural gas	1,232	1,663	2,071	2,944	3,845	4,550	5,194	19	22	26	2.3	1.8	1.5	1.6
Nuclear	186	526	676	671	907	980	1,055	6.0	4.9	5.3	1.0	2.0	0.8	1.3
Hydro	148	184	225	334	425	466	500	2.1	2.5	2.5	2.4	1.6	0.8	1.2
Geothermal	12	34	52	74	177	224	257	0.4	0.5	1.3	3.1	6.0	1.9	3.6
Solar, wind, etc.	0.1	2.7	8.0	126	306	446	608	0.0	0.9	3.1	16.7	6.1	3.5	4.6
Biomass and waste	741	909	1,023	1,323	1,620	1,746	1,790	10	9.7	9.0	1.5	1.4	0.5	0.9

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	5,368	6,268	7,036	9,384	11,346	12,617	13,675	100	100	100	1.6	1.3	0.9	1.1
Industry	1,766	1,809	1,868	2,712	3,146	3,499	3,779	29	29	28	1.6	1.0	0.9	1.0
Transport	1,248	1,573	1,961	2,703	3,230	3,528	3,765	25	29	28	2.2	1.2	0.8	1.0
Buildings, etc.	2,000	2,409	2,591	3,132	3,911	4,367	4,779	38	33	35	1.1	1.5	1.0	1.2
Non-energy use	354	478	617	836	1,060	1,223	1,352	7.6	8.9	9.9	2.3	1.6	1.2	1.4
Coal	703	754	548	1,044	1,096	1,122	1,108	12	11	8.1	1.3	0.3	0.1	0.2
Oil	2,446	2,599	3,115	3,840	4,511	4,942	5,322	41	41	39	1.6	1.1	0.8	0.9
Natural gas	814	945	1,117	1,401	1,772	2,017	2,231	15	15	16	1.6	1.6	1.2	1.3
Electricity	586	835	1,092	1,737	2,373	2,852	3,324	13	19	24	3.0	2.1	1.7	1.9
Heat	121	336	248	271	288	297	299	5.4	2.9	2.2	-0.9	0.4	0.2	0.3
Hydrogen	-	-	-	-	0.4	0.7	0.8	-	-	0.0	n.a.	n.a.	3.1	n.a.
Renewables	698	799	917	1,090	1,306	1,386	1,391	13	12	10	1.3	1.2	0.3	0.7

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	8,283	11,864	15,471	24,255	32,965	39,101	44,838	100	100	100	2.9	2.1	1.5	1.8
Coal	3,137	4,425	6,005	9,538	11,758	13,157	13,997	37	39	31	3.1	1.4	0.9	1.1
Oil	1,659	1,358	1,252	990	1,002	979	892	11	4.1	2.0	-1.3	0.1	-0.6	-0.3
Natural gas	999	1,752	2,753	5,543	7,939	10,337	12,868	15	23	29	4.7	2.4	2.4	2.4
Nuclear	713	2,013	2,591	2,571	3,480	3,759	4,047	17	11	9.0	1.0	2.0	0.8	1.3
Hydro	1,717	2,142	2,619	3,888	4,943	5,419	5,818	18	16	13	2.4	1.6	0.8	1.2
Geothermal	14	36	52	80	191	245	288	0.3	0.3	0.6	3.2	5.9	2.1	3.7
Solar PV	-	0.0	1.0	247	751	1,154	1,667	0.0	1.0	3.7	45.5	7.7	4.1	5.6
Wind	0.0	3.9	31	838	1,891	2,710	3,585	0.0	3.5	8.0	24.0	5.6	3.3	4.2
CSP and marine	0.5	1.5	2.2	27	136	237	385	0.0	0.1	0.9	12.2	11.5	5.3	7.9
Biomass and waste	44	131	164	528	872	1,099	1,287	1.1	2.2	2.9	5.7	3.4	2.0	2.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	27,958	37,797	49,825	75,059	115,303	152,089	191,400	2.8	2.9	2.6	2.7
Population (million)	4,436	5,277	6,108	7,336	8,497	9,152	9,710	1.3	1.0	0.7	0.8
CO_2 emissions (Mt)	18,411	21,205	23,416	32,910	38,142	41,613	44,107	1.8	1.0	0.7	0.8
GDP per capita ($2010 thousand)	6.3	7.2	8.2	10	14	17	20	1.4	1.9	1.9	1.9
Primary energy consump. per capita (toe)	1.6	1.7	1.6	1.9	1.9	2.0	2.0	0.5	0.3	0.2	0.3
Primary energy consumption per GDP[*2]	258	232	201	182	144	121	103	-1.0	-1.6	-1.6	-1.6
CO_2 emissions per GDP[*3]	659	561	470	438	331	274	230	-1.0	-1.9	-1.8	-1.8
CO_2 per primary energy consumption[*4]	2.6	2.4	2.3	2.4	2.3	2.3	2.2	0.0	-0.3	-0.2	-0.2

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A21 | Asia [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	1,439	2,108	2,887	5,459	7,434	8,548	9,351	100	100	100	3.9	2.1	1.2	1.5
Coal	466	785	1,037	2,739	3,320	3,632	3,754	37	50	40	5.1	1.3	0.6	0.9
Oil	477	618	916	1,330	1,820	2,089	2,323	29	24	25	3.1	2.1	1.2	1.6
Natural gas	51	116	232	547	965	1,285	1,567	5.5	10	17	6.4	3.9	2.5	3.1
Nuclear	25	77	132	111	298	369	441	3.6	2.0	4.7	1.5	6.8	2.0	4.0
Hydro	20	32	41	131	182	205	221	1.5	2.4	2.4	5.8	2.2	1.0	1.5
Geothermal	2.6	8.2	23	34	92	115	127	0.4	0.6	1.4	5.9	6.8	1.6	3.8
Solar, wind, etc.	-	1.5	2.2	51	129	194	265	0.1	0.9	2.8	15.3	6.3	3.7	4.8
Biomass and waste	397	471	503	515	625	657	652	22	9.4	7.0	0.4	1.3	0.2	0.7

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1,129	1,551	1,990	3,617	4,838	5,560	6,140	100	100	100	3.4	2.0	1.2	1.5
Industry	383	517	646	1,481	1,759	1,956	2,097	33	41	34	4.3	1.2	0.9	1.0
Transport	126	186	320	648	989	1,149	1,274	12	18	21	5.1	2.9	1.3	2.0
Buildings, etc.	567	733	836	1,124	1,593	1,872	2,126	47	31	35	1.7	2.4	1.5	1.8
Non-energy use	54	115	188	365	496	583	642	7.4	10	10	4.7	2.1	1.3	1.6
Coal	301	424	378	901	951	974	960	27	25	16	3.1	0.4	0.0	0.2
Oil	327	453	727	1,164	1,633	1,896	2,135	29	32	35	3.9	2.3	1.3	1.7
Natural gas	21	47	88	252	446	576	688	3.0	7.0	11	6.9	3.9	2.2	2.9
Electricity	88	158	280	740	1,152	1,441	1,705	10	20	28	6.4	3.0	2.0	2.4
Heat	7.5	14	30	89	105	114	115	0.9	2.5	1.9	7.6	1.1	0.5	0.7
Hydrogen	-	-	-	-	0.2	0.3	0.3	-	-	0.0	n.a.	n.a.	3.5	n.a.
Renewables	386	456	488	471	551	558	536	29	13	8.7	0.1	1.0	-0.1	0.4

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1,196	2,252	4,013	10,204	15,895	19,641	22,874	100	100	100	6.2	3.0	1.8	2.3
Coal	298	863	1,994	6,203	8,742	10,331	11,449	38	61	50	8.2	2.3	1.4	1.8
Oil	476	469	430	250	226	194	139	21	2.5	0.6	-2.5	-0.7	-2.4	-1.7
Natural gas	90	240	565	1,296	2,246	3,148	4,046	11	13	18	7.0	3.7	3.0	3.3
Nuclear	97	294	505	425	1,143	1,417	1,692	13	4.2	7.4	1.5	6.8	2.0	4.0
Hydro	232	367	479	1,521	2,121	2,385	2,569	16	15	11	5.8	2.2	1.0	1.5
Geothermal	3.0	8.4	20	24	63	78	86	0.4	0.2	0.4	4.3	6.7	1.6	3.7
Solar PV	-	0.0	0.6	95	374	617	925	0.0	0.9	4.0	49.6	9.6	4.6	6.7
Wind	-	0.0	2.4	239	696	1,071	1,465	0.0	2.3	6.4	42.5	7.4	3.8	5.3
CSP and marine	-	0.0	0.0	2.0	8.2	17	37	0.0	0.0	0.2	25.5	9.7	7.8	8.6
Biomass and waste	0.0	10	17	150	277	383	466	0.5	1.5	2.0	11.4	4.1	2.6	3.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	4,455	7,586	11,047	22,344	42,637	61,674	81,910	4.4	4.4	3.3	3.8
Population (million)	2,440	2,932	3,407	3,993	4,433	4,595	4,658	1.2	0.7	0.2	0.4
CO_2 emissions (Mt)	3,268	4,918	6,891	15,076	19,461	22,011	23,706	4.6	1.7	1.0	1.3
GDP per capita ($2010 thousand)	1.8	2.6	3.2	5.6	9.6	13	18	3.1	3.7	3.1	3.3
Primary energy consump. per capita (toe)	0.6	0.7	0.8	1.4	1.7	1.9	2.0	2.6	1.4	0.9	1.1
Primary energy consumption per GDP[*2]	323	278	261	244	174	139	114	-0.5	-2.2	-2.1	-2.2
CO_2 emissions per GDP[*3]	733	648	624	675	456	357	289	0.2	-2.6	-2.3	-2.4
CO_2 per primary energy consumption[*4]	2.3	2.3	2.4	2.8	2.6	2.6	2.5	0.7	-0.4	-0.2	-0.2

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A22 | China [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	598	871	1,130	2,973	3,695	4,005	4,021	100	100	100	5.0	1.5	0.4	0.9
Coal	313	528	665	1,982	2,096	2,109	1,935	61	67	48	5.4	0.4	-0.4	-0.1
Oil	89	119	221	534	763	809	795	14	18	20	6.2	2.4	0.2	1.1
Natural gas	12	13	21	159	343	468	561	1.5	5.3	14	10.6	5.3	2.5	3.7
Nuclear	-	-	4.4	45	165	223	282	-	1.5	7.0	n.a.	9.1	2.7	5.4
Hydro	5.0	11	19	96	122	132	135	1.3	3.2	3.4	9.1	1.6	0.5	1.0
Geothermal	-	-	1.7	5.1	7.4	8.7	9.2	-	0.2	0.2	n.a.	2.5	1.1	1.7
Solar, wind, etc.	-	0.0	1.0	41	95	136	176	0.0	1.4	4.4	33.0	5.7	3.1	4.2
Biomass and waste	180	200	198	114	106	120	129	23	3.8	3.2	-2.2	-0.5	1.0	0.4

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	487	654	781	1,906	2,346	2,532	2,555	100	100	100	4.4	1.4	0.4	0.8
Industry	181	234	299	966	965	973	937	36	51	37	5.8	0.0	-0.1	-0.1
Transport	24	33	87	299	504	541	537	5.1	16	21	9.2	3.6	0.3	1.7
Buildings, etc.	272	344	335	483	661	767	814	53	25	32	1.4	2.1	1.0	1.5
Non-energy use	10	43	60	158	215	250	266	6.6	8.3	10	5.3	2.1	1.1	1.5
Coal	214	308	274	701	628	574	486	47	37	19	3.3	-0.7	-1.3	-1.0
Oil	59	85	180	480	700	747	739	13	25	29	7.2	2.5	0.3	1.2
Natural gas	6.4	8.9	12	105	206	269	315	1.4	5.5	12	10.4	4.6	2.1	3.2
Electricity	21	39	89	419	612	731	801	6.0	22	31	10.0	2.5	1.4	1.9
Heat	7.4	13	25	83	98	107	109	2.0	4.4	4.3	7.6	1.1	0.5	0.8
Hydrogen	-	-	-	-	0.1	0.2	0.2	-	-	0.0	n.a.	n.a.	2.8	n.a.
Renewables	180	200	199	116	102	103	105	31	6.1	4.1	-2.2	-0.9	0.2	-0.3

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	301	621	1,356	5,844	8,441	9,970	10,763	100	100	100	9.4	2.5	1.2	1.8
Coal	159	441	1,060	4,109	5,112	5,616	5,509	71	70	51	9.3	1.5	0.4	0.8
Oil	82	50	47	9.7	9.0	7.6	4.9	8.1	0.2	0.0	-6.4	-0.5	-3.0	-1.9
Natural gas	0.7	2.8	5.8	145	427	663	853	0.4	2.5	7.9	17.2	7.4	3.5	5.2
Nuclear	-	-	17	171	632	856	1,081	-	2.9	10	n.a.	9.1	2.7	5.4
Hydro	58	127	222	1,114	1,414	1,531	1,574	20	19	15	9.1	1.6	0.5	1.0
Geothermal	-	0.1	0.1	0.1	0.4	0.4	0.5	0.0	0.0	0.0	3.2	7.6	1.3	4.0
Solar PV	-	0.0	0.0	45	212	302	395	0.0	0.8	3.7	49.3	10.8	3.2	6.4
Wind	-	0.0	0.6	186	507	791	1,088	0.0	3.2	10	58.0	6.9	3.9	5.2
CSP and marine	-	0.0	0.0	0.0	2.5	6.0	12	0.0	0.0	0.1	6.6	33.0	8.3	18.2
Biomass and waste	-	-	2.4	64	126	195	244	-	1.1	2.3	n.a.	4.6	3.4	3.9
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	341	830	2,237	8,910	20,311	30,759	40,328	10.0	5.6	3.5	4.4
Population (million)	981	1,135	1,263	1,371	1,415	1,391	1,340	0.8	0.2	-0.3	-0.1
CO_2 emissions (Mt)	1,505	2,339	3,164	9,333	10,721	11,088	10,517	5.7	0.9	-0.1	0.3
GDP per capita ($2010 thousand)	0.3	0.7	1.8	6.5	14	22	30	9.1	5.4	3.8	4.5
Primary energy consump. per capita (toe)	0.6	0.8	0.9	2.2	2.6	2.9	3.0	4.2	1.2	0.7	0.9
Primary energy consumption per GDP[*2]	1,752	1,050	505	334	182	130	100	-4.5	-4.0	-3.0	-3.4
CO_2 emissions per GDP[*3]	4,410	2,819	1,414	1,048	528	360	261	-3.9	-4.5	-3.5	-3.9
CO_2 per primary energy consumption[*4]	2.5	2.7	2.8	3.1	2.9	2.8	2.6	0.6	-0.5	-0.5	-0.5

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A23 | India [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	200	306	441	851	1,585	2,061	2,545	100	100	100	4.2	4.2	2.4	3.2
Coal	44	93	146	379	720	932	1,143	30	45	45	5.8	4.4	2.3	3.2
Oil	33	61	112	206	377	521	683	20	24	27	5.0	4.1	3.0	3.5
Natural gas	1.3	11	23	43	124	195	274	3.5	5.1	11	5.8	7.3	4.0	5.4
Nuclear	0.8	1.6	4.4	9.8	48	67	79	0.5	1.1	3.1	7.5	11.2	2.5	6.2
Hydro	4.0	6.2	6.4	12	24	31	38	2.0	1.4	1.5	2.7	4.8	2.4	3.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	0.2	4.8	21	38	59	0.0	0.6	2.3	27.8	10.4	5.3	7.4
Biomass and waste	116	133	149	196	269	277	268	44	23	11	1.6	2.1	0.0	0.9

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	174	243	315	578	1,056	1,383	1,729	100	100	100	3.5	4.1	2.5	3.2
Industry	41	67	83	195	376	492	597	27	34	35	4.4	4.5	2.3	3.2
Transport	17	21	32	86	163	236	304	8.6	15	18	5.8	4.3	3.2	3.7
Buildings, etc.	110	142	173	250	420	525	671	59	43	39	2.3	3.5	2.4	2.9
Non-energy use	5.7	13	27	46	97	130	158	5.5	8.0	9.1	5.1	5.0	2.5	3.6
Coal	25	39	35	108	211	277	341	16	19	20	4.2	4.5	2.4	3.3
Oil	27	50	94	174	332	467	622	21	30	36	5.1	4.4	3.2	3.7
Natural gas	0.7	5.6	9.7	29	72	105	137	2.3	5.0	8.0	6.8	6.2	3.3	4.6
Electricity	7.8	18	32	88	205	297	407	7.6	15	24	6.5	5.8	3.5	4.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	7.5	n.a.
Renewables	114	130	144	178	237	237	221	54	31	13	1.3	1.9	-0.3	0.6

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	120	293	570	1,383	3,106	4,311	5,663	100	100	100	6.4	5.5	3.0	4.1
Coal	61	192	390	1,042	2,085	2,753	3,485	65	75	62	7.0	4.7	2.6	3.5
Oil	8.8	13	29	23	30	27	17	4.5	1.7	0.3	2.2	1.8	-2.7	-0.8
Natural gas	0.6	10.0	56	68	254	448	719	3.4	4.9	13	8.0	9.2	5.3	7.0
Nuclear	3.0	6.1	17	37	185	257	303	2.1	2.7	5.3	7.5	11.2	2.5	6.2
Hydro	47	72	74	138	280	364	447	24	10.0	7.9	2.7	4.8	2.4	3.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	0.0	5.6	56	151	281	-	0.4	5.0	n.a.	16.5	8.4	11.8
Wind	-	0.0	1.7	43	154	226	300	0.0	3.1	5.3	33.4	8.9	3.4	5.7
CSP and marine	-	-	-	-	3.1	5.9	13	-	-	0.2	n.a.	n.a.	7.4	n.a.
Biomass and waste	-	-	1.3	27	59	78	99	-	1.9	1.7	n.a.	5.4	2.6	3.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	274	470	809	2,288	6,133	10,236	15,857	6.5	6.8	4.9	5.7
Population (million)	697	871	1,053	1,311	1,515	1,608	1,662	1.7	1.0	0.5	0.7
CO_2 emissions (Mt)	263	542	899	2,107	4,040	5,400	6,850	5.6	4.4	2.7	3.4
GDP per capita ($2010 thousand)	0.4	0.5	0.8	1.7	4.0	6.4	9.5	4.8	5.8	4.4	5.0
Primary energy consump. per capita (toe)	0.3	0.4	0.4	0.6	1.0	1.3	1.5	2.5	3.2	1.9	2.5
Primary energy consumption per GDP*2	731	651	545	372	258	201	160	-2.2	-2.4	-2.4	-2.4
CO_2 emissions per GDP*3	962	1,154	1,112	921	659	528	432	-0.9	-2.2	-2.1	-2.1
CO_2 per primary energy consumption*4	1.3	1.8	2.0	2.5	2.5	2.6	2.7	1.3	0.2	0.3	0.2

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A24 | Japan [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	345	439	518	430	433	414	391	100	100	100	-0.1	0.0	-0.5	-0.3
Coal	60	76	97	117	112	110	104	17	27	27	1.7	-0.3	-0.4	-0.3
Oil	234	250	255	185	151	133	115	57	43	29	-1.2	-1.3	-1.4	-1.4
Natural gas	21	44	66	100	98	100	98	10	23	25	3.3	-0.1	0.0	-0.1
Nuclear	22	53	84	2.5	38	33	33	12	0.6	8.4	-11.5	20.0	-0.7	7.7
Hydro	7.6	7.5	7.3	7.3	7.9	8.1	8.1	1.7	1.7	2.1	-0.1	0.5	0.2	0.3
Geothermal	0.8	1.6	3.1	2.4	5.4	7.4	8.7	0.4	0.6	2.2	1.7	5.6	2.4	3.8
Solar, wind, etc.	-	1.4	0.9	3.9	6.9	9.0	11	0.3	0.9	2.8	4.2	4.0	2.3	3.0
Biomass and waste	-	4.5	4.7	11	13	14	14	1.0	2.7	3.6	3.8	0.9	0.4	0.6

