IEEJ Outlook 2022

Energy, Environment and Economy

Challenges toward carbon neutrality: Voyage in uncharted territory

The Institute of Energy Economics, Japan

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Executive summary

Global energy supply and demand outlook (Reference Scenario)

India, MENA and ASEAN account for three quarters of the global energy consumption growth

- Under the Reference Scenario, which incorporates the expected effects of past trends and extends the energy and environmental policies and technologies to date, global primary energy consumption will increase by about 20% between the current level and 2050. As the macroeconomy expands beyond the increase rate for consumption, the world's energy consumption intensity is decreasing, reflecting efficiency improvements and energy conservation efforts.
- India, the Middle East and North Africa (MENA), and the Association of Southeast Asian Nations (ASEAN) will lead the global increase in primary energy consumption. The global share of these three will increase from 18% in 2019 to 28% in 2050. They will account for 76% of the increase in consumption between 2019 and 2050.
- Although non-fossil energy increases substantially in this scenario, it appears very difficult that they could alone cover all the energy consumption. In the timeline to 2050, it is realistic for the world to expect a combination of fossil fuels and non-fossil energy, especially in the Emerging Markets and Developing Economies where consumption will increase.

Middle Eastern oil producers lead oil supply at low production costs

- In the medium-term, until 2030, global oil demand will increase at an annual rate of 0.5%. In response, the Organization of Petroleum Exporting Countries (OPEC) and non-OPEC countries will both increase crude oil production. In the longer run, oil production in North America will peak out, while production in Middle Eastern OPEC countries, which boast abundant oil reserves, will continue to increase.
- As the main axis of crude oil production will shift to Middle Eastern oil producing countries, Asia's dependence on crude oil from the Middle East will once again intensify. Asia's share will reach almost 80% of the global crude oil imports in 2050, and the world's largest oil importer will shift from China to India, with future imports exceeding those of China today.

Sustained expansion of LNG market due to abundant supply potential

- In the United States, the world's largest producer and consumer of natural gas, production of shale gas will continue to increase at an annual rate of about 1% for a decade or so and stabilise thereafter. Liquefied natural gas (LNG) exports will play an important role in expanding sales channels and improving trade balance.

- East and West Africa, the frontier regions of the world's natural gas, will overtime increase supply. As there are offshore and, in some cases, small- and medium-sized gas resources in these regions, floating LNG production will be considered a practical option for development.

Reduced supply flexibility and unstable supply-demand balance for coal

- Coal production will increasingly be limited to specific countries and regions, as the trend toward decarbonisation is gradually becoming accepted and coal-related investments and loans are severely constrained. Demand remains highly uncertain as the supply structure becomes less flexible.
- By type of coal, production of steam coal will temporarily expand due to an increase in demand for power generation but will decline after peaking around 2040. Coking coal used mainly as feedstocks for steel production will decrease from 1 050 Mt in 2019 to 800 Mt level by 2040.

Power generation is rapidly expanding in Asia. Natural gas will become the largest power source

- Global electricity generation will increase at an annual rate of 1.7%, and by 2050 will be 1.7 times the 2019 level. The increase is equivalent to 2.3 times China's current generation, the world's largest electricity generator. 95% of the increase is coming from the Emerging Markets and Developing Economies.
- Natural gas will be the largest source of energy for electricity generation by 2050. As the introduction of renewable energies increases, the role of balancing supply and demand of electricity will become more important than ever. Coal will continue to play a role as a base-load power source, but its share will fall below current levels.
- It has become difficult for Japan, Korea, the United States and some European countries to build new nuclear power plants as planned. On the other hand, China and a few other countries continue to promote the use of nuclear, while some Middle East countries, and others, are introducing nuclear. As a result, global capacity will gradually increase through 2050.
- Variable renewable energies, such as wind and solar photovoltaics, will generate 8 409 TWh in 2050, increasing their presence to 19% of the electricity generation mix. Achieving harmony with energy and social systems is an important issue.

Advanced Technologies Scenario

Advanced Technologies Scenario is still far from achieving global carbon neutrality in 2050, and it is necessary to mobilise all possible means to further promote energy conservation and climate change measures.

- In the 'Advanced Technologies Scenario', maximum reduction measures for carbon dioxide (CO_2) emissions are expected based on social opportunities and acceptability. Relative to the reference scenario, the reduction in primary energy consumption in 2050

will be 2.9 billion tonnes of oil equivalent (Gtoe) and the reduction in CO_2 emissions will be 15.8 Gt or 42% less than for the Reference Scenario. Although many countries have declared carbon neutrality targets since 2020, it would seem extremely difficult for the world to achieve carbon neutrality as early as 2050.

- The CO_2 emission reduction rates for 2030 will be 33% in the United States (compared to 2005), 40% in the European Union (compared to 1990), 37% in Japan (compared to 2013), and 10% in Canada (compared to 2005). All those reductions fall short of the nationally determined contribution (NDC) rate of reduction in greenhouse gas (GHG) emissions previously announced by those countries. It is clear that further policies and measures beyond those considered in the Advanced Technologies Scenario are required.
- China, the United States, the European Union and Japan have announced net zero emissions and carbon neutral targets. Scenarios from many of these countries and regions are expected to reduce emissions by around 80% in 2050, but none of them will reach their target. It is necessary to further develop and quickly introduce emission reduction technologies that are not commercialised yet.
- Compared to the Reference Scenario, investment in fossil fuels decreases while investment in renewable energy increases. The overall investment cost will be $34 trillion in the 2040s.

Road to carbon neutrality

- Since the Paris Agreement in 2015, many countries, including the United States, the European Union, China, Japan and the United Kingdom, have set carbon-neutral targets for the middle of this century. Carbon neutrality, however, is by no means an easy target given the current high dependence on fossil fuels and the path-dependent effects of existing infrastructure and supply systems.
- While there is of course a positive effect of green growth policies, we should not turn our attention away from the fact that climate change policies inherently have associated costs and growth constraints. Measures to achieve carbon neutrality should not be explained from the perspective of 'growth' but should be positioned as a global 'norm' that each country should pursue while bearing a certain burden.
- One of the major concerns in the process towards carbon neutrality is the emergence and potential expansion of new disparities. Factors such as economic conditions, resource endowment and technological capabilities naturally vary from country to country. Differences in these factors can produce new disparities by creating winners and losers.
- As we move towards carbon neutrality, we will see more electrification, and electricity security will become one of the most important energy security issues. The stable supply of mineral resources (critical minerals), which plays an important role in promoting the introduction of renewable energy and the electrification, is also a new important element for energy security.
- The suspension of new investment in crude oil production does not cause a tight supply-demand situation in a few months. However, in both the Reference Scenario and the Advanced Technologies Scenario in which demand growth slows down, the global oil

supply-demand balance will be a shortage of supply and an excess of demand in 2024. The suspension of new investment could lead to tight supply and demand and higher prices in the not too distant future.

Circular Carbon Economy/4Rs Scenario

- The concept of circular carbon economy is an extension of the conventional concept of circular economy. In contrast to the concept of circular economy in which the use of resources and the generation of waste are controlled through the three 'R's of 'reduce', 'reuse', and 'recycle', the concept of circular carbon economy is to control the total amount of CO_2 in the atmosphere through the four 'R's with 'remove' added.
- In the 'Circular Carbon Economy/4Rs Scenario', which anticipates the spread of more diverse decarbonisation technologies than in the Advanced Technologies Scenario, global CO_2 emissions in 2050 will be reduced to 15.7 Gt, less than half of the current level. Compared to the Advanced Technologies Scenario, more than half of the additional reductions will be in the non-power sector.
- Total primary energy consumption will increase slightly from the Advanced Technologies Scenario because the introduction of various decarbonisation technologies will generate additional demand for energy transformation. The share of fossil fuels in 2050 will be 60%, which is almost the same level as in the Advanced Technologies Scenario. By actively introducing decarbonisation technologies for fossil fuels, significant reductions in emissions can be achieved while continuing to use fossil fuels.
- Clean hydrogen (blue hydrogen and green hydrogen) plays an important role in various sectors and Asia is a particularly large market. The supply will mainly come from North America, the Middle East and Russia, where fossil fuel resources for blue hydrogen are abundant.

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 outlook and 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 divided the world into 42 regions[1] 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

Source: [Map] www.craftmap.box-i.net

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 past trends as well as the energy and environment policies, technologies, etc. that have been in place so far. This does not mean that policies or technologies may be fixed as the present ones because policies expected through traditional and conventional ways of thinking are incorporated into this scenario. On the other hand, we assume that no aggressive energy efficiency improvement or low-carbonisation policies deviating from the past trends will be adopted.

[1] See Table A1 for a detailed definition

Advanced Technologies Scenario

In this scenario, all countries in the world are assumed to strongly implement energy and environment policies contributing to securing stable energy supply and enhancing climate change and air pollution countermeasures. The effects of those policies are assumed to be successfully maximised. Specifically, our projection assumes that advanced technologies for 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

Introduction and enhancement of environmental regulations and national targets

Establishment of national strategies and targets, energy efficiency standards, fuel efficiency standards, low-carbon fuel standards, energy efficiency and environmental labelling systems, renewable energy introduction standards, feed-in-tariff systems, subsidy systems, environment tax, emissions trading, etc.

Promoting technology development and international technology cooperation

R&D investment expansion, development of international energy-efficient technologies (steelmaking, cement and other areas), support for establishing energy efficiency standards, etc.

Demand side technologies

■ Industry

Global deployment of best-practice industrial process technologies (for steelmaking, cement, paper-pulp, etc.).

■ Transport

Further diffusion of clean energy vehicles (highly fuel-efficient vehicles, hybrid vehicles, plug-in hybrid vehicles, electric vehicles, fuel cell vehicles).

■ Buildings

Further diffusion of efficient electric appliances (refrigerators, TVs, etc.), water-heating systems (heat pumps, etc.), air conditioning systems and lighting, as well as the enhancement of heat insulation.

Supply side technologies

■ Renewable energies

Further diffusion of power generation from wind, solar photovoltaic, concentrated solar power (CSP), biomass-fired, marine and biofuels.

■ Nuclear

Acceleration in nuclear power plant construction and improvement in capacity factor.

■ Highly efficient fossil fuel-fired power generation technologies promotion

Further diffusion of SC, USC, A-USC, coal IGCC (Integrated Gasification Combined Cycle) and natural gas MACC (More Advanced Combined Cycle) plants.

■ Next-generation power transmission and distribution technologies

Lower loss type of transformation and voltage regulator will penetrate further.

■ Carbon capture and storage

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

Box 1-1 | Globally growing carbon neutrality initiatives and IEEJ Outlook's response

Carbon neutrality initiatives reached a turning point toward global expansion in 2020.

The Paris Agreement aiming to limit global warming to well below 2°C above pre-industrial levels was adopted in December 2015 and took effect on 4 November 2016. On 8 November just after the effectuation, however, Donald Trump, calling for withdrawing the United States from the climate accord, won in the U.S. presidential election. The United States submitted to the United Nations its official notification of withdrawal from the accord on 4 November 2019, when the process to exit from the accord could be launched.

In the European Union (EU), a proposal for a net zero emission goal for 2050 was presented in June 2019. In the face of opposition from East European countries, however, the EU failed to reach agreement on the proposal. It was discussed again in December 2019 and March 2020, but it failed to be agreed on.

In September 2019, the United Nations Climate Action Summit took place in New York. China was then expected to update its 2030 emission reduction goal and release a long-term strategy through 2050, but it refrained from doing so.

In this way, momentum toward enhancing climate change countermeasures stagnated to various extents in major economies including the United States, the EU and China. However, a breakthrough in such stagnation came in September 2020.

In September 2020, China told the United Nations General Assembly that it would seek to achieve carbon neutrality before 2060. In the wake of the Chinese action and after proposals for a net zero emission goal for 2050 had failed due to opposition from East European countries, the EU finally agreed in October 2020 on a goal of greenhouse gas (GHG) neutrality for 2050. Then, Japan also announced to reach net-zero GHG emissions by 2050. In January 2021, with the inauguration of the Biden administration, the United States announced it was now seeking to achieve net-zero emissions before 2050.

A total of 125 countries have adopted the goal of net-zero emissions or carbon neutrality, covering more than 60% of global GHG emissions. While the realisation of carbon neutrality is by no means easy, it is historically significant that more than 120 countries, including major ones, have pledged to pursue carbon neutrality by the middle of the 21st century. The carbon neutrality goal has thus become a “reality” in the international community.

While countries and regions pursue carbon neutrality, major oil and gas companies are offering their respective net-zero emission goals covering emissions accompanying energy product consumption. On the occasion of the 25th Conference of Parties to the United Nations Framework Convention on Climate Change (COP25) in December 2019, Repsol announced a net-zero emission goal. Equinor did so in November 2020, followed by Occidental in December 2020 and Shell and Eni in February 2021 (Table 1-1). While mainly European companies have proactively presented net-zero emission goals covering up to Scope 3[2], state-run oil companies accounting for a majority of global oil production have yet to adopt such goals. Their future actions will attract attention.

[2] Subjected to Scope 3 are emissions from final consumption of these companies’ products.

Table 1-1 | Major oil/gas companies' net-zero emissions goals

Date	Company name	Goals
2 December 2019	Repsol	Net-zero emissions in scopes 1, 2 and 3 (emissions based on the use of the products from upstream production) (Strategic Plan 2021-2025)
2 November 2020	Equinor	Net-zero GHG emissions in scopes 1, 2 and 3 by 2050
2 December 2020	Occidental	Net-zero for total emissions inventory including product use (scopes 1, 2 and 3) as an ambition to achieve before 2050 (Climate Report 2020)
11 February 2021	Shell	Achieving a net-zero emissions energy business goal (covering emissions from business operations and the use of energy products for sale) by 2050
19 February 2021	Eni	Achieving net-zero GHG lifecycle emissions in scopes 1, 2 and 3 by 2050 (Strategic Plan 2021-2024)

Note: Including emissions from the use of energy products

Given global trends including the accelerated declarations of decarbonisation since the autumn of 2020, the IEEJ Outlook 2022 provides a scenario analysis on future global energy supply and demand, and emissions. Until last year, the IEEJ Outlook analysed global energy supply and demand, and emission scenarios by utilising cost-benefit analysis from the viewpoint of the time when the 2°C goal should be achieved, attempting to provide new knowledge on the decarbonisation issue.

This year's Outlook recognises that, since the autumn of 2020, one after another major countries and businesses have declared carbon neutrality goals by the middle of the 21st century in a manner to turn around the global situation. The IEEJ Outlook 2022 analyses challenges and pathways toward carbon neutrality goals, focusing on how to achieve the goals and what the challenges would be toward the achievement. As the challenges toward these goals are expected to include economic impacts of rising costs, it is important to address how to minimise the various costs accompanying energy transition.

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 economic growth and population among these factors are common to the Reference and Advanced Technologies Scenarios.

Economy

Recent trends

Since early 2020, the coronavirus (COVID-19) pandemic has claimed the lives of many people and exerted unprecedented negative impacts on the global economy. Despite large-scale

monetary easing and fiscal expansion to support growth, most major economies posted substantial contractions in 2020, except for China that recorded a small growth.

As effective COVID-19 vaccines have been developed and approved for a general vaccination program in Advanced Economies and China since late 2020, their economies have rapidly recovered from the COVID-19 disaster. In Emerging Market and Developing Economies, however, vaccination has been limited along with economic recovery. Vaccination gaps have led to economic gaps, leading to calls for developing arrangements for international cooperation in vaccine supply. Even in Advanced Economies, new coronavirus mutations that are more infectious than earlier ones have emerged and spread one after another, dashing hopes for an end to the pandemic.

The large number of COVID-19 infections (the largest in the world) exerted downward pressure on the United States, the world's largest economy, prompting the Federal Reserve Board to proactively lower interest rates and purchase massive bonds in quantitative easing to support the economy. With the vaccination rate surpassing 50% and with living restrictions being lifted, however, the economy has been recovering rapidly. As for the rising Cold War between the United States and China, trade disputes that had worsened under the Trump administration have not escalated under the new Biden administration. Thanks to the economic recovery, bilateral trade has been increasing even with tariffs being kept at high levels. Since the inauguration of the Biden administration in January 2021, however, bilateral confrontation has deepened over human rights abuse in the Xinjiang Uyghur autonomous region and Hong Kong and over information security, affecting economic activities.

The European economy, the second largest after the U.S. economy, lost vitality as mobility restrictions were imposed through repeated lockdowns to counter the COVID-19 spread. It happened at a time when it lacked solidarity due to a political divide caused by the United Kingdom's exit from the EU, the rise of populist political parties and immigration policy differences. In July, however, the European Commission which serves as the executive branch of the EU, decided to create a €750 billion recovery fund for economic reconstruction through measures such as its first common bond issues in history. In December 2020, the allocation of the recovery fund and budgets between 2021 and 2027 were approved. As EU governments have shouldered a common debt through subsidies and loans, the EU has restored a sense of solidarity.

China, the third largest economy in the world, has been in conflict with the United States and other Western advanced countries over trade, human rights and information security, prompting foreign companies to withdraw production sites and switch investment from China. Through sweeping Polymerase Chain Reaction (PCR) tests and quarantine measures, smartphone applications to track and restrict adult mobility, the shutdown of factories where workers tested positive for COVID-19, and other measures, however, China has successfully contained the original COVID-19 virus and almost restored its pre-pandemic livelihood, with its economy recovering rapidly. Recently, however, reports have indicated that mutant COVID-19 infections have spread in a manner to break through the containment in multiple cases.

- International oil prices declined below $40 per barrel or $30/bbl in April and May 2020 due to a rapid decrease in oil demand amid global economic deceleration under the COVID-19

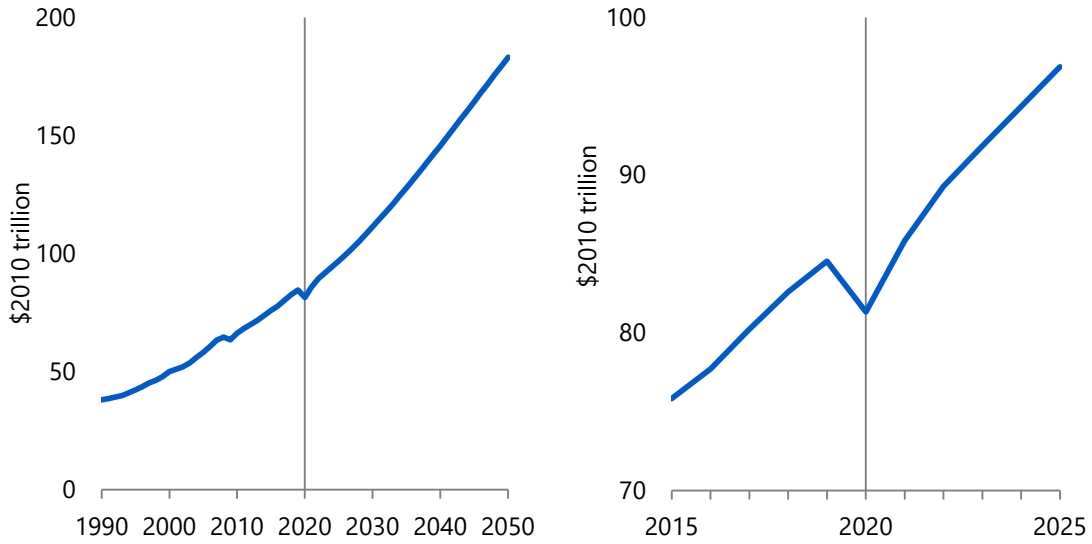
pandemic. As the Organization of the Petroleum Exporting Countries and major non-OPEC oil-producing countries, known as the OPEC-plus group, reduced production in May 2020, prices rose above $40/bbl in June. As the global economic recovery became significant, thanks to progress in the COVID-19 vaccination programs and hopes on the U.S. Biden administration's economic policy in early 2021, oil prices soared back above $60/bbl in February, restoring pre-pandemic levels. They surpassed $70/bbl in July before turning down below that level due to concerns about an economic slowdown caused by the rapid spread of mutant COVID-19 virus infections from August.

Future assumptions

While referring to country-by-country economic development plans and economic outlooks by think tanks in the world, we assume global economic growth as follows:

The negative economic impacts of COVID-19 will rapidly disappear, thanks to a rapid diffusion of vaccination and the improvement of access to medicines in Advanced Economies and some Emerging Market and Developing Economies, like China, within 2021 and in other economies by the end of 2022. From 2023, lockdowns like those seen in March-April 2020 will not be repeated due to an absence of large-scale COVID-19 infection spreads. The global economy will score a 5.5% growth rate in 2021 after a 3.8% contraction in 2020. Global economic growth will slow down to 4.1% in 2022 and will range between 2.5% and 3.5% in and after 2023.

Figure 1-3 | Global GDP



The impacts of COVID-19 on the world economy will be short-lived. Most economies in the world will resume growth over the medium to long term. To this end, however, they will have to improve productivity, achieve technological innovation and implement appropriate fiscal and monetary policies and international cooperation.

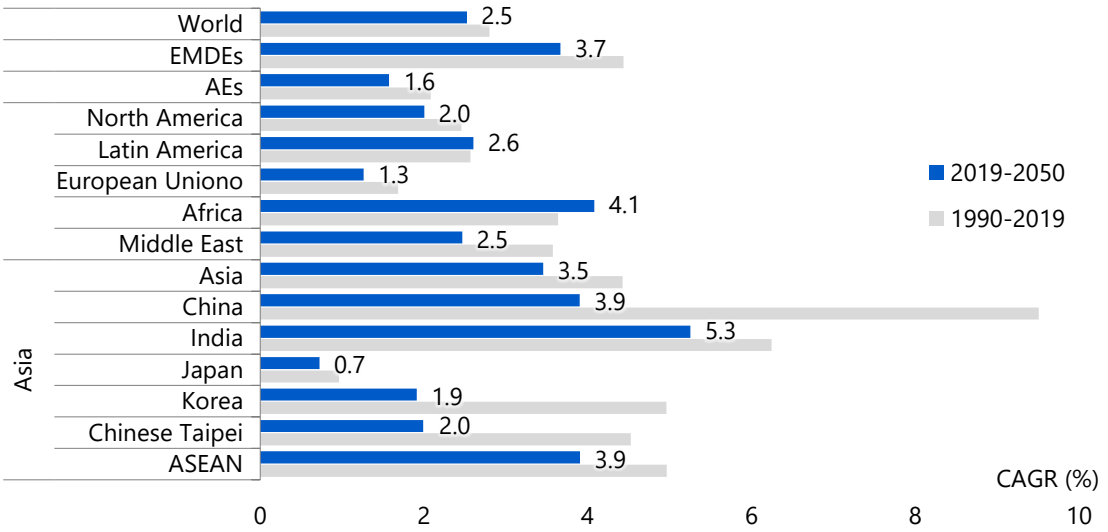
Advanced Economies will grow at the same pace as in the recent past while Emerging Market and Developing Economies in Asia and Africa will remain the driver of the global economic growth. India, though currently plagued with the negative effects of structural reform and

other policies that are slow to penetrate the economy, will grow at the world's fastest annual pace of 5.3% over the outlook period as these policies promote domestic demand expansion and foreign investment over the long term. China will grow at an annual pace of 3.9%, though with growth continuing to slow down. Africa will post an average annual growth rate of 4.1%, the highest growth among regions, with its economic size quintupling from the present level by 2050.

In this way, Emerging Market and Developing Economies are expected to remain the centre of the global economic growth. However, rising wages and citizens' growing consciousness of rights in some countries and growing interests in ethical consumerism seen mainly in Advanced Economies may force these countries to lose the portion of their economic growth that takes advantage of an abundant surplus labour and low costs.

In consideration of the above-explained situation, we assume the world's annual economic growth rate at 2.5% over the outlook period (Figure 1-4).

Figure 1-4 | Economic growth rates

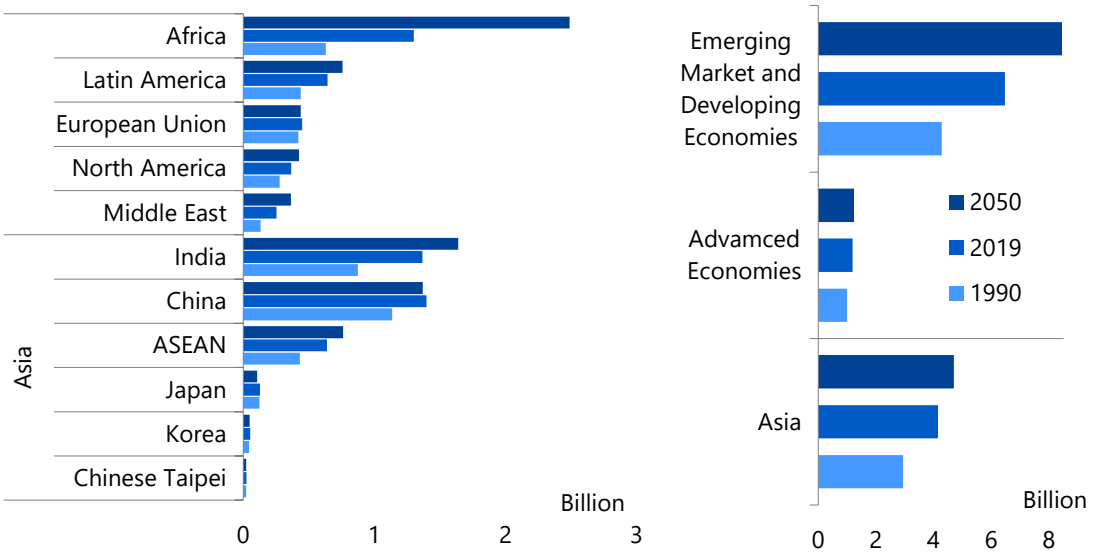


Note: AEs stands for Advanced Economies, and EMDEs for Emerging Market and Developing Economies.

Population

In assuming population changes, we referred to the United Nations' "World Population Prospects". In many Advanced Economies, the total fertility rate (TFR), or the average number of children that would be born to a woman during her lifetime, has slipped below two. Currently, the COVID-19 expansion and subsequent economic stagnation in the world are increasing the downward pressure on population. In Emerging Market and Developing Economies, the TFR is trending down also, in line with income growth and women's increasing social participation. However, their population will continue to increase as the mortality rate is declining due to developing medical technologies and improving food and sanitation conditions. Overall, global population will increase at an annual rate of around 0.8%, expanding to 9.7 billion in 2050 from 5.3 billion in 1990 and 7.7 billion in 2019 (Figure 1-5).

Figure 1-5 | Population



Among Advanced Economies, 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, population will decrease in Germany and Italy while increasing moderately in France and the United Kingdom. The total EU population will increase very moderately before turning downward. In Asia, Japan's population turned down in 2011 and will decrease by some 20% from the current level to 105 million in 2050. In Korea, population will peak out in the middle of the 2020s.

Emerging Market and Developing Economies will continue to increase their population substantially, driven by Africa and India. Africa will nearly double its population from the present level to 2.49 billion in 2050 as a drop in the mortality rate counters a gradual fall in the birth rate. Middle Eastern population will expand 1.5-fold due to governments' financial incentives for increasing population and a growing population influx from other regions. Population in Europe and Eurasia will continue to slightly increase through around 2030 and fall back to the present level in 2050 due to population drops in Russia and Eastern Europe. In Asia, India will maintain a high population growth rate, with its population surpassing the Chinese population soon. By 2050, India will have the world's largest population at 1.6 billion. China's population, currently the largest in the world, will peak at 1.43 billion around 2030 and decrease by about 60 million toward 2050. China is the only country with more than 100 million people aged 65 or more and will see further population aging. Population in the Association of Southeast Asian Nations (ASEAN) will increase by 130 million to 760 million by 2050.

International energy prices

Recent situation

While the world has yet to break away from the COVID-19 pandemic, the oil supply-demand balance has tightened since the second half of 2020 due to increased demand on economic recovery in many countries, the OPEC-plus group's production cut and the stagnation in U.S.

production. In the beginning of 2021, commercial crude oil inventories in the members of the Organisation for Economic Co-operation and Development fell back to the average for the past five years as surplus inventories arising from the COVID-19 pandemic disappeared. As a result, oil prices have restored 2019 levels. The oil supply-demand balance is likely to avoid any substantial easing despite potential U.S. monetary tightening, the potential destabilisation of the OPEC-plus production cut and the potential lifting of U.S. sanctions on Iran. Over the short term, oil prices are expected to remain firm.

Regarding natural gas prices, international interactions have accelerated in recent years.

The average liquefied natural gas (LNG) price for imports into Japan in the third quarter of 2020 declined below $6 per million British thermal units (MBtu) to the lowest level since January 2005 due to the rapid oil price drop from March 2020. In line with an oil price recovery, however, the average rose back above $7/MBtu in December. Responding to firming oil prices, it soared to around $9.5/MBtu in February 2021 before falling back to $7.5/MBtu in March. By July, the average price increased to above $9.5/MBtu.

Meanwhile, assessed Asian spot LNG prices continued a downtrend from January 2020 due to supply expansion and demand growth deceleration, hitting a record low of $1.83/MBtu in late April 2020. They remained above $2/MBtu from May 2020 and increased later due to supply disruptions from multiple production facilities. Prices rose above $10/MBtu in December and shot up to a record high above $30/MBtu due to a rapid demand increase under cold waves in January 2021. The spot LNG prices staged a rapid fall later, hitting a low below $6/MBtu toward late February. In March, prices picked up and by the third quarter of 2021 they were above $17/MBtu driven by the soaring European market. Their high levels and greater volatility have become a matter of concern.

European spot natural gas prices (including Dutch Title Transfer Facility and British National Balancing Point prices) hit record lows below $2/MBtu in the middle of 2020 and rose back in 2021. In the third quarter of 2021, they ranged between $14/MBtu to $16/MBtu. These high levels reflected sharp growth in 2021 European gas demand, a delay in gas charging for underground storage, maintenance work at Norwegian gas fields and concerns over Russian pipeline gas supply.

U.S. Henry Hub natural gas spot prices slipped below $2/MBtu in the first half of 2020 but rose back above $4/MBtu in the second quarter of 2021. Factors behind the price hike included an increase in U.S. LNG exports and a domestic gas consumption rise caused by economic recovery.

Due to the COVID-19 pandemic, international coal prices plunged until the summer of 2020. They increased afterwards and have remained very high since the beginning of 2021. The international coal market tightened because China, which managed to contain COVID-19 and revived its economic activities, increased coal imports while natural disasters and production equipment troubles were causing supply disruptions. As supply-side measures are expected to ease the supply-demand balance gradually, the coal market is becoming structurally unstable due to less flexibility in supply capacity, under the coal phaseout trend.

Reference Scenario

While initiatives for carbon neutrality are enhanced, oil demand in the Reference Scenario will continue to increase, driven by Asian non-OECD countries. Although the United States and other non-OPEC oil-producing countries will expand crude oil production, OECD countries will toughen their oil field development regulations and become more dependent on oil imports from OPEC and Russia. Oil prices will rise over the medium to long term. As many countries enhance decarbonisation initiatives to decelerate oil demand growth, however, oil price hikes will be limited. The real oil price (in 2020 dollars) is assumed to increase to $80/bbl in 2030 and $100/bbl in 2050 (Table 1-2). Under an assumed annual inflation rate of about 2%, the nominal price is projected to reach $98/bbl in 2030 and $181/bbl in 2050.

Table 1-2 | International energy prices

Real prices			Reference			Advanced Technologies		
		2020	2030	2040	2050	2030	2040	2050
Oil	$2020/bbl	41	80	95	100	65	60	50
Natural gas								
Japan	$2020/MBtu	7.8	7.6	7.6	7.5	7.0	6.3	5.1
Europe (U.K.)	$2020/MBtu	3.3	7.5	7.5	7.4	6.9	6.2	5.0
United States	$2020/MBtu	2.1	3.3	3.8	3.8	3.0	3.5	3.5
Steam coal	$2020/t	80	96	97	98	75	69	64

Nominal prices			Reference			Advanced Technologies		
		2020	2030	2040	2050	2030	2040	2050
Oil	$/bbl	41	98	141	181	79	89	91
Natural gas								
Japan	$/MBtu	7.8	9.3	11.3	13.6	8.5	9.4	9.3
Europe (U.K.)	$/MBtu	3.3	9.1	11.1	13.4	8.4	9.2	9.1
United States	$/MBtu	2.1	4.0	5.6	6.9	3.6	5.2	6.3
Steam coal	$/t	80	117	144	178	91	103	116

Note: The annual inflation rate is assumed at about 2%.

Natural gas prices in the United States will remain lower than in other regions, backed by abundant supply capacity. In line with relative development and production cost hikes and an increase in demand including exports, however, prices will rise from their record-lows in 2020. Japan's real natural gas import prices in 2021 are assumed to rise from the $7.8/MBtu in 2020, before turning down later and levelling off until 2050. LNG exports from the United States will increase and become regular, contributing to the diversification of LNG supply sources for Japan and the elimination or easing of the problem of the so-called destination clause for LNG imports. LNG prices are thus assumed to gradually deviate from oil prices. From 2020 to 2021, in fact, spot LNG prices expanded their gaps with long-term contract prices for Asia,

prompting some LNG buyers to review contract terms and conditions including those from suppliers other than the United States. LNG prices in Japan will still be higher than in the United States due to limitations on cost cuts, despite progress in the optimisation of LNG maritime transportation. However, they will become linked to European prices, narrowing bilateral gaps.

The FOB price of steam coal for shipments from New Castle Port in Australia peaked out due to an oversupply in the middle of 2018 and remained above $60 per tonne from the second half of 2019. As demand declined due to the impact of COVID-19, the price temporarily slipped below $50/t and approached the low posted in early 2016. As production is adjusting to weak demand and demand increasing due to some economic recovery in China, the world's largest coal consumer, coal prices will rise in the future. While demand for coal for power generation is expected to increase in other Asian countries as well, tougher environmental regulations are likely to make it difficult to expand coal production capacity. As the supply-demand balance tightens gradually, coal prices will moderately rise over the medium to long term while repeating fluctuations on seasonal factors and temporal collapse of the supply-demand equilibrium. Although prices per thermal unit for coal are lower than those for oil or natural gas, coal's economic advantage will decline amid a global downtrend of natural gas prices in Europe and other regions that introduce carbon prices.

Advanced Technologies Scenario

In the Advanced Technologies Scenario, fossil fuel demand will decline on energy efficiency improvement and fuel switching to nuclear and renewable energy. As a result, oil and natural gas price hikes will be slower than in the Reference Scenario. As natural gas demand growth is held down, with arbitrage between regions making further progress, interregional natural gas price gaps will narrow. Steam coal prices will decrease as Asian demand falls due to energy efficiency improvement in the manufacturing sector, the power generation sector's transition to more efficient coal-fired power plants and thermal efficiency improvement amid technological development in other coal-using sectors over the medium to long term.

2. Energy demand

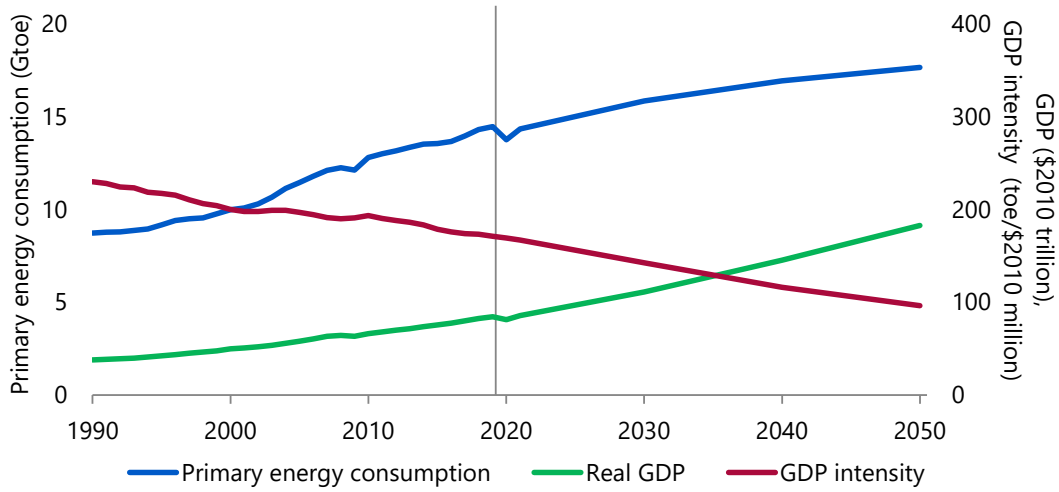
2.1 Primary energy consumption

India, MENA and ASEAN accounting for three quarters of global energy consumption

As floods, droughts, wildfires and other disasters have grown severer due to climate change, decarbonisation initiatives are globally accelerating to help ease such disasters. Since 2020, China, Japan, Korea and the United States have joined Europe in announcing their carbon neutrality policy of seeking net-zero CO_2 emissions. Numerous Emerging Market and Developing Economies have also declared seeking carbon neutrality. However, it would not be easy to reduce fossil fuel consumption, particularly in Emerging Market and Developing Economies that face the great challenge of meeting their long-term energy demand growth while procuring stably and at affordable prices massive amounts of energy, with lower CO_2 emission intensity.

While energy consumption intensity declines on energy efficiency improvement and energy conservation efforts in the world, including Emerging Market and Developing Economies, global primary energy consumption will keep on increasing (Figure 2-1). In 2050, primary energy consumption will increase 1.2-fold from the present level. Annual energy consumption growth will fall from 1.8% between 1990 and 2019 to 0.6% through 2050. Each country will have to further improve energy efficiency to cut consumption.

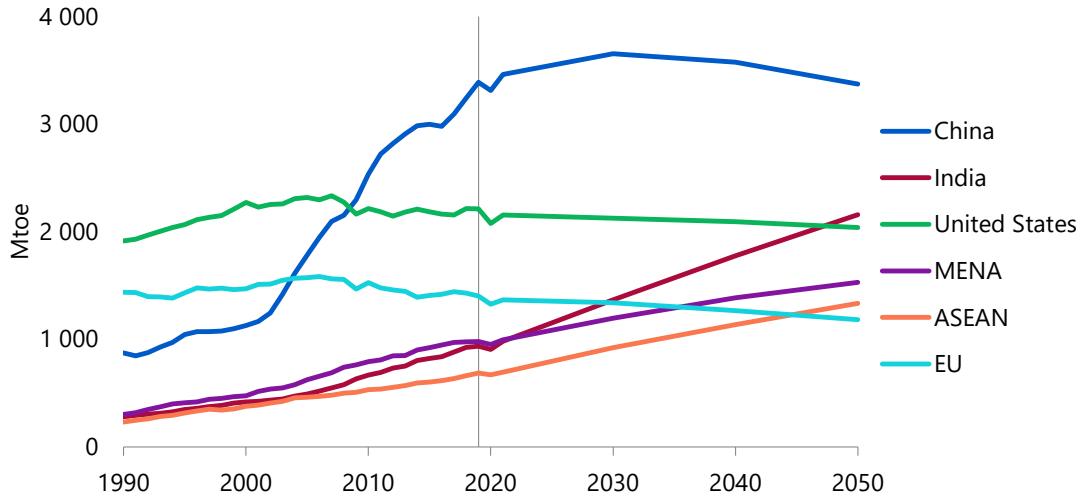
Figure 2-1 | Global primary energy consumption, real GDP, GDP energy intensity [Reference Scenario]



India, the Middle East and North Africa (MENA), and the Association of Southeast Asian Nations (ASEAN) will drive the global primary energy consumption growth (Figure 2-2). The three economies' share of global energy consumption will expand from 18% in 2019 to 28% in 2050 and will account for 76% of the growth in consumption between 2019 and 2050. Therefore,

global energy consumption trends will change depending mainly on the suppression of energy consumption in those three economies.

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



India, MENA and ASEAN, respectively, will boost energy consumption by 2.7%, 1.7% and 2.2% per year from 2019 to 2050 and account for 12%, 9% and 8% of global energy consumption in 2050. Their growth rates will be 2.1, 0.8 and 1.5 percentage points higher than the global average of 0.6%, because gross domestic product (GDP) will grow by 5.3%, 2.7% and 3.9% per year. Decoupling energy consumption from economic growth in India, MENA and ASEAN will become a global challenge.

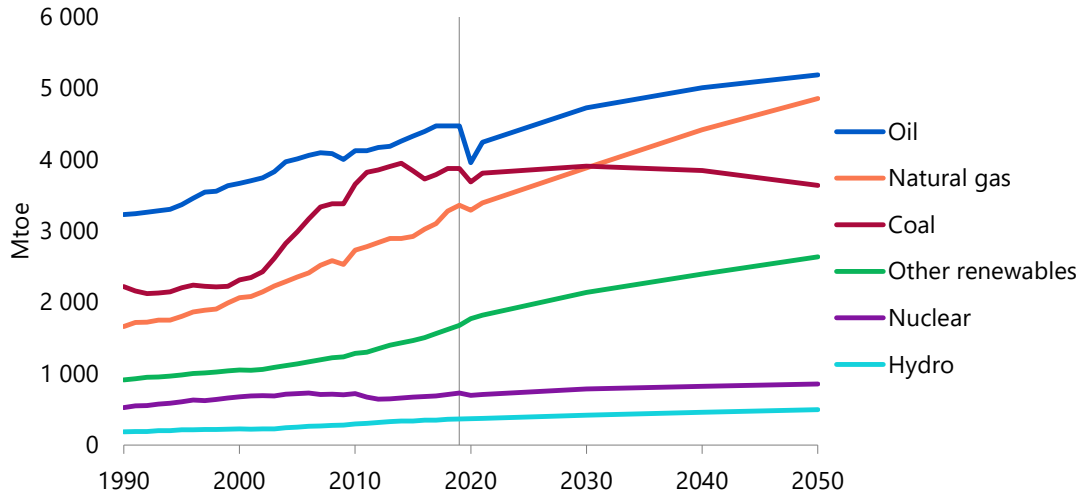
As a matter of course, it will be indispensable for energy-consuming Advanced Economies such as the United States, the European Union (EU) and Japan to continue their energy consumption reduction. The three Advanced Economies' share of global primary consumption in 2050 will be as high as 20% while their share of global GDP will be 36%. To suppress global energy consumption, the United States, Europe and Japan should accelerate their energy consumption reduction while playing a role in boosting the global economy stably through consumption and investment.

To further reduce global energy consumption, international cooperation between the Advanced Economies and the Emerging Market and Developing Economies and each economy's policies within the Emerging Market and Developing Economies will have to be enhanced. As the macroeconomic damage from the COVID-19 pandemic is particularly great in India and ASEAN, they may give priority to economic growth rather than energy consumption reduction during their recovery period. Advanced Economies such as Japan, the United States and Europe will have to provide energy-efficient technologies and support for India and ASEAN to realize economic growth while suppressing energy consumption.

Fossil fuel consumption will continue to grow at an annual rate of 0.5%

Despite global initiatives to pursue carbon neutrality, fossil fuel consumption will continue to grow at an annual rate of 0.5% in the future (Figure 2-3). Natural gas will score the highest consumption growth among fossil fuels and its consumption in 2050 will increase 1.4-fold from 2019, growing at an annual rate of 1.2% centring on power generation. Oil will post the second highest consumption growth, expanding at an annual rate of 0.5% mainly in the transport sector (including automobiles, aircraft and ships). Coal consumption will peak around 2030 due to restrictions against the backdrop of air pollution and climate change and will decline below current levels by 2050.

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



Non-fossil energy sources including nuclear and renewable energy will continue to increase their share of primary energy consumption. Nuclear, and hydro and other renewables (excluding solid biomass) will account for 38% of the primary energy consumption growth between 2019 and 2050 and boost their share from 19% in 1990 and 23% 2019.

Non-fossil energy sources will increase their presence through 2050 but face difficulties in fully meeting energy demand. Through 2050, it will be realistic for the world, including the Emerging Market and Developing Economies which are expanding energy consumption, to use both fossil fuel and non-fossil energy (Figure 2-4).

Dependence on fossil fuels will decrease from 81% in 2019 to 77% in 2050 in the world. (Figure 2-5). The dependence will fall from 82% in 2019 to 75% in 2050 for the United States, from 69% to 64% for the EU and from 88% to 73% for Japan. In contrast, the dependence in 2050 will remain high in the Emerging Market and Developing Economies that will boost fossil fuel consumption as their energy consumption rises. It will be as high as 81% in India, 93% in MENA and 76% in ASEAN.

Figure 2-4 | Primary energy consumption changes [Reference Scenario, 2019-2050]

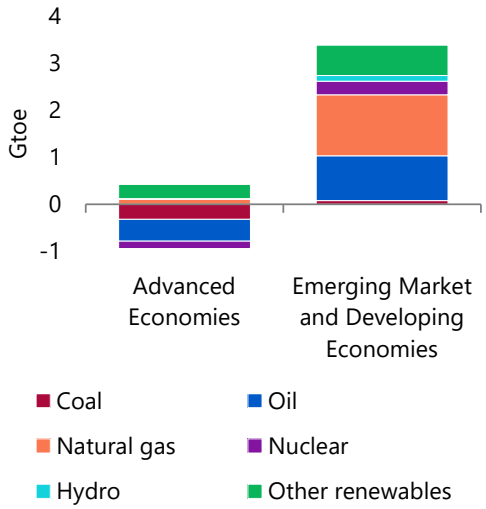
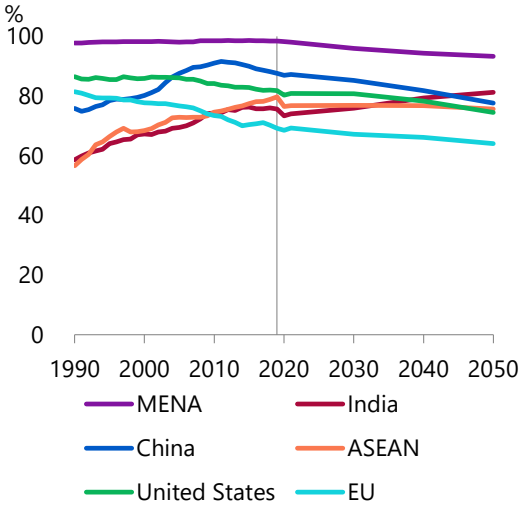


Figure 2-5 | Dependence on fossil fuels in selected countries/regions [Reference Scenario]



Energy consumption reduction and decarbonisation will not be easy in any sector

Among energy consumption sectors, transport and power generation will post the largest consumption growth rates (Figure 2-6). Supported by income growth, automobiles will account for most of the energy consumption increase in the transport sector. Energy consumption by aircraft and ships will also increase sharply. The power generation sector will boost its energy consumption as electricity is increasingly used for its convenience on the strength of income hikes and infrastructure development in unelectrified regions. The energy consumption expansion in the transport and power generation sectors is premised on economic recovery from the COVID-19 pandemic and the development of transport and power generation infrastructure in the Emerging Market and Developing Economies.

The electrification rate on the supply side will rise in almost all countries (Figure 2-7). Electrification will make progress not only in the Emerging Market and Developing Economies but also in the Advanced Economies backed by economic digitalisation. It will not be easy for non-fossil energy to fully cover the growing electricity demand.

Industry and buildings sectors will also boost energy consumption. India, MENA and ASEAN plan to expand their heavy chemicals and other energy-intensive secondary industries and wish to further develop tertiary industries, including call centres for the world. In these economies, a larger industry sector that may increase its energy demand, will lead to improving living standards that will in turn contribute to an energy demand growth in the buildings sector. It will be difficult for those economies to reduce energy consumption while ensuring economic growth.

Figure 2-6 | Contributions to global primary energy consumption growth [Reference Scenario, 2019-2050]

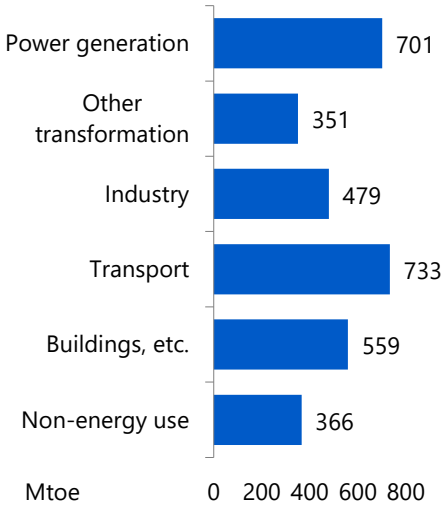
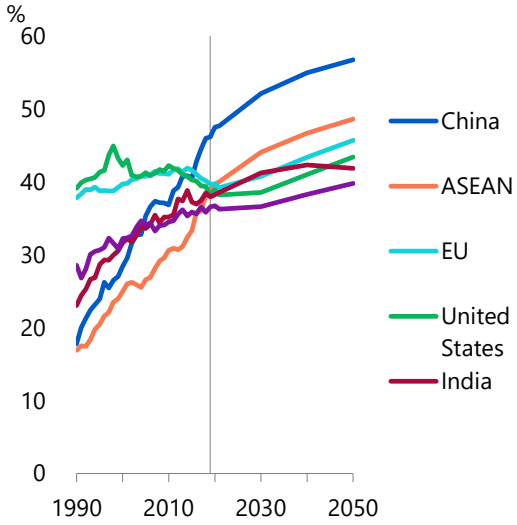


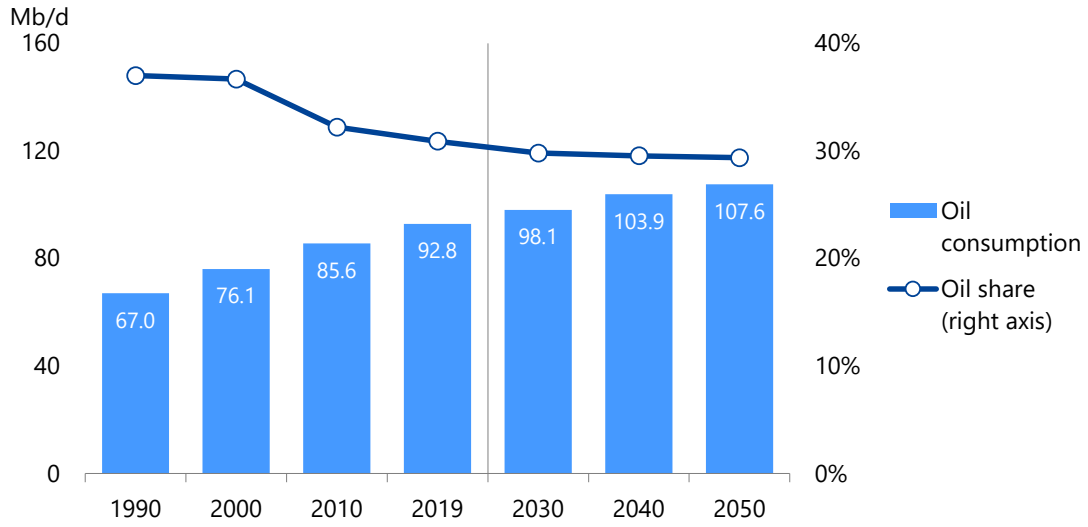
Figure 2-7 | Electrification rates on the supply side in selected countries/regions [Reference Scenario]



Drastic oil consumption reduction will also be difficult

Although oil consumption in 2020 declined by 12% from the previous year due to the COVID-19 pandemic, it will rise again. After standing at 92.8 million barrels per day (Mb/d) in 2019, oil consumption will slowly increase reaching 107.6 Mb/d in 2050 (Figure 2-8). Despite a slight drop in its share of primary energy consumption from 31% in 2019 to 29% in 2050, oil will remain the most consumed energy source in the world in 2050, in the Reference Scenario.

Figure 2-8 | Global oil consumption and its share of primary energy consumption [Reference Scenario]



In the Advanced Economies, however, oil consumption has already peaked (Figure 2-9). After falling at an annual rate of 1.0% from the peak in 2004 to 2019, their oil consumption will continue to decrease by 9.6 Mb/d, or at an annual rate of 0.9%, from 2019 to 2050. A major factor behind the oil consumption decline in the Advanced Economies is a fall in automobile fuel consumption due to fuel efficiency improvements for conventional vehicles and the diffusion of electric vehicles including hybrid cars.

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

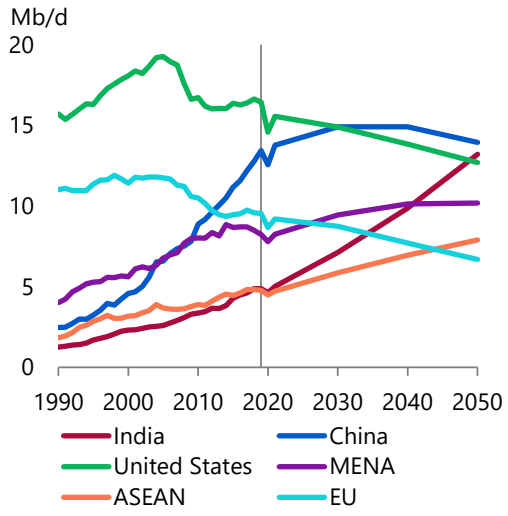
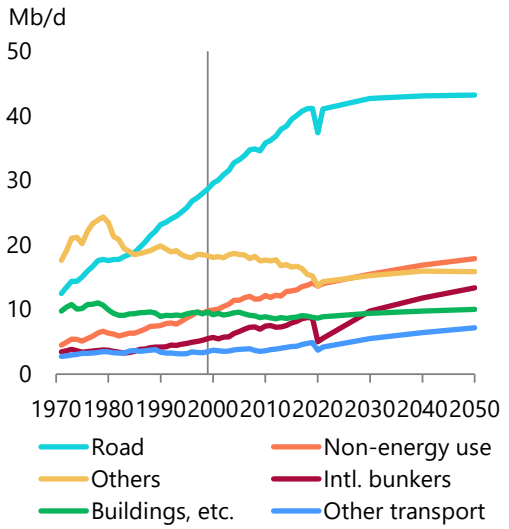


Figure 2-10 | Global oil consumption [Reference Scenario]



In contrast, oil consumption in India, MENA and ASEAN will increase rapidly after decreasing in 2020 by 5.4% from the previous year due to the COVID-19 pandemic. Oil consumption will rise by 13.4 Mb/d, or at an annual rate of 1.8%, from 2019 to 2050. The oil consumption will grow mainly in the transport, non-energy use and buildings sectors, representing 91% of the global oil consumption increase.

In the transport sector of India, MENA and ASEAN, oil consumption for automobiles will increase sharply from 8.0 Mb/d in 2019 to 15.0 Mb/d in 2050. The increase of 7.0 Mb/d is tree times larger than the global oil consumption growth of about 2 Mb/d in the transport sector, meaning that the other economies in the world will substantially reduce their transport sector oil consumption. In the three economies, vehicle ownership will soar 4.2-fold from the present level, thanks to income growth and improvements in transport infrastructure such as roads and bridges. To suppress oil consumption they may have to actively promote a transition to electric vehicles. In the Emerging Market and Developing Economies, the initial electric vehicle costs may be still be considered as high even in 2050, with sales limited to high-income earners.

The non-energy use sector in India, MENA and ASEAN will increase oil consumption mainly for the petrochemical industry by 2.6 Mb/d from 2019 to 2050, accounting for 67% of global oil consumption growth in that sector. While global demand for plastics and other petrochemical products is strong, oil-producing countries hope to foster their petrochemical industries as part of their industrial diversification. Therefore, both the supply and demand sides will drive oil

consumption in the three economies' non-energy use sector. To suppress consumption in the sector, regulations on plastic consumption will need to be toughened.

In the buildings sector in India, MENA and ASEAN, oil consumption will increase by 1.7 Mb/d from 2019 to 2050 mainly for water heating and cooking, accounting for 134% of global consumption growth. This means that the buildings sector oil consumption in the other economies is decreasing. In line with income growth, consumers will switch from coal and solid biomass to oil that is relatively cleaner from a health impact perspective.

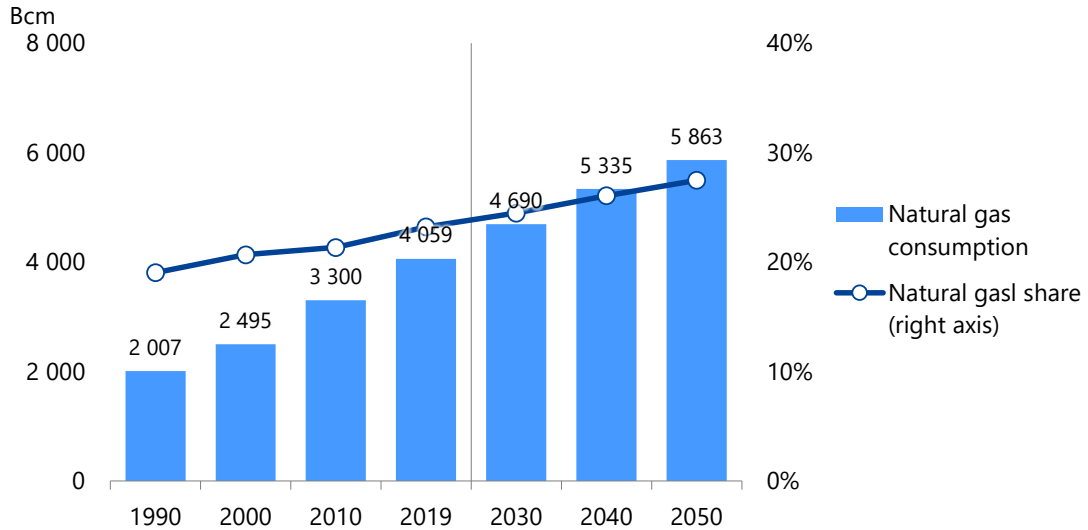
In Sub-Saharan countries other than South Africa, the buildings sector oil consumption will post an increase of 0.4 Mb/d from 2019 to 2050. In those countries, the initial investment of switching and operating on electricity or city gas for water heating and cooking is costly, leading consumers to choose liquefied petroleum gas for that purpose.

China's annual oil consumption will peak at 15.0 Mb/d around 2035 and fall to 13.9 Mb/d in 2050. The transport sector suppresses oil consumption due to a saturation of vehicle ownership, the improvement of vehicle fuel efficiency and the diffusion of electric vehicles. The buildings sector reduces oil consumption due to electrification and city gas service diffusion. To drastically cut global oil consumption, it will also be necessary to accelerate the pace of reduction in oil consumption in China.

How to suppress growing natural gas consumption

Like oil, natural gas posted a consumption decline of 2.1% between 2019 and 2020 due to COVID-19. It will score the largest consumption growth among energy sources through 2050 with an annual increase of 1.4% from 4 059 billion cubic metres (Bcm) in 2019 to 5 863 Bcm in 2050 (Figure 2-11). Natural gas will widen its share of primary energy consumption from 23% in 2019 to 27% in 2050, becoming the second most consumed energy source after oil. How to hold down the growth in natural gas demand is one of the major challenges facing the world.

Figure 2-11 | Global natural gas consumption and natural gas's share of primary energy consumption [Reference Scenario]



India, MENA and ASEAN will account for 47% of the growth totalling 1 804 Bcm between 2019 and 2050, China will account for 14% and the United States for 4% (Figure 2-12). Natural gas consumption in 2050 will reach 270 Bcm in India, 1 101 Bcm in MENA and 371 Bcm in ASEAN. The Middle East will promote domestic natural gas consumption to earn foreign currencies with cost-competitive oil exports. India and ASEAN will boost natural gas consumption mainly for power generation. In China, natural gas consumption mainly for the power generation sector will increase by 260 Bcm by 2050. The United States will expand natural gas consumption by 90 Bcm by around 2040 as shale gas production continues. As EU members shy away from consuming natural gas being one of the fossil fuels, natural gas consumption will decline by 34 Bcm from the current level by 2050.

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

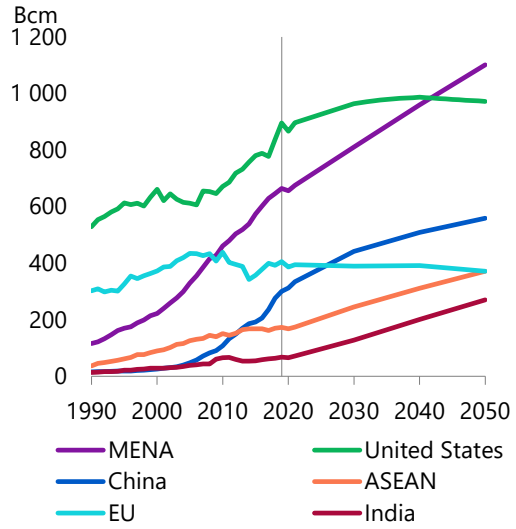
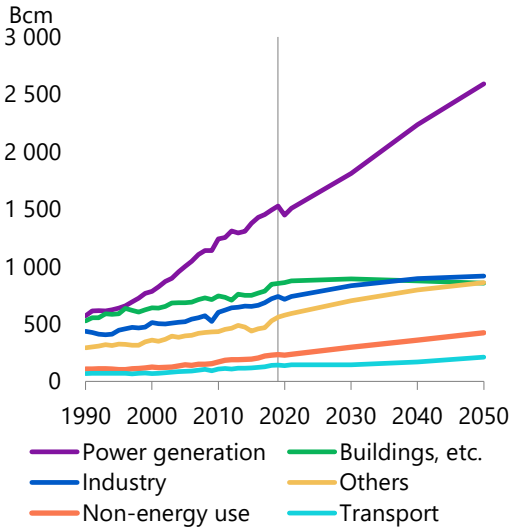


Figure 2-13 | Global natural gas consumption [Reference Scenario]



The power generation and industry sectors will be mainly responsible for the growth in natural gas consumption in the Emerging Market and Developing Economies, including China (Figure 2-13). Natural gas consumption in that sector will increase at an annual rate of 2.2% through 2050, accounting for 79% of the global natural gas consumption growth in the sector. This is attributable to higher costs for oil-fired power generation, environmental issues for coal, difficulties in large-scale power generation and higher grid integration costs for renewable energy.

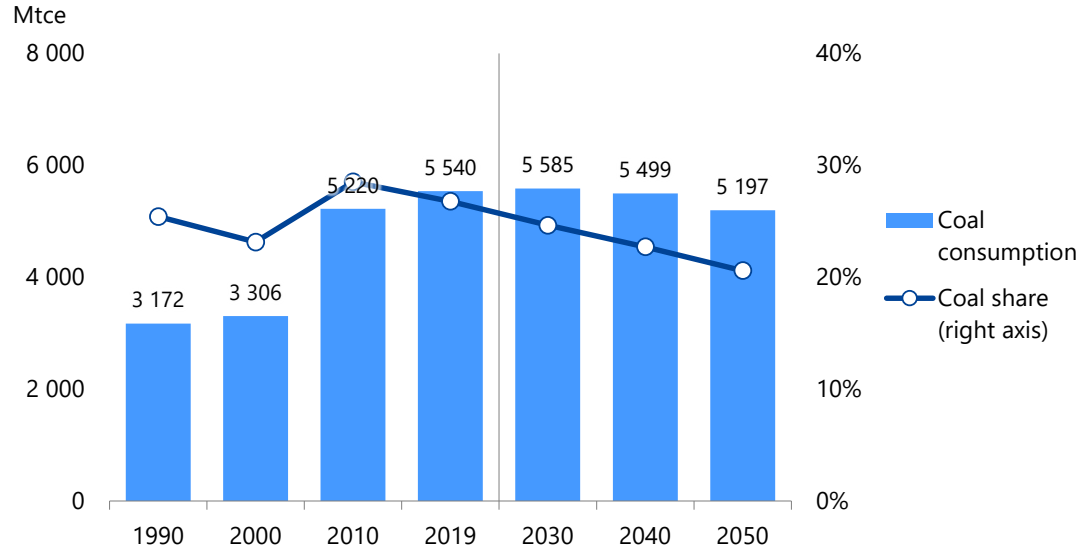
The industry sector's natural gas consumption in the Emerging Market and Developing Economies will grow at an annual rate of 1.2%, amounting to 108% of the global growth. This means that natural gas consumption in the Advanced Economies will decrease. In view of convenience and environmental considerations, the sector will switch from oil and coal to natural gas in the Emerging Market and Developing Economies. Growth in the buildings sector will mostly come from China as it rapidly switches to city gas from solid fuels such as coal and fuel wood that cause air pollution and is damaging for health.

As India, MENA, ASEAN and China drive the growth in natural gas consumption, they should introduce and widely diffuse highly efficient equipment through such measures as the power generation sector's adoption of natural gas combined cycle plants to hold down consumption. Another measure to suppress growth in natural gas consumption will be the technological and market development for the Emerging Market and Developing Economies to supply, at affordable prices, hydrogen and ammonia, which emit no CO_2, as a substitute for natural gas.

Coal consumption will peak out at last around 2030 before falling at a slow annual rate of 0.4%

Coal consumption, which stood at 5 540 million tonnes of coal equivalent (Mtce) in 2019, will peak at 5 585 Mtce around 2030 and decrease at an annual rate of 0.4% later (Figure 2-14). Coal will reduce its share of primary energy consumption from 27% in 2019 to 21% in 2050, being replaced by natural gas as the second most consumed energy source after oil.

Figure 2-14 | Global coal consumption and its share of primary energy consumption [Reference Scenario]



At present, China accounts for 53% of global coal consumption, Europe, the United States and Japan for 15%, and India and ASEAN for 15%. China and the three Advanced Economies will reduce their respective coal consumption shares, while India and ASEAN boost theirs (Figure 2-15).

While coal consumption for power generation increases through 2030 in China, industrial coal consumption will plunge 57% by 2050, with steel and cement production peaking soon. China's coal consumption will thus peak in the first half of the 2020s. Coal consumption in Europe, the United States and Japan will continue falling both for power generation and industrial production, posting a 47% drop in 2050. In contrast to MENA's coal consumption that will be limited, India and ASEAN will expand consumption 2.0-fold and 1.9-fold for power generation and 2.2-fold and 1.6-fold for industrial production.

Figure 2-15 | Coal consumption in selected countries/regions [Reference Scenario]

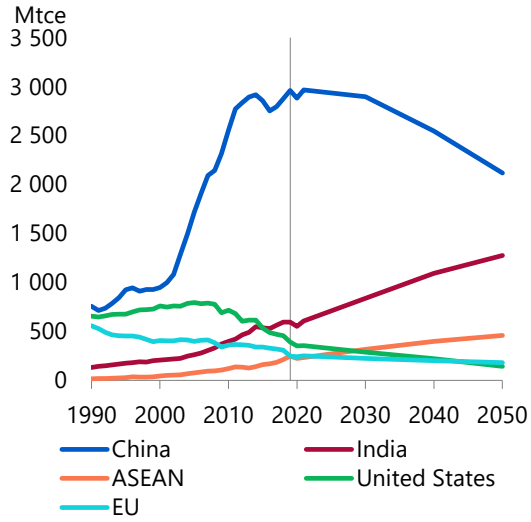
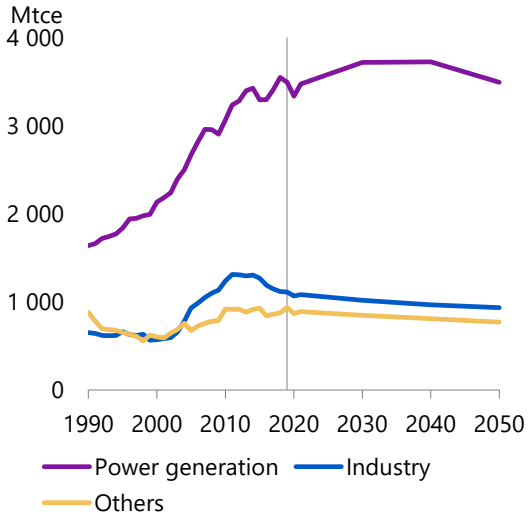


Figure 2-16 | Global coal consumption [Reference Scenario]



Because of the need to address climate change, coal consumption has increasingly come under fire globally. By toughening the regulations on all coal consumption, Europe increased the economic burdens on coal-fired power plants and further restricted CO_2 and mercury emissions. Meanwhile, Asian Emerging Market and Developing Economies, such as China, India and ASEAN, still view coal as an affordable domestic energy source from the viewpoint of energy self-sufficiency and do not necessarily impose severe restrictions on coal consumption. While governments and financial institutions in the Advanced Economies promote coal divestment, financial institutions in China and India do not necessarily support such divestment. To hold down coal consumption, Europe, the United States and Japan should further promote consumption suppression and China, India and ASEAN should switch from coal to other fuels for their power generation and industrial production.

Solar photovoltaic and wind's share of primary energy consumption will be limited

While many countries pursue carbon neutrality and place growing hopes on the expansion of non-fossil energy use, such energy sources' share of primary energy consumption is projected to rise slightly from 19% in 2019 to 23% in 2050. Non-fossil energy consumption for power generation will increase 1.9-fold from 1 557 million tonnes of oil equivalent (Mtoe) at present to 2 917 Mtoe in 2050 (Figure 2-17). Consumption of solar, wind, etc. will post the highest growth among non-fossil energy sources, increasing 4.2-fold from 2019 to 2050, compared to the 300-fold from 0.6 Mtoe in 1990 to 2019. Nuclear and hydro consumption will be subjected to a slow growth due to nuclear policy reform, and overall environmental and social considerations. Their share of non-fossil energy consumption for power generation fall from 58% in 2019 to 46% in 2050.

Figure 2-17 | Non-fossil energy consumption for power generation [Reference Scenario]

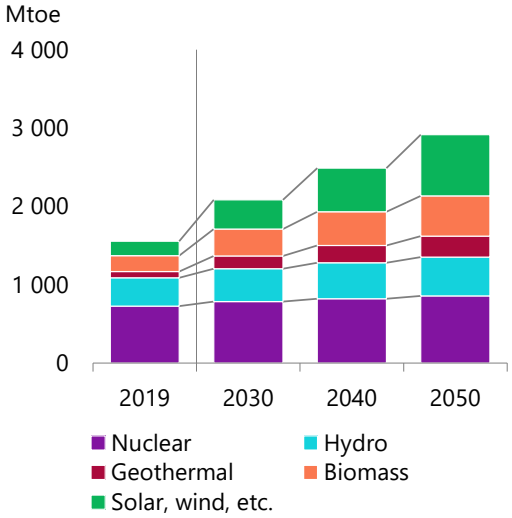
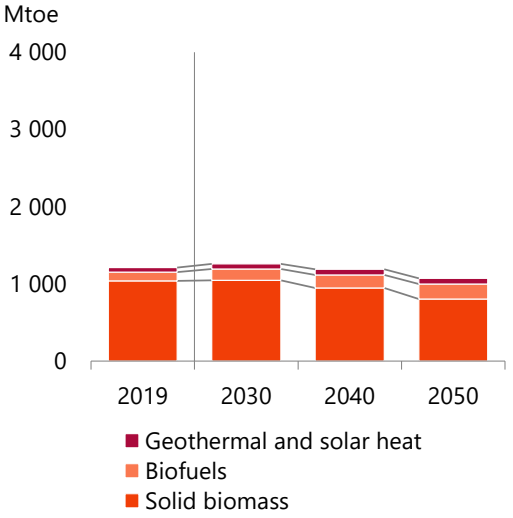


Figure 2-18 | Non-fossil energy consumption for heating [Reference Scenario]



In contrast to power generation, non-fossil energy consumption for heating will turn down during the second half of the 2020s from 1 211 Mtoe at present to 1 073 Mtoe in 2050 (Figure 2-18). About 80% of the non-fossil energy consumption for heating is traditional solid biomass, such as fuel wood and manure, and is used in rural regions of the Emerging Market and Developing Economies. Its consumption will decline as rural residents switch from to modern energy sources in line with their income and living standard improvements. Liquid biofuel for automobiles and buildings and biogas consumption will increase 1.7-fold through 2050, accounting for only 18% of the total non-fossil energy consumption for heating.

Non-fossil energy consumption, though increasing dramatically, will see its share of primary energy consumption limited even in 2050 because of a large growth in overall primary energy consumption. Solar photovoltaic, wind and others are expected to expand in response to substantial cost reductions but will capture only 19% of the global primary energy consumption growth by 2050.

The centre of Asian energy consumption will shift from China to India and ASEAN

Asia will account for 62% of the global energy consumption growth (Figure 2-19) as its share of the global economy increases from 32% in 2020 to 42% in 2050 in real terms. China, India and ASEAN, in particular, will drive the global economy and the energy consumption growth. These economies have similarities and differences.

Figure 2-19 | Asian primary energy consumption [Reference Scenario]

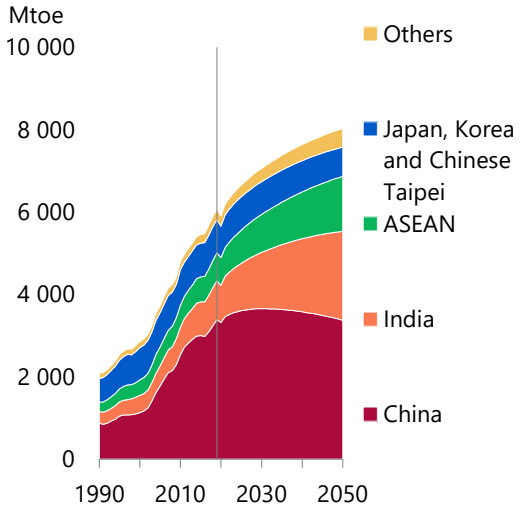
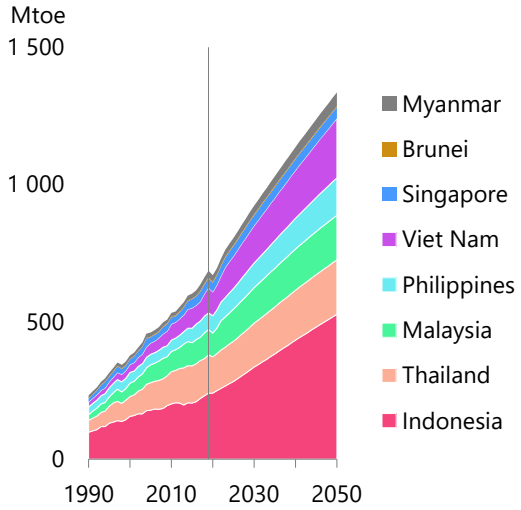


Figure 2-20 | ASEAN primary energy consumption [Reference Scenario]



Let's discuss similarities first. Through 2050, GDP will grow 3.3-fold in China, 4.9-fold in India and 3.3-fold in ASEAN. As a result of those high growth rates, the three economies' share of Asian GDP will rise from 66% in 2020 to 81% in 2050. In line with the economic growth, their share of Asian energy consumption will increase from 83% in 2019 to 86% in 2050. While Advanced Economies such as Japan and Korea see their share of the Asian economy or energy consumption falling, China, India, and ASEAN, which are Emerging Market and Developing Economies, will increase their influence on Asia's economy and energy consumption.

Asian Emerging Market and Developing Economies also have differences. Like Advanced Economies, China reduces energy consumption while growing its economy around 2030. On the other hand, India and ASEAN will continue to expand energy consumption in line with their economic growth (Figure 2-20). After boosting energy consumption at a high annual rate of 4.8% between 1990 and 2019, China will decelerate its annual growth rate to 0.7% between 2019 and 2030 before cutting back on energy consumption. India, after expanding energy consumption at an annual rate of 4.3% between 1990 and 2019, will continue to increase energy consumption at a lower annual rate of 2.7% between 2019 and 2050. ASEAN raised energy consumption at an annual rate of 3.8% between 1990 and 2019, and will expand energy consumption at an annual rate of 2.2% between 2019 and 2050. Factors behind the three economies' differences include changes in their respective levels of economic as well as population growth.

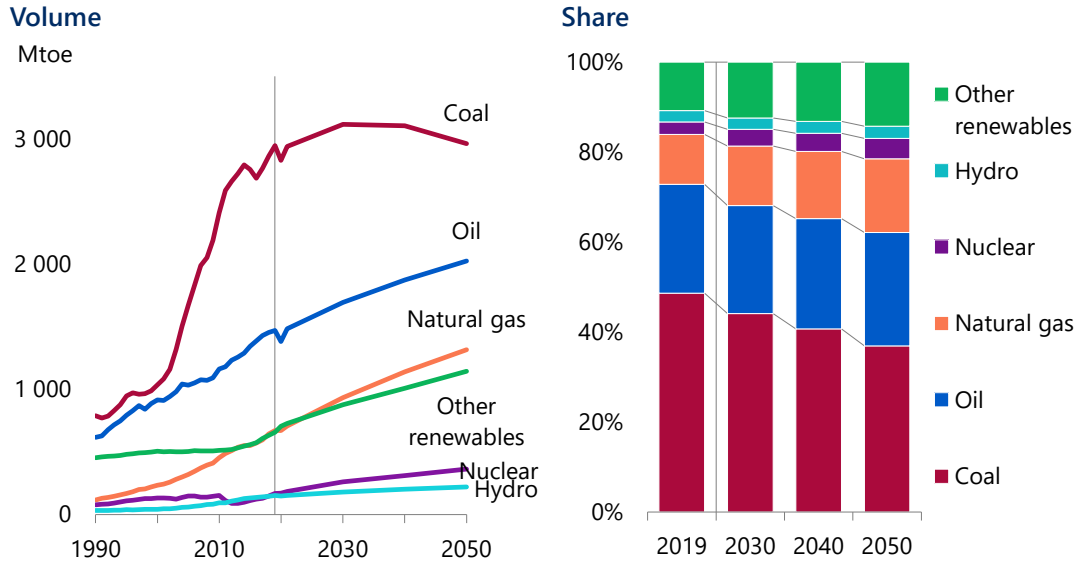
China's share of Asian energy consumption rose from 42% in 1990 to 56% in 2019 and will fall back to 42% in 2050. Its economic size grew 13.9-fold from $800 billion in 1990 to $11.5 trillion in 2019 and will expand 3.3-fold from 2019 to $37.7 trillion in 2050. China's population increased from 1.14 billion in 1990 to 1.4 billion in 2019. It will peak around 2030 before slipping below the current level to 1.37 billion in 2050. As the Chinese population decreases while the economy grows, the GDP per capita will exceed $27 000 in real terms. China is therefore starting its transition to a mature society, conscious of carbon neutrality.

India's share of Asian energy consumption will expand from 13% in 1990 and 15% in 2019 to 27% in 2050. Its economic size grew 5.8-fold from $500 billion in 1990 to $2.9 trillion in 2019 and will increase 4.9-fold from 2019 to $14.3 trillion in 2050. Its population rose from 870 million in 1990 to 1.37 billion in 2019 and will surpass the Chinese population around 2023 before reaching 1.64 billion in 2050. As such, the real GDP per capita will rise from $600 in 1990 to $9 000 in 2050, improving income and living standards. Its energy consumption will keep on increasing.

ASEAN's share of Asian energy consumption will widen from 11% in 1990 and 2019 to 17% in 2050. ASEAN's economic size will increase rapidly from $750 billion in 1990 or $3 trillion in 2019 to $10 trillion in 2050. ASEAN population will grow from 430 million in 1990 to 760 million in 2050. Real GDP per capita rose from $1 700 in 1990 to $4 800 in 2019 and will reach $13 000 in 2050. The increase in income per capita will improve the living standards, leading ASEAN energy consumption to increase constantly.

Let's consider the potential of carbon neutrality in Asia while understanding the similarities and differences and the background. In 2050 when energy consumption in India and ASEAN will still be rising, Asian energy consumption continues to depend on fossil fuels for 79% of its needs, slightly less than the 84% in 2019 (Figure 2-21). As oil and natural gas consumption continues to increase, the Asian fossil fuel share will be 2 percentage points higher than the global fossil fuel share. How to reduce the Asian fossil fuel consumption will be critical to achieve global carbon neutrality and climate change goals.

Figure 2-21 | Asian primary energy consumption [Reference Scenario]



The Asian oil consumption growth will decelerate from 3.0% per year between 1990 and 2019 to 1.0% between 2019 and 2050 (Figure 2-22). The transport sector will account for 61% of the growth through 2050, the non-energy use sector for 21% and the buildings sector for 9%. India will account for 72% of the growth, ASEAN for 27% and China for 4%. The sum of Indian, ASEAN and Chinese shares surpasses 100% because Japan and Korea are cutting consumption.

To suppress oil consumption, the transport sector in India, ASEAN and China should promote fuel efficiency improvements including electrification. As the Asian oil consumption growth captures 78% of the global growth, their oil consumption trends will exert influence on the entire world.

Meanwhile, Asia's oil self-sufficiency rate will decline from 24% in 2019 to 14% in 2050. To secure stable oil supply and address environmental problems, switching from oil to other energy sources and increasing thoroughly their oil consumption efficiency will be essential to the policies of Asian countries.

The growth in Asia's natural gas consumption stood at 6.2% per year between 1990 and 2019 and will decelerate to 2.2% between 2019 and 2050 (Figure 2-23). Of the 2019-2050 growth, the power generation sector will account for 55%, the industry sector for 13% and the non-energy use sector for 13%. China will account for 33% of the growth, India for 26% and ASEAN for 26%. To hold down natural gas consumption, China, India and ASEAN will have to raise power generation efficiency, reduce electricity transmission and distribution losses as well as improving insulation and other efficiencies in the buildings sector. As the Asian natural gas consumption growth captures 43% of the global growth, the three economies' consumption suppression would contribute directly to a global reduction.

Figure 2-22 | Asian oil consumption [Reference Scenario]

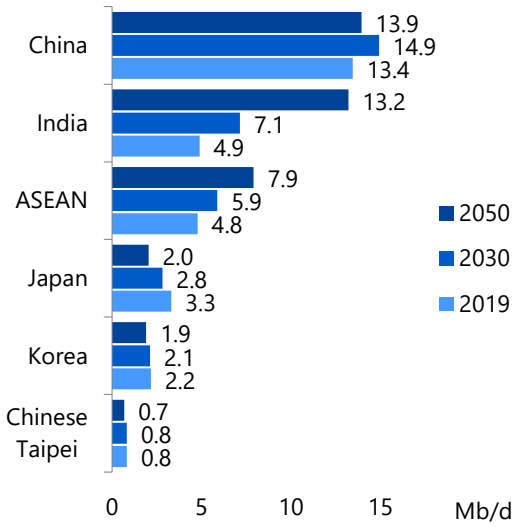
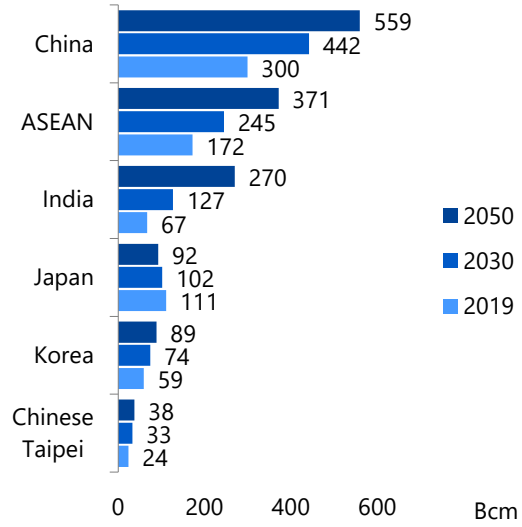


Figure 2-23 | Asian natural gas consumption [Reference Scenario]



Meanwhile, Asia's natural gas self-sufficiency rate will fall from 60% in 2019 to 54% in 2050 due primarily to a decline in local production. Although natural gas is environmentally friendlier than oil or coal, it is still a fossil fuel that emits CO_2 when burning. It is important for the Emerging Market and Developing Economies to promote highly efficient natural gas consumption through such measures as engineers' acquisition of natural gas equipment operation and maintenance check skills and the requirement for the power generation sector to adopt natural gas combined cycle plants.

Liquefied natural gas (LNG) imports will help cover Asian natural gas supply shortages. The Asian LNG consumption will more than double from 254 million tonnes in 2020 to 540 Mt in 2050. The share of Asian LNG consumption will fall from 52% in 2020 to 29% in 2050 for Japan, Korea, and Chinese Taipei, while rising from 43% to 62% for China, India and ASEAN. LNG consumption in India, ASEAN and China will play a greater role.

In contrast to the Asian oil or natural gas consumption, local coal consumption will peak out in the middle of the 2030s. Coal's annual growth in Asia will decelerate from 4.7% between 1990 and 2019 to 0.3% between 2019 and 2035 before declining at an annual rate of 0.3% through 2050. Although coal-fired power plants have come under fire due to considerations given to climate change and air pollution, coal consumption in Asia will increase for power generation but will decline for industry and buildings and will remain the largest energy source in Asia. Asian countries should promote the efficient use of their abundant coal resources, while avoiding the construction of inefficient coal-fired power plants to mitigate the environmental impact through. Asian countries should introduce such measures as carbon capture, utilisation and storage (CCUS) involving Advanced Economies.

Asian non-fossil energy consumption, though being less than oil or natural gas consumption in volume, will increase at a high annual rate of 1.9%. Renewables other than traditional biomass will capture 68% of Asian non-fossil energy consumption growth between 2019 and 2050, followed by 26% for nuclear. Traditional biomass will account for 6% of the growth. China will account for 40% of renewable energy consumption growth excluding traditional biomass, ASEAN for 28% and India for 19%. China will capture 60% of the nuclear consumption growth, followed by 27% for India. Asia's share of global non-fossil energy consumption will rise from the present level by 11 percentage points to 62% in 2050.

China in September 2020 declared the pursuit of carbon neutrality by 2060, setting its direction of holding down oil and coal consumption and promoting natural gas and non-fossil energy consumption toward 2050. Given China's huge fossil fuel consumption, however, it will have to further enhance energy efficiency and decarbonisation policies. It will be necessary for India and ASEAN, which will command most of the energy consumption growth, to take steps to accelerate energy conservation and decarbonisation, including continuing and improving technical and financial support from Japan, the Republic of Korea, China, and other countries. The whole of Asia will thus have to promote energy efficiency improvement and decarbonisation initiatives contributing not only to Asia but also to the entire world.

2.2 Final energy consumption

Global final energy consumption in 2050 will increase 1.2-fold from 2019

In the Reference Scenario, global final energy consumption will increase 1.2-fold from 9 983 Mtoe in 2019 to 12 120 Mtoe in 2050. The increase represents an average annual growth of 0.6%. The change in global final consumption between 2019 and 2050 presents two features.

First, India, ASEAN and MENA will play a central role in boosting global final energy consumption through 2050. Therefore, any event that greatly affects final energy consumption in the three economies will exert influence on global final energy consumption trends. Particular attention may have to be paid to the fluctuating factors, such as the economic growth,

the details and strengths of their energy-related policies, the technological development regarding energy use equipment and its diffusion.

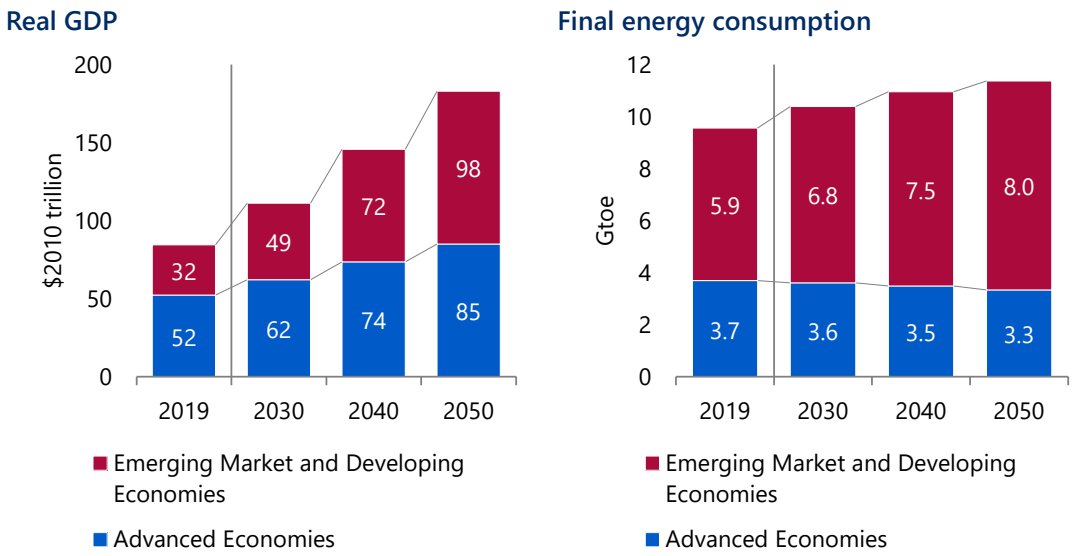
Second, final consumption demand will still be comprised of all major energy sources even in 2050 with coal and renewable energy following a downtrend but fall short of reaching zero even in 2050. Climate change is a significant global issue, but if policy guidance and investment targets are extremely biased toward specific energy sources, the energy supply-demand balance may be lost over the medium to long term. Therefore, it will be important to develop a market that will sufficiently supply each energy source, while considering demand trends and their impacts on climate change.

The following provides insights on final energy consumption changes in the Reference Scenario by economy, region, sector and energy source between 2019 and 2050:

By economy: The Emerging Market and Developing Economies will drive global consumption growth

While the Advanced Economies reduce final energy consumption, robust growth in consumption in the Emerging Market and Developing Economies will more than offset the decline (Figure 2-24). Therefore, from 2019 to 2050, the global final energy consumption will follow an uptrend through 2050.

Figure 2-24 | Real GDP and final energy consumption [Reference Scenario]



In the Emerging Market and Developing Economies, final energy consumption in 2050 will increase 1.4-fold (at an annual rate of 1.0%) from 2019 to 8 039 Mtoe. Although COVID-19 suppressed some economic growth, the Emerging Market and Developing Economies will follow an uptrend over the medium to long term. As progress in energy efficiency improvement is coupled with an expanding services sector, the increase between 2019 and 2050 in final energy consumption growth in those Economies will be slower than the real annual GDP growth of 3.7%.

In the Advanced Economies, final energy consumption in 2050 will decrease by 10% or 0.3% per year from 2019 to 3 334 Mtoe while their real GDP will grow at an annual rate of 1.6% during the same period. Despite economic growth, final energy consumption in the Advanced Economies has been on a downtrend since the second half of the 2000s due to progress in energy efficiency improvement and the services sector's expansion. As a result, the energy-GDP elasticity[3] in the Advanced Economies will change from 0.31 between 1990 and 2019 to -0.21 between 2019 and 2050.

Energy efficiency improvement is one of the key decarbonisation measures that have been attracting global attention. In both the Advanced Economies and the Emerging Market and Developing Economies, the final energy consumption sector will be required to promote energy efficiency improvement initiatives.

By region: India, ASEAN and MENA will drive final energy consumption growth

From 2019 through 2050, India, ASEAN and MENA will strongly drive the growth in global final energy consumption and will account for a dominant share above 70% of the global growth (Figure 2-25).

As a result of the strong demand growth in India and ASEAN, Asia's share of global final energy consumption will widen from 39.3% in 2019 to 43.1% in 2050. In the future, Asia will become an even more significant energy consumption centre.

In addition to India, ASEAN and MENA as final energy consumption growth drivers, the following examines final energy consumption changes in China, the largest energy consumer in the world (Figure 2-26):

Figure 2-25 | Final energy consumption growth in selected countries/regions [Reference Scenario, 2019-2050]

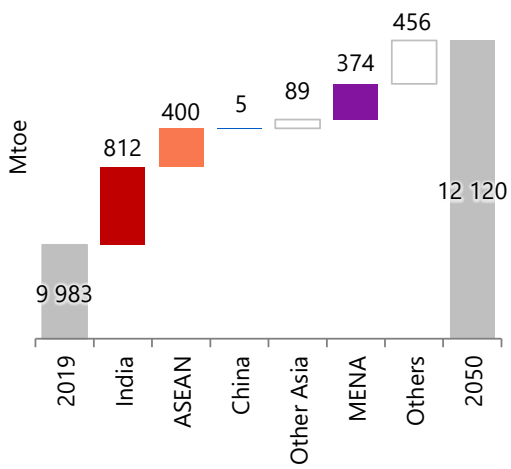
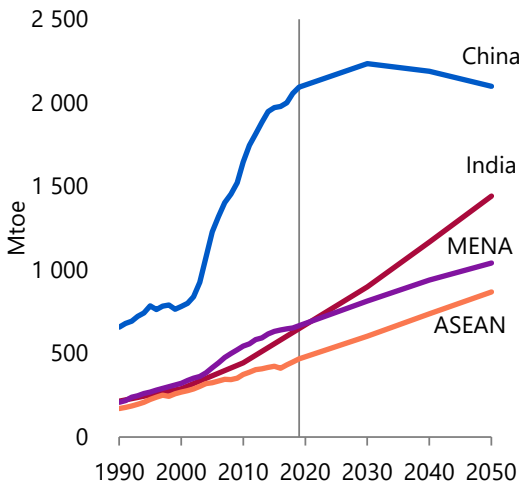


Figure 2-26 | Final energy consumption in China, India, MENA and ASEAN [Reference Scenario]



[3] Final energy consumption-GDP elasticity = final energy consumption growth ÷ real GDP growth

India's population will surpass China's in the first half of the 2020s and top 1.6 billion in 2050. Its GDP will grow at an annual rate of 5.3% between 2019 and 2050, with GDP per capita increasing 4.1-fold, reflecting the progress of urbanisation. Backed by population and GDP growth, India's final energy consumption in 2050 will increase 2.3-fold (at an annual rate of 2.7%) from 630 Mtoe in 2019 to 1 442 Mtoe. India alone will account for 60% of the Asian final energy consumption growth and its share of global final energy consumption will expand from 6.3% in 2019 to 11.9% in 2050. India will become even more important when we consider global energy supply and demand.

Final energy consumption in ASEAN will rise at a rate of 2.0% per year from 467 Mtoe in 2019 to 867 Mtoe in 2050, supported by growth in Indonesia and Viet Nam. Of the 400 Mtoe in final energy consumption growth in ASEAN, Indonesia will account for 150 Mtoe and Viet Nam for 82 Mtoe. In the two countries, population and economic growth will support increases in final energy consumption. Population will increase from 270 million (the largest among ASEAN members) in Indonesia and 96 million (the third largest) in Viet Nam in 2019. GDP per capita will increase 3.1-fold in Indonesia between 2019 and 2050 and 4.5-fold in Viet Nam. Backed by such population and economic growth, Indonesia's final energy consumption will exceed Japan's in the late 2030s.

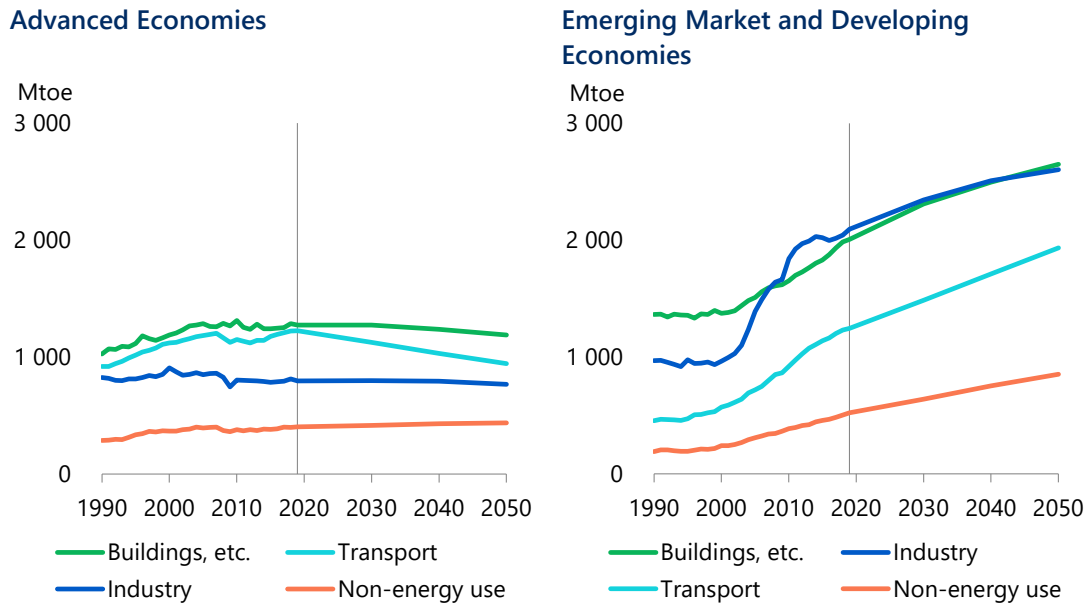
Final energy consumption in China will level off from 2 093 Mtoe in 2019 to 2 099 Mtoe in 2050. China will remain the world's largest final energy consumer through 2050. However, its final energy consumption will gradually decelerate its growth before peaking and entering a downtrend in the second half of the 2020s. Such pattern will differ from the constant uptrend in India or ASEAN. The industry sector will be a key contributor leading China's final energy consumption to peak out. Energy-intensive steelmaking and cement industries will particularly reduce their energy consumption. As initiatives to eliminate excess production capacity takes effect, cement production peaked out around the mid-2010s and crude steel production will soon enter its downtrend.

Final energy consumption in MENA will increase at an annual rate of 1.4% from 667 Mtoe in 2019 to 1 041 Mtoe in 2050, centring on Iran, North Africa and Saudi Arabia. Consumption will rise by 128 Mtoe in Iran, by 99 Mtoe in North Africa and by 72 Mtoe in Saudi Arabia. The three will thus account for most of MENA's consumption growth at 374 Mtoe. This is because GDP per capita will grow 1.7-fold in Iran, 1.9-fold in North Africa and 1.5-fold in Saudi Arabia, although their GDP per capita increases will be slower than in India or ASEAN.

By sector: Emerging Market and Developing Economies will drive consumption growth in each sector

Final energy consumption will increase in all sectors between 2019 and 2050, driven by the Emerging Market and Developing Economies. In the Advanced Economies, final energy consumption will slightly decrease in all sectors other than the non-energy use sector (Figure 2-27).

Figure 2-27 | Final energy consumption in Advanced, and Emerging Market and Developing Economies [Reference Scenario]

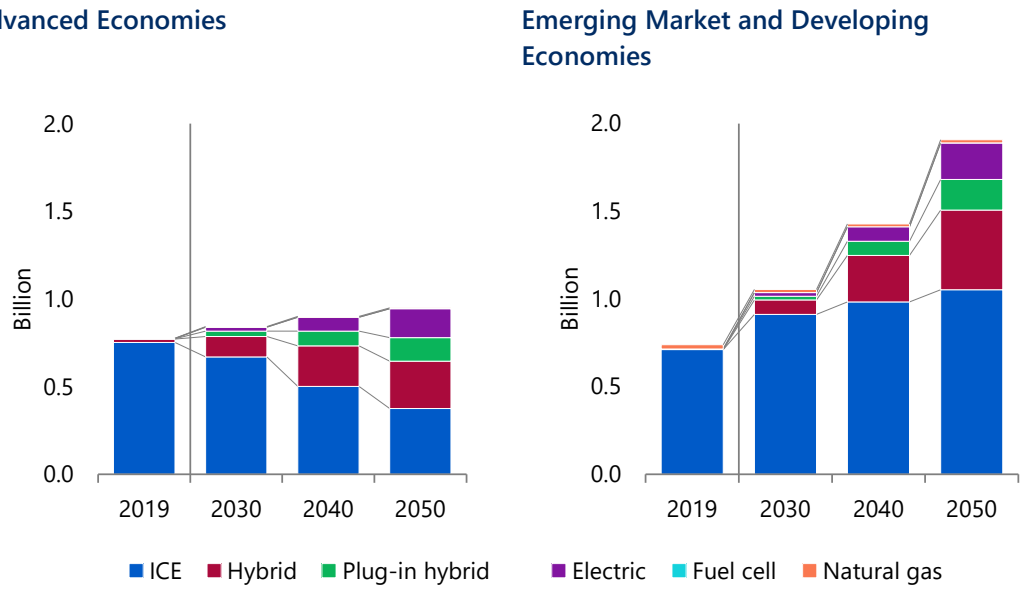


The following discusses the global final energy consumption changes by sector:

In the transport sector, final energy consumption will increase at an annual rate of 0.7% from 2 889 Mtoe in 2019 to 3 623 Mtoe in 2050, supported by growth in the road sector of the Emerging Market and Developing Economies and the international bunker sector. The transport sector's consumption growth will stand at 733 Mtoe, capturing 34% of the overall final energy consumption rise. Vehicle ownership in the Emerging Market and Developing Economies will rapidly increase, supported by economic growth (Figure 2-28), leading the transport sector to boost final energy consumption at an annual rate of 1.4%. In the Advanced Economies, electricity consumption will increase due to the diffusion of electrified vehicles under policy guidance. On the other hand, the road sector's oil consumption declines substantially because of fuel efficiency improvement and a decrease in internal-combustion vehicle ownership. As a result, final energy consumption in the transport sector of the Advanced Economies will fall at an annual rate of 0.8%.

In the industry sector, final energy consumption (mainly electricity and natural gas) will expand at an annual rate of 0.5% from 2 890 Mtoe in 2019 to 3 369 Mtoe in 2050 due to prosperity of the manufacturing industries in the Emerging Market and Developing Economies. The sector's consumption growth will come to 479 Mtoe, commanding 22% of the overall final energy consumption rise. Generally, the manufacturing and other industries have strong incentives to save energy consumption to increase their products' cost competitiveness. Therefore, the global industry sector's final energy consumption between 2019 and 2050 will increase at a slower pace than the secondary industry GDP annual average growth rate of 2.3%.

Figure 2-28 | Vehicle ownership [Reference Scenario]



Note: ICE stands for internal combustion engine.

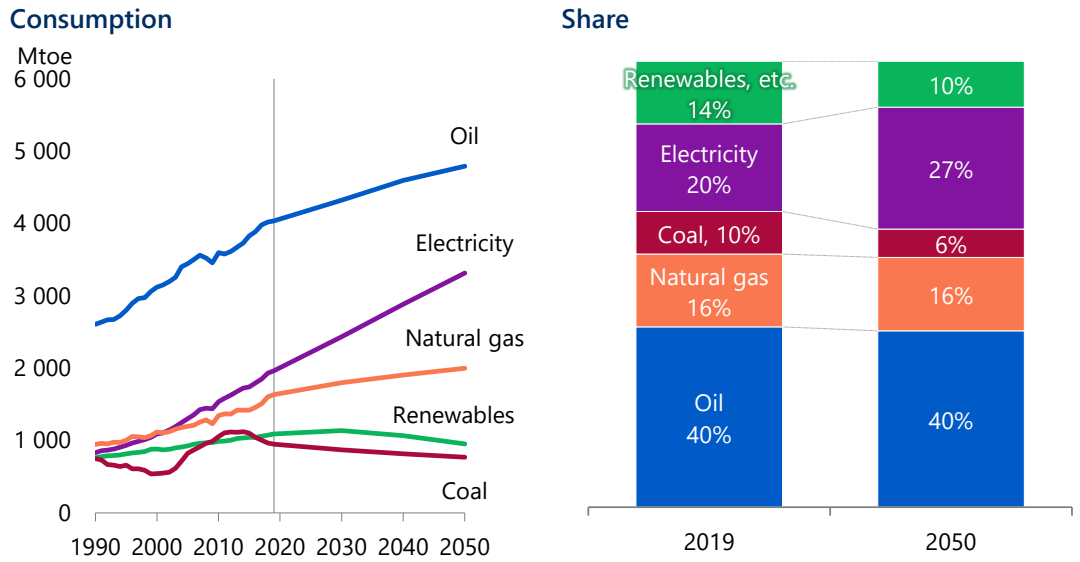
In the buildings sector, final energy consumption will increase at an annual rate of 0.5% from 3 280 Mtoe in 2019 to 3 838 Mtoe in 2050, backed mainly by growth in electricity, city gas and petroleum product consumption in the commercial and residential sectors of the Emerging Market and Developing Economies. The buildings sector's consumption growth will total 559 Mtoe, accounting for 26% of the overall final energy consumption rise. In the Emerging Market and Developing Economies, access to modern energy and appropriate equipment will gradually increase in line with living standard improvement. In particular, the share of traditional biomass in the buildings sector energy consumption will drop in Africa from 79% in 2019 to 50% in 2050 and from 23% to 8% in Asia where traditional biomass including fuel wood and manure has been used.

In the non-energy use sector, final energy consumption will rise at an annual rate of 1.1% from 924 Mtoe in 2019 to 1 290 Mtoe in 2050, driven mainly by growth in oil and natural gas consumption in the Emerging Market and Developing Economies. The sector's consumption growth will stand at 366 Mtoe, capturing 17% of the overall final energy consumption rise. In the Emerging Market and Developing Economies, petrochemical product consumption such as plastics will increase as living standards improve. The non-energy use sector is the only sector posting final energy consumption growth in the Advanced Economies between 2019 and 2050, albeit slightly. In North America, the chemical industry will increase non-energy use as shale gas production expansion allows feedstocks to be procured at low prices. While plastics are convenient, their massive consumption has caused international issues such as, resources and waste constraints, marine plastic waste and contributions to climate change. In response to these issues, plastics made from biomass instead of fossil fuels will be gradually introduced.

By energy source: Demand for all energy sources will remain

Global final energy consumption will follow an uptrend for some major energy sources and a downtrend for others between 2019 and 2050 (Figure 2-29). While oil, electricity and natural gas consumption increases, coal and renewable energy consumption will decline. Even in 2050, however, demand will still exist for coal and renewable energy. Fossil fuels (coal, oil and natural gas) will see their share of global final energy consumption fall from 66% in 2019 to 62% in 2050 while remaining a leading energy source accounting for the majority of the consumption.

Figure 2-29 | Global final energy consumption (by energy source) [Reference Scenario]



The following discusses global final energy consumption changes by energy source:

Final oil consumption will increase at a rate of 0.6% per year from 4 036 Mtoe in 2019 to 4 793 Mtoe in 2050, led by growth in the transport sector including the road sector of the Emerging Market and Developing Economies and the international bunker sector, as noted in the above sector-by-sector analysis. Oil consumption growth in the road sector of India, ASEAN and MENA amid motorisation will total as much as 336 Mtoe, offsetting more than 80% of a 412 Mtoe decrease in the Advanced Economies. The non-energy use sector will post the second fastest oil consumption growth after the transport sector. In the non-energy use sector, the Middle East as well as Asia will expand oil consumption by taking advantage of abundant local resources.

Final electricity consumption will grow at an annual rate of 1.7% from 1 965 Mtoe in 2019 to 3 314 Mtoe in 2050, thanks primarily to consumption growth in the buildings and industry sectors. Electricity is the only energy source that will post consumption growth in the Advanced Economies. Asia including China, India and ASEAN will drive the global consumption growth. Generally, as people's income grows they prefer the convenience of electricity. Another factor behind electricity consumption growth is the penetration of digitalisation to boost the number of electricity-consuming machines and devices. Electricity's

share of global final energy consumption will rise from 20% in 2019 to 27% in 2050. As various economic and social systems grow more and more dependent on electricity, damages resulting from disruptions to electricity supply will increase. While the decarbonisation of electricity is a significant issue, it is important to ensure a stable electricity supply from the viewpoint of energy security.

Final natural gas consumption will rise at an annual rate of 0.7% from 1 634 Mtoe in 2019 to 1 998 Mtoe in 2050, supported by growth in the industry and non-energy use sectors of the Emerging Market and Developing Economies. In India, ASEAN and MENA where manufacturing will prosper, mainly non-material industries will lead natural gas consumption. In the non-energy use sector, India and ASEAN with growing demand for chemicals and the Middle East seeking to expand the gas chemical industry will drive global natural gas consumption growth.

Final coal consumption will decrease at 0.7% per year from 950 Mtoe in 2019 to 770 Mtoe in 2050 due primarily to reductions in China's industry and buildings sectors. As noted in the region-by-region analysis, China's coal-consuming steelmaking and cement industries will reduce production over the medium to long term. Coal consumption in China's industry sector in 2050 will decline to below half the 2019 level. To reduce air pollution and health damage accompanying coal consumption, China's buildings sector will switch from coal to natural gas and electricity.

Final renewable energy consumption will decline at an annual rate of 0.4% from 1 092 Mtoe in 2019 to 954 Mtoe in 2050 due mainly to progress in energy transition in Asian and African Emerging Market and Developing Economies. Although biofuels for automobiles and aircraft are drawing attention, they represented only a small portion of the final renewable energy consumption in 2019. Traditional biomass, including fuel wood and manure used in the Emerging Market and Developing Economies, accounted for the largest share at 71% in 2019, followed by 13% for fuel wood mainly for heating in Europe and North America, 10% for biofuels and 5% for others. As pointed out in the sector-by-sector analysis, modern energy will replace traditional biomass gradually in Asian and African Emerging Market and Developing Economies, leading final renewable energy consumption in the world to gradually decrease from the second half of the 2020s.

2.3 CO_2 emissions

Countries announced net-zero emission or carbon neutrality goals and updated 2030 goals one after another

Since the release of the IEEJ Outlook 2021, various economies have announced net-zero emission or carbon neutrality goals and updated their CO_2 emission reduction goals for 2030.

Regarding net-zero emission or carbon neutrality goals, China in September 2020 announced that it would seek to achieve carbon neutrality before 2060. One month later, the EU members reached agreement on a goal of greenhouse gas (GHG) neutrality by 2050, overcoming opposition from East European countries. Japan also announced to cut GHG emissions to net zero by 2050. In January 2021, the United States inaugurated the Biden administration pursuing net-zero emissions before 2050.

As for goals for 2030, the EU in December 2020 raised the emission reduction goal from 40% to 55% compared to 1990 levels. On the occasion of a climate leaders summit hosted by the United States in April 2021, the U.S. Biden administration submitted a nationally determined contribution (NDC) to cut emissions in 2030 by 50%-52% from 2005. Japan then raised its 2030 emission reduction goal from 26% to 46% compared to 2013 levels. However, China known as the world's largest GHG emitter and India as the third largest have not updated their goals for 2030.

