IEEJ Outlook 2024

Energy, Environment and Economy

Complexity of achieving the energy transition under multiple pathways

The Institute of Energy Economics, Japan

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Summary

Energy supply and demand outlook

- Under the "Reference Scenario" (REF), in which the prevailing changes from the past continue, energy consumption in 2050 will increase by 1.2 times over 2021. Energy demand in China, which has thus far driven global demand growth, will peak around 2030, with India, the Association of Southeast Asian Nations (ASEAN), the Middle East and Africa becoming the main regions for demand growth.
- Energy consumption under the "Advanced Technologies Scenario" (ATS), in which the introduction of energy and environmental technologies is strengthened to ensure a stable supply of energy and combat climate change, will plateau around 2030, and consumption in 2050 will be roughly 0.9 times that in 2021. It should be noted that this outlook is a forecast-type future projection that is based on assumptions about technology and policy trends, and contrasts with a backcast-type analysis that defines a future "landing point" and charts a path to reach it.
- In the Reference Scenario, global energy-related carbon dioxide (CO_2) emissions will remain roughly flat until 2050, and in the Advanced Technologies Scenario, they will be 14.7 Gt (down 56% from 2021), indicating that the world is halfway to achieving carbon neutrality. Reducing to the point of almost eliminating emissions in the non-power generation sectors and Emerging Market and Developing Economies remains a challenge.
- Electricity generation will double from the current level due to economic growth, electrification, and a boost in demand for green hydrogen. As the expansion of variable renewable energy is expected to continue for the foreseeable future, measures such as electricity storage and thermal power generation (with carbon capture and storage [CCS], hydrogen, etc.) will become extremely important to provide stabilisation and balance between electricity supply and demand.
- Oil and natural gas will increase throughout the Reference Scenario but, in the Advanced Technologies Scenario, they will start to decline in the 2020s and the 2030s, respectively. Still, fossil fuels together account for 73% of primary energy consumption (2050) in the Reference Scenario and 53% in the Advanced Technologies Scenario. Along with efforts to improve efficiency and reduce emissions with technologies such as CCS, securing a stable supply will continue to be an important issue.

Toward fulfilling the role of LNG and natural gas

New investment needed for stable supply of LNG and natural gas

- Cumulative required investments in the natural gas production sector from 2022 to 2050 are $9.8 trillion in the Reference Scenario and $7 trillion in the Advanced Technology Scenario. The liquefied natural gas (LNG) production sector will require an annual capacity addition ranging from 8 Mt/year (ATS) to 18 Mt/year (REF) on average, during the outlook period up to 2050.

- There is also uncertainty over those projects for which investment decisions have already been made, with possible delays and failures to materialise.

Cost trends in LNG production projects and challenges in procuring LNG for Japan

- Since 2021, supply chain disruptions triggered by the pandemic have caused delays and rising costs in the construction of LNG production projects. The overall cost pressures associated with the Russo-Ukrainian war are growing. Even after relevant investment decisions, rising instability factors in host countries of LNG production projects have caused delays.
- At the same time, technological innovations in small- and medium-scale liquefaction facilities and the expansion of modular systems ("design-one-and-build-many" strategies) are being introduced to control cost increases.
- In order to secure Japan's necessary LNG procurement in the 2030s and beyond, it will be important to form procurement partnerships such as joint purchasing and volume optimisation between multiple buyers, to make Japanese companies semi-portfolio players, and to provide public-private cooperation and policy support in these areas.

Clarification of LNG role and need for stronger security presented at G7 and at LNG Producer-Consumer Conference

- Whilst the Group of Seven (G7) recognised the importance of natural gas and LNG, it will be crucial to establish standards for acceptable 'abated' LNG in the energy transition. The importance of an internationally aligned approach for measurement and reporting of methane and greenhouse gas (GHG) emissions and their mitigations was emphasised at the G7 Ministerial Meeting and at the LNG Producer-Consumer Conference in 2023.
- The enhancement of the International Energy Agency's (IEA) role in strengthening gas and LNG security, which was presented at the LNG Producer-Consumer Conference, is also noteworthy.
- Furthermore, close dialogue between LNG producing and consuming countries through bilateral government-level consultations, procurement cooperation among consuming countries, and promotion of emergency accommodation cooperation will be important to strengthen gas and LNG security.

Issues for long-term stabilisation and development of the LNG market

- In the international LNG market, LNG investment and construction activities are advancing, especially in the United States, partly supported by LNG offtake commitments under long-term contracts. On the other hand, projects for which investment decisions were made in the past also face uncertainty and delays. Therefore, there is no guarantee that buyers' procurement of LNG with a combination of measures including long-term contracts, as well as suppliers' capability of LNG delivery, are secured yet.
- It is necessary to develop a variety of financial instruments to meet the funding needs of LNG production projects.
- Building partnerships between LNG buyers from the same and/or different countries, including joint procurement, will be effective in light of the buyers' desire for flexibility, especially from emerging LNG markets with the expanding composition of buyers. Such partnership will also contribute to ensuring the stability of Japan's LNG requirements, including long-term contracts.

Growing importance of negative emissions technology

- Interest in negative emission technologies (NETs), which capture GHGs from the atmosphere and store them elsewhere to stay over long periods of time, has increased in recent years both domestically and internationally. It is extremely difficult to achieve carbon neutrality without the contribution of NETs, especially in the industry and long-haul transport sectors, where the use of fossil fuels is certain to continue. Countries should more clearly and specifically position the use of NETs in their emissions reduction plans for long-term carbon neutrality.
- There are a wide variety of NETs, but many will take time to be commercialised. For individual NETs, countries need to take early steps to understand the potential for carbon removal in their countries, consider accurate and transparent methods for measuring removal, reduce removal costs, establish the value chains required for the introduction of each NETs, and assess the impact on surrounding ecosystems.
- International cooperation is also essential to the full-scale introduction of NETs. First, there is a need to widely share international recognition that NETs are an essential means of achieving carbon neutrality, and to accelerate preparatory work towards the establishment of internationally shared measurement, reporting and verification (MRV) systems and carbon removal certification and removal credit systems. At the same time, it is important to deepen discussions at the intergovernmental level in the future with a view to creating a mechanism to realise cross-border removal projects and their reflection in Nationally Determined Contributions (NDCs).

Paths towards ASEAN's energy transition

- ASEAN, with its remarkable economic development, will be at the centre of future global energy demand growth, and of the emission reductions. ASEAN will affect the success or failure of the global decarbonisation. As such, cost reductions are essential for achieving both economic growth and carbon neutrality, while an economically rational energy mix should be pursued.
- Assumptions about future economic growth and energy efficiency improvements will make a big difference in projecting future energy demand. It is not enough to focus only on the 'ratio' of renewable energy, because the total amount of energy demand will significantly change the energy mix we should be aiming for.
- The power generation cost by renewable energy is expected to be low among zero-emission power sources, making it a promising power source. However, it should be kept in mind that there is a possibility of higher electricity costs if the power facilities are spread beyond the suitable area, and that integration costs for stabilising electricity supply and demand will increase if variable renewables account for the majority of the power supply. It is necessary to determine the optimal quantity according to demand, weather conditions and land availability.
- Natural gas plays a major role in reducing emissions in the industry sector (especially for high temperature demand that is difficult to be electrified) and balancing electricity supply and demand. It can be an affordable fuel, especially in reducing emissions during the

transition period toward zero emissions. Expansion of supply capacity and stabilisation of the natural gas supply will contribute to reducing energy transition costs.

Part Ⅰ

Energy supply and demand outlook

1. Framework 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 environmental policies, technologies, etc. that have been in place so far. This scenario incorporates effects expected to appear as a result of traditional and conventional policies – in other words, policies or technologies are not necessarily fixed as they currently are. On the other hand, we assume that no aggressive energy efficiency improvement or low-carbonisation policies deviating from past trends will be adopted.

Advanced Technologies Scenario

In this scenario, all countries in the world are assumed to strongly implement energy and environmental policies contributing to securing stable energy supplies and enhancing countermeasures against climate change and air pollution. The effects of those policies are

[1] See Table A1 for a detailed definition.

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 throughout the world, with their application opportunities and acceptability in the real society considered.

Figure 1-2 | Technology introduction assumptions [Advanced Technologies Scenario]

Introduction and enhancement of environmental regulations and national targets	Promoting technology development and international technology cooperation
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.	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 industrial process technologies at the highest efficiency level (for steelmaking, cement, paper-pulp, etc.); Introduction of hydrogen reduction iron-making technology

Transport
Further diffusion of clean energy vehicles (highly fuel-efficient vehicles, hybrid vehicles, plug-in hybrid vehicles, electric vehicles, hydrogen 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 enhancement of insulation

Supply-side technologies

Renewable energies
Further diffusion of power generation from wind, solar PV, concentrated solar power (CSP), biomass-fired, marine and biofuels

Enhanced introduction of nuclear power
Acceleration in nuclear power plant construction and improvement in capacity factor

Promotion of highly efficient fossil fuel-fired power generation technologies
Further diffusion of SC, USC, A-USC, coal IGCC (Integrated Gasification Combined Cycle) and natural gas MACC II (More Advanced Combined Cycle II) plants

Hydrogen-related technologies
Thermal power generation fuelled by hydrogen and ammonia, and synthetic methane and synthetic fuels using hydrogen

Next-generation power transmission and distribution technologies
Low-loss substation equipment and voltage regulators

Carbon capture and storage (CCS) and carbon dioxide capture, utilisation and storage (CCUS)

Note: SC stands for supercritical thermal power, USC for ultra-supercritical thermal power, A-USC for advanced ultra-supercritical thermal power, IGCC for integrated coal gasification combined cycle, and MACC II for 1 600°C-class combined cycle power generation.

1.2 Major assumptions

The energy supply and demand structure is subject to population, economic growth, other social and economic factors, energy prices, as well as the above-mentioned energy utilisation technologies and energy and environmental policies. The following assumptions for economic growth and population among these factors are common to the Reference and Advanced Technologies Scenarios.

Economy

Recent situation

In 2022, the economy recovered from the blows of Covid-19 and the global economy normalised, resulting in tighter supply and demand. Meanwhile, Russia's prolonged invasion of Ukraine, which began in February 2022, has raised concerns about supplies of energy and food. These factors caused prices to rise worldwide, and monetary policy to resolve the situation was rapidly tightened globally, exerting downward pressure on the economy. On the other hand, some signs of resilient development were seen, mainly due to service consumption such as travel and food services following the economic recovery as Covid-19 subsided, increased capital investments, stabilised employment, excess savings accumulated due to implemented countermeasures against the spread of Covid-19, and measures against soaring prices.

In the United States, the economy has continued to recover moderately due to a pick-up in private consumption following the aggressive monetary easing by the Federal Reserve Board (FRB) which aimed to stabilise prices. As a measure against inflation mainly driven by the large gap between supply and demand (inflation gap) due to supply-side turmoil resulting from Covid-19 and rising energy prices, the FRB lifted its zero-interest rate policy in March 2022 to tighten monetary policy, raising interest rates for the 10th consecutive time. At the June 2023 meeting, further hikes were temporarily paused, but in light of the inflation situation, it was decided to raise the rate again by 0.25% at the July meeting. This brought the policy rate to 5.25%–5.5%, the highest level in 22 years since 2001. These hikes were intended to curb high inflation, but there are fears that they could hurt the economy.

In China, the economy has picked up since the lockdown was lifted in Shanghai in May 2022, driven by infrastructure investment through the accelerated issuance of special local government bonds. On the other hand, with the debt problems of real estate companies continuing, the rate of decline in real estate development investment has accelerated, weakening the performance of the real estate-related sector, which accounts for 30% of gross domestic product (GDP). The resurgence of Covid-19 infections in November caused demand to decline, especially in the service industry, and the relaxation of quarantine measures and the reduction of testing systems progressed, making it difficult to predict the impact on the economy. In addition, the pandemic has caused the birthrate to decline further; accordingly, international organisations have revised their population forecasts downward. The long-term growth of China's GDP may be lower than previously projected.

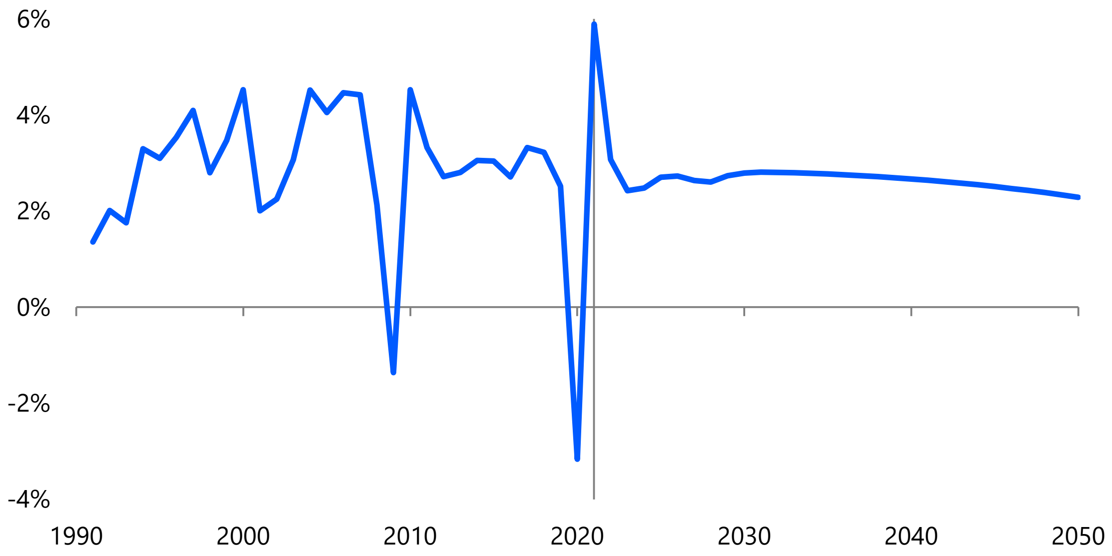
In Europe, while affected by Russia's invasion of Ukraine, the economy continues to recover moderately, boosted by private consumption. High levels of inflation have continued due to soaring fuel and food prices resulted from the embargo on Russian fossil fuels imposed as a sanction against Russia. Against this backdrop, lower energy prices caused by the easing of the supply and demand situation due to the warm winter in 2022, the accompanying easing of supply constraints, and the improvement in employment contributed to the continuation of moderate growth. However, the outlook remains uncertain due to the rising pressure on prices amid soaring energy prices and the effects of rapid monetary tightening to contain that pressure.

Assumptions for the future

While referring to country-by-country economic development plans and economic outlooks prepared by think-tanks around the world, economic growth is assumed to be as follows:

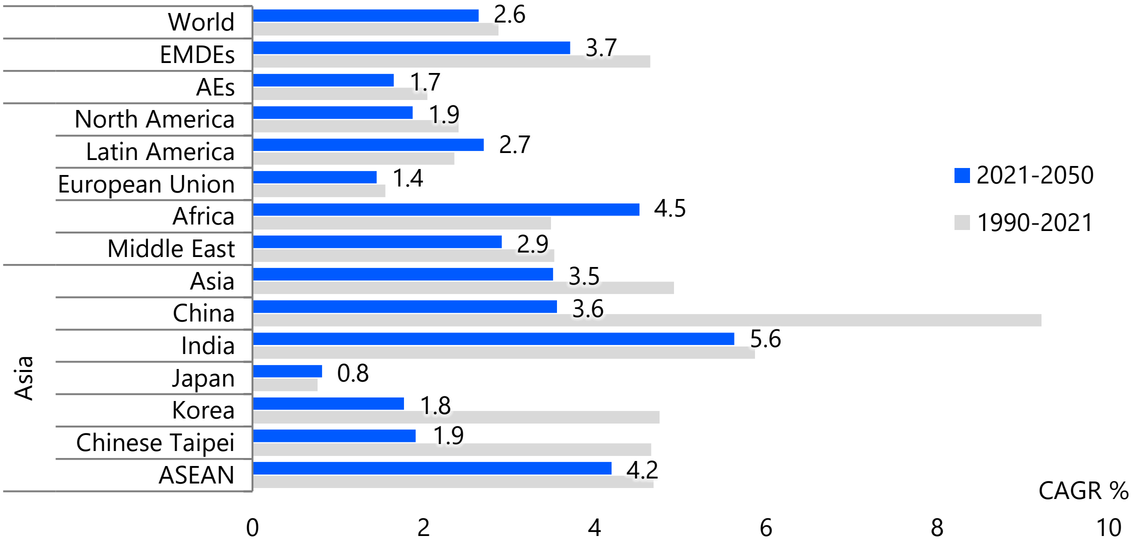
Covid-19 is not expected to cause a large-scale resurgence of infections or associated severe city lockdowns from 2024. In addition, Russia's prolonged invasion of Ukraine will not have a significant impact on the global economy, although it will have local and short-term effects. The economic growth of 2023 will continue in 2024 and is expected to reach 2.5%. The growth rate will gradually decline from 2024 onwards, from near 3% to near 2% (Figure 1-3). The impacts of Covid-19 and Russia's invasion of Ukraine on the world economy will be short-lived. Most economies will resume growth over the medium to long term. However, this will require that countries improve productivity, achieve technological innovation, implement proper fiscal, monetary and distribution policies, extend international cooperation and ensure security.

Figure 1-3 | World economic growth assumption



Advanced economies will continue to grow at roughly the same level as before, while Emerging Market and Developing Economies of Asia, Africa and others will continue to grow at high speed. For example, India will grow the fastest in the world at an average annual rate of 5.6% over the forecast period, China at 3.6% despite a continuous deceleration trend, while Africa will be the fastest-growing region at 4.5%. In view of these rates, we assume the world's annual economic growth rate will be 2.6% over the projection period (Figure 1-4).

Figure 1-4 | Economic growth assumption in selected countries/regions



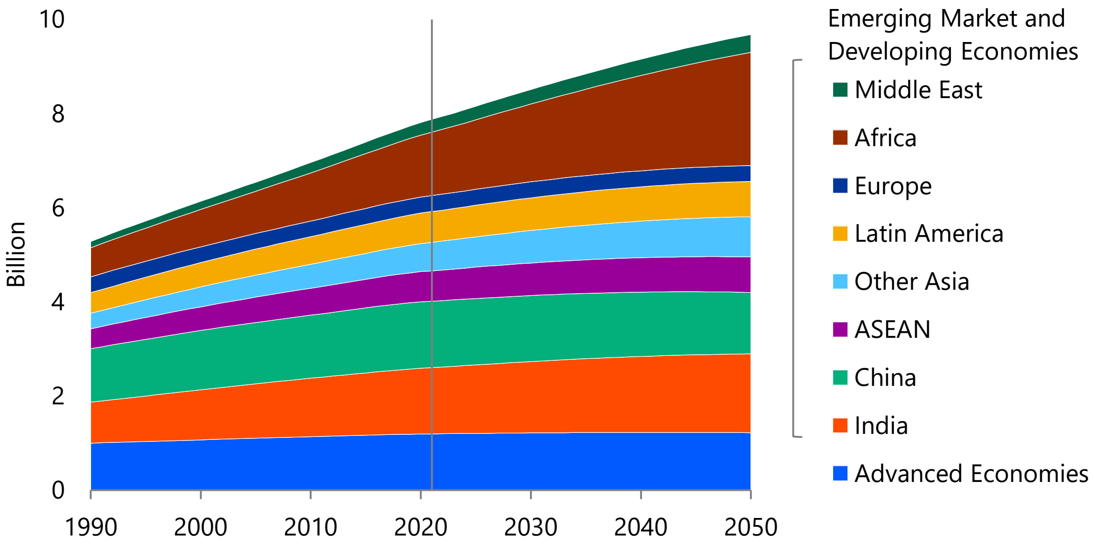
Notes: AEs stands for Advanced Economies. EMDEs stands for Emerging Market and Developing Economies.

Population

For assumptions on 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 born to a woman during her lifetime, has slipped below two. Currently, the spread of Covid-19 and subsequent economic stagnation around the world are increasing the downward pressure on population. In Emerging Market and Developing Economies, the TFR is also trending down, in line with income growth and women's increasing social participation. Nevertheless, the population of Emerging Market and Developing Economies will continue to increase, although at a slower pace, as mortality rates are declining due to improving medical technologies and food and sanitation conditions. The world population will continue to grow at an average annual rate of about 0.7%. As a result, the world population, which was 5.3 billion in 1990 and 7.9 billion in 2021, will reach 9.7 billion by 2050 (Figure 1-5).

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. The population of the European Union will increase very moderately until the 2030s, before turning downward. In Asia, Japan's population started to shrink in 2011 and will decrease by some 20% from the current level to 105 million in 2050. The population of Korea also began to decline from 2021 and will fall below 46 million by 2050.

Figure 1-5 | Population assumption



The population of Emerging Market and Developing Economies will continue to increase substantially, driven by Africa and India. Africa will nearly double its population from its present level to 2.405 billion in 2050, as the lower mortality rate counters a gradual fall in the birth rate. The population of the Middle East will expand by 40%, resulting from governments' financial incentives to increase the population and a growing influx from other regions. In Asia, India's population will continue to grow fast and will soon surpass that of China. At 1.674 billion by 2050, India's population will be the world's largest. China's population which currently is the largest, peaked in 2021 and has begun to decline; it will drop to around 1.3 billion by 2050. The population of the Association of Southeast Asian Nations (ASEAN) will increase by 20% to 750 million by 2050.

International energy prices

Recent situation

Russia's invasion of Ukraine in February 2022 caused fossil fuel prices to soar and price volatility to increase. Import prices in many importing countries, particularly in Europe, which were highly dependent on Russian fossil fuels, rose and pushed up inflation rates. Rapid interest rate hikes in the United States, the European Union and other countries to curb inflation have raised fears of an economic slowdown and recession, making energy demand uncertain. Meanwhile, the releases of emergency oil stocks by IEA member countries, the warm winter, and measures for the supply and demand of natural gas in Europe have been effective, causing international energy prices to remain flat since the fourth quarter of 2022. Brent oil prices soared to nearly $130/bbl in March 2022 after the outbreak of the war in Ukraine, and remained highly volatile until June of the same year. However, as fears over supply disruptions diminished and concerns about declining demand increased, the Brent price fell to around $80/bbl. The Organization of the Petroleum Exporting Countries (OPEC) Plus began cutting production by as much as 2 million bbl per day (Mb/d) in November 2022 and has made further cuts in stages in 2023. However, due to concerns about an economic slowdown and recession in major demand regions, Brent price in 2023 have been generally in the range of $70/bbl-$100/bbl (Figure 1-6).

Figure 1-6 | Brent crude oil prices

Source: Intercontinental Exchange

With regard to natural gas prices, spot liquefied natural gas (LNG) and spot gas prices have been on a downward trend since the latter half of December 2022, and the dominance of oil-linked long-term contract LNG prices has diminished in the Asian LNG market, but these conditions may fluctuate in the short term. The average price for the first half of 2023 was around $14/MBtu[2], down from the 2022 average Asian spot LNG price of $35/MBtu and from the European spot gas price (Title Transfer Facility [TTF], next month delivery) of $43/MBtu. The fact that TTF was regularly traded at a premium to Asian spot LNG prices in 2022 led to the shift of LNG to Europe in the global market.

Spot LNG and spot gas prices (in Europe) have soared since the second half of 2021 after the slump in 2020, accelerating the intensification of volatility. Under such circumstances, spot LNG and gas prices exceeded oil prices on a calorific value basis from August 2021 to April 2023.

From April 2023 onwards, the outlook is expected to ease (with the prospect of a price decline) due to the easing of fears for European natural gas and the recent firm outlook for LNG supply. However, the supply-demand balance could reverse rapidly depending on further declines in Russian pipeline gas supplies, recovery in LNG purchases by China and unexpected LNG production problems. For example, in early June, problems at Norway's LNG production facility caused a slight increase in European spot gas prices.

Japan's average LNG import price generally rose steadily over the following 18 months in line with the rise in Japan's average oil prices through June 2022, reaching a record high of $22.73/MBtu in September 2022. It then fell to $12.05/MBtu in June 2023, partly due to the downward trend in oil prices since July 2022.

The price of steam coal surged to over $400/t in March-August 2022, reaching a new record high by a wide margin, due to a surge in demand in line with the economic recovery from Covid-19, the impact of Russia's military invasion of Ukraine which prompted the European Union, Japan and others to switch from Russian coal to other sources, and production constraints in coal-producing countries caused by bad weather conditions, among other factors. Subsequently,

[2] British Thermal Unit

China, India, and other countries have been actively importing Russian coal, and the coal that these countries had previously imported from South Africa, Columbia and United States started to be supplied to Europe, causing a "rebalancing" of supply. The slackening supply-demand balance due to the mild winter in 2022 also contributed to a significant drop in prices. As of July 2023, the price has been around $130/t. Although significantly lower than the surge in 2022, the price remains high compared to that before the pandemic. In addition, structural instability is becoming apparent in the coal market as supplies become less flexible due to inactive coal investment amid the shift away from coal.

Reference Scenario

Oil demand in the Reference Scenario will continue increasing, driven by Emerging Market and Developing Economies of Asia such as India and ASEAN. On the supply side, while dependence on OPEC will increase over the medium to long term, production in non-OPEC countries will remain sluggish due to stricter oil field development regulations and unwillingness to invest, causing oil prices, which balance supply and demand, to rise over the same period. The real oil price (in 2022 prices) is assumed to be $85/bbl in 2030 and $95/bbl in 2050 (Table 1-1). Under an assumed annual inflation rate of about 2%, the nominal price is projected to reach $97/bbl in 2030 and $140/bbl in 2050.

Table 1-1 | International energy price assumption

Real prices			Reference			Advanced Technologies		
		2022	2030	2040	2050	2030	2040	2050
Oil	$2022/bbl	101	85	90	95	80	75	70
Natural gas								
Japan	$2022/MBtu	17.3	9.5	9.7	9.4	9.0	8.8	8.1
Europe (UK)	$2022/MBtu	37.5	10.1	10.6	10.4	9.9	9.9	9.3
United States	$2022/MBtu	6.4	3.0	4.0	4.0	3.4	4.1	4.0
Steam coal	$2022/t	318	110	115	115	105	100	90

Nominal prices			Reference			Advanced Technologies		
		2022	2030	2040	2050	2030	2040	2050
Oil	$/bbl	101	97	118	140	91	98	103
Natural gas								
Japan	$/MBtu	17.3	10.8	12.7	13.9	10.3	11.5	12.0
Europe (UK)	$/MBtu	37.5	11.4	13.8	15.3	11.3	13.0	13.8
United States	$/MBtu	6.4	3.4	5.3	5.9	3.9	5.4	5.9
Steam coal	$/t	318	125	151	170	119	131	133

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

With regard to Japan's natural gas prices, in this price assumption, the coefficient of the oil price-sensitive portion of Japan's import prices relative to oil prices will be lowered in line with the downward trend in crude oil consumption. The trend is toward stabilisation, factoring in a future recovery in LNG investment, and will remain almost flat from 2040 onward. The increase and regularisation of LNG exports from the United States mainland is expected to lead to diversification of procurement sources and the elimination or relaxation of destination restrictions, which is expected to lead to a gradual shift away from oil prices. The ratio of LNG affected by oil prices is set at about 70%. The gas-price linked portion of Japan's import prices will be set at the remaining 30%, and a certain margin will be added by multiplying the United States Henry Hub price by a premium factor.

The United States Henry Hub price is assumed in consideration of the Reference Case from the United States Energy Information Administration's (EIA) 2023 long-term outlook. The U.S. prices will continue to be cheaper than in other regions thanks to the abundant supply capacity. Based on the current development situation, the price will decline toward 2030. Thereafter, it will rise towards 2040 due to a relative increase in development and production costs and rising demand, including exports outside the region, and will remain flat thereafter. The coefficient for the oil price-sensitive portion of European prices is lowered in line with the downward trend in crude oil consumption. The price will be higher reflecting the phasing-out of Russian pipeline gas, which supported stable prices in the European gas market in the past.

It is assumed that carbon capture and storage (CCS) and electrification will be gradually incorporated into new and existing LNG projects in the future, but the resulting increase in investment costs and the resulting price increases and premiums are not assumed. While there is already a debate about the potential of a premium for LNG, which is differentiated by its cleanliness, there are producers who have clearly stated that they will not factor the additional cost of greenhouse gas (GHG) measures into their prices, and there are consumers who are concerned about premiumisation.

Coal prices (FOB[3] steam coal from Newcastle, Australia) reached a record high in 2022 mainly due to the embargo on Russian coal imposed by major countries, but global supply concerns are already easing and prices are settling down. Thereafter, while demand will decline, partly due to the global trend toward carbon neutrality, supply and demand will gradually tighten as new investment is curbed, and the real price (in 2022 price) will be $115/t by 2050. While demand for coal for power generation will increase in Asian countries such as India and ASEAN members, on the supply side, the expansion of coal production capacity is expected to become almost non-existent, especially in Advanced Economies, due to tighter environmental regulations and the trend toward decarbonisation. As a result, there is concern that risks of short-term fluctuations due to seasonal factors and supply-demand imbalances will increase.

Advanced Technologies Scenario

In the Advanced Technologies Scenario, fossil fuel demand will decline as a result of improvements in energy efficiency and fuel switching to nuclear, renewables and hydrogen. As a result, fossil fuel prices will generally fall compared to the Reference Scenario. For Europe, however, we assume prices to rise in a shrinking natural gas market. Prices may become volatile if a smooth transformation of the energy demand structure and the corresponding supply structure are not coordinated.

Global demand for natural gas will peak in the 2030s followed by a gradually decline. The coefficient for the oil price-sensitive portion of prices for Japan is lowered in line with the downward trend in crude oil consumption. In line with the further downward trend of crude oil consumption in the Advanced Technologies Scenario, the ratio affected by oil prices is set at 50%, which is lower than in the Reference Scenario. The gas-price linked portion of Japan will be set at

[3] Free on Board

the remaining 50%, and a certain margin will be added by multiplying the United States Henry Hub price by a premium factor. The United States Henry Hub price continues to rely on abundant supply capacity, but also refers to the EIA's 2023 long-term outlook. The coefficient for the oil price-sensitive portion of European prices is lowered in line with the downward trend in crude oil consumption. Meanwhile, with the further downward trend of crude oil consumption in the Advanced Technologies Scenario, the ratio affected by oil prices will be reduced. In the shrinking European natural gas market, prices will be higher than in the Reference Scenario.

2. Energy demand

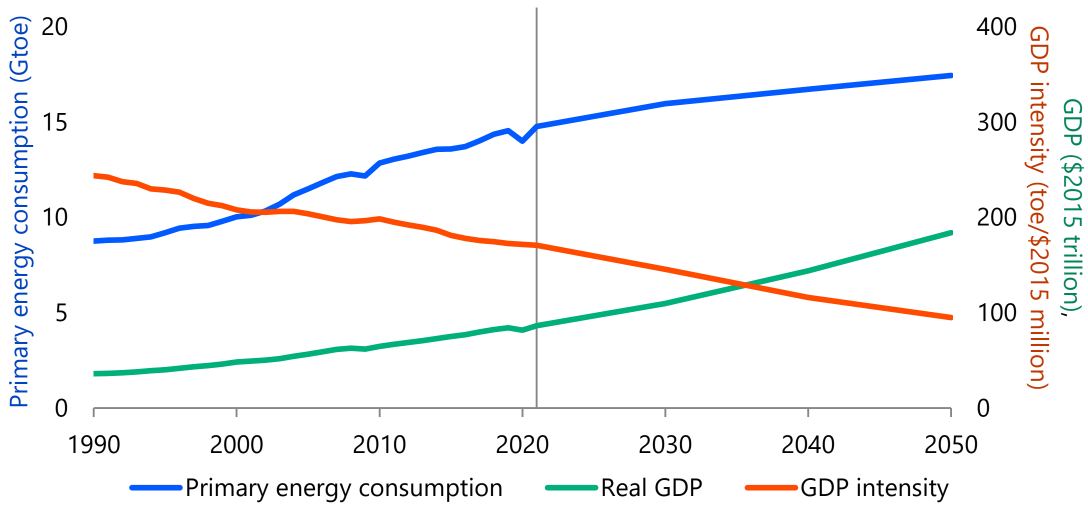
2.1 Primary energy consumption

Energy consumption continues to increase although GDP energy intensity is improving thanks to climate change countermeasures and energy security

The Working Group I report of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states that "it is unequivocal that human influence has warmed the atmosphere, ocean and land". As a countermeasure, more than 150 countries have announced carbon neutral policies that aim to achieve net-zero carbon dioxide (CO_2) emissions by the target year of 2050 or other years. Furthermore, Russia's invasion of Ukraine in February 2022 has highlighted the instability of supply and price of fossil fuel and threatens energy security. The Group of Seven (G7) and Group of 20 (G20) countries have specified the need for stable energy supply and price stability. While identifying the diverse paths of energy transition, each country has indicated the direction of further energy conservation and de-fossilisation through the use of clean technologies.

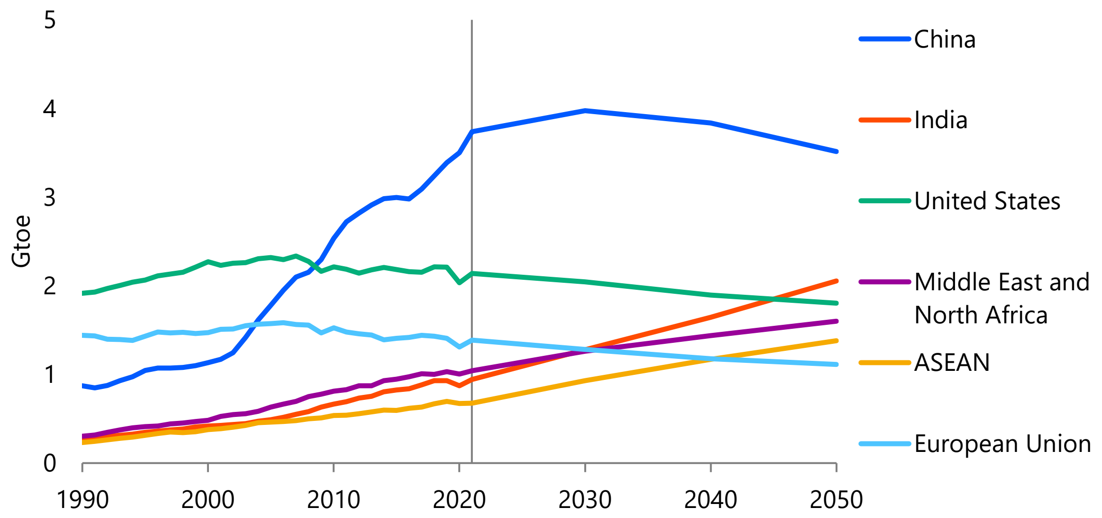
Global primary energy intensity per gross domestic product (GDP) from 2021 to 2050 will decline faster than from 1990 to 2021 as countries around the world promote higher energy efficiency and energy conservation in the context of economic, climate change and energy security actions (Figure 2-1). However, as GDP grows faster than the intensity, global primary energy consumption will continue to increase. The growth of primary energy consumption, which was 1.7% annually from 1990 to 2021, will decline to 0.6% annually from 2021 to 2050 due to progress in energy conservation. Yet, global energy consumption in 2050 will rise to 17 449 million tonnes of oil equivalent (Mtoe), 1.2 times that of 2021. It will be difficult to satisfy the new demand simply by increasing the supply of non-fossil fuels such as nuclear and renewable energies. Each country needs to improve efficiency even more in order to reduce fossil fuel consumption worldwide.

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



By region, primary energy consumption in China, which has driven the global increase since 2000, will peak in the early 2020s and begin to decline due to slower economic growth and energy conservation. On the other hand, those of India, the Middle East and North Africa (MENA) and the Association of Southeast Asian Nations (ASEAN) will continue to increase. The increase in these three countries and regions will account for 88% of the increase in the world's consumption from 2021 to 2050, pushing up global primary energy consumption, with their share growing from 18% in 2021 to 29% in 2050 (Figure 2-2). Therefore, in addition to accelerating the reduction in consumption in Advanced Economies and China, whether India, Middle East and North Africa and ASEAN can curb their energy consumption will determine the global trend of energy consumption and, ultimately, measures for climate change and energy security.

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



India, Middle East and North Africa and ASEAN, respectively, will increase their primary energy consumption by 2.7%, 1.5% and 2.5% per annum from 2021 to 2050 and account for 12%, 9% and 8% of global energy consumption in 2050. This is because their GDP will continue to grow at high annual rates of 5.6%, 3.2%, and 4.2% through 2050. Decoupling energy consumption from economic growth in India, Middle East and North Africa and ASEAN will become a global challenge.

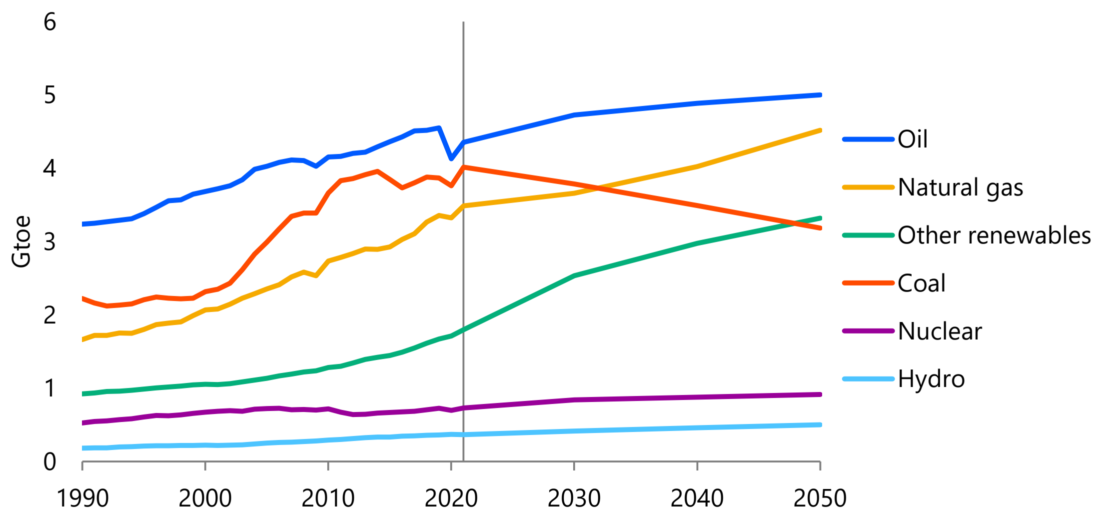
As a matter of course, it will be indispensable for energy-consuming economies such as Advanced Economies including the United States, the European Union (EU) and Japan, as well as China, to continue reducing their energy consumption in view of climate change and energy security concerns. The United States, Europe and Japan will account for 34% of global GDP and China for 24%, while the primary energy consumption of these two groups will each account for 19% and 20%, respectively, a large share of the world total. To suppress global energy consumption, these economies should accelerate their reduction of energy consumption through climate change and energy security measures 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 among the Emerging Market and Developing Economies, as well as each economy's policies will have to be enhanced. Advanced Economies such as the United States, Europe and Japan will need to offer highly efficient technology transfer and support to those Emerging Market and Developing Economies so that it can achieve economic growth while curbing energy consumption by utilising Article 6 of the Paris Agreement, addressing energy security concerns, particularly the instability of fossil fuel supplies.

Fossil fuel consumption, especially of natural gas, continues to expand amid growing concerns about climate change and energy security

In addition to the global trend toward carbon neutrality, Russia's invasion of Ukraine has raised concerns about the stable supply of fossil fuels, mainly in Europe. Non-fossil energy sources, such as nuclear and renewable energy, will continue to expand due to measures addressing climate change and energy security (Figure 2-3). The share of nuclear, hydro, and other renewables (excluding solid biomass) will rise from 20% in 2021 to 27% in 2050. However, while the expansion of renewable energy in the 2010s will be maintained through the 2020s, the growth will slow from 2030 onwards due to constraints on land and power grids. Also, the introduction of hydrogen and ammonia will not progress as the demand is not commensurate with the cost.

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



Fossil fuel consumption declined significantly in 2020, partly due to the economic downturn and voluntary staying indoors (or lockdowns) amid the Covid-19 pandemic. However, in line with the recovery from the pandemic, the consumption is now increasing and will continue to grow at an annual rate of 0.2% from 2021 to 2050. Natural gas has the lowest carbon emissions of all fossil fuels and thus will be most actively introduced to mitigate climate change. Natural gas consumption will increase at an average annual rate of 0.9% through 2050, mainly in the power generation sector, to 1.3 times the 2021 level. Oil will post the second largest consumption growth, expanding at an annual rate of 0.5% mainly in the transport sector (automobiles, aircraft and ships). Coal consumption, which peaked around the early 2010s, started to decline due to restrictions aimed at mitigating air pollution and climate change, and will continue to decline at an annual rate of 0.8% from 2021 to 2050. In 2050, the consumption of coal will be less than those of renewable energies except for hydropower.

Non-fossil energy sources will increase their presence through 2050 but overall demand will grow even more; therefore, non-fossil energy sources face difficulties in fully meeting energy demand alone even 30 years from now. Through 2050, it will remain realistic for the world, especially the

Emerging Market and Developing Economies whose energy consumption is increasing, to use both fossil fuels and non-fossil energy (Figure 2-4).

Figure 2-4 | Primary energy consumption changes [2021-2050, Reference Scenario]

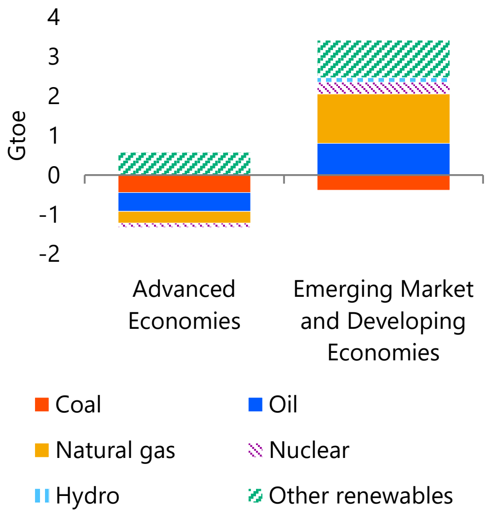
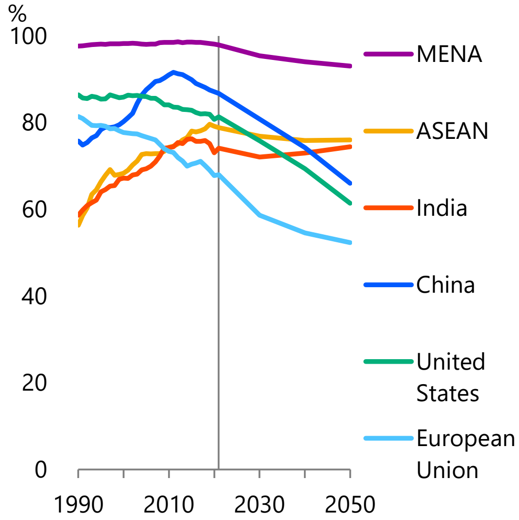


Figure 2-5 | Dependence on fossil fuels in selected countries/regions [Reference Scenario]



Dependence on fossil fuels will decrease from 80% in 2021 to 73% in 2050, but will remain high in Emerging Market and Developing Economies except China (Figure 2-5). The dependence will fall from 81% in 2021 to 61% in 2050 for the United States, from 68% to 52% for the European Union and from 87% to 68% for Japan. The dependence on fossil fuels in India, Middle East and North Africa and ASEAN will remain large, at 74%, 93% and 76%, respectively, as their total energy consumption is increasing and fossil fuels will meet much of the increase.

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

Among sectors, transport will post the largest consumption growth rates mainly in Emerging Market and Developing Economies (Figure 2-6). In the transport sector, the increase in automobile use due to rising incomes in Emerging Market and Developing Economies significantly outweighs the declining contribution due to improvements in fuel efficiency and the shift to next-generation vehicles. In addition, consumption in the aviation and shipping sectors will expand greatly due to the increasing movement of people and trade.

The increased energy consumption by the industry and buildings sectors cannot be ignored. India, Middle East and North Africa and ASEAN plan to expand their energy-intensive secondary industries such as heavy chemicals industry and intend to further develop their tertiary industries, including call centres for the world. In these economies, a larger industry sector, with increased energy demand, will lead to improving living standards, thus contributing to growth in energy demand 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, 2021-2050]

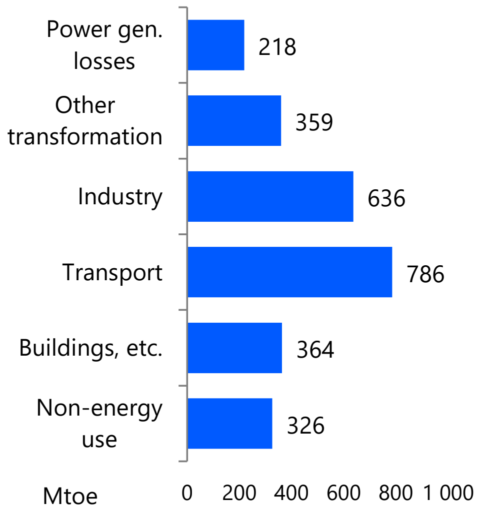
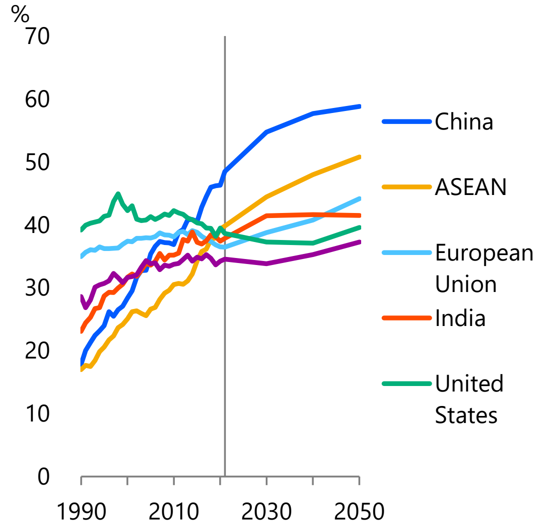


Figure 2-7 | Electrification rates on the supply side in selected countries/regions [Reference Scenario]

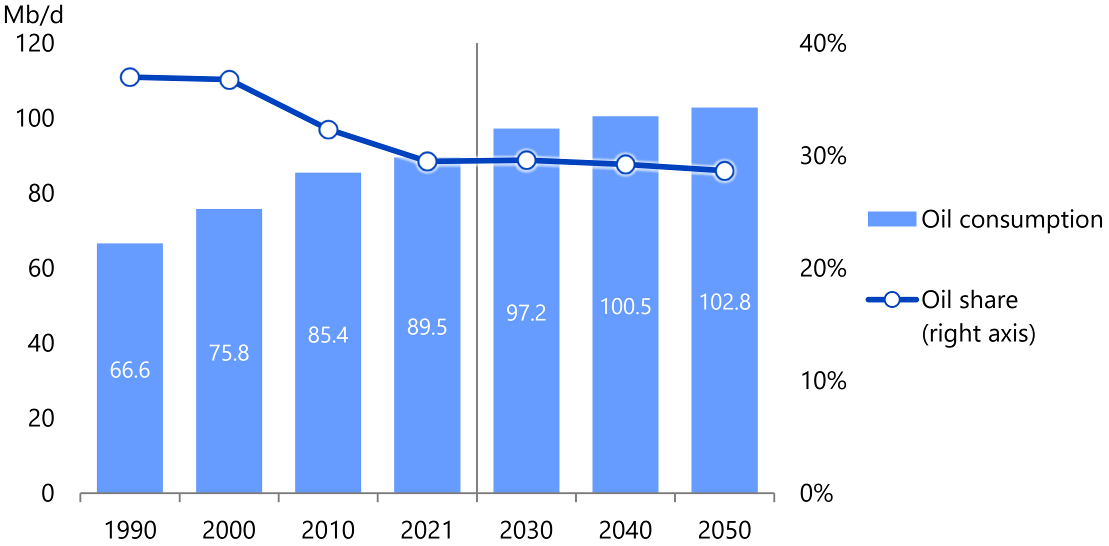


In the power generation sector, fossil fuel consumption will increase following advanced electrification, although the improved power generation efficiency of fossil power sources and the switching to non-fossil power sources will help curb the increase (Figure 2-7). Demand for electricity will expand not only in the increasingly electrified Emerging Market and Developing Economies but also in the Advanced Economies backed by the digitalisation of economies. Although non-fossil energy is expected to expand, it will most likely be unable to fully cover the growing electricity demand. The power generation sector will boost its energy consumption as electricity is increasingly used for its convenience on the strength of rising incomes and infrastructure development in unelectrified regions.

Oil consumption growth curbed but its share in primary energy consumption unchanged

After standing at 89.5 million barrels per day (Mb/d) in 2021, oil consumption will slowly increase, reaching 102.8 Mb/d in 2050 (Figure 2-8). Oil's share in primary energy consumption fell to 29% in 2021 due to the pandemic. It will rise to 30% in 2030 but will fall back to 29% toward 2050. Nevertheless, in the Reference Scenario, oil will remain the most widely used energy source in the world in 2050.

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 1.2% from the peak in 2005 to 2021, their oil consumption will continue to decrease by 7.5 Mb/d, or at an annual rate of 1.0%, from 2021 to 2050. A major factor behind the overall decline in oil consumption in the Advanced Economies is a fall in automobile fuel consumption due to fuel efficiency improvements and the diffusion of electrified vehicles, including hybrid cars. Meanwhile, oil consumption in India, Middle East and North Africa and ASEAN will increase greatly. It will increase at an annual rate of 2.0% from 2021 to 2050, an increase of 13.3 Mb/d. The oil consumption of these three economies will grow mainly in the transport, non-energy use and buildings sectors.

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

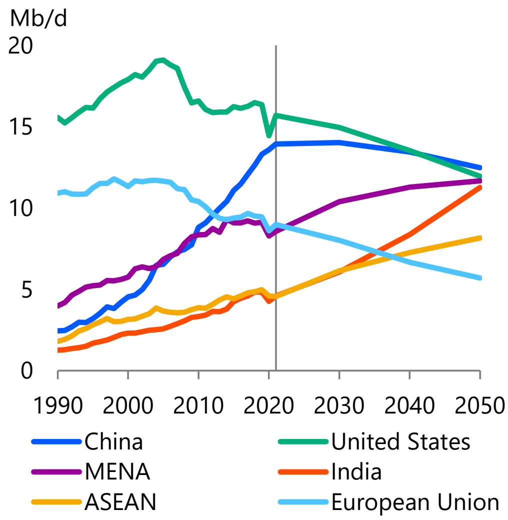
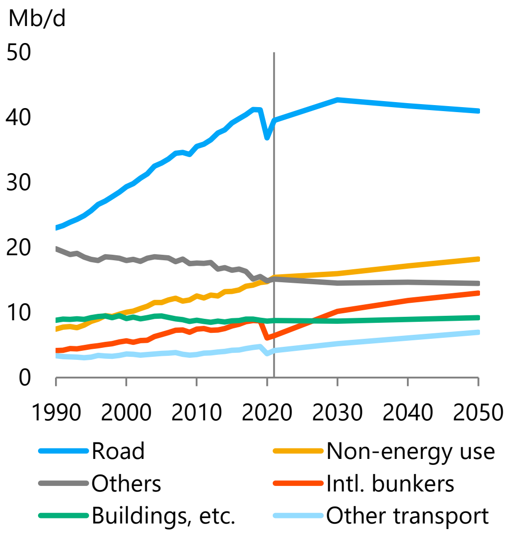


Figure 2-10 | Global oil consumption [Reference Scenario]



By sector, oil consumption will increase in the road sector, which has the largest share, until 2030 in line with the rise in the number of vehicles owned. After 2030, however, it will peak and start declining as the factors of decline such as improved fuel efficiency and the spread of electrified vehicles will exceed the factors of increase due to the increased number of vehicles owned (Figure 2-10). Meanwhile, consumption by other transport sectors, such as international bunkers, domestic aviation and internal navigation, will continue to grow due to the increase in international logistics and people's mobility.

In the transport sector in India, Middle East and North Africa and ASEAN, oil consumption for automobiles will increase sharply from 7.5 Mb/d in 2021 to 14.4 Mb/d in 2050. In the three economies, vehicle ownership will soar 3.5-fold from the present level, thanks to income growth and improvements in transport infrastructure such as roads and bridges. To suppress oil consumption, they would have to actively promote a transition to electric vehicles. In the Emerging Market and Developing Economies, the initial cost of electric vehicles may remain high even in 2050, with sales limited to high-income earners, unless strong countermeasures to climate change are taken.

The non-energy use sector in India, Middle East and North Africa and ASEAN will increase oil consumption mainly for the petrochemical industry by 2.8 Mb/d from 2021 to 2050, accounting for 102% 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 non-energy use sector. To suppress consumption in the sector, regulations on plastics consumption will need to be toughened.

In the buildings sector in India, Middle East and North Africa and ASEAN, oil consumption will increase by 1.2 Mb/d from 2021 to 2050 mainly for water heating and cooking, accounting for 263% of the net global consumption increase. In line with income growth, consumers will switch from coal and solid biomass to oil which is relatively cleaner in terms of health impacts. It should also be noted that in Sub-Saharan countries other than South Africa, oil consumption by the buildings sector will increase by 0.4 Mb/d during the same period. In those countries, the initial investment for 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 oil consumption will peak at 14.0 Mb/d around 2030 and fall to 12.5 Mb/d in 2050. The transport sector will reduce oil consumption due to the saturation of vehicle ownership, improvements in vehicle fuel efficiency and the diffusion of electric vehicles. With the spread of switching to electricity and city gas, the buildings sector will reduce its oil consumption. To drastically cut global oil consumption, it will also be necessary to accelerate the pace of reduction in oil consumption in China.

Box 2-1 | 50 years of the oil crisis

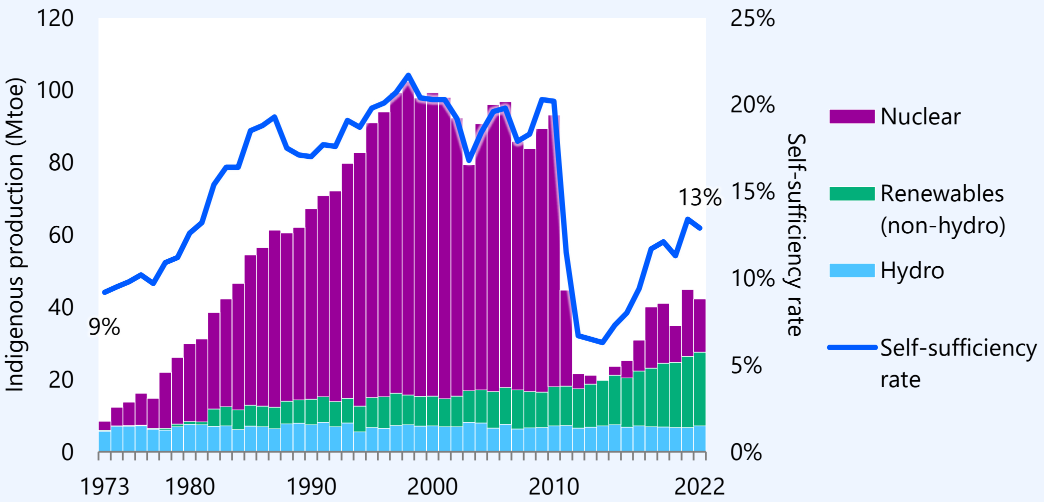
Having learned from the experience of the oil crisis, Japan has taken measures to strengthen its energy security, that is, to increase self-sufficiency and reduce risks associated with essential imports, based on the pillars of (1) strengthening energy conservation, (2) promoting alternative energy, and (3) reducing dependence on the Middle East.

Self-sufficiency still being improved

The improvement of self-sufficiency, which is the essence of energy security, is still in progress. In 1973, when the first oil crisis struck, the self-sufficiency rate was 9%, but by 1998 it was raised to 22% by suppressing the growth in demand through energy conservation and increasing the use of nuclear power generation (Figure 2-11). The self-sufficiency rate plummeted to 6% when all nuclear power plants were shut down following the Great East

Japan Earthquake in 2011, but has since recovered to 13% (2022) thanks to the increased use of renewable energies and gradual restarting of nuclear power plants. The Sixth Strategic Energy Plan aims to achieve a self-sufficiency rate of approximately 30% by 2030 through both renewables and nuclear. It is hoped that energy conservation will be further enhanced and that self-sufficiency will be improved by expanding the use of renewables and steadily restarting nuclear power plants.

Figure 2-11 | Japan's energy self-sufficiency rate and indigenous production of non-fossil fuels of Japan

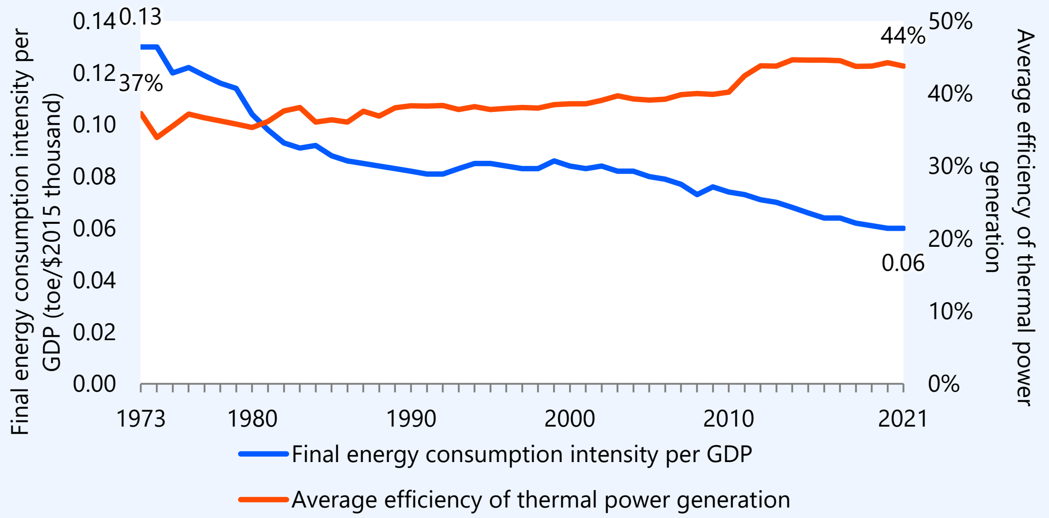


Source: International Energy Agency "World Energy Balances" (2023)

Enhancement of energy conservation

Japan, despite having many energy-intensive manufacturing industries, has achieved one of the world's high levels of efficiency through tireless efforts in all final consumption sectors and transformation sectors, including power generation. On the other hand, the recent pace of improvements in efficiency has been slower than in the 20 years following the oil crisis (Figure 2-12). To achieve carbon neutrality, operational improvements and the introduction of high-efficiency technologies beyond the current improvement pace will be required in all demand sectors. While some supply-side decarbonisation technologies will require further development for commercialisation, demand-side energy conservation has many cost-effective measures, so-called the low hanging fruit, and its role in working toward carbon neutrality will be more important than ever.

Figure 2-12 | Energy efficiency in Japan

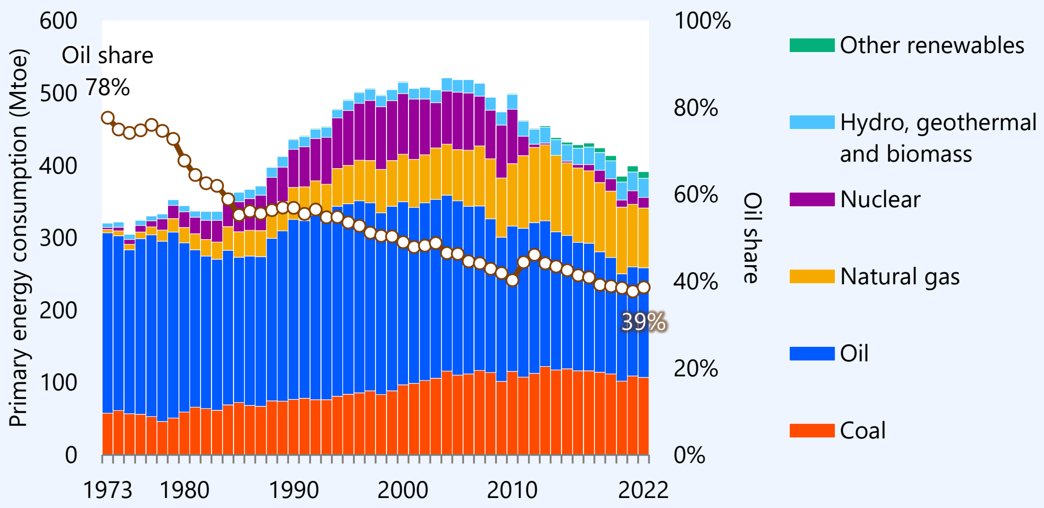


Source: International Energy Agency "World Energy Balances" (2023)

Promoting alternative energy

The key to measures to strengthen energy security is to create a portfolio that incorporates a variety of energies with different risk locations. Japan has been developing renewable energies while increasing the use of coal, natural gas and nuclear, in order to improve the extremely risky situation in which 78% of its primary energy demand was dependent on oil at the time of the first oil crisis (Figure 2-13). The Great East Japan Earthquake in 2011 caused a drastic decline in nuclear power generation and undermined the diversity of the energy mix, but since then, the situation has improved with the restarting of nuclear power plants and the rapid increase in renewables in recent years, bringing down the oil ratio to 39%.

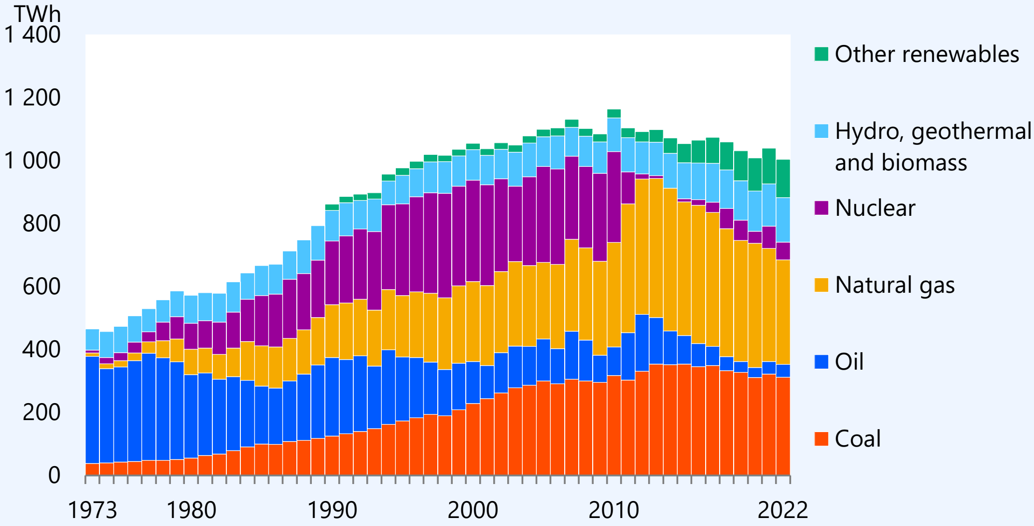
Figure 2-13 | Primary energy consumption in Japan



Source: International Energy Agency "World Energy Balances" (2023)

There are also challenges in maintaining and improving the energy mix. First, the use of renewables and nuclear, which are effective in both improving self-sufficiency and combating climate change, must continue to be expanded. Second, coal, which has contributed to diversifying the energy mix, must be converted into a low-carbon form by applying new technologies such as ammonia co-firing in order to meet the demands of climate change countermeasures. Third, a supply of liquefied natural gas (LNG) must be secured, which helps to ensure a stable supply of energy and control energy transformation costs. It is necessary, in addition to compensating for the dwindling number of long-term LNG contracts, to mitigate the risk concerning Russia, and to use hydrogen and other resources in the long term, in order to ensure carbon neutrality.

Figure 2-14 | Power generation mix in Japan



Source: International Energy Agency "World Energy Balances" (2023)

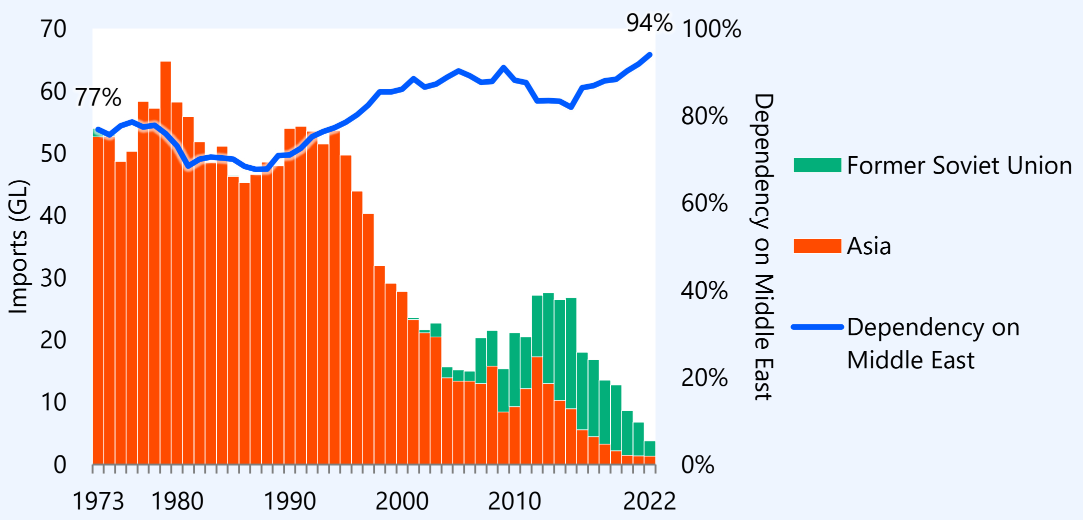
With the goal of achieving carbon neutrality, the electrification in energy consumption and the expansion of renewables are expected to accelerate in the future. However, it should be recognised that too much reliance on renewables can pose risks. The first is the unstable output of solar photovoltaics and wind, which are expected to remain the mainstays of renewables even in the future. In addition to the risk of power supply instability, the cost of integrating renewables into the grid is an economic risk. Second, solar photovoltaics, wind and storage batteries carry the risk of dependence on specific countries for technology and supply of critical minerals needed for manufacturing.

Reducing dependence on the Middle East

Japan has been attempting to reduce its dependence on the Middle East, which was the epicentre of the first oil crisis. In the 1980s, dependence on the Middle East declined partly due to the decrease in oil demand, but since then, the dependence has risen to historically high levels due to the declining export capacity of Asian countries and a new policy aimed at moving away from Russia (Figure 2-15). Given the abundant reserves and low production costs of Middle Eastern crude oil, as well as the expected greater pressure on private oil companies to divest, the situation is unlikely to change much. A realistic way to address this issue is to diversify the energy used and thereby reduce dependence on the Middle East.

In the long term, if the use of imported hydrogen increases as decarbonised energy expands, Japan will need to consider this import risk. It will be necessary to increase the supply of domestically produced hydrogen to the extent possible, while diversifying partner countries of the essential imports.

Figure 2-15 | Dependency on the Middle East for Japan's crude oil imports

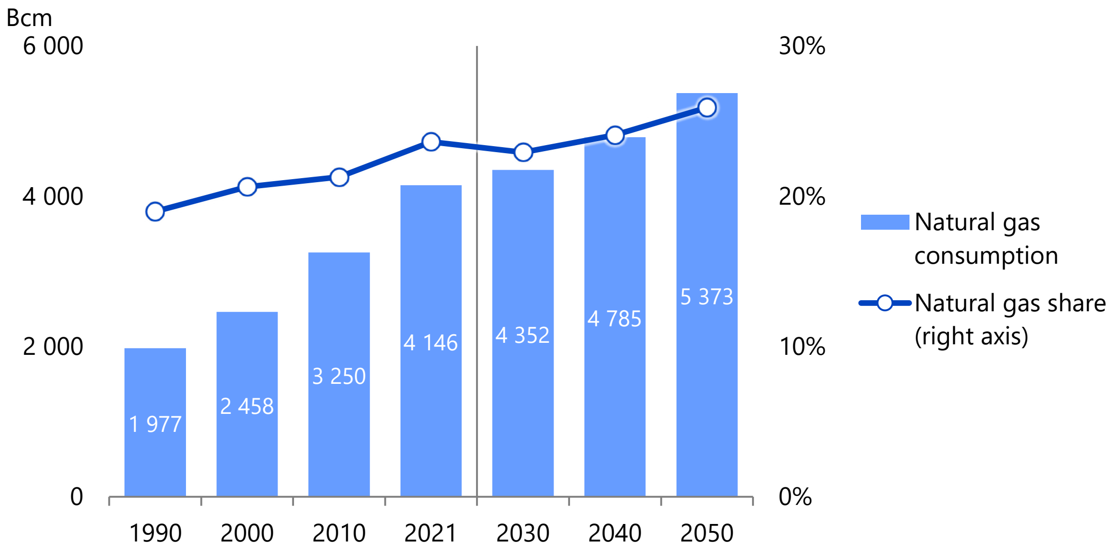


Source: EDMC Databank

Demand for natural gas for power generation continues to grow in India, Middle East and North Africa and ASEAN

Natural gas consumption will show the largest increase of all energy sources through 2050. It will post an annual increase of 0.9% from 4 146 billion cubic metres (Bcm) in 2021 to 5 373 Bcm in 2050 (Figure 2-16). Natural gas will increase its share of primary energy consumption from 24% in 2021 to 26% in 2050, becoming the second most consumed energy source after oil. As the European Union lessens its natural gas dependence on Russia and increases imports from other regions, particularly liquified natural gas (LNG), how to reduce this growth in natural gas demand is one of the challenges facing the world.

Figure 2-16 | Global natural gas consumption and its share of primary energy consumption [Reference Scenario]



India, Middle East and North Africa and ASEAN will account for 66% of the growth of global natural gas consumption totalling 1 227 Bcm between 2021 and 2050 (Figure 2-17). Natural gas consumption in 2050 will reach 255 Bcm in India, 1 071 Bcm in Middle East and North Africa and 403 Bcm in ASEAN. The Middle East will promote domestic natural gas consumption to earn foreign currency with cost-competitive oil exports. India and ASEAN will boost natural gas consumption mainly for power generation in order to meet increasing electricity demand. In China, natural gas consumption mainly for the power generation sector will increase by 148 Bcm by 2050. The United States and the European Union move away from natural gas for the sake of energy security and combating climate change, and reduce the consumption by 266 Bcm and 123 Bcm, respectively, from 2021 to 2050.

Figure 2-17 | Natural gas consumption in selected countries/regions [Reference Scenario]

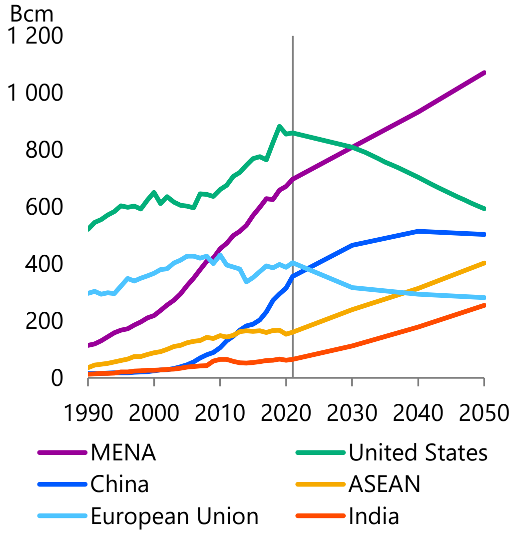
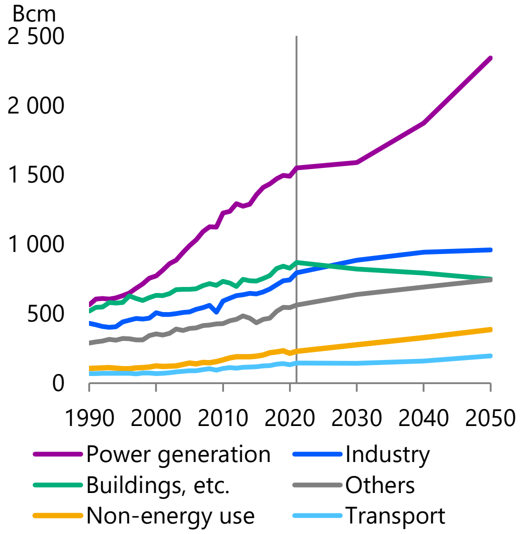


Figure 2-18 | Global natural gas consumption [Reference Scenario]



Natural gas consumption in the buildings sector will tend to decline as energy conservation and electrification progress. It will increase in Emerging Market and Developing Economies, including China, mainly in the power generation and industry sectors (Figure 2-18). In the power generation sector, demand for natural gas remains largely flat due to increase in renewable and other energy sources until 2030, but from 2030 onward, will increase again as the growth in electricity demand will be larger than the introduction of other power sources. Natural gas consumption in the power generation sector in Emerging Market and Developing Economies will increase at an annual rate of 2.7% from 2021 to 2050, accounting for 128% of the growth of global natural gas consumption in the sector. This is because natural gas emits the least amount of CO_2 per unit of energy of all fossil fuels and more easily allows large-scale power generation at lower integration costs than renewables.

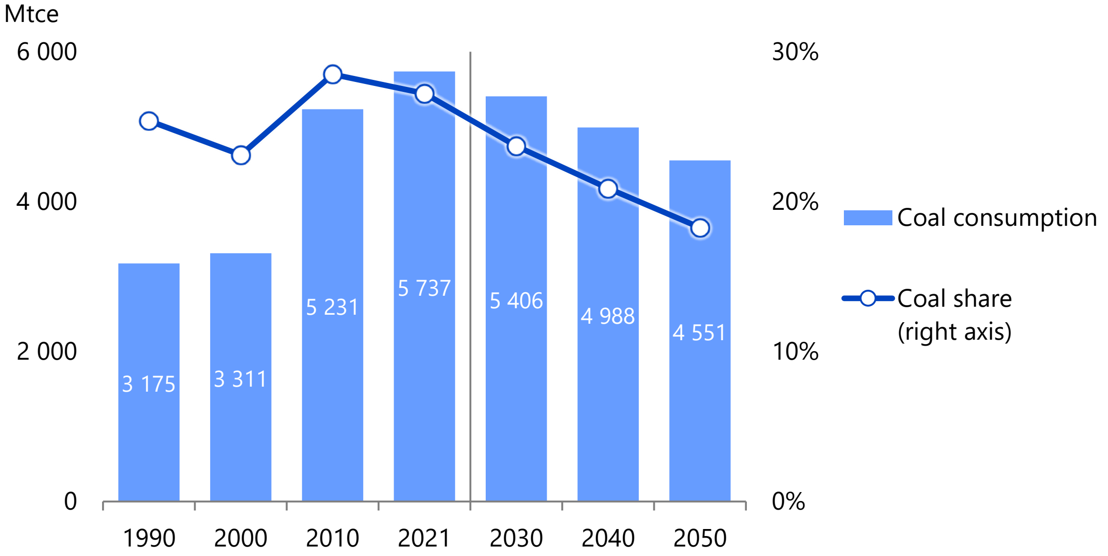
While natural gas consumption in the industry sector in Advanced Economies will decline, consumption in the Emerging Market and Developing Economies will grow at an annual rate of 1.2%, amounting to 115% of the net global growth. In view of convenience and environmental considerations, the sector will switch from oil and coal to natural gas. Consumption 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 adversely affect health and cause air pollution. However, electrification and energy conservation in other countries and regions will lead to declining use.

As India, Middle East and North Africa, 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 thorough adoption of natural gas-fired combined cycle plants to reduce consumption.

Coal consumption peaks in the 2020s due to environmental measures

Coal consumption, which was 5 737 million tonnes of coal equivalent (Mtce) in 2021, will decline at an annual rate of 0.8% due to the impact of environmental measures (Figure 2-19). Coal's share of primary energy consumption will fall from 27% in 2021 to 18% in 2050, being replaced by natural gas as the second most consumed energy source after oil and falling below non-hydro renewables in 2050.

Figure 2-19 | Global coal consumption and its share of primary energy consumption [Reference Scenario]



In 2021, China accounted for 56% of global coal consumption, India and ASEAN combined for 15%, and Europe, the United States and Japan combined for 13%. But by 2050, China and the three Advanced Economies will reduce their coal consumption to 40% and 5%, respectively, while India and ASEAN will boost theirs to 34% (Figure 2-20).

Figure 2-20 | Coal consumption in selected countries/regions [Reference Scenario]

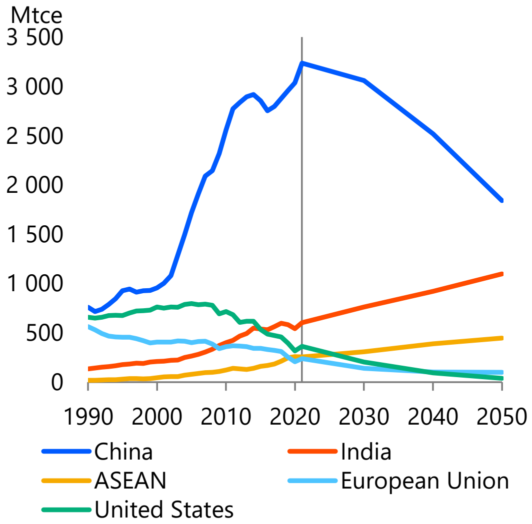
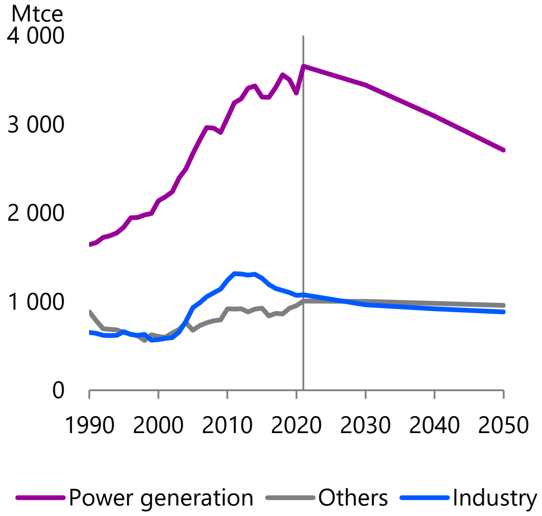


Figure 2-21 | Global coal consumption [Reference Scenario]



In China, coal consumption for industry has been declining after peaking in 2012, while that for power generation will begin to decrease after peaking in the early 2020s, which will result in a sharp decline of overall coal consumption by 43% by 2050. Coal consumption in Europe, the United States and Japan will continue falling both for power generation and industry sectors, posting a 71% drop by 2050. On the other hand, in India and ASEAN, coal use for power generation will increase by 1.6 and 1.8 times, respectively, by 2050, while industrial use will increase by 2.2 and 1.5 times. Note that Middle East and North Africa consumes limited coal due to the large number of oil- and gas-producing countries. 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 India and ASEAN, still view coal as an affordable domestic energy source from the viewpoint of energy self-sufficiency and do not necessarily impose particularly severe restrictions on coal consumption. Although governments and financial institutions in the Advanced Economies promote coal divestment, financial institutions in China and India do not necessarily support such divestment. To curb coal consumption, Europe, the United States and Japan should reduce consumption further, while China, India and ASEAN should switch from coal to natural gas, hydrogen and ammonia for their power generation and industry sectors.

Non-fossil energy, such as solar photovoltaics and wind will increase but their share of primary energy consumption will be limited

While many countries are pursuing carbon neutrality and place growing hopes on the expansion of non-fossil energy, such energy sources' share of primary energy consumption is projected to rise only slightly from 20% in 2021 to 27% in 2050. Non-fossil energy consumption for power generation, mainly nuclear and hydro, will increase 2.2-fold from 1 666 Mtoe in 2021 to 3 738 Mtoe in 2050 (Figure 2-22). Solar photovoltaics, wind and others will grow the most, expanding 6.2-fold by 2050 compared to 2021. Nuclear and hydro will be subject to slow growth due to nuclear policy reforms, as well as overall environmental and social considerations. Their share of non-fossil energy consumption for power generation will fall from 66% in 2021 to 38% in 2050.

Figure 2-22 | Non-fossil energy consumption for power generation [Reference Scenario]

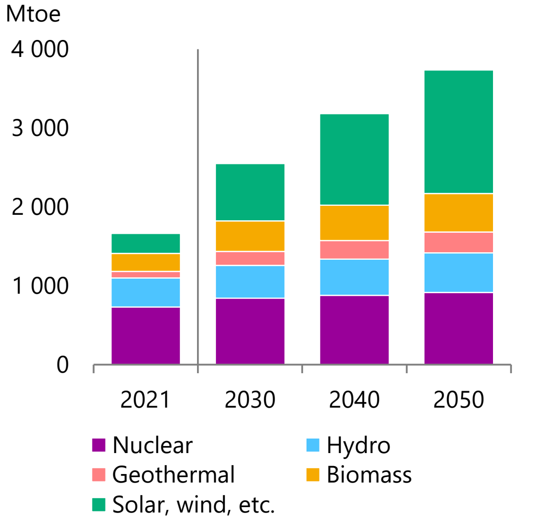
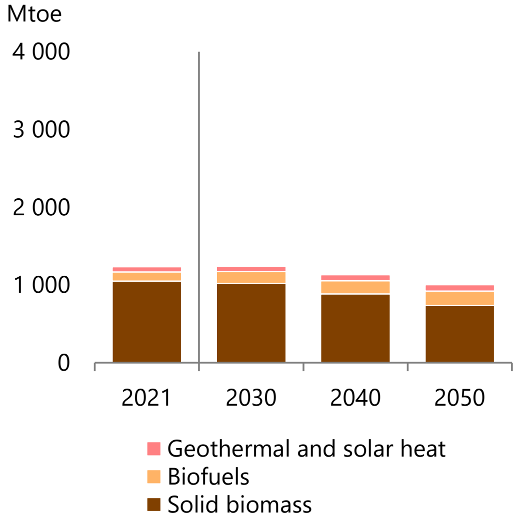


Figure 2-23 | Non-fossil energy consumption for heating [Reference Scenario]



On the other hand, consumption for heating will continue to concentrate on traditional solid biomass such as firewood and manure, which are widely used in rural areas in Emerging Market and Developing Economies. From 1 234 Mtoe in 2021, it will start decreasing in the 2030s, falling to 1 003 Mtoe in 2050 (Figure 2-23). Its consumption will decline as rural residents switch to modern energy sources in line with improvements in their income and living standards. Liquid biofuel for automobiles and buildings and biogas will increase 1.6-fold through 2050, accounting for only 19% of the total non-fossil energy consumption for heating.