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	232	287	328	291	279	266	251	100	100	100	0.1	-0.3	-0.5	-0.4
Industry	91	110	100	82	81	81	78	38	28	31	-1.1	-0.1	-0.2	-0.1
Transport	54	68	84	71	57	52	47	24	24	19	0.2	-1.4	-1.0	-1.2
Buildings, etc.	58	76	103	99	103	97	90	26	34	36	1.1	0.3	-0.6	-0.3
Non-energy use	28	34	41	39	38	37	36	12	13	14	0.6	-0.2	-0.3	-0.3
Coal	25	30	24	24	22	21	20	11	8.1	7.8	-1.0	-0.4	-0.7	-0.5
Oil	157	171	194	152	128	115	102	59	52	41	-0.5	-1.1	-1.1	-1.1
Natural gas	5.8	15	22	29	34	34	34	5.3	10	14	2.7	0.9	0.1	0.4
Electricity	44	66	83	82	90	91	91	23	28	36	0.8	0.6	0.1	0.3
Heat	0.1	0.2	0.5	0.5	0.5	0.5	0.4	0.1	0.2	0.2	3.8	-0.1	-1.2	-0.7
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	-0.8	n.a.
Renewables	-	4.1	3.8	3.8	4.3	4.3	4.1	1.4	1.3	1.6	-0.2	0.8	-0.3	0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	573	873	1,088	1,035	1,136	1,152	1,150	100	100	100	0.7	0.6	0.1	0.3
Coal	55	118	234	343	326	337	336	13	33	29	4.4	-0.4	0.2	-0.1
Oil	265	284	179	103	59	37	14	33	9.9	1.2	-4.0	-3.7	-6.9	-5.5
Natural gas	81	171	254	410	381	390	384	20	40	33	3.6	-0.5	0.0	-0.2
Nuclear	83	202	322	9.4	145	125	125	23	0.9	11	-11.5	20.0	-0.7	7.7
Hydro	88	87	85	85	92	94	94	10.0	8.2	8.2	-0.1	0.5	0.2	0.3
Geothermal	0.9	1.7	3.3	2.6	6.1	8.5	9.9	0.2	0.2	0.9	1.6	5.9	2.4	3.9
Solar PV	-	0.0	0.3	36	63	81	95	0.0	3.5	8.3	52.1	3.8	2.1	2.8
Wind	-	-	0.1	5.2	14	21	29	-	0.5	2.5	n.a.	7.0	3.7	5.1
CSP and marine	-	-	-	-	0.1	0.1	0.4	-	-	0.0	n.a.	n.a.	11.0	n.a.
Biomass and waste	-	9.6	10	41	50	57	61	1.1	4.0	5.3	6.0	1.3	1.0	1.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	2,977	4,683	5,349	5,986	6,948	7,705	8,329	1.0	1.0	0.9	0.9
Population (million)	117	124	127	127	121	114	108	0.1	-0.3	-0.6	-0.5
CO_2 emissions (Mt)	916	1,071	1,195	1,147	1,023	966	884	0.3	-0.8	-0.7	-0.7
GDP per capita ($2010 thousand)	25	38	42	47	58	67	77	0.9	1.3	1.5	1.4
Primary energy consump. per capita (toe)	3.0	3.6	4.1	3.4	3.6	3.6	3.6	-0.2	0.4	0.0	0.2
Primary energy consumption per GDP*2	116	94	97	72	62	54	47	-1.1	-0.9	-1.4	-1.2
CO_2 emissions per GDP*3	308	229	223	192	147	125	106	-0.7	-1.7	-1.6	-1.7
CO_2 per primary energy consumption*4	2.7	2.4	2.3	2.7	2.4	2.3	2.3	0.4	-0.8	-0.2	-0.5

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A25 | Korea [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	41	93	188	273	292	283	263	100	100	100	4.4	0.5	-0.5	-0.1
Coal	14	25	42	81	92	91	82	27	30	31	4.7	0.9	-0.6	0.0
Oil	27	50	99	103	105	99	91	54	38	35	2.9	0.1	-0.7	-0.3
Natural gas	-	2.7	17	39	56	64	68	2.9	14	26	11.3	2.3	1.0	1.6
Nuclear	0.9	14	28	43	31	19	11	15	16	4.1	4.7	-2.2	-5.1	-3.9
Hydro	0.2	0.5	0.3	0.2	0.3	0.3	0.3	0.6	0.1	0.1	-4.3	3.8	0.0	1.6
Geothermal	-	-	-	0.1	0.2	0.2	0.2	-	0.0	0.1	n.a.	1.8	0.6	1.1
Solar, wind, etc.	-	0.0	0.0	0.6	1.8	2.8	4.4	0.0	0.2	1.7	18.1	7.1	4.6	5.7
Biomass and waste	-	0.7	1.4	5.9	6.9	6.9	6.7	0.8	2.2	2.5	8.7	1.1	-0.2	0.4

Final energy consumption

	Mtoe							Shares (%)						
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total	31	65	127	174	191	189	180	100	100	100	4.0	0.6	-0.3	0.1
Industry	10	19	38	49	53	53	50	30	28	28	3.8	0.5	-0.3	0.1
Transport	4.8	15	26	33	36	34	30	22	19	17	3.4	0.4	-0.8	-0.3
Buildings, etc.	13	24	37	44	50	50	48	38	25	27	2.4	0.8	-0.2	0.2
Non-energy use	3.1	6.7	25	47	52	52	52	10	27	29	8.1	0.6	0.0	0.2
Coal	9.7	12	9.1	12	11	9.8	8.1	18	6.8	4.5	0.0	-0.3	-1.6	-1.1
Oil	19	44	80	90	93	89	82	67	52	45	2.9	0.2	-0.7	-0.3
Natural gas	-	0.7	11	20	26	27	27	1.0	12	15	14.6	1.5	0.2	0.7
Electricity	2.8	8.1	23	43	51	54	55	13	24	31	6.9	1.2	0.4	0.7
Heat	-	-	3.3	4.4	4.7	4.3	3.8	-	2.5	2.1	n.a.	0.6	-1.1	-0.4
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	2.8	n.a.
Renewables	-	0.7	1.3	4.7	5.2	5.2	5.1	1.1	2.7	2.8	7.6	0.8	-0.1	0.3

Electricity generation

	(TWh)							Shares (%)						
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total	37	105	289	549	655	694	707	100	100	100	6.8	1.2	0.4	0.7
Coal	2.5	18	111	237	293	314	305	17	43	43	10.9	1.4	0.2	0.7
Oil	29	19	35	13	9.6	5.3	-	18	2.3	-	-1.6	-1.8	-100	-100
Natural gas	-	9.6	29	123	203	261	300	9.1	22	42	10.7	3.4	2.0	2.6
Nuclear	3.5	53	109	165	119	72	41	50	30	5.9	4.7	-2.2	-5.1	-3.9
Hydro	2.0	6.4	4.0	2.1	3.7	3.7	3.7	6.0	0.4	0.5	-4.3	3.8	0.0	1.6
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	0.0	0.0	3.9	14	20	29	0.0	0.7	4.1	39.2	8.9	3.7	5.9
Wind	-	-	0.0	1.2	4.1	6.9	11	-	0.2	1.6	n.a.	8.6	5.1	6.6
CSP and marine	-	-	-	2.0	2.4	5.2	11	-	0.4	1.5	n.a.	1.3	7.7	4.9
Biomass and waste	-	-	0.1	3.2	5.0	5.4	5.6	-	0.6	0.8	n.a.	3.2	0.6	1.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	149	377	710	1,267	1,877	2,284	2,633	5.0	2.7	1.7	2.1
Population (million)	38	43	47	51	53	52	50	0.7	0.3	-0.2	0.0
CO_2 emissions (Mt)	126	239	433	582	656	652	603	3.6	0.8	-0.4	0.1
GDP per capita ($2010 thousand)	3.9	8.8	15	25	36	44	52	4.3	2.4	1.9	2.1
Primary energy consump. per capita (toe)	1.1	2.2	4.0	5.4	5.5	5.4	5.2	3.7	0.2	-0.3	-0.1
Primary energy consumption per GDP[*2]	277	246	265	215	156	124	100	-0.5	-2.1	-2.2	-2.2
CO_2 emissions per GDP[*3]	845	634	610	460	349	285	229	-1.3	-1.8	-2.1	-2.0
CO_2 per primary energy consumption[*4]	3.1	2.6	2.3	2.1	2.2	2.3	2.3	-0.7	0.3	0.1	0.2

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A26 | Chinese Taipei [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	28	48	85	109	110	109	103	100	100	100	3.3	0.1	-0.3	-0.1
Coal	3.9	11	30	40	42	39	33	24	36	32	5.1	0.4	-1.2	-0.5
Oil	20	26	38	42	42	40	37	54	39	36	2.0	-0.1	-0.5	-0.4
Natural gas	1.6	1.4	5.6	15	22	25	27	2.9	14	26	9.9	2.7	1.1	1.7
Nuclear	2.1	8.6	10	9.5	-	-	-	18	8.7	-	0.4	-100	n.a.	-100
Hydro	0.3	0.5	0.4	0.4	0.4	0.4	0.4	1.1	0.4	0.4	-1.4	0.5	0.0	0.2
Geothermal	-	0.0	-	-	-	-	-	0.0	-	-	-100	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	0.1	0.3	0.8	1.2	1.6	0.0	0.3	1.6	12.1	6.4	3.7	4.9
Biomass and waste	-	-	0.6	1.8	3.3	3.6	3.5	-	1.7	3.3	n.a.	3.9	0.3	1.8

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	19	29	49	69	71	71	70	100	100	100	3.4	0.2	-0.1	0.0
Industry	10	12	19	23	23	23	23	42	33	33	2.4	0.1	0.0	0.0
Transport	2.9	6.6	12	12	12	11	9.3	22	18	13	2.6	-0.4	-1.2	-0.8
Buildings, etc.	3.6	6.5	10	12	14	14	14	22	17	20	2.5	1.0	0.1	0.5
Non-energy use	2.0	4.0	7.8	22	23	23	23	14	31	33	7.0	0.3	0.2	0.2
Coal	2.2	3.6	5.0	7.6	7.7	7.2	6.7	12	11	9.7	3.1	0.0	-0.6	-0.4
Oil	12	18	28	38	37	36	34	62	55	49	3.0	-0.2	-0.4	-0.3
Natural gas	1.4	0.9	1.6	2.8	3.6	3.9	4.2	3.0	4.1	6.0	4.8	1.6	0.8	1.1
Electricity	3.2	6.6	14	20	22	24	24	22	29	35	4.5	0.8	0.4	0.6
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	1.1	n.a.
Renewables	-	0.0	0.1	0.3	0.4	0.4	0.4	0.1	0.4	0.6	11.9	2.0	0.5	1.1

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	43	88	181	255	288	303	312	100	100	100	4.3	0.8	0.4	0.6
Coal	6.0	24	88	119	135	127	116	28	47	37	6.5	0.9	-0.8	-0.1
Oil	26	23	30	13	13	11	8.2	26	5.0	2.6	-2.4	0.0	-2.2	-1.3
Natural gas	-	1.2	17	76	121	140	157	1.4	30	50	17.9	3.1	1.3	2.1
Nuclear	8.2	33	39	36	-	-	-	37	14	-	0.4	-100	n.a.	-100
Hydro	2.9	6.4	4.6	4.5	4.8	4.8	4.8	7.2	1.8	1.5	-1.4	0.5	0.0	0.2
Geothermal	-	0.0	-	-	-	-	-	0.0	-	-	-100	n.a.	n.a.	n.a.
Solar PV	-	-	-	0.9	2.8	4.5	6.4	-	0.3	2.1	n.a.	8.0	4.2	5.9
Wind	-	-	0.0	1.5	4.8	7.4	11	-	0.6	3.5	n.a.	8.0	4.2	5.8
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	1.7	3.8	7.2	8.2	8.6	-	1.5	2.8	n.a.	4.3	0.9	2.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	73	162	309	527	715	851	975	4.8	2.1	1.6	1.8
Population (million)	18	20	22	23	24	24	23	0.6	0.2	-0.3	-0.1
CO_2 emissions (Mt)	75	115	225	255	277	263	239	3.2	0.6	-0.7	-0.2
GDP per capita ($2010 thousand)	4.1	7.9	14	22	30	36	43	4.2	1.9	1.9	1.9
Primary energy consump. per capita (toe)	1.6	2.3	3.8	4.6	4.6	4.6	4.5	2.8	-0.1	0.0	-0.1
Primary energy consumption per GDP*2	380	295	274	207	154	128	106	-1.4	-1.9	-1.9	-1.9
CO_2 emissions per GDP*3	1,015	714	727	485	388	309	245	-1.5	-1.5	-2.3	-1.9
CO_2 per primary energy consumption*4	2.7	2.4	2.7	2.3	2.5	2.4	2.3	-0.1	0.5	-0.4	0.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A27 | ASEAN [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	142	233	379	621	982	1,259	1,544	100	100	100	4.0	3.1	2.3	2.6
Coal	3.6	13	32	114	217	300	398	5.4	18	26	9.2	4.4	3.1	3.6
Oil	58	89	153	210	305	394	493	38	34	32	3.5	2.5	2.4	2.5
Natural gas	8.6	30	74	140	216	280	344	13	23	22	6.3	2.9	2.4	2.6
Nuclear	-	-	-	-	2.2	14	23	-	-	1.5	n.a.	n.a.	12.5	n.a.
Hydro	0.8	2.3	4.1	9.2	18	20	22	1.0	1.5	1.4	5.6	4.6	1.1	2.6
Geothermal	1.8	6.6	18	27	79	99	109	2.8	4.3	7.0	5.7	7.5	1.6	4.1
Solar, wind, etc.	-	-	-	0.3	2.3	4.9	9.4	-	0.1	0.6	n.a.	13.5	7.2	9.9
Biomass and waste	70	93	98	119	141	145	143	40	19	9.2	1.0	1.1	0.1	0.5

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	112	173	270	436	645	817	1,006	100	100	100	3.8	2.6	2.2	2.4
Industry	22	43	75	125	198	257	318	25	29	32	4.4	3.1	2.4	2.7
Transport	17	32	61	117	170	215	270	19	27	27	5.2	2.5	2.3	2.4
Buildings, etc.	71	87	113	147	211	262	317	50	34	32	2.1	2.5	2.1	2.2
Non-energy use	2.4	11	21	47	66	83	101	6.3	11	10	6.0	2.3	2.1	2.2
Coal	2.1	6.0	13	34	50	61	70	3.5	7.8	7.0	7.2	2.6	1.7	2.1
Oil	41	67	123	193	285	370	468	38	44	47	4.4	2.6	2.5	2.6
Natural gas	2.5	7.5	17	37	62	83	104	4.4	8.6	10	6.6	3.5	2.6	3.0
Electricity	4.7	11	28	68	129	183	249	6.4	16	25	7.5	4.4	3.3	3.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	5.8	n.a.
Renewables	61	82	89	104	118	119	115	47	24	11	1.0	0.9	-0.2	0.3

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	62	154	370	868	1,670	2,374	3,220	100	100	100	7.2	4.5	3.3	3.8
Coal	3.0	28	79	311	720	1,088	1,582	18	36	49	10.2	5.7	4.0	4.8
Oil	47	66	72	29	23	22	13	43	3.4	0.4	-3.2	-1.7	-2.7	-2.2
Natural gas	0.7	26	154	384	599	811	1,046	17	44	32	11.3	3.0	2.8	2.9
Nuclear	-	-	-	-	8.4	53	88	-	-	2.7	n.a.	n.a.	12.5	n.a.
Hydro	9.8	27	47	107	208	238	259	18	12	8.1	5.6	4.6	1.1	2.6
Geothermal	2.1	6.6	16	21	56	68	75	4.3	2.4	2.3	4.8	6.7	1.5	3.7
Solar PV	-	-	-	2.9	21	46	92	-	0.3	2.9	n.a.	14.1	7.8	10.4
Wind	-	-	-	1.2	6.3	11	16	-	0.1	0.5	n.a.	11.7	4.7	7.7
CSP and marine	-	-	-	-	0.1	0.3	0.5	-	-	0.0	n.a.	n.a.	8.3	n.a.
Biomass and waste	-	0.6	1.0	12	29	38	48	0.4	1.3	1.5	12.5	6.4	2.5	4.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	440	741	1,180	2,490	4,955	7,383	10,390	5.0	4.7	3.8	4.2
Population (million)	347	430	505	608	696	736	761	1.4	0.9	0.4	0.6
CO_2 emissions (Mt)	205	362	711	1,288	2,111	2,812	3,602	5.2	3.4	2.7	3.0
GDP per capita ($2010 thousand)	1.3	1.7	2.3	4.1	7.1	10	14	3.5	3.8	3.3	3.5
Primary energy consump. per capita (toe)	0.4	0.5	0.8	1.0	1.4	1.7	2.0	2.6	2.2	1.8	2.0
Primary energy consumption per GDP*2	323	314	322	249	198	171	149	-0.9	-1.5	-1.4	-1.5
CO_2 emissions per GDP*3	466	489	602	517	426	381	347	0.2	-1.3	-1.0	-1.1
CO_2 per primary energy consumption*4	1.4	1.6	1.9	2.1	2.1	2.2	2.3	1.2	0.2	0.4	0.3

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A28 | Indonesia [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	56	99	156	225	394	511	619	100	100	100	3.4	3.8	2.3	2.9
Coal	0.2	3.5	12	41	87	123	161	3.6	18	26	10.3	5.1	3.2	4.0
Oil	20	33	58	71	107	142	176	34	32	29	3.1	2.8	2.5	2.6
Natural gas	4.9	16	27	38	72	101	131	16	17	21	3.6	4.4	3.0	3.6
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.5	0.9	1.2	1.7	1.8	2.0	0.5	0.5	0.3	3.6	2.3	1.0	1.6
Geothermal	-	1.9	8.4	17	62	80	88	2.0	7.7	14	9.2	8.9	1.7	4.8
Solar, wind, etc.	-	-	-	0.0	0.0	0.1	0.2	-	0.0	0.0	n.a.	29.9	8.4	17.2
Biomass and waste	30	44	50	57	63	64	60	44	25	9.7	1.1	0.7	-0.2	0.2

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	50	80	120	163	245	314	382	100	100	100	2.9	2.8	2.2	2.5
Industry	6.7	18	30	42	69	92	115	23	26	30	3.4	3.4	2.6	3.0
Transport	6.0	11	21	44	68	88	110	13	27	29	5.8	2.9	2.4	2.6
Buildings, etc.	36	44	59	70	97	119	140	55	43	37	1.9	2.2	1.8	2.0
Non-energy use	1.2	7.4	9.8	7.2	11	14	17	9.2	4.4	4.4	-0.1	3.0	2.0	2.4
Coal	0.1	2.2	4.7	9.6	15	20	25	2.7	5.9	6.4	6.1	3.0	2.5	2.7
Oil	17	27	48	63	99	132	166	34	39	43	3.4	3.0	2.6	2.8
Natural gas	2.4	6.0	12	17	31	43	55	7.5	10	14	4.2	4.1	2.9	3.4
Electricity	0.6	2.4	6.8	17	39	57	79	3.0	11	21	8.2	5.5	3.6	4.4
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	5.6	n.a.
Renewables	29	42	49	56	62	62	58	53	34	15	1.1	0.7	-0.3	0.1