Table 2-1 indicates emission reduction goals for 2030 and net-zero emission or carbon neutrality goals of the world's 10 largest GHG emitters as of 2015. The 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26) will be held in October and November in Glasgow, UK. What is currently attracting attention is to know which countries would update goals for 2030 or announce net-zero emission or carbon neutrality goals.

The COP26 will launch talks on the Advanced Economies' new funding goal for emission reduction actions in the Developing Economies. The Advanced Economies now have a $100 billion per year funding goal toward 2025. The COP26 talks are set to deal with a post-2025 funding goal of more than $100 billion per year.

Table 2-1 | 2030 goals and net-zero emission or carbon neutrality goals in the world's 10 largest GHG emitters

	2030 goals	Net-zero emission or carbon neutrality goals
China	Cutting the CO_2-GDP intensity by 60%-65% from 2005	Pursuing carbon neutrality before 2060 (Announced at the United Nations General Assembly on 22 September 2020)
United States	Cutting emissions by 50%-52% from 2005 (NDC submitted on 22 April 2021)	Net-zero emissions before 2050 (President Biden inaugurated on 20 January 2021)
European Union 27	Cutting emissions by 55% from 1990 (Updated NDC submitted on 18 December 2020) (40% cut before updating)	GHG neutrality by 2050 (Agreed on at a Ministerial Council meeting on 23 October 2020)
India	Cutting the GHG-GDP intensity by 33%-35% from 2005	N.A.
Russia	Cutting emissions by 30% from 1990 (NDC submitted on 25 November 2020) (25%-30% cut in INDC)	N.A.
Japan	Cutting emissions by 46% from FY2013 (Announced at a climate leaders summit on 22 April 2021)	Net-zero GHG emissions by 2050 (Announced at the National Diet on 26 October 2020)
Indonesia	Cutting emissions by 29%-41% from BAU (2 869 Mt) (Updated NDC submitted on 22 July 2021) (No change in the goal, BAU given at 2 881 Mt before updating)	Exploring an opportunity of rapid progress toward net-zero emissions by 2060 (A long-term strategy submitted on 22 July 2021)
Canada	Cutting emissions by 40%-45% from 2005 (Updated NDC submitted on 12 July 2021) (30% before updating)	Net-zero GHG emissions by 2050 (Legislated on 29 June 2021)
Iran	NDC has yet to be submitted	N.A.
Mexico	Cutting emissions by 22%-36% from BAU (991 Mt in 2030) (Updated NDC submitted on 30 December 2020) (No change in the goal, BAU given at 1 110 Mt before updating)	N.A.

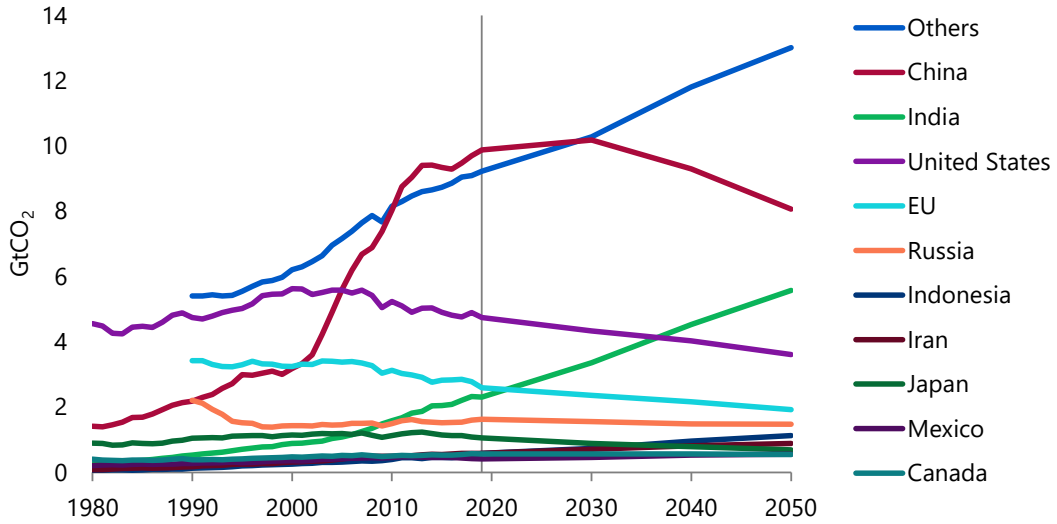
Note: BAU stands for business as usual.

China's CO_2 emissions will peak in the mid-2020s. India will greatly increase CO_2 emissions.

Global energy-related CO_2 emissions will increase from 33.6 gigatons in 2019 to 35.5 Gt in 2030 and to 37.5 Gt in 2050.

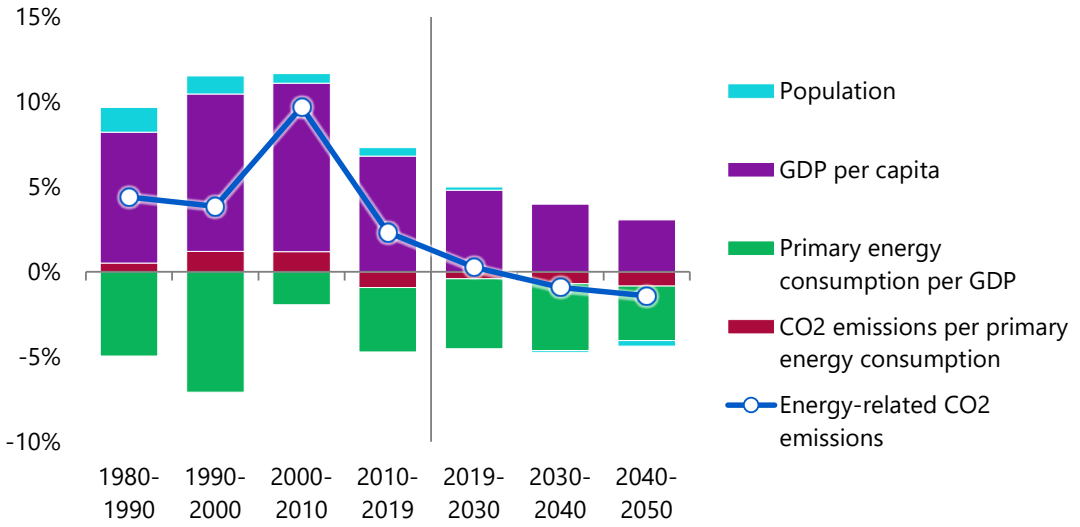
Figure 2-30 indicates energy-related CO_2 emission trends in the 2015 world's 10 largest GHG emitters separately and the others as a group. China's emissions stood at 9.9 Gt in 2019 and will turn down in the middle of the 2020s before falling to 8.1 Gt in 2050. India's emissions will rise from 2.3 Gt in 2019 to 5.6 Gt in 2050. In the United States, the EU 27 and Japan, emissions will decrease between 2019 and 2050. In 2050, Japan's emissions will total 0.7 Gt, surpassed by 1.1 Gt in Indonesia and 0.9 Gt in Iran. Of 3.8 Gt in emission growth between 2019 and 2050 for the others, Africa will account for 1.3 Gt and ASEAN excluding Indonesia for 0.7 Gt.

Figure 2-30 | Energy-related CO_2 emissions in the world's 10 largest emitters [Reference Scenario]



In China, negative contributions of primary energy consumption per unit of GDP, or GDP energy intensity, to emissions will remain unchanged after the 2019-2030 period, but positive contributions of GDP per capita will decrease. This indicates that the deceleration of China's economic growth will be a major factor behind the downturn in energy-related CO_2 emissions in the middle of the 2020s (Figure 2-31).

Figure 2-31 | Changes in China's energy-related CO_2 emissions, etc. [Reference Scenario]



China's CO_2 emissions per unit of GDP will decline by 67% from 1.572 kg/$ in 2005 to 0.516 kg/$ in 2030 (China's goal for 2030 calls for cutting energy-related and other CO_2 emissions per unit of GDP by 60%-65%). India's CO_2 emissions per unit of GDP will decline by 30% from 0.913 kg/$ in 2005 to 0.635 kg/$ in 2030 (India's goal for 2030 calls for cutting GHG emission per unit of GDP by 33%-35%). Whether China or India will update their 2030 goals will attract attention.

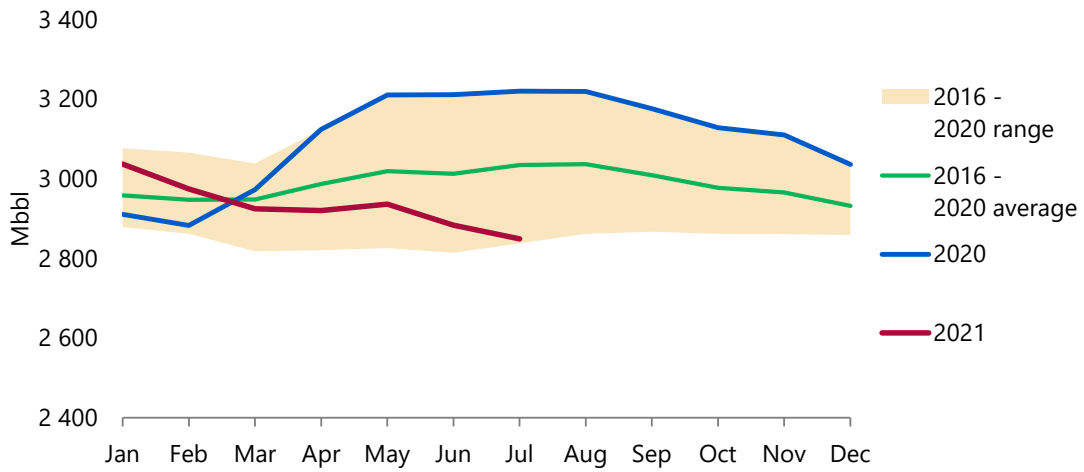
3. Energy Supply

3.1 Crude Oil

Oil prices rising due to OPEC-plus production reduction and anticipated demand recovery

The OPEC-plus group, which consists of the Organization of the Petroleum Exporting Countries (OPEC) and non-OPEC oil-producing countries such as Russia, launched a coordinated oil production cut in January 2017. Initially, the cut was limited 1.8 million barrels per day (Mb/d) and later, in May 2020, it was expanded to 9.7 Mb/d in view of an oil demand loss on the COVID-19 spread. The average Brent crude oil price hit a 16-year low of $27/bbl in April 2020, before increasing later due to the large OPEC-plus production cut and the potential economic recovery in some countries. Because oil demand failed to recover as much as expected due to a second COVID-19 infection wave in Western countries and India, oil supply was still excessive in the second quarter of 2020, and the Brent prices remained in the $40/bbl-$45/bbl range until around October. Commercial oil stocks in the member countries of the Organisation for Economic Co-operation and Development (OECD), an oil supply-demand balance indicator, stayed more than 200 million barrels above their five-year average until October 2020 (Figure 3-1).

Figure 3-1 | Current OECD commercial oil stocks



Source: IEA "Monthly Oil Market Report"

Later, however, the crude oil market turned around and oil prices increased at a remarkably rapid pace after November 2020. On the demand side, oil requirements have grown as the economic recovery accelerated, thanks to the launching of COVID-19 vaccination. Expectations on a large additional economic stimulus package, under the U.S. Biden administration, added fuel to the oil demand pickup. On the supply side, the OPEC-plus group carefully adjusted the production cut to prevent any oversupply. From January 2021, the OPEC-plus group eased its

production cut by limiting the production increase to 0.5 Mb/d against the earlier planned increase of 1.9 Mb/d. From February, Saudi Arabia voluntarily implemented an additional production cut of 1 Mb/d. These actions contributed to tightening the oil supply-demand balance, leading OECD commercial oil stocks to slip below their five-year average in March 2021. The average Brent price in the month stood at $65.7/bbl, rising by about 60% in five months from $41.5/bbl in October 2020.

The United States, which had already remarkably increased shale oil production in response to earlier oil price hikes, has been insensitive to the current hikes. This is because shale oil producers used cash flow not for drilling activities but for debt reduction and other financial consolidation. After a spate of oil price hikes, the number of oil rigs in operation in the United States stood at about 380 in July 2021, far below the 680 operating before the COVID-19 pandemic. U.S. crude oil production in 2021 is expected to increase only slightly from the previous year.

As oil demand continued to increase amid a global economic recovery, oil prices in July rose temporarily to $77.2/bbl, the highest in 33 months since October 2018. Since then, the OPEC-plus group decided to decrease the production cut by 0.4 Mb/d every month from August to December and extend the coordinated production cut framework for eight months until the end of 2022. It may seek to retain the current oil price levels while watching oil market conditions and changing the production cut accordingly.

Middle Eastern oil producers taking advantage of low production costs for leading global crude oil supply

In the Reference Scenario, global oil demand will continue increasing through 2050 on the strength of economic growth, a growing number of middle-class households and the oil's convenience as a liquid fuel (easy to store and suitable for decentralised supply) mainly in Emerging Market and Developing Economies including India, the Association of Southeast Asian Nations (ASEAN) and Africa.

Over the medium term through 2030, global oil demand will increase at an annual rate of 0.5%, prompting OPEC and non-OPEC oil-producing countries to expand production. OPEC, which reduced oil production in 2019 by 5% from the previous year under the OPEC-plus production cut, will take advantage of abundant spare production capacity and low production costs for driving the global crude oil supply growth. Meanwhile, the United States, which increased crude oil production at an amazing annual rate of 9.5% in the 2010s, will not be able to sustain such dominant production growth because shale oil producers gave priority to financial consolidation and temporarily stagnated their upstream investment after the oil price plunge caused by the COVID-19 spread. While North America increases crude oil production at a relatively moderate pace, Latin American countries will boost their presence as non-OPEC oil-producing countries. They will include Brazil where state-run oil company Petrobras plans to invest $32 billion in pre-salt oil and gas exploration and production in five years from 2021. Also among them is Guyana that started crude oil production under its first offshore oil project in late 2019 and quickly prospered with an economic growth topping 40%. The break-even point for crude oil production in Guyana is estimated at between $20/bbl and $30/bbl, indicating higher profitability than U.S. shale oil.

As oil production in North America peaks out over the long term, Middle Eastern OPEC countries boasting abundant oil reserves will further increase their presence. In Saudi Arabia, the OPEC leader, crude oil production costs are estimated to be as low as $4/bbl. On the strength of such low production costs, Saudi Arabia and other Middle Eastern OPEC members will provide most of the growth in global oil demand between 2030 and 2050, estimated at 10 Mb/d. Among non-OPEC oil-producing countries that overall will slow down oil production, Latin American countries alone will post a steady oil production growth over the long term. Among them are Guyana that has already started commercial oil production and Suriname that has found more and more hydrocarbon deposits. They will rise as emerging oil producers.

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

(Mb/d)

	2019	2030	2040	2050	2019-2050	
					Changes	CAGR
Crude oil production	95.0	98.5	104.3	108.1	13.1	0.4%
OPEC	34.9	37.6	42.9	46.4	11.4	0.9%
Middle East	27.0	29.2	33.1	35.3	8.3	0.9%
Others	7.9	8.4	9.8	11.1	3.1	1.1%
Non-OPEC	60.0	60.9	61.4	61.7	1.7	0.1%
North America	22.4	23.4	22.7	21.2	-1.2	-0.2%
Latin America	7.2	8.7	10.5	12.4	5.2	1.8%
Europe and Eurasia	18.2	16.9	16.3	15.9	-2.3	-0.4%
Middle East	3.2	3.4	3.6	4.0	0.9	0.8%
Africa	1.4	1.4	1.5	1.6	0.2	0.3%
Asia and Oceania	7.6	7.0	6.8	6.6	-1.0	-0.5%
Processing gains	2.4	2.6	3.0	3.2	0.9	1.0%
Oil supply	97.3	101.1	107.3	111.3	14.0	0.4%

Note: Crude oil includes NGL.

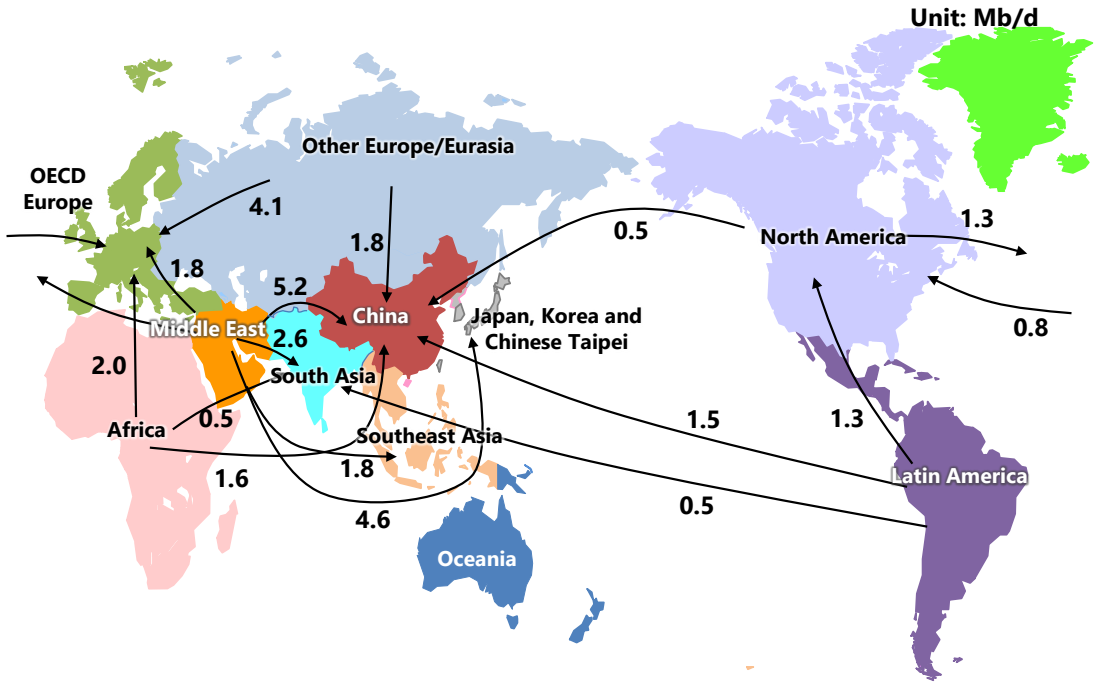
Asia growing dependent on Middle Eastern crude oil

Crude oil trade between major regions in the world totalled about 42 Mb/d in 2020. The fall in crude oil trade was smaller than the oil demand plunge under the COVID-19 pandemic as China, the largest oil importer in the world, increased oil imports by about 10% from the previous year. After a year-on-year decline in oil demand in the first quarter of 2020 under the pandemic, China successfully contained COVID-19 and its oil demand turned up in the second quarter. Of the global oil trade in 2020, exports from the Middle East accounted for 42% of which 80% went to Asia. Exports from the United States grew by about 40% from the previous year to 3.1 Mb/d. As U.S. crude oil exports to China increased remarkably in addition to those to Western Europe, U.S. exports to Asia expanded to 1.3 Mb/d after topping 1 Mb/d in 2019 for the first time ever.

Crude oil trade between major regions will increase in the future as demand grows in non-oil-producing countries. Imports by India and ASEAN countries, which are driving the future oil demand growth, will increase faster than the fall in imports by OECD countries, which are demanding less and less. After recording the world's largest oil import volume of 11.2 Mb/d in 2020, China will moderately expand oil imports through 2030 due to a relatively low oil demand growth combined with domestic production that will stagnate as major oil fields are depleting. In response to a growing demand for oil imports in Asia, North America will boost exports to Asia in a manner to hold down the growth in Asia's dependence on the Middle East.

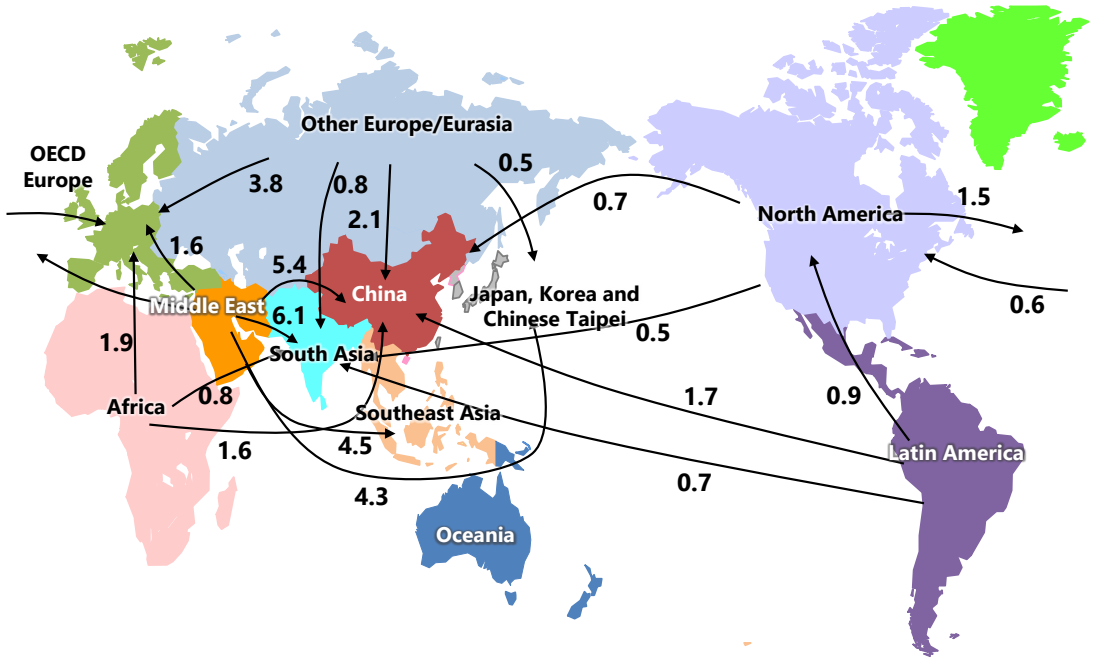
As Middle Eastern oil-producing countries become again the world's oil production centre toward 2050, Asia, accounting for nearly 80% of global crude oil imports will again grow dependent on the Middle East. Factors behind such change will include the peaking out of North American oil production and the limited growth in exports from Africa where local demand will rise. By 2050, India will replace China as the world's largest crude oil importer. Indian imports then will be more than China's current imports.

Figure 3-2 | Major interregional crude oil trade flows [2020]



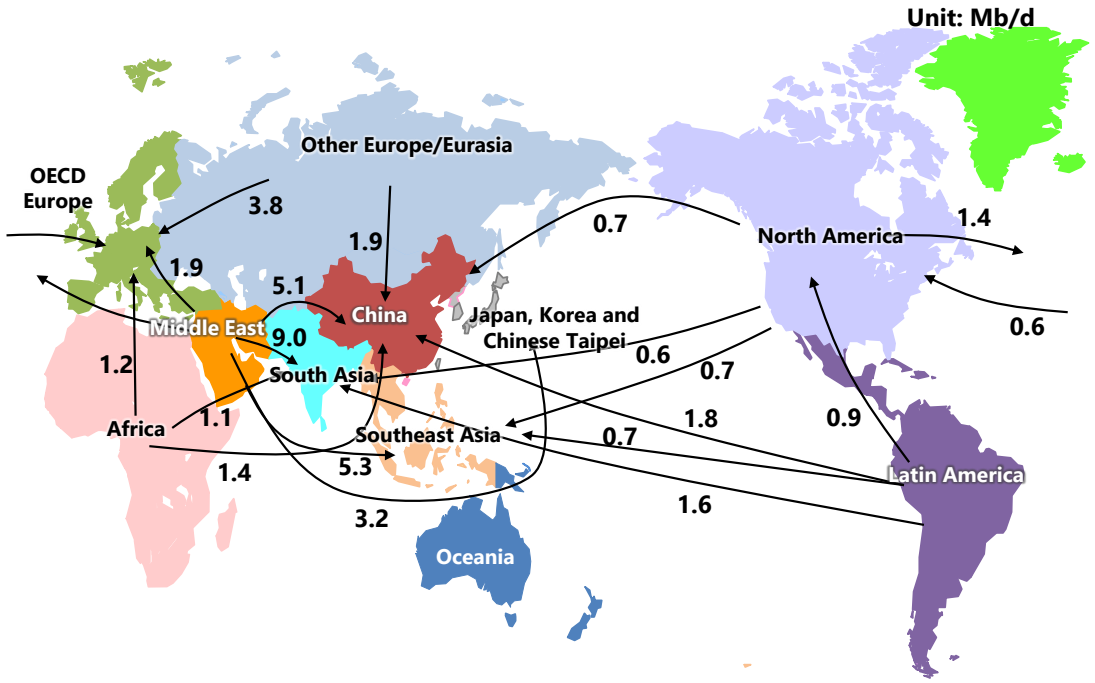
Note: Flows of 0.5 Mb/d or more are covered.
Sources: "BP Statistical Review of World Energy 2021," national trade statistics

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



Note: Flows of 0.5 Mb/d or more are covered.

Figure 3-4 | Major interregional crude oil trade flows [Reference Scenario, 2050]



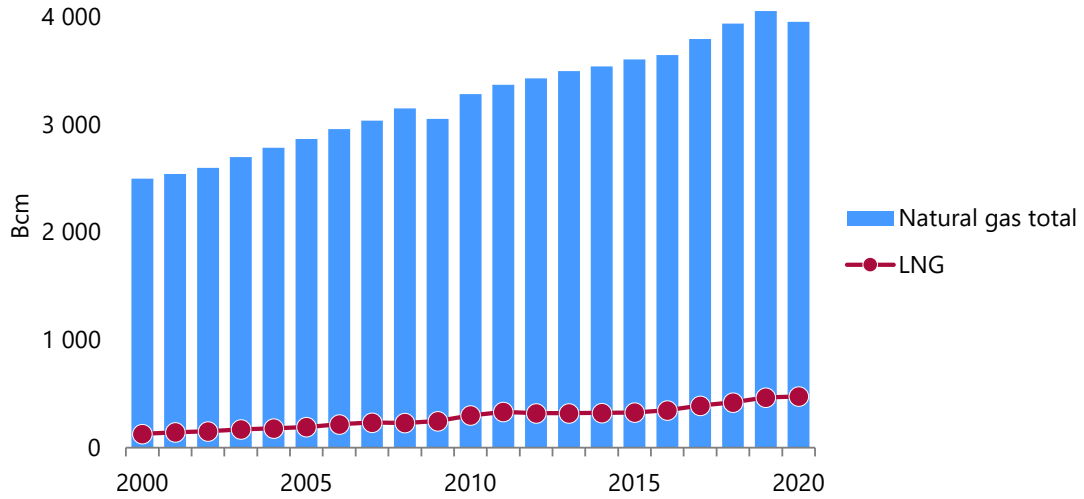
Note: Flows of 0.5 Mb/d or more are covered.

3.2 Natural gas

Abundant supply potential sustaining LNG market expansion

In the past half century, natural gas supply in the world has expanded faster than the overall energy supply. Liquefied natural gas (LNG) supply through international trade and marine transportation has increased even faster than the overall natural gas supply. In 2019, particularly, LNG supply experienced a substantial expansion supported by production launches at U.S., Australian and Russian LNG facilities, scoring a double-digit increase from the previous year. In volume, the increase came to a record of 41 million tonnes (Mt). While U.S. LNG production capacity continued expanding in 2020, capacity utilisation rates fell due to a plunge in global LNG demand and trade in the second and third quarters. As a result, the LNG market expansion in the year was limited. In 2021, the LNG market is quickly expanding in a manner to absorb the increased production capacity, thanks to a robust Northeast Asian demand including Chinese consumption. Over the medium to long term, the LNG market has great potential to keep on expanding on the strength of abundant natural gas resources and their bullish development.

Figure 3-5 | Global natural gas and LNG supply



The annual LNG production capacity subjected to investment decisions in the world hit a record high of 71 Mt in 2019, amounting to some 20% of 350 Mt in global LNG trade in the year. In 2020, however, investment decisions declined substantially due to LNG price fluctuations and uncertain future demand. The United States continuously accounts for many LNG projects expected to become subject to future investment decisions, indicating its great role in expanding future LNG production. Unlike traditional LNG projects, U.S. projects are not necessarily linked to specific upstream gas fields, featuring loose commitments and investment decisions regarding final consumers. The emergence of such U.S. LNG projects in the global market is stimulating structural changes in the LNG market. In 2019, U.S. LNG supply to Japan expanded and demonstrated its advantage as LNG prices indexed to oil prices under most traditional contracts for LNG supply to Asia were high. In 2020, meanwhile, U.S. LNG supply

flexibly absorbed supply fluctuations amid weak gas prices and demand. In 2021, U.S. LNG is demonstrating its flexibility and price advantage amid a global gas price hike, solidifying its position as a supply source for various regions. This has begun to exert impacts on LNG procurement contract negotiations for U.S. and other suppliers. For the moment, Australia reached the final phase of its LNG production capacity expansion in 2019 and boosted its LNG production in 2020 above that of Qatar that had remained the world's largest LNG exporter since 2006. Russia for its part has increased LNG production under its Arctic projects, expanding its share of the European market.

Such production trend has brought about structural changes in the consumption market. Northeast Asia has remained a mainstay LNG consumption market, but its share of the global LNG market narrowed from 62% in 2018 to 56% in 2019 and 2020. The share for Japan, the largest LNG importer in the world, also dropped from 25% in 2018 to 21% in 2020. China among other Northeast Asian countries is expanding its LNG market, though at a slower pace than earlier. In the first half of 2021, Chinese LNG imports surpassed Japanese imports.

In response to U.S. LNG export expansion, Europe rapidly increased its LNG imports since the fourth quarter of 2018. In 2019, Europe imported more LNG than Japan or China. Underground gas storage facilities have played a key role in boosting LNG imports in Europe. These facilities have a total capacity of 70 Mt in terms of LNG as of 2021. Reflecting LNG import growth, inventories at the facilities have fluctuated wildly, serving as a buffer for the global LNG market. Their capacity factor plunged from 97% at October-end 2019 to 54% at March-end 2020 and rose back to 96% at October-end 2020. Mirroring global LNG supply's great shift to Asia in the 2020-2021 winter, the rate nosedived to 30% by March-end 2021. As Europe's presence in the global LNG market increased, European spot gas prices, including the Netherlands' Title Transfer Facility, have expanded their influence on the global market and increased their link to Asian spot LNG prices.

As weaknesses in global spot gas prices affected the Asian spot LNG prices in 2020, the gap with long-term LNG contract prices for Asia, indexed to oil prices, expanded to record levels mainly in the first half of the year. From late 2020 to early 2021 and in the middle of 2021, spot gas and LNG prices shot up, increasing their volatility. This is leading to a downtrend of LNG price's slope to oil prices, the introduction of new LNG price benchmarks, the elimination of destination clauses and other measures to improve the liquidity of the LNG market.

Improvements in LNG transaction terms and conditions, including prices, will accelerate the development of new LNG import projects in Southeast and South Asian Emerging Market Economies and lead to more LNG bunkering initiatives and the diffusion of LNG-fuelled ships.

Gas resources development supporting LNG expansion in various regions

The United States, the world's largest natural gas producer and consumer, will increase shale and other natural gas production throughout the outlook period. Its natural gas production will rise at an annual rate of some 1% until around 2030 before stabilising. LNG exports will play a key role in increasing natural gas sales channels and improving the trade balance of the United States. Shale gas production was at low levels until U.S. natural gas prices increased, around 2005, stimulating its development. Since 2008, shale gas production has expanded substantially as its economic efficiency has improved thanks to the advancement and diffusion

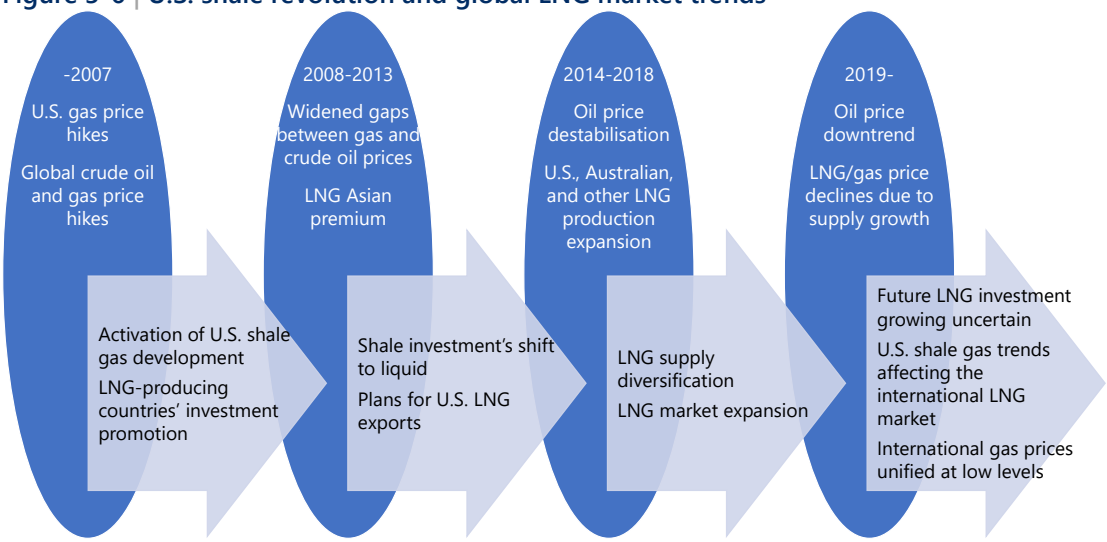
of hydraulic fracturing and horizontal drilling technologies. As of 2021, shale gas production accounts for 70% of natural gas production in the United States.

Natural gas prices in the United States have been at low levels, a result of production growth since 2008. As gaps between natural gas and oil prices have expanded, production technologies for liquid production have been applied and improved in a manner to boost natural gas liquids (NGLs) and crude oil production, as well as associated natural gas liquids production. In the international market, meanwhile, gaps between U.S. natural gas and oil prices have been reflected in those between U.S. natural gas and oil-indexed Asian LNG prices, leading plans to develop U.S. LNG export projects to be launched one after another.

U.S. LNG's competitiveness in the international LNG market is influenced by prices for competing LNG supply sources, including traditional LNG prices for Asian buyers that have been indexed to oil prices. This has contributed greatly to LNG trade flow fluctuations in the global market from 2020 to 2021. U.S. East Coast LNG production projects including those in the Gulf of Mexico have access to Asia through the Panama Canal, leading to the requirement for optimising supply sources and routes through LNG cargo swaps. In this way, cooperation between various players can be promoted. Despite growing LNG trade through the canal, the U.S. LNG exporters failed to meet the sharp increase in Asian LNG demand in the 2020-2021 winter. The requirement for optimising LNG transportation is growing.

LNG production capacity now in operation and some capacity under construction will allow the United States to rival the world's largest LNG exporters Australia and Qatar with supply capacity exceeding 77 Mt per year as early as 2022. If other capacity under construction and capacity still subjected to final investment decisions are added, the annual U.S. LNG production capacity will top 100 Mt.

Figure 3-6 | U.S. shale revolution and global LNG market trends



LNG exports from the United States are priced based on the low U.S. natural gas market prices, instead of the traditional Asian LNG pricing mechanism in which LNG prices have been indexed to oil prices. U.S. LNG exports, though being vulnerable to other energy prices in Asia, can provide competitive prices in the Asian market and are expected to cause changes in the

traditionally rigid Asian LNG pricing mechanism. Given that U.S. LNG exports are mostly based on contracts under which destinations are not specified, they will bring about great changes in global LNG transactions. Such flexibility of U.S. LNG may also be useful for exports to Emerging Market Economies.

Before losing the United States as a gas export destination, due to the shale revolution, Canada used to export nearly half its natural gas production to the United States via pipelines. It now places great hopes on LNG exports for the expansion of gas production. Multiple LNG export projects are planned both for the Pacific and Atlantic sides with one large Pacific coast project that reached final investment decision. These projects will pave the way for Canada to expand gas production particularly after 2030.

LNG exports from Western Australia to Japan were launched in 1989 under a large LNG production project, which has been expanded in two phases. The LNG production project has been combined with the expansion of a domestic gas supply system, becoming a model project for LNG development in Australia. LNG exports started under a project in Australia's Northern Territory in 2006 and under the second project in Western Australia in 2012. In the 2010s, LNG production began under multiple additional projects in Western Australia and new projects in eastern Queensland in response to LNG demand growth in Asia, including Japan and China. Production started under these projects by 2019, bringing Australia's annual LNG production capacity to more than 80 Mt. As of 2020, Australia replaced Qatar as the world's largest LNG producer. These projects are operated by different parties including Japanese companies, providing different terms and conditions for LNG supply. Furthermore, Japanese and other Asian LNG buyers have acquired minor equity stakes in these projects, paving the way for flexible LNG supply including equity-based off-taking. Future upstream gas development projects include those for providing gas to existing LNG production facilities, allowing for the stable operation of LNG facilities to provide a platform for sustainable upstream gas production. LNG production will smoothly expand under these projects before decelerating its growth after 2030.

Russia has been exporting LNG under a Sakhalin project on the Pacific Coast since 2009 and an Arctic project since late 2017. The Arctic project provides Russian LNG not only to Pacific LNG-consuming countries but also to the European market that has traditionally received Russian gas supply via pipelines. In Arctic Russia, the second large LNG project received final investment decision, with construction going on. The project will be available for LNG supply not only to the nearby European market but also to other regions thanks to the planned development of terminals for transferring LNG from ice-breaking LNG tankers that can operate in the Arctic region to conventional LNG carriers to optimise transportation. This will bring about additional structural changes in LNG supply.

In addition, frontier regions in East and West Africa will expand natural gas production including LNG. For offshore or small and medium-sized gas fields in these regions, floating LNG production facilities are realistic options for LNG development. In Cameroon, West Africa, a floating LNG production project has come into operation. Investment decisions were made in 2017 for a floating LNG production project off Mozambique in East Africa and in 2018 for another off Senegal and Mauritania in West Africa. Large LNG players with global

marketing capabilities have made commitments to take delivery of all LNG produced under these projects to promote them.

Mozambique plans multiple onshore LNG production projects in addition to the floating LNG production project. An investment decision was made on one of them in June 2019. Unfortunately, as of 2021, construction is suspended due to the deteriorating local security situation. Mozambique has large-scale natural gas resources, is close to South Asia including India and is free from maritime transportation chokepoints. Furthermore, its strategic location allows Mozambique to access not only the Asian market but also the European market through the Suez Canal or the Cape of Good Hope. Therefore, Mozambique is well positioned to grow as a major LNG supplier over the long term. Backed by the abovementioned projects, global natural gas production will smoothly increase.

Figure 3-7 | Major interregional natural gas trade flows [2019]

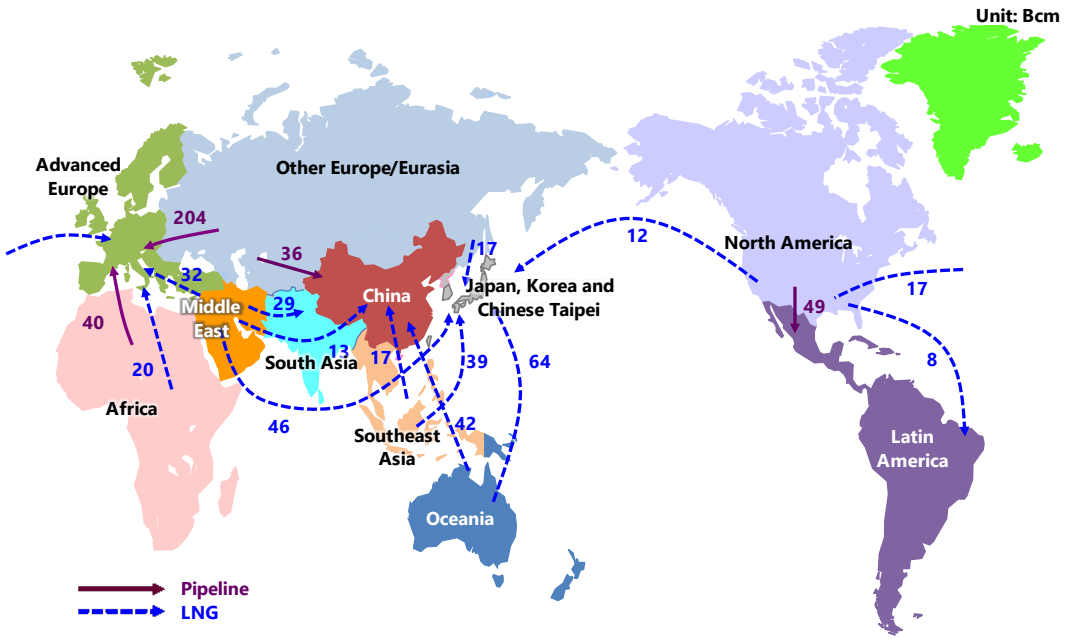
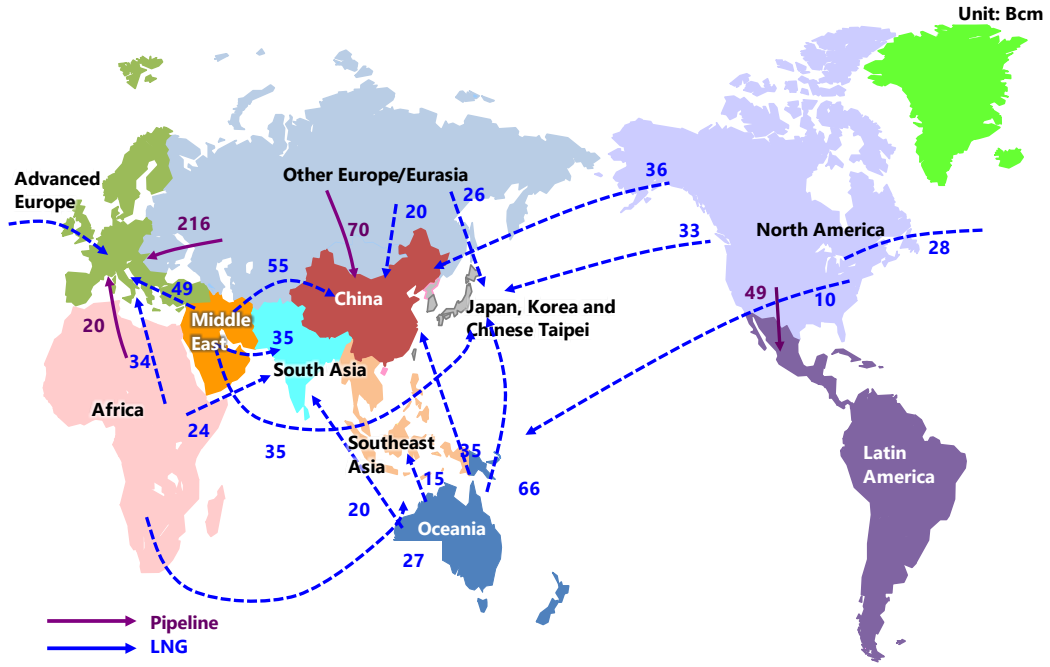
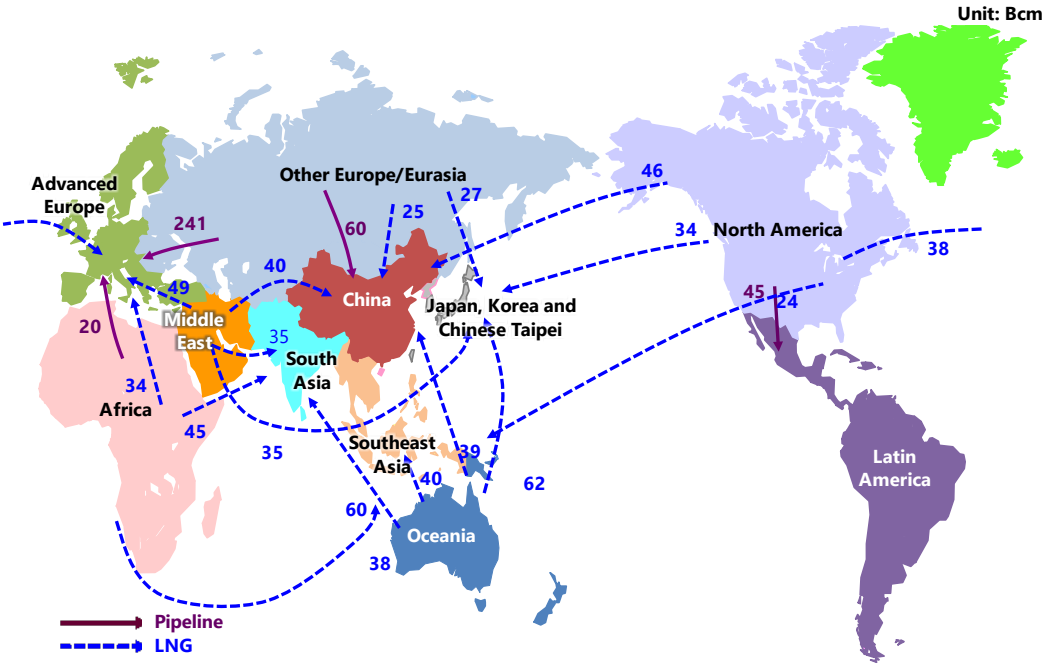


Figure 3-8 | Major interregional natural gas trade flows [Reference Scenario, 2030]



Note: Major trade flows are covered. Some pipeline gas flows could be replaced with LNG flows.

Figure 3-9 | Major interregional natural gas trade flows [Reference Scenario, 2050]



Note: Major trade flows are covered. Some pipeline gas flows could be replaced with LNG flows.

3.3 Coal

The coal market is tightening due to robust demand coupled with production decline and supply disruptions

While economic and social turmoil has continued due to the spread of COVID-19 infections, global momentum for initiatives to reduce greenhouse gas (GHG) emissions has grown even further. Following the promotion of carbon pricing in the European Union (EU), the United States swung back to the enhancement of climate change countermeasures through a government change and China declared a carbon neutrality goal. As major economies have thus shared plans to enhance climate change countermeasures, many economies are going in the direction of restricting production and consumption of coal among fossil fuels. Given the current coal supply and demand situation, however, global coal phaseout is realistically expected to become a long-term initiative.

Global coal production in 2020 decreased by 385 Mt or 4.8% from the previous year to 7 575 Mt. Global production peaked at 7 976 Mt in 2013 and continued falling before rising back from 2017 to 2019, when it rose to 7 960 Mt, close to the past peak. Although global coal production turned down in 2020 due to the COVID-19 pandemic, production falls differed from region to region. While coal production declined by 166 Mt or 23.8% in North America, by 60 Mt or 18.5% in OECD Europe and by 36 Mt or 35.8% in Latin America, the Asia-Pacific region limited the drop to 26 Mt or 0.5%, keeping production close to the 2019 level. The Asia-Pacific region has become the world's coal supply and demand centre, accounting for 76% of global coal production at 5 750 Mt in 2020.

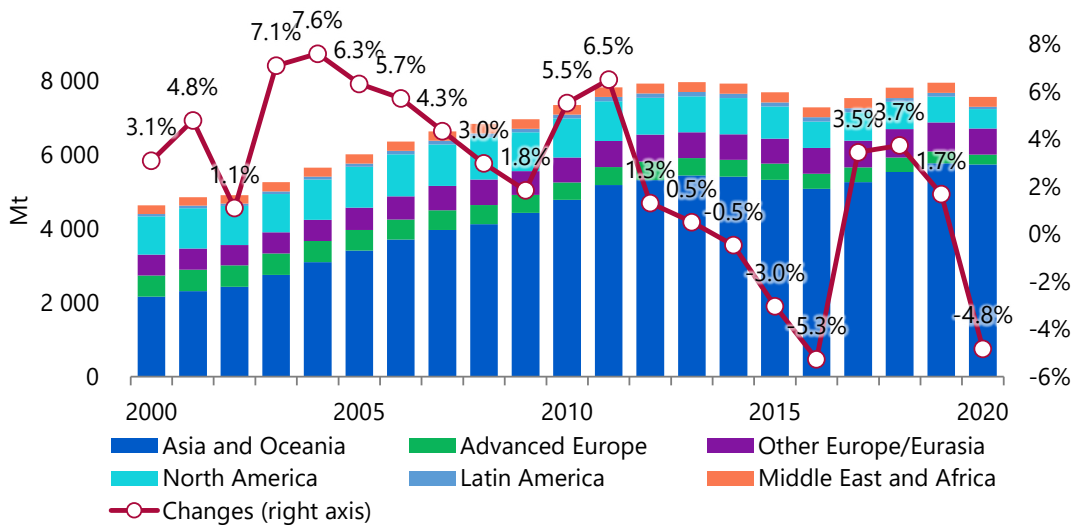
International coal prices have continued rising since early 2021, following a plunge in spring and summer 2020 under the pandemic. Spot steam coal prices (represented by the FOB price of steam coal for shipments from New Castle Port in Australia) stayed around $70/t from the second half of 2019 to early 2020 but plunged to $47/t in late August 2020. The level was close to the recent bottom reached in January 2016. Coking coal prices slipped below $100/t in autumn 2020. Coal prices rebounded later. Spot steam coal prices rose above $80/t in January 2021 and soared beyond $100/t in May and beyond $175/t in August. Coking coal prices rose above $220/t in August.

A major factor behind the coal price hikes is China's expansion of coal imports that came as demand for coal in the power generation and industry sectors recovered, thanks to its economic recovery after the quick containment of the COVID-19 pandemic. The Chinese government has indicated plans to restrict domestic coal production and use imported coal to some extent. While refraining from importing Australian coal amid bilateral diplomatic disputes, China has rapidly increased coal imports mainly from Indonesia.

On the supply side, natural disasters and equipment failures have caused supply disruptions, contributing to the tightening of the coal market. In Australia, a ship loader accident occurred at a major coal-shipping port in late 2020 and still affects coal shipments. Furthermore, excessive precipitation in March has seriously affected Australia's coal transportation network. Indonesia has substantially expanded coal exports to China amid the international coal price hikes. However, the COVID-19 spread is feared to have adverse effects on coal production. In

Colombia, coalminers' protests have led to the shutdown of railways and to coalmine accidents with coal production plunging some 40% year on year in 2020, indicating destabilisation.

Figure 3-10 | Global coal production



Note: Data for 2020 are provisional.
Source: IEA "World Energy Statistics and Balances 2021"

Coal supply capacity has lost flexibility, destabilising the supply-demand balance

While coal phaseout becomes a global trend to substantially restrict coal-related investment and loans, coal production will increasingly concentrate in some regions.

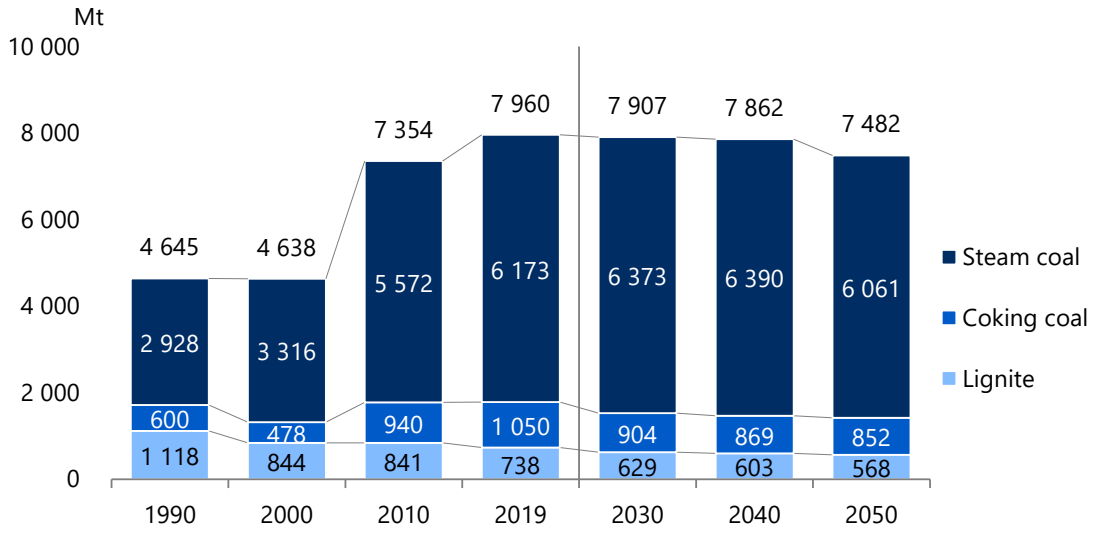
For European and North American Advanced Economies, as well as East European coal-producing EU members such as Poland, it will become more difficult to either develop new coal mines, expand production at coalmines in operation or invest in transportation and export infrastructures. Australia is divided over whether to produce, consume or export coal. Governments of coal-producing states are exploring foreign currency earnings means other than coal export and tightening approvals for coalmine development. As Japan, a major coal export destination for Australia, is reducing coal-fired power generation, investments in coalmine will be discouraged even further. As such, no substantial increase in Australian coal supply is expected. In South Africa and Colombia that have served as coal supply sources for Europe and the United States, companies from Advanced Economies will accelerate their withdrawal from coal production. The two countries may reduce coal production over the medium to long term, while maintaining production for exports to the Asian market. Other Emerging Market Economies will lack official support from development or export-import banks in Advanced Economies, failing to become alternatives for expanding or diversifying coal supply.

Meanwhile, China and India have rapidly constructed coal-fired power plants to consume their domestic coal resources. In the future, they will maintain supply from domestic coalmines and use imported coal in their coastal zones in a manner to remain major coal buyers in the

international market. Indonesia, a major coal exporter, will maintain high-level production and expand exports to China and Viet Nam. It will also enhance supply for domestic consumers.

While coal supply flexibility declines with coal production limited to a small number of countries, demand will remain uncertain. The Chinese government has vowed to peak out its CO_2 emissions by 2030. If China takes drastic policies to cut coal consumption toward the emission reduction goal, it will have great impacts on the global coal supply-demand balance and international coal phaseout initiatives. Given the current massive coal supply and demand, as well as long-term carbon neutrality goals through 2060 or later in Emerging Market Economies and Russia, however, global coal phaseout will take a long time, with coal production remaining high, if demand in China is maintained to a certain extent. Nevertheless, investment in coalmine development or expansion will fail to make progress in the coal market plagued with great uncertainties. Global coal production will remain almost unchanged from 7 960 Mt in 2019 or decrease slowly until 2040. Later, coal production will decline faster and fall to 7 482 Mt in 2050 (Figure 3-11).

Figure 3-11 | Global coal production [Reference Scenario]



Steam coal production will increase from 6 173 Mt in 2019 to 6 390 Mt in 2040 in line with growth in demand for coal for power generation, but peak around 2040. Meanwhile, coking coal production mainly for steelmaking will decline from 1 050 Mt in 2019 to around 800 Mt in 2040. Demand for lignite that is produced and consumed in the same regions will decrease in major lignite-producing and -consuming countries such as Germany, Poland and Thailand. Lignite production will gradually decrease from 738 Mt in 2019 to 568 Mt in 2050 in line with the dismantlement of existing lignite-fired power plants.

Among major coal exporters, Australia, Russia and Africa will expand coal production in response to coal market growth mainly in Asia, with coal trade (exports) increasing from 1 434 Mt in 2019 to 1 551 Mt in 2050. Russia, while losing the European market, will prioritise exports to Asia. In line with the development of coal transportation infrastructure, Russia will

boost coal production from 358 Mt in 2019 to more than 400 Mt in 2050 while expanding exports.

Table 3-2 | Steam coal production [Reference Scenario]

(Mt)

	2019	2030	2040	2050	2019-2050	
					Changes	CAGR
World	6 173	6 373	6 390	6 061	-111	-0.1%
North America	544	379	300	207	-337	-3.1%
United States	528	370	294	201	-327	-3.1%
Latin America	90	82	90	88	-3	-0.1%
Colombia	79	70	78	76	-3	-0.1%
OECD Europe	56	48	45	41	-15	-1.0%
Non-OECD Europe/Eurasia	378	348	398	432	54	0.4%
Russia	261	244	277	305	45	0.5%
Middle East	0	0	0	0	0	0.0%
Africa	266	277	306	313	47	0.5%
South Africa	255	263	287	291	36	0.4%
Asia	4 565	4 954	4 943	4 674	109	0.1%
China	3 186	3 223	2 901	2 454	-732	-0.8%
India	684	968	1 271	1 449	765	2.5%
Indonesia	595	643	639	632	37	0.2%
Oceania	273	285	309	307	34	0.4%
Australia	271	284	308	306	34	0.4%

Table 3-3 | Coking coal production [Reference Scenario]

(Mt)

	2019	2030	2040	2050	2019-2050	
					Changes	CAGR
World	1 050	904	869	852	-198	-0.7%
North America	95	86	85	83	-12	-0.4%
United States	65	57	56	54	-11	-0.6%
Latin America	9	10	11	11	3	0.9%
Colombia	5	6	7	7	2	0.9%
OECD Europe	15	13	13	13	-3	-0.7%
Non-OECD Europe/Eurasia	107	103	104	106	-1	0.0%
Russia	97	93	94	95	-2	-0.1%
Middle East	1	2	2	2	0	0.7%
Africa	9	15	22	30	20	3.8%
Mozambique	3	3	4	4	1	0.9%
Asia	623	500	435	390	-233	-1.5%
China	539	400	303	224	-315	-2.8%
India	49	73	100	130	81	3.2%
Mongolia	6	7	11	18	12	3.7%
Oceania	190	177	198	217	27	0.4%
Australia	189	176	197	216	27	0.4%

Figure 3-12 | Global coal trade (import volume) [Reference Scenario]

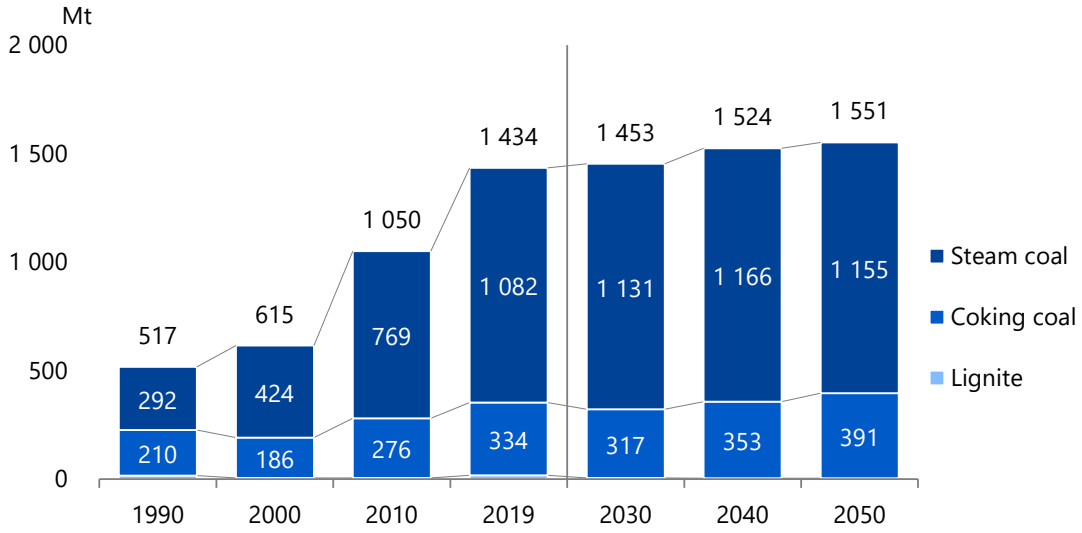
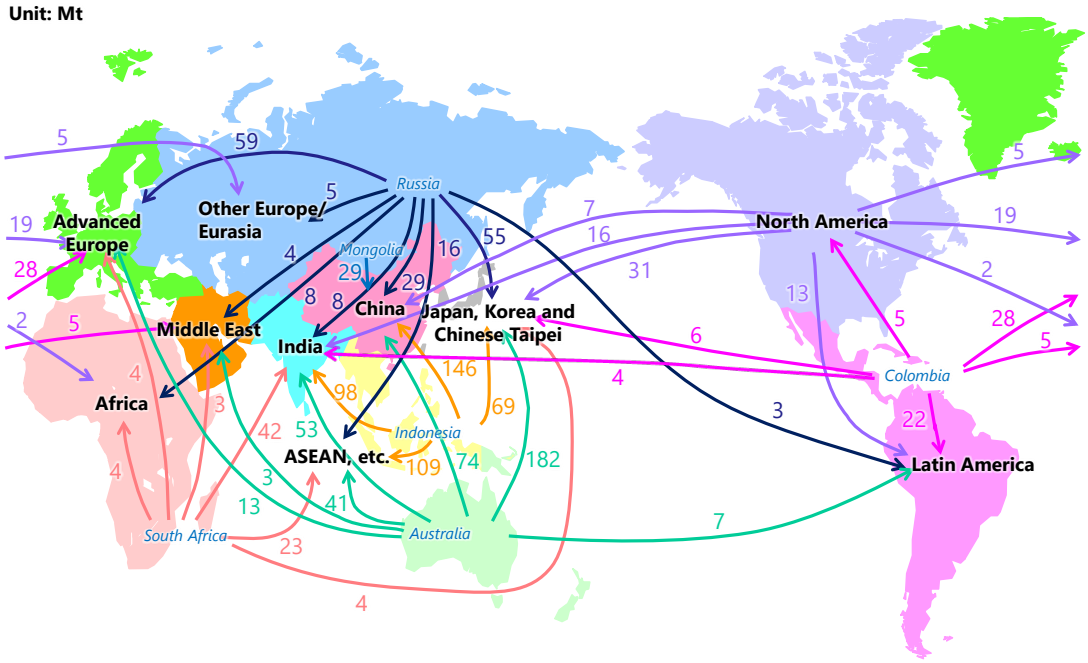
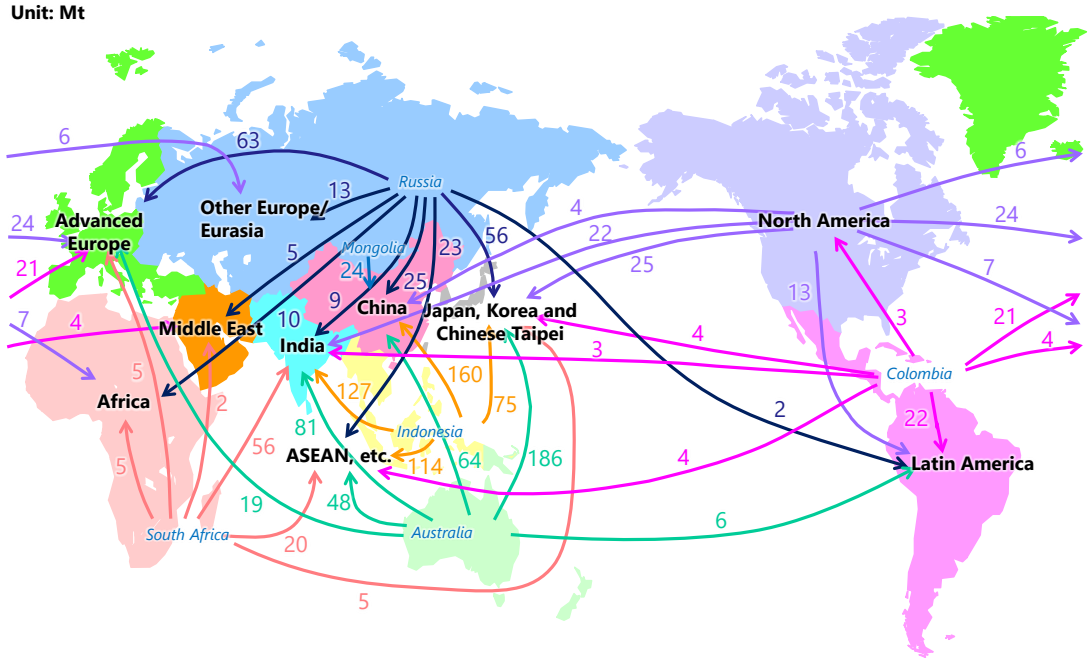


Figure 3-13 | Major interregional coal trade flows [2020]



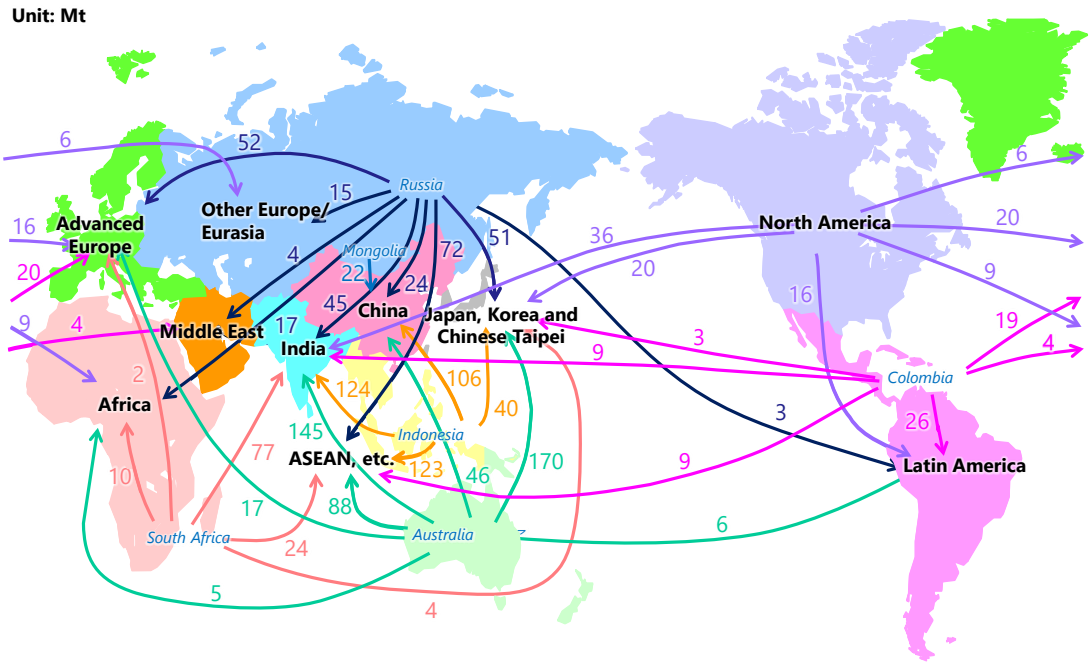
Note: Trade volume covers steam and coking coal. Estimated imports totalling 2 Mt or more are specified. Mozambique is included into South Africa.
Sources: Estimated based on IEA "Coal Information 2020," TEX Report, etc.

Figure 3-14 | Major interregional coal trade flows [Reference Scenario, 2030]



Note: Trade volume covers steam and coking coal. Estimated imports totalling 2 Mt or more are specified. Mozambique is included into South Africa.

Figure 3-15 | Major interregional coal trade flows [Reference Scenario, 2050]



Note: Trade volume covers steam and coking coal. Estimated imports totalling 2 Mt or more are specified. Mozambique is included into South Africa.

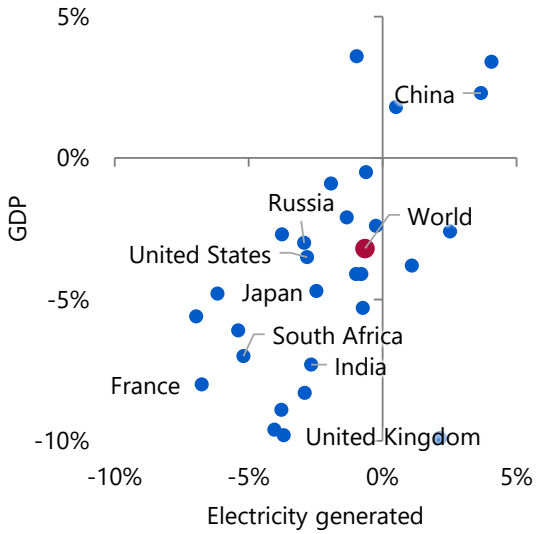
3.4 Power generation

Recent trends

Power generation declined under COVID-19

In 2020, global power generation decreased by 0.9% from the previous year under the economic impacts of the COVID-19 spread[4]. Global power generation thus turned down for the first time in 10 years after growing at an annual rate of 2.9% since 2010. While residential electricity demand increased due to a decrease in the going-out frequency that accompanied telework, demand in the commercial, industry and transport sectors decreased dramatically. The International Monetary Fund (IMF) reported that global GDP contracted by 3.2%[5] during 2020, indicating that the economic contraction affected power generation (Figure 3-16).

Figure 3-16 | GDP growth and year-on-year power generation changes [2020]



Even amid a decline in electricity demand, renewable energy power generation continued expanding, scoring a 6% year-on-year rise in 2020. Thermal power generation decreased, with natural gas-fired power generation falling by 0.9%, oil-fired power generation by 7.6% and coal-fired power generation by 4.1%. Coal's share of the power generation mix hit a record low of 35.1%. In the OECD countries, the sluggish demand was coupled with growing coal phaseout initiatives to drive down coal-fired power generation by 15.6%.

Winter power supply-demand balances tightened in Japan and the United States

In the beginning of 2021, severe cold waves hit Northeast Asia and the United States, leading their power supply-demand balances to tighten.

In January 2021, Japan plagued with cold waves recorded the largest electricity demand in a decade. The supply-demand balance in the Asian LNG market tightened remarkably as cold waves and demand growth, amid an economic recovery, coincided with supply troubles in

[4] BP, Statistical Review of World Energy (2021)

[5] International Monetary Fund, World Economic Outlook (July 2021)

Australia and the United States. As a result, spot LNG prices shot up temporarily above $30/MBtu, forcing Japan's power supply-demand balance to tighten greatly. While no power outage was experienced, electric utilities urged consumers to save electricity consumption. Spot electricity prices on the Japan Electric Power eXchange hit a record JPY251/kWh. The recent spate of coal- and oil-fired power plant shutdowns and a solar photovoltaic power generation decline under bad weather also contributed to the tighter power supply-demand balance.

In Texas in February 2021, electricity demand growth under record cold waves was combined with the freezing of wind turbines and natural gas supply plant shutdowns to tighten the power supply-demand balance, leading to blackouts for 4 993 thousand households accounting for 27% of households in the state. Coal-fired power generation capacity in Texas declined year by year, forcing the state to lose its resistance to power supply troubles for gas-fired and wind power plants as a major power source.

Rapid electricity demand growth under severe cold waves triggered the tightening of power supply-demand balances in Japan and the United States, but other background factors also contributed to the tightening. They include fuel supply troubles for gas-fired power plants, a fall in variable renewable energy power generation and a decline in dispatch power sources such as coal-fired power plants. The Japanese and U.S. incidents indicated the need for securing stable power supply in the course of low-carbonisation and decarbonisation of power sources.

Outlook

Power generation will rapidly increase in Asia

Over the long term, electricity consumption will restore an uptrend as the global economy recovers from the COVID-19 damage. Global electricity generated will increase at an annual rate of 1.7% to 44 376 terawatt-hours (TWh) in 2050, a 1.7-fold rise from the current level (Figure 3-17). The growth of 18 508 TWh through 2050 is 2.3 times as much as the current electricity generated in China, the largest power generator in the world. Of the growth, the Emerging Market and Developing Economies will account for 95%. Electricity generated in rapidly growing Asia will expand at an annual rate of 1.9% from 12 432 TWh in 2019 to 22 124 TWh in 2050, accounting for more than a half of the global total (Figure 3-18).

Figure 3-17 | Global electricity generated and final consumption of electricity [Reference Scenario]

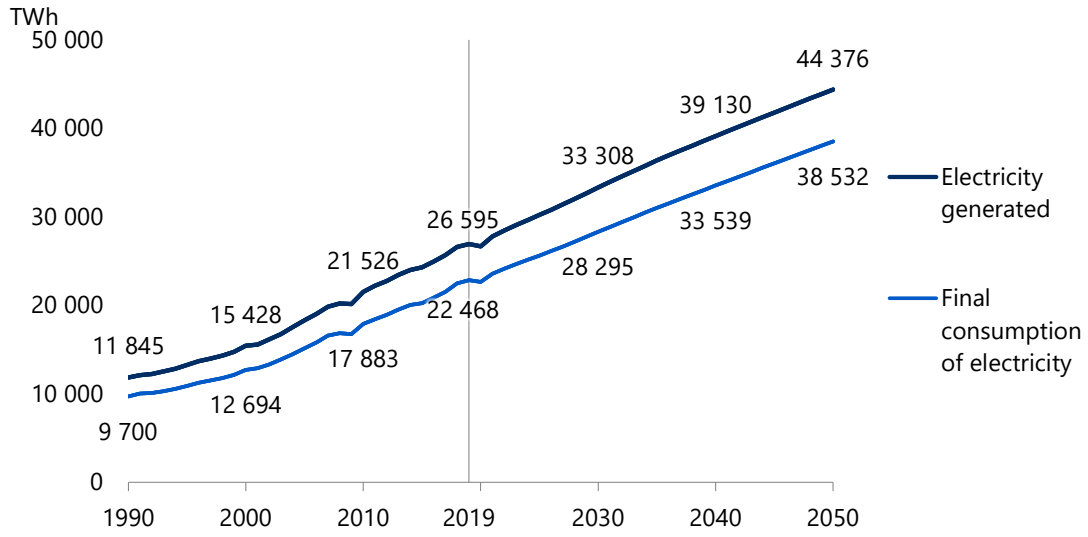
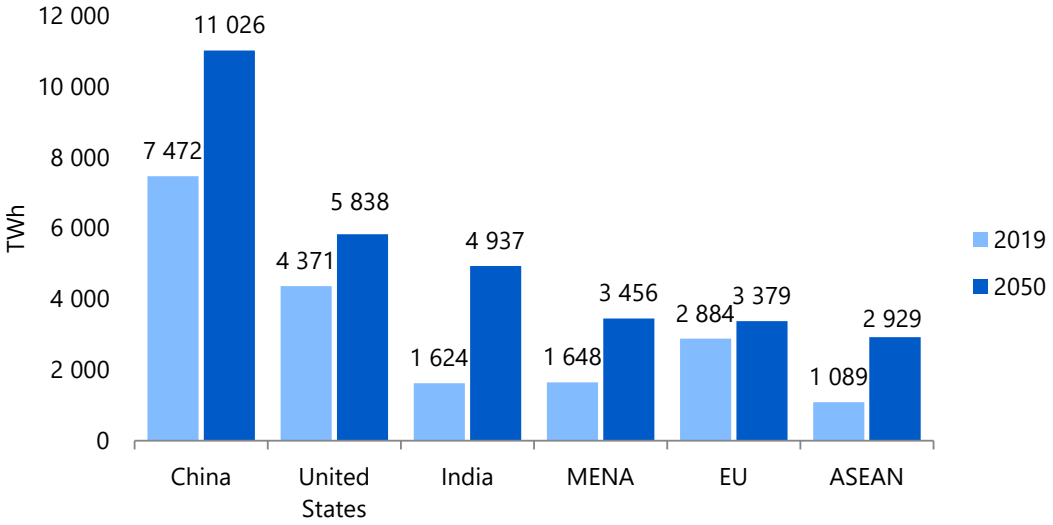


Figure 3-18 | Electricity generated in selected countries/regions [Reference Scenario]

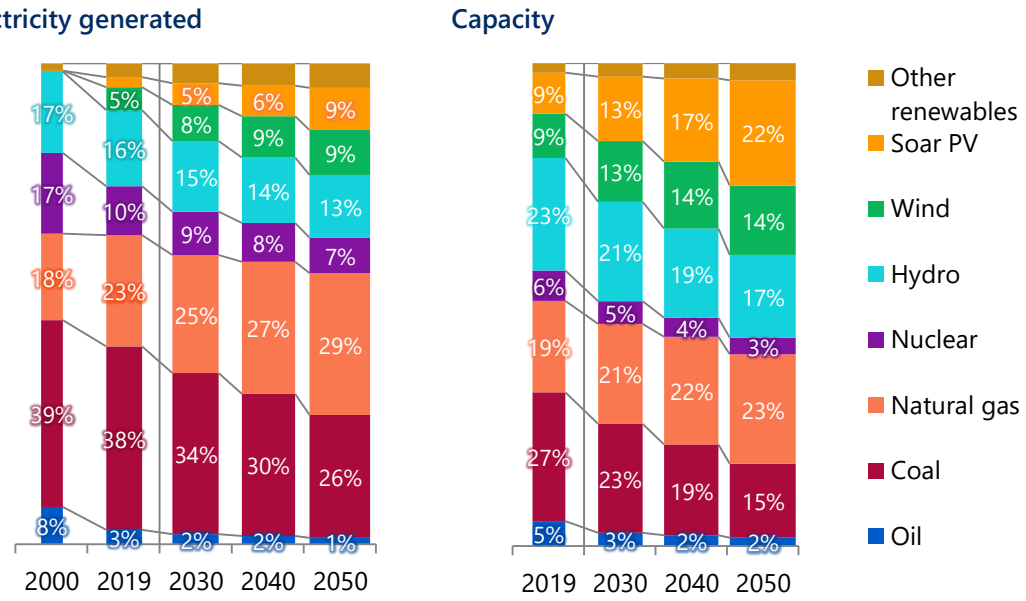


Power generation mix: Natural gas will become the largest power source

Coal now accounts for the largest share of the global power generation mix, but natural gas will replace coal as the largest power source by 2050 (Figure 3-19). Natural gas will continue to serve as a middle and peak power source. Its role in balancing the power supply-demand will become even more important as variable renewable power generation expands. Advanced Economies such as Italy, Canada, the United Kingdom, France and Germany have announced plans to phase out coal-fired power generation. In Emerging Market Economies, coal will lose its share to natural gas but continue to serve as a baseload power source. Oil's share of the

power generation mix will follow a downtrend not only in Advanced Economies but also in others, including the oil-rich Middle East.

Figure 3-19 | Global power generation mix [Reference Scenario]



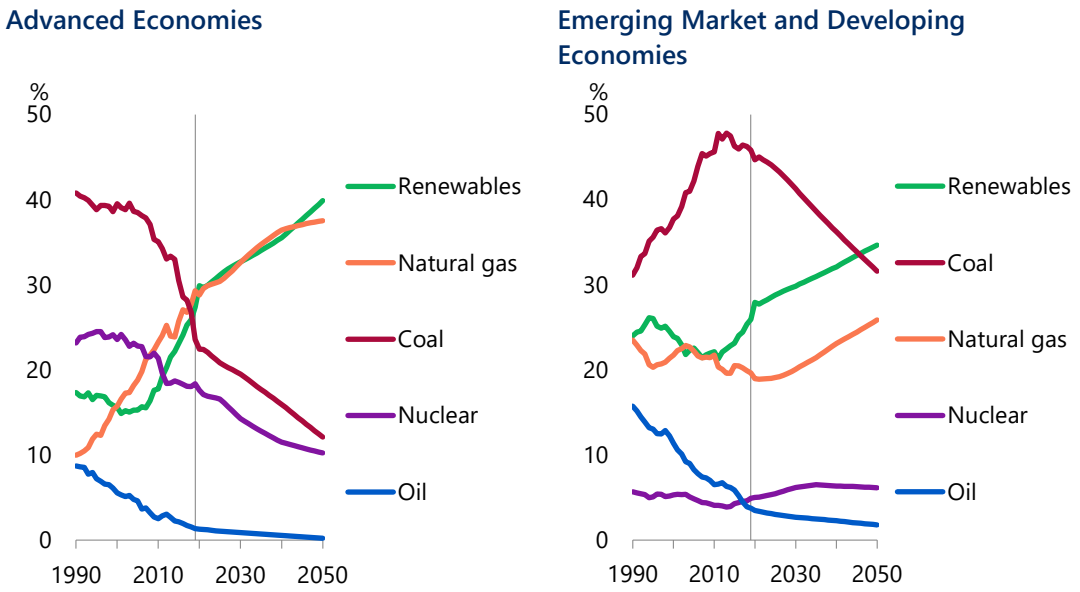
Note: Bar widths are proportionate to total electricity generated.

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

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, leading the nuclear share of electricity generated to fall to 7% in 2050. Wind, solar, geothermal and other renewable energy generation, excluding hydro, will expand at a rapid annual rate of 5% on the strength of policy support and cost reduction, boosting its share in power generation mix to 23% in 2050.

In the Advanced Economies, renewable energy will raise its share of total electricity generated to 33% in 2030 and to 40% in 2050, replacing natural gas as the largest electricity source (Figure 3-20). Solar photovoltaic and wind among renewables will account for 21% of total electricity generated, requiring each economy to promote adjustments for output fluctuations and expand grid networks between suitable power generation sites and consumption areas. Coal's share, now the largest, will substantially decline to 12%, half of the current share, in 2050 under a policy of shifting away from coal-fired power generation in such countries as Canada and Italy and financial institutions' policy of refraining from making investment in and providing loans to coal-fired power generation projects.

Figure 3-20 | Power generation mix in Advanced Economies and in Emerging Market and Developing Economies [Reference Scenario]

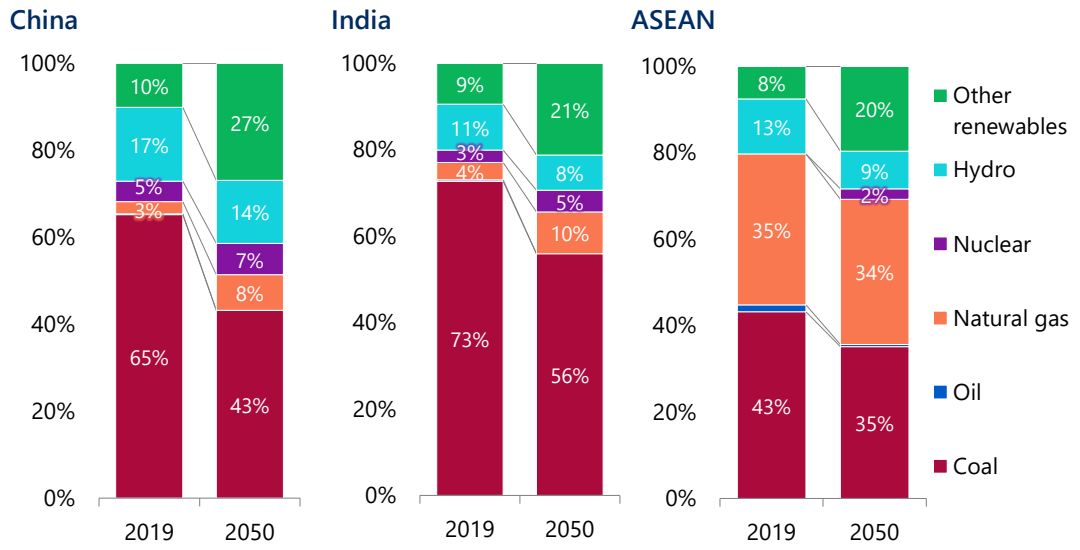


In the Emerging Market and Developing Economies as well, renewables including wind will increase and replace coal as the largest power source by 2050. The coal share, though falling, will remain the largest until 2040. As coal-fired power plants play a great role in supporting robust electricity demand, the development of a highly predictable investment environment and solutions to air pollution and other environmental problems will be urgently required. The natural gas share will increase both in the Advanced Economies and the Emerging Market and Developing Economies.

Coal will lower its power generation mix share but remain the largest power source in Asia. How to address environmental problems will be a challenge

In Asia including China and India, coal will remain a mainstay electricity source in response to the rapid electricity demand growth. However, its share of the power generation mix will fall gradually against the backdrop of air pollution and climate change countermeasures (Figure 3-12). Instead, renewable energy and natural gas will expand their shares. In ASEAN, meanwhile, natural gas's share of the power generation mix will remain unchanged despite an increase in electricity generated from natural gas. Coal-fired power generation trends will differ by country. In India, coal will still account for half the total power generation, even in 2050. In China, the coal's share of the power generation mix will decline under the national policy of spreading renewables. The coal's share will also decrease in ASEAN, influenced by a growing public opinion against coal-fired power generation in Thailand and Viet Nam. ASEAN will expand natural gas and renewable power generation capacity to meet electricity demand growth.

Figure 3-21 | Chinese, Indian and ASEAN power generation mix [Reference Scenario]

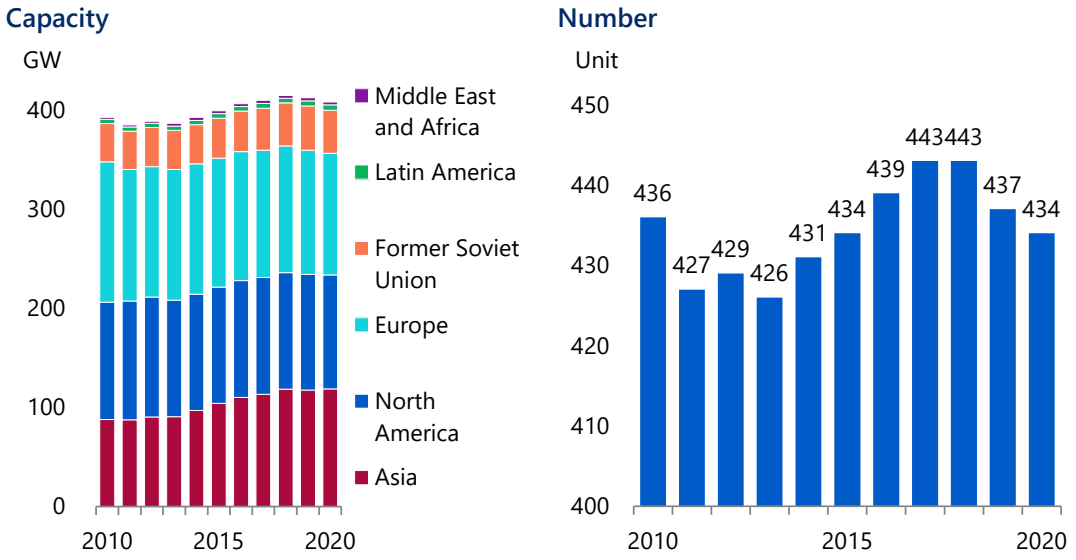


Nuclear

Nuclear power generation capacity declined for the second straight year. How will Europe and the United States respond to robust expansion in China and Russia?

Global installed nuclear power generation capacity and the number of nuclear reactors in the world continued to increase from 2014 to 2018 but declined in 2019 and 2020 (Figure 3-22). The two-year consecutive decrease came as five reactors were closed in Japan in 2019, two in the United States, two in France, one in Russia and one in Sweden in 2020. In contrast, China and Russia have promoted new nuclear power plant construction relatively smoothly. In 2020, one reactor entered commercial operation in China and two in Russia. The two new Russian reactors, though with their capacity limited to 70 MW (35 MW each), constitute the world's first floating nuclear power stations using nuclear-powered submarine technology. Russia is expected to take advantage of the technology to explore new demand for nuclear reactors including those in remote regions where it has been difficult to introduce traditional nuclear reactors. Russia has already expanded nuclear power plant exports robustly and Russian nuclear reactors are under construction in such countries as Belarus, Turkey, Iran, India and Bangladesh. In addition, Russian firms are expected to construct new reactors planned in China and Finland. Meanwhile, new nuclear power plant construction projects have been postponed or frozen in Europe and the United States, indicating that they are urgently required to reform fundraising and project management arrangements.

Figure 3-22 | Capacity and number of nuclear reactors



While new nuclear power plant construction projects have failed to make progress in countries other than a few, Europe and the United States are trying to effectively use existing nuclear reactors. In the United States, many reactors have operated for more than 40 years and been allowed by the Nuclear Regulatory Commission (NRC) to operate for 20 more years (a total of 60 years). Some reactors have been subjected to the second license renewal approval to operate for a total of 80 years. In France as well, the Nuclear Safety Authority known as ASN has clarified rules for the extended operation of nuclear reactors that have operated for more than 40 years, paving the way for reactors to operate longer.

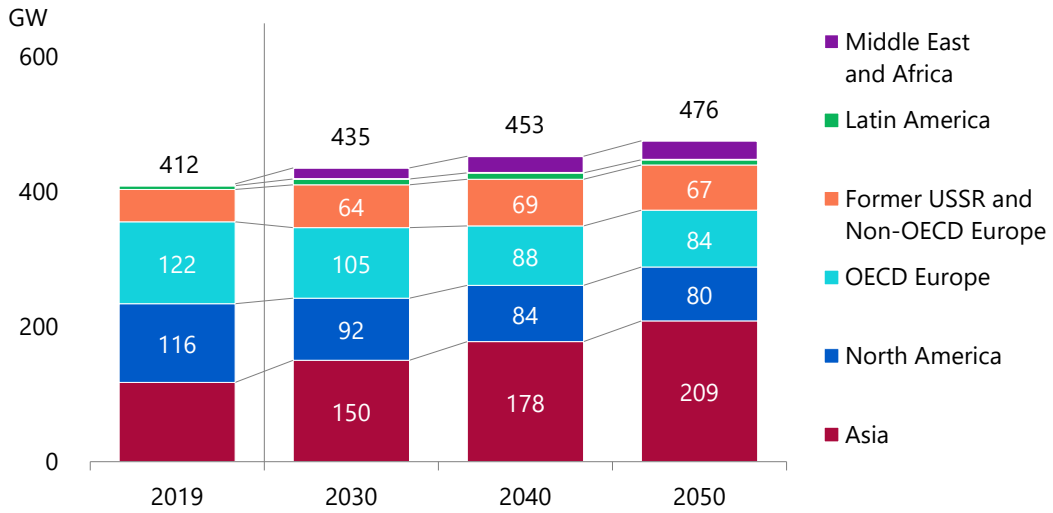
Progress has been seen in the development of new nuclear reactors such as small modular reactors (SMRs) and fourth generation reactors that have attracted attention over recent years. In the United States, the NRC completed the review of the design certification application for NuScale Power's SMR in August 2020, approving the safety aspects of the NuScale design. The United Kingdom announced that advanced modular reactors adopting SMR and fourth generation reactor technologies would be subjected to the design review process. Such regulatory progress is important for introducing new technologies into society.

Outlook: Nuclear reactors will increase in Asia and continue to be used as a key low-carbon, stable power source in Europe and the United States

As the Fukushima Daiichi Nuclear Power Station accident has triggered changes in the public opinion about nuclear power plants, some nuclear power plant construction knowhow has been lost during the long absence of such construction. It is now difficult for Japan, Korea, the United States and some European countries to construct new nuclear reactors as earlier planned. As existing reactors built in the 1970s or 1980s are closing, nuclear power generation may decrease in many countries. Given that competitive nuclear reactors are important business resources for electric power companies, however, these countries will maintain nuclear power generation to some extent. In contrast, multiple countries including China are

planning to further promote nuclear energy. Middle Eastern and some other countries may start nuclear power generation in the future. Therefore, global installed nuclear power generation capacity will gradually increase through 2050 (Figure 3-23).

Figure 3-23 | Nuclear power generation capacity [Reference Scenario]



The United States, though being the world's largest nuclear power generating country with 94 reactors, includes states where decisions have come to close existing reactors earlier than planned for economic reasons. Under electricity market liberalisation, the nuclear power plants are exposed to competition from low-cost natural gas-fired and renewable energy power plants. Although the installed nuclear power generation capacity will decrease through 2050, the United States will make no change to its policy of positioning nuclear as an important energy source. Its new Biden administration is seeking to realise net-zero GHG emissions by 2050, recognising the significance of nuclear power generation as one of the means to do so. Both Democrats and Republicans have admitted the importance of nuclear energy, indicating that the United States has a low risk of changing its nuclear business policy. In such situation, decisions to extend the lifespan of nuclear power plants and construct new ones will be made, depending on electricity market conditions and the investment climate. Some states plan to take measures to avoid any early closure of existing nuclear reactors.

In France, known as the largest nuclear energy promoter in Europe, the Energy Transition Law, enacted in July 2015, aimed at reducing the nuclear share of power generation to 50% by 2025 (from around 75% in 2015). In view of a GHG emission reduction goal, however, France has concluded the attainment of the nuclear share reduction target as difficult and decided to extend the target year to 2035. Therefore, France may maintain the present nuclear power generation capacity or slightly reduce the capacity for the immediate future as the closure of some reactors coincides with the construction of new ones. From 2040, the decommissioning of existing reactors will accelerate, reducing the total nuclear capacity substantially. As noted above, however, initiatives have been taken to pave the way for reactors to operate longer. Electric utilities will consider the balance between nuclear and renewable energy power generation and maintain nuclear power generation capacity provided profitability is secured.

Although the government has indicated a policy of maintaining nuclear power, the United Kingdom installed nuclear power generation capacity will decline until around 2030 due to the decommissioning of outdated reactors. While the Horizon nuclear power plant construction project has been aborted, new projects have been proposed, with efforts seen to secure some nuclear power generation capacity in the future. Thanks to such efforts, nuclear power generation capacity may rise back close to the current level around 2040.

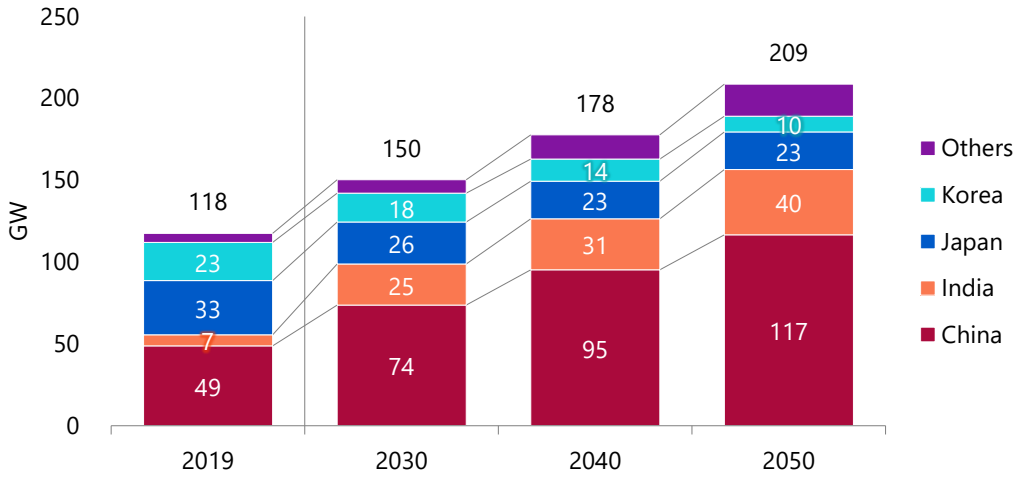
Germany, Switzerland and Belgium have made clear their nuclear phase-out plans in response to the Fukushima Daiichi accident and will eliminate nuclear power generation between 2025 and around 2035 under government plans. Other OECD European countries will reduce their capacity through 2050, despite some moves to construct new capacity, as unprofitable reactors are decommissioned.

Russia has vowed to proactively use nuclear energy at home and abroad. Its domestic installed nuclear power generation capacity will increase from 29 GW in 2020 to 45 GW in 2035. Around 2030, Russia will replace Japan as the world's fourth largest nuclear power generation capacity owner. Given its proactive nuclear reactor exports, its presence in the global nuclear energy market will be greater than indicated by its domestic capacity. Russia has not only promoted the use of its existing large light-water reactors but also introduced the world's first floating nuclear power station as noted above. In addition, it began to construct a demonstration version of a lead-cooled fast reactor in June 2021. It is important to possess a wide range of technologies to enhance the infrastructure of the nuclear energy industry.

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 the region's installed nuclear power generation capacity to 22 GW in 2050. In Latin America, mainly Brazil and Argentina are planning to introduce nuclear power generation to meet domestic electricity demand growth and will construct a few nuclear power plants.

Asia, including China and India, will increase its presence in nuclear power generation more and more because nuclear energy is low-carbon and a stable power source for rapidly growing Asian Emerging Market Economies. China will boost its installed nuclear power generation capacity to 95 GW in 2040, replacing the United States as the largest nuclear power generator in the world (Figure 3-24). Asian installed nuclear power generation capacity will surpass the combined OECD Europe and North American capacity in 2040, reaching 209 GW in 2050. China and India will account for more than 70% of the Asian capacity.

Figure 3-24 | Asian nuclear power generation capacity [Reference Scenario]

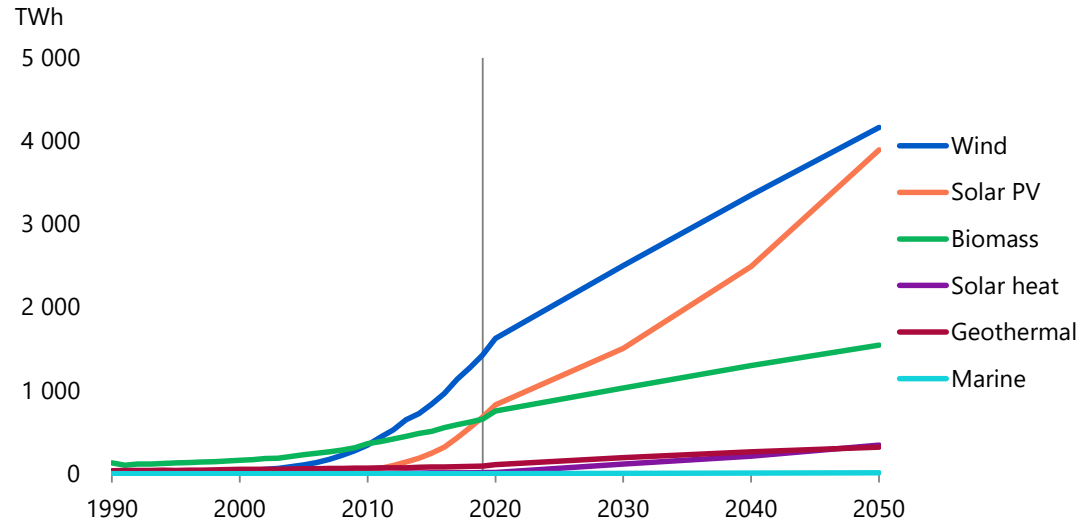


Renewables

Great hopes are globally placed on renewable energy. Since the mid-2000s, variable renewable energy power sources such as solar PV and wind have remarkably increased due to cost drops as well as incentive policies mainly in major European countries, Japan, the United States and China. As the economic efficiency of renewable energy power generation has improved, governments have accelerated efforts to modify or scale down their incentive policies for wind and solar PV power generation in recent years. Meanwhile, many countries have come up with the promotion of green energy investment as part of post-COVID-19 economic recovery measures. At the same time, the number of economies committing to long-term carbon neutrality goals has increased, paving the way for the further diffusion of renewables.

Electricity generated from variable renewables will increase from 2 123 TWh in 2019 to 8 409 TWh in 2050 (Figure 3-25). Variable renewables will boost their share of global power generation from only 8% in 2019 to 19% in 2050, increasing their presence in the electricity system.

Figure 3-25 | Global renewable power generation except hydro [Reference Scenario]



Europe, China and North America are major wind power generation markets at present and will continuously drive global wind power generation growth (Figure 3-26). While the growth in onshore wind power generation capacity decelerates, due to transmission line constraints and a decline in suitable onshore locations for development, offshore wind power generation will take advantage of its increasing economic efficiency to expand overall wind power generation in these regions. Installed wind power generation capacity in the world increased from 3 GW in 2010 to 23 GW in 2018[6]. Europe is the world's most mature offshore wind power generation market, with supply chains developed for offshore wind farms. In recent years, bids have been invited for unsubsidised offshore wind power generation projects, with successful bidders' electricity sales prices falling close to $50/MWh (for projects to launch power generation in or after 2025). In the United States, many offshore wind power generation projects are being implemented. Furthermore, the Biden Administration in March 2021 announced a plan to expand offshore wind power generation capacity to 30 GW by 2030. Attracting attention in Asia is the rapid growth in offshore wind power generation markets in China, Chinese Taipei, Korea and Viet Nam. In Japan, the development of offshore projects has been activated with the passage of the Maritime renewable energy resources act[7] in April 2019. The government is proactively supporting the expansion of offshore wind power generation and the development of relevant domestic supply chains. Global installed wind power generation capacity will more than triple from 622 GW in 2019 to 1 981 GW in 2050.

[6] International Energy Agency (IEA), *Offshore Wind Outlook 2019*, 2019, https://www.iea.org/reports/offshore-wind-outlook-2019

[7] Act on Promoting the Utilization of Sea Areas for the Development of Marine Renewable Energy Power Generation Facilities

Figure 3-26 | Global wind power generation capacity [Reference Scenario]

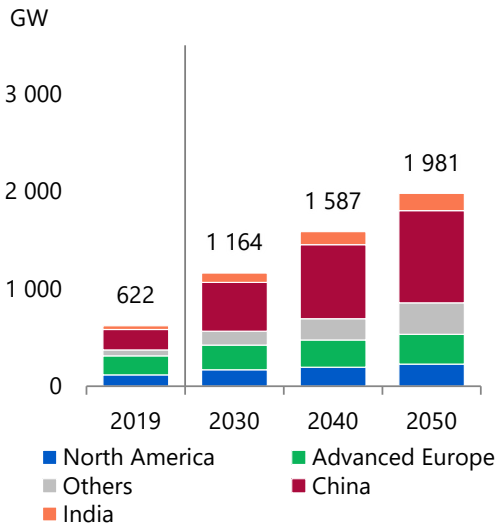
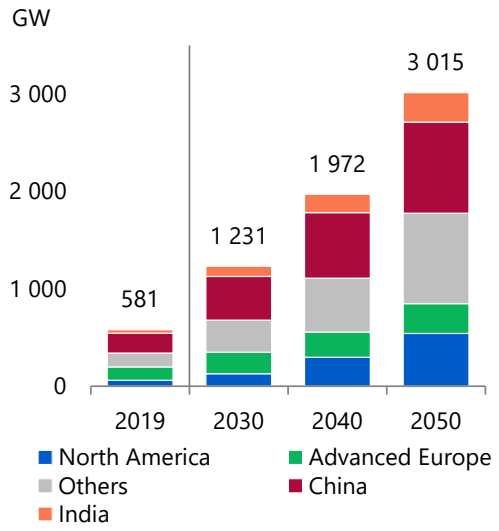


Figure 3-27 | Global solar PV power generation capacity [Reference Scenario]



Solar PV power generation has spread from Europe, the United States, China and Japan with robust subsidisation policies to the rest of the world, thanks to substantial cost drops (Figure 3-27). In large-scale solar PV auctions in Chile, the United Arab Emirates, Saudi Arabia and other countries rich with solar radiation, bid prices of less than $30/MWh have been recorded. Costs for distributed solar PV power generation systems installed at urban housing and commercial facilities have fallen to grid parity levels, competing with electricity retail prices. Solar PV power generation is expected to grow even more competitive and global installed solar PV generation capacity will expand more than five-fold from 581 GW in 2019 to 3 015 GW in 2050. As costs fall continuously over the long term, net capacity growth will accelerate in the second half of the outlook period, reaching 1 043 GW between 2040 and 2050.

Renewable energy will reduce carbon emissions from power supply, lower the dependence on foreign energy sources and improve the resilience of energy systems, leading renewable energy power generation capacity to increase robustly. Given that the electrification of final energy demand will make further progress to realise long-term climate change targets, the low carbonisation of electricity sources will grow even more important. Renewable energy power generation must diffuse more than assumed in the Reference Scenario. As the world becomes more conscious of climate change countermeasures, a rising number of companies have committed to covering 100% of their power consumption with renewable energy, supporting the expansion of renewables. At a time when renewable energy power generation is growing more independent, the need is increasing for replacing feed-in tariff schemes and other renewable energy subsidisation policies with systems and markets that would allow consumers to sign direct power purchase agreements with power generators. Renewables' harmony with energy and social systems will also become a key challenge. For such harmony, variable renewables should be coupled with technologies and institutions for integrating them into the electricity system. Policy guidance should be promoted for developing projects to benefit communities that accept renewable energy power generation facilities. Offshore wind

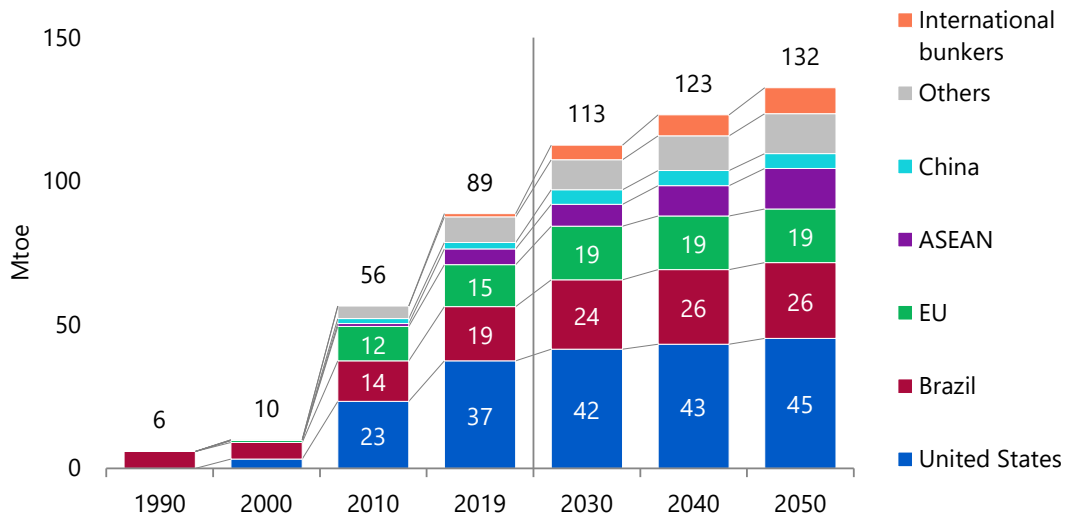
and geothermal power generation should be associated with environmental protection and career training to promote employment for renewable energy.

3.5 Biofuels for transport

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 EU, which accounted for nearly 80% of global biofuel consumption at 78 million tonnes of oil equivalent in 2019.

While biofuel consumption has substantially increased since the 1990s, biofuel investment has remained stagnant since 2010. Due to a plunge in automobile fuel consumption under the impact of the COVID-19 pandemic, biofuel consumption in 2020 might have declined from the previous year. Over the long term, biofuel consumption will recover as climate change countermeasures are enhanced. The biofuel demand growth, however, will decelerate since vehicles are electrified further. Despite the consumption growth deceleration, biofuel consumption for vehicles will increase to 130 Mtoe in 2050 and consumption for automobiles will remain concentrated in the United States, Brazil and the EU (Figure 3-28). As concerns grow over first-generation biofuels' environmental impact and their competition with food production, initiatives will be enhanced to develop and cut costs for next-generation biofuels including cellulosic and algae-derived fuels. Although ASEAN will sharply boost biofuel demand, Asian biofuel consumption will fall short of rivalling European, U.S. or Brazilian levels. Biofuel consumption for international aviation and shipping, which is little at present, will expand in the future.

Figure 3-28 | Biofuel consumption for transport [Reference Scenario]



4. Advanced Technologies Scenario

4.1 Major measures

In the Advanced Technologies Scenario, measures to maximise carbon dioxide (CO_2) emission reduction will be implemented with consideration given to their application opportunities and acceptability to society. Each country will strongly implement aggressive energy conservation and decarbonisation policies that contribute to securing stable energy supply, enhancing climate change measures, and accelerating the development and introduction of innovative technologies globally. Supported by the introduction of environmental regulations and national targets, by the enhancement of technological development and by the promotion of international technological cooperation, the demand side will strongly diffuse energy efficient equipment and the supply side will further promote renewable and nuclear energy (Table 4-1).

Table 4-1 | Assumed technologies [Advanced Technologies Scenario]

2019 → 2050 (Reference Scenario, 2050)

	Advanced Economies	Emerging Market and Developing Economies
Thermal power generation	Developing an initial investment finance scheme	
	Installing CCS for new plants from 2030 (Countries with carbon storage potential excluding aquifers)	
[Natural gas-fired efficiency (stock basis)]	50.0% → 63.0% (60.4%)	37.9% → 54.9% (48.2%)
[Coal-fired efficiency (stock basis)]	37.4% → 42.5% (44.5%)	34.1% → 38.6% (39.2%)
[IGCC share of newly installed plants]	0% → 60% (20%)	
Nuclear power generation	Maintaining appropriate wholesale power prices	Developing an initial investment finance framework
[Capacity]	2019: 302 GW → 306 (197)	2019: 110 GW → 470 (279)
Renewables power generation	System cost reduction	System cost reduction
	Grid stabilisation technology cost reduction	Low-cost finance
	Efficient grid operation	Advancing power systems
[Wind capacity]	328 GW → 1 075 (613)	294 GW → 2 814 (1 369)
[Solar PV capacity]	289 GW → 2 058 (1 084)	291 GW → 3 369 (1 931)
Biofuels for automobiles	Developing next-generation biofuels	Biofuel cost reduction
	Diffusing flexible-fuel vehicles further	Agricultural policy position
[Consumption]	59 Mtoe → 111 (70)	36 Mtoe → 88 (61)

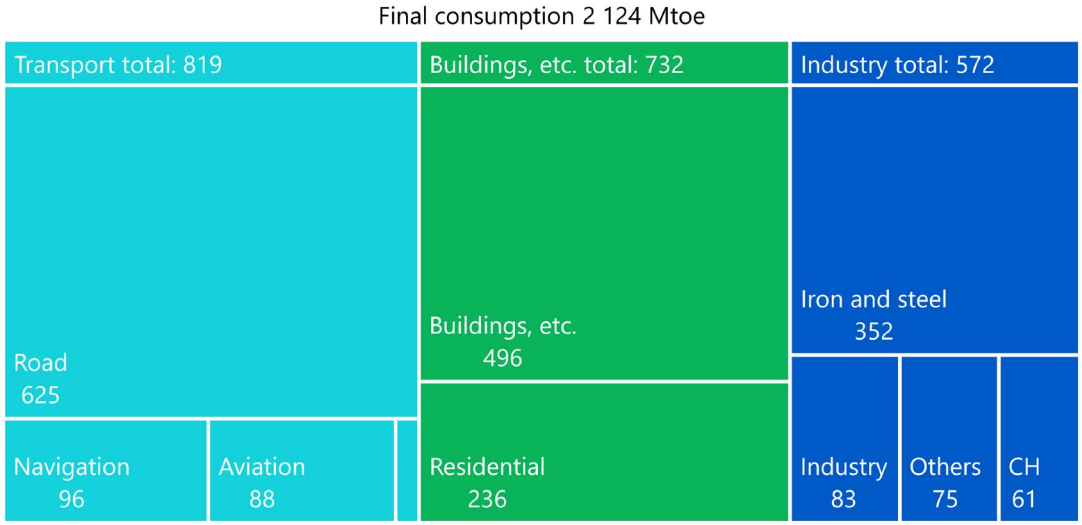
2019 → 2050 (Reference Scenario, 2050)

	Advanced Economies	Emerging Market and Developing Economies
Industry	Full diffusion of best available technologies in 2050	
Transport	Reducing fuel-efficient vehicle costs Doubling zero-emission vehicle (ZEV) travel distances	
[New passenger car fuel efficiency]	15.7 km/L → 50.0 (33.1)	13.6 km/L → 36.5 (24.0)
[ZEV share of new passenger car sales]	2.4% → 80% (52%)	1.8% → 60% (30%)
Buildings	Doubling the pace of improving new electrical appliance and insulation efficiency (an improvement of about 15% from the Reference Scenario in 2050) Electrifying space/water heating and cooking equipment, clean cooking	

Energy efficiency

Final energy consumption in 2050 in the Advanced Technologies Scenario will be 2 124 Mtoe less than in the Reference Scenario. The energy savings amount to 21% of global final energy consumption in 2019. Of the energy savings, the transport sector will account for 819 Mtoe, the buildings sector for 732 Mtoe and the industry sector for 572 Mtoe (Figure 4-1).