Non-fossil energy consumption will dramatically increase toward 2050. However, the growth of its share in primary energy consumption is not large, as overall primary energy consumption is also increasing significantly. Solar photovoltaics, wind and others are expected to expand in response to substantial cost reductions and will capture 50% of the global primary energy consumption growth by 2050.

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

Asia will account for 65% of the global energy consumption growth as its share of the global economy increases from 34% in 2021 to 44% in 2050 in real terms (Figure 2-24). China, India and ASEAN, in particular, will drive the global macro economy. For energy consumption growth, these economies have both similarities and differences. Energy consumption in China will peak in the 2020s, while consumption in India and ASEAN will continue to increase (Figure 2-25). Factors behind the three economies' differences include changes in their respective economic growth as well as population growth.

Figure 2-24 | Asian primary energy consumption [Reference Scenario]

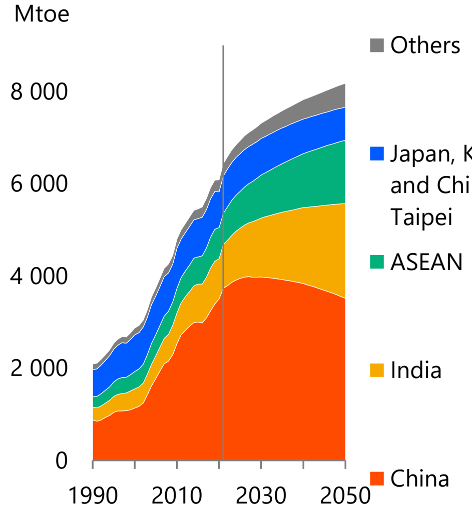
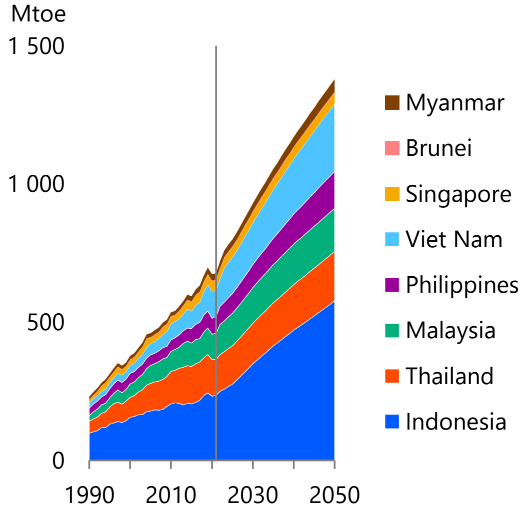


Figure 2-25 | ASEAN's primary energy consumption [Reference Scenario]



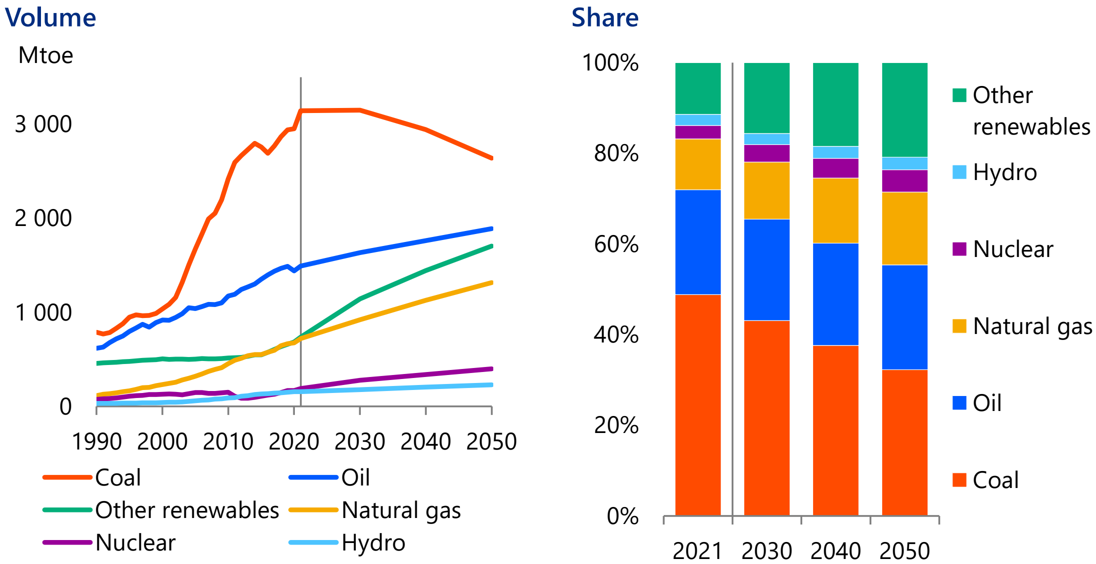
China's economy grew 15.4-fold from $1 trillion in 1990 to $15.8 trillion in 2021 and will expand 2.8-fold from 2021 to $43.5 trillion in 2050. China's population increased from 1.14 billion in 1990 to 1.41236 billion in 2021; it will peak in the early 2020s before slipping below the 2020 level to 1.30472 billion in 2050. In the 14th Five-Year Plan for 2021-2025, China has positioned the transition to a green economy as a means of growth, and by the early 2020s, energy consumption will begin to decline while the economy grows as in Advanced Economies, as energy conservation advances mainly in industry. After energy consumption increased at a high annual rate of 4.8% between 1990 and 2021, it will start to decrease at an annual rate of 0.2% between 2021 and 2050. In 2050, energy consumption will fall below the 2021 level despite the real GDP per capita exceeding $33 000. China is therefore starting its transition to a mature society, conscious of carbon neutrality. China's share of Asian energy consumption rose from 42% in 1990 to 58% in 2021 and will fall back to 43% in 2050.

India's economy grew 5.4-fold from $500 billion in 1990 to $2.6 trillion in 2021 and will increase 4.9-fold from 2021 to $13.6 trillion in 2050. Its population rose from 870 million in 1990 to 1.41 billion in 2021 and will surpass China's population in 2023 before reaching 1.67 billion in 2050. As such, the real GDP per capita will rise from $500 in 1990 to $8 100 in 2050, improving incomes and living standards. Despite its announcement of a commitment to achieve carbon neutrality by 2070, India will continue to increase its energy consumption at an annual rate of 2.7% from 2021 to 2050. Therefore, measures for climate change and energy security will become more important for the country. India's share of Asian energy consumption will expand from 13% in 1990 and 15% in 2021 to 25% in 2050.

ASEAN's economy will increase rapidly from $730 billion in 1990 and $3 trillion in 2021 to $9.9 trillion in 2050. ASEAN's population will grow from 430 million in 1990 to 760 million in 2050. As a result, real GDP per capita, which was $1 700 in 1990 and $4 600 in 2021, will reach $13 100 in 2050, thus improving income and living standards. ASEAN's energy consumption will accelerate steadily at an annual rate of 2.5% from 2021 to 2050, with Indonesia accounting for half of that increase. Despite its announcement of a commitment to achieve carbon neutrality by 2060, Indonesia continues to increase its energy consumption. Therefore, measures for climate change and energy security will become more important for the country. ASEAN's share of Asian energy consumption will widen from 11% in 1990 and 2021 to 17% in 2050.

In 2050, when energy consumption in India and ASEAN will still be rising, Asia will continue to depend on fossil fuels from 83% of its energy needs in 2021 to 71% in 2050 (Figure 2-26). Oil and natural gas consumption will keep expanding, mainly in transport and power generation sectors, respectively. How to reduce Asia's fossil fuel consumption will be critical to achieve a stable global energy supply, carbon neutrality and climate change goals.

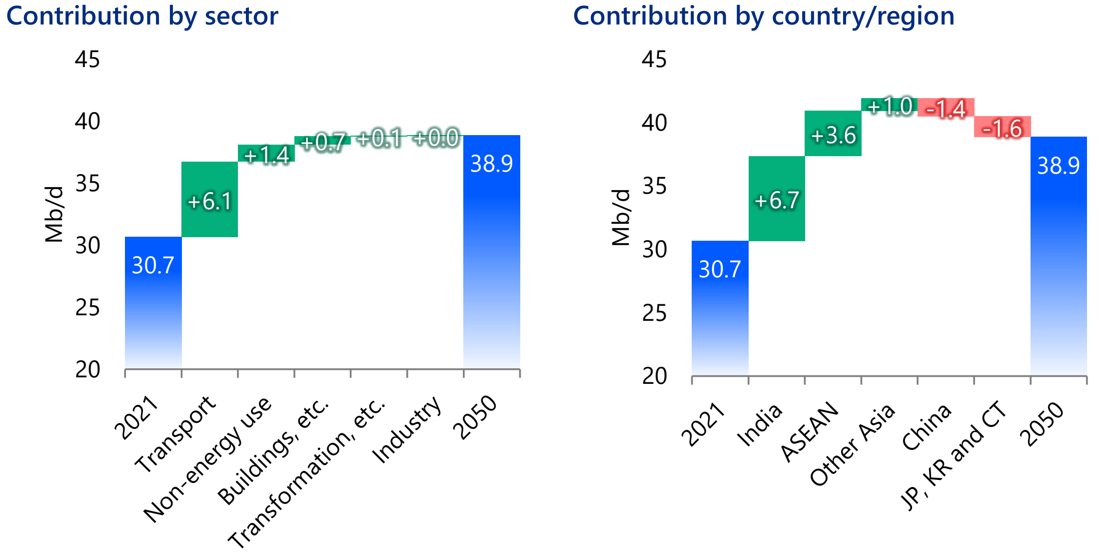
Figure 2-26 | Asian primary energy consumption [Reference Scenario]



Asia's oil consumption growth will decelerate from 2.9% per year between 1990 and 2021 to 0.8% between 2021 and 2050. The transport sector will account for 74% of the growth through 2050, the non-energy use sector for 17% and the buildings sector for 8%. India will account for 81% of the growth, and ASEAN for 44% (Figure 2-27). The share of India and ASEAN combined exceeds 100% because Japan, Korea and China are cutting consumption. To suppress oil consumption, the transport sector in India and ASEAN should promote fuel efficiency improvements including electrification. As Asia's oil consumption growth accounts for 61% of global growth, its oil consumption trend will affect the entire world.

To secure stable oil supplies and address environmental problems, switching from oil to other energy sources and greatly increasing oil consumption efficiency will be essential to the policies of Asian countries.

Figure 2-27 | Asian oil consumption [Reference Scenario, 2021-2050]



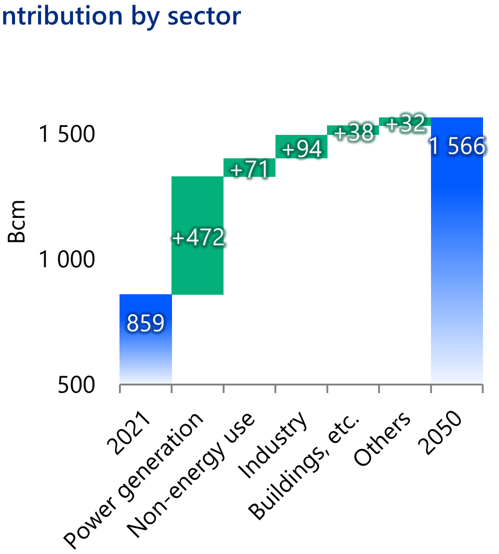
Note: JP, KR and CT stands for Japan, Korea and Chinese Taipei

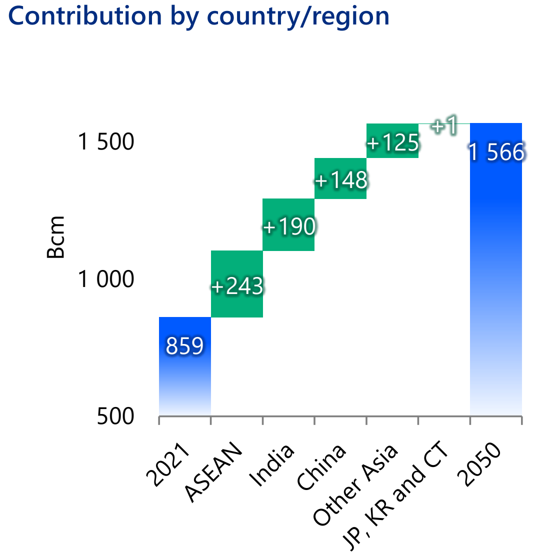
The growth in Asia's natural gas consumption stood at 6.1% per year between 1990 and 2021 and will decelerate to 2.1% between 2021 and 2050. Of the 2021-2050 growth, the power generation sector will account for 67%, the industry sector for 13% and the non-energy use sector for 10%. ASEAN will account for 34% of the growth, India for 27% and China for 21% (Figure 2-28). To suppress natural gas consumption, China, India and ASEAN will have to raise efficiency, reduce electricity transmission and distribution losses, and promote co-firing with hydrogen in the power generation sector, as well as improve insulation and other efficiencies in the buildings sector. As Asia's natural gas consumption growth accounts for 58% of the global growth, suppressing the three economies' consumption would contribute directly to a global reduction.

Although natural gas emits less CO_2 than oil and coal, it is still a fossil fuel that emits CO_2 when combusted. Accordingly, it is important for the Emerging Market and Developing Economies to promote a highly efficient natural gas consumption through measures to raise the engineers' skills in the operation and maintenance of equipment, encourage the power generation sector to construct natural gas-fired combined cycle plants and adopt co-firing with hydrogen.

Liquefied natural gas (LNG) imports will help cover shortages in natural gas supply to Asia. Asia's LNG consumption will increase more than 1.8 times from 273 million tonnes (Mt) in 2021 to 490 Mt in 2050. Japan and Korea were early users and large importers of LNG, but in 2021 China surpassed Japan to become the world's largest importer. The share of Asia's LNG consumption will fall from 52% in 2021 to 29% in 2050 for Japan, Korea and Chinese Taipei combined, while rising from 43% to 63% for China, India and ASEAN combined. The latter will need to secure a stable supply of LNG.

Figure 2-28 | Asian natural gas consumption [Reference Scenario, 2021-2050]





Note: JP, KR and CT stands for Japan, Korea and Chinese Taipei

In contrast to Asia's oil or natural gas consumption, local coal consumption will peak in the 2020s before declining. From 1990 to 2021, it grew rapidly at an annual rate of 4.6%, but it will decline at an annual rate of 0.6% from 2021 to 2050. Mainly because coal-fired power plants have come under global scrutiny due to climate change and air pollution issues, coal consumption in Asia will decline for power generation as more renewable energies will be introduced. Nevertheless, coal will continue to be the largest energy source in Asia, accounting for a 32% share by 2050. Asian countries should avoid new or additional construction of inefficient coal-fired power plants and promote the efficient use of their abundant coal resources while mitigating their environmental impact, including the introduction of carbon capture, utilisation and storage (CCUS), and ammonia co-firing, with the assistance of Advanced Economies.

Asia's non-fossil energy consumption, though being less than oil or natural gas consumption in volume, will increase at a high annual rate of 2.7%. The increase in renewables, other than traditional biomass, will be 98% of the entire Asian non-fossil energy consumption growth between 2021 and 2050, followed by nuclear at 17% and traditional biomass at −15%. China will account for 52% of the renewable energy consumption growth (excluding traditional biomass), ASEAN for 15% and India for 25%. China will capture 62% of the nuclear consumption growth, followed by 23% for India. Asia's share of the global non-fossil energy consumption will rise from 2021 level by 12 percentage points to 49% in 2050.

In September 2020, China declared that it would aim for carbon neutrality by 2060, setting a policy of suppressing oil and coal consumption with larger CO_2 emissions intensity and promoting natural gas and non-fossil energy consumption toward 2050. Given China's huge fossil fuel consumption, however, it will have to greatly enhance energy efficiency and its decarbonisation policies. Meanwhile, India, which accounts for most of the incremental energy consumption in Asia by 2050, has pledged to achieve carbon neutrality by 2070, while many of the ASEAN members, led by Indonesia, have announced they will be carbon neutral. India and ASEAN will have to be proactive and take steps to accelerate energy conservation and decarbonisation, making use of the continued and improved technical and financial assistance from Japan, Korea, China and other economies. These commitments to tackling climate change from China, India and ASEAN will contribute to the development of stable energy supplies, including LNG.

2.2 Final energy consumption

Global final energy consumption in 2050 will increase 1.2-fold from 2021

In the Reference Scenario, global final energy consumption will increase 1.2-fold from 10 082 Mtoe in 2021 to 12 194 Mtoe in 2050. The increase represents an average annual growth of 0.7%. The change in global final consumption between 2021 and 2050 presents two features.

First, India, ASEAN and Middle East and North Africa 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/regions will affect the trends in global final energy consumption. Therefore, particular attention should be paid to the factors that fluctuate final energy consumption in these regions. Those fluctuating factors include economic growth, the details and strengths of their energy-related policies, the technological development and diffusion of equipment using energy.

Second, there will still be a certain degree of final energy consumption for all major energy sources in 2050. Final energy consumption for coal and renewables will follow a downward trend but will not bottom out even by 2050. If policy guidance and investment targets are extremely biased toward specific energy sources to address climate change, which is a major global issue, the energy supply-demand balance for many energy sources may be lost over the medium to long term. It will be important to develop a market that sufficiently supplies each energy source, while considering demand trends and their impacts on climate change.

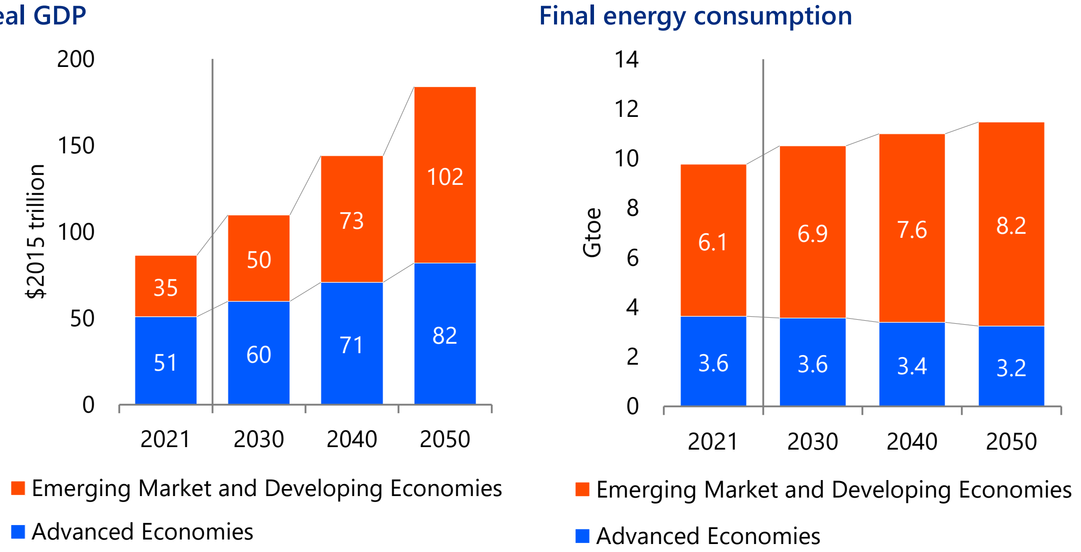
The following provides insights on final energy consumption changes in the Reference Scenario by economy group, region, sector and energy source between 2021 and 2050.

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

The increase in global final energy consumption from 2021 to 2050 will be driven by the Emerging Market and Developing Economies (Figure 2-29). Although final energy consumption in Advanced Economies will decline over the same period, a steady consumption growth in Emerging Market and Developing Economies will offset and exceed the decline in Advanced Economies. Therefore, the global final energy consumption will rise through 2050.

In the Emerging Market and Developing Economies, final energy consumption in 2050 will be 8 230 Mtoe, an increase from 2021 of 1.3-fold (1.0% per annum). Those economies will follow a growth trajectory in the medium to long term. As the progress in energy efficiency improvements is coupled with expanding service sectors, the increase in final energy consumption between 2020 and 2050 will be much slower than the real GDP growth (3.7% per annum).

Figure 2-29 | Real GDP and final energy consumption [Reference Scenario]



In Advanced Economies, on the other hand, final energy consumption in 2050 will be 3 242 Mtoe, down 10% from 2021. Even in those economies, real GDP will grow from 2021 to 2050 (1.7% per annum). However, in contrast to the upward trend in real GDP, final energy consumption will decline at an annual rate of −0.4% over the same period. In Advanced Economies, final energy consumption has been on a downward trend since the late 2000s despite economic growth, due to accelerated energy conservation and the shift of the economy to services. As a result, the final energy consumption-GDP elasticity[4] in the Advanced Economies will change from 0.27 between 1990 and 2021 to −0.24 between 2021 and 2050.

Energy efficiency is one of the key measures for decarbonisation. In both the Advanced Economies and the Emerging Market and Developing Economies, the final energy consumption sectors will be required to promote initiatives to improve energy efficiency.

By region: India, ASEAN and Middle East and North Africa will drive final energy consumption growth

In terms of changes by region in final energy consumption from 2021 to 2050, India, ASEAN and Middle East and North Africa will strongly lead the growth in global final energy consumption (Figures 2-30, 2-31). India, ASEAN and Middle East and North Africa together will account for a dominant share of more than 70% of the global increase over the same period.

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

Figure 2-30 | Global final energy consumption and contribution by country/region [Reference Scenario, 2021-2050]

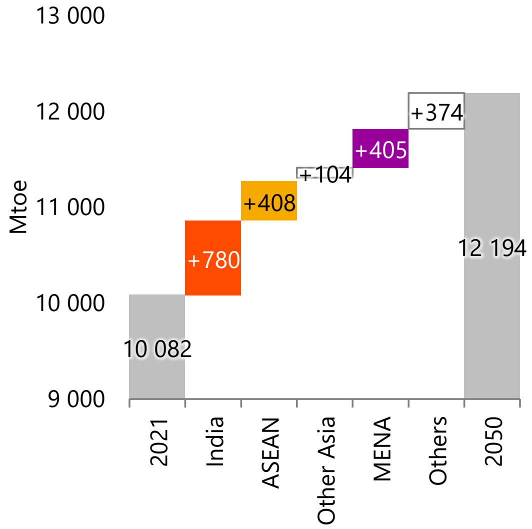
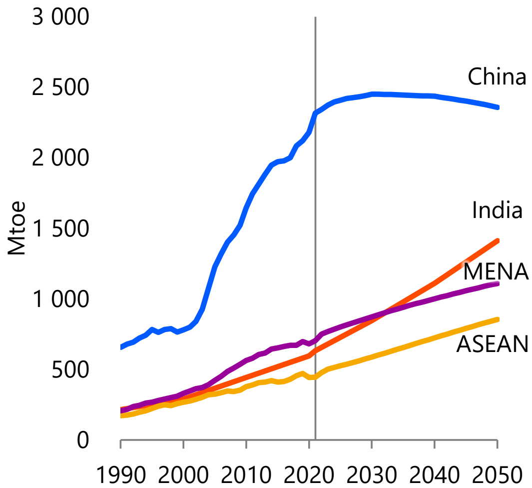


Figure 2-31 | Final energy consumption in China, India, Middle East and North Africa and ASEAN [Reference Scenario]



As a result of the strong demand growth in India and ASEAN, Asia's share of global final energy consumption will widen from 41.0% in 2021 to 44.8% in 2050. In the future, Asia will become an even more significant energy consumption centre.

India's population surpassed that of China in 2023 to become the world's largest and by 2050, it will exceed 1.6 billion, even approaching 1.7 billion. Its GDP will grow at an annual rate of 5.9% between 2021 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 2.2-fold (2.8% per annum) from 632 Mtoe in 2021 to 1 413 Mtoe. The incremental impact of final energy consumption in India alone is large enough to account for 70% of the incremental energy consumption in Asia as a whole. The presence of India is evident not only within Asia: its share of global final energy consumption will expand from 6.3% in 2021 to 11.6% in 2050. Thus, India will become even more relevant in terms of global energy supply and demand.

Final energy consumption in ASEAN will rise at a rate of 2.3% per year from 446 Mtoe in 2021 to 854 Mtoe in 2050, in part due to growth in Indonesia and Viet Nam. Of the 408 Mtoe in final energy consumption growth in ASEAN, Indonesia will account for 155 Mtoe and Viet Nam for 109 Mtoe. The increase in final energy consumption in those two countries reflects their population and economic growth. As of 2021, the populations of Indonesia and Viet Nam were 274 million (first in ASEAN) and 97 million (third), respectively, and are expected to keep growing in the future. GDP per capita will grow 3.2 times in Indonesia and 4.2 times in Viet Nam between 2021 and 2050. Backed by such population and economic growth, Indonesia's final energy consumption will exceed that of Japan in the late 2030s.

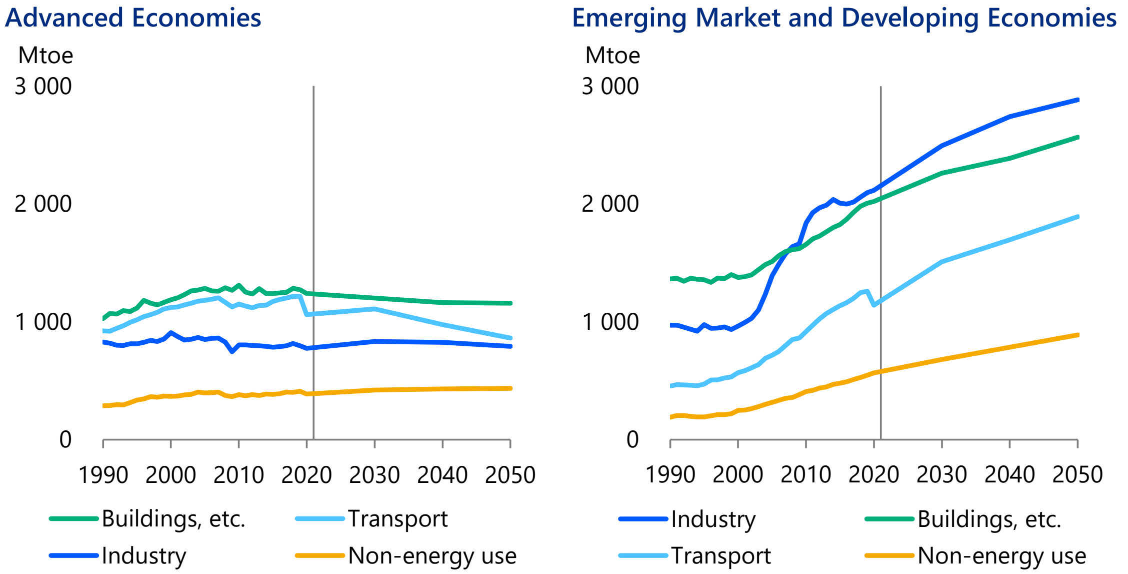
China's final energy consumption will increase from 2 317 Mtoe in 2021 to 2 357 Mtoe in 2050. Despite continuing to be the world's largest final energy consumer over the period, China will see a downward trend after the 2030s. Such pattern will differ from the constant uptrend in India or ASEAN. The industry sector will be a key contributor to China's peaking its final energy consumption. The energy-intensive steelmaking and cement industries, in particular, will substantially reduce their energy consumption. The impact of efforts to eliminate excess capacity gradually became apparent, causing cement production to peak around the mid-2010s. Following this, crude steel production peaked around 2020, then entering a downward trend.

Final energy consumption in Middle East and North Africa will increase at an annual rate of 1.6% from 705 Mtoe in 2021 to 1 110 Mtoe in 2050 mainly in Iran, Saudi Arabia and North Africa. Of particular interest, consumption will rise by 107 Mtoe in Iran, by 96 Mtoe in Saudi Arabia, and by 91 Mtoe in North Africa. The three countries or regions will thus account for most of Middle East and North Africa's consumption growth of 405 Mtoe. Along with increases in population in these countries and region, their GDP per capita will grow 1.8-fold in Iran, 1.7-fold in Saudi Arabia, and 2.2-fold in North Africa although their increases are much smaller than those in India and ASEAN.

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

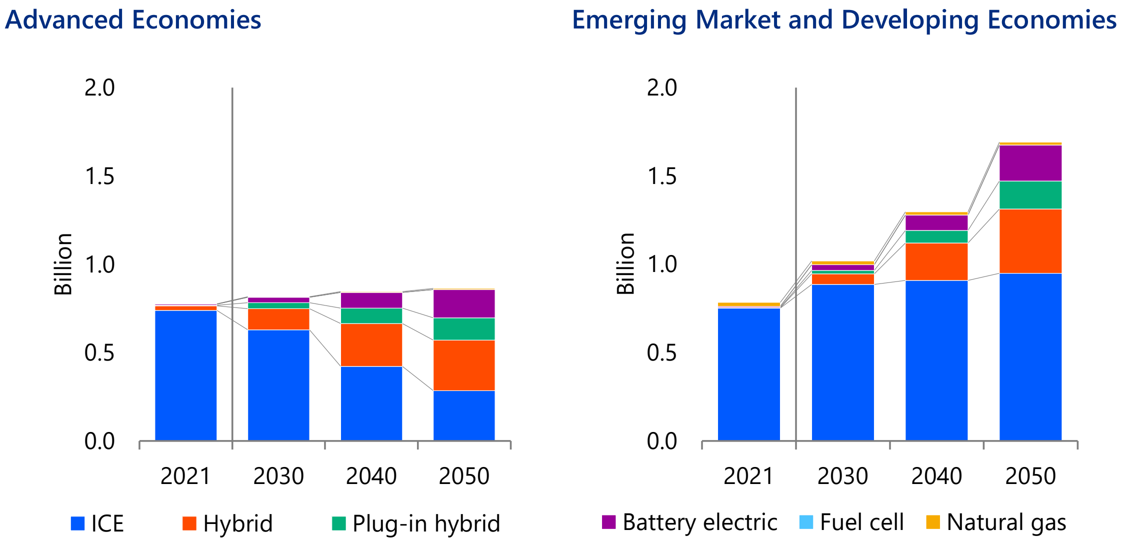
Final energy consumption will increase in all sectors between 2021 and 2050, driven by the Emerging Market and Developing Economies. In the Advanced Economies, final energy consumption will decrease in all sectors other than the non-energy use sector (Figure 2-32).

Figure 2-32 | Final energy consumption in the Advanced Economies, and the Emerging Market and Developing Economies [Reference Scenario]



In the transport sector, final energy consumption will increase at an annual rate of 0.9% from 2 690 Mtoe in 2021 to 3 476 Mtoe in 2050, supported by growth in the road sector of the Emerging Market and Developing Economies. The growth will reach 786 Mtoe, capturing 37% of the overall global rise in final energy consumption. In the Emerging Market and Developing Economies, driven by the economic growth, the ownership of internal combustion, hybrid vehicles and electric vehicles will significantly grow over the same period (Figure 2-33). Therefore, final energy consumption in the transport sector in the Emerging Market and Developing Economies will grow at an annual rate of 1.5%. In the Advanced Economies, electricity consumption will increase due to the diffusion of electric vehicles under policy guidance. On the other hand, the road sector's oil consumption will decline substantially thanks to improvements in fuel efficiency 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 −1.0%.

Figure 2-33 | Vehicle ownership [Reference Scenario]



In the industry sector, final energy consumption (mainly electricity and natural gas) will expand at an annual rate of 0.7% from 3 037 Mtoe in 2021 to 3 673 Mtoe in 2050 due to the development of the manufacturing industries in the Emerging Market and Developing Economies. The sector's consumption growth will reach 636 Mtoe, accounting for 30% of the overall rise in final energy consumption. In general, however, there is a strong incentive in industry sectors, including manufacturing, to reduce the energy consumption of businesses to enhance the cost competitiveness of products. Therefore, the final energy consumption of the global industry sector will increase at a slower pace than the value added growth rate of the global secondary sector from 2021 to 2050 (2.4% per annum).

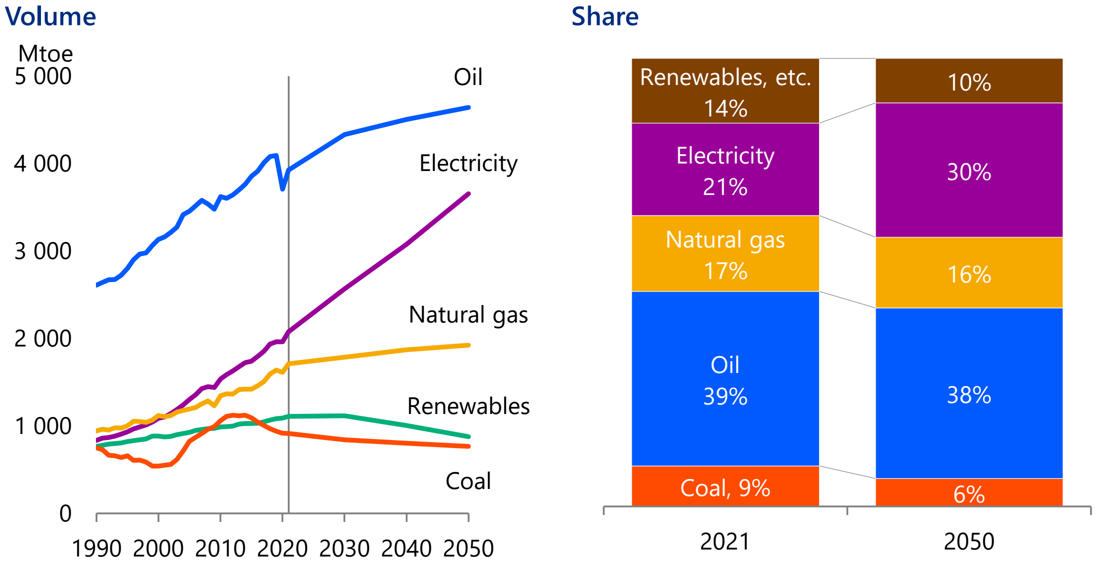
In the buildings sector, final energy consumption will increase at an annual rate of 0.4% from 3 360 Mtoe in 2021 to 3 724 Mtoe in 2050, with growth in the consumption of electricity, city gas and petroleum products in the commercial and residential sectors of the Emerging Market and Developing Economies. The buildings sector's consumption growth will total 364 Mtoe, accounting for 17% of the overall rise in final energy consumption. In the Emerging Market and Developing Economies, access to modern energy and appropriate equipment will gradually increase, in line with the improvement in living standards. In particular, the share of traditional biomass (fuel wood and manure) in the buildings sector energy consumption will drop in Africa from 79% in 2021 to 33% in 2050 and from 22% to 5% in Asia.

In the non-energy use sector, final energy consumption will rise at an annual rate of 1.0% from 995 Mtoe in 2021 to 1 322 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 326 Mtoe, capturing 15% of the overall rise in final energy consumption. In the Emerging Market and Developing Economies, consumption of petrochemical products such as plastics will increase as living standards improve. In the Advanced Economies, consumption will grow slightly between 2021 and 2050. In North America, non-energy use by the petrochemical industry will increase 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 impacts on 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

Changes in global final energy consumption from 2021 to 2050 by major types of energy source can be broadly categorised into those with a share that follows an uptrend and those with a downtrend (Figure 2-34). While only the share of electricity will increase, oil, coal and natural gas, as well as renewable energy, which is dominated by the direct use of biomass, will decrease. Even in 2050, however, there will still be demand for coal and renewables, not to mention natural gas. Fossil fuels (coal, oil and natural gas) will see their share of global final energy consumption fall from 65% in 2021 to 60% in 2050, and will remain the leading energy sources accounting for most of the consumption.

Figure 2-34 | Global final energy consumption (by energy source) [Reference Scenario]



Final oil consumption will increase at a rate of 0.6% per year from 3 926 Mtoe in 2021 to 4 640 Mtoe in 2050, led by growth in the transport sector including the road sector in the Emerging Market and Developing Economies, as noted in the above sector-by-sector analysis. The growth in oil consumption in the road sector in Asia as a whole, including India and ASEAN which are undergoing motorisation, will reach 395 Mtoe, more than offsetting the decrease in the Advanced Economies of 414 Mtoe. 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 2.0% from 2 077 Mtoe in 2021 to 3 654 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. While it will increase in North America and Europe, Asia including China, India and ASEAN will drive the global consumption growth. Generally, as people's income grows, electricity is preferred for its convenience. Another factor behind the growth in electricity consumption is the penetration of digitalisation, which boosts the number of electricity-consuming machines and devices. Electricity's share of global final energy consumption will rise from 21% in 2021 to 30% 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 power sources is a significant issue, it is also important to ensure a stable supply of electricity from the viewpoint of energy security.

Final natural gas consumption will rise at an annual rate of 0.4% from 1 710 Mtoe in 2021 to 1 925 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 Middle East and North Africa where manufacturing will prosper, mainly processing and assembly industries will lead natural gas consumption. In the non-energy use sector, India and ASEAN with their growing demand for chemicals and the Middle East seeking to expand the gas chemical industry will drive the growth of global natural gas consumption.

Final coal consumption will decrease at 0.6% per year from 913 Mtoe in 2021 to 766 Mtoe in 2050 due primarily to reductions in China's industry and buildings sectors. As mentioned in the regional perspective, China's steel and cement manufacturing industries, which consume a large amount of coal, are expected to decline in the medium to long term. As a result, by 2050, China's industry sector will consume less than half of what it did in 2021. In addition, China has pledged its "3060 Goal", which aims to reach peak CO_2 emissions by 2030 and become carbon neutral by 2060. Based on this goal, China plans to reduce coal consumption from 2025, which will accelerate the shift to natural gas and electricity in its industry and buildings sectors.

Final renewable energy consumption will decline at an annual rate of 0.8% from 1 109 Mtoe in 2021 to 879 Mtoe in 2050 due mainly to progress in the energy transition in Asian and African Emerging Market and Developing Economies. An example of renewable energy in the final consumption sector which is attracting attention is liquid biofuels for automobiles and aircraft. However, traditional biomass, including fuel wood and manure used in the Emerging Market and Developing Economies, accounted for the largest share at 71% in 2021, followed by 13% for fuel wood mainly for heating in Europe and North America, 10% for liquid biofuels and 6% for others. As mentioned in the perspective by sector, the use of modern energy is gradually replacing the use of traditional biomass in Emerging Market and Developing Economies in Asia and Africa. As a result, global final consumption of renewables will gradually decline from the late 2020s.

2.3 Carbon dioxide emissions

Estimates of residual carbon budget have been reduced

In the definition of the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), a carbon budget is the maximum amount of cumulative net anthropogenic CO_2 emissions that would result in limiting global warming to a given level with a certain probability, and that amount minus the amount already emitted in the past is called the residual carbon budget. The AR6 Working Group I (WGI) estimated the residual carbon budget of 500 $GtCO_2$ to limit the temperature rise to 1.5°C with a 50% probability. However, this value is the residual value from 1 January 2020 onwards, so if we subtract the approximately 120 $GtCO_2$ emitted into the atmosphere from 2020 to 2022 (estimated for 2022), the residual carbon budget from 2023 onward for 1.5°C (50% probability) shrinks to 380 $GtCO_2$. This is the estimated value of the Global Carbon Budget (GCB) 2022[5].

On the other hand, estimates of the residual carbon budget suffer from uncertainties due to the impacts of non-CO_2 as well as CO_2 on temperature rise. This is because the greater the temperature rise caused by non-CO_2, the smaller the carbon budget will be. Non-CO_2 includes substances with a greenhouse effect, such as methane and nitrous oxide, and substances with a cooling effect, such as sulphate aerosols. In estimating the residual carbon budget, the AR6 WGI uses a simplified climate model to quantify the relationship between non-CO_2 emissions and temperature rise. The same model is also used in the Working Group III (WGIII), but it reflects more recent data on actual and future estimates of non-CO_2 emissions. According to WGIII Chapter 3 Box 3.4, the residual carbon budget to 1.5°C was reduced by 100 $GtCO_2$ when reassessed using the simplified climate model updated for WGIII. This implies that the net greenhouse effect from non-CO_2 has been revised upward towards 1.5°C. Originally, the AR6 WGI assessed the uncertainty from the non-CO_2 emission scenario as ±220 $GtCO_2$, and although the decrease of 100 $GtCO_2$ is within this large uncertainty, it reflects the latest data, resulting in a decrease in the median estimate. The Indicators of Global Climate Change (IGCC) 2022[6] reflects this update on non-CO_2 contributions and the recent year's temperature rise reported in the AR6 Synthesis Report (SYR), and estimates the residual carbon budget from 2023 onwards for 1.5°C (50% probability) to be 250 $GtCO_2$, and for 2°C (50% probability) it is estimated to be 1 150 $GtCO_2$. The above estimates of the residual carbon budget are summarised in Table 2-1. The residual carbon budget of 250 $GtCO_2$ for 1.5°C (50% probability) according to IGCC 2022 is extremely small, equivalent to only about six years of anthropogenic CO_2 emissions based on 41 $GtCO_2$ in 2021 (of which 34 $GtCO_2$ is energy-related).

Table 2-1 | Residual carbon budget

	Temperature rise	Origin	Estimation
IPCC AR6	1.5°C (50% probability)	2020 onwards	500 $GtCO_2$
GCB 2022	1.5°C (50% probability)	2023 onwards	380 $GtCO_2$
IGCC 2022	1.5°C (50% probability)	2023 onwards	250 $GtCO_2$
	2°C (50% probability)	2023 onwards	1 150 $GtCO_2$

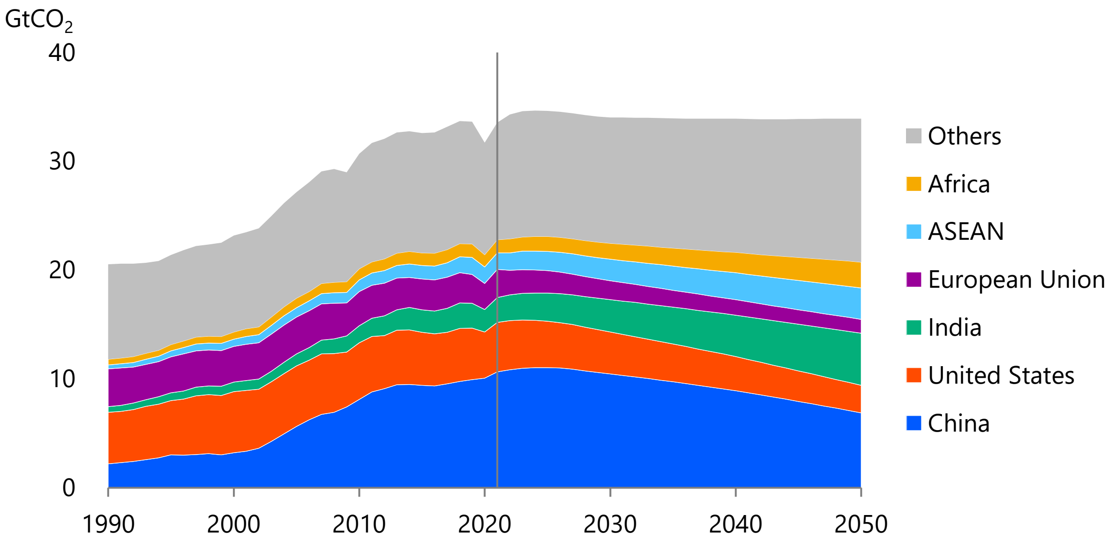
Global emissions will peak by 2025, but will remain at roughly the same level after 2030

As shown in Figure 2-35, global energy-related CO_2 emissions in the Reference Scenario will peak by 2025, but then decline only gradually until 2030 and then remain at about the same level until 2050. Emissions from China, the United States and the European Union will decrease, while those from India, ASEAN and Africa will increase, with the decline in the former largely offset by the increase in the latter. China will continue to be the largest emitter, but by 2050, India will be close behind. The combined emissions of the United States and the European Union, currently at the heart of climate action, will fall below that of India alone or ASEAN and Africa combined by 2045.

[5] Friedlingstein et al. (2022), https://doi.org/10.5194/essd-14-4811-2022

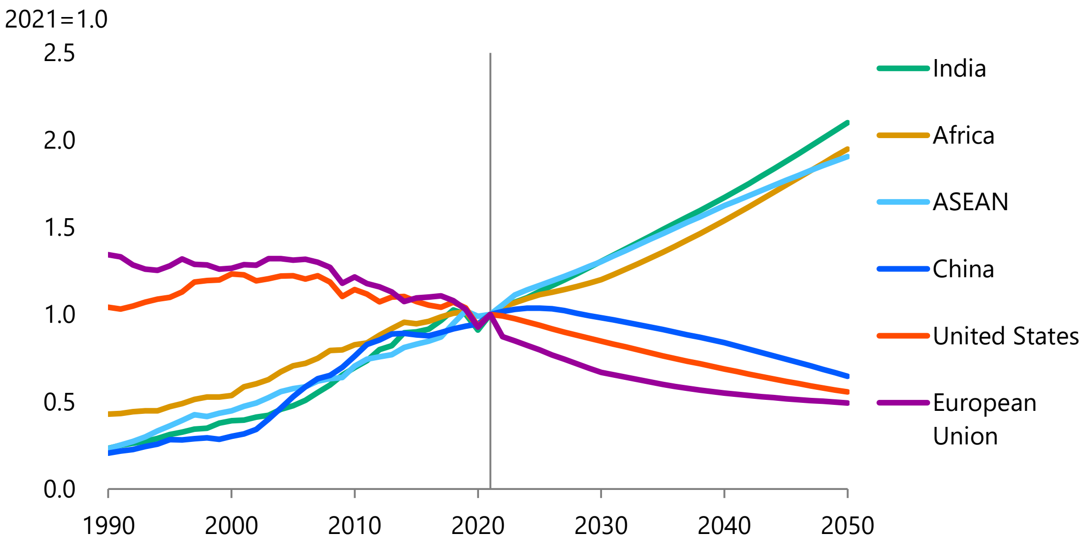
[6] Forster et al. (2023), https://doi.org/10.5194/essd-15-2295-2023

Figure 2-35 | Energy-related CO_2 emissions [Reference Scenario]



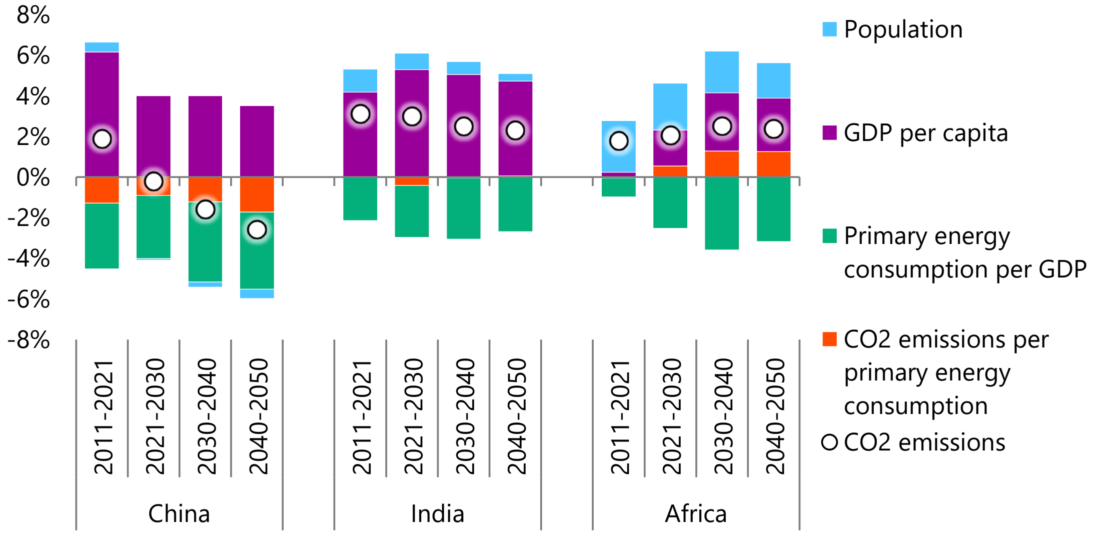
The rate of change in emissions represents the polarisation of emission trends (Figure 2-36). Relative to 2021, India's emissions will increase 2.1-fold by 2050, and Africa's rate of emission growth will accelerate from 2030. Emissions in China, the United States and the European Union will be 35%, 44%, and 51% lower in 2050 than in 2021, respectively. China has a high rate of long-term reductions, the European Union has a high rate of short-term reductions, and the United States lies in between.

Figure 2-36 | Energy-related CO_2 emissions in selected countries/regions [Reference Scenario]



The annual rates of change in emissions are decomposed for China, which will continue to be the world's largest emitter despite declining emissions in the future, and for India and Africa, whose emissions will increase in the future (Figure 2-37). In China, its slowing growth of GDP per capita compared to the past decade will have the largest impact. In addition, improvements in primary energy consumption per unit of GDP and CO_2 emissions per primary energy consumption, which has been a factor in the current decline in combined emissions of just under 5%, will accelerate in the medium to long term. India, in contrast, will maintain rapid economic growth, with emissions expected to grow at the rate of nearly 3% in the short to medium term. Over the past decade, there has been no improvement in CO_2 emissions per primary energy consumption, and this trend continues. In Africa, most of the emissions growth over the past ten years is attributable to population growth, but this will be supplemented by rising GDP per capita. Furthermore, with the transition from traditional biomass to fossil fuels, CO_2 emissions per primary energy consumption will worsen and cause increased emissions. Primary energy consumption per GDP will improve significantly from the current level, serving as the only driver of reduced emissions.

Figure 2-37 | Decomposition of change rates in energy-related CO_2 emissions in China, India and Africa [Reference Scenario]



Note: Confounding terms are not allocated.

3. Energy supply

3.1 Crude oil

Crude oil supply in recent years

OPEC Plus, which consists of the Organization of Petroleum Exporting Countries (OPEC) and non-OPEC major oil-producing countries, has been coordinating production cuts since 2017. From the early stage of the Covid-19 pandemic, in May 2020, the group resumed its production cuts but has been gradually easing the cuts as demand recovers. In response to Russia's invasion of Ukraine in February 2022, Western countries tightened their sanctions, but Russia's production has declined only a little. OPEC Plus has been cutting production again since October 2022 to cope with the sluggish oil prices and is gradually increasing the extent of the production cuts. In the United States, the world's largest oil producer, production plunged as the collapsing oil price in the early days of the pandemic worsened upstream economics, squeezing financing for upstream projects, but has been recovering slowly since the latter half of 2022. Western countries are moving away from Russian oil, with the Group of Seven (G7) and the European Union putting an embargo on Russian oil. In the short term, increased exports to China, India and other countries will support Russian production, but the difficulty of obtaining alternative markets and stagnation in upstream investment will restrain Russian oil production in the medium to long term. Meanwhile, for Western countries, the United States is becoming increasingly important as an alternative supplier to Russia.

Middle Eastern oil producers taking advantage of low production costs to lead the global supply of crude oil

In the Reference Scenario, world oil demand will continue to increase until 2050, mainly in Emerging Market and Developing Economies, such as India, the Association of Southeast Asian Nations (ASEAN) and Africa, on the back of economic growth.

Until 2030, global oil demand will increase at an annual rate of 0.9%, and both OPEC and non-OPEC will respond by raising crude oil production. OPEC member countries, led by the Middle East Gulf countries which enjoy overwhelming cost competitiveness, will drive the increase in world crude oil supply during this period. Europe and Eurasia, where production was expected to decline in the medium to long term, even before the war in Ukraine, will accelerate the speed of decrease as Russia's lack of upstream investment worsens due to embargoes and sanctions by Western countries. Meanwhile, production in North America, mainly the United States which grew enormously in the 2010s, will peak around 2030. Countries such as Brazil and Guyana will slightly increase their production and boost overall output in South America, while production in Africa will level off and those in Asia and Oceania will continue to decline. Although production in North America will decline moderately from 2030, the United States will continue to be the world's largest oil producer in 2050. While production in Latin America will slightly increase, production in non-OPEC regions such as Europe and Eurasia and Asia will decrease, highlighting the increased presence of Middle East OPEC member countries with ample crude oil reserves. These countries, which boast low production costs, led by OPEC leader Saudi Arabia, will capture most of the increase in demand from 2030 to 2050. As a result, the share of OPEC crude oil in the world oil supply will expand from 34% in 2021 to 43% in 2050.

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

(Mb/d)

	2021	2030	2040	2050	2021-2050	
					Changes	CAGR
Crude oil production	90.2	100.0	103.4	105.7	15.5	0.5%
OPEC	31.9	38.4	42.8	46.4	14.6	1.3%
Middle East	25.0	31.3	35.0	37.8	12.8	1.4%
Others	6.9	7.1	7.8	8.7	1.8	0.8%
Non-OPEC	58.3	61.6	60.5	59.3	0.9	0.1%
North America	21.1	25.1	24.6	23.9	2.8	0.4%
Latin America	7.8	8.5	9.8	10.8	3.1	1.2%
Europe and Eurasia	17.7	16.5	15.4	14.1	-3.6	-0.8%
Middle East	2.9	3.3	3.6	3.9	1.0	1.0%
Africa	1.3	1.5	1.5	1.5	0.2	0.5%
Asia and Oceania	7.5	6.8	5.7	5.0	-2.5	-1.4%
Processing gains	2.3	2.6	2.8	2.9	0.6	0.8%
Oil supply	92.5	102.6	106.1	108.6	16.1	0.6%

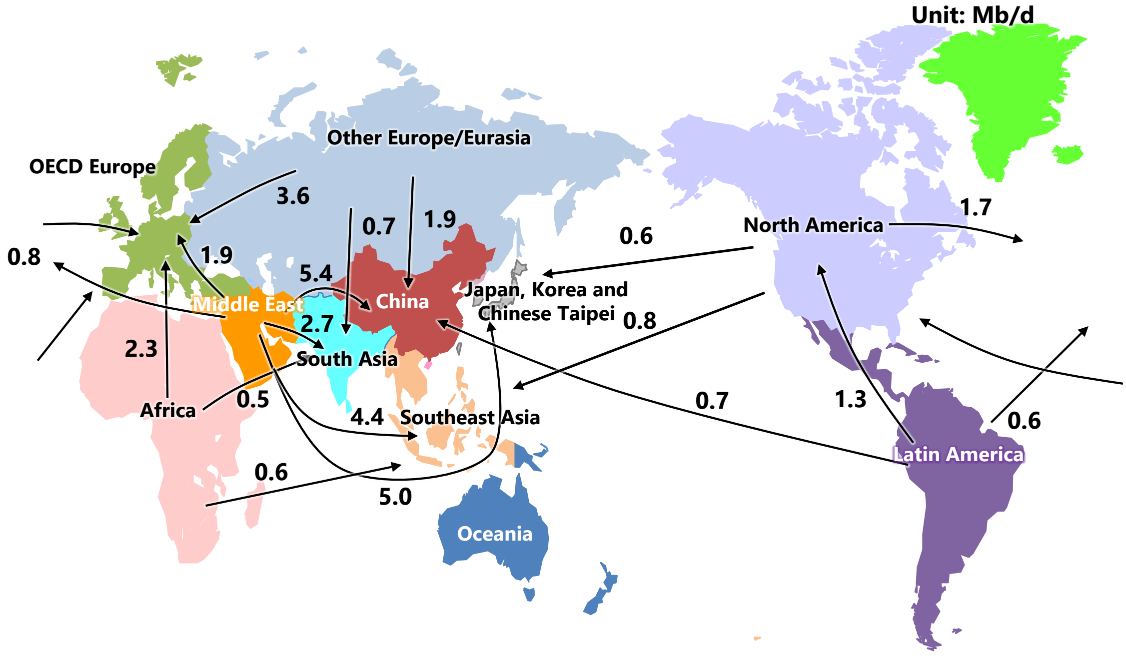
Note: Crude oil includes natural gas liquid (NGL).

Asia growing dependent on Middle Eastern crude oil

Crude oil trade in the world totalled about 43 million barrels per day (Mb/d) in 2022. The Middle East, the largest exporting region, accounts for about 16 Mb/d, or 38% of global exports, followed by Non-OECD[7] Europe/Central Asia, led by Russia, and North America at about 7 Mb/d. 80% of Middle East exports are destined for Asia, while 50% of Non-OECD Europe/Central Asia exports are for Europe and 40% for Asia. Trade in North America is mainly intra-regional (e.g. between the United States and Canada), accounting for 60% of the total, with 20% destined for Asia. As for imports, Asia is by far the largest importing region with about 27 Mb/d, of which China, the world's largest importer, accounts for about 10 Mb/d. Imports by OECD Europe are also large at about 10 Mb/d. The largest supplier for Asia is the Middle East, with 60% dependency for Asia as a whole. Non-OECD Europe/Central Asia continues to be the largest supplier region for OECD Europe. However, OECD Europe's entire dependence on Non-OECD Europe/Central Asia has fallen from 40% before the invasion of Ukraine (the European Union's dependence on Russia was 30%) to 36% for the full year of 2022 (European Union's dependence on Russia: 23% in 2022). Global crude oil trade will increase as demand grows in non-oil-producing countries. In OECD countries, where demand is declining, imports also will continue to shrink, but imports from non-OECD countries will increase at a faster pace than from OECD countries. While China's imports will peak around 2030, those of India and ASEAN are increasing remarkably, boosting Asia's dependence on imports. Non-OECD Europe/Central Asia, led by Russia, will increase their dependency on the Chinese market as supplies to Europe decelerate. While flows from the Americas to Asia will increase, the Middle East will remain the largest supplier for Asia.

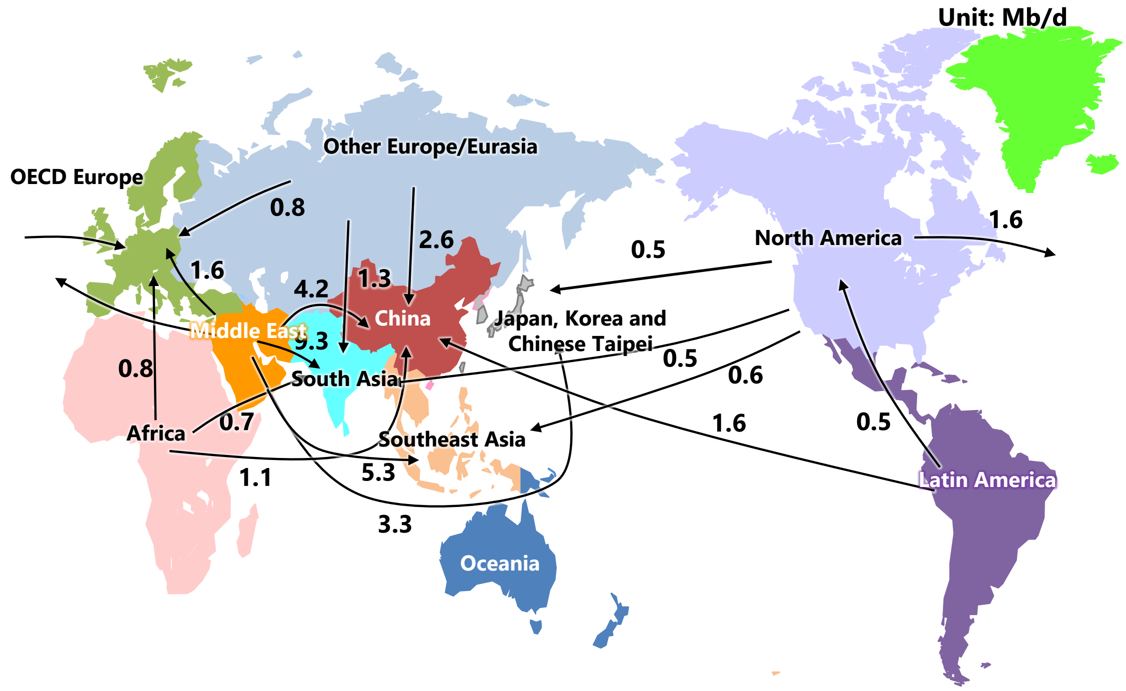
[7] Organisation for Economic Co-operation and Development

Figure 3-1 | Major interregional crude oil trade flows [2022]



Note: Flows of 0.5 Mb/d or more are covered.
Source: Energy Institute "Statistical Review of World Energy 2023", national trade statistics

Figure 3-2 | 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 expansion of the liquid natural gas market, but the outlook is uncertain

In the global liquefied natural gas (LNG) market in the first half of 2023, global LNG ocean transported volume exceeded 200 Mt (up 2% year-on-year). Notably, LNG imports decreased in Japan and increased in Europe and Southeast Asia. However, fluctuations in imports and exports were more moderate than in the same period of the previous year. China's LNG imports started to increase from March, and the rate of increase in the coming months will be worth watching in the 2023 winter season in the northern hemisphere. In the first half of 2023, China's LNG imports exceeded those of Japan, making China the world's largest LNG importer. In Europe, with relatively high levels of natural gas inventories in underground storage facilities, the rate of increase in LNG imports has eased compared to the same period last year.

On the LNG export side, as in the same period of the previous year, the United States, Australia and Qatar competed with respective LNG exports of around 40 Mt each. Russia, in the fourth place, saw a significant decline of 9% year-on-year, with substantial declines also in Nigeria, Egypt and Equatorial Guinea.

In 2022, the supply of Russian pipeline gas to the European Union (EU) fell from just over 8 Mt of LNG equivalent in December 2021 to below 2 Mt by December 2022, due to both the European Union avoiding using Russian fossil fuels and Russia's reduction of energy supply. On the other hand, the supply of Russian LNG to the European Union increased slightly in 2022. However, it should be noted that from 2023 onwards, there are also uncertainties in the supply of Russian LNG, in addition to the remaining Russian pipeline gas supply.

Furthermore, depending on future trends in spot gas prices in Asia and Europe, the ratio of U.S. LNG to Asia and Europe will fluctuate. The ratio of U.S. LNG exports to the European Union and the United Kingdom increased from around 30% in 2021 to two-thirds in 2022 and nearly 70% in the first half of 2023. On the other hand, the ratio to Asia fell from less than half in 2021, to just under a quarter in 2022, to around 20% in the first half of 2023.

In the LNG market in 2022, a shutdown and the postponed restart of one U.S. LNG facility following a fire there became a major factor in the decline in supply and uncertain future outlook. If there are any additional troubles with large LNG production facilities in the future, the market balance could fluctuate significantly. In late 2023 and early 2024, the stable start-up and timing of new projects in Indonesia, Mauritania and Senegal will also be major factors that affect the market.

Australia, one of the world's largest LNG exporters, has announced three regulatory changes that will affect its LNG business in 2022-2023. These are revisions to the Australian Domestic Gas Supply Security Mechanism (ADGSM), the Safeguard Mechanism for regulating greenhouse gas emissions, and the Petroleum Resources Rent Tax (PRRT). The ADGSM amendment is notable for clarifying the protection of long-term LNG sales contracts, the Safeguard Mechanism amendment for detailing the implementation of staged tightening of the emission cap, and the PRRT amendment for its impact on the economic efficiency of LNG operations in the country.

China, the fastest growing and largest natural gas and LNG market over the past few years, experienced a year-on-year decline in natural gas consumption by 1.7% in 2022 for the first time since records began. LNG imports fell by nearly 20% year-on-year. The country's natural gas consumption started increasing in 2023, with LNG imports totalling 33.44 Mt in the first half of the year, up 7.2% year-on-year. Although China is still well below its record high of 39.78 Mt in the first half of 2021, Japan's LNG imports fell by 13.1% year-on-year to 32.62 Mt in the same six months, thus making China again the world's largest LNG importer during the period.

In India, the next fastest-growing natural gas market, natural gas consumption fell by 5% in 2022, in particular with consumption for power generation falling by about a quarter. While LNG imports and natural gas production by state-owned enterprises declined, production by private companies increased by 25%. Since the beginning of 2023, consumption for fertiliser production and for city gas have both increased.

In Southeast Asia and South Asia (excluding India), the impact of fluctuations in prices and supply and demand on the LNG global market has been varied in recent years. In Southeast Asia, LNG imports increased by 20% or 2.50 Mt for the full year 2022 and by 39% or 2.86 Mt in the first half of 2023, but the impact has varied due to the presence of both LNG-exporting and importing countries in Southeast Asia. In 2023, the Philippines and Viet Nam joined the list of LNG importers, leading to a further increase of LNG imports in Southeast Asia.

On the other hand, Bangladesh and Pakistan significantly reduced LNG imports for power generation, with a combined decline of 18% or 2.50 Mt in 2022 and 2.8% or 0.18 Mt in the first half of 2023.

Aiming at stabilising the LNG market: Supply, demand and prices

Since the oil crisis half a century ago, natural gas and LNG have grown as the cleanest and most essential energy sources among fossil fuels (with natural gas accounting for one-quarter of the share of primary energy in both the world and Japan). As a result, the impact of natural gas and LNG on overall energy security has expanded, highlighting the importance of ensuring a stable supply of LNG itself, especially in Asia, where LNG accounts for a major part of the natural gas supply. In particular, LNG traded by sea has increased by more than 60% in the 12 years since 2011. In 2022-2023, Germany, the Philippines, Hong Kong, and Viet Nam joined the list of importing countries and regions.

As natural gas has become the world's major energy source, LNG holds the key to global energy supply security. On the supply side, the key issue in the long-term will be to achieve stable supply from non-Russian sources such as the United States, Australia, Canada and Africa.

For the time being, the United States will play a major role involving projects with a high likelihood of attracting investment. LNG projects in the United States are not vertically integrated, unlike traditional LNG projects in other regions with upstream gas fields closely connected. Furthermore, project construction and investment decisions have been made within loose commitments on LNG purchasing that do not necessarily fix the final consumption destination. On the other hand, after 2021 onwards, long-term contracts which tend to specify the end-user gained momentum again. Thus, as the volume grows, the structure of projects is becoming increasingly diverse.

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 price advantage compared to prices for most traditional contracts for LNG supply to Asia which were high. In 2020, U.S. LNG supply flexibly absorbed demand fluctuations amid weak gas prices. In 2021, U.S. LNG also demonstrated its flexibility and price advantage amid a global gas price hike, solidifying its position as a supply source to different global regions. In 2022, the United States became the largest source of additional natural gas for Europe. In 2023, it is expected to become the world's largest LNG exporter.

The increasing presence of the United States in the global LNG market has begun to exert impacts on LNG procurement contract negotiations for the United States 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 and 2021 above that of Qatar, which had been the world's largest LNG exporter since 2006. Russia has currently increased LNG production from its Arctic region, expanding its share of the European market and its exports to Europe posted a record-high in 2022.

Shift of LNG logistics to Europe and normalisation of high global gas prices

Large-scale projects used to require a long period of time, typically four to five years, from the investment decision to the start of LNG exports. In order to shorten the construction term, efforts are being made to speed up the engineering and assembly construction period through standardising and modularising some of the units; and they are producing results. In addition, some of the emerging project companies have announced the completion of 1.4 Mt/year LNG liquefaction facilities in one to two years, which is significantly faster than usual.

There are frontier regions in East and West Africa expanding 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 already come into operation. Investment decisions have been made in 2017 for a floating LNG production project off Mozambique in East Africa, in 2018 for off Senegal and Mauritania in West Africa, and in 2022 for off the Republic of Congo. Large LNG players with global marketing capabilities have made commitments to take delivery of all LNG produced under these projects to promote them.

Mozambique is planning multiple onshore LNG production projects in addition to its floating LNG production project. An investment decision was made on one of them in June 2019. Unfortunately, as of 2021-2023, construction is suspended due to the deteriorating local security situation. Mozambique which 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 in the future. Backed by the abovementioned projects, natural gas production will increase steadily.

In the short term, it is necessary to cope with the decline in Russian pipeline gas supply, secure stable production in LNG-producing countries, and smoothly launch new LNG production projects in the next one to two years. The short-term stabilisation of LNG production through these measures will raise the reliability of LNG and lead to long-term investment.

On the demand side, it is becoming even more important to respond to fluctuations in the demand outlook due to the impact of long-term decarbonisation initiatives, shifting demand centres to developing economies, and the demand-side trend toward flexible contracts. In the short term, the market balance will be affected by uncertainties in natural gas demand due to the impact of nuclear and renewable energies, volatility in cutting or decreasing natural gas demand in Europe, and the trend of recovering natural gas demand in China, India and Asian emerging markets.

In terms of prices, in the long term, it is necessary to diversify and optimise the contract pricing schemes, and to set prices in a balanced manner that supports stable market growth and investment. In the short term, dealing with increased volatility will continue to plague the industry.

In this regard, it is important to address policy and investment security issues to stabilise the LNG market. Specific measures to ensure stable growth of the LNG market and stable supply sources, especially for fast-growing emerging markets, are to establish the superiority of LNG projects as investment targets and financing sources, by clarifying standards for transition-compliant LNG, clarifying standards for measuring, reporting, and verifying (MRV) greenhouse gas (GHG) emissions standards, and clarifying standards for equipment for clean measures at the government and international levels.

Progress in this regard was made in 2023, when the G7 and LNG Producer-Consumer Conference discussed strengthening the role of the government and the International Energy Agency (IEA) to stabilise the LNG market.

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

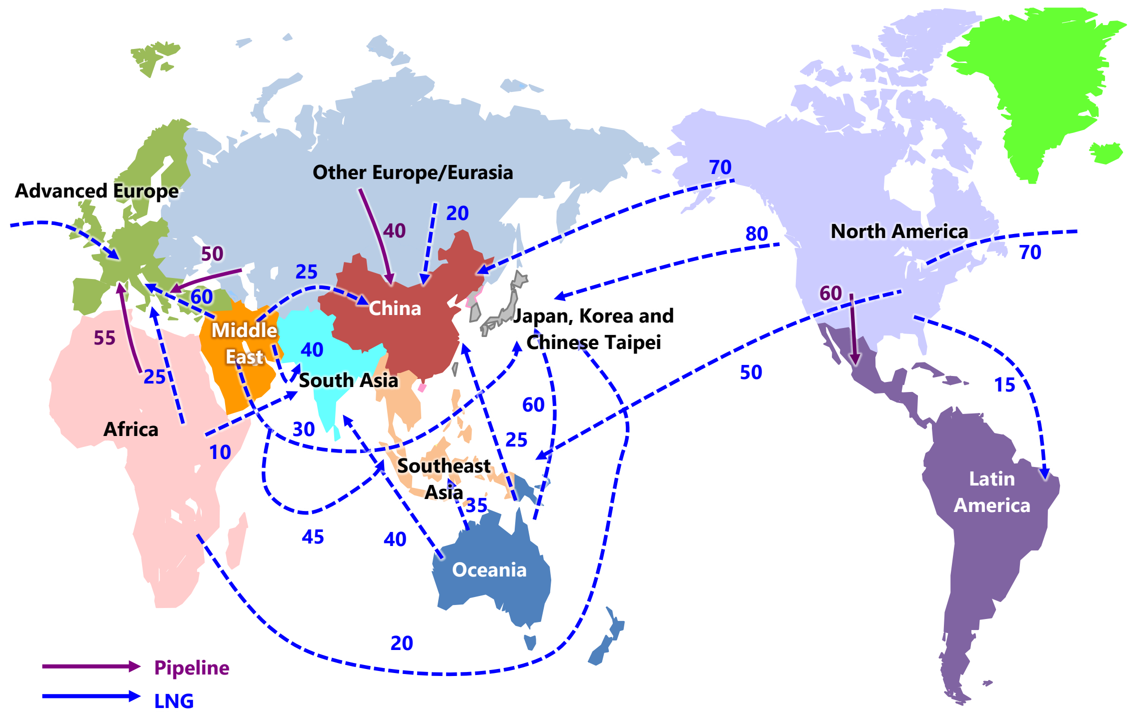
(Bcm)

	2021	2030	2040	2050	2021-2050	
					Changes	CAGR
World	4 207	4 348	4 778	5 368	1 161	0.8%
North America and Mexico	1 208	1 364	1 409	1 432	224	0.6%
Latin America excluding Mexico	152	164	225	313	162	2.5%
Europe	204	150	130	100	-104	-2.4%
Europe/Central Asia	1 010	848	864	909	-101	-0.4%
Russia	794	618	610	609	-185	-0.9%
Middle East	702	766	871	1 035	333	1.3%
Africa	260	253	368	551	291	2.6%
Asia	517	638	726	825	308	1.6%
China	208	240	248	251	43	0.7%
India	32	45	83	110	78	4.3%
ASEAN	193	216	242	261	68	1.1%
Oceania	155	165	185	204	49	0.9%

Figure 3-3 | Major interregional natural gas trade flows [2022]

Note: Major trade flows are covered.

Figure 3-4 | 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

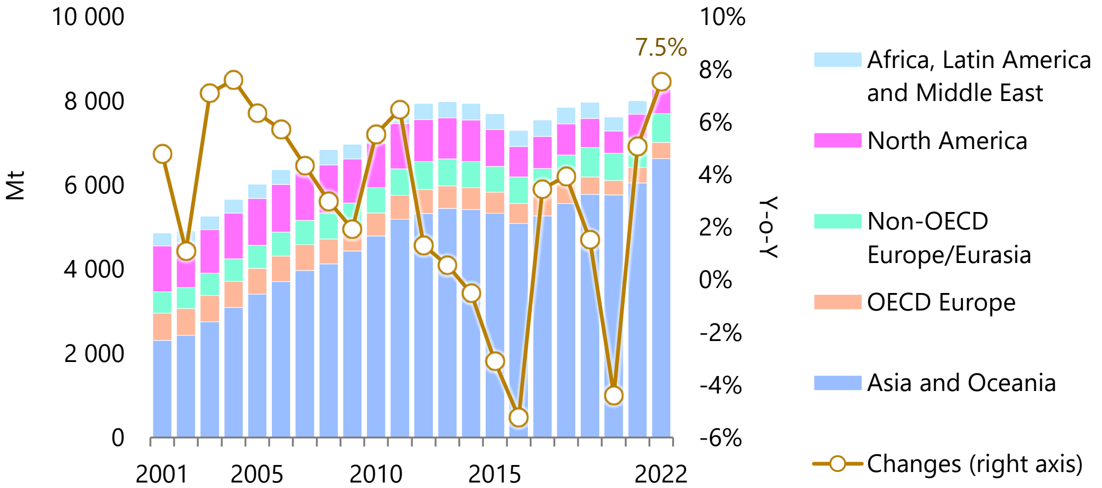
Increasing regional fragmentation of supply and demand in the world

In 2022, coal consumption reached an all-time high as the economy recovered from Covid-19, albeit with some regional unevenness, thanks to its ready availability amid a tighter global natural gas market. Also, production increased drastically in China and India, where domestic demand grew, and in Indonesia, which benefited from expanding export demand. On the other hand, production in other countries rose sluggishly due to supply disruptions caused by various factors, including natural disasters, accidents and personnel shortages caused by the spread of Covid-19.

Global coal consumption in 2022 hit an all-time high of 8 397 Mt (up 3.9% or 313 Mt year-on-year) following the recovery after three years of Covid-19. In 2022, the growth of consumption in China and India has accelerated particularly. China increased by 198 Mt (4.6%) YoY to 4 513 Mt, while that in India increased by 114 Mt (10.8%) YoY to 1 173 Mt. On the other hand, the United States started to contract again with 468 Mt, down 25 Mt (5%) from the previous year. OECD Europe levelled off at 528 Mt year-on-year, but did not recover to pre-pandemic levels, although thermal power generation compensated for the decline in nuclear and hydro power generation in the region. With nuclear and hydro expected to recover, coal consumption in the European Union is likely to shrink further.

Meanwhile, also global coal production in 2022 marked 8 609 Mt (up 7.5% or 603 Mt from the previous year) along with the increase and recovery of demand, far exceeding 7 969 Mt reached in 2019 before the spread of Covid-19 (Figure 3-5).

Figure 3-5 | Global coal production



Note: Figures for 2022 are provisional.
Source: IEA "World Energy Statistics and Balances 2023"

By region, the increase (or decrease in some regions) varied remarkably. In Asia and Oceania, the year-on-year increase was 9.6% (+581 Mt), most of which came from increases in China, India and Indonesia, with China increasing by 8.7% (+349 Mt), India by 14.6% (+121 Mt) and Indonesia by 20.0% (+116 Mt). In other regions, OECD America increased production by 2.2% (+13 Mt), OECD

Europe by 1.2% (+4 Mt), and Non-OECD Europe and Eurasia by −0.1% (−1 Mt), while Africa, Latin America and the Middle East increased production by 1.8% (+6 Mt).

Looking at production trends in 2022 among main exporting countries, Australia saw a decline of about 0.3% or 2 Mt from the previous year to 458 Mt due to slow recovery from the production decrease caused by the pandemic as well as irregular weather due to La Niña. Indonesia saw a substantial increase in production largely because the country responded to the tightening global coal supply-demand environment by aggressively increasing production (to 687 Mt, up 20% or 116 Mt from the previous year). In Colombia, which mainly targets the European market, there was a recovery trend after the withdrawal of Glencore and the disruption caused by workers' protests, but the effect of irregular weather prevented a significant recovery in production, marking 54 Mt, the same level as the previous year. In South Africa, for which the main markets are India and ASEAN as well, production is still showing no signs of recovery, with volumes at the same level as the previous year due to the spread of Covid-19, railway accidents, and declining domestic demand. Meanwhile, in Russia, despite the embargoes imposed by Western countries due to the invasion of Ukraine and bottlenecks along the Trans-Siberian Railway, production recorded 444 Mt, almost the same as the previous year.

In 2022, the global flow of coal changed dramatically due to the impact of sanctions imposed on coal exports from Russia after it invaded Ukraine. This has led to a global shortage of coal supply due to factors such as securing alternative coal supplies to replace Russia, decreased exports due to severe production interruptions caused by bad weather (La Niña) in Australia, and an inability to increase coal production in South Africa due to infrastructure problems despite the incentive of rising market prices. As a result, the trade volume has been suppressed. This phase of rapid price rises also prompted China and India to impose import restrictions and pursue policies to significantly increase domestic production. As a result, in China, the amount of imported coal fell by 11% year-on-year to 295 Mt. In India, however, despite increased domestic production due to strong demand for coal, imports also increased by 12.9% year-on-year to 212 Mt. This market environment resulted in the international trade volume of steam coal of 1 043 Mt (down 1.8% year-on-year). On the other hand, the international trade volume of coking coal also declined due to the sluggish economy, to 292 Mt (down 2.5% from the previous year).

Supply-demand balance amid the continuing invasion of Ukraine

The global coal market has been experiencing a continued increase in demand even in 2023. On a global first-half basis, both the power generation and non-power sectors reportedly showed a year-on-year increase. Notably, as in 2022, increases in China, India and Indonesia have outpaced decreases in the United States, the European Union and Japan.

Looking at the three countries where demand increased in the first half of the year, China's dependency on coal has heightened due to the Covid-19 lockdown weighing on the economy in the first half of 2022 and extremely low hydro power generation in the first half of 2023. In India, continued economic growth led to increased dependency on coal in each industry. Indonesia, similarly to India, has shown an improving economic outlook, and the power sector, smelting sector and other industries have been consuming more coal, thus pushing up demand.

On the other hand, the United States and the European Union, where demand for coal is declining, have seen remarkable declines in the power sector due to a combination of sluggish electricity demand and expansion of renewable energies. In the United States, cheap natural gas has also led to a decline in coal demand. Japan and Korea also saw a drop in consumption in the first half of 2023 due to declining coal-fired power plant operations affected by lower LNG prices than the previous year.

In the meantime, global coal production has continued to increase significantly in China, India and Indonesia in the first half of the year, offsetting declines in the United States and the European Union. As for other countries, coal production in Australia suffered a decline in 2022 due to severe weather caused by La Niña, but has recovered in 2023 without being affected by the weather. Coal production in South Africa is expected to decline further as operations of coal-fired power plants continue to contract due to a chronic lack of maintenance and severe infrastructure issues. Production in Russia has hardly declined despite some impacts of the import ban imposed by Western countries. Depending on how the war evolves, however, further decreases may occur.

The trade of coal in 2023 has seen a dramatic recovery of supplies from the previous year due to the end of the La Niña phenomenon that hampered production in Australia as well as the warm winter in the northern hemisphere. In addition to this increase in coal supply, easing of the natural gas supply-demand environment has caused coal prices to drop from the end of 2022 to mid-2023. The decline in coal prices attracted price-sensitive buyers in China, India and others, but has also been partly offset by the falling exchange rate between the Chinese yuan and the Indian rupee against the U.S. dollar, failing to lead to a surge in trading. However, China has increased its imports year-on-year due to the lifting of an unofficial ban on Australian coal imports in January 2023. From the beginning of the year to the end of April, coal imports by China and India accounted about 50% of the world's imports. It is notable that these two major producers and consumers of coal also account for a large share of imports.

Against this backdrop, the global increase in steam coal import demand in 2023 is expected to mainly be covered by Indonesian exports, as in the previous year.

In the first half of 2023, OECD Europe saw a decline in coal-fired power generation operations reflecting an easing of overall energy supply and demand, and resold steam coal procured in the previous year and stocked at its import terminals, in the form of exports (exported nearly 1 Mt to the entire region in April, to Morocco, India, China, etc.).

Coal market conditions

In 2022, the coal market was extremely tight due to a rapid increase in global demand and the worsening shortage of global supply, triggering unprecedented price levels. Energy prices have risen across the board since Russia invaded Ukraine, but rising natural gas prices caused many countries to switch to coal-fired power generation, thus boosting coal demand. On the supply side, La Niña in Australia seriously affected coal production. Indonesia introduced a temporary export ban in January 2022 (which it has since lifted) to cover domestic supply shortages, causing the trade of steam coal in the market to decrease. In Europe, prices have risen drastically from the previous year partly because of the ban on Russian coal imports from August due to its invasion of Ukraine, despite a rise in demand in Europe.

An overview of price fluctuations suggests that the price of steam coal (freight on board [FOB] price out of Newcastle, Australia) rose gradually to the $250/t range from the beginning of the year, followed by a momentary surge to nearly $400/t in early March after the invasion of Ukraine. The price subsequently returned to the upper $200/t range, but in April it began to rise again, once exceeding $400/t in May. The price then hovered around $400/t, until it rose again to well above $400/t in late August. After that, the price temporarily fell below $400/t, but without hope of a recovery in production towards the end of the year, the price of Australian coal rose again towards the end of the year, exceeding $400/t. Meanwhile, price changes in Europe were similar in the first half of the year, exceeding $400/t from June to July. However, the price declined towards the end of the year, despite a temporary rise in the fourth quarter, following higher Australian coal prices due to forecasts of a warmer winter and higher inventory levels resulting from intermittent procurement on the demand side.

In 2023, a mild winter in Europe further eased coal supply and demand, while demand for Australian coal in Asia remained high. This resulted in a price differential of around $200/t between Europe and Asia at the beginning of the first quarter (less than $200/t in the European Union and around $400/t in Asia in January). Since then, prices have fallen rapidly with the recovery of Australian production and the end of the demand period in the northern hemisphere, reaching the $150/t level in July, almost the same as in Europe.