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	7.5	33	93	234	520	762	1,035	100	100	100	8.2	5.5	3.5	4.3
Coal	-	9.8	34	131	314	472	657	30	56	63	10.9	6.0	3.8	4.7
Oil	6.2	15	18	20	14	14	9.5	47	8.4	0.9	1.0	-2.3	-1.9	-2.0
Natural gas	-	0.7	26	59	134	204	287	2.2	25	28	19.2	5.6	3.9	4.6
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	1.3	5.7	10	14	19	21	24	17	5.9	2.3	3.6	2.3	1.0	1.6
Geothermal	-	1.1	4.9	10	36	46	51	3.4	4.3	4.9	9.2	8.9	1.7	4.8
Solar PV	-	-	-	0.0	0.4	1.4	2.2	-	0.0	0.2	n.a.	34.5	8.6	19.0
Wind	-	-	-	0.0	0.0	0.1	0.1	-	0.0	0.0	n.a.	13.4	6.1	9.2
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	0.0	1.1	2.6	3.5	4.4	-	0.5	0.4	n.a.	5.8	2.6	4.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	182	310	453	988	2,124	3,329	4,819	4.7	5.2	4.2	4.6
Population (million)	147	181	212	258	295	312	322	1.4	0.9	0.4	0.6
CO_2 emissions (Mt)	72	134	262	451	811	1,120	1,440	5.0	4.0	2.9	3.4
GDP per capita ($2010 thousand)	1.2	1.7	2.1	3.8	7.2	11	15	3.3	4.3	3.7	4.0
Primary energy consump. per capita (toe)	0.4	0.5	0.7	0.9	1.3	1.6	1.9	1.9	2.8	1.9	2.3
Primary energy consumption per GDP*2	307	318	343	228	185	154	128	-1.3	-1.4	-1.8	-1.6
CO_2 emissions per GDP*3	394	432	578	457	382	336	299	0.2	-1.2	-1.2	-1.2
CO_2 per primary energy consumption*4	1.3	1.4	1.7	2.0	2.1	2.2	2.3	1.6	0.2	0.6	0.4

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A29 | Malaysia [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	12	22	49	86	120	142	158	100	100	100	5.6	2.3	1.4	1.8
Coal	0.1	1.4	2.3	18	31	38	47	6.2	20	30	10.8	4.0	2.1	2.9
Oil	7.9	11	19	28	34	37	40	53	32	25	3.6	1.4	0.8	1.1
Natural gas	2.2	6.8	25	38	50	57	61	31	44	38	7.1	1.9	1.0	1.4
Nuclear	-	-	-	-	-	3.7	3.7	-	-	2.3	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.3	0.6	1.2	2.4	2.8	3.1	1.6	1.4	2.0	5.1	4.7	1.3	2.8
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.0	0.1	0.3	0.5	-	0.0	0.3	n.a.	11.9	6.8	9.0
Biomass and waste	1.6	1.9	1.9	1.9	2.6	2.8	3.0	8.5	2.3	1.9	0.2	2.0	0.6	1.2

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	7.2	14	30	52	71	82	92	100	100	100	5.4	2.1	1.3	1.7
Industry	3.1	5.6	12	15	24	30	36	40	29	39	4.1	3.1	2.0	2.5
Transport	2.1	4.9	11	21	24	25	25	35	41	27	6.0	0.8	0.3	0.5
Buildings, etc.	1.7	2.6	5.0	9.4	14	17	20	19	18	21	5.2	2.8	1.6	2.1
Non-energy use	0.3	0.8	2.2	5.9	8.5	10	12	6.0	11	13	8.1	2.5	1.6	2.0
Coal	0.1	0.5	1.0	1.8	2.8	3.4	4.0	3.7	3.4	4.3	5.1	3.0	1.8	2.3
Oil	5.3	9.3	18	28	34	37	40	67	54	43	4.4	1.3	0.8	1.0
Natural gas	0.0	1.1	3.9	9.6	14	16	17	7.9	19	19	9.1	2.3	1.2	1.7
Electricity	0.7	1.7	5.3	11	19	25	30	12	22	32	7.9	3.5	2.2	2.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	3.3	n.a.
Renewables	1.0	1.3	1.3	1.2	1.6	1.6	1.7	9.1	2.4	1.8	-0.1	1.7	0.2	0.9

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	10	23	69	150	250	321	388	100	100	100	7.8	3.5	2.2	2.8
Coal	-	2.9	7.7	63	131	164	221	13	42	57	13.1	4.9	2.7	3.6
Oil	8.5	11	3.6	1.7	2.0	1.7	1.2	46	1.2	0.3	-7.0	0.8	-2.4	-1.1
Natural gas	0.1	5.5	51	70	87	103	108	24	47	28	10.7	1.4	1.1	1.2
Nuclear	-	-	-	-	-	14	14	-	-	3.6	n.a.	n.a.	n.a.	n.a.
Hydro	1.4	4.0	7.0	14	28	32	36	17	9.3	9.3	5.1	4.7	1.3	2.8
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	0.3	1.5	3.5	5.6	-	0.2	1.4	n.a.	11.9	6.8	9.0
Wind	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	-	0.8	1.8	2.5	3.1	-	0.5	0.8	n.a.	6.2	2.6	4.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	46	82	163	330	629	895	1,205	5.7	4.4	3.3	3.8
Population (million)	14	18	23	30	36	39	41	2.1	1.2	0.6	0.9
CO_2 emissions (Mt)	29	54	121	227	323	372	421	5.9	2.4	1.3	1.8
GDP per capita ($2010 thousand)	3.3	4.5	6.9	11	17	23	29	3.6	3.1	2.7	2.9
Primary energy consump. per capita (toe)	0.9	1.2	2.1	2.8	3.3	3.6	3.8	3.5	1.0	0.8	0.9
Primary energy consumption per GDP*2	260	267	301	260	191	159	131	-0.1	-2.0	-1.9	-1.9
CO_2 emissions per GDP*3	630	666	744	689	514	416	349	0.1	-1.9	-1.9	-1.9
CO_2 per primary energy consumption*4	2.4	2.5	2.5	2.6	2.7	2.6	2.7	0.2	0.1	-0.1	0.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A30 | Myanmar [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	9.4	11	13	20	35	50	69	100	100	100	2.5	3.9	3.4	3.6
Coal	0.2	0.1	0.3	0.4	2.9	5.4	8.9	0.6	2.2	13	7.9	13.4	5.7	9.0
Oil	1.3	0.7	2.0	5.4	15	24	36	6.8	27	53	8.4	7.1	4.5	5.6
Natural gas	0.3	0.8	1.2	3.0	4.7	7.3	10	7.1	15	15	5.7	3.0	3.9	3.5
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.1	0.2	0.8	3.2	4.2	5.1	1.0	4.1	7.3	8.6	9.5	2.4	5.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	-	0.1	0.1	0.2	-	-	0.3	n.a.	n.a.	6.8	n.a.
Biomass and waste	7.6	9.0	9.2	10	11	11	11	84	51	16	0.5	0.3	0.2	0.3

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	8.4	9.4	11	18	31	43	59	100	100	100	2.6	3.7	3.3	3.5
Industry	0.6	0.4	1.1	2.2	5.1	7.5	9.9	4.2	12	17	7.1	5.8	3.4	4.4
Transport	0.6	0.4	1.2	3.5	10.0	16	25	4.7	20	43	8.6	7.2	4.8	5.8
Buildings, etc.	7.0	8.5	9.1	12	15	19	23	90	66	39	1.3	1.7	2.0	1.9
Non-energy use	0.1	0.1	0.1	0.3	0.4	0.6	0.7	1.0	1.5	1.1	4.2	3.3	2.1	2.6
Coal	0.1	0.1	0.3	0.4	0.5	0.6	0.6	0.5	2.1	1.0	8.3	2.0	0.8	1.3
Oil	1.2	0.6	1.5	5.4	15	24	36	6.2	31	62	9.3	7.0	4.5	5.6
Natural gas	0.1	0.2	0.3	0.7	1.3	1.9	2.6	2.4	4.0	4.4	4.7	3.9	3.7	3.8
Electricity	0.1	0.1	0.3	1.2	3.3	5.4	8.1	1.6	6.5	14	8.5	7.2	4.6	5.7
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	6.6	n.a.
Renewables	6.9	8.4	9.0	10	11	11	11	89	57	19	0.7	0.3	0.2	0.3

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1.5	2.5	5.1	16	66	103	149	100	100	100	7.7	9.9	4.2	6.6
Coal	0.0	0.0	-	0.3	12	25	46	1.6	1.8	31	8.2	28.3	7.0	15.7
Oil	0.5	0.3	0.7	0.1	0.2	0.2	0.2	11	0.3	0.1	-6.2	7.5	1.1	3.8
Natural gas	0.2	1.0	2.5	6.2	16	28	42	39	39	28	7.7	6.5	4.9	5.6
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.8	1.2	1.9	9.4	37	49	59	48	59	39	8.6	9.5	2.4	5.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	-	0.3	0.8	1.8	-	-	1.2	n.a.	n.a.	10.1	n.a.
Wind	-	-	-	-	0.4	0.6	0.8	-	-	0.5	n.a.	n.a.	3.0	n.a.
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	5.9	6.7	13	59	153	252	384	9.1	6.5	4.7	5.5
Population (million)	34	42	48	54	61	63	64	1.0	0.8	0.3	0.5
CO_2 emissions (Mt)	5.2	4.1	9.9	25	68	111	169	7.5	6.9	4.7	5.6
GDP per capita ($2010 thousand)	0.2	0.2	0.3	1.1	2.5	4.0	6.0	8.0	5.7	4.4	5.0
Primary energy consump. per capita (toe)	0.3	0.3	0.3	0.4	0.6	0.8	1.1	1.5	3.1	3.1	3.1
Primary energy consumption per GDP[*2]	1,597	1,593	960	336	230	198	179	-6.0	-2.5	-1.2	-1.8
CO_2 emissions per GDP[*3]	888	606	741	421	445	439	441	-1.4	0.4	0.0	0.1
CO_2 per primary energy consumption[*4]	0.6	0.4	0.8	1.3	1.9	2.2	2.5	4.9	2.9	1.2	1.9

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A31 | Philippines [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	22	29	40	52	97	132	175	100	100	100	2.4	4.3	3.0	3.5
Coal	0.5	1.5	5.2	13	25	36	49	5.3	24	28	8.8	4.7	3.3	3.9
Oil	10	11	16	18	34	49	68	38	34	39	2.0	4.4	3.5	3.9
Natural gas	-	-	0.0	2.9	8.7	15	24	-	5.5	13	n.a.	7.6	5.1	6.2
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.3	0.5	0.7	0.7	0.9	0.9	1.0	1.8	1.4	0.5	1.4	1.5	0.1	0.7
Geothermal	1.8	4.7	10.0	9.5	17	19	21	16	18	12	2.9	3.8	1.1	2.2
Solar, wind, etc.	-	-	-	0.1	0.5	1.1	1.8	-	0.1	1.0	n.a.	13.8	6.2	9.4
Biomass and waste	9.4	11	8.1	8.6	12	12	12	39	17	6.6	-1.0	2.0	0.0	0.8

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	17	20	24	30	58	82	114	100	100	100	1.7	4.6	3.4	3.9
Industry	3.4	4.7	5.3	7.4	13	18	24	24	25	21	1.9	4.0	3.0	3.4
Transport	3.5	4.5	8.1	11	24	35	50	23	36	44	3.5	5.5	3.8	4.5
Buildings, etc.	9.4	10	10	11	19	25	34	52	36	30	0.1	4.0	3.0	3.4
Non-energy use	0.3	0.2	0.3	1.0	2.2	3.5	5.6	1.2	3.5	4.9	6.3	4.9	4.9	4.9
Coal	0.2	0.6	0.8	2.3	4.1	5.3	6.4	3.1	7.7	5.6	5.4	4.0	2.2	3.0
Oil	7.0	8.1	13	15	31	45	65	41	51	57	2.5	5.0	3.7	4.3
Natural gas	-	-	-	0.1	0.4	0.7	1.1	-	0.2	1.0	n.a.	15.2	5.0	9.3
Electricity	1.5	1.8	3.1	5.8	13	21	32	9.3	20	28	4.8	5.7	4.5	5.0
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	6.0	n.a.
Renewables	7.8	9.1	6.9	6.4	9.2	9.6	9.1	46	21	8.0	-1.4	2.5	0.0	1.0

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	18	26	45	82	186	287	434	100	100	100	4.7	5.6	4.3	4.9
Coal	0.2	1.9	17	37	92	144	219	7.3	45	51	12.5	6.3	4.5	5.2
Oil	12	12	9.2	5.9	4.8	4.1	0.9	47	7.1	0.2	-2.9	-1.4	-8.2	-5.3
Natural gas	-	-	0.0	19	53	92	157	-	23	36	n.a.	7.1	5.6	6.2
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	3.5	6.1	7.8	8.7	11	11	11	23	11	2.6	1.4	1.5	0.1	0.7
Geothermal	2.1	5.5	12	11	19	22	24	21	13	5.5	2.9	3.8	1.1	2.2
Solar PV	-	-	-	0.1	3.4	8.1	14	-	0.2	3.2	n.a.	23.7	7.4	14.1
Wind	-	-	-	0.7	2.8	4.4	6.7	-	0.9	1.6	n.a.	9.2	4.5	6.5
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	0.4	-	0.4	0.7	0.9	1.1	1.6	0.4	0.3	-0.6	4.0	2.6	3.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	80	95	125	266	609	901	1,286	4.2	5.7	3.8	4.6
Population (million)	47	62	78	101	124	138	150	2.0	1.4	0.9	1.1
CO_2 emissions (Mt)	33	39	69	108	218	314	440	4.2	4.8	3.6	4.1
GDP per capita ($2010 thousand)	1.7	1.5	1.6	2.6	4.9	6.5	8.6	2.2	4.2	2.8	3.4
Primary energy consump. per capita (toe)	0.5	0.5	0.5	0.5	0.8	1.0	1.2	0.4	2.8	2.0	2.4
Primary energy consumption per GDP[*2]	280	304	319	196	160	146	136	-1.7	-1.4	-0.8	-1.0
CO_2 emissions per GDP[*3]	414	409	550	406	358	348	342	0.0	-0.8	-0.2	-0.5
CO_2 per primary energy consumption[*4]	1.5	1.3	1.7	2.1	2.2	2.4	2.5	1.7	0.5	0.6	0.6

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A32 | Thailand [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	22	42	72	135	174	210	245	100	100	100	4.8	1.7	1.7	1.7
Coal	0.5	3.8	7.7	17	24	30	34	9.1	12	14	6.1	2.4	1.8	2.0
Oil	11	18	32	54	64	75	87	43	40	35	4.5	1.1	1.6	1.4
Natural gas	-	5.0	17	38	49	59	67	12	28	27	8.4	1.7	1.6	1.6
Nuclear	-	-	-	-	-	3.7	8.8	-	-	3.6	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.4	0.5	0.4	0.6	0.7	0.7	1.0	0.3	0.3	-0.2	3.1	0.1	1.4
Geothermal	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3	1.1	4.9
Solar, wind, etc.	-	-	-	0.2	1.4	2.9	6.0	-	0.2	2.4	n.a.	12.9	7.4	9.7
Biomass and waste	11	15	15	25	33	35	37	35	19	15	2.2	1.7	0.6	1.1

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	15	29	51	98	122	144	168	100	100	100	5.0	1.4	1.6	1.5
Industry	4.0	8.7	17	31	38	46	53	30	31	31	5.2	1.5	1.6	1.6
Transport	3.2	9.0	15	24	26	28	30	31	24	18	3.9	0.6	0.7	0.7
Buildings, etc.	7.8	11	14	21	29	35	41	37	22	24	2.7	2.1	1.8	1.9
Non-energy use	0.2	0.4	5.6	23	29	36	44	1.5	23	26	17.2	1.6	2.2	1.9
Coal	0.1	1.3	3.5	8.2	8.9	9.5	10	4.5	8.3	6.0	7.6	0.6	0.6	0.6
Oil	7.3	15	29	52	61	72	83	52	53	50	5.1	1.1	1.5	1.4
Natural gas	-	0.1	1.1	7.2	11	14	19	0.5	7.3	11	17.1	2.6	2.9	2.8
Electricity	1.1	3.3	7.6	15	23	31	38	11	15	23	6.3	3.0	2.5	2.7
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	4.2	n.a.
Renewables	6.7	9.2	9.4	16	18	18	17	32	16	10	2.2	0.6	-0.1	0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	14	44	96	178	260	341	422	100	100	100	5.7	2.6	2.5	2.5
Coal	1.4	11	18	35	65	93	116	25	19	28	4.7	4.3	3.0	3.5
Oil	12	10	10	1.0	0.6	0.1	-	23	0.6	-	-8.9	-3.5	-100	-100
Natural gas	-	18	62	127	150	165	161	40	71	38	8.2	1.1	0.4	0.7
Nuclear	-	-	-	-	-	14	34	-	-	8.0	n.a.	n.a.	n.a.	n.a.
Hydro	1.3	5.0	6.0	4.7	7.5	7.6	7.7	11	2.7	1.8	-0.2	3.1	0.1	1.4
Geothermal	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3	1.1	4.9
Solar PV	-	-	-	2.4	14	29	62	-	1.3	15	n.a.	12.5	7.8	9.8
Wind	-	-	-	0.3	2.3	4.0	5.7	-	0.2	1.3	n.a.	14.0	4.5	8.5
CSP and marine	-	-	-	-	0.1	0.3	0.5	-	-	0.1	n.a.	n.a.	8.3	n.a.
Biomass and waste	-	-	0.5	7.7	21	27	35	-	4.3	8.2	n.a.	6.8	2.6	4.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	67	142	218	392	642	884	1,157	4.2	3.3	3.0	3.1
Population (million)	47	57	63	68	69	68	65	0.7	0.1	-0.3	-0.1
CO_2 emissions (Mt)	34	81	152	252	319	381	428	4.7	1.6	1.5	1.5
GDP per capita ($2010 thousand)	1.4	2.5	3.5	5.8	9.3	13	18	3.4	3.2	3.3	3.3
Primary energy consump. per capita (toe)	0.5	0.7	1.2	2.0	2.5	3.1	3.8	4.0	1.6	2.0	1.9
Primary energy consumption per GDP*2	331	296	332	345	271	238	212	0.6	-1.6	-1.2	-1.4
CO_2 emissions per GDP*3	512	570	697	642	497	431	370	0.5	-1.7	-1.5	-1.6
CO_2 per primary energy consumption*4	1.5	1.9	2.1	1.9	1.8	1.8	1.7	-0.1	-0.1	-0.2	-0.2

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A33 | Viet Nam [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	14	18	29	74	128	178	240	100	100	100	5.8	3.7	3.2	3.4
Coal	2.3	2.2	4.4	25	47	68	97	12	34	41	10.2	4.3	3.7	4.0
Oil	1.8	2.7	7.8	19	32	46	64	15	25	27	8.1	3.6	3.5	3.5
Natural gas	-	0.0	1.1	9.5	18	27	38	0.0	13	16	38.6	4.4	3.7	4.0
Nuclear	-	-	-	-	2.2	6.4	11	-	-	4.4	n.a.	n.a.	8.2	n.a.
Hydro	0.1	0.5	1.3	4.8	9.2	10	11	2.6	6.5	4.4	9.8	4.4	0.7	2.2
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.0	0.1	0.3	0.5	-	0.0	0.2	n.a.	17.8	7.7	11.9
Biomass and waste	10	12	14	16	19	19	18	70	21	7.6	0.9	1.2	-0.1	0.5