Figure 4-1 | Energy savings through technology development (compared with Reference Scenario) [Advanced Technologies Scenario, 2050]



Note: CH stands for chemical and petrochemical.

The road sector will be responsible for 625 Mtoe in the transport sector and the residential sector for 496 Mtoe in the buildings sector. This is because vehicles and home appliances offer

huge potential to improve energy efficiency. The Emerging Market and Developing Economies will capture more than 50% of the energy savings in all final energy consumption sectors, including the industry sector where they will account for 80% of energy savings. Whether or not the Emerging Market and Developing Economies would realise potential energy savings is key to global energy savings progress.

By using already available high-efficiency technologies for steel, cement, chemical, pulp and paper, and other energy-intensive industries, these industries will improve their energy intensity in 2050 by 15%-17% from the Reference Scenario (Table 4-2). Through the energy intensity improvement, the Emerging Market and Developing Economies' industry sector will reduce energy consumption by 457 Mtoe from the Reference Scenario. Asia, where basic materials industries account for a large share of production, will command 59% of the global energy savings. The introduction of highly efficient technologies will make great contributions to improving energy efficiency in the Emerging Market and Developing Economies. It is hoped that energy efficiency improvement technologies will be developed and proactively diffused globally including in the Emerging Market and Developing Economies.

Table 4-2 | Global energy indicators

		2019	2050 Reference	2050 Advanced Technologies
Industry	Intensities (2019 = 100)			
	Iron and steel	100	72.2	60.4
	Non-metallic minerals	100	82.1	68.7
	Chemical	100	79.4	66.4
	Paper and pulp	100	86.7	73.0
	Other industries	100	69.2	58.4
Transport	New passenger vehicle fuel efficiency (km/L)	14.4	25.9	39.2
	ZEVs' share of vehicle sales	1.5%	31%	57%
	Natural gas's share in intl. marine bunkers	0.1%	22%	43%
	Biofuel's share of intl. aviation bunkers	0.0%	3.8%	19%
Buildings, etc.	Overall energy efficiency (2019 = 100)			
	Residential	100	63.6	49.7
	Commercial	100	50.6	43.7
	Electrification rate			
	Residential	25%	41%	51%
	Commercial	54%	69%	76%

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

In the transport sector, fuel efficiency and vehicle fleet mix improvements will make further progress. In addition to hybrid vehicles, electric, plug-in hybrid and fuel cell vehicles will diffuse further. These zero emission vehicles (ZEVs) will expand their share of new vehicle sales in 2050 by 26 percentage points from the Reference Scenario. Due to fuel efficiency and vehicle fleet mix improvements, the global average new vehicle fuel efficiency in 2050 will improve by 13.3 km/L from the Reference Scenario to 39.2 km/L (2.6 L/100 km). The transport sector will post the largest energy savings among sectors in the Advanced Economies as ZEVs'

share of the vehicle fleet mix in those economies increases faster than in the Emerging Market and Developing Economies. 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 43% of international marine bunkers and biofuels for 19% of international aviation bunkers.

It is more difficult for energy conservation incentives to work in the buildings sector than in the industry sector that is highly conscious of energy conservation for economic reasons. Therefore, the buildings sector has great potential to save energy consumption. The overall global energy efficiency will improve by 22% from the Reference Scenario in the residential sector and by 14% in the commercial sector. Energy efficiency improvements for space and water heating systems in cold regions and insulation improvements in the Emerging Market and Developing Economies will make great contributions to saving energy. Since city gas, liquefied petroleum gas, kerosene 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. Traditional biomass consumption including inefficient fuel wood and manure will be reduced through the expansion of electrification and the diffusion of modern cooking equipment in rural areas. Electricity consumption will decline substantially as energy efficiency improvements in wide-ranging fields such as space cooling, powering and lighting more than offset the effect of the electrification of appliances.

Renewables

Major energy-consuming economies, including Europe, Japan, the United States and China, have remarkably expanded variable renewable power sources such as wind and solar PV. Recently, however, some economies have found power system operation challenges emerging from the time variability and uneven spatial distribution of these variable power sources. Challenges attributable to the time variability of wind and solar PV power generation include rapid output fluctuations (frequency fluctuations), surplus electricity, and cloudy and windless weather seen once or twice a year. Among challenges regarding uneven spatial distribution are power transmission capacity shortages. Other challenges include a grid inertia decrease accompanying an increase in asynchronous power sources[8], as well as impacts on natural environments, ecosystems and economic activities around renewable power source locations. Among such impacts are adverse effects of large-scale solar PV facilities on forest development, those of onshore wind power facilities on birds and those of offshore wind power generation on fishing. Technological, institutional and political measures are required to integrate variable renewable power sources into the electricity system.

The diffusion of variable renewable power sources is limited in most of the Emerging Market and Developing Economies. The abovementioned challenges are seen in regions where local power grids are relatively vulnerable. In Viet Nam, an electricity demand decline under the COVID-19 pandemic and rapid solar PV development have brought about surplus electricity and an overload on the grid system, forcing solar PV output to be suppressed. In South

[8] Synchronous power sources with rotation energy have the inertial force of rotating turbines, as well as a synchronising force that leads turbines to rotate at the same speed, contributing to stabilising the power grid. They include thermal, hydro and nuclear power generation. In contrast, asynchronous (inverter) power sources have no such function, including solar PV and wind power plants.

Sulawesi, Indonesia, 154 MW in wind power generation capacity has been introduced against less than 1 000 MW in electric load. South Sulawesi faces power supply overcapacity and is urgently required to address wind power generation.

In response to these challenges, the Advanced Technologies Scenario assumes progress in the commercialisation of technologies for integrating variable renewable power sources into the electricity system, including policy support for their diffusion with a growing environmental consciousness among business operators, investors and consumers. It also assumes an improved social acceptability of electricity infrastructure construction and other measures to promote the further diffusion of renewables including variable renewable power sources. In the scenario, renewables (including hydro) will increase their share of primary energy consumption from 14% in 2019 to 27% in 2050, 13 percentage points higher than in the Reference Scenario. Variable renewable power sources will boost their combined share from 1.5% in 2019 to 10% in 2050. Technologies supporting the spread of renewables in the Advanced Technologies Scenario will include power generation prediction, output control, energy storage (mainly pump-up hydro storage and batteries), output adjustments for backup power sources, power supply adjustments using electric vehicles and smart grid systems combining these and information technologies. As well as the diffusion of these technologies, policies and legal systems to promote power sources' harmony with the natural environment and the regional acceptance of renewables will support a sustainable spread of renewables.

Installed capacity for onshore and offshore wind power generation will increase in all regions faster than in the Reference Scenario, reaching 3 890 GW in 2050 (Figure 4-2), nearly twice as much as in the Reference Scenario. Onshore wind power generation will remarkably expand in China and India as enhanced power transmission infrastructure and cost cuts for energy storage technologies ease the spatial and temporal unevenness of distribution of wind resources. The United States will continue to support wind power generation by extending policy incentives and enhancing grid systems in the Advanced Technologies Scenario, although the termination of power-generation tax credits and the concentration of wind resources in the centre of the North American continent will work to hold down the spread in the Reference Scenario. Offshore wind power generation will increase in Asia (including China, Chinese Taipei and Japan) and the United States as well as in Europe, which has so far led the world in offshore power generation. In addition to continuous technological development and cost-cutting efforts, policy support for wind power generation including enhanced economic assistance, national institution-building efforts for ocean development and a better understanding by fishery business operators and other traditional ocean users will help the diffusion of offshore wind power generation in these regions. China will keep the largest share of global onshore and offshore wind power generation capacity, remaining a major wind power generation market. It will capture 49% of global wind power generation capacity in 2030 and 44% in 2050.

Figure 4-2 | Global installed wind power generation capacity [Advanced Technologies Scenario]

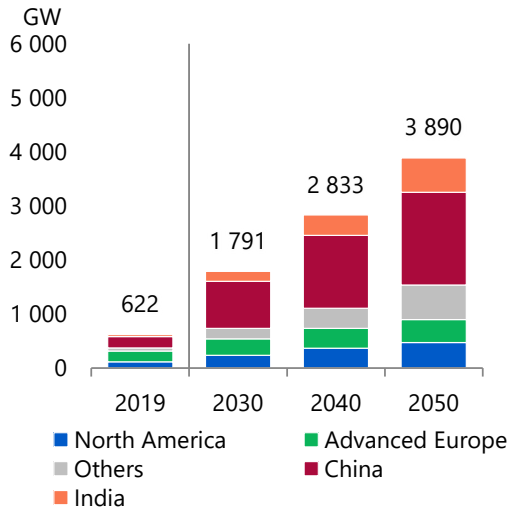
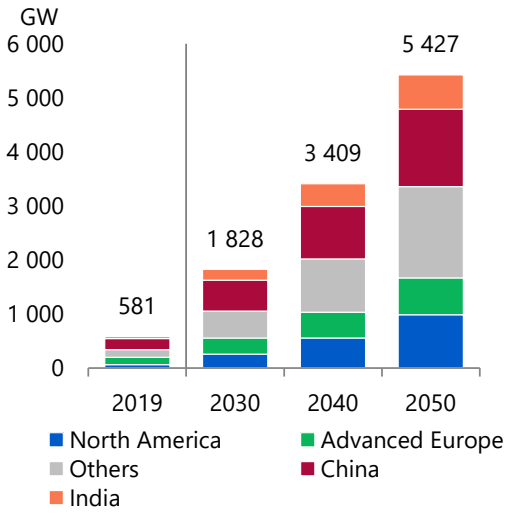


Figure 4-3 | Global installed solar PV power generation capacity [Advanced Technologies Scenario]



Solar PV power generation will also accelerate its expansion globally, boosting its global installed capacity in 2050 to 5 427 GW (Figure 4-3), 1.8 times as much as in the Reference Scenario. In addition to the current major solar PV power generation markets such as China, European Advanced Economies, the United States and Japan, India will increase its presence as a solar PV power generator on the strength of falling costs for solar PV power generation and storage batteries. Furthermore, solar PV power generation will accelerate its growth in the Sun Belt rich with sunlight resources, including the Middle East, Africa and Latin America. Combined installed solar PV power generation capacity in China, the United States and India will come to 3 032 GW in 2050, accounting for 56% of the global total. The Middle East, Africa and Latin America will expand their combined solar PV power generation capacity in 2050 to 602 GW, 1.8 times as much as in the Reference Scenario and 21 times as much as in 2019, becoming major solar PV power generation markets.

Carbon neutrality initiatives have grown globally in recent years, but the diffusion of variable renewable power sources will have to be accelerated more than in the Advanced Technologies Scenario to realise carbon neutrality by around the middle of this century. As the electricity supply and demand picture is expected to turn around in a carbon neutral society, technology choices will have to meet the turnaround. In addition to lithium-ion and sodium-sulphur batteries to store electricity for several hours, technologies to store electricity for a far longer time may be required to respond to weekly, monthly and seasonal fluctuations in output from variable renewable power sources. Such technologies include redox flow batteries and hydrogen. Redox flow batteries, whose output and storage capacities can be designed separately, may be able to store massive electricity for a long time by having more electrolytic solution. Regarding hydrogen, capacities for water electrolysis, hydrogen storage and hydrogen-fired power generation technologies can be chosen separately. Their optimum combination should be pursued, based on their respective characteristics – technological

characteristics, economic efficiency, safety and economic security regarding the procurement of mineral resources (including lithium, nickel, cobalt, vanadium and platinum) as raw materials.

Hydrogen is expected to serve not only as an electricity storage technology but also as gas fuel through the power-to-gas technology. Mainly in Europe, conceptual design and demonstration tests for power-to-gas systems have been conducted in recent years to use hydrogen as fuel for transportation and heat supply in the industry and buildings sectors and as feedstock for industrial processes. The Circular Carbon Economy initiative to synthesise hydrogen from renewable energy and CO_2 into fuel or feedstock has also attracted attention recently. Fuel synthesis processes include methanation and liquid fuel synthesis (Fischer-Tropsch) processes. They would allow surplus electricity from renewables to be utilised across multiple sectors while methane and liquid hydrocarbon fuels are used through existing energy supply infrastructure. If system integration technologies to combine the electric grid with other sectors to promote decarbonisation are diffused over the long term, renewable energy power generation could be further promoted.

Nuclear

Nuclear power generation is useful for multiple policy objectives including stable energy supply, climate change measures and air pollution control. Therefore, nuclear power generation in the Advanced Technologies Scenario will spread more than in the Reference Scenario. Obstacles to the introduction of traditional large light water reactors will be reduced through the accumulation of knowhow and more efficient construction. Powerful policy measures will be implemented to commercialise new nuclear reactors such as small modular reactors (SMRs) and Generation IV reactors, which have remained under development for decades without being commercialised. In recent years, specific candidates for their users have appeared in the United States and Canada, considering introducing such new reactors. Their introduction would depend on whether current demonstration projects could satisfy such user candidates.

Nuclear energy initiatives in non-power sectors will also be important for substantial decarbonisation in the whole of society. Therefore, nuclear energy has been expected to be used not only for power generation but also for multiple other purposes such as district and industrial heat supply, hydrogen production and seawater desalination. Such expectations have been discussed over decades but have yet to materialise. Nuclear energy is still assumed to be used as a baseload electricity source. Before nuclear energy is used for the abovementioned non-power purposes, not only technological improvements but also its effectiveness for the entire energy system should be verified.

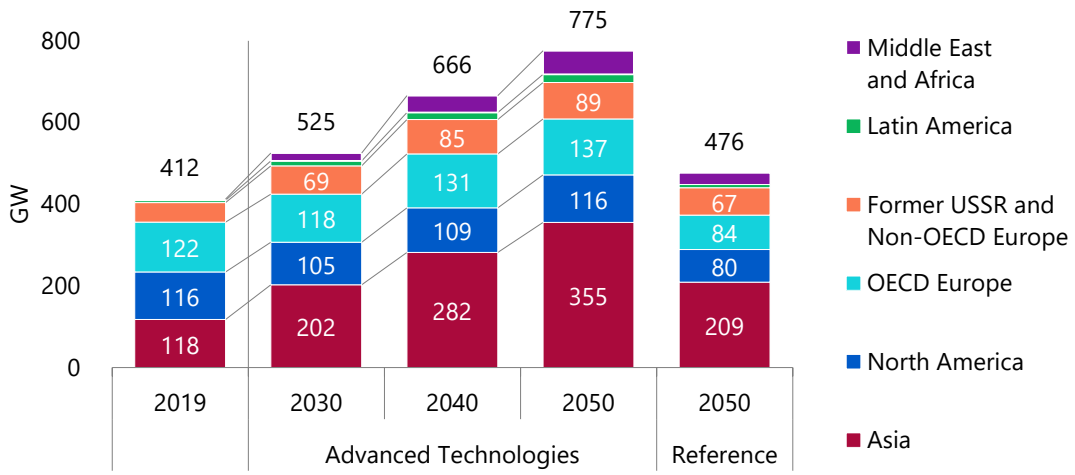
Among countries that have proactively promoted nuclear power generation, the United States and France will reduce their nuclear power generation capacity as most existing reactors become outdated. In the Advanced Technologies Scenario where climate change measures will be implemented more powerfully, more new nuclear power plant construction projects than in the Reference Scenario will be realised to narrow the reduction. The United Kingdom that promotes climate change measures and Russia that emphasises the national security aspect of nuclear technology will construct more nuclear power plants than in the Reference Scenario, boosting their respective nuclear capacity levels in 2050 beyond the current levels. Even

countries that have clarified their nuclear phase-out policies in response to the Fukushima Daiichi accident will change those policies to put off their nuclear power plant closures or replace decommissioned capacity to promote decarbonisation and maintain their industrial competitiveness.

As for Advanced Economies that have offered ambitious decarbonisation initiatives, some Emerging Market Economies will expand nuclear power generation to promote decarbonisation while meeting rapidly growing electricity demand. While the basic motive for introducing nuclear energy is to acquire large stable power sources to meet energy demand, Emerging Market Economies with islands and other remote territories are expected to introduce small nuclear reactors for small grids for those territories.

In the Advanced Technologies Scenario under these assumptions, global installed nuclear power generation capacity will increase from 412 GW in 2019 to 775 GW in 2050 (Figure 4-4), about 1.6 times of 476 GW in the Reference Scenario.

Figure 4-4 | Installed nuclear power generation capacity [Advanced Technologies Scenario]



North America will reduce installed nuclear power generation capacity temporarily before restoring the 2019 level of 116 GW in 2050. Due to competition from cheap natural gas and renewable energy in the liberalised electricity market, some nuclear reactor operators have decided to close their reactors with deteriorated profitability before their lifespans expire. However, the U.S. federal government and some state governments are increasingly giving higher ratings to nuclear energy's low-carbon value and the reliability of nuclear energy supply. In the Advanced Technologies Scenario in which such policy trend will be maximised, support for innovative nuclear technology development and the extension of lifespans for existing nuclear power plants will be greater than in the Reference Scenario. The United States and Canada are proactively promoting the development of SMRs and Generation IV reactors that will be commercialised in or after the 2030s.

In European Advanced Economies that are aiming at ambitious greenhouse gas (GHG) emission reduction goals, the construction of additional nuclear power plants and the

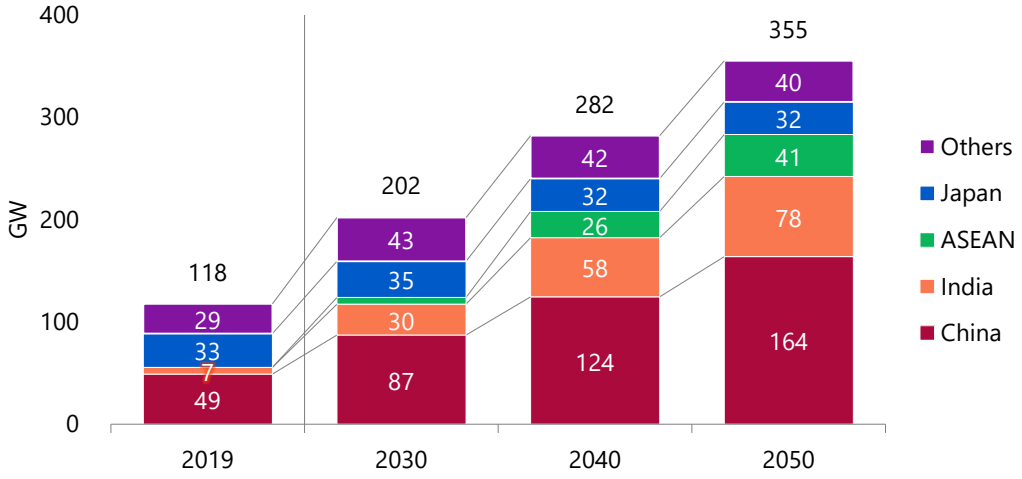
replacement of outdated reactors will be politically promoted, leading installed nuclear power generation capacity to rise from 122 GW in 2019 to 137 GW in 2050. In France known as the largest nuclear power generator in Europe, installed nuclear power generation capacity will decline more slowly than in the Reference Scenario through 2050, with more nuclear power plant construction projects implemented. The United Kingdom will promote the construction of sophisticated large light-water reactors, boosting its installed nuclear power generation capacity from the current level to 16 GW in 2050. In Western countries, the construction of large light-water (Generation III plus) reactors has substantially been delayed due to the loss of construction knowhow for new reactors and design modifications. These problems will be resolved for future nuclear power plant construction projects to reduce risks regarding new plant construction and improve the investment climate for business operators. This will drive the nuclear capacity expansion.

Russia will accelerate new nuclear power plant construction, expanding its installed nuclear power generation capacity from 30 GW in 2019 to 45 GW around 2035. Although the Russian capacity will decrease later due to the closure of outdated reactors, Russia will proactively export nuclear power plants on the strength of economic and energy demand growth in Emerging Market Economies. Russia has already been promoting cooperative relations with many Emerging Market Economies to support their development of nuclear and other industrial infrastructure and human resources, paving the way for its future nuclear power plant exports.

The Middle East, Africa and Latin America, known as emerging nuclear energy markets, will launch the operation of new reactors from around 2025 and steadily expand installed nuclear capacity thereafter. In the Middle East where policy priority will be given to breaking away from heavy dependence on fossil fuels, installed nuclear power generation capacity will reach 15 GW in 2030 and 37 GW in 2050. New nuclear reactors will be built one after another mainly in the United Arab Emirates that has launched nuclear power plant construction and in Saudi Arabia that has announced nuclear power plant construction plans.

As in the Reference Scenario, Asia will have the world's largest installed nuclear power generation capacity in 2050 in the Advanced Technologies Scenario (Figure 4-5). The Asian capacity will top the combined capacity of European Advanced Economies and North America (at 227 GW) in 2035 and reach 355 GW in 2050. As in the Reference Scenario, China and India will drive the growth in Asia. As stable and economically rational low-carbon power sources are required to meet a growing power demand, Southeast Asian countries, now planning to introduce nuclear power generation, will also make progress in the introduction of nuclear capacity. As many of them must reach stability in electricity supply on their islands, the introduction of SMRs or floating nuclear reactors is considered. Due to such motive, ASEAN's installed nuclear power generation capacity, though at zero as of 2019, will surpass Japan's 32 GW reaching 41 GW in 2050 after commercial nuclear power generation starts around 2030.

Figure 4-5 | Asian installed nuclear power generation capacity [Advanced Technologies Scenario]



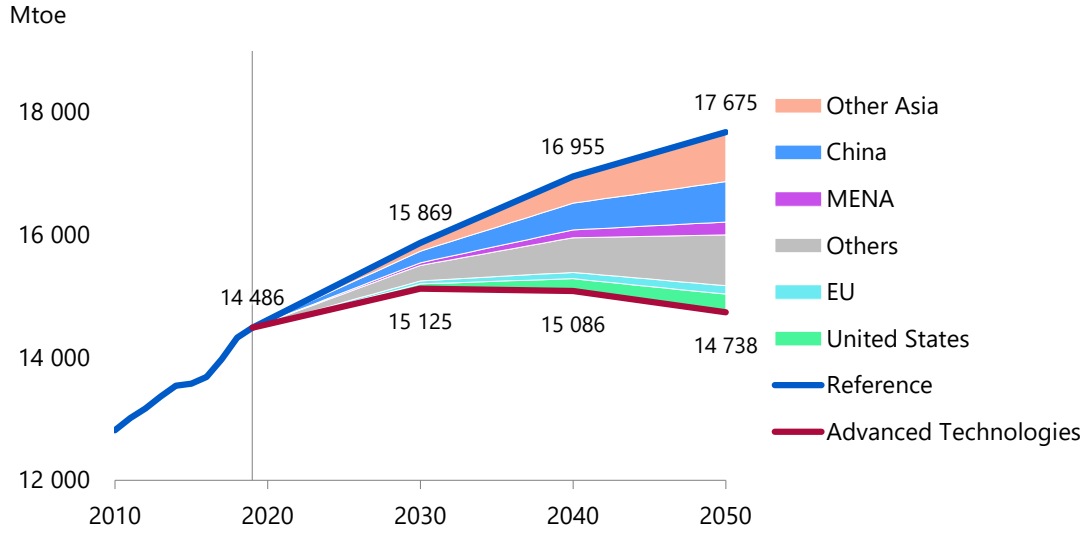
4.2 Energy supply and demand

Even in the Advance Technologies Scenario, the world will fall far short of reaching carbon neutrality in 2050. All means should be mobilised to further promote energy efficiency improvements and climate change countermeasures.

The Advanced Technologies Scenario assumes the enhancement of energy efficiency improvements and climate change countermeasures. Primary energy consumption in 2050 in the Advanced Technologies Scenario will be 2.9 Gtoe or 17% less than in the Reference Scenario. Overall accumulated energy savings through 2050 will total 42.7 Gtoe, with fossil fuel consumption including oil, natural gas and coal declining by 61.5 Gtoe. CO_2 emissions in 2050 will consequently be 15.8 Gt or 42% less (see "section 4.3 CO_2 emissions" for details). Therefore, it would appear to be difficult for the world to realise carbon neutrality in 2050, as announced by many countries since 2020.

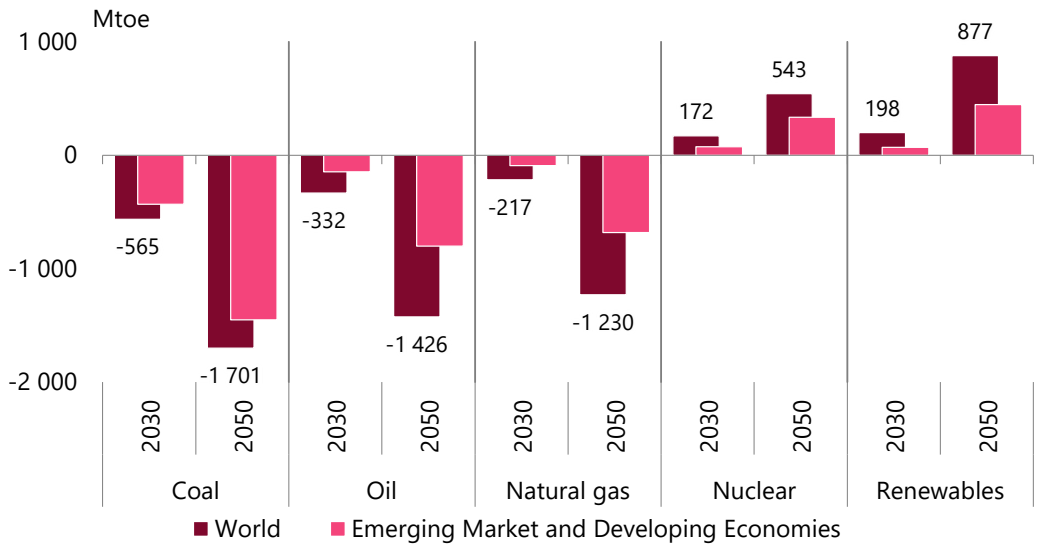
Playing a great role in realising the Advanced Technologies Scenario will be the Emerging Market and Developing Economies such as India, the Middle East and North Africa (MENA) and ASEAN that have great potential to save energy and introduce non-fossil energies. The Emerging Market and Developing Economies will account for 73% of global energy savings from the Reference Scenario in 2050. Particularly, India, MENA and ASEAN will capture a combined share of 29%. The extraordinary promotion of energy efficiency improvements and decarbonisation will hold the key to global climate change countermeasures.

Figure 4-6 | Global primary energy consumption and savings from Reference Scenario by region [Advanced Technologies Scenario]



Fossil fuel consumption in the Advanced Technologies Scenario will be 4.4 Gtoe or 32% less than in the Reference Scenario (Figure 4-7). Consumption will be 39% less for coal, 27% less for oil and 25% less for natural gas. Non-fossil energy consumption will be 1.4 Gtoe more. Nuclear energy consumption will be 63% more and renewable energy consumption 28% more. Even in the Advanced Technologies Scenario featuring great growth in non-fossil energy consumption, the world will not be able to maintain or improve economic, social and living conditions without fossil fuels.

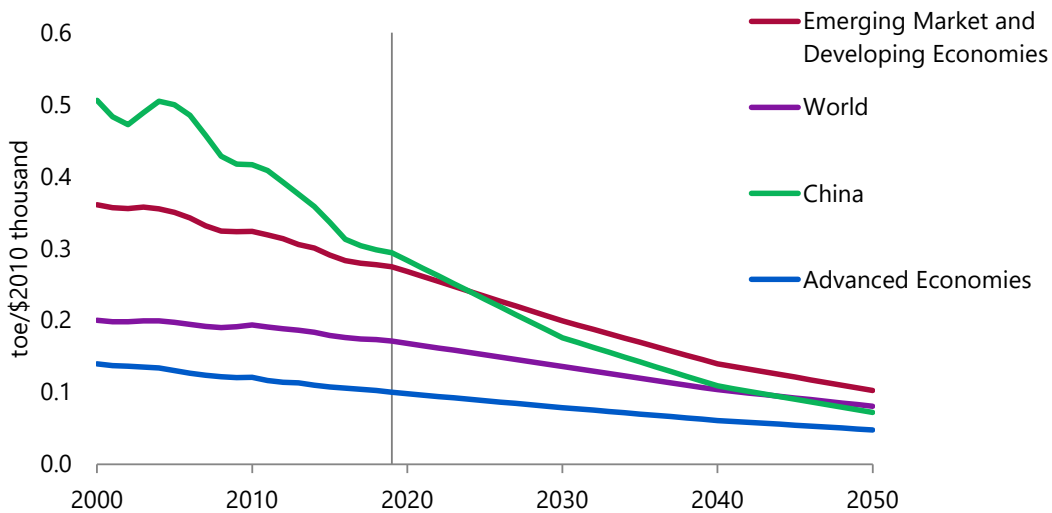
Figure 4-7 | Final energy consumption changes from Reference Scenario [Advanced Technologies Scenario]



Even the Advanced Technologies Scenario is not easy to realise. Of coal consumption savings from the Reference Scenario in 2050, the Emerging Market and Developing Economies will account for 85% with India, MENA and ASEAN capturing a combined 36%. Of nuclear and renewable energy consumption growth, the Emerging Market and Developing Economies will account for 62% and 51%, respectively. India, MENA and ASEAN will command 27% of the nuclear growth and 37% of the renewable energy growth. The Advanced Technologies Scenario thus urges the Emerging Market and Developing Economies to realise such contributions to coal consumption savings and nuclear and renewable energy consumption growth in a short period of 30 years. During the process to realise the Advanced Technologies Scenario, the Emerging Market and Developing Economies are required to implement their energy transition far faster than the Advanced Technologies Scenario did in the past.

In the Advanced Technologies Scenario, energy intensity per unit of GDP decreases in the Advanced Economies and in the Emerging Market and Developing Economies will fall short of leading the world to achieve carbon neutrality (Figure 4-8). The Advanced Economies will post a decline of 52% in their energy intensity from 2019 to 2050, against a 63% fall for the Emerging Market and Developing Economies that have greater potential to improve energy efficiency. China's energy intensity will plunge by 76% due mainly to industrial structure changes, catching up with the global average in the first half of the 2040s. To achieve carbon neutrality, the global energy intensity will have to decrease by 83% from 2019, covering the global energy consumption with non-fossil energy consumption (5.4 Gtoe) in 2050 in the Advanced Technologies Scenario. The decrease would be far steeper than the declines in the Emerging Market and Developing Economies and in China, demonstrating that it would be considerably challenging for the world to realise global carbon neutrality in 2050.

Figure 4-8 | Primary energy intensity per GDP [Advanced Technologies Scenario]



If the Advanced Technologies Scenario is realised to further promote CO_2 emission cuts, both the Advanced Economies and the Emerging Market and Developing Economies will have to improve energy efficiency at a high pace and promote the decarbonisation of energy sources. The Advanced Economies' development of energy efficiency improvement technologies and

their transfer to the Emerging Market and Developing Countries will become indispensable. Such transfer would require international fundraising capabilities and the elimination of energy efficiency improvement barriers including the lack of energy efficiency consciousness. Each country will have to adopt different energy conservation and decarbonisation approaches for urban and rural areas, while setting incentives for low-income people busy with day-to-day life to introduce energy-efficient appliances. It will also be important to improve national and regional education programs to enhance energy efficiency consciousness from the long-term viewpoint.

All policy means will have to be mobilised to plan and implement these CO_2 emission reduction measures, including subsidy, tax, regulatory and other public policies and their exploitation for private businesses. Advanced Economies' bilateral cooperation with Emerging Market and Developing Economies, multilateral cooperation frameworks such as the ASEAN+3 and Asia Pacific Economic Cooperation forums, and the utilisation of international organisations like the International Monetary Fund and the World Bank will also be required.

Vehicle fuel efficiency improvements and electrification hold the key to reducing final energy consumption

Oil will account for more than half the final energy consumption savings in 2050 in the Advanced Technologies Scenario (Figure 4-9). Factors behind oil consumption savings include a decrease in the road sector's oil consumption through vehicle fuel efficiency improvements and fleet mix changes. To further diffuse electrified vehicles, various policy incentives will have to be combined with the acceleration of charging facility expansion, battery production capacity enhancement and relevant cost cuts.

Figure 4-9 | Global final energy consumption changes from Reference Scenario [Advanced Technologies Scenario, 2050]

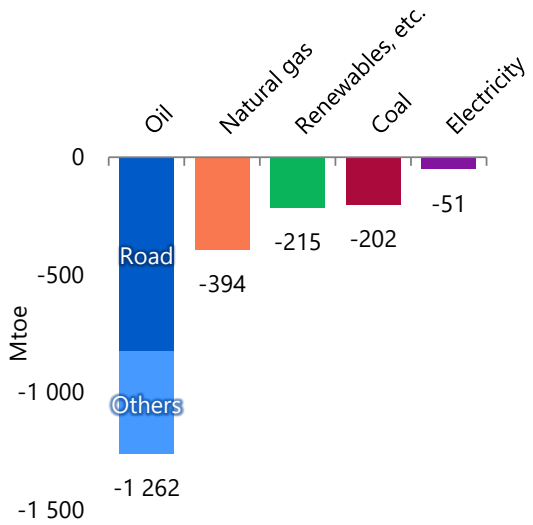
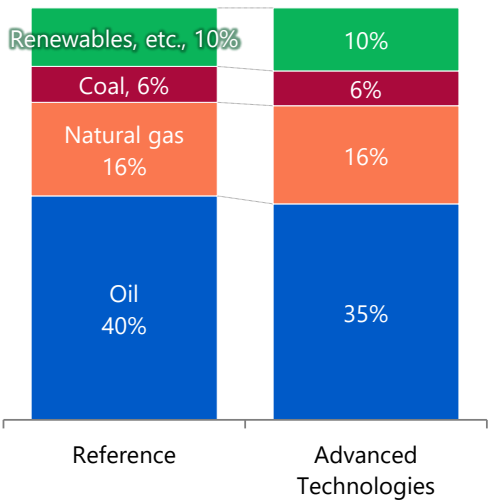


Figure 4-10 | Global final energy consumption mix [2050]



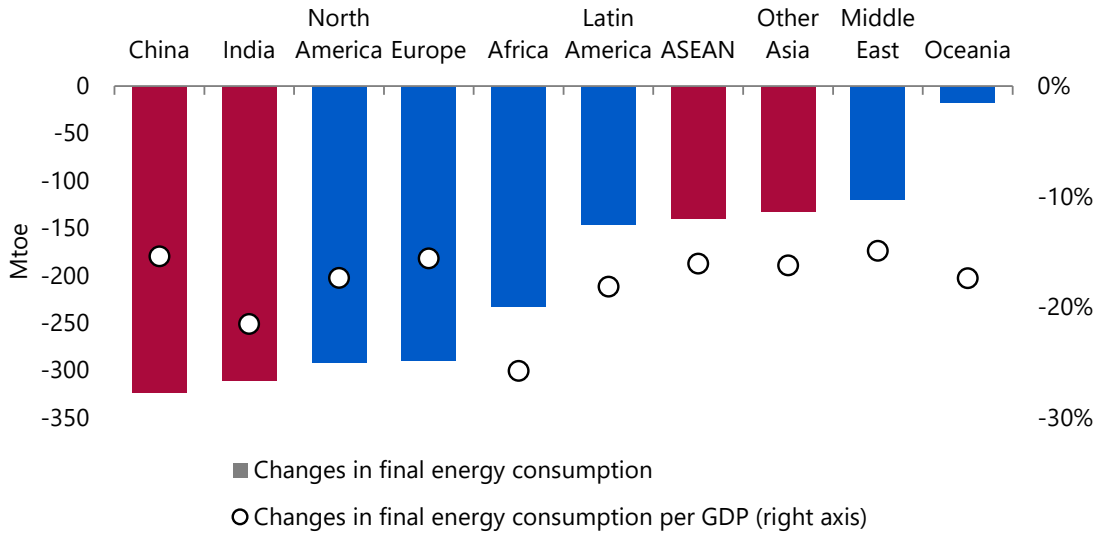
Given oil's large share of total energy savings, steady fuel efficiency improvements and vehicle fleet mix changes will become a key contributor to leading final energy consumption to come closer to the Advanced Technologies Scenario path.

In the Advanced Technologies Scenario, the final consumption of not only oil but also other major energy sources will be reduced from the Reference Scenario. Even so, differences between energy mixes in the two scenarios in 2050 will be limited and demand will exist for all major energy sources even in the Advanced Technologies Scenario (Figure 4-10). It will thus be important to stably supply each energy source in the Advanced Technologies Scenario as in the Reference Scenario.1

Steady progress in energy efficiency improvements will be important in China, India and the United States

Asia including China and India will account for the largest share of final energy consumption savings in 2050, followed by North America, Europe and Africa (Figure 4-11). Steady progress in energy efficiency improvements in China, India, the United States and other economies expected to achieve great energy consumption savings will be important for realising the final energy consumption path in the Advanced Technologies Scenario.

Figure 4-11 | Final energy consumption savings and changes in final energy consumption per GDP from Reference Scenario [Advanced Technologies Scenario, 2050]



Asia's final energy consumption savings in 2050 will total 906 Mtoe, accounting for as much as 43% of global savings. China with 323 Mtoe in savings and India with 311 Mtoe will command a combined 30% of global savings, indicating their great presence. Progress in the two countries' energy savings will exert influence not only on their energy security but also on climate change and other economies' energy security. They will substantially reduce road sector oil consumption and industrial sector coal consumption, reflecting the effects of various technologies assumed in the Advanced Technologies Scenario. It will be important to achieve steady progress in the two countries' energy efficiency improvements through various measures such as Advanced Economies' transfer of highly efficient technologies to them.

Final energy consumption savings in North America will total 291 Mtoe, accounting for 14% of global savings. An oil consumption decline mainly in the road sector will capture more than half of the North American savings. As automobiles are frequently used as mobility or transportation means in North America, road sector oil demand in the region is the second largest in the world after Asian demand. Therefore, road sector oil consumption will decline substantially in response to vehicle fuel efficiency improvements and vehicle mix changes. U.S. final energy consumption savings at 253 Mtoe will be the third largest after Chinese and Indian levels, but far exceeds the other countries. In the United States, therefore, road and other energy consumption sectors will have to make continuous energy-saving efforts.

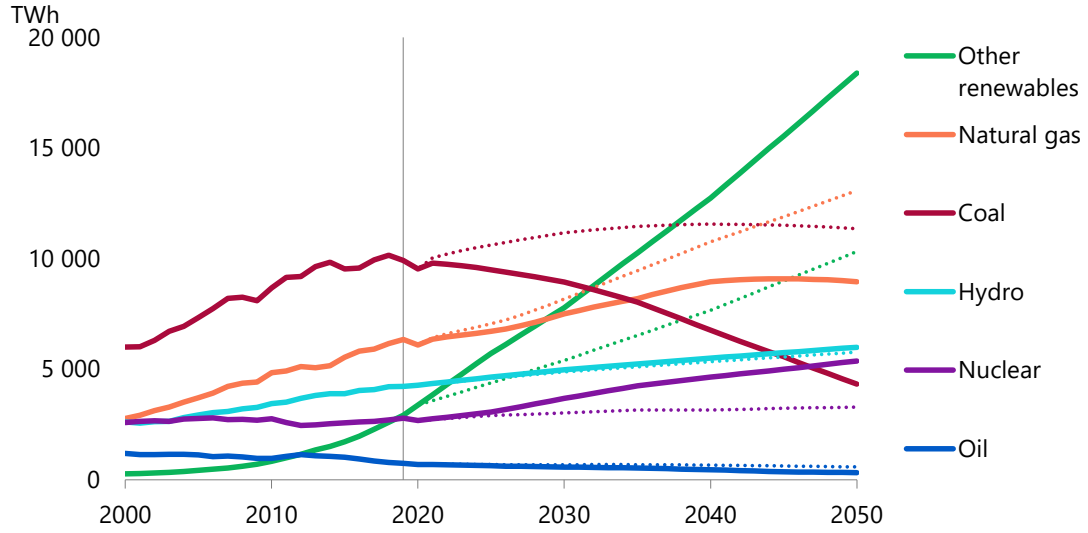
Africa will feature residential sector renewable energy consumption savings that will account for about 70% of the region's final energy consumption savings at 233 Mtoe. This will contribute to leading final energy consumption per GDP to post a 26% decline, steeper than in any other region. Behind the renewable energy consumption savings will be the modernisation of energy consumption and the utilisation of highly efficient energy consumption appliances. It will be important for Africa to diffuse highly efficient energy consumption appliances at affordable prices for a wider range of consumers and develop arrangements for providing modern energy sources to steadily implement residential sector energy savings.

Power generation mix

Electricity generated in 2050 in the Advanced Technologies Scenario will be 1 011 TWh less than in the Reference Scenario. While progress in electrification leads electricity's share of final energy demand to rise by 5 percentage points, a demand decline through energy efficiency improvements will have a bigger impact and bring about the fall in electricity generated. As Advanced Economies take leadership in promoting coal-phaseout policies, coal-fired power generation will decline substantially from the 2020s to less than half the current level in 2050 (Figure 4-12). In contrast, renewables including solar PV, wind and biomass energies will become the largest power source. Variable renewables will account for 35% of total electricity generated, prompting responses to variable output to become a key challenge in each region.

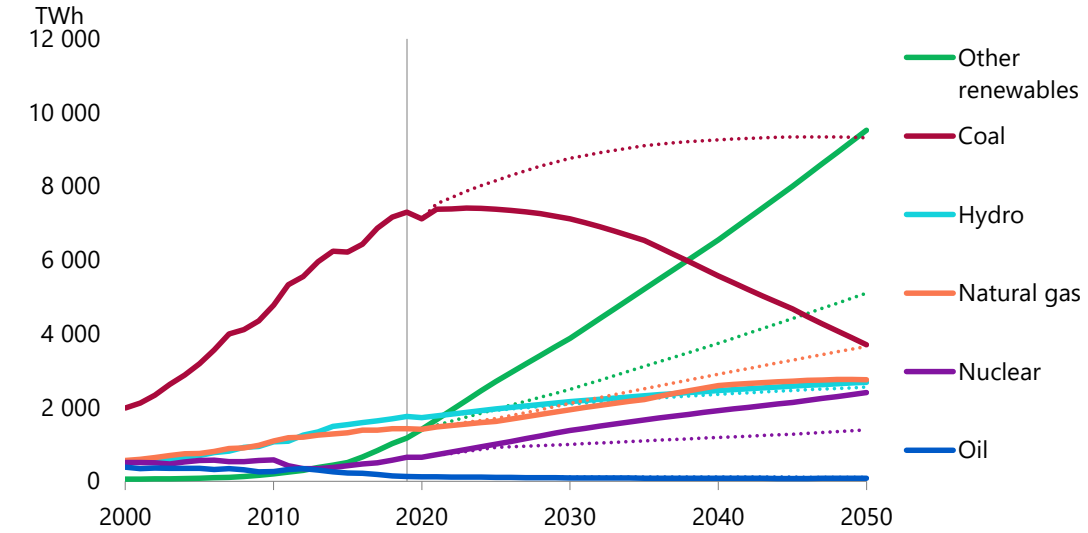
Coal-fired power generation in Asia, though still increasing currently, will peak before 2030 and substantially decrease later (Figure 4-13). Even in 2050, however, coal will still account for some 20% of total power generation, remaining one of the major power sources. In Asia, more efficient coal-fired power generation, the introduction of carbon capture and storage technology to reduce CO_2 emissions from coal-fired power plants and air pollution countermeasures will become important. Renewables will rapidly expand in China and India. As these economies sustain growth, their challenge will be to harmonise renewable energy expansion with affordable and stable electricity supply.

Figure 4-12 | Global power generation mix [Advanced Technologies Scenario]



Note: Dashed lines represent the Reference Scenario.

Figure 4-13 | Asian power generation mix [Advanced Technologies Scenario]



Note: Dashed lines represent the Reference Scenario.

Crude oil production

In the Advanced Technologies Scenario, oil demand growth will be suppressed due to rapid progress in the electrification of automobiles and other fuel switching measures in final consumption sectors, as well as further progress in energy efficiency improvements. Oil demand will rise back close to the pre-COVID-19 level around 2025 but fall later without topping the level. Oil demand in 2050 will total 78 Mb/d, about 30 Mb/d less than in the Reference Scenario. This will amount to combined European and Chinese demand in 2019. Oil supply in each region will be lower than in the Reference Scenario (Table 4-3).

Table 4-3 | Crude oil production [Advanced Technologies Scenario]

(Mb/d)

	2019	2030	2040	2050	2019-2050	
					Changes	CAGR
Crude oil production	95.0	91.6	85.9	78.4	-16.6	-0.6%
OPEC	34.9	35.2	35.7	33.8	-1.1	-0.1%
Middle East	27.0	27.5	28.1	26.7	-0.2	0.0%
Others	7.9	7.8	7.6	7.1	-0.9	-0.4%
Non-OPEC	60.0	56.4	50.2	44.6	-15.5	-1.0%
North America	22.4	21.6	18.2	15.4	-7.1	-1.2%
Latin America	7.2	7.9	8.6	8.3	1.1	0.5%
Europe and Eurasia	18.2	15.8	13.2	11.8	-6.4	-1.4%
Middle East	3.2	3.1	3.0	2.9	-0.3	-0.3%
Africa	1.4	1.3	1.2	1.1	-0.3	-0.7%
Asia and Oceania	7.6	6.7	5.9	5.2	-2.5	-1.3%
Processing gains	2.4	2.4	2.4	2.4	0.0	0.0%
Oil supply	97.3	94.0	88.3	80.8	-16.6	-0.6%

Note: Crude oil includes natural gas liquid.

Oil-producing countries will wage fierce competition for sales channels as oil demand declines. Middle Eastern members of the Organization of the Petroleum Exporting Countries (OPEC) will take advantage of their cost competitiveness to retain the 2019 level of production even in 2050, while adjusting production to avoid any rapid fall in oil prices. Many non-OPEC oil-producing countries will have difficulties in maintaining oil production volume amid low oil prices and falling oil demand. Therefore, OPEC's share of global crude oil production will be higher than in the Reference Scenario. Oil supply will be far less than in the Reference Scenario for less cost competitive North America posting the fastest demand decline of 9.1 Mb/d from 2019 to 2050. It will be the same for Russia (representing Europe and Eurasia) supplying oil mainly to Europe that will record the second fastest demand fall at 7.0 Mb/d. Oil supply in 2050 in Latin America, however, will increase from the current level as oil development is promoted in Guyana, Suriname and other countries that have discovered new oil resources in recent years and are proactively attracting foreign investment. Unlike North America, Latin America will see its limited drop in oil demand even in the Advanced Technologies Scenario, contributing to expanding local production.

Asia, where oil production has already been falling, will reduce supply faster than in the Reference Scenario, like most of the other regions. However, Asia is dominated by net oil-importing countries and includes oil-producing countries where state-run oil companies are undertaking production. Asian oil-producing countries will thus have an incentive to limit their production fall from the viewpoint of supply security even if production costs are higher. Consequently, Asia's oil self-sufficiency will be higher than in the Reference Scenario.

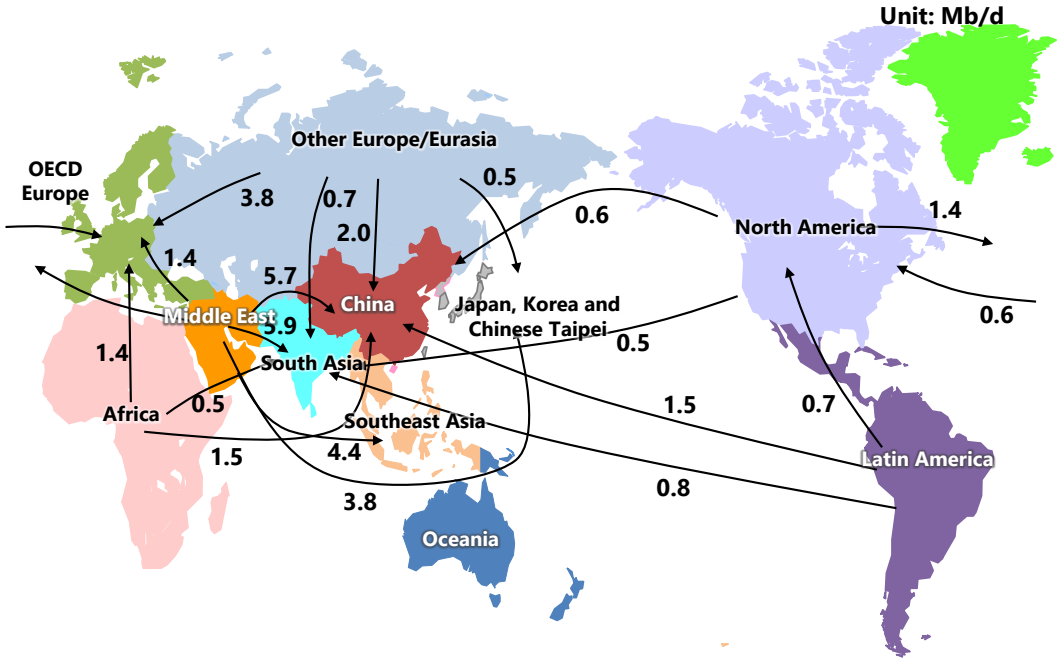
As oil demand peaks out, global crude oil trade will decrease from about 42 Mb/d in 2020 to about 39 Mb/d in 2030 and to about 34 Mb/d in 2050. North America and Europe, though being

major oil importers at present, will persistently reduce oil imports due to an oil demand loss topping 16 Mb/d by 2050, while Asia further increases its presence as an oil importer. In 2050, about 80% of global crude oil trade will flow to Asia and the Middle East that maintains steady crude oil production will account for more than 70% of the Asian crude oil imports.

In the Advanced Technologies Scenario where oil demand will decline remarkably, oil refining industry's trends in each country or region will have great influence on future crude oil trade flows. While international oil majors have reorganised oil refining operations under their low-carbon strategies in recent years, China and the Middle East have built new oil refining and petrochemical plants. In Asia, growth in China's petroleum products exports has affected export-oriented oil refineries in nearby countries such as Korea and Singapore. Surplus oil refining capacity is likely to arise in the future. Depending on oil refining competitiveness gaps, less competitive refineries will have no choice but to close. In contrast, countries or regions with more competitive refineries will maintain their crude oil procurement and increase petroleum products exports to continue oil refining operations without cutting their crude oil procurement even if their oil demand decreases.

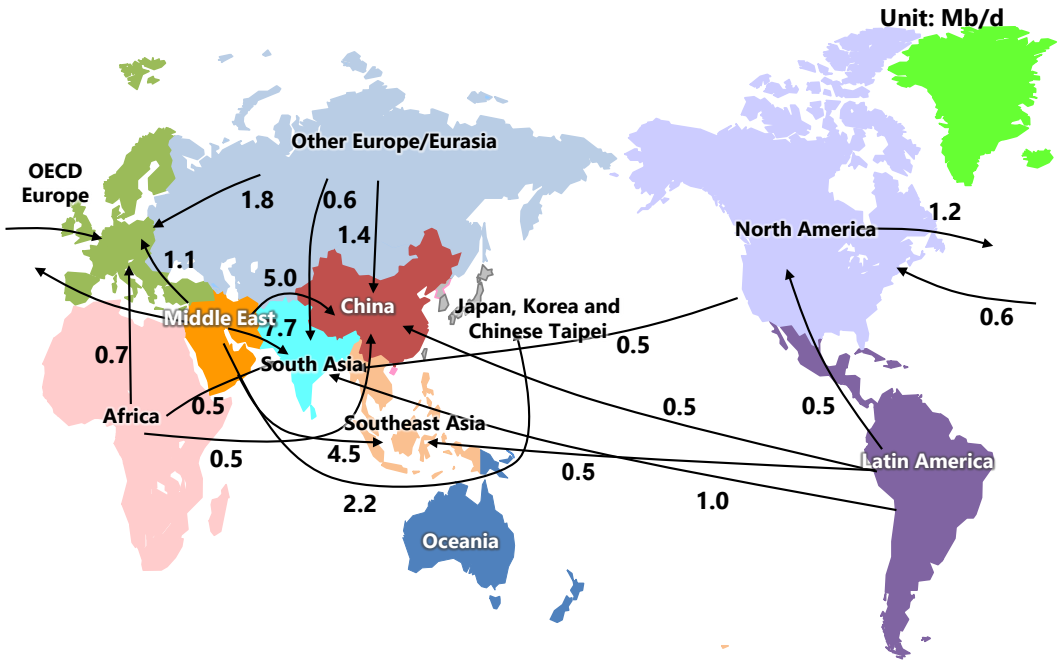
In the Advanced Technologies Scenario, more oil refiners will undoubtedly reach their turning points. As oil demand is lost, oil refiners will have to make choices among various options in line with their market environments and business strategies. The options will include retaining refining operations while enhancing petrochemical operations, switching to affinitive operations such as biofuel production and petroleum product import handling, entering new energy business operations and withdrawal. Given that refineries with wide sites are suitable for installing massive tanks and have sufficient port and harbour equipment, they will have an option to become trading hubs for decarbonised fuels such as ammonia and hydrogen.

Figure 4-14 | Major interregional crude oil trade flows [Advanced Technologies Scenario, 2030]



Note: Flows of 0.5 Mb/d or more are covered.

Figure 4-15 | Major interregional crude oil trade flows [Advanced Technologies Scenario, 2050]



Note: Flows of 0.5 Mb/d or more are covered.

Natural gas supply

As progress in energy efficiency improvement and other energy utilisation technologies suppresses natural gas consumption in the Advanced Technologies Scenario, natural gas production will be 14% less than in the Reference Scenario in 2040 and 25% less in 2050. However, better management of GHG emissions may lead to a greater share for greener natural gas production capacity.

A wide production gap between the Reference and Advanced Technologies Scenarios will be seen in OECD Europe where natural gas development and production costs are relatively higher. The region's natural gas production in 2050 in the Advanced Technologies Scenario will be 30% less than in the Reference Scenario. U.S. and Canadian production will peak around 2040. In contrast, the Middle East and non-OECD Europe including Russia will expand natural gas production steadily, though more slowly than in the Reference Scenario. In the Middle East, Iran, Qatar and Saudi Arabia will sharply increase production even in the Advanced Technologies Scenario.

In the Advanced Technologies Scenario, production changes will depend on progress in technologies for monitoring and cutting CO_2 and methane emissions during natural gas production and transportation and in policies and regulations to support them.

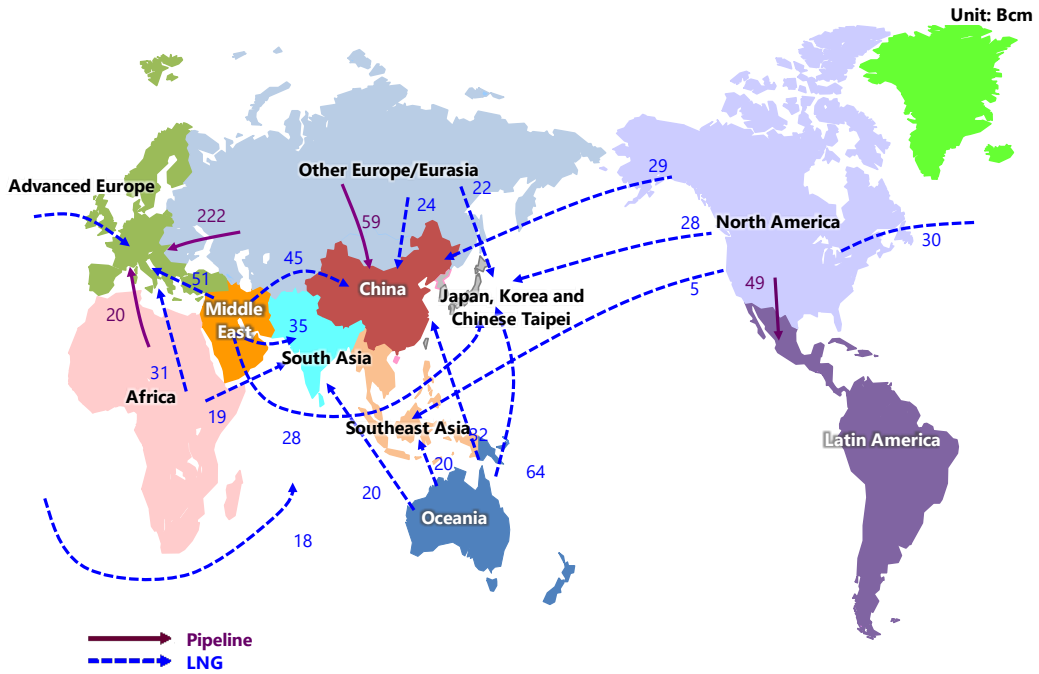
Table 4-4 | Natural gas production [Advanced Technologies Scenario]

(Bcm)

	2019	2030	2040	2050	2019-2050	
					Changes	CAGR
World	4 089	4 461	4 626	4 435	346	0.3%
North America	1 131	1 210	1 160	970	-161	-0.5%
Latin America	201	224	235	217	16	0.2%
OECD Europe	219	91	45	27	-192	-6.5%
Non-OECD Europe/Eurasia	990	988	975	978	-12	0.0%
Russia	750	740	760	770	20	0.1%
Middle East	662	808	843	815	154	0.7%
Africa	250	341	417	465	215	2.0%
Asia	489	605	718	729	240	1.3%
China	178	242	362	375	197	2.4%
India	32	58	72	73	41	2.7%
ASEAN	211	216	207	211	0	0.0%
Oceania	147	195	233	234	87	1.5%

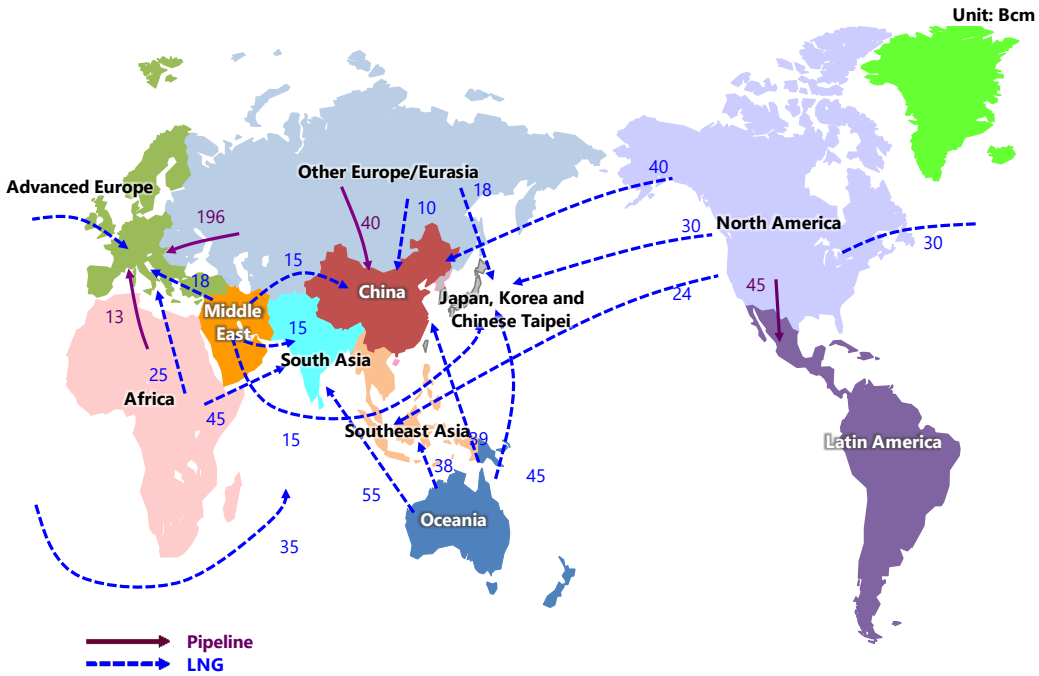
Net natural gas-importing regions will reduce their imports by 20%-60% from the Reference Scenario in 2050. Among net natural gas-exporting regions, non-OECD Europe including Russia will cut exports slightly from the Reference Scenario and the Middle East by about 70%. In North America, demand will decline from the Reference Scenario faster than production. Its net export volume in 2050 will rise nearly two-fold from the Reference Scenario, though being affected by international price falls.

Figure 4-16 | Major interregional natural gas trade flows [Advanced Technologies Scenario, 2030]



Note: Major interregional trade is covered. Some pipeline gas trade could be replaced with LNG trade.

Figure 4-17 | Major interregional natural gas trade flows [Advanced Technologies Scenario, 2050]



Note: Major interregional trade is covered. Some pipeline gas trade could be replaced with LNG trade.

In the Advanced Technologies Scenario, natural gas trade changes will depend on progress in relevant companies' cooperation and efforts to rationalise and optimise natural gas and liquified natural gas (LNG) trade. Such changes will also depend on progress in relevant countries' cooperation and supportive policies and regulations (monitoring and regulating fuel efficiency and emissions for marine transportation). Regarding LNG transportation in particular, relevant parties will be able to increase transportation with the same footprint through cooperation in optimisation including changing destinations and swapping cargoes.

Contributing to developing sustainable natural gas trade will be progress in marine transportation technologies for LNG and compressed natural gas (CNG) carriers, and improvements in compressor efficiency, leak detection and surveillance technologies as well as relevant policy support for pipeline gas trade.

Coal supply

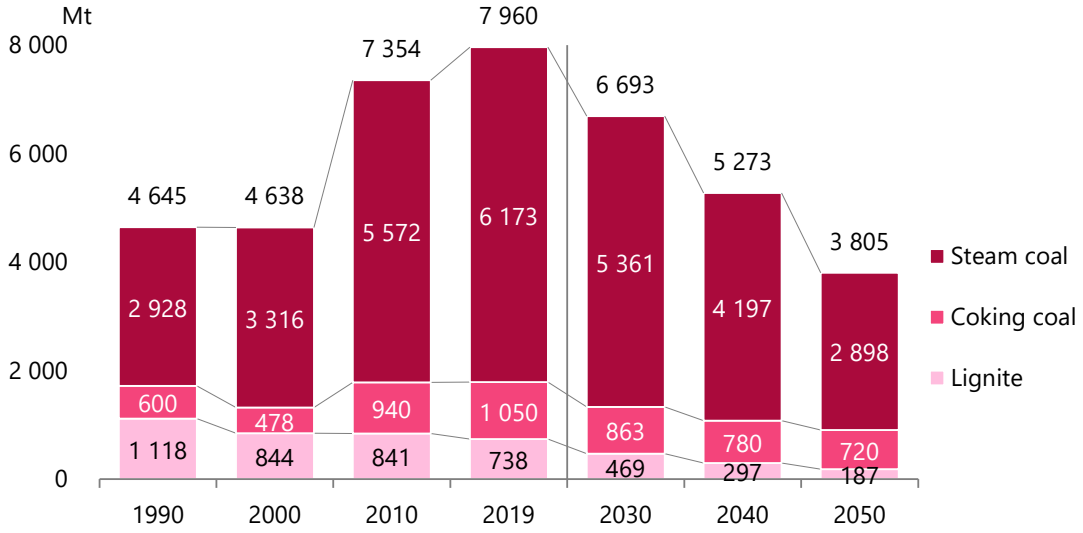
As technologies to increase coal use efficiency and to replace coal with other fuels are enhanced toward carbon neutrality, initiatives to minimise coal use will make progress in various areas including power generation, steelmaking and other industries, as well as heating. Coal's share of the power generation mix will decline in many countries due to the expansion of shares for renewable and nuclear energy. However, some coal-fired power generation capacity will be maintained to secure reserve generation capacity and inertial force to stabilise the electricity system. Coal-fired power generation capacity will also be required for regions where renewables are difficult to introduce.

Advanced Economies will suspend or terminate inefficient coal-fired power plants. Even if some coal-fired power plants are replaced, technologies to minimise coal consumption will be adopted, including those for integrated coal gasification combined cycle (IGCC), mixing ammonia or hydrogen with coal and improving thermal efficiency. While power stations and other industrial facilities reduce coal consumption and CO_2 emission intensity, measures to stimulate coal demand with advanced technologies will be limited in 2050 in response to the international community's strong opposition to coalmining and the expansion of coal use.

Emerging Market and Developing Economies will be strongly urged to adopt low-carbonisation or decarbonisation technologies when replacing outdated or inefficient coal-fired power plants or constructing new ones. Coal demand will be suppressed due to technological advancement to cut costs for other fuels or power sources.

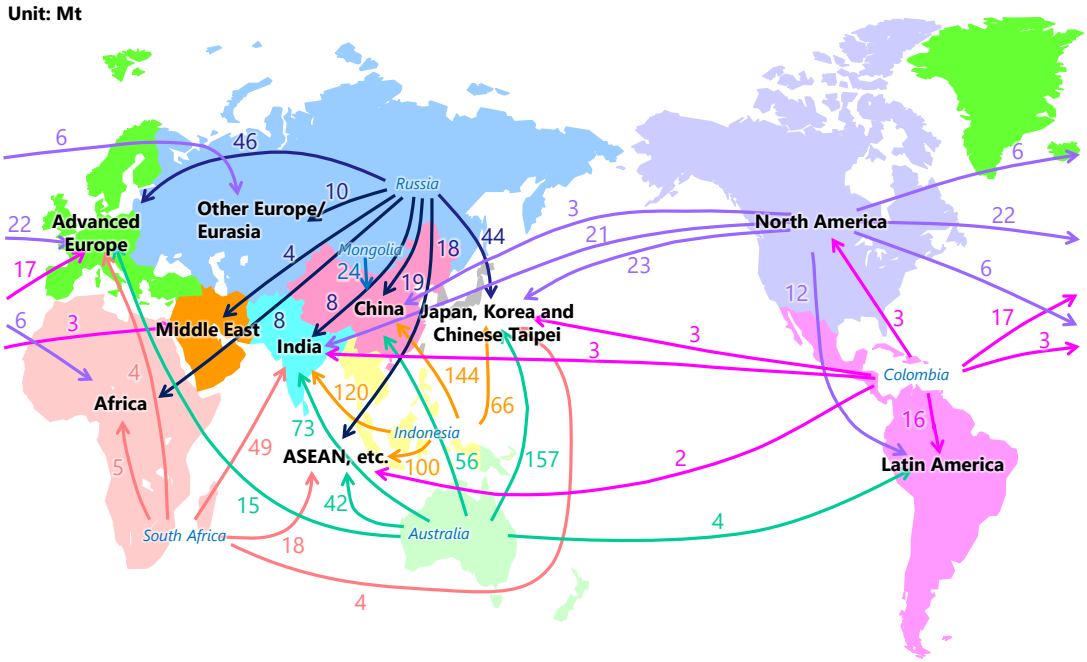
Consequently, coal production will decrease from 7 960 Mt in 2019 to 3 805 Mt in 2050 (Figure 4-18). Steam coal production will decline from 6 173 Mt in 2019 to 2 898 Mt in 2050, coking coal production from 1 050 Mt to 720 Mt and lignite production from 738 Mt to 187 Mt. From the Reference Scenario, coal production in 2050 will decrease by 3 677 Mt. Production will plunge by 3 163 Mt for steam coal, by 381 Mt for lignite and by 132 Mt for coking coal.

Figure 4-18 | Global coal production [Advanced Technologies Scenario]



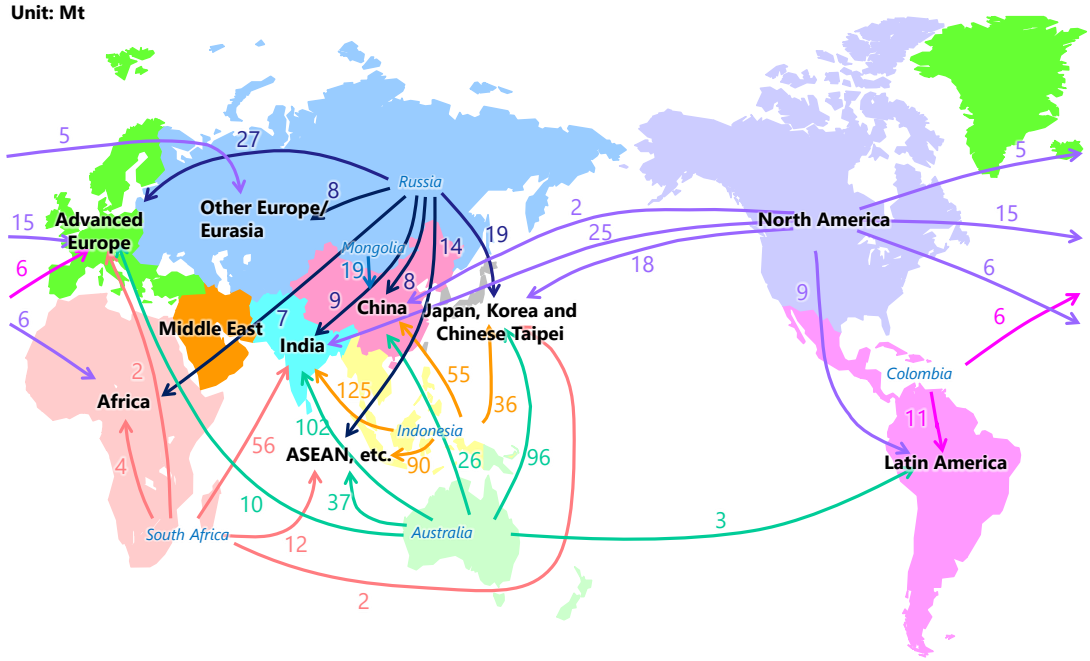
Coal production will decline remarkably in all regions. Asian production in 2050 will plunge by nearly 50% from the current level but as other regions cut coal production faster, Asia's share of global coal production will top 70% in 2050, intensifying the geographical unevenness of coal production.

Figure 4-19 | Major interregional coal trade flows [Advanced Technologies Scenario, 2030]



Note: Steam coal and coking coal are combined. Estimates totalling 2 Mt or more are specified. Flows from Mozambique are included into those from South Africa

Figure 4-20 | Major interregional coal trade flows [Advanced Technologies Scenario, 2050]



Note: Steam coal and coking coal are combined. Estimates totalling 2 Mt or more are specified. Flows from Mozambique are included into those from South Africa.

Table 4-5 | Steam coal production [Advanced Technologies Scenario]

(Mt)

	2019	2030	2040	2050	2019-2050	
					Changes	CAGR
World	6 173	5 361	4 197	2 898	-3 275	-2.4%
North America	544	293	166	64	-481	-6.7%
United States	528	289	163	62	-466	-6.7%
Latin America	90	58	42	28	-62	-3.7%
Colombia	79	50	36	24	-55	-3.8%
OECD Europe	56	31	19	10	-46	-5.5%
Non-OECD Europe/Eurasia	378	277	231	180	-198	-2.4%
Russia	261	187	142	102	-158	-3.0%
Middle East	0	0	0	0	0	0.0%
Africa	266	247	219	180	-86	-1.3%
South Africa	255	235	208	172	-83	-1.3%
Asia	4 565	4 225	3 341	2 322	-2 243	-2.2%
China	3 186	2 781	2 012	1 235	-1 951	-3.0%
India	684	762	686	547	-137	-0.7%
Indonesia	595	573	537	440	-155	-1.0%
Oceania	273	229	177	114	-159	-2.8%
Australia	271	229	177	113	-158	-2.8%

Table 4-6 | Coking coal production [Advanced Technologies Scenario]

(Mt)

	2019	2030	2040	2050	2019-2050	
					Changes	CAGR
World	1 050	863	780	720	-330	-1.2%
North America	95	83	79	76	-19	-0.7%
United States	65	55	52	50	-15	-0.9%
Latin America	9	9	9	9	1	0.2%
Colombia	5	6	6	6	1	0.4%
OECD Europe	15	13	13	13	-2	-0.5%
Non-OECD Europe/Eurasia	107	98	92	86	-21	-0.7%
Russia	97	88	82	77	-20	-0.8%
Middle East	1	2	2	1	0	0.3%
Africa	9	13	18	23	14	2.9%
Mozambique	3	3	4	4	1	0.6%
Asia	623	478	391	328	-295	-2.0%
China	539	384	279	195	-343	-3.2%
India	49	67	85	105	55	2.5%
Mongolia	6	6	8	10	4	1.8%
Oceania	190	168	175	183	-7	-0.1%
Australia	189	167	174	182	-7	-0.1%

4.3 CO_2 emissions

2030 emission reduction and net-zero emission/carbon neutrality goals are difficult to achieve

Global energy-related CO_2 emissions will decrease from 33.6 Gt in 2019 to 21.7 Gt in 2050 (Figure 4-21).

Energy-related CO_2 emissions in the 10 largest GHG-emitting economies as of 2015 and the others will be less than in the Reference Scenario (Figure 4-22). Emissions in 2050 in the Advanced Technologies Scenario will be 3.8 Gt less than in the Reference Scenario in China, 2.5 Gt less in India, 1.8 Gt less in the United States, 0.9 Gt less in the European Union (EU), 1.3 Gt less in ASEAN including Indonesia, 1.0 Gt less in the Middle East including Iran and 0.9 Gt less in Africa. Climate finance after 2025, subject to negotiations from 2021, should be considered to allow Emerging Market and Developing Economies to realise their emission reduction potential.

CO_2 emission drops in 2030 in the Advanced Technologies Scenario will be 33.2% from 2005 in the United States, 40.1% from 1990 in the EU, 37.2% from 2013 in Japan and 9.8% from 2005 in Canada, failing to reach their respective goals in their nationally determined contributions (NDCs). More policies and measures than assumed in the Advanced Technologies Scenario will be required to realise these goals.

Figure 4-21 | Global energy-related CO_2 emissions

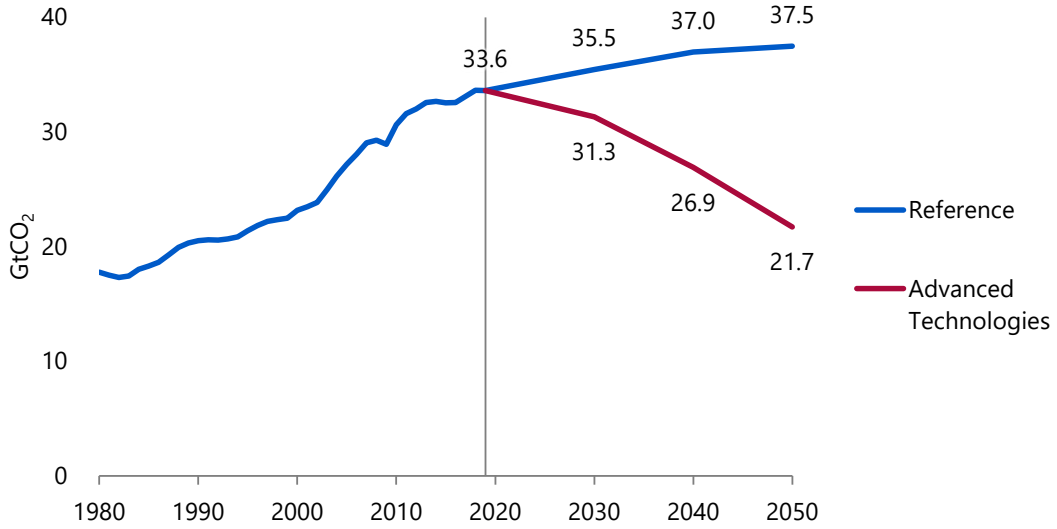
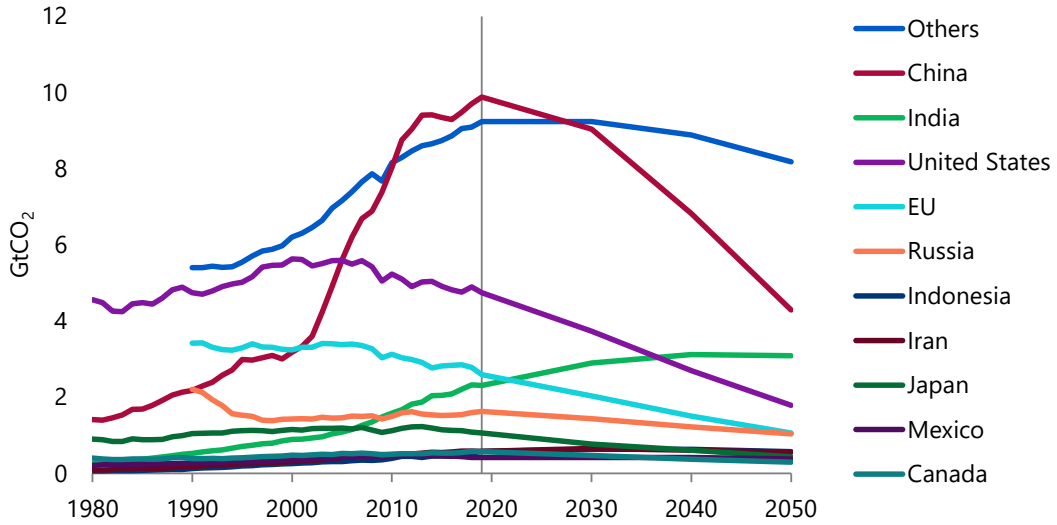


Figure 4-22 | Global energy-related CO_2 emissions [Advanced Technologies Scenario]



China, the United States, the EU and Japan have announced their respective net-zero emission or carbon neutrality goals. In the Advanced Technologies Scenario, emissions in these economies are assumed to decline by some 80% by 2050, indicating that the assumed technologies in the scenario are not sufficient to accomplish their goals. To achieve their respective goals, they will have to develop and introduce emission reduction technologies that have yet to be commercialised.

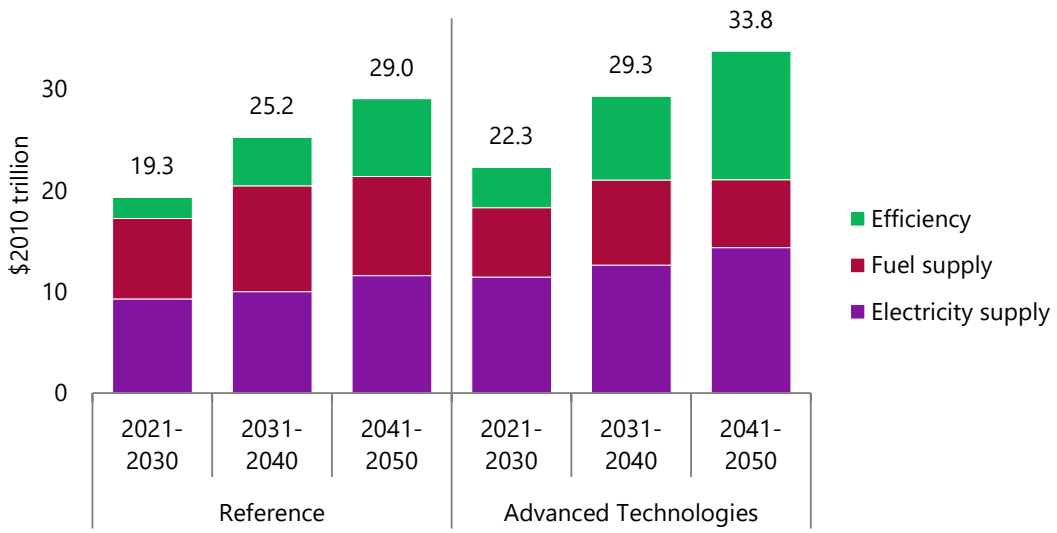
5. Energy-related investments

5.1 Recent trends and outlook

Most energy-related investments are made to develop oil and natural gas resources and renewable energy. Investment in solar photovoltaics (PV) and wind power generation expanded in the 2000s and 2010s, supported by the introduction of feed-in-tariff (FIT) schemes in Europe and other regions and of tax incentives and net metering systems in the United States.

In the Reference Scenario, energy-related investments will increase by about 50% from $19 trillion (in 2010 dollars) in the 2020s to $29 trillion in the 2040s (Figure 5-1). In the Advanced Technologies Scenario, far more renewable energy investment will be required than in the Reference Scenario, though with less fossil fuel investment. In the 2040s, $34 trillion in total energy-related investment will be required in the Advanced Technologies Scenario.

Figure 5-1 | Global energy-related investments



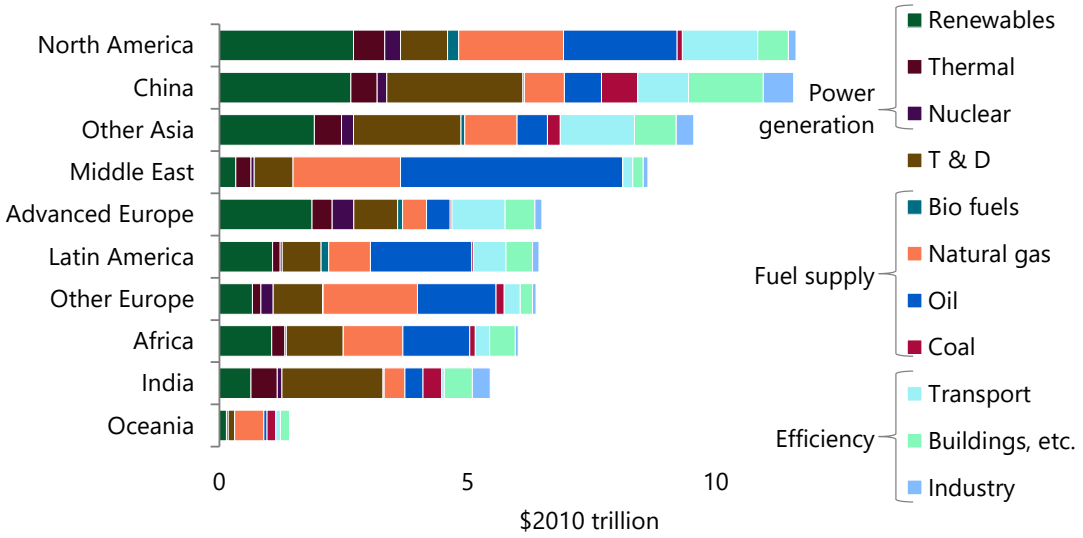
Most Advanced Economies have announced goals of cutting net GHG emissions to zero by 2050. In the Reference Scenario, however, investments in fuel supply will increase in line with growing demand for natural gas and oil. Even in the Advanced Technologies Scenario, about one-fifth of the total investments in 2050 will be made in fuel supply.

Massive investments in renewable energy power generation have been made under government support measures. A tax credit cut in the United States and the abolition of subsidies for new solar PV and wind power generation projects in China may exert downside pressure on renewable energy investment over the short term. Over the medium to long term, however, renewable energy investments will increase as drops in power generation cost stimulate capacity growth.

Energy-related investments have regional characteristics (Figure 5-2). In North America, for instance, oil and natural gas investments account for about a half of total energy-related

investments, with renewable energy investments capturing about a quarter. This is because the development shale oil and gas resources coincides with renewable energy capacity expansion. In China, renewable energy investments accounts for about a quarter of total energy-related investments as is the same case with the United States. However, investments in power transmission and distribution networks exceed renewable energy investments as such networks are required to expand to meet electricity demand growth. In India, progress in electrification has a great impact, leading investments in power transmission and distribution networks to capture nearly 40% of total energy-related investments.

Figure 5-2 | Energy-related investments [Reference Scenario, cumulative total for 2021-2050]



In Oceania and the Middle East, fossil fuel suppliers, fossil fuel supply investments account for a large share of the total investments, with renewable energy investments commanding a small share. In the Middle East, oil and natural gas investments capture about three quarters of the total. Asia, Europe and North America feature significant investments in transport energy efficiency covering fuel-efficient and zero-emission vehicles and infrastructure for hydrogen and electric vehicle stations.

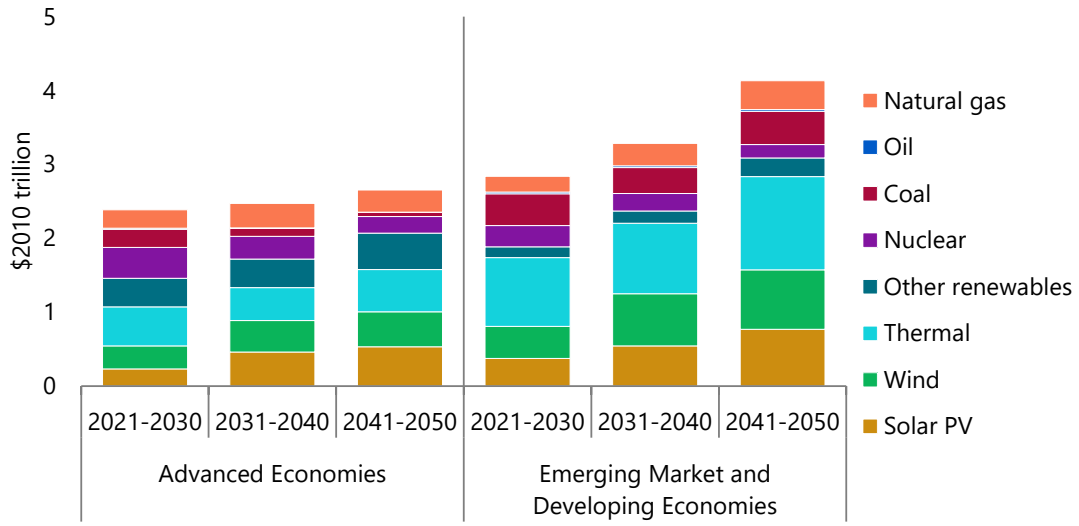
5.2 Electricity investments

Renewable energy investments will increase

In the Reference Scenario, renewable energy facilities featuring high capital costs, account for the largest share of the investments in power generation equipment (Figure 5-3). In Advanced Economies, power generation equipment investments will follow an uptrend as growth in renewable capacity outpaces drops in equipment costs. While investments in coal-fired power plant decrease in response to a coal phaseout trend, natural gas-fired plant investments will be maintained to meet demand for such plants to stabilise electricity supply. In Emerging Market and Developing Economies, power generation equipment investment will increase faster than

in Advanced Economies, centring on solar PV and hydro capacity. Coal-fired plant investments will be maintained at current levels, while natural gas-fired plant investments increase.

Figure 5-3 | Power generation equipment investment [Reference Scenario]

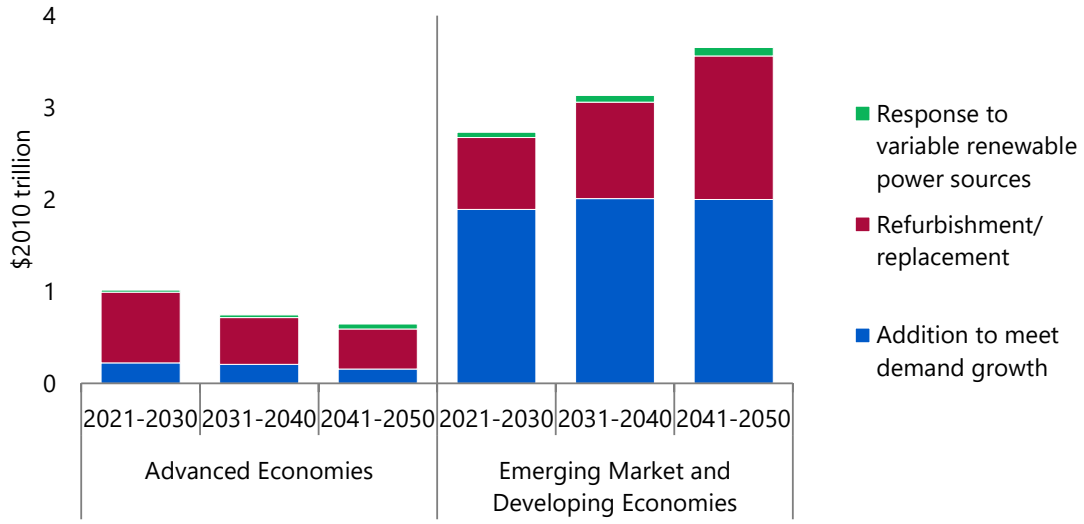


Emerging Market and Developing Economies will increase investments in power transmission and distribution equipment to meet electricity demand growth

In the electricity sector, large-scale investments are required not only for power generation equipment but also for transmission and distribution equipment. Power transmission and distribution equipment spending accounts for about a half of total electricity investments. Such spending covers additional transmission and distribution capacity for electricity demand growth and the refurbishment of outdated equipment (Figure 5-4). Investments in power transmission and distribution equipment related to variable renewable power generation is relatively small.

In Advanced Economies, power transmission and distribution equipment investments already centre on the refurbishment of outdated equipment accounting for about three quarters of total investments in power transmission and distribution equipment. During the 2020s, the service life expiration for power transmission and distribution equipment will peak, leading to an increase in refurbishment and replacement. New York State is discussing the digitalisation of electricity trading that would be timed to coincide with the refurbishment and replacement, indicating that power transmission and distribution equipment could be improved to meet platform trading in electricity. In Emerging Market and Developing Economies, spending on additional power transmission and distribution capacity account for the dominant share of the investments and spending on refurbishment and replacement will increase in the future, with investments in additional capacity continuing.

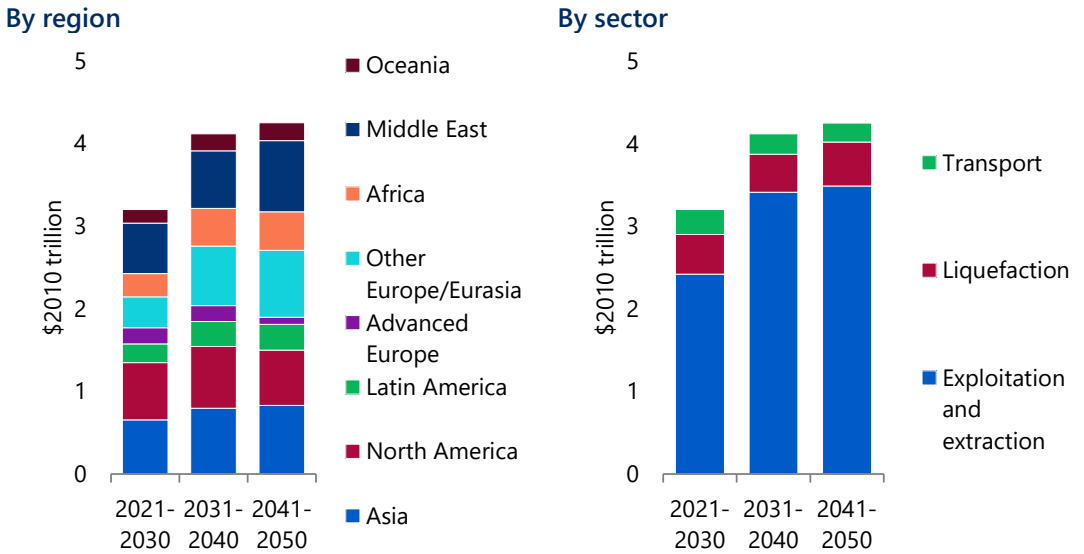
Figure 5-4 | Investments in power transmission and distribution equipment [Reference Scenario]



5.3 Fossil fuel investments

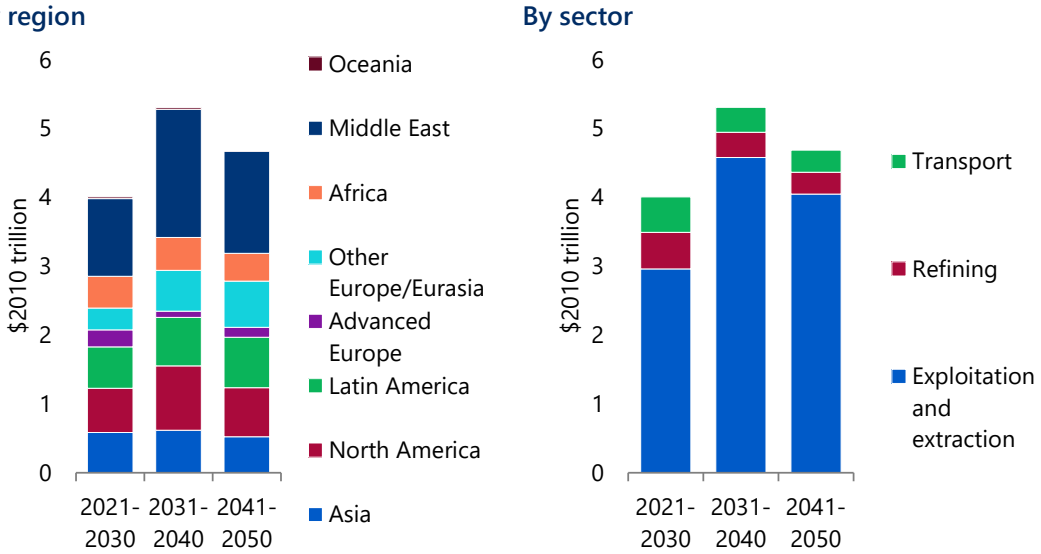
While coal investments decline in line with the coal phaseout trend, investments in natural gas and oil will increase to meet the demand growth. Natural gas investments will increase in most regions to expand production (Figure 5-5). Natural gas investments will cover facilities for liquefying natural gas, as well as the development of natural gas resources.

Figure 5-5 | Natural gas investments [Reference Scenario]



Oil investments will peak in the 2030s and decrease slowly thereafter (Figure 5-6) as crude oil production in 2050 will decline from current levels. North America that features high oil production costs will contribute to the downtrend in oil investments.

Figure 5-6 | Oil investments [Reference Scenario]

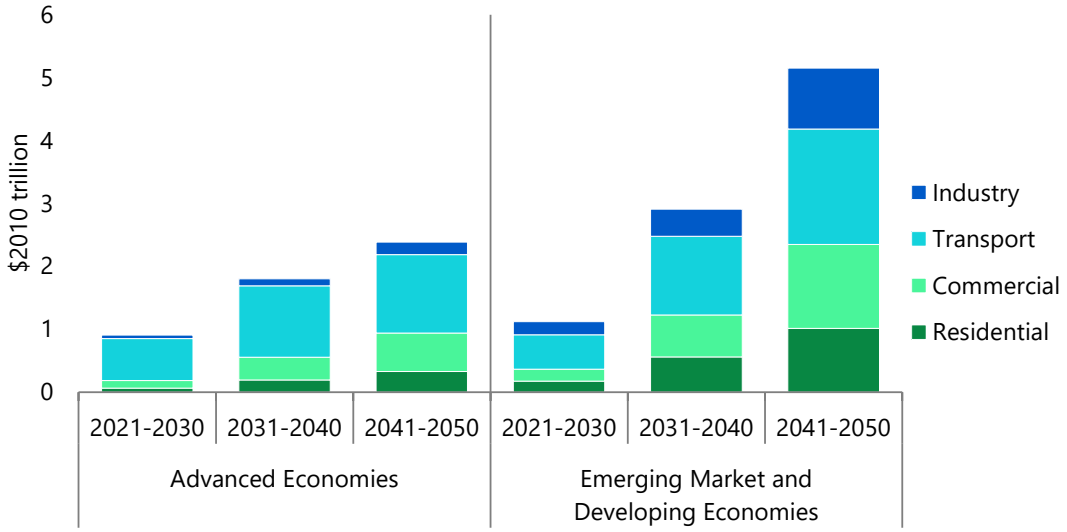


5.4 Energy efficiency investments

On the demand side, the buildings and transport sectors will account for the dominant share of the investments for the introduction of more energy-efficient[9] equipment (Figure 5-7). Within the buildings sector, commercial investments will exceed residential investments and in the Emerging Market and Developing Economies, commercial investments will increase faster than residential investments. The transport sector investments will increase due to the electrification of automobiles.

[9] Energy efficiency levels in 2019 are considered as the baseline.

Figure 5-7 | Energy efficiency investments [Reference Scenario]



Part II

Challenges toward carbon neutrality

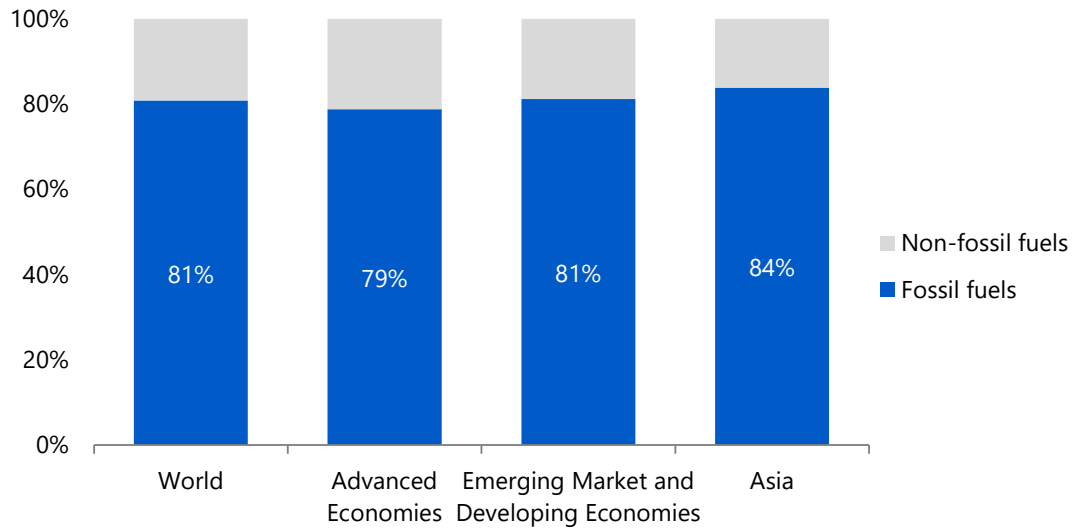
6. Challenges and issues toward carbon neutrality

6.1 Introduction

Since the Paris Agreement in 2015, many economies including the United States, the European Union (EU), China and the United Kingdom have announced that they would seek to achieve carbon neutrality by the middle of the current century. The U.S. Biden administration, inaugurated in January 2021, has cited climate change countermeasures as one of its policy priorities. In May 2021, the International Energy Agency (IEA) released a scenario for net-zero carbon dioxide (CO2) emissions in 2050[10]. These developments have led to growing interest in long-term carbon neutrality goals

Proactive climate change countermeasures toward carbon neutrality are expected to produce various positive effects for the global economy by realising not only massive carbon emission cuts but also the development of innovative technologies and competitive clean energy industries to create new jobs. Given that the world currently depends on fossil fuels for more than 80% of its energy supply (Figure 6-1), it will not be easy to realise carbon neutrality. This chapter focuses on the process toward carbon neutrality and considers challenges arising during the process.

Figure 6-1 | Fossil fuels' share of primary energy supply [2019]



Source: International Energy Agency, World Energy Balances 2021 edition

6.2 How to view climate change countermeasures and economic effects

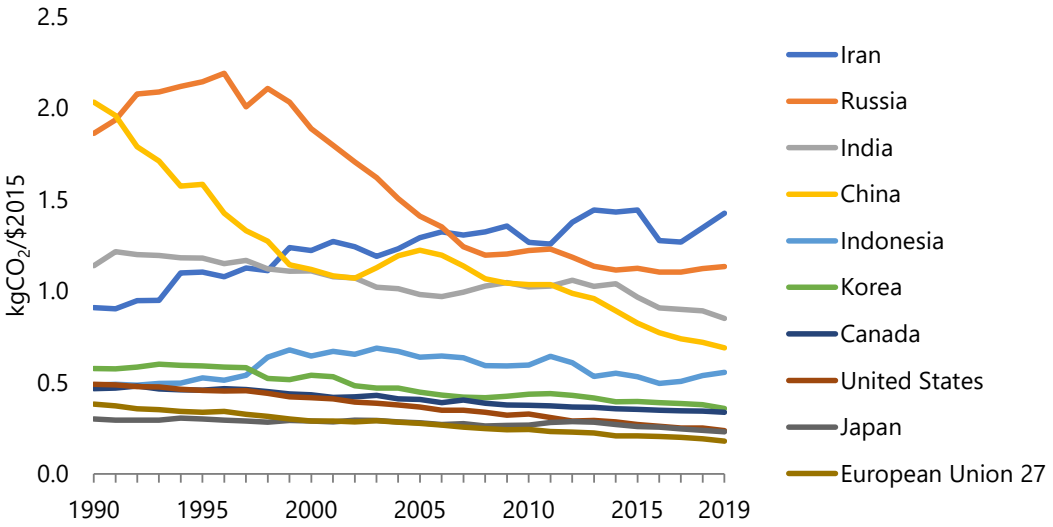
Green growth

The first issue to consider in the process toward carbon neutrality is the relationship between climate change countermeasures and their economic impacts. Recently, the term "green growth" has been cited in the context that climate change countermeasures with their economic

[10] International Energy Agency (IEA), (2021), *Net Zero by 2050*. Paris: IEA

effects exerting positive impacts on each other to produce a virtuous cycle of emission cuts and economic growth. The concept of green growth was shared widely and globally at the Rio+20 United Nations Conference on Sustainable Development in June 2012[11]. It means that CO_2 emissions are decoupled from economic growth, or that CO_2 emissions do not increase even under economic growth[12]. A green growth strategy is designed to decouple economic growth from CO_2 emissions. Meanwhile, the improvement of CO_2 emissions per unit of GDP, or the emission intensity, has been stagnant in most of the world's 10 largest CO_2 emitters (Figure 6-2). Decoupling economic growth from CO_2 emissions, though not necessarily impossible in theory, is extremely difficult to realise in reality.

Figure 6-2 | CO_2 emissions per unit of GDP



Source: International Energy Agency, CO_2 Emissions from Fuel Combustion, 2021

Green deal

The concept of the "Green New Deal" or "Green deal" is also used regarding climate change countermeasures and their economic impacts. This means that proactive climate change countermeasures serve as economic stimulus or industrial policies to simultaneously achieve emission cuts and economic growth. The concept amounts to policies promoted by the EU and the U.S. Biden administration[13]. Specific Green Deal effects expected in the EU include the

[11] United Nations (UN), (2012), *The Future We Want*. New York: UN.

[12] Organisation for Economic Cooperation and Development (OECD), (2011), *Towards Green Growth: A Summary for Policy Makers*. Paris: OECD; United Nations Environment Plan (UNEP), (2011), *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication – A Synthesis for Policy Makers*. Nairobi: UNEP; World Bank, (2012). *Inclusive Green Growth: the Pathway to Sustainable Development*. Washington, DC: World Bank; Jason Hickel and Giorgos Kallis, (2020), "Is Green Growth Possible?" *New Political Economy*, 25:4, 469-486.

[13] Lisa Friedman, (2019), "What Is the Green New Deal? A Climate Proposal, Explained" *The New York Times*, February 21, 2019. https://www.nytimes.com/2019/02/21/climate/green-new-deal-questions-answers.html. Accessed in September 2021.

development of new clean technologies and new products markets to create 160 000 new jobs[14]. The IEA in its Net Zero Emission scenario estimates clean technology investment in the coming decade to boost GDP growth by 0.4 percentage points and create 25 million net new jobs[15].

The EU and IEA have estimated positive economic effects of proactive climate change countermeasures compared with a case without such countermeasures. Essentially, however, climate change countermeasures are accompanied by costs. Positive effects of climate change countermeasures may be greater or smaller than their negative effects or costs depending on national and other conditions. We must not only emphasise the positive impacts but also verify in detail the negative effects.

Costs accompanying climate change countermeasures

Cost issues that accompany climate change countermeasures include (1) negative externalities and (2) carbon lock-in effects. Negative externalities mean that production at individual companies or households reduces production or utilities or increases production costs at others without market transactions[16]. This indicates that economic activities exceed optimum levels because negative effects of external diseconomy fail to be traded as explicit costs in a market mechanism (Figure 6-3). In a typical negative externality situation, individual companies' or households' CO_2 emissions through energy consumption trigger various climate change problems. To resolve these problems, costs that fail to be assessed through the market mechanism must be added to prices of existing products or services[17]. Consequently, market prices increase, forcing market participants to pay additional costs and leading market transactions to decrease.

Another cost problem is the lock-in effect. This means that existing technologies, infrastructure and consumer behaviour synergistically work to bring about inertia in energy consumption to delay the introduction of emission reduction measures[18]. The lock-in effect is seen in many energy consumption scenes including power generation and industrial sectors where large capital investment is required, as well as automobile fuel consumption for which wide energy supply infrastructure networks are necessary. In order to realise a carbon neutral society while resisting the carbon lock-in effect, new infrastructure investment will be required along with energy users' changes to energy use facilities, interindustry labour shifts and human resources development. These measures may be costly.

[14] EC (2021)

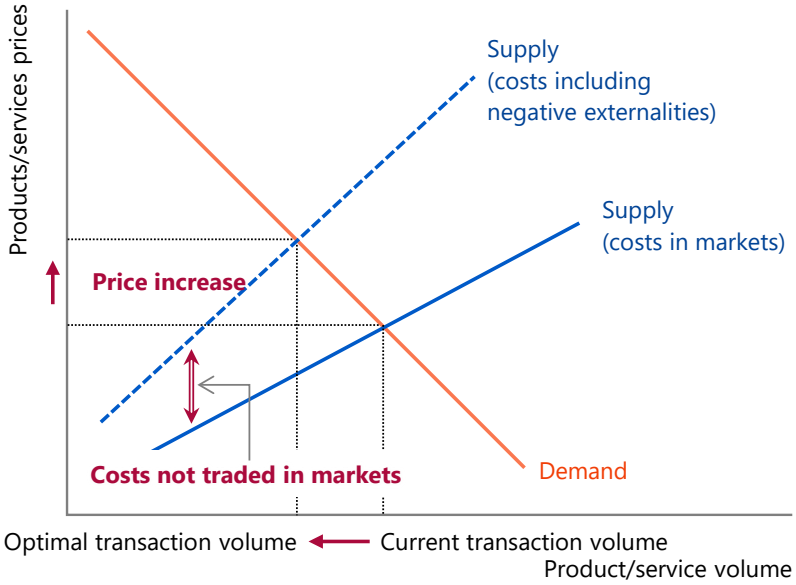
[15] IEA (2021)

[16] Kazuo Nishimura, *Introduction to Microeconomics 2nd edition*, (Iwanami Shoten, Publishers, 1998)

[17] William Baumol and Wallace E. Oates, (1988), *The Theory of Environmental Policy 2nd edition*. Cambridge: Cambridge University Press.

[18] Karen C. Seto, Steven J. Davis, Ronald B. Mitchell, Eleanor C. Stokes,1 Gregory Unruh, and Diana Ürge-Vorsatz, (2016), "Carbon Lock-In: Types, Causes, and Policy Implications," *Annual Review of Environment and Resources*, 41, 425–52.

Figure 6-3 | Internalisation of negative externalities



Net effects will differ by actor or region

There are various views about whether climate change countermeasures' net effects on economic growth or employment would be positive or negative. From the viewpoint of Green growth or Green deal, the world can expect to receive high economic growth and a net employment increase by implementing climate change countermeasures. Given the negative externalities and relevant costs, and given the large-scale transition costs from existing economic and social systems, some people have concluded that it would be difficult to get net positive effects. Others may think that some cost burdens (negative externalities) would be inevitable for protecting global interest regarding climate change.

During the world's transition to carbon neutrality, the balance between positive and negative effects may differ by country or agent. In regions where sunlight and wind conditions or critical minerals[19] are abundant, cheap renewable energy may be introduced to develop industries and generate jobs, leading positive effects to outdo the negative ones. Also exerting influence on the balance between positive and negative effects will be internal factors including governments' administrative capabilities and leadership for realising carbon neutrality, companies' technological and financial resources, entrepreneurship, an industrial structure compatible with clean energy industries, labour market liquidity and the COVID-19 infection status.

As the balance between costs and positive effects of climate change countermeasures differs by country or entity, we cannot discuss whether climate change countermeasures are uniformly positive or negative for the economy. However, we must reserve judgment on an argument that climate change countermeasures would always result in positive effects on the economy.

[19] Natural resources required for renewable energy power generation and electrification

We should also be cautious of discussing climate change countermeasures only from the viewpoint of economic growth.