As substitution of Australian coal is limited due to its high calorie quality compared to Indonesian coal and others, the price is likely to soar if the supply plunges as in 2022. This was evident in the price change in Australian coal in 2022. Under normal market conditions, the price of coking coal is higher than that of steam coal. However, amid the supply-demand environment following the invasion of Ukraine, this gap was reversed, with Australian steam coal prices continuing to exceed coking coal prices from July 2022 to January 2023. Since the end of China's embargo in 2023, the price of coking coal has risen and supply and demand in the steam coal market has eased, resulting in returning to normal i.e. the higher coking coal price than steam coal price.

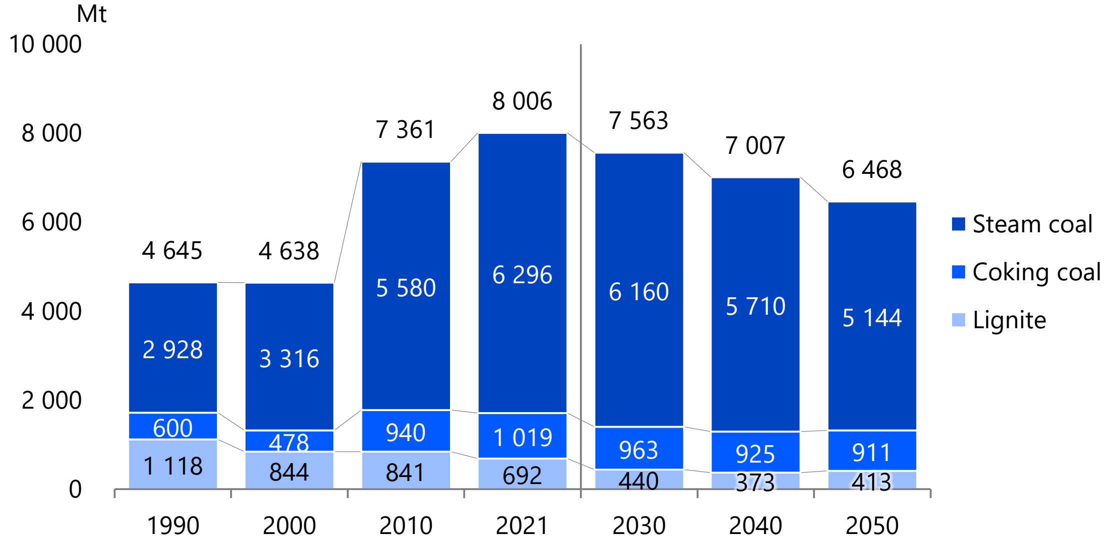
Maintaining a supply system that meets demand

Advanced Economies, including the United States and Europe, have been accelerating their decarbonisation efforts, while Emerging Market and Developing Economies have also declared their commitment to carbon neutrality. As such, many countries now share a common recognition of the need to strictly curb the consumption and production of fossil fuels, especially coal. Already, coal consumption in Europe and the United States has been steadily declining. On the other hand, demand in China and India has continued to increase. In 2022, there was a shift in demand to coal due to a shortage of natural gas after Russia invaded Ukraine, in addition to the recovery of economic activity from the pandemic, which resulted in spreading fears of a supply-demand crunch. Against this backdrop, prices remained significantly higher than in the previous year throughout the year. Despite this supply-demand environment, there has been little impact on the decarbonisation trend to date, and the moves to exit or downsize the upstream coal sector have been accelerating among resource majors and Japanese trading companies.

Given the energy status in each country and current coal demand situation, however, the global phase-out of coal is expected to be a long-term effort in practice. Coal consumption in 2022 increased from the previous year. However, the increase in global demand has been driven by China and India, while the ban on Russian coal imports as a sanction against the country disrupted the coal market in 2022. Such events will cause coal trade flows to change and affect the production of coal-supplying countries in the short and medium term. Again, looking at the global coal demand in the short to medium term, demand will expand in Asia including China, India and ASEAN countries, and Africa, following economic growth. In the long term, demand will increase in Asia, including India and ASEAN, excluding China, and Africa. Producing countries will be required to respond to domestic demand and export demand under severe investment and financing restrictions in the upstream coal industry.

World coal production will increase until the late 2020s in line with demand, then start to decline, with the downward trend intensifying after the 2030s. Production volume will decrease from 7 619 Mt in 2020 to 7 563 Mt in 2030 and to 6 468 Mt in 2050 (Figure 3-6). By coal type, steam coal production will increase until the early 2030s mainly in line with the growth in demand for coal for power generation, followed by a decline. Specifically, the production volume will expand from 5 962 Mt in 2020 to 6 160 Mt in 2030, followed by a decrease to 5 144 Mt in 2050. Meanwhile, coking coal production mainly for steelmaking will gradually decline from 1 015 Mt in 2020 to 911 Mt in 2050. Production of lignite, a locally produced and consumed energy resource, will gradually decrease from 643 Mt in 2020 to 413 Mt in 2050 along with the abolishment of existing lignite-fired power plants.

Figure 3-6 | Global coal production [Reference Scenario]



In the future, coal-supplying countries will produce in response to the export demand, namely, the international coal market, after meeting their own demand. On the other hand, countries that produce but also consume much coal, such as China and India, will expand domestic production to meet domestic demand and import the shortfall from other supplying countries. Countries such as Japan, where coal resources are scarce and production is not economical, will depend on imports.

Looking at the situation in major coal-producing countries and regions, European and North American Advanced Economies, as well as East European coal-producing European Union members such as Poland will find it more difficult to either develop new coal mines, expand production at those in operation, or invest in transportation infrastructure. In Australia, domestic consumption and export of coal is an important concern that divides public opinion. The federal government is set to tighten its existing greenhouse gas measures after the change of government in 2022, which could have a significant impact on the future production of fossil fuels, including coal mines. Coal-producing state governments are also increasingly looking for ways to earn foreign currency other than coal exports while complying with the policies to address climate change. While demand for coal continues to increase in India and the ASEAN region, which are major coal export destinations, exports from Indonesia, currently a competitor, are expected to taper off due to the country’s policy. Supplies from Australia (especially steam coal) might expand, but this may be difficult given the current policy and investment environment. The situation of mergers and acquisitions (M&A) of coal mines in Australia should continue to be closely monitored.

In Colombia, which has served as a supplier of coal mainly for Europe, companies from advanced economies will withdraw from coal production. The country may not increase production significantly in the medium to long term, although it will maintain a certain production volume for exports to Asian markets. South Africa, whose main markets are domestic supply, India and ASEAN, is also witnessing a transformation of its coal industry, including the withdrawal of companies from advanced economies. Reserves in the existing coalfields of South Africa are being depleted forcing it to shift to new coalfields. Indonesia, a major exporter of steam coal, has been expanding production, but as stated above, to restrain production volume and protect its coal resources, the government is announcing production targets every year. Against this backdrop, its domestic demand is expanding, and the government is prioritising domestic supply and imposing coal supply obligations, which will lead to decreased exports in the long term.

Meanwhile, China and India have rapidly constructed coal-fired power plants and consume their domestic coal resources. While Chinese demand will peak around late 2020s before declining, Indian demand will increase toward 2050. Both countries will continue to be important purchasers in the international market, receiving imported coal mainly in coastal areas, while maintaining their supply systems from domestic mines.

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

(Mt)

	2021	2030	2040	2050	2021-2050	
					Changes	CAGR
World	6 296	6 160	5 710	5 144	-1 151	-0.7%
North America	437	267	132	66	-371	-6.3%
United States	425	259	126	61	-364	-6.5%
Latin America	61	56	52	50	-11	-0.7%
Colombia	51	47	42	41	-10	-0.8%
OECD Europe	47	28	20	18	-29	-3.3%
Non-OECD Europe/Eurasia	385	308	329	361	-24	-0.2%
Russia	268	196	202	208	-60	-0.9%
Middle East	0	0	0	0	0	0.3%
Africa	239	247	276	309	70	0.9%
South Africa	226	227	251	280	54	0.7%
Asia	4 878	4 960	4 630	4 086	-792	-0.6%
China	3 477	3 339	2 779	2 040	-1 437	-1.8%
India	734	906	1 072	1 238	504	1.8%
Indonesia	565	594	640	654	90	0.5%
Oceania	249	293	271	254	5	0.1%
Australia	247	292	271	254	6	0.0%

Table 3-4 | Coking coal production [Reference Scenario]

(Mt)

	2021	2030	2040	2050	2021-2050	
					Changes	CAGR
World	1 019	963	925	911	-107	-0.4%
North America	83	78	80	83	0	0.0%
United States	56	57	59	62	6	0.3%
Latin America	6	8	8	9	2	1.1%
Colombia	5	6	7	7	2	1.4%
OECD Europe	15	18	19	20	5	0.9%
Non-OECD Europe/Eurasia	104	98	102	106	2	0.1%
Russia	100	93	98	101	1	0.0%
Middle East	2	1	1	0	-1	-4.2%
Africa	10	15	19	24	14	3.1%
Mozambique	6	11	16	21	15	4.6%
Asia	626	560	494	443	-183	-1.2%
China	548	462	360	257	-290	-2.6%
India	49	74	113	169	120	4.4%
Mongolia	24	15	10	5	-19	-5.2%
Oceania	172	186	202	225	53	0.9%
Australia	171	185	201	224	53	0.9%

Coal trade volume will almost level off from 1 340 Mt in 2020 to 1 333 Mt in 2030, before gradually decreasing to 1 309 Mt in 2050, as imports from Asia and Africa including India and ASEAN increase. By coal type, the trade volume of steam coal is expected to decline from 2030 onwards as China's imports peak in the late 2020s and then start to decline. Trade of coking coal will decrease slightly in Europe and other Advanced Economies as well as in China toward 2050, but will gradually rise due to a significant increase in India's imports.

Among major coal exporters, Australia will continue to increase its supply in line with the expansion of markets, particularly in Asia. Indonesia will reduce its exports gradually after the peak in the 2020s according to its policy. Russia's exports, following a decline in the short to medium term due to the embargo on Russian coal by the European Union and Japan, will remain flat at a lower level. Colombia, also, will gradually decrease its supply from the mid-2020s.

By coal type, exports of steam coal will increase from major exporting countries, but in Indonesia, amid policy restrictions on production ceilings, they will decline after peaking around mid-2020s due to increased domestic demand. Coking coal exports will increase from major coking coal exporting countries, led by Australia, which accounts for more than half of its exports, and Mozambique will post a dramatic increase in exports, mainly to India.

Figure 3-7 | Global coal trade (import volume) [Reference Scenario]

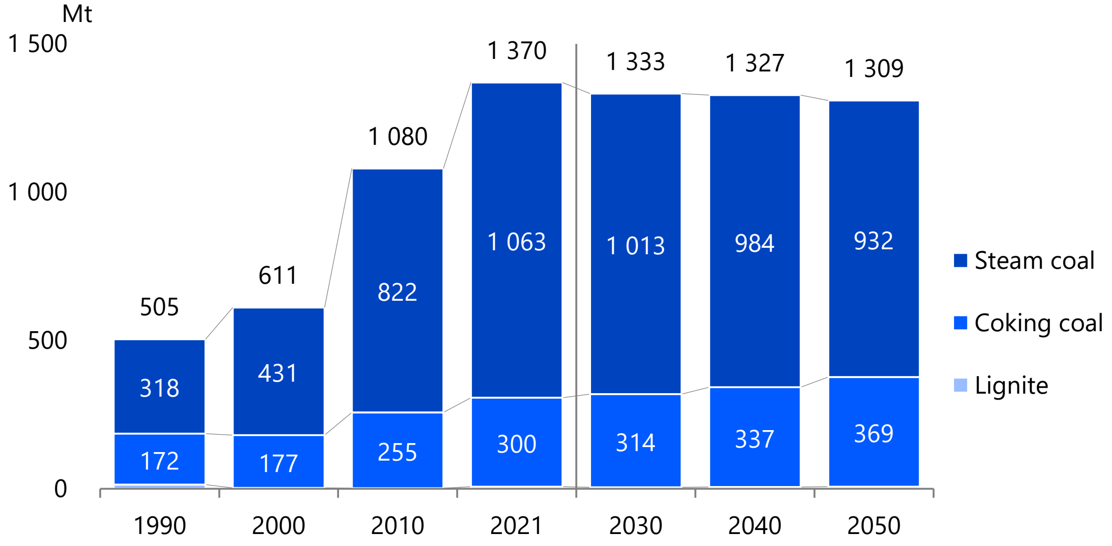
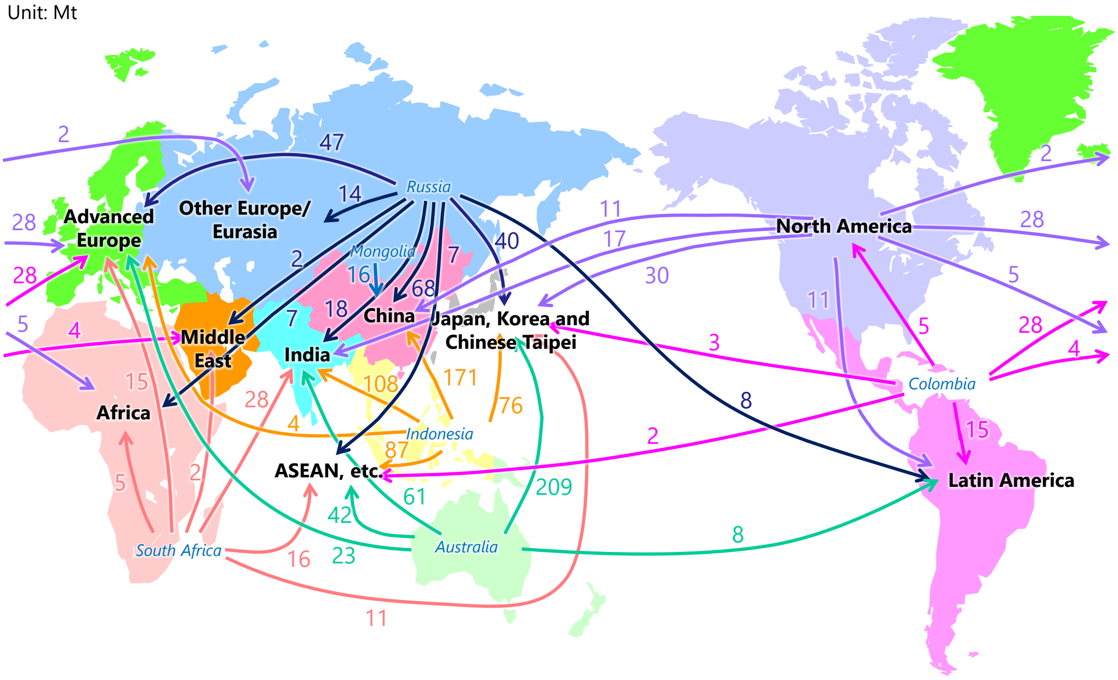


Figure 3-8 | Major interregional coal trade flows [2022]

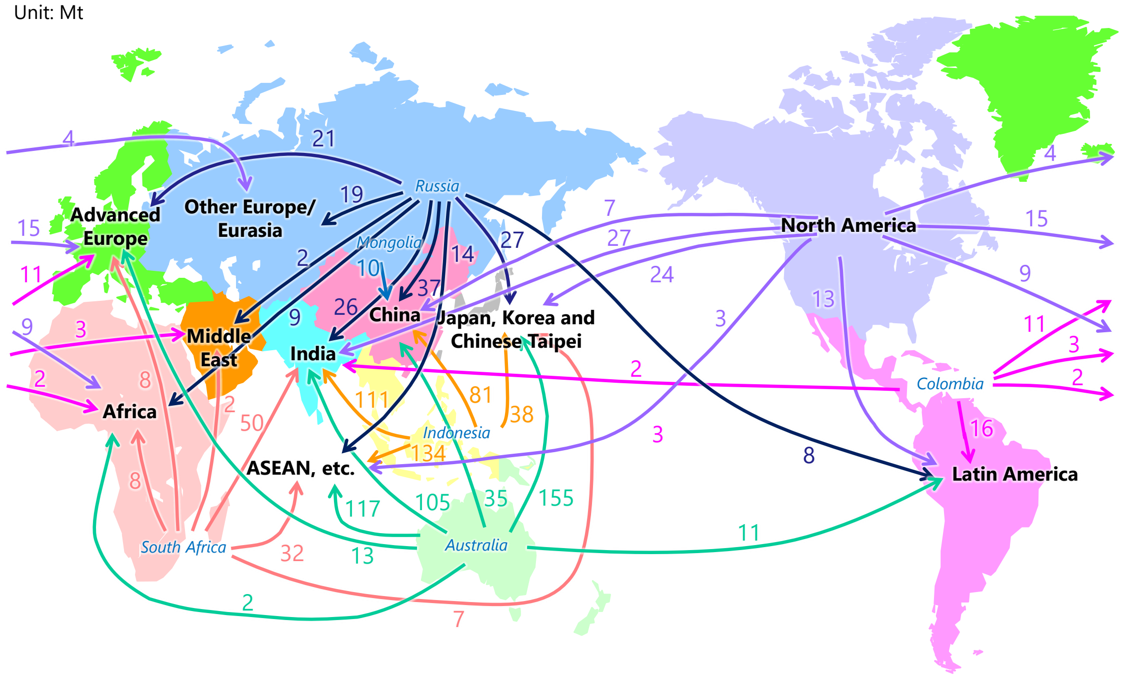
Unit: Mt



Notes: Sum of steam coal and coking coal. 2 Mt or more listed. South Africa includes Mozambique.
Sources: Estimated based on IEA "Coal Information 2023", TEX Report, etc.

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

Unit: Mt



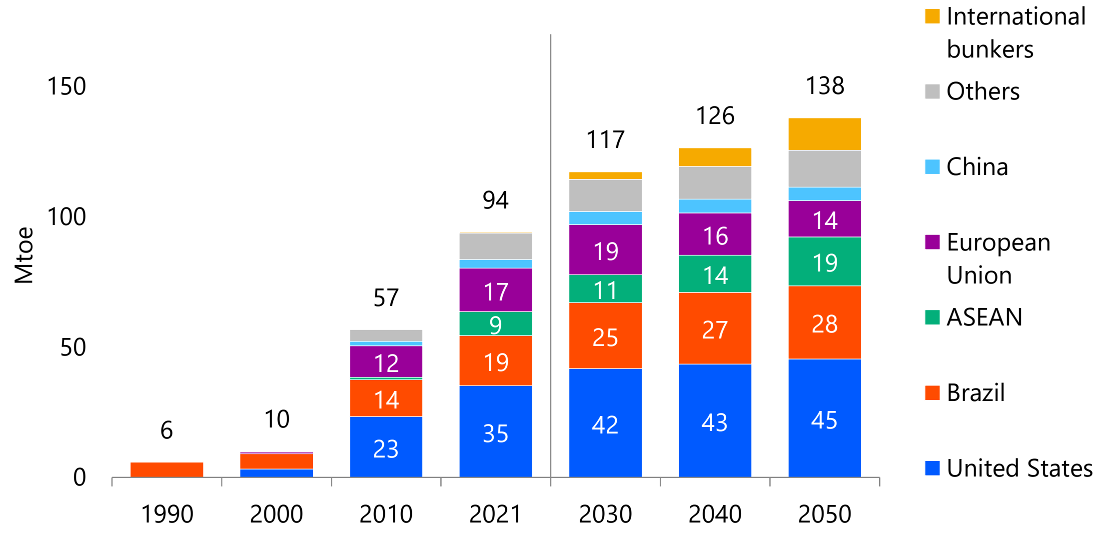
Notes: Sum of steam coal and coking coal. 2 Mt or more listed. South Africa includes Mozambique.

3.4 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 European Union, which accounted for just below 70% of global biofuel consumption of 64 million tonnes of oil equivalent (Mtoe) in 2021.

While biofuel consumption has substantially increased since the 1990s, investment in biofuel has remained stagnant since 2010. Over the long term, biofuel consumption will recover as climate change countermeasures are enhanced, but will decelerate compared with the past as vehicles are being electrified. Nevertheless, by 2050 the consumption of biofuels for automobiles will reach 125 Mtoe (Figure 3-10). As concerns grow over the environmental impact of first-generation biofuels and their competition with food production, initiatives will be enhanced for the development of next-generation biofuels including cellulosic and algae-derived fuels and for cost reductions. Although biofuel demand in ASEAN will increase sharply, biofuel consumption in Asia will fall short of rivalling U.S. or Brazilian levels. In areas other than automobiles, biofuel consumption for international aviation and shipping, which is minimal at present, will expand in the future.

Figure 3-10 | Biofuel consumption for transportation [Reference Scenario]



3.5 Power generation

Recent trends

Electricity demand increases at a slower pace. Renewable energies increase rapidly with countries announcing ambitious plans.

Against the backdrop of global economic growth and mainly electrification in Advanced Economies, global electricity generated has increased at an annual rate of 2.5% in the last decade (2012-2022). In 2022, the pace of increase was slightly lower at 2.3% year-on-year[8]. The surge in resource prices triggered by the Ukraine crisis has put strong downward pressure on power generation, while the mild winter and energy conservation measures, particularly in Europe, have contributed to reduced demand for electricity in the region. The impact of the pandemic was still seen locally, with continued lockdowns in some countries, such as China, pushing down electricity demand across all buildings, transport and industry sectors. On the other hand, electrification, such as electric vehicles and heat pumps, has been progressing rapidly, underpinning electricity demand.

Among the power sources, renewable energies (excluding hydro) continue to grow significantly, with their power generation increasing by 12.6% year-on-year, accounting for 14.4% of total electricity generated. In response to the global fossil fuel supply crisis caused by the war in Ukraine, more ambitious goals than ever for the introduction of renewables have been set in succession, such as the approval of the Inflation Reduction Act of 2022 in the United States and the announcement of the REPowerEU programme in the European Union in 2022. Investment in this sector will increase in the future, mainly in Advanced Economies and China.

Natural gas-fired power generation increased by 1.0% year-on-year, even in the midst of a global surge in natural gas prices. Coal-fired power generation grew by 1.0% year-on-year, mainly in Emerging Market and Developing Economies, despite the similar rise in steam coal prices.

[8] Energy Institute, Statistical Review of World Energy (2023)

However, coal-fired power generation in OECD countries declined by 2.2% year-on-year, reflecting the shift away from coal among Advanced Economies.

Outlook

Electricity generated will rapidly increase in Asia

In the long term, electricity consumption will continue its uptrend at a more conventional pace as the global economy gradually recovers from the impacts of Covid-19 and the Ukraine situation. This will result in global electricity generated increasing at an annual rate of 2.0% to 49 102 terawatt-hours (TWh) in 2050, a 1.9-fold rise from the 2021 level (Figure 3-11). The growth of 20 700 TWh through 2050 is 2.4 times the electricity currently generated in China, the largest power generator in the world, with 85% of the growth coming from Emerging Market and Developing Economies. Among these, electricity generated in the rapidly growing Asia will expand at an annual rate of 2.2% from 13 664 TWh in 2021 to 25 744 TWh in 2050, accounting for about half of the global total. In Asia, the growth of China, which has been driving the increase in demand, will slow down, while demand in ASEAN and India, with their remarkable economic growth, will continue to expand at an annual rate of 3.7% and 4.1%, respectively, by 2050, with electricity generated of India in particular matching that of the United States today (Figure 3-12).

Figure 3-11 | Global electricity generated and final consumption of electricity [Reference Scenario]

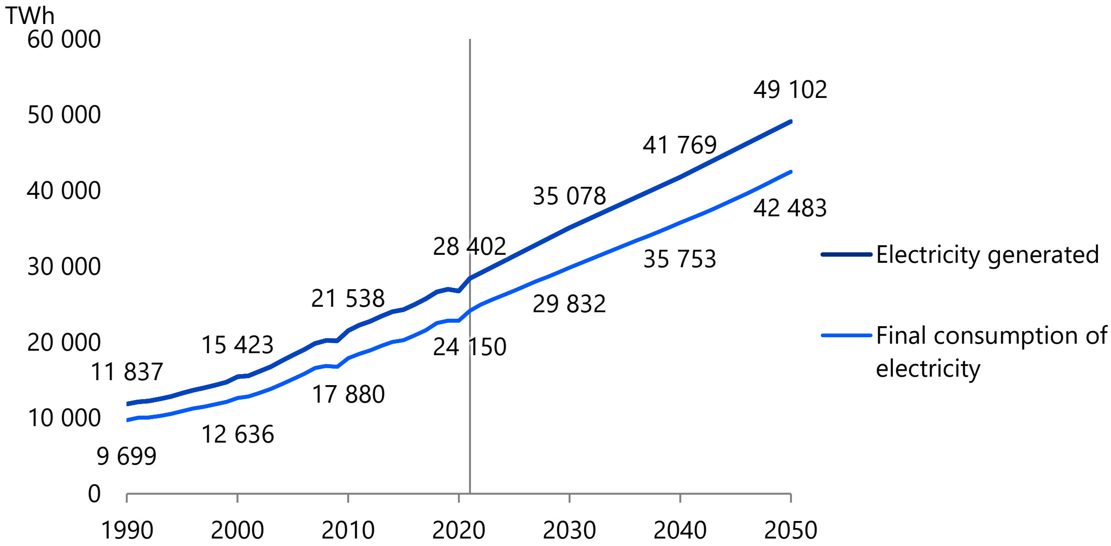
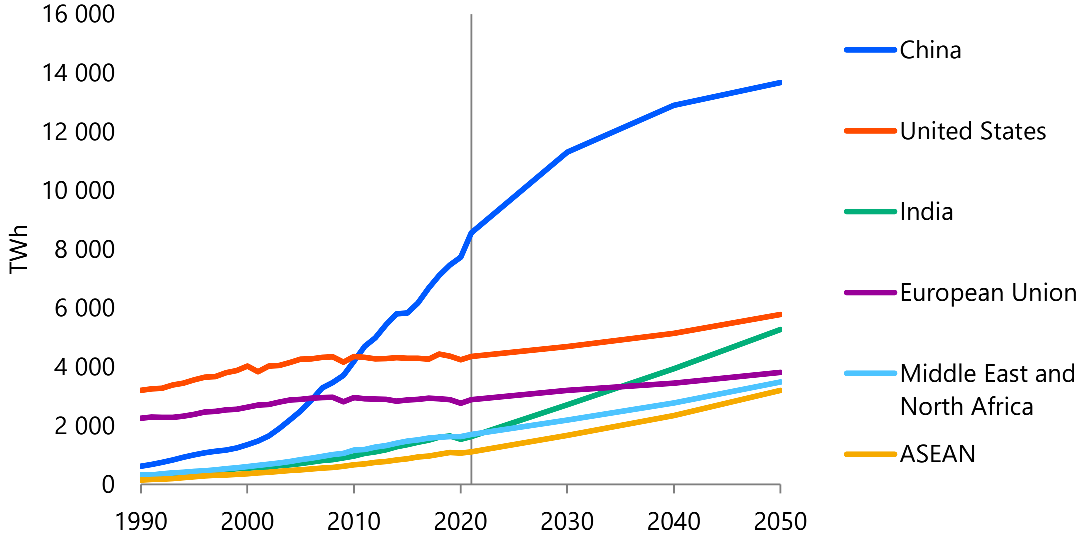


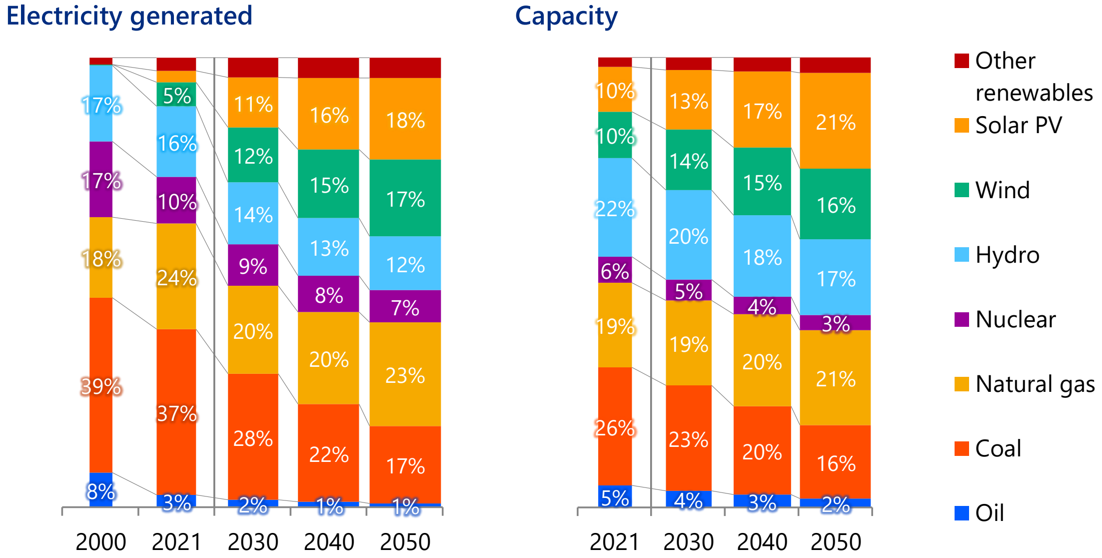
Figure 3-12 | Electricity generated in selected countries/regions [Reference Scenario]



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 it as the largest power source by 2050 (Figure 3-13). In addition to playing its role as middle and peak power source as usual, the role in balancing the power supply-demand will become even more important as variable renewable power generation expands. Currently, natural gas is in the midst of temporary headwinds due to supply disruptions amid the Ukraine crisis and resulting price hikes. With improved supplies and the need for dispatchable power sources that substitute coal-fired power generation, the share of natural gas will rise again toward 2050. Cheap and stable natural gas supplies will continue to be an important issue in the mid- to long-term regardless of whether it is in Advanced Economies or in the Emerging Market and Developing Economies.

Figure 3-13 | Global power generation mix [Reference Scenario]



Note: Bar widths are proportionate to total electricity generated.

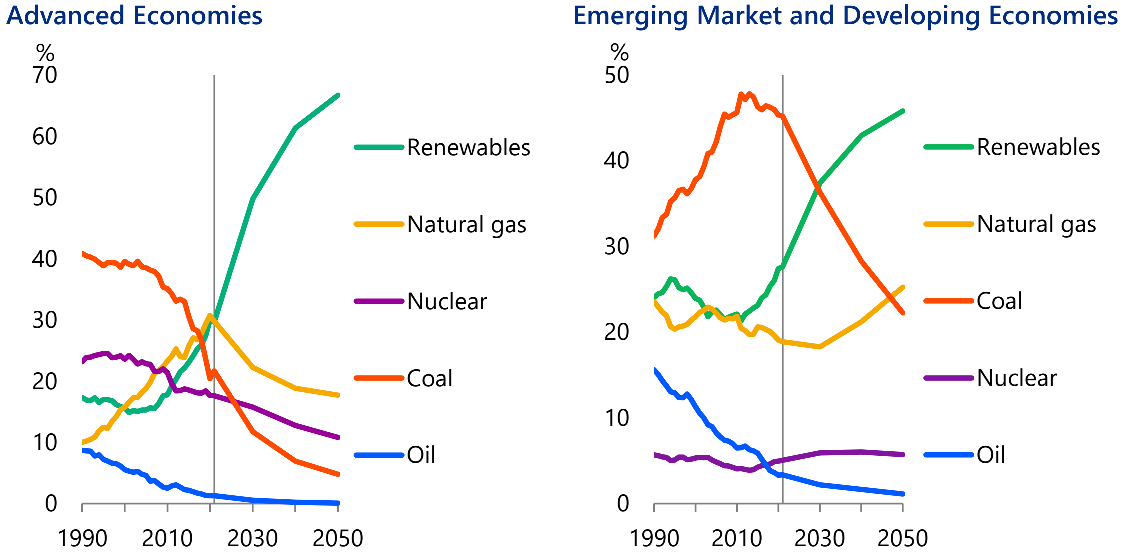
Note: Bar widths are proportionate to total power generation capacity.

With regard to coal, Advanced Economies such as Italy, Canada, the United Kingdom, France and Germany have announced plans to phase out coal-fired power generation, while other Advanced Economies have also declared they will phase out low-efficiency coal. These policies are generally expected to be achieved by close to the target year. In Emerging Market and Developing Economies, the share of coal will also decline from the current level due to the introduction of natural gas and renewables, but it will continue to serve as an inexpensive baseload power source. As a result of these developments, coal's share in 2050 will be about half of the current level, while the coal-fired power generation will be 8 460 TWh, almost 80% of the current level; thus, the maintenance and development of coal-fired power generation facilities, the development of resources for a stable supply of this fuel, and measures against air pollution will continue to be important, especially in Emerging Market and Developing Economies. Because of high generation cost, oil-fired power will follow a downtrend not only in Advanced Economies but also in others, including the oil resource-rich Middle East.

Nuclear power plant construction will make progress mainly in Asia as a measure to ensure energy security and help mitigate climate change, causing nuclear power generation to increase by 25% from the current level. However, the growth of nuclear power generation will fail to exceed that of electricity demand through 2050, leading the nuclear share of electricity generated to fall to 7% in 2050. Wind, solar photovoltaics, geothermal and other renewables power generation will expand at a rapid annual rate of 5% by 2050 on the strength of policy support and cost reduction, boosting its share in the power generation mix to 40%.

In Advanced Economies, the continued rapid introduction of renewables today will lead them to overtake natural gas to become the largest power source by around 2030 (Figure 3-14). The share of renewables in the total electricity generated will reach 50% in 2030 and 67% in 2050, among which output-variable solar photovoltaics and wind will account for 48% of generation in 2050. Emerging issues such as measures to deal with output fluctuations and the expansion of grids to connect suitable areas for power generation with demand areas will become even more important challenges as renewables enhance their position as main power sources.

Figure 3-14 | Power generation mix in Advanced Economies and in Emerging Market and Developing Economies [Reference Scenario]



Coal's share, which was the largest ten years ago, will substantially decline to 5% in 2050 under a policy of shifting away from coal-fired power generation in such countries as Canada and Italy and under a financial institutions' policy of refraining from making investments in and providing loans to coal-fired power generation projects. As a result, the power supply-demand balance will be mainly met by natural gas-fired and pumped-storage hydro power generation and storage batteries, which will spread in the future. Accordingly, while promoting the decarbonisation of all power sources, efforts are required to secure the necessary installed capacity and promote demand response.

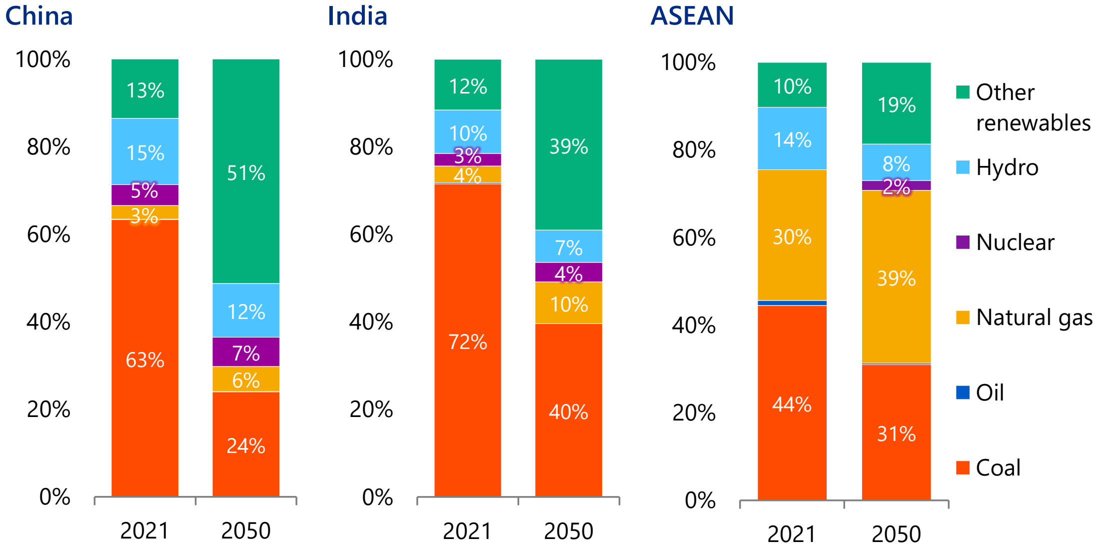
In the Emerging Market and Developing Economies, renewables including wind will increase and replace coal as the largest power source by 2050. Coal-fired power generation will account for about 22% of electricity generated by 2050, although its proportion will decline. As coal-fired power generation plays 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 share of natural gas will also expand from its current level to 2050, and its electricity generated will be roughly equal to half of the total current electricity generated. Securing stable supplies of natural gas is thus essential and will remain a long-term issue. In Emerging Market and Developing Economies, in particular, the share of natural gas will continue to expand after 2030. Widespread renewables are a promising power source that can simultaneously meet the strong demand growth and reduce emissions in Emerging Market and Developing Economies. On the other hand, as electricity demand continues to grow in line with rapid economic growth, a certain amount of stable power sources, which play an indispensable role, is necessary, and thus it is important to maintain and expand installed capacity of natural gas-fired power plants.

Coal is also declining in Asia. Renewables in China and natural gas in ASEAN will be the mainstay of power sources.

In Asia, coal-fired power generation currently holds a large share. Coal will continue to serve as the largest source of electricity in India until 2050, but the gap in share with other renewables is only 1%, and variable renewables will be introduced at a rapid pace (Figure 3-15). Similarly, in

China, the share of renewables will rapidly expand driven by intense promotion measures, to play a main role in power generation. In ASEAN as a whole, the use of natural gas will grow to become the largest power source. However, the situation varies greatly from country to country. While countries such as Thailand, where both the public and private sectors are moving away from coal-fired power generation, will increasingly shift from coal-fired power generation to natural gas-fired power generation and renewables power generation, regions such as Indonesia and the Philippines will continue to use coal-fired power generation as the main power source to meet the rapidly growing demand for electricity.

Figure 3-15 | Chinese, Indian and ASEAN power generation mix [Reference Scenario]

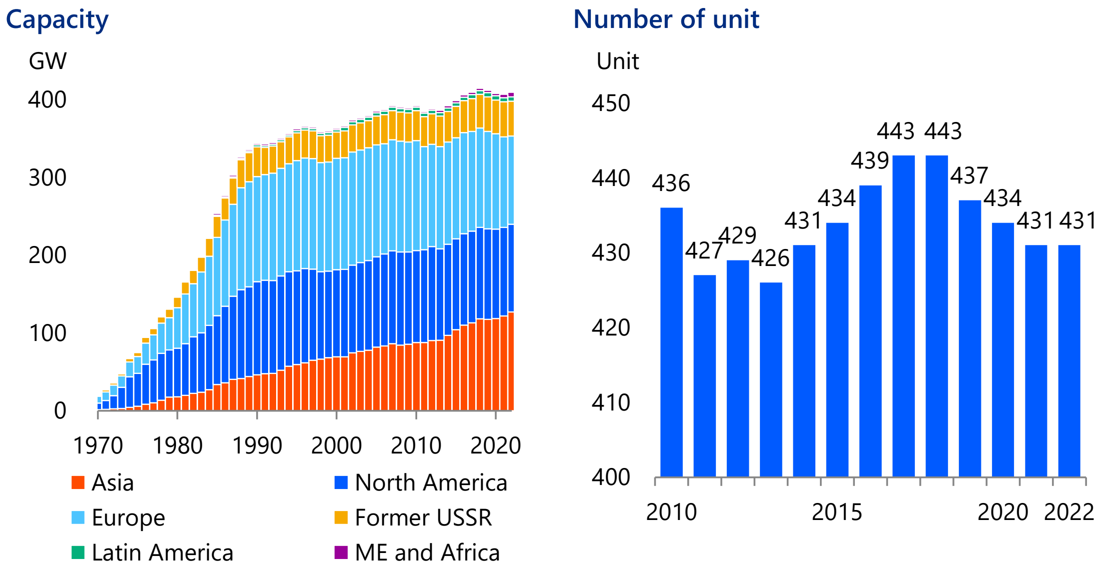


Nuclear

Russia still dominates the global market: Western countries are also moving toward nuclear

The installed capacity of global nuclear power generation declined for three consecutive years from 2019 to 2021, followed by an increase in 2022 (Figure 3-16). This is because the successive closures of existing reactors in Europe and the United States have been more than offset by the increase in Asia and other countries. In Asia, and especially in China, new reactors have continued to enter operation, while in 2022, new reactors also commenced commercial operation in Pakistan, where Chinese companies are making inroads, and in Korea, where the new administration announced its policy to use nuclear power generation. The use of nuclear power generation in the Middle East is also gradually expanding, with the United Arab Emirates (UAE), which joined the list of countries using nuclear in 2021, starting commercial operation of Barakah Unit 2 in 2022.

Figure 3-16 | Global nuclear power generation capacity and number of unit



Note: USSR and ME stand for Soviet Union and Middle East, respectively.

A number of nuclear power plants were built in Japan and Western countries in the 1970s and 1980s, but then the momentum of new constructions slowed down. Many of these earliest nuclear power plants have been closed due to ageing, but there is a growing move to make effective use of these plants over the long term. In the United States, many reactors have operated for more than 40 years and been permitted by the Nuclear Regulatory Commission (NRC) to operate for a further 20 years, making a total of 60 years, while some reactors have received approval for a second extension of operation, making a total of 80 years. Belgium, which was scheduled to complete phasing out nuclear by 2025, announced in March 2022 the 10-year extension of operating periods of its two reactors, Doel Unit 4 and Tihange Unit 3. Finland also announced in February 2023 that Loviisa Units 1 and 2 will continue operating until the end of 2050. Since they commenced commercial operation in 1977 and 1981, respectively, both reactors will be in operation for about 70 years. In Japan, the so-called "GX Decarbonisation Electricity Act" enacted in May 2023 enabled the extension of operating period of nuclear power plants by subtracting the prolonged shutdown period after the Fukushima Daiichi Nuclear Power Station accident (Fukushima Daiichi accident) from the prescribed operating period. It will become increasingly important to check the number of years from startup and the actual operating life of each plant in more detail, as various cases for different plants may emerge.

As such, moves toward the long-term operation of existing reactors are under way in each country, while policies for constructing new plants are being redefined in recent years. The United Kingdom, in its energy security strategy announced in April 2022 in response to the invasion of Ukraine, set a goal of installing up to 24 GW of nuclear power generation capacity by 2050 to cover 25% of its electricity supply. In addition, in order to support the future new construction, it was decided to introduce a regulated asset base (RAB) model, which enables operators to generate revenue from the construction phase. In February 2022, before the invasion of Ukraine, France announced its energy policy to achieve carbon neutrality by 2050, which included the construction of at least six (and up to eight more) new model European Pressurised Water Reactors (EPR 2). Toward this end, facilities are now being expanded at three existing sites, and in June 2023, an application for an installation licence was submitted by Electricité de France (EDF) to the regulatory authority for Penly in the north-western Normandy region.

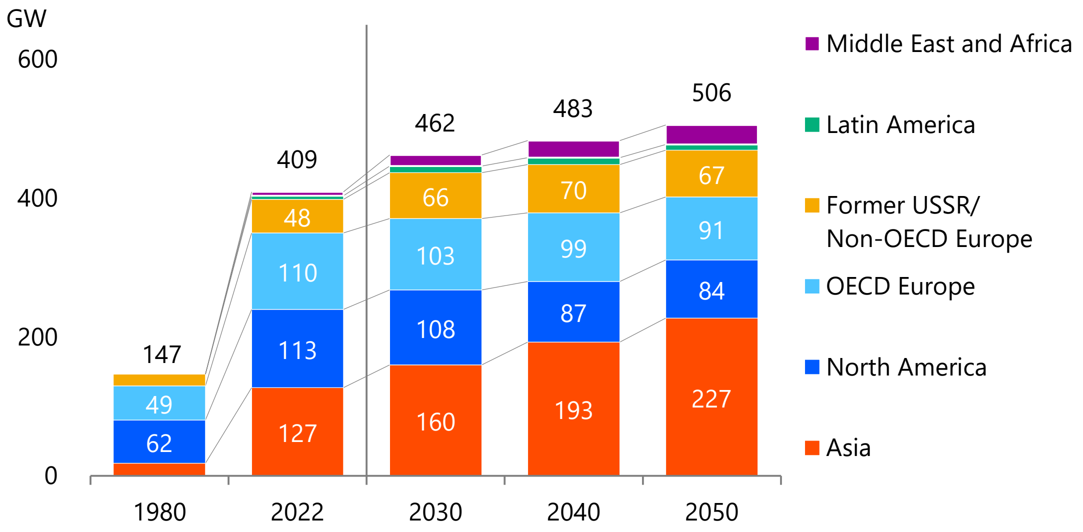
While these moves toward new plant construction in Western countries is noteworthy, the United States, France, and other countries have significantly delayed or derailed new construction plans, and so it is important for future plans to learn from these failures. It should also be recognised that Russian nuclear exports continue to dominate the global nuclear market. Following Russia's invasion of Ukraine in February 2022, Finland terminated new construction contracts with Russian companies, while Russian reactors are being deployed in China, Türkiye, Iran, India and Bangladesh. In July 2022, construction of Egypt's first nuclear power plant began. Russian companies, which have steadily accumulated a track record of construction, have not caused significant delays and are providing comprehensive services, not only for the construction of power plants but also for the supply of fuel and the collection of spent fuel. Since emerging economies, the main importers, want stable large-scale power sources as rapidly as possible, and have not yet accumulated knowledge on the use of nuclear, the proposals from Russia may meet their needs. If the nuclear industries in Western countries intend to recapture a share of the world market, they must be fully aware of Russia's strategies.

There is also growing worldwide interest in advanced reactors, such as small modular reactors (SMRs) and fourth-generation reactors. In the United States, the Biden administration has launched aggressive support measures, and a number of private companies have started to develop advanced reactors. In particular, NuScale's light-water small modular reactor (SMR) attained its first design certification from the NRC in January 2023. In the United Kingdom, the SMR consortium led by Rolls-Royce is also developing a light-water reactor type SMR. In Canada, some provincial governments, such as Ontario, are working on specific implementation plans. In addition, several other countries including Bulgaria, Romania and Estonia have expressed interest in introducing SMRs. In China, meanwhile, the construction of demonstration reactors including fast reactors and SMRs is under way. In Russia, the offshore floating nuclear power plant has already started operation and the country is also planning to launch a land-based SMR scheduled to start operation in 2028. Thus, global competition to develop these advanced reactors is intensifying.

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

The Fukushima Daiichi accident triggered changes in public opinion about nuclear, and some nuclear power plant construction knowhow has been lost during the long absence of such construction. For these reasons, it is now difficult for Japan, Europe and the United States to construct new nuclear reactors as planned earlier. As existing reactors built in the 1970s or 1980s are closing, nuclear power generation may decrease in many countries. Given that competitive nuclear is an important low-carbon baseload power source and a contributor to energy security, serving as business resources for electric power companies, these countries will maintain nuclear power generation to some extent. In contrast, many countries including China are planning to promote nuclear while 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 to reach 506 GW (Figure 3-17).

Figure 3-17 | Installed nuclear power generation capacity [Reference Scenario]



The United States, though being the world's largest nuclear power generating country with 92 reactors, includes states where decisions have been taken to close existing reactors earlier than planned for economic reasons. Under electricity market liberalisation, nuclear power plants are exposed to competition from natural gas-fired and renewable energy power plants. As a result, the installed capacity will decrease by 2050. However, the United States will make no change to its policy of positioning nuclear as an important energy source. The 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, and thus there is little chance that the United States will change its nuclear energy policy. Against this backdrop, extension of the operating period and some new construction plans will continue in the future, depending on market conditions and the investment climate.

In France, known as the largest nuclear energy promoter in Europe, the Energy Transition Law, enacted in July 2015, aimed at reducing the nuclear's share of power generation to 50% by 2025 (from around 75% in 2015). In view of its GHG emission reduction goal, however, France has concluded that it is difficult to attain this reduced target for nuclear, and so the target year was extended to 2035, and then the target itself was withdrawn by a law promulgated in June 2023. In light of these circumstances, the share of nuclear in France will either maintain its current level or slightly decrease for the time being, due to the combination of closing some reactors and constructing new ones. As mentioned earlier, France declared the construction of at least six new reactors (and up to eight more) in February 2022, but after 2035, decommissioning of existing reactors will accelerate due to ageing, leading to a continued decline of nuclear overall. In the meantime, as initiatives have been taken to pave the way for reactors to operate longer, electric utilities will consider the balance between nuclear and renewables power generation and maintain nuclear power generation capacity provided profitability is secured.

In the United Kingdom, the government has indicated a policy of maintaining nuclear, but the installed nuclear power generation capacity will decline until the latter half of 2020 due to decommissioning of outdated reactors. On the other hand, although there was a case recently where Horizon Nuclear Power's project was held up, a new construction project is planned based on the energy security strategy. Thanks to such efforts, nuclear power generation capacity may recover to nearly the current level by around 2035.

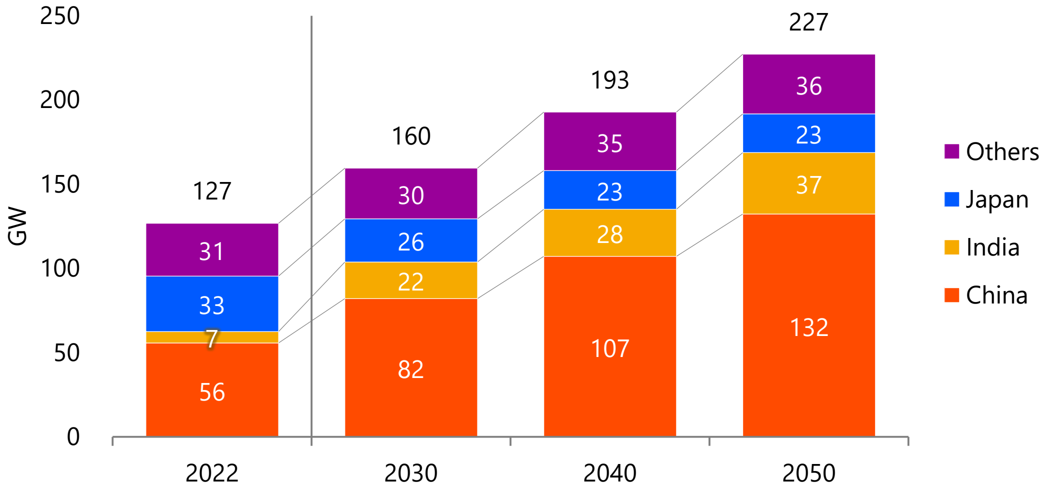
Switzerland has made clear their nuclear phase-out plans in response to the Fukushima Daiichi accident and will cease nuclear power generation by 2035 under the government's decommissioning plan. Belgium had also planned to close all of its nuclear reactors by 2025, but has decided to extend the operating periods of at least two reactors by 10 years considering the recent situation, delaying its nuclear phase-out. Germany had planned to close all its reactors by the end of 2022, but kept its last three reactors operating until April 2023 to ensure a stable power supply during the winter. These decisions, however, will not significantly affect the long-term outlook. In fact, the last three reactors were shut down in April 2023, completing the nuclear phase-out. Other OECD European countries will reduce their installed capacity through 2050, despite some moves to construct new plants, as unprofitable reactors are being decommissioned.

Russia has vowed to proactively use nuclear at home and abroad. Its domestic installed nuclear power generation capacity will increase from 30 GW in 2022 to 43 GW in 2040. 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 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 such a wide range of technologies to enhance the infrastructure of the nuclear industry.

From 2030, Middle Eastern, African, Latin American and other countries, which have so far developed little nuclear power generation capacity, will rise as nuclear power generators. In addition to the United Arab Emirates, which is pioneering the introduction of nuclear, Saudi Arabia and Iran will lead the Middle East and raise the region's installed nuclear power generation capacity to 22 GW by 2050. In Latin America, mainly Brazil and Argentina are planning to introduce nuclear power generation to satisfy the growing domestic electricity demand and will construct a few nuclear power plants.

The presence of Asia, especially China and India, will increase further also in the nuclear field. Emerging Market and Developing Economies in Asia, which are experiencing remarkable economic growth, are highly motivated to introduce nuclear which is low-carbon and a stable large-scale power source. China will boost its installed nuclear power generation capacity to 95 GW in 2035, replacing the United States as the largest nuclear power generator in the world. Asia's installed nuclear power generation capacity will surpass the combined OECD Europe and North American capacity around 2040, reaching 227 GW in 2050. China and India combined will account for more than 70% of Asia's capacity (Figure 3-18).

Figure 3-18 | Asia's installed nuclear power generation capacity [Reference Scenario]



Renewables

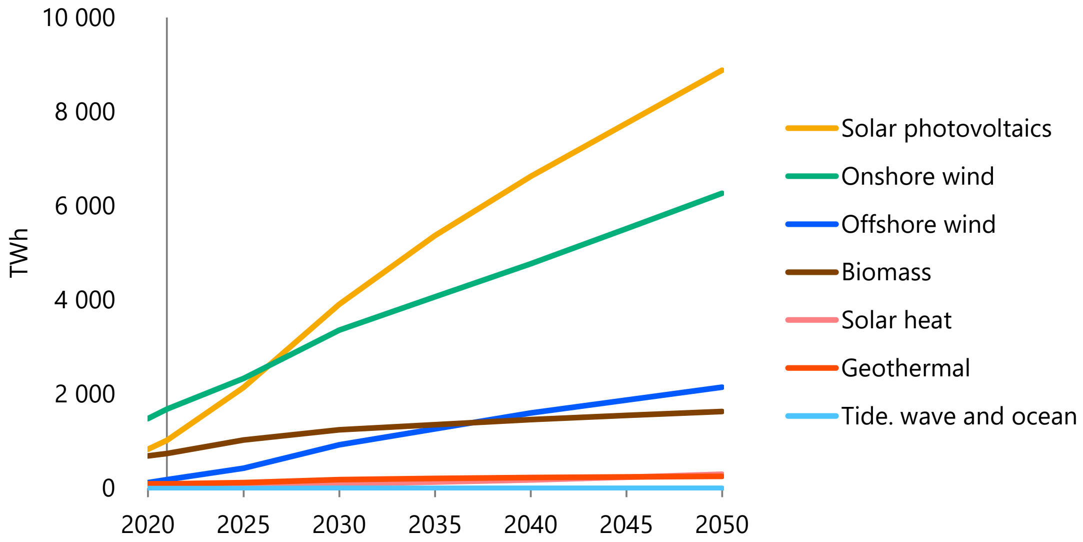
In recent years, the increase in installed capacity of renewables power generation has become even more pronounced. From 2015 to 2019, the growth in global renewable power generation capacity was just under 200 GW per year, but it exceeded 250 GW in 2020 and surpassed 300 GW in 2022. The momentum of this growth of renewable power generation capacity is expected to accelerate and exceed 400 GW per year by around 2030. In particular, there has been remarkable growth in solar photovoltaic and wind (onshore and offshore), which have achieved significantly lower costs of power generation, and these two sources will continue to account for the majority of the increase in renewable power generation capacity. The costs of solar photovoltaic and wind power generation have now also started to increase for the first time, as the cost of installing renewable energy generation equipment, such as solar panels and wind turbines, has risen in line with higher resource prices since 2021. However, the cost of thermal power generation has risen even more, resulting in a further increase in the relative economic efficiency of renewables. The declining trend in the cost of solar photovoltaic and wind power is expected to continue in the long term, maintaining its economic advantage over thermal power generation. In addition to these economic advantages, more and more countries and regions are committing to long-term carbon neutrality and strengthening their respective targets and measures for expanding renewables. This will ensure that renewable power generation capacity continues to grow (Table 3-5). In Europe, in particular, the Ukraine crisis which erupted in early 2022 has led to strong pressure to turn away from Russian natural gas, spurring the introduction of renewable energies. This has also significant implications for the long-term progress of global renewable energy deployment towards 2050.

Table 3-5 | Goals for introducing renewables in major countries and regions

Country or region	Main goals
United States	Decarbonisation of the entire electricity sector by 2035 (renewables, nuclear, hydrogen, CCS, etc.) Biden Administration's decarbonisation goals, April 2021 (The White House)
European Union	42.5% share of renewables in final energy consumption by 2030 (45% as an effort target) Review of the Renewable Directive (provisional political agreement between the European Parliament and the European Council in March 2023) (European Council, European Parliament)
Japan	36% to 38% share of renewables in total electricity generated by 2030 The Sixth Strategic Energy Plan, Cabinet Decision in October 2021 (Ministry of Economy, Trade and Industry)
China	Share of non-fossil fuels in primary energy consumption to 25% by 2030 (Of which 1 200 GW of installed wind and solar photovoltaic power generation capacity) Action Plan for Carbon Dioxide Peaking before 2030, publicised in October 2021 (State Council)
India	50% of electricity consumption to be supplied by renewables by 2030 (500 GW of non-fossil power generation capacity) Declaration by Prime Minister Narendra Modi at COP26, November 2021 (Ministry of External Affairs)
ASEAN	23% of primary energy supply and 35% of installed power generation capacity to be from renewables by 2025 ASEAN Plan of Action and Energy Cooperation Phase II, announced in November 2020 (adopted at the 38th ASEAN Senior Officials of Meeting on Energy)

Figure 3-19 shows the trend in renewables power generation up to 2050. Solar photovoltaic will increase from 1 020 TWh in 2021 to 8 880 TWh in 2050, a growth of almost nine-fold. Offshore wind will also expand 12-fold from 180 TWh in 2021 to 2 150 TWh in 2050. Onshore wind, on the other hand, will increase from 1 730 TWh in 2021 to 6 270 TWh in 2050, a growth of about 3.5 times, which is small compared to solar photovoltaic and offshore wind. As a result of the increase in solar photovoltaic and wind, variable renewables will further boost their share of global electricity generated from 10% in 2020 to 35% in 2050, increasing their presence in the electricity system.

Figure 3-19 | Global renewable (non-hydro) power generation [Reference Scenario]



China, Europe, the United States and India, which currently account for 80% of the cumulative installed capacity of onshore and offshore wind power generation, will continue to lead the market (Figure 3-20). Among others, China's market share, which accounted for 40% of the global market in 2020, will continue to expand, exceeding 50% by 2050. For wind, intense concentration in China will be even more pronounced than for solar photovoltaic, which will be discussed later. This suggests that while the increase in Europe, North America and elsewhere is slowing due to stricter location and grid constraints, there still remains much room for expansion in China.

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

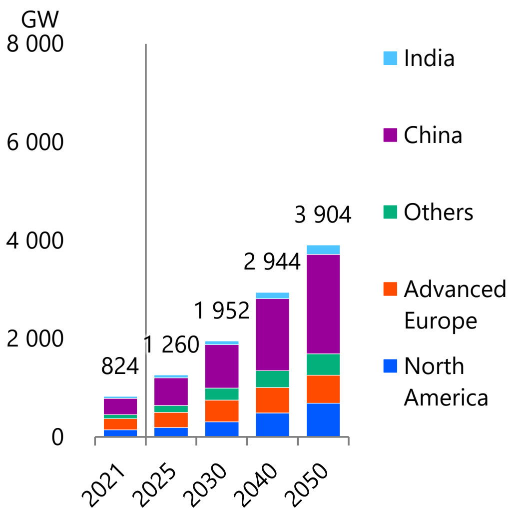
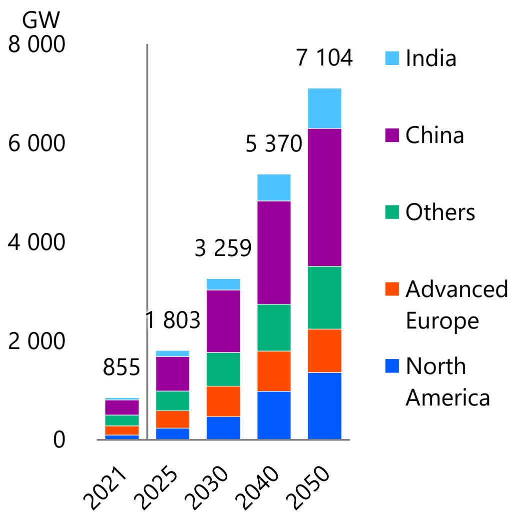


Figure 3-21 | Global solar photovoltaic power generation capacity [Reference Scenario]



For onshore wind, the growth rate will be relatively slow toward 2050 compared to solar photovoltaic and offshore wind, due to site and grid constraints, such as the lack of suitable land for development, which will arise at a relatively early stage. In 2050, the installed capacity of onshore wind power generation will remain 3 240 GW, only about four times the increase of

770 GW in 2021. However, in terms of the absolute installed power generation capacity, it will be five times larger than offshore wind even in 2050, thus maintaining a significant presence.

In contrast, offshore wind, although smaller in scale than onshore wind, is expected to grow very quickly. Looking at the past, installed capacity of offshore wind power generation worldwide drastically increased from 3 GW in 2010 to 63 GW in 2022. Europe is the world's most mature offshore wind power generation market, with supply chains developed for wind farms. However, China has been developing large-scale projects since 2020, rapidly narrowing the gap with Europe. In 2022, the cumulative capacity of offshore wind expanded to 30 GW, roughly on a par with Europe, forming one of the world's two largest markets, and further expansion is envisaged for China toward 2050. The United States, meanwhile, has almost no track record, but a large number of offshore wind power projects are under way. In March 2021, the Biden Administration announced a plan to expand offshore wind power generation capacity to 30 GW by 2030, and thus it is likely to grow into a major market. In Asia excluding China, offshore wind markets are expected to form in Chinese Taipei, Korea and Viet Nam. In Japan, the Act on Promoting the Utilisation of Sea Areas for the Development of Marine Renewable Energy Power Generation Facilities (Renewable Energy Sea Area Utilisation Act) came into effect in April 2019, allowing the designation of promotion areas for offshore wind projects under the Act. The government also has made it clear that it will actively support not only the development of projects but also the expansion of domestic supply chains and development of domestic industries. Coupled with this policy backing, the world offshore wind capacity will grow 19-fold from 54 GW in 2021 to 670 GW in 2050. However, affected by location and grid constraints, the speed of deployment will gradually slow down after 2030.

Solar photovoltaic power generation is spreading not only in China, Europe, the United States and Japan, where its use has expanded, but also all over the world, benefiting from significant reductions in power generation costs (Figure 3-21). China's share will be maintained and expanded, with the single country accounting for 36% of the world's installed power generation capacity in 2021, rising to 39% by 2050. However, compared to wind power generation, the share of solar photovoltaic in the United States, Europe, India and others is relatively high, with somewhat less concentration on China. This reflects the universality of solar photovoltaic, which enables electricity to be generated anywhere there is a certain amount of sunlight, whereas wind power generation has the weakness of suitable locations being geographically dependent on wind conditions.

The global weighted average levelised cost of electricity (LCOE) for large-scale solar photovoltaic in 2021 is estimated to be $48/MWh (≈ ¥7/kWh), making it the lowest-cost power generation source in many countries. In particular, large-scale solar photovoltaic auctions in countries with favourable sunshine conditions, such as Chile, the United Arab Emirates and Saudi Arabia, recorded very low selling prices of $10/MWh (≈ ¥1.4/kWh) in 2021. Costs for distributed solar photovoltaic power generation systems installed on rooftops, etc. at housing and commercial facilities have also fallen to competitive grid parity levels in many countries and regions, coupled with soaring electricity prices. This situation is expected to make solar photovoltaic even more competitive in the future. Global installed solar photovoltaic power generation capacity will increase ten-fold from 855 GW in 2021 to 7 100 GW in 2050. However, in the latter half of the projection period (2030 onwards), location and grid constraints will gradually become apparent. As a result, the net increment of global installed solar photovoltaic power generation capacity, which is estimated to reach 2 540 GW in 2020-2030, will gradually slow down to 2 100 GW in 2030-2040 and 1 730 GW in 2040-2050. In order to overcome this slowing trend and maintain a high growth rate in renewables power generation capacity by 2050, it will be critically important to appropriately address location constraints, integration of naturally variable power sources and grid constraints, through technological innovation. The Advanced Technologies Scenario described below assumes a situation in which these challenges have been alleviated to a certain extent, although not completely, through the progress of policy measures to tackle location constraints, integration technologies for naturally variable power sources and grid development.

4. Advanced Technologies Scenario

4.1 Major measures

In the Advanced Technologies Scenario, measures to maximise the reduction of carbon dioxide (CO_2) emissions and to ensure energy security will be enhanced with consideration given to their application opportunities and acceptability to society. Each country and region will actively implement aggressive energy efficiency and decarbonisation policies that contribute to securing a 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 actively diffuse energy efficient equipment and the supply side will further promote renewables, nuclear, hydrogen and carbon capture and storage (CCS) (Table 4-1). Note that this outlook is a forecast-type analysis, calculated based on assumptions such as the introduction of technologies, not a backcast-type analysis, which first sets a future "landing point" and then charts a path to get there.

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

2021 → 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)]	50.1% → 61.3% (56.8%)	38.1% → 58.0% (47.8%)
[Coal-fired efficiency (stock basis)]	37.5% → 31.7%* (42.4%)	33.6% → 39.9% (38.1%)
[IGCC share of newly installed plants]	0% → 60% (20%)	
Nuclear power generation	Maintaining appropriate wholesale electricity prices	Developing an initial investment finance framework
[Installed capacity]	303 GW → 314 (213)	126 GW → 488 (293)
Renewables power generation	System cost reduction	System cost reduction
	Grid stabilisation technology cost reduction	Low-cost finance
	Efficient grid operation	Advancing power systems
[Wind installed capacity]	376 GW → 1 799 (1 372)	467 GW → 3 371 (2 532)
[Solar photovoltaic installed capacity]	399 GW → 3 397 (2 588)	485 GW → 6 486 (4 516)
Biofuels for automobiles	Developing next-generation biofuels	Biofuel cost reduction
	Diffusing flexible-fuel vehicles	Agricultural policy position

2021 → 2050 (Reference Scenario, 2050)

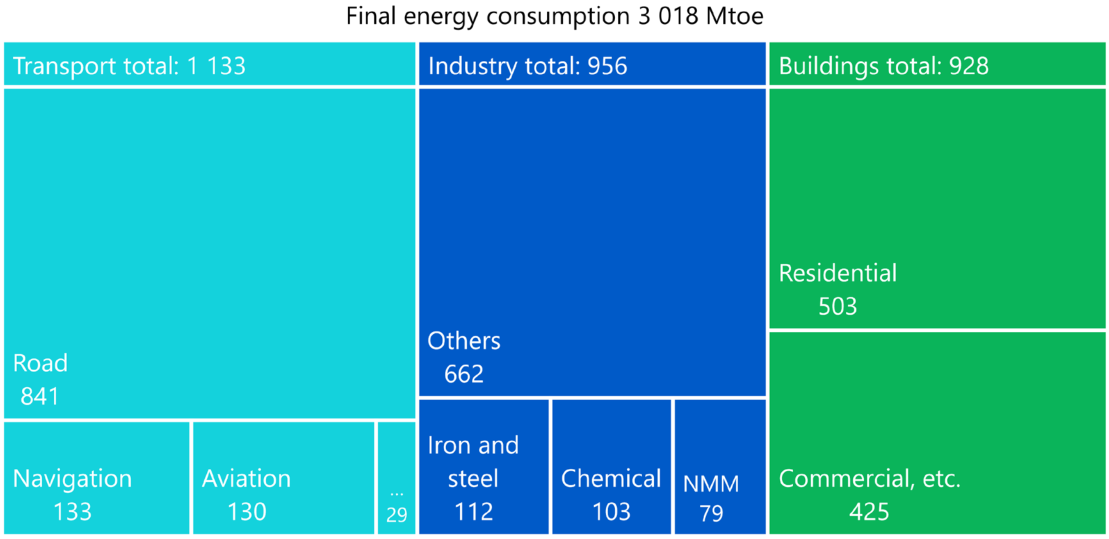
	Advanced Economies	Emerging Market and Developing Economies
[Consumption]	56 Mtoe → 87 (64)	37 Mtoe → 88 (62)
Industry	Full diffusion of best available technologies in 2050	
Transport	Reducing fuel-efficient vehicle costs Doubling zero-emission vehicle (ZEV) travel distances	
[New passenger car fuel efficiency]	16.4 km/L → 46.9 (32.4)	14.1 km/L → 46.5 (24.9)
[ZEV share of new passenger car sales]	6.5% → 91.4% (47.5%)	6.6% → 88.8% (34.7%)
Buildings	Doubling approximately the speed of improvement of new and newly installed home appliances and equipment efficiency and insulation efficiency (approximately 15% improvement compared to the Reference Scenario in 2050) Electrifying space/water heating and cooking equipment, clean cooking	

Note: * In the Advanced Technologies Scenario for Advanced Economies, most coal-fired power plants to be introduced in the future will be accompanied by CCS, which will increase energy consumption for CCS, resulting in reduced efficiency from the current level.

Energy efficiency

Final energy consumption in the Advanced Technologies Scenario will be 502 million tonnes of oil equivalent (Mtoe) or 5% less in 2030 and 3 018 Mtoe or 25% less in 2050 than in the Reference Scenario. Savings in final energy consumption in 2050 are equivalent to 30% of final energy consumption in 2021. Of the energy savings, the transport sector will account for 1 133 Mtoe, the industry sector for 956 Mtoe and the buildings sector for 928 Mtoe (Figure 4-1).

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



Note: NMM stands for Non-metallic minerals.

The road sector will be responsible for 841 Mtoe in the transport sector and the residential sector for 503 Mtoe in the buildings sector. This is because vehicles and energy-consuming home appliances offer huge potential for improving 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 over 80% of energy savings. Whether or not the Emerging Market and Developing Economies actually realise the potential energy savings is key to the progress of global energy savings.

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 2030 by a few percentage from the Reference Scenario (Table 4-2). Furthermore, by accelerating the expansion of high-efficiency technology, it will improve by some 20%-25% as of 2050. Through energy intensity improvements, the Emerging Market and Developing Economies' industry sector will reduce energy consumption by 787 Mtoe from the Reference Scenario. Asia, where basic materials industries account for a large share of production, will account for slightly over 60% 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 | World energy indicators

			Reference		Advanced Technologies	
		2021	2030	2050	2030	2050
Industry	Intensities (2021=100)					
	Iron and steel	100	95.0	81.0	93.2	64.9
	Non-metallic minerals	100	93.4	77.9	91.0	60.3
	Chemical	100	95.7	79.6	94.3	61.8
	Paper and pulp	100	95.7	85.5	93.0	66.9
	Other industries	100	93.8	71.9	91.1	53.9
Transport	New passenger vehicle fuel efficiency (km/L)	15.0	18.6	26.7	24.7	46.6
	ZEVs' share of vehicle sales	5.0%	13%	33%	38%	85%
	Natural gas's share in intl. marine bunkers	0.2%	4.7%	22%	8.2%	44%
	Biofuel's share of intl. aviation bunkers	0.0%	0.9%	2.9%	2.5%	16%
Buildings	Overall energy efficiency (2021 = 100)					
	Residential	100	86.2	65.0	80.4	49.6
	Commercial	100	82.5	49.3	80.3	36.9
	Electrification rate					
	Residential	26%	31%	47%	34%	63%
	Commercial	55%	61%	74%	63%	85%

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 improvements and vehicle fleet mix changes will make further progress. By type of vehicle, in addition to hybrid vehicles (HEVs), electric vehicles (EVs), plug-in hybrid vehicles (PHEVs) and fuel cell vehicles (FCVs) will diffuse further. These zero-emission vehicles (ZEVs) will expand their share of new vehicle sales by 23 percentage points in 2030 and 48 points in 2050 from the Reference Scenario. Due to vehicle fleet mix changes and fuel efficiency improvements, the global average new vehicle fuel efficiency in 2050 will improve by 19.2 km/L from the Reference Scenario to 46.6 km/L (2.1 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. At the same time, given their great potential to switch fuels, natural gas will account for 8.2% of international marine bunkers in 2030 and 44% in 2050. In international aviation bunkers, the share of biofuel will be 2.5% in 2030 and 16% in 2050.

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 reduce energy consumption. The overall global residential energy efficiency will improve by 7% in 2030 and by 24% in 2050 from the Reference Scenario. In addition, the overall efficiency of commercial sector will improve by 3% in 2030 and 25% in 2050. 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 (LPG), kerosene and other fuels are used for water and space heating in various ways depending on national conditions, fuel consumption for these applications will be greatly reduced. Traditional biomass consumption including inefficient fuel wood and manure will be most 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, power and lighting more than offset the effect of the electrification of appliances.

Box 4-1 | Electrification of vehicles and synthetic fuels

Vehicles are becoming increasingly electrified. Electric vehicles (PHEVs and battery electric vehicles [BEVs]) accounted for 14% of global car sales in 2022, a steady rise from 9% in 2021 and from less than 5% in 2020[9]. As governments of each country and region are considering introducing regulations on the sale of engine vehicles, and in response, car manufacturers are expanding their lineups of electric vehicles, electrification is likely to keep growing. This trend is being driven by the move toward carbon neutrality.

On the other hand, it is not enough to focus only on greenhouse gas (GHG) emissions from vehicle fuel consumption when considering how the progress in electrification will actually reduce GHG emissions. It is necessary to broaden the scope of analysis and clarify the possibilities and challenges of reducing GHG emissions from a wider perspective. Therefore, the analysis in this Box focuses on the so-called “Well to Wheel” (WtW), that is, the entire flow of energy, from supply (Well to Tank) to consumption (Tank to Wheel) of the energy used in vehicles[10].

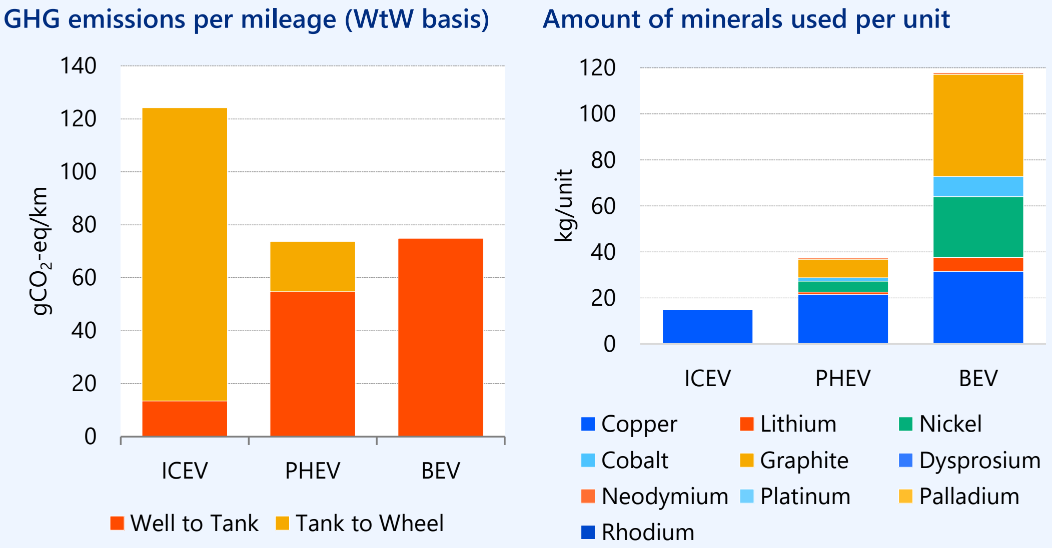
In fact, when looking at GHG emissions on a well-to-wheel basis, electric vehicles (PHEVs and BEVs are almost comparable) have smaller emissions than internal combustion engine vehicles (ICEVs). As the power generation sector becomes more decarbonised, emissions from electric vehicles will be even smaller. Thus, electric vehicles are a crucial means for achieving carbon neutrality.

[9] International Energy Agency (2023) “Global EV Outlook 2023”

[10] The analysis in this Box focuses on energy flows and does not cover life cycle assessment (LCA), which considers emissions related to the manufacture and disposal of vehicles.

Electric vehicles, however, also face challenges. They are equipped with large-capacity drive batteries, and the raw materials for these batteries include rare minerals (critical minerals) such as nickel and graphite, which BEVs use in particularly large amounts: about three times more than in PHEVs. In recent years, the capacity of on-board batteries has been growing in order to increase the mileage per charge; if BEVs continue to expand in large numbers, the supply and demand of mineral resources may become unbalanced (see "IEEJ Outlook 2023" for details).

Figure 4-2 | GHG emissions and mineral consumption (passenger cars)



Notes: Well to Tank represents the global average, but excludes fuel transportation. The fuel economy estimates for Tank to Wheel are: ICEV: 20 km/L, PHEV: 35 km/L, 8 km/kWh, BEV: 8 km/kWh, calculated assuming the EV driving ratio of PHEVs as 70%, and that ICEVs and PHEVs are fuelled by gasoline when running on engines.
Source: GHG emissions are estimated by the Institute of Energy Economics, Japan, and the amount of minerals by JOGMEC[11].

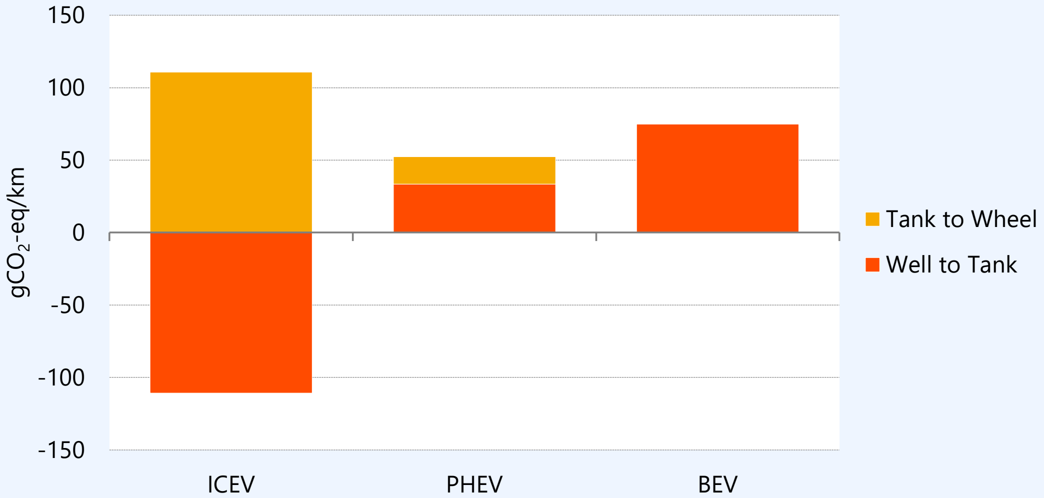
Considering the balance between GHG emissions and mineral demand, the use of PHEVs is of interest. PHEVs usually run in EV mode, and when the electricity in the battery is exhausted, the engine is used to drive the vehicle. Being able to run on the engine, PHEVs do not need to carry a large-capacity battery, unlike BEVs. They can travel about 50 km to 100 km per charge, which is enough for normal commuting and shopping use. When travelling far for leisure or other reasons, the engine will be used, but not so frequently.

However, to achieve carbon neutrality, conventional gasoline is unsuitable for powering the engine. Instead, carbon-free gasoline should be used. This is a synthetic fuel (e-fuel) made from hydrogen. If we assume the use of e-fuels, the GHG emissions of PHEVs are lower than those of BEVs, as shown in Figure 4-3. The emissions from the electricity used by BEVs and PHEVs are calculated based on the current global power generation mix, while for the production of hydrogen, which is the raw material for e-fuel, water splitting by renewable electricity is assumed. Since there are significant differences in the power generation mix depending on the country and region, GHG emissions from Well to Tank will be smaller in

[11] Japan Organization for Metals and Energy Security (2022) "Survey Report on Supply and Demand of Mineral Resources for Achieving Carbon Neutrality"

countries and regions with a higher proportion of zero-emission power sources. Although there are still no internal or external regulations on to whom and where the CO_2 capture effect (negative emissions) of e-fuel raw materials belong, upstream or downstream, in this analysis, the calculations assumed that they belong to the downstream and user side (vehicle users). Thus, the emissions during e-fuel production (Well to Tank) are negative and offset by emissions during direct combustion (Tank to Wheel), which may be environmentally superior.

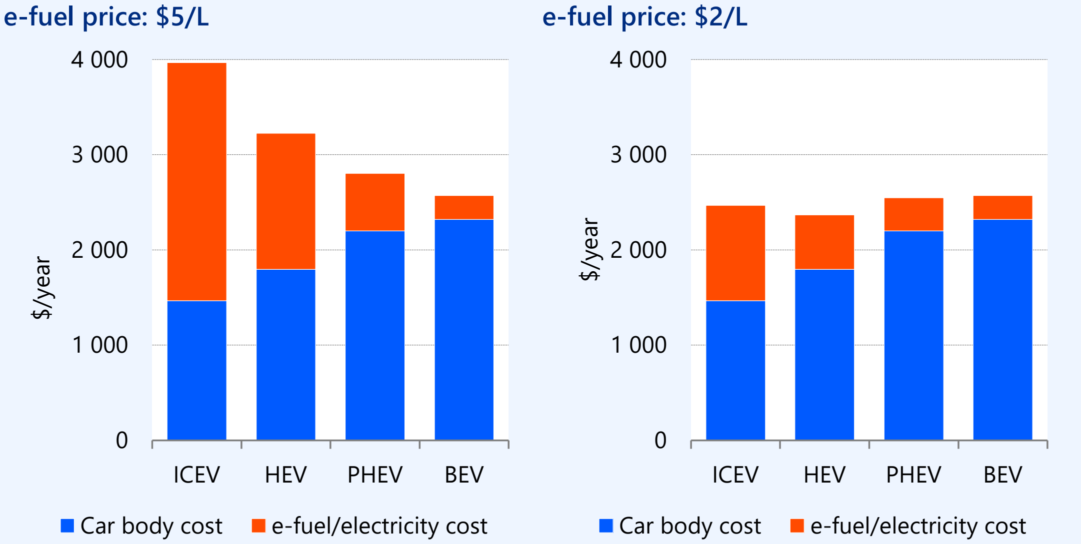
Figure 4-3 | GHG emissions when using e-fuels (passenger cars)



Note: ICEVs and PHEVs are fuelled by e-fuel when running on engines. Other assumptions are the same as in Figure 4-2.