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	13	16	25	58	96	128	167	100	100	100	5.3	3.4	2.8	3.1
Industry	3.8	4.5	7.9	23	42	57	73	28	39	44	6.7	4.1	2.9	3.4
Transport	0.6	1.4	3.5	11	15	20	27	8.6	18	16	8.5	2.4	2.9	2.7
Buildings, etc.	8.6	10	14	21	33	43	55	63	36	33	3.0	3.0	2.6	2.8
Non-energy use	0.0	0.0	0.1	3.6	6.3	8.5	11	0.2	6.1	6.5	21.5	3.8	2.8	3.2
Coal	1.5	1.3	3.2	12	19	22	25	8.3	20	15	9.1	3.1	1.4	2.1
Oil	1.7	2.3	6.5	18	31	44	62	15	31	37	8.5	3.7	3.5	3.6
Natural gas	-	-	0.0	1.5	3.6	5.2	7.0	-	2.6	4.2	n.a.	6.1	3.4	4.5
Electricity	0.2	0.5	1.9	12	26	38	56	3.3	21	34	13.4	5.0	4.0	4.4
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	9.1	n.a.
Renewables	9.7	12	13	15	18	18	17	74	25	10	0.8	1.2	-0.1	0.5

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	3.6	8.7	27	153	320	487	716	100	100	100	12.2	5.0	4.1	4.5
Coal	1.4	2.0	3.1	45	106	190	322	23	30	45	13.3	5.8	5.7	5.8
Oil	0.7	1.3	4.5	0.7	1.1	1.2	1.0	15	0.5	0.1	-2.2	2.4	-0.1	1.0
Natural gas	-	0.0	4.4	51	97	151	224	0.1	33	31	43.6	4.4	4.3	4.3
Nuclear	-	-	-	-	8.4	25	41	-	-	5.7	n.a.	n.a.	8.2	n.a.
Hydro	1.5	5.4	15	56	106	117	122	62	37	17	9.8	4.4	0.7	2.2
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	-	0.7	2.2	3.5	-	-	0.5	n.a.	n.a.	8.6	n.a.
Wind	-	-	-	0.1	0.7	1.5	2.7	-	0.1	0.4	n.a.	12.7	6.7	9.2
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	-	0.1	0.2	0.2	0.3	-	0.0	0.0	n.a.	6.5	2.6	4.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	17	29	61	155	367	607	957	6.9	5.9	4.9	5.3
Population (million)	54	66	78	92	104	109	112	1.3	0.9	0.4	0.6
CO_2 emissions (Mt)	15	17	44	168	308	449	635	9.6	4.1	3.7	3.9
GDP per capita ($2010 thousand)	0.3	0.4	0.8	1.7	3.5	5.6	8.5	5.5	5.0	4.5	4.7
Primary energy consump. per capita (toe)	0.3	0.3	0.4	0.8	1.2	1.6	2.1	4.5	2.9	2.8	2.8
Primary energy consumption per GDP[*2]	851	606	470	478	349	293	250	-1.0	-2.1	-1.6	-1.8
CO_2 emissions per GDP[*3]	860	579	711	1,088	839	739	663	2.6	-1.7	-1.2	-1.4
CO_2 per primary energy consumption[*4]	1.0	1.0	1.5	2.3	2.4	2.5	2.7	3.5	0.4	0.5	0.4

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A34 | North America [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	1,997	2,126	2,527	2,458	2,420	2,382	2,312	100	100	100	0.6	-0.1	-0.2	-0.2
Coal	397	485	565	393	289	230	168	23	16	7.3	-0.8	-2.0	-2.7	-2.4
Oil	885	833	958	888	805	751	695	39	36	30	0.3	-0.7	-0.7	-0.7
Natural gas	522	493	622	733	819	877	905	23	30	39	1.6	0.7	0.5	0.6
Nuclear	80	179	227	243	229	208	183	8.4	9.9	7.9	1.2	-0.4	-1.1	-0.8
Hydro	46	49	53	54	61	62	62	2.3	2.2	2.7	0.4	0.8	0.1	0.4
Geothermal	4.6	14	13	9.0	21	26	31	0.7	0.4	1.3	-1.8	5.8	1.9	3.6
Solar, wind, etc.	-	0.3	2.1	25	63	89	124	0.0	1.0	5.4	19.0	6.4	3.4	4.7
Biomass and waste	62	73	87	113	132	138	144	3.4	4.6	6.2	1.7	1.1	0.4	0.7

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1,466	1,455	1,738	1,714	1,711	1,701	1,669	100	100	100	0.7	0.0	-0.1	-0.1
Industry	437	331	388	304	305	305	299	23	18	18	-0.3	0.0	-0.1	-0.1
Transport	470	531	640	690	640	609	584	36	40	35	1.1	-0.5	-0.5	-0.5
Buildings, etc.	446	460	537	574	607	621	623	32	34	37	0.9	0.4	0.1	0.2
Non-energy use	114	134	173	145	160	166	164	9.2	8.4	9.8	0.3	0.7	0.1	0.4
Coal	60	59	36	22	19	17	15	4.0	1.3	0.9	-3.9	-1.0	-1.3	-1.2
Oil	769	752	874	847	776	727	676	52	49	41	0.5	-0.6	-0.7	-0.6
Natural gas	374	346	413	380	403	410	406	24	22	24	0.4	0.4	0.0	0.2
Electricity	200	262	342	368	413	446	471	18	21	28	1.4	0.8	0.7	0.7
Heat	1.0	2.8	6.1	6.1	6.7	7.0	7.1	0.2	0.4	0.4	3.2	0.6	0.3	0.4
Hydrogen	-	-	-	-	0.1	0.1	0.1	-	-	0.0	n.a.	n.a.	1.4	n.a.
Renewables	62	33	66	90	94	94	94	2.3	5.2	5.6	4.1	0.3	0.0	0.1

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	2,801	3,685	4,631	4,968	5,538	5,929	6,218	100	100	100	1.2	0.7	0.6	0.6
Coal	1,303	1,782	2,247	1,537	1,189	982	708	48	31	11	-0.6	-1.7	-2.6	-2.2
Oil	277	147	133	47	32	25	14	4.0	0.9	0.2	-4.5	-2.4	-4.1	-3.4
Natural gas	380	391	668	1,440	1,888	2,296	2,615	11	29	42	5.3	1.8	1.6	1.7
Nuclear	304	685	871	932	879	799	701	19	19	11	1.2	-0.4	-1.1	-0.8
Hydro	530	570	612	632	712	721	725	15	13	12	0.4	0.8	0.1	0.4
Geothermal	5.4	16	15	19	44	56	65	0.4	0.4	1.1	0.6	5.9	2.0	3.6
Solar PV	-	0.0	0.2	35	119	163	226	0.0	0.7	3.6	45.4	8.5	3.3	5.5
Wind	-	3.1	5.9	219	443	574	739	0.1	4.4	12	18.6	4.8	2.6	3.5
CSP and marine	-	0.7	0.6	14	67	116	192	0.0	0.3	3.1	12.9	10.8	5.4	7.7
Biomass and waste	1.8	90	80	93	164	199	231	2.5	1.9	3.7	0.1	3.9	1.7	2.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	7,310	10,078	14,056	18,394	25,027	30,559	36,274	2.4	2.1	1.9	2.0
Population (million)	252	277	313	357	397	419	436	1.0	0.7	0.5	0.6
CO_2 emissions (Mt)	5,170	5,236	6,126	5,574	5,066	4,786	4,438	0.3	-0.6	-0.7	-0.6
GDP per capita ($2010 thousand)	29	36	45	51	63	73	83	1.4	1.4	1.4	1.4
Primary energy consump. per capita (toe)	7.9	7.7	8.1	6.9	6.1	5.7	5.3	-0.4	-0.8	-0.7	-0.7
Primary energy consumption per GDP[*2]	273	211	180	134	97	78	64	-1.8	-2.1	-2.1	-2.1
CO_2 emissions per GDP[*3]	707	520	436	303	202	157	122	-2.1	-2.7	-2.5	-2.6
CO_2 per primary energy consumption[*4]	2.6	2.5	2.4	2.3	2.1	2.0	1.9	-0.3	-0.5	-0.4	-0.5

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A35 | United States [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	1,805	1,915	2,273	2,188	2,154	2,116	2,049	100	100	100	0.5	-0.1	-0.2	-0.2
Coal	376	460	534	374	278	221	162	24	17	7.9	-0.8	-2.0	-2.7	-2.4
Oil	797	757	871	794	717	670	622	40	36	30	0.2	-0.7	-0.7	-0.7
Natural gas	477	438	548	646	724	772	794	23	30	39	1.6	0.8	0.5	0.6
Nuclear	69	159	208	216	209	191	165	8.3	9.9	8.1	1.2	-0.2	-1.2	-0.8
Hydro	24	23	22	22	25	26	26	1.2	1.0	1.3	-0.3	1.1	0.1	0.5
Geothermal	4.6	14	13	9.0	21	26	31	0.7	0.4	1.5	-1.8	5.8	1.9	3.6
Solar, wind, etc.	-	0.3	2.1	22	57	81	115	0.0	1.0	5.6	18.5	6.5	3.6	4.8
Biomass and waste	54	62	73	99	118	124	130	3.3	4.5	6.3	1.9	1.2	0.5	0.8

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1,311	1,294	1,546	1,520	1,516	1,506	1,477	100	100	100	0.6	0.0	-0.1	-0.1
Industry	387	284	332	262	264	265	259	22	17	18	-0.3	0.1	-0.1	0.0
Transport	425	488	588	629	578	550	528	38	41	36	1.0	-0.6	-0.5	-0.5
Buildings, etc.	397	403	473	506	537	549	551	31	33	37	0.9	0.4	0.1	0.2
Non-energy use	102	119	153	123	137	142	139	9.2	8.1	9.4	0.1	0.7	0.1	0.3
Coal	56	56	33	20	17	15	13	4.3	1.3	0.9	-4.1	-1.0	-1.2	-1.1
Oil	689	683	793	758	689	646	601	53	50	41	0.4	-0.6	-0.7	-0.7
Natural gas	337	303	360	333	354	360	355	23	22	24	0.4	0.4	0.0	0.2
Electricity	174	226	301	325	365	393	415	18	21	28	1.5	0.8	0.6	0.7
Heat	-	2.2	5.3	5.5	6.1	6.5	6.6	0.2	0.4	0.4	3.8	0.8	0.4	0.5
Hydrogen	-	-	-	-	0.1	0.1	0.1	-	-	0.0	n.a.	n.a.	1.3	n.a.
Renewables	54	23	54	79	84	85	86	1.8	5.2	5.8	5.1	0.4	0.1	0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	2,427	3,203	4,026	4,297	4,829	5,169	5,414	100	100	100	1.2	0.8	0.6	0.7
Coal	1,243	1,700	2,129	1,471	1,150	949	690	53	34	13	-0.6	-1.6	-2.5	-2.1
Oil	263	131	118	39	28	20	11	4.1	0.9	0.2	-4.7	-2.3	-4.4	-3.5
Natural gas	370	382	634	1,373	1,807	2,171	2,451	12	32	45	5.3	1.8	1.5	1.7
Nuclear	266	612	798	830	801	732	635	19	19	12	1.2	-0.2	-1.2	-0.8
Hydro	279	273	253	251	295	298	300	8.5	5.8	5.5	-0.3	1.1	0.1	0.5
Geothermal	5.4	16	15	19	44	56	65	0.5	0.4	1.2	0.6	5.9	2.0	3.6
Solar PV	-	0.0	0.2	32	112	155	216	0.0	0.7	4.0	44.9	8.7	3.3	5.6
Wind	-	3.1	5.7	193	391	508	662	0.1	4.5	12	18.0	4.8	2.7	3.6
CSP and marine	-	0.7	0.5	9.1	59	108	183	0.0	0.2	3.4	11.0	13.3	5.8	9.0
Biomass and waste	0.5	86	72	80	143	173	200	2.7	1.9	3.7	-0.3	3.9	1.7	2.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	6,529	9,064	12,713	16,597	22,629	27,677	32,902	2.4	2.1	1.9	2.0
Population (million)	227	250	282	321	356	376	391	1.0	0.7	0.5	0.6
CO_2 emissions (Mt)	4,744	4,820	5,617	5,071	4,598	4,328	4,004	0.2	-0.7	-0.7	-0.7
GDP per capita ($2010 thousand)	29	36	45	52	64	74	84	1.4	1.4	1.4	1.4
Primary energy consump. per capita (toe)	7.9	7.7	8.1	6.8	6.0	5.6	5.2	-0.5	-0.8	-0.7	-0.7
Primary energy consumption per GDP[*2]	276	211	179	132	95	76	62	-1.9	-2.1	-2.1	-2.1
CO_2 emissions per GDP[*3]	727	532	442	305	203	156	122	-2.2	-2.7	-2.5	-2.6
CO_2 per primary energy consumption[*4]	2.6	2.5	2.5	2.3	2.1	2.0	2.0	-0.3	-0.5	-0.4	-0.5

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A36 | Latin America [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	382	465	600	851	1,092	1,264	1,378	100	100	100	2.5	1.7	1.2	1.4
Coal	13	21	27	47	59	68	72	4.5	5.6	5.3	3.3	1.4	1.1	1.2
Oil	223	238	303	377	449	487	491	51	44	36	1.9	1.2	0.4	0.8
Natural gas	48	72	119	207	281	364	437	16	24	32	4.3	2.1	2.2	2.2
Nuclear	0.6	3.2	5.3	8.7	26	28	28	0.7	1.0	2.1	4.0	7.6	0.4	3.4
Hydro	19	33	50	60	77	82	88	7.2	7.1	6.4	2.4	1.7	0.7	1.1
Geothermal	1.2	5.1	6.3	6.5	19	27	35	1.1	0.8	2.6	1.0	7.3	3.2	4.9
Solar, wind, etc.	-	0.0	0.2	4.6	13	22	32	0.0	0.5	2.3	25.0	7.2	4.5	5.7
Biomass and waste	78	92	89	139	167	184	193	20	16	14	1.7	1.2	0.7	0.9

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	288	343	447	610	773	891	975	100	100	100	2.3	1.6	1.2	1.3
Industry	98	114	148	191	229	274	310	33	31	32	2.1	1.2	1.5	1.4
Transport	85	103	140	222	284	316	332	30	36	34	3.1	1.7	0.8	1.2
Buildings, etc.	89	101	120	160	212	246	272	29	26	28	1.9	1.9	1.3	1.5
Non-energy use	16	26	38	38	48	55	61	7.5	6.3	6.3	1.6	1.5	1.2	1.3
Coal	6.1	7.8	11	15	18	21	21	2.3	2.5	2.2	2.7	1.2	0.8	0.9
Oil	159	179	240	304	374	414	432	52	50	44	2.1	1.4	0.7	1.0
Natural gas	27	38	53	78	100	120	137	11	13	14	3.0	1.7	1.6	1.6
Electricity	27	44	69	111	163	209	251	13	18	26	3.7	2.6	2.2	2.4
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.1	0.1	0.1	-	-	0.0	n.a.	n.a.	3.5	n.a.
Renewables	69	74	74	102	118	128	133	22	17	14	1.3	0.9	0.6	0.7

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	380	623	1,009	1,598	2,314	2,906	3,426	100	100	100	3.8	2.5	2.0	2.2
Coal	7.8	23	43	106	148	190	215	3.8	6.7	6.3	6.2	2.2	1.9	2.0
Oil	111	128	198	198	183	168	102	21	12	3.0	1.8	-0.5	-2.9	-1.9
Natural gas	35	60	141	436	702	1,063	1,406	9.6	27	41	8.3	3.2	3.5	3.4
Nuclear	2.3	12	20	33	101	109	109	2.0	2.1	3.2	4.0	7.6	0.4	3.4
Hydro	218	386	584	701	899	959	1,027	62	44	30	2.4	1.7	0.7	1.1
Geothermal	1.4	5.9	7.8	10	29	44	58	1.0	0.6	1.7	2.2	7.3	3.5	5.1
Solar PV	-	0.0	0.0	2.5	14	27	49	0.0	0.2	1.4	36.8	12.3	6.3	8.8
Wind	-	0.0	0.2	40	120	200	292	0.0	2.5	8.5	52.8	7.6	4.6	5.8
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	3.9	7.6	14	69	118	146	167	1.2	4.3	4.9	9.3	3.6	1.7	2.5
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	2,404	2,779	3,767	5,779	8,545	11,704	14,903	3.0	2.6	2.8	2.7
Population (million)	361	442	522	629	715	754	777	1.4	0.9	0.4	0.6
CO_2 emissions (Mt)	801	909	1,206	1,724	2,137	2,469	2,651	2.6	1.4	1.1	1.2
GDP per capita ($2010 thousand)	6.7	6.3	7.2	9.2	12	16	19	1.5	1.8	2.4	2.1
Primary energy consump. per capita (toe)	1.1	1.1	1.2	1.4	1.5	1.7	1.8	1.0	0.8	0.8	0.8
Primary energy consumption per GDP[*2]	159	167	159	147	128	108	92	-0.5	-0.9	-1.6	-1.3
CO_2 emissions per GDP[*3]	333	327	320	298	250	211	178	-0.4	-1.2	-1.7	-1.5
CO_2 per primary energy consumption[*4]	2.1	2.0	2.0	2.0	2.0	2.0	1.9	0.1	-0.2	-0.1	-0.1

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A37 | OECD Europe [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	1,494	1,629	1,752	1,706	1,658	1,606	1,561	100	100	100	0.2	-0.2	-0.3	-0.3
Coal	464	449	331	285	226	186	154	28	17	9.9	-1.8	-1.5	-1.9	-1.7
Oil	688	611	653	554	484	433	387	38	32	25	-0.4	-0.9	-1.1	-1.0
Natural gas	206	262	394	389	425	431	426	16	23	27	1.6	0.6	0.0	0.3
Nuclear	60	205	245	222	203	206	216	13	13	14	0.3	-0.6	0.3	-0.1
Hydro	36	39	47	49	51	52	54	2.4	2.9	3.4	0.9	0.3	0.2	0.3
Geothermal	3.0	4.9	7.2	15	21	24	26	0.3	0.9	1.7	4.6	2.2	1.1	1.6
Solar, wind, etc.	0.1	0.3	2.7	40	77	100	121	0.0	2.4	7.7	21.1	4.4	2.3	3.2
Biomass and waste	36	55	72	149	168	173	176	3.4	8.7	11	4.0	0.8	0.2	0.5

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1,081	1,134	1,233	1,202	1,188	1,157	1,123	100	100	100	0.2	-0.1	-0.3	-0.2
Industry	356	328	326	280	279	276	271	29	23	24	-0.6	0.0	-0.1	-0.1
Transport	209	267	317	335	293	264	241	24	28	21	0.9	-0.9	-1.0	-0.9
Buildings, etc.	425	438	475	485	509	508	501	39	40	45	0.4	0.3	-0.1	0.1
Non-energy use	90	101	115	103	108	109	109	8.9	8.6	9.8	0.1	0.3	0.1	0.2
Coal	156	125	63	46	43	41	38	11	3.9	3.4	-3.9	-0.4	-0.7	-0.6
Oil	551	524	572	501	437	390	347	46	42	31	-0.2	-0.9	-1.1	-1.0
Natural gas	161	203	268	255	267	267	265	18	21	24	0.9	0.3	0.0	0.1
Electricity	147	192	233	261	289	306	319	17	22	28	1.2	0.7	0.5	0.6
Heat	35	43	41	47	48	47	47	3.8	3.9	4.2	0.3	0.2	-0.1	0.0
Hydrogen	-	-	-	-	0.0	0.1	0.1	-	-	0.0	n.a.	n.a.	2.7	n.a.
Renewables	31	47	55	92	103	106	107	4.2	7.6	9.6	2.7	0.8	0.2	0.5