6.3 Potential disparities emerging from carbon neutrality initiatives

One of the major concerns in the process toward carbon neutrality is the emergence and expansion of new disparities. Factors such as economic conditions, resources endowment, technological capabilities, financial resources, industrial structure, leadership and entrepreneurship naturally differ by country or agent. The problem is that differences in these factors can produce new disparities between countries that would successfully respond to carbon neutrality and those that would fail to do so. Such disparities may be divided into the following four categories:

(1) Disparities among Advanced Economies and among Developing Economies

(2) Disparities between Advanced and Developing Economies

(3) Disparities between resource exporting countries and importing countries

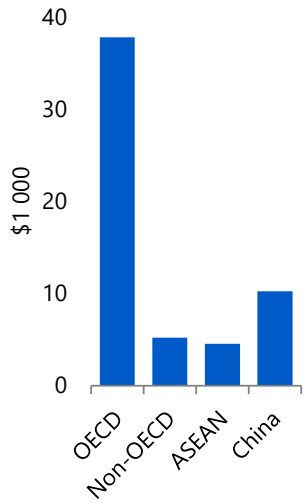
(4) Disparities between citizens within the same country

These disparities, particularly the second to fourth ones, could become serious problems.

(2) Disparities between Advanced and Developing Economies

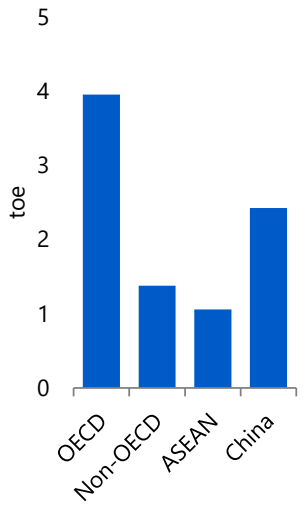
There are still great disparities between Advanced and Developing Economies in terms of income, energy consumption and CO_2 emissions (Figures 6-4, 6-5 and 6-6).

Figure 6-4 | GDP per capita [2019]



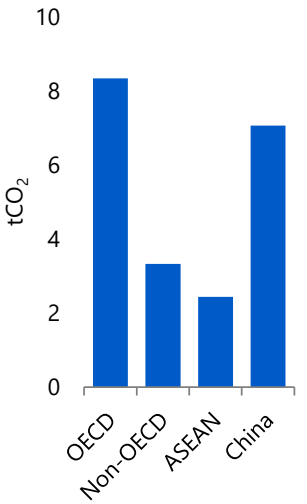
Source: International Energy Agency, World Energy Balances, 2021

Figure 6-5 | Energy consumption per capita [2019]



Source: International Energy Agency, World Energy Balances, 2021

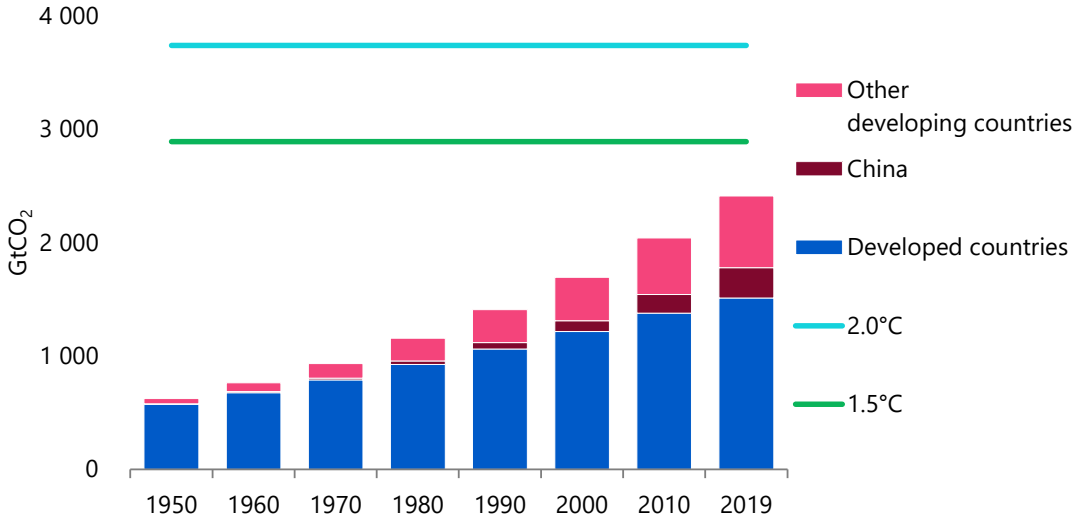
Figure 6-6 | CO_2 emissions per capita [2019]



Source: International Energy Agency, CO_2 Emissions from Fuel Combustion, 2021

Disparities between Advanced and Developing Economies regarding future emission cuts may look sharper if we consider the carbon budget, or cumulative emissions required to limit future temperature rise to a given level. Figure 6-7 indicates carbon budgets to limit temperature rise to 1.5℃ and 2.0℃, as well as past cumulative emissions. Even if temperature rise is to be limited to 2.0℃, more than 60% of the carbon budget has already been spent. Advanced Economies that account for 18% of global population commanded some 60% of the spent carbon budget. From the viewpoint of Developing Economies that are to start economic growth from now on, it may be unreasonable for Advanced Economies, which have achieved economic growth by spending a large part of the carbon budget, to ask Developing Economies to cut emissions as much as Advanced Economies under the carbon budget constraints.

Figure 6-7 | Carbon budgets and cumulative emissions



Note: Temperature rise has a probability of 50%.
Sources: Carbon budgets were prepared from Intergovernmental Panel on Climate Change, (2021), "Summary for Policymakers." In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge: Cambridge University Press. Cumulative emissions are from Friedlingstein et al., (2020), "Global Carbon Budget 2020," Earth System Science Data, 12, 3269–3340.

Let's assume that Advanced Economies in general will smoothly adapt to transition to carbon neutrality and achieve economic growth through the successful expansion of clean energy investment and the development of new green industries. If Developing Economies fail in doing so due to macroeconomic constraints and underdeveloped investment climate and see their climate change countermeasure costs affecting their economic growth, however, disparities between Advanced and Developing Economies would expand further, triggering a new North-South confrontation.

In the members of the Association of Southeast Asian Nations (ASEAN), the average emission reduction cost is estimated at $213 per tonne of CO_2 for the 2050 carbon neutrality goal and at

$197/t for the 2060 goal (Figure 6-8). Average additional costs for the emission reduction are estimated to amount to 2.9% of ASEAN GDP for the 2050 goal and 2.5% for the 2060 goal. The IEA's Net Zero roadmap estimates the global average cost at 1% for the 2050 carbon neutrality goal, indicating that additional costs for the emission reduction in Developing Economies would be relatively higher. This means that if Advanced and Developing Economies simultaneously introduce the same new energy technologies, Developing Economies that are smaller than Advanced Economies in size would have to pay relatively higher costs. In the past, Developing Economies introduced new energy technologies after they were diffused enough in Advanced Economies to cut their costs. The average electricity price in ASEAN is estimated to triple from the current level in 2060 if carbon neutrality is to be realised in the year (Figure 6-9). The IEA roadmap projects the global average electricity price to rise some 1.5-fold for the 2050 carbon neutrality goal. The pursuit of carbon neutrality over a short term would thus require a huge national burden increase in ASEAN.

Figure 6-8 | Average emission reduction cost levels for the 2050 and 2060 carbon neutrality goals in ASEAN

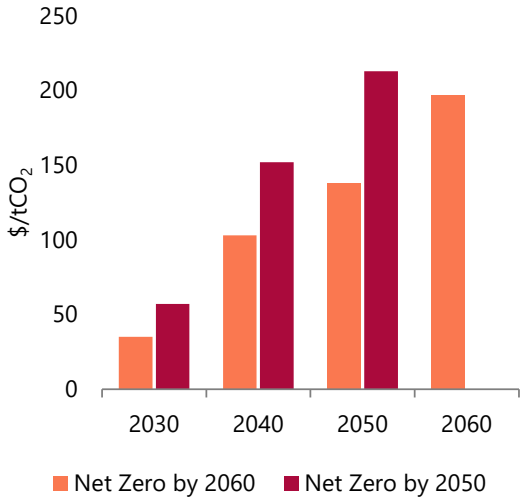
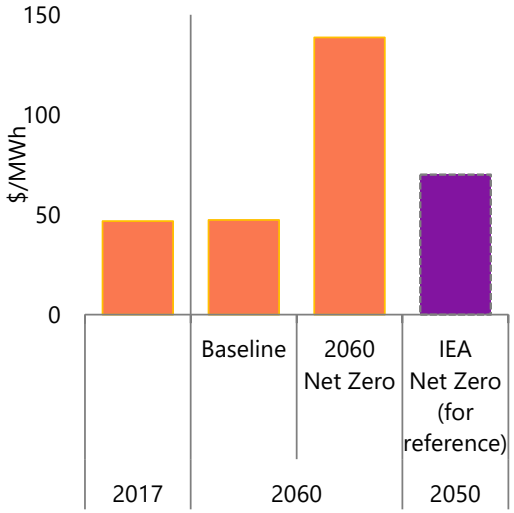


Figure 6-9 | Electricity price for the 2060 carbon neutrality goal in ASEAN



Note: The reference electricity price for the IEA Net Zero roadmap represents an increase of 50% from the 2017 level in a scenario for realising net zero emissions in 2050.
Sources: IEEJ; International Energy Agency, Net Zero by 2050, 2021

These estimates are purely theoretical as there is no guarantee that ASEAN countries would accept such huge costs only to realise an early carbon neutrality. The estimates imply that Advanced and Developing Economies are in different conditions and each would have to shoulder far different costs to realise carbon neutrality. It is not appropriate to ask Developing Economies to adopt any uniform transition path to carbon neutrality. Countries' various conditions should be considered to provide roadmaps to carbon neutrality that meet their respective conditions.

According to the Circular Carbon Economy/4Rs Scenario, Developing Economies could reduce CO_2 emissions by an additional 3.8 Gt without changing their fossil fuel consumption if they

introduce technologies to decarbonise fossil fuels for consumption (Figures 6-10 and 6-11). Developing Economies should consider introducing fossil fuel decarbonisation technologies proactively from the viewpoint of technological neutrality to realistically reduce emissions.

Figure 6-10 | Primary energy consumption in Emerging Market and Developing Economies

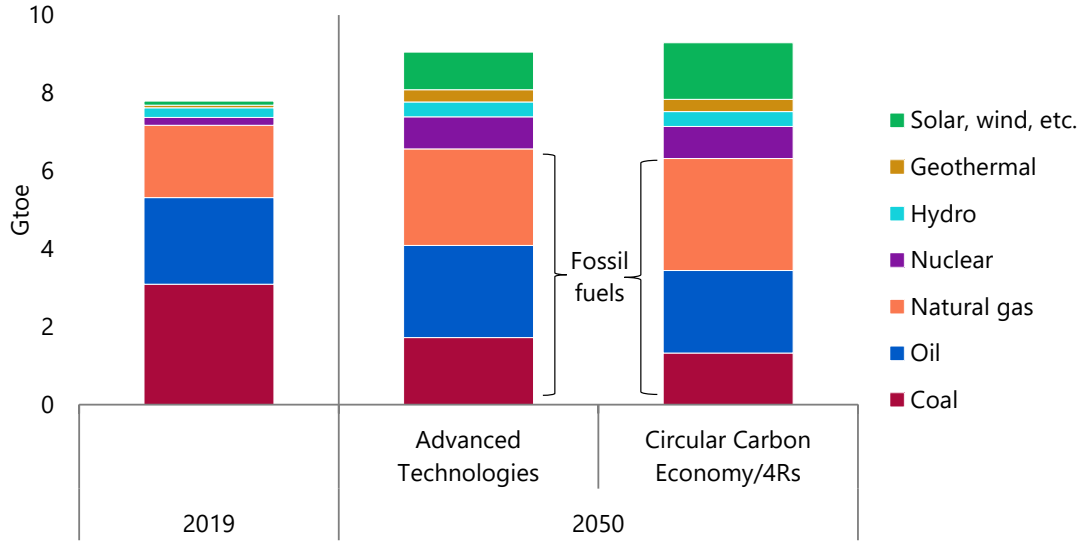
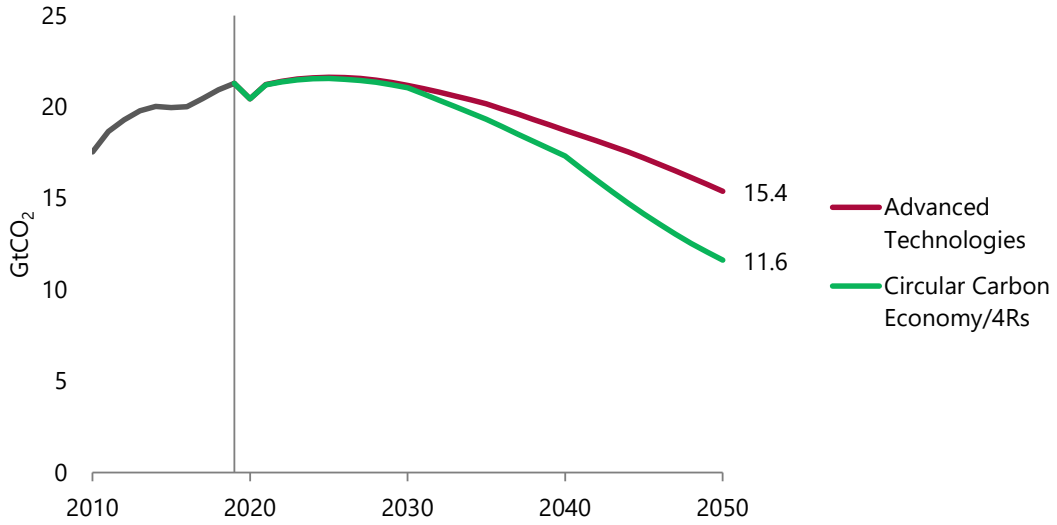


Figure 6-11 | CO_2 emissions in Emerging Market and Developing Economies



(3) Disparities between resource exporting countries and importing countries

The third king of disparities emerging from the transition to carbon neutrality are between countries that depend on fossil fuel exports and those that do not. Such disparities may slightly vary depending on the level of success of the exporting countries in decarbonising fossil fuels. For instance, oil- and gas-producing countries may secure stable export revenue in a carbon neutral world if they export hydrogen and ammonia produced through the decarbonisation of

fossil fuels. In a world where fossil fuel demand will decrease considerably, oil- and gas-producing countries that lag behind in decarbonising exports may gradually lose rents from which they have benefited. Therefore, these resource-rich countries should swiftly develop arrangements to produce energy sources through the decarbonisation of fossil fuels as cheaply and massively as possible.

(4) Disparities between citizens within the same country

The fourth and last disparities emerging from the transition to carbon neutrality are between citizens within a country. This means that a social divide and discontent would grow in a country as citizens who can successfully adapt to carbon neutrality are separated from those who cannot. In November 2018, a fuel tax increase triggered the Yellow Vest social movement in France. This kind of cost hike as part of climate change countermeasures, if steep, may cause a divide between citizens whether in Advanced or Developing Economies.

6.4 Two scenarios for transition to carbon neutrality

The transition to carbon neutrality may not necessarily bring about a dark future. Despite the abovementioned problems, we may see a scenario toward a bright future if countries and agents that successfully adapt to carbon neutrality account for a large share of the world economy. The reduction of costs for realising carbon neutrality and the sharing of knowledge for the cost reduction are key to a bright future scenario.

In the bright future scenario, Advanced Economies will lead technological development to achieve a breakthrough in the reduction of costs for introducing clean energy sources. The technological development to cut costs arising from the transition to carbon neutrality is key to realising a bright future scenario. Technologies to cut the costs will spill over from Advanced Economies to Developing Economies in the scenario. In the spill-over process, international cooperation accompanied by massive fund transfers and the entrepreneurship of companies pursuing business opportunities will play great roles. In parallel, resource-rich countries will promote the production and export of hydrogen, ammonia, synthetic fuels and other decarbonised fuels from fossil fuels in line with substantial cost cuts. If countries and agents that successfully adapt to a carbon neutral world become dominant, the negative macroeconomic effects on the world will be minimised. As new industries and business opportunities spread throughout the world, the expansion of domestic disparities will be suppressed to facilitate social and economic systems' transition to carbon neutrality.

In a dark future scenario, however, only a few countries and actors will successfully adapt to carbon neutrality, leaving the rest behind. In this scenario, the spirit of international cooperation will not work. Unilateralism will grow dominant to promote the containment of technologies, which will impede the spill-over of the successful adaptation to carbon neutrality. As a result, the presence and deterioration of the abovementioned disparities will divide the world. Economic growth and job creation through new industries and business opportunities will fail to fully resolve the problem of costs arising from the transition to carbon neutrality. The emergence and deterioration of such disparities and divides will lead to conflicts or clashes between global and national interests, weakening the discipline for pursuing global interests.

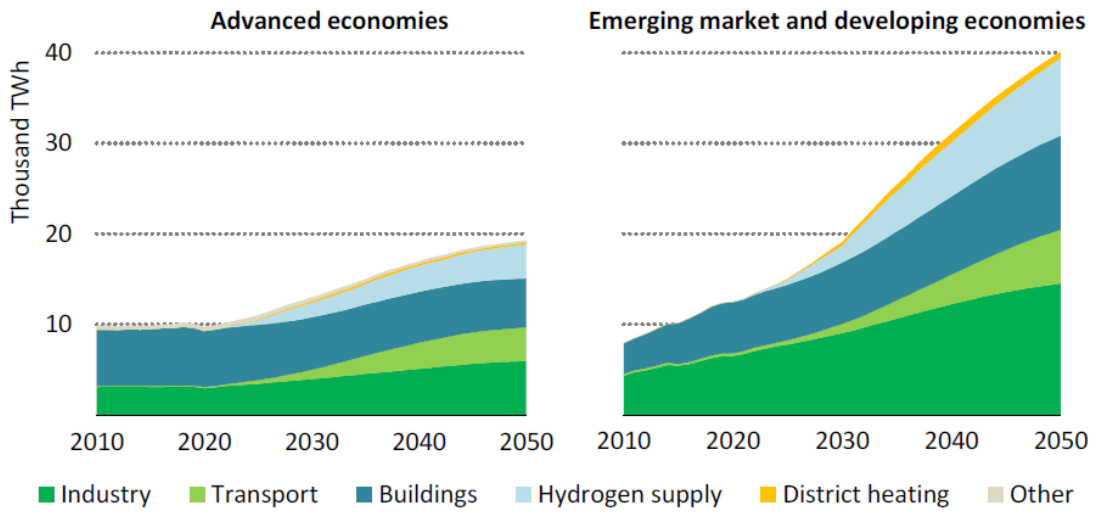
6.5 Energy security issues to grow multiplex and complex

There is a view that traditional energy security issues will become less significant in the process toward carbon neutrality. This means that as domestically available renewable energy expands its energy mix share, traditional energy security issues originating from heavy dependence on energy imports will gradually become insignificant.

As noted above, however, fossil fuels still account for 80% of global energy consumption. Countries that depend heavily on imports for fossil fuel supply will remain plagued with traditional energy security issues, at least during the transition to carbon neutrality. If countries rich with cheap renewable energy sources and those with low-cost carbon capture and storage (CCS) technologies take advantage of their resources to become major exporters of hydrogen, ammonia and synthetic fuels, their importers may continue to have energy security issues.

In addition to such traditional energy security issues, new threats and risk factors regarding energy security will arise and grow significant in a carbon neutral world. During the transition to carbon neutrality, electrification based on renewable energy will undoubtedly make progress. An IEA analysis indicates that if the world realises net-zero emissions as of 2050, electricity consumption will double from the current level in Advanced Economies and more than triple in Developing Economies (Figure 6-12). Amid such large-scale electrification, each country will have to simultaneously address the issue of intermittent power generation and inertia losses accompanying the renewable energy spread, the promotion of electricity market system reform, defence against cyberattacks and other significant problems. Stable electricity supply has been the key to energy security and will have far greater influence and significance regarding overall energy supply during the transition to a carbon neutral society. Stable supply of critical minerals that play key roles in promoting renewable energy and electrification will also become a new important energy security challenge.

Figure 6-12 | Electricity demand



Source: International Energy Agency, Net Zero by 2050, 2021

6.6 Energy supply problems arising from upstream investment suppression

While energy security issues discussed in 6.5 are rather medium to long-term events, the issue of investments in existing energy supply capacity that emerges during the transition to carbon neutrality is extremely important over the short term.

IEA report

One of the reasons the investment issue is important is that the IEA in its report titled "Net Zero by 2050: A Roadmap for the Global Energy Sector" and released on 17 May 2021, stated, "Beyond projects already committed as of 2021, there are no new oil and gas fields approved for development in our pathway, and no new coal mines or mine extensions are required". The IEA report was prepared to support the government of the United Kingdom, the chair of the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change, or COP26, in November 2021. It aimed to give a specific pathway to net-zero emissions in 2050, providing a roadmap for energy supply and demand in each sector through 2050. The report adopted a back-casting approach, indicating what should be done, when and how to proceed to reach the ultimate goal of net-zero emissions in 2050. This is different from an approach that the IEA has employed traditionally for its long-term World Energy Outlook.

The IEA report includes detailed descriptions about investments in oil, natural gas and liquefied natural gas (LNG) production capacity. It gives three points regarding oil: (1) no exploration for new resources is required, (2) investments in existing sources of oil production may be continued, and (3) only oil fields approved for development may be developed for production. The suppression of new investment may inevitably lead to a decline in production capacity. "If all capital investment in producing oil fields were to cease immediately, this would lead to a loss of over 8% of supply each year. If investment were to continue in producing fields but no new fields were developed, then the average annual loss of supply would be around 4.5%", the IEA report states. In the IEA's Net-Zero Emissions Scenario, global oil demand is projected to decline by 4% per year through 2050. The difference of some 0.5 percentage points between the supply loss and the oil demand fall may be covered by fields that have already been approved for development (p. 101 in the IEA report). The IEA's Net-Zero Emissions Scenario assumes that no new natural gas fields will be needed beyond those already under development and that many of the LNG liquefaction facilities currently under construction or at the planning stage will not be needed (p. 102).

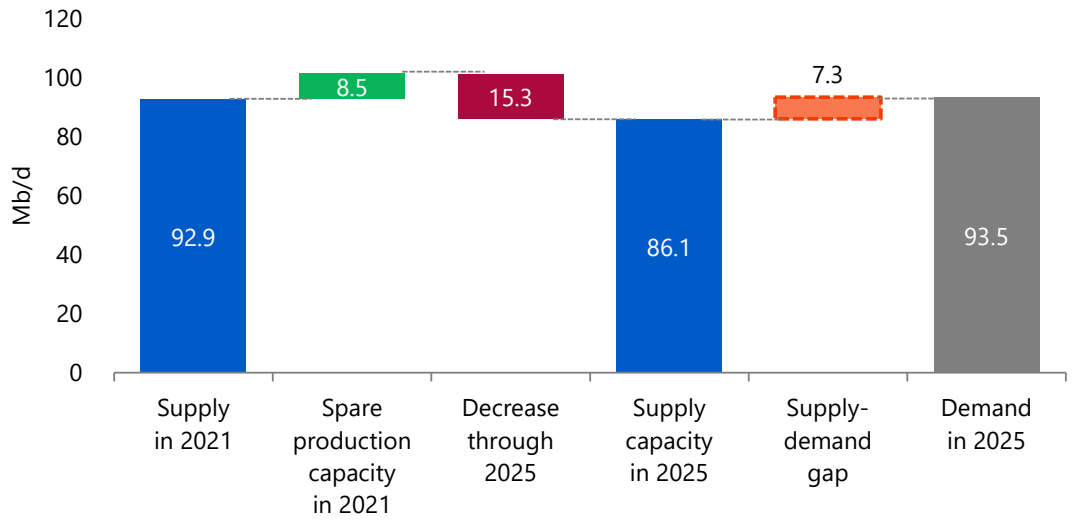
Regarding the investment analysis, the IEA report also provides fossil fuel prices projected in the Net-Zero Emissions Scenario. All fossil fuel prices are projected to decline substantially as the supply-demand balance eases in line with a demand fall. The weighted average import price of crude oil for IEA members in real terms is projected to decrease sharply from current levels to $35/bbl in 2030 and to $24/bbl in 2050. The average LNG import price for Japan is expected to decline steeply from current levels to $4.4/MBtu in 2030 and to $4.1/MBtu in 2050 (p. 51). The report notes that the oil price decline would exert great impacts on public finance of resource-rich countries dependent on oil exports and that a large part of existing oil production infrastructure would turn into stranded assets.

The above Net-Zero Emissions Scenario has been prepared by the IEA under a back-casting approach. This does not mean that the IEA views future upstream investment as unnecessary or predicts oil prices to plunge.

What would happen if investments in new production sources is stopped?

We here would like to overview the energy supply-demand balance for the case in which investments in new production sources are stopped, as assumed in the IEA report. Oil supply capacity in 2021 is estimated at 101.4 million barrels per day (Mb/d). This is determined by deducting 3.3 Mb/d in biofuels from the 96.1 Mb/d in liquid fuel supply and by adding back 8.5 Mb/d[20] as spare production capacity. If the oil supply capacity declines at a pace of 4% per year, it will come to 86.1 Mb/d in 2025, 7 Mb/d less than the oil demand in the Reference Scenario (Figure 6-13). Figure 6-14 compares the global oil supply and demand on a time-series basis. Given the high-level of spare production capacity in 2021, the termination of investments in new production sources, assumed in the IEA report, may not lead the supply-demand balance to tighten immediately. In 2024, however, the global oil supply-demand balance will indicate an undersupply and an overdemand, not only in the Reference Scenario but also in the Advanced Technologies Scenario where demand growth will be slower than in the Reference Scenario. As this represents a case in which production capacity is fully used, effects of a tightening supply-demand balance may arise in the market earlier. We must recognise once again that the termination of investments in new production sources could lead to a tighter supply-demand balance and higher prices in the not-so-distant future.

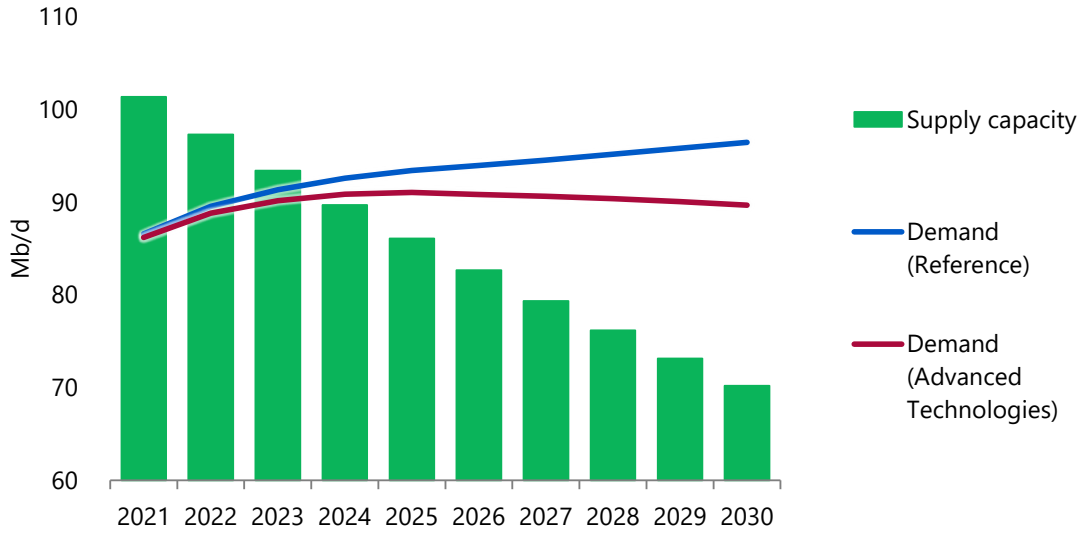
Figure 6-13 | Oil supply capacity without investments in new production sources [2025]



Note: Supply or demand does not include biofuels. Existing capacity is assumed to decrease at an annual rate of 4% (assumed for investment limited to producing oil fields and fields approved for development in the IEA report). Demand represents the Reference Scenario.
Sources: Complied from IEA Net Zero by 2050; IEA, Oil market Report

[20] International Energy Agency, Oil Market Report. 14 September 2021. p.19 and p.65

Figure 6-14 | Global oil supply capacity and demand without investments in new production sources



Note: Existing capacity is assumed to decrease at an annual rate of 4%.
Sources: Complied from IEA Net Zero by 2050; IEA, Oil market Report

As final investment decisions (FDIs) have been made for large-scale LNG projects in Africa, Russia and Canada, LNG supply capacity is projected to continue expanding until around 2028, even in the absence of new investments in projects other than those still subjected to final investment decisions (Figure 6-15). This projection assumes that projects will start operations as currently planned but if supply under these new projects is delayed, the supply-demand balance will be tighter. Unlike an oil development project, an LNG project takes a much longer lead time to start production. As any structurally tight supply-demand balance would take much time to correct, robust investment decisions to meet future demand trends are significant. In the current LNG market, spot prices are rising for many reasons. The economic recovery from the COVID-19 disaster, the introduction of low-carbonisation measures, the rapid demand growth in China and other countries combined with a European demand rise cause of a drop in wind power generation and Russian pipeline gas supply problems are all contributing to the increase in spot price (Figure 6-16). If investments in new LNG projects is stopped in this situation, the supply-demand balance may further tighten and become more uncertain over the medium term, leading LNG prices to destabilise.

Figure 6-15 | Global natural gas liquefaction capacity

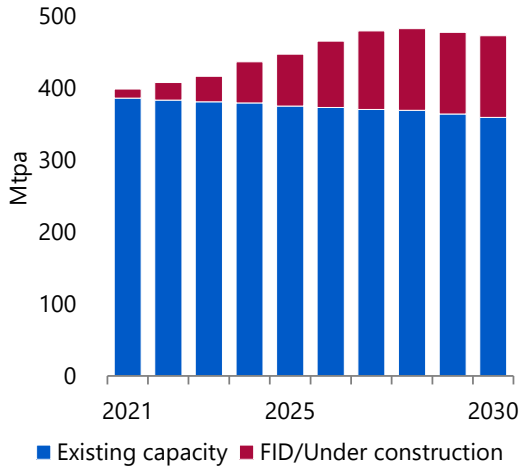
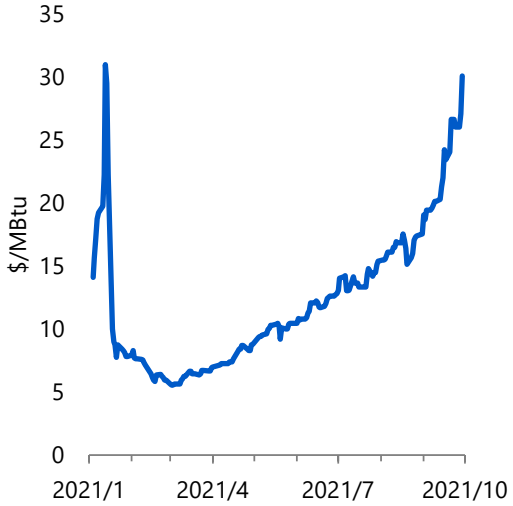


Figure 6-16 | Asian LNG spot prices



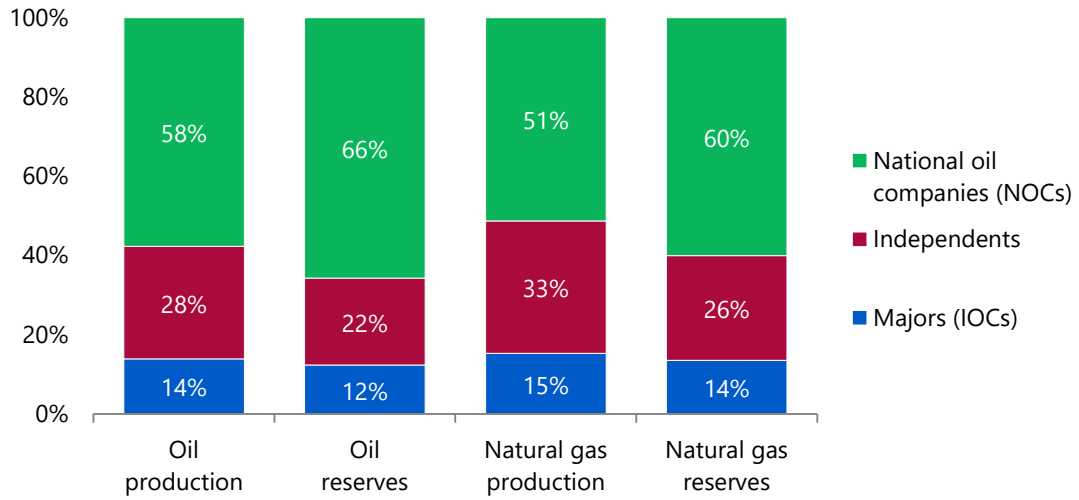
The above projections have been made for the case in which upstream investments are stopped as assumed in the IEA scenario. In reality, international oil market players would dispassionately analyse the situation and try to implement due investments. Recently, however, European and U.S. international oil companies have been urged not only by environmental non-government organisations but also by institutional investors and judicial institutions to enhance climate change countermeasures[21], making it difficult for them to freely invest in the upstream sector. Particularly, some European oil majors have set net-zero GHG emission goals for 2050 covering their product sales. New investments in oil and natural gas production capacity that emits CO_2 tends to be checked by investors.

In contrast, national oil companies in oil-producing and emerging market countries are positioned to be invulnerable to such decarbonisation pressure. These companies owned by their respective governments can continue upstream investment as in the past, unless their governments require them to take stronger climate change countermeasures[22] as is the case with China and India. National oil companies have exerted great influence on global oil and natural gas supply (Figure 6-17). The deceleration of upstream investments by international oil companies in Advanced Economies could worsen the unevenness of resources supply. As oil supply from the Organization of the Petroleum Exporting Countries (OPEC) and natural gas supply from Qatar or Russia increase robustly, these resource-rich countries' market dominance will grow further at least during the transition to a carbon neutral world.

[21] In May 2021, three new board members were elected for ExxonMobil as recommended by institutional investors calling for the expansion of decarbonisation projects. In the same month, Chevron shareholders adopted a proposal to substantially reduce emissions from products sold by the company. In the same month, the District Court in The Hague of the Netherlands ordered Shell to cut GHG emissions by 45% from 2019 by 2030.

[22] However, it may become difficult for these national companies to raise funds from European and U.S. financial institutions.

Figure 6-17 | Global oil and natural gas supply by business category [2018]



Note: Values for national oil companies cover those for International National Oil Company and National Oil Company in the source data.
Source: IEA, The Oil and Gas Industry in Energy Transitions, January 2020

Box 6-1 | Japan's new Strategic Energy Plan and LNG imports

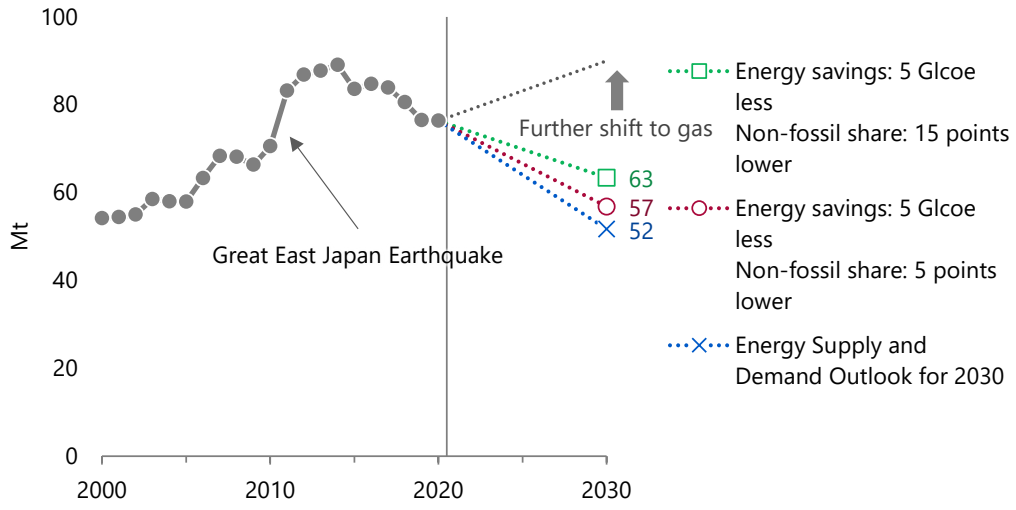
On 3 September 2021, the Agency for Natural Resources and Energy (ANRE) of Japan released a draft of the Sixth Strategic Energy Plan for public comments. To achieve an extremely ambitious GHG emission reduction goal for 2030, the energy supply and demand outlook in the draft includes about 62 billion litres of crude oil equivalent (Glcoe) in energy savings and a non-fossil energy sources' power generation mix share of about 59%. Meanwhile, primary natural gas supply is projected to decline substantially from the current level, requiring LNG procurement to be considered.

The ANRE Energy Supply and Demand Outlook for 2030 represents ambitious additions to the current outlook that already assumes thorough energy efficiency improvements and renewable energy expansion initiatives. This does not reflect any reasonable picture of the future. If energy savings are 5 Glcoe less and the non-fossil power sources' share 5 percentage points lower, the additional primary energy supply will need to be covered by fossil fuels. Although the outlook projects primary natural gas supply at around 80 Glcoe and we estimate LNG imports at around 52 Mt, the LNG imports would need rise to 57 Mt-63 Mt to make up for the lower energy savings and non-fossil power sources (Figure 6-18). If a new GHG emission reduction goal is pursued, additional measures including a further shift to gas may be required.

Given such fluctuations in LNG demand including LNG for power generation, an implication for future LNG procurement is that LNG procurement's effective flexibility for responding to demand fluctuations would have to be improved further. LNG procurement contract flexibility has recently been improved through additions and cuts

in delivery volumes, schedule changes, swaps and the removal of destination clauses. Short-term contracts and spot transactions have expanded to promote liquidity.

Figure 6-18 | Japan's LNG imports



While the flexibility for responding to short-term demand changes has expanded, thanks to these measures, the volatility of spot LNG prices has increased due to sudden seasonal demand changes and disruptions to production, making short-term seasonal procurement difficult. The abovementioned improvements in short-term procurement through flexible procurement contract volume and the elimination of destination clauses may not necessarily respond to the need for short-term procurement that will grow even more difficult. Measures will be required to respond to LNG demand fluctuations, including not only short-term seasonal changes in electricity and gas demand but also medium-term changes depending on progress in renewable energy diffusion and in energy efficiency improvement.

Particularly, it will become more important to increase or decrease delivery volumes based on greater flexible procurement volumes that would be secured under medium-term contracts in line with more elaborate outlooks covering two to three years.

LNG demand indicated in the ANRE Energy Supply and Demand Outlook for 2030 should be considered the minimum demand to be covered by long-term contracts for large projects including new ones for which long-term commitments are required. Additional demand subject to flexible responses should be covered by medium-term (two to five-year) contracts for U.S. and other supply sources and existing Asia-Pacific projects that are subject to long-term contracts expiring in several years and have already recovered initial capital investment. Japanese LNG procurers must become LNG market players with comprehensive capabilities including not only contract negotiation but also marketing to control delivery volumes effectively and proactively.

6.7 China's growing presence and geopolitical challenges

In a world heading toward carbon neutrality, China will further increase its presence. Its presence is likely to become greater not only in fossil fuel markets but also in the renewable energy industry, critical mineral supply, and in diplomacy and economic cooperation for Developing Economies over carbon neutrality initiatives. Its global presence will be huge regarding investments in renewable energy power generation through 2050 (Figure 6-19) and regarding its capacity to process fossil fuels and critical minerals (Figure 6-20). China is almost certain to retain a great influence in the world during the transition to carbon neutrality.

Figure 6-19 | Investments in renewable energy power generation [Reference Scenario, 2021-2050]

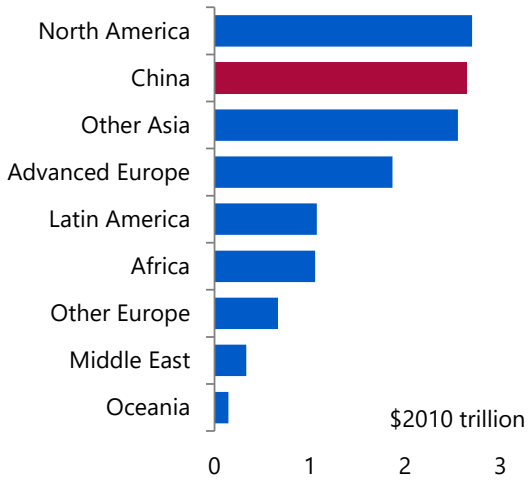
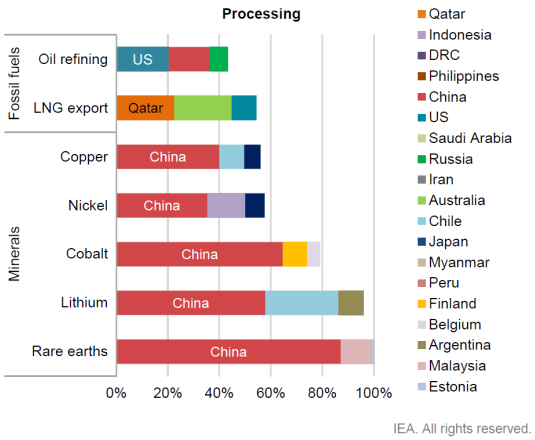


Figure 6-20 | Global capacity to process fossil fuels and critical minerals [2019]



Note: Oil refining and LNG export capacity
Source: International Energy Agency, The Role of Critical Minerals in Clean Energy Transitions, 2021

As the Advanced Economies will reform their supply chains they will compete with China regarding strategic materials, goods and technologies. How successful will they be in doing so is uncertain. If Advanced Economies enhance their China containment network, China may strengthen cooperation with Russia, Asia and other Developing Economies, as well as resource-rich economies, deepening the division of the international community.

A divided international community is undesirable given that climate change countermeasures fundamentally pursue a common global interest. Although global cooperation is essential and ideal in climate change countermeasures, the reality is that national interests often clash with each other. Given the abovementioned difficult international environment and geopolitical situation, desirable cooperation cannot work well. Therefore, China's presence and the risk of a divided international community will exert great influence on the world pursuing carbon neutrality. To carry out the transition to carbon neutrality in a bright future scenario, countries would have to overcome various problems to promote international cooperation and diffuse the knowledge of carbon neutrality throughout the world. If such knowledge fails to spread, the future of carbon neutrality would be darker and plagued with widening divisions and disparities.

6.8 Conclusion

The process toward carbon neutrality will produce not only positive economic effects through technological innovation and the creation of clean energy industries and markets, but also generate costs associated essentially with climate change countermeasures. The relationship between such positive and negative effects may differ by country or agent. There is no guarantee that positive effects will outdo negative ones.

Energy security issues will grow more multiplex and complex. Even in the process toward carbon neutrality, the issue of dependence on energy imports may remain a significant challenge. In addition to traditional energy security issue, electricity and critical mineral supply security issues may emerge as new significant challenges.

Any unwarranted argument that denies the need for upstream investment may become a risk factor. Back-casting scenarios such as the IEA Net-Zero Emissions Scenario are important and worthwhile for comparing benchmarks in the current world and a desirable future world scenario. However, such back-casting scenarios could also discourage originally required or justifiable investments in a manner to invite a tighter supply-demand balance in the future.

Nonetheless, the transition toward carbon neutrality should be promoted inclusively despite the fact that costs may produce not only positive effects but also various disparities and divides. It may be extremely difficult to eliminate such problems, however, it would be desirable to prevent any countries or actors from being left behind, while suppressing as much as possible such disparities and divides.

The Advanced Economies should cooperate with the Developing Economies during the transition period. They should realise paths to carbon neutrality that are securely implementable over the long term, while avoiding exerting excessive burdens on the developing world. Specifically, the measures should consider the different national circumstances regarding industrial and social structure, resources endowment and geographical characteristics. The Advanced Economies should collaborate with the Developing Economies in preparing realistic roadmaps to carbon neutrality and be prepared to provide the technological, financial and human resources support required to implement them.

Advanced Economies have so far implemented international cooperation in energy and environmental fields related to emission reduction. The significance of international cooperation to realise the long-term carbon neutrality goal, however, is fundamentally different and is far more complex than for simple emission reduction. To realise a bright future in which more countries and agents will successfully reach carbon neutrality, Advanced Economies are required to redouble their efforts to promote a closer international cooperation.

7. Circular Carbon Economy/4Rs Scenario

7.1 What is the Circular Carbon Economy/4Rs Scenario?

Concept and components

The Circular Carbon Economy/4Rs Scenario (CCE Scenario) was first covered and explained in the IEEJ Outlook 2021 released in October 2020. The IEEJ Outlook 2022 provides a revised version of the scenario[23].

As major economies such as the United States, China, the European Union (EU), Japan and the United Kingdom have declared their respective long-term goals of net-zero greenhouse gas (GHG) emissions, initiatives to enhance GHG emission cuts have unprecedentedly gained momentum. Also contributing to growing interests in the net-zero emissions has been a report published by the International Energy Agency (IEA) in 2021 on a Roadmap for the Global Energy Sector to net-zero by 2050.

The IEEJ Outlook 2022 does not adopt the IEA report's back-casting approach in which a pathway to a desirable future picture is planned backward from the future goal. Instead, IEEJ believes that it should start from the present energy supply and demand situation and use an econometric approach to estimate global energy demand for a scenario where conceivable decarbonisation technologies will be introduced to the maximum extent. In the Advanced Technologies Scenario, each country is assumed to come up with and successfully implement strong energy and environmental policies for securing stable energy supply and enhancing climate change countermeasures, and will introduce energy and environmental technologies to the maximum extent. The CCE Scenario combines the Advanced Technologies Scenario with the introduction of technologies for decarbonising fossil fuels. The potential to introduce these technologies has increased in recent years. The Circular Carbon Economy (CCE) approach seeks to reduce atmospheric carbon dioxides (CO_2) from a comprehensive perspective covering the 4Rs (Reduce, Reuse, Recycle and Remove) cycle. At a Group of 20 summit in November 2020, the CCE platform with the 4Rs framework was appreciated as an integrated, inclusive and pragmatic approach to tackle global issues including economic growth and environmental conservation[24].

The traditional circular economy concept has been developed into the CCE concept. While the circular economy concept seeks to hold down the use of resources or the generation of waste through three Rs – Reduce, Reuse and Recycle, the CCE concept calls for reducing atmospheric

[23] For details of the significance and basic concept of the scenario, see IEEJ Outlook 2021, pp.127-136.

[24] The 2020 G20 summit leaders' declaration included the following:

"We endorse the Circular Carbon Economy (CCE) Platform, with its 4Rs framework (Reduce, Reuse, Recycle and Remove), recognising the key importance and ambition of reducing emissions, taking into account system efficiency and national circumstances. The CCE is a voluntary, holistic, integrated, inclusive, pragmatic, and complementary approach to promote economic growth while enhancing environmental stewardship through managing emissions in all sectors including, but not limited to, energy, industry, mobility, and food". G20 Riyadh Summit Leaders' Declaration. 21-22 November 2020. P9.

CO_2 through four Rs – the above 3Rs plus Remove. In the CCE, the 4Rs technologies (Table 7-1) will be introduced to reduce emissions while decarbonising and using fossil fuels.

Table 7-1 | 4Rs technologies for Circular Carbon Economy

	Overview	Major technologies
Reduce	Reducing fossil fuel consumption volume to reduce CO_2 emissions into the atmosphere	Promoting energy efficiency Promoting renewables diffusion Promoting nuclear energy diffusion Using advanced ultra-supercritical pressure coal-fired power plants Promoting fuel cell and hydrogen vehicle diffusion Hydrogen-fired power generation Using hydrogen in industry and buildings sectors Using ammonia as fuel for power plants and ships Using coal ash and other admixtures to reduce cement production Hydrogen-reduction ironmaking process
Reuse	Using captured CO_2 for some purposes without transforming it chemically	Enhanced oil recovery using the CO_2 at oil fields Concentrating the CO_2 in greenhouses for agricultural production Using the CO_2 for increasing algae biofuel feedstock production Producing reed-based jet fuel
Recycle	Transforming captured CO_2 chemically for some purposes	Allowing the CO_2 to be absorbed into concrete Fixing the CO_2 as carbonate Producing synthetic liquid fuels from the CO_2 and hydrogen Producing synthetic methane from the CO_2 and hydrogen Producing chemical materials from the CO_2 and hydrogen
Remove	Capturing and removing atmospheric CO_2	Carbon capture and storage (CCS) Direct air capture (DAC) of CO_2

Source: Mansouri, N. Y. *et al.* (2020) "A Carbon Management System of Innovation: Towards a Circular Carbon Economy"

Significance and components

Next, we discuss the significance of the Circular Carbon Economy/4Rs Scenario in the context of the present energy and environment situation. Coming first is the significance of adopting a decarbonisation scenario using a bottom-up approach. The IEA's energy supply and demand outlook regarding the long-term net-zero emission goal represents a back-casting approach to consider what should be done to reach a pre-fixed future goal. This can be described as a

normative outlook in that a desirable future is given as a premise. If the reduction of GHG emissions to mitigate climate change is shared as a common global norm and the world acts in a rational way, based on the norm, such normative outlook may have greater potential to be realised. In real energy markets, however, all energy consumers or suppliers do not necessarily act in a rational way. Actual energy demand and supply is influenced by current political, economic and social factors. There may be a situation in which all conditions are favourable for reducing GHG emissions but if governments with a negative attitude toward climate change countermeasures emerge or a global economic crisis forces the countermeasures to be given less priority, they may stagnate. We must recognise that a normative energy supply and demand outlook, though being worthwhile as a target benchmark, does not represent any scenario that is highly likely to be realised in the real world.

Actual energy supply is based on various infrastructure (including upstream assets and transport infrastructure such as pipelines and ships). As economies of scale work in energy supply, considerably strong political intervention may be required to achieve a discontinuous energy transition. Being difficult to implement, however, such intervention may trigger rapid energy price fluctuations and employment adjustment. In this sense, a bottom-up approach that considers potential future changes on the premise of current infrastructure and energy supply systems may provide a more accurate energy supply and demand outlook than the back-casting approach that sets a desirable future goal and considers how to narrow gaps between the present status and the future goal.

Depicting an energy supply and demand pathway to a pre-fixed goal may be worthwhile for verifying gaps between the present status and the goal and identifying challenges to fill the gaps. However, the pathway depicted in this way may be rather virtual. The energy industry that does business and considers business investment may have to base business decisions on a realistic outlook as well as such virtual one. Being aware of the above, the IEEJ Outlook 2022 adopts a decarbonisation scenario using a bottom-up approach to assume the introduction of various energy and environmental technologies in line with the present status and conduct a more grounded analysis.

The second significant point of the Circular Carbon Economy/4Rs Scenario is that it is worthwhile to put fossil fuels into an energy mix. Fossil fuel resources are unevenly distributed and less attractive from the viewpoint of energy self-sufficiency. However, oil and coal, for example, are internationally integrated markets. If unexpected disruptions to supply come, it may be easy to procure oil or coal from international markets to cover shortages. Even for liquefied natural gas (LNG), spot transactions and short-term contracts covered nearly 40% of global transactions in 2020 and the LNG's liquidity in the international market has been improving year by year. Fossil fuels are convenient in that they can be stockpiled to respond to any long supply disruptions. As renewable energy power generation spreads, thermal power generation using fossil fuels is worthwhile and important for adjusting electricity supply to fluctuations in output from renewable energy facilities and for maintaining power generation inertia. As a matter of course, fossil fuels may have to be decarbonised with carbon capture, utilisation and storage (CCUS) technologies in the future. This indicates that fossil fuels may be effectively used even in a decarbonised world if excellent decarbonisation methods are found.

The third significant point is a technology-neutral approach. To realise ambitious emission cuts, a technology-neutral approach that focuses on emission reduction effects without prioritising or subordinating any energy sources is required. All emission reduction technologies must be mobilised to realise the ambitious emission reduction goals offered by countries in the world. In this respect, the decarbonisation of fossil fuels should be positioned as one of the major emission reduction options. A key point of climate change countermeasures is that CO_2 and methane emissions from fossil fuel consumption should be reduced. Fossil fuels themselves are not evil and the use of decarbonised fossil fuels can be balanced with the reduction of emissions. The decarbonisation of fossil fuels based on such approach, as well as energy efficiency improvement or renewable energy promotion, should be positioned as one of the major emission reduction measures. The Circular Carbon Economy/4Rs Scenario quantitatively and explicitly demonstrates the emission reduction effects of the fossil fuel decarbonisation.

7.2 Scenario assumptions

The Circular Carbon Economy/4Rs Scenario concept calls for realistic emissions reductions while using various fossil fuel decarbonisation technologies under a technology-neutral approach. Based on the CCE concept, the Circular Carbon Economy/4Rs Scenario assumes the introduction of decarbonisation technologies cited in Table 7-2. As noted above, the assumptions other than the technology assumptions in Table 7-2 are common to the Circular Carbon Economy/4Rs and Advanced Technologies Scenarios.

Changes from the Circular Carbon Economy/4Rs Scenario in the IEEJ Outlook 2021 include the elaboration of technology introduction conditions in line with national and regional characteristics. Hydrogen and ammonia use for power generation are assumed separately. The revised Circular Carbon Economy/4Rs Scenario newly assumes the introduction of synthetic fuels, also known as E-fuels, as one of the carbon recycling technologies. The introduction of synthetic methane is assumed as a leading decarbonisation means for sectors where electrification is difficult. Hydrogen introduction is assumed not only for the power generation sector but also for industry, buildings and other sectors.

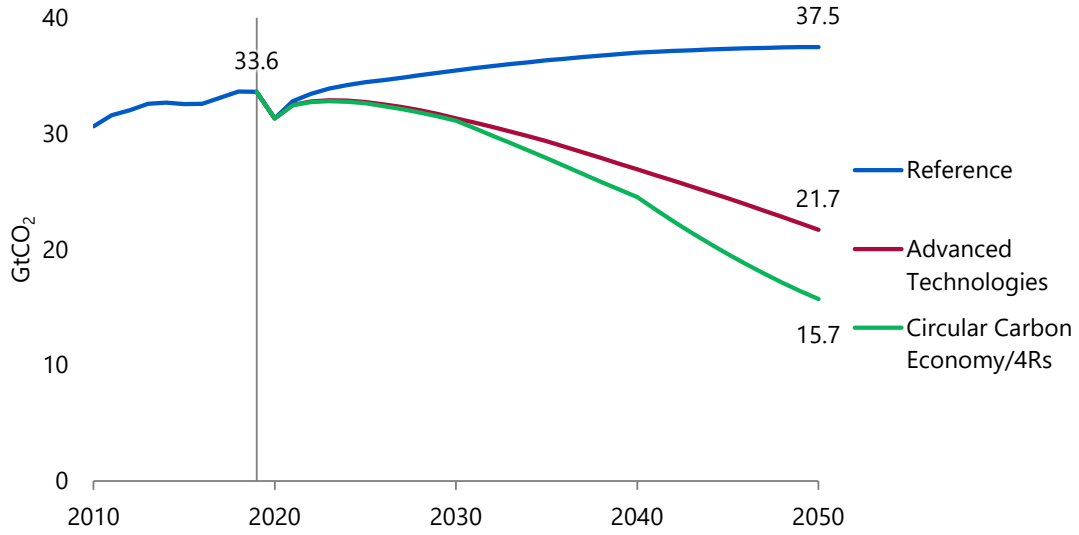
Table 7-2 | Technology assumptions [Circular Carbon Economy/4Rs Scenario]

4Rs	Technologies assumed for the scenario	Assumption
Reduce	Using hydrogen for power generation	Hydrogen (including ammonia) will be introduced for 50%-75% of non-CCS coal/gas-fired power plants in 2050.
	Using hydrogen for transport	Hydrogen will cover 10%-15% of oil demand in the road transport sector and 20%-30% of such demand in the international transport sector in 2050.
	Using hydrogen in industry	Hydrogen will cover 10%-30% of energy demand in industry in 2050 in Advanced Economies and others where hydrogen supply is abundant.
	Hydrogen-reduction ironmaking	Hydrogen-reduction ironmaking technology using blue hydrogen will be introduced for 25% of crude steel production in the Advanced Economies, China, India and Brazil in 2050.
	Using hydrogen in buildings	Hydrogen will cover 10% of energy demand in buildings in 2050 in Advanced Economies.
	Reducing cement production	Coal ash, limestone calcined clay and other admixtures will be used to cut global cement production in 2050 by 25%.
Reuse	Concentrating CO_2 to increase algae biofuel production	Biodiesel production in 2050 will increase by 50%.
	CO_2-absorbing concrete	CO_2 absorption technology will be introduced for 25%-50% of global concrete production in 2050.
	Synthetic methane	Synthetic methane will cover 20%-40% of fuel demand in industry and buildings in 2050.
Recycle	Synthetic fuels	Synthetic fuels will cover 10%-20% of oil demand in the road transport sector in 2050.
Remove	Carbon capture and storage	Additional CCS will be implemented for blue hydrogen production

7.3 Supply/demand picture

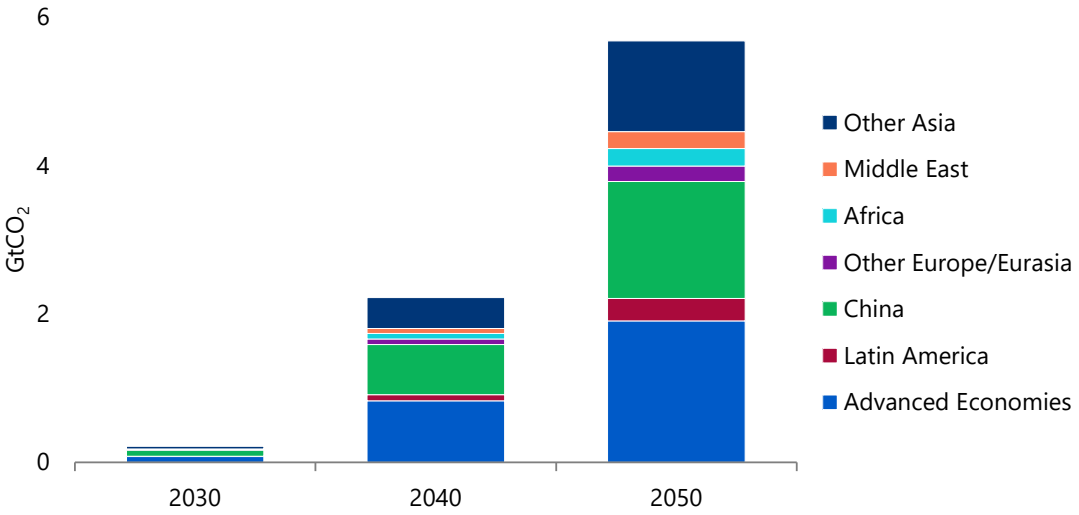
In the Circular Carbon Economy/4Rs Scenario, global CO_2 emissions in 2050 will be more than halved from 33.6 Gt in 2019 to 15.7 Gt (Figure 7-1), 21.7 Gt less than in the Reference Scenario and 6.0 Gt less than in the Advanced Technologies Scenario. Of the decrease from the Advanced Technologies Scenario, more than a half (3.4 Gt) comes from non-power sectors.

Figure 7-1 | Global CO_2 emissions



Emerging Market and Developing Economies account for nearly 70% of the additional emission cuts in 2050 (Figure 7-2). This indicates that if fossil fuel decarbonisation technologies are promoted further in Emerging Market and Developing Economies, the world may reduce emissions further while using fossil fuels.

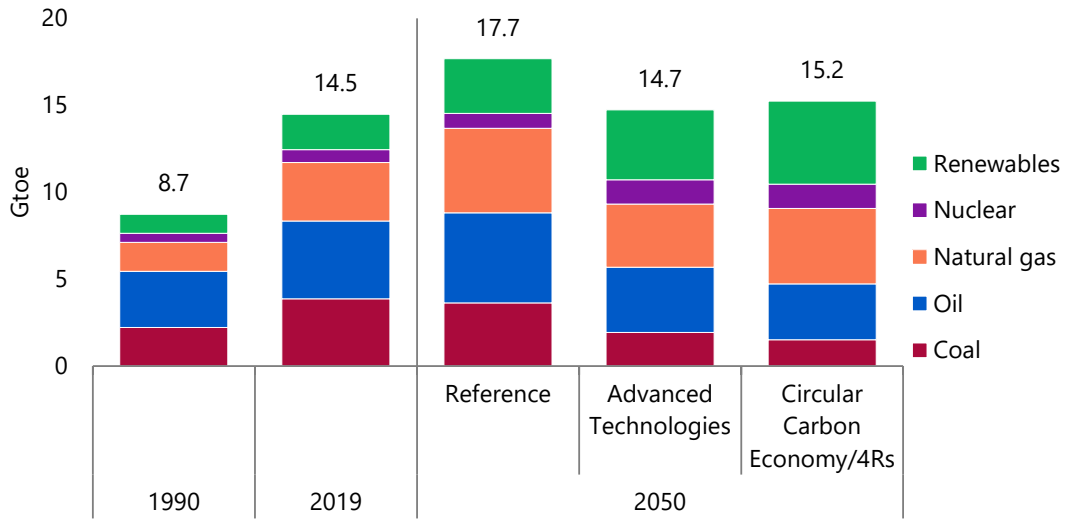
Figure 7-2 | Additional CO_2 emission cuts (compared with the Advanced Technologies Scenario) [Circular Carbon Economy/4Rs Scenario]



Note: Emission cuts through hydrogen, ammonia, synthetic methane and synthetic fuel consumption are attributed to consumption sites

Primary energy consumption in the Circular Carbon Economy/4Rs Scenario will be slightly more than in the Advanced Technologies Scenario (Figure 7-3). This is because the introduction of various decarbonisation technologies will generate additional demand for energy transformation. Fossil fuels' energy mix share in 2050 will be 60%, far lower than 77% in the Reference Scenario but close to 63% in the Advanced Technologies Scenario. The proactive introduction of fossil fuel decarbonisation technologies will allow the world to realise substantial emission cuts while continuing to use fossil fuels. Among fossil fuels, oil and coal will see their energy mix shares decreasing, with the natural gas share expanding. This is because coal and oil consumption in the power generation and transport sectors will be replaced by blue hydrogen[25] from natural gas.

Figure 7-3 | Global primary energy consumption [2050]



Note: Natural gas includes synthetic methane.

[25] Blue hydrogen is produced from the decomposition of fossil fuels while the emitted CO_2 is captured.

Power generation mix shares in the Circular Carbon Economy/4Rs Scenario will be lower than in the Advanced Technologies Scenario for coal and others (including hydro and biomass) and higher for renewables and hydrogen (including ammonia) (Figure 7-5). The higher share for renewables is attributable mainly to an increase in green hydrogen[26] production. Fossil fuels' share will decline from 32% in the Advanced Technologies Scenario to 23%. Hydrogen will account for 4% of power generation, replacing some fossil fuels.

Figure 7-4 | Global power generation [2050]

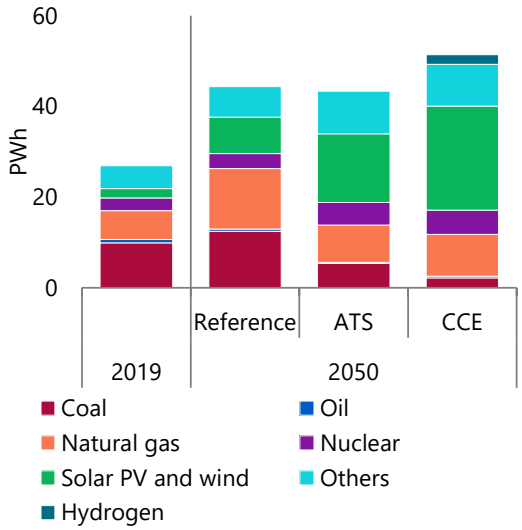
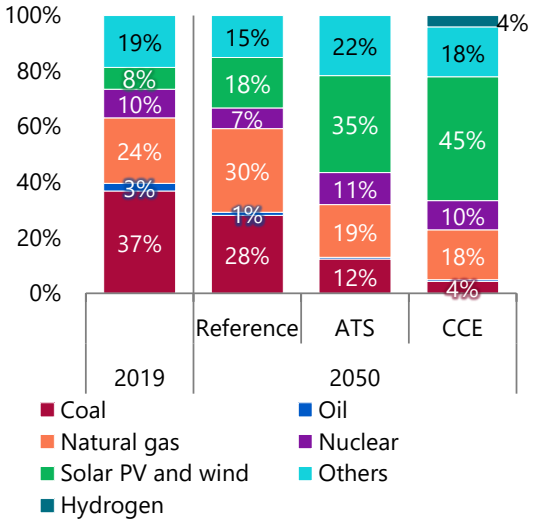


Figure 7-5 | Global power generation mix [2050]

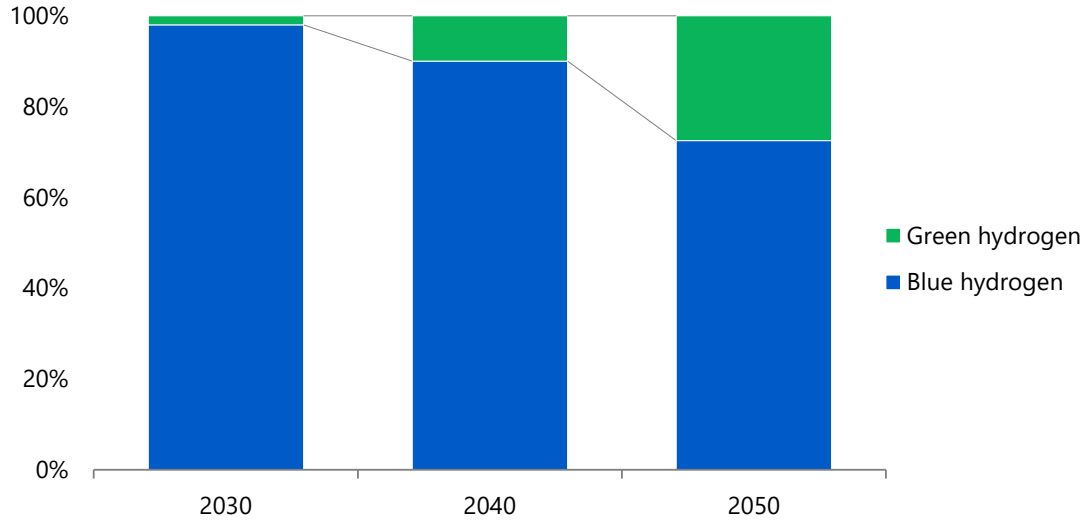


Notes: ATS stands for Advanced Technologies Scenario. CCE stands for Circular Carbon Economy/4Rs Scenario. Natural gas includes synthetic methane.

In the Circular Carbon Economy/4Rs Scenario, clean hydrogen (blue and green hydrogen) will play great roles in various sectors. In 2050, blue hydrogen will account for about 70% of hydrogen consumption and green hydrogen for about 30%. While green hydrogen emits less CO_2 than blue hydrogen over a lifecycle, blue hydrogen is easier to secure the quantity. This is because green hydrogen production capacity per plant is smaller. If surplus electricity is used for green hydrogen production, capacity factor may be lower, leading to even lower production. From the viewpoint of economic efficiency, blue hydrogen will be cheaper to produce than green hydrogen for the immediate future. Toward 2050, however, the production cost gap is expected to narrow. Blue hydrogen will diffuse first before green hydrogen does, thanks to the resolution of production capacity and cost problems through technological advancement (Figure 7-6).

[26] Green hydrogen is produced through water electrolysis with renewable energy.

Figure 7-6 | Hydrogen consumption breakdown [Circular Carbon Economy/4Rs Scenario]



Hydrogen demand will expand in almost all regions. A particularly major demand region will be Asia (Figure 7-7) because the decarbonisation of the power generation sector in Asia is likely to be slower than in other regions. In China, Southeast Asia and South Asia, demand will increase substantially for hydrogen to be mixed with other fuels for thermal power generation. In Advanced Economies including Europe and the United States, hydrogen demand will expand as in Emerging Market and Developing Economies. As Advanced Economies make greater progress in the decarbonisation of the power generation sector and in the introduction of carbon capture and storage (CCS) technologies for residual thermal power plants, hydrogen demand will increase in the transport and industry sectors as well as in the power generation sector. Hydrogen will be used for producing synthetic methane and synthetic fuels designed to promote decarbonisation while using existing infrastructure, playing a great role as feedstock for these tertiary fuels.

As blue hydrogen plays great roles as described above, major hydrogen suppliers will be North America, the Middle East and Russia that are rich with fossil fuel resources used for producing blue hydrogen (Figure 7-8). While green hydrogen is produced almost evenly in the world, Latin America, the Middle East and North Africa that feature cheaper renewable energy resources than other regions will produce relatively more.

Figure 7-7 | Global hydrogen demand [Circular Carbon Economy/4Rs Scenario]

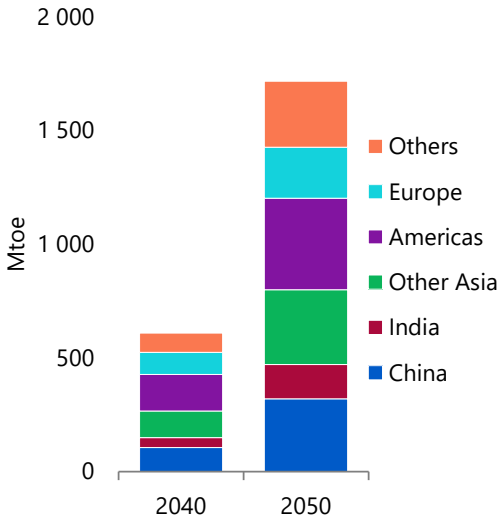


Figure 7-8 | Global hydrogen supply [Circular Carbon Economy/4Rs Scenario]

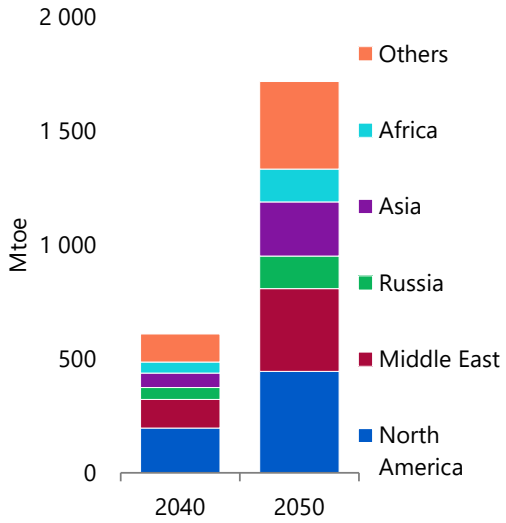
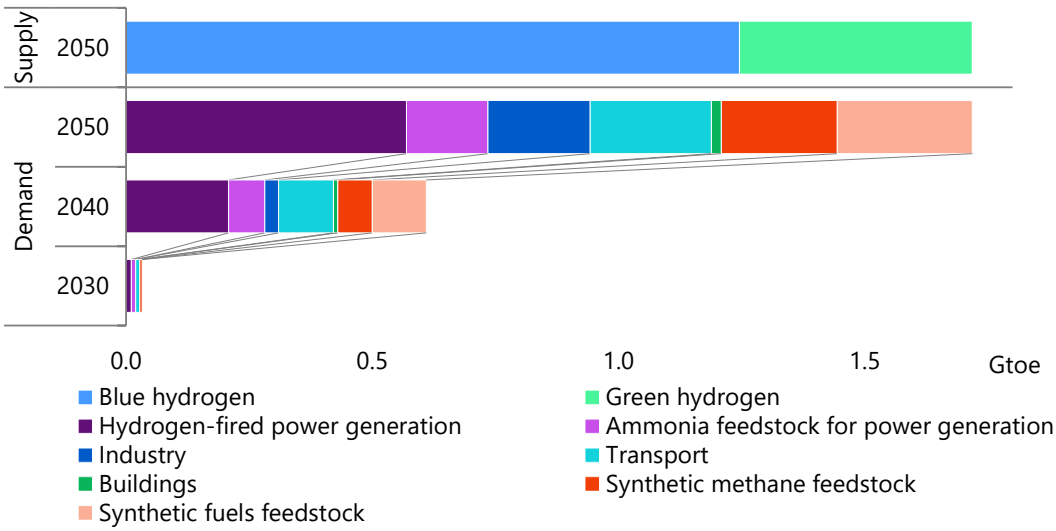


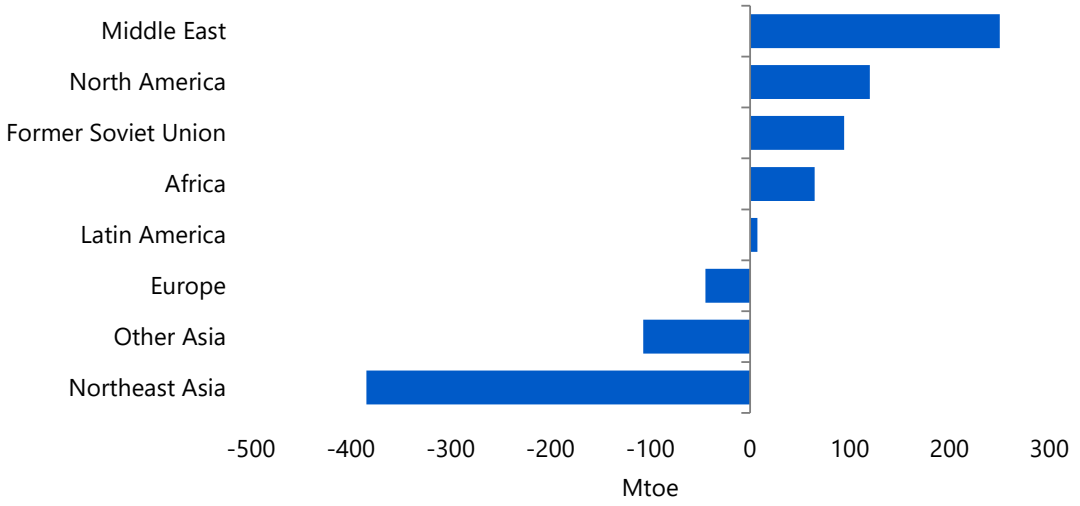
Figure 7-9 indicates hydrogen demand by sector. The power generation sector will be the largest hydrogen consumer, accounting for 40% of hydrogen demand including ammonia. The Circular Carbon Economy/4Rs Scenario assumes the direct combustion of ammonia as a hydrogen use method in the power generation sector. Mainly, the power generation sector will expand the consumption of ammonia viewed as a relatively cost-competitive hydrogen carrier. The power generation sector's ammonia introduction will start mainly in Japan in the mid-2020s. In 2050, ammonia will account for 23% of global hydrogen demand in the power generation sector and Asia will capture most of the global ammonia demand.

Figure 7-9 | Global hydrogen demand [Circular Carbon Economy/4Rs Scenario]



As hydrogen is difficult to transport, local production for local consumption is desirable. If the world promotes decarbonisation in the future, however, international hydrogen trade will emerge between regions that can produce massive hydrogen cheaply and the other regions. Major hydrogen exporters assumed in the Circular Carbon Economy/4Rs Scenario are the Middle East and North America that are expected to produce blue and green hydrogen more cheaply than other regions (Figure 7-10). In contrast, Asia with its growing energy demand will become a major hydrogen importer, procuring hydrogen mainly in the form of ammonia.

Figure 7-10 | Net hydrogen exports [Circular Carbon Economy/4Rs Scenario, 2050]



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, Cambodia, DPR Korea, Lao PDR, 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, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela, and Other Non–OECD Americas in IEA statistics
Europe	Advanced Europe	France
		Germany
		Italy
		United Kingdom

		Others	Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Iceland, Ireland, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and Turkey
	Other Europe/Eurasia	Russia	
		Other Former Soviet Union	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan
		Other Emerging and Developing Europe	Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Gibraltar, Kosovo, Malta, Montenegro, Republic of North Macedonia, 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, and Sweden
Advanced Economies	Advanced Europe, Hong Kong, Japan, Korea, North America, Oceania, Singapore, and Chinese Taipei
Emerging Market and Developing Economies	Africa, Brunei Darussalam, People's Republic of China, India, Indonesia, Latin America, Malaysia, Middle East, Myanmar, Other Europe/Eurasia, Other Asia, Philippines, Thailand, and Viet Nam
Organization of the Petroleum Exporting Countries (OPEC)	Algeria, Angola, Republic of the Congo, Equatorial Guinea, Gabon, Iraq, Iran, Kuwait, Libya, Nigeria, Saudi Arabia, United Arab Emirates, and Venezuela

Notes: (1) Other Former Soviet Union includes Estonia, Latvia and Lithuania before 1990, and (2) Advanced Economies, and Emerging Market and Developing Economies include regions.

Table A2 | Major energy and economic indicators

				Reference		Advanced Technologies		CAGR (%)		
								1990/	2019/2050	
		1990	2019	2030	2050	2030	2050	2019	Reference	Adv. Tech.
Total primary energy consumption (Mtoe)	**World**	**8,738**	**14,486**	**15,869**	**17,675**	**15,125**	**14,738**	**1.8**	**0.6**	**0.1**
	AEs*1	4,465	5,236	5,084	4,717	4,895	4,055	0.6	-0.3	-0.8
	EMDEs*2	4,070	8,829	10,297	12,211	9,772	10,056	2.7	1.1	0.4
	Asia	2,083	6,064	7,063	8,028	6,740	6,562	3.8	0.9	0.3
	Non-Asia	6,453	8,002	8,318	8,900	7,928	7,549	0.7	0.3	-0.2
Oil consumption (Mtoe)	**World**	**3,232**	**4,475**	**4,728**	**5,188**	**4,396**	**3,762**	**1.1**	**0.5**	**-0.6**
	AEs	1,824	1,837	1,679	1,373	1,539	973	0.0	-0.9	-2.0
	EMDEs	1,206	2,219	2,578	3,170	2,432	2,368	2.1	1.2	0.2
	Asia	616	1,470	1,695	2,024	1,605	1,511	3.0	1.0	0.1
	Non-Asia	2,414	2,585	2,562	2,519	2,366	1,830	0.2	-0.1	-1.1
Natural gas consumption (Mtoe)	**World**	**1,662**	**3,363**	**3,885**	**4,857**	**3,668**	**3,627**	**2.5**	**1.2**	**0.2**
	AEs	827	1,503	1,592	1,611	1,458	1,013	2.1	0.2	-1.3
	EMDEs	835	1,859	2,279	3,158	2,189	2,477	2.8	1.7	0.9
	Asia	116	670	933	1,315	885	1,009	6.2	2.2	1.3
	Non-Asia	1,547	2,692	2,939	3,454	2,761	2,481	1.9	0.8	-0.3
Coal consumption (Mtoe)	**World**	**2,220**	**3,878**	**3,910**	**3,638**	**3,344**	**1,937**	**1.9**	**-0.2**	**-2.2**
	AEs	1,088	786	652	466	518	217	-1.1	-1.7	-4.1
	EMDEs	1,133	3,092	3,258	3,171	2,826	1,719	3.5	0.1	-1.9
	Asia	788	2,947	3,115	2,963	2,694	1,596	4.7	0.0	-2.0
	Non-Asia	1,432	932	794	675	650	340	-1.5	-1.0	-3.2
Power generation (TWh)	**World**	**11,845**	**26,936**	**33,308**	**44,376**	**33,444**	**43,364**	**2.9**	**1.6**	**1.5**
	AEs	7,667	10,913	11,860	13,688	11,922	13,670	1.2	0.7	0.7
	EMDEs	4,178	16,023	21,449	30,688	21,522	29,694	4.7	2.1	2.0
	Asia	2,237	12,432	16,577	22,124	16,570	21,153	6.1	1.9	1.7
	Non-Asia	9,608	14,504	16,731	22,252	16,874	22,212	1.4	1.4	1.4
Energy-related carbon dioxide emissions (Mt)	**World**	**20,511**	**33,613**	**35,461**	**37,479**	**31,330**	**21,706**	**1.7**	**0.4**	**-1.4**
	AEs	10,782	11,019	10,156	8,527	8,783	4,688	0.1	-0.8	-2.7
	EMDEs	9,102	21,292	23,813	26,746	21,176	15,391	3.0	0.7	-1.0
	Asia	4,682	16,148	17,954	18,921	15,802	10,594	4.4	0.5	-1.4
	Non-Asia	15,202	16,163	16,015	16,352	14,157	9,486	0.2	0.0	-1.7
GDP ($2010 billion)	**World**	**37,974**	**84,540**	**111,268**	**183,075**	**111,268**	**183,075**	**2.8**	**2.5**	**2.5**
	AEs	28,841	52,404	62,231	84,998	62,231	84,998	2.1	1.6	1.6
	EMDEs	9,133	32,136	49,037	98,077	49,037	98,077	4.4	3.7	3.7
	Asia	7,634	26,795	40,632	76,784	40,632	76,784	4.4	3.5	3.5
	Non-Asia	30,340	57,745	70,636	106,292	70,636	106,292	2.2	2.0	2.0
Population (Million)	**World**	**5,277**	**7,663**	**8,506**	**9,694**	**8,506**	**9,694**	**1.3**	**0.8**	**0.8**
	AEs	998	1,191	1,222	1,238	1,222	1,238	0.6	0.1	0.1
	EMDEs	4,279	6,472	7,285	8,456	7,285	8,456	1.4	0.9	0.9
	Asia	2,938	4,150	4,462	4,697	4,462	4,697	1.2	0.4	0.4
	Non-Asia	2,339	3,513	4,044	4,997	4,044	4,997	1.4	1.1	1.1

*1 Advanced Economies *2 Emerging Market and Developing Economies

Table A3 | Population

(Million)

	1990	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	5,277 (100)	6,919 (100)	7,663 (100)	8,506 (100)	9,157 (100)	9,694 (100)	1.3	1.0	0.7	0.6	0.8
Asia	2,938 (55.7)	3,824 (55.3)	4,150 (54.2)	4,462 (52.5)	4,632 (50.6)	4,697 (48.5)	1.2	0.7	0.4	0.1	0.4
China	1,135 (21.5)	1,338 (19.3)	1,398 (18.2)	1,429 (16.8)	1,414 (15.4)	1,368 (14.1)	0.7	0.2	-0.1	-0.3	-0.1
India	873 (16.5)	1,234 (17.8)	1,366 (17.8)	1,504 (17.7)	1,593 (17.4)	1,639 (16.9)	1.6	0.9	0.6	0.3	0.6
Japan	124 (2.3)	128 (1.9)	126 (1.6)	120 (1.4)	113 (1.2)	105 (1.1)	0.1	-0.5	-0.6	-0.7	-0.6
Korea	43 (0.8)	50 (0.7)	52 (0.7)	51 (0.6)	50 (0.5)	47 (0.5)	0.6	-0.1	-0.3	-0.6	-0.3
Chinese Taipei	20 (0.4)	23 (0.3)	24 (0.3)	24 (0.3)	23 (0.3)	22 (0.2)	0.5	0.1	-0.2	-0.5	-0.2
ASEAN	431 (8.2)	575 (8.3)	637 (8.3)	699 (8.2)	738 (8.1)	761 (7.9)	1.4	0.8	0.5	0.3	0.6
Indonesia	181 (3.4)	242 (3.5)	271 (3.5)	299 (3.5)	319 (3.5)	331 (3.4)	1.4	0.9	0.6	0.4	0.7
Malaysia	18 (0.3)	28 (0.4)	32 (0.4)	36 (0.4)	39 (0.4)	41 (0.4)	2.0	1.1	0.7	0.5	0.8
Myanmar	41 (0.8)	51 (0.7)	54 (0.7)	58 (0.7)	61 (0.7)	62 (0.6)	0.9	0.7	0.5	0.2	0.5
Philippines	62 (1.2)	94 (1.4)	108 (1.4)	124 (1.5)	136 (1.5)	144 (1.5)	1.9	1.2	0.9	0.6	0.9
Singapore	3 (0.1)	5 (0.1)	6 (0.1)	6 (0.1)	6 (0.1)	6 (0.1)	2.2	0.7	0.3	-0.1	0.3
Thailand	57 (1.1)	67 (1.0)	70 (0.9)	70 (0.8)	69 (0.8)	66 (0.7)	0.7	0.1	-0.2	-0.5	-0.2
Viet Nam	68 (1.3)	88 (1.3)	96 (1.3)	104 (1.2)	108 (1.2)	110 (1.1)	1.2	0.7	0.3	0.2	0.4
North America	277 (5.3)	343 (5.0)	366 (4.8)	390 (4.6)	410 (4.5)	425 (4.4)	1.0	0.6	0.5	0.4	0.5
United States	250 (4.7)	309 (4.5)	328 (4.3)	350 (4.1)	366 (4.0)	379 (3.9)	0.9	0.6	0.5	0.3	0.5
Latin America	438 (8.3)	586 (8.5)	643 (8.4)	701 (8.2)	737 (8.0)	757 (7.8)	1.3	0.8	0.5	0.3	0.5
Advanced Europe	505 (9.6)	556 (8.0)	580 (7.6)	588 (6.9)	590 (6.4)	586 (6.0)	0.5	0.1	0.0	-0.1	0.0
European Union	420 (8.0)	442 (6.4)	448 (5.8)	447 (5.3)	445 (4.9)	437 (4.5)	0.2	0.0	-0.1	-0.2	-0.1
Other Europe/Eurasia	336 (6.4)	332 (4.8)	341 (4.5)	344 (4.0)	342 (3.7)	340 (3.5)	0.0	0.1	-0.1	-0.1	0.0
Africa	630 (11.9)	1,039 (15.0)	1,301 (17.0)	1,688 (19.8)	2,077 (22.7)	2,489 (25.7)	2.5	2.4	2.1	1.8	2.1
Middle East	132 (2.5)	213 (3.1)	252 (3.3)	299 (3.5)	333 (3.6)	362 (3.7)	2.3	1.6	1.1	0.8	1.2
Oceania	20 (0.4)	26 (0.4)	30 (0.4)	33 (0.4)	36 (0.4)	39 (0.4)	1.4	0.9	0.8	0.7	0.8
Advanced Economies	998 (18.9)	1,139 (16.5)	1,191 (15.5)	1,222 (14.4)	1,237 (13.5)	1,238 (12.8)	0.6	0.2	0.1	0.0	0.1
Emerging Market and Developing Economies	4,279 (81.1)	5,780 (83.5)	6,472 (84.5)	7,285 (85.6)	7,920 (86.5)	8,456 (87.2)	1.4	1.1	0.8	0.7	0.9

Source: United Nations "Population Estimates and Projections: The 2019 Revision", World Bank "World Development Indicators"

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

Table A4 | GDP

($2010 billion)

	1990	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	37,974 (100)	66,176 (100)	84,540 (100)	111,268 (100)	145,690 (100)	183,075 (100)	2.8	2.5	2.7	2.3	2.5
Asia	7,634 (20.1)	17,747 (26.8)	26,795 (31.7)	40,632 (36.5)	57,782 (39.7)	76,784 (41.9)	4.4	3.9	3.6	2.9	3.5
China	828 (2.2)	6,087 (9.2)	11,520 (13.6)	19,727 (17.7)	28,857 (19.8)	37,739 (20.6)	9.5	5.0	3.9	2.7	3.9
India	506 (1.3)	1,670 (2.5)	2,930 (3.5)	5,301 (4.8)	9,066 (6.2)	14,321 (7.8)	6.2	5.5	5.5	4.7	5.3
Japan	4,704 (12.4)	5,700 (8.6)	6,211 (7.3)	6,664 (6.0)	7,227 (5.0)	7,761 (4.2)	1.0	0.6	0.8	0.7	0.7
Korea	364 (1.0)	1,144 (1.7)	1,482 (1.8)	1,885 (1.7)	2,308 (1.6)	2,665 (1.5)	5.0	2.2	2.0	1.4	1.9
Chinese Taipei	155 (0.4)	446 (0.7)	560 (0.7)	740 (0.7)	893 (0.6)	1,030 (0.6)	4.5	2.6	1.9	1.4	2.0
ASEAN	746 (2.0)	1,970 (3.0)	3,040 (3.6)	4,692 (4.2)	7,044 (4.8)	9,967 (5.4)	5.0	4.0	4.1	3.5	3.9
Indonesia	310 (0.8)	755 (1.1)	1,204 (1.4)	1,965 (1.8)	3,129 (2.1)	4,595 (2.5)	4.8	4.6	4.8	3.9	4.4
Malaysia	82 (0.2)	255 (0.4)	399 (0.5)	614 (0.6)	876 (0.6)	1,182 (0.6)	5.6	4.0	3.6	3.0	3.6
Myanmar	7 (0.0)	41 (0.1)	73 (0.1)	105 (0.1)	175 (0.1)	270 (0.1)	8.6	3.4	5.2	4.4	4.3
Philippines	98 (0.3)	208 (0.3)	361 (0.4)	572 (0.5)	829 (0.6)	1,156 (0.6)	4.6	4.3	3.8	3.4	3.8
Singapore	69 (0.2)	240 (0.4)	336 (0.4)	422 (0.4)	521 (0.4)	599 (0.3)	5.6	2.1	2.1	1.4	1.9
Thailand	142 (0.4)	341 (0.5)	453 (0.5)	612 (0.6)	849 (0.6)	1,118 (0.6)	4.1	2.8	3.3	2.8	3.0
Viet Nam	29 (0.1)	116 (0.2)	201 (0.2)	384 (0.3)	643 (0.4)	1,023 (0.6)	6.8	6.1	5.3	4.7	5.4
North America	10,014 (26.4)	16,606 (25.1)	20,240 (23.9)	24,902 (22.4)	31,012 (21.3)	37,433 (20.4)	2.5	1.9	2.2	1.9	2.0
United States	9,001 (23.7)	14,992 (22.7)	18,300 (21.6)	22,575 (20.3)	28,191 (19.4)	34,109 (18.6)	2.5	1.9	2.2	1.9	2.0
Latin America	2,828 (7.4)	5,249 (7.9)	5,894 (7.0)	7,405 (6.7)	10,220 (7.0)	13,074 (7.1)	2.6	2.1	3.3	2.5	2.6
Advanced Europe	12,710 (33.5)	18,523 (28.0)	21,589 (25.5)	25,122 (22.6)	28,657 (19.7)	31,986 (17.5)	1.8	1.4	1.3	1.1	1.3
European Union	10,242 (27.0)	14,556 (22.0)	16,619 (19.7)	19,290 (17.3)	22,002 (15.1)	24,509 (13.4)	1.7	1.4	1.3	1.1	1.3
Other Europe/Eurasia	2,140 (5.6)	2,429 (3.7)	2,940 (3.5)	3,761 (3.4)	4,762 (3.3)	5,958 (3.3)	1.1	2.3	2.4	2.3	2.3
Africa	896 (2.4)	1,956 (3.0)	2,526 (3.0)	3,674 (3.3)	5,899 (4.0)	8,724 (4.8)	3.6	3.5	4.9	4.0	4.1
Middle East	1,032 (2.7)	2,326 (3.5)	2,854 (3.4)	3,636 (3.3)	4,772 (3.3)	6,074 (3.3)	3.6	2.2	2.8	2.4	2.5
Oceania	722 (1.9)	1,340 (2.0)	1,702 (2.0)	2,137 (1.9)	2,586 (1.8)	3,044 (1.7)	3.0	2.1	1.9	1.6	1.9
Advanced Economies	28,841 (75.9)	44,228 (66.8)	52,404 (62.0)	62,231 (55.9)	73,632 (50.5)	84,998 (46.4)	2.1	1.6	1.7	1.4	1.6
Emerging Market and Developing Economies	9,133 (24.1)	21,949 (33.2)	32,136 (38.0)	49,037 (44.1)	72,058 (49.5)	98,077 (53.6)	4.4	3.9	3.9	3.1	3.7

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

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

Table A5 | GDP per capita

($2010 thousand/person)

							CAGR (%)				
	1990	2010	2019	2030	2040	2050	1990/ 2019	2019/ 2030	2030/ 2040	2040/ 2050	2019/ 2050
World	7.2	9.6	11.0	13.1	15.9	18.9	1.5	1.6	2.0	1.7	1.7
Asia	2.6	4.6	6.5	9.1	12.5	16.3	3.2	3.2	3.2	2.7	3.0
China	0.7	4.6	8.2	13.8	20.4	27.6	8.7	4.8	4.0	3.1	4.0
India	0.6	1.4	2.1	3.5	5.7	8.7	4.6	4.6	4.9	4.4	4.6
Japan	38.1	44.5	49.2	55.5	64.1	73.8	0.9	1.1	1.5	1.4	1.3
Korea	8.5	23.1	28.7	36.7	46.1	56.6	4.3	2.3	2.3	2.1	2.2
Chinese Taipei	7.6	19.3	23.7	30.9	38.0	46.2	4.0	2.4	2.1	2.0	2.2
ASEAN	1.7	3.4	4.8	6.7	9.5	13.1	3.6	3.2	3.6	3.2	3.3
Indonesia	1.7	3.1	4.5	6.6	9.8	13.9	3.4	3.6	4.1	3.5	3.7
Malaysia	4.5	9.0	12.5	17.0	22.6	29.1	3.6	2.8	2.9	2.6	2.8
Myanmar	0.2	0.8	1.3	1.8	2.9	4.3	7.6	2.7	4.8	4.2	3.9
Philippines	1.6	2.2	3.3	4.6	6.1	8.0	2.6	3.0	2.8	2.7	2.9
Singapore	22.6	47.2	58.8	68.6	82.2	95.0	3.4	1.4	1.8	1.5	1.6
Thailand	2.5	5.1	6.5	8.7	12.3	17.0	3.3	2.7	3.5	3.3	3.1
Viet Nam	0.4	1.3	2.1	3.7	6.0	9.3	5.6	5.3	4.9	4.6	5.0
North America	36.1	48.4	55.3	63.8	75.7	88.1	1.5	1.3	1.7	1.5	1.5
United States	36.1	48.5	55.8	64.6	76.9	89.9	1.5	1.3	1.8	1.6	1.6
Latin America	6.5	9.0	9.2	10.6	13.9	17.3	1.2	1.3	2.8	2.2	2.1
Advanced Europe	25.2	33.3	37.2	42.7	48.5	54.6	1.4	1.3	1.3	1.2	1.2
European Union	24.4	33.0	37.1	43.1	49.5	56.1	1.5	1.4	1.4	1.3	1.3
Other Europe/Eurasia	6.4	7.3	8.6	10.9	13.9	17.5	1.1	2.2	2.4	2.3	2.3
Africa	1.4	1.9	1.9	2.2	2.8	3.5	1.1	1.0	2.7	2.1	1.9
Middle East	7.8	10.9	11.3	12.1	14.3	16.8	1.3	0.6	1.7	1.6	1.3
Oceania	35.4	50.8	56.1	63.8	71.5	78.9	1.6	1.2	1.1	1.0	1.1
Advanced Economies	28.9	38.8	44.0	50.9	59.5	68.7	1.5	1.3	1.6	1.4	1.4
Emerging Market and Developing Economies	2.1	3.8	5.0	6.7	9.1	11.6	3.0	2.8	3.1	2.5	2.8

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

Table A6 | International energy prices

Real prices			Reference			Advanced Technologies		
		2020	2030	2040	2050	2030	2040	2050
Oil	$2020/bbl	41	80	95	100	65	60	50
Natural gas								
Japan	$2020/MBtu	7.8	7.6	7.6	7.5	7.0	6.3	5.1
Europe (UK)	$2020/MBtu	3.3	7.5	7.5	7.4	6.9	6.2	5.0
United States	$2020/MBtu	2.1	3.3	3.8	3.8	3.0	3.5	3.5
Steam coal	$2020/t	80	96	97	98	75	69	64

Nominal prices			Reference			Advanced Technologies		
		2020	2030	2040	2050	2030	2040	2050
Oil	$/bbl	41	98	141	181	79	89	91
Natural gas								
Japan	$/MBtu	7.8	9.3	11.3	13.6	8.5	9.4	9.3
Europe (UK)	$/MBtu	3.3	9.1	11.1	13.4	8.4	9.2	9.1
United States	$/MBtu	2.1	4.0	5.6	6.9	3.6	5.2	6.3
Steam coal	$/t	80	117	144	178	91	103	116

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

Table A7 | Primary energy consumption [Reference Scenario]

(Mtoe)

							CAGR (%)				
	1990	2010	2019	2030	2040	2050	1990/ 2019	2019/ 2030	2030/ 2040	2040/ 2050	2019/ 2050
World	8,738 (100)	12,813 (100)	14,486 (100)	15,869 (100)	16,955 (100)	17,675 (100)	1.8	0.8	0.7	0.4	0.6
Asia	2,083 (23.8)	4,781 (37.3)	6,064 (41.9)	7,063 (44.5)	7,639 (45.1)	8,028 (45.4)	3.8	1.4	0.8	0.5	0.9
China	874 (10.0)	2,536 (19.8)	3,389 (23.4)	3,655 (23.0)	3,576 (21.1)	3,373 (19.1)	4.8	0.7	-0.2	-0.6	0.0
India	280 (3.2)	667 (5.2)	938 (6.5)	1,367 (8.6)	1,776 (10.5)	2,158 (12.2)	4.3	3.5	2.7	2.0	2.7
Japan	437 (5.0)	500 (3.9)	415 (2.9)	392 (2.5)	366 (2.2)	340 (1.9)	-0.2	-0.5	-0.7	-0.7	-0.6
Korea	93 (1.1)	250 (2.0)	280 (1.9)	288 (1.8)	282 (1.7)	263 (1.5)	3.9	0.2	-0.2	-0.7	-0.2
Chinese Taipei	47 (0.5)	109 (0.8)	110 (0.8)	115 (0.7)	113 (0.7)	107 (0.6)	3.0	0.4	-0.1	-0.6	-0.1
ASEAN	232 (2.7)	533 (4.2)	686 (4.7)	923 (5.8)	1,137 (6.7)	1,336 (7.6)	3.8	2.7	2.1	1.6	2.2
Indonesia	99 (1.1)	202 (1.6)	241 (1.7)	336 (2.1)	433 (2.6)	527 (3.0)	3.1	3.1	2.6	2.0	2.6
Malaysia	21 (0.2)	72 (0.6)	92 (0.6)	129 (0.8)	150 (0.9)	162 (0.9)	5.2	3.2	1.5	0.8	1.9
Myanmar	11 (0.1)	14 (0.1)	24 (0.2)	31 (0.2)	40 (0.2)	50 (0.3)	2.8	2.6	2.6	2.2	2.5
Philippines	28 (0.3)	42 (0.3)	62 (0.4)	90 (0.6)	112 (0.7)	136 (0.8)	2.8	3.5	2.2	2.0	2.6
Singapore	12 (0.1)	24 (0.2)	34 (0.2)	38 (0.2)	40 (0.2)	41 (0.2)	3.8	0.9	0.6	0.1	0.5
Thailand	42 (0.5)	118 (0.9)	139 (1.0)	159 (1.0)	182 (1.1)	199 (1.1)	4.2	1.3	1.3	0.9	1.2
Viet Nam	18 (0.2)	59 (0.5)	91 (0.6)	136 (0.9)	175 (1.0)	216 (1.2)	5.8	3.7	2.5	2.2	2.8
North America	2,126 (24.3)	2,477 (19.3)	2,518 (17.4)	2,447 (15.4)	2,416 (14.3)	2,350 (13.3)	0.6	-0.3	-0.1	-0.3	-0.2
United States	1,914 (21.9)	2,216 (17.3)	2,213 (15.3)	2,128 (13.4)	2,095 (12.4)	2,039 (11.5)	0.5	-0.4	-0.2	-0.3	-0.3
Latin America	464 (5.3)	788 (6.2)	829 (5.7)	940 (5.9)	1,085 (6.4)	1,166 (6.6)	2.0	1.1	1.5	0.7	1.1
Advanced Europe	1,643 (18.8)	1,835 (14.3)	1,715 (11.8)	1,638 (10.3)	1,549 (9.1)	1,457 (8.2)	0.1	-0.4	-0.6	-0.6	-0.5
European Union	1,439 (16.5)	1,527 (11.9)	1,403 (9.7)	1,341 (8.5)	1,267 (7.5)	1,182 (6.7)	-0.1	-0.4	-0.6	-0.7	-0.6
Other Europe/Eurasia	1,514 (17.3)	1,112 (8.7)	1,167 (8.1)	1,191 (7.5)	1,234 (7.3)	1,269 (7.2)	-0.9	0.2	0.4	0.3	0.3
Africa	385 (4.4)	687 (5.4)	857 (5.9)	1,021 (6.4)	1,200 (7.1)	1,354 (7.7)	2.8	1.6	1.6	1.2	1.5
Middle East	223 (2.5)	630 (4.9)	766 (5.3)	929 (5.9)	1,060 (6.3)	1,159 (6.6)	4.4	1.8	1.3	0.9	1.3
Oceania	99 (1.1)	144 (1.1)	149 (1.0)	152 (1.0)	151 (0.9)	146 (0.8)	1.4	0.1	-0.1	-0.3	-0.1
Advanced Economies	4,465 (51.1)	5,352 (41.8)	5,236 (36.1)	5,084 (32.0)	4,931 (29.1)	4,717 (26.7)	0.6	-0.3	-0.3	-0.4	-0.3
Emerging Market and Developing Economies	4,070 (46.6)	7,103 (55.4)	8,829 (61.0)	10,297 (64.9)	11,403 (67.3)	12,211 (69.1)	2.7	1.4	1.0	0.7	1.1

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	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	2,220 (100)	3,654 (100)	3,878 (100)	3,910 (100)	3,849 (100)	3,638 (100)	1.9	0.1	-0.2	-0.6	-0.2
Asia	788 (35.5)	2,409 (65.9)	2,947 (76.0)	3,115 (79.7)	3,105 (80.7)	2,963 (81.4)	4.7	0.5	0.0	-0.5	0.0
China	531 (23.9)	1,790 (49.0)	2,072 (53.4)	2,028 (51.9)	1,784 (46.3)	1,483 (40.8)	4.8	-0.2	-1.3	-1.8	-1.1
India	93 (4.2)	279 (7.6)	418 (10.8)	588 (15.0)	767 (19.9)	894 (24.6)	5.3	3.2	2.7	1.5	2.5
Japan	77 (3.5)	116 (3.2)	115 (3.0)	92 (2.4)	84 (2.2)	74 (2.0)	1.4	-2.0	-0.9	-1.3	-1.4
Korea	25 (1.1)	73 (2.0)	80 (2.1)	80 (2.1)	76 (2.0)	66 (1.8)	4.0	0.0	-0.5	-1.5	-0.6
Chinese Taipei	11 (0.5)	38 (1.0)	39 (1.0)	44 (1.1)	41 (1.1)	37 (1.0)	4.6	1.0	-0.6	-1.2	-0.2
ASEAN	13 (0.6)	85 (2.3)	174 (4.5)	224 (5.7)	279 (7.2)	321 (8.8)	9.5	2.3	2.2	1.4	2.0
Indonesia	4 (0.2)	32 (0.9)	69 (1.8)	87 (2.2)	117 (3.0)	136 (3.7)	10.8	2.2	2.9	1.5	2.2
Malaysia	1 (0.1)	15 (0.4)	22 (0.6)	29 (0.8)	33 (0.9)	35 (1.0)	10.2	2.5	1.2	0.5	1.4
Myanmar	0 (0.0)	0 (0.0)	1 (0.0)	3 (0.1)	4 (0.1)	7 (0.2)	11.0	6.4	5.2	3.9	5.2
Philippines	1 (0.1)	7 (0.2)	18 (0.5)	21 (0.5)	25 (0.7)	29 (0.8)	9.0	1.6	1.8	1.3	1.6
Singapore	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	11.1	-0.1	-0.3	-1.3	-0.6
Thailand	4 (0.2)	16 (0.4)	16 (0.4)	16 (0.4)	16 (0.4)	15 (0.4)	5.1	-0.2	0.2	-0.9	-0.3
Viet Nam	2 (0.1)	15 (0.4)	47 (1.2)	66 (1.7)	83 (2.1)	100 (2.7)	11.1	3.3	2.2	1.9	2.5
North America	484 (21.8)	525 (14.4)	289 (7.4)	208 (5.3)	159 (4.1)	104 (2.9)	-1.8	-3.0	-2.7	-4.1	-3.2
United States	460 (20.7)	501 (13.7)	275 (7.1)	201 (5.2)	155 (4.0)	101 (2.8)	-1.8	-2.8	-2.6	-4.2	-3.2
Latin America	21 (1.0)	39 (1.1)	44 (1.1)	42 (1.1)	47 (1.2)	47 (1.3)	2.6	-0.5	1.3	0.0	0.2
Advanced Europe	448 (20.2)	301 (8.2)	213 (5.5)	186 (4.8)	170 (4.4)	152 (4.2)	-2.5	-1.2	-0.9	-1.1	-1.1
European Union	391 (17.6)	252 (6.9)	175 (4.5)	157 (4.0)	143 (3.7)	127 (3.5)	-2.7	-1.0	-1.0	-1.2	-1.0
Other Europe/Eurasia	365 (16.5)	211 (5.8)	216 (5.6)	191 (4.9)	191 (5.0)	190 (5.2)	-1.8	-1.1	0.0	0.0	-0.4
Africa	74 (3.3)	108 (3.0)	119 (3.1)	123 (3.1)	136 (3.5)	145 (4.0)	1.6	0.3	1.1	0.6	0.7
Middle East	3 (0.1)	10 (0.3)	8 (0.2)	10 (0.3)	9 (0.2)	8 (0.2)	3.4	1.9	-0.5	-1.4	0.1
Oceania	36 (1.6)	52 (1.4)	43 (1.1)	36 (0.9)	32 (0.8)	28 (0.8)	0.6	-1.7	-1.1	-1.4	-1.4
Advanced Economies	1,088 (49.0)	1,111 (30.4)	786 (20.3)	652 (16.7)	568 (14.8)	466 (12.8)	-1.1	-1.7	-1.4	-2.0	-1.7
Emerging Market and Developing Economies	1,133 (51.0)	2,543 (69.6)	3,092 (79.7)	3,258 (83.3)	3,281 (85.2)	3,171 (87.2)	3.5	0.5	0.1	-0.3	0.1

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	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	3,232 (100)	4,126 (100)	4,475 (100)	4,728 (100)	5,008 (100)	5,188 (100)	1.1	0.5	0.6	0.4	0.5
Asia	616 (19.1)	1,161 (28.1)	1,470 (32.9)	1,695 (35.9)	1,873 (37.4)	2,024 (39.0)	3.0	1.3	1.0	0.8	1.0
China	119 (3.7)	428 (10.4)	648 (14.5)	719 (15.2)	719 (14.4)	672 (13.0)	6.0	0.9	0.0	-0.7	0.1
India	61 (1.9)	162 (3.9)	235 (5.3)	344 (7.3)	476 (9.5)	637 (12.3)	4.8	3.5	3.3	3.0	3.3
Japan	249 (7.7)	201 (4.9)	159 (3.6)	135 (2.9)	116 (2.3)	98 (1.9)	-1.5	-1.5	-1.6	-1.6	-1.5
Korea	50 (1.5)	95 (2.3)	104 (2.3)	102 (2.2)	98 (2.0)	92 (1.8)	2.6	-0.2	-0.4	-0.7	-0.4
Chinese Taipei	26 (0.8)	44 (1.1)	40 (0.9)	39 (0.8)	37 (0.7)	32 (0.6)	1.5	0.0	-0.7	-1.2	-0.6
ASEAN	89 (2.7)	188 (4.6)	231 (5.2)	283 (6.0)	335 (6.7)	381 (7.3)	3.3	1.9	1.7	1.3	1.6
Indonesia	33 (1.0)	67 (1.6)	75 (1.7)	91 (1.9)	111 (2.2)	128 (2.5)	2.9	1.7	2.0	1.5	1.7
Malaysia	11 (0.4)	25 (0.6)	27 (0.6)	31 (0.7)	30 (0.6)	28 (0.5)	3.0	1.4	-0.3	-1.0	0.1
Myanmar	1 (0.0)	1 (0.0)	7 (0.2)	10 (0.2)	15 (0.3)	20 (0.4)	8.1	3.3	4.2	3.0	3.5
Philippines	11 (0.3)	14 (0.3)	19 (0.4)	32 (0.7)	44 (0.9)	57 (1.1)	2.0	4.6	3.3	2.8	3.6
Singapore	11 (0.4)	16 (0.4)	24 (0.5)	26 (0.5)	27 (0.5)	28 (0.5)	2.6	0.5	0.5	0.3	0.4
Thailand	18 (0.6)	45 (1.1)	55 (1.2)	60 (1.3)	66 (1.3)	70 (1.4)	3.9	0.8	1.0	0.6	0.8
Viet Nam	3 (0.1)	18 (0.4)	21 (0.5)	32 (0.7)	40 (0.8)	48 (0.9)	7.4	3.6	2.4	1.8	2.6
North America	833 (25.8)	903 (21.9)	896 (20.0)	813 (17.2)	754 (15.1)	690 (13.3)	0.2	-0.9	-0.7	-0.9	-0.8
United States	757 (23.4)	807 (19.5)	793 (17.7)	718 (15.2)	667 (13.3)	612 (11.8)	0.2	-0.9	-0.7	-0.9	-0.8
Latin America	238 (7.4)	365 (8.9)	338 (7.6)	356 (7.5)	382 (7.6)	380 (7.3)	1.2	0.5	0.7	0.0	0.4
Advanced Europe	617 (19.1)	606 (14.7)	560 (12.5)	513 (10.8)	452 (9.0)	394 (7.6)	-0.3	-0.8	-1.3	-1.4	-1.1
European Union	531 (16.4)	506 (12.3)	460 (10.3)	422 (8.9)	371 (7.4)	323 (6.2)	-0.5	-0.8	-1.3	-1.4	-1.1
Other Europe/Eurasia	459 (14.2)	216 (5.2)	237 (5.3)	236 (5.0)	231 (4.6)	226 (4.4)	-2.3	0.0	-0.2	-0.2	-0.2
Africa	85 (2.6)	162 (3.9)	198 (4.4)	247 (5.2)	332 (6.6)	423 (8.2)	2.9	2.1	3.0	2.5	2.5
Middle East	146 (4.5)	306 (7.4)	307 (6.9)	349 (7.4)	373 (7.4)	369 (7.1)	2.6	1.2	0.6	-0.1	0.6
Oceania	35 (1.1)	48 (1.2)	50 (1.1)	47 (1.0)	43 (0.9)	37 (0.7)	1.3	-0.5	-1.0	-1.4	-0.9
Advanced Economies	1,824 (56.4)	1,917 (46.5)	1,837 (41.0)	1,679 (35.5)	1,530 (30.5)	1,373 (26.5)	0.0	-0.8	-0.9	-1.1	-0.9
Emerging Market and Developing Economies	1,206 (37.3)	1,850 (44.8)	2,219 (49.6)	2,578 (54.5)	2,910 (58.1)	3,170 (61.1)	2.1	1.4	1.2	0.9	1.2