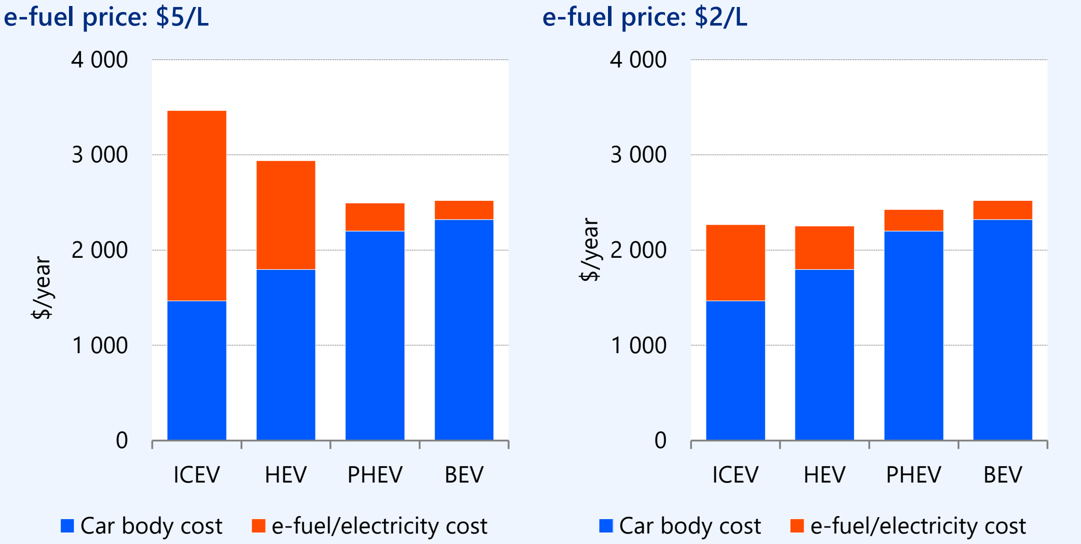
However, e-fuel is still in the development stage and remains very expensive. The current supply price is estimated to be about $5/L, assuming the current supply price of hydrogen and the cost of e-fuel production, suggesting that the total cost of BEVs will be lower than PHEVs even when considering the vehicle body price (Figure 4-4, left). If the supply price drops to around $2/L due to mass production and other effects, the cost will be comparable to that of BEVs (Figure 4-4, right). However, for users with low mileage, for example, if the EV mode of PHEVs reaches 90% of the driving distance, the current $5/L will be comparable to the total cost of BEVs, as shown in Figure 4-5. It goes without saying, however, that the body price of BEVs are expected to be reduced in the future by means of lower battery prices and other factors.

Figure 4-4 | Estimated annual costs for the use of passenger cars



Notes: The period of use is set at 15 years, the annual mileage at 10 000 km, and the fuel economy at the same level as in Figure 4-2. The electricity price is set at $200/MWh, and the vehicle price is set at $22 000 for ICEV, $33 000 for PHEV, and $35 000 for BEV, by referring to ERIA[12]. Taxes, insurance, maintenance costs, etc. are not included.

Figure 4-5 | Estimated annual costs for the use of passenger cars (assuming low mileage)



Notes: The annual mileage is assumed at 8 000 km, and PHEVs' driving ratio at 90%. Other assumptions are the same as in Figure 4-4.

[12] Economic Research Institute for ASEAN and East Asia (2020) "The Influence on Energy and the Economy of Electrified Vehicle Penetration in ASEAN"

The challenge for e-fuel is to reduce its cost from the current ¥700/L to ¥200/L by 2050[13]. Basically, the high cost of hydrogen generation is an issue in producing hydrogen from surplus electricity and synthesising it with CO_2. To overcome this high cost, e-fuel projects mainly using green hydrogen, from renewable energies, are under way in South America, Scandinavia, the United States and other countries. By starting with a low blending ratio that takes advantage of the characteristic of e-fuel as a drop-in fuel, while first establishing a supply system focusing on such relatively inexpensive foreign imports (¥300/L[14]), it is possible to benefit from the use of existing infrastructure such as distribution and sales, and from gradual and realistic emission reduction effects from existing vehicles (stock). Furthermore, the globally dispersed suppliers of hydrogen will contribute to energy security, including domestic production, while e-fuels, as with oil, have the advantages of storability at room temperature, portability, and high user convenience. In particular, e-fuels produced from synthetic raw oil are expected to be in demand for industrial applications where a large demand for heat remains, transport applications with large vehicles, and aircraft fuels. The supply of e-fuels is also effective not only for gasoline but also as a co-product of diesel oil and jet fuel. For example, a €89 million e-fuel demonstration project is under way in Germany, to meet the demand for large vehicles and aviation fuels, which are particularly difficult to electrify.

Thus, the potential advantages of e-fuels include lower GHG emissions and less use of critical minerals than BEVs, as well as improved economic efficiency as a fuel. As shown in Figure 4-4, ICEVs and PHEVs will become more competitive as the price of e-fuels decreases. In addition, e-fuels can be easily used with existing infrastructure and can be easily stored and used not only as fuel for passenger cars but also for other applications. A comprehensive and realistic assessment that includes energy security is needed.

However, the high cost of e-fuels is an issue. Thus, in addition to reducing the cost of hydrogen, attention will focus on market trends towards technological development and the establishment of a mass production system, as well as technological development of batteries for BEVs, which are expected to be relatively less expensive in the future. In addition to establishing a method for certifying the environmental value, it will also be necessary to keep a close eye on trends in bilateral demonstrations in the market to see whether the environmental value belongs to the supply side or the demand side, especially when supplying e-fuels across borders.

Renewable energies

In the Advanced Technologies Scenario, variable renewables such as wind and solar photovoltaics will be introduced at a faster pace. In the scenario, renewables (including hydro) will increase their share of primary energy consumption from 15% in 2021 to 20% in 2030, 1 percentage points higher than in the Reference Scenario, and 22 points higher to 36% in 2050. The share of variable renewables will expand from 2% in 2021 to 6% in 2030 and 21% in 2050.

If the share of variable renewables increases to this level, challenges in power system operations are likely to emerge in some countries and regions. For example, challenges attributable to the

[13] Ministry of Economy, Trade and Industry "Interim Report of the Synthetic Fuels Study Group" (April 2021)

[14] Ministry of Economy, Trade and Industry "2023 Interim Report of Public-Private Council for Promoting the Introduction of Synthetic Fuels (e-Fuels)" (June 2023)

time variability of wind and solar photovoltaic power generation include rapid output fluctuations (frequency fluctuations), surplus electricity, and cloudy or windless weather observed once or twice a year. One of the challenges regarding the uneven spatial distribution is power transmission capacity shortages. Other challenges include a decrease in grid inertia accompanying an increase in asynchronous power sources[15], as well as negative impacts on the natural environment, ecosystems and economic activities near renewable power source locations. Such impacts include the adverse effects of large-scale solar photovoltaic facilities on forest development, those of onshore wind facilities on birds, and the increasing impact of offshore wind power generation on fishing.

In light of these challenges, technological, institutional and political measures will be required to integrate variable renewable power sources into the electricity system. The Advanced Technologies Scenario referred to here assumes progress in the commercialisation of technologies for integrating variable renewable power sources into the electricity system, policy support for their implementation in society, growing environmental awareness among business operators, investors and consumers, and improved social acceptance of electricity infrastructure construction. Technologies supporting the spread of variable renewables will include power generation prediction, output control, energy storage (mainly pumped hydro storage and batteries), output adjustments for backup power sources, power supply adjustments using EVs, grid enhancement and interregional power supply, and smart grid systems combining these and information and communications technology. For these technologies to diffuse, policies and legal systems to promote the harmony of power sources with the natural environment and the regional acceptance of renewables will be required to support the 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 2 270 GW in 2030 and 5 170 GW in 2050 (Figure 4-6). Onshore wind power generation will remarkably expand in China and India as enhanced power transmission infrastructure and cost reductions for energy storage technologies ease the spatial and temporal unevenness of the distribution of wind resources. 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 smoother development and adjustment based on a better understanding of fishery business operators and other traditional ocean users will help the diffusion of offshore wind power generation in these regions. China will retain the largest share of global onshore and offshore wind power generation capacity, remaining a major wind power generation market. China will account for 41% of the world's installed capacity in 2030 and 49% in 2050. Overcoming location and grid constraints through advanced technologies will contribute to further expansion of wind power generation in Europe, the United States, India and elsewhere, but also in China. As a result, China’s share in 2050 itself will not significantly differ from the Reference Scenario.

[15] 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 photovoltaic and wind power generation.

Figure 4-6 | Global wind power generation capacity [Advanced Technologies Scenario]

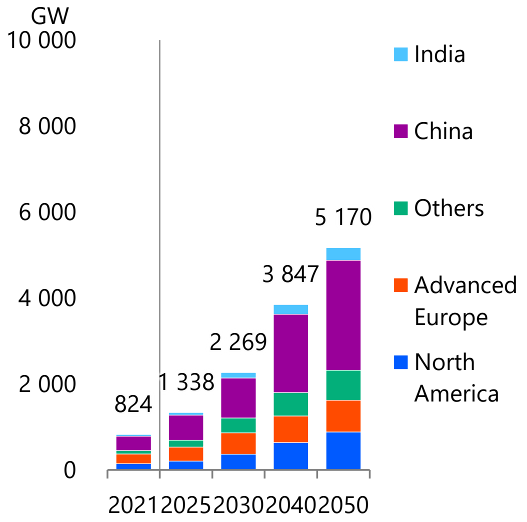
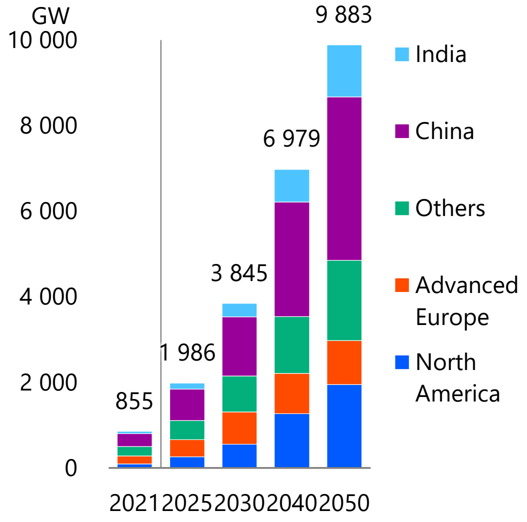


Figure 4-7 | Global solar photovoltaic power generation capacity [Advanced Technologies Scenario]



Solar photovoltaic power generation is also being introduced ambitiously, with global installed capacity reaching 3 845 GW in 2030 and 9 883 GW in 2050 (Figure 4-7). As a result of technological advances which have overcome location and grid constraints to a certain extent, wind and solar photovoltaics will increase by 1.3 times and 1.4 times, respectively, compared to the Reference Scenario for 2050. In addition to the current major solar photovoltaic power generation markets such as China, European Advanced Economies, the United States and Japan, the presence of India will increase as a solar photovoltaic power generator on the back of falling costs for solar photovoltaic power generation and storage batteries. Furthermore, the growth of solar photovoltaic power generation will accelerate in the Sun Belt which has abundant sunlight resources, including the Middle East, Africa and Latin America. Comparing the Reference Scenario and the Advanced Technologies Scenario for solar photovoltaics, the latter shows a 1.2-fold expansion in Europe, a 1.5-fold increase in India, and a 1.4-fold increase in countries and regions other than China, North America and Europe (Middle East, Africa, Latin America, etc.), which are relatively high figures. This suggests that these countries and regions, which are not currently major markets, could become more promising solar photovoltaic power generation markets through advanced technologies.

Carbon neutrality initiatives have grown globally in recent years. The diffusion of variable renewable power sources will have to accelerate much faster than in the Advanced Technologies Scenario to realise carbon neutrality by around the middle of this century. As the electricity supply and demand structure is expected to change drastically in a carbon neutral society, technology choices will have to adapt to the change. In addition to using lithium-ion and sodium-sulphur (NAS) 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 amounts of electricity for a long time by increasing the amount of electrolytic solution. Regarding hydrogen, capacities for water electrolysis, hydrogen storage and hydrogen-fired power generation technologies can be chosen separately. Energy storage technology is also expected to be used to provide ancillary services such as power system frequency regulation. Storage batteries have already entered the ancillary services market in Europe and the United States. Water electrolysis technology is also being tested, mainly in Europe, aiming at the institutional design for practical use in ancillary services. Energy storage should be pursued to achieve optimal combinations, by comprehensively considering and combining the characteristics of each technology, such as technical features, economy, safety and economic security including the procurement of mineral resources as raw materials, such as lithium, nickel, cobalt, vanadium and platinum.

Nuclear

Nuclear power generation is useful for multiple policy objectives including climate change mitigation, air pollution control and energy security. Therefore, nuclear 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 know-how and more efficient construction. Meanwhile, powerful policy measures will be implemented to commercialise advanced nuclear reactors such as small modular reactors (SMRs) and Generation IV reactors, which have been particularly under development in recent years. These advanced reactors have been under development for decades without being commercialised. In recent years, some potential users have emerged in the United States and Canada and are considering introducing such reactors, while many other countries and regions are expressing interest. Therefore, the introduction of these advanced reactors in the future will depend on whether planned or current projects for demonstration reactors sufficiently satisfy potential users around the world.

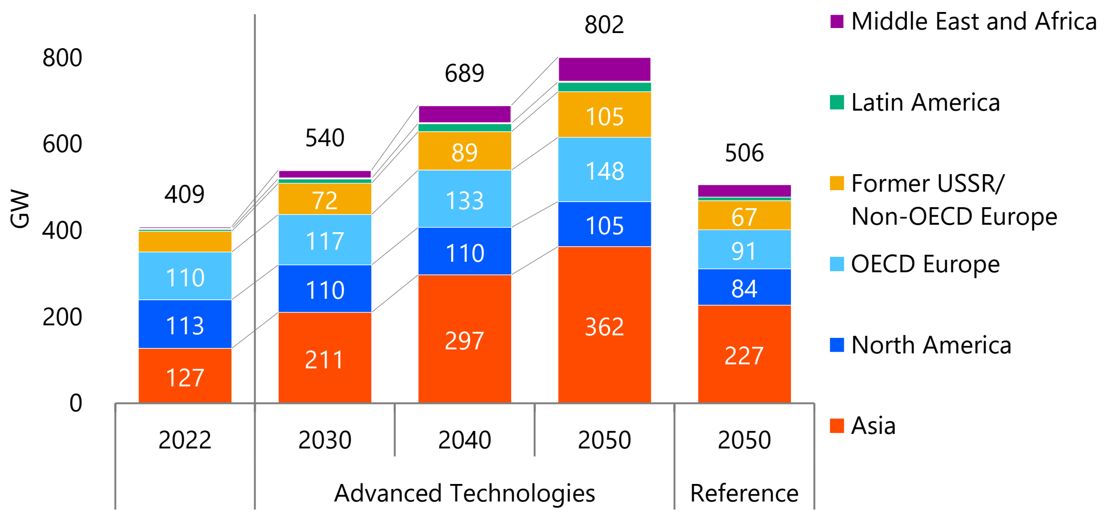
Efforts in non-power sectors will also be important for substantial decarbonisation throughout society. Therefore, nuclear technology is expected to be used not only for power generation but also for multiple other purposes such as district and industrial heat supply, hydrogen production and seawater desalination. However, nuclear is currently supposed to be used as a baseload power source, and this will not change even in 2050, as large amounts of energy demand will continue to be electrified in the future. The effective use of surplus electricity and heat will be considered only after the primary role of nuclear for supplying electricity is fulfilled.

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 same is true in the United Kingdom, where new construction will be implemented beyond the Reference Scenario by 2050. Some of the countries that have announced their nuclear phase-out policies in response to the Fukushima Daiichi Nuclear Power Station accident will change those policies and postpone closure of their nuclear power plants or replace decommissioned capacity to promote decarbonisation and maintain their industrial competitiveness.

Not only Advanced Economies that have announced ambitious decarbonisation initiatives, but also some Emerging Market and Developing Economies will expand nuclear to promote decarbonisation and meet their rapidly growing electricity demand. While the basic motive for introducing nuclear is to acquire large stable power sources to meet energy demand, Emerging Market and Developing Economies with islands or remote territories are expected to introduce small nuclear reactors for small grids of such areas.

In the Advanced Technologies Scenario under these assumptions, global installed nuclear power generation capacity will increase from 409 GW in 2022 to 802 GW in 2050 (Figure 4-8). This is equivalent to 1.6 times the amount of 506 GW in the Reference Scenario.

Figure 4-8 | Nuclear power generation capacity [Advanced Technologies Scenario]



In North America, the installed capacity will slightly decline after 2025, but will remain around 105 GW until 2050, by carrying out the necessary maintenance of existing reactors and by constructing new reactors. The U.S. federal government and some state governments are increasingly giving higher ratings to nuclear's low carbon contribution and reliability of energy supply. In the Advanced Technologies Scenario in which such policy trends will be maximised, support for innovative nuclear technology development and extension of the lifespans of 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, which will be commercialised in or after the 2030s. However, the impact of SMRs in those countries' total installed capacity will be limited due to the small capacity per unit.

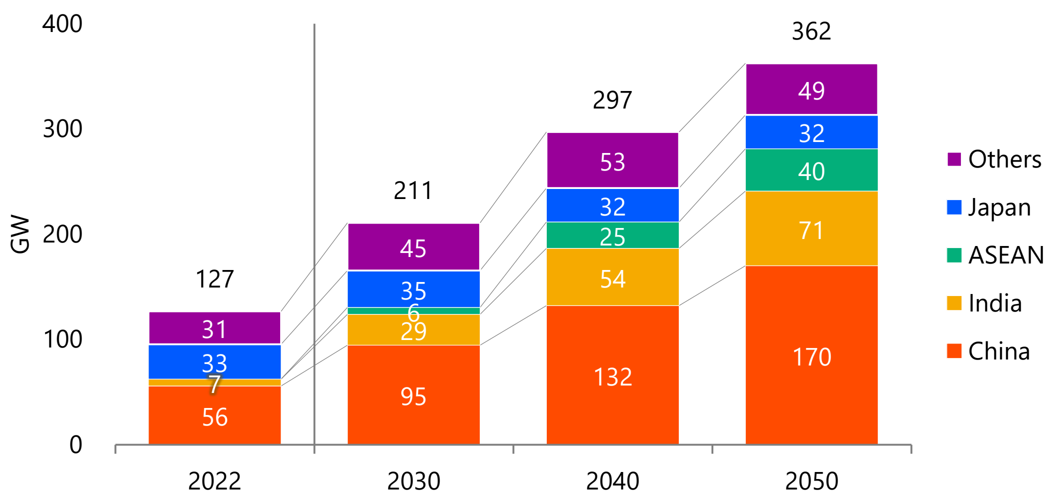
In European Advanced Economies that are aiming at ambitious targets for reducing greenhouse gas (GHG) emissions, while aging existing reactors are being decommissioned, the construction of additional plants and the replacement of plants will be politically promoted. As a result, installed nuclear power generation capacity will expand from 110 GW in 2022 to 148 GW in 2050. In France, the largest nuclear power user in Europe, installed nuclear power generation capacity will decline more slowly than in the Reference Scenario through 2050, as the number of nuclear plant construction projects increases. The construction of state-of-the-art large light-water reactors will be further promoted in the United Kingdom, and by 2050 the maximum target set by the Energy Security Strategy, 24 GW cumulatively (including existing plants) will be realised. In Western countries, the construction of large-scaled light-water (Generation III plus) reactors has been substantially delayed due to the loss of construction know-how for new reactors and design modifications after construction starts. These problems will be corrected for future nuclear power plant construction projects to reduce the risks related to new plant construction and improve the investment climate for business operators. This will drive the expansion of nuclear capacity.

Russia will accelerate construction of new nuclear power plants, continuing to expand its installed capacity from 30 GW in 2022 to 53 GW in 2050. Furthermore, exports from Russia will actively proceed against the backdrop of economic growth and growing energy demand in the Emerging Market and Developing Economies. Russia has already been promoting cooperative relations with many Emerging Market and Developing Economies to help them develop nuclear and other industrial infrastructure and human resources, paving the way for exporting its nuclear power plants in the future.

The Middle East, Africa and Latin America, known as emerging nuclear markets, will commence operation of new reactors from around 2025 and steadily expand installed nuclear power generation capacity thereafter. In the Middle East where policy priority will be given to breaking away from heavy dependence on fossil fuels, installed 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 (UAE) which has already launched plant construction and in Saudi Arabia which has announced plans for nuclear power plant construction.

As in the Reference Scenario, Asia will have the world's largest installed nuclear power generation capacity in 2050 in the Advanced Technologies Scenario. Asia's installed capacity will exceed the total combined capacity of European Advanced Economies and North America around 2035 and reach 362 GW in 2050 (Figure 4-9). The increase will be driven by China and India, as in the Reference Scenario. In addition, Southeast Asian countries, now just planning to introduce nuclear power generation, will also make progress in introducing nuclear as they require stable and economically efficient low-carbon power sources to meet their growing electricity demand. As many of these countries need to achieve stable electricity supply on their islands, the introduction of SMRs or floating nuclear reactors is being considered. With this background, ASEAN's installed capacity, though zero as of 2022, will reach 40 GW in 2050 as commercial nuclear power generation starts around 2030. That figure will exceed Japan's installed capacity of 32 GW in that year.

Figure 4-9 | Asia's nuclear power generation capacity [Advanced Technologies Scenario]



Hydrogen

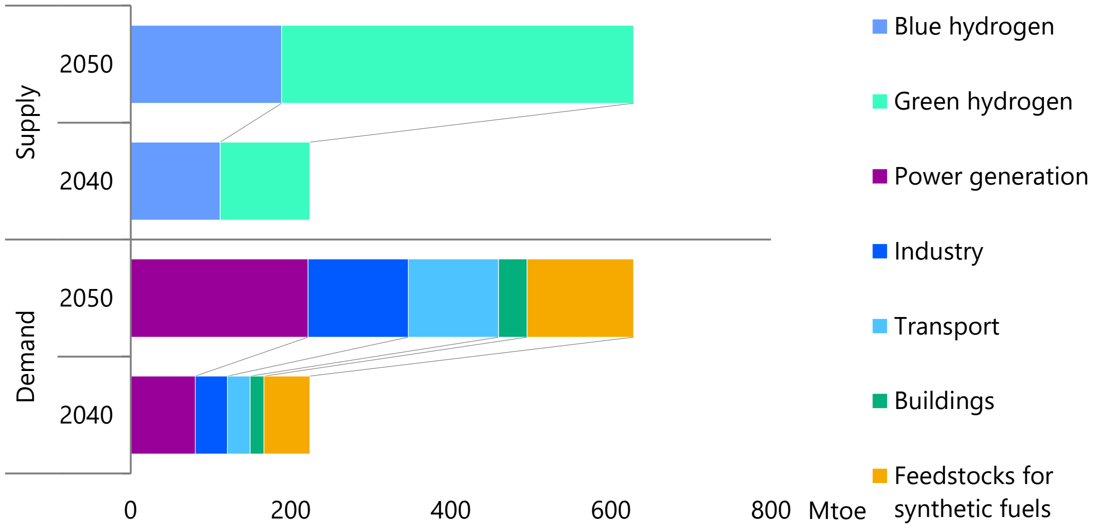
Clean hydrogen and low-carbon fuels made from clean hydrogen (ammonia, synthetic methane, synthetic fuels [e-fuel], etc.) are attracting attention as a decarbonisation measure for applications where electrification is difficult, and as an alternative to thermal power generation primarily as a balancing power source.

The United States launched a 10-year tax credit for clean hydrogen production through the Inflation Reduction Act, which was passed in August 2022. In addition, based on the Bipartisan Infrastructure Law, the United States will select 6 to 10 Regional Clean Hydrogen Hubs (H2Hubs) and implement a support scheme of about 7 billion dollars to create a clean hydrogen network, including the use of hydrogen. The European Union (EU) is increasingly promoting the use of renewables-derived hydrogen (green hydrogen) as part of its shift away from Russia since the Ukraine crisis. The REPowerEU plan set in March 2022 aims to supply 10 Mt/year of renewables-derived hydrogen from domestic production and 10 Mt/year from imports by 2030. Also, through the European Hydrogen Bank (EHB) established in March 2023, the European Union will establish the intra-EU market distribution of renewables-derived hydrogen and implement a support mechanism for renewables-derived hydrogen imported into the European Union. In Asia, China announced its "Medium- and Long-Term Development Plan for the Hydrogen Energy Industry" in March 2022, with the goal of producing 100 kt/year-200 kt/year of renewables-derived hydrogen and holding 50 000 fuel cell vehicles by 2025. In addition, a series of large-scale renewables-derived hydrogen production projects have commenced in regions where wind and solar resources are abundant and can be procured inexpensively. Korea has established the world's first hydrogen-fired power generation bidding system, aiming to expand the use of hydrogen- and ammonia-fired power generation. Meanwhile, in June 2023 Japan revised its Basic Hydrogen Strategy for the first time in six years, setting targets for introducing clean hydrogen and low-carbon fuels of up to 3 Mt/year by 2030, 12 Mt/year by 2040, and 20 Mt/year by 2050.

In the Advanced Technologies Scenario, the main applications of clean hydrogen are in power generation, synthesis of low-carbon fuels, the industrial sector, and the transport sector (Figure 4-10). Currently, the main destination of hydrogen in the transport sector is fuel cell vehicles, with the main application being heavy duty vehicles such as buses and trucks, which have high annual mileages and are difficult to electrify. In addition, hydrogen and hydrogen-derived ammonia, synthetic methanol (e-methanol) and synthetic kerosene (e-kerosene) will be important options for the decarbonisation of ships and planes. Another application of hydrogen and hydrogen-derived low-carbon fuels will be in the industry sector, especially for high-temperature heat demand. In addition, steelmaking technologies using hydrogen, such as blast furnace hydrogen reduction and direct hydrogen reduction, are still at the demonstration stage, but their introduction will expand in the future as an important means of decarbonising the iron and steel sector. In the buildings sector, hydrogen will be mainly used in areas with delivery infrastructure such as hydrogen piping.

Regarding hydrogen production, fossil fuel-derived hydrogen with CCS (blue hydrogen) will grow in the short term thanks to its price competitiveness, but in the medium to long term, renewables-derived hydrogen will increase as the cost of renewable power generation and water electrolysis systems falls, causing renewables-derived hydrogen to account for about 70% of the clean hydrogen supply by 2050 (Figure 4-10). Other promising sources of clean hydrogen production and supply will include countries or regions with abundant renewable energy resources such as Latin America, Australia and Africa, in addition to traditional energy-producing areas such as the Middle East and North America. The main destinations for clean hydrogen and low-carbon fuels will include Europe, North America, East Asia and India.

Figure 4-10 | Supply and demand of clean hydrogen [Advanced Technologies Scenario]



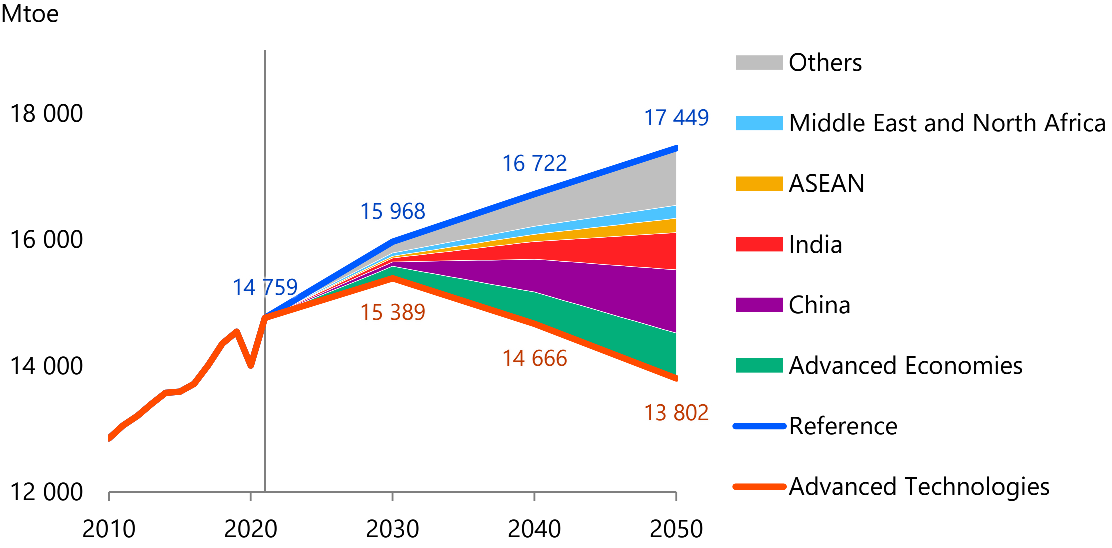
Transforming hydrogen into a hydrogen carrier for the purpose of hydrogen transport requires large capital investment and additional energy input, which will increase costs. Therefore, such transformation and transport should be kept to a minimum, so the production of and demand for hydrogen should be geographically close to each other. However, for countries or regions such as Europe, Japan and Korea, where demand for hydrogen is expected to be high but where the supply of inexpensive clean hydrogen is limited, long-distance transport of hydrogen from abroad will also be necessary. To establish an economical international supply chain for clean hydrogen, it is necessary to significantly reduce the cost of hydrogen carrier synthesis such as liquefied hydrogen, methylcyclohexane (MCH), ammonia, synthetic methane and synthetic fuels. Controlling CO_2 emissions throughout the supply chain is another important issue, which will require the establishment of a carbon footprint certification scheme for clean hydrogen and low-carbon fuels.

4.2 Energy supply and demand

Even in the Advanced 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 2030 in the Advanced Technologies Scenario will increase from 2021 but will be −579 Mtoe (−3.6%), lower when compared with the Reference Scenario (Figure 4-11). After 2030, primary energy consumption will begin to decline due to further progress in energy efficiency improvements, and the reduction in primary energy consumption relative to the Reference Scenario in 2050 will reach 3 647 Mtoe (20.9%). Cumulative savings by 2050 will be 46.1 Gtoe. 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, which have great potential to save energy and introduce non-fossil energies.

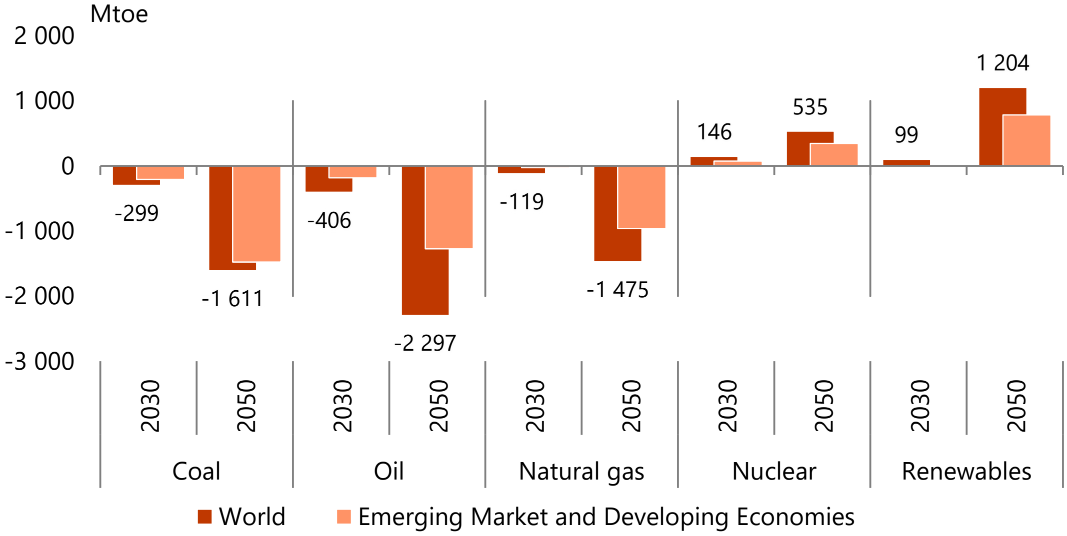
Figure 4-11 | Global primary energy consumption and energy savings (relative to Reference Scenario) [Advanced Technologies Scenario]



The Emerging Market and Developing Economies will account for 75% of global energy savings from the Advanced Technologies Scenario in 2050. Particularly, India, MENA and ASEAN will capture a combined share of 28%. Extraordinary efforts to boost energy efficiency improvements and decarbonisation in these countries will be key to global energy security and climate change countermeasures.

By energy source, fossil fuels will decrease by only 5.4 Gtoe (42%) in 2050 compared to the Reference Scenario, with a cumulative reduction of 65.6 Gtoe (Figure 4-12), partly due to progress in fuel switching. Coal for power generation is being switched in Emerging Market and Developing Economies, with these economies accounting for 70% of the reduction in 2030 and 90% in 2050. Led by the spread of electrified vehicles, oil consumption will decrease by 0.4 Gtoe in 2030 and by 2.3 Gtoe in 2050, achieving the highest energy savings. Natural gas consumption will decline only by 0.1 Gtoe in 2030 and by 1.5 Gtoe in 2050. The small saving in natural gas consumption in 2050, however, might partly result from an increase in the use for feedstock for hydrogen production. Non-fossil energy consumption will increase by 0.2 Gtoe in 2030 and by 1.7 Gtoe in 2050. Nuclear and renewables consumption will rise by 58% and 31%, respectively, from the Reference Scenario in 2050. 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 4-12 | Primary energy consumption changes (relative to Reference Scenario) [Advanced Technologies Scenario]

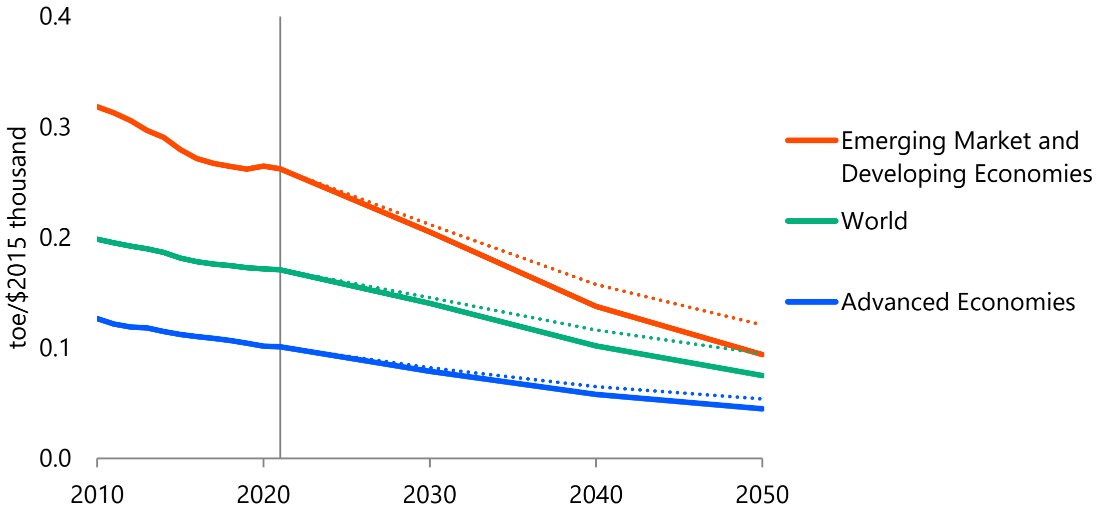


Realisation of the Advanced Technologies Scenario is not easy. The Emerging Market and Developing Economies will account for 92% of the coal consumption savings from the Reference Scenario in 2050, with India, Middle East and North Africa and ASEAN capturing a combined 32%. The Emerging Market and Developing Economies will account for 65% of the consumption growth in each of nuclear and renewables. India, Middle East and North Africa and ASEAN will account for 27% of the nuclear growth and 33% of the renewables growth. The Advanced Technologies Scenario thus urges the Emerging Market and Developing Economies to realise such contributions to coal consumption savings and nuclear and renewables consumption growth in a short period of less than 30 years. During the process of realising the Advanced Technologies Scenario, the Emerging Market and Developing Economies are required to implement their energy transition far faster than the Advanced Economies did in the past.

In the Advanced Technologies Scenario, the decrease in energy intensity per unit of GDP in the Advanced Economies and in the Emerging Market and Developing Economies will fall short of bringing the world to carbon neutrality (Figure 4-13). The Advanced Economies will post a decline of 55% in their energy intensity from 2021 to 2050, compared with a fall of 64% for the Emerging Market and Developing Economies which have greater potential to improve energy efficiency. The global energy intensity per unit of GDP will have to decrease by 79% from 2021 if the global energy consumption of 6.7 Gtoe in 2050 in the Advanced Technologies Scenario is covered by only nuclear, renewables and fossil fuels for blue hydrogen[16], and achieve carbon neutrality. The decrease would be far steeper than the declines in the Emerging Market and Developing Economies and in China, demonstrating the considerable difficulty for the world to realise global carbon neutrality in 2050.

[16] Hydrogen produced by decomposing fossil fuels and capturing CO_2 emitted in the process

Figure 4-13 | Primary energy intensity per GDP [Advanced Technologies Scenario]



Note: Dotted lines represent the Reference Scenario.

If the Advanced Technologies Scenario is realised and further CO_2 emission cuts are made, 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. Thus, the Advanced Economies' development of energy efficiency improvement technologies, their transfer to the Emerging Market and Developing Economies, international fundraising capabilities and the elimination of barriers to energy savings including insufficient awareness will become indispensable. Each country will have to adopt appropriate energy conservation and decarbonisation approaches for urban and rural areas, while introducing incentives for energy-efficient appliances for low-income people busy with day-to-day life. It will also be important to improve national and regional education programmes to enhance energy efficiency awareness over the long term.

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 (APEC) forums, and the utilisation of international organisations like the International Monetary Fund (IMF) 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 about 70% of the net final energy consumption savings in 2050 in the Advanced Technologies Scenario (Figure 4-14). Factors behind oil consumption savings include a decrease in the road sector's oil consumption due to 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 4-14 | Global final energy consumption changes (relative to Reference Scenario) [Advanced Technologies Scenario, 2050]

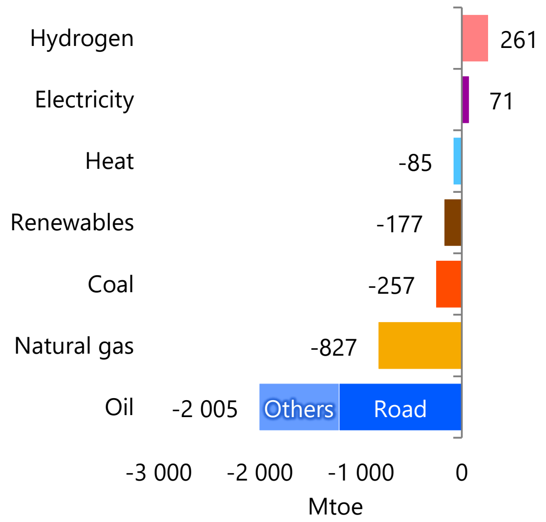
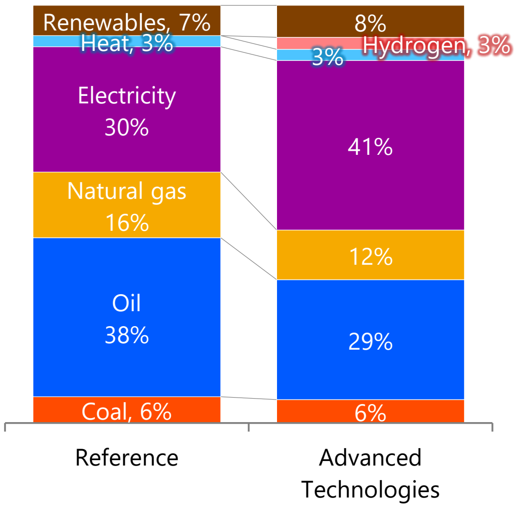


Figure 4-15 | Global final energy consumption mix [2050]



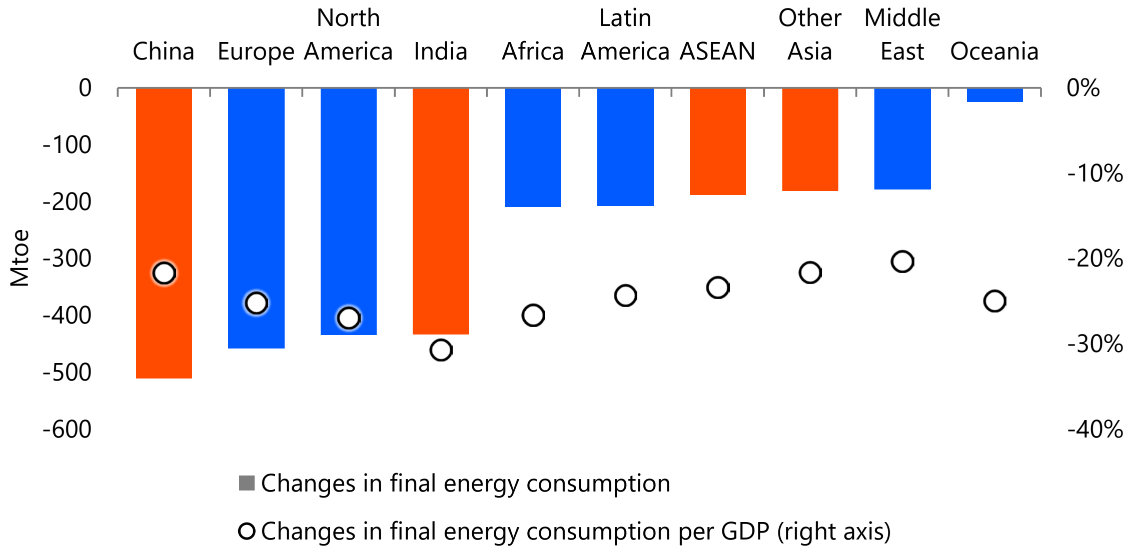
Given oil's large share of total energy savings, steady fuel efficiency improvements and vehicle fleet mix changes will become a key contributor to bringing final energy consumption closer to the Advanced Technologies Scenario path.

The final energy consumption in the Advanced Technologies Scenario will be reduced compared to the Reference Scenario for all fossil fuels such as oil, natural gas and coal due to progress in energy conservation. On the other hand, electricity consumption will increase with the promotion of electrification with the aim of saving energy and reducing CO_2 emissions through high-efficiency, low-carbon electricity. In 2050, the share of electricity will increase by 11 percentage points from the Reference Scenario (Figure 4-15). Hydrogen, which is expected to be a low-carbon means for applications where electrification is difficult, is hardly introduced in the Reference Scenario, but will see the greatest increase among energy sources in the transition to the Advanced Technologies Scenario. Renewable energies will decrease in volume as traditional biomass such as firewood and livestock manure is replaced with clean energy, but at a slower rate than fossil fuels, so the share will be similar to the Reference Scenario. Amid such fluctuations in volume from the Reference Scenario, there still exists demand for all major energy sources even in the Advanced Technologies Scenario. It will thus be important to stably supply each energy source in the Advanced Technologies Scenario as in the Reference Scenario.

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

Asia including China and India will account for the largest share of final energy consumption savings in 2050, followed by Europe, North America and Africa (Figure 4-16). Steady progress in energy efficiency improvements in China, India, Europe, the United States and other economies that are expected to achieve great energy consumption savings will be important for realising the final energy consumption path in the Advanced Technologies Scenario.

Figure 4-16 | Final energy consumption savings and changes in final energy consumption per GDP (relative to Reference Scenario) [Advanced Technologies Scenario, 2050]



Asia's final energy consumption savings in 2050 will total 1 334 Mtoe, accounting for as much as 44% of global savings. China with 511 Mtoe in savings and India with 434 Mtoe will account for a combined 30% of global savings, highlighting their great presence. Especially in India, final energy consumption per GDP fell by 31%, a greater decrease than in other countries or regions. Progress in the two countries' energy savings will affect not only their energy security but also climate change and other economies' energy security. They will substantially reduce oil consumption in the road sector and coal consumption in the industrial sector, 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.

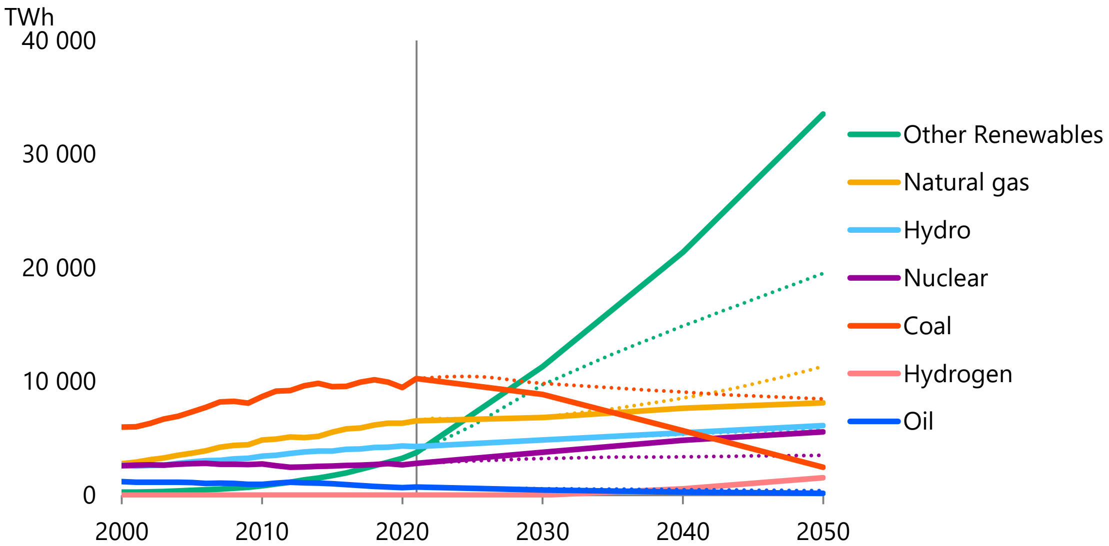
Final energy consumption savings in Europe will total 458 Mtoe, accounting for 15% of global savings. It is notable that about half of the savings will be accounted for by the buildings sector. Mainly led by the Organisation for Economic Co-operation and Development (OECD) countries, more efficient equipment for households and commercial use will be actively introduced. Final energy consumption savings in North America will total 435 Mtoe, accounting for 14% of global savings. The decline in oil consumption mainly in the road sector will account for about half of the savings in North America. As automobiles are frequently used as mobility or transportation means in North America, oil demand in the road sector in the two countries, the United States and Canada, is the second largest in the world after that in Asia. Therefore, oil consumption in the road sector will decline substantially, driven by improvements in vehicle fuel efficiency and changes in the vehicle fleet mix.

Africa is unique in terms of savings by sector. Of Africa's 209 Mtoe net final energy consumption savings, about one-third comes from savings in renewable energy consumption in the residential sector, leading to a 27% decline in final energy consumption per GDP, second only to India. The savings in renewables consumption will be led by 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 to 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 8 672 TWh higher than in the Reference Scenario reaching 57 517 TWh, double that in 2021. The main reason for this is that the share of electricity in final demand will increase by 11 percentage points from 29% in the Reference Scenario in line with the progress of electrification, as well as increased electricity input for hydrogen production. As Advanced Economies take the lead in promoting policies to phase out coal, coal-fired power generation will decline substantially from the present to less than half the current level in 2050 (Figure 4-17). In contrast, renewables including solar photovoltaics, wind and biomass will become the largest power source. Meanwhile, variable renewables will account for 50% of total electricity generated, making the handling of variable output a key challenge in each region. As a dispatch power source to replace coal and gas-fired power plants, thermal power generation with CCS will be introduced in areas where CCS storage potential exists, whereas hydrogen-fired power plants will be introduced in earnest from around 2040 in areas where no such potential exists. In addition, storage batteries for both grid and consumer use will rapidly spread, contributing to the adjustment of the balance between electricity supply and demand.

Figure 4-17 | Global electricity generated [Advanced Technologies Scenario]

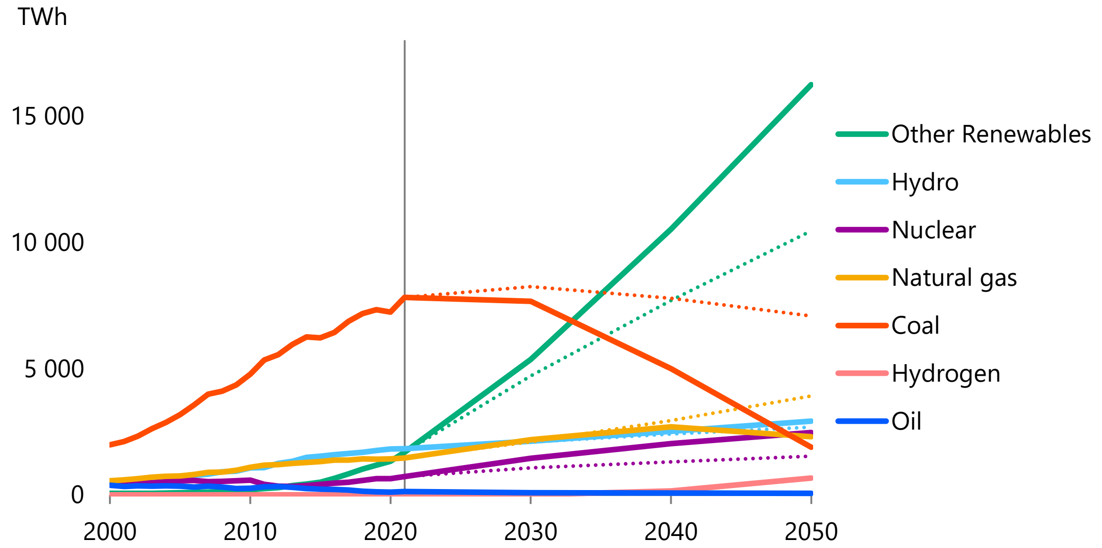


Note: Dotted lines represent the Reference Scenario.

In Asia, coal-fired power generation, currently the largest power source, will similarly decline, giving up its position as the largest power source to renewables (other than hydro) by around 2030 (Figure 4-18). Although there will be a decline in Advanced Economies such as Japan and Korea, in Emerging Market and Developing Economies a certain number of coal-fired power plants will be constructed. Needless to say, ensuring more efficient coal-fired power generation and air pollution countermeasures is important, and it is also desirable to reduce CO_2 emissions in the future by adopting CCS and co-firing of hydrogen, ammonia and biomass. The introduction of renewables, which has accelerated in recent years, will increase even faster from 2030, particularly in China and India. As these economies sustain growth, their challenge will be to harmonise renewable energy expansion with affordable and stable electricity supply. It is necessary to consider all power generation options, not only variable renewable energies, but also other renewables such as hydro, geothermal, nuclear and emissions-controlled thermal power, in order to meet the strong growth in demand.

Natural gas-fired power generation will increase steadily until around 2040, serving as a promising regulator for fluctuations in renewable energy output. In addition, hydrogen-fired power generation will be introduced in earnest through the 2050s, and will support supply-demand adjustment as with natural gas.

Figure 4-18 | Asia's electricity generated [Advanced Technologies Scenario]



Note: Dotted 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 energy consumption sectors, as well as further progress in energy efficiency improvements. Oil demand will peak by 2030, and the demand will be 57.0 million barrels per day (Mb/d) in 2050, 46% less than in the Reference Scenario. This decrease in demand will cause production to decline in all regions that are less cost-competitive than the OPEC. Production will decline also in non-Middle Eastern OPEC countries, but cost-competitive Middle Eastern OPEC countries will maintain their production at 25.6 Mb/d even in 2050. As a result, OPEC's market share will increase faster than in the Reference Scenario, reaching 44% in 2050.

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

(Mb/d)

	2021	2030	2040	2050	2021-2050	
					Changes	CAGR
Crude oil production	90.2	91.4	74.9	57.0	-33.2	-1.6%
OPEC	31.9	34.0	29.9	25.6	-6.3	-0.8%
Middle East	25.0	26.4	23.5	20.6	-4.4	-0.7%
Others	6.9	7.6	6.4	5.0	-1.9	-1.1%
Non-OPEC	58.3	57.4	45.0	31.5	-26.9	-2.1%
North America	21.1	24.6	18.3	13.5	-7.6	-1.5%
Latin America	7.8	7.9	7.4	5.6	-2.1	-1.1%
Europe and Eurasia	17.7	14.3	11.4	6.8	-10.9	-3.2%
Middle East	2.9	3.1	2.6	2.1	-0.9	-1.2%
Africa	1.3	1.3	1.1	0.8	-0.5	-1.7%
Asia and Oceania	7.5	6.2	4.1	2.6	-4.9	-3.6%
Processing gains	2.3	2.4	2.1	1.7	-0.6	-1.0%
Oil supply	92.5	93.8	77.0	58.7	-33.8	-1.6%

Note: Crude oil includes natural gas liquid.

Natural gas supply

As progress in energy efficiency improvements and other energy utilisation technologies suppresses natural gas consumption in the Advanced Technologies Scenario, natural gas production will be 12% less than in the Reference Scenario in 2040 and 20% 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 40%-50% less than in the Reference Scenario. In North America, production in the United States and Canada will not surge after 2030. Meanwhile, growth in production in non-OECD Europe, including Russia, will also slow down. In the Middle East, Qatar and Saudi Arabia will sharply increase production even in the Advanced Technologies Scenario, but production in the entire Middle East will slightly decrease after 2040.

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

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

(Bcm)

	2021	2030	2040	2050	2021-2050	
					Changes	CAGR
World	4 207	4 213	4 088	3 631	-576	-0.5%
North America and Mexico	1 208	1 322	1 308	1 162	-46	-0.1%
Latin America excluding Mexico	152	147	151	130	-22	-0.5%
Europe	204	101	58	45	-159	-5.1%
Europe/Central Asia	1 010	800	771	579	-430	-1.9%
Russia	794	550	520	320	-474	-3.1%
Middle East	702	726	714	679	-22	-0.1%
Africa	260	330	453	448	188	1.9%
Asia	517	598	448	402	-115	-0.9%
China	208	220	100	40	-168	-5.5%
India	32	58	42	23	-9	-1.1%
ASEAN	193	216	207	211	18	0.3%
Oceania	155	190	185	185	30	0.6%

Net natural gas-importing regions will reduce their imports by 20%-80% from the Reference Scenario in 2050. Among net natural gas-exporting regions, non-OECD Europe including Russia will cut exports slightly while the Middle East will reduce its net exports (excluding intra-regional trade) by about 90% from the Reference Scenario. In North America, production will be lower than in the Reference Scenario, but this is outweighed by the decline in demand. In spite of declining international prices, net exports in 2050 will more than double the Reference Scenario.

In the Advanced Technologies Scenario, changes in natural gas trade will depend on progress in relevant companies' cooperation and efforts to rationalise and optimise the trading of natural gas and liquefied natural gas (LNG). Such changes will also depend on progress in relevant countries' cooperation and support 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.

Policy and investment issues leading to stabilisation of the LNG market

The importance of natural gas and LNG was recognised at the Group of Seven (G7) Ministers' Meeting on Climate, Energy and Environment in April 2023 and at the Summit meeting in the following May. In the future, it will be important to establish standards for LNG that are "abated", i.e., acceptable for transitions. In this context, the importance of strengthening methane and GHG emission measurement and international standardisation, as well as of international cooperation in emission reduction measures, were emphasised at the above-stated G7 ministerial meetings and the LNG Producer-Consumer Conference.

Table 4-5 | Natural gas-related key points in the communiqué of the G7 Ministerial Meeting

Excerpts from relevant articles	Impact and considerations
49. Energy security and clean energy transitions: ... commitment. ... to accelerate the *phase-out of unabated fossil fuels*	It is important to clarify standards for fossil fuels that are "abated".
61. Methane: ... *an internationally aligned approach for measurement, monitoring, reporting, and verification of methane and other GHG* emissions to create an international market that minimizes GHG emissions across oil, gas, and coal value chains, including by minimizing flaring and venting, and adopting best available leak detection and repair solutions and standards.	The importance of strengthening methane and GHG emissions measurement and international standardisation is pointed out. The importance of international cooperation in emission reduction measures is pointed out.
69. Natural gas and LNG ... *investment in the gas sector can be appropriate* to help address potential market shortfalls provoked by the crisis, subject to clearly defined national circumstances, and *if implemented in a manner consistent with our climate objectives* and without creating lock-in effects, for example by ensuring that projects are integrated into national strategies for the development of low-carbon and renewable hydrogen.	The importance of natural gas and LNG is recognised. Establishing LNG standards acceptable for transition is a challenge for the future.

Reflecting these discussions, initiatives led by companies and supported by relevant governments were announced from June to July 2023, including "Coalition for LNG Emission Abatement toward Net-zero" (CLEAN) by JERA, the Korea Gas Corporation (KOGAS) and the Japan Organization for Metals and Energy Security (JOGMEC), as well as "ASEAN Energy Sector Methane Leadership Program" (MLP) by Petronas, Pertamina, PTT Public Company Limited, JOGMEC and others.

It is also worth noting the role of the International Energy Agency (IEA) in strengthening gas and LNG security, as indicated at the LNG Producer-Consumer Conference.

From March 2022 onwards, with the increase in offtake commitments that are based on long-term contracts in the international LNG market, there have been expectations for increased LNG-related investments and construction activities, especially in the United States. These LNG projects under consideration and planning are increasingly adopting CCS for reducing GHG emissions and electric drivers that use renewable energies. In the Advanced Technologies Scenario, these measures are expected to be increasingly incorporated in both new LNG projects and existing LNG production facilities.

Such incorporation of measures will emphasise the economic and environmental advantages of LNG projects, which will lead to the development of various financial instruments that meet the financing needs of LNG project development.

In the Advanced Technologies Scenario, it will be effective to build links between domestic and foreign buyers, including joint procurement, in order to secure clean LNG for the transition of these markets, taking into account the demand for flexibility and shorter contract terms by buyers, including those in developing economy markets, and the expanding base of buyers with relatively low credit scores. This will also help Japan secure the amount of LNG it needs in a stable manner, including through long-term contracts.

Table 4-6 | Long-term challenges to stabilising the LNG market

Realisation of new LNG projects in the United States, Canada, Australia, East Africa, etc. Maintenance and expansion of existing LNG production facilities (incorporating appropriate climate change measures) Trends in gas-producing countries Utilisation of amortised LNG production projects to contribute to market flexibility
Large gaps in demand projections depending on transition scenarios Shift in focus of demand growth to developing economies Need for LNG buyers to take measures to ensure stable demand and long-term commitments, among flexibility requirements (long-term and short-term transactions combined)
Changes in long-term contract pricing methods: diversification of pricing schemes, from mainstream oil-indexed pricing to more gas hub pricing, more complex composite factors, etc.
Clarification of transition-resilient LNG project standards Standardisation of CC(U)S/electrification in liquefaction
Development of financing methods also taking into account the trend of shortened contracts (addressing the gap between the requirement for shorter contracts and need for long-term commitments) Response to the expanded base of less creditworthy buyers (buyer-to-buyer alliances)

Coal supply

As efforts to replace coal with other fuels and to increase the efficiency of coal use are enhanced toward carbon neutrality, initiatives to minimise coal use will make progress in various sectors including power generation, steelmaking and other industries. Coal's share of the power generation mix will decline in many countries as the shares of renewables and nuclear expand. However, a certain level of coal-fired power generation will be maintained to secure reserve generation capacity and grid inertia to stabilise the electricity system. Also, a certain level of coal-fired power generation will be required for economic reasons in countries and regions where renewables are difficult to introduce.

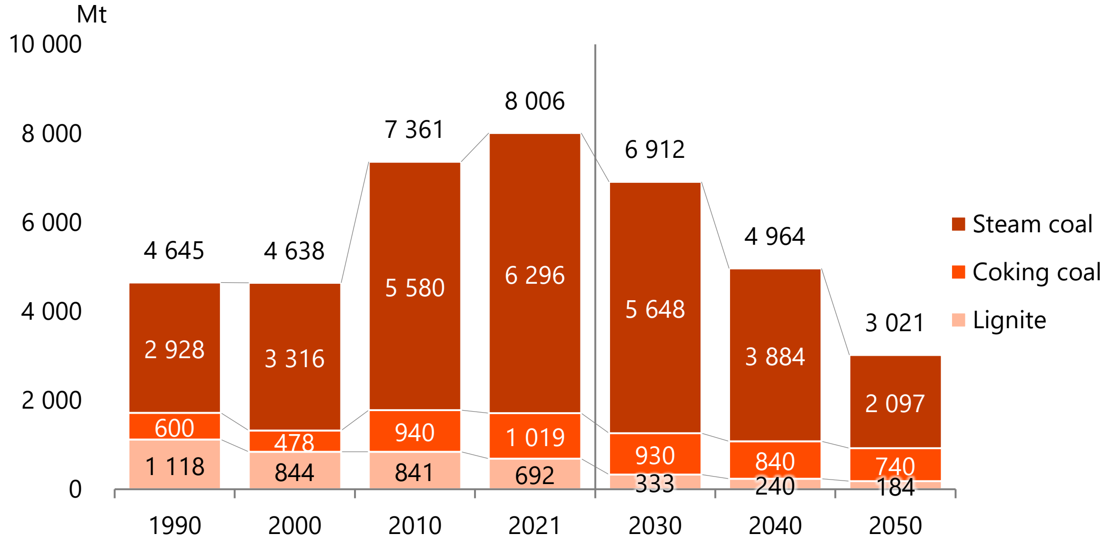
Advanced Economies will suspend or terminate inefficient coal-fired power plants. Even if some coal-fired power plants are replaced, technologies to fully minimise coal consumption by high thermal efficiency technologies such as integrated coal gasification combined cycle (IGCC) and co-firing technologies including and ammonia or hydrogen co-firing will be adopted. Coal consumption efficiency at individual power plants and industrial facilities will improve while CO_2 emission intensities will decline.

Emerging Market and Developing Economies will be strongly urged to adopt low-carbonisation or decarbonisation technologies when replacing aged or inefficient coal-fired power plants or constructing large new power plants. Coal demand will be suppressed as other fuels and power sources become more viable options due to lower costs through technological progress.

Consequently, coal production will decrease from 8 006 million tonnes (Mt) in 2021 to 3 021 Mt in 2050 (Figure 4-19). By coal type, steam coal production will decline from 6 296 Mt in 2021 to 2 097 Mt in 2050, coking coal production from 1 019 Mt to 740 Mt and lignite production from 692 Mt to 184 Mt. From the Reference Scenario, total coal production in 2050 will decrease by

3 447 Mt, with steam coal plunging by 3 047 Mt and lignite by 229 Mt, as well as coking coal decreasing by 171 Mt.

Figure 4-19 | Global coal production [Advanced Technologies Scenario]



Coal production will decline in all regions in the world due to decreased demand. In particular, production in the United States will plunge due to declining domestic demand: production in 2050 will be 16% of the 2021 level. Meanwhile, in Asia, production in China and India in 2050 will be 21% and 89% of those in 2021, both showing declines.

Table 4-7 | Steam coal production [Advanced Technologies Scenario]

(Mt)

	2021	2030	2040	2050	2021-2050	
					Changes	CAGR
World	6 296	5 648	3 884	2 097	-4 199	-3.7%
North America	437	206	41	29	-409	-9.0%
United States	425	201	37	27	-398	-9.0%
Latin America	61	43	29	21	-40	-3.6%
Colombia	51	36	23	16	-35	-3.9%
OECD Europe	47	21	16	12	-34	-4.5%
Non-OECD Europe/Eurasia	385	282	249	203	-182	-2.2%
Russia	268	178	146	94	-173	-3.5%
Middle East	0	0	0	0	0	-0.7%
Africa	239	213	177	139	-101	-1.9%
South Africa	226	195	160	125	-101	-2.0%
Asia	4 878	4 635	3 212	1 623	-3 254	-3.7%
China	3 477	3 206	1 965	610	-2 867	-5.8%
India	734	793	689	560	-174	-0.9%
Indonesia	565	525	445	350	-215	-1.6%
Oceania	249	248	160	70	-179	-4.3%
Australia	247	247	160	70	-178	-0.1%

Table 4-8 | Coking coal production [Advanced Technologies Scenario]

(Mt)

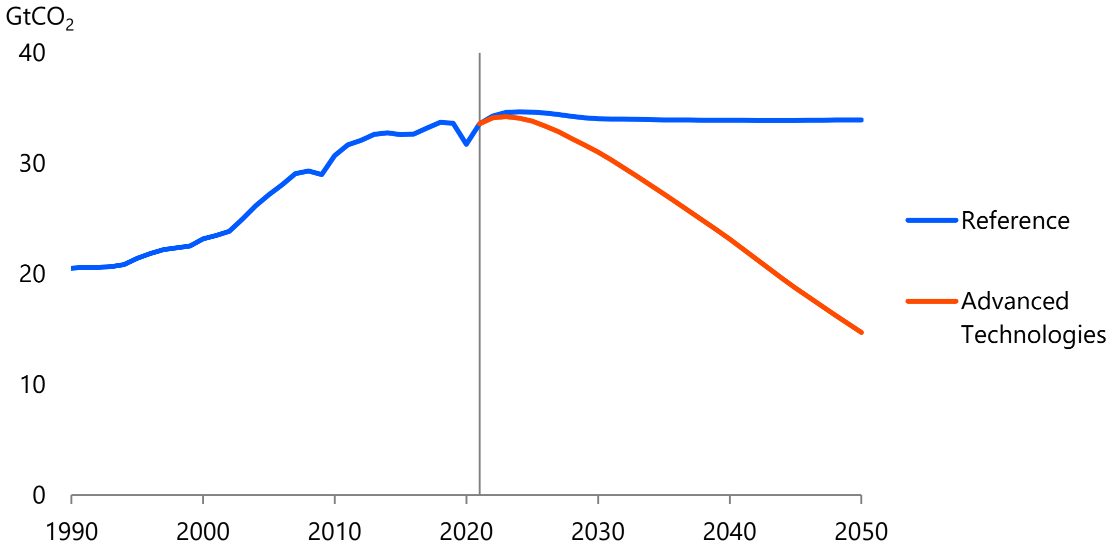
	2021	2030	2040	2050	2021-2050 Changes	2021-2050 CAGR
World	1 019	930	840	740	-278	-1.1%
North America	83	75	73	68	-15	-0.7%
United States	56	55	55	52	-4	-0.3%
Latin America	6	8	8	8	2	0.8%
Colombia	5	6	6	6	2	1.0%
OECD Europe	15	18	18	18	3	0.6%
Non-OECD Europe/Eurasia	104	93	89	81	-23	-0.8%
Russia	100	89	85	77	-23	-0.9%
Middle East	2	1	1	0	-1	-4.9%
Africa	10	13	15	16	6	1.7%
Mozambique	6	9	11	13	7	2.9%
Asia	626	546	459	377	-250	-1.7%
China	548	451	337	222	-326	-3.1%
India	49	72	105	145	96	3.8%
Mongolia	24	14	8	4	-20	-6.2%
Oceania	172	177	177	172	0	0.0%
Australia	171	176	176	171	0	0.0%

4.3 Carbon dioxide emissions

Emissions in 2050 will be 56% lower than in 2021, but well off the 1.5°C target. As the milestone of the Paris Agreement approaches, realistic reduction measures that suit the actual situation of each country or region are necessary.

In contrast to the Reference Scenario, where energy-related CO_2 emissions remain almost unchanged, in the Advanced Technologies Scenario, emissions will be reduced to 31 $GtCO_2$ in 2030 (down 8% from 2021) and 15 $GtCO_2$ in 2050 (down 56% from 2021) (Figure 4-20). The speed of reductions will accelerate to −0.9% per annum in 2021-2030, −2.9% in 2030-2040, and −4.4% in 2040-2050.

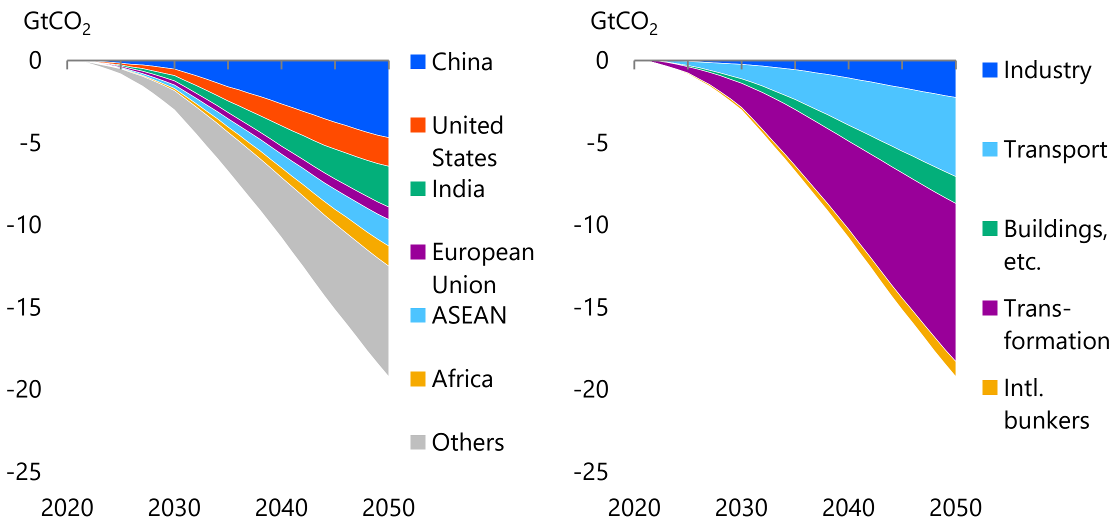
Figure 4-20 | Global energy-related CO_2 emissions



Looking at the breakdown of reductions from the Reference Scenario by selected countries/regions, China will account for 24% of the total reductions in 2021-2050, followed by 12% in India and 11% in the United States (Figure 4-21). Although these three countries play a significant role, their combined contribution will be less than 50%. Thus, it will be difficult to achieve or exceed a reduction path in the Advanced Technologies Scenario unless each country around the world makes reduction efforts under the principles of the Paris Agreement. On the other hand, by sector, the energy transformation sector will account for 50% of the total, followed by transport at 26% and industry at 10%. Once again, low-carbon power sources will play a key role in reducing emissions.

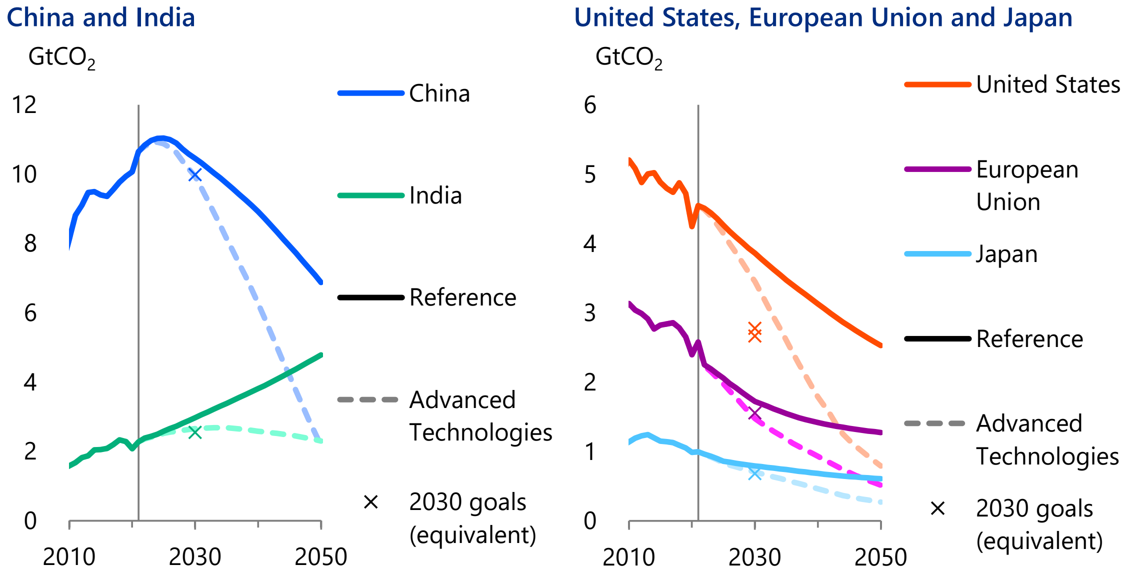
Figure 4-21 | Global energy-related CO_2 emissions and reduction (relative to Reference Scenario) [Advanced Technologies Scenario]

By country/region **By sector**



Next, a comparison of the 2030 goals by selected countries/regions was made (Figure 4-22). One of China's 2030 goals is to reduce CO_2 emissions per GDP by more than 65% (compared to 2005), which is on the path of the Reference Scenario. India has also set a goal for reducing GHG emissions per GDP (33%-35% reduction from 2005), and it will be kept close to the goal in the Advanced Technologies Scenario. The 2030 goals of the United States (50%-52% reduction from 2005), the European Union (55% reduction from 1990), and Japan (45% reduction from 2013[17]) will be, in the Advanced Technologies Scenario, achieved by the European Union, and mostly achieved by Japan, but not by the United States.

Figure 4-22 | Comparison of energy-related CO_2 emissions and 2030 goals for selected countries/regions



Notes: The 2030 goals of China and India are emission per GDP reduction goals converted to absolute equivalents based on the GDP assumptions in this Outlook. India's value is a GHG target, but the CO_2 target is also considered equivalent. The 2030 goals of both countries include renewable energy introduction targets which are not reflected in the above figure.

Currently, the first progress assessment process under the Paris Agreement (Global Stocktake) is under way, and the assessment results will be provided for consideration in the next Nationally Determined Contributions (NDCs)[18] to be submitted by 2025. A crucial milestone for the future of the Paris Agreement is approaching—whether the pledges and reviews will work effectively and whether more ambitious goals will be set in each country—but needless to say, the targets must be backed by feasible measures.

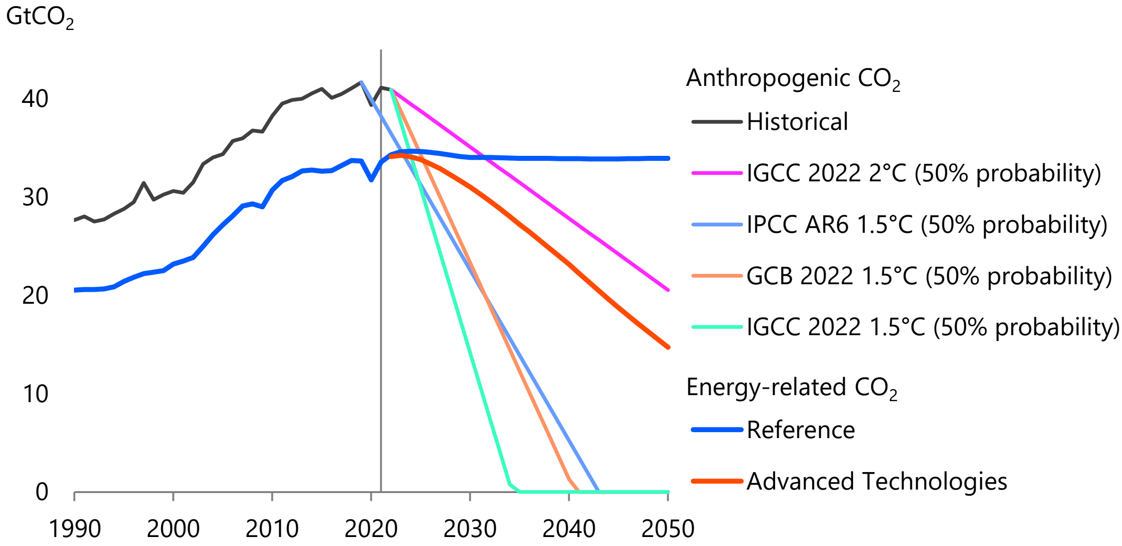
At the end of this section, the residual carbon budget introduced in 2.3 Carbon dioxide emissions is considered again. While recognising the large uncertainty in the estimated values, Figure 4-23 compares the linear emission reduction path (anthropogenic CO_2) that meets each residual carbon budget shown in Table 2-1 and the emission path (energy-related CO_2) in this Outlook. As already mentioned, a residual carbon budget of 250 $GtCO_2$ for 1.5°C (50% probability) according to the Indicator of Global Climate Change (IGCC) 2022, is equivalent to six years' worth of anthropogenic CO_2 emissions of 41 $GtCO_2$ in 2021. In order to meet this budget, reductions must

[17] Energy-related CO_2

[18] Setting targets for 2035 is recommended.

proceed at a faster pace than the 2020 emission reductions brought about by Covid-19. This linear path to zero emissions by 2035 is effectively unachievable. At the very least, it is necessary to envisage a so-called overshoot scenario, where the temperature rise temporarily exceeds 1.5°C but is reduced by large-scale CO_2 removal. On the other hand, compared to the IGCC 2022 emission reduction path for a residual carbon budget of 2°C (50% probability) (zero emissions around 2080), the path of the Advanced Technologies Scenario appears to be broadly consistent until at least 2050, though it depends on the outlook for non-energy-related CO_2. Anyhow, in order to get as close as possible to the emission path of the Advanced Technologies Scenario, realistic reduction measures should be pursued according to the actual situation of each country.

Figure 4-23 | Comparison between the residual carbon budget-based emissions reduction path and the Outlook



Note: The legend of the residual carbon budget corresponds to Table 2-1.
Source: Anthropogenic CO_2 results are from IGCC 2022. Including emissions from cement production processes, flaring, land use, land use change and forestry sector.

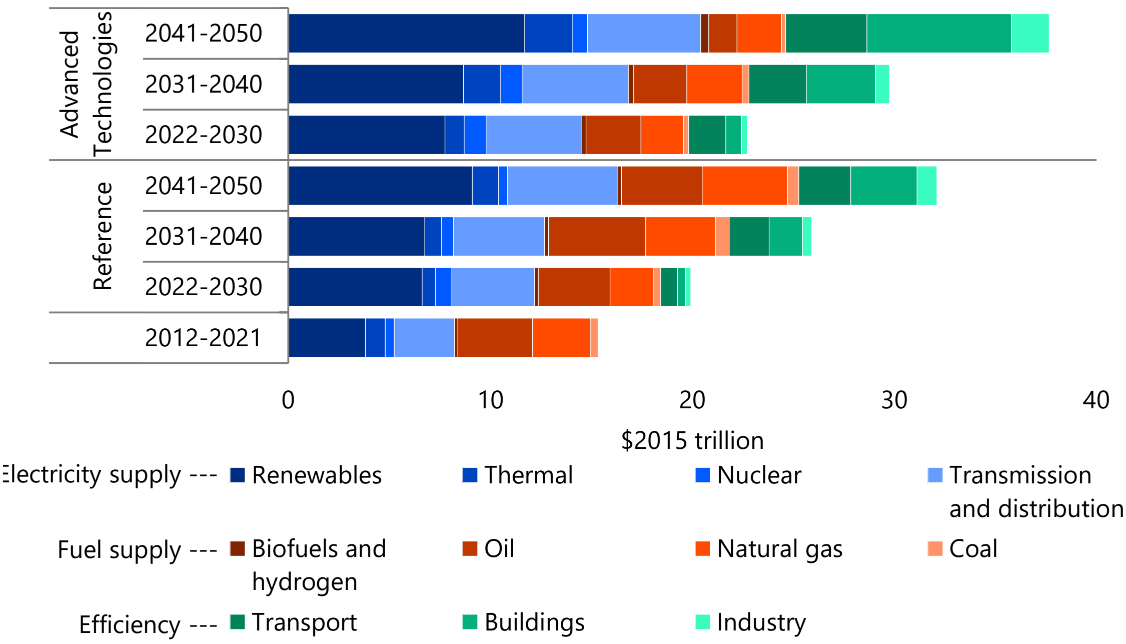
5. Energy-related investments

5.1 Recent trends and outlook

Most energy-related investments are made to oil production, natural gas production and renewables. In the last decade (2012-2021), investments have targeted primarily electric infrastructure such as renewables and transmission and distribution facilities, followed by facilities related to oil and natural gas production. From the 2020s onwards, the accelerated movement toward carbon neutrality will lead to significantly lower capital costs for renewable energy facilities, encouraging investments in renewables. Investments in energy-saving facilities will also increase to break away from dependence on fossil fuels.

In the Reference Scenario, energy-related investments[19] will increase 2.1 times from $15.4 trillion (in 2015 dollars) in the last 10 years to $32.1 trillion in the 2040s (Figure 5-1). In the Advanced Technologies Scenario, investments in fossil fuels will be less than in the Reference Scenario. On the other hand, further investments in renewables and energy efficiency will be required, with the necessary investments in the 2040s being $37.7 trillion, up $22.3 trillion from the last ten years. Cumulative global energy investments required by 2050 will reach $90.1 trillion (annual average of $3.1 trillion).

Figure 5-1 | Global energy-related investments



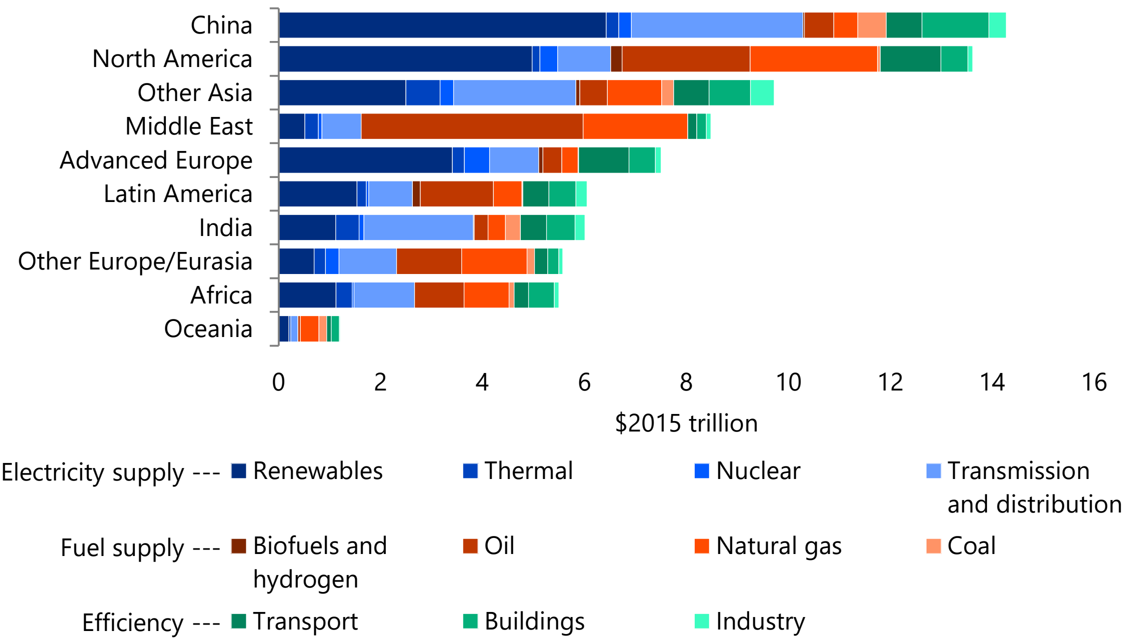
Note: Values of 2012-2021 are estimates.