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	2,049	2,668	3,227	3,559	3,913	4,099	4,231	100	100	100	1.2	0.6	0.4	0.5
Coal	887	1,030	968	859	731	603	482	39	24	11	-0.7	-1.1	-2.1	-1.6
Oil	364	206	179	57	40	28	17	7.7	1.6	0.4	-5.0	-2.3	-4.3	-3.4
Natural gas	138	169	513	585	731	780	785	6.3	16	19	5.1	1.5	0.4	0.8
Nuclear	230	787	939	853	781	791	829	29	24	20	0.3	-0.6	0.3	-0.1
Hydro	416	451	549	569	596	610	623	17	16	15	0.9	0.3	0.2	0.3
Geothermal	2.7	3.6	6.2	15	22	26	29	0.1	0.4	0.7	5.9	2.7	1.3	1.9
Solar PV	-	0.0	0.1	100	176	220	267	0.0	2.8	6.3	43.0	3.8	2.1	2.9
Wind	0.0	0.8	22	306	527	684	802	0.0	8.6	19	27.0	3.7	2.1	2.8
CSP and marine	0.5	0.7	1.6	9.9	36	51	70	0.0	0.3	1.6	10.9	9.0	3.4	5.7
Biomass and waste	11	21	48	204	273	305	325	0.8	5.7	7.7	9.6	2.0	0.9	1.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	9,940	12,666	15,889	19,517	24,815	28,286	31,565	1.7	1.6	1.2	1.4
Population (million)	479	502	524	566	586	591	589	0.5	0.2	0.0	0.1
CO_2 emissions (Mt)	4,165	3,971	3,897	3,436	3,057	2,752	2,471	-0.6	-0.8	-1.1	-0.9
GDP per capita ($2010 thousand)	21	25	30	34	42	48	54	1.3	1.4	1.2	1.3
Primary energy consump. per capita (toe)	3.1	3.2	3.3	3.0	2.8	2.7	2.6	-0.3	-0.4	-0.3	-0.4
Primary energy consumption per GDP[*2]	150	129	110	87	67	57	49	-1.5	-1.8	-1.5	-1.6
CO_2 emissions per GDP[*3]	419	313	245	176	123	97	78	-2.3	-2.4	-2.2	-2.3
CO_2 per primary energy consumption[*4]	2.8	2.4	2.2	2.0	1.8	1.7	1.6	-0.8	-0.6	-0.8	-0.7

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A38 | Non-OECD Europe [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	1,241	1,530	1,000	1,106	1,216	1,322	1,451	100	100	100	-1.3	0.6	0.9	0.8
Coal	362	367	209	211	185	183	183	24	19	13	-2.2	-0.9	-0.1	-0.4
Oil	464	465	201	238	247	271	301	30	21	21	-2.6	0.3	1.0	0.7
Natural gas	355	600	487	526	598	676	751	39	48	52	-0.5	0.9	1.1	1.0
Nuclear	21	59	64	82	118	112	121	3.9	7.4	8.3	1.3	2.5	0.1	1.1
Hydro	20	23	23	25	28	29	30	1.5	2.2	2.1	0.4	0.9	0.3	0.5
Geothermal	-	0.0	0.1	0.2	0.6	0.6	0.7	0.0	0.0	0.0	9.3	6.4	1.0	3.3
Solar, wind, etc.	-	-	0.0	1.5	4.8	8.7	14	-	0.1	0.9	n.a.	7.9	5.3	6.4
Biomass and waste	21	17	16	23	35	42	52	1.1	2.1	3.6	1.3	2.7	2.0	2.3

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	869	1,067	651	701	768	836	918	100	100	100	-1.7	0.6	0.9	0.8
Industry	394	394	205	191	214	243	275	37	27	30	-2.9	0.8	1.3	1.0
Transport	107	171	110	143	147	153	162	16	20	18	-0.7	0.2	0.5	0.3
Buildings, etc.	301	436	287	274	291	298	307	41	39	33	-1.8	0.4	0.3	0.3
Non-energy use	67	66	49	93	115	142	174	6.2	13	19	1.4	1.5	2.1	1.8
Coal	152	113	36	34	33	34	34	11	4.9	3.7	-4.7	-0.1	0.1	0.0
Oil	310	278	145	203	217	238	264	26	29	29	-1.2	0.4	1.0	0.7
Natural gas	215	260	200	213	241	264	289	24	30	32	-0.8	0.8	0.9	0.9
Electricity	95	126	87	105	131	157	186	12	15	20	-0.7	1.5	1.8	1.7
Heat	78	276	171	129	128	128	130	26	18	14	-3.0	-0.1	0.1	0.0
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	3.3	n.a.
Renewables	21	13	11	16	17	16	16	1.2	2.3	1.7	0.9	0.3	-0.5	-0.1

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1,461	1,888	1,428	1,738	2,083	2,383	2,713	100	100	100	-0.3	1.2	1.3	1.3
Coal	471	429	338	386	412	461	483	23	22	18	-0.4	0.4	0.8	0.6
Oil	357	256	70	21	18	18	15	14	1.2	0.6	-9.5	-0.9	-1.0	-1.0
Natural gas	295	714	503	706	787	984	1,170	38	41	43	0.0	0.7	2.0	1.5
Nuclear	79	226	242	313	453	431	464	12	18	17	1.3	2.5	0.1	1.1
Hydro	232	262	272	289	329	340	347	14	17	13	0.4	0.9	0.3	0.5
Geothermal	-	0.0	0.1	0.5	1.8	2.1	2.2	0.0	0.0	0.1	11.8	9.5	1.1	4.6
Solar PV	-	-	-	4.6	16	28	43	-	0.3	1.6	n.a.	8.8	5.0	6.6
Wind	-	-	0.0	12	38	70	113	-	0.7	4.2	n.a.	8.1	5.6	6.6
CSP and marine	-	-	-	-	0.0	0.0	0.1	-	-	0.0	n.a.	n.a.	12.7	n.a.
Biomass and waste	27	0.0	2.6	5.0	26	47	75	0.0	0.3	2.8	20.4	11.5	5.5	8.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	1,748	2,142	1,496	2,658	3,862	5,106	6,671	0.9	2.5	2.8	2.7
Population (million)	317	341	339	341	344	341	337	0.0	0.1	-0.1	0.0
CO_2 emissions (Mt)	3,497	4,104	2,455	2,543	2,577	2,749	2,928	-1.9	0.1	0.6	0.4
GDP per capita ($2010 thousand)	5.5	6.3	4.4	7.8	11	15	20	0.9	2.5	2.9	2.7
Primary energy consump. per capita (toe)	3.9	4.5	3.0	3.2	3.5	3.9	4.3	-1.3	0.6	1.0	0.8
Primary energy consumption per GDP[*2]	710	714	668	416	315	259	217	-2.1	-1.8	-1.8	-1.8
CO_2 emissions per GDP[*3]	2,000	1,916	1,641	957	667	538	439	-2.7	-2.4	-2.1	-2.2
CO_2 per primary energy consumption[*4]	2.8	2.7	2.5	2.3	2.1	2.1	2.0	-0.6	-0.5	-0.2	-0.4

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A39 | European Union [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	n.a.	1,647	1,695	1,586	1,545	1,499	1,458	100	100	100	-0.1	-0.2	-0.3	-0.2
Coal	n.a.	455	321	263	210	173	144	28	17	9.9	-2.2	-1.5	-1.9	-1.7
Oil	n.a.	608	625	516	450	401	357	37	33	24	-0.7	-0.9	-1.2	-1.0
Natural gas	n.a.	297	396	358	393	400	397	18	23	27	0.7	0.6	0.0	0.3
Nuclear	n.a.	207	246	223	204	206	216	13	14	15	0.3	-0.6	0.3	-0.1
Hydro	n.a.	25	31	29	31	31	32	1.5	1.8	2.2	0.6	0.3	0.2	0.2
Geothermal	n.a.	3.2	4.6	6.5	8.3	9.1	9.9	0.2	0.4	0.7	2.9	1.7	0.9	1.2
Solar, wind, etc.	n.a.	0.3	2.4	39	76	99	120	0.0	2.5	8.2	21.5	4.5	2.3	3.3
Biomass and waste	n.a.	48	67	149	171	176	180	2.9	9.4	12	4.7	0.9	0.2	0.5

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	n.a.	1,136	1,180	1,114	1,168	1,138	1,106	100	100	100	-0.1	0.3	-0.3	0.0
Industry	n.a.	347	309	254	279	279	278	31	23	25	-1.2	0.6	0.0	0.3
Transport	n.a.	259	303	312	273	245	223	23	28	20	0.8	-0.9	-1.0	-1.0
Buildings, etc.	n.a.	430	454	450	515	511	501	38	40	45	0.2	0.9	-0.1	0.3
Non-energy use	n.a.	100	113	97	101	103	103	8.8	8.7	9.3	-0.1	0.3	0.1	0.2
Coal	n.a.	122	52	36	33	31	29	11	3.2	2.6	-4.8	-0.5	-0.7	-0.6
Oil	n.a.	506	543	465	405	360	320	45	42	29	-0.3	-0.9	-1.2	-1.1
Natural gas	n.a.	227	272	241	253	253	251	20	22	23	0.2	0.3	0.0	0.1
Electricity	n.a.	186	217	236	263	279	292	16	21	26	1.0	0.7	0.5	0.6
Heat	n.a.	55	45	46	111	110	109	4.9	4.1	9.9	-0.7	6.1	-0.1	2.5
Hydrogen	n.a.	-	-	-	0.0	0.1	0.1	-	-	0.0	n.a.	n.a.	2.7	n.a.
Renewables	n.a.	40	50	90	103	104	105	3.5	8.1	9.5	3.3	0.8	0.1	0.4

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	n.a.	2,577	3,006	3,204	3,571	3,774	3,935	100	100	100	0.9	0.7	0.5	0.6
Coal	n.a.	1,050	968	826	716	597	483	41	26	12	-1.0	-0.9	-2.0	-1.5
Oil	n.a.	224	181	61	45	32	20	8.7	1.9	0.5	-5.1	-2.1	-4.0	-3.2
Natural gas	n.a.	193	480	497	633	684	697	7.5	15	18	3.9	1.6	0.5	1.0
Nuclear	n.a.	795	945	857	782	792	829	31	27	21	0.3	-0.6	0.3	-0.1
Hydro	n.a.	290	357	341	358	365	372	11	11	9.5	0.6	0.3	0.2	0.2
Geothermal	n.a.	3.2	4.8	6.5	8.5	9.5	10	0.1	0.2	0.3	2.9	1.8	0.9	1.3
Solar PV	n.a.	0.0	0.1	102	185	236	290	0.0	3.2	7.4	43.6	4.0	2.3	3.0
Wind	n.a.	0.8	22	302	529	689	809	0.0	9.4	21	26.9	3.8	2.1	2.9
CSP and marine	n.a.	0.7	1.6	9.5	35	53	79	0.0	0.3	2.0	11.1	9.0	4.2	6.3
Biomass and waste	n.a.	20	46	201	275	313	343	0.8	6.3	8.7	9.8	2.1	1.1	1.5
Hydrogen	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	n.a.	11,888	14,768	17,885	22,762	26,005	29,079	1.6	1.6	1.2	1.4
Population (million)	n.a.	478	488	510	524	526	523	0.3	0.2	0.0	0.1
CO_2 emissions (Mt)	n.a.	4,068	3,783	3,176	2,835	2,552	2,292	-1.0	-0.8	-1.1	-0.9
GDP per capita ($2010 thousand)	n.a.	25	30	35	43	49	56	1.4	1.4	1.2	1.3
Primary energy consump. per capita (toe)	n.a.	3.4	3.5	3.1	3.0	2.8	2.8	-0.4	-0.4	-0.3	-0.3
Primary energy consumption per GDP*2	n.a.	139	115	89	68	58	50	-1.8	-1.8	-1.5	-1.6
CO_2 emissions per GDP*3	n.a.	342	256	178	125	98	79	-2.6	-2.3	-2.3	-2.3
CO_2 per primary energy consumption*4	n.a.	2.5	2.2	2.0	1.8	1.7	1.6	-0.8	-0.6	-0.8	-0.7

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A40 | Africa [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	273	393	496	788	1,086	1,349	1,635	100	100	100	2.8	2.2	2.1	2.1
Coal	52	74	90	107	122	134	150	19	14	9.2	1.5	0.8	1.1	1.0
Oil	61	86	97	176	252	340	458	22	22	28	2.9	2.4	3.0	2.8
Natural gas	12	30	47	108	183	253	359	7.5	14	22	5.3	3.6	3.4	3.5
Nuclear	-	2.2	3.4	3.2	8.6	19	24	0.6	0.4	1.5	1.5	6.9	5.2	5.9
Hydro	4.1	4.8	6.4	10	19	29	39	1.2	1.3	2.4	3.1	4.1	3.7	3.9
Geothermal	-	0.3	0.4	3.9	16	23	29	0.1	0.5	1.7	11.0	9.7	3.1	5.9
Solar, wind, etc.	-	0.0	0.0	1.0	8.6	18	29	0.0	0.1	1.8	35.7	15.2	6.3	10.0
Biomass and waste	143	196	250	377	478	532	547	50	48	33	2.7	1.6	0.7	1.1

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	218	292	369	573	804	1,005	1,216	100	100	100	2.7	2.3	2.1	2.2
Industry	46	55	58	87	126	173	222	19	15	18	1.9	2.5	2.9	2.7
Transport	27	38	54	105	149	196	247	13	18	20	4.2	2.4	2.6	2.5
Buildings, etc.	139	188	242	362	499	595	695	64	63	57	2.7	2.2	1.7	1.9
Non-energy use	5.4	11	15	18	29	40	53	3.8	3.2	4.4	2.0	3.1	3.0	3.1
Coal	22	20	19	20	24	29	32	6.7	3.5	2.6	0.1	1.3	1.4	1.3
Oil	54	71	89	154	226	305	409	24	27	34	3.2	2.6	3.0	2.8
Natural gas	2.8	8.6	14	34	56	78	101	2.9	5.9	8.3	5.6	3.5	3.0	3.2
Electricity	14	22	31	53	88	130	197	7.6	9.3	16	3.6	3.4	4.2	3.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	5.5	n.a.
Renewables	126	171	216	312	410	463	477	59	54	39	2.4	1.8	0.8	1.2

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	184	316	442	781	1,266	1,832	2,717	100	100	100	3.7	3.3	3.9	3.6
Coal	100	165	209	257	321	373	446	52	33	16	1.8	1.5	1.7	1.6
Oil	22	41	51	88	116	152	206	13	11	7.6	3.1	1.9	2.9	2.5
Natural gas	14	45	92	285	489	741	1,268	14	37	47	7.7	3.7	4.9	4.4
Nuclear	-	8.4	13	12	33	73	91	2.7	1.6	3.4	1.5	6.9	5.2	5.9
Hydro	47	56	75	121	220	336	455	18	15	17	3.1	4.1	3.7	3.9
Geothermal	-	0.3	0.4	4.5	18	26	33	0.1	0.6	1.2	11.0	9.7	3.1	5.9
Solar PV	-	-	0.0	2.6	18	36	64	-	0.3	2.3	n.a.	13.6	6.6	9.6
Wind	-	-	0.2	7.5	22	39	72	-	1.0	2.6	n.a.	7.3	6.2	6.7
CSP and marine	-	-	-	0.0	19	42	66	-	0.0	2.4	n.a.	71.2	6.4	30.5
Biomass and waste	0.2	0.5	1.1	1.9	7.7	11	14	0.1	0.2	0.5	5.9	9.7	3.1	5.9
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	717	876	1,145	2,261	4,224	6,841	10,197	3.9	4.3	4.5	4.4
Population (million)	477	631	813	1,185	1,691	2,085	2,509	2.6	2.4	2.0	2.2
CO_2 emissions (Mt)	403	593	718	1,168	1,605	2,064	2,705	2.7	2.1	2.6	2.4
GDP per capita ($2010 thousand)	1.5	1.4	1.4	1.9	2.5	3.3	4.1	1.3	1.8	2.5	2.2
Primary energy consump. per capita (toe)	0.6	0.6	0.6	0.7	0.6	0.6	0.7	0.3	-0.2	0.1	-0.1
Primary energy consumption per GDP*2	381	449	433	348	257	197	160	-1.0	-2.0	-2.3	-2.2
CO_2 emissions per GDP*3	563	677	627	516	380	302	265	-1.1	-2.0	-1.8	-1.9
CO_2 per primary energy consumption*4	1.5	1.5	1.4	1.5	1.5	1.5	1.7	-0.1	0.0	0.6	0.3

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A41 | Middle East [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	121	223	372	752	993	1,153	1,291	100	100	100	5.0	1.9	1.3	1.6
Coal	1.2	3.0	8.1	9.8	16	18	19	1.3	1.3	1.5	4.9	3.3	1.0	2.0
Oil	90	146	217	341	422	485	536	66	45	41	3.4	1.4	1.2	1.3
Natural gas	29	72	145	397	523	602	677	32	53	52	7.1	1.9	1.3	1.5
Nuclear	-	-	-	0.8	24	36	42	-	0.1	3.2	n.a.	25.7	2.9	12.1
Hydro	0.8	1.0	0.7	1.5	2.1	2.3	2.5	0.5	0.2	0.2	1.6	2.1	1.0	1.5
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.4	0.7	0.7	4.2	7.6	13	0.2	0.1	1.0	2.3	12.3	5.8	8.5
Biomass and waste	0.3	0.4	0.4	0.9	0.9	0.8	0.8	0.2	0.1	0.1	2.8	0.0	-0.7	-0.4

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	84	157	253	489	652	766	868	100	100	100	4.6	1.9	1.4	1.7
Industry	30	47	71	150	203	241	274	30	31	32	4.8	2.0	1.5	1.7
Transport	26	51	75	141	180	206	229	32	29	26	4.2	1.6	1.2	1.4
Buildings, etc.	22	40	75	129	170	197	222	25	26	26	4.8	1.9	1.3	1.6
Non-energy use	5.6	20	32	69	99	122	143	12	14	16	5.2	2.4	1.9	2.1
Coal	0.3	0.2	0.5	2.6	3.9	4.9	5.7	0.1	0.5	0.7	11.1	2.8	1.9	2.3
Oil	67	108	153	236	304	357	400	69	48	46	3.2	1.7	1.4	1.5
Natural gas	9.8	31	65	173	232	267	300	20	35	35	7.1	2.0	1.3	1.6
Electricity	6.5	17	33	77	110	135	160	11	16	18	6.2	2.5	1.9	2.1
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	4.4	n.a.
Renewables	0.2	0.7	1.0	1.3	1.5	1.6	1.8	0.5	0.3	0.2	2.3	0.7	1.1	0.9

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	95	244	472	1,111	1,585	1,902	2,215	100	100	100	6.2	2.4	1.7	2.0
Coal	0.1	11	30	30	51	57	63	4.3	2.7	2.8	4.3	3.6	1.1	2.2
Oil	47	108	188	322	378	390	393	44	29	18	4.5	1.1	0.2	0.6
Natural gas	39	114	246	737	1,013	1,233	1,474	47	66	67	7.7	2.1	1.9	2.0
Nuclear	-	-	-	2.9	91	140	161	-	0.3	7.2	n.a.	25.7	2.9	12.1
Hydro	9.7	12	8.0	18	24	27	30	4.9	1.6	1.3	1.6	2.1	1.0	1.5
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	1.2	16	29	47	-	0.1	2.1	n.a.	19.1	5.5	11.1
Wind	-	0.0	0.0	0.4	5.7	16	28	0.0	0.0	1.2	26.4	20.4	8.2	13.3
CSP and marine	-	-	-	0.2	6.0	10	20	-	0.0	0.9	n.a.	23.9	6.2	13.4
Biomass and waste	-	-	-	0.1	0.3	0.4	0.5	-	0.0	0.0	n.a.	8.3	2.2	4.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	858	949	1,430	2,582	4,001	5,302	6,834	4.1	3.0	2.7	2.8
Population (million)	92	132	168	235	297	332	364	2.3	1.6	1.0	1.3
CO_2 emissions (Mt)	332	573	945	1,822	2,310	2,630	2,910	4.7	1.6	1.2	1.3
GDP per capita ($2010 thousand)	9.3	7.2	8.5	11	13	16	19	1.7	1.4	1.7	1.5
Primary energy consump. per capita (toe)	1.3	1.7	2.2	3.2	3.3	3.5	3.5	2.6	0.3	0.3	0.3
Primary energy consumption per GDP[*2]	142	235	260	291	248	217	189	0.9	-1.1	-1.4	-1.2
CO_2 emissions per GDP[*3]	387	603	661	706	577	496	426	0.6	-1.3	-1.5	-1.4
CO_2 per primary energy consumption[*4]	2.7	2.6	2.5	2.4	2.3	2.3	2.3	-0.2	-0.3	-0.2	-0.2