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	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	1,662 (100)	2,734 (100)	3,363 (100)	3,885 (100)	4,420 (100)	4,857 (100)	2.5	1.3	1.3	0.9	1.2
Asia	116 (7.0)	453 (16.6)	670 (19.9)	933 (24.0)	1,140 (25.8)	1,315 (27.1)	6.2	3.1	2.0	1.4	2.2
China	13 (0.8)	89 (3.3)	248 (7.4)	366 (9.4)	422 (9.5)	463 (9.5)	10.8	3.6	1.4	0.9	2.0
India	11 (0.6)	54 (2.0)	55 (1.7)	105 (2.7)	167 (3.8)	224 (4.6)	5.9	6.0	4.7	3.0	4.6
Japan	44 (2.7)	86 (3.1)	92 (2.7)	84 (2.2)	82 (1.9)	77 (1.6)	2.6	-0.8	-0.2	-0.7	-0.6
Korea	3 (0.2)	39 (1.4)	49 (1.5)	62 (1.6)	69 (1.6)	73 (1.5)	10.5	2.1	1.2	0.6	1.3
Chinese Taipei	1 (0.1)	13 (0.5)	20 (0.6)	27 (0.7)	30 (0.7)	31 (0.6)	9.5	3.0	0.9	0.5	1.5
ASEAN	30 (1.8)	125 (4.6)	143 (4.2)	203 (5.2)	258 (5.8)	308 (6.3)	5.5	3.3	2.4	1.8	2.5
Indonesia	16 (1.0)	39 (1.4)	39 (1.2)	58 (1.5)	83 (1.9)	107 (2.2)	3.2	3.7	3.6	2.5	3.3
Malaysia	7 (0.4)	31 (1.1)	39 (1.2)	64 (1.6)	76 (1.7)	87 (1.8)	6.2	4.4	1.8	1.4	2.6
Myanmar	1 (0.0)	1 (0.0)	3 (0.1)	9 (0.2)	13 (0.3)	18 (0.4)	5.4	8.6	4.5	2.8	5.4
Philippines	- (-)	3 (0.1)	4 (0.1)	6 (0.2)	10 (0.2)	14 (0.3)	-	4.9	4.5	3.8	4.4
Singapore	- (-)	6 (0.2)	9 (0.3)	10 (0.3)	11 (0.2)	10 (0.2)	-	1.1	0.5	-0.3	0.4
Thailand	5 (0.3)	33 (1.2)	37 (1.1)	38 (1.0)	40 (0.9)	39 (0.8)	7.1	0.3	0.6	-0.4	0.2
Viet Nam	0 (0.0)	8 (0.3)	9 (0.3)	16 (0.4)	22 (0.5)	30 (0.6)	32.0	5.7	3.5	3.3	4.2
North America	493 (29.7)	632 (23.1)	859 (25.6)	945 (24.3)	980 (22.2)	972 (20.0)	1.9	0.9	0.4	-0.1	0.4
United States	438 (26.4)	556 (20.3)	742 (22.1)	798 (20.5)	817 (18.5)	806 (16.6)	1.8	0.7	0.2	-0.1	0.3
Latin America	71 (4.3)	179 (6.5)	207 (6.2)	239 (6.1)	317 (7.2)	376 (7.7)	3.8	1.3	2.9	1.7	1.9
Advanced Europe	267 (16.1)	473 (17.3)	433 (12.9)	417 (10.7)	417 (9.4)	395 (8.1)	1.7	-0.3	0.0	-0.5	-0.3
European Union	250 (15.0)	363 (13.3)	336 (10.0)	322 (8.3)	324 (7.3)	308 (6.3)	1.0	-0.4	0.1	-0.5	-0.3
Other Europe/Eurasia	596 (35.8)	566 (20.7)	575 (17.1)	571 (14.7)	585 (13.2)	604 (12.4)	-0.1	-0.1	0.2	0.3	0.2
Africa	30 (1.8)	89 (3.3)	135 (4.0)	185 (4.8)	261 (5.9)	343 (7.1)	5.4	2.9	3.5	2.7	3.0
Middle East	72 (4.3)	311 (11.4)	444 (13.2)	538 (13.8)	628 (14.2)	716 (14.7)	6.5	1.8	1.6	1.3	1.6
Oceania	19 (1.1)	31 (1.1)	38 (1.1)	44 (1.1)	47 (1.1)	48 (1.0)	2.5	1.2	0.8	0.2	0.7
Advanced Economies	827 (49.8)	1,283 (46.9)	1,503 (44.7)	1,592 (41.0)	1,641 (37.1)	1,611 (33.2)	2.1	0.5	0.3	-0.2	0.2
Emerging Market and Developing Economies	835 (50.2)	1,451 (53.1)	1,859 (55.3)	2,279 (58.7)	2,735 (61.9)	3,158 (65.0)	2.8	1.9	1.8	1.4	1.7

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)

							CAGR (%)				
	1990	2010	2019	2030	2040	2050	1990/ 2019	2019/ 2030	2030/ 2040	2040/ 2050	2019/ 2050
World	6,236 (100)	8,801 (100)	9,983 (100)	10,880 (100)	11,576 (100)	12,120 (100)	1.6	0.8	0.6	0.5	0.6
Asia	1,529 (24.5)	3,156 (35.9)	3,919 (39.3)	4,511 (41.5)	4,895 (42.3)	5,226 (43.1)	3.3	1.3	0.8	0.7	0.9
China	658 (10.5)	1,645 (18.7)	2,093 (21.0)	2,233 (20.5)	2,189 (18.9)	2,099 (17.3)	4.1	0.6	-0.2	-0.4	0.0
India	215 (3.4)	444 (5.0)	630 (6.3)	899 (8.3)	1,166 (10.1)	1,442 (11.9)	3.8	3.3	2.6	2.1	2.7
Japan	291 (4.7)	314 (3.6)	279 (2.8)	259 (2.4)	240 (2.1)	222 (1.8)	-0.1	-0.7	-0.8	-0.8	-0.7
Korea	65 (1.0)	158 (1.8)	182 (1.8)	190 (1.7)	189 (1.6)	180 (1.5)	3.6	0.4	0.0	-0.5	0.0
Chinese Taipei	30 (0.5)	70 (0.8)	70 (0.7)	74 (0.7)	73 (0.6)	70 (0.6)	3.0	0.6	-0.1	-0.5	0.0
ASEAN	171 (2.7)	375 (4.3)	467 (4.7)	604 (5.5)	737 (6.4)	867 (7.2)	3.5	2.4	2.0	1.6	2.0
Indonesia	79 (1.3)	146 (1.7)	161 (1.6)	200 (1.8)	254 (2.2)	311 (2.6)	2.5	2.0	2.4	2.0	2.2
Malaysia	13 (0.2)	42 (0.5)	65 (0.7)	94 (0.9)	108 (0.9)	117 (1.0)	5.6	3.4	1.4	0.8	1.9
Myanmar	9 (0.2)	13 (0.1)	20 (0.2)	24 (0.2)	29 (0.3)	35 (0.3)	2.7	1.5	2.0	1.9	1.8
Philippines	19 (0.3)	25 (0.3)	36 (0.4)	54 (0.5)	70 (0.6)	90 (0.7)	2.3	3.6	2.7	2.5	3.0
Singapore	5 (0.1)	15 (0.2)	19 (0.2)	22 (0.2)	23 (0.2)	24 (0.2)	4.7	1.1	0.7	0.2	0.7
Thailand	29 (0.5)	84 (1.0)	102 (1.0)	117 (1.1)	134 (1.2)	146 (1.2)	4.4	1.2	1.4	0.9	1.1
Viet Nam	16 (0.3)	48 (0.5)	62 (0.6)	92 (0.8)	117 (1.0)	143 (1.2)	4.8	3.8	2.4	2.0	2.8
North America	1,452 (23.3)	1,700 (19.3)	1,794 (18.0)	1,759 (16.2)	1,726 (14.9)	1,679 (13.8)	0.7	-0.2	-0.2	-0.3	-0.2
United States	1,294 (20.7)	1,513 (17.2)	1,588 (15.9)	1,553 (14.3)	1,525 (13.2)	1,485 (12.3)	0.7	-0.2	-0.2	-0.3	-0.2
Latin America	344 (5.5)	570 (6.5)	598 (6.0)	668 (6.1)	753 (6.5)	806 (6.7)	1.9	1.0	1.2	0.7	1.0
Advanced Europe	1,142 (18.3)	1,289 (14.6)	1,245 (12.5)	1,202 (11.0)	1,129 (9.8)	1,056 (8.7)	0.3	-0.3	-0.6	-0.7	-0.5
European Union	995 (16.0)	1,070 (12.2)	1,015 (10.2)	983 (9.0)	922 (8.0)	859 (7.1)	0.1	-0.3	-0.6	-0.7	-0.5
Other Europe/Eurasia	1,057 (17.0)	711 (8.1)	772 (7.7)	787 (7.2)	794 (6.9)	802 (6.6)	-1.1	0.2	0.1	0.1	0.1
Africa	285 (4.6)	496 (5.6)	613 (6.1)	726 (6.7)	827 (7.1)	906 (7.5)	2.7	1.6	1.3	0.9	1.3
Middle East	157 (2.5)	431 (4.9)	526 (5.3)	639 (5.9)	730 (6.3)	802 (6.6)	4.3	1.8	1.3	0.9	1.4
Oceania	66 (1.1)	89 (1.0)	97 (1.0)	101 (0.9)	100 (0.9)	98 (0.8)	1.3	0.3	-0.1	-0.3	0.0
Advanced Economies	3,057 (49.0)	3,642 (41.4)	3,694 (37.0)	3,615 (33.2)	3,489 (30.1)	3,334 (27.5)	0.7	-0.2	-0.4	-0.5	-0.3
Emerging Market and Developing Economies	2,977 (47.7)	4,801 (54.5)	5,869 (58.8)	6,777 (62.3)	7,466 (64.5)	8,039 (66.3)	2.4	1.3	1.0	0.7	1.0

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	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	1,795 (100)	2,642 (100)	2,890 (100)	3,142 (100)	3,300 (100)	3,369 (100)	1.7	0.8	0.5	0.2	0.5
Asia	506 (28.2)	1,401 (53.0)	1,638 (56.7)	1,787 (56.9)	1,831 (55.5)	1,838 (54.6)	4.1	0.8	0.2	0.0	0.4
China	234 (13.0)	924 (35.0)	1,024 (35.5)	967 (30.8)	829 (25.1)	712 (21.1)	5.2	-0.5	-1.5	-1.5	-1.2
India	59 (3.3)	158 (6.0)	243 (8.4)	381 (12.1)	489 (14.8)	555 (16.5)	5.0	4.2	2.5	1.3	2.7
Japan	108 (6.0)	92 (3.5)	81 (2.8)	73 (2.3)	67 (2.0)	61 (1.8)	-1.0	-1.0	-0.9	-0.9	-0.9
Korea	19 (1.1)	45 (1.7)	47 (1.6)	51 (1.6)	51 (1.5)	48 (1.4)	3.1	0.7	0.0	-0.6	0.1
Chinese Taipei	12 (0.7)	24 (0.9)	24 (0.8)	26 (0.8)	26 (0.8)	25 (0.7)	2.3	0.8	0.0	-0.5	0.1
ASEAN	42 (2.3)	120 (4.6)	164 (5.7)	216 (6.9)	272 (8.2)	320 (9.5)	4.8	2.5	2.3	1.6	2.2
Indonesia	17 (1.0)	49 (1.9)	58 (2.0)	74 (2.4)	99 (3.0)	121 (3.6)	4.2	2.2	2.9	2.0	2.4
Malaysia	6 (0.3)	15 (0.6)	20 (0.7)	28 (0.9)	35 (1.1)	40 (1.2)	4.6	2.9	2.3	1.3	2.2
Myanmar	0 (0.0)	1 (0.0)	4 (0.1)	5 (0.2)	8 (0.2)	10 (0.3)	8.2	3.1	4.4	2.5	3.3
Philippines	4 (0.2)	6 (0.2)	8 (0.3)	10 (0.3)	13 (0.4)	15 (0.5)	2.0	2.8	2.2	1.8	2.3
Singapore	1 (0.0)	5 (0.2)	7 (0.2)	8 (0.3)	8 (0.3)	8 (0.2)	8.8	1.2	0.5	-0.1	0.5
Thailand	9 (0.5)	26 (1.0)	34 (1.2)	40 (1.3)	48 (1.5)	53 (1.6)	4.8	1.6	1.8	1.0	1.5
Viet Nam	5 (0.3)	17 (0.7)	33 (1.1)	50 (1.6)	61 (1.8)	73 (2.2)	7.1	3.8	2.0	1.8	2.6
North America	331 (18.4)	313 (11.9)	315 (10.9)	313 (10.0)	317 (9.6)	313 (9.3)	-0.2	-0.1	0.1	-0.1	0.0
United States	284 (15.8)	270 (10.2)	268 (9.3)	266 (8.4)	268 (8.1)	265 (7.9)	-0.2	-0.1	0.1	-0.1	0.0
Latin America	114 (6.3)	181 (6.9)	171 (5.9)	199 (6.3)	239 (7.2)	262 (7.8)	1.4	1.4	1.8	0.9	1.4
Advanced Europe	330 (18.4)	296 (11.2)	292 (10.1)	297 (9.5)	292 (8.9)	281 (8.3)	-0.4	0.1	-0.2	-0.4	-0.1
European Union	313 (17.4)	247 (9.3)	240 (8.3)	244 (7.8)	242 (7.3)	233 (6.9)	-0.9	0.2	-0.1	-0.4	-0.1
Other Europe/Eurasia	391 (21.8)	205 (7.8)	207 (7.2)	220 (7.0)	233 (7.1)	242 (7.2)	-2.2	0.5	0.6	0.4	0.5
Africa	53 (2.9)	85 (3.2)	90 (3.1)	116 (3.7)	157 (4.7)	193 (5.7)	1.9	2.3	3.0	2.1	2.5
Middle East	47 (2.6)	134 (5.1)	149 (5.2)	181 (5.8)	202 (6.1)	211 (6.3)	4.1	1.8	1.1	0.4	1.1
Oceania	23 (1.3)	27 (1.0)	27 (0.9)	29 (0.9)	30 (0.9)	29 (0.9)	0.5	0.8	0.1	-0.3	0.2
Advanced Economies	826 (46.0)	802 (30.4)	795 (27.5)	798 (25.4)	792 (24.0)	766 (22.7)	-0.1	0.0	-0.1	-0.3	-0.1
Emerging Market and Developing Economies	969 (54.0)	1,840 (69.6)	2,095 (72.5)	2,344 (74.6)	2,508 (76.0)	2,603 (77.3)	2.7	1.0	0.7	0.4	0.7

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	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	1,576 (100)	2,430 (100)	2,889 (100)	3,100 (100)	3,361 (100)	3,623 (100)	2.1	0.6	0.8	0.8	0.7
Asia	188 (11.9)	494 (20.3)	719 (24.9)	867 (28.0)	1,002 (29.8)	1,150 (31.7)	4.7	1.7	1.5	1.4	1.5
China	30 (1.9)	197 (8.1)	324 (11.2)	390 (12.6)	406 (12.1)	391 (10.8)	8.5	1.7	0.4	-0.4	0.6
India	21 (1.3)	65 (2.7)	105 (3.6)	155 (5.0)	237 (7.0)	362 (10.0)	5.8	3.6	4.4	4.4	4.1
Japan	72 (4.6)	79 (3.2)	69 (2.4)	59 (1.9)	50 (1.5)	43 (1.2)	-0.1	-1.4	-1.6	-1.5	-1.5
Korea	15 (0.9)	30 (1.2)	37 (1.3)	34 (1.1)	31 (0.9)	27 (0.7)	3.2	-0.6	-0.9	-1.4	-1.0
Chinese Taipei	7 (0.4)	12 (0.5)	12 (0.4)	11 (0.4)	9 (0.3)	7 (0.2)	2.1	-0.6	-1.8	-2.6	-1.6
ASEAN	33 (2.1)	86 (3.6)	135 (4.7)	167 (5.4)	200 (6.0)	234 (6.5)	5.0	1.9	1.8	1.6	1.8
Indonesia	11 (0.7)	30 (1.2)	54 (1.9)	66 (2.1)	81 (2.4)	97 (2.7)	5.8	1.8	2.1	1.8	1.9
Malaysia	5 (0.3)	15 (0.6)	22 (0.8)	23 (0.7)	21 (0.6)	19 (0.5)	5.3	0.6	-0.7	-1.3	-0.5
Myanmar	0 (0.0)	1 (0.0)	2 (0.1)	3 (0.1)	5 (0.2)	8 (0.2)	5.6	3.7	4.9	3.8	4.1
Philippines	5 (0.3)	8 (0.3)	13 (0.4)	22 (0.7)	31 (0.9)	43 (1.2)	3.6	5.2	3.6	3.1	4.0
Singapore	1 (0.1)	2 (0.1)	3 (0.1)	2 (0.1)	2 (0.1)	2 (0.1)	2.1	-0.3	-0.8	-1.4	-0.8
Thailand	9 (0.6)	19 (0.8)	27 (0.9)	28 (0.9)	31 (0.9)	32 (0.9)	3.8	0.4	0.8	0.5	0.6
Viet Nam	1 (0.1)	10 (0.4)	14 (0.5)	21 (0.7)	27 (0.8)	33 (0.9)	8.3	3.7	2.7	1.8	2.8
North America	531 (33.7)	656 (27.0)	705 (24.4)	655 (21.1)	614 (18.3)	575 (15.9)	1.0	-0.7	-0.7	-0.6	-0.7
United States	488 (30.9)	596 (24.5)	637 (22.1)	590 (19.0)	554 (16.5)	520 (14.4)	0.9	-0.7	-0.6	-0.6	-0.7
Latin America	103 (6.5)	197 (8.1)	227 (7.8)	250 (8.1)	271 (8.1)	282 (7.8)	2.8	0.9	0.8	0.4	0.7
Advanced Europe	269 (17.1)	335 (13.8)	356 (12.3)	324 (10.5)	285 (8.5)	253 (7.0)	1.0	-0.9	-1.3	-1.2	-1.1
European Union	220 (13.9)	279 (11.5)	289 (10.0)	263 (8.5)	232 (6.9)	205 (5.7)	1.0	-0.9	-1.3	-1.2	-1.1
Other Europe/Eurasia	170 (10.8)	145 (6.0)	155 (5.4)	153 (4.9)	146 (4.3)	141 (3.9)	-0.3	-0.2	-0.5	-0.4	-0.3
Africa	38 (2.4)	88 (3.6)	121 (4.2)	153 (4.9)	202 (6.0)	251 (6.9)	4.0	2.2	2.8	2.2	2.4
Middle East	51 (3.2)	121 (5.0)	147 (5.1)	172 (5.6)	185 (5.5)	191 (5.3)	3.7	1.5	0.7	0.3	0.8
Oceania	24 (1.5)	35 (1.4)	39 (1.4)	37 (1.2)	36 (1.1)	33 (0.9)	1.7	-0.4	-0.5	-0.6	-0.5
Advanced Economies	919 (58.4)	1,151 (47.3)	1,224 (42.4)	1,126 (36.3)	1,030 (30.6)	943 (26.0)	1.0	-0.8	-0.9	-0.9	-0.8
Emerging Market and Developing Economies	454 (28.8)	921 (37.9)	1,245 (43.1)	1,486 (47.9)	1,711 (50.9)	1,933 (53.4)	3.5	1.6	1.4	1.2	1.4

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	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	2,389 (100)	2,964 (100)	3,280 (100)	3,583 (100)	3,732 (100)	3,838 (100)	1.1	0.8	0.4	0.3	0.5
Asia	720 (30.2)	972 (32.8)	1,163 (35.5)	1,369 (38.2)	1,505 (40.3)	1,627 (42.4)	1.7	1.5	0.9	0.8	1.1
China	351 (14.7)	411 (13.9)	567 (17.3)	666 (18.6)	727 (19.5)	769 (20.0)	1.7	1.5	0.9	0.6	1.0
India	122 (5.1)	187 (6.3)	231 (7.0)	289 (8.1)	335 (9.0)	386 (10.1)	2.2	2.1	1.5	1.4	1.7
Japan	78 (3.3)	109 (3.7)	95 (2.9)	96 (2.7)	93 (2.5)	88 (2.3)	0.7	0.1	-0.4	-0.5	-0.2
Korea	24 (1.0)	44 (1.5)	45 (1.4)	48 (1.3)	47 (1.3)	44 (1.2)	2.2	0.5	-0.2	-0.6	-0.1
Chinese Taipei	6 (0.3)	12 (0.4)	12 (0.4)	13 (0.4)	13 (0.4)	13 (0.3)	2.2	0.7	0.2	-0.1	0.3
ASEAN	86 (3.6)	128 (4.3)	112 (3.4)	138 (3.9)	162 (4.3)	191 (5.0)	0.9	1.9	1.6	1.6	1.7
Indonesia	44 (1.8)	57 (1.9)	39 (1.2)	47 (1.3)	56 (1.5)	69 (1.8)	-0.4	1.7	1.8	2.0	1.8
Malaysia	2 (0.1)	8 (0.3)	9 (0.3)	12 (0.3)	15 (0.4)	17 (0.4)	5.1	2.8	1.9	1.3	2.0
Myanmar	8 (0.4)	11 (0.4)	14 (0.4)	15 (0.4)	15 (0.4)	16 (0.4)	1.7	0.6	0.2	0.8	0.6
Philippines	10 (0.4)	11 (0.4)	15 (0.5)	20 (0.5)	23 (0.6)	28 (0.7)	1.4	2.4	1.8	1.7	2.0
Singapore	1 (0.0)	2 (0.1)	3 (0.1)	3 (0.1)	3 (0.1)	3 (0.1)	3.1	1.3	0.6	0.0	0.6
Thailand	11 (0.5)	20 (0.7)	18 (0.6)	21 (0.6)	22 (0.6)	23 (0.6)	1.8	1.2	0.6	0.3	0.7
Viet Nam	10 (0.4)	18 (0.6)	13 (0.4)	20 (0.6)	27 (0.7)	35 (0.9)	1.0	3.6	3.0	2.7	3.1
North America	456 (19.1)	573 (19.3)	596 (18.2)	606 (16.9)	600 (16.1)	587 (15.3)	0.9	0.2	-0.1	-0.2	0.0
United States	403 (16.9)	511 (17.3)	525 (16.0)	534 (14.9)	529 (14.2)	518 (13.5)	0.9	0.2	-0.1	-0.2	0.0
Latin America	101 (4.2)	147 (5.0)	164 (5.0)	178 (5.0)	195 (5.2)	208 (5.4)	1.7	0.8	0.9	0.7	0.8
Advanced Europe	442 (18.5)	545 (18.4)	492 (15.0)	476 (13.3)	447 (12.0)	419 (10.9)	0.4	-0.3	-0.6	-0.6	-0.5
European Union	374 (15.7)	446 (15.1)	395 (12.0)	384 (10.7)	358 (9.6)	333 (8.7)	0.2	-0.3	-0.7	-0.7	-0.5
Other Europe/Eurasia	431 (18.0)	281 (9.5)	315 (9.6)	316 (8.8)	309 (8.3)	305 (8.0)	-1.1	0.0	-0.2	-0.1	-0.1
Africa	183 (7.7)	305 (10.3)	380 (11.6)	432 (12.0)	437 (11.7)	423 (11.0)	2.6	1.2	0.1	-0.3	0.3
Middle East	40 (1.7)	119 (4.0)	144 (4.4)	179 (5.0)	211 (5.6)	240 (6.2)	4.5	2.0	1.6	1.3	1.6
Oceania	15 (0.6)	23 (0.8)	25 (0.7)	27 (0.8)	28 (0.8)	29 (0.8)	1.8	1.0	0.4	0.1	0.5
Advanced Economies	1,025 (42.9)	1,312 (44.2)	1,273 (38.8)	1,274 (35.6)	1,236 (33.1)	1,189 (31.0)	0.7	0.0	-0.3	-0.4	-0.2
Emerging Market and Developing Economies	1,363 (57.1)	1,653 (55.8)	2,007 (61.2)	2,309 (64.4)	2,495 (66.9)	2,650 (69.0)	1.3	1.3	0.8	0.6	0.9

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	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	9,700 (100)	17,883 (100)	22,844 (100)	28,295 (100)	33,539 (100)	38,532 (100)	3.0	2.0	1.7	1.4	1.7
Asia	1,822 (18.8)	6,678 (37.3)	10,828 (47.4)	14,375 (50.8)	17,095 (51.0)	19,563 (50.8)	6.3	2.6	1.7	1.4	1.9
China	454 (4.7)	3,450 (19.3)	6,522 (28.5)	8,378 (29.6)	9,251 (27.6)	9,804 (25.4)	9.6	2.3	1.0	0.6	1.3
India	212 (2.2)	720 (4.0)	1,311 (5.7)	2,219 (7.8)	3,210 (9.6)	4,225 (11.0)	6.5	4.9	3.8	2.8	3.8
Japan	765 (7.9)	1,035 (5.8)	927 (4.1)	937 (3.3)	972 (2.9)	995 (2.6)	0.7	0.1	0.4	0.2	0.2
Korea	94 (1.0)	449 (2.5)	524 (2.3)	604 (2.1)	654 (1.9)	667 (1.7)	6.1	1.3	0.8	0.2	0.8
Chinese Taipei	77 (0.8)	218 (1.2)	246 (1.1)	284 (1.0)	307 (0.9)	318 (0.8)	4.1	1.3	0.8	0.4	0.8
ASEAN	130 (1.3)	601 (3.4)	983 (4.3)	1,487 (5.3)	2,038 (6.1)	2,651 (6.9)	7.2	3.8	3.2	2.7	3.3
Indonesia	28 (0.3)	147 (0.8)	260 (1.1)	416 (1.5)	627 (1.9)	882 (2.3)	7.9	4.4	4.2	3.5	4.0
Malaysia	20 (0.2)	111 (0.6)	159 (0.7)	233 (0.8)	309 (0.9)	379 (1.0)	7.4	3.6	2.9	2.0	2.8
Myanmar	2 (0.0)	6 (0.0)	20 (0.1)	35 (0.1)	58 (0.2)	84 (0.2)	8.7	5.4	5.2	3.8	4.8
Philippines	21 (0.2)	55 (0.3)	87 (0.4)	132 (0.5)	185 (0.6)	248 (0.6)	5.0	3.8	3.5	3.0	3.4
Singapore	13 (0.1)	42 (0.2)	52 (0.2)	62 (0.2)	68 (0.2)	70 (0.2)	4.9	1.7	1.0	0.3	1.0
Thailand	38 (0.4)	149 (0.8)	193 (0.8)	252 (0.9)	312 (0.9)	361 (0.9)	5.7	2.5	2.2	1.5	2.0
Viet Nam	6 (0.1)	87 (0.5)	209 (0.9)	353 (1.2)	473 (1.4)	621 (1.6)	12.9	4.9	3.0	2.8	3.6
North America	3,051 (31.5)	4,264 (23.8)	4,359 (19.1)	4,772 (16.9)	5,358 (16.0)	5,886 (15.3)	1.2	0.8	1.2	0.9	1.0
United States	2,633 (27.1)	3,788 (21.2)	3,829 (16.8)	4,192 (14.8)	4,707 (14.0)	5,176 (13.4)	1.3	0.8	1.2	1.0	1.0
Latin America	518 (5.3)	1,128 (6.3)	1,332 (5.8)	1,677 (5.9)	2,150 (6.4)	2,580 (6.7)	3.3	2.1	2.5	1.8	2.2
Advanced Europe	2,248 (23.2)	3,106 (17.4)	3,125 (13.7)	3,375 (11.9)	3,621 (10.8)	3,768 (9.8)	1.1	0.7	0.7	0.4	0.6
European Union	1,887 (19.4)	2,510 (14.0)	2,484 (10.9)	2,685 (9.5)	2,884 (8.6)	3,002 (7.8)	1.0	0.7	0.7	0.4	0.6
Other Europe/Eurasia	1,448 (14.9)	1,193 (6.7)	1,268 (5.6)	1,463 (5.2)	1,728 (5.2)	1,974 (5.1)	-0.5	1.3	1.7	1.3	1.4
Africa	256 (2.6)	543 (3.0)	669 (2.9)	990 (3.5)	1,523 (4.5)	2,276 (5.9)	3.4	3.6	4.4	4.1	4.0
Middle East	199 (2.0)	722 (4.0)	1,009 (4.4)	1,344 (4.7)	1,729 (5.2)	2,120 (5.5)	5.8	2.6	2.5	2.1	2.4
Oceania	158 (1.6)	250 (1.4)	254 (1.1)	299 (1.1)	335 (1.0)	364 (0.9)	1.7	1.5	1.1	0.8	1.2
Advanced Economies	6,429 (66.3)	9,407 (52.6)	9,531 (41.7)	10,382 (36.7)	11,368 (33.9)	12,121 (31.5)	1.4	0.8	0.9	0.6	0.8
Emerging Market and Developing Economies	3,272 (33.7)	8,476 (47.4)	13,312 (58.3)	17,913 (63.3)	22,172 (66.1)	26,411 (68.5)	5.0	2.7	2.2	1.8	2.2

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

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

Table A16 | Electricity generated [Reference Scenario]

(TWh)

	1990	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	11,845 (100)	21,526 (100)	26,936 (100)	33,308 (100)	39,130 (100)	44,376 (100)	2.9	1.9	1.6	1.3	1.6
Asia	2,237 (18.9)	7,990 (37.1)	12,432 (46.2)	16,577 (49.8)	19,567 (50.0)	22,124 (49.9)	6.1	2.7	1.7	1.2	1.9
China	621 (5.2)	4,197 (19.5)	7,472 (27.7)	9,604 (28.8)	10,517 (26.9)	11,026 (24.8)	9.0	2.3	0.9	0.5	1.3
India	289 (2.4)	974 (4.5)	1,624 (6.0)	2,756 (8.3)	3,879 (9.9)	4,937 (11.1)	6.1	4.9	3.5	2.4	3.7
Japan	862 (7.3)	1,164 (5.4)	1,037 (3.9)	1,045 (3.1)	1,079 (2.8)	1,099 (2.5)	0.6	0.1	0.3	0.2	0.2
Korea	105 (0.9)	497 (2.3)	578 (2.1)	666 (2.0)	720 (1.8)	733 (1.7)	6.0	1.3	0.8	0.2	0.8
Chinese Taipei	87 (0.7)	244 (1.1)	271 (1.0)	313 (0.9)	337 (0.9)	349 (0.8)	4.0	1.3	0.7	0.3	0.8
ASEAN	154 (1.3)	675 (3.1)	1,089 (4.0)	1,646 (4.9)	2,255 (5.8)	2,929 (6.6)	7.0	3.8	3.2	2.6	3.2
Indonesia	33 (0.3)	170 (0.8)	295 (1.1)	472 (1.4)	709 (1.8)	992 (2.2)	7.9	4.4	4.1	3.4	4.0
Malaysia	23 (0.2)	125 (0.6)	176 (0.7)	259 (0.8)	344 (0.9)	420 (0.9)	7.3	3.6	2.9	2.0	2.9
Myanmar	2 (0.0)	9 (0.0)	24 (0.1)	62 (0.2)	99 (0.3)	137 (0.3)	8.2	9.0	4.7	3.4	5.8
Philippines	26 (0.2)	68 (0.3)	106 (0.4)	159 (0.5)	219 (0.6)	290 (0.7)	4.9	3.7	3.3	2.8	3.3
Singapore	16 (0.1)	46 (0.2)	54 (0.2)	65 (0.2)	72 (0.2)	74 (0.2)	4.4	1.7	1.0	0.3	1.0
Thailand	44 (0.4)	159 (0.7)	191 (0.7)	230 (0.7)	282 (0.7)	323 (0.7)	5.2	1.7	2.1	1.3	1.7
Viet Nam	9 (0.1)	95 (0.4)	238 (0.9)	394 (1.2)	525 (1.3)	686 (1.5)	12.1	4.7	2.9	2.7	3.5
North America	3,685 (31.1)	4,957 (23.0)	5,016 (18.6)	5,479 (16.4)	6,121 (15.6)	6,678 (15.0)	1.1	0.8	1.1	0.9	0.9
United States	3,203 (27.0)	4,354 (20.2)	4,371 (16.2)	4,777 (14.3)	5,341 (13.6)	5,838 (13.2)	1.1	0.8	1.1	0.9	0.9
Latin America	623 (5.3)	1,407 (6.5)	1,652 (6.1)	2,063 (6.2)	2,602 (6.7)	3,060 (6.9)	3.4	2.0	2.3	1.6	2.0
Advanced Europe	2,697 (22.8)	3,625 (16.8)	3,610 (13.4)	3,890 (11.7)	4,149 (10.6)	4,285 (9.7)	1.0	0.7	0.6	0.3	0.6
European Union	2,259 (19.1)	2,957 (13.7)	2,884 (10.7)	3,112 (9.3)	3,299 (8.4)	3,379 (7.6)	0.8	0.7	0.6	0.2	0.5
Other Europe/Eurasia	1,856 (15.7)	1,689 (7.8)	1,791 (6.7)	2,021 (6.1)	2,299 (5.9)	2,515 (5.7)	-0.1	1.1	1.3	0.9	1.1
Africa	316 (2.7)	672 (3.1)	851 (3.2)	1,244 (3.7)	1,876 (4.8)	2,733 (6.2)	3.5	3.5	4.2	3.8	3.8
Middle East	244 (2.1)	888 (4.1)	1,275 (4.7)	1,674 (5.0)	2,119 (5.4)	2,557 (5.8)	5.9	2.5	2.4	1.9	2.3
Oceania	187 (1.6)	298 (1.4)	308 (1.1)	360 (1.1)	397 (1.0)	424 (1.0)	1.7	1.4	1.0	0.7	1.0
Advanced Economies	7,667 (64.7)	10,869 (50.5)	10,913 (40.5)	11,860 (35.6)	12,922 (33.0)	13,688 (30.8)	1.2	0.8	0.9	0.6	0.7
Emerging Market and Developing Economies	4,178 (35.3)	10,657 (49.5)	16,023 (59.5)	21,449 (64.4)	26,208 (67.0)	30,688 (69.2)	4.7	2.7	2.0	1.6	2.1

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)

							CAGR (%)				
	1990	2010	2019	2030	2040	2050	1990/ 2019	2019/ 2030	2030/ 2040	2040/ 2050	2019/ 2050
World	1.66	1.85	1.89	1.87	1.85	1.82	0.5	-0.1	-0.1	-0.2	-0.1
Asia	0.71	1.25	1.46	1.58	1.65	1.71	2.5	0.7	0.4	0.4	0.5
China	0.77	1.90	2.42	2.56	2.53	2.46	4.0	0.5	-0.1	-0.3	0.1
India	0.32	0.54	0.69	0.91	1.12	1.32	2.7	2.6	2.1	1.7	2.1
Japan	3.54	3.91	3.29	3.27	3.24	3.23	-0.3	-0.1	-0.1	0.0	-0.1
Korea	2.17	5.05	5.42	5.59	5.63	5.60	3.2	0.3	0.1	-0.1	0.1
Chinese Taipei	2.29	4.69	4.64	4.81	4.82	4.79	2.5	0.3	0.0	-0.1	0.1
ASEAN	0.54	0.93	1.08	1.32	1.54	1.75	2.4	1.9	1.5	1.3	1.6
Indonesia	0.54	0.83	0.89	1.12	1.36	1.59	1.7	2.1	1.9	1.6	1.9
Malaysia	1.18	2.57	2.88	3.59	3.88	4.01	3.1	2.0	0.8	0.3	1.1
Myanmar	0.26	0.27	0.44	0.53	0.66	0.81	1.8	1.9	2.1	2.0	2.0
Philippines	0.45	0.44	0.57	0.72	0.82	0.94	0.8	2.2	1.3	1.3	1.6
Singapore	3.78	4.63	6.04	6.16	6.32	6.44	1.6	0.2	0.3	0.2	0.2
Thailand	0.75	1.75	1.99	2.27	2.63	3.01	3.4	1.2	1.5	1.4	1.3
Viet Nam	0.26	0.67	0.95	1.31	1.62	1.97	4.5	3.0	2.2	2.0	2.4
North America	7.67	7.21	6.88	6.27	5.90	5.53	-0.4	-0.8	-0.6	-0.6	-0.7
United States	7.67	7.16	6.74	6.09	5.72	5.37	-0.4	-0.9	-0.6	-0.6	-0.7
Latin America	1.06	1.35	1.29	1.34	1.47	1.54	0.7	0.4	0.9	0.4	0.6
Advanced Europe	3.25	3.30	2.96	2.78	2.62	2.49	-0.3	-0.5	-0.6	-0.5	-0.6
European Union	3.42	3.46	3.13	3.00	2.85	2.70	-0.3	-0.4	-0.5	-0.5	-0.5
Other Europe/Eurasia	4.50	3.35	3.42	3.46	3.61	3.73	-0.9	0.1	0.4	0.3	0.3
Africa	0.61	0.66	0.66	0.60	0.58	0.54	0.3	-0.8	-0.5	-0.6	-0.6
Middle East	1.69	2.96	3.04	3.10	3.19	3.21	2.0	0.2	0.3	0.1	0.2
Oceania	4.85	5.47	4.92	4.53	4.17	3.78	0.0	-0.7	-0.8	-1.0	-0.8
Advanced Economies	4.47	4.70	4.40	4.16	3.99	3.81	-0.1	-0.5	-0.4	-0.5	-0.5
Emerging Market and Developing Economies	0.95	1.23	1.36	1.41	1.44	1.44	1.3	0.3	0.2	0.0	0.2

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)

							CAGR (%)				
	1990	2010	2019	2030	2040	2050	1990/ 2019	2019/ 2030	2030/ 2040	2040/ 2050	2019/ 2050
World	230	194	171	143	116	97	-1.0	-1.7	-2.0	-1.9	-1.8
Asia	273	269	226	174	132	105	-0.6	-2.4	-2.7	-2.3	-2.5
China	1,055	417	294	185	124	89	-4.3	-4.1	-3.9	-3.2	-3.8
India	554	400	320	258	196	151	-1.9	-1.9	-2.7	-2.6	-2.4
Japan	93	88	67	59	51	44	-1.1	-1.2	-1.5	-1.4	-1.4
Korea	255	219	189	153	122	99	-1.0	-1.9	-2.2	-2.1	-2.1
Chinese Taipei	301	244	196	155	127	104	-1.5	-2.1	-2.0	-2.0	-2.0
ASEAN	311	270	226	197	161	134	-1.1	-1.2	-2.0	-1.8	-1.7
Indonesia	318	267	200	171	139	115	-1.6	-1.4	-2.1	-1.9	-1.8
Malaysia	259	284	230	211	171	137	-0.4	-0.8	-2.1	-2.2	-1.7
Myanmar	1,594	335	323	297	231	185	-5.4	-0.8	-2.5	-2.2	-1.8
Philippines	285	200	171	157	135	118	-1.8	-0.8	-1.5	-1.4	-1.2
Singapore	168	98	103	90	77	68	-1.7	-1.2	-1.5	-1.3	-1.3
Thailand	299	346	306	261	214	178	0.1	-1.5	-1.9	-1.9	-1.7
Viet Nam	607	506	454	354	272	212	-1.0	-2.2	-2.6	-2.5	-2.4
North America	212	149	124	98	78	63	-1.8	-2.1	-2.3	-2.1	-2.2
United States	213	148	121	94	74	60	-1.9	-2.2	-2.4	-2.2	-2.2
Latin America	164	150	141	127	106	89	-0.5	-0.9	-1.8	-1.7	-1.5
Advanced Europe	129	99	79	65	54	46	-1.7	-1.8	-1.9	-1.7	-1.8
European Union	141	105	84	70	58	48	-1.7	-1.7	-1.9	-1.8	-1.8
Other Europe/Eurasia	708	458	397	317	259	213	-2.0	-2.0	-2.0	-1.9	-2.0
Africa	429	351	339	278	203	155	-0.8	-1.8	-3.1	-2.7	-2.5
Middle East	216	271	268	256	222	191	0.8	-0.4	-1.4	-1.5	-1.1
Oceania	137	108	88	71	58	48	-1.5	-1.9	-1.9	-1.9	-1.9
Advanced Economies	155	121	100	82	67	55	-1.5	-1.8	-2.0	-1.9	-1.9
Emerging Market and Developing Economies	446	324	275	210	158	125	-1.7	-2.4	-2.8	-2.4	-2.5

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	2010	2019	2030	2040	2050	CAGR (%) 1990/2019	2019/2030	2030/2040	2040/2050	2019/2050
World	20,511 (100)	30,624 (100)	33,613 (100)	35,461 (100)	36,991 (100)	37,479 (100)	1.7	0.5	0.4	0.1	0.4
Asia	4,682 (22.8)	12,934 (42.2)	16,148 (48.0)	17,954 (50.6)	18,744 (50.7)	18,921 (50.5)	4.4	1.0	0.4	0.1	0.5
China	2,181 (10.6)	8,033 (26.2)	9,882 (29.4)	10,188 (28.7)	9,298 (25.1)	8,067 (21.5)	5.3	0.3	-0.9	-1.4	-0.7
India	530 (2.6)	1,586 (5.2)	2,310 (6.9)	3,366 (9.5)	4,535 (12.3)	5,574 (14.9)	5.2	3.5	3.0	2.1	2.9
Japan	1,049 (5.1)	1,127 (3.7)	1,059 (3.2)	885 (2.5)	792 (2.1)	691 (1.8)	0.0	-1.6	-1.1	-1.4	-1.4
Korea	210 (1.0)	533 (1.7)	587 (1.7)	595 (1.7)	581 (1.6)	531 (1.4)	3.6	0.1	-0.2	-0.9	-0.3
Chinese Taipei	107 (0.5)	245 (0.8)	256 (0.8)	287 (0.8)	272 (0.7)	244 (0.7)	3.1	1.0	-0.5	-1.1	-0.1
ASEAN	355 (1.7)	1,080 (3.5)	1,580 (4.7)	2,009 (5.7)	2,464 (6.7)	2,835 (7.6)	5.3	2.2	2.1	1.4	1.9
Indonesia	131 (0.6)	397 (1.3)	584 (1.7)	739 (2.1)	961 (2.6)	1,128 (3.0)	5.3	2.2	2.7	1.6	2.1
Malaysia	54 (0.3)	193 (0.6)	237 (0.7)	294 (0.8)	321 (0.9)	333 (0.9)	5.2	2.0	0.9	0.4	1.1
Myanmar	4 (0.0)	8 (0.0)	35 (0.1)	62 (0.2)	95 (0.3)	129 (0.3)	7.7	5.2	4.4	3.1	4.3
Philippines	37 (0.2)	75 (0.2)	135 (0.4)	190 (0.5)	247 (0.7)	307 (0.8)	4.6	3.1	2.7	2.2	2.7
Singapore	28 (0.1)	51 (0.2)	47 (0.1)	51 (0.1)	53 (0.1)	52 (0.1)	1.8	0.7	0.4	-0.3	0.3
Thailand	80 (0.4)	223 (0.7)	251 (0.7)	257 (0.7)	268 (0.7)	256 (0.7)	4.0	0.2	0.4	-0.4	0.1
Viet Nam	17 (0.1)	126 (0.4)	282 (0.8)	408 (1.1)	512 (1.4)	623 (1.7)	10.2	3.4	2.3	2.0	2.6
North America	5,135 (25.0)	5,741 (18.7)	5,315 (15.8)	4,907 (13.8)	4,599 (12.4)	4,161 (11.1)	0.1	-0.7	-0.6	-1.0	-0.8
United States	4,743 (23.1)	5,234 (17.1)	4,744 (14.1)	4,340 (12.2)	4,029 (10.9)	3,614 (9.6)	0.0	-0.8	-0.7	-1.1	-0.9
Latin America	856 (4.2)	1,520 (5.0)	1,529 (4.6)	1,637 (4.6)	1,899 (5.1)	2,015 (5.4)	2.0	0.6	1.5	0.6	0.9
Advanced Europe	3,939 (19.2)	3,818 (12.5)	3,299 (9.8)	3,007 (8.5)	2,766 (7.5)	2,479 (6.6)	-0.6	-0.8	-0.8	-1.1	-0.9
European Union	3,445 (16.8)	3,132 (10.2)	2,650 (7.9)	2,364 (6.7)	2,165 (5.9)	1,927 (5.1)	-0.9	-1.0	-0.9	-1.2	-1.0
Other Europe/Eurasia	3,896 (19.0)	2,515 (8.2)	2,534 (7.5)	2,445 (6.9)	2,449 (6.6)	2,463 (6.6)	-1.5	-0.3	0.0	0.1	-0.1
Africa	532 (2.6)	1,024 (3.3)	1,263 (3.8)	1,544 (4.4)	2,009 (5.4)	2,491 (6.6)	3.0	1.8	2.7	2.2	2.2
Middle East	566 (2.8)	1,547 (5.1)	1,810 (5.4)	2,094 (5.9)	2,299 (6.2)	2,414 (6.4)	4.1	1.3	0.9	0.5	0.9
Oceania	279 (1.4)	413 (1.3)	414 (1.2)	380 (1.1)	360 (1.0)	330 (0.9)	1.4	-0.8	-0.5	-0.9	-0.7
Advanced Economies	10,782 (52.6)	11,968 (39.1)	11,019 (32.8)	10,156 (28.6)	9,465 (25.6)	8,527 (22.8)	0.1	-0.7	-0.7	-1.0	-0.8
Emerging Market and Developing Economies	9,102 (44.4)	17,543 (57.3)	21,292 (63.3)	23,813 (67.2)	25,661 (69.4)	26,746 (71.4)	3.0	1.0	0.8	0.4	0.7

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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	8,738	10,003	12,813	14,486	15,869	16,955	17,675	100	100	100	1.8	0.8	0.5	0.6
Coal	2,220	2,314	3,654	3,878	3,910	3,849	3,638	25	27	21	1.9	0.1	-0.4	-0.2
Oil	3,232	3,669	4,126	4,475	4,728	5,008	5,188	37	31	29	1.1	0.5	0.5	0.5
Natural gas	1,662	2,067	2,734	3,363	3,885	4,420	4,857	19	23	27	2.5	1.3	1.1	1.2
Nuclear	526	675	719	728	786	821	857	6.0	5.0	4.8	1.1	0.7	0.4	0.5
Hydro	184	225	297	363	419	459	496	2.1	2.5	2.8	2.4	1.3	0.8	1.0
Geothermal	34	52	62	100	191	248	297	0.4	0.7	1.7	3.8	6.0	2.2	3.6
Solar, wind, etc.	2.5	8.1	49	220	416	601	829	0.0	1.5	4.7	16.7	6.0	3.5	4.4
Biomass and waste	876	991	1,173	1,357	1,532	1,546	1,511	10	9.4	8.5	1.5	1.1	-0.1	0.3

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	6,236	7,004	8,801	9,983	10,880	11,576	12,120	100	100	100	1.6	0.8	0.5	0.6
Industry	1,795	1,871	2,642	2,890	3,142	3,300	3,369	29	29	28	1.7	0.8	0.3	0.5
Transport	1,576	1,964	2,430	2,889	3,100	3,361	3,623	25	29	30	2.1	0.6	0.8	0.7
Buildings, etc.	2,389	2,564	2,964	3,280	3,583	3,732	3,838	38	33	32	1.1	0.8	0.3	0.5
Non-energy use	477	606	764	924	1,054	1,182	1,290	7.7	9.3	11	2.3	1.2	1.0	1.1
Coal	752	542	1,057	950	870	816	770	12	9.5	6.4	0.8	-0.8	-0.6	-0.7
Oil	2,606	3,118	3,596	4,036	4,320	4,595	4,793	42	40	40	1.5	0.6	0.5	0.6
Natural gas	944	1,119	1,346	1,634	1,801	1,907	1,998	15	16	16	1.9	0.9	0.5	0.7
Electricity	834	1,092	1,538	1,965	2,433	2,884	3,314	13	20	27	3.0	2.0	1.6	1.7
Heat	336	248	275	306	317	306	291	5.4	3.1	2.4	-0.3	0.3	-0.4	-0.2
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	-0.1	n.a.
Renewables	764	885	990	1,092	1,140	1,068	954	12	11	7.9	1.2	0.4	-0.9	-0.4

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	11,845	15,428	21,526	26,936	33,308	39,130	44,376	100	100	100	2.9	1.9	1.4	1.6
Coal	4,430	5,995	8,671	9,914	11,166	11,555	11,348	37	37	26	2.8	1.1	0.1	0.4
Oil	1,324	1,188	967	747	679	663	577	11	2.8	1.3	-2.0	-0.9	-0.8	-0.8
Natural gas	1,748	2,771	4,844	6,346	8,173	10,758	13,072	15	24	29	4.5	2.3	2.4	2.4
Nuclear	2,013	2,591	2,756	2,790	3,015	3,150	3,287	17	10	7.4	1.1	0.7	0.4	0.5
Hydro	2,140	2,613	3,449	4,221	4,877	5,335	5,770	18	16	13	2.4	1.3	0.8	1.0
Geothermal	36	52	68	91	191	264	319	0.3	0.3	0.7	3.2	7.0	2.6	4.1
Solar PV	0.1	0.8	32	681	1,506	2,492	3,892	0.0	2.5	8.8	36.0	7.5	4.9	5.8
Wind	3.9	31	342	1,427	2,502	3,349	4,164	0.0	5.3	9.4	22.6	5.2	2.6	3.5
CSP and marine	1.2	1.1	2.2	14	120	215	352	0.0	0.1	0.8	8.9	21.3	5.5	10.9
Biomass and waste	129	162	362	655	1,030	1,300	1,545	1.1	2.4	3.5	5.8	4.2	2.0	2.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	22	34	49	49	49	49	0.2	0.2	0.1	3.1	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	37,974	49,930	66,176	84,540	111,268	145,690	183,075	2.8	2.5	2.5	2.5
Population (million)	5,277	6,111	6,919	7,663	8,506	9,157	9,694	1.3	1.0	0.7	0.8
CO_2 emissions (Mt)	20,511	23,159	30,624	33,613	35,461	36,991	37,479	1.7	0.5	0.3	0.4
GDP per capita ($2010 thousand)	7.2	8.2	9.6	11	13	16	19	1.5	1.6	1.9	1.7
Primary energy consump. per capita (toe)	1.7	1.6	1.9	1.9	1.9	1.9	1.8	0.5	-0.1	-0.1	-0.1
Primary energy consumption per GDP[*2]	230	200	194	171	143	116	97	-1.0	-1.7	-1.9	-1.8
CO_2 emissions per GDP[*3]	540	464	463	398	319	254	205	-1.1	-2.0	-2.2	-2.1
CO_2 per primary energy consumption[*4]	2.3	2.3	2.4	2.3	2.2	2.2	2.1	0.0	-0.3	-0.3	-0.3

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	2,083	2,860	4,781	6,064	7,063	7,639	8,028	100	100	100	3.8	1.4	0.6	0.9
Coal	788	1,035	2,409	2,947	3,115	3,105	2,963	38	49	37	4.7	0.5	-0.3	0.0
Oil	616	915	1,161	1,470	1,695	1,873	2,024	30	24	25	3.0	1.3	0.9	1.0
Natural gas	116	233	453	670	933	1,140	1,315	5.6	11	16	6.2	3.1	1.7	2.2
Nuclear	77	132	152	169	260	309	362	3.7	2.8	4.5	2.8	4.0	1.7	2.5
Hydro	32	41	92	151	180	203	220	1.5	2.5	2.7	5.5	1.6	1.0	1.2
Geothermal	8.2	23	31	55	103	128	153	0.4	0.9	1.9	6.8	5.9	2.0	3.4
Solar, wind, etc.	1.3	2.1	16	100	202	299	408	0.1	1.7	5.1	16.2	6.6	3.6	4.6
Biomass and waste	444	480	467	501	573	580	582	21	8.3	7.3	0.4	1.2	0.1	0.5

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	1,529	1,973	3,156	3,919	4,511	4,895	5,226	100	100	100	3.3	1.3	0.7	0.9
Industry	506	654	1,401	1,638	1,787	1,831	1,838	33	42	35	4.1	0.8	0.1	0.4
Transport	188	321	494	719	867	1,002	1,150	12	18	22	4.7	1.7	1.4	1.5
Buildings, etc.	720	817	972	1,163	1,369	1,505	1,627	47	30	31	1.7	1.5	0.9	1.1
Non-energy use	115	181	288	399	488	557	612	7.5	10	12	4.4	1.8	1.1	1.4
Coal	423	373	894	796	724	678	642	28	20	12	2.2	-0.9	-0.6	-0.7
Oil	463	740	988	1,289	1,505	1,676	1,824	30	33	35	3.6	1.4	1.0	1.1
Natural gas	46	89	200	344	466	532	581	3.0	8.8	11	7.2	2.8	1.1	1.7
Electricity	157	280	574	931	1,236	1,470	1,682	10	24	32	6.3	2.6	1.6	1.9
Heat	14	30	69	120	131	127	120	0.9	3.1	2.3	7.6	0.8	-0.4	0.0
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	0.3	n.a.
Renewables	426	462	430	437	449	413	376	28	11	7.2	0.1	0.2	-0.9	-0.5

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	2,237	3,971	7,990	12,432	16,577	19,567	22,124	100	100	100	6.1	2.7	1.5	1.9
Coal	868	1,984	4,776	7,299	8,763	9,264	9,315	39	59	42	7.6	1.7	0.3	0.8
Oil	433	381	262	127	115	112	107	19	1.0	0.5	-4.1	-0.9	-0.4	-0.6
Natural gas	237	566	1,096	1,425	2,113	2,905	3,656	11	11	17	6.4	3.6	2.8	3.1
Nuclear	294	505	582	647	999	1,188	1,390	13	5.2	6.3	2.8	4.0	1.7	2.5
Hydro	368	477	1,072	1,758	2,095	2,358	2,554	16	14	12	5.5	1.6	1.0	1.2
Geothermal	8.4	20	22	28	61	78	95	0.4	0.2	0.4	4.2	7.4	2.2	4.0
Solar PV	0.1	0.4	5.2	375	846	1,360	2,076	0.0	3.0	9.4	34.4	7.7	4.6	5.7
Wind	0.0	2.4	70	498	1,132	1,704	2,194	0.0	4.0	9.9	39.2	7.7	3.4	4.9
CSP and marine	0.0	0.0	0.0	1.6	9.1	15	26	0.0	0.0	0.1	20.5	17.2	5.5	9.5
Biomass and waste	8.9	15	82	252	422	561	690	0.4	2.0	3.1	12.2	4.8	2.5	3.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	20	21	21	21	21	21	0.9	0.2	0.1	0.3	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	7,634	11,121	17,747	26,795	40,632	57,782	76,784	4.4	3.9	3.2	3.5
Population (million)	2,938	3,420	3,824	4,150	4,462	4,632	4,697	1.2	0.7	0.3	0.4
CO_2 emissions (Mt)	4,682	6,790	12,934	16,148	17,954	18,744	18,921	4.4	1.0	0.3	0.5
GDP per capita ($2010 thousand)	2.6	3.3	4.6	6.5	9.1	12	16	3.2	3.2	3.0	3.0
Primary energy consump. per capita (toe)	0.7	0.8	1.3	1.5	1.6	1.6	1.7	2.5	0.7	0.4	0.5
Primary energy consumption per GDP[*2]	273	257	269	226	174	132	105	-0.6	-2.4	-2.5	-2.5
CO_2 emissions per GDP[*3]	613	611	729	603	442	324	246	-0.1	-2.8	-2.9	-2.8
CO_2 per primary energy consumption[*4]	2.2	2.4	2.7	2.7	2.5	2.5	2.4	0.6	-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 A22 | China [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	874	1,130	2,536	3,389	3,655	3,576	3,373	100	100	100	4.8	0.7	-0.4	0.0
Coal	531	665	1,790	2,072	2,028	1,784	1,483	61	61	44	4.8	-0.2	-1.6	-1.1
Oil	119	221	428	648	719	719	672	14	19	20	6.0	0.9	-0.3	0.1
Natural gas	13	21	89	248	366	422	463	1.5	7.3	14	10.8	3.6	1.2	2.0
Nuclear	-	4.4	19	91	131	170	208	-	2.7	6.2	n.a.	3.4	2.3	2.7
Hydro	11	19	61	109	123	133	137	1.2	3.2	4.1	8.3	1.1	0.6	0.7
Geothermal	-	1.7	3.6	19	22	23	24	-	0.6	0.7	n.a.	1.4	0.4	0.8
Solar, wind, etc.	0.0	1.0	12	77	145	208	263	0.0	2.3	7.8	30.7	5.9	3.0	4.0
Biomass and waste	200	198	133	127	123	121	125	23	3.7	3.7	-1.6	-0.3	0.1	0.0

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	658	781	1,645	2,093	2,233	2,189	2,099	100	100	100	4.1	0.6	-0.3	0.0
Industry	234	302	924	1,024	967	829	712	36	49	34	5.2	-0.5	-1.5	-1.2
Transport	30	84	197	324	390	406	391	4.6	15	19	8.5	1.7	0.0	0.6
Buildings, etc.	351	338	411	567	666	727	769	53	27	37	1.7	1.5	0.7	1.0
Non-energy use	43	58	113	178	210	227	228	6.5	8.5	11	5.0	1.5	0.4	0.8
Coal	311	274	712	574	449	348	269	47	27	13	2.1	-2.2	-2.5	-2.4
Oil	85	180	369	542	607	608	567	13	26	27	6.6	1.0	-0.3	0.1
Natural gas	8.9	12	73	179	222	226	224	1.3	8.6	11	10.9	2.0	0.0	0.7
Electricity	39	89	297	561	721	796	843	5.9	27	40	9.6	2.3	0.8	1.3
Heat	13	26	62	111	121	117	110	2.0	5.3	5.3	7.6	0.8	-0.5	0.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	200	199	132	125	114	95	85	30	6.0	4.1	-1.6	-0.9	-1.4	-1.2

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	621	1,356	4,197	7,472	9,604	10,517	11,026	100	100	100	9.0	2.3	0.7	1.3
Coal	441	1,060	3,240	4,876	5,620	5,288	4,763	71	65	43	8.6	1.3	-0.8	-0.1
Oil	50	47	15	11	9.6	6.8	3.8	8.1	0.1	0.0	-5.3	-0.8	-4.5	-3.2
Natural gas	2.8	5.8	78	213	512	729	900	0.4	2.8	8.2	16.1	8.3	2.9	4.8
Nuclear	-	17	74	348	503	652	797	-	4.7	7.2	n.a.	3.4	2.3	2.7
Hydro	127	222	711	1,273	1,429	1,545	1,597	20	17	14	8.3	1.1	0.6	0.7
Geothermal	0.1	0.1	0.1	0.1	0.3	0.5	0.5	0.0	0.0	0.0	2.8	9.4	2.2	4.7
Solar PV	0.0	0.0	0.7	224	453	680	945	0.0	3.0	8.6	49.3	6.6	3.7	4.8
Wind	0.0	0.6	45	406	905	1,373	1,712	0.0	5.4	16	52.4	7.6	3.2	4.8
CSP and marine	0.0	0.0	0.0	1.1	2.6	4.0	8.6	0.0	0.0	0.1	19.1	8.0	6.2	6.8
Biomass and waste	-	2.4	34	121	171	239	298	-	1.6	2.7	n.a.	3.2	2.8	2.9
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	828	2,232	6,087	11,520	19,727	28,857	37,739	9.5	5.0	3.3	3.9
Population (million)	1,135	1,263	1,338	1,398	1,429	1,414	1,368	0.7	0.2	-0.2	-0.1
CO_2 emissions (Mt)	2,181	3,181	8,033	9,882	10,188	9,298	8,067	5.3	0.3	-1.2	-0.7
GDP per capita ($2010 thousand)	0.7	1.8	4.6	8.2	14	20	28	8.7	4.8	3.5	4.0
Primary energy consump. per capita (toe)	0.8	0.9	1.9	2.4	2.6	2.5	2.5	4.0	0.5	-0.2	0.1
Primary energy consumption per GDP[*2]	1,055	506	417	294	185	124	89	-4.3	-4.1	-3.6	-3.8
CO_2 emissions per GDP[*3]	2,634	1,425	1,320	858	516	322	214	-3.8	-4.5	-4.3	-4.4
CO_2 per primary energy consumption[*4]	2.5	2.8	3.2	2.9	2.8	2.6	2.4	0.5	-0.4	-0.8	-0.6

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	280	418	667	938	1,367	1,776	2,158	100	100	100	4.3	3.5	2.3	2.7
Coal	93	146	279	418	588	767	894	33	45	41	5.3	3.2	2.1	2.5
Oil	61	112	162	235	344	476	637	22	25	30	4.8	3.5	3.1	3.3
Natural gas	11	23	54	55	105	167	224	3.8	5.9	10	5.9	6.0	3.8	4.6
Nuclear	1.6	4.4	6.8	12	41	51	65	0.6	1.3	3.0	7.2	11.7	2.3	5.6
Hydro	6.2	6.4	11	15	21	28	35	2.2	1.6	1.6	3.1	3.0	2.6	2.8
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	0.0	0.2	2.0	11	34	55	82	0.0	1.2	3.8	27.3	10.5	4.4	6.5
Biomass and waste	108	126	152	191	233	234	224	39	20	10	2.0	1.8	-0.2	0.5

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	215	290	444	630	899	1,166	1,442	100	100	100	3.8	3.3	2.4	2.7
Industry	59	85	158	243	381	489	555	27	39	38	5.0	4.2	1.9	2.7
Transport	21	32	65	105	155	237	362	9.6	17	25	5.8	3.6	4.4	4.1
Buildings, etc.	122	147	187	231	289	335	386	57	37	27	2.2	2.1	1.5	1.7
Non-energy use	13	27	34	51	75	106	139	6.2	8.2	9.6	4.8	3.5	3.1	3.3
Coal	38	33	87	107	151	189	220	18	17	15	3.6	3.2	1.9	2.4
Oil	50	94	138	208	310	434	586	23	33	41	5.0	3.7	3.2	3.4
Natural gas	6.1	12	19	34	65	97	126	2.8	5.5	8.7	6.1	6.0	3.4	4.3
Electricity	18	32	62	113	191	276	363	8.5	18	25	6.5	4.9	3.3	3.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	102	119	138	168	183	170	147	48	27	10	1.7	0.8	-1.1	-0.4

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	289	561	974	1,624	2,756	3,879	4,937	100	100	100	6.1	4.9	3.0	3.7
Coal	189	387	658	1,181	1,731	2,338	2,763	65	73	56	6.5	3.5	2.4	2.8
Oil	13	25	21	6.0	5.4	2.8	-	4.3	0.4	-	-2.5	-1.0	-100	-100
Natural gas	10.0	56	107	65	162	308	475	3.4	4.0	9.6	6.7	8.7	5.5	6.6
Nuclear	6.1	17	26	46	157	196	249	2.1	2.9	5.0	7.2	11.7	2.3	5.6
Hydro	72	74	125	172	240	320	402	25	11	8.1	3.1	3.0	2.6	2.8
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	0.0	0.1	51	205	367	592	-	3.1	12	n.a.	13.5	5.5	8.3
Wind	0.0	1.7	20	70	164	224	297	0.0	4.3	6.0	30.4	8.0	3.0	4.8
CSP and marine	-	-	-	-	3.2	5.9	9.5	-	-	0.2	n.a.	n.a.	5.6	n.a.
Biomass and waste	-	0.2	17	33	89	118	149	-	2.0	3.0	n.a.	9.5	2.6	5.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	506	870	1,670	2,930	5,301	9,066	14,321	6.2	5.5	5.1	5.3
Population (million)	873	1,057	1,234	1,366	1,504	1,593	1,639	1.6	0.9	0.4	0.6
CO_2 emissions (Mt)	530	890	1,586	2,310	3,366	4,535	5,574	5.2	3.5	2.6	2.9
GDP per capita ($2010 thousand)	0.6	0.8	1.4	2.1	3.5	5.7	8.7	4.6	4.6	4.6	4.6
Primary energy consump. per capita (toe)	0.3	0.4	0.5	0.7	0.9	1.1	1.3	2.7	2.6	1.9	2.1
Primary energy consumption per GDP[*2]	554	480	400	320	258	196	151	-1.9	-1.9	-2.6	-2.4
CO_2 emissions per GDP[*3]	1,048	1,023	950	788	635	500	389	-1.0	-1.9	-2.4	-2.3
CO_2 per primary energy consumption[*4]	1.9	2.1	2.4	2.5	2.5	2.6	2.6	0.9	0.0	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 A24 | Japan [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	437	516	500	415	392	366	340	100	100	100	-0.2	-0.5	-0.7	-0.6
Coal	77	97	116	115	92	84	74	18	28	22	1.4	-2.0	-1.1	-1.4
Oil	249	253	201	159	135	116	98	57	38	29	-1.5	-1.5	-1.6	-1.5
Natural gas	44	66	86	92	84	82	77	10	22	23	2.6	-0.8	-0.5	-0.6
Nuclear	53	84	75	17	41	37	37	12	4.0	11	-3.9	8.5	-0.6	2.6
Hydro	7.6	7.2	7.2	6.8	7.8	8.1	8.2	1.7	1.6	2.4	-0.3	1.2	0.2	0.6
Geothermal	1.6	3.1	2.4	2.6	5.3	8.4	11	0.4	0.6	3.2	1.7	6.8	3.7	4.8
Solar, wind, etc.	1.2	0.9	1.1	6.8	9.1	12	16	0.3	1.6	4.8	6.1	2.7	2.9	2.8
Biomass and waste	4.2	5.0	11	16	17	18	19	1.0	3.8	5.6	4.6	0.9	0.5	0.6

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	291	336	314	279	259	240	222	100	100	100	-0.1	-0.7	-0.8	-0.7
Industry	108	103	92	81	73	67	61	37	29	27	-1.0	-1.0	-0.9	-0.9
Transport	72	89	79	69	59	50	43	25	25	19	-0.1	-1.4	-1.6	-1.5
Buildings, etc.	78	108	109	95	96	93	88	27	34	40	0.7	0.1	-0.4	-0.2
Non-energy use	33	36	35	33	32	31	30	11	12	14	0.0	-0.4	-0.3	-0.3
Coal	27	21	23	21	17	15	13	9.3	7.4	5.9	-0.9	-1.7	-1.4	-1.5
Oil	181	206	166	143	124	107	92	62	51	42	-0.8	-1.2	-1.5	-1.4
Natural gas	14	21	29	29	31	28	25	4.7	10	11	2.6	0.5	-1.0	-0.5
Electricity	66	84	89	80	81	84	86	23	29	39	0.7	0.1	0.3	0.2
Heat	0.2	0.5	0.6	0.5	0.5	0.5	0.4	0.1	0.2	0.2	3.5	-0.1	-1.5	-1.0
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	-16.4	n.a.
Renewables	3.8	4.1	6.1	6.5	6.4	6.0	5.6	1.3	2.3	2.5	1.9	-0.2	-0.7	-0.5

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	862	1,055	1,164	1,037	1,045	1,079	1,099	100	100	100	0.6	0.1	0.3	0.2
Coal	125	228	317	329	257	247	221	14	32	20	3.4	-2.2	-0.8	-1.3
Oil	250	133	91	36	19	9.6	0.1	29	3.5	0.0	-6.4	-5.6	-22.4	-16.8
Natural gas	168	255	332	385	338	358	354	19	37	32	2.9	-1.2	0.2	-0.3
Nuclear	202	322	288	64	157	141	141	23	6.1	13	-3.9	8.5	-0.6	2.6
Hydro	88	84	84	80	91	94	95	10	7.7	8.7	-0.3	1.2	0.2	0.6
Geothermal	1.7	3.3	2.6	2.8	6.0	9.7	13	0.2	0.3	1.1	1.7	7.1	3.7	4.9
Solar PV	0.1	0.4	3.5	69	86	106	123	0.0	6.6	11	27.0	2.1	1.8	1.9
Wind	-	0.1	4.0	7.7	18	32	64	-	0.7	5.8	n.a.	7.9	6.6	7.1
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	8.1	9.2	21	45	54	63	70	0.9	4.3	6.4	6.1	1.7	1.3	1.5
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	20	21	19	19	19	19	2.3	1.8	1.7	-0.1	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	4,704	5,349	5,700	6,211	6,664	7,227	7,761	1.0	0.6	0.8	0.7
Population (million)	124	127	128	126	120	113	105	0.1	-0.5	-0.7	-0.6
CO_2 emissions (Mt)	1,049	1,152	1,127	1,059	885	792	691	0.0	-1.6	-1.2	-1.4
GDP per capita ($2010 thousand)	38	42	45	49	55	64	74	0.9	1.1	1.4	1.3
Primary energy consump. per capita (toe)	3.5	4.1	3.9	3.3	3.3	3.2	3.2	-0.3	-0.1	-0.1	-0.1
Primary energy consumption per GDP[*2]	93	96	88	67	59	51	44	-1.1	-1.2	-1.5	-1.4
CO_2 emissions per GDP[*3]	223	215	198	171	133	110	89	-0.9	-2.2	-2.0	-2.1
CO_2 per primary energy consumption[*4]	2.4	2.2	2.3	2.6	2.3	2.2	2.0	0.2	-1.1	-0.5	-0.7

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	93	188	250	280	288	282	263	100	100	100	3.9	0.2	-0.4	-0.2
Coal	25	42	73	80	80	76	66	27	29	25	4.0	0.0	-1.0	-0.6
Oil	50	99	95	104	102	98	92	54	37	35	2.6	-0.2	-0.5	-0.4
Natural gas	2.7	17	39	49	62	69	73	2.9	17	28	10.5	2.1	0.9	1.3
Nuclear	14	28	39	38	33	25	18	15	14	6.8	3.6	-1.4	-3.0	-2.4
Hydro	0.5	0.3	0.3	0.2	0.3	0.3	0.3	0.6	0.1	0.1	-2.8	2.2	0.0	0.8
Geothermal	-	-	0.0	0.2	0.3	0.2	0.2	-	0.1	0.1	n.a.	1.0	-1.0	-0.3
Solar, wind, etc.	0.0	0.0	0.2	1.6	2.8	4.3	6.3	0.0	0.6	2.4	19.2	5.2	4.1	4.5
Biomass and waste	0.7	1.4	3.5	6.7	7.5	8.0	8.1	0.8	2.4	3.1	7.9	1.1	0.4	0.6

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	65	127	158	182	190	189	180	100	100	100	3.6	0.4	-0.3	0.0
Industry	19	38	45	47	51	51	48	30	26	27	3.1	0.7	-0.3	0.1
Transport	15	26	30	37	34	31	27	22	20	15	3.2	-0.6	-1.1	-1.0
Buildings, etc.	24	37	44	45	48	47	44	38	25	25	2.2	0.5	-0.4	-0.1
Non-energy use	6.7	25	38	53	57	60	60	10	29	33	7.4	0.7	0.3	0.4
Coal	12	9.1	9.5	7.9	6.8	5.8	4.7	18	4.4	2.6	-1.3	-1.4	-1.8	-1.6
Oil	44	80	82	98	96	93	86	67	54	48	2.8	-0.1	-0.5	-0.4
Natural gas	0.7	11	21	22	25	24	22	1.0	12	12	12.7	1.1	-0.6	0.0
Electricity	8.1	23	39	45	52	56	57	13	25	32	6.1	1.3	0.5	0.8
Heat	-	3.3	4.3	5.5	5.6	5.3	4.9	-	3.0	2.7	n.a.	0.1	-0.7	-0.4
Hydrogen	-	-	-	-	0.0	0.0	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	0.7	1.3	2.7	4.2	4.5	4.7	4.7	1.1	2.3	2.6	6.2	0.7	0.2	0.4

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	105	289	497	578	666	720	733	100	100	100	6.0	1.3	0.5	0.8
Coal	18	111	219	246	272	277	249	17	43	34	9.5	0.9	-0.4	0.0
Oil	19	35	19	9.3	5.0	-	-	18	1.6	-	-2.4	-5.5	-100	-100
Natural gas	9.6	29	103	146	213	277	323	9.1	25	44	9.8	3.5	2.1	2.6
Nuclear	53	109	149	146	125	97	68	50	25	9.3	3.6	-1.4	-3.0	-2.4
Hydro	6.4	4.0	3.7	2.8	3.6	3.6	3.6	6.0	0.5	0.5	-2.8	2.2	0.0	0.8
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	0.0	0.0	0.8	13	24	35	49	0.0	2.2	6.7	38.6	5.6	3.7	4.4
Wind	-	0.0	0.8	2.7	5.7	9.7	16	-	0.5	2.2	n.a.	7.1	5.2	5.9
CSP and marine	-	-	-	0.5	3.2	4.7	8.0	-	0.1	1.1	n.a.	18.9	4.7	9.6
Biomass and waste	-	0.1	1.1	9.3	12	13	14	-	1.6	1.9	n.a.	2.1	0.9	1.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	0.3	2.4	2.4	2.4	2.4	-	0.4	0.3	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	364	724	1,144	1,482	1,885	2,308	2,665	5.0	2.2	1.7	1.9
Population (million)	43	47	50	52	51	50	47	0.6	-0.1	-0.4	-0.3
CO_2 emissions (Mt)	210	406	533	587	595	581	531	3.6	0.1	-0.6	-0.3
GDP per capita ($2010 thousand)	8.5	15	23	29	37	46	57	4.3	2.3	2.2	2.2
Primary energy consump. per capita (toe)	2.2	4.0	5.0	5.4	5.6	5.6	5.6	3.2	0.3	0.0	0.1
Primary energy consumption per GDP[*2]	255	260	219	189	153	122	99	-1.0	-1.9	-2.1	-2.1
CO_2 emissions per GDP[*3]	578	561	466	396	316	252	199	-1.3	-2.0	-2.3	-2.2
CO_2 per primary energy consumption[*4]	2.3	2.2	2.1	2.1	2.1	2.1	2.0	-0.3	-0.1	-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 A26 | Chinese Taipei [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	47	82	109	110	115	113	107	100	100	100	3.0	0.4	-0.4	-0.1
Coal	11	28	38	39	44	41	37	23	36	34	4.6	1.0	-0.9	-0.2
Oil	26	38	44	40	39	37	32	55	36	30	1.5	0.0	-1.0	-0.6
Natural gas	1.4	5.6	13	20	27	30	31	3.0	18	29	9.5	3.0	0.7	1.5
Nuclear	8.6	10	11	8.4	-	-	-	18	7.7	-	-0.1	-100	n.a.	-100
Hydro	0.5	0.4	0.4	0.5	0.5	0.5	0.5	1.2	0.4	0.4	-0.5	-0.2	0.1	0.0
Geothermal	0.0	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.6	0.0	0.0	0.0
Solar, wind, etc.	0.0	0.1	0.2	0.6	1.4	2.1	2.9	0.0	0.5	2.7	12.9	8.0	3.8	5.3
Biomass and waste	0.0	0.8	1.6	1.5	2.6	2.9	3.0	0.1	1.4	2.8	12.9	5.0	0.8	2.2

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	30	50	70	70	74	73	70	100	100	100	3.0	0.6	-0.3	0.0
Industry	12	20	24	24	26	26	25	41	34	36	2.3	0.8	-0.3	0.1
Transport	6.6	11	12	12	11	9.4	7.3	22	17	10	2.1	-0.6	-2.2	-1.6
Buildings, etc.	6.5	10	12	12	13	13	13	22	17	19	2.2	0.7	0.1	0.3
Non-energy use	4.4	8.6	22	22	24	24	24	15	31	35	5.6	0.8	0.1	0.4
Coal	3.4	5.2	6.2	5.3	5.0	4.5	3.8	11	7.6	5.5	1.5	-0.6	-1.3	-1.0
Oil	19	29	40	37	37	35	31	63	53	45	2.4	0.1	-0.9	-0.5
Natural gas	0.9	1.6	2.2	4.0	4.9	4.9	4.5	3.0	5.7	6.5	5.3	1.9	-0.4	0.4
Electricity	6.6	14	19	21	24	26	27	22	30	39	4.1	1.3	0.6	0.8
Heat	-	0.0	1.4	1.7	2.0	1.9	1.8	-	2.5	2.6	n.a.	1.2	-0.3	0.2
Hydrogen	-	-	-	-	0.0	0.0	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	0.0	0.3	0.6	0.5	0.6	0.7	0.8	0.1	0.7	1.1	12.0	2.3	1.1	1.5

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	87	181	244	271	313	337	349	100	100	100	4.0	1.3	0.5	0.8
Coal	24	88	122	126	145	136	121	28	47	35	5.8	1.2	-0.9	-0.1
Oil	22	31	11	5.8	5.1	3.0	0.7	26	2.2	0.2	-4.5	-1.3	-9.4	-6.6
Natural gas	1.2	18	60	91	135	161	180	1.4	34	52	16.1	3.7	1.4	2.2
Nuclear	33	39	42	32	-	-	-	38	12	-	-0.1	-100	n.a.	-100
Hydro	6.4	4.6	4.2	5.5	5.4	5.5	5.5	7.3	2.0	1.6	-0.5	-0.2	0.1	0.0
Geothermal	0.0	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-4.6	0.0	0.0	0.0
Solar PV	-	-	0.0	4.0	6.3	9.3	12	-	1.5	3.4	n.a.	4.2	3.1	3.5
Wind	-	0.0	1.0	1.9	8.8	14	21	-	0.7	6.1	n.a.	15.0	4.5	8.1
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	0.2	1.8	3.4	3.8	7.2	8.2	8.7	0.2	1.4	2.5	10.5	6.0	0.9	2.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	155	297	446	560	740	893	1,030	4.5	2.6	1.7	2.0
Population (million)	20	22	23	24	24	23	22	0.5	0.1	-0.3	-0.2
CO_2 emissions (Mt)	107	209	245	256	287	272	244	3.1	1.0	-0.8	-0.1
GDP per capita ($2010 thousand)	7.6	13	19	24	31	38	46	4.0	2.4	2.0	2.2
Primary energy consump. per capita (toe)	2.3	3.7	4.7	4.6	4.8	4.8	4.8	2.5	0.3	0.0	0.1
Primary energy consumption per GDP[*2]	301	278	244	196	155	127	104	-1.5	-2.1	-2.0	-2.0
CO_2 emissions per GDP[*3]	689	705	550	457	388	305	237	-1.4	-1.5	-2.4	-2.1
CO_2 per primary energy consumption[*4]	2.3	2.5	2.3	2.3	2.5	2.4	2.3	0.1	0.6	-0.4	-0.1

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	232	378	533	686	923	1,137	1,336	100	100	100	3.8	2.7	1.9	2.2
Coal	13	31	85	174	224	279	321	5.4	25	24	9.5	2.3	1.8	2.0
Oil	89	153	188	231	283	335	381	38	34	29	3.3	1.9	1.5	1.6
Natural gas	30	74	125	143	203	258	308	13	21	23	5.5	3.3	2.1	2.5
Nuclear	-	-	-	-	-	9.7	18	-	-	1.4	n.a.	n.a.	n.a.	n.a.
Hydro	2.3	4.1	6.1	12	18	20	22	1.0	1.7	1.6	5.8	3.7	1.0	2.0
Geothermal	6.6	18	25	33	75	96	117	2.9	4.9	8.8	5.7	7.6	2.3	4.1
Solar, wind, etc.	-	-	0.0	1.6	7.3	15	30	-	0.2	2.3	n.a.	14.7	7.4	9.9
Biomass and waste	92	97	104	90	111	121	133	40	13	10.0	-0.1	1.9	0.9	1.3

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	171	269	375	467	604	737	867	100	100	100	3.5	2.4	1.8	2.0
Industry	42	75	120	164	216	272	320	24	35	37	4.8	2.5	2.0	2.2
Transport	33	61	86	135	167	200	234	19	29	27	5.0	1.9	1.7	1.8
Buildings, etc.	86	112	128	112	138	162	191	50	24	22	0.9	1.9	1.6	1.7
Non-energy use	11	21	40	56	83	102	122	6.4	12	14	5.8	3.6	2.0	2.5
Coal	5.4	13	40	53	62	75	86	3.1	11	9.9	8.2	1.4	1.6	1.6
Oil	67	123	163	217	269	320	366	39	46	42	4.1	2.0	1.6	1.7
Natural gas	7.5	17	29	46	78	101	120	4.4	9.9	14	6.5	4.9	2.2	3.1
Electricity	11	28	52	85	128	175	228	6.5	18	26	7.2	3.8	2.9	3.3
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	0.9	n.a.
Renewables	81	88	91	66	66	66	68	47	14	7.8	-0.7	0.1	0.1	0.1

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	154	370	675	1,089	1,646	2,255	2,929	100	100	100	7.0	3.8	2.9	3.2
Coal	28	79	185	471	647	851	1,029	18	43	35	10.3	2.9	2.3	2.6
Oil	66	72	59	18	19	19	14	43	1.6	0.5	-4.5	0.8	-1.4	-0.6
Natural gas	26	154	336	380	549	762	985	17	35	34	9.7	3.4	3.0	3.1
Nuclear	-	-	-	-	-	37	71	-	-	2.4	n.a.	n.a.	n.a.	n.a.
Hydro	27	47	71	139	207	235	254	18	13	8.7	5.8	3.7	1.0	2.0
Geothermal	6.6	16	19	25	54	67	81	4.3	2.3	2.8	4.7	7.3	2.1	3.9
Solar PV	-	-	0.0	13	59	127	281	-	1.2	9.6	n.a.	15.0	8.1	10.5
Wind	-	-	0.1	5.9	25	43	71	-	0.5	2.4	n.a.	14.0	5.4	8.4
CSP and marine	-	-	-	-	0.1	0.2	0.3	-	-	0.0	n.a.	n.a.	8.3	n.a.
Biomass and waste	0.6	1.0	5.7	39	85	113	142	0.4	3.5	4.9	15.4	7.5	2.6	4.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	746	1,187	1,970	3,040	4,692	7,044	9,967	5.0	4.0	3.8	3.9
Population (million)	431	507	575	637	699	738	761	1.4	0.8	0.4	0.6
CO_2 emissions (Mt)	355	689	1,080	1,580	2,009	2,464	2,835	5.3	2.2	1.7	1.9
GDP per capita ($2010 thousand)	1.7	2.3	3.4	4.8	6.7	9.5	13	3.6	3.2	3.4	3.3
Primary energy consump. per capita (toe)	0.5	0.7	0.9	1.1	1.3	1.5	1.8	2.4	1.9	1.4	1.6
Primary energy consumption per GDP[*2]	311	319	270	226	197	161	134	-1.1	-1.2	-1.9	-1.7
CO_2 emissions per GDP[*3]	475	581	548	520	428	350	284	0.3	-1.7	-2.0	-1.9
CO_2 per primary energy consumption[*4]	1.5	1.8	2.0	2.3	2.2	2.2	2.1	1.4	-0.5	-0.1	-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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	99	156	202	241	336	433	527	100	100	100	3.1	3.1	2.3	2.6
Coal	3.5	12	32	69	87	117	136	3.6	29	26	10.8	2.2	2.2	2.2
Oil	33	58	67	75	91	111	128	34	31	24	2.9	1.7	1.7	1.7
Natural gas	16	27	39	39	58	83	107	16	16	20	3.2	3.7	3.1	3.3
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.5	0.9	1.5	1.8	2.2	2.7	3.2	0.5	0.8	0.6	4.6	1.6	1.9	1.8
Geothermal	1.9	8.4	16	24	58	76	96	2.0	10	18	9.1	8.2	2.6	4.5
Solar, wind, etc.	-	-	0.0	0.1	1.1	3.7	13	-	0.0	2.5	n.a.	32.2	13.0	19.5
Biomass and waste	44	50	46	31	37	40	44	44	13	8.3	-1.1	1.6	0.8	1.1

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	79	120	146	161	200	254	311	100	100	100	2.5	2.0	2.2	2.2
Industry	17	30	49	58	74	99	121	22	36	39	4.2	2.2	2.5	2.4
Transport	11	21	30	54	66	81	97	14	34	31	5.8	1.8	2.0	1.9
Buildings, etc.	44	59	57	39	47	56	69	55	25	22	-0.4	1.7	1.9	1.8
Non-energy use	7.4	9.8	10	8.3	12	17	23	9.3	5.2	7.5	0.4	3.5	3.3	3.4
Coal	1.5	4.6	17	25	27	36	43	1.9	15	14	10.1	1.0	2.3	1.8
Oil	27	48	55	72	88	107	125	34	45	40	3.4	1.9	1.8	1.8
Natural gas	6.0	12	16	17	26	37	46	7.6	10	15	3.5	4.3	2.9	3.4
Electricity	2.4	6.8	13	22	36	54	76	3.1	14	24	7.9	4.4	3.8	4.0
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	42	49	45	25	22	20	20	53	16	6.6	-1.7	-1.1	-0.5	-0.7

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	33	93	170	295	472	709	992	100	100	100	7.9	4.4	3.8	4.0
Coal	9.8	34	68	174	244	345	414	30	59	42	10.5	3.1	2.7	2.8
Oil	15	18	34	10	11	11	7.8	47	3.4	0.8	-1.5	0.9	-1.7	-0.8
Natural gas	0.7	26	40	61	108	185	265	2.2	21	27	16.5	5.3	4.6	4.8
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	5.7	10	17	21	25	31	37	17	7.2	3.7	4.6	1.6	1.9	1.8
Geothermal	1.1	4.9	9.4	14	34	44	56	3.4	4.8	5.6	9.1	8.2	2.6	4.5
Solar PV	-	-	0.0	0.1	5.8	28	118	-	0.0	12	n.a.	42.5	16.3	25.0
Wind	-	-	0.0	0.5	7.2	15	33	-	0.2	3.3	n.a.	27.8	7.8	14.5
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	0.0	0.1	13	37	49	62	-	4.5	6.2	n.a.	9.6	2.6	5.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	310	453	755	1,204	1,965	3,129	4,595	4.8	4.6	4.3	4.4
Population (million)	181	212	242	271	299	319	331	1.4	0.9	0.5	0.7
CO_2 emissions (Mt)	131	255	397	584	739	961	1,128	5.3	2.2	2.1	2.1
GDP per capita ($2010 thousand)	1.7	2.1	3.1	4.5	6.6	9.8	14	3.4	3.6	3.8	3.7
Primary energy consump. per capita (toe)	0.5	0.7	0.8	0.9	1.1	1.4	1.6	1.7	2.1	1.8	1.9
Primary energy consumption per GDP[*2]	318	343	267	200	171	139	115	-1.6	-1.4	-2.0	-1.8
CO_2 emissions per GDP[*3]	422	563	526	485	376	307	245	0.5	-2.3	-2.1	-2.2
CO_2 per primary energy consumption[*4]	1.3	1.6	2.0	2.4	2.2	2.2	2.1	2.1	-0.9	-0.1	-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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	21	48	72	92	129	150	162	100	100	100	5.2	3.2	1.1	1.9
Coal	1.4	2.3	15	22	29	33	35	6.4	24	21	10.2	2.5	0.8	1.4
Oil	11	19	25	27	31	30	28	54	29	17	3.0	1.4	-0.6	0.1
Natural gas	6.8	25	31	39	64	76	87	32	43	54	6.2	4.4	1.6	2.6
Nuclear	-	-	-	-	-	3.7	3.7	-	-	2.2	n.a.	n.a.	n.a.	n.a.
Hydro	0.3	0.6	0.6	2.3	3.0	3.4	3.5	1.6	2.5	2.2	6.8	2.6	0.8	1.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.1	0.5	1.5	2.9	-	0.1	1.8	n.a.	18.1	9.1	12.2
Biomass and waste	1.2	1.3	0.8	0.8	1.6	2.2	2.7	5.9	0.9	1.7	-1.3	6.2	2.6	3.9

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	13	29	42	65	94	108	117	100	100	100	5.6	3.4	1.1	1.9
Industry	5.6	12	15	20	28	35	40	41	31	34	4.6	2.9	1.8	2.2
Transport	4.9	11	15	22	23	21	19	36	33	16	5.3	0.6	-1.0	-0.5
Buildings, etc.	2.1	4.3	8.2	9.1	12	15	17	16	14	14	5.1	2.8	1.6	2.0
Non-energy use	0.8	2.2	3.7	14	30	36	42	6.3	21	36	10.2	7.4	1.6	3.6
Coal	0.5	1.0	1.8	1.9	2.1	2.2	2.2	3.8	2.9	1.9	4.6	0.9	0.3	0.5
Oil	9.3	18	24	29	34	33	31	70	45	26	4.1	1.3	-0.5	0.1
Natural gas	1.1	3.9	6.3	20	37	45	50	8.2	30	43	10.5	5.9	1.6	3.1
Electricity	1.7	5.3	9.5	14	20	27	33	13	21	28	7.4	3.6	2.5	2.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	-	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	0.8	0.7	0.2	0.4	0.6	0.8	1.0	5.7	0.6	0.9	-2.5	3.9	3.2	3.5

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	23	69	125	176	259	344	420	100	100	100	7.3	3.6	2.5	2.9
Coal	2.9	7.7	43	81	108	125	138	13	46	33	12.1	2.7	1.2	1.7
Oil	11	3.6	3.7	1.0	0.8	0.2	-	46	0.6	-	-7.9	-2.1	-100	-100
Natural gas	5.5	51	71	65	105	143	188	24	37	45	8.9	4.5	3.0	3.5
Nuclear	-	-	-	-	-	14	14	-	-	3.3	n.a.	n.a.	n.a.	n.a.
Hydro	4.0	7.0	6.5	27	35	40	41	17	15	9.8	6.8	2.6	0.8	1.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	0.9	5.9	17	33	-	0.5	7.9	n.a.	18.1	9.1	12.2
Wind	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	1.0	1.4	3.4	4.5	5.7	-	0.8	1.4	n.a.	8.3	2.6	4.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	82	163	255	399	614	876	1,182	5.6	4.0	3.3	3.6
Population (million)	18	23	28	32	36	39	41	2.0	1.1	0.6	0.8
CO_2 emissions (Mt)	54	116	193	237	294	321	333	5.2	2.0	0.6	1.1
GDP per capita ($2010 thousand)	4.5	7.0	9.0	12	17	23	29	3.6	2.8	2.7	2.8
Primary energy consump. per capita (toe)	1.2	2.1	2.6	2.9	3.6	3.9	4.0	3.1	2.0	0.6	1.1
Primary energy consumption per GDP[*2]	259	297	284	230	211	171	137	-0.4	-0.8	-2.1	-1.7
CO_2 emissions per GDP[*3]	656	711	758	593	480	366	282	-0.3	-1.9	-2.6	-2.4
CO_2 per primary energy consumption[*4]	2.5	2.4	2.7	2.6	2.3	2.1	2.0	0.1	-1.1	-0.5	-0.7

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	11	13	14	24	31	40	50	100	100	100	2.8	2.6	2.4	2.5
Coal	0.1	0.3	0.4	1.4	2.7	4.5	6.6	0.6	5.8	13	11.0	6.4	4.6	5.2
Oil	0.7	2.0	1.3	7.1	10	15	20	6.8	30	41	8.1	3.3	3.6	3.5
Natural gas	0.8	1.2	1.3	3.5	8.7	13	18	7.1	15	35	5.4	8.6	3.6	5.4
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.2	0.5	0.9	1.3	1.6	1.8	1.0	3.8	3.6	7.8	3.4	1.6	2.2
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.0	0.1	0.2	0.5	-	0.0	0.9	n.a.	36.1	7.0	16.6
Biomass and waste	9.0	9.2	10	11	10	8.0	6.3	84	46	13	0.6	-0.7	-2.3	-1.7

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	9.4	11	13	20	24	29	35	100	100	100	2.7	1.5	2.0	1.8
Industry	0.4	1.2	1.3	3.8	5.3	8.2	10	4.2	19	30	8.2	3.1	3.4	3.3
Transport	0.4	1.2	0.8	2.2	3.2	5.2	7.5	4.7	11	21	5.6	3.7	4.3	4.1
Buildings, etc.	8.5	9.1	11	14	15	15	16	90	68	47	1.7	0.6	0.5	0.6
Non-energy use	0.1	0.1	0.1	0.5	0.6	0.7	0.9	1.0	2.4	2.4	5.8	1.1	2.3	1.9
Coal	0.1	0.3	0.2	0.3	0.3	0.4	0.4	0.5	1.5	1.2	6.4	0.3	1.4	1.0
Oil	0.6	1.5	1.0	7.0	10.0	15	20	6.2	34	58	8.9	3.3	3.7	3.5
Natural gas	0.2	0.3	0.6	0.6	0.7	0.9	1.0	2.4	2.9	2.9	3.4	1.1	2.2	1.8
Electricity	0.1	0.3	0.5	1.7	3.0	5.0	7.2	1.6	8.3	20	8.7	5.4	4.5	4.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	-5.2	n.a.
Renewables	8.4	9.0	10	11	10.0	7.9	6.2	89	53	18	0.9	-0.7	-2.3	-1.7

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	2.5	5.1	8.6	24	62	99	137	100	100	100	8.2	9.0	4.0	5.8
Coal	0.0	-	0.6	2.3	9.2	18	29	1.6	9.3	21	14.9	13.6	6.0	8.6
Oil	0.3	0.7	0.0	0.1	0.2	0.2	0.1	11	0.4	0.1	-3.1	7.8	-5.0	-0.7
Natural gas	1.0	2.5	1.8	11	36	60	82	39	47	60	8.8	11.2	4.1	6.6
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	1.2	1.9	6.2	11	15	18	21	48	43	15	7.8	3.4	1.6	2.2
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	0.0	1.1	1.9	4.6	-	0.2	3.4	n.a.	33.3	7.6	16.1
Wind	-	-	-	0.0	0.3	0.4	0.7	-	0.0	0.5	n.a.	138	4.4	39.8
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	-	0.0	0.0	0.0	0.0	-	0.0	0.0	n.a.	0.0	0.0	0.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	6.7	13	41	73	105	175	270	8.6	3.4	4.8	4.3
Population (million)	41	47	51	54	58	61	62	0.9	0.7	0.3	0.5
CO_2 emissions (Mt)	4.0	9.5	8.1	35	62	95	129	7.7	5.2	3.8	4.3
GDP per capita ($2010 thousand)	0.2	0.3	0.8	1.3	1.8	2.9	4.3	7.6	2.7	4.5	3.9
Primary energy consump. per capita (toe)	0.3	0.3	0.3	0.4	0.5	0.7	0.8	1.8	1.9	2.1	2.0
Primary energy consumption per GDP[*2]	1,594	960	335	323	297	231	185	-5.4	-0.8	-2.3	-1.8
CO_2 emissions per GDP[*3]	603	714	195	483	584	542	478	-0.8	1.7	-1.0	0.0
CO_2 per primary energy consumption[*4]	0.4	0.7	0.6	1.5	2.0	2.3	2.6	4.8	2.5	1.3	1.8

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	28	39	42	62	90	112	136	100	100	100	2.8	3.5	2.1	2.6
Coal	1.5	4.8	7.2	18	21	25	29	5.3	29	21	9.0	1.6	1.5	1.6
Oil	11	16	14	19	32	44	57	39	31	42	2.0	4.6	3.0	3.6
Natural gas	-	0.0	3.1	3.7	6.2	9.6	14	-	5.9	10	n.a.	4.9	4.1	4.4
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.5	0.7	0.7	0.7	1.1	1.1	1.2	1.9	1.1	0.9	1.0	3.9	0.7	1.9
Geothermal	4.7	10	8.5	9.2	17	19	21	17	15	16	2.3	5.8	1.1	2.8
Solar, wind, etc.	-	-	0.0	0.2	0.7	1.5	2.6	-	0.3	1.9	n.a.	12.7	6.5	8.6
Biomass and waste	10	7.6	8.7	11	12	11	11	37	18	8.1	0.1	0.6	-0.3	0.0

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	19	23	25	36	54	70	90	100	100	100	2.3	3.6	2.6	3.0
Industry	4.3	5.1	6.0	7.5	10	13	15	22	21	17	2.0	2.8	2.0	2.3
Transport	4.5	8.1	8.0	13	22	31	43	24	35	47	3.6	5.2	3.3	4.0
Buildings, etc.	10.0	9.9	11	15	20	23	28	53	42	31	1.4	2.4	1.8	2.0
Non-energy use	0.2	0.3	0.1	1.0	1.7	2.7	4.1	1.2	2.7	4.6	5.2	4.9	4.6	4.7
Coal	0.6	0.8	1.9	2.3	2.9	3.4	3.8	3.2	6.4	4.3	4.7	2.0	1.4	1.6
Oil	8.1	13	11	19	31	43	56	43	51	63	2.9	4.7	3.1	3.7
Natural gas	-	-	0.1	0.1	0.1	0.2	0.3	-	0.2	0.3	n.a.	7.9	3.9	5.3
Electricity	1.8	3.1	4.8	7.5	11	16	21	9.6	21	24	5.0	3.8	3.2	3.4
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	-	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	8.4	6.4	6.9	7.9	8.6	8.1	7.7	44	22	8.6	-0.2	0.7	-0.5	-0.1

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	26	45	68	106	159	219	290	100	100	100	4.9	3.7	3.1	3.3
Coal	1.9	17	23	58	74	97	118	7.3	55	41	12.4	2.3	2.3	2.3
Oil	12	9.2	7.1	3.8	3.8	3.7	2.5	47	3.5	0.9	-4.0	0.2	-2.1	-1.3
Natural gas	-	0.0	20	22	39	64	98	-	21	34	n.a.	5.1	4.8	4.9
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	6.1	7.8	7.8	8.0	12	13	14	23	7.6	4.9	1.0	3.9	0.7	1.9
Geothermal	5.5	12	9.9	11	20	23	25	21	10	8.6	2.3	5.8	1.1	2.8
Solar PV	-	-	0.0	1.2	4.3	10	19	-	1.2	6.6	n.a.	12.0	7.7	9.2
Wind	-	-	0.1	1.0	4.2	6.9	11	-	1.0	3.7	n.a.	13.5	4.8	7.8
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	0.4	-	0.0	1.0	1.3	1.8	2.2	1.6	1.0	0.8	3.1	2.3	2.6	2.5
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	98	130	208	361	572	829	1,156	4.6	4.3	3.6	3.8
Population (million)	62	78	94	108	124	136	144	1.9	1.2	0.8	0.9
CO_2 emissions (Mt)	37	66	75	135	190	247	307	4.6	3.1	2.4	2.7
GDP per capita ($2010 thousand)	1.6	1.7	2.2	3.3	4.6	6.1	8.0	2.6	3.0	2.8	2.9
Primary energy consump. per capita (toe)	0.5	0.5	0.4	0.6	0.7	0.8	0.9	0.8	2.2	1.3	1.6
Primary energy consumption per GDP[*2]	285	301	200	171	157	135	118	-1.8	-0.8	-1.4	-1.2
CO_2 emissions per GDP[*3]	372	506	361	375	332	298	266	0.0	-1.1	-1.1	-1.1
CO_2 per primary energy consumption[*4]	1.3	1.7	1.8	2.2	2.1	2.2	2.3	1.8	-0.3	0.3	0.1

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	42	73	118	139	159	182	199	100	100	100	4.2	1.3	1.1	1.2
Coal	3.8	7.7	16	16	16	16	15	9.0	12	7.5	5.1	-0.2	-0.3	-0.3
Oil	18	32	45	55	60	66	70	43	40	35	3.9	0.8	0.8	0.8
Natural gas	5.0	17	33	37	38	40	39	12	26	20	7.1	0.3	0.1	0.2
Nuclear	-	-	-	-	-	1.8	6.2	-	-	3.1	n.a.	n.a.	n.a.	n.a.
Hydro	0.4	0.5	0.5	0.6	0.8	0.9	0.9	1.0	0.4	0.5	0.9	3.2	0.8	1.7
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	11.6	1.1	4.7
Solar, wind, etc.	-	-	0.0	0.8	2.4	4.6	7.2	-	0.6	3.6	n.a.	10.7	5.7	7.5
Biomass and waste	15	15	23	27	38	46	54	35	20	27	2.1	3.1	1.8	2.2

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	29	51	84	102	117	134	146	100	100	100	4.4	1.2	1.1	1.1
Industry	8.7	17	26	34	40	48	53	30	33	36	4.8	1.6	1.4	1.5
Transport	9.2	15	19	27	28	31	32	32	26	22	3.8	0.4	0.7	0.6
Buildings, etc.	11	14	20	18	21	22	23	37	18	16	1.8	1.2	0.4	0.7
Non-energy use	0.4	5.6	18	24	27	33	38	1.5	23	26	14.8	1.4	1.7	1.6
Coal	1.3	3.5	9.2	7.8	7.7	8.0	8.0	4.5	7.6	5.4	6.4	-0.2	0.2	0.1
Oil	15	29	43	55	60	66	70	52	54	48	4.5	0.8	0.8	0.8
Natural gas	0.1	1.1	4.6	7.1	8.7	11	13	0.5	6.9	8.8	14.5	1.9	1.9	1.9
Electricity	3.3	7.6	13	17	22	27	31	11	16	21	5.7	2.5	1.8	2.0
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	9.3	9.4	14	16	19	21	24	32	16	16	1.9	1.4	1.3	1.3

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	44	96	159	191	230	282	323	100	100	100	5.2	1.7	1.7	1.7
Coal	11	18	30	36	36	38	34	25	19	11	4.1	0.1	-0.3	-0.1
Oil	10	10.0	1.1	0.2	-	-	-	23	0.1	-	-12.2	-100	n.a.	-100
Natural gas	18	62	120	121	121	126	111	40	64	34	6.8	0.0	-0.4	-0.3
Nuclear	-	-	-	-	-	7.0	24	-	-	7.4	n.a.	n.a.	n.a.	n.a.
Hydro	5.0	6.0	5.6	6.4	9.1	10	11	11	3.4	3.3	0.9	3.2	0.8	1.7
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	11.6	1.1	4.7
Solar PV	-	-	0.0	5.1	20	42	70	-	2.7	22	n.a.	13.3	6.4	8.8
Wind	-	-	-	3.7	6.7	10	12	-	1.9	3.8	n.a.	5.7	3.0	4.0
CSP and marine	-	-	-	-	0.1	0.2	0.3	-	-	0.1	n.a.	n.a.	8.3	n.a.
Biomass and waste	-	0.5	3.4	18	36	48	60	-	9.7	19	n.a.	6.2	2.6	3.9
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	142	218	341	453	612	849	1,118	4.1	2.8	3.1	3.0
Population (million)	57	63	67	70	70	69	66	0.7	0.1	-0.3	-0.2
CO_2 emissions (Mt)	80	151	223	251	257	268	256	4.0	0.2	0.0	0.1
GDP per capita ($2010 thousand)	2.5	3.5	5.1	6.5	8.7	12	17	3.3	2.7	3.4	3.1
Primary energy consump. per capita (toe)	0.7	1.2	1.8	2.0	2.3	2.6	3.0	3.4	1.2	1.4	1.3
Primary energy consumption per GDP[*2]	299	334	346	306	261	214	178	0.1	-1.5	-1.9	-1.7
CO_2 emissions per GDP[*3]	564	692	653	555	420	315	229	-0.1	-2.5	-3.0	-2.8
CO_2 per primary energy consumption[*4]	1.9	2.1	1.9	1.8	1.6	1.5	1.3	-0.1	-1.1	-1.1	-1.1

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	18	29	59	91	136	175	216	100	100	100	5.8	3.7	2.3	2.8
Coal	2.2	4.4	15	47	66	83	100	12	51	46	11.1	3.3	2.1	2.5
Oil	2.7	7.8	18	21	32	40	48	15	24	22	7.4	3.6	2.1	2.6
Natural gas	0.0	1.1	8.1	8.5	16	22	30	0.0	9.4	14	32.0	5.7	3.4	4.2
Nuclear	-	-	-	-	-	4.2	8.6	-	-	4.0	n.a.	n.a.	n.a.	n.a.
Hydro	0.5	1.3	2.4	5.7	9.4	11	11	2.6	6.2	5.2	9.0	4.7	0.9	2.2
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	0.0	0.5	2.4	3.1	4.1	-	0.5	1.9	n.a.	15.7	2.8	7.2
Biomass and waste	12	14	15	8.3	10.0	11	13	70	9.1	6.1	-1.4	1.7	1.4	1.5

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	16	25	48	62	92	117	143	100	100	100	4.8	3.8	2.2	2.8
Industry	4.5	7.9	17	33	50	61	73	28	54	51	7.1	3.8	1.9	2.6
Transport	1.4	3.5	10	14	21	27	33	8.7	23	23	8.3	3.7	2.3	2.8
Buildings, etc.	10	13	18	13	20	27	35	63	22	24	1.0	3.6	2.9	3.1
Non-energy use	0.0	0.1	2.3	1.2	1.8	2.5	3.2	0.2	1.9	2.2	13.8	3.9	2.9	3.3
Coal	1.3	3.2	9.8	16	22	25	28	8.3	26	20	9.0	2.6	1.4	1.8
Oil	2.3	6.5	17	21	31	39	47	15	34	33	7.9	3.6	2.1	2.6
Natural gas	-	0.0	0.5	0.7	3.3	4.9	6.6	-	1.1	4.6	n.a.	15.7	3.6	7.8
Electricity	0.5	1.9	7.5	18	30	41	53	3.3	29	37	12.9	4.9	2.9	3.6
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	12	13	14	5.6	6.3	7.0	8.1	74	9.2	5.6	-2.5	1.1	1.2	1.2

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	8.7	27	95	238	394	525	686	100	100	100	12.1	4.7	2.8	3.5
Coal	2.0	3.1	20	119	174	227	294	23	50	43	15.1	3.5	2.7	3.0
Oil	1.3	4.5	3.4	2.2	2.9	3.3	3.6	15	0.9	0.5	1.8	2.4	1.1	1.6
Natural gas	0.0	4.4	44	43	75	113	169	0.1	18	25	35.8	5.2	4.2	4.6
Nuclear	-	-	-	-	-	16	33	-	-	4.8	n.a.	n.a.	n.a.	n.a.
Hydro	5.4	15	28	66	110	123	130	62	28	19	9.0	4.7	0.9	2.2
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	4.8	21	25	33	-	2.0	4.8	n.a.	14.3	2.3	6.4
Wind	-	-	0.1	0.7	6.5	11	15	-	0.3	2.2	n.a.	22.2	4.3	10.3
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	0.1	2.8	4.8	6.4	8.1	-	1.2	1.2	n.a.	4.9	2.6	3.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	29	61	116	201	384	643	1,023	6.8	6.1	5.0	5.4
Population (million)	68	80	88	96	104	108	110	1.2	0.7	0.3	0.4
CO_2 emissions (Mt)	17	43	126	282	408	512	623	10.2	3.4	2.1	2.6
GDP per capita ($2010 thousand)	0.4	0.8	1.3	2.1	3.7	6.0	9.3	5.6	5.3	4.8	5.0
Primary energy consump. per capita (toe)	0.3	0.4	0.7	0.9	1.3	1.6	2.0	4.5	3.0	2.1	2.4
Primary energy consumption per GDP[*2]	607	470	506	454	354	272	212	-1.0	-2.2	-2.5	-2.4
CO_2 emissions per GDP[*3]	579	709	1,086	1,405	1,062	796	609	3.1	-2.5	-2.7	-2.7
CO_2 per primary energy consumption[*4]	1.0	1.5	2.1	3.1	3.0	2.9	2.9	4.1	-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 A34 | North America [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	2,126	2,527	2,477	2,518	2,447	2,416	2,350	100	100	100	0.6	-0.3	-0.2	-0.2
Coal	484	565	525	289	208	159	104	23	11	4.4	-1.8	-3.0	-3.4	-3.2
Oil	833	958	903	896	813	754	690	39	36	29	0.2	-0.9	-0.8	-0.8
Natural gas	493	622	632	859	945	980	972	23	34	41	1.9	0.9	0.1	0.4
Nuclear	179	227	242	246	188	172	165	8.4	9.8	7.0	1.1	-2.4	-0.7	-1.3
Hydro	49	53	53	58	61	63	63	2.3	2.3	2.7	0.6	0.5	0.2	0.3
Geothermal	14	13	8.4	9.1	18	31	37	0.7	0.4	1.6	-1.5	6.2	3.8	4.6
Solar, wind, etc.	0.3	2.1	11	40	74	113	170	0.0	1.6	7.2	18.1	5.7	4.2	4.8
Biomass and waste	73	87	103	122	142	146	149	3.4	4.9	6.4	1.8	1.4	0.2	0.7