The amount of energy-related investment varies by region (Figure 5-2). For example, in European Advanced Economies, which is moving away from dependence on fossil fuels, investments in renewables and energy efficiency will account for more than half of the total investments. On the

[19] The investment amounts are estimated based on the amount of newly introduced energy technologies and capital costs in each year, while the historical investments are calculated values.

other hand, in Oceania and the Middle East, among fossil fuel suppliers, investments in oil and natural gas account for a large share of the total investments, with renewable energy investments commanding a smaller share. In the United States, investments in renewables will account for 40% of total investments, while those in the production of fossil fuels, such as the development of shale oil and gas, will account for a similar proportion. In China, investment in renewable energy facilities is accelerating, accounting for nearly half of the total, aiming to achieve the "3060 Target", a national strategy to reach peak carbon dioxide (CO_2) emissions by 2030 and achieve carbon neutrality by 2060. Furthermore, the amount of investment in power transmission and distribution will also be significant, due to the need for constructing new networks to meet the growing electricity demand, which will make China's cumulative investment the largest by country and region.

Figure 5-2 | related investments [Reference Scenario, cumulative total for 2022-2050]

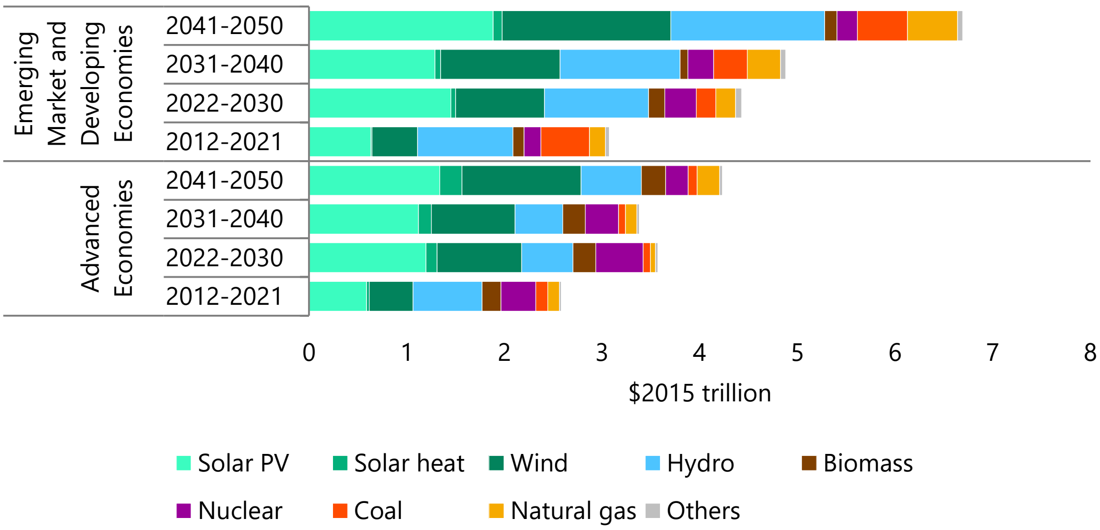


5.2 Electricity investments

Increased investment in renewable energy, especially in Emerging Market and Developing Economies

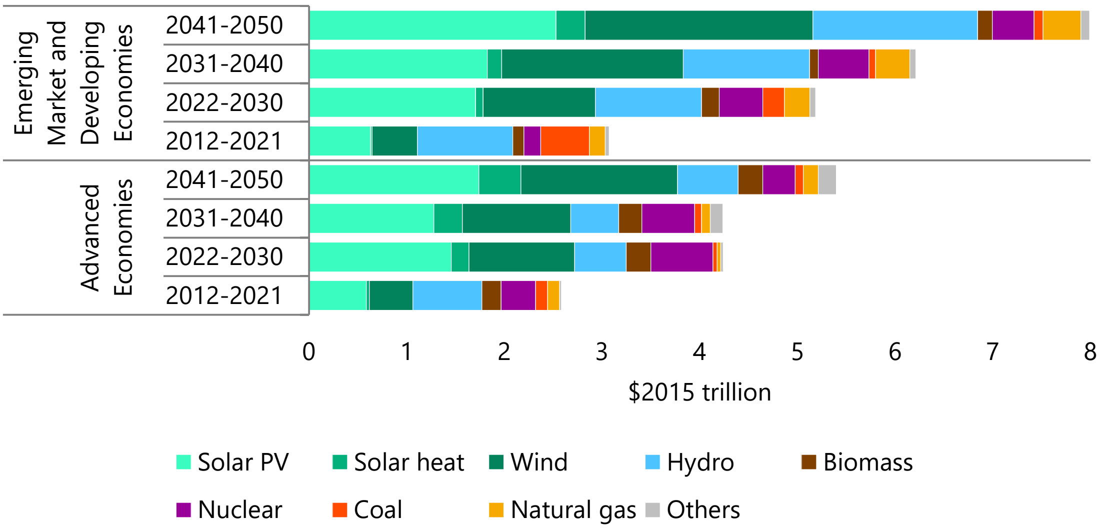
Of the investments in power generation equipment, those in renewable energy facilities account for the largest share (Figures 5-3 and 5-4). In the last decade, feed-in tariffs and net metring systems contributed to active investments in renewable energy facilities in many regions. From the 2020s onward, investments in Emerging Market and Developing Economies will increase significantly both in the Reference and the Advanced Technologies Scenarios.

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



Note: 2012-2021 are estimates.

Figure 5-4 | Power generation equipment investment [Advanced Technologies Scenario]



Note: Values of 2012-2021 are estimates.

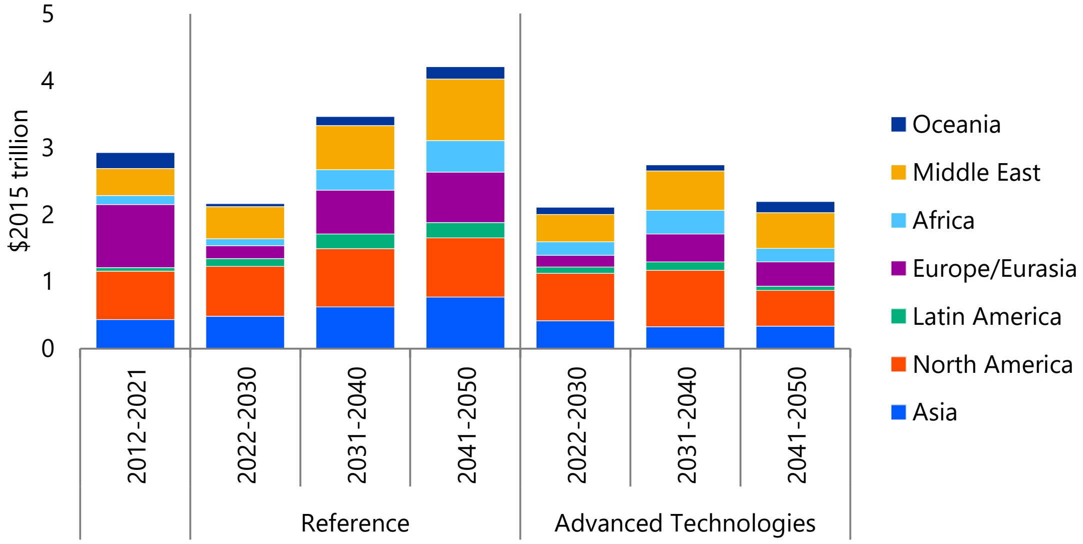
In the Reference Scenario, investments after the 2020s will be higher than in the last 10 years. In the 2020s (2022-2030), in particular, cumulative investments in both Advanced Economies and Emerging Market and Developing Economies will increase rapidly by about 1.4 times compared to the last decade as economies expand their investments in renewable energy facilities to achieve their "Nationally Determined Contributions" (NDC). In Advanced Economies, the amount of investments will decrease in the 2030s due to lower capital costs caused by cheaper solar panels and larger wind turbines, but will grow again in the 2040s due to the increase in solar photovoltaics and wind. In Emerging Market and Developing Economies, investments will continue to expand after the 2030s, followed by significant growth in the 2040s due to a marked increase in solar photovoltaics and wind. In the Advanced Technologies Scenario, renewables and nuclear will be more actively introduced compared with the Reference Scenario. These increases in investments will also lift overall investment.

5.3 Investments in natural gas and oil

Although there are moves toward carbon neutrality and a shift from dependence on certain regions including Russia for fossil fuel supply, investments in natural gas and oil which enjoy increasing demand, especially in Emerging Market and Developing Economies, will not necessarily decline in the future.

Investments in natural gas will increase in the Reference Scenario, mainly in the Middle East and North America, expanding about 1.4 times in the 2040s from the last decade (Figure 5-5). On the other hand, in the Advanced Technologies Scenario, in which renewables and nuclear increase further, from the 2020s onwards, the investments will remain lower than in the most recent decade, peaking in the 2030s, followed by a decline. As a result, investments in the 2040s will be about 80% of those in the last 10 years.

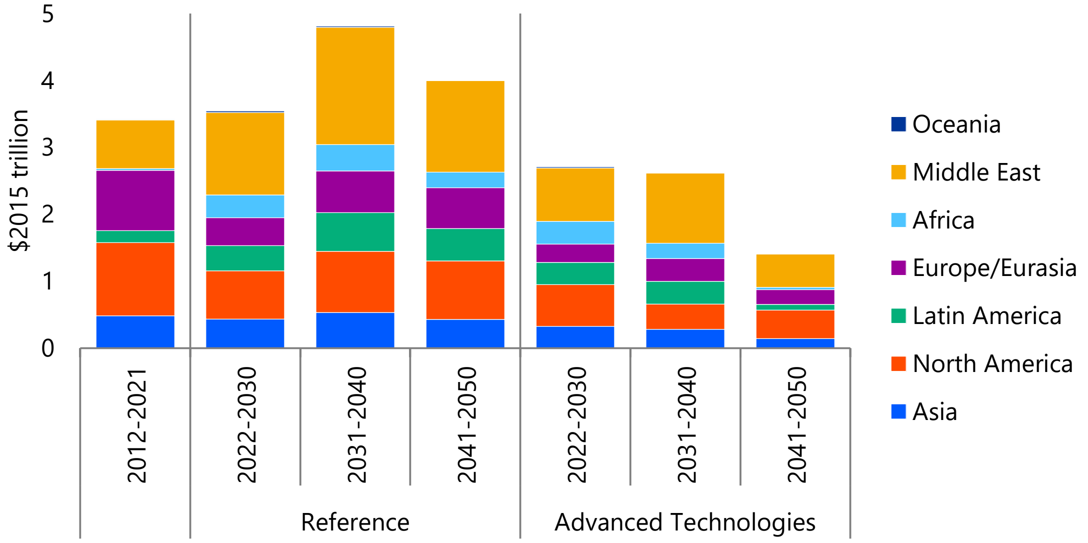
Figure 5-5 | Investment in the natural gas sector



Note: Values of 2012-2021 are estimates.

Investments in oil will peak in the 2030s in the Reference Scenario, followed by a gradual decline (Figure 5-6). On the other hand, in the Advanced Technologies Scenario, investments will be lower than in the last decade after 2020s, followed by a decline, due to further savings for transport fuels and the shift to non-oil energy sources. As a result, investments in the 2040s will be less than half of those in the last 10 years.

Figure 5-6 | Investment in the oil sector



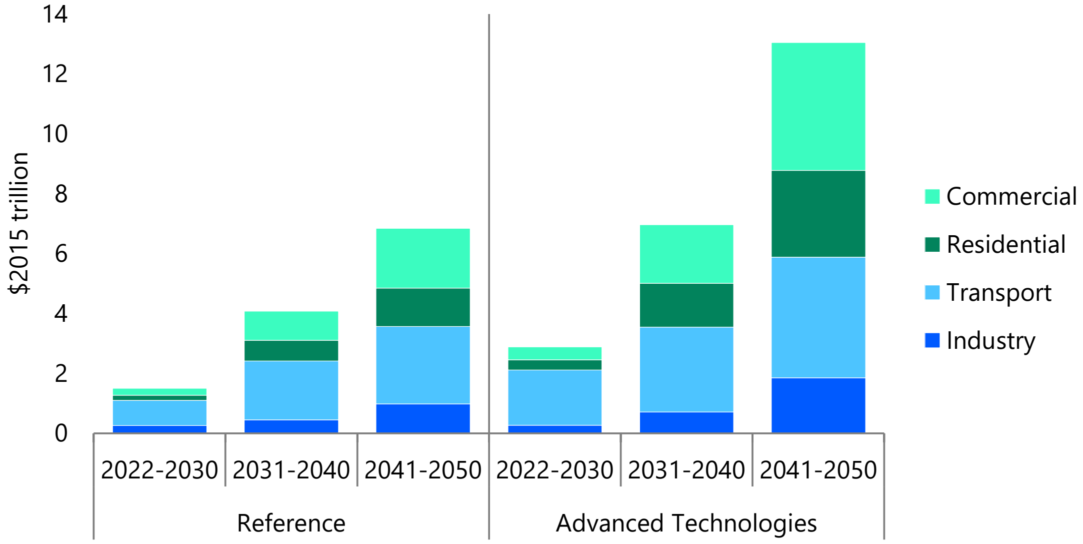
Note: Values of 2012-2021 are estimates.

5.4 Energy efficiency investments

On the demand side, the buildings and transport sectors will account for the dominant share of investments for introducing more energy-efficient[20] equipment (Figure 5-7). In the buildings sector, investments in the commercial sector will exceed those in the residential sector. In the transport sector, investments will increase due to the shift from conventional internal combustion engine vehicles such as gasoline- and diesel-fuelled vehicles to zero-emission vehicles such as electric vehicles. In the Advanced Technologies Scenario, investments will increase significantly due to accelerated electrification caused by the expanded use of electric vehicles and the introduction of fuel cell vehicles that use hydrogen.

[20] Energy efficiency levels in 2021 are considered as the baseline.

Figure 5-7 | Global energy efficiency investments



Part II

Complexity of achieving the energy transition under multiple pathways

6. Enabling LNG and natural gas to play their roles

Among fossil fuels, liquefied natural gas (LNG) and natural gas are expected to continue to play a role during the energy transition. In this chapter, we summarise the issues in fulfilling these roles, as well as the countermeasures.

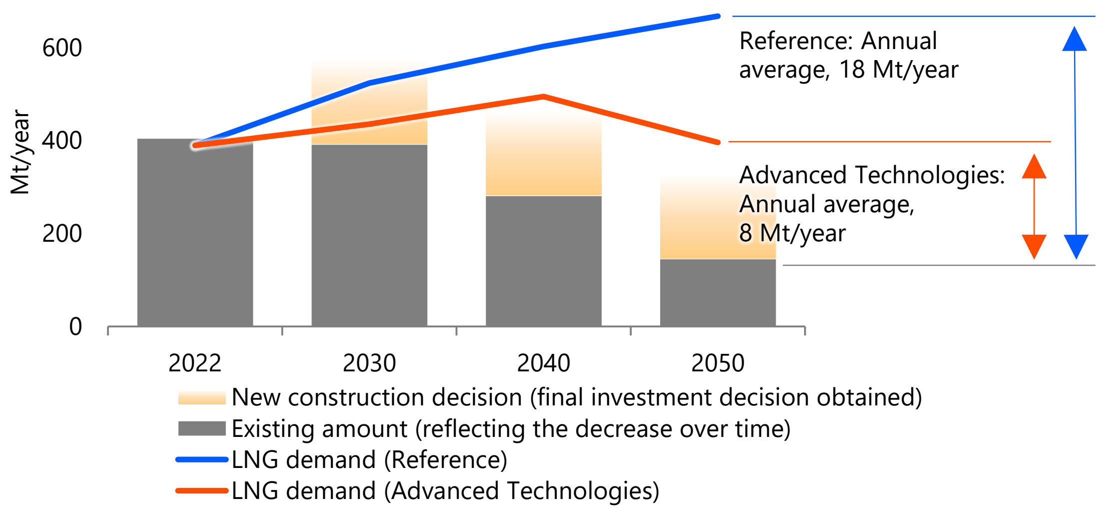
6.1 New investments required to ensure a stable supply of LNG and natural gas

Investments are required to cover net increases in LNG demand and existing LNG production facilities, and to replace aging feedstock gas fields

The cumulative investment required for the natural gas production sector (2022-2050) reaches $9.8 trillion in the Reference Scenario and $7 trillion in the Advanced Technologies Scenario. The LNG production sector will require an annual capacity addition ranging from 8 Mt/year (Advanced Technologies Scenario) to 18 Mt/year (Reference Scenario) on average, during the outlook period up to 2050. The production sector will require investments in new projects, in new gas fields as alternative supplies (backfill), compensation for the decline in production in the feedstock gas fields, and rejuvenation and renovation of existing LNG liquefaction and other facilities.

There is always the uncertainty as to whether the already approved construction plans will be implemented. The possibility that they will be delayed or called off should be monitored.

Figure 6-1 | Investment required for the LNG production sector



6.2 Cost trends of LNG production projects, challenges in Japan's LNG procurement

Cost trends of LNG production projects in recent years

Since 2021, the construction of LNG production projects has experienced delays and rising costs due to supply chain disruptions caused by the pandemic and the growing overall cost pressures associated with the Russia-Ukraine war. There have also been delays in implementing the investment decisions that were made due to unrest arising in host countries of LNG production projects.

At the same time, more efforts to reduce costs (or curb cost increases) through technological innovation are being made at small- and medium-scale liquefaction facilities. In addition, with the expansion of the ecosystem and overall scale of LNG production projects, efforts are also being made to reduce costs by expanding the use of a modular system (repeated application of the same design). Furthermore, the phasing-out of Russian gas and development of LNG production projects in other regions are accelerating.

Factors contributing to the overall increase in costs include higher costs of basic materials such as steel and concrete, and higher financing costs. In addition, the promotion for clean LNG with carbon capture and storage (CCS) and electrification (renewable energy) also increases costs. On the other hand, production project companies will be competing for the limited LNG market opportunities of the second half of the 2020s and will therefore strive to reduce costs.

Trends toward cleaner and greener LNG production projects

As the primary means of achieving cleaner and greener LNG production projects, the electrification of the process and the greening of the power supply that were under consideration have started to be implemented.

Full electrification of the liquefaction process is expected to improve operational reliability, reduce maintenance costs, improve liquefaction efficiency, improve greenhouse gas (GHG) emission management, and reduce gas consumption related to the process itself.

Meanwhile, the challenge is whether sufficient green power supply can be secured to meet the necessary power demand and the backup power capacity. Securing nearby renewable energy sources is crucial for success. LNG projects, which are often located in remote areas would benefit if they are in an industrial area with an access to high adjustment capacity and the availability of renewable energy sources. Furthermore, the higher initial investment caused by any additional facilities must also be considered.

In the United States Gulf Coast, the current centre of the development of LNG production projects, the electrification of power supply and the greening of electricity, including measures against air pollution, are gradually making progress. In western Canada, where new LNG production projects are being developed, there are plans to receive abundant hydroelectric power supply from the grid. In Qatar, where a major expansion of LNG production projects is under way, a construction project for large-scale solar power generation facilities is being promoted in parallel for the North Field East (NFE) and North Field South (NFS) expansion plans.

There are two main types of CCS for LNG production projects: CCS of the carbon dioxide (CO_2) already present in the feedstock gas source and of the CO_2 generated from the gas pumping and liquefaction process for LNG production. The former involves the separation of CO_2 from the feedstock gas flow to maintain LNG quality, while the recovery of CO_2 from the latter process requires relatively new technologies. As in the case of clean electrification, the economic advantage will be greater if the project is in an industrial area and can capture CO_2 from neighbouring industries.

Table 6-1 | Cost trends for LNG production projects

	Key trends	Cost reduction factors, project driving factors
2010-2014	In response to the rapid increase in LNG demand in Northeast Asia, including Japan and China, there was a development boom in LNG production projects in Australia; costs increased due to the concentration of project construction activities.	The trend of high costs in Australia, which was then the centre of LNG production project development, made development in other regions a realistic option.
2015-2020	The centre of LNG production project development shifted to the United States, and the pace of cost increases slowed down relatively in both the upstream and liquefaction sectors for LNG feedstock supply. The cost of feedstock gas for American LNG is supplied through the same network as the country's gas consumption market, and though the gas is not exceptionally cheap, it is expected to be stable over the long term.	Due to the slump in the use of LNG import terminals in the United States, the infrastructure facilities were repurposed to be used for developing LNG export facilities, which also drove down costs. The overall separation of the gas production sector from the feedstock gas transportation sector in the United States is also reducing risk and costs. Floating liquefaction (FLNG) is also becoming more popular as a competitive option for remote gas field development, as in other regions.
2021-2023	Logistical disruptions caused by the pandemic led to construction delays, resulting in higher costs. Costs generally increased due to the Russia-Ukraine war (inflation). Construction fell behind schedule after the investment decision was made due to unrest arising in host countries of LNG production projects.	Costs decreased due to technological innovation at small- and medium-scale liquefaction facilities. Costs are decreasing due to the expansion of a modular system (repeated application of the same design) with the expansion of the ecosystem and overall scale of LNG production projects. With the phase-out of Russian gas, the development of LNG production projects in other regions is accelerating.
Going forward	Concerns for rising costs of basic materials. Concerns for rising financing costs. Additional costs associated with CCS and electrification (renewable energy)	Production projects competing for LNG market opportunities in the second half of the 2020s will continue to suppress costs.

Challenges include whether there are nearby geological formations suitable for CO_2 storage, and whether it is possible to create a demand for CO_2. The higher initial investment is expected to be more than 10% (indicative) for LNG production projects as a whole and will depend on the location and the need to shut down production at existing LNG facilities for about six months in the case of newly incorporating CCS.

In addition, it is necessary to verify whether CO_2 capture, and storage can be conducted in a stable manner. As mentioned earlier, recovery from the process will be more technologically challenging than separating and recovering CO_2 from the feedstock gas.

In this sense, it is highly likely that government tax incentives and other support measures expected in the United States, and elsewhere, will work in favour of companies promoting LNG projects that incorporate CCS technologies. In the case of Qatar, CCS has already been incorporated in the NFE and NFS expansion plans. In addition, Qatar has also been engaged in the recovery and re-liquefaction of boil-off gas (BOG) from piers as part of existing projects, steadily promoting GHG reduction in LNG production projects.

Japan's LNG procurement—Procurement alliances and dependence on portfolio players expected to increase

In order for Japan to secure the LNG it needs in the 2030s and beyond, public-private collaboration and policy support are expected to grow in importance in areas including: procurement alliances such as joint purchasing and mutual provision of supplies among domestic and foreign companies, the transformation of major Japanese buyers and trading companies into quasi-portfolio players, and consideration of the optimal procurement mix (combination of long-term, short-term, and spot purchasing).

At present, the amount of term contracts secured by Japanese LNG buyers is expected to decline from just over 60 Mt per year until around 2025 to 50 Mt in 2030. Japan will need to carry out additional purchases to secure the required amount going forward.

In this Outlook, the Reference Scenario assumes that Japan's LNG demand will remain at just under 60 Mt per year until 2050. As it is becoming difficult for individual companies (especially electric power companies) to sign independent large-scale, long-term contracts, the ratio of short- to medium-term and spot purchases is expected to increase in the future.

In this respect, public-private sector cooperation and policy support for various measures will be vital. Going forward, procurement from domestic and foreign portfolio players will play an important role and major Japanese buyers and trading companies will be expected to become quasi-portfolio players. Strengthening procurement alliances such as joint purchasing and mutual provision of supplies with overseas companies will also gain weight as an option. It is important for major Japanese companies to work together to expand the share of Japan's purchases by diversifying risks and purchasing jointly.

6.3 Longer-distance LNG transportation and the need for rationalisation of transportation

LNG transportation after the expansion of the Panama Canal

With the diversification of LNG supply sources, transportation routes and distances have come to vary depending on the source and consumption areas. The completion of the expansion of the Panama Canal in 2016 has enabled LNG carriers to pass through, improving the convenience of transporting American LNG to Asia. Since the shale revolution, the production of liquefied petroleum gas (LPG) and of natural gas has increased contributing to a surge in the transportation of (LPG) to Asia.

Despite the steady increase in the volume of LNG shipments, waiting times are still long when demand for LNG imports rises in Asia. Although progress has been made in streamlining the use and reservations of the canal, waiting times have been relatively long in recent years. Drops in water level caused by droughts have led to restrictions on the number of large vessels that can pass through.

The average LNG ocean transport distance has also become longer in the past years, especially during unexpected spikes in demand. With the advent of LNG produced in the United States Gulf Coast, long-distance transportation to Asia increased. Going forward, as American LNG production expands, the need to streamline transportation is likely to increase. The full-scale LNG exports from the West Coast of North America and East Africa will also be important for rationalising and optimising LNG transportation.

6.4 G7 and LNG Producer-Consumer Conference: Need to clarify the role of LNG and strengthen security

Clarification of standards and close dialogue are important for strengthening LNG security

The Group of Seven (G7) countries have recognised the importance of natural gas and LNG, and the importance to establish standards for "abated" LNG that can be allowed in the energy transition. At the G7 ministerial meetings (in April 2023) and the LNG Producer-Consumer Conference (in July 2023), the importance of international standards for methane and GHG emissions measurements as well as the importance of international cooperation in emission reduction initiative, were emphasised.

At the LNG Producer-Consumer Conference, the International Energy Agency (IEA) member countries, LNG producer countries, and LNG consumer countries presented their own approaches to the clean use of LNG to achieve net zero and expressed their expectations for LNG and natural gas in terms of energy security. Japan emphasised the importance of promoting a green transition while pointing out the need to secure LNG reserves for emergencies and for mutual cooperation. Japan introduced the concept of Strategic Buffer LNG (SBL). Furthermore, it expressed its support for a global cooperation toward the abolition of destination clauses and its support to LNG trading by Japan Export and Investment Insurance (NEXI). In addition, the Japan-European Union joint statement on LNG cooperation pledged to strengthen LNG security through international cooperation by working with international organisations (specifically, the IEA), improving the transparency of LNG market information, and promoting cooperation in addressing methane emissions.

Plans to strengthen the IEA's role in bolstering gas and LNG security indicated at the LNG Producer-Consumer Conference also deserve attention. This is expected to lead to strengthened information-sharing on gas security and a heightened advisory function for all countries, including non-IEA member countries.

To strengthen gas and LNG security it will be essential to promote a close dialogue with LNG producer countries through bilateral consultations at the intergovernmental level, procurement cooperation among consumer countries, and through cooperation in the mutual supply of gas in emergencies.

6.5 Challenges to the long-term stability and development of the LNG market

Optimal procurement methods and importance of international collaboration

With the increase in offtake commitments that are based on long-term contracts in the international LNG market, LNG-related investments and construction activities are making progress especially in the United States. Meanwhile, as there are uncertainties and delays in some projects for which investment decisions have already been made, it remains unclear whether sufficient LNG procurement and LNG supply capacity can be secured through an appropriate combination of procurement methods, including long-term contracts.

It is necessary to develop a variety of financial instruments to meet the financing needs of LNG production projects. This will increase the importance of support from export credit agencies and other bodies of LNG consumer countries, which in turn will increase the need to steadily carry out LNG production projects.

To meet buyers' demand for flexibility, including in developing markets, and to respond to the expansion of the buyer base, it will be effective to establish alliances among domestic and overseas buyers for joint procurement and other purposes. This will also help Japan secure the amount of LNG it needs in a stable manner, including through long-term contracts.

7. Growing importance of negative emissions technologies

In recent years, there has been a growing interest in negative emissions technologies as an option for achieving carbon neutrality in the future. This chapter summarises the outline and significance of the technologies, as well as the challenges in promoting their introduction in the future and measures for resolving those challenges.

7.1 What are negative emissions technologies?

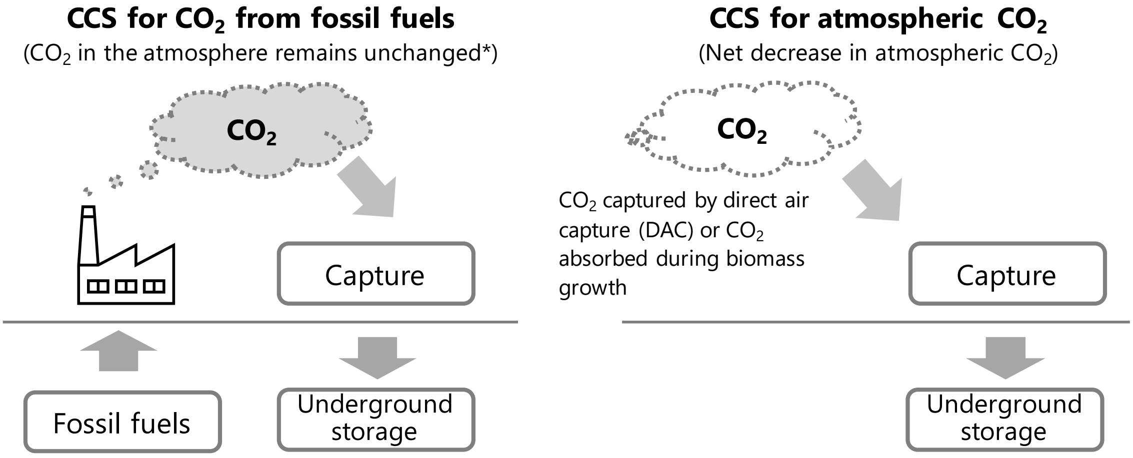
Concept

"Negative emissions technologies" (NETs) is a general term for technologies that capture greenhouse gases from the atmosphere and fix them for long periods of time. Among greenhouse gases, the term carbon dioxide removal (CDR) is sometimes used to describe the act of capturing and fixing carbon dioxide (CO_2). As we will focus on CO_2 in the rest of this chapter, NETs and CDR are considered to be synonymous.

The difference between NETs (carbon removal) and conventional climate action is that CO_2 is captured from the atmosphere and fixed elsewhere for a long time, thereby reducing the concentration of atmospheric CO_2. To start with, "carbon neutrality" is a state in which the amount of CO_2 emitted into the atmosphere is in balance with the amount of CO_2 removed anthropogenically from the atmosphere. Meanwhile, negative emissions technologies create a "carbon negative" state, albeit locally, by further lowering the concentration of CO_2 in the atmosphere from a carbon neutral state in net terms.

The difference between conventional climate change countermeasures and negative emissions technologies is illustrated using carbon capture and storage (CCS) as an example (Figure 7-1). First, the normal emission reduction technology shown on the left side of the figure consists of burning fossil fuels that formed in the ground, capturing the CO_2 generated from the process, and storing it underground using CCS technology. In this case, if we focus on the movement of carbon, we extract carbon (fossil fuels) from the ground, capture the CO_2 generated from using it, and return it to the ground. In terms of the amount of atmospheric CO_2, the difference before and after the process is zero and the atmosphere remains carbon neutral. On the other hand, in the case of NETs, instead of extracting fossil fuels from underground, CO_2 is captured directly from the atmosphere through technology-based or nature-based methods and stored underground by CCS. From the perspective of the movement of carbon, it moves from the atmosphere to the underground. In this case, the atmospheric CO_2 decreases in net terms as the CO_2 is taken from the atmosphere and stored underground, creating a carbon-negative state.

Figure 7-1 | Emission reduction measures and negative emissions (carbon removal) technologies using CCS

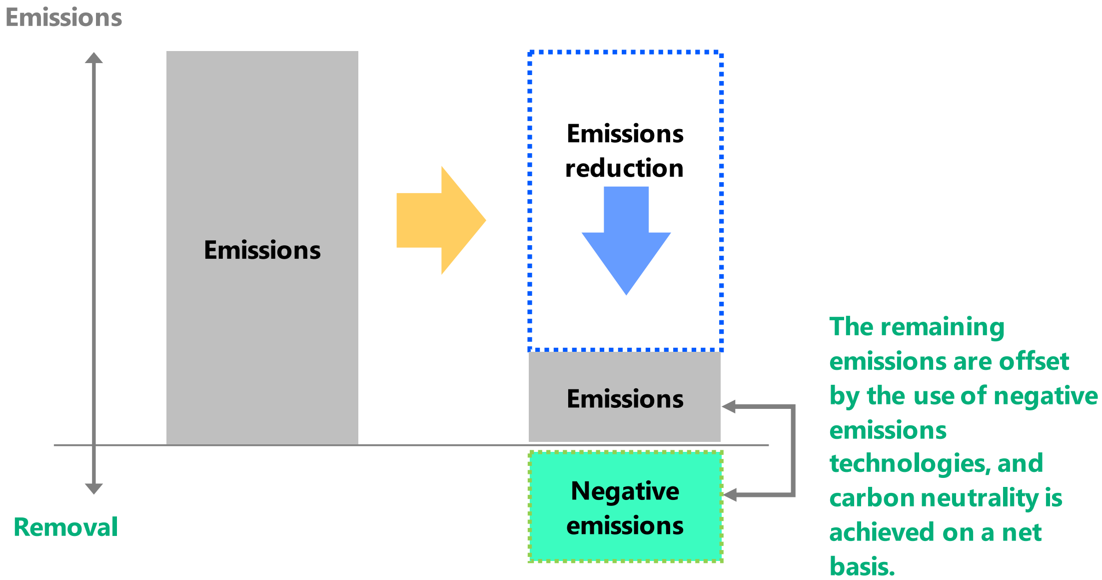


* For simplification, it is assumed that the entire amount will be captured.

Significance

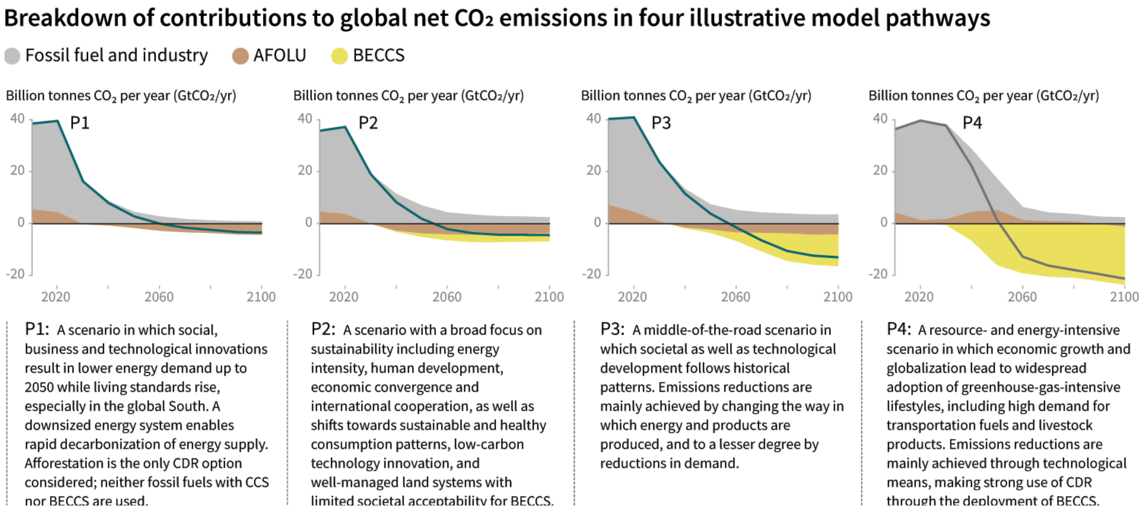
NETs are significant in that they can directly reduce the concentration of CO_2 in the atmosphere, meaning they can create net carbon neutrality for the atmosphere as a whole, which includes the CO_2 emitted elsewhere. Aiming to achieve carbon neutrality by 2050, CO_2 emissions are expected to decrease considerably as we make further use of not only energy conservation, renewable energy, and nuclear power but also decarbonisation measures such as hydrogen, ammonia, carbon recycling, and CCS, which are not yet widely commercialised. However, in the heavy industry sector whose CO_2 emissions are inherently difficult to reduce (steel, cement, chemicals, oil refining, etc.), it is highly likely that fossil fuels will continue to be used even if all such decarbonisation measures are mobilised. By applying NETs to such residual CO_2 emissions, it is more likely that carbon neutrality will be achieved in net terms as a whole (Figure 7-2).

Figure 7-2 | The role of negative emissions technologies in achieving carbon neutrality



With regard to NETs, some consider that anticipating the introduction of technologies like NETs may allow emissions from fossil fuels to survive for longer. This view is correct in the sense that expectations for NETs should not be excessive, but it is wrong in the sense that carbon neutrality can be completed through decarbonisation using renewable energy, nuclear power, hydrogen, ammonia, etc., without using NETs. Figure 7-3 conceptually illustrates the multiple reduction scenarios for achieving global carbon neutrality in the future, as outlined in the report of the Intergovernmental Panel on Climate Change (IPCC). All scenarios assume that residual CO_2 emissions will arise, that NETs will be applied to offset those emissions, and that the amount of NETs introduced will need to be increased from 2050 to 2100. We can see that the introduction of NETs is a decarbonisation option clearly stated in the IPCC report, and it is not necessarily a technology that justifies extending the life of fossil fuels.

Figure 7-3 | Illustration of emission reduction pathways and introduction of NETs (carbon removal) in an IPCC report



Note: AFOLU: Agriculture, Forestry, Other Land Use; BECCS: Bioenergy with Carbon Capture and Storage
Source: Babiker *et al.* (2022) Cross-sectoral Perspectives. In IPCC, 2022: Climate Change 2022: *Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*

Japan is particularly susceptible to the above-mentioned problem of residual CO_2 emissions as it has little renewable energy resources while having some of the world's leading steel and chemical industries. Under such circumstances, implementing NETs in society at an early stage will make it more likely that carbon neutrality will be achieved in the future. For some countries or regions, when considering their respective resource reserves and industrial structure, NETs can be regarded as a particularly important carbon neutrality technology.

Key negative emissions technologies and their characteristics

There are many different negative emission technologies, or NETs. NETs can be broadly divided into technology-based methods that capture CO_2 from the atmosphere and fix it elsewhere using technology-based methods, and nature-based methods that speed up the fixation of CO_2 from the atmosphere by artificially accelerating the carbon cycling process that takes place in nature.

Direct air capture with carbon storage

The leading technology-based NETs is direct air capture with carbon storage (DACCS). This is a combination of direct air capture (DAC), which directly captures the CO_2 that makes up about

0.04% of the atmosphere, and CCS technology, which stores the captured CO_2 underground. CO_2 is captured directly from the atmosphere through a chemical absorption method that uses a chemical solution to absorb CO_2, a physical absorption method that also uses a chemical solution but physically adsorbs the CO_2 then collects it afterwards, a membrane separation method that uses a membrane to collect CO_2, and a humidity swing method that collects CO_2 using a difference in humidity, among others. According to data compiled by the International Energy Agency (IEA), 18 DAC projects are already in operation, but all of them are small in scale with an annual average recovery capacity of 1 000 tonnes or less[21]. Among the plants of a certain scale operating commercially is Climeworks' plant in Iceland that captures 4 000 tonnes per year[22]. In this plant, the captured CO_2 is stored underground and fixed by mineralisation.

In the case of DAC, the cost of recovery is higher than that of regular CO_2 recovery, estimated at \$125t/CO_2-\$335/tCO_2, because the gas it recovers comes from the atmosphere, whose CO_2 concentration is very low[23]. In the case of DACCS, the cost of transporting and storing the captured CO_2 is added on to this, so this decarbonisation method is not economically advantageous. For DACCS, a major tax deduction of \$130/tCO_2-\$180/tCO_2 was introduced under the Inflation Reduction Act of the United States passed in August 2022, depending on whether the captured CO_2 is used to improve oil production (the former) or is simply stored underground (the latter). This has led to a high level of interest among investors around the world in the practical application of the technology, raising hopes that the carbon recovery cost will be significantly reduced in the future due to rapid progress in development investment.

Bioenergy with carbon capture and storage

The next leading technology-based NETs is the bioenergy with carbon capture and storage (BECCS). This captures the CO_2 generated during the use of bioenergy and stores it underground. Since the CO_2 emitted during the use of bioenergy is taken in from the atmosphere during the growth of biomass, it is carbon neutral even if the CO_2 is emitted directly into the atmosphere. By capturing and storing the CO_2 instead of emitting it, the amount of atmospheric CO_2 is reduced in net terms. An example is a project to capture and store the CO_2 emitted from a bioethanol production plant currently in operation in the United States[24]. In the United Kingdom as well, there is a plan for a project to capture CO_2 emitted from biomass-fired power plants and store it underground[25]. Furthermore, if we mix bio pellets in coal-fired power generation, capture the CO_2 emitted there and store it underground, then it can be said that NETs have been used for the portion of CO_2 generated from bio pellets. BECCS has the advantage that it can be implemented at a lower cost than DACCS if bioenergy can be successfully combined with CCS, since the use of bioenergy has already been commercialised. Meanwhile, as with the use of biomass energy in general, securing a stable supply of biomass energy over the long term will be a major challenge.

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[21] International Energy Agency, *Direct Air Capture: A Key Technology for Net Zero* (Paris: 2022, International Energy Agency), p19.

[22] Climeworks, "Orca: the first large-scale plant", https://climeworks.com/roadmap/orca, (accessed 27 July 2023).

[23] International Energy Agency, *Direct Air Capture: A Key Technology for Net Zero* (Paris: International Energy Agency, 2022), p.9.

[24] ADM, "ADM and Carbon Capture and Storage", 2023, https://www.adm.com/en-us/standalone-pages/adm-and-carbon-capture-and-storage/, (accessed 8 August 2023).

[25] Drax, "BECCS and negative emissions", https://www.drax.com/about-us/our-projects/bioenergy-carbon-capture-use-and-storage-beccs/, (accessed 27 July 2023).

Afforestation and forest management

The primary nature-based NETs are afforestation and forest management. This refers to a technology that reduces the amount of atmospheric CO_2 by planting new trees that absorb CO_2 during their growth. Since the amount of CO_2 absorbed by trees decreases when they grow to a certain stage, the absorption of CO_2 can be further promoted by cutting down those trees and planting new ones. Recently, wildfires have become a serious problem in many parts of the world, and ensuring that trees continue to absorb CO_2 by actively preventing deforestation by forest fires is also considered a type of NETs. Afforestation has already been introduced as NETs in many parts of the world, and voluntary credit markets have been formed based on the amount of reforestation. In recent years, new species of trees that grow faster and absorb more CO_2 than typical trees have been developed, raising hopes of further enhancing the effect of NETs through afforestation. While afforestation and forest management are able to remove large amounts of CO_2 at a relatively low cost, it is difficult to accurately measure the amount of CO_2 actually removed. The amount of CO_2 absorbed by each tree varies depending on its location and hours of daylight. Thus, establishing a more accurate method for measuring the amount of CO_2 absorption is a key challenge for this technology.

Soil carbon sequestration

Soil carbon sequestration is another leading nature-based negative emission technology. There are several ways to reduce CO_2 in the atmosphere through the use of soil. One of them is to use compost instead of chemical fertilisers, which can reduce the amount of CO_2 released into the atmosphere from the soil. Another method is to reduce the amount of CO_2 emitted from the ground during ploughing by using no-till cultivation, that is, by not ploughing the fields. Furthermore, covering the ground surface with plants is also known to reduce the CO_2 emitted from the surface. In this context, forest farming, in which crops are grown in forests, also has the advantage of emitting less CO_2 into the atmosphere compared to cultivating crops on conventional farmland. However, all of these require significant changes to normal crop production, and their impact needs to be scrutinised. In addition, it is difficult to accurately measure the reduction in CO_2 emissions by this change, so it is necessary to establish an objective and scientific measurement method.

Biochar

Other nature-based NETs include biochar. Normally, biomass such as wood releases into the atmosphere the carbon it contains in the form of CO_2 in the process of decomposition. Biochar stops the CO_2 release process by carbonising biomass and stores the carbon for a long time in the form of charcoal. Biomass is commonly carbonised by pyrolysis. By using biochar with compost on farmland, it not only stores carbon underground for a long time, but also helps fertilise the soil and prevent plant diseases as side benefits (co-benefits).

Promotion of mineralisation by weathering

Another nature-based NET is the promotion of weathering. This is a technology in which rocks that react with CO_2 and solidify (mineralise) in their natural state are exposed by scraping the soil to promote their mineralisation, or such rocks are ground into sand and scattered on the ground to promote the reaction and fixation of CO_2, thereby reducing atmospheric CO_2. Examples of such rocks include basalt, peridotite, and serpentine. While this technology may be relatively cheap to implement because it merely promotes natural mineralisation reactions, it is difficult to measure the amount of CO_2 that has actually been absorbed and immobilised, as with other nature-based NETs.

Ocean alkalisation

Among nature-based NETs, alkalisation of the ocean is a leading technology for the ocean. The idea is to promote additional absorption of CO_2, which takes place at the sea surface, by alkalising seawater. This is done by sprinkling calcium oxide and other substances into the ocean to promote the absorption of CO_2. Although this technology is considered not to affect the marine environment significantly because it returns to its original state after temporary alkalisation as the absorption of CO_2 progresses, the actual degree of impact requires further verification.

Blue carbon

Lastly, blue carbon is a technology used to promote the removal of CO_2 in coastal waters. Blue carbon includes a variety of NETs, but a leading example is growing mangrove forests in coastal areas, which, like afforestation, promotes the fixation of atmospheric CO_2 by the absorption of CO_2 by mangroves. A study is also under way on a technology for cultivating seaweed to fix the marine CO_2 in those plants, in the same way that mangroves fix CO_2. In Japan, which has one of the longest coastlines in the world, there has been strong interest in blue carbon as a means to remove CO_2. In order to accelerate efforts to mitigate and adapt to climate change using blue carbon, the J Blue Credit® system has been established as a new carbon credit system[26].

Table 7-1 lists the various NETs as described above. The technology readiness level (TRL) of the two technology-based NETs, DACCS and BECCS, is about 5-6, and the technologies are now in the transition stage from demonstration testing in the real world to being established as a system. Although BECCS has lower costs, DACCS is regarded as having higher removal potential as it is not limited by raw materials such as biomass.

Meanwhile, for nature-based NETs, afforestation and forest management and soil carbon sequestration have a high level of technological readiness and are almost ready for actual use, and the cost is relatively low. However, other nature-based NETs have issues such as low technological readiness, small removal potential, and high cost (or the technology is not mature enough to calculate the cost), and further technology development efforts are needed to assess their potential.

Among these diverse types of NETs, DACCS and BECCS have been attracting particular interest overseas in recent years, for four reasons. The first is that these technologies have a relatively high technological readiness. These technologies both involve CCS, which is a technology that has already been introduced and implemented in societies in various parts of the world. Furthermore, DACCS is already in operation in Iceland, while a project is under way in the United States to capture 1 Mt of CO_2 per year. In addition, the use of bioenergy itself is a technology that has already been commercialized in various parts of the world. DACCS and BECCS are a combination of these elemental technologies, and their technological readiness is relatively high compared to other NETs.

Second, the amount of CO_2 that can be removed by these technologies is potentially large. According to an analysis by the IPCC, the removal potential of these technologies is estimated to be up to 40 Gt per year (for DACCS). This potential is determined mainly by the amount of CO_2 that can be stored underground, but the amount that can be removed is also larger than that of other NETs. Thus, these are relatively promising technologies to focus on in the future.

[26] J-Blue Credits by Japan Blue Economy Association, https://www.blueeconomy.jp/credit/

Table 7-1 | Features of the leading NETs

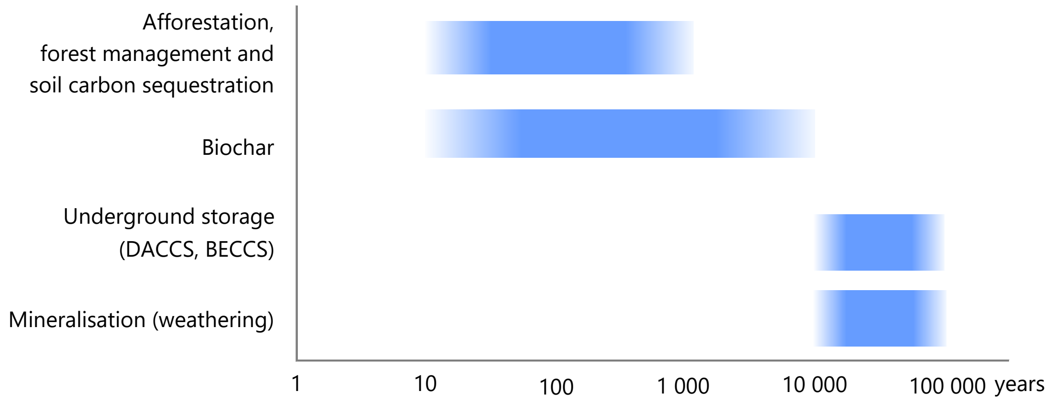
Technology	Process	Technological readiness level (TRL)*	Cost of removal ($/tCO$_2$)	Removal potential (GtCO$_2$/year)
Direct air capture + CCS (DACCS)	Technology-based	6	100-300	5-40
Bioenergy + CCS (BECCS)	Technology-based	5-6	15-400	0.5-11
Afforestation and forest management	Nature-based	8-9	0-240	0.5-10
Soil carbon sequestration	Nature-based	8-9	−45-100**	0.6-9.3
Biochar	Nature-based	6-7	10-345	0.3-6.6
Promotion of mineralisation by weathering process	Nature-based	3-4	50-200	2-4
Blue carbon	Nature-based	2-3	N/A	<1
Ocean alkalisation	Nature-based	1-2	40-260	1-100

* Technology Readiness Level: An indicator used to evaluate the maturity level of a particular technology. It is rated on a nine-point scale, with a TRL of 9 having the highest readiness and 1 having the lowest.
** Soil carbon sequestration may also produce a profit (negative cost) as a whole when the benefits associated with soil improvement are significant.
Source: Babiker et al. (2022) Cross-sectoral Perspectives. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

Third, the amount of CO_2 that they remove can be accurately measured. There are already well-established methods for measuring the amount of CO_2 captured by DAC or absorbed by biomass. In addition, the quantity stored underground by CCS can be accurately grasped. In contrast, in the case of nature-based NETs, it is often difficult to accurately measure how much CO_2 the technology can remove from the atmosphere. In this sense, these technologies, for which the decrease in the concentration of CO_2 in the atmosphere can be reliably confirmed, have a high degree of dependability.

Fourth, these technologies can fix CO_2 for relatively long periods. The duration of CO_2 fixation by NETs varies greatly depending on the technology and how it is applied (Figure 7-4). For example, in the case of afforestation, the atmospheric CO_2 absorbed by trees will only be fixed for several decades if the trees are cut down and used for paper or furniture. On the other hand, DACCS and BECCS basically store the CO_2 semi-permanently if the gas can be stored underground. Needless to say, a semi-permanent storage technology is preferable to one that releases the carbon back into the atmosphere after a relatively short period, and so DACCS and BECCS are superior to other NETs in this respect.

Figure 7-4 | CO_2 fixation period of NETs



Source: Smith *et al.* (2023). *The States of Carbon Dioxide Removal* 1st Edition, p.15

7.2 Initiatives for the introduction of NETs in Japan and overseas

Initiatives by the governments of Japan and other countries

The introduction of negative emissions technologies has also been promoted by the governments of Europe and the United States. First of all, the United States government's support measures are noteworthy in terms of the scale of support and the impact they will have going forward. In June 2022, the United States government enacted the Inflation Reduction Act, which included generous support for the introduction of a wide variety of decarbonisation measures. Among NETs, support measures were introduced for DACCS, which is a tax deduction of \$130/tCO_2 if the CO_2 captured directly from the atmosphere is used to increase production in oil fields (by enhanced recovery), and \$180/tCO_2 if it is stored underground as it is[27]. As mentioned earlier, DACCS is certain to cost at least \$100/tCO_2 or more to implement, and this level of support should stimulate the introduction of DACCS significantly. In addition to these tax credits, the United States government plans to create a DACCS hub in the country where DACCS is implemented intensively, aiming to spend as much as \$3.5 billion for this purpose[28]. In addition, the government has set a target to remove 1 Gt of CO_2 per year at less than \$100/tCO_2 by introducing NETs in the future[29].

Policies have also been adopted in the United Kingdom for the introduction of NETs. Financial support worth £100 million is planned for the development of technologies such as innovative

[27] International Energy Agency, "Inflation Reduction Act 2022: Sec. 13104 Extension and Modification of Credit for Carbon Oxide Sequestration", 17 November 2022, https://www.iea.org/policies/16255-inflation-reduction-act-2022-sec-13104-extension-and-modification-of-credit-for-carbon-oxide-sequestration, (accessed 7 August 2023).

[28] The United States Department of Energy, "Funding Notice: Bipartisan Infrastructure Law: Regional Direct Air Capture Hubs", https://www.energy.gov/fecm/funding-notice-bipartisan-infrastructure-law-regional-direct-air-capture-hubs#:~:text=On%20December%2013%2C%202022%2C%20the%20U.S.%20Department%20of,geologic%20formation%20or%20through%20its%20conversion%20into%20products, 15 March 2023, (accessed 7 August 2023).

[29] The United States Department of Energy, "Carbon Negative Earthshot", 5 November 2021, https://www.energy.gov/fecm/carbon-negative-shot, (accessed 7 August 2023).

NETs[30]. The country has also set specific targets for the amount of NETs to be introduced, namely removing 5 Mt in 2030 and 75 Mt–81 Mt in 2050 through technology-based methods[31]. The inclusion of credits resulting from the removal of carbon into the existing UK Emissions Trading Scheme (UK-ETS) is also expected to be considered.

Similarly, the European Union (EU) has begun discussions on the future handling of NETs. Overall, the European Union has focused on renewable energy in its decarbonisation strategy, and in some ways has not been as active as the United Stats and United Kingdom in using NETs, which are predicated on the continued use of fossil fuels. Discussions are currently under way on how NETs should be treated in the future decarbonisation process. As a numerical target, it has set 310 Mt by 2030 for carbon removal through land use and land use changes[32]. In addition, like the United Kingdom, the European Union has begun to consider how to reflect the credits resulting from carbon removal into its existing emissions trading system, the EU Emissions Trading Scheme (EU-ETS).

In Japan, a task force has been launched to discuss the measures for creating a negative emissions market. Unlike in Europe and the United States, no specific numerical targets have been set, but studies have already begun on methods such as price difference compensation, government purchase, and purchase of surplus credits as options for government support for the development of DAC and other technologies and policy responses for creating a negative emissions market in the future (Table 7-2).

[30] HM Government, *Net Zero Strategy: Build Back Greener*, October 2021, p.185, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf, (accessed 7 August 2023).

[31] HM Government, *Net Zero Strategy: Build Back Greener*, October 2021, pp.188-189, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf, (accessed 7 August 2023).

[32] Council of the European Union, "'Fit for 55': provisional agreement sets ambitious carbon removal targets in the land use, land use change and forestry sector", 11 November 2022, https://www.consilium.europa.eu/en/press/press-releases/2022/11/11/fit-for-55-provisional-agreement-sets-ambitious-carbon-removal-targets-in-the-land-use-land-use-change-and-forestry-sector/, (accessed 7 August 2023).

Table 7-2 | Policy options being considered to promote the introduction of NETs in Japan

Method	Summary
(1) Price difference compensation	When the reference price (linked to the market price) falls below the exercise price (the price set based on the cost), the government will compensate for the difference.
(2) Government purchase	The government buys the negative emissions generated by businesses at a fixed price.
(3) Purchase of surplus credits	The government buys the credits that negative emission businesses could not sell.
(4) Tax deductions	Tax credits are offered for negative emissions.
(5) Support for capital investment and demonstrations	Support for feasibility studies, basic design surveys, project development, procurement, construction, etc.
(6) R&D support	Support for the development of various NETs technologies to reduce their costs
(7) Assignment of quota	Sets a quota for high-emission sectors to purchase NETs projects (or credits) for a percentage of their emissions.

Source: Created based on the "Study Group for Creating Markets of Negative Emissions Technologies: Outline of Draft Proposal" by the Energy Conservation and Environmental Innovation Strategy Office (2023)

Initiatives by domestic and overseas companies

In addition, early starter companies spanning a wide range of industries, from information and communication technology (ICT) to logistics, aviation, finance and consumer goods manufacturing have begun to consider introducing NETs. While Western companies are more active about introducing NETs, Japanese companies are also starting to consider building a platform to handle carbon removal credits (Table 7-3).

Table 7-3 | Introduction of NETs by domestic and foreign companies

Industry	Company name	Initiatives
ICT (logistics)	Amazon	Amazon is investing in nature-based CDR technologies, including afforestation and reforestation.
ICT	Microsoft	Microsoft plans to purchase carbon removal (through forests, biochar, blue carbon, etc.), aiming to become carbon negative by 2030. In FY2022, Microsoft signed contracts to remove more than 1.5 Mt of carbon. For DAC, it purchased 10 kt of carbon removal over 10 years from Climeworks. It also purchased 2.76 Mt of carbon removal by BECCS from Orsted over 11 years.
Finance	JP Morgan Chase	On 23 May 2023, the company announced that it will purchase 800 kt of carbon removal, including DACCS, to balance its residual emissions in 2030.
Manufacturing	Airbus	Airbus agreed to purchase 400 kt of carbon removal over four years from 1PointFive. It also agreed to negotiate with seven major airlines, including Air Canada, on the supply of carbon removal for the four-year period from 2025 to 2028.
Petroleum	Occidental	Occidental invested in 1PointFive, a DAC business operator.
Aviation	United	United invested in 1PointFive, a DAC business operator.
Consumer goods	Unilever	Aiming for net zero emissions by 2039, Unilever is working on conserving 15 000 km^2 of forests, land and oceans.
Trading company	Mitsubishi Corporation	Mitsubishi established a NextGen CDR Facility as a platform for trading carbon removals by technology-based methods.
Shipping	Mitsui O.S.K. Lines	The company participates in the NextGen CDR Facility as a buyer. NextGen already buys carbon removals through biomass, DACCS and biochar.
Aviation	All Nippon Airways	The company has purchased more than 30 kt of removal credits over three years from 1PointFive, a DAC business operator.

Source: Created based on materials published by each company

7.3 Challenges facing the introduction of negative emissions technologies

Clarification of the position of NETs in achieving carbon neutrality

The first point to consider is clarifying the position of NETs in the respective plans for achieving carbon neutrality. In aiming for carbon neutrality, it may be possible to achieve net zero for electricity demand by using energy sources such as renewables, nuclear and hydrogen, but it is very likely that fossil fuels will remain in use for heat demand for industrial use. As such, NETs, which offset these residual emissions, are certain to become indispensable for many countries that seek to become carbon neutral. In this sense, countries need to indicate with some degree of certainty how much NETs they will need when formulating their decarbonisation plans for the future. This quantitative target should also be used as a base for allocating various resources (funds, technologies, and human resources) necessary to achieve them.

In deciding the position of NETs, it is necessary to organise, among the various types of NETs, which ones should be used and how. In doing so, it is necessary to verify the following items: (1) the level of cost required for CO_2 removal, (2) whether it can be completed in Japan, (3) the potential scale of the final removal amount, and (4) the year in which full-scale practical application can be realized. Some NETs have just entered the full-scale research and development (R&D) stage and the progress of their development is highly uncertain. As such, the position of individual NETs should be reviewed constantly, considering the progress of their development.

Cost reduction and technological development

When introducing NETs in earnest, we cannot avoid discussing their costs. Some NETs involve capturing CO_2 from the atmosphere which has a low carbon concentration, and their introduction cost generally tends to be high. Some NETs, such as soil carbon sequestration, have side benefits (co-benefits) which offset the cost of their introduction, but their cost per tCO_2 is higher than that of conventional emission reduction measures such as renewables, hydrogen, ammonia and carbon capture, utilisation and storage (CCUS). For this reason, rather than introducing NETs in full scale at once, we must start by adopting technologies such as renewables and hydrogen, which are relatively inexpensive to introduce, while improving the technology and reducing the cost of NETs to introduce them in the longer run.

While steady technological development is the only way to reduce the cost of introduction, NETs is a relatively new area and there is still room for significant cost reductions and technological innovation. Start-ups such as Climeworks are actively engaging in technological development in this area. It is also important to create an environment for providing sufficient funds and talent to companies such as Climeworks that are developing innovative technologies not bound by conventional ideas. In addition, regulatory incentives for such companies when they demonstrate and commercialise their technologies can also serve as useful support measures.

Establishment of a credit system

To promote the social implementation of NETs, the establishment of a credit system is also essential. One of the significances of introducing NETs is their ability to offset the residual CO_2 emissions for achieving carbon neutrality. In the process of offsetting those emissions, it is essential to somehow quantify the amount of CO_2 that NETs have removed from the atmosphere so that the amount can be transferred and traded between companies. In fact, in the United Kingdom and the European Union, discussions on including carbon removal credits into the existing emissions trading schemes are already under way. In Japan, meanwhile, the removal of CO_2 by using biochar on farmland is already recognised by the J-credit system[33]. The carbon removal credits arising from NETs are qualitatively different from those generated by the use of renewable energy, energy conservation, and the use of CCS for fossil fuels, because in the former case CO_2 is directly removed from the atmosphere (Table 7-4). Both credits represent the amount of CO_2 reduced against the baseline emission scenario (or emission allowance), but whereas reduction credits are based on reductions of CO_2 that will be emitted in the future, removal credits are based on removals of CO_2 that is already present in the atmosphere. It is generally believed that emission reduction credits can be utilised effectively in the transition toward carbon neutrality, while carbon removal credits play a major role in the stage of actually becoming carbon

[33] Ministry of Agriculture, Forestry and Fisheries, Environmental Policy Office, "Methodology for Applying Biochar on Farmland" (November 2020). The J-Credit Scheme is a system that certifies amounts of greenhouse gas emissions reduced or absorbed through the introduction of energy-saving and renewable energy facilities and forest management, and is operated by the Japanese government.

neutral[34]. In voluntary credit markets, where removal credits are sometimes traded alongside reduction credits, removal credits are traded at higher prices than reduction credits because carbon removal can reduce the amount of CO_2 that is already in the atmosphere unlike emission reduction, and is thus considered to make a greater contribution as a climate change countermeasure[35]. Going forward, it is necessary to consider how to institutionalise these two different types of credits and how to encourage businesses to use them.

Table 7-4 | Reduction and removal credits

Industry	Reduction credits	Removal credits
CO_2 counted as credits	The amount of CO_2 emissions reduced compared to a specific base case scenario or emission allowance	CO_2 emissions removed from the atmosphere compared to a specific base case scenario
Target CO_2	CO_2 emissions expected hereafter	CO_2 already present in the atmosphere
Main means of credit generation	Energy conservation, renewables, nuclear, etc.	NETs
Time span in which credits will be utilised	Relatively short- to medium-term	Relatively medium- to long-term

Establishment of a measurement, reporting and verification system

In order for NETs to be used as an effective means of decarbonisation, it is also necessary to urgently establish a so-called measurement, reporting and verification (MRV) method to objectively and accurately measure, report and verify the amount of CO_2 removed by each NET. Among NETs, there are some, especially nature-based ones, that are certain to lead to the absorption and fixation of atmospheric CO_2 but it is difficult to accurately identify how much CO_2 they capture and fix. For such technologies, a method to objectively and accurately grasp the amount of removal must be established so that the amount of recovery and fixation is not overestimated, and the technology is not misused. In addition, it is important to monitor the CO_2 fixed by NETs so that it is not soon released back into the atmosphere; a method for this must also be established.

To proceed with the actual development of a MRV process, it is necessary to: (1) develop elemental technologies, including those related to the future MRV process and environmental impacts, (2) verify CO_2 removal effects, (3) develop the actual MRV process, and (4) establish the international credibility of the MRV process so that the NET can be counted in the “nationally determined contributions” (NDCs). However, for many NETs the MRV process is still in stage (1), and depending on the type of NET, the difficulty and time required for the steps after (2) will vary and therefore must be treated separately for each type of NET[36]. MRV processes are being

[34] For example, the representative guidelines for companies to achieve net zero do not allow companies to use reduction credits once they have achieved net zero, and require that they neutralise residual emissions by using removal credits. Science Based Targets initiative (SBTi), *Foundations for Science-based Net-Zero Target Setting in the Corporate Sector*. September 2020.

[35] World Bank, *State and Trends of Carbon Pricing 2023*, p.41

[36] Ministry of Economy, Trade and Industry, Energy and Environmental Innovation Strategy Office, “Formulation of Rules for the Creation of CDR Markets”, (May 2023).

developed around the world: as of May 2023, 69 MRV methods have been developed, although they vary greatly in the target categories and systems[37]. As an MRV process must be refined to internationally acceptable levels to be used for NDCs, it is also important to develop an international cooperation framework as described below.

The need for international cooperation

To promote the widespread adoption of NETs, international cooperation is also essential. While views toward nature-based NETs such as afforestation and soil modification are positive, there are negative views toward technology-based NETs such as BECCS and DACCS, which are more artificial in nature. However, as described above, it is technology-based NETs whose CO_2 removal can be grasped more accurately, which NETs have a large potential CO_2 removal, and which NETs can immobilise the CO_2 for relatively longer periods. It is desirable for not only nature-based but also technology-based NETs to be internationally recognised as important decarbonisation measures going forward.

In addition, carbon removal can be conducted through NETs in overseas regions with lower CCS costs, with Japan using the amount removed to offset its domestic residual emissions. For such cross-border use of NETs, it is necessary to reach an agreement with the partner country on the amount of removal and the handling of credits, as well as to set an international standard for the MRV of the removal effect and to obtain international certification for the amount removed. In the future, Japan should pursue a mechanism that allows carbon removal effects obtained overseas to be counted in its own reduction targets (NDCs). When using such NETs involving multiple countries, it is necessary to conduct bilateral discussions between governments with common interests, and to form a multilateral consensus at international organisations such as the International Energy Agency.

Early social implementation of CCS technology

To promote the widespread adoption of NETs, it is essential to implement CCS in society early on. CCS is a key technology for achieving carbon neutrality by capturing CO_2 emissions from fossil fuels and storing them underground. As many as 30 projects are in commercial operation worldwide, and its adoption is expected to accelerate. In addition to playing an important role as a normal decarbonisation technology, CCS is also indispensable for NETs such as DACCS and BECCS and is thus critically important. CCS will be used to reduce fossil fuel-related CO_2 emissions for the time being, but will remain in use for a considerable time as an important element of NETs long after the world has largely stopped consuming fossil fuel. For this reason, CCS should be regarded correctly as a key elemental technology for NETs to achieve carbon neutrality in the more distant future, rather than as a means to extend the life of fossil fuel use; further efforts to encourage its social implementation must be made.

[37] Leo Mercer and Josh Burke, *Strengthening MRV Standards for Greenhouse Gas Removals to Improve Climate Change Governance*, May 2023, https://www.lse.ac.uk/granthaminstitute/publication/strengthening-mrv-standards-for-greenhouse-gas-removals/, (accessed 30 September 2023).

8. Paths towards ASEAN's energy transition

8.1 Background

ASEAN's energy demand continues to grow

In aiming to reduce carbon dioxide (CO_2) emissions on a global scale, the importance of the Emerging Market and Developing Economies, relative to the Advanced Economies, cannot be ignored. According to the Reference Scenario, about 80% or 25.1 Gt of the 31.8 Gt of global CO_2 emissions in 2050 will come from Emerging Market and Developing Economies (see Section 2.3 Carbon dioxide emissions).

Among Emerging Market and Developing Economies, the Association of Southeast Asian Nations (ASEAN) has recently achieved remarkable economic development. Its population increased by 10%, while its real gross domestic product (GDP) increased by 50% in the 10 years from 2011 to 2021[38]. In sync with this growth, its primary energy consumption has increased by 30% in the last decade and will double by 2050 according to the Reference Scenario. A stable supply of energy at low cost is key to the region's economic development. Meanwhile, as climate change countermeasures grow in importance globally, the region is facing the challenge of curbing CO_2 emissions while increasing its energy supply.

This chapter examines what kind of energy mix the region should aim for as it undergoes an energy transition, and how a stable supply, cost reduction, and emission reduction should be achieved during the transition period.

The ASEAN countries' efforts toward zero emissions

Even in the ASEAN, where energy demand continues to grow, more and more countries have been setting long-term decarbonisation goals since the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in 2021. Eight of the 10 ASEAN member states have already declared their net zero emissions goals (Table 8-1).

[38] World Bank "World Development Indicators"

Table 8-1 | ASEAN countries' declaration of carbon neutrality and net zero emissions

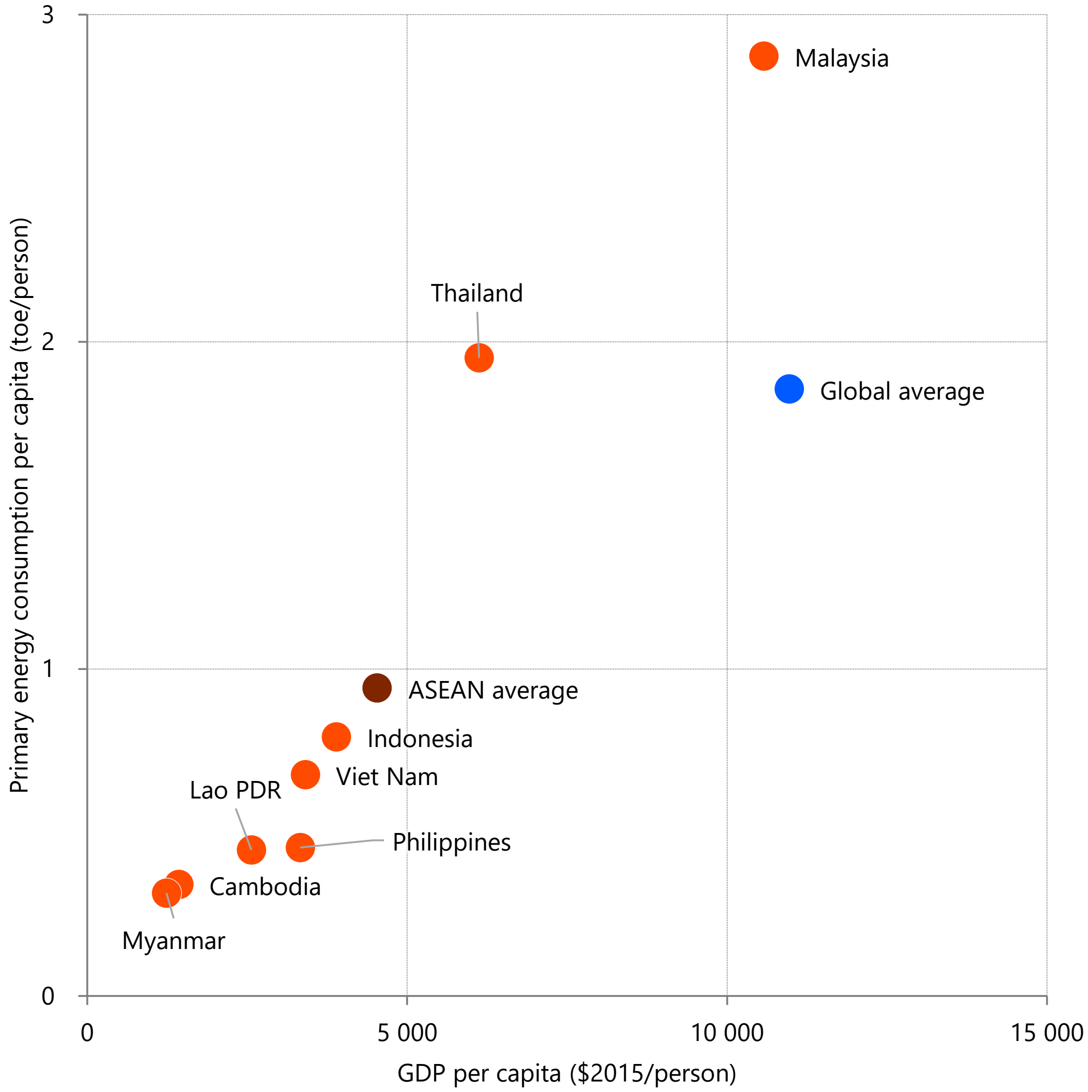
Country	Declaration details
Brunei Darussalam	No declaration
Cambodia	Carbon neutrality by 2050 (Long-term strategy, December 2021)
Indonesia	Net zero by 2060 or earlier (Long-term strategy, July 2021)
Lao PDR	Carbon neutrality by 2050 (Climate Ambition Alliance)
Malaysia	Carbon neutrality by 2050 (Prime Minister's announcement, September 2021)
Myanmar	Carbon neutrality by 2050 (Climate Ambition Alliance)
Philippines	No declaration
Singapore	Net zero by 2050 (Long-term strategy, November 2022)
Thailand	Carbon neutrality by 2050, net zero by 2065 (Prime Minister's announcement, November 2021)
Viet Nam	Carbon neutrality by 2050 (Prime Minister's announcement, November 2021)

Source: Created based on national statements, etc.

On the other hand, countries such as the Philippines have not yet committed to a specific target year for net zero in their latest energy plan[39]. There are significant differences among the ASEAN member states in terms of economic development and energy supply and demand structure, and it is not possible to chart a uniform path toward net zero emissions for the region. Currently, GDP per capita and energy consumption vary greatly among the countries. For example, Thailand, Malaysia, and Singapore, whose economies have developed substantially, have a high primary energy consumption per capita and a reasonable level of energy access (Figure 8-1). In these countries, the groundwork is relatively well prepared to start working on the next challenge of reducing CO_2 emissions.

[39] https://powerphilippines.com/doe-no-net-zero-target-yet-under-new-energy-plan/

Figure 8-1 | ASEAN's GDP per capita and primary energy consumption per capita [2021]



Note: The GDPs of Singapore and Brunei are external to the figure (Singapore: $66 000/person, 5.2 toe/person, Brunei: $30 000/person, 7.4 toe/person).
Source: Compiled based on the International Energy Agency "World Energy Balances" and the World Bank "World Development Indicators"

In contrast, countries such as Myanmar, the Philippines and Cambodia have ample room for economic development and their energy demand is expected to grow significantly going forward in line with industrialisation and the spread of electrical appliances and automobiles. While it is also important for these countries to reduce emissions, securing access to affordable energy is even more urgent, and a realistic policy would be to minimise emissions while securing affordable energy.

With ASEAN countries' commitment to reducing emissions, other countries including Japan are stepping up efforts to provide technical and economic assistance. In May 2021, the Ministry of Economy, Trade and Industry (METI) announced the Asia Energy Transition Initiative (AETI), which includes a range of support measures for realising a diverse and realistic energy transition in Asia. First, AETI will support each country in drawing up its energy transition roadmap. It will then provide $10 billion in financial support for renewable energy, energy conservation, liquefied natural gas (LNG), carbon capture, utilisation and storage (CCUS) and other projects in line with the roadmap. The formulation of a roadmap for the 10 ASEAN countries is being assisted through studies by the Economic Research Institute for ASEAN and East Asia (ERIA)/Institute of Energy Economics, Japan (IEEJ), and its output is serving as the base for this analysis[40]. In 2022, a group of wealthy economies consisting of the Group of Seven (G7) and the European Union (EU) issued a joint statement on the Just Energy Transition Partnership (JETP) with Viet Nam and Indonesia among the ASEAN countries. The Partnership, which will provide transition funds, aims to support the early retirement of coal-fired power plants and investment in decarbonising infrastructure such as renewable energy in each partner country.

Box 8-1 | What is a path to zero emissions that is compatible with robust economic growth? A comparison of the ASEAN decarbonisation scenarios of the IEA and ERIA/IEEJ

As confirmed at the G7 in 2023, countries around the world have their own economic and energy circumstances, and while they share the goal of carbon neutrality (CN), their pathways for achieving it are diverse. The path to be pursued will vary greatly depending on the kind of future economic growth and energy demand a country anticipates.

This is clearly illustrated in the "Decarbonisation Pathways for Southeast Asia", a report published by the International Energy Agency (IEA) with the full cooperation of the IEEJ as a contribution to the G7 Sapporo Ministerial Meeting on Climate, Energy and the Environment held in April 2023.

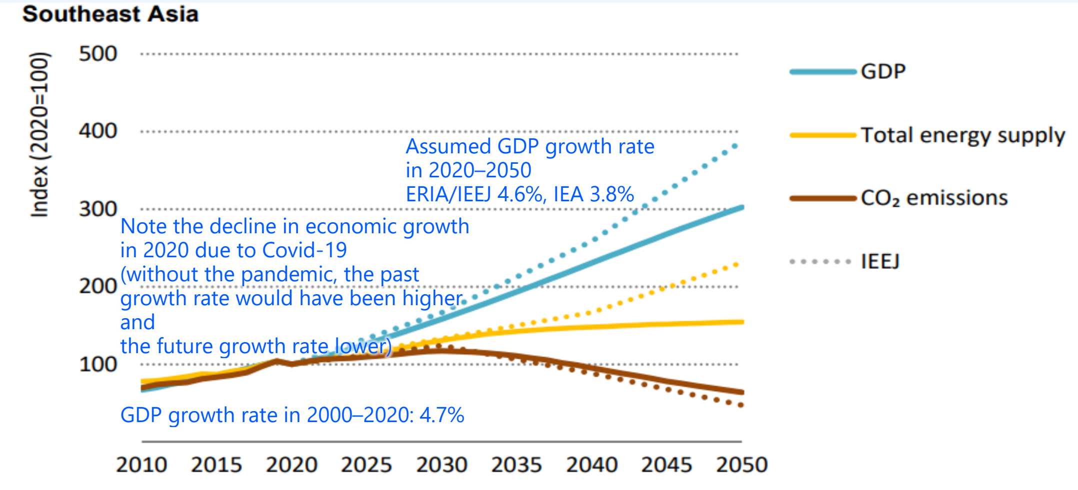
Comparison of the ASEAN decarbonisation scenarios of the IEA and ERIA/IEEJ

The IEA report outlines the pathways to decarbonisation in ASEAN and Indonesia in its World Energy Outlook 2022 and the "Decarbonisation of ASEAN Energy Systems: Optimum Technologies" developed by the IEEJ in collaboration with the ERIA. This is a comparative analysis of the scenarios (CN2050/2060) of the Technology Selection Model Analysis to 2060. It should be noted that these analyses take a backcasting approach which assumes that carbon neutrality will be achieved in the future and analyse the optimal path to get there, while the analysis in this Outlook takes a forecasting approach that projects into the future based on past trends.

In this comparative analysis, the first point worth mentioning is the difference in assumptions about future economic growth, which will have a critical impact on final energy consumption. The projections for future population growth are almost identical for both analyses, however, the IEA projects the ASEAN's real GDP from 2020 to 2050 to grow 3.0 times (annual growth of 3.8%) and Indonesia 3.3 times (4.1%), while the ERIA/IEEJ projects the region to grow 3.9 times (4.6% per year) and Indonesia 4.4 times (5.0%/y) (Figure 1-1). These differences are because the IEA took into account the tendency of the growth rate to decline as income levels rise, based on past macroeconomic analyses, while the ERIA/IEEJ took into account the future economic growth outlook of the ASEAN countries made by the countries themselves. In fact, the Indonesian government's long-term strategy submitted to the United Nations Framework Convention on Climate Change (UNFCCC) projects an economic growth comparable to that envisioned by the ERIA/IEEJ.

[40] In January 2022, the establishment of the Asia Zero Emission Community (AZEC) was announced as Japan's initiative to achieve carbon neutrality in Asia. Under AZEC, ERIA/IEEJ's support for the development of the roadmap is one of the main pillars of Japan's cooperation.

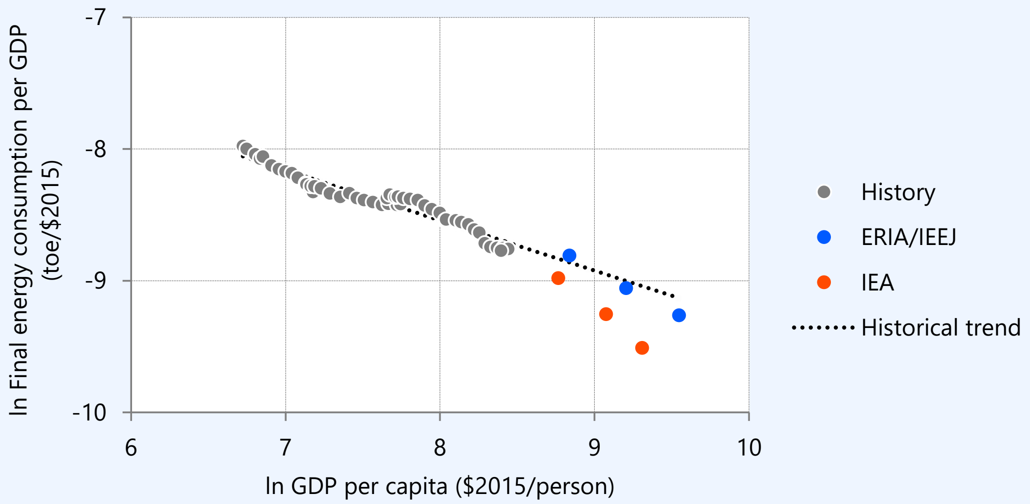
Figure 8-2 | ASEAN's historical and assumed economic growth



Source: IEA "Decarbonisation Pathways for Southeast Asia"; text added

In addition, the IEA foresees greater progress of energy conservation (reduction in final energy consumption per GDP) than the ERIA/IEEJ does. If we look at the relationship between GDP per capita and final energy consumption per unit of GDP over the past 50 years or so, the IEA projects that the rate of energy conservation relative to economic growth will accelerate to twice the past trends, while the ERIA/IEEJ projects that it will follow the historical trend (Figure 8-3).