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A42 | Oceania [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	79	99	120	146	153	152	150	100	100	100	1.6	0.3	-0.1	0.1
Coal	28	36	44	44	39	34	31	37	30	21	0.8	-0.9	-1.1	-1.0
Oil	34	35	40	49	48	46	44	35	33	29	1.4	0.0	-0.5	-0.3
Natural gas	8.3	19	24	36	42	44	45	19	25	30	2.7	1.0	0.3	0.6
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	2.7	3.2	3.5	3.3	3.5	3.6	3.6	3.2	2.2	2.4	0.1	0.6	0.0	0.3
Geothermal	1.0	1.5	1.9	4.9	7.7	8.1	8.5	1.5	3.3	5.7	4.9	3.1	0.5	1.6
Solar, wind, etc.	0.0	0.1	0.1	2.1	5.5	8.2	11	0.1	1.4	7.4	11.9	6.6	3.6	4.9
Biomass and waste	4.1	4.7	6.2	6.5	7.1	7.1	7.0	4.8	4.4	4.7	1.3	0.6	-0.1	0.2

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	54	66	83	95	102	104	104	100	100	100	1.5	0.5	0.1	0.3
Industry	20	23	28	28	30	30	30	35	30	29	0.9	0.5	0.0	0.2
Transport	19	24	30	37	37	37	36	36	39	34	1.8	0.0	-0.2	-0.1
Buildings, etc.	11	15	19	24	29	31	33	22	25	31	2.0	1.2	0.6	0.9
Non-energy use	3.1	4.6	6.1	5.5	5.7	5.7	5.6	6.9	5.8	5.4	0.7	0.2	-0.1	0.1
Coal	5.3	5.2	4.7	2.9	2.6	2.3	2.0	7.9	3.1	1.9	-2.3	-0.7	-1.5	-1.1
Oil	31	33	40	49	49	47	45	50	51	43	1.6	0.0	-0.4	-0.2
Natural gas	5.4	10	14	16	18	18	18	16	17	17	1.8	0.6	0.1	0.3
Electricity	8.5	14	18	22	27	30	33	20	23	32	1.9	1.5	1.0	1.2
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	3.4	n.a.
Renewables	4.0	4.1	5.6	5.9	6.4	6.3	6.1	6.2	6.2	5.9	1.5	0.5	-0.2	0.1

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	118	187	249	296	370	409	444	100	100	100	1.9	1.5	0.9	1.2
Coal	70	122	176	160	164	159	151	65	54	34	1.1	0.1	-0.4	-0.2
Oil	5.2	3.6	1.8	6.8	6.6	6.1	5.4	1.9	2.3	1.2	2.6	-0.2	-1.0	-0.7
Natural gas	8.7	20	26	59	82	94	103	11	20	23	4.4	2.2	1.1	1.6
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	32	37	41	38	41	41	41	20	13	9.3	0.1	0.6	0.0	0.3
Geothermal	1.2	2.1	2.9	7.9	13	13	14	1.1	2.6	3.1	5.4	3.2	0.5	1.6
Solar PV	-	-	0.0	6.0	18	33	46	-	2.0	10	n.a.	7.8	4.7	6.0
Wind	-	-	0.2	14	39	55	74	-	4.7	17	n.a.	7.1	3.3	4.9
CSP and marine	-	0.1	0.1	0.1	0.1	0.1	0.2	0.0	0.0	0.0	-0.3	-0.9	6.7	3.4
Biomass and waste	0.7	1.3	1.7	4.2	6.1	7.6	8.6	0.7	1.4	1.9	5.0	2.5	1.7	2.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	526	721	995	1,524	2,192	2,619	3,045	3.0	2.5	1.7	2.0
Population (million)	18	20	23	28	33	36	39	1.3	1.1	0.8	0.9
CO_2 emissions (Mt)	227	281	337	395	385	366	347	1.4	-0.2	-0.5	-0.4
GDP per capita ($2010 thousand)	30	35	43	54	66	72	78	1.7	1.3	0.9	1.1
Primary energy consump. per capita (toe)	4.4	4.9	5.2	5.1	4.6	4.2	3.9	0.2	-0.8	-0.9	-0.8
Primary energy consumption per GDP*2	149	138	121	96	70	58	49	-1.4	-2.1	-1.7	-1.9
CO_2 emissions per GDP*3	432	389	339	259	176	140	114	-1.6	-2.5	-2.1	-2.3
CO_2 per primary energy consumption*4	2.9	2.8	2.8	2.7	2.5	2.4	2.3	-0.2	-0.5	-0.4	-0.4

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A43 | OECD [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	4,060	4,524	5,281	5,236	5,240	5,162	5,032	100	100	100	0.6	0.0	-0.2	-0.1
Coal	966	1,079	1,089	941	786	685	575	24	18	11	-0.5	-1.2	-1.6	-1.4
Oil	1,938	1,867	2,105	1,885	1,714	1,588	1,455	41	36	29	0.0	-0.6	-0.8	-0.7
Natural gas	778	845	1,164	1,367	1,531	1,628	1,674	19	26	33	1.9	0.8	0.4	0.6
Nuclear	162	451	586	514	506	473	449	10.0	9.8	8.9	0.5	-0.1	-0.6	-0.4
Hydro	94	102	115	119	130	132	134	2.3	2.3	2.7	0.6	0.6	0.2	0.3
Geothermal	10	27	30	35	64	81	96	0.6	0.7	1.9	1.1	4.2	2.0	2.9
Solar, wind, etc.	0.1	2.2	5.9	73	158	214	278	0.0	1.4	5.5	15.1	5.3	2.8	3.9
Biomass and waste	111	150	185	301	348	360	370	3.3	5.8	7.3	2.8	1.0	0.3	0.6

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	2,937	3,102	3,624	3,622	3,652	3,619	3,549	100	100	100	0.6	0.1	-0.1	-0.1
Industry	940	840	914	789	806	815	808	27	22	23	-0.2	0.1	0.0	0.1
Transport	781	936	1,139	1,227	1,131	1,067	1,012	30	34	29	1.1	-0.5	-0.6	-0.5
Buildings, etc.	972	1,036	1,201	1,260	1,344	1,359	1,353	33	35	38	0.8	0.4	0.0	0.2
Non-energy use	243	290	370	345	370	378	375	9.4	9.5	11	0.7	0.5	0.1	0.2
Coal	259	233	139	111	103	96	87	7.5	3.1	2.5	-2.9	-0.5	-0.8	-0.7
Oil	1,570	1,580	1,831	1,726	1,584	1,474	1,360	51	48	38	0.4	-0.6	-0.8	-0.7
Natural gas	559	590	744	718	768	781	776	19	20	22	0.8	0.5	0.1	0.2
Electricity	408	553	715	803	912	982	1,038	18	22	29	1.5	0.8	0.7	0.7
Heat	36	46	51	58	60	59	58	1.5	1.6	1.6	0.9	0.3	-0.2	0.0
Hydrogen	-	-	-	-	0.2	0.3	0.3	-	-	0.0	n.a.	n.a.	1.9	n.a.
Renewables	105	101	144	207	225	227	228	3.2	5.7	6.4	2.9	0.6	0.1	0.3

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	5,656	7,652	9,730	10,794	12,189	13,031	13,670	100	100	100	1.4	0.8	0.6	0.7
Coal	2,319	3,083	3,764	3,198	2,802	2,520	2,127	40	30	16	0.1	-0.9	-1.4	-1.2
Oil	980	723	623	260	177	127	68	9.4	2.4	0.5	-4.0	-2.5	-4.7	-3.8
Natural gas	618	775	1,544	2,814	3,582	4,228	4,720	10	26	35	5.3	1.6	1.4	1.5
Nuclear	621	1,729	2,249	1,971	1,942	1,813	1,724	23	18	13	0.5	-0.1	-0.6	-0.4
Hydro	1,093	1,184	1,342	1,381	1,510	1,538	1,558	15	13	11	0.6	0.6	0.2	0.3
Geothermal	11	29	33	50	103	133	160	0.4	0.5	1.2	2.3	4.9	2.2	3.4
Solar PV	-	0.0	0.7	182	397	528	681	0.0	1.7	5.0	44.3	5.3	2.7	3.8
Wind	0.0	3.8	29	556	1,058	1,381	1,706	0.1	5.2	12	22.0	4.4	2.4	3.3
CSP and marine	0.5	1.5	2.2	26	105	172	273	0.0	0.2	2.0	12.1	9.7	4.9	6.9
Biomass and waste	13	123	143	353	512	590	651	1.6	3.3	4.8	4.3	2.5	1.2	1.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	21,475	29,226	38,029	48,159	63,177	74,658	85,986	2.0	1.8	1.6	1.7
Population (million)	984	1,065	1,151	1,275	1,358	1,392	1,409	0.7	0.4	0.2	0.3
CO_2 emissions (Mt)	10,864	11,120	12,402	11,687	10,860	10,277	9,551	0.2	-0.5	-0.6	-0.6
GDP per capita ($2010 thousand)	22	27	33	38	47	54	61	1.3	1.4	1.4	1.4
Primary energy consump. per capita (toe)	4.1	4.2	4.6	4.1	3.9	3.7	3.6	-0.1	-0.4	-0.4	-0.4
Primary energy consumption per GDP*2	189	155	139	109	83	69	59	-1.4	-1.8	-1.7	-1.8
CO_2 emissions per GDP*3	506	380	326	243	172	138	111	-1.8	-2.3	-2.2	-2.2
CO_2 per primary energy consumption*4	2.7	2.5	2.3	2.2	2.1	2.0	1.9	-0.4	-0.5	-0.4	-0.5

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A44 | Non-OECD [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	2,967	4,048	4,472	8,029	10,812	12,613	14,096	100	100	100	2.8	2.0	1.3	1.6
Coal	817	1,141	1,222	2,895	3,468	3,801	3,956	28	36	28	3.8	1.2	0.7	0.9
Oil	986	1,166	1,281	2,068	2,815	3,315	3,780	29	26	27	2.3	2.1	1.5	1.7
Natural gas	454	818	908	1,577	2,305	2,905	3,493	20	20	25	2.7	2.6	2.1	2.3
Nuclear	24	74	89	157	401	507	605	1.8	2.0	4.3	3.0	6.4	2.1	3.9
Hydro	54	82	110	216	295	334	366	2.0	2.7	2.6	3.9	2.1	1.1	1.5
Geothermal	2.2	7.6	22	39	113	143	161	0.2	0.5	1.1	6.8	7.3	1.8	4.1
Solar, wind, etc.	-	0.5	2.1	53	147	233	330	0.0	0.7	2.3	20.8	7.0	4.1	5.3
Biomass and waste	631	759	838	1,022	1,265	1,374	1,401	19	13	9.9	1.2	1.4	0.5	0.9

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	2,252	2,964	3,138	5,380	7,184	8,399	9,465	100	100	100	2.4	1.9	1.4	1.6
Industry	825	968	954	1,923	2,340	2,684	2,970	33	36	31	2.8	1.3	1.2	1.3
Transport	289	435	547	1,095	1,588	1,862	2,092	15	20	22	3.8	2.5	1.4	1.9
Buildings, etc.	1,027	1,373	1,390	1,872	2,567	3,008	3,425	46	35	36	1.2	2.1	1.5	1.7
Non-energy use	111	187	247	491	690	845	977	6.3	9.1	10	3.9	2.3	1.8	2.0
Coal	444	521	409	933	993	1,026	1,020	18	17	11	2.4	0.4	0.1	0.3
Oil	697	817	1,010	1,732	2,431	2,899	3,347	28	32	35	3.1	2.3	1.6	1.9
Natural gas	256	354	372	684	995	1,219	1,428	12	13	15	2.7	2.5	1.8	2.1
Electricity	178	283	377	934	1,461	1,871	2,285	9.5	17	24	4.9	3.0	2.3	2.6
Heat	85	290	197	214	228	238	241	9.8	4.0	2.5	-1.2	0.4	0.3	0.3
Hydrogen	-	-	-	-	0.2	0.4	0.5	-	-	0.0	n.a.	n.a.	3.9	n.a.
Renewables	592	698	773	884	1,075	1,147	1,143	24	16	12	0.9	1.3	0.3	0.7

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	2,628	4,212	5,741	13,461	20,776	26,070	31,168	100	100	100	4.8	2.9	2.0	2.4
Coal	817	1,342	2,242	6,340	8,956	10,637	11,869	32	47	38	6.4	2.3	1.4	1.8
Oil	678	635	628	729	825	852	824	15	5.4	2.6	0.6	0.8	0.0	0.3
Natural gas	381	977	1,209	2,729	4,357	6,110	8,147	23	20	26	4.2	3.2	3.2	3.2
Nuclear	93	283	341	601	1,538	1,946	2,323	6.7	4.5	7.5	3.0	6.5	2.1	3.9
Hydro	624	959	1,277	2,508	3,433	3,882	4,260	23	19	14	3.9	2.1	1.1	1.5
Geothermal	2.6	7.8	19	30	88	112	128	0.2	0.2	0.4	5.5	7.4	1.9	4.2
Solar PV	-	0.0	0.3	64	354	626	986	0.0	0.5	3.2	51.5	12.0	5.3	8.1
Wind	-	0.0	2.8	282	833	1,329	1,879	0.0	2.1	6.0	43.3	7.5	4.2	5.6
CSP and marine	-	0.0	0.0	0.3	31	65	112	0.0	0.0	0.4	16.0	36.7	6.7	18.6
Biomass and waste	31	7.7	21	175	360	510	637	0.2	1.3	2.0	13.3	4.9	2.9	3.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	6,482	8,572	11,796	26,900	52,126	77,431	105,413	4.7	4.5	3.6	4.0
Population (million)	3,452	4,213	4,957	6,062	7,139	7,760	8,301	1.5	1.1	0.8	0.9
CO_2 emissions (Mt)	6,999	9,464	10,174	20,051	25,738	29,551	32,605	3.0	1.7	1.2	1.4
GDP per capita ($2010 thousand)	1.9	2.0	2.4	4.4	7.3	10.0	13	3.2	3.4	2.8	3.0
Primary energy consump. per capita (toe)	0.9	1.0	0.9	1.3	1.5	1.6	1.7	1.3	0.9	0.6	0.7
Primary energy consumption per GDP[*2]	458	472	379	298	207	163	134	-1.8	-2.4	-2.2	-2.3
CO_2 emissions per GDP[*3]	1,080	1,104	862	745	494	382	309	-1.6	-2.7	-2.3	-2.5
CO_2 per primary energy consumption[*4]	2.4	2.3	2.3	2.5	2.4	2.3	2.3	0.3	-0.3	-0.1	-0.2

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A45 | World [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	7,205	8,774	10,028	13,647	15,717	16,693	17,219	100	100	100	1.8	0.9	0.5	0.7
Coal	1,783	2,220	2,311	3,836	3,606	3,372	2,937	25	28	17	2.2	-0.4	-1.0	-0.8
Oil	3,102	3,235	3,660	4,334	4,625	4,655	4,656	37	32	27	1.2	0.4	0.0	0.2
Natural gas	1,232	1,663	2,071	2,944	3,584	3,976	4,157	19	22	24	2.3	1.3	0.7	1.0
Nuclear	186	526	676	671	1,180	1,441	1,754	6.0	4.9	10	1.0	3.8	2.0	2.8
Hydro	148	184	225	334	425	466	500	2.1	2.5	2.9	2.4	1.6	0.8	1.2
Geothermal	12	34	52	74	240	340	420	0.4	0.5	2.4	3.1	8.1	2.8	5.1
Solar, wind, etc.	0.1	2.7	8.0	126	415	677	996	0.0	0.9	5.8	16.7	8.2	4.5	6.1
Biomass and waste	741	909	1,023	1,323	1,639	1,761	1,794	10	9.7	10	1.5	1.4	0.5	0.9

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	5,368	6,268	7,036	9,384	10,787	11,439	11,831	100	100	100	1.6	0.9	0.5	0.7
Industry	1,766	1,809	1,868	2,712	3,044	3,233	3,273	29	29	28	1.6	0.8	0.4	0.5
Transport	1,248	1,573	1,961	2,703	2,990	3,055	3,100	25	29	26	2.2	0.7	0.2	0.4
Buildings, etc.	2,000	2,409	2,591	3,132	3,692	3,929	4,106	38	33	35	1.1	1.1	0.5	0.8
Non-energy use	354	478	617	836	1,060	1,223	1,352	7.6	8.9	11	2.3	1.6	1.2	1.4
Coal	703	754	548	1,044	1,064	1,046	979	12	11	8.3	1.3	0.1	-0.4	-0.2
Oil	2,446	2,599	3,115	3,840	4,191	4,265	4,320	41	41	37	1.6	0.6	0.2	0.3
Natural gas	814	945	1,117	1,401	1,708	1,876	1,987	15	15	17	1.6	1.3	0.8	1.0
Electricity	586	835	1,092	1,737	2,288	2,670	3,012	13	19	25	3.0	1.9	1.4	1.6
Heat	121	336	248	271	276	273	259	5.4	2.9	2.2	-0.9	0.1	-0.3	-0.1
Hydrogen	-	-	-	-	0.4	1.1	2.6	-	-	0.0	n.a.	n.a.	10.5	n.a.
Renewables	698	799	917	1,090	1,261	1,308	1,272	13	12	11	1.3	1.0	0.0	0.4

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	8,283	11,864	15,471	24,255	31,482	35,926	39,733	100	100	100	2.9	1.8	1.2	1.4
Coal	3,137	4,425	6,005	9,538	8,920	8,069	6,672	37	39	17	3.1	-0.4	-1.4	-1.0
Oil	1,659	1,358	1,252	990	790	638	440	11	4.1	1.1	-1.3	-1.5	-2.9	-2.3
Natural gas	999	1,752	2,753	5,543	7,039	8,100	8,591	15	23	22	4.7	1.6	1.0	1.3
Nuclear	713	2,013	2,591	2,571	4,527	5,530	6,729	17	11	17	1.0	3.8	2.0	2.8
Hydro	1,717	2,142	2,619	3,888	4,943	5,419	5,818	18	16	15	2.4	1.6	0.8	1.2
Geothermal	14	36	52	80	269	376	467	0.3	0.3	1.2	3.2	8.4	2.8	5.2
Solar PV	-	0.0	1.0	247	1,068	1,874	2,794	0.0	1.0	7.0	45.5	10.3	4.9	7.2
Wind	0.0	3.9	31	838	2,686	4,145	5,761	0.0	3.5	15	24.0	8.1	3.9	5.7
CSP and marine	0.5	1.5	2.2	27	212	458	870	0.0	0.1	2.2	12.2	14.9	7.3	10.5
Biomass and waste	44	131	164	528	1,024	1,313	1,586	1.1	2.2	4.0	5.7	4.5	2.2	3.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	27,958	37,797	49,825	75,059	115,303	152,089	191,400	2.8	2.9	2.6	2.7
Population (million)	4,436	5,277	6,108	7,336	8,497	9,152	9,710	1.3	1.0	0.7	0.8
CO_2 emissions (Mt)	18,411	21,205	23,416	32,910	33,377	32,055	29,699	1.8	0.1	-0.6	-0.3
GDP per capita ($2010 thousand)	6.3	7.2	8.2	10	14	17	20	1.4	1.9	1.9	1.9
Primary energy consump. per capita (toe)	1.6	1.7	1.6	1.9	1.8	1.8	1.8	0.5	0.0	-0.2	-0.1
Primary energy consumption per GDP*2	258	232	201	182	136	110	90	-1.0	-1.9	-2.1	-2.0
CO_2 emissions per GDP*3	659	561	470	438	289	211	155	-1.0	-2.7	-3.1	-2.9
CO_2 per primary energy consumption*4	2.6	2.4	2.3	2.4	2.1	1.9	1.7	0.0	-0.8	-1.0	-1.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A46 | Asia [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	1,439	2,108	2,887	5,459	7,078	7,794	8,156	100	100	100	3.9	1.7	0.7	1.2
Coal	466	785	1,037	2,739	2,848	2,769	2,499	37	50	31	5.1	0.3	-0.7	-0.3
Oil	477	618	916	1,330	1,720	1,860	1,974	29	24	24	3.1	1.7	0.7	1.1
Natural gas	51	116	232	547	906	1,141	1,294	5.5	10	16	6.4	3.4	1.8	2.5
Nuclear	25	77	132	111	516	722	918	3.6	2.0	11	1.5	10.8	2.9	6.2
Hydro	20	32	41	131	182	205	221	1.5	2.4	2.7	5.8	2.2	1.0	1.5
Geothermal	2.6	8.2	23	34	122	180	222	0.4	0.6	2.7	5.9	8.8	3.0	5.5
Solar, wind, etc.	-	1.5	2.2	51	171	279	406	0.1	0.9	5.0	15.3	8.3	4.4	6.1
Biomass and waste	397	471	503	515	611	635	622	22	9.4	7.6	0.4	1.2	0.1	0.5