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	1,452	1,734	1,700	1,794	1,759	1,726	1,679	100	100	100	0.7	-0.2	-0.2	-0.2
Industry	331	388	313	315	313	317	313	23	18	19	-0.2	-0.1	0.0	0.0
Transport	531	640	656	705	655	614	575	37	39	34	1.0	-0.7	-0.6	-0.7
Buildings, etc.	456	533	573	596	606	600	587	31	33	35	0.9	0.2	-0.2	0.0
Non-energy use	134	173	158	178	184	195	203	9.2	9.9	12	1.0	0.3	0.5	0.4
Coal	59	36	30	18	14	12	9.9	4.1	1.0	0.6	-4.0	-2.5	-1.6	-1.9
Oil	749	870	851	857	788	733	674	52	48	40	0.5	-0.8	-0.8	-0.8
Natural gas	346	413	364	435	438	415	387	24	24	23	0.8	0.0	-0.6	-0.4
Electricity	262	342	367	375	410	461	506	18	21	30	1.2	0.8	1.1	1.0
Heat	2.8	6.1	7.1	6.6	6.1	5.8	5.3	0.2	0.4	0.3	3.0	-0.7	-0.7	-0.7
Hydrogen	-	-	-	-	0.0	-	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	33	66	81	102	103	99	96	2.3	5.7	5.7	4.0	0.1	-0.3	-0.2

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	3,685	4,631	4,957	5,016	5,479	6,121	6,678	100	100	100	1.1	0.8	1.0	0.9
Coal	1,782	2,247	2,074	1,112	917	711	452	48	22	6.8	-1.6	-1.7	-3.5	-2.9
Oil	147	133	56	41	33	24	12	4.0	0.8	0.2	-4.3	-2.1	-5.0	-4.0
Natural gas	391	668	1,070	1,708	2,173	2,656	2,943	11	34	44	5.2	2.2	1.5	1.8
Nuclear	685	871	930	945	721	659	631	19	19	9.5	1.1	-2.4	-0.7	-1.3
Hydro	570	612	614	669	711	727	736	15	13	11	0.6	0.5	0.2	0.3
Geothermal	16	15	18	18	36	64	77	0.4	0.4	1.2	0.5	6.4	3.8	4.7
Solar PV	0.0	0.2	3.3	98	183	420	765	0.0	2.0	11	43.1	5.9	7.4	6.9
Wind	3.1	5.9	104	331	486	559	654	0.1	6.6	9.8	17.5	3.6	1.5	2.2
CSP and marine	0.7	0.6	0.9	3.5	52	100	174	0.0	0.1	2.6	5.8	27.6	6.3	13.4
Biomass and waste	90	80	82	85	162	197	228	2.5	1.7	3.4	-0.2	6.1	1.7	3.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	6.8	5.2	5.2	5.2	5.2	-	0.1	0.1	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	10,014	13,827	16,606	20,240	24,902	31,012	37,433	2.5	1.9	2.1	2.0
Population (million)	277	313	343	366	390	410	425	1.0	0.6	0.4	0.5
CO_2 emissions (Mt)	5,135	6,114	5,741	5,315	4,907	4,599	4,161	0.1	-0.7	-0.8	-0.8
GDP per capita ($2010 thousand)	36	44	48	55	64	76	88	1.5	1.3	1.6	1.5
Primary energy consump. per capita (toe)	7.7	8.1	7.2	6.9	6.3	5.9	5.5	-0.4	-0.8	-0.6	-0.7
Primary energy consumption per GDP[*2]	212	183	149	124	98	78	63	-1.8	-2.1	-2.2	-2.2
CO_2 emissions per GDP[*3]	513	442	346	263	197	148	111	-2.3	-2.6	-2.8	-2.7
CO_2 per primary energy consumption[*4]	2.4	2.4	2.3	2.1	2.0	1.9	1.8	-0.5	-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 A35 | United States [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	1,914	2,273	2,216	2,213	2,128	2,095	2,039	100	100	100	0.5	-0.4	-0.2	-0.3
Coal	460	533	501	275	201	155	101	24	12	5.0	-1.8	-2.8	-3.4	-3.2
Oil	757	871	807	793	718	667	612	40	36	30	0.2	-0.9	-0.8	-0.8
Natural gas	438	548	556	742	798	817	806	23	34	40	1.8	0.7	0.0	0.3
Nuclear	159	208	219	220	167	158	157	8.3	9.9	7.7	1.1	-2.5	-0.3	-1.1
Hydro	23	22	23	25	26	27	27	1.2	1.1	1.3	0.2	0.4	0.2	0.3
Geothermal	14	13	8.4	9.1	18	31	37	0.7	0.4	1.8	-1.5	6.2	3.8	4.6
Solar, wind, etc.	0.3	2.1	11	37	68	105	160	0.0	1.7	7.8	17.8	5.7	4.4	4.8
Biomass and waste	62	73	89	108	128	132	136	3.3	4.9	6.7	1.9	1.5	0.3	0.7

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	1,294	1,546	1,513	1,588	1,553	1,525	1,485	100	100	100	0.7	-0.2	-0.2	-0.2
Industry	284	332	270	268	266	268	265	22	17	18	-0.2	-0.1	0.0	0.0
Transport	488	588	596	637	590	554	520	38	40	35	0.9	-0.7	-0.6	-0.7
Buildings, etc.	403	473	511	525	534	529	518	31	33	35	0.9	0.2	-0.2	0.0
Non-energy use	119	153	135	158	164	174	181	9.2	9.9	12	1.0	0.3	0.5	0.4
Coal	56	33	27	15	12	9.9	8.3	4.3	1.0	0.6	-4.3	-2.6	-1.7	-2.0
Oil	683	793	762	764	699	651	599	53	48	40	0.4	-0.8	-0.8	-0.8
Natural gas	303	360	322	383	384	364	340	23	24	23	0.8	0.0	-0.6	-0.4
Electricity	226	301	326	329	360	405	445	18	21	30	1.3	0.8	1.1	1.0
Heat	2.2	5.3	6.6	6.0	5.6	5.2	4.8	0.2	0.4	0.3	3.6	-0.7	-0.8	-0.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	23	54	70	91	93	90	88	1.8	5.7	5.9	4.9	0.1	-0.3	-0.1

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	3,203	4,026	4,354	4,371	4,777	5,341	5,838	100	100	100	1.1	0.8	1.0	0.9
Coal	1,700	2,129	1,994	1,070	904	710	450	53	24	7.7	-1.6	-1.5	-3.4	-2.8
Oil	131	118	48	36	29	20	10	4.1	0.8	0.2	-4.4	-2.0	-5.0	-3.9
Natural gas	382	634	1,018	1,640	2,062	2,465	2,703	12	38	46	5.2	2.1	1.4	1.6
Nuclear	612	798	839	843	640	605	602	19	19	10	1.1	-2.5	-0.3	-1.1
Hydro	273	253	262	290	304	311	315	8.5	6.6	5.4	0.2	0.4	0.2	0.3
Geothermal	16	15	18	18	36	64	77	0.5	0.4	1.3	0.5	6.4	3.8	4.7
Solar PV	0.0	0.2	3.1	94	176	408	748	0.0	2.1	13	42.9	5.9	7.5	6.9
Wind	3.1	5.7	95	298	425	478	550	0.1	6.8	9.4	17.1	3.3	1.3	2.0
CSP and marine	0.7	0.5	0.9	3.5	52	100	174	0.0	0.1	3.0	5.9	27.6	6.3	13.4
Biomass and waste	86	72	73	74	144	175	203	2.7	1.7	3.5	-0.5	6.3	1.7	3.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	3.7	5.1	5.1	5.1	5.1	-	0.1	0.1	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	9,001	12,620	14,992	18,300	22,575	28,191	34,109	2.5	1.9	2.1	2.0
Population (million)	250	282	309	328	350	366	379	0.9	0.6	0.4	0.5
CO_2 emissions (Mt)	4,743	5,633	5,234	4,744	4,340	4,029	3,614	0.0	-0.8	-0.9	-0.9
GDP per capita ($2010 thousand)	36	45	48	56	65	77	90	1.5	1.3	1.7	1.6
Primary energy consump. per capita (toe)	7.7	8.1	7.2	6.7	6.1	5.7	5.4	-0.4	-0.9	-0.6	-0.7
Primary energy consumption per GDP[*2]	213	180	148	121	94	74	60	-1.9	-2.2	-2.3	-2.2
CO_2 emissions per GDP[*3]	527	446	349	259	192	143	106	-2.4	-2.7	-2.9	-2.8
CO_2 per primary energy consumption[*4]	2.5	2.5	2.4	2.1	2.0	1.9	1.8	-0.5	-0.5	-0.7	-0.6

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	464	608	788	829	940	1,085	1,166	100	100	100	2.0	1.1	1.1	1.1
Coal	21	27	39	44	42	47	47	4.6	5.3	4.0	2.6	-0.5	0.6	0.2
Oil	238	310	365	338	356	382	380	51	41	33	1.2	0.5	0.3	0.4
Natural gas	71	118	179	207	239	317	376	15	25	32	3.8	1.3	2.3	1.9
Nuclear	3.2	5.3	7.2	9.3	16	17	14	0.7	1.1	1.2	3.7	5.1	-0.7	1.3
Hydro	33	50	63	62	73	80	86	7.2	7.4	7.4	2.2	1.6	0.8	1.1
Geothermal	5.1	6.5	6.4	6.6	21	30	36	1.1	0.8	3.1	0.9	11.2	2.7	5.7
Solar, wind, etc.	0.0	0.2	0.9	12	24	33	44	0.0	1.4	3.8	25.2	6.8	3.1	4.4
Biomass and waste	93	90	128	150	167	179	182	20	18	16	1.7	1.0	0.4	0.6

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	344	443	570	598	668	753	806	100	100	100	1.9	1.0	0.9	1.0
Industry	114	144	181	171	199	239	262	33	29	32	1.4	1.4	1.4	1.4
Transport	103	140	197	227	250	271	282	30	38	35	2.8	0.9	0.6	0.7
Buildings, etc.	101	122	147	164	178	195	208	29	27	26	1.7	0.8	0.8	0.8
Non-energy use	26	38	45	37	41	48	54	7.6	6.2	6.7	1.2	0.9	1.4	1.2
Coal	8.1	11	15	13	13	15	15	2.3	2.2	1.8	1.8	-0.1	0.5	0.3
Oil	178	236	284	291	316	344	352	52	49	44	1.7	0.8	0.5	0.6
Natural gas	38	54	75	70	79	91	100	11	12	12	2.1	1.1	1.2	1.1
Electricity	45	69	97	115	144	185	222	13	19	28	3.3	2.1	2.2	2.2
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	75	74	99	110	116	119	118	22	18	15	1.3	0.5	0.1	0.2

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	623	1,010	1,407	1,652	2,063	2,602	3,060	100	100	100	3.4	2.0	2.0	2.0
Coal	24	44	75	93	87	111	114	3.8	5.6	3.7	4.8	-0.6	1.4	0.7
Oil	129	198	189	139	111	104	65	21	8.4	2.1	0.3	-2.1	-2.7	-2.4
Natural gas	58	141	325	445	533	835	1,114	9.3	27	36	7.3	1.6	3.8	3.0
Nuclear	12	20	28	36	62	66	54	2.0	2.2	1.8	3.7	5.1	-0.7	1.3
Hydro	386	584	731	717	854	929	997	62	43	33	2.2	1.6	0.8	1.1
Geothermal	5.9	8.0	9.9	9.9	34	49	60	1.0	0.6	2.0	1.8	11.8	2.9	6.0
Solar PV	0.0	0.0	0.1	25	67	103	151	0.0	1.5	4.9	41.9	9.2	4.2	5.9
Wind	0.0	0.3	4.7	95	190	254	332	0.0	5.8	11	48.5	6.5	2.8	4.1
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	7.5	13	44	78	112	139	159	1.2	4.7	5.2	8.4	3.3	1.7	2.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	0.4	0.5	14	14	14	14	-	0.8	0.4	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	2,828	3,823	5,249	5,894	7,405	10,220	13,074	2.6	2.1	2.9	2.6
Population (million)	438	517	586	643	701	737	757	1.3	0.8	0.4	0.5
CO_2 emissions (Mt)	856	1,182	1,520	1,529	1,637	1,899	2,015	2.0	0.6	1.0	0.9
GDP per capita ($2010 thousand)	6.5	7.4	9.0	9.2	11	14	17	1.2	1.3	2.5	2.1
Primary energy consump. per capita (toe)	1.1	1.2	1.3	1.3	1.3	1.5	1.5	0.7	0.4	0.7	0.6
Primary energy consumption per GDP[*2]	164	159	150	141	127	106	89	-0.5	-0.9	-1.7	-1.5
CO_2 emissions per GDP[*3]	303	309	290	259	221	186	154	-0.5	-1.4	-1.8	-1.7
CO_2 per primary energy consumption[*4]	1.8	1.9	1.9	1.8	1.7	1.7	1.7	0.0	-0.5	0.0	-0.2

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

Table A37 | Advanced Europe [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	1,643	1,759	1,835	1,715	1,638	1,549	1,457	100	100	100	0.1	-0.4	-0.6	-0.5
Coal	448	331	301	213	186	170	152	27	12	10	-2.5	-1.2	-1.0	-1.1
Oil	617	654	606	560	513	452	394	38	33	27	-0.3	-0.8	-1.3	-1.1
Natural gas	267	396	473	433	417	417	395	16	25	27	1.7	-0.3	-0.3	-0.3
Nuclear	210	247	239	214	180	154	146	13	12	10	0.1	-1.5	-1.0	-1.2
Hydro	39	47	48	49	51	52	53	2.4	2.8	3.7	0.8	0.4	0.3	0.3
Geothermal	4.9	7.1	11	21	28	30	32	0.3	1.2	2.2	5.1	2.8	0.8	1.5
Solar, wind, etc.	0.4	2.9	18	57	83	95	108	0.0	3.3	7.4	19.2	3.4	1.4	2.1
Biomass and waste	56	72	137	166	178	177	173	3.4	9.7	12	3.8	0.7	-0.1	0.1

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	1,142	1,235	1,289	1,245	1,202	1,129	1,056	100	100	100	0.3	-0.3	-0.6	-0.5
Industry	330	325	296	292	297	292	281	29	23	27	-0.4	0.1	-0.3	-0.1
Transport	269	318	335	356	324	285	253	24	29	24	1.0	-0.9	-1.2	-1.1
Buildings, etc.	442	477	545	492	476	447	419	39	40	40	0.4	-0.3	-0.6	-0.5
Non-energy use	101	114	113	104	105	104	102	8.9	8.4	9.7	0.1	0.1	-0.1	0.0
Coal	124	62	55	40	35	29	25	11	3.2	2.3	-3.8	-1.3	-1.7	-1.6
Oil	527	573	537	512	470	412	359	46	41	34	-0.1	-0.8	-1.3	-1.1
Natural gas	205	269	285	275	257	239	220	18	22	21	1.0	-0.6	-0.8	-0.7
Electricity	193	234	267	269	290	311	324	17	22	31	1.1	0.7	0.6	0.6
Heat	45	42	53	48	47	43	39	3.9	3.9	3.7	0.2	-0.3	-0.9	-0.7
Hydrogen	-	-	-	-	0.0	0.0	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	48	56	92	101	102	95	89	4.2	8.1	8.5	2.6	0.1	-0.7	-0.4

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	2,697	3,238	3,625	3,610	3,890	4,149	4,285	100	100	100	1.0	0.7	0.5	0.6
Coal	1,030	968	873	579	545	520	461	38	16	11	-2.0	-0.5	-0.8	-0.7
Oil	210	180	80	48	37	31	16	7.8	1.3	0.4	-4.9	-2.3	-4.1	-3.4
Natural gas	176	514	858	744	864	1,092	1,167	6.5	21	27	5.1	1.4	1.5	1.5
Nuclear	804	948	916	820	692	591	562	30	23	13	0.1	-1.5	-1.0	-1.2
Hydro	451	549	560	567	590	606	622	17	16	15	0.8	0.4	0.3	0.3
Geothermal	3.6	6.2	11	22	30	34	37	0.1	0.6	0.9	6.4	3.2	0.9	1.7
Solar PV	0.0	0.1	23	141	239	280	331	0.0	3.9	7.7	36.7	5.0	1.6	2.8
Wind	0.8	22	153	449	572	629	684	0.0	12	16	24.5	2.2	0.9	1.4
CSP and marine	0.5	0.5	1.2	6.2	34	47	65	0.0	0.2	1.5	9.0	16.6	3.3	7.9
Biomass and waste	21	48	146	227	280	313	334	0.8	6.3	7.8	8.6	1.9	0.9	1.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	0.3	1.5	4.6	6.3	6.3	6.3	6.3	0.0	0.2	0.1	10.5	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	12,710	15,976	18,523	21,589	25,122	28,657	31,986	1.8	1.4	1.2	1.3
Population (million)	505	527	556	580	588	590	586	0.5	0.1	0.0	0.0
CO_2 emissions (Mt)	3,939	3,915	3,818	3,299	3,007	2,766	2,479	-0.6	-0.8	-1.0	-0.9
GDP per capita ($2010 thousand)	25	30	33	37	43	49	55	1.4	1.3	1.2	1.2
Primary energy consump. per capita (toe)	3.3	3.3	3.3	3.0	2.8	2.6	2.5	-0.3	-0.5	-0.6	-0.6
Primary energy consumption per GDP[*2]	129	110	99	79	65	54	46	-1.7	-1.8	-1.8	-1.8
CO_2 emissions per GDP[*3]	310	245	206	153	120	97	77	-2.4	-2.2	-2.2	-2.2
CO_2 per primary energy consumption[*4]	2.4	2.2	2.1	1.9	1.8	1.8	1.7	-0.8	-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 A38 | Other Europe/Eurasia [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	1,514	988	1,112	1,167	1,191	1,234	1,269	100	100	100	-0.9	0.2	0.3	0.3
Coal	365	209	211	216	191	191	190	24	18	15	-1.8	-1.1	0.0	-0.4
Oil	459	199	216	237	236	231	226	30	20	18	-2.3	0.0	-0.2	-0.2
Natural gas	596	481	566	575	571	585	604	39	49	48	-0.1	-0.1	0.3	0.2
Nuclear	55	61	76	84	113	125	119	3.6	7.2	9.4	1.5	2.7	0.3	1.1
Hydro	22	23	26	27	29	31	32	1.5	2.3	2.5	0.6	0.8	0.4	0.6
Geothermal	0.0	0.1	0.6	0.3	0.6	0.6	0.6	0.0	0.0	0.1	8.5	7.4	0.6	3.0
Solar, wind, etc.	-	0.0	0.2	2.2	4.9	7.5	11	-	0.2	0.9	n.a.	7.4	4.1	5.2
Biomass and waste	17	15	19	27	48	65	87	1.1	2.3	6.9	1.7	5.2	3.1	3.8

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	1,057	647	711	772	787	794	802	100	100	100	-1.1	0.2	0.1	0.1
Industry	391	205	205	207	220	233	242	37	27	30	-2.2	0.5	0.5	0.5
Transport	170	110	145	155	153	146	141	16	20	18	-0.3	-0.2	-0.4	-0.3
Buildings, etc.	431	285	281	315	316	309	305	41	41	38	-1.1	0.0	-0.2	-0.1
Non-energy use	65	47	80	94	99	106	113	6.2	12	14	1.3	0.5	0.7	0.6
Coal	113	36	41	51	51	48	45	11	6.7	5.6	-2.7	-0.1	-0.6	-0.4
Oil	275	144	174	203	209	204	198	26	26	25	-1.0	0.3	-0.3	-0.1
Natural gas	258	200	233	258	249	247	246	24	33	31	0.0	-0.3	-0.1	-0.1
Electricity	125	86	103	109	126	149	170	12	14	21	-0.5	1.3	1.5	1.4
Heat	274	170	147	131	133	130	127	26	17	16	-2.5	0.1	-0.2	-0.1
Hydrogen	-	-	-	-	0.0	0.0	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	13	11	14	19	18	17	16	1.2	2.5	1.9	1.4	-0.3	-0.9	-0.7

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	1,856	1,415	1,689	1,791	2,021	2,299	2,515	100	100	100	-0.1	1.1	1.1	1.1
Coal	429	338	396	393	394	442	475	23	22	19	-0.3	0.0	0.9	0.6
Oil	252	69	22	16	14	12	9.8	14	0.9	0.4	-9.1	-1.5	-1.6	-1.6
Natural gas	707	504	671	716	746	853	974	38	40	39	0.0	0.4	1.3	1.0
Nuclear	209	234	289	322	433	478	455	11	18	18	1.5	2.7	0.3	1.1
Hydro	259	267	306	312	343	362	374	14	17	15	0.6	0.8	0.4	0.6
Geothermal	0.0	0.1	0.5	0.5	1.8	2.1	2.3	0.0	0.0	0.1	10.6	12.0	1.1	4.8
Solar PV	-	-	0.0	9.2	20	33	48	-	0.5	1.9	n.a.	7.4	4.5	5.5
Wind	-	0.0	1.2	15	35	53	75	-	0.8	3.0	n.a.	8.0	4.0	5.4
CSP and marine	-	-	-	-	0.0	0.1	0.2	-	-	0.0	n.a.	n.a.	12.7	n.a.
Biomass and waste	0.0	2.6	3.3	7.3	35	64	100	0.0	0.4	4.0	18.9	15.3	5.4	8.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	0.0	0.2	0.2	0.2	0.2	-	0.0	0.0	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	2,140	1,478	2,429	2,940	3,761	4,762	5,958	1.1	2.3	2.3	2.3
Population (million)	336	334	332	341	344	342	340	0.0	0.1	-0.1	0.0
CO_2 emissions (Mt)	3,896	2,344	2,515	2,534	2,445	2,449	2,463	-1.5	-0.3	0.0	-0.1
GDP per capita ($2010 thousand)	6.4	4.4	7.3	8.6	11	14	18	1.1	2.2	2.4	2.3
Primary energy consump. per capita (toe)	4.5	3.0	3.4	3.4	3.5	3.6	3.7	-0.9	0.1	0.4	0.3
Primary energy consumption per GDP[*2]	708	669	458	397	317	259	213	-2.0	-2.0	-2.0	-2.0
CO_2 emissions per GDP[*3]	1,821	1,586	1,035	862	650	514	413	-2.5	-2.5	-2.2	-2.3
CO_2 per primary energy consumption[*4]	2.6	2.4	2.3	2.2	2.1	2.0	1.9	-0.6	-0.5	-0.3	-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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	1,439	1,471	1,527	1,403	1,341	1,267	1,182	100	100	100	-0.1	-0.4	-0.6	-0.6
Coal	391	285	252	175	157	143	127	27	12	11	-2.7	-1.0	-1.1	-1.0
Oil	531	550	506	460	422	371	323	37	33	27	-0.5	-0.8	-1.3	-1.1
Natural gas	250	309	363	336	322	324	308	17	24	26	1.0	-0.4	-0.2	-0.3
Nuclear	190	224	223	199	170	147	133	13	14	11	0.2	-1.5	-1.2	-1.3
Hydro	24	30	32	28	30	31	31	1.7	2.0	2.6	0.4	0.7	0.2	0.4
Geothermal	3.2	4.6	5.5	6.9	9.0	9.8	11	0.2	0.5	0.9	2.7	2.4	0.8	1.4
Solar, wind, etc.	0.3	2.5	16	47	69	80	92	0.0	3.4	7.8	18.9	3.5	1.5	2.2
Biomass and waste	47	65	128	150	161	159	155	3.3	11	13	4.1	0.6	-0.2	0.1

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	995	1,027	1,070	1,015	983	922	859	100	100	100	0.1	-0.3	-0.7	-0.5
Industry	313	274	247	240	244	242	233	31	24	27	-0.9	0.2	-0.2	-0.1
Transport	220	262	279	289	263	232	205	22	29	24	1.0	-0.9	-1.3	-1.1
Buildings, etc.	374	391	446	395	384	358	333	38	39	39	0.2	-0.3	-0.7	-0.5
Non-energy use	88	100	98	91	91	90	88	8.9	8.9	10	0.1	0.1	-0.2	-0.1
Coal	109	47	38	28	25	21	18	11	2.7	2.1	-4.6	-0.9	-1.7	-1.4
Oil	445	479	448	420	386	338	294	45	41	34	-0.2	-0.8	-1.4	-1.1
Natural gas	185	220	231	214	203	189	174	19	21	20	0.5	-0.5	-0.8	-0.7
Electricity	162	189	216	214	231	248	258	16	21	30	1.0	0.7	0.6	0.6
Heat	55	43	52	46	44	41	37	5.5	4.5	4.3	-0.6	-0.3	-0.9	-0.7
Hydrogen	-	-	-	-	0.0	-	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	39	50	86	94	94	85	78	4.0	9.3	9.1	3.0	0.0	-0.9	-0.6

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	2,259	2,631	2,957	2,884	3,112	3,299	3,379	100	100	100	0.8	0.7	0.4	0.5
Coal	844	846	755	491	481	455	400	37	17	12	-1.9	-0.2	-0.9	-0.7
Oil	190	173	82	52	41	33	18	8.4	1.8	0.5	-4.4	-2.2	-4.0	-3.4
Natural gas	188	331	590	569	633	796	858	8.3	20	25	3.9	1.0	1.5	1.3
Nuclear	729	860	854	765	652	566	511	32	27	15	0.2	-1.5	-1.2	-1.3
Hydro	285	352	373	320	347	355	363	13	11	11	0.4	0.7	0.2	0.4
Geothermal	3.2	4.8	5.6	6.7	10	11	12	0.1	0.2	0.4	2.6	3.8	0.9	1.9
Solar PV	0.0	0.1	22	120	207	245	293	0.0	4.2	8.7	36.2	5.1	1.8	2.9
Wind	0.8	21	140	367	475	525	572	0.0	13	17	23.7	2.4	0.9	1.4
CSP and marine	0.5	0.5	1.2	6.2	34	47	65	0.0	0.2	1.9	9.0	16.6	3.3	7.9
Biomass and waste	19	42	129	181	229	259	281	0.8	6.3	8.3	8.1	2.1	1.0	1.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	0.2	1.4	4.4	4.9	4.7	4.7	4.7	0.0	0.2	0.1	11.5	-0.5	0.0	-0.2

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	10,242	12,702	14,556	16,619	19,290	22,002	24,509	1.7	1.4	1.2	1.3
Population (million)	420	429	442	448	447	445	437	0.2	0.0	-0.1	-0.1
CO_2 emissions (Mt)	3,445	3,265	3,132	2,650	2,364	2,165	1,927	-0.9	-1.0	-1.0	-1.0
GDP per capita ($2010 thousand)	24	30	33	37	43	49	56	1.5	1.4	1.3	1.3
Primary energy consump. per capita (toe)	3.4	3.4	3.5	3.1	3.0	2.8	2.7	-0.3	-0.4	-0.5	-0.5
Primary energy consumption per GDP[*2]	141	116	105	84	70	58	48	-1.7	-1.7	-1.8	-1.8
CO_2 emissions per GDP[*3]	336	257	215	159	123	98	79	-2.5	-2.4	-2.2	-2.3
CO_2 per primary energy consumption[*4]	2.4	2.2	2.1	1.9	1.8	1.7	1.6	-0.8	-0.6	-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 A40 | Africa [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	385	490	687	857	1,021	1,200	1,354	100	100	100	2.8	1.6	1.4	1.5
Coal	74	90	108	119	123	136	145	19	14	11	1.6	0.3	0.8	0.7
Oil	85	101	162	198	247	332	423	22	23	31	2.9	2.1	2.7	2.5
Natural gas	30	47	89	135	185	261	343	7.7	16	25	5.4	2.9	3.1	3.0
Nuclear	2.2	3.4	3.2	3.5	7.3	12	12	0.6	0.4	0.9	1.6	7.1	2.6	4.2
Hydro	4.8	6.4	9.4	12	19	25	36	1.3	1.4	2.7	3.1	4.4	3.3	3.7
Geothermal	0.3	0.4	1.3	4.2	13	21	29	0.1	0.5	2.2	9.8	11.1	4.0	6.5
Solar, wind, etc.	0.0	0.0	0.3	3.0	14	31	53	0.0	0.4	3.9	35.1	15.2	6.7	9.6
Biomass and waste	188	241	312	383	411	382	311	49	45	23	2.5	0.7	-1.4	-0.7

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	285	363	496	613	726	827	906	100	100	100	2.7	1.6	1.1	1.3
Industry	53	57	85	90	116	157	193	19	15	21	1.9	2.3	2.5	2.5
Transport	38	55	88	121	153	202	251	13	20	28	4.0	2.2	2.5	2.4
Buildings, etc.	183	237	305	380	432	437	423	64	62	47	2.6	1.2	-0.1	0.3
Non-energy use	11	15	18	21	25	32	39	3.8	3.4	4.3	2.2	1.7	2.2	2.0
Coal	20	19	17	24	26	28	28	7.0	4.0	3.1	0.7	0.7	0.4	0.5
Oil	70	90	138	170	216	283	351	25	28	39	3.1	2.2	2.5	2.4
Natural gas	8.6	14	29	45	59	76	94	3.0	7.4	10	5.9	2.4	2.4	2.4
Electricity	22	31	47	58	85	131	196	7.7	9.4	22	3.4	3.6	4.2	4.0
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	-	-	-	-	-	n.a.	n.a.	-100	n.a.
Renewables	164	209	266	316	340	309	236	58	51	26	2.3	0.7	-1.8	-0.9

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	316	442	672	851	1,244	1,876	2,733	100	100	100	3.5	3.5	4.0	3.8
Coal	164	209	259	260	276	331	376	52	31	14	1.6	0.6	1.6	1.2
Oil	41	37	64	71	96	167	261	13	8.4	9.5	1.9	2.8	5.1	4.3
Natural gas	45	106	220	334	473	735	1,102	14	39	40	7.2	3.2	4.3	3.9
Nuclear	8.4	13	12	13	28	45	47	2.7	1.6	1.7	1.6	7.1	2.6	4.2
Hydro	56	75	110	136	219	286	418	18	16	15	3.1	4.4	3.3	3.7
Geothermal	0.3	0.4	1.5	4.9	16	24	34	0.1	0.6	1.3	9.8	11.1	4.0	6.5
Solar PV	-	0.0	0.3	7.4	65	156	300	-	0.9	11	n.a.	21.7	8.0	12.7
Wind	-	0.2	2.4	17	39	70	107	-	2.1	3.9	n.a.	7.7	5.1	6.0
CSP and marine	-	-	-	2.7	20	42	66	-	0.3	2.4	n.a.	19.7	6.2	10.8
Biomass and waste	0.7	1.4	2.1	2.0	11	16	20	0.2	0.2	0.7	3.7	16.4	3.2	7.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	0.1	0.6	1.6	1.6	1.6	1.6	-	0.2	0.1	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	896	1,173	1,956	2,526	3,674	5,899	8,724	3.6	3.5	4.4	4.1
Population (million)	630	810	1,039	1,301	1,688	2,077	2,489	2.5	2.4	2.0	2.1
CO_2 emissions (Mt)	532	661	1,024	1,263	1,544	2,009	2,491	3.0	1.8	2.4	2.2
GDP per capita ($2010 thousand)	1.4	1.4	1.9	1.9	2.2	2.8	3.5	1.1	1.0	2.4	1.9
Primary energy consump. per capita (toe)	0.6	0.6	0.7	0.7	0.6	0.6	0.5	0.3	-0.8	-0.5	-0.6
Primary energy consumption per GDP[*2]	429	418	351	339	278	203	155	-0.8	-1.8	-2.9	-2.5
CO_2 emissions per GDP[*3]	594	564	524	500	420	341	285	-0.6	-1.6	-1.9	-1.8
CO_2 per primary energy consumption[*4]	1.4	1.3	1.5	1.5	1.5	1.7	1.8	0.2	0.2	1.0	0.7

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	223	372	630	766	929	1,060	1,159	100	100	100	4.4	1.8	1.1	1.3
Coal	3.0	8.1	9.8	8.0	9.8	9.3	8.1	1.3	1.0	0.7	3.4	1.9	-1.0	0.1
Oil	146	217	306	307	349	373	369	66	40	32	2.6	1.2	0.3	0.6
Natural gas	72	145	311	444	538	628	716	32	58	62	6.5	1.8	1.4	1.6
Nuclear	-	-	-	1.9	21	32	38	-	0.2	3.3	n.a.	24.5	3.1	10.3
Hydro	1.0	0.7	1.5	1.7	2.1	2.2	2.4	0.5	0.2	0.2	1.7	1.9	0.7	1.1
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	0.4	0.7	1.3	1.8	7.7	13	23	0.2	0.2	2.0	5.1	14.4	5.6	8.7
Biomass and waste	0.5	0.4	1.0	1.1	1.2	1.6	2.1	0.2	0.1	0.2	3.0	1.5	2.6	2.2

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	157	252	431	526	639	730	802	100	100	100	4.3	1.8	1.1	1.4
Industry	47	71	134	149	181	202	211	30	28	26	4.1	1.8	0.8	1.1
Transport	51	75	121	147	172	185	191	32	28	24	3.7	1.5	0.5	0.8
Buildings, etc.	40	74	119	144	179	211	240	25	27	30	4.5	2.0	1.5	1.6
Non-energy use	20	32	57	86	106	132	160	12	16	20	5.2	1.9	2.1	2.0
Coal	0.2	0.5	1.2	3.0	3.1	3.0	2.7	0.1	0.6	0.3	10.1	0.4	-0.7	-0.3
Oil	108	153	220	244	296	329	348	69	46	43	2.9	1.8	0.8	1.2
Natural gas	31	65	146	191	222	247	266	20	36	33	6.4	1.4	0.9	1.1
Electricity	17	33	62	87	116	149	182	11	16	23	5.8	2.6	2.3	2.4
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	-0.1	n.a.
Renewables	0.7	1.0	2.2	1.5	1.6	2.0	2.4	0.5	0.3	0.3	2.5	0.8	1.9	1.5

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	244	472	888	1,275	1,674	2,119	2,557	100	100	100	5.9	2.5	2.1	2.3
Coal	11	30	35	23	30	30	26	4.3	1.8	1.0	2.7	2.8	-0.8	0.5
Oil	108	189	286	298	269	210	104	44	23	4.1	3.6	-0.9	-4.6	-3.3
Natural gas	114	246	549	915	1,202	1,603	2,033	47	72	80	7.4	2.5	2.7	2.6
Nuclear	-	-	-	7.1	80	124	148	-	0.6	5.8	n.a.	24.5	3.1	10.3
Hydro	12	8.0	18	19	24	26	28	4.9	1.5	1.1	1.7	1.9	0.7	1.1
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	0.1	10	51	90	155	-	0.8	6.1	n.a.	15.5	5.7	9.1
Wind	0.0	0.0	0.2	1.7	12	25	43	0.0	0.1	1.7	29.1	19.4	6.7	11.0
CSP and marine	-	-	-	0.3	6.1	10	20	-	0.0	0.8	n.a.	31.0	6.2	14.4
Biomass and waste	-	0.0	0.1	0.1	0.3	0.4	0.6	-	0.0	0.0	n.a.	16.6	2.9	7.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	0.0	0.2	0.2	0.2	0.2	-	0.0	0.0	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	1,032	1,534	2,326	2,854	3,636	4,772	6,074	3.6	2.2	2.6	2.5
Population (million)	132	168	213	252	299	333	362	2.3	1.6	0.9	1.2
CO_2 emissions (Mt)	566	944	1,547	1,810	2,094	2,299	2,414	4.1	1.3	0.7	0.9
GDP per capita ($2010 thousand)	7.8	9.2	11	11	12	14	17	1.3	0.6	1.6	1.3
Primary energy consump. per capita (toe)	1.7	2.2	3.0	3.0	3.1	3.2	3.2	2.0	0.2	0.2	0.2
Primary energy consumption per GDP[*2]	216	243	271	268	256	222	191	0.8	-0.4	-1.4	-1.1
CO_2 emissions per GDP[*3]	549	615	665	634	576	482	397	0.5	-0.9	-1.8	-1.5
CO_2 per primary energy consumption[*4]	2.5	2.5	2.5	2.4	2.3	2.2	2.1	-0.2	-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 A42 | Oceania [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	99	125	144	149	152	151	146	100	100	100	1.4	0.1	-0.2	-0.1
Coal	36	49	52	43	36	32	28	36	29	19	0.6	-1.7	-1.3	-1.4
Oil	35	40	48	50	47	43	37	35	33	25	1.3	-0.5	-1.2	-0.9
Natural gas	19	24	31	38	44	47	48	19	26	33	2.5	1.2	0.5	0.7
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	3.2	3.5	3.3	3.5	3.5	3.5	3.4	3.2	2.4	2.4	0.3	0.0	-0.1	-0.1
Geothermal	1.5	2.0	3.3	4.7	7.4	7.7	8.1	1.5	3.1	5.5	4.0	4.2	0.5	1.8
Solar, wind, etc.	0.1	0.1	0.9	3.5	6.6	9.5	13	0.1	2.3	8.8	12.1	6.1	3.3	4.3
Biomass and waste	4.7	6.2	6.1	6.1	7.3	7.9	8.4	4.8	4.1	5.7	0.9	1.6	0.7	1.0

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	66	83	89	97	101	100	98	100	100	100	1.3	0.3	-0.2	0.0
Industry	23	28	27	27	29	30	29	35	27	29	0.5	0.8	-0.1	0.2
Transport	24	30	35	39	37	36	33	36	40	34	1.7	-0.4	-0.6	-0.5
Buildings, etc.	15	19	23	25	27	28	29	22	25	30	1.8	1.0	0.3	0.5
Non-energy use	4.6	6.1	5.4	6.9	6.9	6.9	6.8	6.9	7.1	6.9	1.4	0.1	-0.1	0.0
Coal	5.2	4.7	3.1	3.7	3.6	3.2	2.8	7.9	3.8	2.9	-1.2	-0.2	-1.1	-0.8
Oil	33	40	45	51	49	46	41	50	52	42	1.5	-0.4	-0.8	-0.7
Natural gas	10	14	14	15	17	17	17	16	16	17	1.4	0.9	-0.1	0.3
Electricity	14	18	21	22	26	29	31	20	22	32	1.7	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.	-11.8	n.a.
Renewables	4.1	5.6	5.7	5.5	5.8	5.7	5.4	6.2	5.7	5.5	1.0	0.4	-0.3	-0.1

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	187	249	298	308	360	397	424	100	100	100	1.7	1.4	0.8	1.0
Coal	122	176	182	157	153	145	128	65	51	30	0.9	-0.2	-0.9	-0.6
Oil	3.6	1.8	6.1	4.9	4.2	3.4	2.5	1.9	1.6	0.6	1.1	-1.4	-2.7	-2.2
Natural gas	20	26	54	59	69	79	83	11	19	19	3.8	1.6	0.9	1.1
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	37	41	38	41	41	41	40	20	13	9.4	0.3	0.0	-0.1	-0.1
Geothermal	2.1	2.9	5.9	8.0	13	14	14	1.1	2.6	3.3	4.7	4.3	0.5	1.8
Solar PV	-	0.0	0.4	15	35	50	67	-	4.9	16	n.a.	7.9	3.4	5.0
Wind	-	0.2	6.7	20	38	56	76	-	6.5	18	n.a.	5.9	3.6	4.4
CSP and marine	-	-	0.0	0.0	0.0	0.1	0.2	-	0.0	0.0	n.a.	28.3	6.5	13.7
Biomass and waste	1.2	1.7	3.4	4.1	7.4	10	13	0.7	1.3	3.0	4.2	5.4	2.8	3.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.1	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	722	998	1,340	1,702	2,137	2,586	3,044	3.0	2.1	1.8	1.9
Population (million)	20	23	26	30	33	36	39	1.4	0.9	0.7	0.8
CO_2 emissions (Mt)	279	360	413	414	380	360	330	1.4	-0.8	-0.7	-0.7
GDP per capita ($2010 thousand)	35	43	51	56	64	72	79	1.6	1.2	1.1	1.1
Primary energy consump. per capita (toe)	4.9	5.4	5.5	4.9	4.5	4.2	3.8	0.0	-0.7	-0.9	-0.8
Primary energy consumption per GDP[*2]	137	126	108	88	71	58	48	-1.5	-1.9	-1.9	-1.9
CO_2 emissions per GDP[*3]	386	360	308	243	178	139	108	-1.6	-2.8	-2.4	-2.6
CO_2 per primary energy consumption[*4]	2.8	2.9	2.9	2.8	2.5	2.4	2.3	-0.1	-0.9	-0.5	-0.7

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

Table A43 | Advanced Economies [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	4,465	5,230	5,352	5,236	5,084	4,931	4,717	100	100	100	0.6	-0.3	-0.4	-0.3
Coal	1,088	1,116	1,111	786	652	568	466	24	15	9.9	-1.1	-1.7	-1.7	-1.7
Oil	1,824	2,066	1,917	1,837	1,679	1,530	1,373	41	35	29	0.0	-0.8	-1.0	-0.9
Natural gas	827	1,135	1,283	1,503	1,592	1,641	1,611	19	29	34	2.1	0.5	0.1	0.2
Nuclear	463	596	606	523	442	388	365	10	10.0	7.7	0.4	-1.5	-0.9	-1.1
Hydro	100	111	112	117	124	127	129	2.2	2.2	2.7	0.6	0.5	0.2	0.3
Geothermal	22	25	25	37	58	78	89	0.5	0.7	1.9	1.8	4.2	2.1	2.8
Solar, wind, etc.	2.1	6.1	31	110	177	236	316	0.0	2.1	6.7	14.7	4.4	3.0	3.5
Biomass and waste	139	173	263	319	357	362	364	3.1	6.1	7.7	2.9	1.0	0.1	0.4

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	3,057	3,582	3,642	3,694	3,615	3,489	3,334	100	100	100	0.7	-0.2	-0.4	-0.3
Industry	826	907	802	795	798	792	766	27	22	23	-0.1	0.0	-0.2	-0.1
Transport	919	1,120	1,151	1,224	1,126	1,030	943	30	33	28	1.0	-0.8	-0.9	-0.8
Buildings, etc.	1,025	1,189	1,312	1,273	1,274	1,236	1,189	34	34	36	0.7	0.0	-0.3	-0.2
Non-energy use	287	366	378	403	416	431	437	9.4	11	13	1.2	0.3	0.2	0.3
Coal	231	138	127	96	81	69	59	7.5	2.6	1.8	-3.0	-1.5	-1.6	-1.5
Oil	1,559	1,808	1,736	1,714	1,582	1,444	1,302	51	46	39	0.3	-0.7	-1.0	-0.9
Natural gas	578	732	717	782	774	730	676	19	21	20	1.1	-0.1	-0.7	-0.5
Electricity	553	719	809	820	893	978	1,042	18	22	31	1.4	0.8	0.8	0.8
Heat	48	52	66	63	61	56	52	1.6	1.7	1.5	0.9	-0.3	-0.8	-0.6
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	-11.3	n.a.
Renewables	89	133	188	220	223	212	203	2.9	6.0	6.1	3.2	0.1	-0.5	-0.3

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	7,667	9,706	10,869	10,913	11,860	12,922	13,688	100	100	100	1.2	0.8	0.7	0.7
Coal	3,129	3,837	3,812	2,573	2,314	2,062	1,657	41	24	12	-0.7	-1.0	-1.7	-1.4
Oil	668	539	273	146	104	72	32	8.7	1.3	0.2	-5.1	-3.1	-5.8	-4.8
Natural gas	766	1,528	2,528	3,199	3,869	4,709	5,138	10.0	29	38	5.1	1.7	1.4	1.5
Nuclear	1,776	2,288	2,324	2,007	1,695	1,488	1,402	23	18	10	0.4	-1.5	-0.9	-1.1
Hydro	1,159	1,294	1,304	1,366	1,442	1,477	1,503	15	13	11	0.6	0.5	0.2	0.3
Geothermal	23	27	37	51	86	121	140	0.3	0.5	1.0	2.7	4.8	2.5	3.3
Solar PV	0.1	0.7	31	340	575	902	1,348	0.0	3.1	9.8	33.0	4.9	4.4	4.5
Wind	3.8	29	269	812	1,127	1,298	1,516	0.1	7.4	11	20.3	3.0	1.5	2.0
CSP and marine	1.2	1.1	2.1	10	88	152	247	0.0	0.1	1.8	7.7	21.7	5.3	10.8
Biomass and waste	121	142	257	375	526	608	673	1.6	3.4	4.9	4.0	3.1	1.2	1.9
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	22	33	33	33	33	33	0.3	0.3	0.2	1.8	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	28,841	37,461	44,228	52,404	62,231	73,632	84,998	2.1	1.6	1.6	1.6
Population (million)	998	1,070	1,139	1,191	1,222	1,237	1,238	0.6	0.2	0.1	0.1
CO_2 emissions (Mt)	10,782	12,240	11,968	11,019	10,156	9,465	8,527	0.1	-0.7	-0.9	-0.8
GDP per capita ($2010 thousand)	29	35	39	44	51	60	69	1.5	1.3	1.5	1.4
Primary energy consump. per capita (toe)	4.5	4.9	4.7	4.4	4.2	4.0	3.8	-0.1	-0.5	-0.4	-0.5
Primary energy consumption per GDP[*2]	155	140	121	100	82	67	55	-1.5	-1.8	-1.9	-1.9
CO_2 emissions per GDP[*3]	374	327	271	210	163	129	100	-2.0	-2.3	-2.4	-2.4
CO_2 per primary energy consumption[*4]	2.4	2.3	2.2	2.1	2.0	1.9	1.8	-0.5	-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 A44 | Emerging Market and Developing Economies [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	4,070	4,499	7,103	8,829	10,297	11,403	12,211	100	100	100	2.7	1.4	0.9	1.1
Coal	1,133	1,198	2,543	3,092	3,258	3,281	3,171	28	35	26	3.5	0.5	-0.1	0.1
Oil	1,206	1,328	1,850	2,219	2,578	2,910	3,170	30	25	26	2.1	1.4	1.0	1.2
Natural gas	835	933	1,451	1,859	2,279	2,735	3,158	21	21	26	2.8	1.9	1.6	1.7
Nuclear	62	79	113	205	344	433	491	1.5	2.3	4.0	4.2	4.8	1.8	2.9
Hydro	84	113	184	245	295	332	367	2.1	2.8	3.0	3.8	1.7	1.1	1.3
Geothermal	12	27	36	63	133	171	208	0.3	0.7	1.7	5.9	7.0	2.3	3.9
Solar, wind, etc.	0.5	2.1	17	110	240	366	513	0.0	1.2	4.2	20.6	7.3	3.9	5.1
Biomass and waste	738	818	911	1,038	1,171	1,176	1,133	18	12	9.3	1.2	1.1	-0.2	0.3

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	2,977	3,148	4,801	5,869	6,777	7,466	8,039	100	100	100	2.4	1.3	0.9	1.0
Industry	969	964	1,840	2,095	2,344	2,508	2,603	33	36	32	2.7	1.0	0.5	0.7
Transport	454	570	921	1,245	1,486	1,711	1,933	15	21	24	3.5	1.6	1.3	1.4
Buildings, etc.	1,363	1,374	1,653	2,007	2,309	2,495	2,650	46	34	33	1.3	1.3	0.7	0.9
Non-energy use	191	240	387	521	638	752	853	6.4	8.9	11	3.5	1.8	1.5	1.6
Coal	521	404	930	854	789	746	711	18	15	8.8	1.7	-0.7	-0.5	-0.6
Oil	845	1,036	1,502	1,902	2,266	2,582	2,846	28	32	35	2.8	1.6	1.1	1.3
Natural gas	367	388	629	852	1,013	1,134	1,234	12	15	15	2.9	1.6	1.0	1.2
Electricity	281	372	729	1,145	1,541	1,907	2,271	9.5	20	28	5.0	2.7	2.0	2.2
Heat	288	196	209	244	256	249	240	9.7	4.2	3.0	-0.6	0.4	-0.3	-0.1
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	0.5	n.a.
Renewables	674	752	802	872	913	848	737	23	15	9.2	0.9	0.4	-1.1	-0.5

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	4,178	5,722	10,657	16,023	21,449	26,208	30,688	100	100	100	4.7	2.7	1.8	2.1
Coal	1,301	2,158	4,859	7,341	8,851	9,493	9,691	31	46	32	6.1	1.7	0.5	0.9
Oil	656	650	693	601	575	591	545	16	3.7	1.8	-0.3	-0.4	-0.3	-0.3
Natural gas	982	1,244	2,315	3,147	4,303	6,049	7,934	24	20	26	4.1	2.9	3.1	3.0
Nuclear	236	303	432	783	1,319	1,662	1,885	5.7	4.9	6.1	4.2	4.9	1.8	2.9
Hydro	981	1,319	2,145	2,855	3,435	3,858	4,267	23	18	14	3.8	1.7	1.1	1.3
Geothermal	13	25	31	40	106	143	179	0.3	0.3	0.6	4.0	9.2	2.7	4.9
Solar PV	0.0	0.1	1.4	341	932	1,591	2,545	0.0	2.1	8.3	49.4	9.6	5.2	6.7
Wind	0.0	2.8	73	615	1,375	2,051	2,649	0.0	3.8	8.6	39.9	7.6	3.3	4.8
CSP and marine	0.0	0.0	0.0	4.2	32	63	105	0.0	0.0	0.3	24.6	20.3	6.2	11.0
Biomass and waste	8.7	20	105	280	504	691	872	0.2	1.7	2.8	12.7	5.5	2.8	3.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	0.5	1.1	16	16	16	16	-	0.1	0.1	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	9,133	12,469	21,949	32,136	49,037	72,058	98,077	4.4	3.9	3.5	3.7
Population (million)	4,279	5,042	5,780	6,472	7,285	7,920	8,456	1.4	1.1	0.7	0.9
CO_2 emissions (Mt)	9,102	10,069	17,543	21,292	23,813	25,661	26,746	3.0	1.0	0.6	0.7
GDP per capita ($2010 thousand)	2.1	2.5	3.8	5.0	6.7	9.1	12	3.0	2.8	2.8	2.8
Primary energy consump. per capita (toe)	1.0	0.9	1.2	1.4	1.4	1.4	1.4	1.3	0.3	0.1	0.2
Primary energy consumption per GDP[*2]	446	361	324	275	210	158	125	-1.7	-2.4	-2.6	-2.5
CO_2 emissions per GDP[*3]	997	808	799	663	486	356	273	-1.4	-2.8	-2.8	-2.8
CO_2 per primary energy consumption[*4]	2.2	2.2	2.5	2.4	2.3	2.3	2.2	0.3	-0.4	-0.3	-0.3

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	8,738	10,003	12,813	14,486	15,125	15,086	14,738	100	100	100	1.8	0.4	-0.1	0.1
Coal	2,220	2,314	3,654	3,878	3,344	2,658	1,937	25	27	13	1.9	-1.3	-2.7	-2.2
Oil	3,232	3,669	4,126	4,475	4,396	4,121	3,762	37	31	26	1.1	-0.2	-0.8	-0.6
Natural gas	1,662	2,067	2,734	3,363	3,668	3,798	3,627	19	23	25	2.5	0.8	-0.1	0.2
Nuclear	526	675	719	728	958	1,209	1,400	6.0	5.0	9.5	1.1	2.5	1.9	2.1
Hydro	184	225	297	363	427	473	515	2.1	2.5	3.5	2.4	1.5	0.9	1.1
Geothermal	34	52	62	100	237	344	440	0.4	0.7	3.0	3.8	8.1	3.1	4.9
Solar, wind, etc.	2.5	8.1	49	220	605	1,033	1,542	0.0	1.5	10	16.7	9.6	4.8	6.5
Biomass and waste	876	991	1,173	1,357	1,488	1,449	1,514	10	9.4	10	1.5	0.8	0.1	0.4

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	6,236	7,004	8,801	9,983	10,321	10,192	9,996	100	100	100	1.6	0.3	-0.2	0.0
Industry	1,795	1,871	2,642	2,890	3,079	3,017	2,797	29	29	28	1.7	0.6	-0.5	-0.1
Transport	1,576	1,964	2,430	2,889	2,862	2,791	2,803	25	29	28	2.1	-0.1	-0.1	-0.1
Buildings, etc.	2,389	2,564	2,964	3,280	3,326	3,203	3,107	38	33	31	1.1	0.1	-0.3	-0.2
Non-energy use	477	606	764	924	1,053	1,181	1,289	7.7	9.3	13	2.3	1.2	1.0	1.1
Coal	752	542	1,057	950	795	675	568	12	9.5	5.7	0.8	-1.6	-1.7	-1.6
Oil	2,606	3,118	3,596	4,036	4,036	3,824	3,530	42	40	35	1.5	0.0	-0.7	-0.4
Natural gas	944	1,119	1,346	1,634	1,731	1,681	1,604	15	16	16	1.9	0.5	-0.4	-0.1
Electricity	834	1,092	1,538	1,965	2,446	2,891	3,263	13	20	33	3.0	2.0	1.5	1.6
Heat	336	248	275	306	305	269	227	5.4	3.1	2.3	-0.3	0.0	-1.5	-1.0
Hydrogen	-	-	-	-	0.2	0.6	1.4	-	-	0.0	n.a.	n.a.	10.2	n.a.
Renewables	764	885	990	1,092	1,008	851	802	12	11	8.0	1.2	-0.7	-1.1	-1.0

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	11,845	15,428	21,526	26,936	33,444	39,043	43,364	100	100	100	2.9	2.0	1.3	1.5
Coal	4,430	5,995	8,671	9,914	8,939	6,761	4,331	37	37	10.0	2.8	-0.9	-3.6	-2.6
Oil	1,324	1,188	967	747	575	452	326	11	2.8	0.8	-2.0	-2.4	-2.8	-2.6
Natural gas	1,748	2,771	4,844	6,346	7,497	8,952	8,957	15	24	21	4.5	1.5	0.9	1.1
Nuclear	2,013	2,591	2,756	2,790	3,675	4,641	5,371	17	10	12	1.1	2.5	1.9	2.1
Hydro	2,140	2,613	3,449	4,221	4,972	5,498	5,989	18	16	14	2.4	1.5	0.9	1.1
Geothermal	36	52	68	91	248	370	482	0.3	0.3	1.1	3.2	9.5	3.4	5.5
Solar PV	0.1	0.8	32	681	2,309	4,401	7,060	0.0	2.5	16	36.0	11.7	5.7	7.8
Wind	3.9	31	342	1,427	3,756	5,900	8,049	0.0	5.3	19	22.6	9.2	3.9	5.7
CSP and marine	1.2	1.1	2.2	14	174	427	812	0.0	0.1	1.9	8.9	25.4	8.0	13.9
Biomass and waste	129	162	362	655	1,251	1,594	1,938	1.1	2.4	4.5	5.8	6.1	2.2	3.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	22	34	49	49	49	49	0.2	0.2	0.1	3.1	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	37,974	49,930	66,176	84,540	111,268	145,690	183,075	2.8	2.5	2.5	2.5
Population (million)	5,277	6,111	6,919	7,663	8,506	9,157	9,694	1.3	1.0	0.7	0.8
CO_2 emissions (Mt)	20,511	23,159	30,624	33,613	31,330	26,913	21,706	1.7	-0.6	-1.8	-1.4
GDP per capita ($2010 thousand)	7.2	8.2	9.6	11	13	16	19	1.5	1.6	1.9	1.7
Primary energy consump. per capita (toe)	1.7	1.6	1.9	1.9	1.8	1.6	1.5	0.5	-0.6	-0.8	-0.7
Primary energy consumption per GDP[*2]	230	200	194	171	136	104	81	-1.0	-2.1	-2.6	-2.4
CO_2 emissions per GDP[*3]	540	464	463	398	282	185	119	-1.1	-3.1	-4.2	-3.8
CO_2 per primary energy consumption[*4]	2.3	2.3	2.4	2.3	2.1	1.8	1.5	0.0	-1.0	-1.7	-1.5

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	2,083	2,860	4,781	6,064	6,740	6,765	6,562	100	100	100	3.8	1.0	-0.1	0.3
Coal	788	1,035	2,409	2,947	2,694	2,176	1,596	38	49	24	4.7	-0.8	-2.6	-2.0
Oil	616	915	1,161	1,470	1,605	1,592	1,511	30	24	23	3.0	0.8	-0.3	0.1
Natural gas	116	233	453	670	885	1,013	1,009	5.6	11	15	6.2	2.6	0.7	1.3
Nuclear	77	132	152	169	359	500	626	3.7	2.8	9.5	2.8	7.1	2.8	4.3
Hydro	32	41	92	151	186	212	231	1.5	2.5	3.5	5.5	1.9	1.1	1.4
Geothermal	8.2	23	31	55	125	185	235	0.4	0.9	3.6	6.8	7.8	3.2	4.8
Solar, wind, etc.	1.3	2.1	16	100	310	523	764	0.1	1.7	12	16.2	10.8	4.6	6.8
Biomass and waste	444	480	467	501	575	565	589	21	8.3	9.0	0.4	1.3	0.1	0.5

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	1,529	1,973	3,156	3,919	4,329	4,369	4,320	100	100	100	3.3	0.9	0.0	0.3
Industry	506	654	1,401	1,638	1,749	1,663	1,503	33	42	35	4.1	0.6	-0.8	-0.3
Transport	188	321	494	719	799	816	846	12	18	20	4.7	1.0	0.3	0.5
Buildings, etc.	720	817	972	1,163	1,294	1,334	1,360	47	30	31	1.7	1.0	0.3	0.5
Non-energy use	115	181	288	399	487	556	610	7.5	10	14	4.4	1.8	1.1	1.4
Coal	423	373	894	796	676	574	485	28	20	11	2.2	-1.5	-1.6	-1.6
Oil	463	740	988	1,289	1,427	1,424	1,358	30	33	31	3.6	0.9	-0.2	0.2
Natural gas	46	89	200	344	453	468	456	3.0	8.8	11	7.2	2.5	0.0	0.9
Electricity	157	280	574	931	1,236	1,448	1,622	10	24	38	6.3	2.6	1.4	1.8
Heat	14	30	69	120	127	112	93	0.9	3.1	2.1	7.6	0.5	-1.6	-0.8
Hydrogen	-	-	-	-	0.1	0.2	0.4	-	-	0.0	n.a.	n.a.	8.4	n.a.
Renewables	426	462	430	437	409	343	306	28	11	7.1	0.1	-0.6	-1.4	-1.1

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	2,237	3,971	7,990	12,432	16,570	19,170	21,153	100	100	100	6.1	2.6	1.2	1.7
Coal	868	1,984	4,776	7,299	7,121	5,569	3,700	39	59	17	7.6	-0.2	-3.2	-2.2
Oil	433	381	262	127	90	82	83	19	1.0	0.4	-4.1	-3.1	-0.4	-1.4
Natural gas	237	566	1,096	1,425	1,943	2,593	2,757	11	11	13	6.4	2.9	1.8	2.2
Nuclear	294	505	582	647	1,380	1,917	2,403	13	5.2	11	2.8	7.1	2.8	4.3
Hydro	368	477	1,072	1,758	2,159	2,461	2,684	16	14	13	5.5	1.9	1.1	1.4
Geothermal	8.4	20	22	28	76	116	151	0.4	0.2	0.7	4.2	9.6	3.5	5.6
Solar PV	0.1	0.4	5.2	375	1,248	2,351	3,669	0.0	3.0	17	34.4	11.6	5.5	7.6
Wind	0.0	2.4	70	498	1,992	3,336	4,742	0.0	4.0	22	39.2	13.4	4.4	7.5
CSP and marine	0.0	0.0	0.0	1.6	13	29	65	0.0	0.0	0.3	20.5	20.9	8.5	12.7
Biomass and waste	8.9	15	82	252	527	695	876	0.4	2.0	4.1	12.2	6.9	2.6	4.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	20	21	21	21	21	21	0.9	0.2	0.1	0.3	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	7,634	11,121	17,747	26,795	40,632	57,782	76,784	4.4	3.9	3.2	3.5
Population (million)	2,938	3,420	3,824	4,150	4,462	4,632	4,697	1.2	0.7	0.3	0.4
CO_2 emissions (Mt)	4,682	6,790	12,934	16,148	15,802	13,577	10,594	4.4	-0.2	-2.0	-1.4
GDP per capita ($2010 thousand)	2.6	3.3	4.6	6.5	9.1	12	16	3.2	3.2	3.0	3.0
Primary energy consump. per capita (toe)	0.7	0.8	1.3	1.5	1.5	1.5	1.4	2.5	0.3	-0.4	-0.1
Primary energy consumption per GDP[*2]	273	257	269	226	166	117	85	-0.6	-2.8	-3.3	-3.1
CO_2 emissions per GDP[*3]	613	611	729	603	389	235	138	-0.1	-3.9	-5.0	-4.6
CO_2 per primary energy consumption[*4]	2.2	2.4	2.7	2.7	2.3	2.0	1.6	0.6	-1.2	-1.8	-1.6

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	874	1,130	2,536	3,389	3,467	3,141	2,714	100	100	100	4.8	0.2	-1.2	-0.7
Coal	531	665	1,790	2,072	1,778	1,284	801	61	61	30	4.8	-1.4	-3.9	-3.0
Oil	119	221	428	648	688	614	510	14	19	19	6.0	0.5	-1.5	-0.8
Natural gas	13	21	89	248	353	404	378	1.5	7.3	14	10.8	3.2	0.4	1.4
Nuclear	-	4.4	19	91	155	222	292	-	2.7	11	n.a.	5.0	3.2	3.8
Hydro	11	19	61	109	127	139	144	1.2	3.2	5.3	8.3	1.3	0.6	0.9
Geothermal	-	1.7	3.6	19	21	20	18	-	0.6	0.7	n.a.	1.0	-0.8	-0.2
Solar, wind, etc.	0.0	1.0	12	77	212	322	423	0.0	2.3	16	30.7	9.6	3.5	5.6
Biomass and waste	200	198	133	127	135	138	150	23	3.7	5.5	-1.6	0.6	0.5	0.6

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	658	781	1,645	2,093	2,166	1,988	1,775	100	100	100	4.1	0.3	-1.0	-0.5
Industry	234	302	924	1,024	951	769	605	36	49	34	5.2	-0.7	-2.2	-1.7
Transport	30	84	197	324	363	333	287	4.6	15	16	8.5	1.1	-1.2	-0.4
Buildings, etc.	351	338	411	567	643	661	657	53	27	37	1.7	1.1	0.1	0.5
Non-energy use	43	58	113	178	210	225	226	6.5	8.5	13	5.0	1.5	0.4	0.8
Coal	311	274	712	574	420	295	204	47	27	11	2.1	-2.8	-3.5	-3.3
Oil	85	180	369	542	581	518	429	13	26	24	6.6	0.6	-1.5	-0.8
Natural gas	8.9	12	73	179	215	194	166	1.3	8.6	9.3	10.9	1.7	-1.3	-0.2
Electricity	39	89	297	561	720	783	808	5.9	27	46	9.6	2.3	0.6	1.2
Heat	13	26	62	111	117	103	85	2.0	5.3	4.8	7.6	0.5	-1.6	-0.9
Hydrogen	-	-	-	-	0.0	0.0	0.1	-	-	0.0	n.a.	n.a.	8.3	n.a.
Renewables	200	199	132	125	113	94	83	30	6.0	4.7	-1.6	-0.9	-1.5	-1.3

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	621	1,356	4,197	7,472	9,595	10,310	10,510	100	100	100	9.0	2.3	0.5	1.1
Coal	441	1,060	3,240	4,876	4,670	3,363	1,986	71	65	19	8.6	-0.4	-4.2	-2.9
Oil	50	47	15	11	8.1	4.6	1.8	8.1	0.1	0.0	-5.3	-2.4	-7.2	-5.5
Natural gas	2.8	5.8	78	213	489	777	799	0.4	2.8	7.6	16.1	7.9	2.5	4.4
Nuclear	-	17	74	348	596	852	1,119	-	4.7	11	n.a.	5.0	3.2	3.8
Hydro	127	222	711	1,273	1,474	1,612	1,673	20	17	16	8.3	1.3	0.6	0.9
Geothermal	0.1	0.1	0.1	0.1	0.4	0.6	0.8	0.0	0.0	0.0	2.8	12.0	2.8	6.0
Solar PV	0.0	0.0	0.7	224	575	981	1,447	0.0	3.0	14	49.3	8.9	4.7	6.2
Wind	0.0	0.6	45	406	1,574	2,433	3,100	0.0	5.4	29	52.4	13.1	3.4	6.8
CSP and marine	0.0	0.0	0.0	1.1	3.7	12	31	0.0	0.0	0.3	19.1	11.7	11.2	11.4
Biomass and waste	-	2.4	34	121	206	276	352	-	1.6	3.4	n.a.	4.9	2.7	3.5
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	828	2,232	6,087	11,520	19,727	28,857	37,739	9.5	5.0	3.3	3.9
Population (million)	1,135	1,263	1,338	1,398	1,429	1,414	1,368	0.7	0.2	-0.2	-0.1
CO_2 emissions (Mt)	2,181	3,181	8,033	9,882	9,038	6,824	4,292	5.3	-0.8	-3.7	-2.7
GDP per capita ($2010 thousand)	0.7	1.8	4.6	8.2	14	20	28	8.7	4.8	3.5	4.0
Primary energy consump. per capita (toe)	0.8	0.9	1.9	2.4	2.4	2.2	2.0	4.0	0.0	-1.0	-0.6
Primary energy consumption per GDP[*2]	1,055	506	417	294	176	109	72	-4.3	-4.6	-4.4	-4.4
CO_2 emissions per GDP[*3]	2,634	1,425	1,320	858	458	236	114	-3.8	-5.5	-6.7	-6.3
CO_2 per primary energy consumption[*4]	2.5	2.8	3.2	2.9	2.6	2.2	1.6	0.5	-1.0	-2.5	-2.0

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	280	418	667	938	1,283	1,497	1,648	100	100	100	4.3	2.9	1.3	1.8
Coal	93	146	279	418	490	486	457	33	45	28	5.3	1.5	-0.3	0.3
Oil	61	112	162	235	326	403	447	22	25	27	4.8	3.0	1.6	2.1
Natural gas	11	23	54	55	104	142	162	3.8	5.9	9.8	5.9	5.9	2.2	3.5
Nuclear	1.6	4.4	6.8	12	49	95	128	0.6	1.3	7.8	7.2	13.7	4.9	7.9
Hydro	6.2	6.4	11	15	22	30	38	2.2	1.6	2.3	3.1	3.6	2.8	3.1
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	0.0	0.2	2.0	11	63	129	206	0.0	1.2	12	27.3	16.8	6.1	9.8
Biomass and waste	108	126	152	191	229	213	211	39	20	13	2.0	1.6	-0.4	0.3

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	215	290	444	630	852	1,010	1,132	100	100	100	3.8	2.8	1.4	1.9
Industry	59	85	158	243	367	418	409	27	39	36	5.0	3.8	0.6	1.7
Transport	21	32	65	105	141	191	258	9.6	17	23	5.8	2.7	3.1	2.9
Buildings, etc.	122	147	187	231	269	296	326	57	37	29	2.2	1.4	1.0	1.1
Non-energy use	13	27	34	51	75	106	139	6.2	8.2	12	4.8	3.5	3.1	3.3
Coal	38	33	87	107	140	158	163	18	17	14	3.6	2.5	0.7	1.4
Oil	50	94	138	208	294	366	408	23	33	36	5.0	3.2	1.7	2.2
Natural gas	6.1	12	19	34	63	86	100	2.8	5.5	8.9	6.1	5.7	2.3	3.5
Electricity	18	32	62	113	191	269	353	8.5	18	31	6.5	4.9	3.1	3.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	10.8	n.a.
Renewables	102	119	138	168	163	131	107	48	27	9.5	1.7	-0.2	-2.1	-1.4

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	289	561	974	1,624	2,744	3,703	4,657	100	100	100	6.1	4.9	2.7	3.5
Coal	189	387	658	1,181	1,315	1,132	896	65	73	19	6.5	1.0	-1.9	-0.9
Oil	13	25	21	6.0	4.2	1.5	-	4.3	0.4	-	-2.5	-3.2	-100	-100
Natural gas	10.0	56	107	65	155	242	292	3.4	4.0	6.3	6.7	8.3	3.2	5.0
Nuclear	6.1	17	26	46	190	364	492	2.1	2.9	11	7.2	13.7	4.9	7.9
Hydro	72	74	125	172	255	349	446	25	11	9.6	3.1	3.6	2.8	3.1
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	0.0	0.1	51	393	811	1,237	-	3.1	27	n.a.	20.5	5.9	10.9
Wind	0.0	1.7	20	70	309	634	1,064	0.0	4.3	23	30.4	14.5	6.4	9.2
CSP and marine	-	-	-	-	5.1	11	22	-	-	0.5	n.a.	n.a.	7.6	n.a.
Biomass and waste	-	0.2	17	33	118	158	210	-	2.0	4.5	n.a.	12.4	2.9	6.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	506	870	1,670	2,930	5,301	9,066	14,321	6.2	5.5	5.1	5.3
Population (million)	873	1,057	1,234	1,366	1,504	1,593	1,639	1.6	0.9	0.4	0.6
CO_2 emissions (Mt)	530	890	1,586	2,310	2,898	3,125	3,091	5.2	2.1	0.3	0.9
GDP per capita ($2010 thousand)	0.6	0.8	1.4	2.1	3.5	5.7	8.7	4.6	4.6	4.6	4.6
Primary energy consump. per capita (toe)	0.3	0.4	0.5	0.7	0.9	0.9	1.0	2.7	2.0	0.8	1.2
Primary energy consumption per GDP[*2]	554	480	400	320	242	165	115	-1.9	-2.5	-3.6	-3.2
CO_2 emissions per GDP[*3]	1,048	1,023	950	788	547	345	216	-1.0	-3.3	-4.5	-4.1
CO_2 per primary energy consumption[*4]	1.9	2.1	2.4	2.5	2.3	2.1	1.9	0.9	-0.8	-0.9	-0.9

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	437	516	500	415	388	344	304	100	100	100	-0.2	-0.6	-1.2	-1.0
Coal	77	97	116	115	76	59	38	18	28	13	1.4	-3.7	-3.4	-3.5
Oil	249	253	201	159	127	102	83	57	38	27	-1.5	-2.0	-2.1	-2.1
Natural gas	44	66	86	92	73	62	42	10	22	14	2.6	-2.1	-2.7	-2.5
Nuclear	53	84	75	17	64	59	58	12	4.0	19	-3.9	13.1	-0.5	4.1
Hydro	7.6	7.2	7.2	6.8	7.9	8.2	8.3	1.7	1.6	2.7	-0.3	1.3	0.2	0.6
Geothermal	1.6	3.1	2.4	2.6	6.5	11	16	0.4	0.6	5.1	1.7	8.9	4.5	6.0
Solar, wind, etc.	1.2	0.9	1.1	6.8	12	20	33	0.3	1.6	11	6.1	5.4	5.1	5.2
Biomass and waste	4.2	5.0	11	16	21	23	25	1.0	3.8	8.3	4.6	2.6	1.0	1.5

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	291	336	314	279	250	219	194	100	100	100	-0.1	-1.0	-1.3	-1.2
Industry	108	103	92	81	72	63	54	37	29	28	-1.0	-1.2	-1.4	-1.3
Transport	72	89	79	69	55	43	37	25	25	19	-0.1	-2.2	-2.0	-2.0
Buildings, etc.	78	108	109	95	93	83	73	27	34	38	0.7	-0.3	-1.1	-0.8
Non-energy use	33	36	35	33	32	31	30	11	12	15	0.0	-0.4	-0.3	-0.3
Coal	27	21	23	21	15	12	9.4	9.3	7.4	4.8	-0.9	-2.7	-2.5	-2.5
Oil	181	206	166	143	118	95	78	62	51	40	-0.8	-1.7	-2.1	-1.9
Natural gas	14	21	29	29	29	24	19	4.7	10	9.7	2.6	0.2	-2.2	-1.4
Electricity	66	84	89	80	80	82	81	23	29	42	0.7	0.1	0.0	0.0
Heat	0.2	0.5	0.6	0.5	0.5	0.4	0.3	0.1	0.2	0.1	3.5	-0.5	-2.9	-2.0
Hydrogen	-	-	-	-	0.0	0.1	0.3	-	-	0.1	n.a.	n.a.	9.0	n.a.
Renewables	3.8	4.1	6.1	6.5	6.2	5.9	6.2	1.3	2.3	3.2	1.9	-0.4	0.0	-0.2

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	862	1,055	1,164	1,037	1,041	1,054	1,036	100	100	100	0.6	0.0	0.0	0.0
Coal	125	228	317	329	187	132	47	14	32	4.5	3.4	-5.0	-6.7	-6.1
Oil	250	133	91	36	9.9	6.0	0.0	29	3.5	0.0	-6.4	-11.1	-23.8	-19.5
Natural gas	168	255	332	385	272	248	162	19	37	16	2.9	-3.1	-2.6	-2.8
Nuclear	202	322	288	64	247	225	224	23	6.1	22	-3.9	13.1	-0.5	4.1
Hydro	88	84	84	80	92	95	96	10	7.7	9.3	-0.3	1.3	0.2	0.6
Geothermal	1.7	3.3	2.6	2.8	7.5	13	18	0.2	0.3	1.8	1.7	9.2	4.5	6.2
Solar PV	0.1	0.4	3.5	69	113	148	183	0.0	6.6	18	27.0	4.6	2.4	3.2
Wind	-	0.1	4.0	7.7	27	88	196	-	0.7	19	n.a.	12.0	10.5	11.0
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	8.1	9.2	21	45	67	82	91	0.9	4.3	8.7	6.1	3.8	1.5	2.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	20	21	19	19	19	19	2.3	1.8	1.8	-0.1	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	4,704	5,349	5,700	6,211	6,664	7,227	7,761	1.0	0.6	0.8	0.7
Population (million)	124	127	128	126	120	113	105	0.1	-0.5	-0.7	-0.6
CO_2 emissions (Mt)	1,049	1,152	1,127	1,059	775	610	435	0.0	-2.8	-2.8	-2.8
GDP per capita ($2010 thousand)	38	42	45	49	55	64	74	0.9	1.1	1.4	1.3
Primary energy consump. per capita (toe)	3.5	4.1	3.9	3.3	3.2	3.1	2.9	-0.3	-0.2	-0.6	-0.4
Primary energy consumption per GDP[*2]	93	96	88	67	58	48	39	-1.1	-1.2	-2.0	-1.7
CO_2 emissions per GDP[*3]	223	215	198	171	116	84	56	-0.9	-3.4	-3.6	-3.5
CO_2 per primary energy consumption[*4]	2.4	2.2	2.3	2.6	2.0	1.8	1.4	0.2	-2.2	-1.7	-1.9

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	232	378	533	686	906	1,076	1,197	100	100	100	3.8	2.6	1.4	1.8
Coal	13	31	85	174	190	191	164	5.4	25	14	9.5	0.8	-0.7	-0.2
Oil	89	153	188	231	262	279	284	38	34	24	3.3	1.2	0.4	0.7
Natural gas	30	74	125	143	193	217	223	13	21	19	5.5	2.8	0.7	1.5
Nuclear	-	-	-	-	12	47	75	-	-	6.3	n.a.	n.a.	9.6	n.a.
Hydro	2.3	4.1	6.1	12	18	21	23	1.0	1.7	1.9	5.8	3.8	1.1	2.1
Geothermal	6.6	18	25	33	97	153	200	2.9	4.9	17	5.7	10.1	3.7	5.9
Solar, wind, etc.	-	-	0.0	1.6	14	36	76	-	0.2	6.3	n.a.	21.6	8.9	13.2
Biomass and waste	92	97	104	90	117	129	148	40	13	12	-0.1	2.4	1.2	1.6

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	171	269	375	467	577	660	728	100	100	100	3.5	1.9	1.2	1.4
Industry	42	75	120	164	212	251	270	24	35	37	4.8	2.4	1.2	1.6
Transport	33	61	86	135	153	163	176	19	29	24	5.0	1.1	0.7	0.9
Buildings, etc.	86	112	128	112	130	144	160	50	24	22	0.9	1.3	1.1	1.2
Non-energy use	11	21	40	56	83	102	122	6.4	12	17	5.8	3.6	2.0	2.5
Coal	5.4	13	40	53	59	65	67	3.1	11	9.2	8.2	0.8	0.7	0.7
Oil	67	123	163	217	250	267	275	39	46	38	4.1	1.3	0.5	0.8
Natural gas	7.5	17	29	46	76	92	100	4.4	9.9	14	6.5	4.6	1.4	2.5
Electricity	11	28	52	85	128	173	218	6.5	18	30	7.2	3.9	2.7	3.1
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	3.1	n.a.
Renewables	81	88	91	66	63	62	67	47	14	9.2	-0.7	-0.4	0.3	0.1

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	154	370	675	1,089	1,657	2,251	2,835	100	100	100	7.0	3.9	2.7	3.1
Coal	28	79	185	471	527	528	427	18	43	15	10.3	1.0	-1.0	-0.3
Oil	66	72	59	18	16	12	6.4	43	1.6	0.2	-4.5	-0.8	-4.5	-3.2
Natural gas	26	154	336	380	522	630	655	17	35	23	9.7	2.9	1.1	1.8
Nuclear	-	-	-	-	46	181	287	-	-	10	n.a.	n.a.	9.6	n.a.
Hydro	27	47	71	139	210	241	262	18	13	9.2	5.8	3.8	1.1	2.1
Geothermal	6.6	16	19	25	67	102	131	4.3	2.3	4.6	4.7	9.5	3.4	5.5
Solar PV	-	-	0.0	13	105	283	577	-	1.2	20	n.a.	21.2	8.9	13.1
Wind	-	-	0.1	5.9	55	129	305	-	0.5	11	n.a.	22.5	8.9	13.6
CSP and marine	-	-	-	-	0.1	0.2	0.5	-	-	0.0	n.a.	n.a.	8.8	n.a.
Biomass and waste	0.6	1.0	5.7	39	108	145	183	0.4	3.5	6.5	15.4	9.8	2.7	5.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	746	1,187	1,970	3,040	4,692	7,044	9,967	5.0	4.0	3.8	3.9
Population (million)	431	507	575	637	699	738	761	1.4	0.8	0.4	0.6
CO_2 emissions (Mt)	355	689	1,080	1,580	1,741	1,680	1,517	5.3	0.9	-0.7	-0.1
GDP per capita ($2010 thousand)	1.7	2.3	3.4	4.8	6.7	9.5	13	3.6	3.2	3.4	3.3
Primary energy consump. per capita (toe)	0.5	0.7	0.9	1.1	1.3	1.5	1.6	2.4	1.7	1.0	1.2
Primary energy consumption per GDP[*2]	311	319	270	226	193	153	120	-1.1	-1.4	-2.3	-2.0
CO_2 emissions per GDP[*3]	475	581	548	520	371	238	152	0.3	-3.0	-4.4	-3.9
CO_2 per primary energy consumption[*4]	1.5	1.8	2.0	2.3	1.9	1.6	1.3	1.4	-1.6	-2.1	-1.9

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	1,914	2,273	2,216	2,213	2,052	1,894	1,743	100	100	100	0.5	-0.7	-0.8	-0.8
Coal	460	533	501	275	158	88	32	24	12	1.8	-1.8	-4.9	-7.7	-6.7
Oil	757	871	807	793	651	511	411	40	36	24	0.2	-1.8	-2.3	-2.1
Natural gas	438	548	556	742	741	655	494	23	34	28	1.8	0.0	-2.0	-1.3
Nuclear	159	208	219	220	194	203	218	8.3	9.9	12	1.1	-1.1	0.6	0.0
Hydro	23	22	23	25	28	31	33	1.2	1.1	1.9	0.2	1.1	0.9	1.0
Geothermal	14	13	8.4	9.1	25	41	57	0.7	0.4	3.3	-1.5	9.6	4.2	6.1
Solar, wind, etc.	0.3	2.1	11	37	107	204	322	0.0	1.7	18	17.8	10.1	5.6	7.2
Biomass and waste	62	73	89	108	145	159	173	3.3	4.9	10.0	1.9	2.7	0.9	1.5

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	1,294	1,546	1,513	1,588	1,481	1,346	1,232	100	100	100	0.7	-0.6	-0.9	-0.8
Industry	284	332	270	268	261	247	225	22	17	18	-0.2	-0.3	-0.7	-0.6
Transport	488	588	596	637	544	455	404	38	40	33	0.9	-1.4	-1.5	-1.5
Buildings, etc.	403	473	511	525	512	470	422	31	33	34	0.9	-0.2	-1.0	-0.7
Non-energy use	119	153	135	158	164	174	181	9.2	9.9	15	1.0	0.3	0.5	0.4
Coal	56	33	27	15	7.8	5.8	4.3	4.3	1.0	0.3	-4.3	-6.0	-3.0	-4.1
Oil	683	793	762	764	637	508	416	53	48	34	0.4	-1.6	-2.1	-1.9
Natural gas	303	360	322	383	359	298	235	23	24	19	0.8	-0.6	-2.1	-1.6
Electricity	226	301	326	329	364	416	452	18	21	37	1.3	0.9	1.1	1.0
Heat	2.2	5.3	6.6	6.0	5.4	4.5	3.6	0.2	0.4	0.3	3.6	-1.1	-2.0	-1.7
Hydrogen	-	-	-	-	0.0	0.2	0.7	-	-	0.1	n.a.	n.a.	15.3	n.a.
Renewables	23	54	70	91	107	113	122	1.8	5.7	9.9	4.9	1.5	0.6	0.9

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	3,203	4,026	4,354	4,371	4,838	5,509	5,936	100	100	100	1.1	0.9	1.0	1.0
Coal	1,700	2,129	1,994	1,070	681	369	101	53	24	1.7	-1.6	-4.0	-9.1	-7.3
Oil	131	118	48	36	24	14	4.3	4.1	0.8	0.1	-4.4	-3.6	-8.2	-6.6
Natural gas	382	634	1,018	1,640	1,801	1,786	1,295	12	38	22	5.2	0.9	-1.6	-0.8
Nuclear	612	798	839	843	745	779	835	19	19	14	1.1	-1.1	0.6	0.0
Hydro	273	253	262	290	326	358	389	8.5	6.6	6.6	0.2	1.1	0.9	1.0
Geothermal	16	15	18	18	52	86	119	0.5	0.4	2.0	0.5	9.9	4.2	6.2
Solar PV	0.0	0.2	3.1	94	352	767	1,365	0.0	2.1	23	42.9	12.8	7.0	9.0
Wind	3.1	5.7	95	298	610	946	1,221	0.1	6.8	21	17.1	6.7	3.5	4.7
CSP and marine	0.7	0.5	0.9	3.5	84	208	376	0.0	0.1	6.3	5.9	33.4	7.8	16.2
Biomass and waste	86	72	73	74	158	192	224	2.7	1.7	3.8	-0.5	7.2	1.8	3.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	3.7	5.1	5.1	5.1	5.1	-	0.1	0.1	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	9,001	12,620	14,992	18,300	22,575	28,191	34,109	2.5	1.9	2.1	2.0
Population (million)	250	282	309	328	350	366	379	0.9	0.6	0.4	0.5
CO_2 emissions (Mt)	4,743	5,633	5,234	4,744	3,734	2,701	1,788	0.0	-2.2	-3.6	-3.1
GDP per capita ($2010 thousand)	36	45	48	56	65	77	90	1.5	1.3	1.7	1.6
Primary energy consump. per capita (toe)	7.7	8.1	7.2	6.7	5.9	5.2	4.6	-0.4	-1.2	-1.2	-1.2
Primary energy consumption per GDP[*2]	213	180	148	121	91	67	51	-1.9	-2.6	-2.8	-2.7
CO_2 emissions per GDP[*3]	527	446	349	259	165	96	52	-2.4	-4.0	-5.6	-5.0
CO_2 per primary energy consumption[*4]	2.5	2.5	2.4	2.1	1.8	1.4	1.0	-0.5	-1.5	-2.8	-2.4

*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 (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	1,439	1,471	1,527	1,403	1,293	1,164	1,043	100	100	100	-0.1	-0.7	-1.1	-1.0
Coal	391	285	252	175	113	72	48	27	12	4.6	-2.7	-3.9	-4.1	-4.1
Oil	531	550	506	460	386	296	228	37	33	22	-0.5	-1.6	-2.6	-2.2
Natural gas	250	309	363	336	295	253	184	17	24	18	1.0	-1.2	-2.3	-1.9
Nuclear	190	224	223	199	198	210	217	13	14	21	0.2	-0.1	0.5	0.3
Hydro	24	30	32	28	29	29	30	1.7	2.0	2.9	0.4	0.4	0.2	0.3
Geothermal	3.2	4.6	5.5	6.9	10	12	13	0.2	0.5	1.2	2.7	3.6	1.0	2.0
Solar, wind, etc.	0.3	2.5	16	47	84	116	148	0.0	3.4	14	18.9	5.4	2.9	3.8
Biomass and waste	47	65	128	150	175	173	169	3.3	11	16	4.1	1.4	-0.2	0.4

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	995	1,027	1,070	1,015	939	818	712	100	100	100	0.1	-0.7	-1.4	-1.1
Industry	313	274	247	240	242	225	199	31	24	28	-0.9	0.1	-1.0	-0.6
Transport	220	262	279	289	242	188	156	22	29	22	1.0	-1.6	-2.2	-2.0
Buildings, etc.	374	391	446	395	366	318	275	38	39	39	0.2	-0.7	-1.4	-1.2
Non-energy use	88	100	98	91	90	87	83	8.9	8.9	12	0.1	-0.1	-0.4	-0.3
Coal	109	47	38	28	16	12	8.7	11	2.7	1.2	-4.6	-5.0	-2.9	-3.7
Oil	445	479	448	420	355	272	210	45	41	30	-0.2	-1.5	-2.6	-2.2
Natural gas	185	220	231	214	195	163	132	19	21	19	0.5	-0.8	-1.9	-1.5
Electricity	162	189	216	214	232	251	259	16	21	36	1.0	0.7	0.6	0.6
Heat	55	43	52	46	43	35	27	5.5	4.5	3.8	-0.6	-0.7	-2.2	-1.7
Hydrogen	-	-	-	-	0.0	0.0	0.1	-	-	0.0	n.a.	n.a.	8.9	n.a.
Renewables	39	50	86	94	98	86	75	4.0	9.3	10	3.0	0.4	-1.4	-0.7

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	2,259	2,631	2,957	2,884	3,159	3,396	3,469	100	100	100	0.8	0.8	0.5	0.6
Coal	844	846	755	491	315	148	54	37	17	1.6	-1.9	-4.0	-8.4	-6.9
Oil	190	173	82	52	29	16	3.9	8.4	1.8	0.1	-4.4	-5.1	-9.6	-8.0
Natural gas	188	331	590	569	550	555	322	8.3	20	9.3	3.9	-0.3	-2.6	-1.8
Nuclear	729	860	854	765	761	804	833	32	27	24	0.2	0.0	0.5	0.3
Hydro	285	352	373	320	333	341	349	13	11	10	0.4	0.4	0.2	0.3
Geothermal	3.2	4.8	5.6	6.7	11	14	16	0.1	0.2	0.5	2.6	4.9	1.6	2.8
Solar PV	0.0	0.1	22	120	284	451	655	0.0	4.2	19	36.2	8.2	4.3	5.6
Wind	0.8	21	140	367	566	682	789	0.0	13	23	23.7	4.0	1.7	2.5
CSP and marine	0.5	0.5	1.2	6.2	38	70	99	0.0	0.2	2.9	9.0	17.8	5.0	9.4
Biomass and waste	19	42	129	181	266	309	343	0.8	6.3	9.9	8.1	3.5	1.3	2.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	0.2	1.4	4.4	4.9	4.9	4.9	4.9	0.0	0.2	0.1	11.5	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	10,242	12,702	14,556	16,619	19,313	22,028	24,538	1.7	1.4	1.2	1.3
Population (million)	420	429	442	448	447	444	437	0.2	0.0	-0.1	-0.1
CO_2 emissions (Mt)	3,445	3,265	3,132	2,650	2,032	1,506	1,066	-0.9	-2.4	-3.2	-2.9
GDP per capita ($2010 thousand)	24	30	33	37	43	50	56	1.5	1.4	1.3	1.3
Primary energy consump. per capita (toe)	3.4	3.4	3.5	3.1	2.9	2.6	2.4	-0.3	-0.7	-1.0	-0.9
Primary energy consumption per GDP[*2]	141	116	105	84	67	53	43	-1.7	-2.1	-2.2	-2.2
CO_2 emissions per GDP[*3]	336	257	215	159	105	68	43	-2.5	-3.7	-4.3	-4.1
CO_2 per primary energy consumption[*4]	2.4	2.2	2.1	1.9	1.6	1.3	1.0	-0.8	-1.7	-2.1	-2.0

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

Table A53 | Advanced Economies [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	4,465	5,230	5,352	5,236	4,895	4,478	4,055	100	100	100	0.6	-0.6	-0.9	-0.8
Coal	1,088	1,116	1,111	786	518	357	217	24	15	5.4	-1.1	-3.7	-4.3	-4.1
Oil	1,824	2,066	1,917	1,837	1,539	1,216	973	41	35	24	0.0	-1.6	-2.3	-2.0
Natural gas	827	1,135	1,283	1,503	1,458	1,299	1,013	19	29	25	2.1	-0.3	-1.8	-1.3
Nuclear	463	596	606	523	539	557	574	10	10.0	14	0.4	0.3	0.3	0.3
Hydro	100	111	112	117	127	132	137	2.2	2.2	3.4	0.6	0.7	0.4	0.5
Geothermal	22	25	25	37	71	99	122	0.5	0.7	3.0	1.8	6.0	2.8	3.9
Solar, wind, etc.	2.1	6.1	31	110	242	397	580	0.0	2.1	14	14.7	7.4	4.5	5.5
Biomass and waste	139	173	263	319	399	418	435	3.1	6.1	11	2.9	2.1	0.4	1.0

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	3,057	3,582	3,642	3,694	3,454	3,102	2,790	100	100	100	0.7	-0.6	-1.1	-0.9
Industry	826	907	802	795	783	732	651	27	22	23	-0.1	-0.1	-0.9	-0.6
Transport	919	1,120	1,151	1,224	1,034	838	724	30	33	26	1.0	-1.5	-1.8	-1.7
Buildings, etc.	1,025	1,189	1,312	1,273	1,221	1,102	978	34	34	35	0.7	-0.4	-1.1	-0.8
Non-energy use	287	366	378	403	416	431	437	9.4	11	16	1.2	0.3	0.2	0.3
Coal	231	138	127	96	60	45	34	7.5	2.6	1.2	-3.0	-4.2	-2.8	-3.3
Oil	1,559	1,808	1,736	1,714	1,460	1,164	944	51	46	34	0.3	-1.4	-2.2	-1.9
Natural gas	578	732	717	782	733	609	483	19	21	17	1.1	-0.6	-2.1	-1.5
Electricity	553	719	809	820	898	991	1,043	18	22	37	1.4	0.8	0.8	0.8
Heat	48	52	66	63	59	49	38	1.6	1.7	1.4	0.9	-0.6	-2.1	-1.6
Hydrogen	-	-	-	-	0.1	0.4	1.1	-	-	0.0	n.a.	n.a.	12.0	n.a.
Renewables	89	133	188	220	245	243	246	2.9	6.0	8.8	3.2	1.0	0.0	0.4

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	7,667	9,706	10,869	10,913	11,922	13,096	13,670	100	100	100	1.2	0.8	0.7	0.7
Coal	3,129	3,837	3,812	2,573	1,730	1,095	492	41	24	3.6	-0.7	-3.5	-6.1	-5.2
Oil	668	539	273	146	77	42	10	8.7	1.3	0.1	-5.1	-5.6	-9.6	-8.2
Natural gas	766	1,528	2,528	3,199	3,348	3,402	2,608	10.0	29	19	5.1	0.4	-1.2	-0.7
Nuclear	1,776	2,288	2,324	2,007	2,068	2,137	2,203	23	18	16	0.4	0.3	0.3	0.3
Hydro	1,159	1,294	1,304	1,366	1,473	1,538	1,594	15	13	12	0.6	0.7	0.4	0.5
Geothermal	23	27	37	51	108	158	201	0.3	0.5	1.5	2.7	7.1	3.2	4.5
Solar PV	0.1	0.7	31	340	888	1,597	2,535	0.0	3.1	19	33.0	9.1	5.4	6.7
Wind	3.8	29	269	812	1,464	2,094	2,706	0.1	7.4	20	20.3	5.5	3.1	4.0
CSP and marine	1.2	1.1	2.1	10	126	285	487	0.0	0.1	3.6	7.7	25.6	7.0	13.3
Biomass and waste	121	142	257	375	606	716	801	1.6	3.4	5.9	4.0	4.5	1.4	2.5
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	22	33	33	33	33	33	0.3	0.3	0.2	1.8	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	28,841	37,461	44,228	52,404	62,231	73,632	84,998	2.1	1.6	1.6	1.6
Population (million)	998	1,070	1,139	1,191	1,222	1,237	1,238	0.6	0.2	0.1	0.1
CO_2 emissions (Mt)	10,782	12,240	11,968	11,019	8,783	6,627	4,688	0.1	-2.0	-3.1	-2.7
GDP per capita ($2010 thousand)	29	35	39	44	51	60	69	1.5	1.3	1.5	1.4
Primary energy consump. per capita (toe)	4.5	4.9	4.7	4.4	4.0	3.6	3.3	-0.1	-0.8	-1.0	-0.9
Primary energy consumption per GDP[*2]	155	140	121	100	79	61	48	-1.5	-2.2	-2.5	-2.4
CO_2 emissions per GDP[*3]	374	327	271	210	141	90	55	-2.0	-3.6	-4.6	-4.2
CO_2 per primary energy consumption[*4]	2.4	2.3	2.2	2.1	1.8	1.5	1.2	-0.5	-1.4	-2.2	-1.9

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

Table A54 | Emerging Market and Developing Economies [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	4,070	4,499	7,103	8,829	9,772	10,058	10,056	100	100	100	2.7	0.9	0.1	0.4
Coal	1,133	1,198	2,543	3,092	2,826	2,301	1,719	28	35	17	3.5	-0.8	-2.5	-1.9
Oil	1,206	1,328	1,850	2,219	2,432	2,452	2,368	30	25	24	2.1	0.8	-0.1	0.2
Natural gas	835	933	1,451	1,859	2,189	2,428	2,477	21	21	25	2.8	1.5	0.6	0.9
Nuclear	62	79	113	205	419	652	826	1.5	2.3	8.2	4.2	6.7	3.5	4.6
Hydro	84	113	184	245	301	340	378	2.1	2.8	3.8	3.8	1.9	1.1	1.4
Geothermal	12	27	36	63	166	245	317	0.3	0.7	3.2	5.9	9.2	3.3	5.3
Solar, wind, etc.	0.5	2.1	17	110	363	636	962	0.0	1.2	9.6	20.6	11.5	5.0	7.3
Biomass and waste	738	818	911	1,038	1,078	1,005	1,011	18	12	10	1.2	0.4	-0.3	-0.1

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	2,977	3,148	4,801	5,869	6,409	6,540	6,581	100	100	100	2.4	0.8	0.1	0.4
Industry	969	964	1,840	2,095	2,296	2,285	2,146	33	36	33	2.7	0.8	-0.3	0.1
Transport	454	570	921	1,245	1,371	1,403	1,454	15	21	22	3.5	0.9	0.3	0.5
Buildings, etc.	1,363	1,374	1,653	2,007	2,106	2,101	2,129	46	34	32	1.3	0.4	0.1	0.2
Non-energy use	191	240	387	521	637	750	852	6.4	8.9	13	3.5	1.8	1.5	1.6
Coal	521	404	930	854	735	630	535	18	15	8.1	1.7	-1.4	-1.6	-1.5
Oil	845	1,036	1,502	1,902	2,151	2,206	2,165	28	32	33	2.8	1.1	0.0	0.4
Natural gas	367	388	629	852	977	1,001	984	12	15	15	2.9	1.3	0.0	0.5
Electricity	281	372	729	1,145	1,548	1,900	2,220	9.5	20	34	5.0	2.8	1.8	2.2
Heat	288	196	209	244	246	220	189	9.7	4.2	2.9	-0.6	0.1	-1.3	-0.8
Hydrogen	-	-	-	-	0.1	0.2	0.3	-	-	0.0	n.a.	n.a.	6.5	n.a.
Renewables	674	752	802	872	752	583	488	23	15	7.4	0.9	-1.3	-2.1	-1.9

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	4,178	5,722	10,657	16,023	21,522	25,947	29,694	100	100	100	4.7	2.7	1.6	2.0
Coal	1,301	2,158	4,859	7,341	7,209	5,667	3,839	31	46	13	6.1	-0.2	-3.1	-2.1
Oil	656	650	693	601	497	410	315	16	3.7	1.1	-0.3	-1.7	-2.3	-2.1
Natural gas	982	1,244	2,315	3,147	4,149	5,550	6,349	24	20	21	4.1	2.5	2.2	2.3
Nuclear	236	303	432	783	1,607	2,504	3,168	5.7	4.9	11	4.2	6.8	3.5	4.6
Hydro	981	1,319	2,145	2,855	3,498	3,960	4,395	23	18	15	3.8	1.9	1.1	1.4
Geothermal	13	25	31	40	140	212	281	0.3	0.3	0.9	4.0	12.0	3.5	6.5
Solar PV	0.0	0.1	1.4	341	1,421	2,804	4,525	0.0	2.1	15	49.4	13.9	6.0	8.7
Wind	0.0	2.8	73	615	2,292	3,805	5,344	0.0	3.8	18	39.9	12.7	4.3	7.2
CSP and marine	0.0	0.0	0.0	4.2	48	142	325	0.0	0.0	1.1	24.6	24.9	10.0	15.1
Biomass and waste	8.7	20	105	280	644	879	1,137	0.2	1.7	3.8	12.7	7.9	2.9	4.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	0.5	1.1	16	16	16	16	-	0.1	0.1	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	9,133	12,469	21,949	32,136	49,037	72,058	98,077	4.4	3.9	3.5	3.7
Population (million)	4,279	5,042	5,780	6,472	7,285	7,920	8,456	1.4	1.1	0.7	0.9
CO_2 emissions (Mt)	9,102	10,069	17,543	21,292	21,176	18,712	15,391	3.0	0.0	-1.6	-1.0
GDP per capita ($2010 thousand)	2.1	2.5	3.8	5.0	6.7	9.1	12	3.0	2.8	2.8	2.8
Primary energy consump. per capita (toe)	1.0	0.9	1.2	1.4	1.3	1.3	1.2	1.3	-0.2	-0.6	-0.4
Primary energy consumption per GDP[*2]	446	361	324	275	199	140	103	-1.7	-2.9	-3.3	-3.1
CO_2 emissions per GDP[*3]	997	808	799	663	432	260	157	-1.4	-3.8	-4.9	-4.5
CO_2 per primary energy consumption[*4]	2.2	2.2	2.5	2.4	2.2	1.9	1.5	0.3	-1.0	-1.7	-1.5

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

Table A55 | World [Circular Carbon Economy/4Rs Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	8,738	10,003	12,813	14,486	15,107	15,215	15,236	100	100	100	1.8	0.4	0.0	0.2
Coal	2,220	2,314	3,654	3,878	3,311	2,501	1,528	25	27	10	1.9	-1.4	-3.8	-3.0
Oil	3,232	3,669	4,126	4,475	4,384	3,876	3,201	37	31	21	1.1	-0.2	-1.6	-1.1
Natural gas	1,662	2,067	2,734	3,363	3,695	4,213	4,340	19	23	28	2.5	0.9	0.8	0.8
Nuclear	526	675	719	728	958	1,209	1,400	6.0	5.0	9.2	1.1	2.5	1.9	2.1
Hydro	184	225	297	363	427	473	515	2.1	2.5	3.4	2.4	1.5	0.9	1.1
Geothermal	34	52	62	100	237	344	439	0.4	0.7	2.9	3.8	8.1	3.1	4.9
Solar, wind, etc.	2.5	8.1	49	220	606	1,127	2,260	0.0	1.5	15	16.7	9.6	6.8	7.8
Biomass and waste	876	991	1,173	1,357	1,487	1,469	1,551	10	9.4	10	1.5	0.8	0.2	0.4

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	6,236	7,004	8,801	9,983	10,303	10,157	9,914	100	100	100	1.6	0.3	-0.2	0.0
Industry	1,795	1,871	2,642	2,890	3,061	2,983	2,715	29	29	27	1.7	0.5	-0.6	-0.2
Transport	1,576	1,964	2,430	2,889	2,862	2,791	2,804	25	29	28	2.1	-0.1	-0.1	-0.1
Buildings, etc.	2,389	2,564	2,964	3,280	3,326	3,203	3,107	38	33	31	1.1	0.1	-0.3	-0.2
Non-energy use	477	606	764	924	1,053	1,181	1,289	7.7	9.3	13	2.3	1.2	1.0	1.1
Coal	752	542	1,057	950	786	659	531	12	9.5	5.4	0.8	-1.7	-1.9	-1.9
Oil	2,606	3,118	3,596	4,036	4,025	3,686	3,232	42	40	33	1.5	0.0	-1.1	-0.7
Natural gas	944	1,119	1,346	1,634	1,728	1,653	1,493	15	16	15	1.9	0.5	-0.7	-0.3
Electricity	834	1,092	1,538	1,965	2,444	2,886	3,252	13	20	33	3.0	2.0	1.4	1.6
Heat	336	248	275	306	305	268	226	5.4	3.1	2.3	-0.3	0.0	-1.5	-1.0
Hydrogen	-	-	-	-	8.6	132	341	-	-	3.4	n.a.	n.a.	20.2	n.a.
Renewables	764	885	990	1,092	1,007	872	839	12	11	8.5	1.2	-0.7	-0.9	-0.8

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	11,845	15,428	21,526	26,936	33,424	40,122	51,651	100	100	100	2.9	2.0	2.2	2.1
Coal	4,430	5,995	8,671	9,914	8,803	5,772	2,200	37	37	4.3	2.8	-1.1	-6.7	-4.7
Oil	1,324	1,188	967	747	574	452	327	11	2.8	0.6	-2.0	-2.4	-2.8	-2.6
Natural gas	1,748	2,771	4,844	6,346	7,486	8,075	6,138	15	24	12	4.5	1.5	-1.0	-0.1
Nuclear	2,013	2,591	2,756	2,790	3,675	4,641	5,371	17	10	10	1.1	2.5	1.9	2.1
Hydro	2,140	2,613	3,449	4,221	4,972	5,498	5,989	18	16	12	2.4	1.5	0.9	1.1
Geothermal	36	52	68	91	248	370	482	0.3	0.3	0.9	3.2	9.5	3.4	5.5
Solar PV	0.1	0.8	32	681	2,316	4,988	11,755	0.0	2.5	23	36.0	11.8	8.5	9.6
Wind	3.9	31	342	1,427	3,762	6,411	11,702	0.0	5.3	23	22.6	9.2	5.8	7.0
CSP and marine	1.2	1.1	2.2	14	174	427	812	0.0	0.1	1.6	8.9	25.4	8.0	13.9
Biomass and waste	129	162	362	655	1,251	1,594	1,938	1.1	2.4	3.8	5.8	6.1	2.2	3.6
Hydrogen	-	-	-	-	116	1,847	4,887	-	-	9.5	n.a.	n.a.	20.6	n.a.
Others	20	22	34	49	49	49	49	0.2	0.2	0.1	3.1	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	37,974	49,930	66,176	84,540	111,268	145,690	183,075	2.8	2.5	2.5	2.5
Population (million)	5,277	6,111	6,919	7,663	8,506	9,157	9,694	1.3	1.0	0.7	0.8
CO_2 emissions (Mt)	20,511	23,159	30,624	33,613	31,115	24,518	15,713	1.7	-0.7	-3.4	-2.4
GDP per capita ($2010 thousand)	7.2	8.2	9.6	11	13	16	19	1.5	1.6	1.9	1.7
Primary energy consump. per capita (toe)	1.7	1.6	1.9	1.9	1.8	1.7	1.6	0.5	-0.6	-0.6	-0.6
Primary energy consumption per GDP[*2]	230	200	194	171	136	104	83	-1.0	-2.1	-2.4	-2.3
CO_2 emissions per GDP[*3]	540	464	463	398	280	168	86	-1.1	-3.1	-5.7	-4.8
CO_2 per primary energy consumption[*4]	2.3	2.3	2.4	2.3	2.1	1.6	1.0	0.0	-1.1	-3.4	-2.6

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

Table A56 | Advanced Economies [Circular Carbon Economy/4Rs Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	4,465	5,230	5,352	5,236	4,896	4,589	4,356	100	100	100	0.6	-0.6	-0.6	-0.6
Coal	1,088	1,116	1,111	786	512	352	200	24	15	4.6	-1.1	-3.8	-4.6	-4.3
Oil	1,824	2,066	1,917	1,837	1,530	1,111	770	41	35	18	0.0	-1.6	-3.4	-2.8
Natural gas	827	1,135	1,283	1,503	1,471	1,490	1,330	19	29	31	2.1	-0.2	-0.5	-0.4
Nuclear	463	596	606	523	539	557	574	10	10.0	13	0.4	0.3	0.3	0.3
Hydro	100	111	112	117	127	132	137	2.2	2.2	3.1	0.6	0.7	0.4	0.5
Geothermal	22	25	25	37	71	99	122	0.5	0.7	2.8	1.8	6.0	2.8	3.9
Solar, wind, etc.	2.1	6.1	31	110	242	426	807	0.0	2.1	19	14.7	7.4	6.2	6.6
Biomass and waste	139	173	263	319	399	427	455	3.1	6.1	10	2.9	2.0	0.7	1.1

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	3,057	3,582	3,642	3,694	3,450	3,094	2,774	100	100	100	0.7	-0.6	-1.1	-0.9
Industry	826	907	802	795	780	724	635	27	22	23	-0.1	-0.2	-1.0	-0.7
Transport	919	1,120	1,151	1,224	1,034	838	724	30	33	26	1.0	-1.5	-1.8	-1.7
Buildings, etc.	1,025	1,189	1,312	1,273	1,221	1,102	978	34	34	35	0.7	-0.4	-1.1	-0.8
Non-energy use	287	366	378	403	416	431	437	9.4	11	16	1.2	0.3	0.2	0.3
Coal	231	138	127	96	59	44	32	7.5	2.6	1.2	-3.0	-4.3	-3.0	-3.5
Oil	1,559	1,808	1,736	1,714	1,451	1,128	869	51	46	31	0.3	-1.5	-2.5	-2.2
Natural gas	578	732	717	782	732	586	397	19	21	14	1.1	-0.6	-3.0	-2.2
Electricity	553	719	809	820	897	990	1,040	18	22	38	1.4	0.8	0.7	0.8
Heat	48	52	66	63	59	48	38	1.6	1.7	1.4	0.9	-0.6	-2.2	-1.6
Hydrogen	-	-	-	-	7.8	46	133	-	-	4.8	n.a.	n.a.	15.3	n.a.
Renewables	89	133	188	220	245	252	265	2.9	6.0	9.5	3.2	1.0	0.4	0.6

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	7,667	9,706	10,869	10,913	11,918	13,463	16,354	100	100	100	1.2	0.8	1.6	1.3
Coal	3,129	3,837	3,812	2,573	1,686	910	291	41	24	1.8	-0.7	-3.8	-8.4	-6.8
Oil	668	539	273	146	77	42	11	8.7	1.3	0.1	-5.1	-5.6	-9.4	-8.1
Natural gas	766	1,528	2,528	3,199	3,344	2,900	1,448	10.0	29	8.9	5.1	0.4	-4.1	-2.5
Nuclear	1,776	2,288	2,324	2,007	2,068	2,137	2,203	23	18	13	0.4	0.3	0.3	0.3
Hydro	1,159	1,294	1,304	1,366	1,473	1,538	1,594	15	13	9.7	0.6	0.7	0.4	0.5
Geothermal	23	27	37	51	108	158	201	0.3	0.5	1.2	2.7	7.1	3.2	4.5
Solar PV	0.1	0.7	31	340	890	1,738	3,752	0.0	3.1	23	33.0	9.1	7.5	8.1
Wind	3.8	29	269	812	1,466	2,299	4,132	0.1	7.4	25	20.3	5.5	5.3	5.4
CSP and marine	1.2	1.1	2.1	10	126	285	487	0.0	0.1	3.0	7.7	25.6	7.0	13.3
Biomass and waste	121	142	257	375	606	716	801	1.6	3.4	4.9	4.0	4.5	1.4	2.5
Hydrogen	-	-	-	-	41	707	1,402	-	-	8.6	n.a.	n.a.	19.3	n.a.
Others	20	22	33	33	33	33	33	0.3	0.3	0.2	1.8	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	28,841	37,461	44,228	52,404	62,231	73,632	84,998	2.1	1.6	1.6	1.6
Population (million)	998	1,070	1,139	1,191	1,222	1,237	1,238	0.6	0.2	0.1	0.1
CO_2 emissions (Mt)	10,782	12,240	11,968	11,019	8,705	5,798	2,782	0.1	-2.1	-5.5	-4.3
GDP per capita ($2010 thousand)	29	35	39	44	51	60	69	1.5	1.3	1.5	1.4
Primary energy consump. per capita (toe)	4.5	4.9	4.7	4.4	4.0	3.7	3.5	-0.1	-0.8	-0.6	-0.7
Primary energy consumption per GDP[*2]	155	140	121	100	79	62	51	-1.5	-2.1	-2.1	-2.1
CO_2 emissions per GDP[*3]	374	327	271	210	140	79	33	-2.0	-3.6	-7.0	-5.8
CO_2 per primary energy consumption[*4]	2.4	2.3	2.2	2.1	1.8	1.3	0.6	-0.5	-1.5	-5.0	-3.8

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

Table A57 | Emerging Market and Developing Economies [Circular Carbon Economy/4Rs Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050	1990/2019	2019/2030	2030/2050	2019/2050
Total[*1]	4,070	4,499	7,103	8,829	9,753	10,076	10,253	100	100	100	2.7	0.9	0.3	0.5
Coal	1,133	1,198	2,543	3,092	2,800	2,149	1,329	28	35	13	3.5	-0.9	-3.7	-2.7
Oil	1,206	1,328	1,850	2,219	2,429	2,367	2,111	30	25	21	2.1	0.8	-0.7	-0.2
Natural gas	835	933	1,451	1,859	2,202	2,653	2,874	21	21	28	2.8	1.5	1.3	1.4
Nuclear	62	79	113	205	419	652	826	1.5	2.3	8.1	4.2	6.7	3.5	4.6
Hydro	84	113	184	245	301	340	378	2.1	2.8	3.7	3.8	1.9	1.1	1.4
Geothermal	12	27	36	63	166	245	317	0.3	0.7	3.1	5.9	9.2	3.3	5.3
Solar, wind, etc.	0.5	2.1	17	110	364	701	1,453	0.0	1.2	14	20.6	11.5	7.2	8.7
Biomass and waste	738	818	911	1,038	1,078	1,016	1,028	18	12	10	1.2	0.3	-0.2	0.0

Final energy consumption

	Mtoe							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	2,977	3,148	4,801	5,869	6,395	6,513	6,514	100	100	100	2.4	0.8	0.1	0.3
Industry	969	964	1,840	2,095	2,282	2,258	2,080	33	36	32	2.7	0.8	-0.5	0.0
Transport	454	570	921	1,245	1,371	1,403	1,453	15	21	22	3.5	0.9	0.3	0.5
Buildings, etc.	1,363	1,374	1,653	2,007	2,106	2,101	2,129	46	34	33	1.3	0.4	0.1	0.2
Non-energy use	191	240	387	521	637	750	852	6.4	8.9	13	3.5	1.8	1.5	1.6
Coal	521	404	930	854	727	615	499	18	15	7.7	1.7	-1.5	-1.9	-1.7
Oil	845	1,036	1,502	1,902	2,148	2,160	2,044	28	32	31	2.8	1.1	-0.2	0.2
Natural gas	367	388	629	852	974	997	960	12	15	15	2.9	1.2	-0.1	0.4
Electricity	281	372	729	1,145	1,547	1,896	2,212	9.5	20	34	5.0	2.8	1.8	2.1
Heat	288	196	209	244	246	220	188	9.7	4.2	2.9	-0.6	0.1	-1.3	-0.8
Hydrogen	-	-	-	-	0.8	30	106	-	-	1.6	n.a.	n.a.	27.6	n.a.
Renewables	674	752	802	872	752	595	505	23	15	7.8	0.9	-1.3	-2.0	-1.7

Electricity generation

	(TWh)							Shares (%)			1990/2019	2019/2030	2030/2050	2019/2050
	1990	2000	2010	2019	2030	2040	2050	1990	2019	2050				
Total	4,178	5,722	10,657	16,023	21,506	26,659	35,296	100	100	100	4.7	2.7	2.5	2.6
Coal	1,301	2,158	4,859	7,341	7,116	4,862	1,909	31	46	5.4	6.1	-0.3	-6.4	-4.3
Oil	656	650	693	601	497	410	316	16	3.7	0.9	-0.3	-1.7	-2.2	-2.0
Natural gas	982	1,244	2,315	3,147	4,143	5,175	4,690	24	20	13	4.1	2.5	0.6	1.3
Nuclear	236	303	432	783	1,607	2,504	3,168	5.7	4.9	9.0	4.2	6.8	3.5	4.6
Hydro	981	1,319	2,145	2,855	3,498	3,960	4,395	23	18	12	3.8	1.9	1.1	1.4
Geothermal	13	25	31	40	140	212	281	0.3	0.3	0.8	4.0	12.0	3.5	6.5
Solar PV	0.0	0.1	1.4	341	1,426	3,251	8,003	0.0	2.1	23	49.4	13.9	9.0	10.7
Wind	0.0	2.8	73	615	2,296	4,112	7,570	0.0	3.8	21	39.9	12.7	6.1	8.4
CSP and marine	0.0	0.0	0.0	4.2	48	142	325	0.0	0.0	0.9	24.6	24.9	10.0	15.1
Biomass and waste	8.7	20	105	280	644	879	1,137	0.2	1.7	3.2	12.7	7.9	2.9	4.6
Hydrogen	-	-	-	-	75	1,139	3,485	-	-	9.9	n.a.	n.a.	21.2	n.a.
Others	-	0.5	1.1	16	16	16	16	-	0.1	0.0	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2019	2030	2040	2050	1990/2019	2019/2030	2030/2050	2019/2050
GDP ($2010 billion)	9,133	12,469	21,949	32,136	49,037	72,058	98,077	4.4	3.9	3.5	3.7
Population (million)	4,279	5,042	5,780	6,472	7,285	7,920	8,456	1.4	1.1	0.7	0.9
CO_2 emissions (Mt)	9,102	10,069	17,543	21,292	21,040	17,320	11,616	3.0	-0.1	-2.9	-1.9
GDP per capita ($2010 thousand)	2.1	2.5	3.8	5.0	6.7	9.1	12	3.0	2.8	2.8	2.8
Primary energy consump. per capita (toe)	1.0	0.9	1.2	1.4	1.3	1.3	1.2	1.3	-0.2	-0.5	-0.4
Primary energy consumption per GDP[*2]	446	361	324	275	199	140	105	-1.7	-2.9	-3.2	-3.1
CO_2 emissions per GDP[*3]	997	808	799	663	429	240	118	-1.4	-3.9	-6.2	-5.4
CO_2 per primary energy consumption[*4]	2.2	2.2	2.5	2.4	2.2	1.7	1.1	0.3	-1.0	-3.2	-2.4

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

Slides

The 439th Forum on Research Work

IEEJ Outlook 2022

Challenges toward carbon neutrality: Voyage in uncharted territory

Energy, Environment and Economy

Tokyo, 15 October 2021

The Institute of Energy Economics, Japan

Energy Supply and Demand Outlook by 2050

REF ATS CCE

IEEJ Outlook 2022

What is IEEJ Outlook?