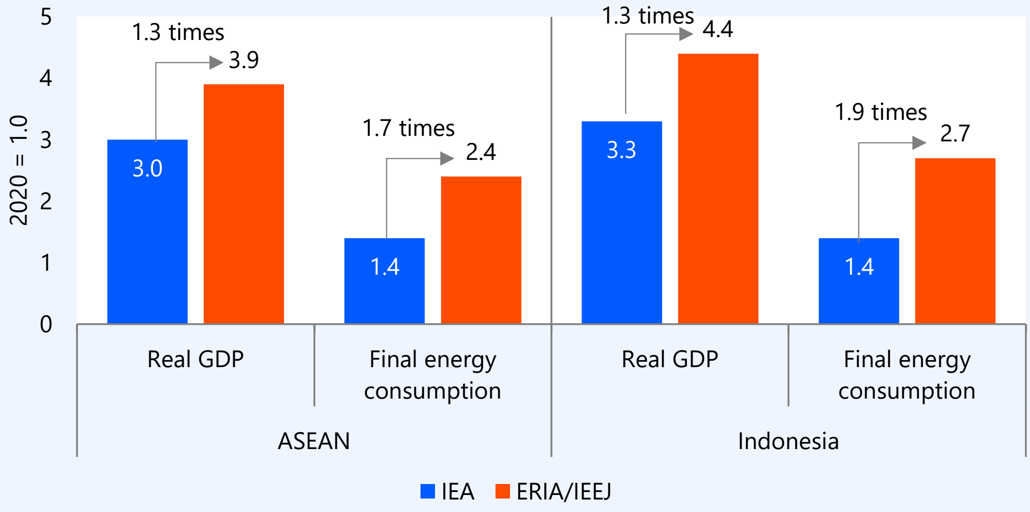
Figure 8-3 | ASEAN's GDP per capita and final energy consumption per unit GDP



Note: History: 1971-2020, projection: 2030-2050
Source: Computed based on the IEA's "Decarbonisation Pathways for Southeast Asia" and "World Energy Balances"

As a result, the final energy consumption in 2050 differs between the IEA and ERIA/IEEJ by 1.7 times for ASEAN and 1.9 times for Indonesia (Figure 8-4). Incidentally, the final energy consumption in 2050 projected by the Indonesian government in its long-term strategy is slightly higher still than that of the ERIA/IEEJ. The amount of absolute energy demand, factoring in the progress of energy conservation, will have a decisive impact on decarbonisation.

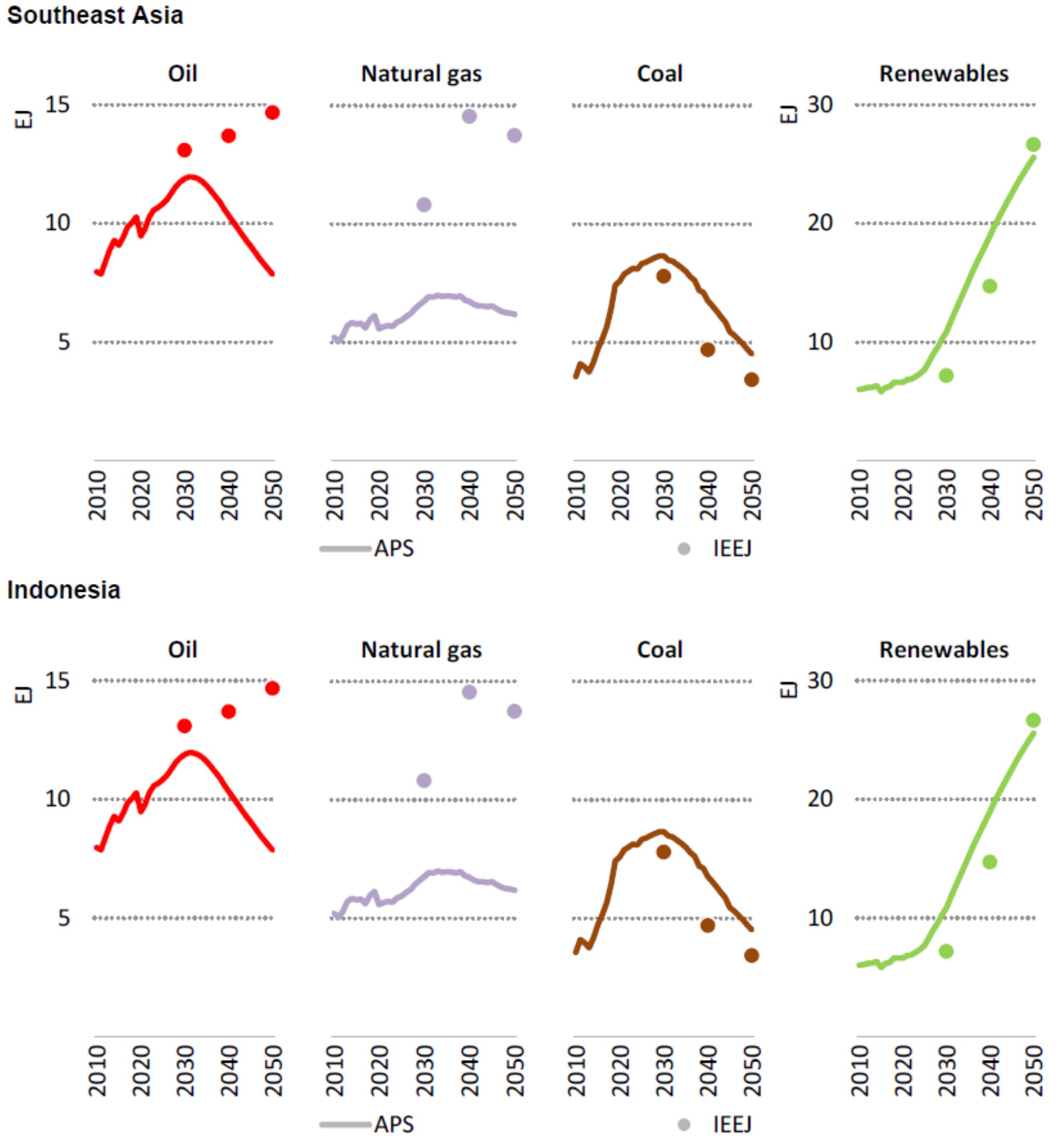
Figure 8-4 | Real GDP and final energy consumption of the ASEAN and Indonesia [2050]



Next, we take a look at how the nearly two times difference in the projected final energy consumption between the IEA and ERIA/IEEJ analyses translates into differences in carbon neutrality pathways by looking at each type of energy.

First, in terms of primary energy supply, oil is expected to increase until 2030 in both analyses, but the IEA expects the supply to peak thereafter, while the ERIA/IEEJ expects growth to continue in transportation (commercial vehicles) and industry. For natural gas, the difference is the largest between both scenarios, with the IEA projecting a slight increase while the ERIA/IEEJ projects a significant increase in demand in 2030 and 2040 for the industry and power generation, followed by a slight decrease until 2050 (Figure 8-5).

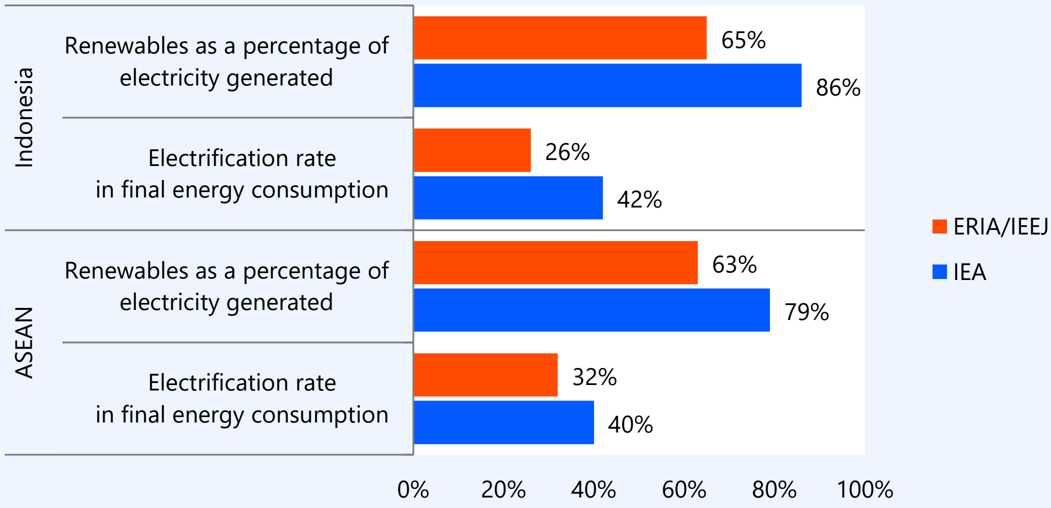
Figure 8-5 | Primary energy supply of the ASEAN and Indonesia



Source: IEA "Decarbonisation Pathways for Southeast Asia"

Next, in terms of electricity, the ERIA/IEEJ projects a greater electricity generated in 2050 than the IEA, but since the ERIA/IEEJ foresees an even larger final energy consumption, the ERIA/IEEJ's electrification rate (ratio of electricity to final energy consumption) is lower than the IEA's. Similarly, the ERIA/IEEJ projects a larger renewable electricity generation than the IEA for the ASEAN, but because the ERIA/IEEJ's overall electricity generated is even larger, its renewables ratio (the ratio of renewables to total electricity generated) is smaller than the IEA's (Figure 8-6). In addition, the ERIA/IEEJ scenario assumes that natural gas- and coal-fired power plants will continue to be used to meet the strong demand for electricity, leading to the introduction of carbon capture and storage (CCS) and hydrogen-ammonia co-firing and mono-firing to decarbonise them, but the IEA scenario expects these will be introduced only in small amounts.

Figure 8-6 | Electrification rate and renewables ratio of the ASEAN and Indonesia [2050]



In terms of energy-related CO_2 emissions, the IEA projects almost no introduction of technology-based carbon dioxide removal (bioenergy carbon capture and storage [BECCS], direct air capture and storage [DACCS]) even in the long term, whereas the ERIA/IEEJ expects a major introduction of technology-based carbon removal as the optimal solution for minimising cost (about 0.7 Gt for the whole of the ASEAN in 2050).

In summary, the biggest difference between the IEA and ERIA/IEEJ analyses lies in the assumptions made for future economic growth and the outlook for progress in energy conservation. Compared to the ERIA/IEEJ, the IEA expects smaller economic growth and greater energy conservation, and its pathway is centred on electrification plus switching to renewable power sources. On the other hand, in order to respond to strong economic growth and energy demand, the ERIA/IEEJ projects that the ASEAN will need to increase the use of fossil fuels (especially natural gas) for the time being, while introducing more renewable energy than in the IEA scenario. At the same time and to achieve net zero, the ERIA/IEEJ analysis depends on more decarbonise fossil fuels by utilising carbon removal measures such as DACCS, BECCS, and forest sinks and introducing hydrogen, ammonia and CCS.

The need for a path that allows for future uncertainty

When discussing the roadmap to net zero, the focus tends to be on the ratio of renewables. However, the issue of fundamental importance is how to estimate the amount of energy required for the economy and society, which has a decisive impact on the energy mix to aim for. There are uncertainties about the future economic growth of Emerging Market and Developing Economies, but as it will take many years to develop their energy infrastructure, it is necessary to consider a pathway that accommodates these uncertainties.

8.2 Exploring the optimal energy mix

Analytical framework

This analysis attempts to identify an energy mix that can achieve the carbon neutrality target of ASEAN countries at the lowest possible cost, and to use it as a guideline for a realistic energy transition. It reflects the assumption that energy demand will increase as in the ERIA/IEEJ scenario described in Box 8-1.

Specifically, we employed the model used in the ERIA/IEEJ analysis[41] to derive the combination of energy sources with the lowest total cost under various technical and economic constraints (combination of primary energy consumption, final energy consumption, electricity sources, etc.). For this calculation, we performed simulations using a bottom-up technology selection model. Typical constraints that were considered included CO_2 emission targets and an upper limit on renewable energy capacity, while creating a realistically reasonable mix.

Renewable energy and natural gas play an important role in reducing emissions in the ASEAN. To assess the impact of not being able to achieve an optimal energy mix, we set cases whose conditions for natural gas and renewables deviate from the optimal case, while not changing the assumptions regarding demand for energy services. The "gas supply constraints" case, in which natural gas supply does not increase from the current (2019) level, the "RE40" case in which the share of renewables in the power generation mix is fixed at 40%, the "RE80" case in which the share of renewables is fixed at 80%, and the "combo" case which combines the natural gas constraints with the 80% share limit (Table 8-2). By analysing how costs increase in these non-optimal cases and how the overall energy mix changes, we aim to gain deeper insight into the role of each technology and realistic energy transitions. In addition, for comparison, we established a "baseline" case, in which CO_2 emissions are not limited in any way.

Table 8-2 | Various cases related to the ASEAN's carbon neutrality goal

Case name	Net zero year	Share of renewable energy (in the power generation mix, 2040 onwards)	Domestic supply of natural gas
Optimal	2050/2060 * Established according to the policy goals of each country.	No constraints (about 60%)	No constraints
Gas Supply Constraints		No constraints	Remains flat from 2019*
RE40		40%	No constraints
RE80		80%	No constraints
Combo		80%	Remains flat from 2019
(Reference) Baseline	No emission target	No constraints	No constraints

Note: * Approximately 140 Mtoe for the ASEAN as a whole. This is the maximum value up to 2021, and we assume that the natural gas supply capacity for both imports and domestic production will not increase.

With regard to each country's emission target, the timing of achieving net zero emissions was set as shown in Table 8-3 by referring to policy targets. It should be noted that some countries have not actually made net-zero commitments, and for those countries, tentative emissions paths were set. In addition, "net zero" greenhouse gases (GHGs) means net zero considering not only energy-related CO_2, which is the subject of this analysis, but also the existence of sinks such as carbon

[41] Economic Research Institute for ASEAN and East Asia "Decarbonisation of ASEAN Energy Systems: Optimum Technology Selection Model Analysis up to 2060" (2022) https://www.eria.org/research/decarbonisation-of-asean-energy-systems-optimum-technology-selection-model-analysis-up-to-2060

sinks. The potential of sinks is determined based on the opinions of each country. It is not necessary to aim for net-zero emissions for energy-related CO_2 on its own, and especially for countries with abundant forest sinks, using sinks to offset the hard-to-reduce emissions could be a realistic solution.

Table 8-3 | Setting the target net-zero year for energy-related CO_2 emissions

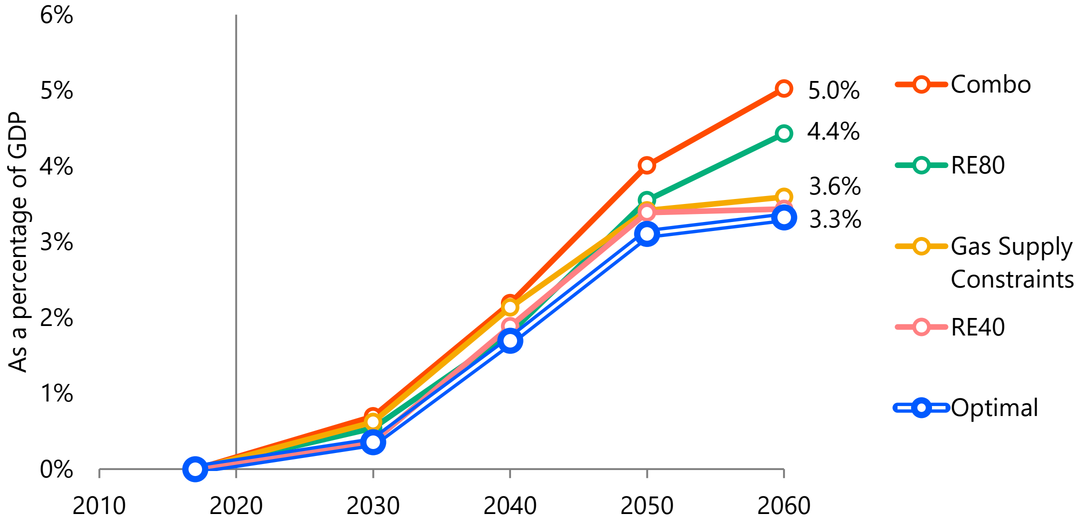
Country	Year net zero achieved	Energy-related CO_2 (Compared to 2017)
Brunei	2050	-100%
Cambodia	2050	-100%
Indonesia	2060	-50%
Lao PDR	2050	-100%
Malaysia	2050	-50%
Myanmar	2060	-60%
Philippines	2060	-100%
Singapore	2050	-100%
Thailand	2050	-50%
Viet Nam	2050	-70%

Cost comparison

In 2060, the cost of reducing CO_2 emissions required for the entire ASEAN to achieve net zero is $570 billion (2015 real prices), equivalent to 3.3% of GDP for a cost-optimal energy mix (Figure 8-7). The characteristics of each case in comparison to the optimal case are as follows:

- If the optimal energy mix is not achieved, the cost would naturally be higher. An increase in cost to 4.4% and 3.6% of GDP will be required in the RE80 Case (with too much renewable energy introduced) and the Gas Supply Constraints Case, respectively, in 2060. When both constraints are combined, the cost of reducing emissions would be 5.0% of GDP, which is about 1.5 times that of the Optimal Case.
- While the Gas Supply Constraints Case has a moderate increase in the cost of reducing emissions in the 2050-2060 decade, the increase is rather steep in the transition period from 2030 to 2040. The results suggest the significant role played by natural gas in providing low-cost energy, especially during the transition period.
- In terms of cumulative costs, $10.7 trillion would be required in the Optimal Case over the target period. An additional $2.5 trillion will be required for the RE80 Case and $1.3 trillion for the Gas Supply Constraints Case. For comparison, only $26.9 billion (as of October 2023) has been invested in the Green Climate Fund, and even for the ASEAN alone, the reduction cost required for reaching carbon neutrality is much larger than the climate funds currently accumulated.

Figure 8-7 | CO_2 reduction cost of the ASEAN (% of GDP)



Notes: The cost of CO_2 reduction is the difference of the total cost of energy supply (capital costs, fuel costs, facility operation and maintenance costs, etc.) from the Baseline Case in which no emission reductions are performed. Future GDP is estimated using ERIA "Energy Outlook and Energy Saving Potential in East Asia 2020" (2021) as a reference, and all amounts are in real dollars in 2017 (base year) terms.

In the following sections, we will examine the background to these results, specifically, why the cost increases when the share of renewable energy is higher or lower than the Optimal Case, or when the primary supply of natural gas cannot be expanded during the transition period.

Discussion of renewable energy share: About 60% of power sources in the optimal solution

In the Optimal Case, renewables account for 60% of the power generation mix (of which 45% comes from variable renewable energies such as solar photovoltaics and wind), nuclear about 10%, and thermal power (mostly decarbonised by CCS and hydrogen) for the remaining 30% (Figure 8-8). In the RE40 Case, in which the amount of renewables falls short of the Optimal Case, greater amounts of natural gas-hydrogen co-firing and ammonia-fired are used than in the Optimal Case to cover the gap in electricity generated. These power sources have a higher generation cost per MWh (levelised cost of electricity [LCOE]) than that of renewables such as solar photovoltaics and wind (Figure 8-9, using Thailand as the example). Expanding the renewable energy can be effective for reducing both CO_2 emissions and power generation costs up to a certain level and is worth pursuing with high priority for the ASEAN.

Nevertheless, if we look at RE80 Case, in which renewables are introduced in greater amounts, the total cost is in fact higher. This is because in order to increase renewables to this level, it must also be introduced in areas with poor weather and topographical conditions, pushing up the cost of power generation.

Figure 8-8 | Electricity generated of the ASEAN

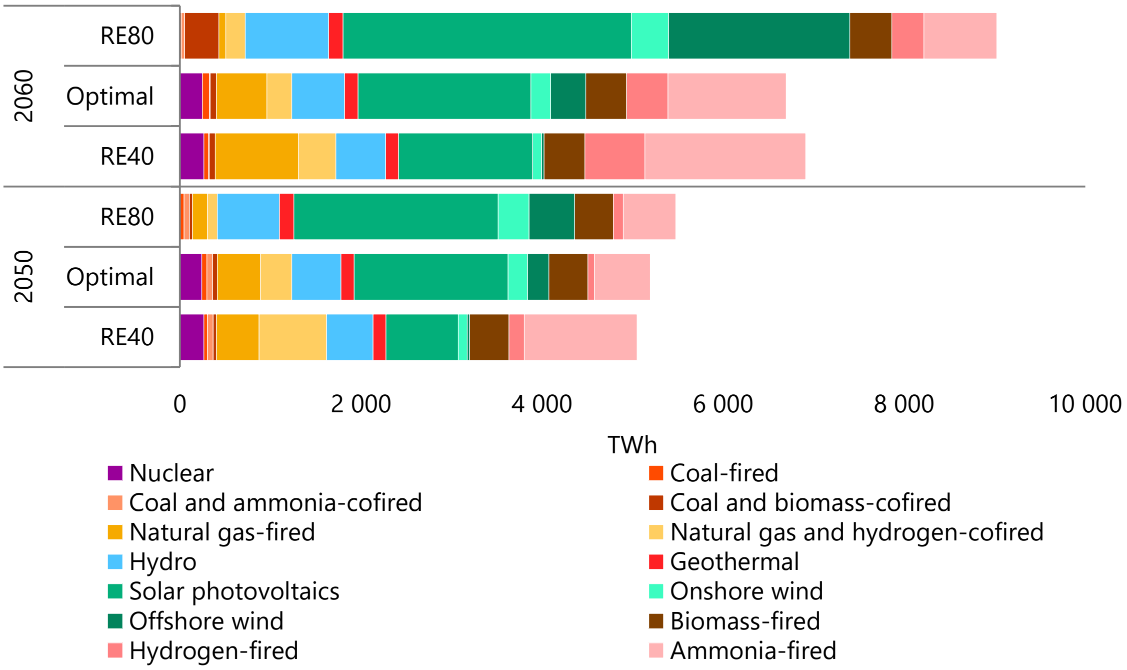
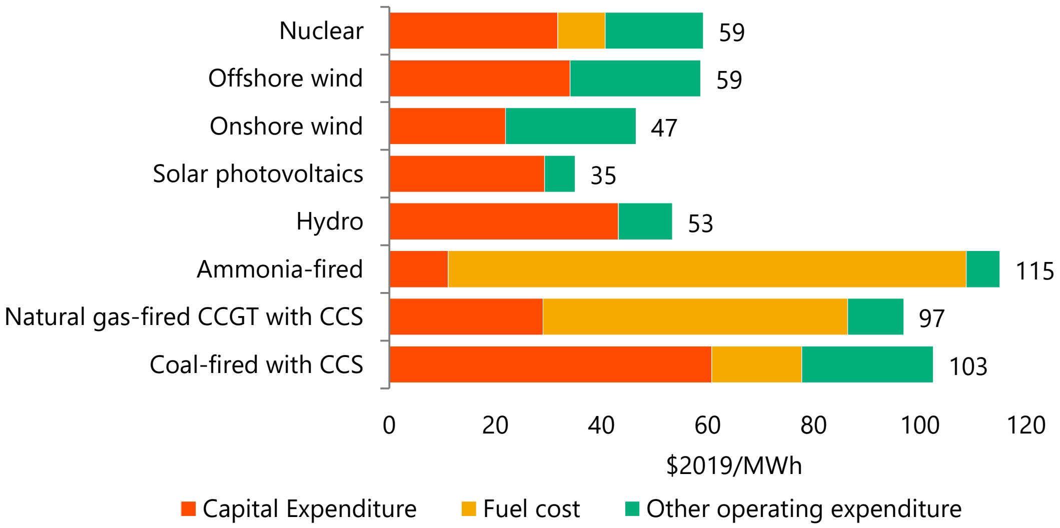


Figure 8-9 | Thailand's power generation cost per MWh [2050]



Notes: CCGT stands for combined cycle gas turbine. The figures show the sum of capital costs, fuel costs, and operation and maintenance costs of the power generation facilities themselves, and not other costs, such as grid maintenance and supply-demand balancing costs.
Source: Estimated based on Danish Energy Agency (2021)

In addition, as mentioned earlier, the per-MWh generation cost of solar photovoltaics and wind are lower than that of other zero-emission sources as of 2050, but solar photovoltaics and wind suffer from severe fluctuations in output and so will incur additional costs for balancing supply and demand. To implement the power generation mix of the RE80 Case, 737 GW of batteries and 110 GW of water electrolysers will be required across the ASEAN in 2050. The combined capacity of these facilities is 2.2 times that of the Optimal Case and accounts for 80% of the average electricity demand (in kW) of the entire ASEAN. These extremely large storage facilities for handling output fluctuations drive up the cost of the energy system. In addition, the absence of nuclear in the power generation mix also pushes up costs. As variable renewables increase, thermal power is given priority as a means to balance supply and demand, causing nuclear, which is less responsive to load fluctuations, to be driven out of the grid.

Generally speaking, generation costs from renewable energies, especially solar photovoltaics and wind, have been decreasing in recent years, and if this trend continues steadily, they can be viewed as promising power sources that will support the ASEAN's decarbonisation. However, if introduced in excess, renewables will be located in areas with poor cost performance, driving up the costs for supply-demand balancing and in turn the entire power system.

Based on the current demand, the appropriate share of renewables is estimated at about 60% of the region's power supply but, as mentioned earlier, the level of future demand is very uncertain. In any case, it is desirable to not depend excessively on renewables and to develop and invest in appropriate technologies for other power sources as well.

By 2060, the differences in total electricity generated and power generation mix will be even more extreme. In the RE80 Case, the amount of electricity generated will increase significantly by 2060. In many ASEAN countries, renewables will not be able to cover 80% of the electricity demand due to weather and land-use conditions even if solar photovoltaics and wind is introduced to the maximum. For this reason, to meet the "80% renewable energy in the ASEAN region" requirement, renewables power generation and water electrolysis would have to be carried out on an extremely large scale in regions with abundant renewables potential (especially offshore wind) like Viet Nam, resulting in a very unbalanced power generation mix.

As mentioned in the comparison of the IEA and ERIA/IEEJ outlook, there is considerable uncertainty in future energy demand, especially in the ASEAN whose economies are growing remarkably fast. If demand for electricity does not increase much, it may be feasible to cover most of the increase with renewables. However, if demand growth is strong, power supply shortages may occur, especially in regions with poor renewables potential. It is necessary to identify alternative power sources such as thermal power (decarbonised as necessary) and nuclear, and gradually incorporate them into the supply plan in step with the trend of economic growth and rising demand.

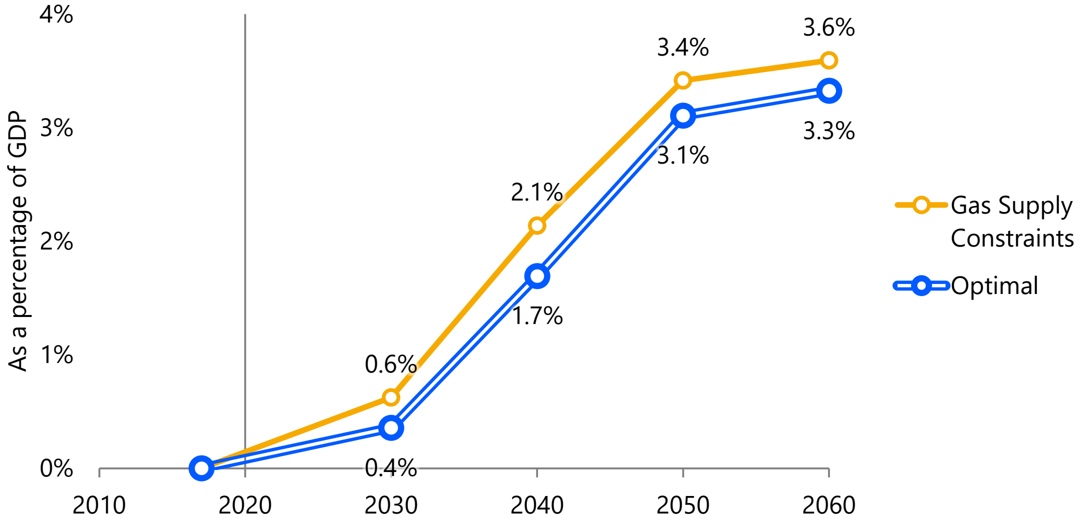
With regard to international transmission lines, this analysis assumes that the ASEAN Power Grid plan[42], for which a memorandum of understanding (MoU) was signed among the ASEAN member states in 2007, will be realised. This means that the international transmission capacity will be expanded significantly from the current 5.7 GW to reach 55 GW as of 2050. If this is not achieved, it will be difficult to transmit the geographically dispersed renewables between various areas of the region, resulting in less renewables in the optimal solution. It should also be noted that since each country is represented as a single point in the simulations in this report, the cost and installation feasibility of domestic power grids may not be sufficiently represented in the simulation.

[42] ASEAN "Memorandum of Understanding on the ASEAN Power Grid" (2007) https://agreement.asean.org/media/download/20140119102307.pdf

Natural gas: An important fuel for both power generation and final demand during the transition period

In the case where it is not possible to increase natural gas supply, the increase in CO_2 reduction costs will be particularly large in 2040 (Figure 8-10). This suggests that the use of natural gas will help reduce costs in the process of energy transition.

Figure 8-10 | CO_2 reduction costs of the ASEAN (% of GDP)



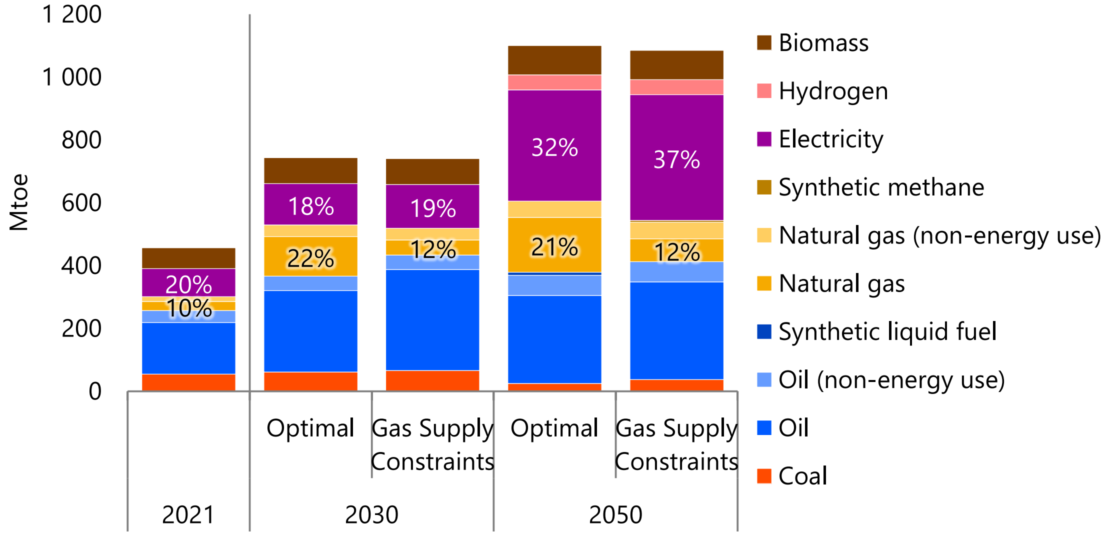
Note: Only the Optimal Case and the Gas Supply Constraint Case are reproduced from Figure 8-7.

Natural gas supports the energy supply, especially during the energy transition, in terms of both final energy consumption and power generation.

As of 2021, natural gas as a fuel accounts for 10% of final energy consumption. Going forward, it will be consumed mainly to meet the high-temperature heat demand of industrial furnaces, which are extremely difficult to electrify in the industrial sector, and as feedstocks for petrochemicals. As a result, in the Optimal Case, natural gas will account for 21% of final energy consumption by 2050, contributing to the reduction of emissions and costs (Figure 8-11).

Since it will take a long time to realise a low-cost hydrogen supply, the use of fossil fuels is expected to continue in the interim in the demand sectors that are hard to electrify. However, in the effort to achieve carbon neutrality, implicit carbon prices through regulations or explicit carbon prices such as a carbon tax or emission allowance are expected to be introduced, making emissions an important factor in the selection of fuels.

Figure 8-11 | Final energy consumption in the ASEAN



Note: Percentages represent the share in final energy consumption (including for non-energy use).
Source: IEA "World Energy Balances" (2023) [historical]

Assuming that carbon prices are introduced in the future, either explicitly or implicitly, and rise with the progress in emissions reduction, the cost advantages and disadvantages of fuels will be as follows (Figure 8-12):

(1) In the absence of carbon prices, coal is the cheapest per calorific value. Heavy fuel oil and natural gas are at a similar level.

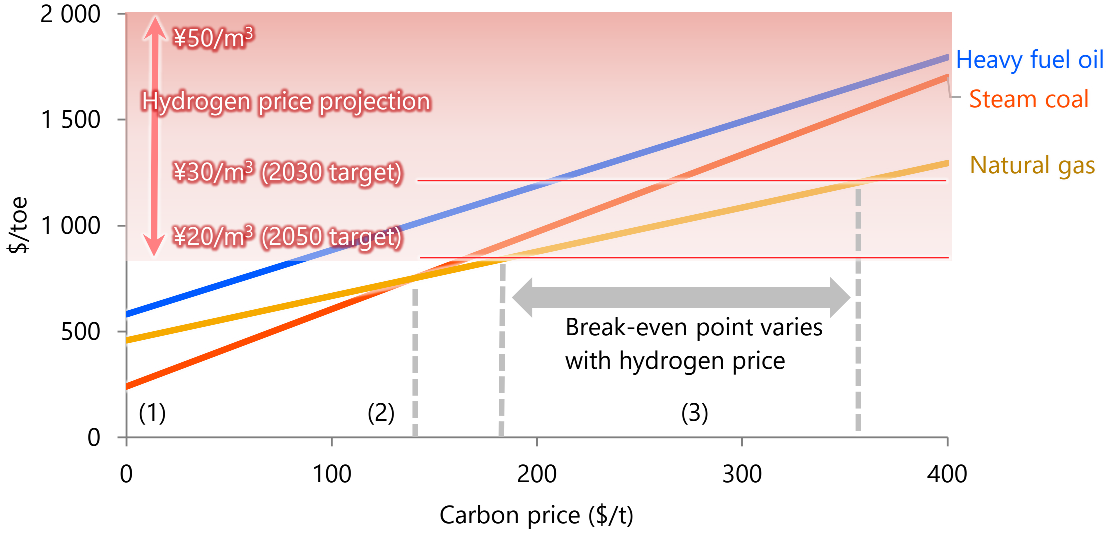
(2) When the carbon price rises to about $150/t, the price of natural gas will be the cheapest.

(3) If the carbon price rises significantly and the cost of hydrogen production decreases, the price of hydrogen may fall below that of natural gas.

However, in order for hydrogen to become more economically rational than natural gas including the carbon price as described in (3), the price of hydrogen must become sufficiently low. There is uncertainty about the extent of this decrease, and it is expected to take a long time to reach a very low level, such as ¥20/m^3. Until then, natural gas will be a particularly competitive fuel in the transition period when the carbon price will remain mostly between (2) and (3).

Natural gas will play a certain role not only in final energy consumption but also in power generation. In the Optimal Case, it will account for 30% of power sources in 2030 and 16% in 2050, and will serve as the peak power source for responding to output fluctuations. On the other hand, in the Gas Supply Constraint Case, coal with high CO_2 emissions and hydrogen with high unit price will have to be introduced as peak power sources. As the renewable energy increases, it will be necessary to secure an ever-greater adjustment capacity to respond to sudden fluctuations in output. In the future, storage batteries and carbon-free hydrogen-fired power are expected to serve this role as their costs go down, but their costs will not be cheap enough in the medium term, suggesting that natural gas-fired power generation will support the supply-demand balance during the transition period.

Figure 8-12 | Fuel economics of the ASEAN [2050]



Note: This is a simple comparison of fuel prices, and the cost difference at the final consumption stage varies depending on the end user prices and the performance of appliances.
Source: Adjusted 2050 price assumptions in the Advanced Technologies Scenario for the ASEAN

In conclusion, natural gas supports final energy consumption, especially of industrial furnaces that are hard to electrify, as well as supply-demand balance, not only for the target zero-emission year but also throughout the transition period. Steadily expanding the natural gas supply capacity is an important measure to achieve a low-cost and stable energy supply.

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 Türkiye

	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, Eswatini, Ethiopia, Gabon, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, South Sudan, Sudan, Togo, United Republic of Tanzania, Uganda, 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/	2021/2050	
		1990	2021	2030	2050	2030	2050	2021	Reference	Adv. Tech.
Total primary energy	**World**	**8 754**	**14 759**	**15 968**	**17 449**	**15 389**	**13 802**	**1.7**	**0.6**	**-0.2**
consumption	AEs[*1]	4 471	5 139	4 900	4 397	4 711	3 681	0.5	-0.5	-1.1
(Mtoe)	EMDEs[*2]	4 081	9 306	10 559	12 330	10 211	9 590	2.7	1.0	0.1
	Asia	2 088	6 439	7 310	8 179	7 127	6 173	3.7	0.8	-0.1
	Non-Asia	6 463	8 006	8 149	8 549	7 795	7 098	0.7	0.2	-0.4
Oil consumption	**World**	**3 237**	**4 352**	**4 727**	**5 001**	**4 321**	**2 704**	**1.0**	**0.5**	**-1.6**
(Mtoe)	AEs	1 827	1 771	1 671	1 298	1 502	595	-0.1	-1.1	-3.7
	EMDEs	1 208	2 267	2 562	3 070	2 379	1 796	2.1	1.1	-0.8
	Asia	618	1 491	1 634	1 889	1 522	1 096	2.9	0.8	-1.1
	Non-Asia	2 416	2 547	2 599	2 479	2 358	1 295	0.2	-0.1	-2.3
Natural gas	**World**	**1 662**	**3 487**	**3 660**	**4 519**	**3 541**	**3 044**	**2.4**	**0.9**	**-0.5**
consumption	AEs	827	1 508	1 368	1 209	1 269	664	2.0	-0.8	-2.8
(Mtoe)	EMDEs	835	1 979	2 280	3 233	2 255	2 269	2.8	1.7	0.5
	Asia	116	722	923	1 317	906	684	6.1	2.1	-0.2
	Non-Asia	1 547	2 764	2 725	3 125	2 618	2 249	1.9	0.4	-0.7
Coal consumption	**World**	**2 223**	**4 016**	**3 784**	**3 186**	**3 485**	**1 575**	**1.9**	**-0.8**	**-3.2**
(Mtoe)	AEs	1 090	741	492	297	402	164	-1.2	-3.1	-5.1
	EMDEs	1 133	3 275	3 293	2 888	3 083	1 411	3.5	-0.4	-2.9
	Asia	789	3 142	3 150	2 638	2 951	1 248	4.6	-0.6	-3.1
	Non-Asia	1 434	874	635	548	534	327	-1.6	-1.6	-3.3
Power generation	**World**	**11 837**	**28 402**	**35 078**	**49 102**	**36 128**	**57 517**	**2.9**	**1.9**	**2.5**
(TWh)	AEs	7 666	10 972	11 799	14 035	12 123	17 420	1.2	0.9	1.6
	EMDEs	4 171	17 430	23 278	35 066	24 005	40 097	4.7	2.4	2.9
	Asia	2 237	13 664	18 317	25 744	18 866	26 570	6.0	2.2	2.3
	Non-Asia	9 600	14 738	16 761	23 358	17 262	30 947	1.4	1.6	2.6
Energy-related	**World**	**20 522**	**33 568**	**34 019**	**33 922**	**31 010**	**14 704**	**1.6**	**0.0**	**-2.8**
carbon dioxide	AEs	10 784	10 593	8 898	6 646	7 809	2 393	-0.1	-1.6	-5.0
emissions	EMDEs	9 102	21 990	23 544	25 113	21 779	11 069	2.9	0.5	-2.3
(Mt)	Asia	4 700	16 776	17 635	17 000	16 331	6 812	4.2	0.0	-3.1
	Non-Asia	15 186	15 807	14 807	14 759	13 257	6 650	0.1	-0.2	-2.9
GDP	**World**	**35 916**	**86 438**	**109 746**	**184 046**	**109 746**	**184 046**	**2.9**	**2.6**	**2.6**
($2015 billion)	AEs	27 230	50 940	59 864	81 906	59 864	81 906	2.0	1.7	1.7
	EMDEs	8 685	35 497	49 883	102 141	49 883	102 141	4.6	3.7	3.7
	Asia	6 690	29 673	41 194	80 738	41 194	80 738	4.9	3.5	3.5
	Non-Asia	29 226	56 764	68 552	103 308	68 552	103 308	2.2	2.1	2.1
Population	**World**	**5 286**	**7 877**	**8 511**	**9 680**	**8 511**	**9 680**	**1.3**	**0.7**	**0.7**
(Million)	AEs	998	1 197	1 218	1 222	1 218	1 222	0.6	0.1	0.1
	EMDEs	4 288	6 681	7 293	8 457	7 293	8 457	1.4	0.8	0.8
	Asia	2 955	4 284	4 507	4 772	4 507	4 772	1.2	0.4	0.4
	Non-Asia	2 331	3 593	4 004	4 908	4 004	4 908	1.4	1.1	1.1

Table A3 | Population

(Million)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	5 286 (100)	6 960 (100)	7 877 (100)	8 511 (100)	9 155 (100)	9 680 (100)	1.3	0.9	0.7	0.6	0.7
Asia	2 955 (55.9)	3 874 (55.7)	4 284 (54.4)	4 507 (53.0)	4 686 (51.2)	4 772 (49.3)	1.2	0.6	0.4	0.2	0.4
China	1 135 (21.5)	1 338 (19.2)	1 412 (17.9)	1 404 (16.5)	1 367 (14.9)	1 305 (13.5)	0.7	-0.1	-0.3	-0.5	-0.3
India	870 (16.5)	1 241 (17.8)	1 408 (17.9)	1 514 (17.8)	1 613 (17.6)	1 674 (17.3)	1.6	0.8	0.6	0.4	0.6
Japan	123 (2.3)	128 (1.8)	126 (1.6)	120 (1.4)	112 (1.2)	105 (1.1)	0.1	-0.6	-0.6	-0.7	-0.6
Korea	43 (0.8)	50 (0.7)	52 (0.7)	51 (0.6)	49 (0.5)	46 (0.5)	0.6	-0.1	-0.4	-0.7	-0.4
Chinese Taipei	20 (0.4)	23 (0.3)	23 (0.3)	24 (0.3)	23 (0.3)	22 (0.2)	0.5	0.1	-0.2	-0.5	-0.2
ASEAN	427 (8.1)	578 (8.3)	650 (8.3)	697 (8.2)	736 (8.0)	760 (7.8)	1.4	0.8	0.6	0.3	0.5
Indonesia	182 (3.4)	244 (3.5)	274 (3.5)	292 (3.4)	309 (3.4)	318 (3.3)	1.3	0.7	0.5	0.3	0.5
Malaysia	18 (0.3)	29 (0.4)	34 (0.4)	37 (0.4)	39 (0.4)	41 (0.4)	2.1	1.0	0.7	0.4	0.7
Myanmar	40 (0.8)	49 (0.7)	54 (0.7)	57 (0.7)	59 (0.6)	60 (0.6)	1.0	0.7	0.4	0.1	0.4
Philippines	62 (1.2)	95 (1.4)	114 (1.4)	130 (1.5)	145 (1.6)	158 (1.6)	2.0	1.4	1.2	0.9	1.1
Singapore	3 (0.1)	5 (0.1)	5 (0.1)	6 (0.1)	6 (0.1)	6 (0.1)	1.9	0.6	0.3	-0.1	0.2
Thailand	55 (1.0)	68 (1.0)	72 (0.9)	72 (0.8)	71 (0.8)	68 (0.7)	0.8	0.1	-0.1	-0.4	-0.2
Viet Nam	67 (1.3)	87 (1.3)	97 (1.2)	103 (1.2)	106 (1.2)	107 (1.1)	1.2	0.6	0.3	0.1	0.3
North America	277 (5.2)	343 (4.9)	370 (4.7)	388 (4.6)	405 (4.4)	416 (4.3)	0.9	0.5	0.4	0.3	0.4
United States	250 (4.7)	309 (4.4)	332 (4.2)	347 (4.1)	361 (3.9)	370 (3.8)	0.9	0.5	0.4	0.2	0.4
Latin America	438 (8.3)	586 (8.4)	652 (8.3)	694 (8.2)	729 (8.0)	748 (7.7)	1.3	0.7	0.5	0.3	0.5
Advanced Europe	505 (9.6)	557 (8.0)	582 (7.4)	589 (6.9)	589 (6.4)	583 (6.0)	0.5	0.1	0.0	-0.1	0.0
European Union	420 (8.0)	442 (6.3)	447 (5.7)	449 (5.3)	446 (4.9)	437 (4.5)	0.2	0.0	-0.1	-0.2	-0.1
Other Europe/Eurasia	337 (6.4)	332 (4.8)	342 (4.3)	340 (4.0)	340 (3.7)	339 (3.5)	0.0	0.0	0.0	0.0	0.0
Africa	620 (11.7)	1 021 (14.7)	1 346 (17.1)	1 652 (19.4)	2 024 (22.1)	2 405 (24.8)	2.5	2.3	2.0	1.7	2.0
Middle East	133 (2.5)	220 (3.2)	270 (3.4)	307 (3.6)	345 (3.8)	379 (3.9)	2.3	1.5	1.2	0.9	1.2
Oceania	20 (0.4)	26 (0.4)	31 (0.4)	33 (0.4)	36 (0.4)	38 (0.4)	1.3	0.9	0.7	0.6	0.7
Advanced Economies	998 (18.9)	1 140 (16.4)	1 197 (15.2)	1 218 (14.3)	1 228 (13.4)	1 222 (12.6)	0.6	0.2	0.1	0.0	0.1
Emerging Market and Developing Economies	4 288 (81.1)	5 820 (83.6)	6 681 (84.8)	7 293 (85.7)	7 927 (86.6)	8 457 (87.4)	1.4	1.0	0.8	0.6	0.8

Source: United Nations "World Population Prospects 2022", World Bank "World Development Indicators"

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

Table A4 | GDP

($2015 billion)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	35 916 (100)	64 773 (100)	86 438 (100)	109 746 (100)	144 034 (100)	184 046 (100)	2.9	2.7	2.8	2.5	2.6
Asia	6 690 (18.6)	17 895 (27.6)	29 673 (34.3)	41 194 (37.5)	59 070 (41.0)	80 738 (43.9)	4.9	3.7	3.7	3.2	3.5
China	1 027 (2.9)	7 554 (11.7)	15 802 (18.3)	22 368 (20.4)	32 274 (22.4)	43 522 (23.6)	9.2	3.9	3.7	3.0	3.6
India	475 (1.3)	1 567 (2.4)	2 782 (3.2)	4 761 (4.3)	8 307 (5.8)	13 614 (7.4)	5.9	6.2	5.7	5.1	5.6
Japan	3 510 (9.8)	4 219 (6.5)	4 435 (5.1)	4 744 (4.3)	5 178 (3.6)	5 607 (3.0)	0.8	0.8	0.9	0.8	0.8
Korea	402 (1.1)	1 261 (1.9)	1 694 (2.0)	2 060 (1.9)	2 479 (1.7)	2 817 (1.5)	4.8	2.2	1.9	1.3	1.8
Chinese Taipei	161 (0.4)	463 (0.7)	658 (0.8)	812 (0.7)	990 (0.7)	1 137 (0.6)	4.7	2.4	2.0	1.4	1.9
ASEAN	728 (2.0)	1 947 (3.0)	3 011 (3.5)	4 570 (4.2)	6 979 (4.8)	9 916 (5.4)	4.7	4.7	4.3	3.6	4.2
Indonesia	270 (0.8)	658 (1.0)	1 066 (1.2)	1 657 (1.5)	2 664 (1.8)	4 013 (2.2)	4.5	5.0	4.9	4.2	4.7
Malaysia	75 (0.2)	233 (0.4)	355 (0.4)	535 (0.5)	756 (0.5)	992 (0.5)	5.2	4.7	3.5	2.8	3.6
Myanmar	7 (0.0)	43 (0.1)	67 (0.1)	87 (0.1)	137 (0.1)	209 (0.1)	7.5	3.0	4.6	4.3	4.0
Philippines	107 (0.3)	229 (0.4)	379 (0.4)	654 (0.6)	1 057 (0.7)	1 479 (0.8)	4.2	6.2	4.9	3.4	4.8
Singapore	71 (0.2)	248 (0.4)	361 (0.4)	447 (0.4)	539 (0.4)	611 (0.3)	5.4	2.4	1.9	1.3	1.8
Thailand	144 (0.4)	347 (0.5)	438 (0.5)	582 (0.5)	805 (0.6)	1 066 (0.6)	3.7	3.2	3.3	2.8	3.1
Viet Nam	45 (0.1)	177 (0.3)	332 (0.4)	591 (0.5)	1 000 (0.7)	1 521 (0.8)	6.7	6.6	5.4	4.3	5.4
North America	10 626 (29.6)	17 783 (27.5)	22 210 (25.7)	26 292 (24.0)	32 069 (22.3)	38 016 (20.7)	2.4	1.9	2.0	1.7	1.9
United States	9 811 (27.3)	16 383 (25.3)	20 529 (23.8)	24 289 (22.1)	29 608 (20.6)	35 085 (19.1)	2.4	1.9	2.0	1.7	1.9
Latin America	2 597 (7.2)	4 830 (7.5)	5 348 (6.2)	6 670 (6.1)	8 934 (6.2)	11 587 (6.3)	2.4	2.5	3.0	2.6	2.7
Advanced Europe	11 682 (32.5)	16 894 (26.1)	19 669 (22.8)	23 173 (21.1)	26 699 (18.5)	30 170 (16.4)	1.7	1.8	1.4	1.2	1.5
European Union	9 107 (25.4)	12 897 (19.9)	14 681 (17.0)	17 280 (15.7)	19 827 (13.8)	22 275 (12.1)	1.6	1.8	1.4	1.2	1.4
Other Europe/Eurasia	1 832 (5.1)	2 089 (3.2)	2 628 (3.0)	3 085 (2.8)	3 867 (2.7)	4 805 (2.6)	1.2	1.8	2.3	2.2	2.1
Africa	920 (2.6)	1 998 (3.1)	2 663 (3.1)	3 830 (3.5)	6 227 (4.3)	9 596 (5.2)	3.5	4.1	5.0	4.4	4.5
Middle East	910 (2.5)	2 064 (3.2)	2 664 (3.1)	3 563 (3.2)	4 727 (3.3)	6 120 (3.3)	3.5	3.3	2.9	2.6	2.9
Oceania	658 (1.8)	1 220 (1.9)	1 583 (1.8)	1 939 (1.8)	2 441 (1.7)	3 015 (1.6)	2.9	2.3	2.3	2.1	2.2
Advanced Economies	27 230 (75.8)	42 356 (65.4)	50 940 (58.9)	59 864 (54.5)	70 870 (49.2)	81 906 (44.5)	2.0	1.8	1.7	1.5	1.7
Emerging Market and Developing Economies	8 685 (24.2)	22 418 (34.6)	35 497 (41.1)	49 883 (45.5)	73 163 (50.8)	102 141 (55.5)	4.6	3.9	3.9	3.4	3.7

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

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

Table A5 | GDP per capita

($2015 thousand/person)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	6.8	9.3	11.0	12.9	15.7	19.0	1.6	1.8	2.0	1.9	1.9
Asia	2.3	4.6	6.9	9.1	12.6	16.9	3.7	3.1	3.3	3.0	3.1
China	0.9	5.6	11.2	15.9	23.6	33.4	8.4	4.0	4.0	3.5	3.8
India	0.5	1.3	2.0	3.1	5.1	8.1	4.2	5.3	5.1	4.7	5.0
Japan	28.4	32.9	35.3	39.7	46.2	53.5	0.7	1.3	1.5	1.5	1.4
Korea	9.4	25.5	32.7	40.2	50.2	61.4	4.1	2.3	2.2	2.0	2.2
Chinese Taipei	7.9	20.0	28.0	34.3	42.5	51.3	4.2	2.3	2.2	1.9	2.1
ASEAN	1.7	3.4	4.6	6.6	9.5	13.1	3.3	3.9	3.7	3.2	3.6
Indonesia	1.5	2.7	3.9	5.7	8.6	12.6	3.2	4.3	4.3	3.9	4.1
Malaysia	4.3	8.1	10.6	14.6	19.2	24.1	3.0	3.6	2.8	2.3	2.9
Myanmar	0.2	0.9	1.2	1.5	2.3	3.5	6.4	2.4	4.2	4.1	3.6
Philippines	1.7	2.4	3.3	5.0	7.3	9.3	2.1	4.7	3.7	2.5	3.6
Singapore	23.3	48.8	66.2	77.9	91.3	104.7	3.4	1.8	1.6	1.4	1.6
Thailand	2.6	5.1	6.1	8.1	11.3	15.7	2.8	3.1	3.5	3.3	3.3
Viet Nam	0.7	2.0	3.4	5.7	9.4	14.2	5.4	6.0	5.1	4.2	5.0
North America	38.3	51.8	60.0	67.8	79.2	91.4	1.5	1.4	1.6	1.4	1.5
United States	39.3	53.0	61.9	70.1	82.0	94.8	1.5	1.4	1.6	1.5	1.5
Latin America	5.9	8.2	8.2	9.6	12.3	15.5	1.1	1.8	2.5	2.4	2.2
Advanced Europe	23.1	30.3	33.8	39.3	45.3	51.8	1.2	1.7	1.4	1.3	1.5
European Union	21.7	29.2	32.8	38.5	44.5	51.0	1.3	1.8	1.5	1.4	1.5
Other Europe/Eurasia	5.4	6.3	7.7	9.1	11.4	14.2	1.1	1.8	2.3	2.2	2.1
Africa	1.5	2.0	2.0	2.3	3.1	4.0	0.9	1.8	2.9	2.6	2.4
Middle East	6.8	9.4	9.9	11.6	13.7	16.2	1.2	1.8	1.7	1.7	1.7
Oceania	32.2	46.3	51.4	57.9	68.0	79.4	1.5	1.3	1.6	1.6	1.5
Advanced Economies	27.3	37.2	42.6	49.2	57.7	67.0	1.4	1.6	1.6	1.5	1.6
Emerging Market and Developing Economies	2.0	3.9	5.3	6.8	9.2	12.1	3.2	2.8	3.0	2.7	2.9

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

Table A6 | International energy prices

Real prices			Reference			Advanced Technologies		
		2022	2030	2040	2050	2030	2040	2050
Oil	$2022/bbl	101	85	90	95	80	75	70
Natural gas								
Japan	$2022/MBtu	17.3	9.5	9.7	9.4	9.0	8.8	8.1
Europe (UK)	$2022/MBtu	37.5	10.1	10.6	10.4	9.9	9.9	9.3
United States	$2022/MBtu	6.4	3.0	4.0	4.0	3.4	4.1	4.0
Steam coal	$2022/t	318	110	115	115	105	100	90

Nominal prices			Reference			Advanced Technologies		
		2022	2030	2040	2050	2030	2040	2050
Oil	$/bbl	101	97	118	140	91	98	103
Natural gas								
Japan	$/MBtu	17.3	10.8	12.7	13.9	10.3	11.5	12.0
Europe (UK)	$/MBtu	37.5	11.4	13.8	15.3	11.3	13.0	13.8
United States	$/MBtu	6.4	3.4	5.3	5.9	3.9	5.4	5.9
Steam coal	$/t	318	125	151	170	119	131	133

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

Table A7 | Primary energy consumption [Reference Scenario]

(Mtoe)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	8 754 (100)	12 850 (100)	14 759 (100)	15 968 (100)	16 722 (100)	17 449 (100)	1.7	0.9	0.5	0.4	0.6
Asia	2 088 (23.9)	4 803 (37.4)	6 439 (43.6)	7 310 (45.8)	7 823 (46.8)	8 179 (46.9)	3.7	1.4	0.7	0.4	0.8
China	874 (10.0)	2 536 (19.7)	3 738 (25.3)	3 977 (24.9)	3 837 (22.9)	3 514 (20.1)	4.8	0.7	-0.4	-0.9	-0.2
India	280 (3.2)	667 (5.2)	944 (6.4)	1 280 (8.0)	1 645 (9.8)	2 054 (11.8)	4.0	3.4	2.5	2.2	2.7
Japan	437 (5.0)	500 (3.9)	400 (2.7)	376 (2.4)	348 (2.1)	329 (1.9)	-0.3	-0.7	-0.8	-0.5	-0.7
Korea	93 (1.1)	250 (1.9)	292 (2.0)	296 (1.9)	288 (1.7)	276 (1.6)	3.8	0.2	-0.3	-0.4	-0.2
Chinese Taipei	51 (0.6)	119 (0.9)	123 (0.8)	121 (0.8)	118 (0.7)	110 (0.6)	2.9	-0.1	-0.3	-0.6	-0.4
ASEAN	231 (2.6)	536 (4.2)	678 (4.6)	930 (5.8)	1 171 (7.0)	1 380 (7.9)	3.5	3.6	2.3	1.7	2.5
Indonesia	99 (1.1)	204 (1.6)	235 (1.6)	350 (2.2)	471 (2.8)	577 (3.3)	2.8	4.5	3.0	2.0	3.1
Malaysia	21 (0.2)	72 (0.6)	95 (0.6)	129 (0.8)	146 (0.9)	156 (0.9)	5.0	3.4	1.3	0.6	1.7
Myanmar	11 (0.1)	14 (0.1)	22 (0.1)	28 (0.2)	36 (0.2)	46 (0.3)	2.3	3.0	2.4	2.6	2.6
Philippines	27 (0.3)	42 (0.3)	61 (0.4)	83 (0.5)	109 (0.7)	134 (0.8)	2.7	3.5	2.7	2.1	2.7
Singapore	12 (0.1)	24 (0.2)	35 (0.2)	38 (0.2)	39 (0.2)	40 (0.2)	3.7	0.7	0.4	0.3	0.5
Thailand	42 (0.5)	118 (0.9)	130 (0.9)	147 (0.9)	165 (1.0)	179 (1.0)	3.7	1.4	1.2	0.8	1.1
Viet Nam	18 (0.2)	59 (0.5)	95 (0.6)	152 (0.9)	200 (1.2)	244 (1.4)	5.5	5.3	2.8	2.0	3.3
North America	2 126 (24.3)	2 473 (19.2)	2 429 (16.5)	2 354 (14.7)	2 214 (13.2)	2 126 (12.2)	0.4	-0.4	-0.6	-0.4	-0.5
United States	1 914 (21.9)	2 216 (17.2)	2 139 (14.5)	2 045 (12.8)	1 897 (11.3)	1 804 (10.3)	0.4	-0.5	-0.7	-0.5	-0.6
Latin America	467 (5.3)	788 (6.1)	821 (5.6)	921 (5.8)	1 031 (6.2)	1 143 (6.6)	1.8	1.3	1.1	1.0	1.1
Advanced Europe	1 644 (18.8)	1 833 (14.3)	1 698 (11.5)	1 549 (9.7)	1 428 (8.5)	1 352 (7.7)	0.1	-1.0	-0.8	-0.5	-0.8
European Union	1 441 (16.5)	1 527 (11.9)	1 388 (9.4)	1 284 (8.0)	1 176 (7.0)	1 112 (6.4)	-0.1	-0.9	-0.9	-0.6	-0.8
Other Europe/Eurasia	1 514 (17.3)	1 112 (8.7)	1 225 (8.3)	1 190 (7.5)	1 217 (7.3)	1 296 (7.4)	-0.7	-0.3	0.2	0.6	0.2
Africa	390 (4.5)	685 (5.3)	853 (5.8)	975 (6.1)	1 100 (6.6)	1 228 (7.0)	2.6	1.5	1.2	1.1	1.3
Middle East	223 (2.5)	649 (5.0)	829 (5.6)	1 009 (6.3)	1 138 (6.8)	1 253 (7.2)	4.3	2.2	1.2	1.0	1.4
Oceania	99 (1.1)	144 (1.1)	150 (1.0)	153 (1.0)	152 (0.9)	151 (0.9)	1.4	0.2	-0.1	-0.1	0.0
Advanced Economies	4 471 (51.1)	5 357 (41.7)	5 139 (34.8)	4 900 (30.7)	4 599 (27.5)	4 397 (25.2)	0.5	-0.5	-0.6	-0.4	-0.5
Emerging Market and Developing Economies	4 081 (46.6)	7 132 (55.5)	9 306 (63.0)	10 559 (66.1)	11 502 (68.8)	12 330 (70.7)	2.7	1.4	0.9	0.7	1.0

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	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	2 223 (100)	3 662 (100)	4 016 (100)	3 784 (100)	3 492 (100)	3 186 (100)	1.9	-0.7	-0.8	-0.9	-0.8
Asia	789 (35.5)	2 416 (66.0)	3 142 (78.2)	3 150 (83.2)	2 941 (84.2)	2 638 (82.8)	4.6	0.0	-0.7	-1.1	-0.6
China	531 (23.9)	1 790 (48.9)	2 266 (56.4)	2 143 (56.6)	1 763 (50.5)	1 290 (40.5)	4.8	-0.6	-1.9	-3.1	-1.9
India	93 (4.2)	279 (7.6)	421 (10.5)	533 (14.1)	644 (18.5)	767 (24.1)	5.0	2.6	1.9	1.8	2.1
Japan	77 (3.5)	115 (3.2)	109 (2.7)	77 (2.0)	65 (1.9)	57 (1.8)	1.1	-3.8	-1.7	-1.4	-2.2
Korea	25 (1.1)	73 (2.0)	75 (1.9)	75 (2.0)	73 (2.1)	66 (2.1)	3.6	0.0	-0.3	-0.9	-0.4
Chinese Taipei	11 (0.5)	42 (1.1)	43 (1.1)	43 (1.1)	38 (1.1)	33 (1.0)	4.4	-0.1	-1.1	-1.5	-0.9
ASEAN	12 (0.6)	85 (2.3)	178 (4.4)	216 (5.7)	271 (7.8)	313 (9.8)	9.0	2.2	2.3	1.4	2.0
Indonesia	4 (0.2)	32 (0.9)	71 (1.8)	90 (2.4)	123 (3.5)	153 (4.8)	10.2	2.6	3.2	2.2	2.7
Malaysia	1 (0.1)	15 (0.4)	23 (0.6)	24 (0.6)	24 (0.7)	22 (0.7)	9.5	0.8	0.0	-1.1	-0.2
Myanmar	0 (0.0)	0 (0.0)	1 (0.0)	3 (0.1)	5 (0.2)	9 (0.3)	9.5	12.5	5.1	4.8	7.2
Philippines	1 (0.1)	7 (0.2)	19 (0.5)	22 (0.6)	27 (0.8)	29 (0.9)	9.1	1.7	2.0	0.8	1.5
Singapore	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	10.4	0.1	-0.1	-1.0	-0.4
Thailand	4 (0.2)	16 (0.4)	16 (0.4)	13 (0.4)	13 (0.4)	12 (0.4)	4.7	-1.7	-0.2	-1.0	-0.9
Viet Nam	2 (0.1)	15 (0.4)	47 (1.2)	62 (1.6)	78 (2.2)	88 (2.8)	10.3	3.1	2.4	1.3	2.2
North America	484 (21.8)	525 (14.3)	264 (6.6)	145 (3.8)	68 (1.9)	30 (0.9)	-1.9	-6.5	-7.3	-7.9	-7.3
United States	460 (20.7)	501 (13.7)	254 (6.3)	141 (3.7)	66 (1.9)	28 (0.9)	-1.9	-6.3	-7.4	-8.3	-7.4
Latin America	21 (1.0)	39 (1.1)	39 (1.0)	36 (1.0)	43 (1.2)	43 (1.3)	2.0	-0.7	1.6	0.1	0.3
Advanced Europe	450 (20.3)	301 (8.2)	204 (5.1)	114 (3.0)	83 (2.4)	79 (2.5)	-2.5	-6.3	-3.1	-0.5	-3.2
European Union	393 (17.7)	252 (6.9)	166 (4.1)	97 (2.6)	71 (2.0)	68 (2.1)	-2.7	-5.8	-3.1	-0.3	-3.0
Other Europe/Eurasia	365 (16.4)	211 (5.8)	212 (5.3)	192 (5.1)	198 (5.7)	222 (7.0)	-1.7	-1.1	0.3	1.2	0.2
Africa	74 (3.3)	109 (3.0)	105 (2.6)	107 (2.8)	123 (3.5)	141 (4.4)	1.1	0.2	1.4	1.3	1.0
Middle East	3 (0.1)	10 (0.3)	8 (0.2)	9 (0.2)	8 (0.2)	7 (0.2)	3.3	0.8	-0.6	-1.8	-0.6
Oceania	36 (1.6)	52 (1.4)	42 (1.0)	32 (0.8)	28 (0.8)	26 (0.8)	0.5	-2.9	-1.2	-0.7	-1.6
Advanced Economies	1 090 (49.0)	1 114 (30.4)	741 (18.5)	492 (13.0)	362 (10.4)	297 (9.3)	-1.2	-4.5	-3.0	-1.9	-3.1
Emerging Market and Developing Economies	1 133 (51.0)	2 548 (69.6)	3 275 (81.5)	3 293 (87.0)	3 130 (89.6)	2 888 (90.7)	3.5	0.1	-0.5	-0.8	-0.4

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	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	3 237 (100)	4 155 (100)	4 352 (100)	4 727 (100)	4 887 (100)	5 001 (100)	1.0	0.9	0.3	0.2	0.5
Asia	618 (19.1)	1 172 (28.2)	1 491 (34.3)	1 634 (34.6)	1 763 (36.1)	1 889 (37.8)	2.9	1.0	0.8	0.7	0.8
China	119 (3.7)	428 (10.3)	678 (15.6)	682 (14.4)	654 (13.4)	607 (12.1)	5.8	0.1	-0.4	-0.7	-0.4
India	61 (1.9)	162 (3.9)	223 (5.1)	295 (6.2)	407 (8.3)	548 (11.0)	4.3	3.1	3.3	3.0	3.1
Japan	249 (7.7)	201 (4.8)	151 (3.5)	134 (2.8)	115 (2.4)	100 (2.0)	-1.6	-1.3	-1.5	-1.4	-1.4
Korea	50 (1.5)	95 (2.3)	112 (2.6)	109 (2.3)	101 (2.1)	92 (1.8)	2.6	-0.2	-0.8	-0.9	-0.7
Chinese Taipei	28 (0.9)	49 (1.2)	44 (1.0)	43 (0.9)	40 (0.8)	35 (0.7)	1.4	-0.1	-0.7	-1.3	-0.7
ASEAN	88 (2.7)	189 (4.5)	222 (5.1)	298 (6.3)	354 (7.2)	397 (7.9)	3.0	3.4	1.7	1.2	2.0
Indonesia	33 (1.0)	67 (1.6)	68 (1.6)	91 (1.9)	109 (2.2)	123 (2.5)	2.3	3.3	1.8	1.2	2.0
Malaysia	11 (0.4)	25 (0.6)	26 (0.6)	35 (0.7)	35 (0.7)	32 (0.6)	2.6	3.6	0.0	-0.8	0.8
Myanmar	1 (0.0)	1 (0.0)	6 (0.1)	8 (0.2)	12 (0.2)	15 (0.3)	6.8	3.8	3.9	2.8	3.5
Philippines	10 (0.3)	14 (0.3)	18 (0.4)	30 (0.6)	44 (0.9)	56 (1.1)	2.1	5.7	3.8	2.5	3.9
Singapore	11 (0.4)	17 (0.4)	25 (0.6)	25 (0.5)	27 (0.5)	27 (0.5)	2.5	0.4	0.4	0.3	0.4
Thailand	18 (0.6)	45 (1.1)	56 (1.3)	62 (1.3)	67 (1.4)	69 (1.4)	3.7	1.2	0.8	0.4	0.8
Viet Nam	3 (0.1)	18 (0.4)	23 (0.5)	46 (1.0)	60 (1.2)	73 (1.5)	7.1	7.9	2.7	2.1	4.1
North America	833 (25.7)	901 (21.7)	859 (19.7)	825 (17.5)	747 (15.3)	659 (13.2)	0.1	-0.4	-1.0	-1.2	-0.9
United States	757 (23.4)	807 (19.4)	764 (17.5)	728 (15.4)	658 (13.5)	581 (11.6)	0.0	-0.5	-1.0	-1.2	-0.9
Latin America	241 (7.4)	365 (8.8)	333 (7.6)	364 (7.7)	383 (7.8)	395 (7.9)	1.0	1.0	0.5	0.3	0.6
Advanced Europe	617 (19.1)	605 (14.6)	530 (12.2)	477 (10.1)	395 (8.1)	338 (6.7)	-0.5	-1.2	-1.9	-1.6	-1.5
European Union	531 (16.4)	506 (12.2)	437 (10.0)	390 (8.2)	324 (6.6)	277 (5.5)	-0.6	-1.3	-1.8	-1.6	-1.6
Other Europe/Eurasia	459 (14.2)	216 (5.2)	251 (5.8)	232 (4.9)	224 (4.6)	213 (4.3)	-1.9	-0.9	-0.4	-0.5	-0.6
Africa	85 (2.6)	161 (3.9)	195 (4.5)	243 (5.1)	311 (6.4)	378 (7.5)	2.7	2.5	2.5	2.0	2.3
Middle East	146 (4.5)	324 (7.8)	331 (7.6)	405 (8.6)	439 (9.0)	453 (9.1)	2.7	2.3	0.8	0.3	1.1
Oceania	35 (1.1)	48 (1.2)	49 (1.1)	53 (1.1)	49 (1.0)	45 (0.9)	1.1	0.8	-0.7	-0.8	-0.3
Advanced Economies	1 827 (56.4)	1 920 (46.2)	1 771 (40.7)	1 671 (35.3)	1 477 (30.2)	1 298 (26.0)	-0.1	-0.6	-1.2	-1.3	-1.1
Emerging Market and Developing Economies	1 208 (37.3)	1 873 (45.1)	2 267 (52.1)	2 562 (54.2)	2 834 (58.0)	3 070 (61.4)	2.1	1.4	1.0	0.8	1.1

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	2021	2030	2040	2050	CAGR (%) 1990/2021	CAGR (%) 2021/2030	CAGR (%) 2030/2040	CAGR (%) 2040/2050	CAGR (%) 2021/2050
World	1 662 (100)	2 734 (100)	3 487 (100)	3 660 (100)	4 025 (100)	4 519 (100)	2.4	0.5	1.0	1.2	0.9
Asia	116 (7.0)	455 (16.6)	722 (20.7)	923 (25.2)	1 128 (28.0)	1 317 (29.1)	6.1	2.8	2.0	1.6	2.1
China	13 (0.8)	89 (3.3)	299 (8.6)	391 (10.7)	433 (10.8)	423 (9.4)	10.7	3.0	1.0	-0.2	1.2
India	11 (0.6)	54 (2.0)	55 (1.6)	94 (2.6)	150 (3.7)	215 (4.7)	5.5	6.1	4.8	3.6	4.8
Japan	44 (2.7)	86 (3.1)	87 (2.5)	72 (2.0)	69 (1.7)	68 (1.5)	2.2	-2.0	-0.5	-0.1	-0.8
Korea	3 (0.2)	39 (1.4)	54 (1.6)	52 (1.4)	60 (1.5)	68 (1.5)	10.1	-0.5	1.4	1.3	0.8
Chinese Taipei	2 (0.1)	15 (0.5)	26 (0.7)	28 (0.8)	30 (0.7)	31 (0.7)	9.4	1.1	0.6	0.4	0.7
ASEAN	30 (1.8)	125 (4.6)	135 (3.9)	201 (5.5)	264 (6.6)	339 (7.5)	5.0	4.6	2.8	2.5	3.2
Indonesia	16 (1.0)	39 (1.4)	34 (1.0)	55 (1.5)	85 (2.1)	123 (2.7)	2.5	5.4	4.5	3.8	4.6
Malaysia	7 (0.4)	31 (1.1)	43 (1.2)	64 (1.8)	77 (1.9)	90 (2.0)	6.1	4.7	1.8	1.6	2.6
Myanmar	1 (0.0)	1 (0.0)	3 (0.1)	8 (0.2)	12 (0.3)	18 (0.4)	5.0	10.3	4.1	3.7	5.8
Philippines	- (-)	3 (0.1)	3 (0.1)	6 (0.2)	12 (0.3)	21 (0.5)	-	8.8	6.9	5.9	7.1
Singapore	- (-)	6 (0.2)	10 (0.3)	10 (0.3)	11 (0.3)	11 (0.2)	-	0.9	0.5	0.3	0.5
Thailand	5 (0.3)	33 (1.2)	34 (1.0)	39 (1.1)	41 (1.0)	40 (0.9)	6.3	1.7	0.6	-0.2	0.6
Viet Nam	0 (0.0)	8 (0.3)	6 (0.2)	16 (0.4)	24 (0.6)	34 (0.7)	28.4	11.0	3.8	3.7	6.0
North America	493 (29.7)	632 (23.1)	840 (24.1)	818 (22.4)	753 (18.7)	680 (15.1)	1.7	-0.3	-0.8	-1.0	-0.7
United States	438 (26.4)	556 (20.3)	723 (20.7)	681 (18.6)	592 (14.7)	499 (11.0)	1.6	-0.7	-1.4	-1.7	-1.3
Latin America	71 (4.3)	178 (6.5)	207 (5.9)	206 (5.6)	270 (6.7)	351 (7.8)	3.5	-0.1	2.7	2.7	1.8
Advanced Europe	267 (16.1)	473 (17.3)	447 (12.8)	342 (9.3)	308 (7.7)	299 (6.6)	1.7	-2.9	-1.0	-0.3	-1.4
European Union	250 (15.0)	363 (13.3)	340 (9.7)	266 (7.3)	247 (6.1)	237 (5.2)	1.0	-2.7	-0.7	-0.4	-1.2
Other Europe/Eurasia	596 (35.8)	566 (20.7)	611 (17.5)	581 (15.9)	599 (14.9)	668 (14.8)	0.1	-0.6	0.3	1.1	0.3
Africa	30 (1.8)	88 (3.2)	141 (4.0)	182 (5.0)	253 (6.3)	361 (8.0)	5.2	2.9	3.4	3.6	3.3
Middle East	72 (4.3)	311 (11.4)	478 (13.7)	554 (15.1)	632 (15.7)	719 (15.9)	6.3	1.7	1.3	1.3	1.4
Oceania	19 (1.1)	31 (1.1)	40 (1.1)	42 (1.1)	45 (1.1)	47 (1.0)	2.5	0.6	0.6	0.6	0.6
Advanced Economies	827 (49.8)	1 285 (47.0)	1 508 (43.2)	1 368 (37.4)	1 278 (31.8)	1 209 (26.8)	2.0	-1.1	-0.7	-0.6	-0.8
Emerging Market and Developing Economies	835 (50.2)	1 449 (53.0)	1 979 (56.7)	2 280 (62.3)	2 710 (67.3)	3 233 (71.5)	2.8	1.6	1.7	1.8	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)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	6 242 (100)	8 829 (100)	10 082 (100)	11 014 (100)	11 618 (100)	12 194 (100)	1.6	1.0	0.5	0.5	0.7
Asia	1 534 (24.6)	3 166 (35.9)	4 131 (41.0)	4 653 (42.2)	5 071 (43.7)	5 464 (44.8)	3.2	1.3	0.9	0.7	1.0
China	658 (10.5)	1 645 (18.6)	2 317 (23.0)	2 451 (22.2)	2 435 (21.0)	2 357 (19.3)	4.1	0.6	-0.1	-0.3	0.1
India	215 (3.4)	443 (5.0)	632 (6.3)	846 (7.7)	1 110 (9.6)	1 413 (11.6)	3.5	3.3	2.8	2.4	2.8
Japan	290 (4.7)	314 (3.6)	267 (2.7)	253 (2.3)	234 (2.0)	218 (1.8)	-0.3	-0.6	-0.8	-0.7	-0.7
Korea	65 (1.0)	158 (1.8)	182 (1.8)	185 (1.7)	181 (1.6)	174 (1.4)	3.4	0.2	-0.2	-0.4	-0.2
Chinese Taipei	32 (0.5)	75 (0.8)	79 (0.8)	82 (0.7)	81 (0.7)	77 (0.6)	3.0	0.4	-0.1	-0.5	-0.1
ASEAN	171 (2.7)	377 (4.3)	446 (4.4)	588 (5.3)	724 (6.2)	854 (7.0)	3.1	3.1	2.1	1.7	2.3
Indonesia	79 (1.3)	148 (1.7)	152 (1.5)	195 (1.8)	249 (2.1)	307 (2.5)	2.1	2.8	2.5	2.1	2.4
Malaysia	13 (0.2)	42 (0.5)	56 (0.6)	80 (0.7)	91 (0.8)	97 (0.8)	4.7	4.0	1.3	0.7	1.9
Myanmar	9 (0.2)	13 (0.1)	18 (0.2)	20 (0.2)	23 (0.2)	28 (0.2)	2.2	1.0	1.6	1.9	1.5
Philippines	19 (0.3)	25 (0.3)	35 (0.3)	50 (0.5)	68 (0.6)	87 (0.7)	2.0	4.0	3.2	2.5	3.2
Singapore	5 (0.1)	15 (0.2)	19 (0.2)	20 (0.2)	22 (0.2)	23 (0.2)	4.4	1.0	0.7	0.5	0.7
Thailand	29 (0.5)	84 (1.0)	94 (0.9)	108 (1.0)	121 (1.0)	131 (1.1)	3.9	1.5	1.2	0.8	1.1
Viet Nam	16 (0.3)	48 (0.5)	69 (0.7)	114 (1.0)	148 (1.3)	179 (1.5)	4.9	5.7	2.6	1.9	3.3
North America	1 452 (23.3)	1 697 (19.2)	1 731 (17.2)	1 719 (15.6)	1 667 (14.3)	1 615 (13.2)	0.6	-0.1	-0.3	-0.3	-0.2
United States	1 294 (20.7)	1 513 (17.1)	1 540 (15.3)	1 521 (13.8)	1 471 (12.7)	1 423 (11.7)	0.6	-0.1	-0.3	-0.3	-0.3
Latin America	344 (5.5)	569 (6.4)	574 (5.7)	662 (6.0)	733 (6.3)	806 (6.6)	1.7	1.6	1.0	1.0	1.2
Advanced Europe	1 142 (18.3)	1 289 (14.6)	1 255 (12.4)	1 193 (10.8)	1 097 (9.4)	1 027 (8.4)	0.3	-0.6	-0.8	-0.7	-0.7
European Union	995 (15.9)	1 070 (12.1)	1 023 (10.1)	972 (8.8)	893 (7.7)	833 (6.8)	0.1	-0.6	-0.8	-0.7	-0.7
Other Europe/Eurasia	1 057 (16.9)	711 (8.1)	802 (8.0)	782 (7.1)	782 (6.7)	793 (6.5)	-0.9	-0.3	0.0	0.1	0.0
Africa	286 (4.6)	495 (5.6)	614 (6.1)	689 (6.3)	744 (6.4)	785 (6.4)	2.5	1.3	0.8	0.5	0.9
Middle East	157 (2.5)	451 (5.1)	568 (5.6)	708 (6.4)	803 (6.9)	882 (7.2)	4.2	2.5	1.3	0.9	1.5
Oceania	66 (1.1)	90 (1.0)	92 (0.9)	100 (0.9)	101 (0.9)	100 (0.8)	1.1	0.9	0.1	0.0	0.3
Advanced Economies	3 058 (49.0)	3 644 (41.3)	3 632 (36.0)	3 561 (32.3)	3 390 (29.2)	3 242 (26.6)	0.6	-0.2	-0.5	-0.4	-0.4
Emerging Market and Developing Economies	2 981 (47.8)	4 824 (54.6)	6 135 (60.9)	6 945 (63.1)	7 607 (65.5)	8 230 (67.5)	2.4	1.4	0.9	0.8	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	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	1 797 (100)	2 643 (100)	3 037 (100)	3 326 (100)	3 565 (100)	3 673 (100)	1.7	1.0	0.7	0.3	0.7
Asia	508 (28.3)	1 405 (53.1)	1 750 (57.6)	1 930 (58.0)	2 065 (57.9)	2 116 (57.6)	4.1	1.1	0.7	0.2	0.7
China	234 (13.0)	924 (35.0)	1 129 (37.2)	1 100 (33.1)	1 011 (28.4)	876 (23.8)	5.2	-0.3	-0.8	-1.4	-0.9
India	59 (3.3)	158 (6.0)	247 (8.1)	379 (11.4)	515 (14.4)	627 (17.1)	4.7	4.9	3.1	2.0	3.3
Japan	108 (6.0)	92 (3.5)	80 (2.6)	75 (2.2)	69 (1.9)	64 (1.7)	-1.0	-0.8	-0.8	-0.8	-0.8
Korea	19 (1.1)	45 (1.7)	47 (1.6)	50 (1.5)	50 (1.4)	47 (1.3)	2.9	0.7	0.0	-0.6	0.0
Chinese Taipei	13 (0.7)	24 (0.9)	27 (0.9)	28 (0.9)	29 (0.8)	28 (0.8)	2.4	0.7	0.2	-0.4	0.1
ASEAN	41 (2.3)	120 (4.6)	162 (5.3)	215 (6.5)	273 (7.7)	320 (8.7)	4.5	3.2	2.4	1.6	2.4
Indonesia	17 (1.0)	49 (1.9)	56 (1.9)	75 (2.3)	101 (2.8)	127 (3.4)	3.9	3.2	3.0	2.3	2.8
Malaysia	6 (0.3)	15 (0.6)	19 (0.6)	25 (0.7)	31 (0.9)	35 (0.9)	4.0	3.2	2.3	1.0	2.2
Myanmar	0 (0.0)	1 (0.0)	3 (0.1)	4 (0.1)	6 (0.2)	8 (0.2)	7.0	3.4	3.9	3.0	3.4
Philippines	4 (0.2)	6 (0.2)	7 (0.2)	10 (0.3)	13 (0.4)	15 (0.4)	1.6	4.1	2.9	1.6	2.8
Singapore	1 (0.0)	5 (0.2)	7 (0.2)	8 (0.2)	8 (0.2)	8 (0.2)	8.1	1.0	0.5	-0.1	0.4
Thailand	9 (0.5)	26 (1.0)	30 (1.0)	36 (1.1)	42 (1.2)	45 (1.2)	4.1	2.0	1.5	0.8	1.4
Viet Nam	5 (0.3)	17 (0.7)	40 (1.3)	58 (1.7)	72 (2.0)	82 (2.2)	7.3	4.2	2.2	1.3	2.5
North America	331 (18.4)	313 (11.8)	324 (10.7)	333 (10.0)	338 (9.5)	330 (9.0)	-0.1	0.3	0.2	-0.2	0.1
United States	284 (15.8)	270 (10.2)	278 (9.2)	285 (8.6)	287 (8.1)	279 (7.6)	-0.1	0.3	0.1	-0.3	0.0
Latin America	114 (6.3)	179 (6.8)	169 (5.6)	202 (6.1)	237 (6.7)	267 (7.3)	1.3	2.0	1.6	1.2	1.6
Advanced Europe	330 (18.4)	296 (11.2)	305 (10.1)	307 (9.2)	298 (8.4)	280 (7.6)	-0.3	0.1	-0.3	-0.6	-0.3
European Union	313 (17.4)	247 (9.3)	246 (8.1)	251 (7.5)	244 (6.9)	230 (6.3)	-0.8	0.2	-0.3	-0.6	-0.2
Other Europe/Eurasia	391 (21.8)	205 (7.8)	211 (7.0)	208 (6.3)	217 (6.1)	221 (6.0)	-2.0	-0.2	0.4	0.2	0.2
Africa	53 (3.0)	84 (3.2)	90 (3.0)	111 (3.3)	148 (4.1)	185 (5.0)	1.7	2.3	2.9	2.3	2.5
Middle East	47 (2.6)	134 (5.1)	160 (5.3)	205 (6.2)	230 (6.5)	242 (6.6)	4.0	2.8	1.2	0.5	1.4
Oceania	23 (1.3)	26 (1.0)	27 (0.9)	30 (0.9)	31 (0.9)	32 (0.9)	0.5	1.3	0.6	0.2	0.6
Advanced Economies	826 (46.0)	803 (30.4)	817 (26.9)	832 (25.0)	825 (23.1)	790 (21.5)	0.0	0.2	-0.1	-0.4	-0.1
Emerging Market and Developing Economies	970 (54.0)	1 840 (69.6)	2 219 (73.1)	2 494 (75.0)	2 740 (76.9)	2 883 (78.5)	2.7	1.3	0.9	0.5	0.9