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1,129	1,551	1,990	3,617	4,619	5,068	5,337	100	100	100	3.4	1.6	0.7	1.1
Industry	383	517	646	1,481	1,700	1,798	1,797	33	41	34	4.3	0.9	0.3	0.6
Transport	126	186	320	648	918	1,002	1,058	12	18	20	5.1	2.4	0.7	1.4
Buildings, etc.	567	733	836	1,124	1,505	1,686	1,839	47	31	34	1.7	2.0	1.0	1.4
Non-energy use	54	115	188	365	496	583	642	7.4	10	12	4.7	2.1	1.3	1.6
Coal	301	424	378	901	924	909	850	27	25	16	3.1	0.2	-0.4	-0.2
Oil	327	453	727	1,164	1,550	1,699	1,827	29	32	34	3.9	1.9	0.8	1.3
Natural gas	21	47	88	252	426	525	593	3.0	7.0	11	6.9	3.6	1.7	2.5
Electricity	88	158	280	740	1,108	1,338	1,527	10	20	29	6.4	2.7	1.6	2.1
Heat	7.5	14	30	89	101	104	98	0.9	2.5	1.8	7.6	0.8	-0.1	0.3
Hydrogen	-	-	-	-	0.2	0.7	1.6	-	-	0.0	n.a.	n.a.	11.3	n.a.
Renewables	386	456	488	471	510	494	441	29	13	8.3	0.1	0.5	-0.7	-0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1,196	2,252	4,013	10,204	15,136	17,884	20,032	100	100	100	6.2	2.7	1.4	1.9
Coal	298	863	1,994	6,203	6,760	6,519	5,776	38	61	29	8.2	0.6	-0.8	-0.2
Oil	476	469	430	250	184	136	79	21	2.5	0.4	-2.5	-2.0	-4.1	-3.2
Natural gas	90	240	565	1,296	2,097	2,757	3,248	11	13	16	7.0	3.3	2.2	2.7
Nuclear	97	294	505	425	1,981	2,769	3,523	13	4.2	18	1.5	10.8	2.9	6.2
Hydro	232	367	479	1,521	2,121	2,385	2,569	16	15	13	5.8	2.2	1.0	1.5
Geothermal	3.0	8.4	20	24	82	119	147	0.4	0.2	0.7	4.3	8.6	3.0	5.3
Solar PV	-	0.0	0.6	95	524	979	1,504	0.0	0.9	7.5	49.6	12.1	5.4	8.2
Wind	-	0.0	2.4	239	1,041	1,718	2,504	0.0	2.3	13	42.5	10.3	4.5	6.9
CSP and marine	-	0.0	0.0	2.0	15	37	85	0.0	0.0	0.4	25.5	14.2	9.1	11.2
Biomass and waste	0.0	10	17	150	332	466	598	0.5	1.5	3.0	11.4	5.4	3.0	4.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	4,455	7,586	11,047	22,344	42,637	61,674	81,910	4.4	4.4	3.3	3.8
Population (million)	2,440	2,932	3,407	3,993	4,433	4,595	4,658	1.2	0.7	0.2	0.4
CO_2 emissions (Mt)	3,268	4,918	6,891	15,076	17,007	16,968	15,977	4.6	0.8	-0.3	0.2
GDP per capita ($2010 thousand)	1.8	2.6	3.2	5.6	9.6	13	18	3.1	3.7	3.1	3.3
Primary energy consump. per capita (toe)	0.6	0.7	0.8	1.4	1.6	1.7	1.8	2.6	1.0	0.5	0.7
Primary energy consumption per GDP[*2]	323	278	261	244	166	126	100	-0.5	-2.5	-2.5	-2.5
CO_2 emissions per GDP[*3]	733	648	624	675	399	275	195	0.2	-3.4	-3.5	-3.5
CO_2 per primary energy consumption[*4]	2.3	2.3	2.4	2.8	2.4	2.2	2.0	0.7	-0.9	-1.0	-1.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A47 | China [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	598	871	1,130	2,973	3,485	3,591	3,416	100	100	100	5.0	1.1	-0.1	0.4
Coal	313	528	665	1,982	1,806	1,599	1,219	61	67	36	5.4	-0.6	-1.9	-1.4
Oil	89	119	221	534	722	717	673	14	18	20	6.2	2.0	-0.4	0.7
Natural gas	12	13	21	159	333	422	448	1.5	5.3	13	10.6	5.1	1.5	3.0
Nuclear	-	-	4.4	45	274	411	548	-	1.5	16	n.a.	12.9	3.5	7.4
Hydro	5.0	11	19	96	122	132	135	1.3	3.2	4.0	9.1	1.6	0.5	1.0
Geothermal	-	-	1.7	5.1	7.1	7.9	8.1	-	0.2	0.2	n.a.	2.2	0.7	1.4
Solar, wind, etc.	-	0.0	1.0	41	118	180	251	0.0	1.4	7.3	33.0	7.3	3.9	5.3
Biomass and waste	180	200	198	114	104	122	135	23	3.8	4.0	-2.2	-0.6	1.3	0.5

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	487	654	781	1,906	2,240	2,304	2,215	100	100	100	4.4	1.1	-0.1	0.4
Industry	181	234	299	966	934	897	804	36	51	36	5.8	-0.2	-0.7	-0.5
Transport	24	33	87	299	470	476	456	5.1	16	21	9.2	3.1	-0.2	1.2
Buildings, etc.	272	344	335	483	621	682	689	53	25	31	1.4	1.7	0.5	1.0
Non-energy use	10	43	60	158	215	250	266	6.6	8.3	12	5.3	2.1	1.1	1.5
Coal	214	308	274	701	613	543	446	47	37	20	3.3	-0.9	-1.6	-1.3
Oil	59	85	180	480	664	665	630	13	25	28	7.2	2.2	-0.3	0.8
Natural gas	6.4	8.9	12	105	194	237	260	1.4	5.5	12	10.4	4.1	1.5	2.6
Electricity	21	39	89	419	587	673	704	6.0	22	32	10.0	2.3	0.9	1.5
Heat	7.4	13	25	83	94	97	92	2.0	4.4	4.2	7.6	0.8	-0.1	0.3
Hydrogen	-	-	-	-	0.1	0.6	1.4	-	-	0.1	n.a.	n.a.	12.0	n.a.
Renewables	180	200	199	116	88	88	82	31	6.1	3.7	-2.2	-1.9	-0.4	-1.0

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	301	621	1,356	5,844	8,036	9,041	9,298	100	100	100	9.4	2.1	0.7	1.3
Coal	159	441	1,060	4,109	3,933	3,417	2,316	71	70	25	9.3	-0.3	-2.6	-1.6
Oil	82	50	47	9.7	7.2	4.9	2.3	8.1	0.2	0.0	-6.4	-2.0	-5.6	-4.1
Natural gas	0.7	2.8	5.8	145	472	630	594	0.4	2.5	6.4	17.2	8.2	1.2	4.1
Nuclear	-	-	17	171	1,052	1,577	2,103	-	2.9	23	n.a.	12.9	3.5	7.4
Hydro	58	127	222	1,114	1,414	1,531	1,574	20	19	17	9.1	1.6	0.5	1.0
Geothermal	-	0.1	0.1	0.1	0.5	0.6	0.7	0.0	0.0	0.0	3.2	9.4	2.1	5.2
Solar PV	-	0.0	0.0	45	272	429	596	0.0	0.8	6.4	49.3	12.7	4.0	7.6
Wind	-	0.0	0.6	186	729	1,210	1,783	0.0	3.2	19	58.0	9.5	4.6	6.7
CSP and marine	-	0.0	0.0	0.0	6.1	16	39	0.0	0.0	0.4	6.6	41.1	9.8	22.2
Biomass and waste	-	-	2.4	64	152	225	290	-	1.1	3.1	n.a.	6.0	3.3	4.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	341	830	2,237	8,910	20,311	30,759	40,328	10.0	5.6	3.5	4.4
Population (million)	981	1,135	1,263	1,371	1,415	1,391	1,340	0.8	0.2	-0.3	-0.1
CO_2 emissions (Mt)	1,505	2,339	3,164	9,333	9,399	8,579	6,939	5.7	0.0	-1.5	-0.8
GDP per capita ($2010 thousand)	0.3	0.7	1.8	6.5	14	22	30	9.1	5.4	3.8	4.5
Primary energy consump. per capita (toe)	0.6	0.8	0.9	2.2	2.5	2.6	2.6	4.2	0.9	0.2	0.5
Primary energy consumption per GDP[*2]	1,752	1,050	505	334	172	117	85	-4.5	-4.3	-3.5	-3.8
CO_2 emissions per GDP[*3]	4,410	2,819	1,414	1,048	463	279	172	-3.9	-5.3	-4.8	-5.0
CO_2 per primary energy consumption[*4]	2.5	2.7	2.8	3.1	2.7	2.4	2.0	0.6	-1.0	-1.4	-1.2

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A48 | India [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	200	306	441	851	1,492	1,837	2,158	100	100	100	4.2	3.8	1.9	2.7
Coal	44	93	146	379	606	697	775	30	45	36	5.8	3.2	1.2	2.1
Oil	33	61	112	206	358	465	582	20	24	27	5.0	3.8	2.5	3.0
Natural gas	1.3	11	23	43	122	178	235	3.5	5.1	11	5.8	7.2	3.3	5.0
Nuclear	0.8	1.6	4.4	9.8	78	122	156	0.5	1.1	7.2	7.5	14.9	3.5	8.2
Hydro	4.0	6.2	6.4	12	24	31	38	2.0	1.4	1.8	2.7	4.8	2.4	3.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	0.0	0.2	4.8	36	68	107	0.0	0.6	5.0	27.8	14.3	5.6	9.3
Biomass and waste	116	133	149	196	267	276	264	44	23	12	1.6	2.1	-0.1	0.8

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	174	243	315	578	1,009	1,258	1,494	100	100	100	3.5	3.8	2.0	2.8
Industry	41	67	83	195	359	440	491	27	34	33	4.4	4.1	1.6	2.7
Transport	17	21	32	86	151	204	246	8.6	15	16	5.8	3.8	2.5	3.0
Buildings, etc.	110	142	173	250	402	483	599	59	43	40	2.3	3.2	2.0	2.5
Non-energy use	5.7	13	27	46	97	130	158	5.5	8.0	11	5.1	5.0	2.5	3.6
Coal	25	39	35	108	201	249	286	16	19	19	4.2	4.2	1.8	2.8
Oil	27	50	94	174	317	418	530	21	30	35	5.1	4.1	2.6	3.2
Natural gas	0.7	5.6	9.7	29	70	100	126	2.3	5.0	8.4	6.8	6.1	3.0	4.3
Electricity	7.8	18	32	88	197	275	364	7.6	15	24	6.5	5.5	3.1	4.1
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.1	-	-	0.0	n.a.	n.a.	12.9	n.a.
Renewables	114	130	144	178	225	216	188	54	31	13	1.3	1.6	-0.9	0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	120	293	570	1,383	2,904	3,815	4,845	100	100	100	6.4	5.1	2.6	3.6
Coal	61	192	390	1,042	1,586	1,722	1,900	65	75	39	7.0	2.8	0.9	1.7
Oil	8.8	13	29	23	24	18	10	4.5	1.7	0.2	2.2	0.2	-4.1	-2.2
Natural gas	0.6	10.0	56	68	256	405	604	3.4	4.9	12	8.0	9.2	4.4	6.4
Nuclear	3.0	6.1	17	37	300	467	599	2.1	2.7	12	7.5	14.9	3.5	8.2
Hydro	47	72	74	138	280	364	447	24	10.0	9.2	2.7	4.8	2.4	3.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	0.0	5.6	115	296	513	-	0.4	11	n.a.	22.2	7.8	13.8
Wind	-	0.0	1.7	43	262	417	586	0.0	3.1	12	33.4	12.8	4.1	7.8
CSP and marine	-	-	-	-	5.4	13	29	-	-	0.6	n.a.	n.a.	8.8	n.a.
Biomass and waste	-	-	1.3	27	76	113	156	-	1.9	3.2	n.a.	7.2	3.7	5.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	274	470	809	2,288	6,133	10,236	15,857	6.5	6.8	4.9	5.7
Population (million)	697	871	1,053	1,311	1,515	1,608	1,662	1.7	1.0	0.5	0.7
CO_2 emissions (Mt)	263	542	899	2,107	3,491	4,107	4,699	5.6	3.4	1.5	2.3
GDP per capita ($2010 thousand)	0.4	0.5	0.8	1.7	4.0	6.4	9.5	4.8	5.8	4.4	5.0
Primary energy consump. per capita (toe)	0.3	0.4	0.4	0.6	1.0	1.1	1.3	2.5	2.8	1.4	2.0
Primary energy consumption per GDP*2	731	651	545	372	243	179	136	-2.2	-2.8	-2.9	-2.8
CO_2 emissions per GDP*3	962	1,154	1,112	921	569	401	296	-0.9	-3.2	-3.2	-3.2
CO_2 per primary energy consumption*4	1.3	1.8	2.0	2.5	2.3	2.2	2.2	1.3	-0.4	-0.4	-0.4

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A49 | Japan [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	345	439	518	430	425	397	369	100	100	100	-0.1	-0.1	-0.7	-0.4
Coal	60	76	97	117	103	91	76	17	27	21	1.7	-0.9	-1.5	-1.2
Oil	234	250	255	185	141	118	100	57	43	27	-1.2	-1.8	-1.7	-1.7
Natural gas	21	44	66	100	86	86	82	10	23	22	3.3	-1.0	-0.2	-0.6
Nuclear	22	53	84	2.5	58	56	56	12	0.6	15	-11.5	23.5	-0.2	9.3
Hydro	7.6	7.5	7.3	7.3	7.9	8.1	8.1	1.7	1.7	2.2	-0.1	0.5	0.2	0.3
Geothermal	0.8	1.6	3.1	2.4	6.7	9.9	14	0.4	0.6	3.7	1.7	7.1	3.6	5.1
Solar, wind, etc.	-	1.4	0.9	3.9	8.0	12	15	0.3	0.9	4.1	4.2	5.0	3.3	4.0
Biomass and waste	-	4.5	4.7	11	14	16	18	1.0	2.7	4.8	3.8	1.4	1.1	1.3

Final energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total	232	287	328	291	267	249	231	100	100	100	0.1	-0.6	-0.7	-0.7
Industry	91	110	100	82	81	80	77	38	28	33	-1.1	-0.1	-0.2	-0.2
Transport	54	68	84	71	51	42	37	24	24	16	0.2	-2.2	-1.6	-1.8
Buildings, etc.	58	76	103	99	98	90	81	26	34	35	1.1	-0.1	-0.9	-0.6
Non-energy use	28	34	41	39	38	37	36	12	13	15	0.6	-0.2	-0.3	-0.3
Coal	25	30	24	24	22	21	19	11	8.1	8.3	-1.0	-0.4	-0.8	-0.6
Oil	157	171	194	152	120	102	89	59	52	38	-0.5	-1.6	-1.5	-1.5
Natural gas	5.8	15	22	29	33	33	32	5.3	10	14	2.7	0.7	-0.1	0.2
Electricity	44	66	83	82	88	88	86	23	28	37	0.8	0.5	-0.1	0.2
Heat	0.1	0.2	0.5	0.5	0.5	0.4	0.4	0.1	0.2	0.2	3.8	-0.4	-1.3	-1.0
Hydrogen	-	-	-	-	0.0	0.1	0.1	-	-	0.0	n.a.	n.a.	6.3	n.a.
Renewables	-	4.1	3.8	3.8	4.3	4.2	4.0	1.4	1.3	1.7	-0.2	0.7	-0.4	0.1

Electricity generation

	(TWh)							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total	573	873	1,088	1,035	1,109	1,108	1,091	100	100	100	0.7	0.5	-0.1	0.1
Coal	55	118	234	343	279	239	197	13	33	18	4.4	-1.4	-1.7	-1.6
Oil	265	284	179	103	49	28	9.7	33	9.9	0.9	-4.0	-4.8	-7.8	-6.5
Natural gas	81	171	254	410	313	315	302	20	40	28	3.6	-1.8	-0.2	-0.9
Nuclear	83	202	322	9.4	224	215	215	23	0.9	20	-11.5	23.5	-0.2	9.3
Hydro	88	87	85	85	92	94	94	10.0	8.2	8.7	-0.1	0.5	0.2	0.3
Geothermal	0.9	1.7	3.3	2.6	7.6	11	16	0.2	0.2	1.4	1.6	7.5	3.7	5.3
Solar PV	-	0.0	0.3	36	72	107	131	0.0	3.5	12	52.1	4.8	3.0	3.8
Wind	-	-	0.1	5.2	18	31	43	-	0.5	4.0	n.a.	8.5	4.6	6.3
CSP and marine	-	-	-	-	0.1	0.3	0.8	-	-	0.1	n.a.	n.a.	11.9	n.a.
Biomass and waste	-	9.6	10	41	55	67	82	1.1	4.0	7.5	6.0	1.9	2.0	2.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	2,977	4,683	5,349	5,986	6,948	7,705	8,329	1.0	1.0	0.9	0.9
Population (million)	117	124	127	127	121	114	108	0.1	-0.3	-0.6	-0.5
CO_2 emissions (Mt)	916	1,071	1,195	1,147	925	811	691	0.3	-1.4	-1.4	-1.4
GDP per capita ($2010 thousand)	25	38	42	47	58	67	77	0.9	1.3	1.5	1.4
Primary energy consump. per capita (toe)	3.0	3.6	4.1	3.4	3.5	3.5	3.4	-0.2	0.3	-0.1	0.0
Primary energy consumption per GDP[*2]	116	94	97	72	61	52	44	-1.1	-1.1	-1.6	-1.4
CO_2 emissions per GDP[*3]	308	229	223	192	133	105	83	-0.7	-2.4	-2.3	-2.4
CO_2 per primary energy consumption[*4]	2.7	2.4	2.3	2.7	2.2	2.0	1.9	0.4	-1.3	-0.7	-1.0