- Study to quantify the future global energy supply and demand situation until 2050.
- Outlook with forecast-approach, using econometric models etc.
- Scenario analysis on progress and trends in technologies and policies.

[Reference Scenario (REF)]
A scenario in which trends and changes continue while reflecting current energy and environmental policies.

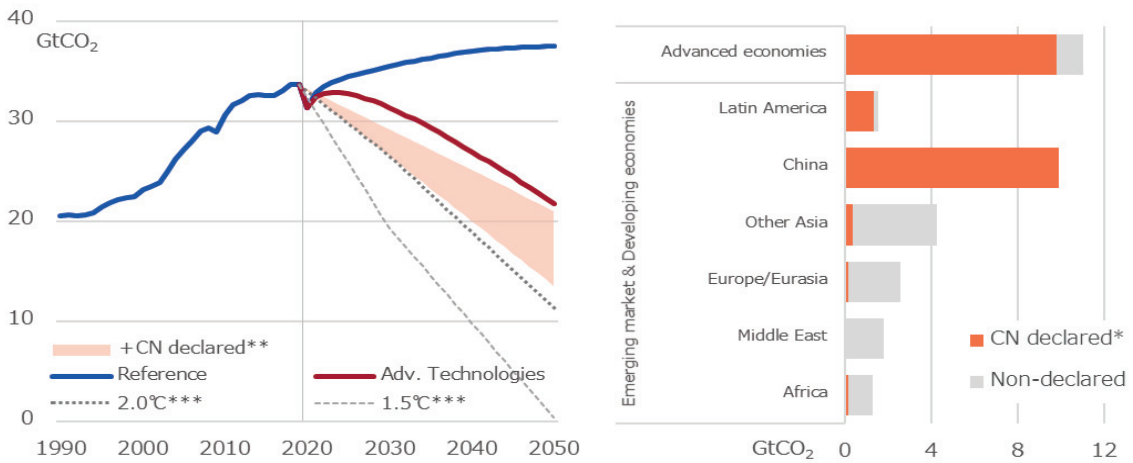
[Advanced Technologies Scenario (ATS)]
A scenario in which energy and environmental technologies are introduced to the maximum extent in order to secure a stable energy supply and strengthen climate change countermeasures.

[Circular Carbon Economy/4R Scenario (CCE)]
A scenario based on the concept of a circular carbon economy with the "4Rs" (Reduce, Reuse, Recycle, Remove). The scenario reflects not only the Advanced Technologies Scenario assumptions, but also examines the maximum introduction of decarbonization technology using fossil fuels.

REF ATS

Emitters of two-thirds of the emissions declare CN, but...

❖ Energy-related CO_2 emissions (global) ❖ Breakdown of CO_2 Emissions (2019)



* United States, Brazil, South Korea, Poland, China and Climate Ambitions Alliance (121 countries). ** When the CN-stated countries achieve zero emissions in 2050 based on the emissions in the Reference / Advanced Technologies scenarios (For China, that announced 2060 CN, the emissions as of 2050 by linear interpolation between today and 2060). *** Average paths referred to the IPCC "Global Warming of 1.5°C".

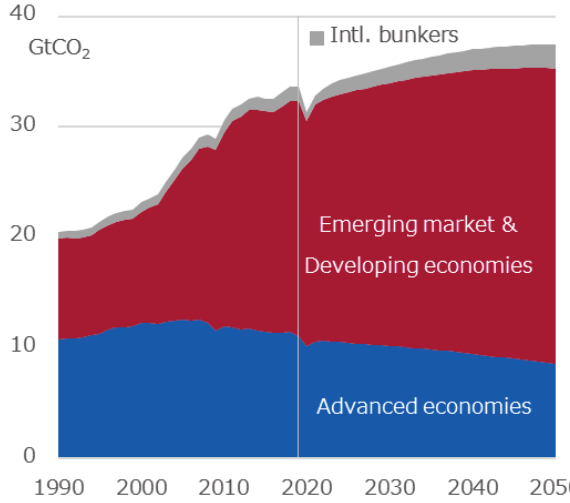
There is a worldwide movement to pursue carbon neutral (CN).

Currently, countries and regions emitting about two-thirds of the world's CO_2 emissions have announced CN. Even if those countries succeed, global emissions in 2050 will be only half of current levels.

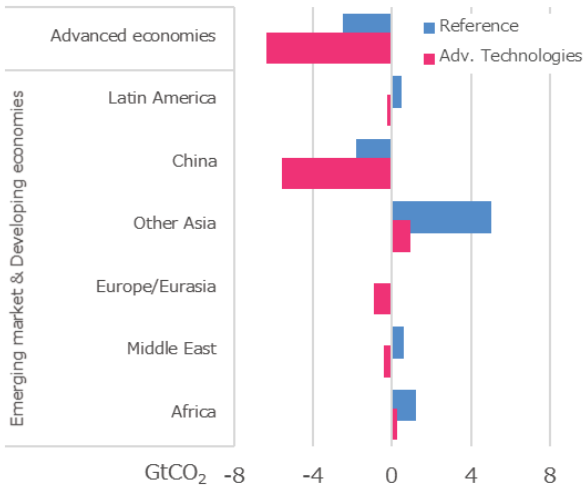
REF ATS

Emissions in countries that have not declared CN increase

❖ Energy-related CO_2 emissions (Reference)



❖ Changes in emissions (2019-2050)



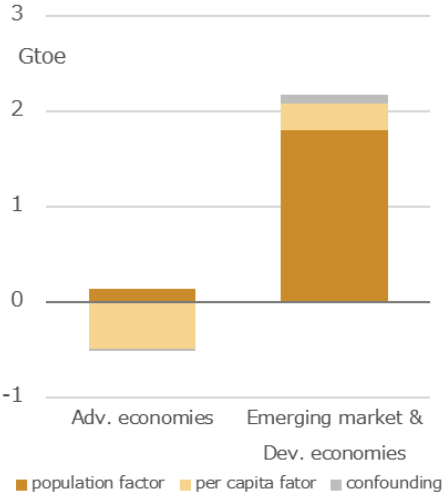
In the REF, CO_2 emissions are expected to increase in Asian, including India and ASEAN, Middle Eastern and African countries, which have not declared pursuing CN.

Even in the ATS, it is not easy to turn emissions into declines in these regions.

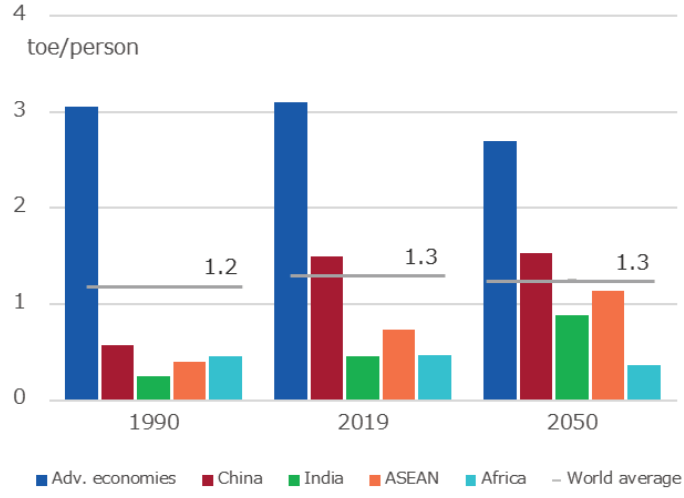
REF

Developing economies need more energy

❖ Decomposition of the increase in final energy consumption (Reference, 2019-2050)



❖ Energy consumption per capita



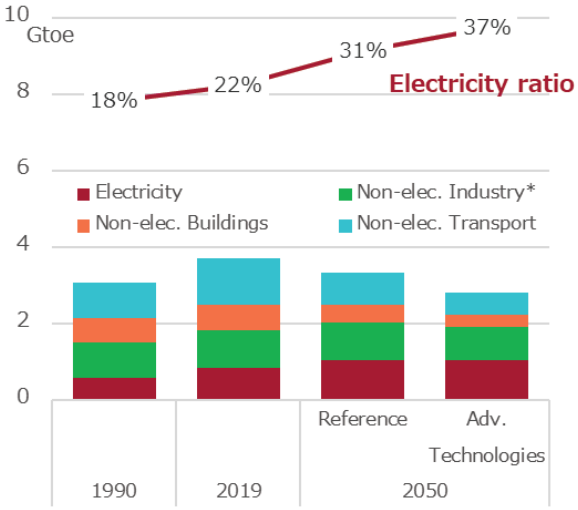
Energy demand in developing economies is growing significantly, but the growth is mainly due to a growing population.

In developing economies, the energy consumption per capita is still small compared to advanced economies, and there is much room for further increase in demand.

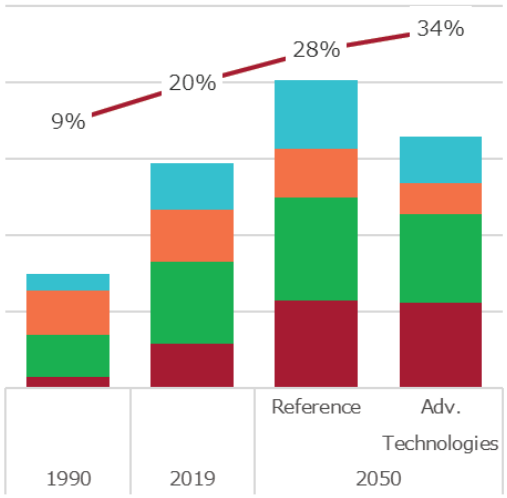
REF ATS

Power demand is certain to grow

❖ Final Energy Consumption (Advanced Economies)



❖Final Energy Consumption (Emerging and Developing Economies)



* Industry includes agriculture, forestry and fisheries and non-energy sector.

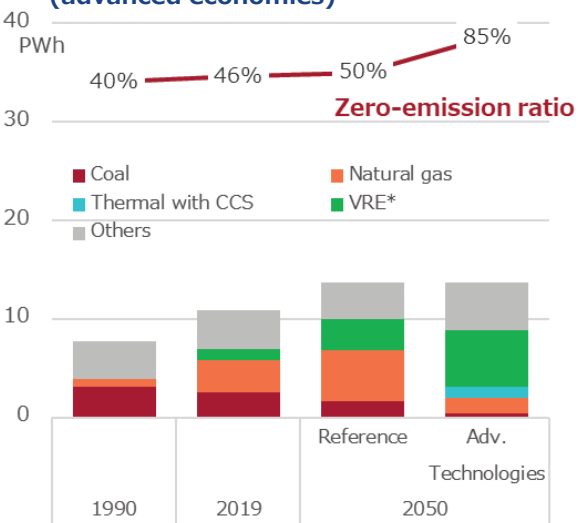
Energy demand in both developed and developing countries will be electrified more. Although the electrification of heat demand in the industrial sector is limited, the electricity ratio will rise further in the ATS.

Electricity demand is not much different between both scenarios. The stability, reliability and security of electricity supply are issues that must be addressed.

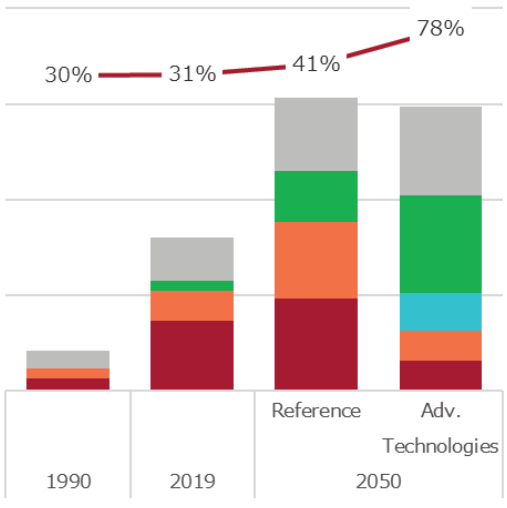
REF ATS

Decarbonization of the power sector is progressing

❖ Power Generation Mix (advanced economies)



❖ Power Generation Mix (Emerging and Developing Economies)



* VRE (Variable Renewable Energy): photovoltaic power, wind power, etc.

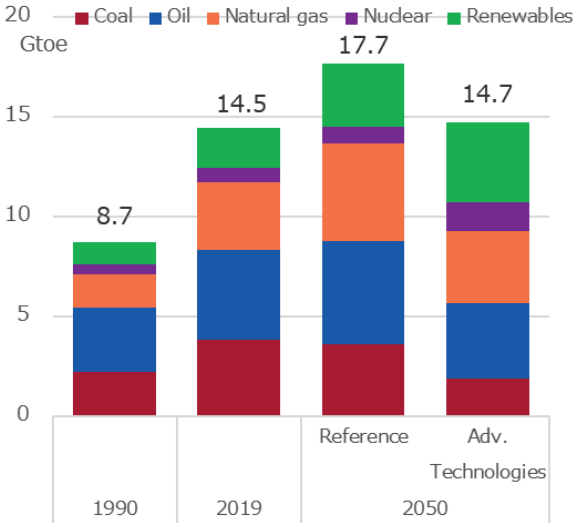
In the REF, more than half of the increase in electricity demand is supplied by VRE. However, in emerging and developing economies, thermal power generation remains necessary to meet a strong electricity demand.

In the ATS, the decarbonization of the power generation sector will be greatly advanced by a large introduction of VRE and thermal power with CCS.

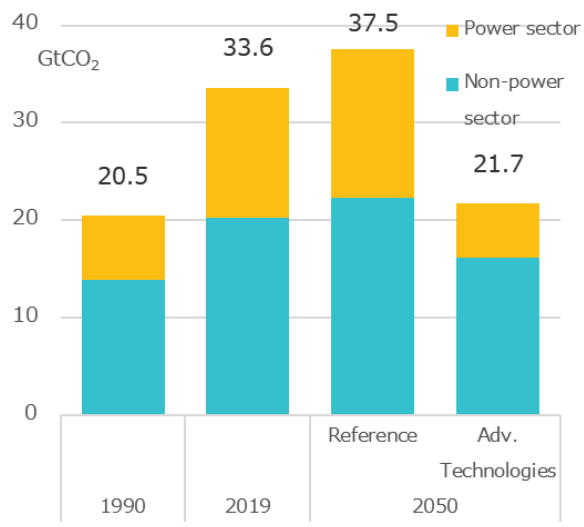
REF ATS

Decarbonization of non-power generation sector is difficult

❖ Primary energy demand



❖ Energy-related CO_2 emissions



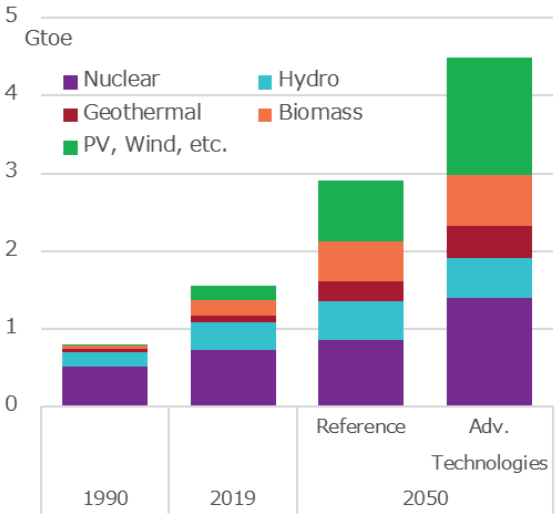
The primary energy demand in the ATS in 2050 is almost the same as today. Demand for fossil fuels declines, but still accounts for 60% of the total.

On the other hand, CO_2 emissions are two-thirds of current levels. The emissions reduction from the power generation sector is significant, however, the reductions in the non-power generation sector are not progressing much.

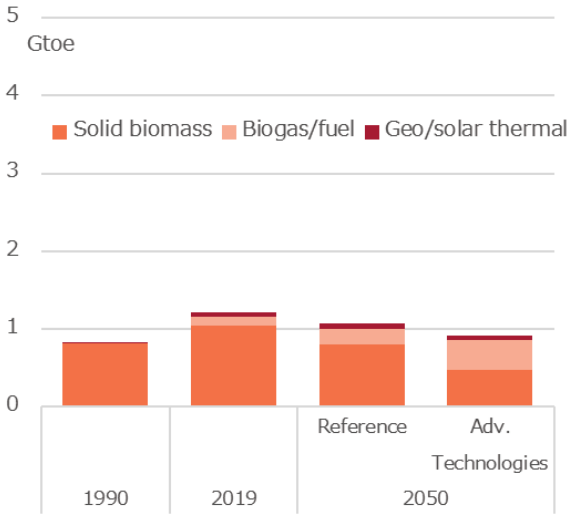
REF ATS

The introduction of non-fossil energy in non-power sectors is a challenge

❖ Non-fossil energy in the power generation sector



❖ Non-fossil energy in the non-power generation sector



The introduction of non-fossil energy is progressing in the power generation sector, while only a few in the non-power generation sector.

Electrification is being promoted in the non-power generation sector, but there are limits in the industrial sector, which often uses high-temperature heat. Decarbonization other than electrification is a challenge.

CCE

Circular Carbon Economy/4R Scenario

❖ Assumptions in CCE (in addition to the ATS)

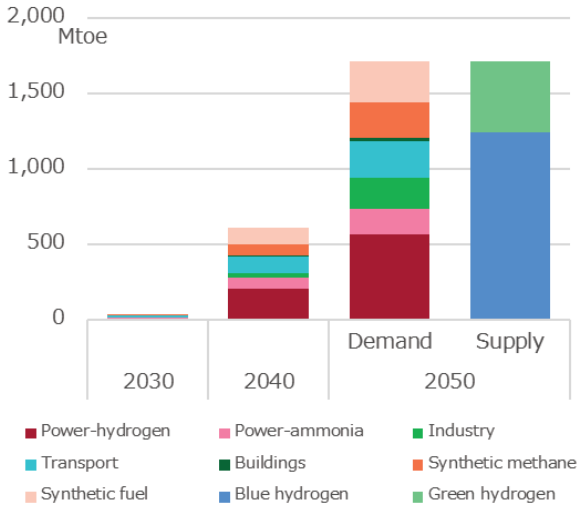
4R	Technology	Assumptions
Reduce	Hydrogen for power generation	Adopt hydrogen/ammonia power generation for 50-75% of coal- and gas-fired power plants without CCS facility as of 2050.
	Hydrogen for transportation	Replace 10-15% of liquid fuels demand in the road sector in advanced economies and 20-30% in the international bunkers with hydrogen as of 2050.
	Hydrogen in industry sector	Replace 10-30% of natural gas demand in the industry sector with hydrogen as of 2050 in advanced economies with abundant hydrogen supply.
	Direct reduction in steel making by hydrogen	Adopt direct reduction technology utilizing blue hydrogen to 25% of crude steel production in advanced economies, China, India and Brazil as of 2050.
	Hydrogen in building sector	Replace 10% of natural gas demand in the building sector with hydrogen as of 2050 in advanced economies.
	Reduction of cement production	Reduction of cement production by 25% utilizing coal ash and limestone and calcined clay as of 2050
Reuse	Algae synthesis to produce biofuel	Increase algae-based bio-diesel by 50% from ATS as o 2050.
Recycle	Concrete curing capturing CO_2	Adopt concrete curing capturing CO_2 technology to 25-50% of the world concrete production as of 2050.
	Synthetic methane	Replace 20-40% of natural gas demand in the industry and building sectors with synthetic methane as of 2050.
	Synthetic fuels	Replace 10-20% of liquid fuels demand in the transport sectors with synthetic fuels as of 2050.
Remove	Carbon capture and storage	Adopt CCS for blue hydrogen production.

From the perspective of decarbonizing fossil fuel utilization, this scenario considers the maximum introduction of 4R (Reduce, Reuse, Recycle, Remove) technologies in addition to the ATS assumptions.

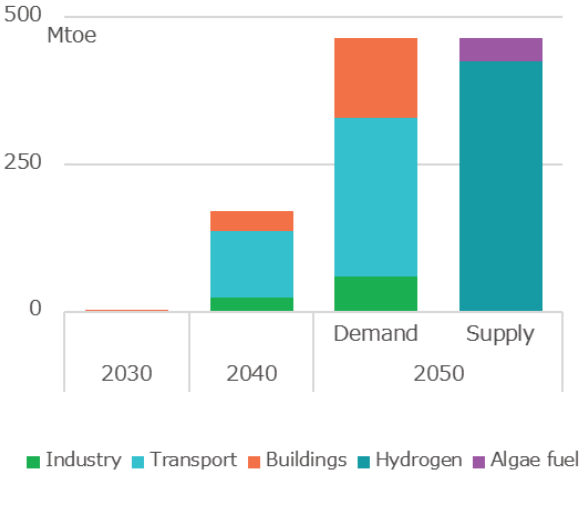
CCE

Utilize clean hydrogen/ammonia

❖ Supply and demand of hydrogen/ammonia



❖ Supply and demand of synthetic methane/fuel



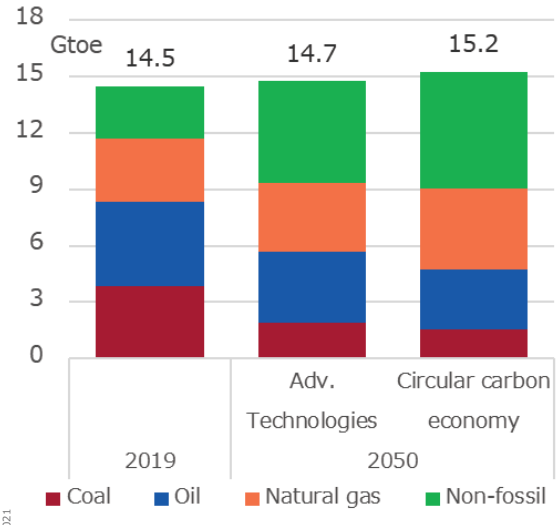
Hydrogen/ammonia, not emit CO_2 during combustion, are utilized in the industry sector and for power generation. Hydrogen production could be blue, using fossil fuels and CCS, or green, using renewable energy.

Synthetic methane and fuels produced from clean hydrogen can be used in sectors where electrification is difficult, by utilizing existing infrastructure in the non-power generation sector.

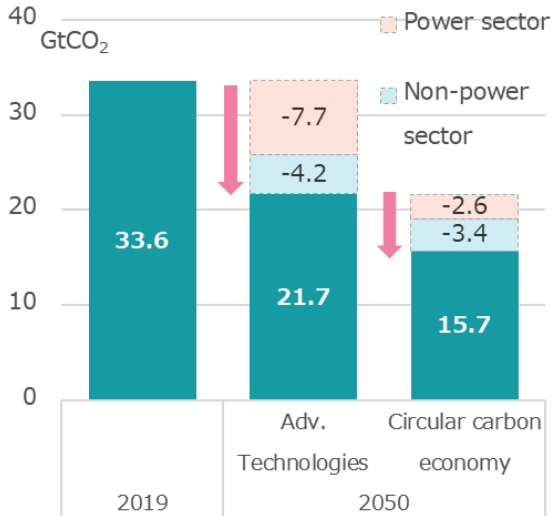
CCE

Reduce CO_2 emissions without reducing fossil fuels

❖ Primary energy demand



❖ Energy-related CO_2 emissions

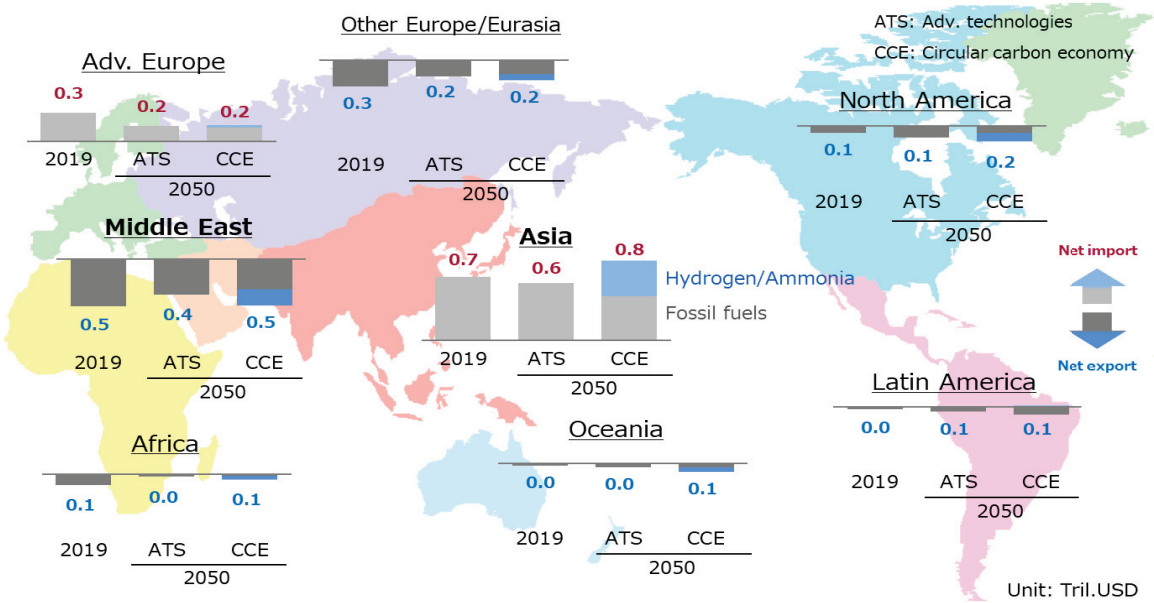


Fossil fuel consumption in the CCE scenario is almost the same as that in the ATS. Demand for natural gas for hydrogen production will increase slightly.

On the other hand, the CO_2 emissions decline significantly. The center of gravity for emission reductions is shifting to the non-power generation sector.

CCE

Asia-Middle East relations remain unchanged



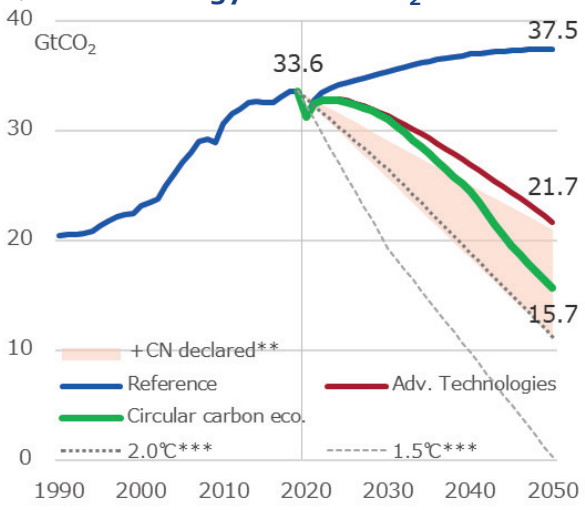
In the CCE, there is a shift from fossil fuel trade to hydrogen/ammonia trade.

In the Middle East, hydrogen exports compensate for the decline in oil and gas exports. On the other hand, imports of hydrogen will increase significantly in Asia. Even in a world aiming for decarbonization, the importance of trade relations between Asia and the Middle East remains unchanged.

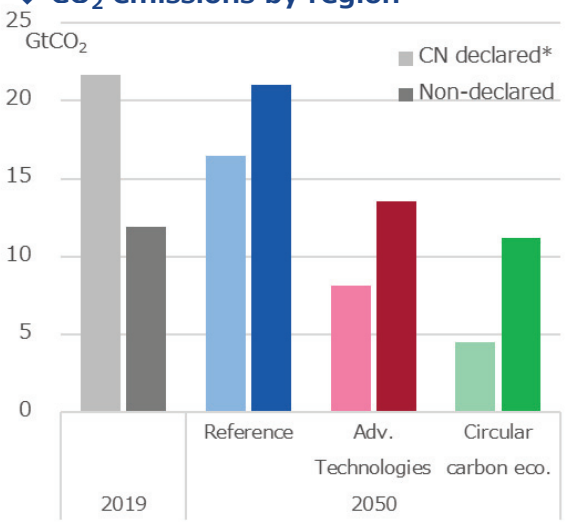
REF ATS CCE

There remain many challenges for CN in the world

❖ Global energy-related CO_2 emissions



❖ CO_2 emissions by region



* United States, Brazil, South Korea, Poland, China and Climate Ambitions Alliance (121 countries). ** When the CN-stated countries achieve zero emissions in 2050 based on the emissions in the REF / CCE scenarios (For China, that announced 2060 CN, the emissions as of 2050 by linear interpolation between today and 2060). *** Average paths referred to the IPCC "Global Warming of 1.5°C".

To realize CN, it is essential to utilize new decarbonization technologies such as hydrogen and CCUS in addition to existing clean technologies. Reducing emissions is a must for all countries, not only developed economies but also emerging and developing economies.

It is important to promote and share decarbonization technologies under international cooperation, in order to reduce emissions in the world-scale.

REF ATS CCE

Summary

【 **Reference** and **Advanced Technologies Scenarios**】

- CO_2 emissions are expected to grow in countries that have not expressed carbon neutrality (CN), such as India, ASEAN, the Middle East, Africa, and others.
- Electricity demand increases in both the Reference Scenario that reflects the current situation and in the Advanced Technologies Scenario where decarbonization is progressing. The stability and security of electricity supply must be improved.
- CO_2 reduction in the power generation sector is likely to proceed, but emission reductions in the non-power generation sectors will not progress much. Decarbonization in the non-power generation sector is key to achieve CN.

【**Circular Carbon Economy Scenario**】

- In order to decarbonize the non-power generation sector, clean hydrogen/ammonia and synthetic methane/fuels using these materials will be required.
- There is a shift from fossil fuel trade to hydrogen/ammonia trade, but the importance of trade relations between Asia and the Middle East remains unchanged.
- In order to achieve a world-wide CN, it is important to promote and share decarbonization technologies under international cooperation.

Challenges and Issues toward Carbon Neutrality

Growing interests in carbon neutrality

- An increasing number of countries announced reaching carbon neutrality (CN) as a target by mid-century. Interest in CN is growing globally.
- Climate actions are expected to not only achieve emissions reduction but should also provide multiple economic benefits.
- Given that the world depends on fossil fuels for over 80% of its energy requirements, achieving CN will not be an easy task. Several challenges and issues lie ahead.
- The net balance between benefits and costs of climate actions can vary across country, organization, and individual.

- **Examples of challenges and issues related to CN**
  - ✓ Positive and negative economic effects of climate actions
  - ✓ Disparity caused by climate actions
  - ✓ Energy security issues growing in complexity
  - ✓ Supply stability issue caused by restrained upstream investments
  - ✓ Geopolitical impacts

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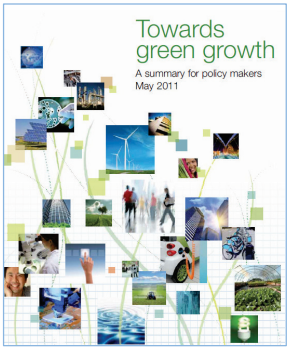
Economic benefits of climate actions

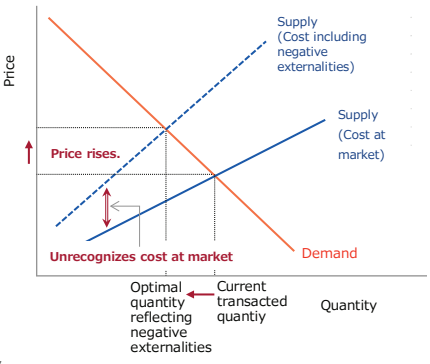
- Green growth and Green deal
  - "Green growth" is a condition where economic growth and carbon emissions are decoupled (OECD 2011; UNEP 2011; World Bank 2012).
  - "Green deal" is a government's policy that aims to simultaneously achieve economic stimulus, development of a clean energy industry with job creation, along with emissions reduction (Friedman 2019; European Commission 2021).
- Economic benefits of Green deal
  - EU estimates its Green deal will create over 160,000 jobs through the development of a clean energy market and products until 2030 (European Commission 2021).
  - IEA's Net Zero scenario is estimated to add 4% to the world's GDP and generate 25 million jobs through the development of clean energy industry by 2030 (IEA 2021).



Two kinds of economic costs of climate actions

- Costs associated with negative externalities
  - Climate change is a typical case of negative externalities.
  - Addressing negative externalities means to account for unrecognized costs that could eventually raise prices and reduce the transacted volume of traded goods and services (Baumol and Oates 1988).
  - An increase in prices may result in leakage of national wealth.
- Costs associated with carbon lock-in
  - Carbon lock-in is the "inertia" caused by consumer behaviors and existing fossil fuel infrastructure. It inhibits or delays the adoption of emissions reduction technologies (Seto *et al.* 2016)
  - Carbon lock-in occurs in sectors where large-scale infrastructure or supply network development are needed.
  - Realizing CN means overcoming the lock-in effect with significant investments in new infrastructures, the replacement of existing facilities while requiring job switching and vocational training.

❖ **Internalization of negative externalities**

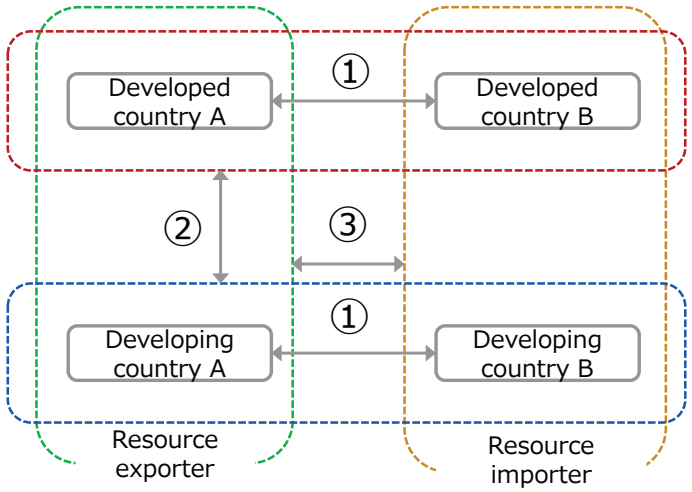


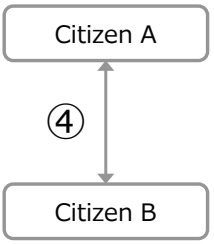
Balance of positive and negative effects

- Various views on the net effect of climate actions exist.
  - Concepts of Green growth or Green deal expect that the world benefits from the net positive effects of climate actions through stimulated economic activities and job creation
  - Concepts of negative externalities and carbon lock-in, by contrast, suggest that climate actions cannot be free from increased economic burdens, and would result in net overall negative economic effects.
  - If climate actions and emission reductions are recognized by all as a new global “norm”, it may be sufficient as a justification and the responsibility for everybody to accept the negative economic impacts.
- The net balance between the positive and negative effects can vary for each country, organization, and individual.
  - External factors: Geographical factors, indigenous resources, renewable energy resources, etc.
  - Internal factors: Administrative capabilities and leadership of the government, technological capacity, financial capacity, entrepreneurship, industrial structure, liquidity in labor market, containment of COVID-19, etc.

Disparity caused by climate actions

- Climate actions can widen disparity of various kinds because of differed capacities and resource endowments of each actor.
  - ① Disparity among developed countries and among developing countries.
  - ② Disparity between developed and developing countries
  - ③ Disparity between resource exporting country and importing country
  - ④ Disparity between citizens within same country

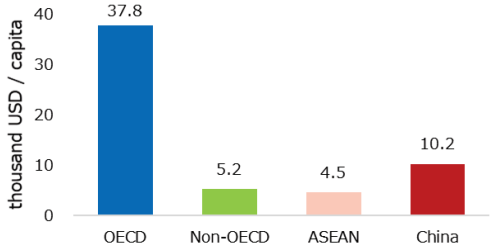




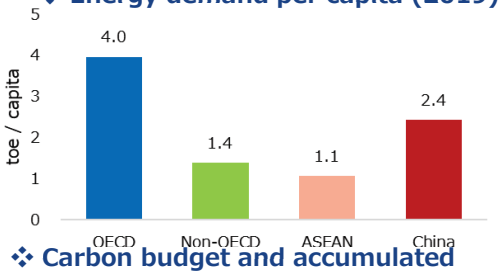
Comparison between developed and developing countries

- The existing differences are large.

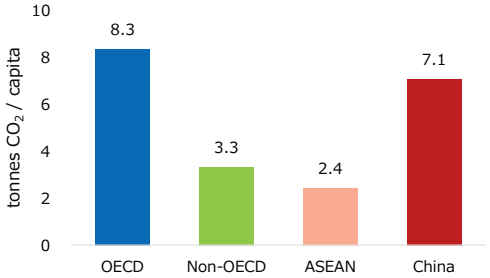
❖ GDP per capita (2019)



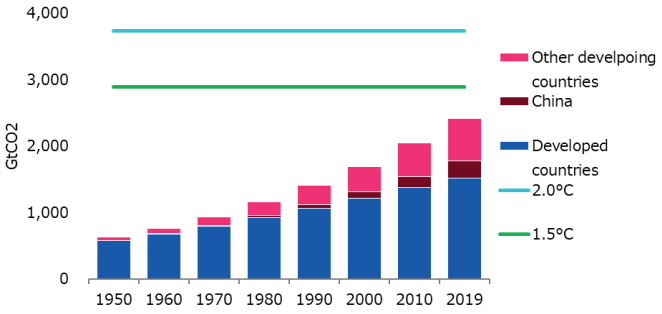
❖ Energy demand per capita (2019)



❖ CO_2 emissions per capita (2019)



❖ Carbon budget and accumulated emissions

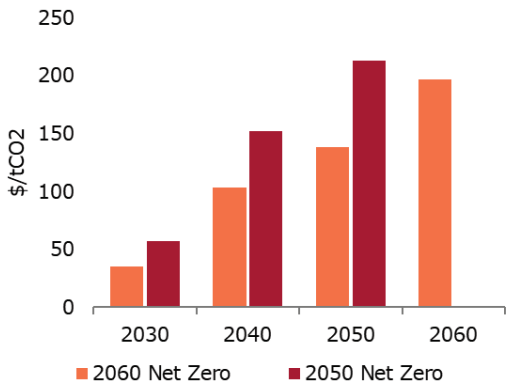


Note: Carbon budget figure are 50% expectation values
Source : IEA, IPCC, Global Carbon Budget 2020; Friedlingstein et al (2020); IEEJ estimate

Economic burden for the developing world (in the case of ASEAN)

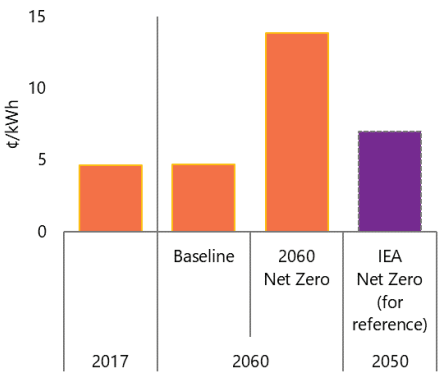
- Seeking for CN in a shorter period may cause a significant burden for ASEAN.
  - Average reduction cost for CN in 2050 or 2060 will be around \$200/t-CO_2.
  - Electricity price for CN in 2060 will triple from current levels.
  - Additional costs for CN in 2050 and 2060 will be equivalent to 2.9% and 2.5% of annual GDP, respectively.
  - Supports to make a pragmatic roadmap toward CN are needed.

❖ Average CO_2 reduction cost in ASEAN



Source : IEEJ; IEA

❖ Electricity price in ASEAN

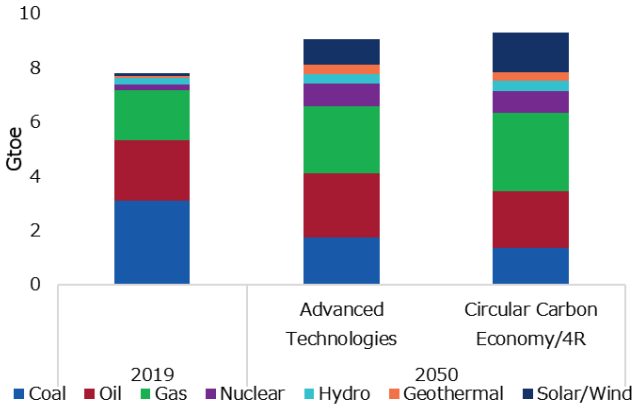


Note : Figure of IEA Net Zero is based on the estimated increased rate of electricity price in the world (+50%)
Source: IEEJ; IEA

Use of decarbonized fossil fuels in the developing world

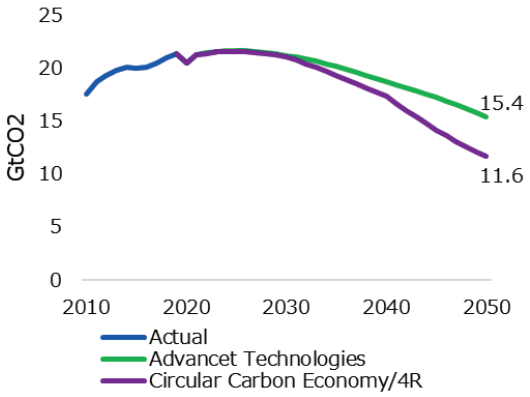
- The use of decarbonized fossil fuels can be an effective mean of emissions reduction in developing countries.
  - CCE scenario in this outlook shows that 3.8Gt of CO_2 emissions reduction is feasible while maintaining the share of fossil fuels.

❖ Primary energy supply of developing countries



Source: IEEJ

❖ CO_2 emissions of developing countries



Source: IEEJ

Two different scenarios toward CN

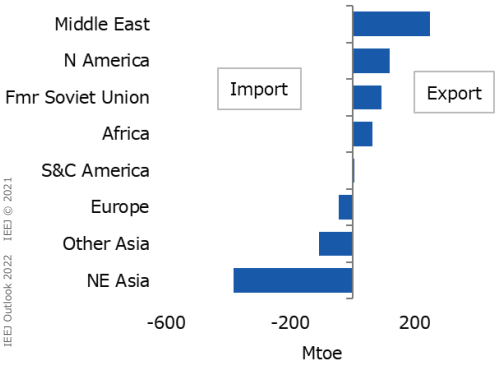
- Reduction of transition cost and its extensive sharing will drive the Bright Future scenario.

Bright Future	Hard Future
• Developed countries lead the technological development, which is smoothly transferred to developing countries. • Decarbonization of fossil fuel resources and exports of (hydrogen, ammonia, etc.) will proceed with a significant reduction in costs. • An increasing number of countries is adapting well to a CN world. • Adverse economic effects of climate actions will be minimized as new industries and business opportunities will spread and the entire economic structure will ~~be~~ adapt~~ed~~ to CN.	• Only a few succeed in achieving CN, and a large number of countries are "left behind." • The rise of unilateralism emphasizes the rights to advanced technologies and hinders the spread of successful adaptation to CN. • The economic traction and job creation effects of new industries and businesses created by climate actions cannot fully offset various costs. • Widening of disparities in the world will make countries to prioritize their national interests and weaken the motivation to pursue climate actions as a normative efforts.

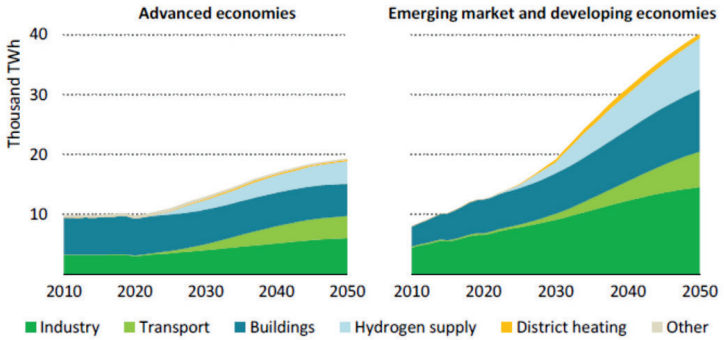
Energy security with increased complexity

- Energy security risks growing in significance
  - The world continues to depend on fossil fuels during the transition to CN.
  - Existing resource exporters may reinvent themselves as exporters of decarbonized fossil fuels, such as hydrogen and ammonia.
  - As power demand grows, issues of electricity supply security becomes far more important while VRE's intermittency, system reform, cyber attacks remain important critical issues.
  - Supply security of critical minerals emerged as a new potential security issue.

❖ Hydrogen trade balance as of 2050 in CCE scenario



❖ Electricity demand in IEA Net Zero scenario

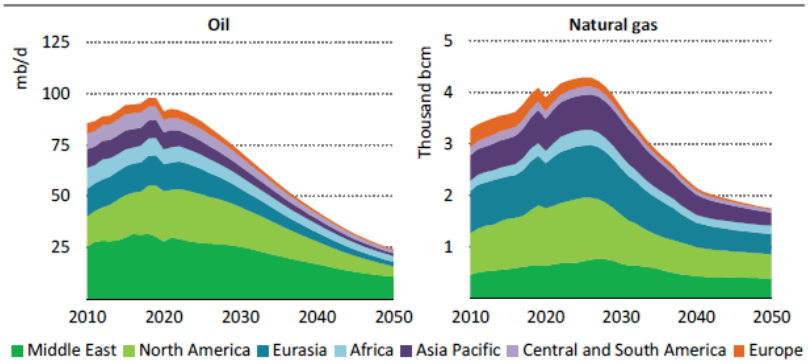


Source : IEA, Net Zero by 2050

No new upstream investment is needed to achieve CN by 2050?

- The "No new upstream investment" conclusion from IEA's Net-zero scenario
  - In May, IEA provided a back-casting scenario to achieve CN in 2050 and implied that there are no need for new oil and gas field to be approved for development and that no new coal mines or mine extensions are required.
  - IEA did not necessarily recommend no new upstream investments.
  - In the net zero scenario, the crude oil price will fall to $35/bbl in 2030 and $24/bbl in 2050. Likewise, the LNG price will decline to $4.4/mmbtu in 2030, and $4.1/mmbtu in 2050.

Figure 3.3 ▷ Oil and natural gas production in the NZE

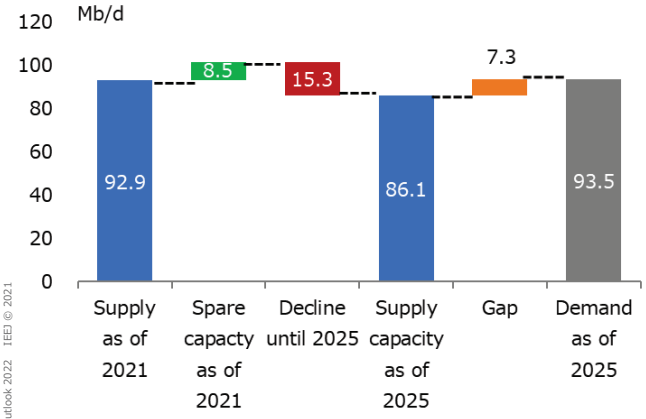


Source : IEA

What if investments in oil markets stop?

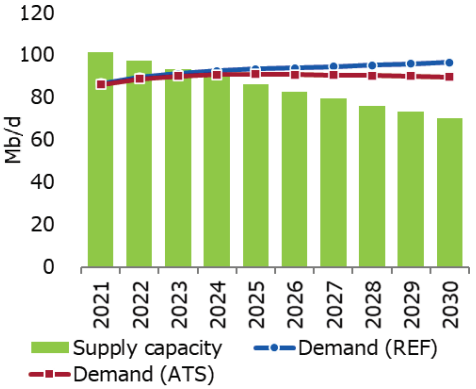
- If investment in new oil and gas field development stops, demand will surpass supply capacity by 2024.
  - No outright supply crunch expected because of large spare capacities
  - World oil demand may return to a growing trend in the post-COVID world; the "No new upstream investment" conclusion may bring "chilling effect" on legitimate investments to meet such growing demand.

❖ World oil demand and supply capacity as of 2025 if investment stops



Note: Bio fuels are excluded. Supply capacity is assumed to decline by 4% annually.
Source : IEA; IEEJ estimate

❖ World oil demand and supply capacity if investment stops

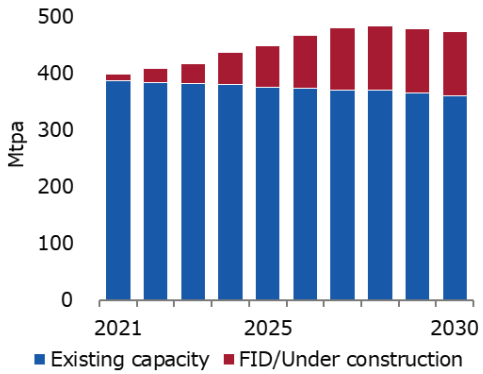


Note: Demand excludes biol fuels.
Sources: IEA, IEEJ estimates

What if no new investments are made in the LNG market?

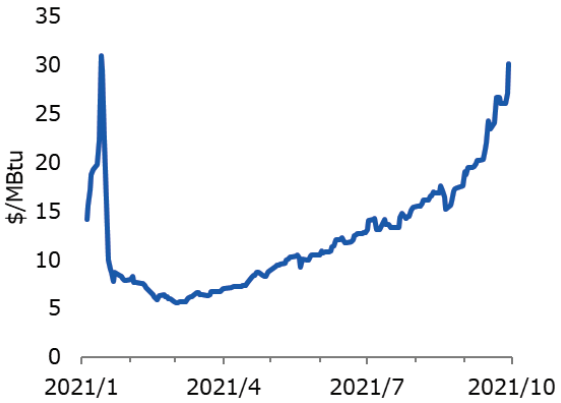
- LNG supply capacity is expected to grow until the late 2020s.
- LNG spot prices have sharply risen
  - Multiple factors such as post-COVID demand recovery, switching to low-carbon power sources, wind condition in Europe caused recent spike in prices.
  - Restrained investments will aggravate the market's uncertainties and trigger price instabilities.

❖ World LNG supply capacities



Source: IEEJ

❖ Spot LNG prices in Asia (2021)



Source: ICIS

Further uneven distribution of sources

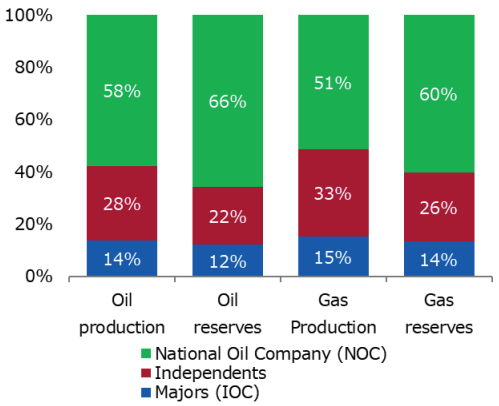
- As developed countries consider not investing in fossil fuels, the financing may come from oil-exporting countries and emerging economies in the future.
  - International oil companies (IOC) in developed countries are less likely to invest in upstream while they are allocating a growing capital to decarbonization technologies.
  - Meanwhile, state-owned oil companies (NOCs) in oil-producing and emerging countries, are more likely to invest in fossil fuels than decarbonization and will become more influential in international markets.

❖ Allocation of CAPEX by major IOCs

Company	Investment plan
Chevron	Invest over 300M$ to energy transition.
Shell	Share of upstream investments wil be lowered from 42% to 25-30% from 2020 to 2025; Share of gas and chemical will be lowered from 43% to 30-40%; Share of renewable and markteing will be raised from 16% to 35-40%.
bp	Share of low-carbon electricity and energy and consumer and mobility will be raised from 15% in 2019 to 40% in 2030.
TotalEnergies	Share of investment to LNG will be maintained at 15-20% until 2030; Share of renewable and electicity will be raised from 10% (from 2016 to 2020) to 15% (2021 to 2025) and 20% (from 2026 to 2030).
ENI	Share of upstream investments will be 65% from 2021 to 2024. Share of green and marketing will be 20%.
Repsol	Share of upstream investments will be 44% from 2021 to 2025; Share of downstream (incl bio fuels) will be 25%; Share of low carbon power generation will be 22%.
Equinor	Share of renewable and low carbon sectors will be raised from 4% in 2020 to more than 50% in 2030.

Source: each company's web-site

❖ Share of IOC and NOC in the world oil and gas supply in 2018

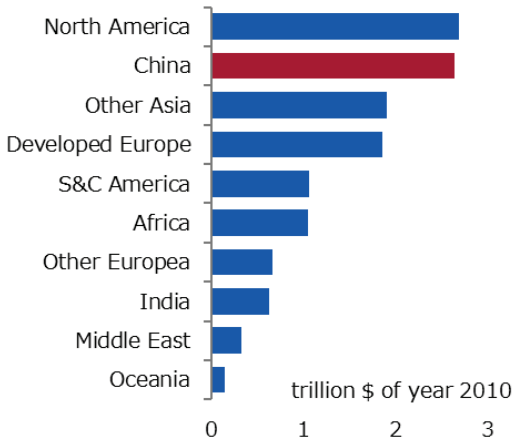


Source: IEA, Oil and Gas Industry in Energy Transitions

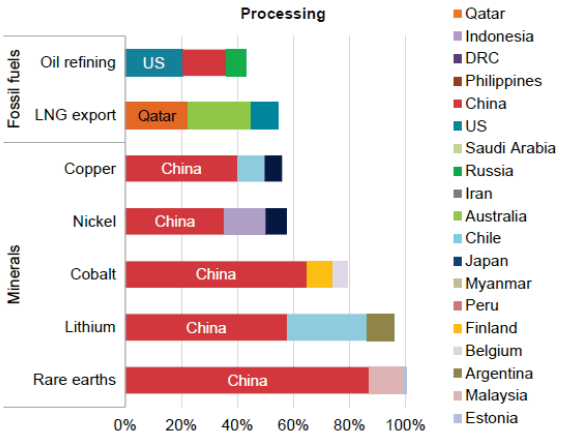
China's growing presence in a CN world

- China's presence is likely to expand in a world heading toward CN.
  - Its presence will grow in the field of renewable energy, critical minerals, as well as fossil fuels.
  - A high level of competition with developed countries could lead to international divisions or conflicts.

❖ Investments in renewable power generation in Reference scenario



❖ Process capacity of fossil fuels and critical minerals



Source : IEA, The Role of Critical Minerals in Clean Energy Transitions

Summary

- The transition to CN will provide positive economic impacts, as well as incur costs.
  - The net impact varies from country to country.
- The traditional energy security issues are becoming multidimensional and complex.
  - Issues of import dependence on resources, issues of power supply security and issues of securing critical minerals.
- The “no new upstream investment” conclusion is an added risk factor that could destabilize supply.
  - It is necessary to design a pragmatic CN transition process based on actual supply and demand conditions of existing energy sources, and based on the current situation of each consuming country’s energy market.
- The transition to CN should proceed in an inclusive manner.
  - The diverse energy and economic profiles of each country should be respected so as not to cause disproportionate burdens to achieve CN.
  - Assistance to develop a realistic roadmap for CN, cooperation for the introduction of fossil fuel decarbonization technologies, provision of financing, human resource development need to be provided for smooth transition to CN by developing countries.

Reference materials

Geographical coverage

Countries/regions in the world are geographically aggregated into 42 regions.
Especially the Asian energy supply/demand structure is considered in detail, aggregating the area into 15 regions. That of the Middle East is also aggregated into 8 regions.

Source: [Map] www.craftmap.box-i.net

Modelling framework

Major assumptions

GDP, population, energy prices, exchange rates, international trade, etc.

Macroeconomic model

Calculate GDP-related indices, price indices, activity indices including material production, etc. consistently.

Technology assessment model

Use a bottom-up approach to calculate future efficiencies of appliances, vehicles, etc.

Optimal power generation planning model

Calculate the cost-optimal power generation mix to meet the projected future electricity demand.

Energy supply-demand model

Econometric model to project future energy supply and demand by regression analysis of historical trends based on the energy balance tables data of the International Energy Agency.

This model calculates energy demand, supply and transformation as well as related indices including CO_2 emissions, CO_2 intensities and energy self-sufficiency ratios.

Experts' opinions

World trade model

Use the linear programming (LP) method to calculate the future international trade flows of crude oil, petroleum products, etc.

Computable general equilibrium model

Estimate economic impacts induced by changes in energy supply and demand, based on input-output table data.

Climate change model

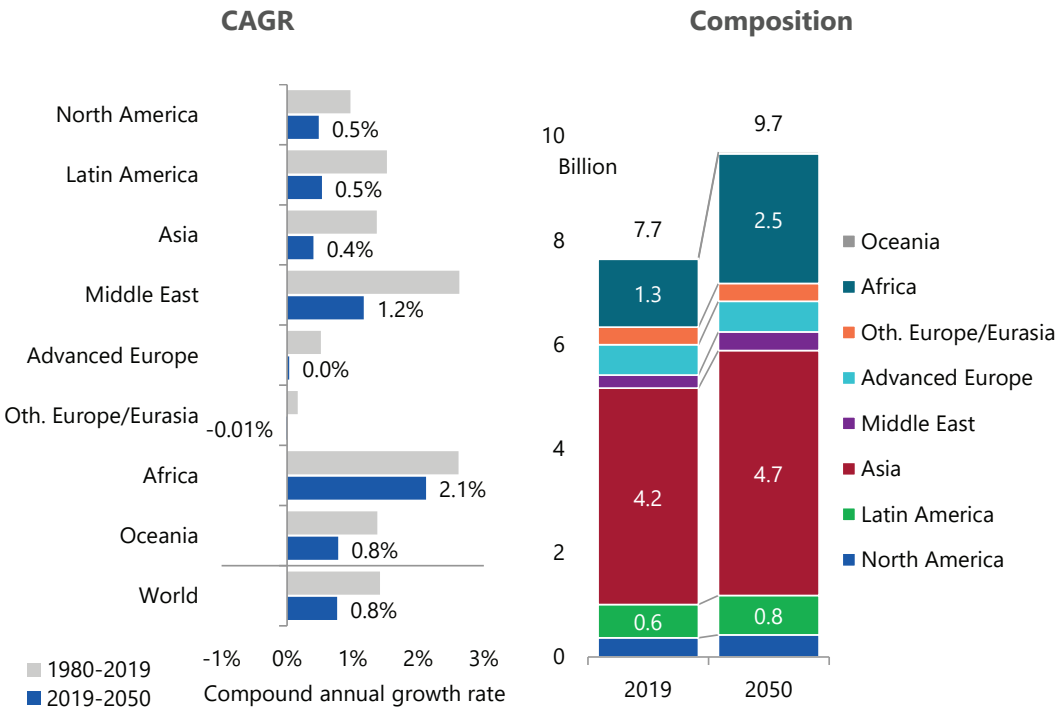
Calculate future GHG concentration in the atmosphere, temperature rise, damage caused by climate change, etc.

Basic scenarios in IEEJ Outlook

	Reference Scenario	Advanced Technologies Scenario
	Reflects past trends with technology progress and current energy policies, without any aggressive policies for low-carbon measures	Assumes introduction of powerful policies to address energy security and climate change issues with the utmost penetration of low-carbon technologies
Socio-economic structure	Stable growth led by developing economies despite slower population growth. Rapid penetration of energy consuming appliances and vehicles due to higher income.	
International energy prices	**Oil** supply cost increases along with demand growth. **Natural gas** prices converge among Europe, North America and Asia markets. **Coal** keeps unchanged with today's level.	Slower price increase due to lower demand growth (coal price decreases)
Energy and environmental policies	Gradual reinforcement of low-carbon policies with past pace	Further reinforcement of domestic policies along with international collaboration
Energy and environmental technologies	Improving efficiency and declining cost of existing technology with past pace	Further declining cost of existing and promising technology

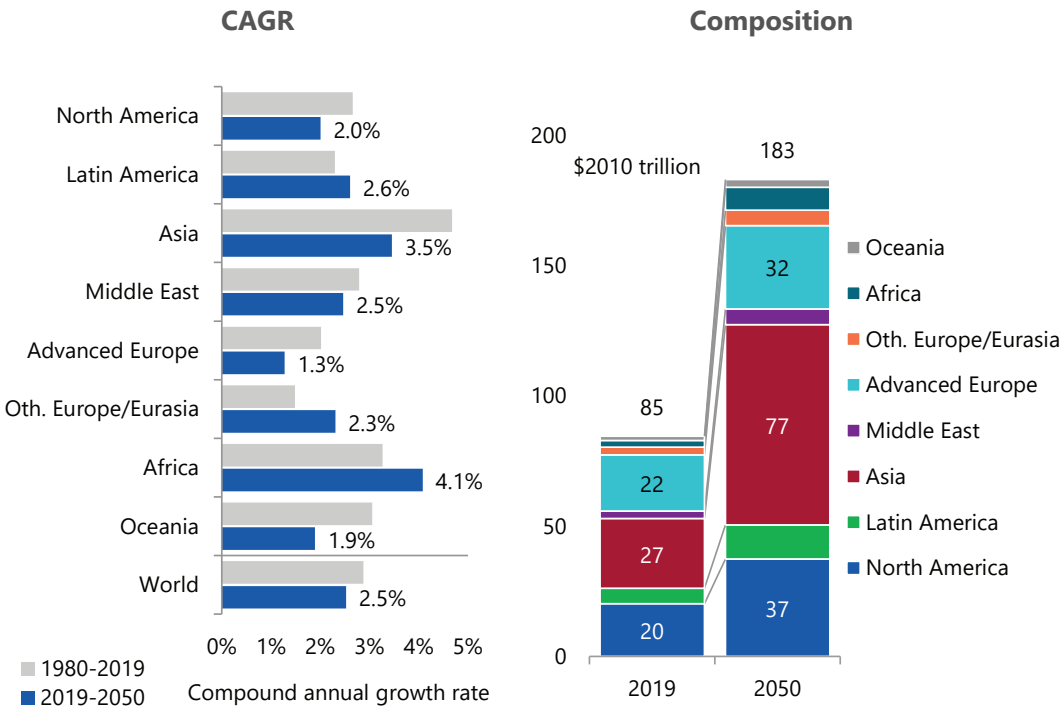
Assumptions

Population



Assumptions

Real GDP

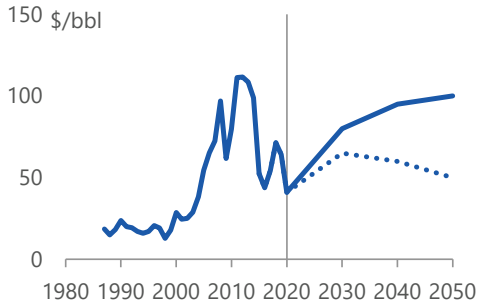


Assumptions

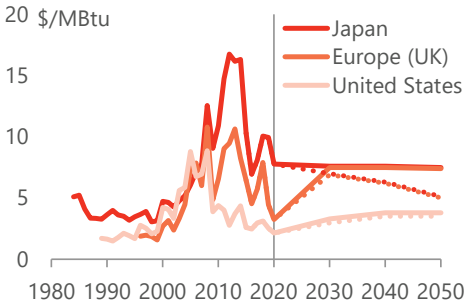
International energy prices

Reference：
Advanced Technologies：

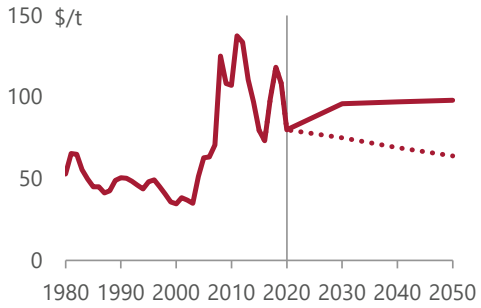
Crude oil



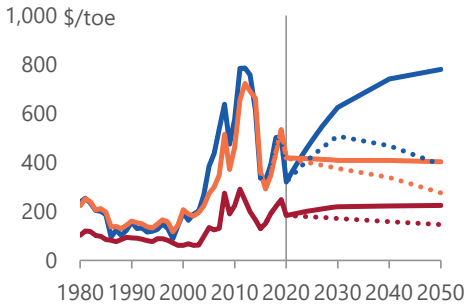
Natural gas



Coal



CIF import prices for Japan



Note: Historical prices are nominal. Assumed future prices as real in $2020.

Assumptions

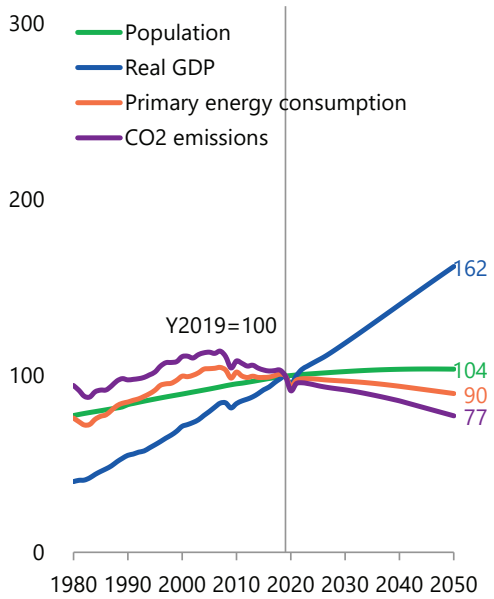
Energy and environmental technology

		2019	2050 Reference	2050 Advanced Technologies	Assumptions for Advanced Technologies Scenario
Improving energy efficiency					
Industry	Intensity in steel industry (ktoe/kt)	0.271	0.244	0.205	100% penetration of Best Available Technology by 2050.
	Intensity in non-metallic minerals industry	0.092	0.076	0.064	
Transport	Electrified vehicle share in passenger car sales	5%	63%	91%	Cost reduction of electrified vehicles. Promotion measures including fuel supply infrastructure.
	Average fuel efficiency in new passenger car (km/L)	14.4	26.8	37.0	*electrified vehicle includes hybrid vehicle, plug-in hybrid vehicle, electric vehicle and fuel-cell vehicle
Buildings	Residential total efficiency (Y2019=100)	100	157	201	Efficiency improvement at twice the speed for newly installed appliance, equipment and insulation.
	Commercial total efficiency	100	153	178	Electrification in space heating, water heater and cooking (clean cooking in developing regions).
Power	Thermal generation efficiency (Power transmission end)	38%	46%	46%	Financial scheme for initial investment in high-efficient thermal power plant.
Penetrating low-carbon technology					
Biofuels for transport (Mtoe)		95	145	268	Development of next generation biofuel with cost reduction. Relating to agricultural policy in developing regions.
Nuclear power generation capacity (GW)		428	476	731	Appropriate price in wholesale electricity market. Framework for financing initial investment in developing regions.
Wind power generation capacity (GW)		622	1,981	3,890	Further reduction of generation cost. Cost reduction of grid stabilization technology. Efficient operation of power system.
Solar PV power generation capacity		581	3,015	5,427	
Thermal power generation capacity with CCS (GW)		0	0	1,152	Installing CCS after 2030 (regions which have storage potential except for aquifer).
Zero-emission generation ratio (incl. CCS)		37%	44%	80%	Efficient operation of power system including international power grid.

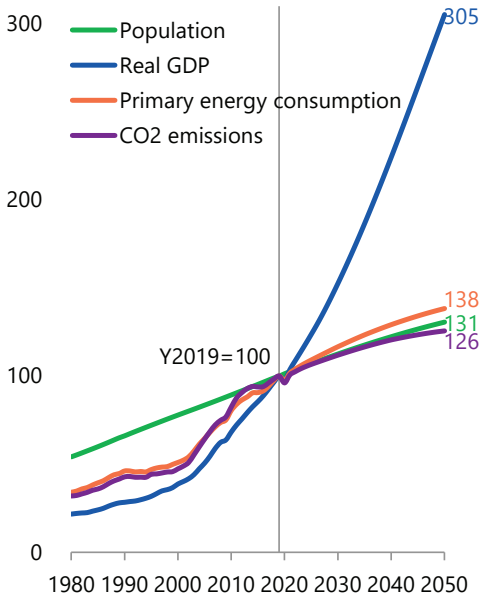
Reference Scenario

Population, GDP, energy and CO_2

Advanced Economies



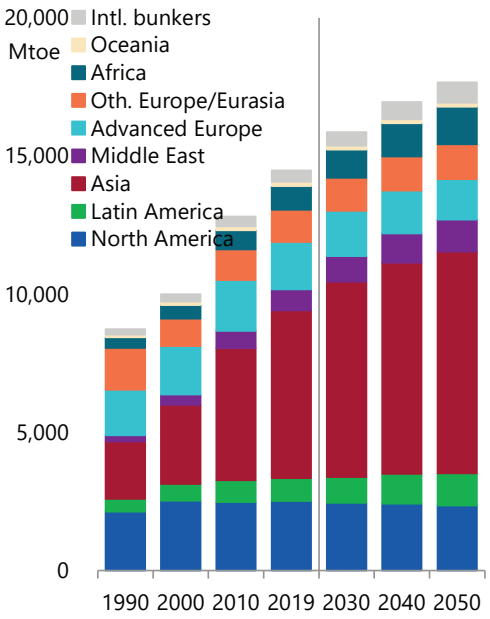
Emerging Market and Developing Economies



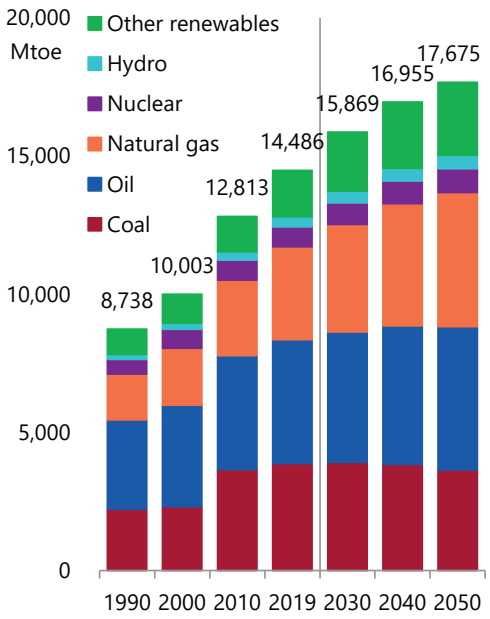
Reference Scenario

Primary energy consumption

By region



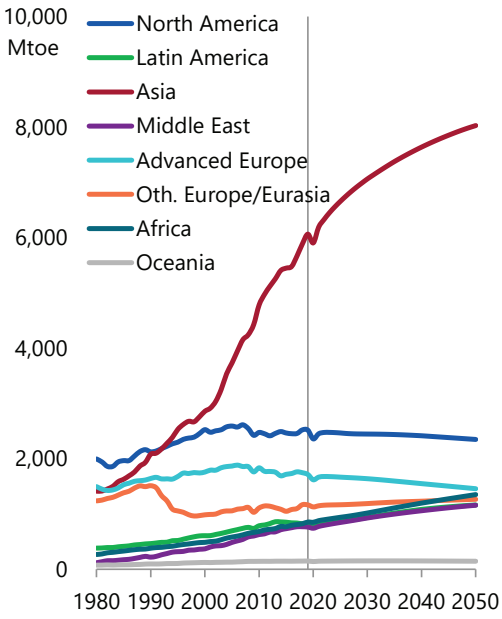
By energy source



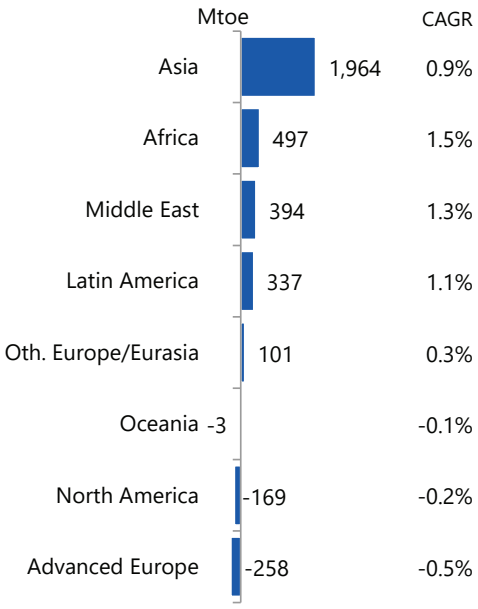
Reference Scenario

Primary energy consumption (by region)

Energy consumption



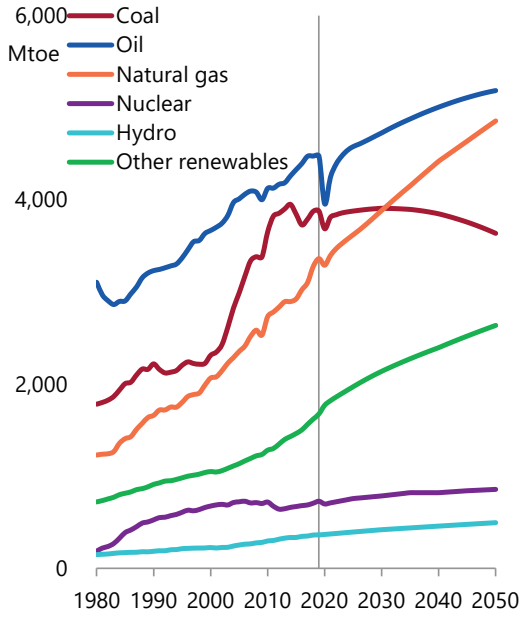
Changes (2019-2050)



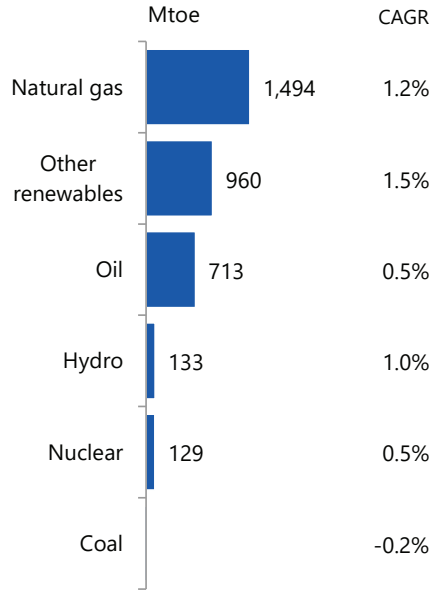
Reference Scenario

Primary energy consumption (by energy source)

Energy consumption



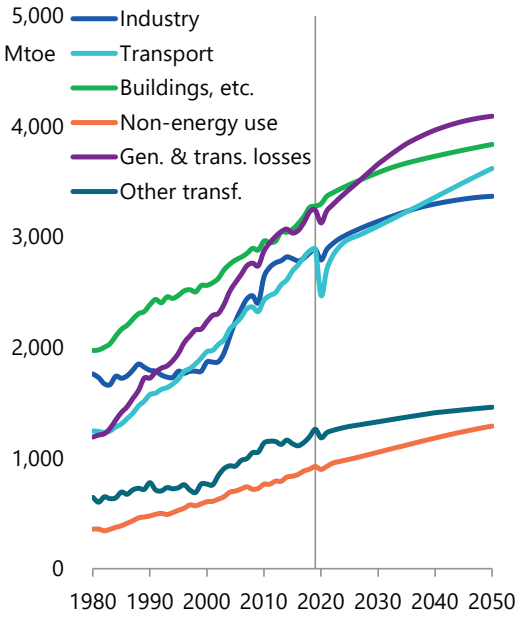
Changes (2019-2050)



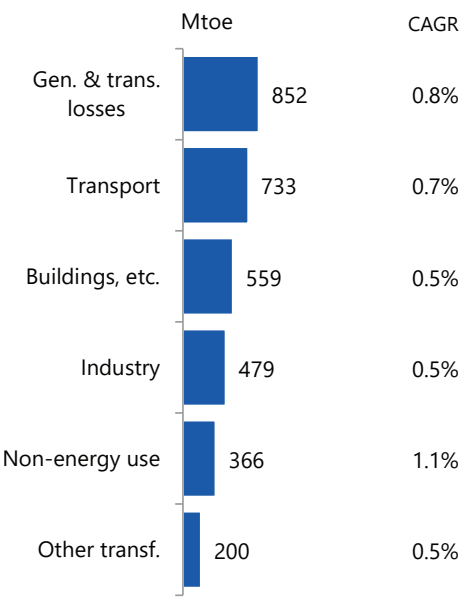
Reference Scenario

Primary energy consumption (by sector)

Energy consumption



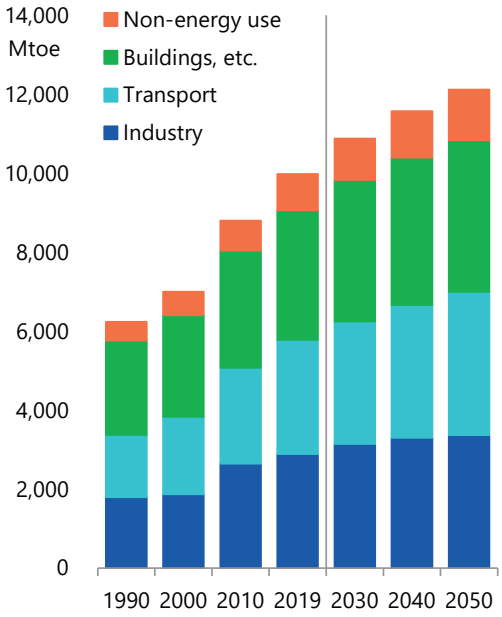
Changes (2019-2050)



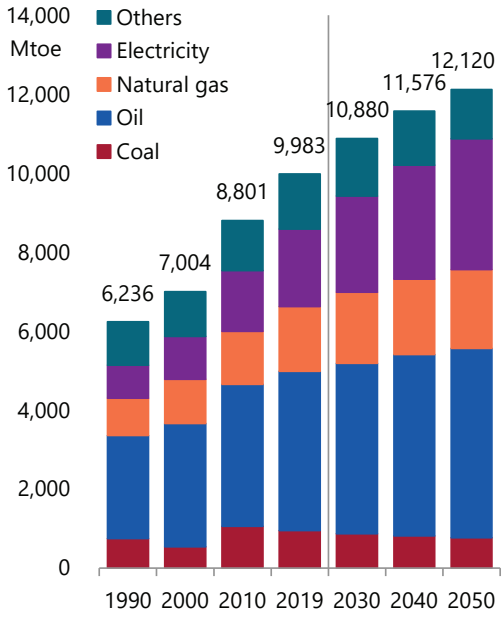
Reference Scenario

Final energy consumption

By sector

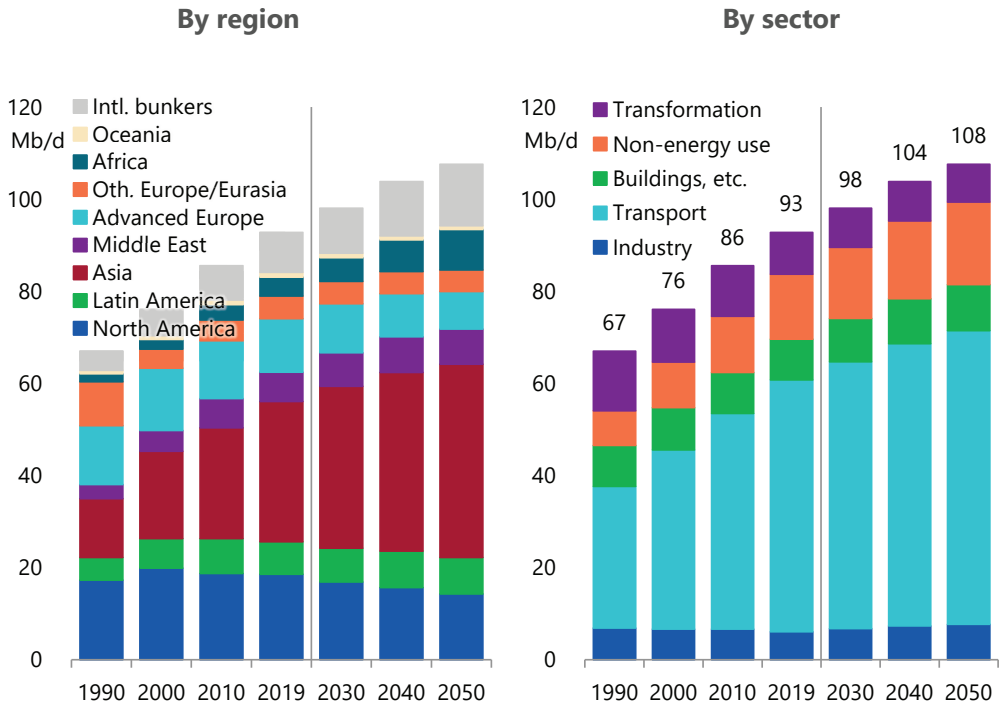


By energy source



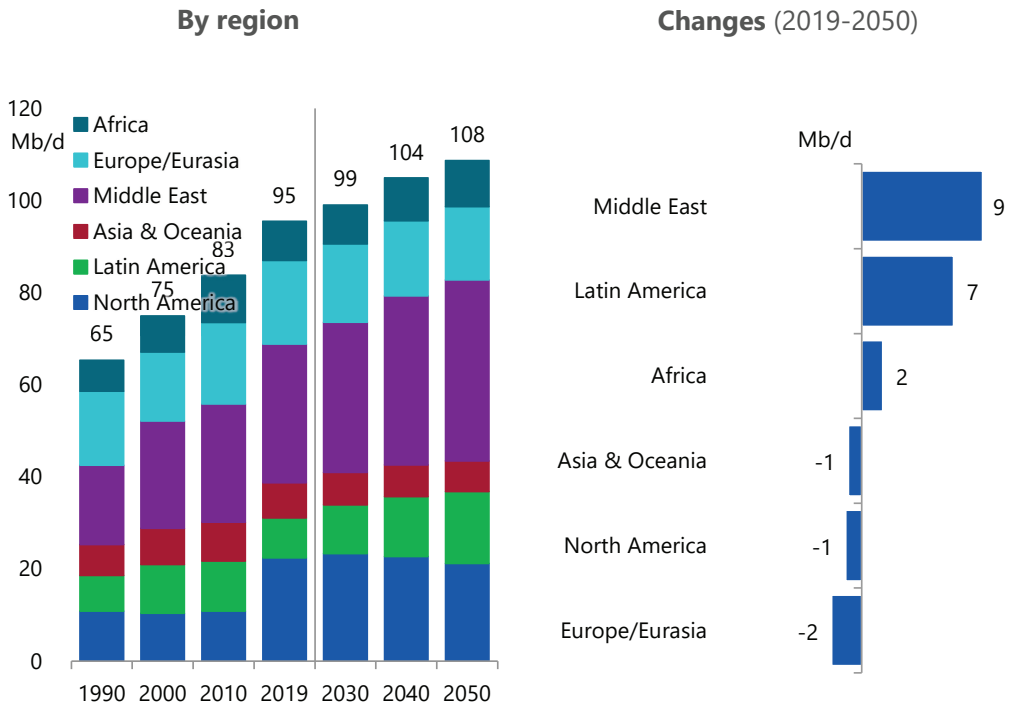
Reference Scenario

Oil consumption



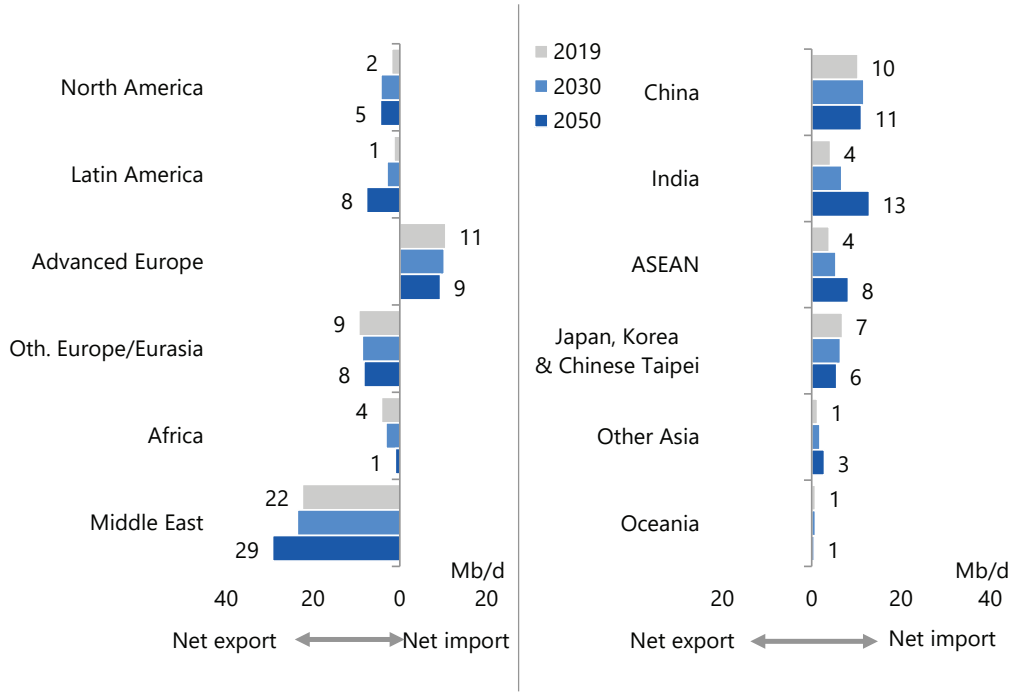
Reference Scenario

Crude oil production



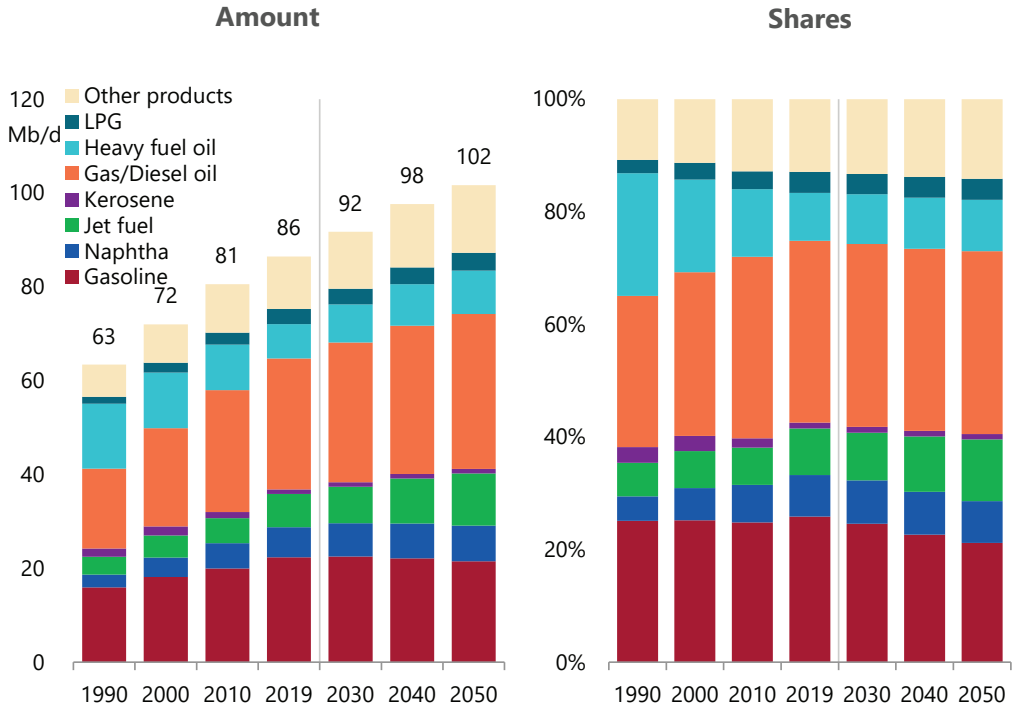
Reference Scenario

Net exports and imports of oil



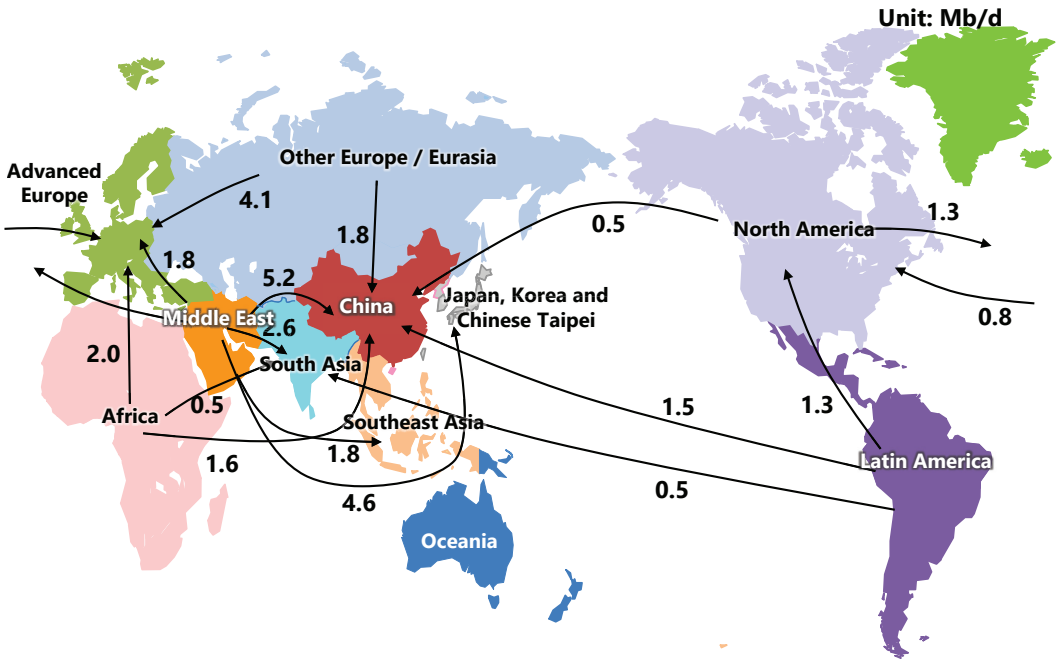
Reference Scenario

Petroleum product consumption



Reference Scenario

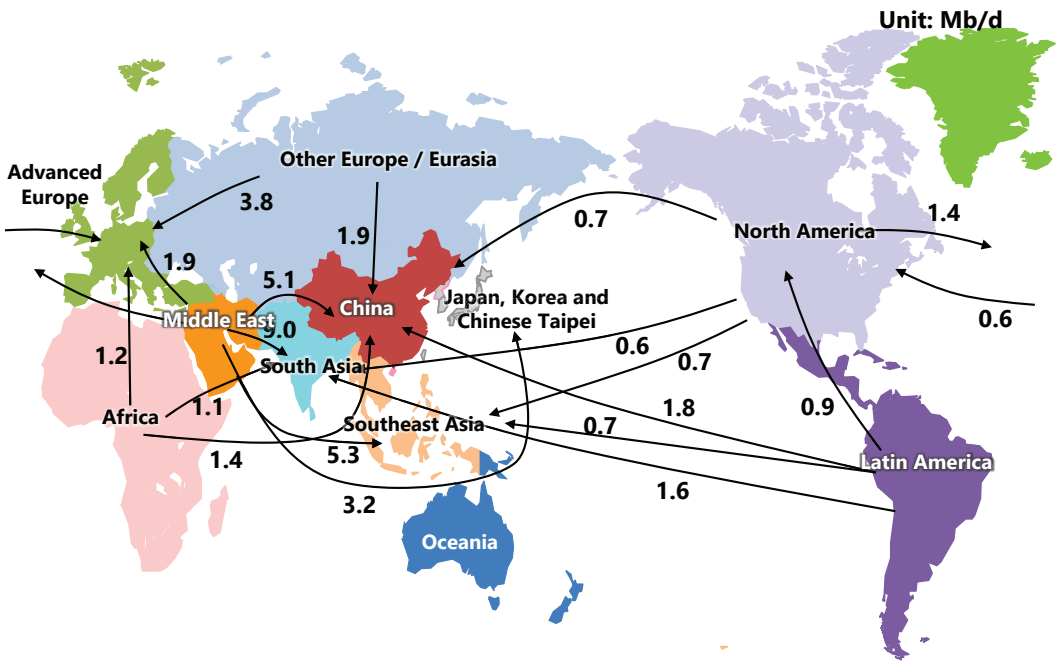
Major trade flows of crude oil (2020)



Note: 0.5 Mb/d or more are shown

Reference Scenario

Major trade flows of crude oil (2050)

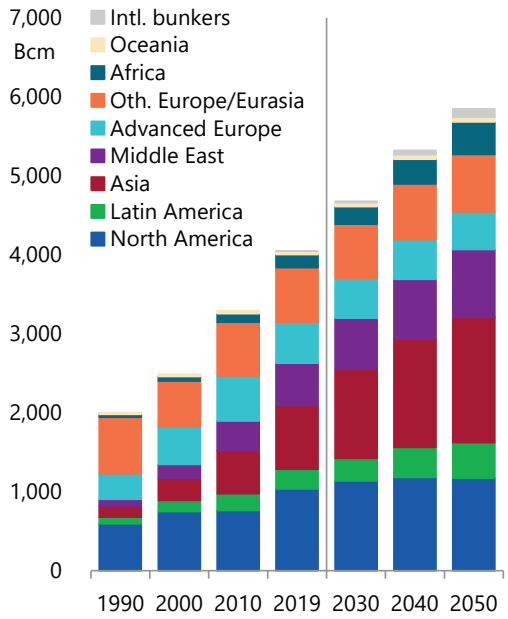


Note: 0.5 Mb/d or more are shown

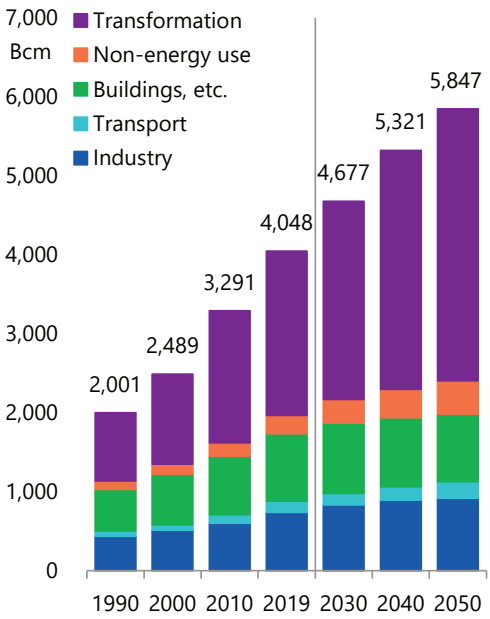
Reference Scenario

Natural gas consumption

By region



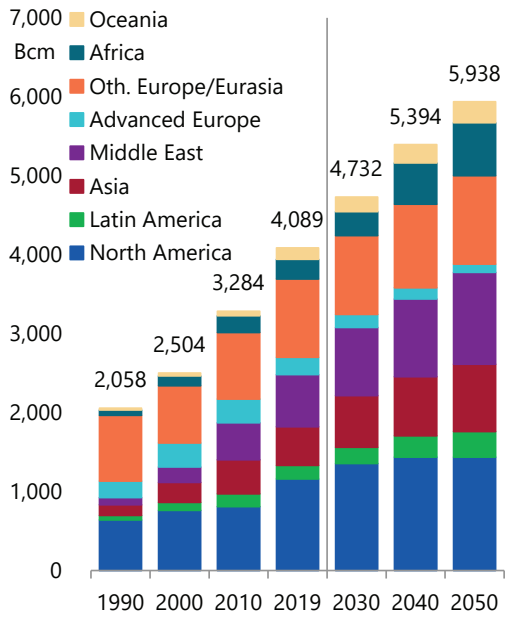
By sector



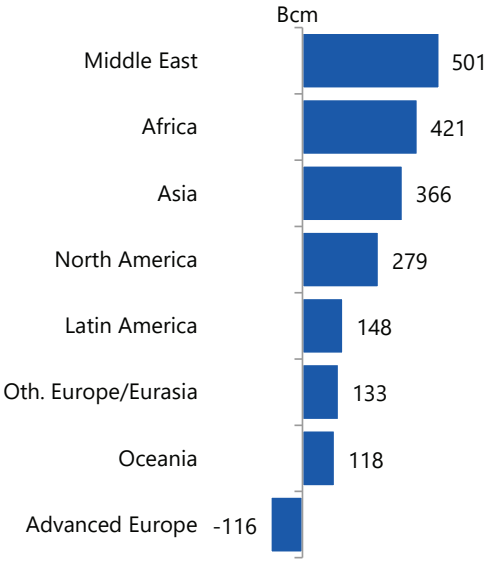
Reference Scenario

Natural gas production

By region

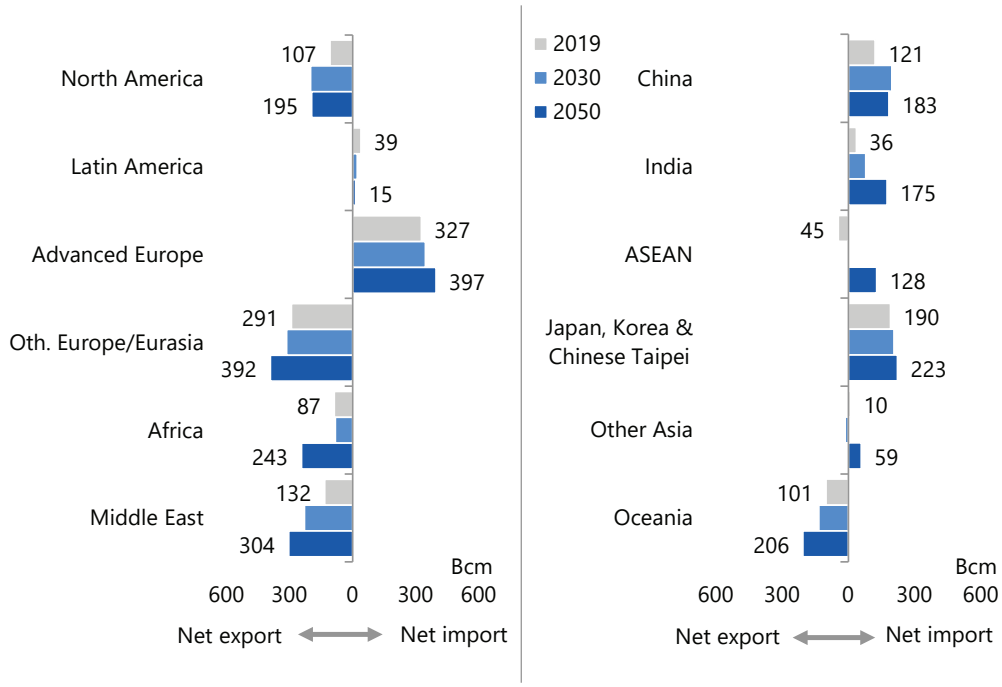


Changes (2019-2050)



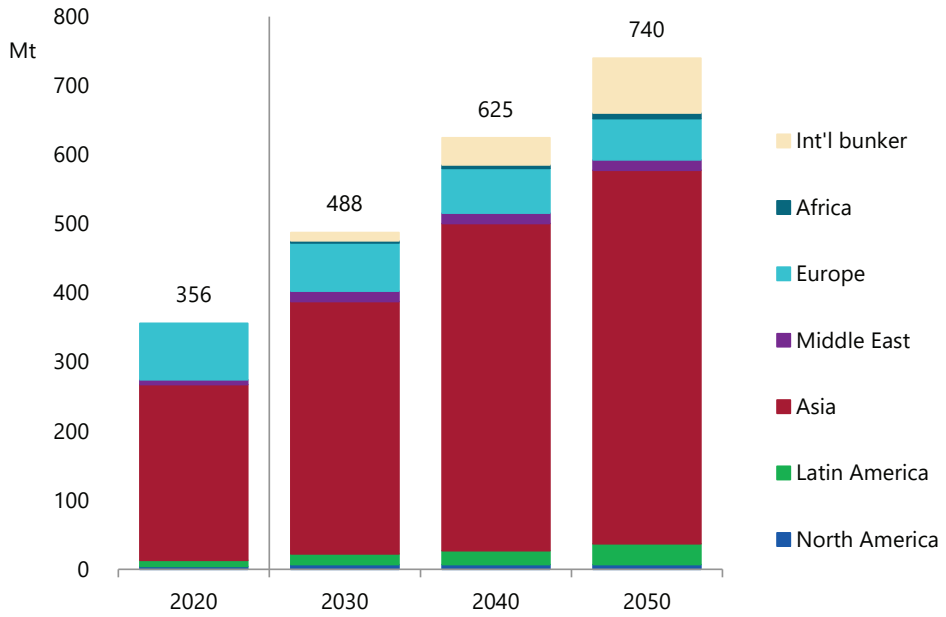
Reference Scenario

Net exports and imports of natural gas



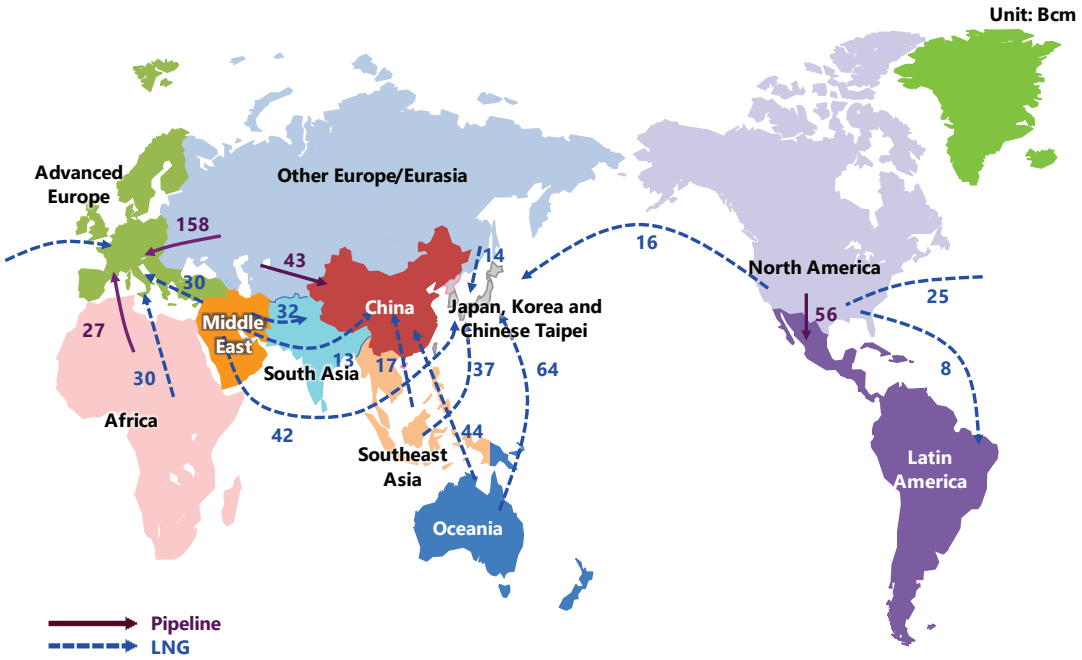
Reference Scenario

LNG demand in selected regions



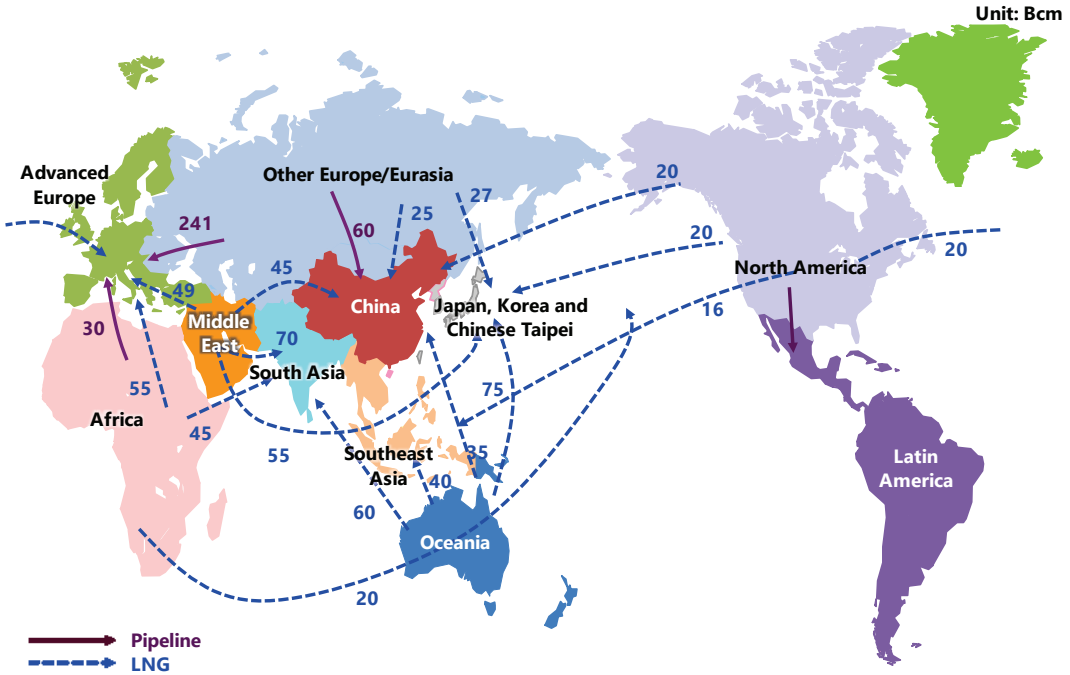
Reference Scenario

Major trade flows of natural gas (2020)



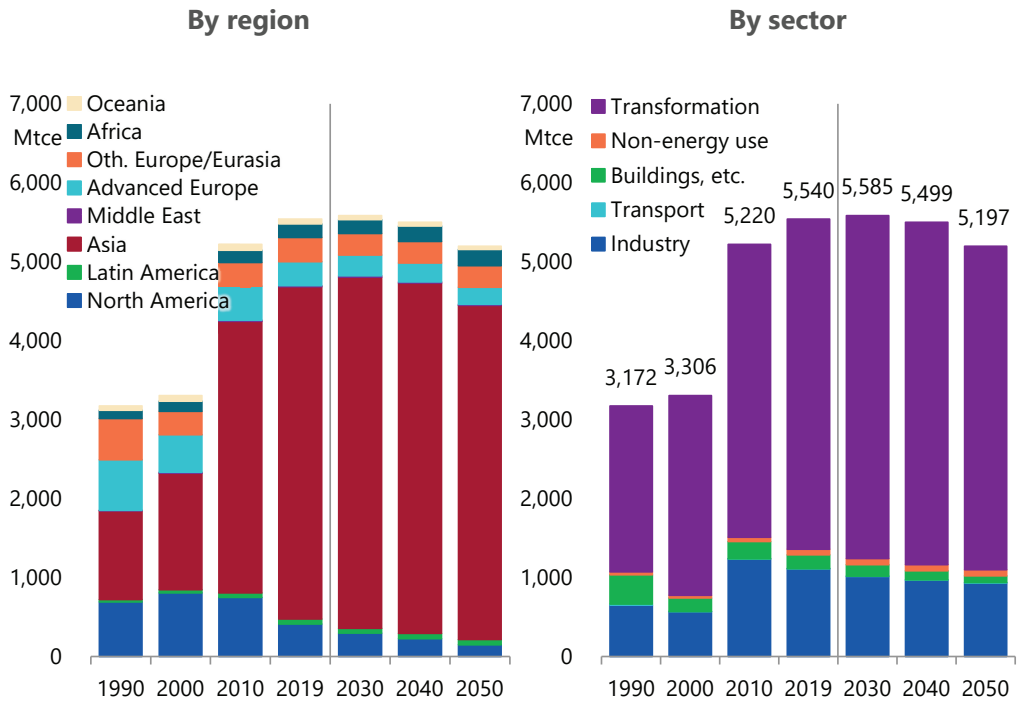
Reference Scenario

Major trade flows of natural gas (2050)



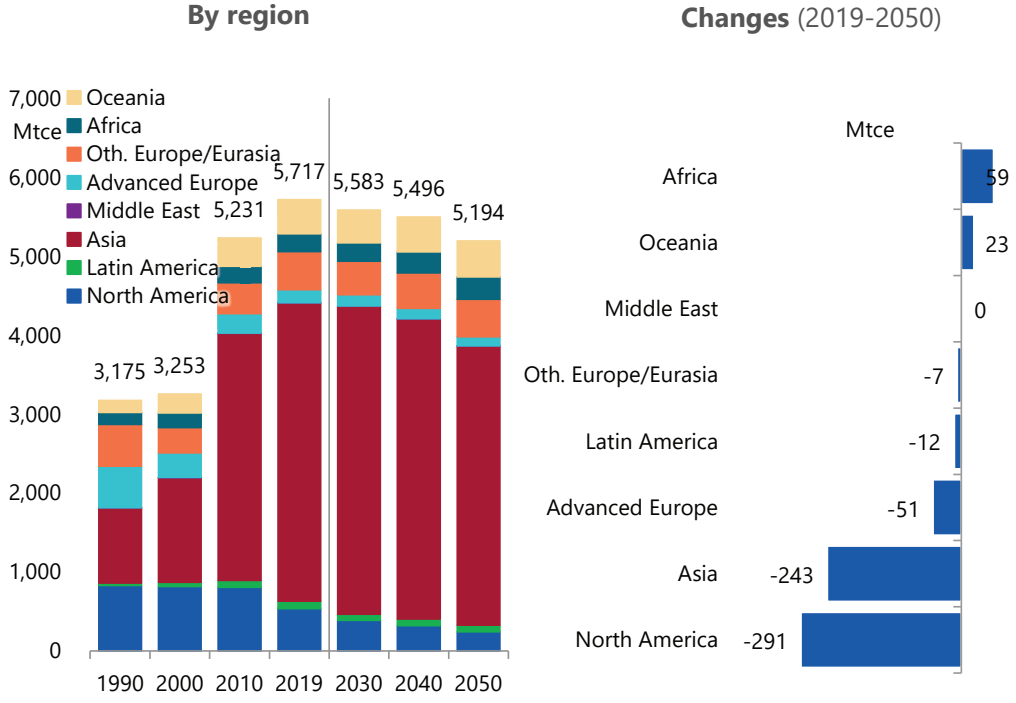
Reference Scenario

Coal consumption



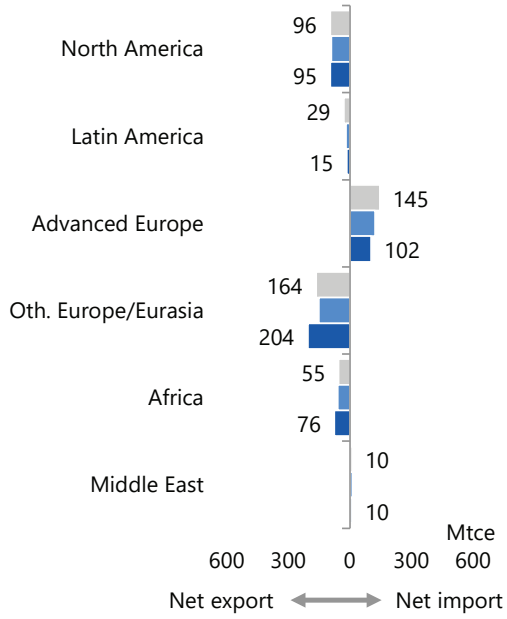
Reference Scenario

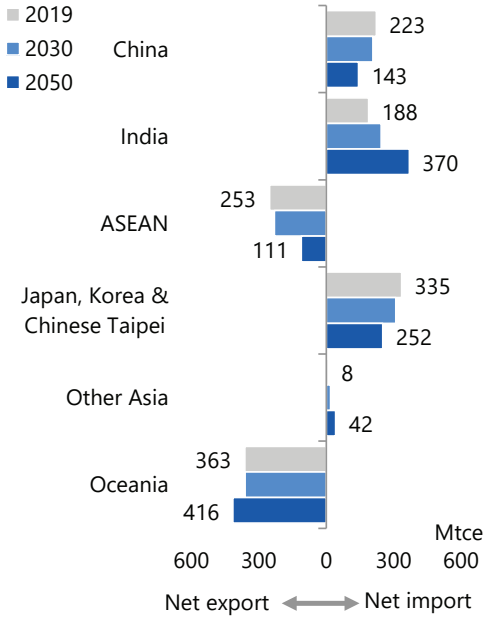
Coal production



Reference Scenario

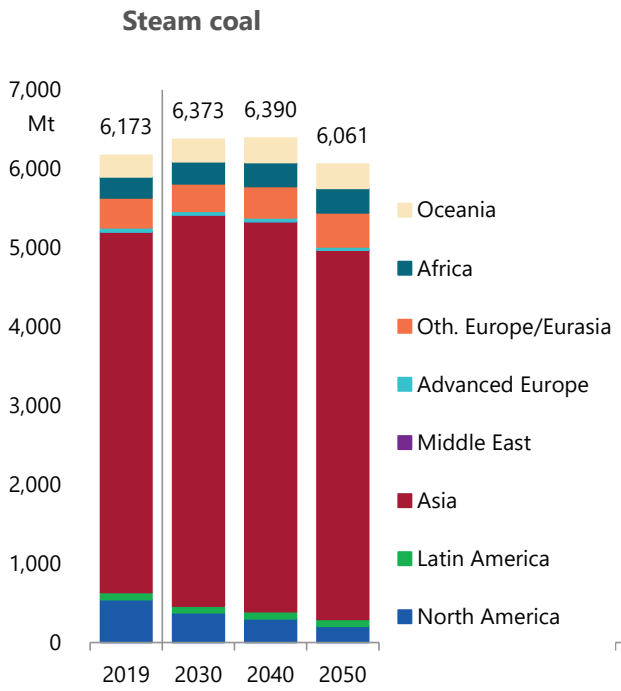
Net exports and imports of coal

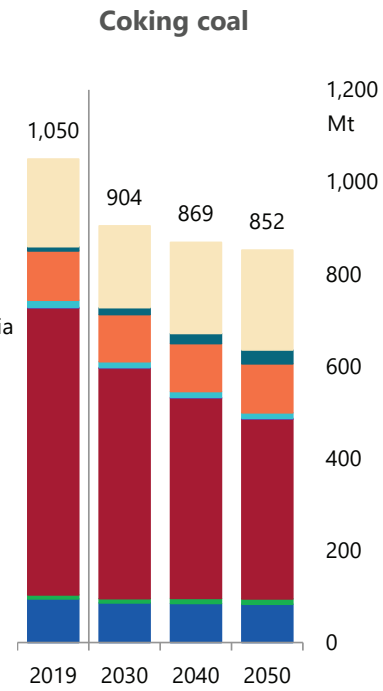




Reference Scenario

Coal production (steam and coking coal)

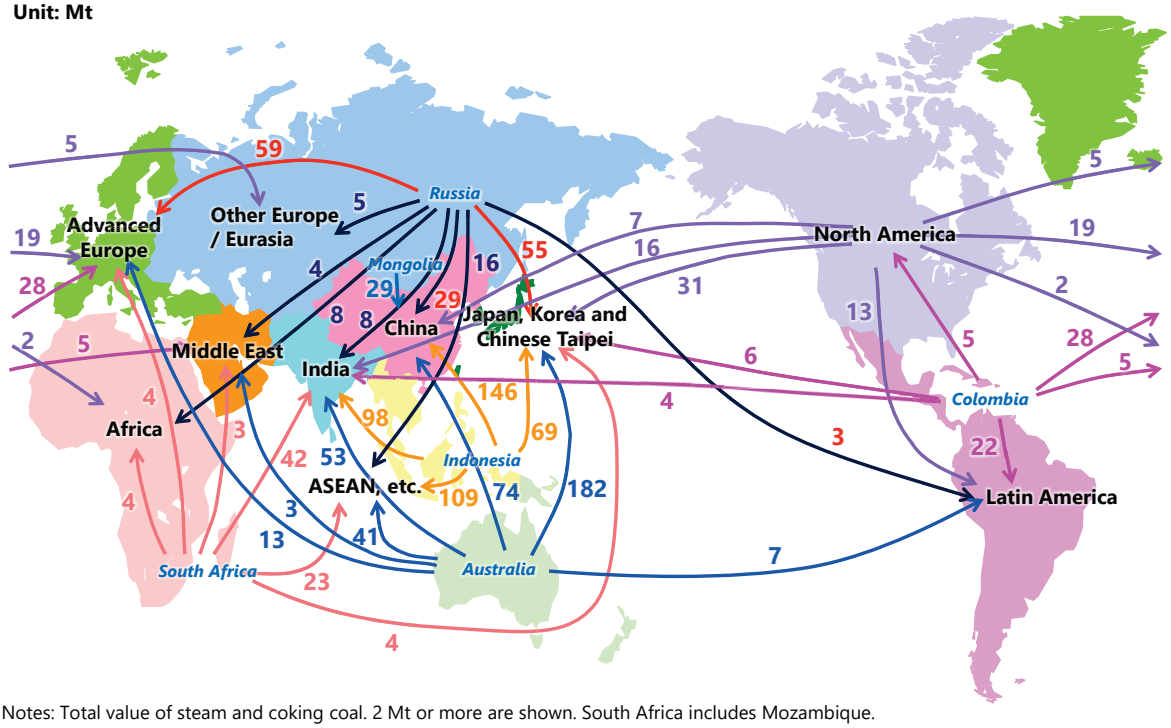




Reference Scenario

Major trade flows of steam and coking coal (2020)

Unit: Mt

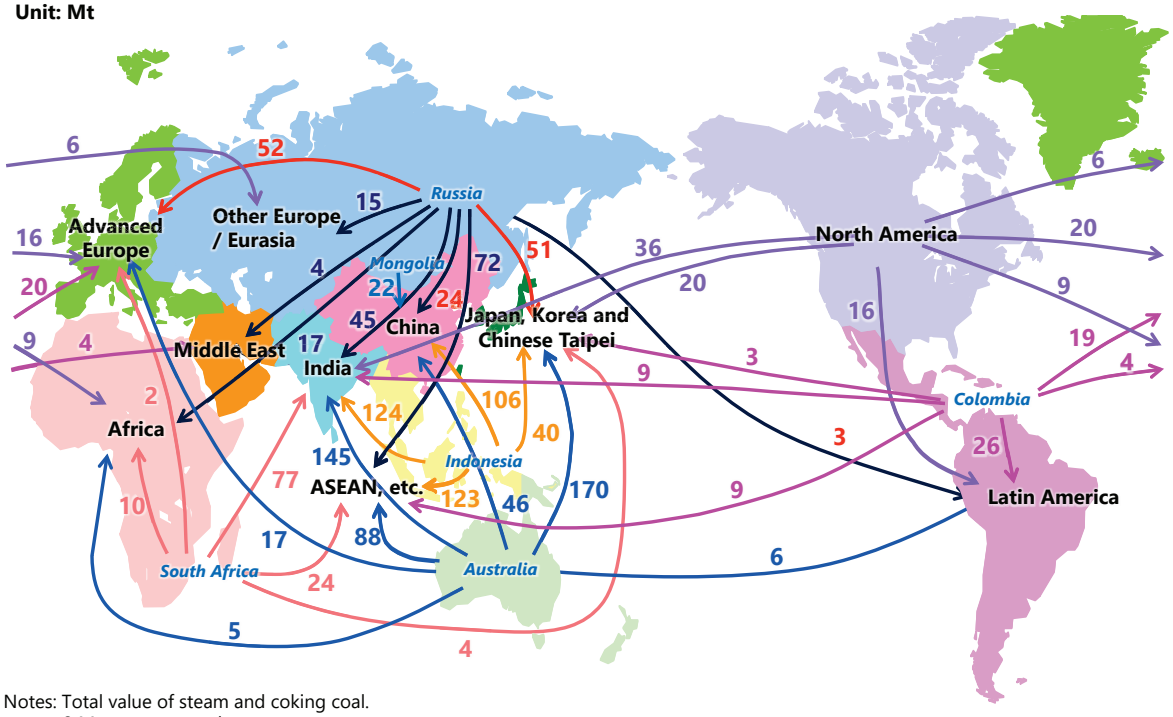


Notes: Total value of steam and coking coal. 2 Mt or more are shown. South Africa includes Mozambique.
Source: Estimated from IEA "Coal Information 2021", "TEX Report", etc.