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	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	1 578 (100)	2 430 (100)	2 690 (100)	3 127 (100)	3 291 (100)	3 476 (100)	1.7	1.7	0.5	0.5	0.9
Asia	189 (12.0)	493 (20.3)	719 (26.7)	884 (28.3)	984 (29.9)	1 101 (31.7)	4.4	2.3	1.1	1.1	1.5
China	30 (1.9)	195 (8.0)	346 (12.9)	420 (13.4)	422 (12.8)	406 (11.7)	8.2	2.2	0.0	-0.4	0.5
India	21 (1.3)	65 (2.7)	102 (3.8)	141 (4.5)	205 (6.2)	304 (8.8)	5.3	3.6	3.8	4.1	3.8
Japan	72 (4.6)	79 (3.2)	63 (2.4)	60 (1.9)	52 (1.6)	45 (1.3)	-0.4	-0.5	-1.6	-1.5	-1.2
Korea	15 (0.9)	30 (1.2)	36 (1.3)	34 (1.1)	29 (0.9)	24 (0.7)	2.9	-0.6	-1.5	-1.8	-1.3
Chinese Taipei	7 (0.5)	13 (0.5)	13 (0.5)	13 (0.4)	11 (0.3)	8 (0.2)	1.8	0.1	-1.6	-2.6	-1.4
ASEAN	33 (2.1)	86 (3.6)	120 (4.5)	169 (5.4)	204 (6.2)	236 (6.8)	4.3	3.9	1.9	1.5	2.4
Indonesia	11 (0.7)	30 (1.2)	51 (1.9)	70 (2.2)	84 (2.5)	97 (2.8)	5.2	3.4	1.8	1.5	2.2
Malaysia	5 (0.3)	15 (0.6)	17 (0.6)	25 (0.8)	24 (0.7)	23 (0.6)	4.2	4.0	-0.1	-0.7	0.9
Myanmar	0 (0.0)	1 (0.0)	2 (0.1)	3 (0.1)	4 (0.1)	6 (0.2)	4.4	5.8	4.3	3.3	4.4
Philippines	5 (0.3)	8 (0.3)	11 (0.4)	19 (0.6)	29 (0.9)	37 (1.1)	2.9	6.2	4.2	2.7	4.3
Singapore	1 (0.1)	2 (0.1)	2 (0.1)	2 (0.1)	2 (0.1)	2 (0.1)	1.7	0.0	-1.0	-1.5	-0.9
Thailand	9 (0.6)	19 (0.8)	25 (0.9)	28 (0.9)	30 (0.9)	31 (0.9)	3.3	1.3	0.6	0.3	0.7
Viet Nam	1 (0.1)	10 (0.4)	11 (0.4)	23 (0.7)	32 (1.0)	41 (1.2)	6.8	8.6	3.4	2.6	4.7
North America	531 (33.6)	655 (26.9)	660 (24.5)	647 (20.7)	588 (17.9)	531 (15.3)	0.7	-0.2	-0.9	-1.0	-0.7
United States	488 (30.9)	596 (24.5)	604 (22.4)	586 (18.8)	535 (16.2)	483 (13.9)	0.7	-0.3	-0.9	-1.0	-0.8
Latin America	104 (6.6)	197 (8.1)	205 (7.6)	246 (7.9)	263 (8.0)	282 (8.1)	2.2	2.1	0.7	0.7	1.1
Advanced Europe	269 (17.0)	335 (13.8)	338 (12.6)	313 (10.0)	254 (7.7)	217 (6.2)	0.7	-0.8	-2.1	-1.6	-1.5
European Union	220 (13.9)	279 (11.5)	274 (10.2)	251 (8.0)	205 (6.2)	175 (5.0)	0.7	-1.0	-2.0	-1.6	-1.5
Other Europe/Eurasia	170 (10.8)	145 (6.0)	156 (5.8)	142 (4.5)	135 (4.1)	129 (3.7)	-0.3	-1.1	-0.5	-0.5	-0.7
Africa	38 (2.4)	87 (3.6)	122 (4.6)	157 (5.0)	199 (6.1)	241 (6.9)	3.8	2.8	2.4	1.9	2.4
Middle East	51 (3.2)	121 (5.0)	140 (5.2)	192 (6.1)	211 (6.4)	220 (6.3)	3.3	3.5	0.9	0.4	1.6
Oceania	24 (1.5)	35 (1.4)	35 (1.3)	38 (1.2)	36 (1.1)	34 (1.0)	1.2	0.9	-0.5	-0.6	-0.1
Advanced Economies	921 (58.3)	1 151 (47.3)	1 149 (42.7)	1 109 (35.5)	974 (29.6)	862 (24.8)	0.7	-0.4	-1.3	-1.2	-1.0
Emerging Market and Developing Economies	455 (28.8)	918 (37.8)	1 227 (45.6)	1 509 (48.3)	1 697 (51.6)	1 892 (54.4)	3.3	2.3	1.2	1.1	1.5

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	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	2 390 (100)	2 968 (100)	3 360 (100)	3 462 (100)	3 548 (100)	3 724 (100)	1.1	0.3	0.2	0.5	0.4
Asia	721 (30.2)	977 (32.9)	1 222 (36.4)	1 337 (38.6)	1 463 (41.2)	1 637 (44.0)	1.7	1.0	0.9	1.1	1.0
China	351 (14.7)	413 (13.9)	629 (18.7)	703 (20.3)	767 (21.6)	838 (22.5)	1.9	1.2	0.9	0.9	1.0
India	122 (5.1)	187 (6.3)	228 (6.8)	250 (7.2)	285 (8.0)	342 (9.2)	2.0	1.0	1.3	1.8	1.4
Japan	78 (3.2)	108 (3.6)	94 (2.8)	88 (2.5)	84 (2.4)	82 (2.2)	0.6	-0.7	-0.5	-0.3	-0.5
Korea	24 (1.0)	44 (1.5)	46 (1.4)	46 (1.3)	45 (1.3)	46 (1.2)	2.0	0.0	-0.1	0.3	0.1
Chinese Taipei	7 (0.3)	12 (0.4)	13 (0.4)	13 (0.4)	14 (0.4)	14 (0.4)	2.0	0.3	0.2	0.1	0.2
ASEAN	86 (3.6)	130 (4.4)	110 (3.3)	125 (3.6)	151 (4.3)	187 (5.0)	0.8	1.4	1.9	2.1	1.8
Indonesia	44 (1.8)	59 (2.0)	38 (1.1)	41 (1.2)	52 (1.5)	67 (1.8)	-0.5	0.9	2.4	2.7	2.0
Malaysia	2 (0.1)	8 (0.3)	9 (0.3)	12 (0.3)	14 (0.4)	17 (0.4)	4.8	3.2	1.7	1.5	2.1
Myanmar	8 (0.4)	10 (0.3)	13 (0.4)	13 (0.4)	12 (0.3)	13 (0.4)	1.4	-0.5	-0.1	0.7	0.0
Philippines	10 (0.4)	11 (0.4)	16 (0.5)	18 (0.5)	23 (0.6)	29 (0.8)	1.5	1.9	2.2	2.5	2.2
Singapore	1 (0.0)	2 (0.1)	3 (0.1)	3 (0.1)	3 (0.1)	4 (0.1)	3.0	1.1	0.6	1.1	0.9
Thailand	11 (0.5)	20 (0.7)	16 (0.5)	17 (0.5)	19 (0.5)	20 (0.5)	1.2	0.9	0.7	0.8	0.8
Viet Nam	10 (0.4)	18 (0.6)	16 (0.5)	21 (0.6)	28 (0.8)	36 (1.0)	1.5	3.0	3.0	2.7	2.9
North America	456 (19.1)	572 (19.3)	570 (17.0)	555 (16.0)	546 (15.4)	554 (14.9)	0.7	-0.3	-0.2	0.1	-0.1
United States	403 (16.9)	511 (17.2)	504 (15.0)	488 (14.1)	479 (13.5)	484 (13.0)	0.7	-0.4	-0.2	0.1	-0.1
Latin America	100 (4.2)	148 (5.0)	166 (4.9)	177 (5.1)	188 (5.3)	208 (5.6)	1.6	0.7	0.6	1.0	0.8
Advanced Europe	442 (18.5)	544 (18.3)	506 (15.0)	466 (13.4)	439 (12.4)	426 (11.4)	0.4	-0.9	-0.6	-0.3	-0.6
European Union	374 (15.7)	447 (15.0)	408 (12.1)	376 (10.9)	352 (9.9)	338 (9.1)	0.3	-0.9	-0.7	-0.4	-0.6
Other Europe/Eurasia	431 (18.0)	281 (9.5)	331 (9.8)	327 (9.4)	319 (9.0)	325 (8.7)	-0.9	-0.1	-0.3	0.2	-0.1
Africa	184 (7.7)	306 (10.3)	380 (11.3)	397 (11.5)	365 (10.3)	321 (8.6)	2.4	0.5	-0.8	-1.3	-0.6
Middle East	40 (1.7)	118 (4.0)	160 (4.8)	178 (5.2)	201 (5.7)	226 (6.1)	4.6	1.2	1.2	1.2	1.2
Oceania	15 (0.6)	23 (0.8)	25 (0.7)	26 (0.8)	27 (0.8)	28 (0.8)	1.7	0.6	0.4	0.4	0.5
Advanced Economies	1 025 (42.9)	1 310 (44.1)	1 260 (37.5)	1 201 (34.7)	1 162 (32.7)	1 157 (31.1)	0.7	-0.5	-0.3	0.0	-0.3
Emerging Market and Developing Economies	1 365 (57.1)	1 658 (55.9)	2 101 (62.5)	2 261 (65.3)	2 386 (67.3)	2 567 (68.9)	1.4	0.8	0.5	0.7	0.7

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

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

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

(TWh)

							CAGR (%)				
	1990	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	9 699	17 880	24 150	29 832	35 753	42 483	3.0	2.4	1.8	1.7	2.0
	(100)	(100)	(100)	(100)	(100)	(100)					
Asia	1 823	6 677	11 896	15 826	19 281	22 549	6.2	3.2	2.0	1.6	2.2
	(18.8)	(37.3)	(49.3)	(53.0)	(53.9)	(53.1)					
China	454	3 450	7 580	9 954	11 395	12 181	9.5	3.1	1.4	0.7	1.6
	(4.7)	(19.3)	(31.4)	(33.4)	(31.9)	(28.7)					
India	212	718	1 206	2 034	3 067	4 299	5.8	6.0	4.2	3.4	4.5
	(2.2)	(4.0)	(5.0)	(6.8)	(8.6)	(10.1)					
Japan	765	1 035	932	919	946	992	0.6	-0.2	0.3	0.5	0.2
	(7.9)	(5.8)	(3.9)	(3.1)	(2.6)	(2.3)					
Korea	94	449	536	602	659	718	5.8	1.3	0.9	0.9	1.0
	(1.0)	(2.5)	(2.2)	(2.0)	(1.8)	(1.7)					
Chinese Taipei	77	218	264	295	318	335	4.1	1.2	0.8	0.5	0.8
	(0.8)	(1.2)	(1.1)	(1.0)	(0.9)	(0.8)					
ASEAN	130	601	1 018	1 513	2 124	2 895	6.9	4.5	3.4	3.1	3.7
	(1.3)	(3.4)	(4.2)	(5.1)	(5.9)	(6.8)					
Indonesia	28	147	286	445	695	1 062	7.8	5.0	4.6	4.3	4.6
	(0.3)	(0.8)	(1.2)	(1.5)	(1.9)	(2.5)					
Malaysia	20	111	155	226	298	369	6.8	4.3	2.8	2.2	3.0
	(0.2)	(0.6)	(0.6)	(0.8)	(0.8)	(0.9)					
Myanmar	2	6	17	29	50	85	7.6	6.4	5.5	5.6	5.8
	(0.0)	(0.0)	(0.1)	(0.1)	(0.1)	(0.2)					
Philippines	21	55	87	139	204	288	4.7	5.3	3.9	3.5	4.2
	(0.2)	(0.3)	(0.4)	(0.5)	(0.6)	(0.7)					
Singapore	13	42	53	61	67	73	4.7	1.6	0.9	0.8	1.1
	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)					
Thailand	38	149	191	243	300	357	5.3	2.7	2.1	1.8	2.2
	(0.4)	(0.8)	(0.8)	(0.8)	(0.8)	(0.8)					
Viet Nam	6	87	223	364	504	655	12.3	5.6	3.3	2.6	3.8
	(0.1)	(0.5)	(0.9)	(1.2)	(1.4)	(1.5)					
North America	3 051	4 265	4 362	4 722	5 215	5 917	1.2	0.9	1.0	1.3	1.1
	(31.5)	(23.9)	(18.1)	(15.8)	(14.6)	(13.9)					
United States	2 633	3 788	3 838	4 140	4 552	5 144	1.2	0.8	1.0	1.2	1.0
	(27.1)	(21.2)	(15.9)	(13.9)	(12.7)	(12.1)					
Latin America	516	1 125	1 375	1 723	2 195	2 751	3.2	2.5	2.4	2.3	2.4
	(5.3)	(6.3)	(5.7)	(5.8)	(6.1)	(6.5)					
Advanced Europe	2 248	3 106	3 151	3 383	3 600	3 944	1.1	0.8	0.6	0.9	0.8
	(23.2)	(17.4)	(13.0)	(11.3)	(10.1)	(9.3)					
European Union	1 887	2 510	2 487	2 686	2 857	3 115	0.9	0.9	0.6	0.9	0.8
	(19.5)	(14.0)	(10.3)	(9.0)	(8.0)	(7.3)					
Other Europe/Eurasia	1 448	1 193	1 349	1 476	1 790	2 331	-0.2	1.0	1.9	2.7	1.9
	(14.9)	(6.7)	(5.6)	(4.9)	(5.0)	(5.5)					
Africa	256	543	696	1 004	1 561	2 393	3.3	4.2	4.5	4.4	4.4
	(2.6)	(3.0)	(2.9)	(3.4)	(4.4)	(5.6)					
Middle East	199	719	1 066	1 390	1 761	2 207	5.6	3.0	2.4	2.3	2.5
	(2.0)	(4.0)	(4.4)	(4.7)	(4.9)	(5.2)					
Oceania	158	252	255	308	349	391	1.6	2.1	1.3	1.2	1.5
	(1.6)	(1.4)	(1.1)	(1.0)	(1.0)	(0.9)					
Advanced Economies	6 429	9 410	9 600	10 338	11 204	12 424	1.3	0.8	0.8	1.0	0.9
	(66.3)	(52.6)	(39.7)	(34.7)	(31.3)	(29.2)					
Emerging Market and Developing Economies	3 270	8 469	14 551	19 494	24 548	30 059	4.9	3.3	2.3	2.0	2.5
	(33.7)	(47.4)	(60.3)	(65.3)	(68.7)	(70.8)					

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

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

Table A16 | Electricity generated [Reference Scenario]

(TWh)

							CAGR (%)				
	1990	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	11 837 (100)	21 538 (100)	28 402 (100)	35 078 (100)	41 769 (100)	49 102 (100)	2.9	2.4	1.8	1.6	1.9
Asia	2 237 (18.9)	7 992 (37.1)	13 664 (48.1)	18 317 (52.2)	22 235 (53.2)	25 744 (52.4)	6.0	3.3	2.0	1.5	2.2
China	621 (5.2)	4 197 (19.5)	8 560 (30.1)	11 305 (32.2)	12 894 (30.9)	13 678 (27.9)	8.8	3.1	1.3	0.6	1.6
India	289 (2.4)	972 (4.5)	1 635 (5.8)	2 715 (7.7)	3 939 (9.4)	5 274 (10.7)	5.7	5.8	3.8	3.0	4.1
Japan	862 (7.3)	1 164 (5.4)	1 040 (3.7)	1 024 (2.9)	1 050 (2.5)	1 094 (2.2)	0.6	-0.2	0.3	0.4	0.2
Korea	105 (0.9)	497 (2.3)	608 (2.1)	682 (1.9)	743 (1.8)	805 (1.6)	5.8	1.3	0.9	0.8	1.0
Chinese Taipei	87 (0.7)	244 (1.1)	287 (1.0)	321 (0.9)	346 (0.8)	365 (0.7)	3.9	1.2	0.8	0.5	0.8
ASEAN	154 (1.3)	675 (3.1)	1 107 (3.9)	1 667 (4.8)	2 349 (5.6)	3 203 (6.5)	6.6	4.7	3.5	3.2	3.7
Indonesia	33 (0.3)	170 (0.8)	309 (1.1)	488 (1.4)	769 (1.8)	1 179 (2.4)	7.5	5.2	4.7	4.4	4.7
Malaysia	23 (0.2)	125 (0.6)	180 (0.6)	259 (0.7)	340 (0.8)	419 (0.9)	6.9	4.1	2.7	2.1	3.0
Myanmar	2 (0.0)	9 (0.0)	20 (0.1)	56 (0.2)	91 (0.2)	142 (0.3)	6.9	12.3	4.9	4.6	7.0
Philippines	26 (0.2)	68 (0.3)	106 (0.4)	168 (0.5)	243 (0.6)	338 (0.7)	4.6	5.2	3.8	3.3	4.1
Singapore	16 (0.1)	46 (0.2)	56 (0.2)	65 (0.2)	71 (0.2)	77 (0.2)	4.2	1.6	0.9	0.8	1.1
Thailand	44 (0.4)	159 (0.7)	177 (0.6)	219 (0.6)	268 (0.6)	317 (0.6)	4.6	2.4	2.1	1.7	2.0
Viet Nam	9 (0.1)	95 (0.4)	253 (0.9)	406 (1.2)	561 (1.3)	725 (1.5)	11.5	5.4	3.3	2.6	3.7
North America	3 685 (31.1)	4 957 (23.0)	4 997 (17.6)	5 400 (15.4)	5 940 (14.2)	6 702 (13.6)	1.0	0.9	1.0	1.2	1.0
United States	3 203 (27.1)	4 354 (20.2)	4 354 (15.3)	4 694 (13.4)	5 143 (12.3)	5 785 (11.8)	1.0	0.8	0.9	1.2	1.0
Latin America	623 (5.3)	1 406 (6.5)	1 726 (6.1)	2 131 (6.1)	2 671 (6.4)	3 281 (6.7)	3.3	2.4	2.3	2.1	2.2
Advanced Europe	2 695 (22.8)	3 623 (16.8)	3 637 (12.8)	3 897 (11.1)	4 125 (9.9)	4 487 (9.1)	1.0	0.8	0.6	0.8	0.7
European Union	2 256 (19.1)	2 955 (13.7)	2 885 (10.2)	3 198 (9.1)	3 452 (8.3)	3 818 (7.8)	0.8	1.2	0.8	1.0	1.0
Other Europe/Eurasia	1 856 (15.7)	1 689 (7.8)	1 867 (6.6)	2 007 (5.7)	2 356 (5.6)	2 946 (6.0)	0.0	0.8	1.6	2.3	1.6
Africa	309 (2.6)	686 (3.2)	885 (3.1)	1 262 (3.6)	1 919 (4.6)	2 867 (5.8)	3.4	4.0	4.3	4.1	4.1
Middle East	244 (2.1)	888 (4.1)	1 316 (4.6)	1 692 (4.8)	2 109 (5.0)	2 616 (5.3)	5.6	2.8	2.2	2.2	2.4
Oceania	187 (1.6)	298 (1.4)	310 (1.1)	372 (1.1)	416 (1.0)	459 (0.9)	1.6	2.1	1.1	1.0	1.4
Advanced Economies	7 666 (64.8)	10 867 (50.5)	10 972 (38.6)	11 799 (33.6)	12 732 (30.5)	14 035 (28.6)	1.2	0.8	0.8	1.0	0.9
Emerging Market and Developing Economies	4 171 (35.2)	10 671 (49.5)	17 430 (61.4)	23 278 (66.4)	29 037 (69.5)	35 066 (71.4)	4.7	3.3	2.2	1.9	2.4

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

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

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

(toe/person)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	1.66	1.85	1.87	1.88	1.83	1.80	0.4	0.0	-0.3	-0.1	-0.1
Asia	0.71	1.24	1.50	1.62	1.67	1.71	2.5	0.9	0.3	0.3	0.5
China	0.77	1.90	2.65	2.83	2.81	2.69	4.1	0.8	-0.1	-0.4	0.1
India	0.32	0.54	0.67	0.85	1.02	1.23	2.4	2.6	1.9	1.9	2.1
Japan	3.54	3.90	3.18	3.15	3.10	3.14	-0.3	-0.1	-0.2	0.1	0.0
Korea	2.17	5.05	5.64	5.77	5.83	6.01	3.1	0.3	0.1	0.3	0.2
Chinese Taipei	2.50	5.13	5.22	5.14	5.06	4.98	2.4	-0.2	-0.1	-0.2	-0.2
ASEAN	0.54	0.93	1.04	1.34	1.59	1.82	2.1	2.8	1.8	1.3	1.9
Indonesia	0.54	0.84	0.86	1.20	1.53	1.81	1.5	3.8	2.4	1.7	2.6
Malaysia	1.21	2.52	2.83	3.50	3.72	3.78	2.8	2.4	0.6	0.2	1.0
Myanmar	0.27	0.28	0.40	0.49	0.60	0.76	1.3	2.4	2.0	2.4	2.2
Philippines	0.43	0.44	0.54	0.64	0.75	0.84	0.7	2.0	1.5	1.2	1.6
Singapore	3.78	4.76	6.46	6.56	6.67	6.92	1.7	0.2	0.2	0.4	0.2
Thailand	0.77	1.73	1.81	2.03	2.32	2.63	2.8	1.3	1.3	1.3	1.3
Viet Nam	0.27	0.67	0.98	1.47	1.88	2.27	4.3	4.7	2.5	1.9	3.0
North America	7.67	7.20	6.56	6.07	5.47	5.11	-0.5	-0.9	-1.0	-0.7	-0.9
United States	7.67	7.16	6.44	5.90	5.25	4.88	-0.6	-1.0	-1.2	-0.7	-1.0
Latin America	1.07	1.35	1.26	1.33	1.41	1.53	0.5	0.6	0.6	0.8	0.7
Advanced Europe	3.25	3.29	2.92	2.63	2.42	2.32	-0.4	-1.1	-0.8	-0.4	-0.8
European Union	3.43	3.46	3.10	2.86	2.64	2.55	-0.3	-0.9	-0.8	-0.4	-0.7
Other Europe/Eurasia	4.50	3.35	3.59	3.50	3.58	3.82	-0.7	-0.3	0.2	0.7	0.2
Africa	0.63	0.67	0.63	0.59	0.54	0.51	0.0	-0.8	-0.8	-0.6	-0.7
Middle East	1.67	2.95	3.07	3.28	3.29	3.31	2.0	0.7	0.0	0.0	0.3
Oceania	4.85	5.46	4.87	4.57	4.22	3.97	0.0	-0.7	-0.8	-0.6	-0.7
Advanced Economies	4.48	4.70	4.29	4.02	3.74	3.60	-0.1	-0.7	-0.7	-0.4	-0.6
Emerging Market and Developing Economies	0.95	1.23	1.39	1.45	1.45	1.46	1.2	0.4	0.0	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/$2015 million)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	244	198	171	145	116	95	-1.1	-1.8	-2.2	-2.0	-2.0
Asia	312	268	217	177	132	101	-1.2	-2.2	-2.9	-2.6	-2.6
China	850	336	237	178	119	81	-4.0	-3.1	-3.9	-3.8	-3.6
India	590	426	339	269	198	151	-1.8	-2.6	-3.0	-2.7	-2.8
Japan	124	118	90	79	67	59	-1.0	-1.4	-1.7	-1.3	-1.5
Korea	231	198	172	144	116	98	-0.9	-2.0	-2.1	-1.7	-1.9
Chinese Taipei	315	256	186	150	119	97	-1.7	-2.4	-2.3	-2.0	-2.2
ASEAN	317	275	225	204	168	139	-1.1	-1.1	-1.9	-1.9	-1.6
Indonesia	365	310	221	211	177	144	-1.6	-0.5	-1.8	-2.1	-1.5
Malaysia	284	312	268	240	194	157	-0.2	-1.2	-2.1	-2.1	-1.8
Myanmar	1 489	318	323	323	260	220	-4.8	0.0	-2.2	-1.7	-1.3
Philippines	249	182	161	127	103	90	-1.4	-2.6	-2.1	-1.3	-2.0
Singapore	163	98	98	84	73	66	-1.6	-1.6	-1.4	-1.0	-1.3
Thailand	294	340	296	252	205	168	0.0	-1.8	-2.1	-2.0	-1.9
Viet Nam	397	330	286	256	200	161	-1.0	-1.2	-2.4	-2.2	-2.0
North America	200	139	109	90	69	56	-1.9	-2.2	-2.6	-2.1	-2.3
United States	195	135	104	84	64	51	-2.0	-2.3	-2.7	-2.2	-2.4
Latin America	180	163	154	138	115	99	-0.5	-1.2	-1.8	-1.6	-1.5
Advanced Europe	141	109	86	67	53	45	-1.6	-2.8	-2.2	-1.8	-2.2
European Union	158	118	95	74	59	50	-1.6	-2.6	-2.2	-1.7	-2.2
Other Europe/Eurasia	826	532	466	386	315	270	-1.8	-2.1	-2.0	-1.5	-1.9
Africa	424	343	320	255	177	128	-0.9	-2.5	-3.6	-3.2	-3.1
Middle East	245	314	311	283	241	205	0.8	-1.0	-1.6	-1.6	-1.4
Oceania	150	118	95	79	62	50	-1.5	-2.0	-2.4	-2.1	-2.2
Advanced Economies	164	126	101	82	65	54	-1.6	-2.3	-2.3	-1.9	-2.2
Emerging Market and Developing Economies	470	318	262	212	157	121	-1.9	-2.3	-2.9	-2.6	-2.6

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	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	20 522 (100)	30 703 (100)	33 568 (100)	34 019 (100)	33 905 (100)	33 922 (100)	1.6	0.1	0.0	0.0	0.0
Asia	4 700 (22.9)	13 032 (42.4)	16 776 (50.0)	17 635 (51.8)	17 515 (51.7)	17 000 (50.1)	4.2	0.6	-0.1	-0.3	0.0
China	2 195 (10.7)	8 110 (26.4)	10 649 (31.7)	10 454 (30.7)	8 925 (26.3)	6 874 (20.3)	5.2	-0.2	-1.6	-2.6	-1.5
India	531 (2.6)	1 588 (5.2)	2 279 (6.8)	2 976 (8.7)	3 810 (11.2)	4 786 (14.1)	4.8	3.0	2.5	2.3	2.6
Japan	1 056 (5.1)	1 137 (3.7)	998 (3.0)	794 (2.3)	685 (2.0)	607 (1.8)	-0.2	-2.5	-1.5	-1.2	-1.7
Korea	208 (1.0)	528 (1.7)	559 (1.7)	537 (1.6)	522 (1.5)	495 (1.5)	3.2	-0.4	-0.3	-0.5	-0.4
Chinese Taipei	109 (0.5)	254 (0.8)	267 (0.8)	270 (0.8)	247 (0.7)	216 (0.6)	2.9	0.1	-0.9	-1.3	-0.7
ASEAN	350 (1.7)	1 069 (3.5)	1 517 (4.5)	1 979 (5.8)	2 465 (7.3)	2 891 (8.5)	4.8	3.0	2.2	1.6	2.2
Indonesia	131 (0.6)	397 (1.3)	557 (1.7)	742 (2.2)	989 (2.9)	1 226 (3.6)	4.8	3.3	2.9	2.2	2.8
Malaysia	50 (0.2)	185 (0.6)	226 (0.7)	289 (0.8)	309 (0.9)	315 (0.9)	5.0	2.8	0.7	0.2	1.1
Myanmar	4 (0.0)	8 (0.0)	28 (0.1)	54 (0.2)	83 (0.2)	119 (0.4)	6.4	7.8	4.4	3.7	5.2
Philippines	35 (0.2)	75 (0.2)	132 (0.4)	184 (0.5)	253 (0.7)	315 (0.9)	4.3	3.8	3.2	2.2	3.0
Singapore	29 (0.1)	51 (0.2)	46 (0.1)	48 (0.1)	49 (0.1)	49 (0.1)	1.5	0.6	0.3	0.0	0.3
Thailand	80 (0.4)	223 (0.7)	235 (0.7)	248 (0.7)	254 (0.8)	244 (0.7)	3.5	0.6	0.3	-0.4	0.1
Viet Nam	16 (0.1)	122 (0.4)	285 (0.8)	404 (1.2)	518 (1.5)	615 (1.8)	9.6	4.0	2.5	1.7	2.7
North America	5 126 (25.0)	5 698 (18.6)	5 055 (15.1)	4 383 (12.9)	3 674 (10.8)	3 085 (9.1)	0.0	-1.6	-1.7	-1.7	-1.7
United States	4 740 (23.1)	5 204 (17.0)	4 549 (13.6)	3 859 (11.3)	3 132 (9.2)	2 529 (7.5)	-0.1	-1.8	-2.1	-2.1	-2.0
Latin America	867 (4.2)	1 524 (5.0)	1 453 (4.3)	1 519 (4.5)	1 730 (5.1)	1 939 (5.7)	1.7	0.5	1.3	1.1	1.0
Advanced Europe	3 944 (19.2)	3 823 (12.5)	3 242 (9.7)	2 467 (7.3)	2 027 (6.0)	1 827 (5.4)	-0.6	-3.0	-1.9	-1.0	-2.0
European Union	3 464 (16.9)	3 135 (10.2)	2 579 (7.7)	1 724 (5.1)	1 419 (4.2)	1 274 (3.8)	-0.9	-4.4	-1.9	-1.1	-2.4
Other Europe/Eurasia	3 878 (18.9)	2 511 (8.2)	2 584 (7.7)	2 424 (7.1)	2 454 (7.2)	2 662 (7.8)	-1.3	-0.7	0.1	0.8	0.1
Africa	524 (2.6)	1 008 (3.3)	1 218 (3.6)	1 463 (4.3)	1 876 (5.5)	2 375 (7.0)	2.8	2.1	2.5	2.4	2.3
Middle East	569 (2.8)	1 553 (5.1)	1 862 (5.5)	2 192 (6.4)	2 393 (7.1)	2 542 (7.5)	3.9	1.8	0.9	0.6	1.1
Oceania	279 (1.4)	421 (1.4)	392 (1.2)	360 (1.1)	341 (1.0)	328 (1.0)	1.1	-1.0	-0.5	-0.4	-0.6
Advanced Economies	10 784 (52.5)	11 954 (38.9)	10 593 (31.6)	8 898 (26.2)	7 584 (22.4)	6 646 (19.6)	-0.1	-1.9	-1.6	-1.3	-1.6
Emerging Market and Developing Economies	9 102 (44.4)	17 615 (57.4)	21 990 (65.5)	23 544 (69.2)	24 426 (72.0)	25 113 (74.0)	2.9	0.8	0.4	0.3	0.5

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	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	8 754	10 026	12 850	14 759	15 968	16 722	17 449	100	100	100	1.7	0.9	0.4	0.6
Coal	2 223	2 318	3 662	4 016	3 784	3 492	3 186	25	27	18	1.9	-0.7	-0.9	-0.8
Oil	3 237	3 684	4 155	4 352	4 727	4 887	5 001	37	29	29	1.0	0.9	0.3	0.5
Natural gas	1 662	2 068	2 734	3 487	3 660	4 025	4 519	19	24	26	2.4	0.5	1.1	0.9
Nuclear	526	675	719	732	842	878	915	6.0	5.0	5.2	1.1	1.6	0.4	0.8
Hydro	184	225	296	369	416	461	505	2.1	2.5	2.9	2.3	1.3	1.0	1.1
Geothermal	34	52	62	111	210	269	298	0.4	0.8	1.7	3.9	7.4	1.7	3.5
Solar, wind, etc.	2.5	8.2	48	291	769	1 208	1 612	0.0	2.0	9.2	16.5	11.4	3.8	6.1
Biomass and waste	885	994	1 173	1 397	1 556	1 499	1 412	10	9.5	8.1	1.5	1.2	-0.5	0.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	6 242	7 012	8 829	10 082	11 014	11 618	12 194	100	100	100	1.6	1.0	0.5	0.7
Industry	1 797	1 869	2 643	3 037	3 326	3 565	3 673	29	30	30	1.7	1.0	0.5	0.7
Transport	1 578	1 966	2 430	2 690	3 127	3 291	3 476	25	27	29	1.7	1.7	0.5	0.9
Buildings, etc.	2 390	2 561	2 968	3 360	3 462	3 548	3 724	38	33	31	1.1	0.3	0.4	0.4
Non-energy use	477	616	788	995	1 100	1 214	1 322	7.6	9.9	11	2.4	1.1	0.9	1.0
Coal	751	542	1 061	913	843	803	766	12	9.1	6.3	0.6	-0.9	-0.5	-0.6
Oil	2 608	3 130	3 621	3 926	4 331	4 505	4 640	42	39	38	1.3	1.1	0.3	0.6
Natural gas	945	1 120	1 344	1 710	1 787	1 870	1 925	15	17	16	1.9	0.5	0.4	0.4
Electricity	834	1 087	1 538	2 077	2 566	3 075	3 654	13	21	30	3.0	2.4	1.8	2.0
Heat	336	248	275	347	370	359	331	5.4	3.4	2.7	0.1	0.7	-0.6	-0.2
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	0.8	n.a.
Renewables	768	886	990	1 109	1 117	1 006	879	12	11	7.2	1.2	0.1	-1.2	-0.8

Electricity generation

	(TWh)							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	11 837	15 423	21 538	28 402	35 078	41 769	49 102	100	100	100	2.9	2.4	1.7	1.9
Coal	4 430	5 995	8 674	10 252	9 831	9 083	8 460	37	36	17	2.7	-0.5	-0.7	-0.7
Oil	1 317	1 184	963	723	565	497	396	11	2.5	0.8	-1.9	-2.7	-1.8	-2.1
Natural gas	1 748	2 772	4 856	6 556	6 876	8 550	11 332	15	23	23	4.4	0.5	2.5	1.9
Nuclear	2 013	2 591	2 756	2 808	3 233	3 371	3 511	17	9.9	7.2	1.1	1.6	0.4	0.8
Hydro	2 139	2 611	3 447	4 293	4 835	5 364	5 871	18	15	12	2.3	1.3	1.0	1.1
Geothermal	36	52	68	96	180	228	255	0.3	0.3	0.5	3.2	7.3	1.7	3.4
Solar PV	0.1	0.8	32	1 020	3 905	6 627	8 884	0.0	3.6	18	35.1	16.1	4.2	7.7
Wind	3.9	31	342	1 864	4 278	6 370	8 416	0.0	6.6	17	22.0	9.7	3.4	5.3
CSP and marine	1.2	1.1	2.2	16	96	180	307	0.0	0.1	0.6	8.6	22.4	6.0	10.8
Biomass and waste	130	163	362	735	1 238	1 460	1 630	1.1	2.6	3.3	5.7	6.0	1.4	2.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	22	35	39	39	39	39	0.2	0.1	0.1	2.2	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	35 916	48 229	64 773	86 438	109 746	144 034	184 046	2.9	2.7	2.6	2.6
Population (million)	5 286	6 135	6 960	7 877	8 511	9 155	9 680	1.3	0.9	0.6	0.7
CO_2 emissions (Mt)	20 522	23 175	30 703	33 568	34 019	33 905	33 922	1.6	0.1	0.0	0.0
GDP per capita ($2015 thousand)	6.8	7.9	9.3	11	13	16	19	1.6	1.8	2.0	1.9
Primary energy consump. per capita (toe)	1.7	1.6	1.8	1.9	1.9	1.8	1.8	0.4	0.0	-0.2	-0.1
Primary energy consumption per GDP[*2]	244	208	198	171	145	116	95	-1.1	-1.8	-2.1	-2.0
CO_2 emissions per GDP[*3]	571	481	474	388	310	235	184	-1.2	-2.5	-2.6	-2.5
CO_2 per primary energy consumption[*4]	2.3	2.3	2.4	2.3	2.1	2.0	1.9	-0.1	-0.7	-0.5	-0.5

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A21 | Asia [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	2 088	2 867	4 803	6 439	7 310	7 823	8 179	100	100	100	3.7	1.4	0.6	0.8
Coal	789	1 038	2 416	3 142	3 150	2 941	2 638	38	49	32	4.6	0.0	-0.9	-0.6
Oil	618	918	1 172	1 491	1 634	1 763	1 889	30	23	23	2.9	1.0	0.7	0.8
Natural gas	116	233	455	722	923	1 128	1 317	5.5	11	16	6.1	2.8	1.8	2.1
Nuclear	77	132	152	189	279	340	399	3.7	2.9	4.9	3.0	4.4	1.8	2.6
Hydro	32	41	92	157	180	207	230	1.5	2.4	2.8	5.3	1.5	1.2	1.3
Geothermal	8.2	23	31	64	133	173	187	0.4	1.0	2.3	6.8	8.5	1.7	3.8
Solar, wind, etc.	1.3	2.1	16	142	371	616	845	0.1	2.2	10	16.4	11.3	4.2	6.3
Biomass and waste	448	480	469	530	638	654	672	21	8.2	8.2	0.5	2.1	0.3	0.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 534	1 976	3 166	4 131	4 653	5 071	5 464	100	100	100	3.2	1.3	0.8	1.0
Industry	508	654	1 405	1 750	1 930	2 065	2 116	33	42	39	4.1	1.1	0.5	0.7
Transport	189	323	493	719	884	984	1 101	12	17	20	4.4	2.3	1.1	1.5
Buildings, etc.	721	818	977	1 222	1 337	1 463	1 637	47	30	30	1.7	1.0	1.0	1.0
Non-energy use	115	181	291	439	502	559	610	7.5	11	11	4.4	1.5	1.0	1.1
Coal	423	373	897	762	703	671	645	28	18	12	1.9	-0.9	-0.4	-0.6
Oil	465	743	993	1 343	1 488	1 614	1 739	30	33	32	3.5	1.1	0.8	0.9
Natural gas	46	89	201	392	459	516	558	3.0	9.5	10	7.1	1.8	1.0	1.2
Electricity	157	279	574	1 023	1 361	1 658	1 939	10	25	35	6.2	3.2	1.8	2.2
Heat	14	30	69	157	185	183	169	0.9	3.8	3.1	8.1	1.9	-0.5	0.3
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	0.0	n.a.
Renewables	429	462	433	454	456	429	414	28	11	7.6	0.2	0.0	-0.5	-0.3

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	2 237	3 971	7 992	13 664	18 317	22 235	25 744	100	100	100	6.0	3.3	1.7	2.2
Coal	868	1 984	4 780	7 824	8 250	7 788	7 079	39	57	27	7.4	0.6	-0.8	-0.3
Oil	433	381	260	130	98	92	84	19	1.0	0.3	-3.8	-3.1	-0.8	-1.5
Natural gas	237	566	1 096	1 466	2 100	2 949	3 916	11	11	15	6.1	4.1	3.2	3.4
Nuclear	294	505	582	727	1 071	1 303	1 533	13	5.3	6.0	3.0	4.4	1.8	2.6
Hydro	368	478	1 072	1 825	2 091	2 407	2 678	16	13	10	5.3	1.5	1.2	1.3
Geothermal	8.4	20	22	30	76	99	108	0.4	0.2	0.4	4.2	10.8	1.8	4.5
Solar PV	0.1	0.4	5.2	560	2 069	3 639	5 073	0.0	4.1	20	33.6	15.6	4.6	7.9
Wind	0.0	2.4	70	761	1 878	3 108	4 284	0.0	5.6	17	38.1	10.6	4.2	6.1
CSP and marine	0.0	0.0	0.0	2.5	11	17	32	0.0	0.0	0.1	20.8	17.5	5.6	9.2
Biomass and waste	9.0	15	82	315	651	810	935	0.4	2.3	3.6	12.2	8.4	1.8	3.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	20	21	23	23	23	23	0.9	0.2	0.1	0.5	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	6 690	10 397	17 895	29 673	41 194	59 070	80 738	4.9	3.7	3.4	3.5
Population (million)	2 955	3 454	3 874	4 284	4 507	4 686	4 772	1.2	0.6	0.3	0.4
CO_2 emissions (Mt)	4 700	6 817	13 032	16 776	17 635	17 515	17 000	4.2	0.6	-0.2	0.0
GDP per capita ($2015 thousand)	2.3	3.0	4.6	6.9	9.1	13	17	3.7	3.1	3.1	3.1
Primary energy consump. per capita (toe)	0.7	0.8	1.2	1.5	1.6	1.7	1.7	2.5	0.9	0.3	0.5
Primary energy consumption per GDP*2	312	276	268	217	177	132	101	-1.2	-2.2	-2.8	-2.6
CO_2 emissions per GDP*3	703	656	728	565	428	297	211	-0.7	-3.0	-3.5	-3.3
CO_2 per primary energy consumption*4	2.3	2.4	2.7	2.6	2.4	2.2	2.1	0.5	-0.9	-0.7	-0.8

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A22 | China [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	874	1 133	2 536	3 738	3 977	3 837	3 514	100	100	100	4.8	0.7	-0.6	-0.2
Coal	531	668	1 790	2 266	2 143	1 763	1 290	61	61	37	4.8	-0.6	-2.5	-1.9
Oil	119	221	428	678	682	654	607	14	18	17	5.8	0.1	-0.6	-0.4
Natural gas	13	21	89	299	391	433	423	1.5	8.0	12	10.7	3.0	0.4	1.2
Nuclear	-	4.4	19	106	147	193	237	-	2.8	6.7	n.a.	3.7	2.4	2.8
Hydro	11	19	61	112	121	135	145	1.2	3.0	4.1	7.8	0.9	0.9	0.9
Geothermal	-	1.7	3.6	24	28	30	31	-	0.6	0.9	n.a.	1.7	0.6	0.9
Solar, wind, etc.	0.0	1.0	12	111	275	440	589	0.0	3.0	17	29.9	10.6	3.9	5.9
Biomass and waste	200	198	133	144	192	191	193	23	3.9	5.5	-1.1	3.3	0.0	1.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	658	781	1 645	2 317	2 451	2 435	2 357	100	100	100	4.1	0.6	-0.2	0.1
Industry	234	302	924	1 129	1 100	1 011	876	36	49	37	5.2	-0.3	-1.1	-0.9
Transport	30	83	195	346	420	422	406	4.6	15	17	8.2	2.2	-0.2	0.5
Buildings, etc.	351	339	413	629	703	767	838	53	27	36	1.9	1.2	0.9	1.0
Non-energy use	43	58	113	212	227	235	237	6.5	9.2	10	5.3	0.7	0.2	0.4
Coal	311	274	712	542	437	347	277	47	23	12	1.8	-2.4	-2.2	-2.3
Oil	85	180	369	619	625	602	562	13	27	24	6.6	0.1	-0.5	-0.3
Natural gas	8.9	12	73	223	242	241	228	1.3	9.6	9.7	11.0	0.9	-0.3	0.1
Electricity	39	89	297	652	856	980	1 048	5.9	28	44	9.5	3.1	1.0	1.6
Heat	13	26	62	147	176	174	159	2.0	6.4	6.8	8.1	2.0	-0.5	0.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	200	199	132	133	115	93	84	30	5.8	3.6	-1.3	-1.6	-1.6	-1.6

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	621	1 356	4 197	8 560	11 305	12 894	13 678	100	100	100	8.8	3.1	1.0	1.6
Coal	441	1 060	3 240	5 417	5 505	4 571	3 285	71	63	24	8.4	0.2	-2.5	-1.7
Oil	50	47	15	11	9.8	6.3	3.0	8.1	0.1	0.0	-4.7	-1.7	-5.7	-4.5
Natural gas	2.8	5.8	78	268	561	763	787	0.4	3.1	5.8	15.9	8.6	1.7	3.8
Nuclear	-	17	74	408	564	739	910	-	4.8	6.7	n.a.	3.7	2.4	2.8
Hydro	127	222	711	1 300	1 406	1 566	1 684	20	15	12	7.8	0.9	0.9	0.9
Geothermal	0.1	0.1	0.1	0.1	1.1	1.5	1.6	0.0	0.0	0.0	2.6	27.9	1.6	9.1
Solar PV	0.0	0.0	0.7	327	1 275	2 112	2 813	0.0	3.8	21	47.3	16.3	4.0	7.7
Wind	0.0	0.6	45	656	1 591	2 654	3 649	0.0	7.7	27	50.6	10.3	4.2	6.1
CSP and marine	0.0	0.0	0.0	2.0	4.1	6.3	14	0.0	0.0	0.1	20.0	8.2	6.2	6.8
Biomass and waste	-	2.4	34	170	388	476	532	-	2.0	3.9	n.a.	9.6	1.6	4.0
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	1 027	2 770	7 554	15 802	22 368	32 274	43 522	9.2	3.9	3.4	3.6
Population (million)	1 135	1 263	1 338	1 412	1 404	1 367	1 305	0.7	-0.1	-0.4	-0.3
CO_2 emissions (Mt)	2 195	3 209	8 110	10 649	10 454	8 925	6 874	5.2	-0.2	-2.1	-1.5
GDP per capita ($2015 thousand)	0.9	2.2	5.6	11	16	24	33	8.4	4.0	3.8	3.8
Primary energy consump. per capita (toe)	0.8	0.9	1.9	2.6	2.8	2.8	2.7	4.1	0.8	-0.3	0.1
Primary energy consumption per GDP[*2]	850	409	336	237	178	119	81	-4.0	-3.1	-3.9	-3.6
CO_2 emissions per GDP[*3]	2 137	1 158	1 074	674	467	277	158	-3.7	-4.0	-5.3	-4.9
CO_2 per primary energy consumption[*4]	2.5	2.8	3.2	2.8	2.6	2.3	2.0	0.4	-0.9	-1.5	-1.3

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A23 | India [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	280	418	667	944	1 280	1 645	2 054	100	100	100	4.0	3.4	2.4	2.7
Coal	93	146	279	421	533	644	767	33	45	37	5.0	2.6	1.8	2.1
Oil	61	112	162	223	295	407	548	22	24	27	4.3	3.1	3.1	3.1
Natural gas	11	23	54	55	94	150	215	3.8	5.8	10	5.5	6.1	4.2	4.8
Nuclear	1.6	4.4	6.8	12	36	47	61	0.6	1.3	3.0	6.8	12.8	2.6	5.7
Hydro	6.2	6.4	11	14	20	27	34	2.2	1.5	1.6	2.7	3.9	2.7	3.1
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	0.0	0.2	2.0	15	53	113	169	0.0	1.5	8.2	26.3	15.3	6.0	8.8
Biomass and waste	108	126	152	204	249	257	261	39	22	13	2.1	2.3	0.2	0.9
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	215	290	443	632	846	1 110	1 413	100	100	100	3.5	3.3	2.6	2.8
Industry	59	85	158	247	379	515	627	27	39	44	4.7	4.9	2.5	3.3
Transport	21	32	65	102	141	205	304	9.6	16	22	5.3	3.6	3.9	3.8
Buildings, etc.	122	147	187	228	250	285	342	57	36	24	2.0	1.0	1.6	1.4
Non-energy use	13	27	34	55	76	105	139	6.2	8.8	9.9	4.7	3.6	3.1	3.2
Coal	38	33	87	107	138	180	218	18	17	15	3.4	2.9	2.3	2.5
Oil	50	94	138	205	275	381	516	23	32	37	4.6	3.3	3.2	3.2
Natural gas	6.1	12	19	38	57	87	118	2.8	6.0	8.4	6.1	4.7	3.7	4.0
Electricity	18	32	62	104	175	264	370	8.5	16	26	5.8	6.0	3.8	4.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	102	119	138	179	202	199	191	48	28	13	1.8	1.4	-0.3	0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	289	561	972	1 635	2 715	3 939	5 274	100	100	100	5.7	5.8	3.4	4.1
Coal	189	387	658	1 170	1 503	1 756	2 088	65	72	40	6.1	2.8	1.7	2.0
Oil	13	25	19	4.5	1.4	-	-	4.3	0.3	-	-3.2	-12.5	-100	-100
Natural gas	10.0	56	107	62	176	309	505	3.4	3.8	9.6	6.1	12.4	5.4	7.5
Nuclear	6.1	17	26	47	140	179	234	2.1	2.9	4.4	6.8	12.8	2.6	5.7
Hydro	72	74	125	162	230	309	391	25	9.9	7.4	2.7	3.9	2.7	3.1
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	0.0	0.1	76	452	1 055	1 589	-	4.6	30	n.a.	22.0	6.5	11.1
Wind	0.0	1.7	20	77	126	214	320	0.0	4.7	6.1	28.6	5.6	4.8	5.0
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	37	82	110	139	-	2.3	2.6	n.a.	9.3	2.6	4.7
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	475	817	1 567	2 782	4 761	8 307	13 614	5.9	6.2	5.4	5.6
Population (million)	870	1 060	1 241	1 408	1 514	1 613	1 674	1.6	0.8	0.5	0.6
CO_2 emissions (Mt)	531	892	1 588	2 279	2 976	3 810	4 786	4.8	3.0	2.4	2.6
GDP per capita ($2015 thousand)	0.5	0.8	1.3	2.0	3.1	5.1	8.1	4.2	5.3	4.9	5.0
Primary energy consump. per capita (toe)	0.3	0.4	0.5	0.7	0.8	1.0	1.2	2.4	2.6	1.9	2.1
Primary energy consumption per GDP[*2]	590	512	426	339	269	198	151	-1.8	-2.6	-2.8	-2.8
CO_2 emissions per GDP[*3]	1 119	1 092	1 013	819	625	459	352	-1.0	-3.0	-2.8	-2.9
CO_2 per primary energy consumption[*4]	1.9	2.1	2.4	2.4	2.3	2.3	2.3	0.8	-0.4	0.0	-0.1

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A24 | Japan [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	437	516	500	400	376	348	329	100	100	100	-0.3	-0.7	-0.7	-0.7
Coal	77	97	115	109	77	65	57	18	27	17	1.1	-3.8	-1.5	-2.2
Oil	249	253	201	151	134	115	100	57	38	30	-1.6	-1.3	-1.5	-1.4
Natural gas	44	66	86	87	72	69	68	10	22	21	2.2	-2.0	-0.3	-0.8
Nuclear	53	84	75	18	41	37	37	12	4.6	11	-3.3	9.3	-0.6	2.4
Hydro	7.6	7.2	7.2	6.8	7.9	8.3	8.4	1.7	1.7	2.6	-0.4	1.7	0.3	0.8
Geothermal	1.6	3.1	2.4	2.7	4.4	5.5	6.3	0.4	0.7	1.9	1.8	5.5	1.8	2.9
Solar, wind, etc.	1.2	0.9	1.1	8.4	15	19	20	0.3	2.1	6.1	6.4	6.4	1.6	3.1
Biomass and waste	4.2	5.0	11	17	26	29	33	1.0	4.2	9.9	4.6	4.8	1.2	2.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	290	336	314	267	253	234	218	100	100	100	-0.3	-0.6	-0.7	-0.7
Industry	108	103	92	80	75	69	64	37	30	29	-1.0	-0.8	-0.8	-0.8
Transport	72	89	79	63	60	52	45	25	24	20	-0.4	-0.5	-1.5	-1.2
Buildings, etc.	78	108	108	94	88	84	82	27	35	37	0.6	-0.7	-0.4	-0.5
Non-energy use	32	36	35	30	30	29	29	11	11	13	-0.2	-0.2	-0.2	-0.2
Coal	27	21	23	20	18	16	14	9.3	7.5	6.2	-1.0	-1.4	-1.3	-1.3
Oil	180	205	166	132	123	106	92	62	49	42	-1.0	-0.8	-1.4	-1.2
Natural gas	14	21	29	28	26	24	21	4.7	11	9.8	2.4	-0.7	-1.1	-0.9
Electricity	66	84	89	80	79	81	85	23	30	39	0.6	-0.2	0.4	0.2
Heat	0.2	0.5	0.6	0.5	0.5	0.4	0.3	0.1	0.2	0.1	3.1	-0.7	-2.4	-1.9
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	0.0	n.a.
Renewables	3.8	4.1	6.1	6.5	6.5	6.1	5.7	1.3	2.4	2.6	1.8	-0.1	-0.7	-0.5

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	862	1 055	1 164	1 040	1 024	1 050	1 094	100	100	100	0.6	-0.2	0.3	0.2
Coal	125	228	317	322	183	146	124	14	31	11	3.1	-6.1	-2.0	-3.2
Oil	250	133	91	39	13	4.1	-	29	3.8	-	-5.8	-11.6	-100	-100
Natural gas	168	255	332	359	285	294	323	19	35	29	2.5	-2.5	0.6	-0.4
Nuclear	202	322	288	71	157	141	141	23	6.8	13	-3.3	9.3	-0.6	2.4
Hydro	88	84	84	79	92	96	98	10	7.6	8.9	-0.4	1.7	0.3	0.8
Geothermal	1.7	3.3	2.6	3.0	5.0	6.2	7.2	0.2	0.3	0.7	1.8	5.7	1.9	3.1
Solar PV	0.1	0.4	3.5	86	126	152	156	0.0	8.3	14	26.0	4.3	1.1	2.1
Wind	-	0.1	4.0	9.4	43	65	78	-	0.9	7.2	n.a.	18.5	3.0	7.6
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	8.1	9.2	21	53	101	126	150	0.9	5.1	14	6.2	7.5	2.0	3.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	20	21	18	18	18	18	2.3	1.7	1.6	-0.3	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	3 510	3 987	4 219	4 435	4 744	5 178	5 607	0.8	0.8	0.8	0.8
Population (million)	123	127	128	126	120	112	105	0.1	-0.6	-0.7	-0.6
CO_2 emissions (Mt)	1 056	1 161	1 137	998	794	685	607	-0.2	-2.5	-1.3	-1.7
GDP per capita ($2015 thousand)	28	31	33	35	40	46	54	0.7	1.3	1.5	1.4
Primary energy consump. per capita (toe)	3.5	4.1	3.9	3.2	3.1	3.1	3.1	-0.3	-0.1	0.0	0.0
Primary energy consumption per GDP[*2]	124	129	118	90	79	67	59	-1.0	-1.4	-1.5	-1.5
CO_2 emissions per GDP[*3]	301	291	270	225	167	132	108	-0.9	-3.2	-2.1	-2.5
CO_2 per primary energy consumption[*4]	2.4	2.3	2.3	2.5	2.1	2.0	1.8	0.1	-1.9	-0.7	-1.0

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A25 | Korea [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	93	187	250	292	296	288	276	100	100	100	3.8	0.2	-0.3	-0.2
Coal	25	40	73	75	75	73	66	27	26	24	3.6	0.0	-0.6	-0.4
Oil	50	99	95	112	109	101	92	54	38	33	2.6	-0.2	-0.9	-0.7
Natural gas	2.7	17	39	54	52	60	68	2.9	19	25	10.1	-0.5	1.4	0.8
Nuclear	14	28	39	41	42	35	28	15	14	10.0	3.6	0.2	-2.1	-1.4
Hydro	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.6	0.1	0.1	-2.3	1.7	0.0	0.5
Geothermal	-	-	0.0	0.3	0.4	0.4	0.4	-	0.1	0.1	n.a.	4.6	0.2	1.6
Solar, wind, etc.	0.0	0.0	0.2	2.8	7.5	9.0	11	0.0	0.9	3.9	19.9	11.8	1.9	4.8
Biomass and waste	0.7	1.4	3.5	6.3	8.7	9.5	9.9	0.8	2.2	3.6	7.2	3.7	0.6	1.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	65	127	158	182	185	181	174	100	100	100	3.4	0.2	-0.3	-0.2
Industry	19	38	45	47	50	50	47	30	26	27	2.9	0.7	-0.3	0.0
Transport	15	26	30	36	34	29	24	22	20	14	2.9	-0.6	-1.7	-1.3
Buildings, etc.	24	37	44	46	46	45	46	38	25	27	2.0	0.0	0.1	0.1
Non-energy use	6.7	25	38	53	55	57	56	10	29	32	6.9	0.4	0.1	0.2
Coal	12	9.1	9.5	7.1	6.4	5.7	4.6	18	3.9	2.6	-1.6	-1.0	-1.7	-1.5
Oil	44	80	82	97	95	89	80	67	54	46	2.6	-0.2	-0.9	-0.7
Natural gas	0.7	11	21	22	22	21	19	1.0	12	11	11.9	0.0	-0.8	-0.5
Electricity	8.1	23	39	46	52	57	62	13	25	36	5.8	1.3	0.9	1.0
Heat	-	3.3	4.3	5.5	5.3	4.9	4.4	-	3.0	2.5	n.a.	-0.5	-1.0	-0.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	0.7	1.3	2.7	3.9	4.4	4.5	4.5	1.1	2.1	2.6	5.5	1.3	0.2	0.5

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	105	289	497	608	682	743	805	100	100	100	5.8	1.3	0.8	1.0
Coal	18	111	219	208	221	227	217	17	34	27	8.3	0.7	-0.1	0.1
Oil	19	35	19	8.2	4.5	-	-	18	1.3	-	-2.7	-6.4	-100	-100
Natural gas	9.6	29	103	190	183	249	325	9.1	31	40	10.1	-0.4	2.9	1.9
Nuclear	53	109	149	158	161	134	106	50	26	13	3.6	0.2	-2.1	-1.4
Hydro	6.4	4.0	3.7	3.1	3.6	3.6	3.6	6.0	0.5	0.4	-2.3	1.7	0.0	0.5
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	0.0	0.0	0.8	23	67	76	87	0.0	3.8	11	38.3	12.4	1.3	4.6
Wind	-	0.0	0.8	3.2	17	23	31	-	0.5	3.8	n.a.	20.2	3.1	8.1
CSP and marine	-	-	-	0.5	3.2	4.7	8.0	-	0.1	1.0	n.a.	24.1	4.7	10.4
Biomass and waste	-	0.1	1.1	8.6	17	21	23	-	1.4	2.9	n.a.	8.1	1.5	3.5
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	0.3	4.7	4.7	4.7	4.7	-	0.8	0.6	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	402	799	1 261	1 694	2 060	2 479	2 817	4.8	2.2	1.6	1.8
Population (million)	43	47	50	52	51	49	46	0.6	-0.1	-0.5	-0.4
CO_2 emissions (Mt)	208	399	528	559	537	522	495	3.2	-0.4	-0.4	-0.4
GDP per capita ($2015 thousand)	9.4	17	25	33	40	50	61	4.1	2.3	2.1	2.2
Primary energy consump. per capita (toe)	2.2	4.0	5.0	5.6	5.8	5.8	6.0	3.1	0.3	0.2	0.2
Primary energy consumption per GDP[*2]	231	234	198	172	144	116	98	-0.9	-2.0	-1.9	-1.9
CO_2 emissions per GDP[*3]	517	499	418	330	261	211	176	-1.4	-2.6	-2.0	-2.1
CO_2 per primary energy consumption[*4]	2.2	2.1	2.1	1.9	1.8	1.8	1.8	-0.5	-0.6	-0.1	-0.2

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A26 | Chinese Taipei [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	51	90	119	123	121	118	110	100	100	100	2.9	-0.1	-0.5	-0.4
Coal	11	30	42	43	43	38	33	23	35	30	4.4	-0.1	-1.3	-0.9
Oil	28	42	49	44	43	40	35	56	36	32	1.4	-0.1	-1.0	-0.7
Natural gas	1.6	6.2	15	26	28	30	31	3.1	21	28	9.4	1.1	0.5	0.7
Nuclear	8.6	10	11	7.2	-	-	-	17	5.9	-	-0.5	-100	n.a.	-100
Hydro	0.5	0.4	0.3	0.3	0.4	0.4	0.4	1.1	0.2	0.4	-2.2	4.9	0.2	1.6
Geothermal	0.0	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0
Solar, wind, etc.	0.0	0.1	0.2	1.0	4.9	6.9	8.7	0.0	0.8	7.9	13.4	20.0	2.9	7.9
Biomass and waste	0.0	0.9	1.8	1.7	1.8	1.8	1.9	0.1	1.4	1.7	12.0	0.6	0.3	0.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	32	54	75	79	82	81	77	100	100	100	3.0	0.4	-0.3	-0.1
Industry	13	21	24	27	28	29	28	40	34	36	2.4	0.7	-0.1	0.1
Transport	7.3	12	13	13	13	11	8.5	23	16	11	1.8	0.1	-2.1	-1.4
Buildings, etc.	6.9	11	12	13	13	14	14	22	16	18	2.0	0.3	0.1	0.2
Non-energy use	4.9	9.5	25	27	28	28	27	15	34	35	5.6	0.3	0.0	0.1
Coal	3.5	5.3	6.4	5.5	5.2	4.7	4.0	11	7.0	5.1	1.5	-0.6	-1.4	-1.1
Oil	21	32	45	43	43	41	36	65	55	47	2.4	0.0	-0.9	-0.6
Natural gas	1.0	1.8	2.4	5.1	5.5	5.7	5.6	3.1	6.4	7.3	5.4	0.9	0.1	0.4
Electricity	6.6	14	19	23	25	27	29	21	29	37	4.1	1.2	0.6	0.8
Heat	-	0.0	1.6	2.1	2.1	2.1	1.9	-	2.6	2.5	n.a.	0.2	-0.4	-0.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	0.0	0.4	0.7	0.5	0.7	0.7	0.8	0.1	0.7	1.0	11.2	2.4	1.1	1.5

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	87	181	244	287	321	346	365	100	100	100	3.9	1.2	0.6	0.8
Coal	24	88	122	129	126	110	91	28	45	25	5.5	-0.3	-1.6	-1.2
Oil	22	31	11	5.3	4.2	2.0	-	26	1.9	-	-4.5	-2.6	-100	-100
Natural gas	1.2	18	60	108	126	146	165	1.4	38	45	15.6	1.7	1.4	1.5
Nuclear	33	39	42	28	-	-	-	38	9.7	-	-0.5	-100	n.a.	-100
Hydro	6.2	4.6	3.9	3.1	4.8	4.9	5.0	7.1	1.1	1.4	-2.2	4.9	0.2	1.6
Geothermal	0.0	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0
Solar PV	-	-	0.0	8.0	19	25	30	-	2.8	8.1	n.a.	10.0	2.3	4.6
Wind	-	0.0	1.0	2.2	38	55	71	-	0.8	19	n.a.	37.0	3.2	12.7
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	0.2	1.8	3.4	3.8	3.8	3.8	3.8	0.2	1.3	1.0	9.8	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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	161	307	463	658	812	990	1 137	4.7	2.4	1.7	1.9
Population (million)	20	22	23	23	24	23	22	0.5	0.1	-0.3	-0.2
CO_2 emissions (Mt)	109	215	254	267	270	247	216	2.9	0.1	-1.1	-0.7
GDP per capita ($2015 thousand)	7.9	14	20	28	34	43	51	4.2	2.3	2.0	2.1
Primary energy consump. per capita (toe)	2.5	4.0	5.1	5.2	5.1	5.1	5.0	2.4	-0.2	-0.2	-0.2
Primary energy consumption per GDP*2	315	293	256	186	150	119	97	-1.7	-2.4	-2.1	-2.2
CO_2 emissions per GDP*3	677	701	548	406	333	250	190	-1.6	-2.2	-2.8	-2.6
CO_2 per primary energy consumption*4	2.1	2.4	2.1	2.2	2.2	2.1	2.0	0.0	0.2	-0.6	-0.4

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A27 | ASEAN [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	231	378	536	678	930	1 171	1 380	100	100	100	3.5	3.6	2.0	2.5
Coal	12	31	85	178	216	271	313	5.3	26	23	9.0	2.2	1.9	2.0
Oil	88	153	189	222	298	354	397	38	33	29	3.0	3.4	1.4	2.0
Natural gas	30	74	125	135	201	264	339	13	20	25	5.0	4.6	2.6	3.2
Nuclear	-	-	-	-	-	9.7	18	-	-	1.3	n.a.	n.a.	n.a.	n.a.
Hydro	2.3	4.1	6.1	14	18	21	23	1.0	2.0	1.7	5.8	3.3	1.2	1.8
Geothermal	6.6	18	25	37	93	129	142	2.9	5.4	10	5.7	11.0	2.1	4.8
Solar, wind, etc.	-	-	0.0	4.0	12	21	36	-	0.6	2.6	n.a.	13.6	5.5	8.0
Biomass and waste	92	97	106	87	88	97	107	40	13	7.8	-0.2	0.2	1.0	0.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	171	269	377	446	588	724	854	100	100	100	3.1	3.1	1.9	2.3
Industry	41	74	120	162	215	273	320	24	36	38	4.5	3.2	2.0	2.4
Transport	33	62	86	120	169	204	236	19	27	28	4.3	3.9	1.7	2.4
Buildings, etc.	86	112	130	110	125	151	187	50	25	22	0.8	1.4	2.0	1.8
Non-energy use	11	21	40	54	78	95	110	6.5	12	13	5.2	4.2	1.7	2.5
Coal	5.4	13	40	54	67	79	83	3.2	12	9.7	7.7	2.4	1.1	1.5
Oil	67	123	163	198	269	321	363	39	44	43	3.6	3.4	1.5	2.1
Natural gas	7.5	17	29	44	65	81	94	4.4	9.8	11	5.8	4.4	1.8	2.6
Electricity	11	28	52	88	130	183	249	6.5	20	29	6.9	4.5	3.3	3.7
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	0.0	0.0	-	-	0.0	n.a.	n.a.	n.a.	n.a.
Renewables	81	88	93	62	57	60	65	47	14	7.6	-0.8	-1.0	0.7	0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	154	370	675	1 107	1 667	2 349	3 203	100	100	100	6.6	4.7	3.3	3.7
Coal	28	79	185	492	594	795	992	18	44	31	9.7	2.1	2.6	2.4
Oil	66	72	59	13	18	17	10	43	1.2	0.3	-5.1	3.7	-2.9	-0.9
Natural gas	26	154	336	330	580	858	1 265	17	30	39	8.5	6.5	4.0	4.7
Nuclear	-	-	-	-	-	37	71	-	-	2.2	n.a.	n.a.	n.a.	n.a.
Hydro	27	47	71	158	212	244	267	18	14	8.3	5.8	3.3	1.2	1.8
Geothermal	6.6	16	19	27	61	83	90	4.3	2.4	2.8	4.6	9.7	2.0	4.3
Solar PV	-	-	0.0	37	91	165	322	-	3.4	10	n.a.	10.4	6.5	7.7
Wind	-	-	0.1	8.6	54	79	101	-	0.8	3.1	n.a.	22.7	3.2	8.8
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	41	57	72	85	0.4	3.7	2.7	14.6	3.7	2.0	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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	728	1 167	1 947	3 011	4 570	6 979	9 916	4.7	4.7	3.9	4.2
Population (million)	427	507	578	650	697	736	760	1.4	0.8	0.4	0.5
CO_2 emissions (Mt)	350	680	1 069	1 517	1 979	2 465	2 891	4.8	3.0	1.9	2.2
GDP per capita ($2015 thousand)	1.7	2.3	3.4	4.6	6.6	9.5	13	3.3	3.9	3.5	3.6
Primary energy consump. per capita (toe)	0.5	0.7	0.9	1.0	1.3	1.6	1.8	2.1	2.8	1.5	1.9
Primary energy consumption per GDP*2	317	324	275	225	204	168	139	-1.1	-1.1	-1.9	-1.6
CO_2 emissions per GDP*3	481	583	549	504	433	353	292	0.2	-1.7	-2.0	-1.9
CO_2 per primary energy consumption*4	1.5	1.8	2.0	2.2	2.1	2.1	2.1	1.3	-0.6	-0.1	-0.2

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A28 | Indonesia [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	99	156	204	235	350	471	577	100	100	100	2.8	4.5	2.5	3.1
Coal	3.5	12	32	71	90	123	153	3.6	30	26	10.2	2.6	2.7	2.7
Oil	33	58	67	68	91	109	123	34	29	21	2.3	3.3	1.5	2.0
Natural gas	16	27	39	34	55	85	123	16	14	21	2.5	5.4	4.2	4.6
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.5	0.9	1.5	2.1	2.7	3.0	3.4	0.5	0.9	0.6	4.8	2.6	1.2	1.6
Geothermal	1.9	8.4	16	27	81	117	128	2.0	12	22	8.9	12.9	2.3	5.5
Solar, wind, etc.	-	-	0.0	0.1	1.1	3.2	12	-	0.0	2.1	n.a.	40.2	12.5	20.5
Biomass and waste	44	50	48	33	29	31	35	44	14	6.0	-0.9	-1.3	0.9	0.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	79	120	148	152	195	249	307	100	100	100	2.1	2.8	2.3	2.4
Industry	17	30	49	56	75	101	127	22	37	41	3.9	3.2	2.7	2.8
Transport	11	21	30	51	70	84	97	14	34	32	5.2	3.4	1.7	2.2
Buildings, etc.	44	59	59	38	41	52	67	55	25	22	-0.5	0.9	2.5	2.0
Non-energy use	7.4	9.8	10	7.0	9.3	13	16	9.3	4.6	5.3	-0.1	3.1	2.9	2.9
Coal	1.5	4.6	17	21	27	33	37	1.9	14	12	8.9	2.7	1.6	2.0
Oil	27	48	55	66	88	105	119	34	43	39	2.9	3.3	1.5	2.1
Natural gas	6.0	12	16	16	23	31	38	7.6	11	12	3.3	3.7	2.6	2.9
Electricity	2.4	6.8	13	25	38	60	91	3.1	16	30	7.8	5.0	4.4	4.6
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	42	49	48	25	19	20	22	53	16	7.3	-1.7	-2.8	0.8	-0.4

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	33	93	170	309	488	769	1 179	100	100	100	7.5	5.2	4.5	4.7
Coal	9.8	34	68	190	244	363	494	30	61	42	10.0	2.8	3.6	3.4
Oil	15	18	34	8.7	10	8.8	2.1	47	2.8	0.2	-1.8	1.7	-7.5	-4.8
Natural gas	0.7	26	40	52	119	229	398	2.2	17	34	14.7	9.7	6.2	7.3
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	5.7	10	17	25	31	35	39	17	8.0	3.3	4.8	2.6	1.2	1.6
Geothermal	1.1	4.9	9.4	16	47	68	75	3.4	5.2	6.3	8.9	12.9	2.3	5.5
Solar PV	-	-	0.0	0.2	9.7	30	127	-	0.1	11	n.a.	54.6	13.7	25.1
Wind	-	-	0.0	0.4	3.5	7.1	13	-	0.1	1.1	n.a.	25.8	6.7	12.3
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	0.0	0.1	17	23	28	31	-	5.7	2.6	n.a.	3.2	1.5	2.0
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	270	395	658	1 066	1 657	2 664	4 013	4.5	5.0	4.5	4.7
Population (million)	182	214	244	274	292	309	318	1.3	0.7	0.4	0.5
CO_2 emissions (Mt)	131	255	397	557	742	989	1 226	4.8	3.3	2.5	2.8
GDP per capita ($2015 thousand)	1.5	1.8	2.7	3.9	5.7	8.6	13	3.2	4.3	4.1	4.1
Primary energy consump. per capita (toe)	0.5	0.7	0.8	0.9	1.2	1.5	1.8	1.5	3.8	2.1	2.6
Primary energy consumption per GDP[*2]	365	394	310	221	211	177	144	-1.6	-0.5	-1.9	-1.5
CO_2 emissions per GDP[*3]	484	647	604	522	448	371	306	0.2	-1.7	-1.9	-1.8
CO_2 per primary energy consumption[*4]	1.3	1.6	1.9	2.4	2.1	2.1	2.1	1.9	-1.2	0.0	-0.4

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A29 | Malaysia [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	21	48	72	95	129	146	156	100	100	100	5.0	3.4	1.0	1.7
Coal	1.4	2.3	15	23	24	24	22	6.4	24	14	9.5	0.8	-0.6	-0.2
Oil	11	19	25	26	35	35	32	54	27	21	2.6	3.6	-0.4	0.8
Natural gas	6.8	25	31	43	64	77	90	32	45	58	6.1	4.7	1.7	2.6
Nuclear	-	-	-	-	-	3.7	3.7	-	-	2.3	n.a.	n.a.	n.a.	n.a.
Hydro	0.3	0.6	0.6	2.7	3.0	3.4	3.5	1.6	2.8	2.3	6.8	1.2	0.8	0.9
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.2	0.4	1.5	2.8	-	0.2	1.8	n.a.	10.1	10.1	10.1
Biomass and waste	1.2	1.2	0.8	1.2	1.3	1.5	1.7	5.8	1.3	1.1	0.0	0.8	1.2	1.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	13	29	42	56	80	91	97	100	100	100	4.7	4.0	1.0	1.9
Industry	5.5	12	15	19	25	31	35	41	33	36	4.0	3.2	1.7	2.2
Transport	4.9	11	15	17	25	24	23	36	31	23	4.2	4.0	-0.4	0.9
Buildings, etc.	2.1	4.3	8.2	9.1	12	14	17	16	16	17	4.8	3.2	1.6	2.1
Non-energy use	0.8	2.2	3.7	11	18	21	23	6.3	19	24	8.6	5.8	1.3	2.6
Coal	0.5	1.0	1.8	0.6	0.7	0.7	0.7	3.8	1.1	0.7	0.6	1.2	0.0	0.4
Oil	9.3	18	24	23	32	32	30	70	42	30	3.0	3.5	-0.4	0.8
Natural gas	1.1	3.9	6.3	18	27	31	34	8.2	32	35	9.4	4.6	1.2	2.2
Electricity	1.7	5.3	9.5	13	19	26	32	13	24	33	6.8	4.3	2.5	3.0
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	0.7	0.7	0.2	0.8	0.9	1.0	1.2	5.6	1.5	1.2	0.3	1.3	1.2	1.2

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	23	69	125	180	259	340	419	100	100	100	6.9	4.1	2.4	3.0
Coal	2.9	7.7	43	86	90	87	77	13	48	18	11.5	0.5	-0.8	-0.4
Oil	11	3.6	3.7	1.0	0.8	0.3	-	46	0.6	-	-7.3	-2.4	-100	-100
Natural gas	5.5	51	71	58	128	181	252	24	32	60	7.9	9.1	3.5	5.2
Nuclear	-	-	-	-	-	14	14	-	-	3.3	n.a.	n.a.	n.a.	n.a.
Hydro	4.0	7.0	6.5	31	35	39	41	17	17	9.7	6.8	1.2	0.8	0.9
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	2.0	4.8	17	33	-	1.1	7.9	n.a.	10.1	10.1	10.1
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	1.2	1.2	1.5	1.6	-	0.7	0.4	n.a.	0.0	1.5	1.0
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	75	148	233	355	535	756	992	5.2	4.7	3.1	3.6
Population (million)	18	23	29	34	37	39	41	2.1	1.0	0.6	0.7
CO_2 emissions (Mt)	50	108	185	226	289	309	315	5.0	2.8	0.4	1.1
GDP per capita ($2015 thousand)	4.3	6.5	8.1	11	15	19	24	3.0	3.6	2.5	2.9
Primary energy consump. per capita (toe)	1.2	2.1	2.5	2.8	3.5	3.7	3.8	2.8	2.4	0.4	1.0
Primary energy consumption per GDP[*2]	284	326	312	268	240	194	157	-0.2	-1.2	-2.1	-1.8
CO_2 emissions per GDP[*3]	674	731	797	636	540	409	317	-0.2	-1.8	-2.6	-2.4
CO_2 per primary energy consumption[*4]	2.4	2.2	2.6	2.4	2.2	2.1	2.0	0.0	-0.6	-0.5	-0.6

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A30 | Myanmar [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	11	13	14	22	28	36	46	100	100	100	2.3	3.0	2.5	2.6
Coal	0.1	0.3	0.4	1.1	3.2	5.3	8.5	0.6	5.2	19	9.5	12.5	5.0	7.2
Oil	0.7	2.0	1.3	5.7	7.9	12	15	6.8	26	33	6.8	3.8	3.3	3.5
Natural gas	0.8	1.2	1.3	3.4	8.3	12	18	7.1	16	38	5.0	10.3	3.9	5.8
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.2	0.5	0.8	1.3	1.6	2.0	1.0	3.8	4.3	6.9	5.0	2.2	3.0
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.0	0.0	0.2	0.4	-	0.0	0.9	n.a.	34.8	15.5	21.2
Biomass and waste	9.0	9.2	10	11	9.1	7.0	5.2	84	49	11	0.5	-1.7	-2.7	-2.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	9.4	11	13	18	20	23	28	100	100	100	2.2	1.0	1.7	1.5
Industry	0.4	1.2	1.3	3.2	4.3	6.3	8.5	4.2	17	30	7.0	3.4	3.4	3.4
Transport	0.4	1.2	0.8	1.7	2.8	4.3	5.9	4.7	9.3	21	4.4	5.8	3.8	4.4
Buildings, etc.	8.5	9.1	10	13	13	12	13	90	71	47	1.4	-0.5	0.3	0.0
Non-energy use	0.1	0.1	0.1	0.4	0.4	0.5	0.6	1.0	2.2	2.2	4.8	0.8	1.8	1.5
Coal	0.1	0.3	0.2	0.2	0.2	0.2	0.2	0.5	1.1	0.8	4.7	0.3	0.3	0.3
Oil	0.6	1.5	1.0	5.6	7.7	11	15	6.2	31	52	7.6	3.6	3.3	3.4
Natural gas	0.2	0.3	0.6	0.5	0.6	0.7	0.8	2.4	2.8	2.8	2.7	1.7	1.4	1.4
Electricity	0.1	0.3	0.5	1.4	2.5	4.3	7.3	1.6	7.8	26	7.6	6.4	5.6	5.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	0.0	-	-	0.0	n.a.	n.a.	n.a.	n.a.
Renewables	8.4	9.0	10	11	9.1	7.0	5.2	89	58	18	0.8	-1.7	-2.8	-2.4

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	2.5	5.1	8.6	20	56	91	142	100	100	100	6.9	12.3	4.7	7.0
Coal	0.0	-	0.6	2.1	12	23	42	1.6	11	29	13.7	21.6	6.3	10.8
Oil	0.3	0.7	0.0	0.1	0.4	0.6	0.7	11	0.6	0.5	-2.7	16.0	2.8	6.7
Natural gas	1.0	2.5	1.8	7.9	28	46	72	39	40	51	7.0	15.2	4.8	7.9
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	1.2	1.9	6.2	9.5	15	19	23	48	48	16	6.9	5.0	2.2	3.0
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	0.0	0.3	1.9	4.6	-	0.1	3.3	n.a.	34.8	15.5	21.2
Wind	-	-	-	0.0	0.0	0.0	0.0	-	0.0	0.0	n.a.	0.0	0.0	0.0
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	7.2	14	43	67	87	137	209	7.5	3.0	4.5	4.0
Population (million)	40	46	49	54	57	59	60	1.0	0.7	0.3	0.4
CO_2 emissions (Mt)	4.0	9.5	8.1	28	54	83	119	6.4	7.8	4.0	5.2
GDP per capita ($2015 thousand)	0.2	0.3	0.9	1.2	1.5	2.3	3.5	6.4	2.4	4.2	3.6
Primary energy consump. per capita (toe)	0.3	0.3	0.3	0.4	0.5	0.6	0.8	1.3	2.4	2.2	2.2
Primary energy consumption per GDP[*2]	1 489	942	318	323	323	260	220	-4.8	0.0	-1.9	-1.3
CO_2 emissions per GDP[*3]	564	700	188	415	622	606	572	-1.0	4.6	-0.4	1.1
CO_2 per primary energy consumption[*4]	0.4	0.7	0.6	1.3	1.9	2.3	2.6	4.0	4.6	1.5	2.5

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A31 | Philippines [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	27	39	42	61	83	109	134	100	100	100	2.7	3.5	2.4	2.7
Coal	1.3	4.6	7.0	19	22	27	29	4.7	31	22	9.1	1.7	1.4	1.5
Oil	9.7	16	14	18	30	44	56	36	30	42	2.1	5.7	3.2	3.9
Natural gas	-	0.0	3.1	2.8	6.1	12	21	-	4.6	16	n.a.	8.8	6.4	7.1
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.5	0.7	0.7	0.8	1.1	1.2	1.4	2.0	1.3	1.1	1.3	3.4	1.5	2.1
Geothermal	4.7	10	8.5	9.2	12	13	13	18	15	9.9	2.2	2.9	0.5	1.3
Solar, wind, etc.	-	-	0.0	0.2	1.7	2.3	3.0	-	0.4	2.3	n.a.	24.9	2.8	9.2
Biomass and waste	10	7.6	8.7	11	10	10	10	39	18	7.6	0.1	-0.5	-0.1	-0.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	19	23	25	35	50	68	87	100	100	100	2.0	4.0	2.8	3.2
Industry	4.1	4.6	5.9	6.8	9.8	13	15	22	19	18	1.6	4.1	2.3	2.8
Transport	4.5	8.3	8.0	11	19	29	37	24	31	43	2.9	6.2	3.4	4.3
Buildings, etc.	10.0	9.9	11	16	18	23	29	52	44	33	1.5	1.9	2.3	2.2
Non-energy use	0.4	0.4	0.2	1.6	2.6	3.9	5.6	2.1	4.7	6.4	4.7	5.1	4.0	4.3
Coal	0.7	0.8	1.9	2.2	2.8	3.3	3.4	3.7	6.2	3.9	3.7	2.8	1.0	1.6
Oil	8.1	13	11	18	28	41	53	43	50	60	2.5	5.3	3.2	3.8
Natural gas	-	-	0.1	0.0	0.0	0.1	0.2	-	0.0	0.2	n.a.	63.9	9.3	23.9
Electricity	1.8	3.1	4.8	7.5	12	18	25	9.6	21	28	4.7	5.3	3.7	4.2
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	8.4	6.4	6.9	7.7	6.8	6.4	6.3	44	22	7.2	-0.3	-1.3	-0.4	-0.7