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A50 | ASEAN [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	142	233	379	621	966	1,228	1,472	100	100	100	4.0	3.0	2.1	2.5
Coal	3.6	13	32	114	185	239	300	5.4	18	20	9.2	3.3	2.5	2.8
Oil	58	89	153	210	288	354	422	38	34	29	3.5	2.1	1.9	2.0
Natural gas	8.6	30	74	140	200	249	295	13	23	20	6.3	2.4	2.0	2.2
Nuclear	-	-	-	-	26	60	87	-	-	5.9	n.a.	n.a.	6.3	n.a.
Hydro	0.8	2.3	4.1	9.2	18	20	22	1.0	1.5	1.5	5.6	4.6	1.1	2.6
Geothermal	1.8	6.6	18	27	108	161	199	2.8	4.3	13	5.7	9.7	3.1	5.9
Solar, wind, etc.	-	-	-	0.3	3.9	9.2	17	-	0.1	1.2	n.a.	17.5	7.6	11.7
Biomass and waste	70	93	98	119	135	132	126	40	19	8.5	1.0	0.8	-0.4	0.2

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	112	173	270	436	613	742	873	100	100	100	3.8	2.3	1.8	2.0
Industry	22	43	75	125	192	238	277	25	29	32	4.4	2.9	1.9	2.3
Transport	17	32	61	117	158	189	227	19	27	26	5.2	2.1	1.8	1.9
Buildings, etc.	71	87	113	147	197	231	268	50	34	31	2.1	2.0	1.6	1.7
Non-energy use	2.4	11	21	47	66	83	101	6.3	11	12	6.0	2.3	2.1	2.2
Coal	2.1	6.0	13	34	49	56	61	3.5	7.8	6.9	7.2	2.4	1.1	1.7
Oil	41	67	123	193	271	335	402	38	44	46	4.4	2.3	2.0	2.1
Natural gas	2.5	7.5	17	37	60	76	89	4.4	8.6	10	6.6	3.2	2.0	2.5
Electricity	4.7	11	28	68	124	170	225	6.4	16	26	7.5	4.1	3.0	3.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	7.7	n.a.
Renewables	61	82	89	104	110	105	96	47	24	11	1.0	0.4	-0.7	-0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	62	154	370	868	1,594	2,188	2,882	100	100	100	7.2	4.1	3.0	3.5
Coal	3.0	28	79	311	575	760	1,022	18	36	35	10.2	4.2	2.9	3.5
Oil	47	66	72	29	20	17	10	43	3.4	0.4	-3.2	-2.6	-3.1	-2.9
Natural gas	0.7	26	154	384	538	687	879	17	44	31	11.3	2.3	2.5	2.4
Nuclear	-	-	-	-	99	230	335	-	-	12	n.a.	n.a.	6.3	n.a.
Hydro	9.8	27	47	107	208	238	259	18	12	9.0	5.6	4.6	1.1	2.6
Geothermal	2.1	6.6	16	21	73	106	129	4.3	2.4	4.5	4.8	8.6	2.9	5.3
Solar PV	-	-	-	2.9	34	84	161	-	0.3	5.6	n.a.	17.9	8.1	12.2
Wind	-	-	-	1.2	12	22	34	-	0.1	1.2	n.a.	16.3	5.5	10.0
CSP and marine	-	-	-	-	0.1	0.3	0.6	-	-	0.0	n.a.	n.a.	9.9	n.a.
Biomass and waste	-	0.6	1.0	12	35	44	52	0.4	1.3	1.8	12.5	7.7	2.0	4.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	440	741	1,180	2,490	4,955	7,383	10,390	5.0	4.7	3.8	4.2
Population (million)	347	430	505	608	696	736	761	1.4	0.9	0.4	0.6
CO_2 emissions (Mt)	205	362	711	1,288	1,824	2,062	2,270	5.2	2.3	1.1	1.6
GDP per capita ($2010 thousand)	1.3	1.7	2.3	4.1	7.1	10	14	3.5	3.8	3.3	3.5
Primary energy consump. per capita (toe)	0.4	0.5	0.8	1.0	1.4	1.7	1.9	2.6	2.1	1.7	1.8
Primary energy consumption per GDP[*2]	323	314	322	249	195	166	142	-0.9	-1.6	-1.6	-1.6
CO_2 emissions per GDP[*3]	466	489	602	517	368	279	219	0.2	-2.2	-2.6	-2.4
CO_2 per primary energy consumption[*4]	1.4	1.6	1.9	2.1	1.9	1.7	1.5	1.2	-0.6	-1.0	-0.8

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A51 | United States [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	1,805	1,915	2,273	2,188	2,037	1,917	1,800	100	100	100	0.5	-0.5	-0.6	-0.6
Coal	376	460	534	374	225	144	73	24	17	4.1	-0.8	-3.3	-5.5	-4.6
Oil	797	757	871	794	644	543	460	40	36	26	0.2	-1.4	-1.7	-1.5
Natural gas	477	438	548	646	664	643	558	23	30	31	1.6	0.2	-0.9	-0.4
Nuclear	69	159	208	216	209	207	236	8.3	9.9	13	1.2	-0.2	0.6	0.3
Hydro	24	23	22	22	25	26	26	1.2	1.0	1.4	-0.3	1.1	0.1	0.5
Geothermal	4.6	14	13	9.0	33	43	51	0.7	0.4	2.8	-1.8	9.1	2.1	5.1
Solar, wind, etc.	-	0.3	2.1	22	91	151	223	0.0	1.0	12	18.5	9.8	4.6	6.8
Biomass and waste	54	62	73	99	140	155	168	3.3	4.5	9.3	1.9	2.3	0.9	1.5

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	1,311	1,294	1,546	1,520	1,432	1,352	1,269	100	100	100	0.6	-0.4	-0.6	-0.5
Industry	387	284	332	262	255	243	221	22	17	17	-0.3	-0.2	-0.7	-0.5
Transport	425	488	588	629	535	475	437	38	41	34	1.0	-1.1	-1.0	-1.0
Buildings, etc.	397	403	473	506	505	493	473	31	33	37	0.9	0.0	-0.3	-0.2
Non-energy use	102	119	153	123	137	142	139	9.2	8.1	11	0.1	0.7	0.1	0.3
Coal	56	56	33	20	16	14	11	4.3	1.3	0.9	-4.1	-1.2	-1.8	-1.5
Oil	689	683	793	758	622	527	451	53	50	36	0.4	-1.3	-1.6	-1.5
Natural gas	337	303	360	333	332	321	300	23	22	24	0.4	0.0	-0.5	-0.3
Electricity	174	226	301	325	354	373	383	18	21	30	1.5	0.6	0.4	0.5
Heat	-	2.2	5.3	5.5	5.9	6.0	5.7	0.2	0.4	0.5	3.8	0.5	-0.1	0.1
Hydrogen	-	-	-	-	0.1	0.2	0.6	-	-	0.0	n.a.	n.a.	11.5	n.a.
Renewables	54	23	54	79	102	111	118	1.8	5.2	9.3	5.1	1.7	0.7	1.1

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	2,427	3,203	4,026	4,297	4,655	4,860	4,946	100	100	100	1.2	0.5	0.3	0.4
Coal	1,243	1,700	2,129	1,471	867	516	204	53	34	4.1	-0.6	-3.5	-7.0	-5.5
Oil	263	131	118	39	22	13	4.8	4.1	0.9	0.1	-4.7	-3.6	-7.4	-5.8
Natural gas	370	382	634	1,373	1,551	1,518	1,159	12	32	23	5.3	0.8	-1.4	-0.5
Nuclear	266	612	798	830	801	792	907	19	19	18	1.2	-0.2	0.6	0.3
Hydro	279	273	253	251	295	298	300	8.5	5.8	6.1	-0.3	1.1	0.1	0.5
Geothermal	5.4	16	15	19	71	91	108	0.5	0.4	2.2	0.6	9.3	2.2	5.1
Solar PV	-	0.0	0.2	32	171	316	448	0.0	0.7	9.1	44.9	11.8	4.9	7.8
Wind	-	3.1	5.7	193	611	906	1,205	0.1	4.5	24	18.0	8.0	3.5	5.4
CSP and marine	-	0.7	0.5	9.1	109	218	388	0.0	0.2	7.8	11.0	18.0	6.6	11.3
Biomass and waste	0.5	86	72	80	156	190	221	2.7	1.9	4.5	-0.3	4.5	1.8	2.9
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	6,529	9,064	12,713	16,597	22,629	27,677	32,902	2.4	2.1	1.9	2.0
Population (million)	227	250	282	321	356	376	391	1.0	0.7	0.5	0.6
CO_2 emissions (Mt)	4,744	4,820	5,617	5,071	3,931	3,141	2,422	0.2	-1.7	-2.4	-2.1
GDP per capita ($2010 thousand)	29	36	45	52	64	74	84	1.4	1.4	1.4	1.4
Primary energy consump. per capita (toe)	7.9	7.7	8.1	6.8	5.7	5.1	4.6	-0.5	-1.2	-1.1	-1.1
Primary energy consumption per GDP*2	276	211	179	132	90	69	55	-1.9	-2.5	-2.5	-2.5
CO_2 emissions per GDP*3	727	532	442	305	174	114	74	-2.2	-3.7	-4.2	-4.0
CO_2 per primary energy consumption*4	2.6	2.5	2.5	2.3	1.9	1.6	1.3	-0.3	-1.2	-1.8	-1.5

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A52 | European Union [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total*1	n.a.	1,647	1,695	1,586	1,465	1,363	1,276	100	100	100	-0.1	-0.5	-0.7	-0.6
Coal	n.a.	455	321	263	151	101	63	28	17	4.9	-2.2	-3.6	-4.3	-4.0
Oil	n.a.	608	625	516	417	339	277	37	33	22	-0.7	-1.4	-2.0	-1.8
Natural gas	n.a.	297	396	358	352	319	269	18	23	21	0.7	-0.1	-1.4	-0.8
Nuclear	n.a.	207	246	223	229	242	265	13	14	21	0.3	0.2	0.7	0.5
Hydro	n.a.	25	31	29	31	31	32	1.5	1.8	2.5	0.6	0.3	0.2	0.2
Geothermal	n.a.	3.2	4.6	6.5	10	12	12	0.2	0.4	1.0	2.9	3.2	0.9	1.9
Solar, wind, etc.	n.a.	0.3	2.4	39	94	132	167	0.0	2.5	13	21.5	6.0	2.9	4.2
Biomass and waste	n.a.	48	67	149	179	185	188	2.9	9.4	15	4.7	1.2	0.3	0.7

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	n.a.	1,136	1,180	1,114	1,107	1,027	954	100	100	100	-0.1	0.0	-0.7	-0.4
Industry	n.a.	347	309	254	270	261	245	31	23	26	-1.2	0.4	-0.5	-0.1
Transport	n.a.	259	303	312	248	202	171	23	28	18	0.8	-1.5	-1.8	-1.7
Buildings, etc.	n.a.	430	454	450	487	462	434	38	40	45	0.2	0.5	-0.6	-0.1
Non-energy use	n.a.	100	113	97	101	103	103	8.8	8.7	11	-0.1	0.3	0.1	0.2
Coal	n.a.	122	52	36	32	29	26	11	3.2	2.7	-4.8	-0.7	-1.1	-0.9
Oil	n.a.	506	543	465	378	307	250	45	42	26	-0.3	-1.4	-2.0	-1.8
Natural gas	n.a.	227	272	241	239	229	217	20	22	23	0.2	-0.1	-0.5	-0.3
Electricity	n.a.	186	217	236	254	264	270	16	21	28	1.0	0.5	0.3	0.4
Heat	n.a.	55	45	46	106	101	95	4.9	4.1	10.0	-0.7	5.8	-0.6	2.1
Hydrogen	n.a.	-	-	-	0.0	0.1	0.1	-	-	0.0	n.a.	n.a.	7.9	n.a.
Renewables	n.a.	40	50	90	98	97	95	3.5	8.1	9.9	3.3	0.5	-0.2	0.1

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	n.a.	2,577	3,006	3,204	3,474	3,604	3,711	100	100	100	0.9	0.5	0.3	0.4
Coal	n.a.	1,050	968	826	431	240	80	41	26	2.2	-1.0	-4.2	-8.1	-6.4
Oil	n.a.	224	181	61	31	16	5.4	8.7	1.9	0.1	-5.1	-4.4	-8.3	-6.7
Natural gas	n.a.	193	480	497	494	372	177	7.5	15	4.8	3.9	0.0	-5.0	-2.9
Nuclear	n.a.	795	945	857	879	929	1,017	31	27	27	0.3	0.2	0.7	0.5
Hydro	n.a.	290	357	341	358	365	372	11	11	10	0.6	0.3	0.2	0.2
Geothermal	n.a.	3.2	4.8	6.5	11	12	13	0.1	0.2	0.4	2.9	3.5	0.9	2.0
Solar PV	n.a.	0.0	0.1	102	246	328	410	0.0	3.2	11	43.6	6.0	2.6	4.0
Wind	n.a.	0.8	22	302	671	902	1,115	0.0	9.4	30	26.9	5.5	2.6	3.8
CSP and marine	n.a.	0.7	1.6	9.5	39	77	117	0.0	0.3	3.1	11.1	10.0	5.6	7.4
Biomass and waste	n.a.	20	46	201	310	362	402	0.8	6.3	11	9.8	2.9	1.3	2.0
Hydrogen	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	n.a.	11,888	14,768	17,885	22,762	26,005	29,079	1.6	1.6	1.2	1.4
Population (million)	n.a.	478	488	510	524	526	523	0.3	0.2	0.0	0.1
CO_2 emissions (Mt)	n.a.	4,068	3,783	3,176	2,402	1,882	1,424	-1.0	-1.8	-2.6	-2.3
GDP per capita ($2010 thousand)	n.a.	25	30	35	43	49	56	1.4	1.4	1.2	1.3
Primary energy consump. per capita (toe)	n.a.	3.4	3.5	3.1	2.8	2.6	2.4	-0.4	-0.7	-0.7	-0.7
Primary energy consumption per GDP*2	n.a.	139	115	89	64	52	44	-1.8	-2.1	-1.9	-2.0
CO_2 emissions per GDP*3	n.a.	342	256	178	106	72	49	-2.6	-3.4	-3.8	-3.6
CO_2 per primary energy consumption*4	n.a.	2.5	2.2	2.0	1.6	1.4	1.1	-0.8	-1.3	-1.9	-1.7

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

Table A53 | World [Peak Oil Demand Case]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
Total[*1]	7,205	8,774	10,028	13,647	16,333	17,888	19,115	100	100	100	1.8	1.2	0.8	1.0
Coal	1,783	2,220	2,311	3,836	4,317	4,701	4,963	25	28	26	2.2	0.8	0.7	0.7
Oil	3,102	3,235	3,660	4,334	4,702	4,585	4,254	37	32	22	1.2	0.5	-0.5	-0.1
Natural gas	1,232	1,663	2,071	2,944	3,892	4,779	5,765	19	22	30	2.3	1.9	2.0	1.9
Nuclear	186	526	676	671	907	980	1,055	6.0	4.9	5.5	1.0	2.0	0.8	1.3
Hydro	148	184	225	334	425	466	500	2.1	2.5	2.6	2.4	1.6	0.8	1.2
Geothermal	12	34	52	74	177	224	257	0.4	0.5	1.3	3.1	6.0	1.9	3.6
Solar, wind, etc.	0.1	2.7	8.0	126	306	446	608	0.0	0.9	3.2	16.7	6.1	3.5	4.6
Biomass and waste	741	909	1,023	1,323	1,604	1,702	1,708	10	9.7	8.9	1.5	1.3	0.3	0.7

Final energy consumption

	Mtoe							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	5,368	6,268	7,036	9,384	11,057	11,878	12,446	100	100	100	1.6	1.1	0.6	0.8
Industry	1,766	1,809	1,868	2,712	3,146	3,499	3,779	29	29	30	1.6	1.0	0.9	1.0
Transport	1,248	1,573	1,961	2,703	2,940	2,787	2,530	25	29	20	2.2	0.6	-0.7	-0.2
Buildings, etc.	2,000	2,409	2,591	3,132	3,911	4,369	4,785	38	33	38	1.1	1.5	1.0	1.2
Non-energy use	354	478	617	836	1,060	1,223	1,352	7.6	8.9	11	2.3	1.6	1.2	1.4
Coal	703	754	548	1,044	1,096	1,122	1,108	12	11	8.9	1.3	0.3	0.1	0.2
Oil	2,446	2,599	3,115	3,840	4,200	4,074	3,757	41	41	30	1.6	0.6	-0.6	-0.1
Natural gas	814	945	1,117	1,401	1,761	1,994	2,190	15	15	18	1.6	1.5	1.1	1.3
Electricity	586	835	1,092	1,737	2,418	3,035	3,736	13	19	30	3.0	2.2	2.2	2.2
Heat	121	336	248	271	288	297	299	5.4	2.9	2.4	-0.9	0.4	0.2	0.3
Hydrogen	-	-	-	-	2.9	13	47	-	-	0.4	n.a.	n.a.	15.0	n.a.
Renewables	698	799	917	1,090	1,291	1,343	1,309	13	12	11	1.3	1.1	0.1	0.5

Electricity generation

	(TWh)							Shares (%)			1990/	2015/	2030/	2015/
	1980	1990	2000	2015	2030	2040	2050	1990	2015	2050	2015	2030	2050	2050
Total	8,283	11,864	15,471	24,255	33,589	41,618	50,430	100	100	100	2.9	2.2	2.1	2.1
Coal	3,137	4,425	6,005	9,538	12,031	14,145	16,055	37	39	32	3.1	1.6	1.5	1.5
Oil	1,659	1,358	1,252	990	1,047	1,147	1,187	11	4.1	2.4	-1.3	0.4	0.6	0.5
Natural gas	999	1,752	2,753	5,543	8,244	11,698	16,106	15	23	32	4.7	2.7	3.4	3.1
Nuclear	713	2,013	2,591	2,571	3,480	3,759	4,047	17	11	8.0	1.0	2.0	0.8	1.3
Hydro	1,717	2,142	2,619	3,888	4,943	5,419	5,818	18	16	12	2.4	1.6	0.8	1.2
Geothermal	14	36	52	80	191	245	288	0.3	0.3	0.6	3.2	5.9	2.1	3.7
Solar PV	-	0.0	1.0	247	751	1,154	1,667	0.0	1.0	3.3	45.5	7.7	4.1	5.6
Wind	0.0	3.9	31	838	1,891	2,710	3,585	0.0	3.5	7.1	24.0	5.6	3.3	4.2
CSP and marine	0.5	1.5	2.2	27	136	237	385	0.0	0.1	0.8	12.2	11.5	5.3	7.9
Biomass and waste	44	131	164	528	872	1,099	1,287	1.1	2.2	2.6	5.7	3.4	2.0	2.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1980	1990	2000	2015	2030	2040	2050	1990/ 2015	2015/ 2030	2030/ 2050	2015/ 2050
GDP ($2010 billion)	27,958	37,797	49,825	75,059	115,303	152,089	191,400	2.8	2.9	2.6	2.7
Population (million)	4,436	5,277	6,108	7,336	8,497	9,152	9,710	1.3	1.0	0.7	0.8
CO_2 emissions (Mt)	18,411	21,205	23,416	32,910	37,506	40,282	42,261	1.8	0.9	0.6	0.7
GDP per capita ($2010 thousand)	6.3	7.2	8.2	10	14	17	20	1.4	1.9	1.9	1.9
Primary energy consump. per capita (toe)	1.6	1.7	1.6	1.9	1.9	2.0	2.0	0.5	0.2	0.1	0.2
Primary energy consumption per GDP[*2]	258	232	201	182	142	118	100	-1.0	-1.7	-1.7	-1.7
CO_2 emissions per GDP[*3]	659	561	470	438	325	265	221	-1.0	-2.0	-1.9	-1.9
CO_2 per primary energy consumption[*4]	2.6	2.4	2.3	2.4	2.3	2.3	2.2	0.0	-0.3	-0.2	-0.2

*1 Trade of electricity, heat and hydrogen are not shown, *2 toe/$2010 million,
*3 t/$2010 million, *4 t/toe

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