Reference Scenario

Major trade flows of steam and coking coal (2050)

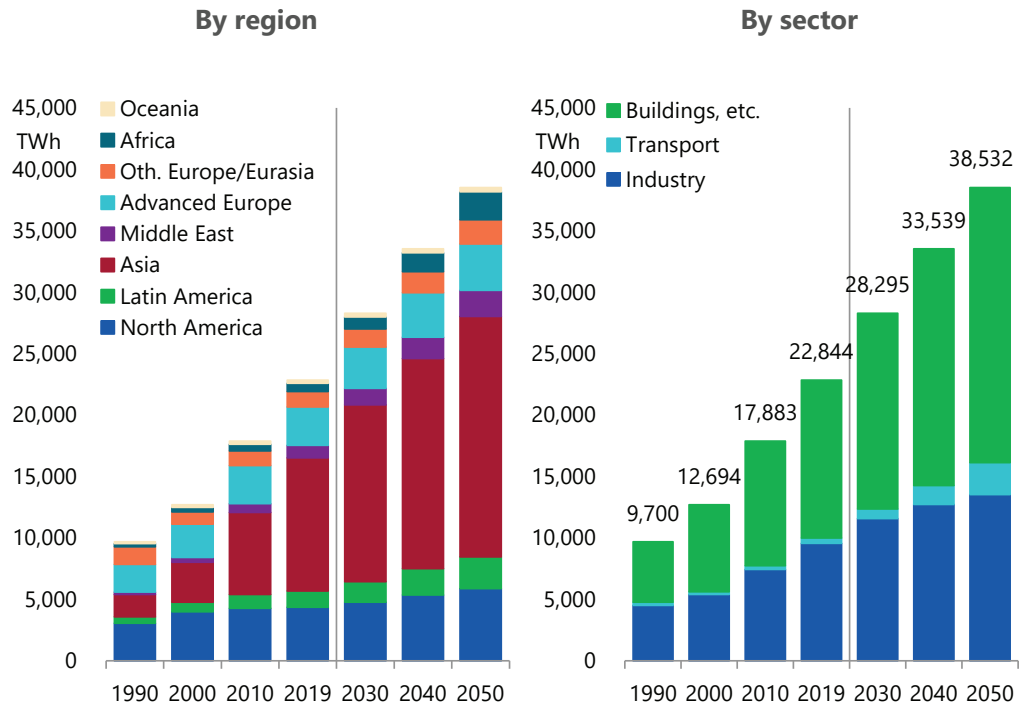
Unit: Mt



Notes: Total value of steam and coking coal.
2 Mt or more are shown.
South Africa includes Mozambique.

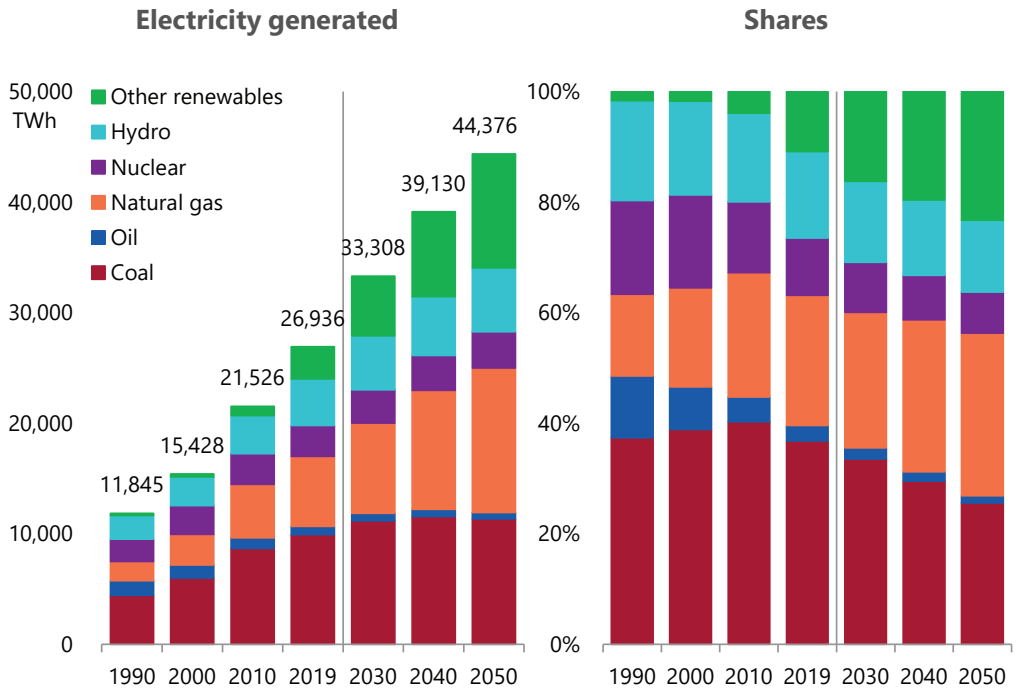
Reference Scenario

Final consumption of electricity



Reference Scenario

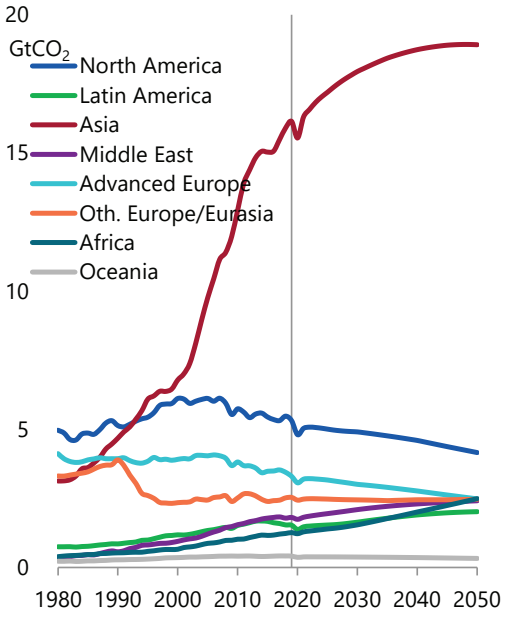
Power generation mix



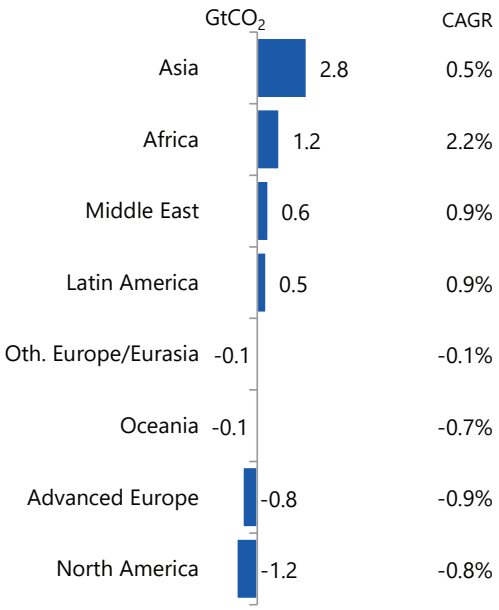
Reference Scenario

Energy-related CO_2 emissions

Emissions



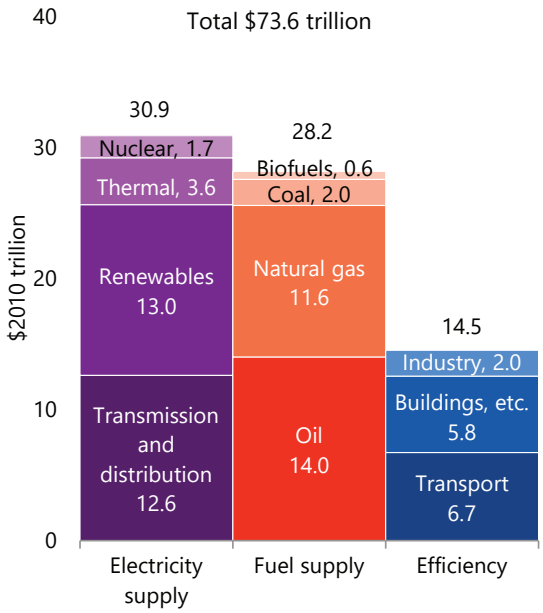
Changes (2019-2050)



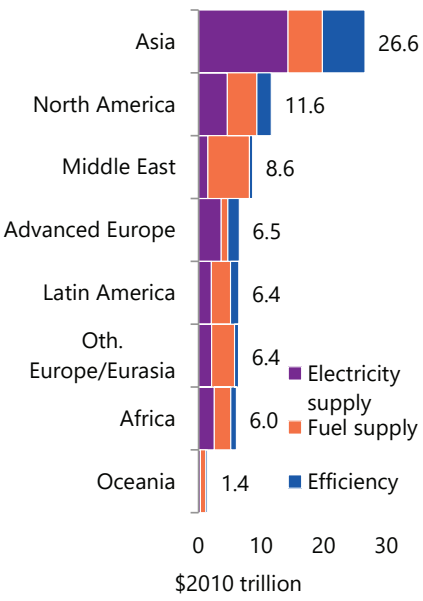
Reference Scenario

Energy-related investments (2021 – 2050)

By sector

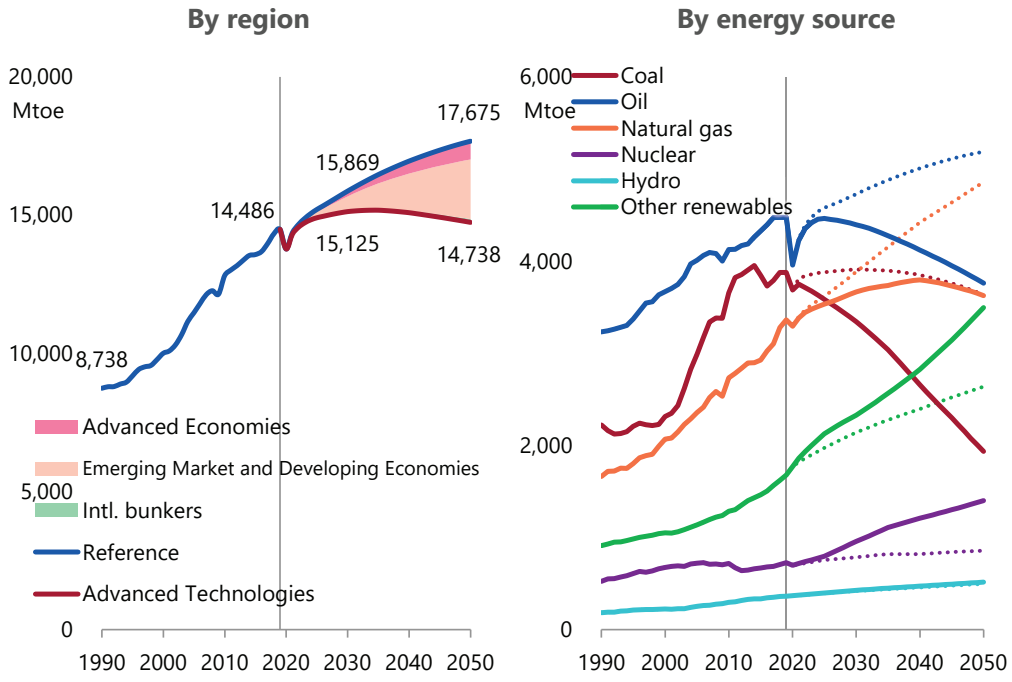


By region



Advanced Technologies Scenario

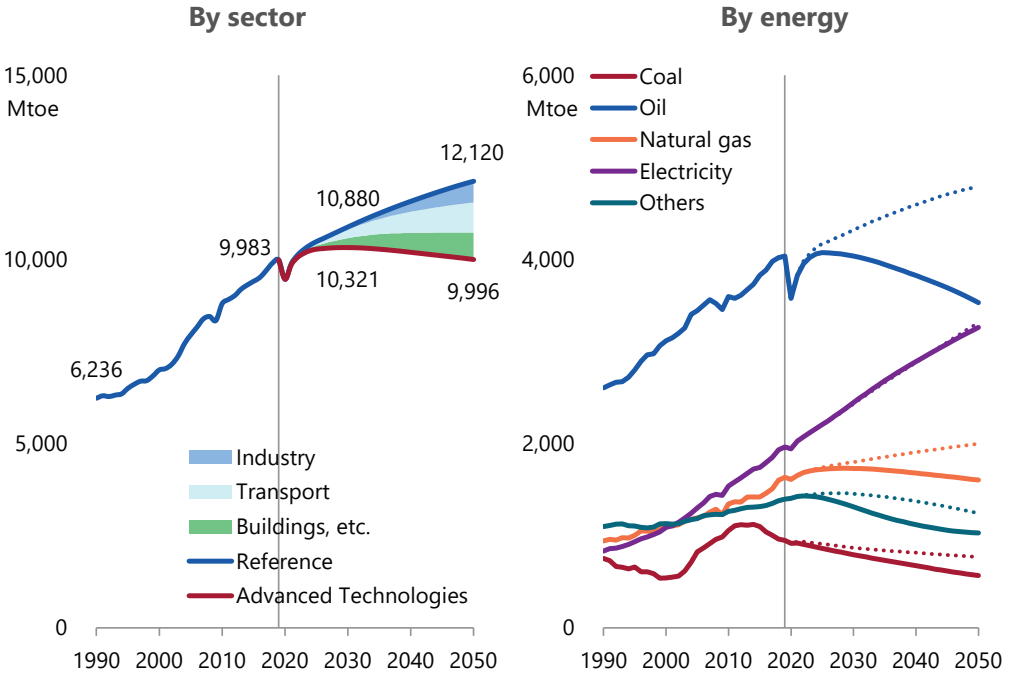
Primary energy consumption



Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

Advanced Technologies Scenario

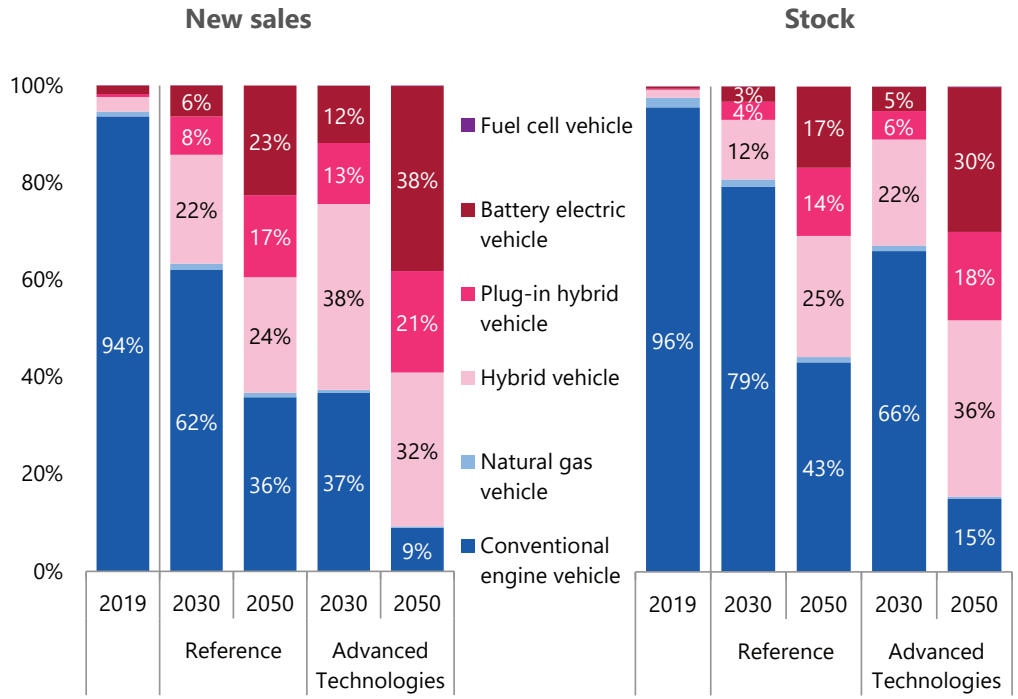
Final energy consumption



Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

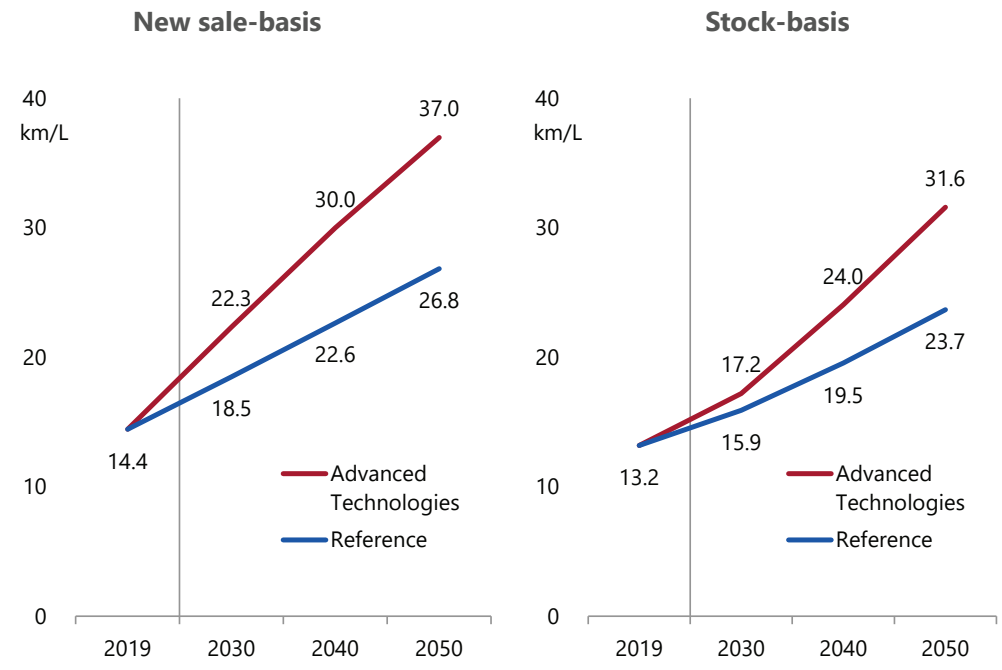
Advanced Technologies Scenario

Share of passenger vehicle



Advanced Technologies Scenario

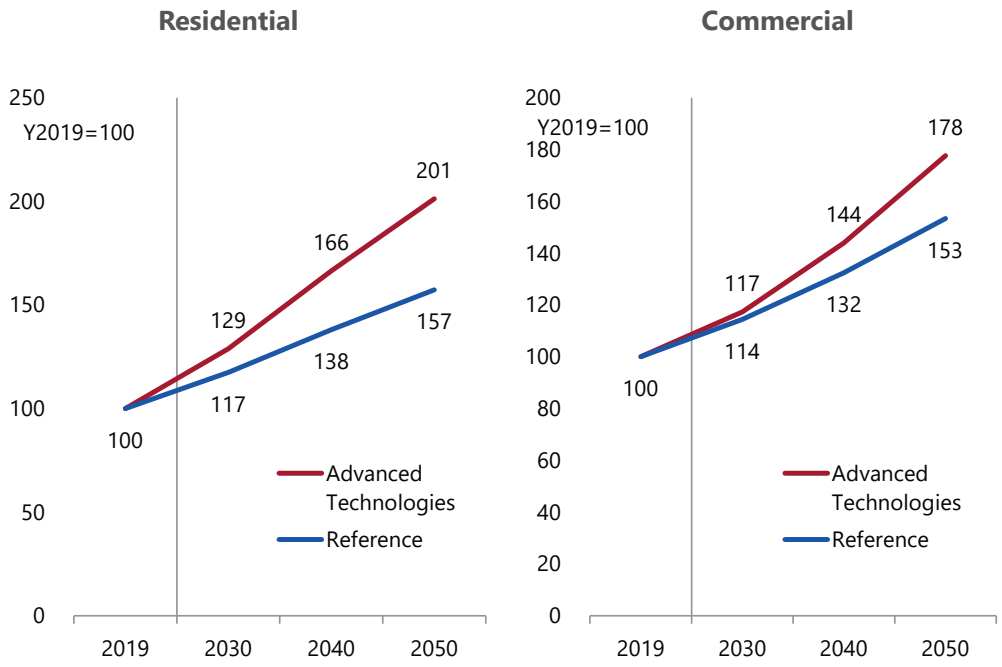
Fuel efficiency of passenger vehicle



Note: Litres of gasoline equivalent

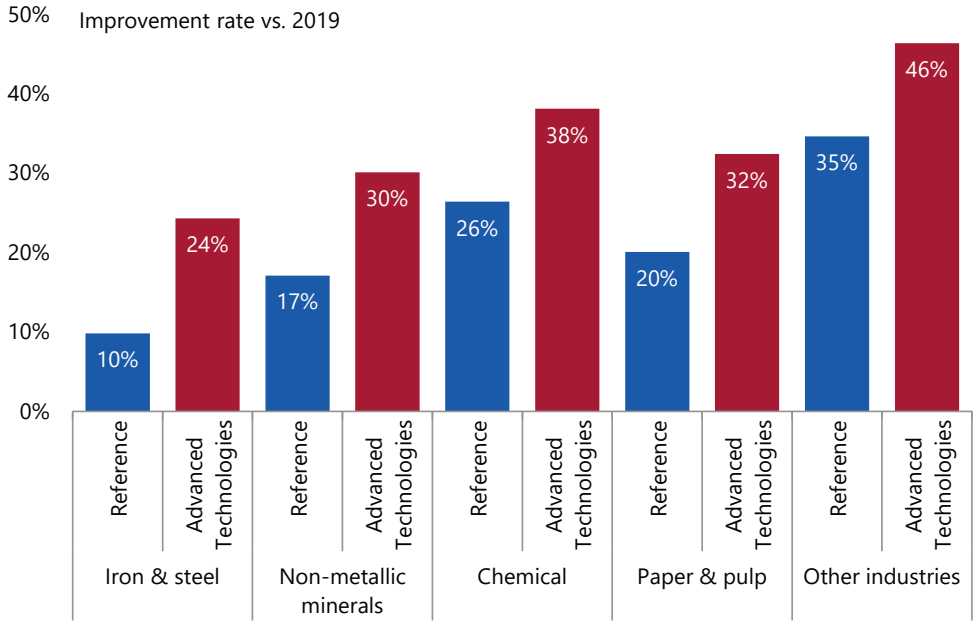
Advanced Technologies Scenario

Energy efficiency in buildings sector



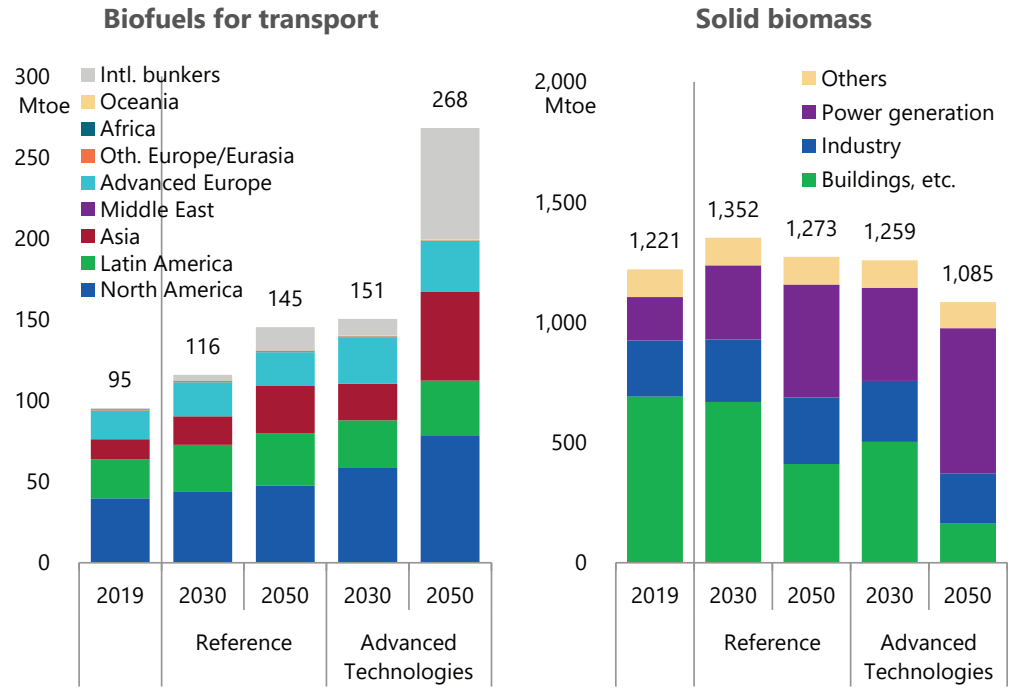
Advanced Technologies Scenario

Energy intensity improvement in industry sector



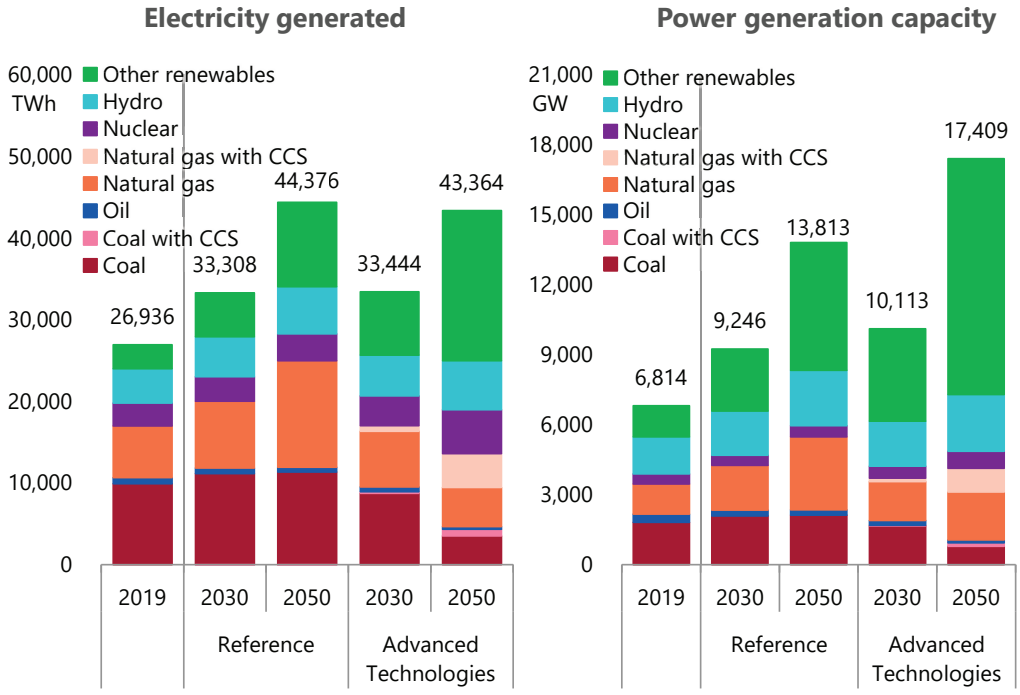
Advanced Technologies Scenario

Biomass



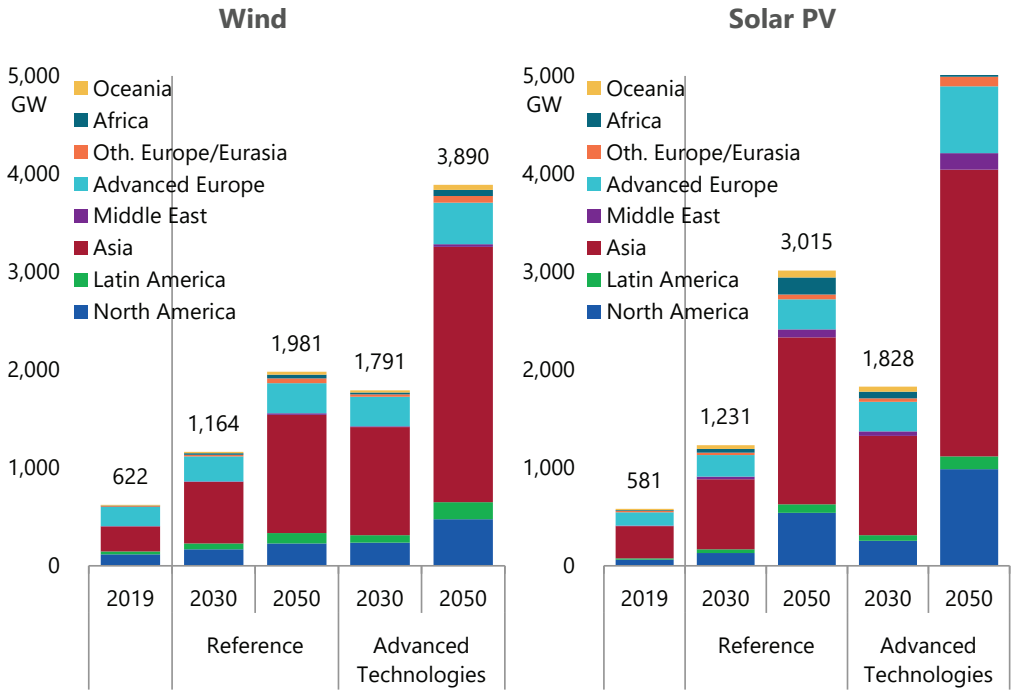
Advanced Technologies Scenario

Power generation mix



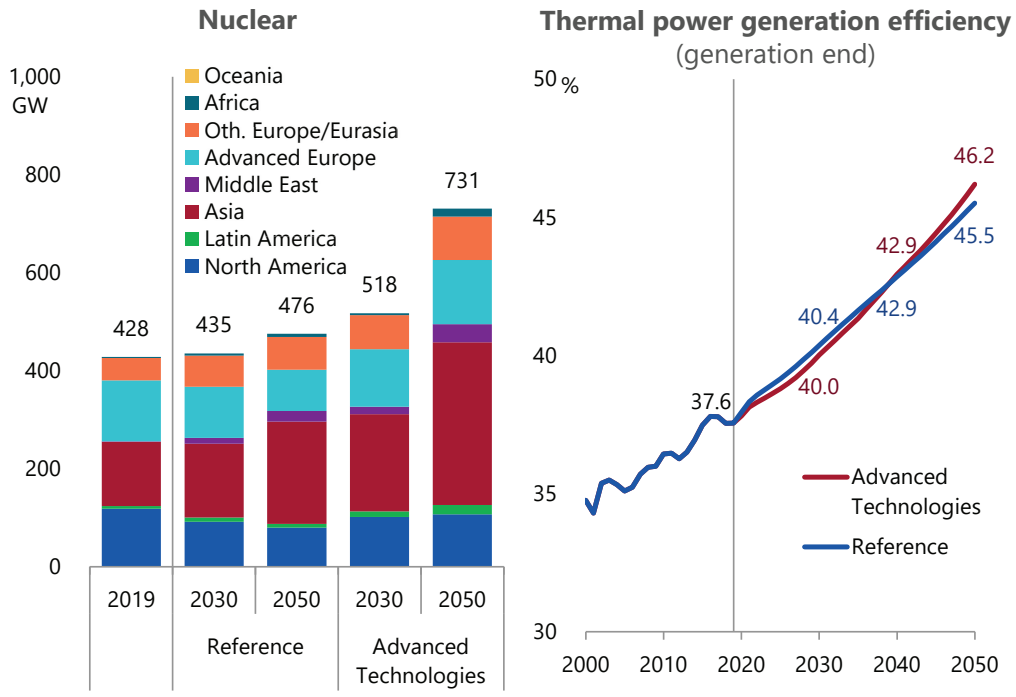
Advanced Technologies Scenario

Wind and solar PV power generation capacity



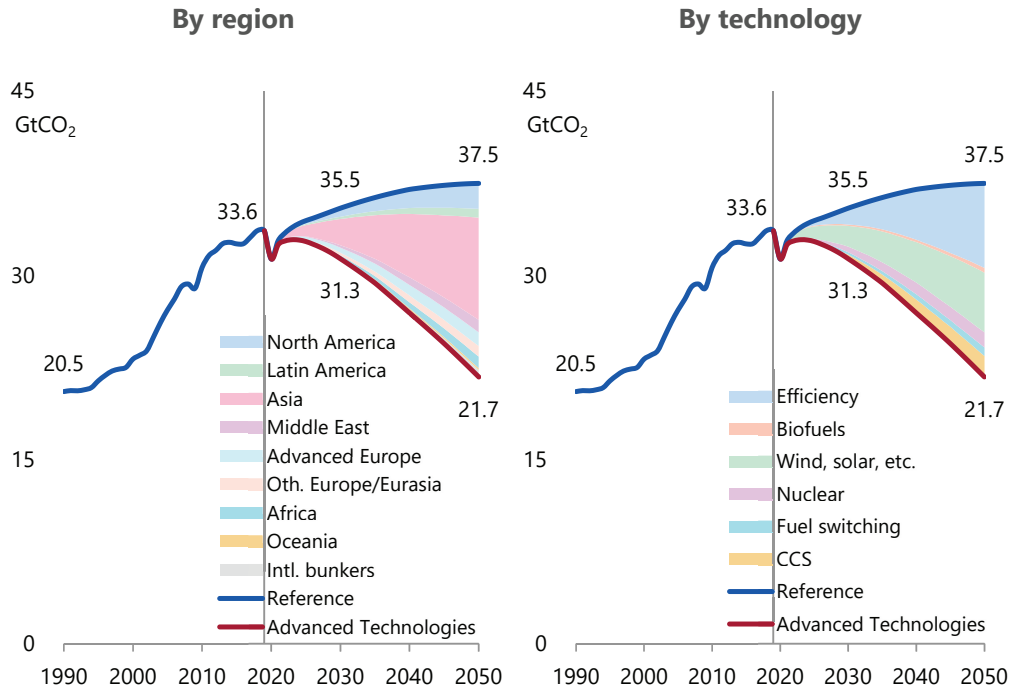
Advanced Technologies Scenario

Nuclear power generation capacity and thermal power generation efficiency



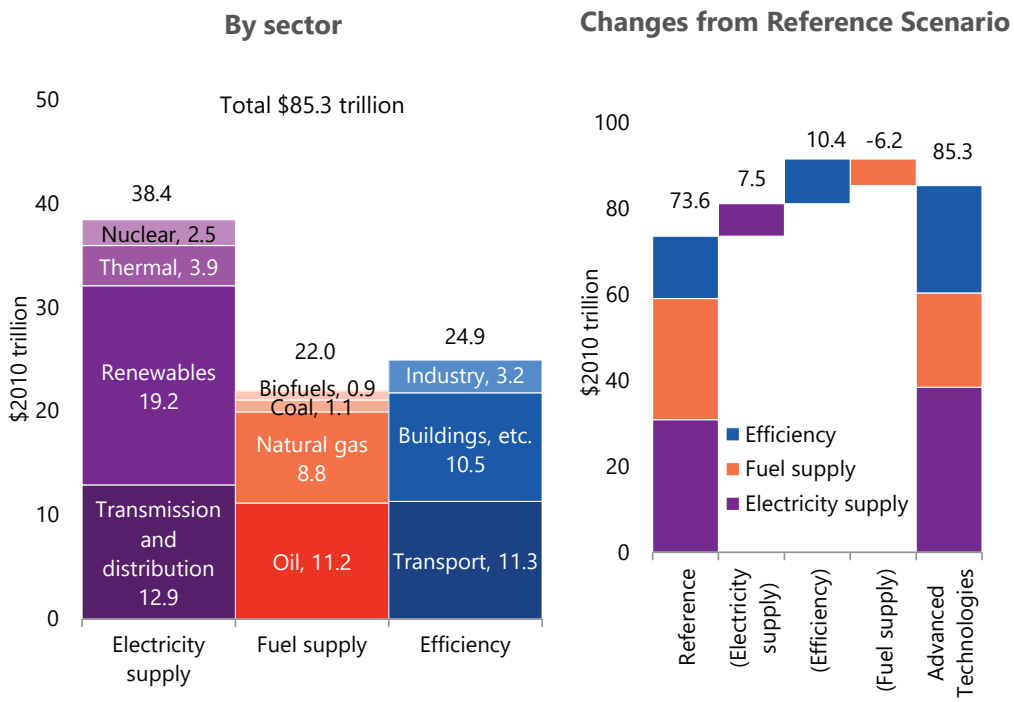
Advanced Technologies Scenario

Energy-related CO_2 emissions



Advanced Technologies Scenario

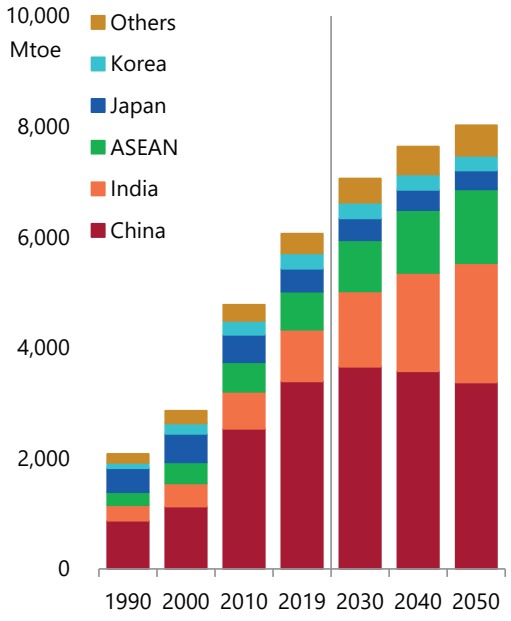
Energy-related investments (2021 – 2050)



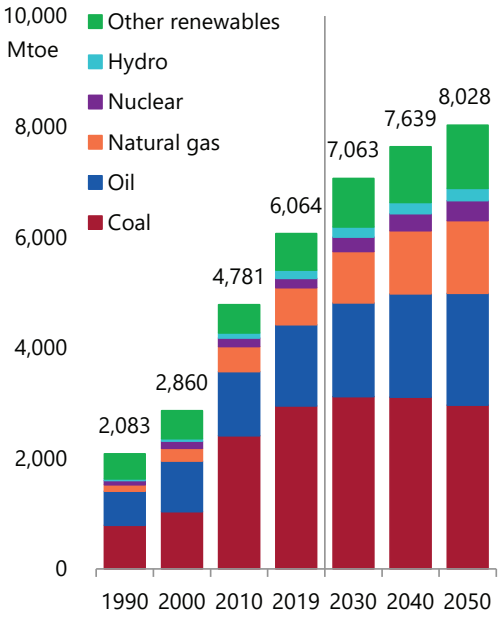
Asia | Reference Scenario

Primary energy consumption

By region



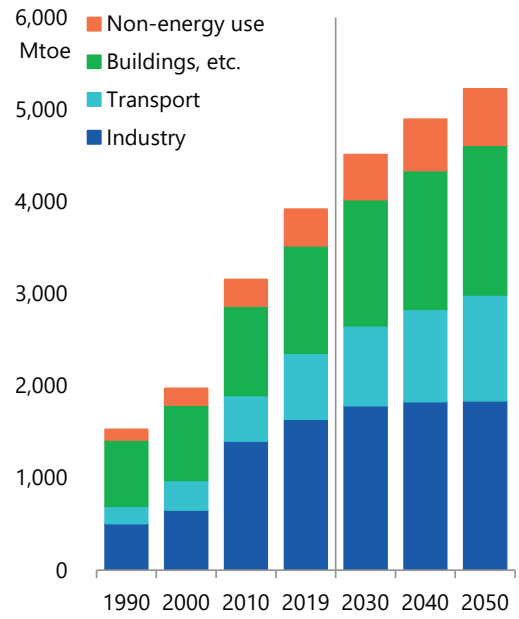
By energy source



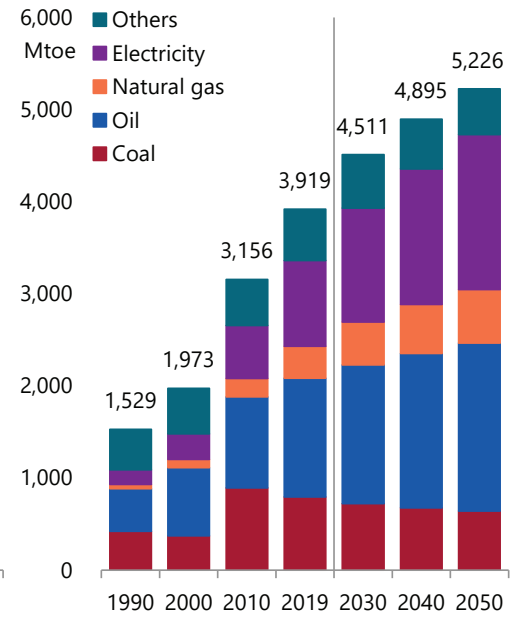
Asia | Reference Scenario

Final energy consumption

By sector

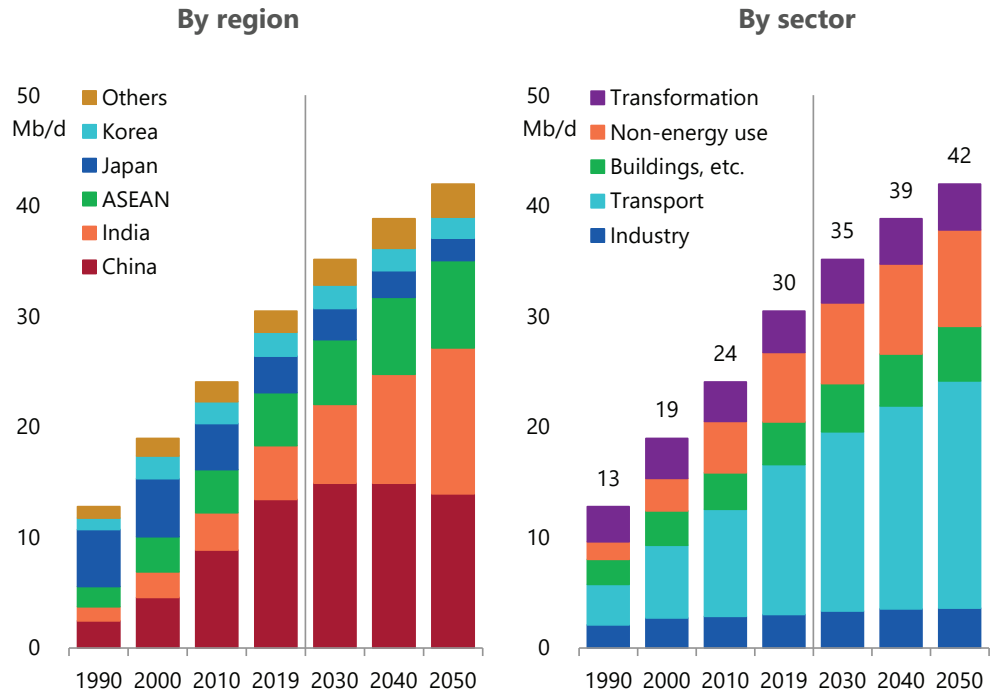


By energy source



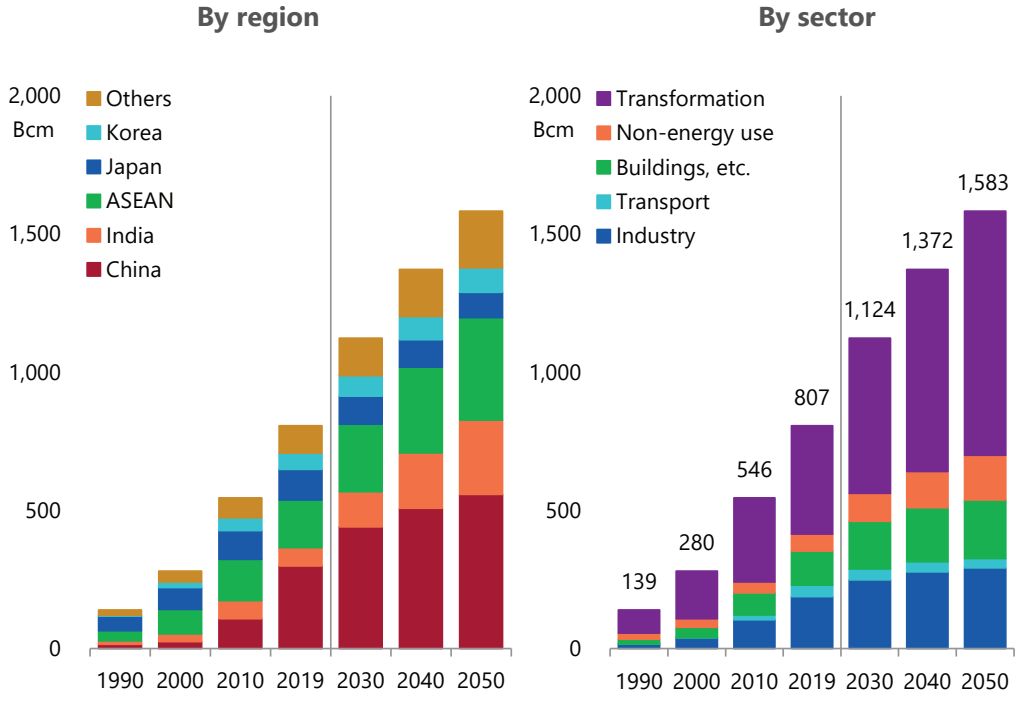
Asia | Reference Scenario

Oil consumption



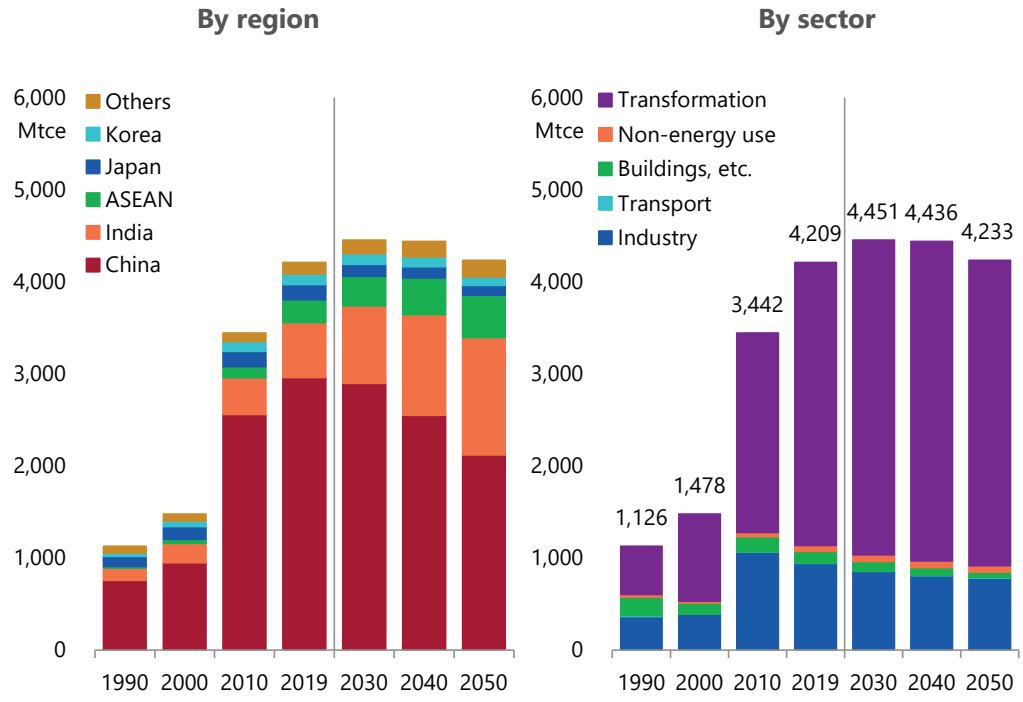
Asia | Reference Scenario

Natural gas consumption



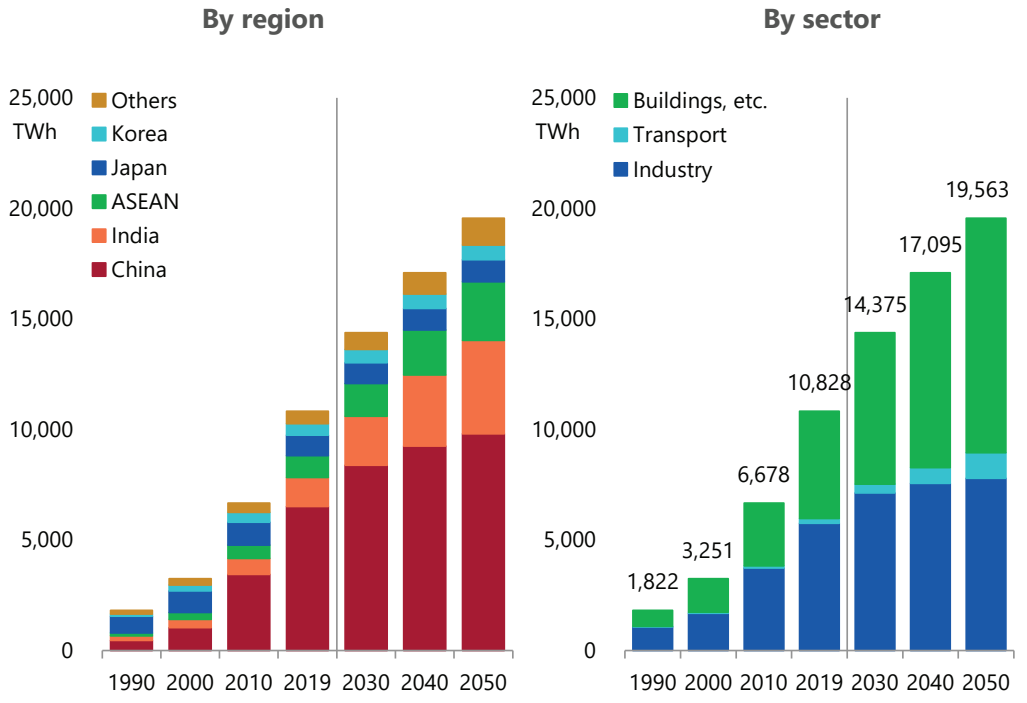
Asia | Reference Scenario

Coal consumption



Asia | Reference Scenario

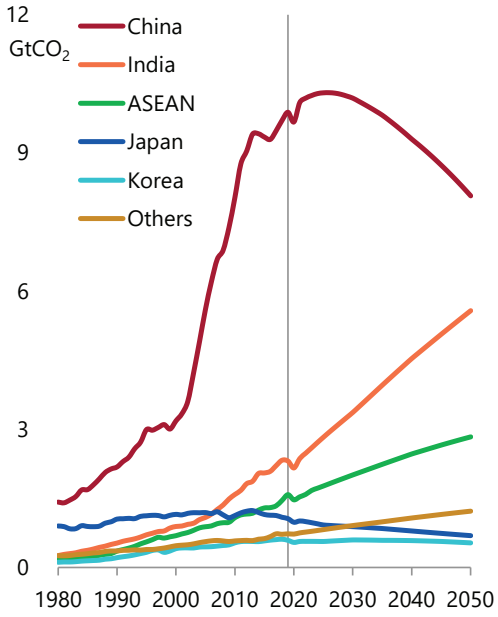
Final consumption of electricity



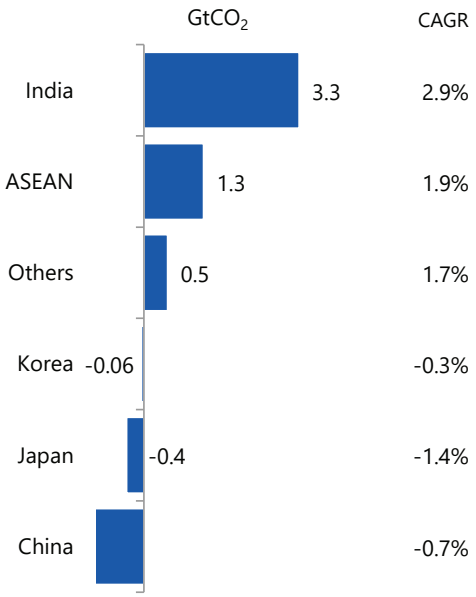
Asia | Reference Scenario

Energy-related CO_2 emissions

Emissions



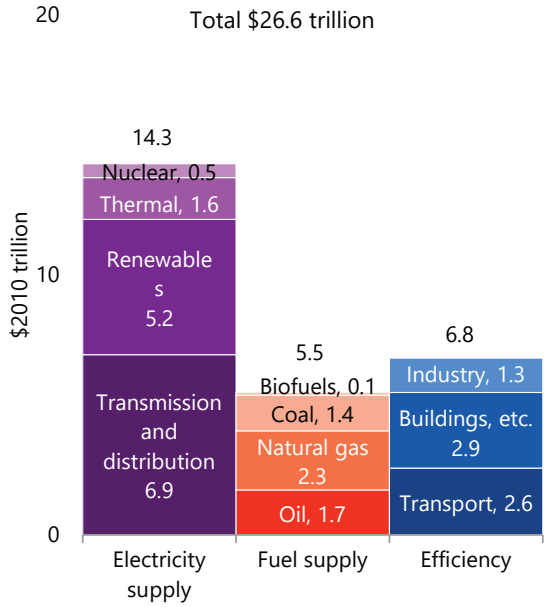
Changes (2019-2050)



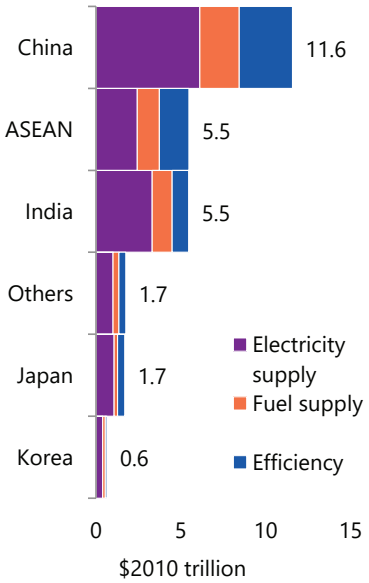
Asia | Reference Scenario

Energy-related investments (2021 – 2050)

By sector

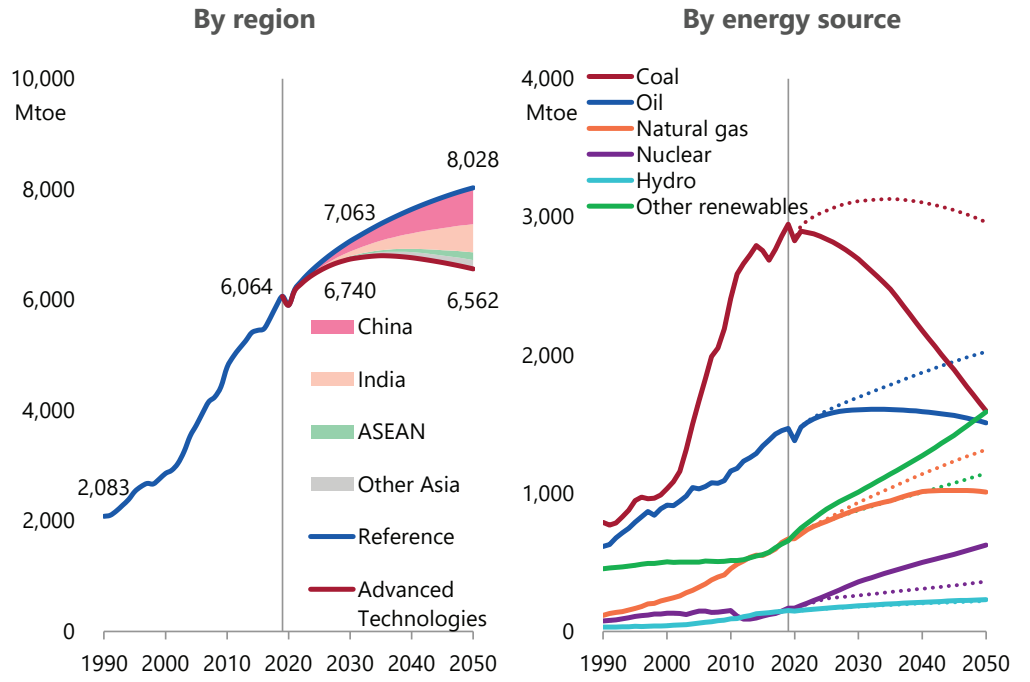


By region



Asia | Advanced Technologies Scenario

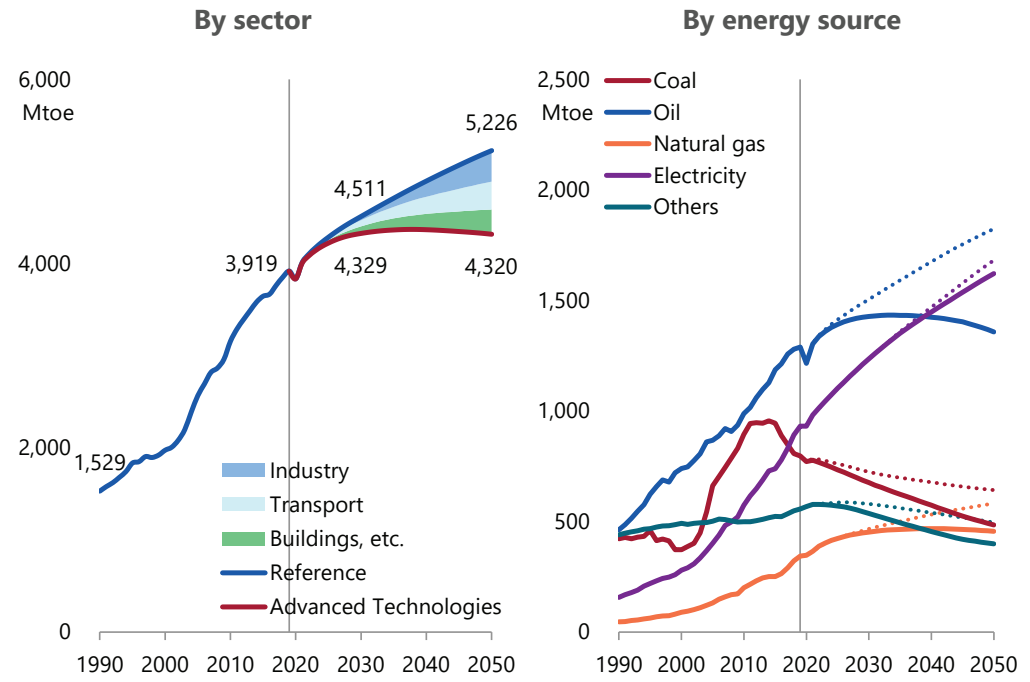
Primary energy consumption



Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

Asia | Advanced Technologies Scenario

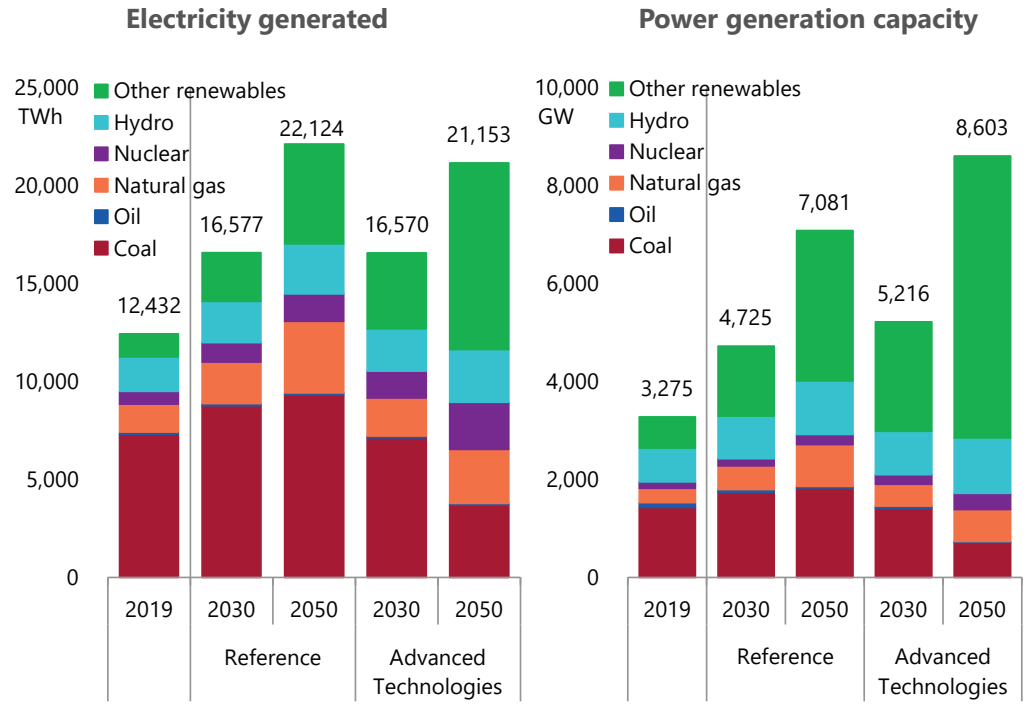
Final energy consumption



Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

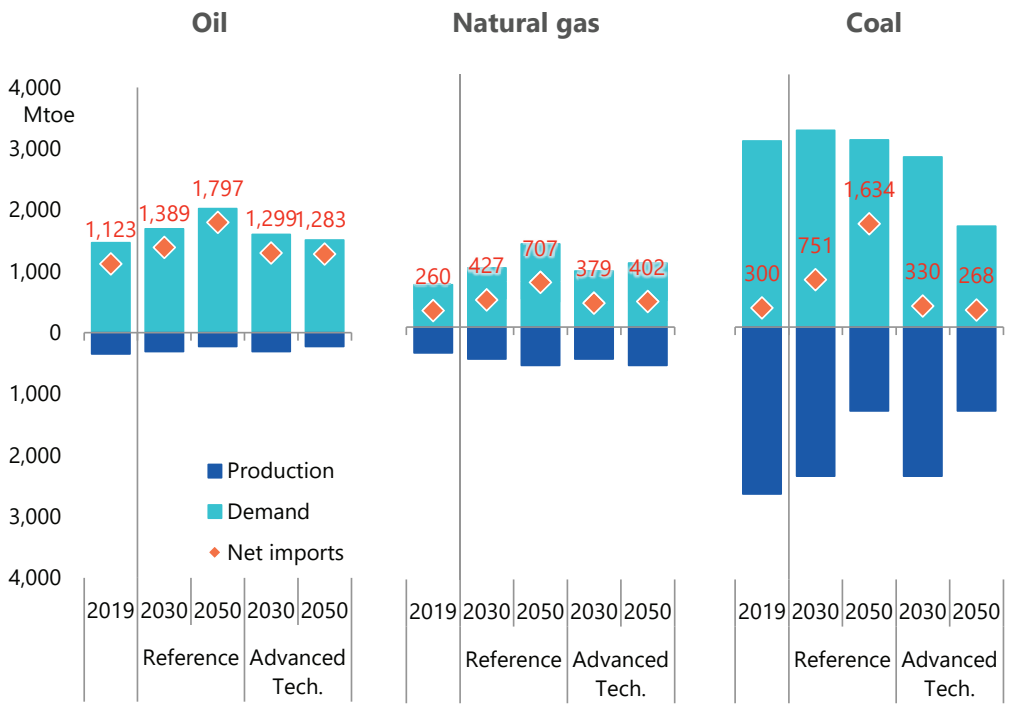
Asia | Advanced Technologies Scenario

Power generation mix



Asia | Advanced Technologies Scenario

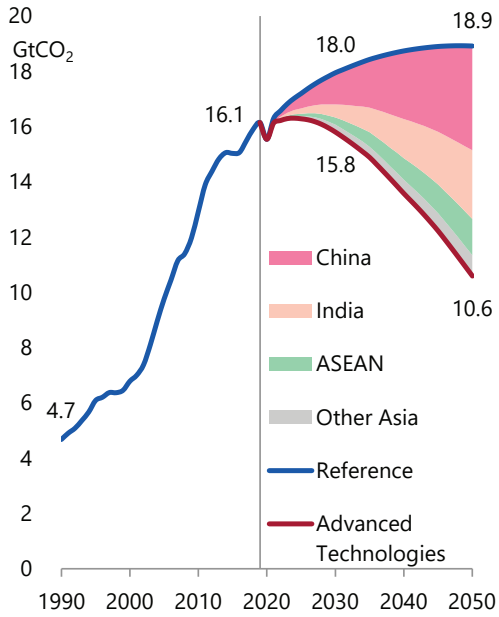
Supply and demand balance of fossil fuels



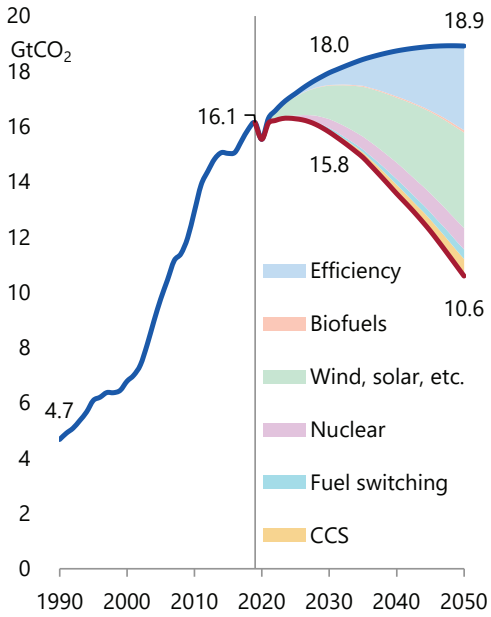
Asia | Advanced Technologies Scenario

Energy-related CO_2 emissions

By region



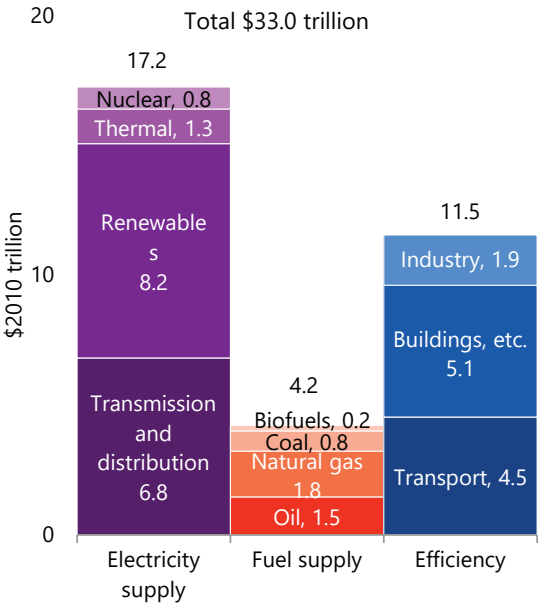
By technology



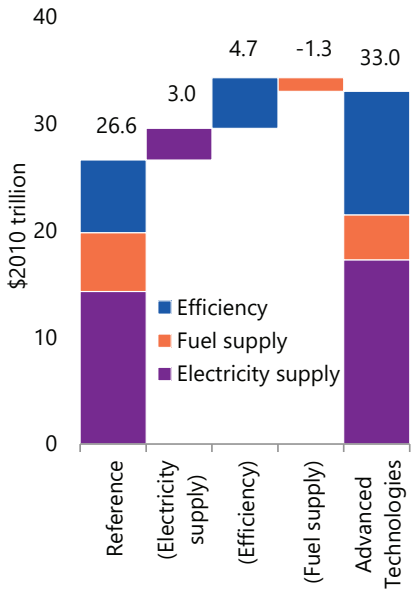
Asia | Advanced Technologies Scenario

Energy-related investments (2021 – 2050)

By sector

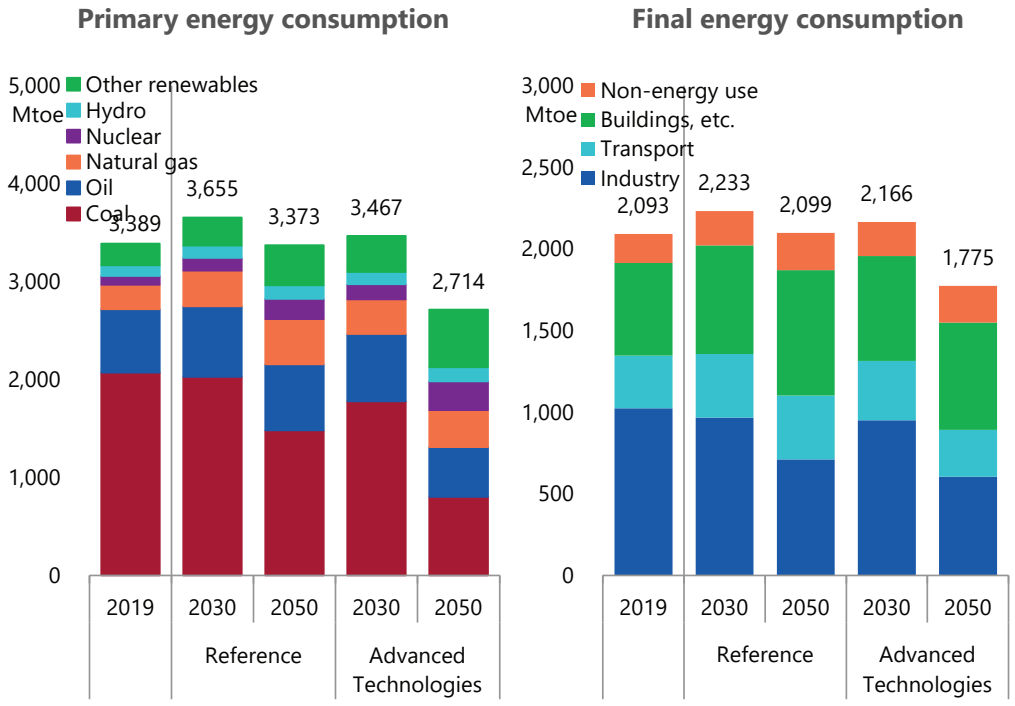


Changes from Reference Scenario



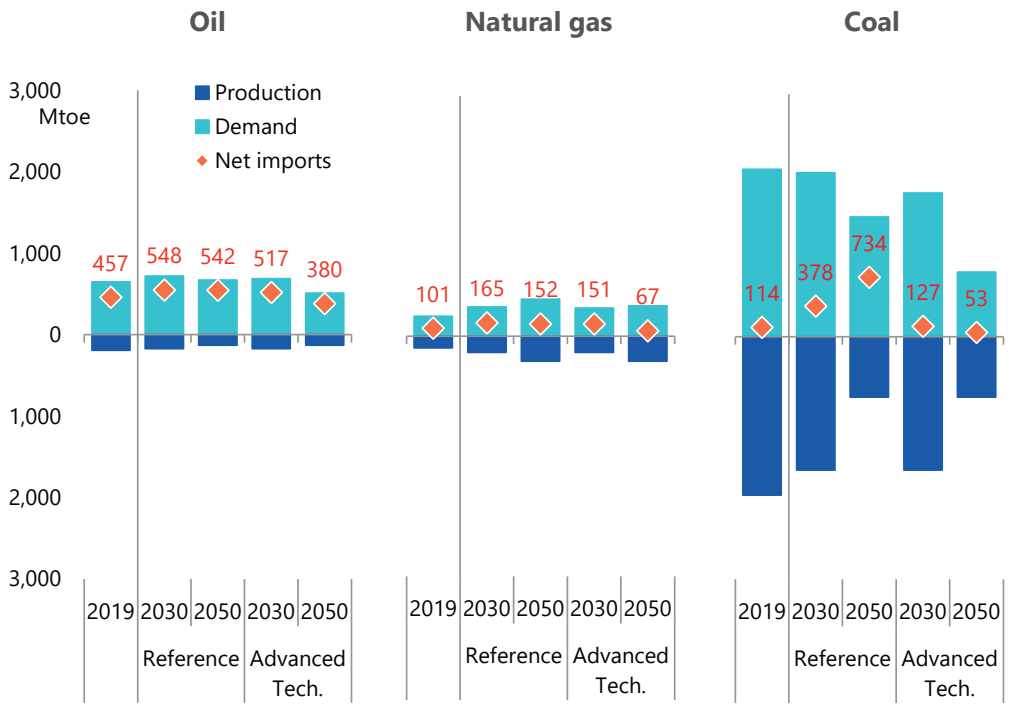
China

Energy consumption



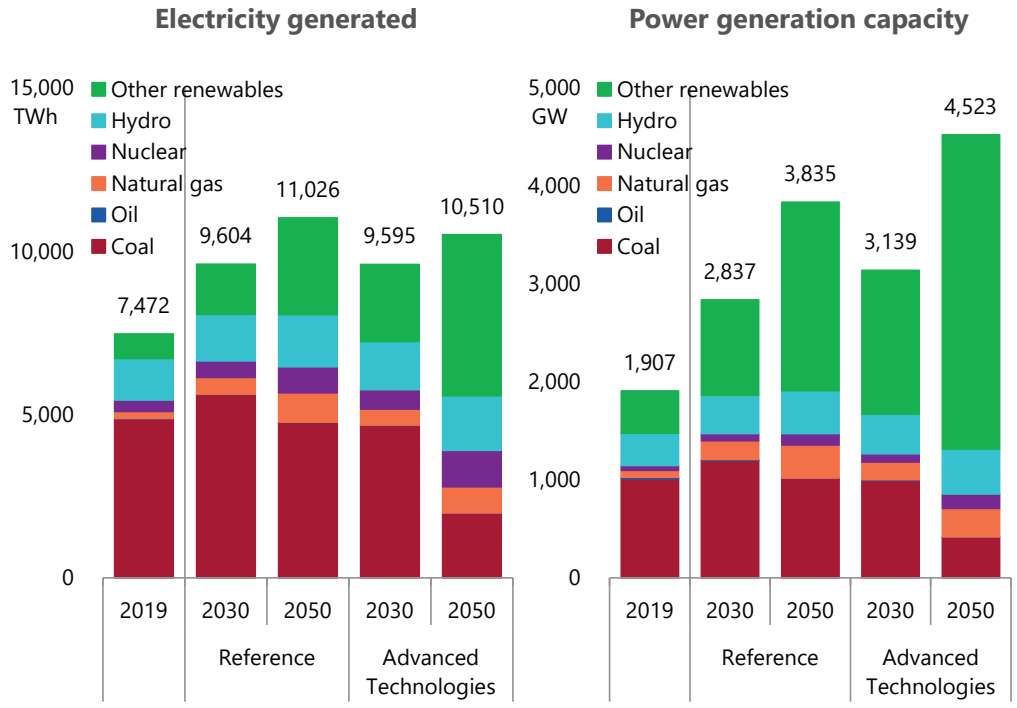
China

Supply and demand balance of fossil fuels



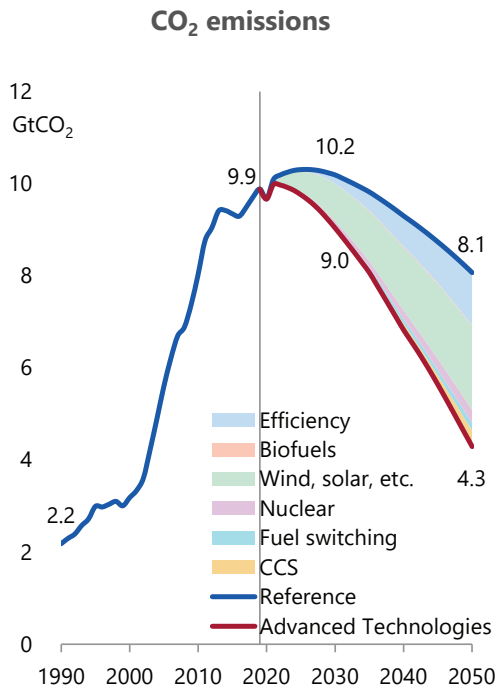
China

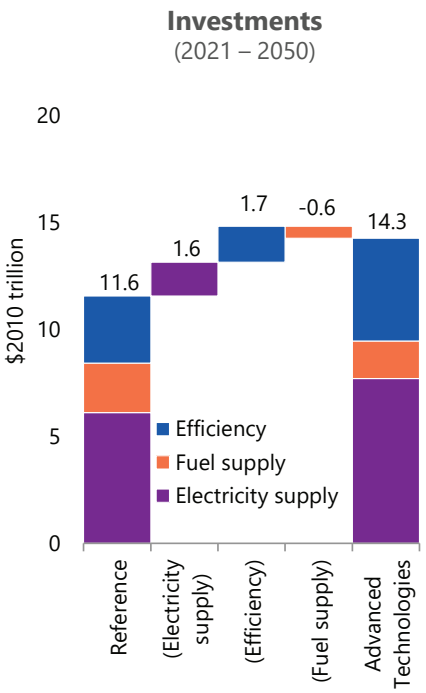
Power generation mix



China

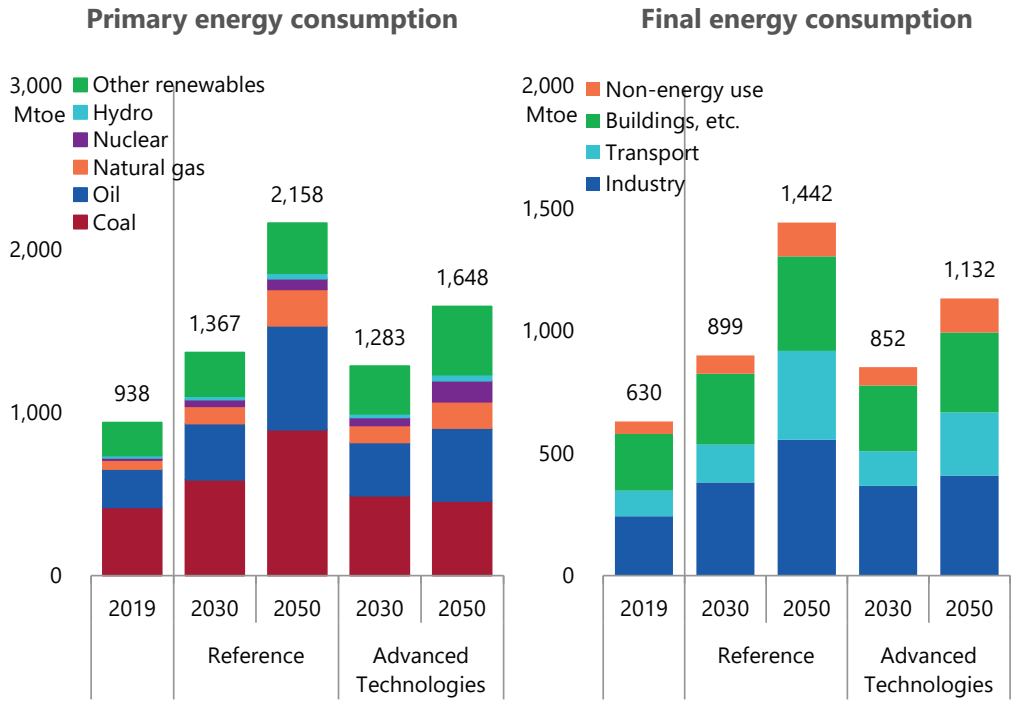
Energy-related CO_2 emissions and investments





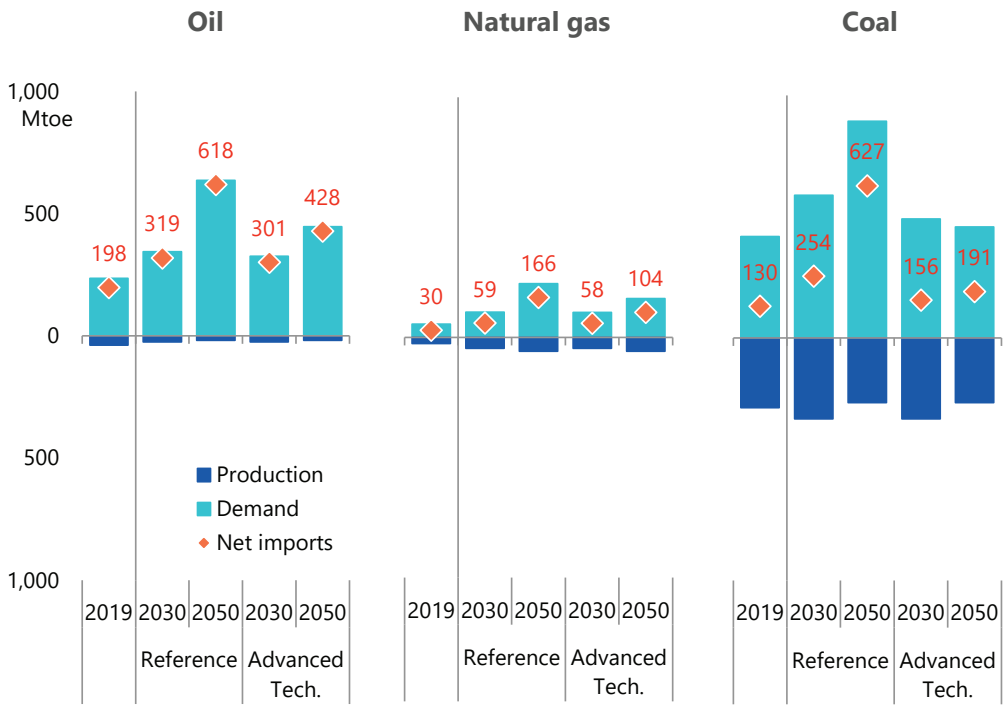
India

Energy consumption



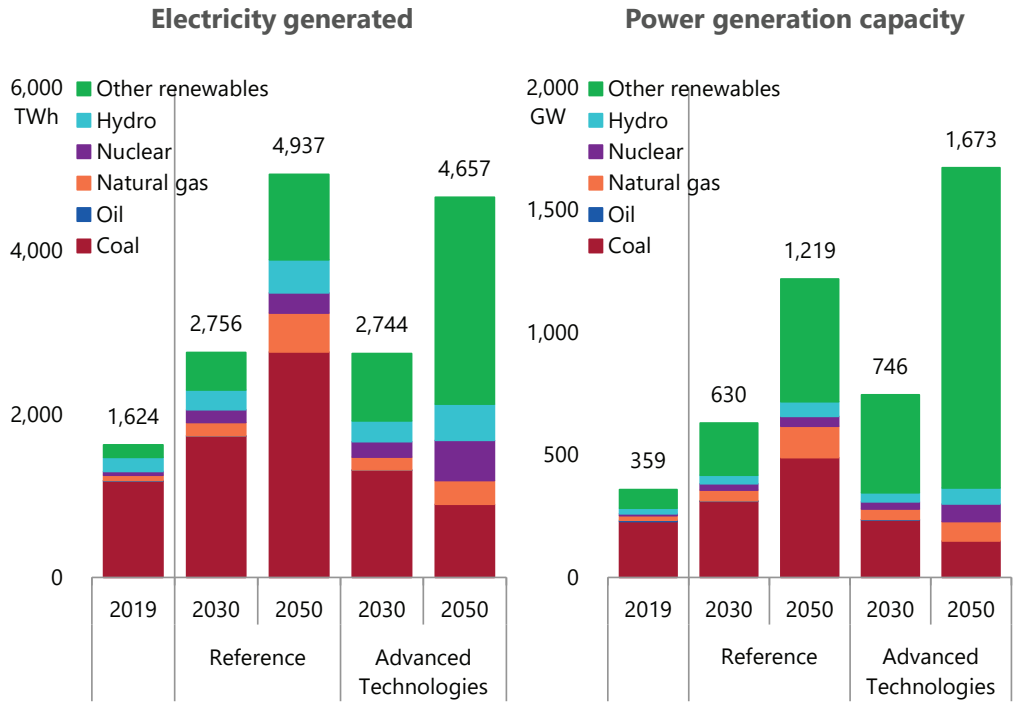
India

Supply and demand balance of fossil fuels



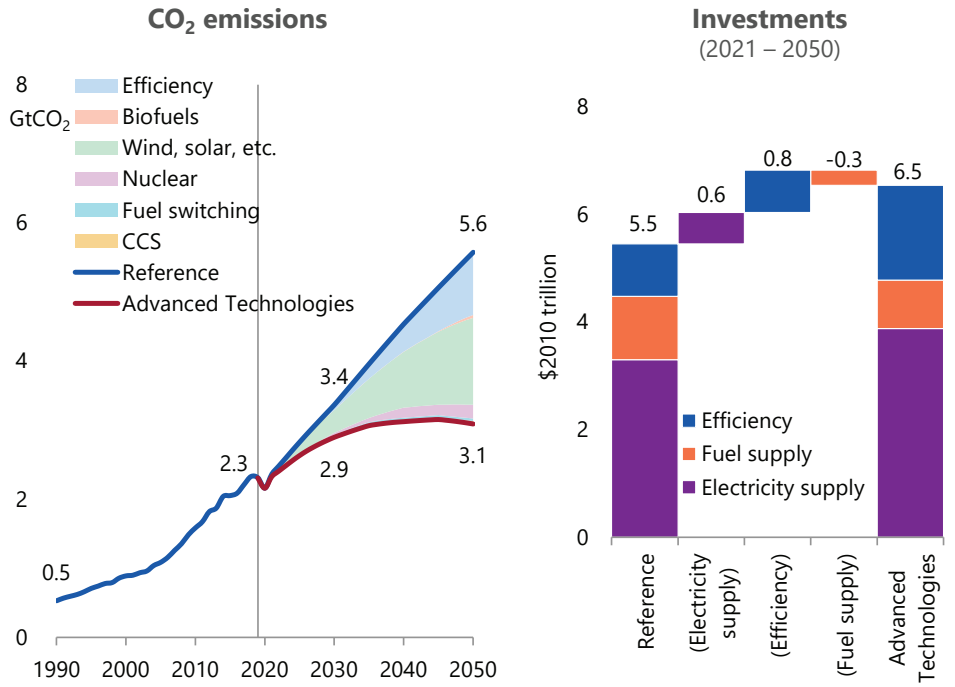
India

Power generation mix



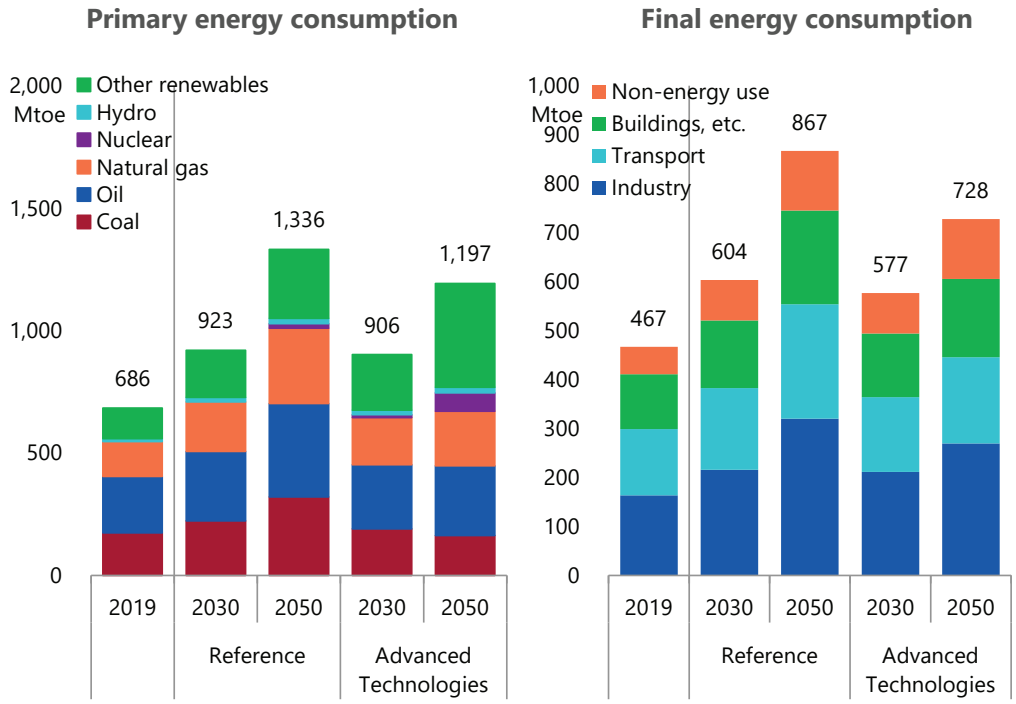
India

Energy-related CO_2 emissions and investments



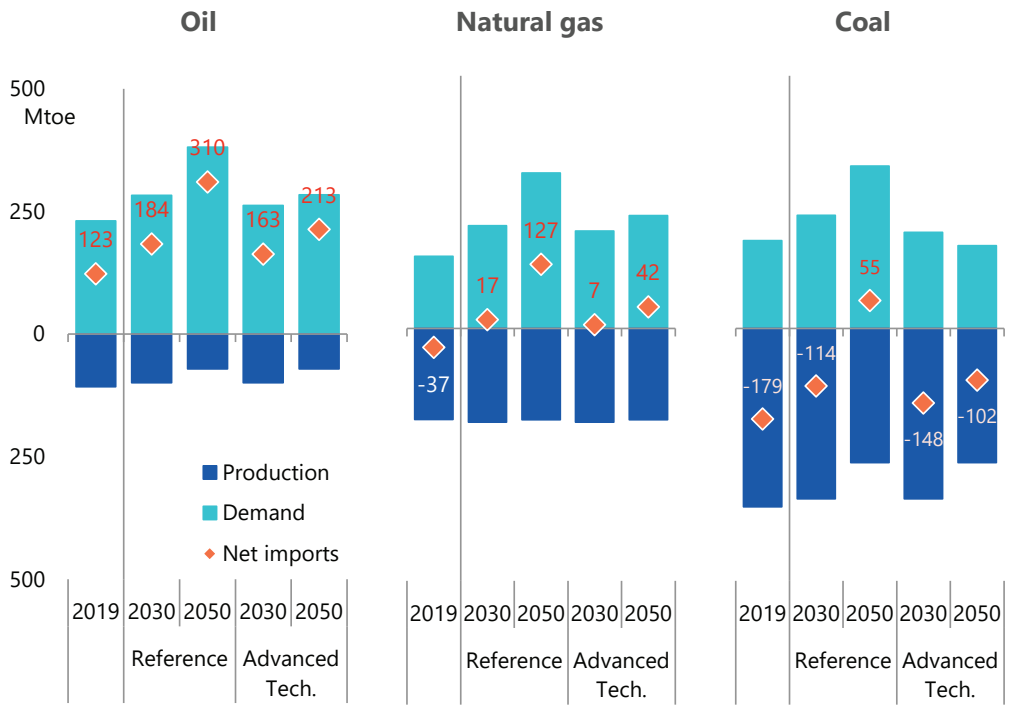
ASEAN

Energy consumption



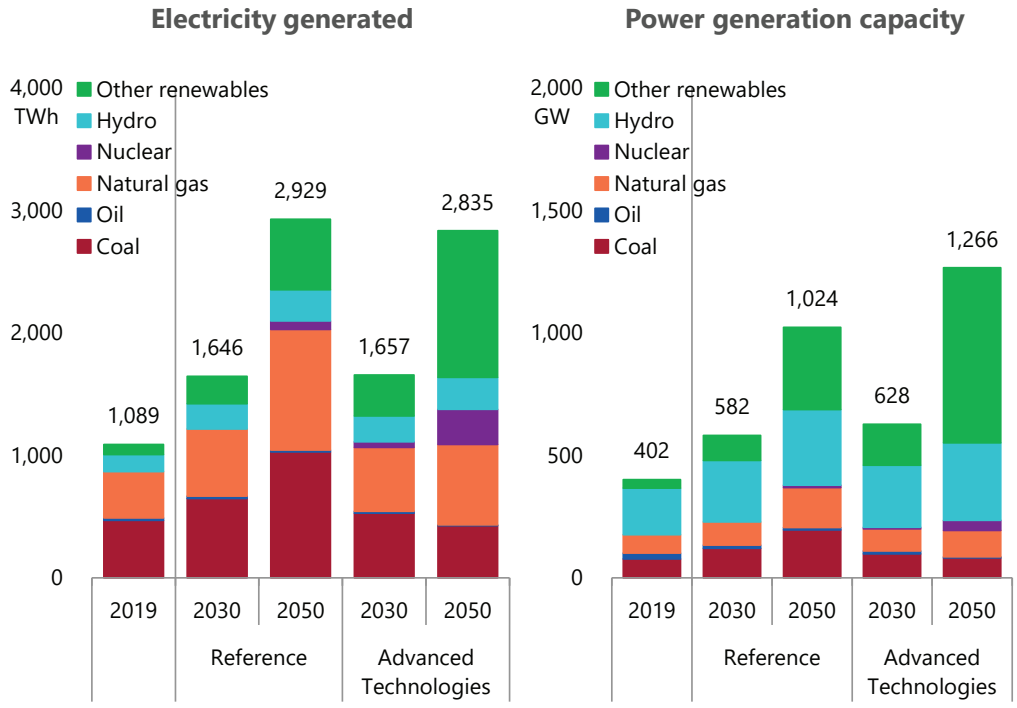
ASEAN

Supply and demand balance of fossil fuels



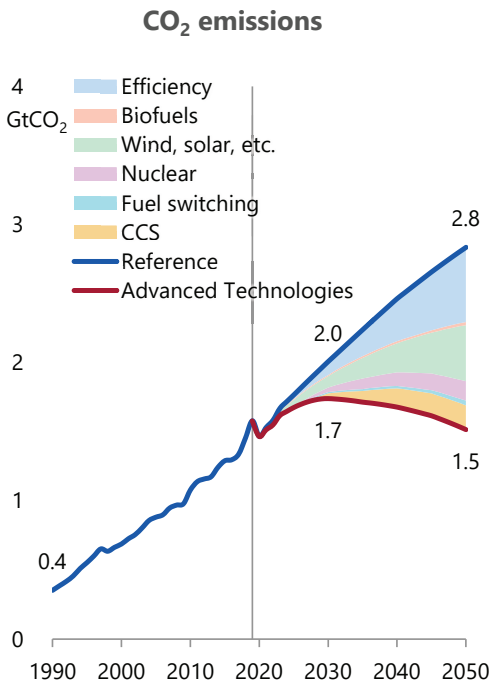
ASEAN

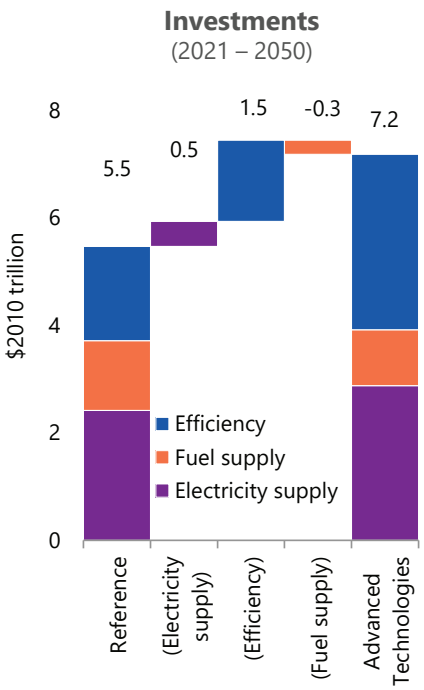
Power generation mix



ASEAN

Energy-related CO_2 emissions and investments





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October 2021

The Institute of Energy Economics, Japan

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