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	26	45	68	106	168	243	338	100	100	100	4.6	5.2	3.6	4.1
Coal	1.9	17	23	62	74	97	112	7.3	58	33	11.8	1.9	2.1	2.1
Oil	12	9.2	7.1	1.6	4.0	4.3	3.4	47	1.5	1.0	-6.4	10.5	-0.7	2.6
Natural gas	-	0.0	20	19	41	83	151	-	18	45	n.a.	9.2	6.7	7.5
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	6.1	7.8	7.8	9.2	12	14	17	23	8.7	5.0	1.3	3.4	1.5	2.1
Geothermal	5.5	12	9.9	11	14	15	15	21	10	4.6	2.2	2.9	0.5	1.3
Solar PV	-	-	0.0	1.5	12	14	19	-	1.4	5.7	n.a.	25.8	2.6	9.3
Wind	-	-	0.1	1.3	8.7	12	16	-	1.2	4.7	n.a.	23.9	3.0	9.1
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	0.4	-	0.0	1.2	2.2	2.9	3.3	1.6	1.1	1.0	3.3	7.3	2.1	3.7
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	107	143	229	379	654	1 057	1 479	4.2	6.2	4.2	4.8
Population (million)	62	78	95	114	130	145	158	2.0	1.4	1.0	1.1
CO_2 emissions (Mt)	35	65	75	132	184	253	315	4.3	3.8	2.7	3.0
GDP per capita ($2015 thousand)	1.7	1.8	2.4	3.3	5.0	7.3	9.3	2.1	4.7	3.1	3.6
Primary energy consump. per capita (toe)	0.4	0.5	0.4	0.5	0.6	0.7	0.8	0.7	2.0	1.4	1.6
Primary energy consumption per GDP*2	249	272	182	161	127	103	90	-1.4	-2.6	-1.7	-2.0
CO_2 emissions per GDP*3	330	454	327	349	282	240	213	0.2	-2.3	-1.4	-1.7
CO_2 per primary energy consumption*4	1.3	1.7	1.8	2.2	2.2	2.3	2.4	1.6	0.3	0.3	0.3

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A32 | Thailand [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	42	73	118	130	147	165	179	100	100	100	3.7	1.4	1.0	1.1
Coal	3.8	7.7	16	16	13	13	12	9.0	12	6.7	4.7	-1.7	-0.6	-0.9
Oil	18	32	45	56	62	67	69	43	43	38	3.7	1.2	0.6	0.8
Natural gas	5.0	17	33	34	39	41	40	12	26	22	6.3	1.7	0.2	0.6
Nuclear	-	-	-	-	-	1.8	6.2	-	-	3.5	n.a.	n.a.	n.a.	n.a.
Hydro	0.4	0.5	0.5	0.4	0.9	1.0	1.1	1.0	0.3	0.6	-0.2	9.2	1.1	3.5
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	-3.9	3.0	0.8
Solar, wind, etc.	-	-	0.0	0.7	1.8	4.2	6.8	-	0.6	3.8	n.a.	10.1	6.9	7.9
Biomass and waste	15	15	23	21	26	32	38	35	16	21	1.1	2.4	1.9	2.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	29	51	84	94	108	121	131	100	100	100	3.9	1.5	1.0	1.1
Industry	8.7	17	26	30	36	42	45	30	32	34	4.1	2.0	1.2	1.4
Transport	9.2	15	19	25	28	30	31	32	26	23	3.3	1.3	0.4	0.7
Buildings, etc.	11	14	20	16	17	19	20	37	17	15	1.2	0.9	0.8	0.8
Non-energy use	0.4	5.8	18	24	27	31	35	1.5	25	27	13.8	1.3	1.4	1.3
Coal	1.3	3.6	9.2	8.1	8.1	8.1	7.5	4.6	8.6	5.7	6.0	0.1	-0.4	-0.3
Oil	15	29	43	54	60	65	68	52	57	52	4.2	1.2	0.6	0.8
Natural gas	0.1	1.1	4.6	5.4	5.7	6.7	7.4	0.5	5.7	5.7	12.5	0.7	1.3	1.1
Electricity	3.3	7.6	13	16	21	26	31	11	17	24	5.3	2.7	1.9	2.2
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	9.3	9.4	14	11	13	15	17	32	11	13	0.4	2.0	1.6	1.7

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	44	96	159	177	219	268	317	100	100	100	4.6	2.4	1.9	2.0
Coal	11	18	30	35	25	26	25	25	20	7.8	3.8	-3.7	-0.1	-1.2
Oil	10	10.0	1.1	0.7	-	-	-	23	0.4	-	-8.5	-100	n.a.	-100
Natural gas	18	62	120	110	139	143	138	40	62	43	6.1	2.6	-0.1	0.8
Nuclear	-	-	-	-	-	7.0	24	-	-	7.5	n.a.	n.a.	n.a.	n.a.
Hydro	5.0	6.0	5.6	4.7	10	12	13	11	2.6	4.0	-0.2	9.2	1.1	3.5
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	-3.9	3.0	0.8
Solar PV	-	-	0.0	5.0	15	42	70	-	2.8	22	n.a.	13.1	8.0	9.5
Wind	-	-	-	3.6	5.1	6.3	7.4	-	2.0	2.3	n.a.	4.1	1.9	2.6
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	24	32	40	-	10	13	n.a.	3.3	2.6	2.8
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	144	221	347	438	582	805	1 066	3.7	3.2	3.1	3.1
Population (million)	55	63	68	72	72	71	68	0.8	0.1	-0.3	-0.2
CO_2 emissions (Mt)	80	151	223	235	248	254	244	3.5	0.6	-0.1	0.1
GDP per capita ($2015 thousand)	2.6	3.5	5.1	6.1	8.1	11	16	2.8	3.1	3.4	3.3
Primary energy consump. per capita (toe)	0.8	1.2	1.7	1.8	2.0	2.3	2.6	2.8	1.3	1.3	1.3
Primary energy consumption per GDP*2	294	328	340	296	252	205	168	0.0	-1.8	-2.0	-1.9
CO_2 emissions per GDP*3	557	683	644	535	426	316	228	-0.1	-2.5	-3.1	-2.9
CO_2 per primary energy consumption*4	1.9	2.1	1.9	1.8	1.7	1.5	1.4	-0.1	-0.8	-1.1	-1.0

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A33 | Viet Nam [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	18	29	59	95	152	200	244	100	100	100	5.5	5.3	2.4	3.3
Coal	2.2	4.4	15	47	62	78	88	12	49	36	10.3	3.1	1.8	2.2
Oil	2.7	7.8	18	23	46	60	73	15	24	30	7.1	7.9	2.4	4.1
Natural gas	0.0	1.1	8.1	6.3	16	24	34	0.0	6.6	14	28.4	11.0	3.8	6.0
Nuclear	-	-	-	-	-	4.2	8.6	-	-	3.5	n.a.	n.a.	n.a.	n.a.
Hydro	0.5	1.3	2.4	6.8	9.3	11	12	2.6	7.1	4.7	9.0	3.7	1.1	1.9
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	0.0	2.7	7.2	9.4	11	-	2.8	4.6	n.a.	11.7	2.2	5.0
Biomass and waste	12	14	15	9.7	11	14	16	70	10	6.7	-0.8	1.4	2.0	1.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	16	25	48	69	114	148	179	100	100	100	4.9	5.7	2.3	3.3
Industry	4.5	7.9	17	40	58	72	82	28	57	46	7.3	4.2	1.8	2.5
Transport	1.4	3.5	10	11	23	32	41	8.7	15	23	6.8	8.6	3.0	4.7
Buildings, etc.	10	13	18	16	21	28	36	63	23	20	1.5	3.0	2.9	2.9
Non-energy use	0.0	0.1	2.3	2.9	13	16	19	0.2	4.2	11	16.2	18.2	1.8	6.7
Coal	1.3	3.2	9.8	22	29	33	34	8.3	31	19	9.4	3.0	0.9	1.6
Oil	2.3	6.5	17	19	39	52	64	15	27	36	7.0	8.4	2.5	4.3
Natural gas	-	0.0	0.5	1.7	7.0	9.3	11	-	2.5	6.3	n.a.	16.8	2.4	6.7
Electricity	0.5	1.9	7.5	19	31	43	56	3.3	28	32	12.3	5.6	3.0	3.8
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	12	13	14	7.6	8.2	10	12	74	11	7.0	-1.4	0.8	2.1	1.7

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	8.7	27	95	253	406	561	725	100	100	100	11.5	5.4	2.9	3.7
Coal	2.0	3.1	20	115	147	196	240	23	45	33	14.0	2.7	2.5	2.6
Oil	1.3	4.5	3.4	0.3	2.5	3.0	3.5	15	0.1	0.5	-4.7	26.4	1.8	8.9
Natural gas	0.0	4.4	44	26	61	106	179	0.1	10	25	31.1	9.8	5.5	6.8
Nuclear	-	-	-	-	-	16	33	-	-	4.5	n.a.	n.a.	n.a.	n.a.
Hydro	5.4	15	28	79	109	125	134	62	31	19	9.0	3.7	1.1	1.9
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	28	47	56	64	-	11	8.9	n.a.	6.0	1.6	2.9
Wind	-	-	0.1	3.3	37	53	65	-	1.3	8.9	n.a.	30.5	2.9	10.8
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	0.1	2.1	3.5	4.7	6.0	-	0.8	0.8	n.a.	6.0	2.6	3.7
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	45	94	177	332	591	1 000	1 521	6.7	6.6	4.8	5.4
Population (million)	67	79	87	97	103	106	107	1.2	0.6	0.2	0.3
CO_2 emissions (Mt)	16	42	122	285	404	518	615	9.6	4.0	2.1	2.7
GDP per capita ($2015 thousand)	0.7	1.2	2.0	3.4	5.7	9.4	14	5.4	6.0	4.6	5.0
Primary energy consump. per capita (toe)	0.3	0.4	0.7	1.0	1.5	1.9	2.3	4.3	4.7	2.2	3.0
Primary energy consumption per GDP[*2]	397	307	330	286	256	200	161	-1.0	-1.2	-2.3	-2.0
CO_2 emissions per GDP[*3]	365	444	689	857	683	518	405	2.8	-2.5	-2.6	-2.6
CO_2 per primary energy consumption[*4]	0.9	1.4	2.1	3.0	2.7	2.6	2.5	3.9	-1.3	-0.3	-0.6

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A34 | North America [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	2 126	2 525	2 473	2 429	2 354	2 214	2 126	100	100	100	0.4	-0.4	-0.5	-0.5
Coal	484	565	525	264	145	68	30	23	11	1.4	-1.9	-6.5	-7.6	-7.3
Oil	833	958	901	859	825	747	659	39	35	31	0.1	-0.4	-1.1	-0.9
Natural gas	493	622	632	840	818	753	680	23	35	32	1.7	-0.3	-0.9	-0.7
Nuclear	179	227	242	236	223	181	174	8.4	9.7	8.2	0.9	-0.6	-1.2	-1.0
Hydro	49	53	53	55	61	63	64	2.3	2.3	3.0	0.4	1.3	0.2	0.5
Geothermal	14	13	8.4	9.4	11	13	14	0.7	0.4	0.7	-1.3	1.6	1.2	1.3
Solar, wind, etc.	0.3	2.1	11	53	149	268	383	0.0	2.2	18	17.9	12.2	4.8	7.1
Biomass and waste	73	86	101	115	121	122	123	3.5	4.7	5.8	1.5	0.5	0.1	0.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 452	1 728	1 697	1 731	1 719	1 667	1 615	100	100	100	0.6	-0.1	-0.3	-0.2
Industry	331	386	313	324	333	338	330	23	19	20	-0.1	0.3	0.0	0.1
Transport	531	640	655	660	647	588	531	37	38	33	0.7	-0.2	-1.0	-0.7
Buildings, etc.	456	528	572	570	555	546	554	31	33	34	0.7	-0.3	0.0	-0.1
Non-energy use	134	173	158	177	185	195	201	9.2	10	12	0.9	0.5	0.4	0.4
Coal	59	36	30	16	15	13	10	4.1	0.9	0.6	-4.2	-0.9	-1.6	-1.4
Oil	749	870	850	818	792	723	645	52	47	40	0.3	-0.4	-1.0	-0.8
Natural gas	346	413	364	421	403	383	354	24	24	22	0.6	-0.5	-0.6	-0.6
Electricity	262	338	367	375	406	449	509	18	22	32	1.2	0.9	1.1	1.1
Heat	2.8	6.1	7.1	6.2	5.9	5.6	5.2	0.2	0.4	0.3	2.6	-0.5	-0.7	-0.6
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	33	64	80	95	97	94	92	2.3	5.5	5.7	3.5	0.2	-0.3	-0.1

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	3 685	4 632	4 957	4 997	5 400	5 940	6 702	100	100	100	1.0	0.9	1.1	1.0
Coal	1 782	2 247	2 074	1 026	541	207	41	48	21	0.6	-1.8	-6.9	-12.1	-10.5
Oil	147	133	56	40	23	12	2.8	4.0	0.8	0.0	-4.1	-6.0	-10.0	-8.8
Natural gas	391	668	1 070	1 711	1 546	1 264	1 019	11	34	15	4.9	-1.1	-2.1	-1.8
Nuclear	685	871	930	904	857	693	667	19	18	9.9	0.9	-0.6	-1.2	-1.0
Hydro	570	612	614	636	715	732	743	15	13	11	0.4	1.3	0.2	0.5
Geothermal	16	15	18	19	22	27	29	0.4	0.4	0.4	0.6	1.7	1.3	1.4
Solar PV	0.0	0.2	3.3	154	649	1 354	1 887	0.0	3.1	28	41.9	17.3	5.5	9.0
Wind	3.1	5.9	104	418	895	1 431	2 000	0.1	8.4	30	17.2	8.8	4.1	5.5
CSP and marine	0.7	0.6	0.9	3.2	52	100	174	0.0	0.1	2.6	5.0	36.3	6.3	14.8
Biomass and waste	91	80	82	80	96	116	135	2.5	1.6	2.0	-0.4	2.1	1.7	1.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	6.8	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/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	2021	2030	2050	2050
GDP ($2015 billion)	10 626	14 918	17 783	22 210	26 292	32 069	38 016	2.4	1.9	1.9	1.9
Population (million)	277	313	343	370	388	405	416	0.9	0.5	0.4	0.4
CO_2 emissions (Mt)	5 126	6 085	5 698	5 055	4 383	3 674	3 085	0.0	-1.6	-1.7	-1.7
GDP per capita ($2015 thousand)	38	48	52	60	68	79	91	1.5	1.4	1.5	1.5
Primary energy consump. per capita (toe)	7.7	8.1	7.2	6.6	6.1	5.5	5.1	-0.5	-0.9	-0.9	-0.9
Primary energy consumption per GDP[*2]	200	169	139	109	90	69	56	-1.9	-2.2	-2.3	-2.3
CO_2 emissions per GDP[*3]	482	408	320	228	167	115	81	-2.4	-3.4	-3.5	-3.5
CO_2 per primary energy consumption[*4]	2.4	2.4	2.3	2.1	1.9	1.7	1.5	-0.5	-1.2	-1.2	-1.2

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A35 | United States [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	1 914	2 273	2 216	2 139	2 045	1 897	1 804	100	100	100	0.4	-0.5	-0.6	-0.6
Coal	460	533	501	254	141	66	28	24	12	1.5	-1.9	-6.3	-7.8	-7.4
Oil	757	871	807	764	728	658	581	40	36	32	0.0	-0.5	-1.1	-0.9
Natural gas	438	548	556	723	681	592	499	23	34	28	1.6	-0.7	-1.5	-1.3
Nuclear	159	208	219	211	202	166	166	8.3	9.9	9.2	0.9	-0.5	-1.0	-0.8
Hydro	23	22	23	22	27	27	28	1.2	1.0	1.5	-0.2	2.3	0.2	0.9
Geothermal	14	13	8.4	9.4	11	13	14	0.7	0.4	0.8	-1.3	1.6	1.2	1.3
Solar, wind, etc.	0.3	2.1	11	49	143	260	373	0.0	2.3	21	17.6	12.5	4.9	7.2
Biomass and waste	62	73	89	103	109	111	113	3.3	4.8	6.2	1.6	0.7	0.2	0.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)						
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total	1 294	1 546	1 513	1 540	1 521	1 471	1 423	100	100	100	0.6	-0.1	-0.3	-0.3
Industry	284	332	270	278	285	287	279	22	18	20	-0.1	0.3	-0.1	0.0
Transport	488	588	596	604	586	535	483	38	39	34	0.7	-0.3	-1.0	-0.8
Buildings, etc.	403	473	511	504	488	479	484	31	33	34	0.7	-0.4	0.0	-0.1
Non-energy use	119	153	135	154	162	170	177	9.2	10.0	12	0.8	0.5	0.4	0.5
Coal	56	33	27	14	13	11	9.1	4.3	0.9	0.6	-4.5	-0.8	-1.6	-1.3
Oil	683	793	762	735	706	644	574	53	48	40	0.2	-0.5	-1.0	-0.9
Natural gas	303	360	322	370	353	334	309	23	24	22	0.6	-0.5	-0.7	-0.6
Electricity	226	301	326	330	356	391	442	18	21	31	1.2	0.8	1.1	1.0
Heat	2.2	5.3	6.6	5.6	5.3	5.1	4.6	0.2	0.4	0.3	3.1	-0.6	-0.7	-0.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	23	54	70	85	88	86	84	1.8	5.5	5.9	4.3	0.3	-0.2	-0.1

Electricity generation

	(TWh)							Shares (%)						
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total	3 203	4 026	4 354	4 354	4 694	5 143	5 785	100	100	100	1.0	0.8	1.1	1.0
Coal	1 700	2 129	1 994	992	535	205	39	53	23	0.7	-1.7	-6.6	-12.2	-10.5
Oil	131	118	48	36	19	8.6	2.8	4.1	0.8	0.0	-4.1	-6.7	-9.2	-8.4
Natural gas	382	634	1 018	1 634	1 422	1 051	683	12	38	12	4.8	-1.5	-3.6	-3.0
Nuclear	612	798	839	812	776	639	637	19	19	11	0.9	-0.5	-1.0	-0.8
Hydro	273	253	262	253	311	319	324	8.5	5.8	5.6	-0.2	2.3	0.2	0.9
Geothermal	16	15	18	19	22	27	29	0.5	0.4	0.5	0.6	1.7	1.3	1.4
Solar PV	0.0	0.2	3.1	148	634	1 332	1 860	0.0	3.4	32	41.7	17.5	5.5	9.1
Wind	3.1	5.7	95	383	833	1 355	1 911	0.1	8.8	33	16.8	9.0	4.2	5.7
CSP and marine	0.7	0.5	0.9	3.2	52	100	174	0.0	0.1	3.0	5.2	36.3	6.3	14.8
Biomass and waste	86	72	73	69	85	103	119	2.7	1.6	2.1	-0.7	2.3	1.7	1.9
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	-	3.7	4.7	4.7	4.7	4.7	-	0.1	0.1	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	9 811	13 754	16 383	20 529	24 289	29 608	35 085	2.4	1.9	1.9	1.9
Population (million)	250	282	309	332	347	361	370	0.9	0.5	0.3	0.4
CO_2 emissions (Mt)	4 740	5 611	5 204	4 549	3 859	3 132	2 529	-0.1	-1.8	-2.1	-2.0
GDP per capita ($2015 thousand)	39	49	53	62	70	82	95	1.5	1.4	1.5	1.5
Primary energy consump. per capita (toe)	7.7	8.1	7.2	6.4	5.9	5.3	4.9	-0.6	-1.0	-0.9	-1.0
Primary energy consumption per GDP[*2]	195	165	135	104	84	64	51	-2.0	-2.3	-2.4	-2.4
CO_2 emissions per GDP[*3]	483	408	318	222	159	106	72	-2.5	-3.6	-3.9	-3.8
CO_2 per primary energy consumption[*4]	2.5	2.5	2.3	2.1	1.9	1.7	1.4	-0.5	-1.3	-1.5	-1.4

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A36 | Latin America [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	467	610	788	821	921	1 031	1 143	100	100	100	1.8	1.3	1.1	1.1
Coal	21	28	39	39	36	43	43	4.6	4.7	3.8	2.0	-0.7	0.8	0.3
Oil	241	313	365	333	364	383	395	52	41	35	1.0	1.0	0.4	0.6
Natural gas	71	118	178	207	206	270	351	15	25	31	3.5	-0.1	2.7	1.8
Nuclear	3.2	5.3	7.2	9.8	17	18	15	0.7	1.2	1.3	3.6	6.3	-0.7	1.5
Hydro	33	50	63	60	72	77	82	7.1	7.3	7.2	1.9	2.0	0.7	1.1
Geothermal	5.1	6.5	6.4	6.2	13	15	17	1.1	0.8	1.5	0.7	8.2	1.6	3.6
Solar, wind, etc.	0.0	0.2	0.9	17	45	56	67	0.0	2.0	5.9	22.2	11.6	2.0	4.9
Biomass and waste	93	90	128	149	168	170	173	20	18	15	1.6	1.3	0.2	0.5
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	344	442	569	574	662	733	806	100	100	100	1.7	1.6	1.0	1.2
Industry	114	143	179	169	202	237	267	33	29	33	1.3	2.0	1.4	1.6
Transport	104	140	197	205	246	263	282	30	36	35	2.2	2.1	0.7	1.1
Buildings, etc.	100	122	148	166	177	188	208	29	29	26	1.6	0.7	0.8	0.8
Non-energy use	26	38	45	34	38	44	50	7.6	5.9	6.2	0.9	1.1	1.5	1.4
Coal	8.2	11	15	13	14	14	14	2.4	2.2	1.7	1.4	0.9	0.0	0.3
Oil	178	235	284	271	310	331	349	52	47	43	1.4	1.5	0.6	0.9
Natural gas	38	54	74	63	73	82	90	11	11	11	1.6	1.7	1.0	1.3
Electricity	44	68	97	118	148	189	237	13	21	29	3.2	2.5	2.4	2.4
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	75	74	99	109	117	116	117	22	19	15	1.2	0.8	0.0	0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	623	1 009	1 406	1 726	2 131	2 671	3 281	100	100	100	3.3	2.4	2.2	2.2
Coal	24	44	75	84	72	98	101	3.8	4.9	3.1	4.2	-1.8	1.7	0.6
Oil	130	197	188	143	80	64	33	21	8.3	1.0	0.3	-6.2	-4.4	-5.0
Natural gas	58	142	326	492	444	770	1 228	9.3	29	37	7.1	-1.1	5.2	3.2
Nuclear	12	20	28	38	65	69	57	2.0	2.2	1.7	3.6	6.3	-0.7	1.5
Hydro	386	584	731	700	833	896	952	62	41	29	1.9	2.0	0.7	1.1
Geothermal	5.9	8.0	9.9	9.2	18	21	24	1.0	0.5	0.7	1.4	7.8	1.5	3.4
Solar PV	0.0	0.0	0.1	48	220	278	318	0.0	2.8	9.7	41.6	18.3	1.9	6.7
Wind	0.0	0.3	4.7	127	283	352	439	0.0	7.3	13	46.1	9.4	2.2	4.4
CSP and marine	-	-	-	0.2	0.2	0.2	0.2	-	0.0	0.0	n.a.	0.0	0.0	0.0
Biomass and waste	7.4	13	44	82	111	120	127	1.2	4.8	3.9	8.1	3.5	0.6	1.5
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	0.4	0.5	2.4	2.4	2.4	2.4	-	0.1	0.1	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	2 597	3 524	4 830	5 348	6 670	8 934	11 587	2.4	2.5	2.8	2.7
Population (million)	438	518	586	652	694	729	748	1.3	0.7	0.4	0.5
CO_2 emissions (Mt)	867	1 195	1 524	1 453	1 519	1 730	1 939	1.7	0.5	1.2	1.0
GDP per capita ($2015 thousand)	5.9	6.8	8.2	8.2	9.6	12	15	1.1	1.8	2.4	2.2
Primary energy consump. per capita (toe)	1.1	1.2	1.3	1.3	1.3	1.4	1.5	0.5	0.6	0.7	0.7
Primary energy consumption per GDP[*2]	180	173	163	154	138	115	99	-0.5	-1.2	-1.7	-1.5
CO_2 emissions per GDP[*3]	334	339	315	272	228	194	167	-0.7	-1.9	-1.5	-1.7
CO_2 per primary energy consumption[*4]	1.9	2.0	1.9	1.8	1.6	1.7	1.7	-0.2	-0.8	0.1	-0.1

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A37 | Advanced Europe [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	1 644	1 759	1 833	1 698	1 549	1 428	1 352	100	100	100	0.1	-1.0	-0.7	-0.8
Coal	450	331	301	204	114	83	79	27	12	5.8	-2.5	-6.3	-1.8	-3.2
Oil	617	654	605	530	477	395	338	38	31	25	-0.5	-1.2	-1.7	-1.5
Natural gas	267	396	473	447	342	308	299	16	26	22	1.7	-2.9	-0.7	-1.4
Nuclear	210	247	239	201	177	171	157	13	12	12	-0.1	-1.4	-0.6	-0.8
Hydro	39	47	48	49	50	52	53	2.4	2.9	3.9	0.8	0.2	0.3	0.2
Geothermal	4.9	7.1	11	22	32	36	37	0.3	1.3	2.7	5.0	4.2	0.7	1.8
Solar, wind, etc.	0.4	2.9	18	64	152	187	204	0.0	3.8	15	18.3	10.0	1.5	4.1
Biomass and waste	56	72	137	178	202	193	183	3.4	10	14	3.8	1.4	-0.5	0.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 142	1 235	1 289	1 255	1 193	1 097	1 027	100	100	100	0.3	-0.6	-0.7	-0.7
Industry	330	325	296	305	307	298	280	29	24	27	-0.3	0.1	-0.5	-0.3
Transport	269	318	335	338	313	254	217	24	27	21	0.7	-0.8	-1.8	-1.5
Buildings, etc.	442	477	544	506	466	439	426	39	40	41	0.4	-0.9	-0.4	-0.6
Non-energy use	101	114	113	106	107	106	104	8.9	8.5	10	0.1	0.1	-0.1	-0.1
Coal	124	62	55	43	37	30	25	11	3.4	2.4	-3.4	-1.5	-2.0	-1.9
Oil	528	573	538	493	450	373	319	46	39	31	-0.2	-1.0	-1.7	-1.5
Natural gas	205	269	285	292	266	249	223	18	23	22	1.1	-1.0	-0.9	-0.9
Electricity	193	234	267	271	291	310	339	17	22	33	1.1	0.8	0.8	0.8
Heat	45	42	53	50	46	44	40	3.9	4.0	3.9	0.3	-0.7	-0.7	-0.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	48	56	91	106	103	91	81	4.2	8.5	7.9	2.6	-0.4	-1.2	-0.9

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	2 695	3 236	3 623	3 637	3 897	4 125	4 487	100	100	100	1.0	0.8	0.7	0.7
Coal	1 030	968	873	535	172	55	59	38	15	1.3	-2.1	-11.8	-5.2	-7.3
Oil	209	180	81	43	13	5.2	1.5	7.8	1.2	0.0	-4.9	-12.6	-10.2	-11.0
Natural gas	176	514	857	769	347	280	468	6.5	21	10	4.9	-8.5	1.5	-1.7
Nuclear	804	948	916	769	680	657	603	30	21	13	-0.1	-1.4	-0.6	-0.8
Hydro	450	547	559	575	586	602	617	17	16	14	0.8	0.2	0.3	0.2
Geothermal	3.6	6.2	11	23	36	42	42	0.1	0.6	0.9	6.2	5.0	0.8	2.1
Solar PV	0.0	0.1	23	184	677	893	949	0.0	5.0	21	35.2	15.6	1.7	5.8
Wind	0.8	22	153	485	1 015	1 190	1 324	0.0	13	30	23.1	8.6	1.3	3.5
CSP and marine	0.5	0.5	1.2	5.7	7.5	9.7	14	0.0	0.2	0.3	8.1	3.1	3.3	3.2
Biomass and waste	21	48	146	241	356	385	402	0.8	6.6	9.0	8.2	4.4	0.6	1.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	0.3	1.5	4.6	6.7	6.7	6.7	6.7	0.0	0.2	0.1	10.0	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	11 682	14 633	16 894	19 669	23 173	26 699	30 170	1.7	1.8	1.3	1.5
Population (million)	505	528	557	582	589	589	583	0.5	0.1	-0.1	0.0
CO_2 emissions (Mt)	3 944	3 916	3 823	3 242	2 467	2 027	1 827	-0.6	-3.0	-1.5	-2.0
GDP per capita ($2015 thousand)	23	28	30	34	39	45	52	1.2	1.7	1.4	1.5
Primary energy consump. per capita (toe)	3.3	3.3	3.3	2.9	2.6	2.4	2.3	-0.4	-1.1	-0.6	-0.8
Primary energy consumption per GDP*2	141	120	109	86	67	53	45	-1.6	-2.8	-2.0	-2.2
CO_2 emissions per GDP*3	338	268	226	165	106	76	61	-2.3	-4.7	-2.8	-3.4
CO_2 per primary energy consumption*4	2.4	2.2	2.1	1.9	1.6	1.4	1.4	-0.7	-2.0	-0.8	-1.2

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A38 | Other Europe/Eurasia [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	1 514	988	1 112	1 225	1 190	1 217	1 296	100	100	100	-0.7	-0.3	0.4	0.2
Coal	365	209	211	212	192	198	222	24	17	17	-1.7	-1.1	0.7	0.2
Oil	459	199	216	251	232	224	213	30	20	16	-1.9	-0.9	-0.4	-0.6
Natural gas	596	481	566	611	581	599	668	39	50	52	0.1	-0.6	0.7	0.3
Nuclear	55	61	76	90	117	125	119	3.6	7.4	9.2	1.6	2.9	0.1	1.0
Hydro	22	23	26	30	30	32	33	1.5	2.4	2.6	0.9	0.1	0.6	0.4
Geothermal	0.0	0.1	0.6	0.2	0.3	0.3	0.3	0.0	0.0	0.0	7.7	1.2	0.3	0.6
Solar, wind, etc.	-	0.0	0.2	3.2	7.2	10	13	-	0.3	1.0	n.a.	9.3	2.8	4.8
Biomass and waste	17	15	19	31	33	31	29	1.1	2.5	2.3	1.9	0.8	-0.6	-0.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 057	647	711	802	782	782	793	100	100	100	-0.9	-0.3	0.1	0.0
Industry	391	205	205	211	208	217	221	37	26	28	-2.0	-0.2	0.3	0.2
Transport	170	110	145	156	142	135	129	16	19	16	-0.3	-1.1	-0.5	-0.7
Buildings, etc.	431	285	281	331	327	319	325	41	41	41	-0.9	-0.1	0.0	-0.1
Non-energy use	65	47	80	104	105	111	118	6.2	13	15	1.5	0.0	0.6	0.4
Coal	113	36	41	52	46	45	42	11	6.4	5.3	-2.5	-1.3	-0.5	-0.7
Oil	275	144	174	214	204	197	187	26	27	24	-0.8	-0.6	-0.4	-0.5
Natural gas	258	200	233	265	251	242	230	24	33	29	0.1	-0.6	-0.4	-0.5
Electricity	125	86	103	116	127	154	201	12	14	25	-0.2	1.0	2.3	1.9
Heat	274	170	147	135	132	126	116	26	17	15	-2.3	-0.2	-0.6	-0.5
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	13	11	14	21	22	19	17	1.2	2.6	2.1	1.6	0.7	-1.3	-0.7

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 856	1 415	1 689	1 867	2 007	2 356	2 946	100	100	100	0.0	0.8	1.9	1.6
Coal	429	338	396	372	392	474	646	23	20	22	-0.5	0.6	2.5	1.9
Oil	252	69	22	22	13	12	11	14	1.2	0.4	-7.5	-5.8	-0.7	-2.3
Natural gas	707	504	671	735	707	884	1 279	38	39	43	0.1	-0.4	3.0	1.9
Nuclear	209	234	289	345	451	480	457	11	18	16	1.6	3.0	0.1	1.0
Hydro	259	267	306	345	347	373	389	14	18	13	0.9	0.1	0.6	0.4
Geothermal	0.0	0.1	0.5	0.5	0.6	0.6	0.6	0.0	0.0	0.0	9.9	0.7	0.0	0.2
Solar PV	-	-	0.0	15	42	60	72	-	0.8	2.5	n.a.	12.0	2.8	5.5
Wind	-	0.0	1.2	21	40	55	70	-	1.1	2.4	n.a.	7.5	2.9	4.3
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	10	14	17	20	0.0	0.5	0.7	18.9	3.5	1.8	2.3
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	1 832	1 264	2 089	2 628	3 085	3 867	4 805	1.2	1.8	2.2	2.1
Population (million)	337	335	332	342	340	340	339	0.0	0.0	0.0	0.0
CO_2 emissions (Mt)	3 878	2 339	2 511	2 584	2 424	2 454	2 662	-1.3	-0.7	0.5	0.1
GDP per capita ($2015 thousand)	5.4	3.8	6.3	7.7	9.1	11	14	1.1	1.8	2.3	2.1
Primary energy consump. per capita (toe)	4.5	3.0	3.4	3.6	3.5	3.6	3.8	-0.7	-0.3	0.4	0.2
Primary energy consumption per GDP[*2]	826	782	532	466	386	315	270	-1.8	-2.1	-1.8	-1.9
CO_2 emissions per GDP[*3]	2 116	1 850	1 202	983	786	635	554	-2.4	-2.5	-1.7	-2.0
CO_2 per primary energy consumption[*4]	2.6	2.4	2.3	2.1	2.0	2.0	2.1	-0.6	-0.4	0.0	-0.1

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A39 | European Union [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	1 441	1 471	1 527	1 388	1 284	1 176	1 112	100	100	100	-0.1	-0.9	-0.7	-0.8
Coal	393	285	252	166	97	71	68	27	12	6.1	-2.7	-5.8	-1.7	-3.0
Oil	531	550	506	437	390	324	277	37	32	25	-0.6	-1.3	-1.7	-1.6
Natural gas	250	309	363	340	266	247	237	17	24	21	1.0	-2.7	-0.6	-1.2
Nuclear	190	224	223	191	172	152	139	13	14	12	0.0	-1.1	-1.1	-1.1
Hydro	24	30	32	30	30	31	31	1.7	2.2	2.8	0.7	0.0	0.2	0.2
Geothermal	3.2	4.6	5.5	6.8	8.0	8.2	8.2	0.2	0.5	0.7	2.5	1.8	0.1	0.6
Solar, wind, etc.	0.3	2.5	16	52	120	147	160	0.0	3.8	14	18.0	9.7	1.4	3.9
Biomass and waste	47	65	128	163	182	172	161	3.3	12	15	4.1	1.3	-0.6	0.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	995	1 027	1 070	1 023	972	893	833	100	100	100	0.1	-0.6	-0.8	-0.7
Industry	313	274	247	246	251	244	230	31	24	28	-0.8	0.2	-0.4	-0.2
Transport	220	262	279	274	251	205	175	22	27	21	0.7	-1.0	-1.8	-1.5
Buildings, etc.	374	391	447	408	376	352	338	38	40	41	0.3	-0.9	-0.5	-0.6
Non-energy use	88	100	98	94	95	93	90	8.9	9.2	11	0.2	0.0	-0.3	-0.2
Coal	109	47	37	28	25	20	17	11	2.8	2.0	-4.2	-1.4	-2.0	-1.8
Oil	445	479	448	406	367	307	263	45	40	32	-0.3	-1.1	-1.7	-1.5
Natural gas	185	220	231	227	209	196	176	19	22	21	0.7	-0.9	-0.9	-0.9
Electricity	162	189	216	214	231	246	268	16	21	32	0.9	0.9	0.7	0.8
Heat	55	43	52	47	44	42	38	5.5	4.6	4.6	-0.5	-0.8	-0.7	-0.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	39	50	86	101	95	82	71	4.0	9.8	8.5	3.1	-0.6	-1.5	-1.2

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	2 256	2 630	2 955	2 885	3 198	3 452	3 818	100	100	100	0.8	1.2	0.9	1.0
Coal	844	846	755	453	182	80	88	37	16	2.3	-2.0	-9.6	-3.6	-5.5
Oil	189	173	82	47	17	8.8	3.3	8.4	1.6	0.1	-4.4	-10.6	-7.9	-8.7
Natural gas	188	331	589	552	274	269	382	8.3	19	10	3.5	-7.5	1.7	-1.3
Nuclear	729	860	854	732	662	584	533	32	25	14	0.0	-1.1	-1.1	-1.1
Hydro	284	350	372	348	349	357	364	13	12	9.5	0.7	0.0	0.2	0.2
Geothermal	3.2	4.8	5.6	6.5	12	14	14	0.1	0.2	0.4	2.3	6.8	0.8	2.7
Solar PV	0.0	0.1	22	159	575	759	808	0.0	5.5	21	34.8	15.4	1.7	5.8
Wind	0.8	21	140	387	827	1 055	1 285	0.0	13	34	22.2	8.8	2.2	4.2
CSP and marine	0.5	0.5	1.2	5.7	7.4	9.7	14	0.0	0.2	0.4	8.1	3.1	3.3	3.2
Biomass and waste	19	42	129	191	289	311	322	0.8	6.6	8.4	7.7	4.7	0.5	1.8
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	0.2	1.4	4.4	5.0	5.0	5.0	5.0	0.0	0.2	0.1	10.8	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	9 107	11 262	12 897	14 681	17 280	19 827	22 275	1.6	1.8	1.3	1.4
Population (million)	420	429	442	447	449	446	437	0.2	0.0	-0.1	-0.1
CO_2 emissions (Mt)	3 464	3 265	3 135	2 579	1 724	1 419	1 274	-0.9	-4.4	-1.5	-2.4
GDP per capita ($2015 thousand)	22	26	29	33	38	45	51	1.3	1.8	1.4	1.5
Primary energy consump. per capita (toe)	3.4	3.4	3.5	3.1	2.9	2.6	2.5	-0.3	-0.9	-0.6	-0.7
Primary energy consumption per GDP[*2]	158	131	118	95	74	59	50	-1.6	-2.6	-2.0	-2.2
CO_2 emissions per GDP[*3]	380	290	243	176	100	72	57	-2.5	-6.1	-2.7	-3.8
CO_2 per primary energy consumption[*4]	2.4	2.2	2.1	1.9	1.3	1.2	1.1	-0.8	-3.6	-0.8	-1.7

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A40 | Africa [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	390	495	685	853	975	1 100	1 228	100	100	100	2.6	1.5	1.2	1.3
Coal	74	90	109	105	107	123	141	19	12	11	1.1	0.2	1.4	1.0
Oil	85	100	161	195	243	311	378	22	23	31	2.7	2.5	2.2	2.3
Natural gas	30	47	88	141	182	253	361	7.6	17	29	5.2	2.9	3.5	3.3
Nuclear	2.2	3.4	3.2	3.2	7.3	12	12	0.6	0.4	1.0	1.2	9.5	2.6	4.7
Hydro	4.8	6.4	9.4	13	17	25	36	1.2	1.5	2.9	3.2	3.0	3.9	3.6
Geothermal	0.3	0.4	0.9	4.3	17	27	37	0.1	0.5	3.1	9.2	16.1	4.2	7.7
Solar, wind, etc.	0.0	0.0	0.3	4.3	18	36	54	0.0	0.5	4.4	33.9	17.7	5.5	9.2
Biomass and waste	194	245	312	387	384	313	210	50	45	17	2.2	-0.1	-3.0	-2.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	286	366	495	614	689	744	785	100	100	100	2.5	1.3	0.7	0.9
Industry	53	58	84	90	111	148	185	19	15	24	1.7	2.3	2.6	2.5
Transport	38	54	87	122	157	199	241	13	20	31	3.8	2.8	2.2	2.4
Buildings, etc.	184	239	306	380	397	365	321	64	62	41	2.4	0.5	-1.1	-0.6
Non-energy use	11	15	19	21	25	31	38	3.8	3.4	4.9	2.1	1.9	2.2	2.1
Coal	20	19	18	21	22	24	24	7.0	3.5	3.1	0.2	0.1	0.6	0.4
Oil	70	89	137	170	212	271	328	24	28	42	2.9	2.5	2.2	2.3
Natural gas	8.6	14	27	45	56	72	88	3.0	7.3	11	5.5	2.5	2.3	2.3
Electricity	22	31	47	60	86	134	206	7.7	9.7	26	3.3	4.2	4.4	4.4
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	166	213	267	317	313	243	139	58	52	18	2.1	-0.1	-4.0	-2.8

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	309	439	686	885	1 262	1 919	2 867	100	100	100	3.4	4.0	4.2	4.1
Coal	164	208	259	246	261	324	403	53	28	14	1.3	0.6	2.2	1.7
Oil	35	34	64	55	68	91	109	11	6.2	3.8	1.5	2.3	2.4	2.4
Natural gas	45	106	234	371	514	805	1 345	15	42	47	7.0	3.7	4.9	4.5
Nuclear	8.4	13	12	12	28	45	47	2.7	1.4	1.6	1.2	9.5	2.6	4.7
Hydro	56	75	110	151	196	285	419	18	17	15	3.2	3.0	3.9	3.6
Geothermal	0.3	0.4	1.1	5.0	19	31	44	0.1	0.6	1.5	9.2	16.1	4.2	7.7
Solar PV	-	0.0	0.4	14	76	181	287	-	1.6	10	n.a.	20.3	6.9	10.9
Wind	-	0.2	2.4	23	76	108	139	-	2.6	4.9	n.a.	13.9	3.1	6.4
CSP and marine	-	-	-	2.9	20	42	66	-	0.3	2.3	n.a.	23.6	6.2	11.3
Biomass and waste	0.5	1.4	2.4	2.2	4.3	5.2	6.2	0.2	0.2	0.2	5.0	7.9	1.8	3.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	0.1	1.9	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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	920	1 208	1 998	2 663	3 830	6 227	9 596	3.5	4.1	4.7	4.5
Population (million)	620	794	1 021	1 346	1 652	2 024	2 405	2.5	2.3	1.9	2.0
CO_2 emissions (Mt)	524	652	1 008	1 218	1 463	1 876	2 375	2.8	2.1	2.5	2.3
GDP per capita ($2015 thousand)	1.5	1.5	2.0	2.0	2.3	3.1	4.0	0.9	1.8	2.8	2.4
Primary energy consump. per capita (toe)	0.6	0.6	0.7	0.6	0.6	0.5	0.5	0.0	-0.8	-0.7	-0.7
Primary energy consumption per GDP[*2]	424	410	343	320	255	177	128	-0.9	-2.5	-3.4	-3.1
CO_2 emissions per GDP[*3]	569	540	504	458	382	301	248	-0.7	-2.0	-2.1	-2.1
CO_2 per primary energy consumption[*4]	1.3	1.3	1.5	1.4	1.5	1.7	1.9	0.2	0.6	1.3	1.0

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A41 | Middle East [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	223	381	649	829	1 009	1 138	1 253	100	100	100	4.3	2.2	1.1	1.4
Coal	3.0	8.1	9.8	8.1	8.7	8.2	6.9	1.3	1.0	0.5	3.3	0.8	-1.2	-0.6
Oil	146	226	324	331	405	439	453	66	40	36	2.7	2.3	0.6	1.1
Natural gas	72	145	311	478	554	632	719	32	58	57	6.3	1.7	1.3	1.4
Nuclear	-	-	-	3.4	21	32	38	-	0.4	3.1	n.a.	22.2	3.1	8.7
Hydro	1.0	0.7	1.5	1.9	2.0	2.2	2.3	0.5	0.2	0.2	2.0	0.5	0.8	0.7
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	0.4	0.7	1.3	2.7	14	19	29	0.2	0.3	2.3	6.2	20.3	3.7	8.6
Biomass and waste	0.5	0.4	1.0	1.1	1.8	2.2	2.7	0.2	0.1	0.2	3.0	5.4	1.9	3.0
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	157	261	451	568	708	803	882	100	100	100	4.2	2.5	1.1	1.5
Industry	47	71	134	160	205	230	242	30	28	27	4.0	2.8	0.8	1.4
Transport	51	75	121	140	192	211	220	32	25	25	3.3	3.5	0.7	1.6
Buildings, etc.	40	74	118	160	178	201	226	25	28	26	4.6	1.2	1.2	1.2
Non-energy use	20	41	77	108	132	161	194	12	19	22	5.7	2.3	1.9	2.1
Coal	0.2	0.5	1.2	3.2	3.5	3.5	3.1	0.1	0.6	0.4	9.6	1.1	-0.6	-0.1
Oil	108	162	240	254	331	373	399	69	45	45	2.8	3.0	0.9	1.6
Natural gas	31	65	146	218	252	274	289	20	38	33	6.5	1.6	0.7	1.0
Electricity	17	32	62	92	120	151	190	11	16	22	5.6	3.0	2.3	2.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	0.0	n.a.
Renewables	0.7	1.0	2.2	1.6	1.6	1.9	2.2	0.5	0.3	0.3	2.6	0.0	1.6	1.1

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	244	472	888	1 316	1 692	2 109	2 616	100	100	100	5.6	2.8	2.2	2.4
Coal	11	30	35	21	24	23	19	4.3	1.6	0.7	2.2	1.6	-1.2	-0.4
Oil	108	189	286	283	267	220	152	44	22	5.8	3.2	-0.7	-2.8	-2.1
Natural gas	114	246	549	956	1 155	1 520	1 980	47	73	76	7.1	2.1	2.7	2.5
Nuclear	-	-	-	13	80	124	148	-	1.0	5.6	n.a.	22.2	3.1	8.7
Hydro	12	8.0	18	22	23	25	27	4.9	1.7	1.0	2.0	0.5	0.8	0.7
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	0.1	16	108	139	202	-	1.2	7.7	n.a.	23.3	3.2	9.0
Wind	0.0	0.0	0.2	3.0	28	46	67	0.0	0.2	2.6	29.4	28.1	4.6	11.4
CSP and marine	-	-	-	1.2	6.8	11	21	-	0.1	0.8	n.a.	21.5	5.7	10.3
Biomass and waste	-	0.0	0.1	0.0	0.5	0.6	0.7	-	0.0	0.0	n.a.	38.0	2.0	12.0
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	910	1 377	2 064	2 664	3 563	4 727	6 120	3.5	3.3	2.7	2.9
Population (million)	133	171	220	270	307	345	379	2.3	1.5	1.0	1.2
CO_2 emissions (Mt)	569	948	1 553	1 862	2 192	2 393	2 542	3.9	1.8	0.7	1.1
GDP per capita ($2015 thousand)	6.8	8.0	9.4	9.9	12	14	16	1.2	1.8	1.7	1.7
Primary energy consump. per capita (toe)	1.7	2.2	2.9	3.1	3.3	3.3	3.3	2.0	0.7	0.0	0.3
Primary energy consumption per GDP[*2]	245	277	314	311	283	241	205	0.8	-1.0	-1.6	-1.4
CO_2 emissions per GDP[*3]	625	689	752	699	615	506	415	0.4	-1.4	-1.9	-1.8
CO_2 per primary energy consumption[*4]	2.6	2.5	2.4	2.2	2.2	2.1	2.0	-0.4	-0.4	-0.3	-0.4

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A42 | Oceania [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	99	125	144	150	153	152	151	100	100	100	1.4	0.2	-0.1	0.0
Coal	36	49	52	42	32	28	26	36	28	18	0.5	-2.9	-0.9	-1.6
Oil	35	40	48	49	53	49	45	35	33	30	1.1	0.8	-0.8	-0.3
Natural gas	19	24	31	40	42	45	47	19	27	31	2.5	0.6	0.6	0.6
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	3.2	3.5	3.3	3.4	3.7	3.8	3.9	3.2	2.2	2.6	0.1	1.2	0.2	0.5
Geothermal	1.5	2.0	3.3	4.9	5.0	4.9	4.9	1.5	3.2	3.3	3.9	0.2	0.0	0.0
Solar, wind, etc.	0.1	0.1	0.9	5.2	11	14	17	0.1	3.5	11	12.8	9.1	1.9	4.1
Biomass and waste	4.7	6.0	5.9	5.8	6.1	6.3	6.3	4.7	3.8	4.2	0.7	0.7	0.2	0.3
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	66	82	90	92	100	101	100	100	100	100	1.1	0.9	0.0	0.3
Industry	23	28	26	27	30	31	32	34	29	32	0.5	1.3	0.4	0.6
Transport	24	30	35	35	38	36	34	36	38	33	1.2	0.9	-0.5	-0.1
Buildings, etc.	15	19	23	25	26	27	28	22	27	28	1.7	0.6	0.4	0.5
Non-energy use	4.6	6.1	5.9	6.4	6.6	6.7	6.7	6.9	7.0	6.7	1.1	0.3	0.1	0.2
Coal	5.2	4.7	3.1	3.2	3.3	3.3	3.2	7.9	3.5	3.1	-1.5	0.2	-0.2	-0.1
Oil	33	40	45	47	50	47	43	50	51	43	1.2	0.5	-0.7	-0.3
Natural gas	10	14	14	15	15	15	15	16	16	15	1.1	0.3	0.0	0.1
Electricity	14	18	22	22	26	30	34	21	24	33	1.6	2.1	1.2	1.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	3.8	5.2	5.3	5.0	5.1	5.1	5.1	5.8	5.5	5.1	0.9	0.2	0.0	0.0

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	187	249	298	310	372	416	459	100	100	100	1.6	2.1	1.1	1.4
Coal	122	176	182	144	120	115	112	65	46	24	0.5	-2.0	-0.3	-0.8
Oil	3.6	1.8	6.1	4.7	3.5	3.1	2.7	1.9	1.5	0.6	0.9	-3.1	-1.3	-1.9
Natural gas	20	26	54	55	64	78	96	11	18	21	3.3	1.7	2.1	2.0
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	37	41	38	39	43	44	45	20	13	9.8	0.1	1.2	0.2	0.5
Geothermal	2.1	2.9	5.9	8.4	8.6	8.6	8.6	1.1	2.7	1.9	4.5	0.2	0.0	0.1
Solar PV	-	0.0	0.4	28	64	82	96	-	9.0	21	n.a.	9.7	2.0	4.3
Wind	-	0.2	6.7	27	64	80	93	-	8.8	20	n.a.	9.9	1.9	4.3
CSP and marine	-	-	0.0	0.0	0.0	0.1	0.2	-	0.0	0.0	n.a.	27.7	6.5	12.6
Biomass and waste	1.6	2.0	3.5	4.1	5.2	5.7	6.0	0.9	1.3	1.3	3.1	2.5	0.7	1.3
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	-1.2	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	658	908	1 220	1 583	1 939	2 441	3 015	2.9	2.3	2.2	2.2
Population (million)	20	23	26	31	33	36	38	1.3	0.9	0.6	0.7
CO_2 emissions (Mt)	279	359	421	392	360	341	328	1.1	-1.0	-0.5	-0.6
GDP per capita ($2015 thousand)	32	40	46	51	58	68	79	1.5	1.3	1.6	1.5
Primary energy consump. per capita (toe)	4.9	5.5	5.5	4.9	4.6	4.2	4.0	0.0	-0.7	-0.7	-0.7
Primary energy consumption per GDP*2	150	138	118	95	79	62	50	-1.5	-2.0	-2.3	-2.2
CO_2 emissions per GDP*3	424	396	345	248	185	140	109	-1.7	-3.2	-2.6	-2.8
CO_2 per primary energy consumption*4	2.8	2.9	2.9	2.6	2.3	2.2	2.2	-0.2	-1.2	-0.4	-0.6

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A43 | Advanced Economies [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	4 471	5 234	5 357	5 139	4 900	4 599	4 397	100	100	100	0.5	-0.5	-0.5	-0.5
Coal	1 090	1 116	1 114	741	492	362	297	24	14	6.8	-1.2	-4.5	-2.5	-3.1
Oil	1 827	2 071	1 920	1 771	1 671	1 477	1 298	41	34	30	-0.1	-0.6	-1.3	-1.1
Natural gas	827	1 135	1 285	1 508	1 368	1 278	1 209	19	29	27	2.0	-1.1	-0.6	-0.8
Nuclear	463	596	606	503	484	423	395	10	9.8	9.0	0.3	-0.4	-1.0	-0.8
Hydro	100	111	112	115	124	128	130	2.2	2.2	3.0	0.5	0.9	0.2	0.4
Geothermal	22	25	25	39	52	60	62	0.5	0.8	1.4	1.9	3.3	0.9	1.6
Solar, wind, etc.	2.1	6.1	31	134	340	504	643	0.0	2.6	15	14.4	10.9	3.2	5.5
Biomass and waste	139	172	261	324	366	364	359	3.1	6.3	8.2	2.8	1.4	-0.1	0.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	3 058	3 579	3 644	3 632	3 561	3 390	3 242	100	100	100	0.6	-0.2	-0.5	-0.4
Industry	826	906	803	817	832	825	790	27	22	24	0.0	0.2	-0.3	-0.1
Transport	921	1 121	1 151	1 149	1 109	974	862	30	32	27	0.7	-0.4	-1.3	-1.0
Buildings, etc.	1 025	1 185	1 310	1 260	1 201	1 162	1 157	34	35	36	0.7	-0.5	-0.2	-0.3
Non-energy use	286	367	380	407	419	430	434	9.4	11	13	1.1	0.3	0.2	0.2
Coal	230	138	127	95	85	73	61	7.5	2.6	1.9	-2.8	-1.2	-1.7	-1.5
Oil	1 561	1 812	1 739	1 646	1 570	1 395	1 232	51	45	38	0.2	-0.5	-1.2	-1.0
Natural gas	578	732	717	784	740	699	640	19	22	20	1.0	-0.6	-0.7	-0.7
Electricity	553	715	809	826	889	964	1 068	18	23	33	1.3	0.8	0.9	0.9
Heat	48	52	66	64	60	57	52	1.6	1.8	1.6	0.9	-0.7	-0.7	-0.7
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	0.0	n.a.
Renewables	89	131	185	217	216	202	189	2.9	6.0	5.8	2.9	0.0	-0.7	-0.5

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	7 666	9 705	10 867	10 972	11 799	12 732	14 035	100	100	100	1.2	0.8	0.9	0.9
Coal	3 129	3 837	3 812	2 378	1 386	882	669	41	22	4.8	-0.9	-5.8	-3.6	-4.3
Oil	667	539	274	142	62	26	7.4	8.7	1.3	0.1	-4.9	-8.9	-10.1	-9.7
Natural gas	766	1 528	2 527	3 269	2 625	2 394	2 488	10.0	30	18	4.8	-2.4	-0.3	-0.9
Nuclear	1 776	2 288	2 324	1 930	1 856	1 625	1 516	23	18	11	0.3	-0.4	-1.0	-0.8
Hydro	1 158	1 293	1 302	1 335	1 445	1 483	1 512	15	12	11	0.5	0.9	0.2	0.4
Geothermal	23	27	37	54	71	83	87	0.3	0.5	0.6	2.7	3.3	1.0	1.7
Solar PV	0.1	0.7	31	484	1 604	2 585	3 207	0.0	4.4	23	32.1	14.2	3.5	6.7
Wind	3.8	29	269	944	2 072	2 843	3 596	0.1	8.6	26	19.4	9.1	2.8	4.7
CSP and marine	1.2	1.1	2.1	9.3	62	114	196	0.0	0.1	1.4	6.9	23.5	5.9	11.1
Biomass and waste	121	142	257	392	583	661	723	1.6	3.6	5.2	3.9	4.5	1.1	2.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	20	22	33	35	35	35	35	0.3	0.3	0.2	1.8	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	27 230	35 871	42 356	50 940	59 864	70 870	81 906	2.0	1.8	1.6	1.7
Population (million)	998	1 070	1 140	1 197	1 218	1 228	1 222	0.6	0.2	0.0	0.1
CO_2 emissions (Mt)	10 784	12 220	11 954	10 593	8 898	7 584	6 646	-0.1	-1.9	-1.4	-1.6
GDP per capita ($2015 thousand)	27	34	37	43	49	58	67	1.4	1.6	1.6	1.6
Primary energy consump. per capita (toe)	4.5	4.9	4.7	4.3	4.0	3.7	3.6	-0.1	-0.7	-0.6	-0.6
Primary energy consumption per GDP*2	164	146	126	101	82	65	54	-1.6	-2.3	-2.1	-2.2
CO_2 emissions per GDP*3	396	341	282	208	149	107	81	-2.1	-3.7	-3.0	-3.2
CO_2 per primary energy consumption*4	2.4	2.3	2.2	2.1	1.8	1.6	1.5	-0.5	-1.4	-0.9	-1.1

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A44 | Emerging Market and Developing Economies [Reference Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	4 081	4 516	7 132	9 306	10 559	11 502	12 330	100	100	100	2.7	1.4	0.8	1.0
Coal	1 133	1 201	2 548	3 275	3 293	3 130	2 888	28	35	23	3.5	0.1	-0.7	-0.4
Oil	1 208	1 338	1 873	2 267	2 562	2 834	3 070	30	24	25	2.1	1.4	0.9	1.1
Natural gas	835	933	1 449	1 979	2 280	2 710	3 233	20	21	26	2.8	1.6	1.8	1.7
Nuclear	62	79	113	229	359	455	520	1.5	2.5	4.2	4.3	5.1	1.9	2.9
Hydro	84	113	184	254	292	334	375	2.1	2.7	3.0	3.6	1.5	1.3	1.3
Geothermal	12	27	36	72	158	209	235	0.3	0.8	1.9	5.9	9.2	2.0	4.2
Solar, wind, etc.	0.5	2.1	17	157	429	703	968	0.0	1.7	7.9	20.4	11.8	4.2	6.5
Biomass and waste	747	823	913	1 072	1 187	1 128	1 040	18	12	8.4	1.2	1.1	-0.7	-0.1
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	2 981	3 158	4 824	6 135	6 945	7 607	8 230	100	100	100	2.4	1.4	0.9	1.0
Industry	970	963	1 840	2 219	2 494	2 740	2 883	33	36	35	2.7	1.3	0.7	0.9
Transport	455	569	918	1 227	1 509	1 697	1 892	15	20	23	3.3	2.3	1.1	1.5
Buildings, etc.	1 365	1 377	1 658	2 101	2 261	2 386	2 567	46	34	31	1.4	0.8	0.6	0.7
Non-energy use	191	249	408	589	681	784	888	6.4	9.6	11	3.7	1.6	1.3	1.4
Coal	521	404	934	818	759	731	705	17	13	8.6	1.5	-0.8	-0.4	-0.5
Oil	844	1 043	1 521	1 965	2 267	2 533	2 776	28	32	34	2.8	1.6	1.0	1.2
Natural gas	367	388	627	926	1 035	1 133	1 207	12	15	15	3.0	1.3	0.8	0.9
Electricity	281	372	728	1 251	1 677	2 111	2 585	9.4	20	31	4.9	3.3	2.2	2.5
Heat	288	196	209	283	309	302	279	9.7	4.6	3.4	-0.1	1.0	-0.5	-0.1
Hydrogen	-	-	-	-	0.0	0.0	0.0	-	-	0.0	n.a.	n.a.	5.6	n.a.
Renewables	679	755	805	892	898	797	678	23	15	8.2	0.9	0.1	-1.4	-0.9

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	4 171	5 718	10 671	17 430	23 278	29 037	35 066	100	100	100	4.7	3.3	2.1	2.4
Coal	1 301	2 158	4 862	7 874	8 445	8 201	7 791	31	45	22	6.0	0.8	-0.4	0.0
Oil	650	645	689	580	503	471	388	16	3.3	1.1	-0.4	-1.6	-1.3	-1.4
Natural gas	982	1 244	2 329	3 287	4 252	6 155	8 844	24	19	25	4.0	2.9	3.7	3.5
Nuclear	236	303	432	878	1 376	1 747	1 996	5.7	5.0	5.7	4.3	5.1	1.9	2.9
Hydro	981	1 319	2 145	2 958	3 391	3 881	4 359	24	17	12	3.6	1.5	1.3	1.3
Geothermal	13	25	31	42	109	145	169	0.3	0.2	0.5	3.9	11.2	2.2	4.9
Solar PV	0.0	0.1	1.4	536	2 301	4 041	5 677	0.0	3.1	16	47.7	17.6	4.6	8.5
Wind	0.0	2.8	73	920	2 207	3 527	4 820	0.0	5.3	14	38.7	10.2	4.0	5.9
CSP and marine	0.0	0.0	0.0	6.3	34	66	111	0.0	0.0	0.3	24.5	20.7	6.1	10.4
Biomass and waste	8.5	21	105	343	655	798	907	0.2	2.0	2.6	12.7	7.5	1.6	3.4
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	0.5	2.4	4.3	4.3	4.3	4.3	-	0.0	0.0	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	8 685	12 357	22 418	35 497	49 883	73 163	102 141	4.6	3.9	3.6	3.7
Population (million)	4 288	5 065	5 820	6 681	7 293	7 927	8 457	1.4	1.0	0.7	0.8
CO_2 emissions (Mt)	9 102	10 092	17 615	21 990	23 544	24 426	25 113	2.9	0.8	0.3	0.5
GDP per capita ($2015 thousand)	2.0	2.4	3.9	5.3	6.8	9.2	12	3.2	2.8	2.9	2.9
Primary energy consump. per capita (toe)	1.0	0.9	1.2	1.4	1.4	1.5	1.5	1.2	0.4	0.0	0.2
Primary energy consumption per GDP*2	470	365	318	262	212	157	121	-1.9	-2.3	-2.8	-2.6
CO_2 emissions per GDP*3	1 048	817	786	619	472	334	246	-1.7	-3.0	-3.2	-3.1
CO_2 per primary energy consumption*4	2.2	2.2	2.5	2.4	2.2	2.1	2.0	0.2	-0.6	-0.5	-0.5

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A45 | Primary energy consumption [Advanced Technologies Scenario]

(Mtoe)

							CAGR (%)				
	1990	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	8 754 (100)	12 850 (100)	14 759 (100)	15 389 (100)	14 666 (100)	13 802 (100)	1.7	0.5	-0.5	-0.6	-0.2
Asia	2 088 (23.9)	4 803 (37.4)	6 439 (43.6)	7 127 (46.3)	6 815 (46.5)	6 173 (44.7)	3.7	1.1	-0.4	-1.0	-0.1
China	874 (10.0)	2 536 (19.7)	3 738 (25.3)	3 908 (25.4)	3 317 (22.6)	2 510 (18.2)	4.8	0.5	-1.6	-2.7	-1.4
India	280 (3.2)	667 (5.2)	944 (6.4)	1 217 (7.9)	1 365 (9.3)	1 464 (10.6)	4.0	2.9	1.1	0.7	1.5
Japan	437 (5.0)	500 (3.9)	400 (2.7)	375 (2.4)	324 (2.2)	283 (2.0)	-0.3	-0.7	-1.5	-1.3	-1.2
Korea	93 (1.1)	250 (1.9)	292 (2.0)	293 (1.9)	269 (1.8)	233 (1.7)	3.8	0.0	-0.8	-1.4	-0.8
Chinese Taipei	51 (0.6)	119 (0.9)	123 (0.8)	119 (0.8)	108 (0.7)	90 (0.7)	2.9	-0.3	-1.0	-1.7	-1.0
ASEAN	231 (2.6)	536 (4.2)	678 (4.6)	901 (5.9)	1 055 (7.2)	1 153 (8.4)	3.5	3.2	1.6	0.9	1.9
Indonesia	99 (1.1)	204 (1.6)	235 (1.6)	339 (2.2)	437 (3.0)	519 (3.8)	2.8	4.1	2.6	1.7	2.8
Malaysia	21 (0.2)	72 (0.6)	95 (0.6)	123 (0.8)	126 (0.9)	123 (0.9)	5.0	2.9	0.2	-0.3	0.9
Myanmar	11 (0.1)	14 (0.1)	22 (0.1)	25 (0.2)	29 (0.2)	35 (0.3)	2.3	1.9	1.3	1.8	1.7
Philippines	27 (0.3)	42 (0.3)	61 (0.4)	82 (0.5)	100 (0.7)	107 (0.8)	2.7	3.3	2.0	0.7	2.0
Singapore	12 (0.1)	24 (0.2)	35 (0.2)	37 (0.2)	37 (0.3)	36 (0.3)	3.7	0.6	0.1	-0.5	0.0
Thailand	42 (0.5)	118 (0.9)	130 (0.9)	145 (0.9)	148 (1.0)	149 (1.1)	3.7	1.3	0.2	0.0	0.5
Viet Nam	18 (0.2)	59 (0.5)	95 (0.6)	146 (0.9)	174 (1.2)	182 (1.3)	5.5	4.8	1.8	0.5	2.3
North America	2 126 (24.3)	2 473 (19.2)	2 429 (16.5)	2 244 (14.6)	1 916 (13.1)	1 721 (12.5)	0.4	-0.9	-1.6	-1.1	-1.2
United States	1 914 (21.9)	2 216 (17.2)	2 139 (14.5)	1 958 (12.7)	1 650 (11.2)	1 475 (10.7)	0.4	-1.0	-1.7	-1.1	-1.3
Latin America	467 (5.3)	788 (6.1)	821 (5.6)	884 (5.7)	904 (6.2)	923 (6.7)	1.8	0.8	0.2	0.2	0.4
Advanced Europe	1 644 (18.8)	1 833 (14.3)	1 698 (11.5)	1 489 (9.7)	1 303 (8.9)	1 182 (8.6)	0.1	-1.4	-1.3	-1.0	-1.2
European Union	1 441 (16.5)	1 527 (11.9)	1 388 (9.4)	1 246 (8.1)	1 085 (7.4)	972 (7.0)	-0.1	-1.2	-1.4	-1.1	-1.2
Other Europe/Eurasia	1 514 (17.3)	1 112 (8.7)	1 225 (8.3)	1 171 (7.6)	1 125 (7.7)	1 061 (7.7)	-0.7	-0.5	-0.4	-0.6	-0.5
Africa	390 (4.5)	685 (5.3)	853 (5.8)	901 (5.9)	926 (6.3)	998 (7.2)	2.6	0.6	0.3	0.8	0.5
Middle East	223 (2.5)	649 (5.0)	829 (5.6)	965 (6.3)	1 040 (7.1)	1 087 (7.9)	4.3	1.7	0.7	0.4	0.9
Oceania	99 (1.1)	144 (1.1)	150 (1.0)	141 (0.9)	128 (0.9)	125 (0.9)	1.4	-0.7	-1.0	-0.2	-0.6
Advanced Economies	4 471 (51.1)	5 357 (41.7)	5 139 (34.8)	4 711 (30.6)	4 096 (27.9)	3 681 (26.7)	0.5	-1.0	-1.4	-1.1	-1.1
Emerging Market and Developing Economies	4 081 (46.6)	7 132 (55.5)	9 306 (63.0)	10 211 (66.4)	10 060 (68.6)	9 590 (69.5)	2.7	1.0	-0.1	-0.5	0.1

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

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

Table A46 | Primary energy consumption, coal [Advanced Technologies Scenario]

(Mtoe)

							CAGR (%)				
	1990	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	2 223 (100)	3 662 (100)	4 016 (100)	3 485 (100)	2 532 (100)	1 575 (100)	1.9	-1.6	-3.1	-4.6	-3.2
Asia	789 (35.5)	2 416 (66.0)	3 142 (78.2)	2 951 (84.7)	2 146 (84.7)	1 248 (79.2)	4.6	-0.7	-3.1	-5.3	-3.1
China	531 (23.9)	1 790 (48.9)	2 266 (56.4)	2 062 (59.2)	1 316 (52.0)	518 (32.9)	4.8	-1.0	-4.4	-8.9	-5.0
India	93 (4.2)	279 (7.6)	421 (10.5)	472 (13.5)	443 (17.5)	407 (25.9)	5.0	1.3	-0.6	-0.8	-0.1
Japan	77 (3.5)	115 (3.2)	109 (2.7)	69 (2.0)	51 (2.0)	33 (2.1)	1.1	-5.0	-3.1	-4.1	-4.0
Korea	25 (1.1)	73 (2.0)	75 (1.9)	63 (1.8)	49 (1.9)	23 (1.5)	3.6	-1.9	-2.5	-7.2	-4.0
Chinese Taipei	11 (0.5)	42 (1.1)	43 (1.1)	39 (1.1)	28 (1.1)	12 (0.8)	4.4	-1.1	-3.2	-7.9	-4.2
ASEAN	12 (0.6)	85 (2.3)	178 (4.4)	189 (5.4)	185 (7.3)	169 (10.7)	9.0	0.7	-0.2	-1.0	-0.2
Indonesia	4 (0.2)	32 (0.9)	71 (1.8)	80 (2.3)	88 (3.5)	94 (6.0)	10.2	1.3	1.0	0.7	1.0
Malaysia	1 (0.1)	15 (0.4)	23 (0.6)	22 (0.6)	18 (0.7)	11 (0.7)	9.5	-0.3	-2.1	-4.4	-2.4
Myanmar	0 (0.0)	0 (0.0)	1 (0.0)	3 (0.1)	4 (0.2)	6 (0.4)	9.5	11.3	3.8	3.5	6.0
Philippines	1 (0.1)	7 (0.2)	19 (0.5)	18 (0.5)	19 (0.7)	18 (1.2)	9.1	-0.8	0.5	-0.1	-0.1
Singapore	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	10.4	-0.1	-2.0	-6.3	-2.9
Thailand	4 (0.2)	16 (0.4)	16 (0.4)	12 (0.3)	10 (0.4)	7 (0.4)	4.7	-2.8	-2.3	-3.2	-2.8
Viet Nam	2 (0.1)	15 (0.4)	47 (1.2)	53 (1.5)	46 (1.8)	31 (1.9)	10.3	1.5	-1.5	-3.9	-1.4
North America	484 (21.8)	525 (14.3)	264 (6.6)	114 (3.3)	24 (1.0)	20 (1.3)	-1.9	-8.9	-14.3	-1.9	-8.5
United States	460 (20.7)	501 (13.7)	254 (6.3)	111 (3.2)	22 (0.9)	18 (1.2)	-1.9	-8.8	-15.0	-1.8	-8.7
Latin America	21 (1.0)	39 (1.1)	39 (1.0)	30 (0.9)	25 (1.0)	23 (1.5)	2.0	-2.8	-1.9	-0.8	-1.8
Advanced Europe	450 (20.3)	301 (8.2)	204 (5.1)	90 (2.6)	74 (2.9)	64 (4.1)	-2.5	-8.7	-2.0	-1.5	-3.9
European Union	393 (17.7)	252 (6.9)	166 (4.1)	77 (2.2)	61 (2.4)	50 (3.2)	-2.7	-8.2	-2.4	-1.9	-4.0
Other Europe/Eurasia	365 (16.4)	211 (5.8)	212 (5.3)	179 (5.1)	160 (6.3)	141 (8.9)	-1.7	-1.9	-1.1	-1.3	-1.4
Africa	74 (3.3)	109 (3.0)	105 (2.6)	93 (2.7)	81 (3.2)	68 (4.3)	1.1	-1.3	-1.4	-1.8	-1.5
Middle East	3 (0.1)	10 (0.3)	8 (0.2)	7 (0.2)	6 (0.3)	5 (0.3)	3.3	-1.2	-1.2	-2.9	-1.8
Oceania	36 (1.6)	52 (1.4)	42 (1.0)	21 (0.6)	15 (0.6)	6 (0.4)	0.5	-7.4	-3.2	-8.5	-6.4
Advanced Economies	1 090 (49.0)	1 114 (30.4)	741 (18.5)	402 (11.5)	246 (9.7)	164 (10.4)	-1.2	-6.6	-4.8	-4.0	-5.1
Emerging Market and Developing Economies	1 133 (51.0)	2 548 (69.6)	3 275 (81.5)	3 083 (88.5)	2 286 (90.3)	1 411 (89.6)	3.5	-0.7	-2.9	-4.7	-2.9

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

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

Table A47 | Primary energy consumption, oil [Advanced Technologies Scenario]

(Mtoe)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	3 237 (100)	4 155 (100)	4 352 (100)	4 321 (100)	3 545 (100)	2 704 (100)	1.0	-0.1	-2.0	-2.7	-1.6
Asia	618 (19.1)	1 172 (28.2)	1 491 (34.3)	1 522 (35.2)	1 347 (38.0)	1 096 (40.5)	2.9	0.2	-1.2	-2.0	-1.1
China	119 (3.7)	428 (10.3)	678 (15.6)	639 (14.8)	502 (14.2)	364 (13.5)	5.8	-0.6	-2.4	-3.2	-2.1
India	61 (1.9)	162 (3.9)	223 (5.1)	272 (6.3)	299 (8.4)	288 (10.7)	4.3	2.2	0.9	-0.4	0.9
Japan	249 (7.7)	201 (4.8)	151 (3.5)	122 (2.8)	84 (2.4)	59 (2.2)	-1.6	-2.3	-3.6	-3.6	-3.2
Korea	50 (1.5)	95 (2.3)	112 (2.6)	105 (2.4)	86 (2.4)	71 (2.6)	2.6	-0.7	-1.9	-2.0	-1.6
Chinese Taipei	28 (0.9)	49 (1.2)	44 (1.0)	41 (0.9)	34 (0.9)	27 (1.0)	1.4	-0.8	-1.9	-2.1	-1.6
ASEAN	88 (2.7)	189 (4.5)	222 (5.1)	278 (6.4)	272 (7.7)	222 (8.2)	3.0	2.6	-0.2	-2.0	0.0
Indonesia	33 (1.0)	67 (1.6)	68 (1.6)	83 (1.9)	78 (2.2)	55 (2.1)	2.3	2.3	-0.6	-3.4	-0.7
Malaysia	11 (0.4)	25 (0.6)	26 (0.6)	33 (0.8)	27 (0.8)	19 (0.7)	2.6	2.9	-2.1	-3.7	-1.1
Myanmar	1 (0.0)	1 (0.0)	6 (0.1)	7 (0.2)	9 (0.3)	9 (0.3)	6.8	2.9	2.1	0.1	1.7
Philippines	10 (0.3)	14 (0.3)	18 (0.4)	27 (0.6)	32 (0.9)	26 (0.9)	2.1	4.6	1.7	-2.3	1.2
Singapore	11 (0.4)	17 (0.4)	25 (0.6)	25 (0.6)	23 (0.6)	21 (0.8)	2.5	0.2	-0.9	-0.6	-0.5
Thailand	18 (0.6)	45 (1.1)	56 (1.3)	58 (1.3)	54 (1.5)	46 (1.7)	3.7	0.4	-0.7	-1.5	-0.6
Viet Nam	3 (0.1)	18 (0.4)	23 (0.5)	43 (1.0)	48 (1.4)	45 (1.7)	7.1	7.2	1.1	-0.7	2.3
North America	833 (25.7)	901 (21.7)	859 (19.7)	732 (16.9)	459 (12.9)	239 (8.8)	0.1	-1.8	-4.6	-6.3	-4.3
United States	757 (23.4)	807 (19.4)	764 (17.5)	645 (14.9)	400 (11.3)	202 (7.5)	0.0	-1.9	-4.7	-6.6	-4.5
Latin America	241 (7.4)	365 (8.8)	333 (7.6)	339 (7.8)	292 (8.2)	236 (8.7)	1.0	0.2	-1.5	-2.1	-1.2
Advanced Europe	617 (19.1)	605 (14.6)	530 (12.2)	426 (9.9)	267 (7.5)	159 (5.9)	-0.5	-2.4	-4.6	-5.0	-4.1
European Union	531 (16.4)	506 (12.2)	437 (10.0)	349 (8.1)	221 (6.2)	133 (4.9)	-0.6	-2.5	-4.5	-5.0	-4.0
Other Europe/Eurasia	459 (14.2)	216 (5.2)	251 (5.8)	218 (5.0)	173 (4.9)	127 (4.7)	-1.9	-1.5	-2.3	-3.0	-2.3
Africa	85 (2.6)	161 (3.9)	195 (4.5)	223 (5.2)	230 (6.5)	222 (8.2)	2.7	1.5	0.3	-0.4	0.4
Middle East	146 (4.5)	324 (7.8)	331 (7.6)	372 (8.6)	343 (9.7)	291 (10.8)	2.7	1.3	-0.8	-1.6	-0.4
Oceania	35 (1.1)	48 (1.2)	49 (1.1)	48 (1.1)	34 (1.0)	20 (0.7)	1.1	-0.2	-3.4	-5.4	-3.1
Advanced Economies	1 827 (56.4)	1 920 (46.2)	1 771 (40.7)	1 502 (34.8)	988 (27.9)	595 (22.0)	-0.1	-1.8	-4.1	-5.0	-3.7
Emerging Market and Developing Economies	1 208 (37.3)	1 873 (45.1)	2 267 (52.1)	2 379 (55.1)	2 159 (60.9)	1 796 (66.4)	2.1	0.5	-1.0	-1.8	-0.8

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

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

Table A48 | Primary energy consumption, natural gas [Advanced Technologies Scenario]

(Mtoe)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	1 662 (100)	2 734 (100)	3 487 (100)	3 541 (100)	3 432 (100)	3 044 (100)	2.4	0.2	-0.3	-1.2	-0.5
Asia	116 (7.0)	455 (16.6)	722 (20.7)	906 (25.6)	904 (26.3)	684 (22.5)	6.1	2.5	0.0	-2.7	-0.2
China	13 (0.8)	89 (3.3)	299 (8.6)	396 (11.2)	332 (9.7)	110 (3.6)	10.7	3.2	-1.7	-10.5	-3.4
India	11 (0.6)	54 (2.0)	55 (1.6)	98 (2.8)	126 (3.7)	138 (4.5)	5.5	6.6	2.6	0.9	3.2
Japan	44 (2.7)	86 (3.1)	87 (2.5)	63 (1.8)	53 (1.6)	24 (0.8)	2.2	-3.5	-1.7	-7.6	-4.3
Korea	3 (0.2)	39 (1.4)	54 (1.6)	49 (1.4)	42 (1.2)	11 (0.4)	10.1	-1.3	-1.5	-12.7	-5.4
Chinese Taipei	2 (0.1)	15 (0.5)	26 (0.7)	27 (0.8)	22 (0.6)	3 (0.1)	9.4	0.4	-2.1	-18.0	-7.2
ASEAN	30 (1.8)	125 (4.6)	135 (3.9)	195 (5.5)	216 (6.3)	239 (7.9)	5.0	4.2	1.0	1.0	2.0
Indonesia	16 (1.0)	39 (1.4)	34 (1.0)	54 (1.5)	70 (2.0)	92 (3.0)	2.5	5.4	2.6	2.7	3.5
Malaysia	7 (0.4)	31 (1.1)	43 (1.2)	61 (1.7)	66 (1.9)	63 (2.1)	6.1	4.0	0.8	-0.4	1.4
Myanmar	1 (0.0)	1 (0.0)	3 (0.1)	9 (0.2)	12 (0.3)	16 (0.5)	5.0	10.8	3.4	3.0	5.5
Philippines	- (-)	3 (0.1)	3 (0.1)	5 (0.1)	9 (0.3)	18 (0.6)	-	6.6	6.5	6.9	6.7
Singapore	- (-)	6 (0.2)	10 (0.3)	10 (0.3)	8 (0.2)	4 (0.1)	-	0.6	-2.4	-7.8	-3.4
Thailand	5 (0.3)	33 (1.2)	34 (1.0)	39 (1.1)	31 (0.9)	28 (0.9)	6.3	1.7	-2.1	-1.0	-0.6
Viet Nam	0 (0.0)	8 (0.3)	6 (0.2)	15 (0.4)	17 (0.5)	15 (0.5)	28.4	10.2	0.9	-0.8	3.1
North America	493 (29.7)	632 (23.1)	840 (24.1)	782 (22.1)	607 (17.7)	491 (16.1)	1.7	-0.8	-2.5	-2.1	-1.8
United States	438 (26.4)	556 (20.3)	723 (20.7)	658 (18.6)	487 (14.2)	390 (12.8)	1.6	-1.0	-3.0	-2.2	-2.1
Latin America	71 (4.3)	178 (6.5)	207 (5.9)	193 (5.5)	215 (6.3)	229 (7.5)	3.5	-0.8	1.1	0.6	0.3
Advanced Europe	267 (16.1)	473 (17.3)	447 (12.8)	296 (8.4)	200 (5.8)	106 (3.5)	1.7	-4.5	-3.9	-6.2	-4.9
European Union	250 (15.0)	363 (13.3)	340 (9.7)	235 (6.6)	163 (4.7)	87 (2.9)	1.0	-4.0	-3.6	-6.0	-4.6
Other Europe/Eurasia	596 (35.8)	566 (20.7)	611 (17.5)	578 (16.3)	555 (16.2)	512 (16.8)	0.1	-0.6	-0.4	-0.8	-0.6
Africa	30 (1.8)	88 (3.2)	141 (4.0)	199 (5.6)	272 (7.9)	299 (9.8)	5.2	3.9	3.2	1.0	2.6
Middle East	72 (4.3)	311 (11.4)	478 (13.7)	531 (15.0)	589 (17.2)	589 (19.4)	6.3	1.2	1.0	0.0	0.7
Oceania	19 (1.1)	31 (1.1)	40 (1.1)	39 (1.1)	32 (0.9)	23 (0.7)	2.5	-0.1	-2.2	-3.3	-1.9
Advanced Economies	827 (49.8)	1 285 (47.0)	1 508 (43.2)	1 269 (35.8)	966 (28.1)	664 (21.8)	2.0	-1.9	-2.7	-3.7	-2.8
Emerging Market and Developing Economies	835 (50.2)	1 449 (53.0)	1 979 (56.7)	2 255 (63.7)	2 407 (70.1)	2 269 (74.5)	2.8	1.5	0.7	-0.6	0.5

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

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

Table A49 | Final energy consumption [Advanced Technologies Scenario]

(Mtoe)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	6 242 (100)	8 829 (100)	10 082 (100)	10 513 (100)	9 900 (100)	9 176 (100)	1.6	0.5	-0.6	-0.8	-0.3
Asia	1 534 (24.6)	3 166 (35.9)	4 131 (41.0)	4 487 (42.7)	4 397 (44.4)	4 130 (45.0)	3.2	0.9	-0.2	-0.6	0.0
China	658 (10.5)	1 645 (18.6)	2 317 (23.0)	2 384 (22.7)	2 160 (21.8)	1 846 (20.1)	4.1	0.3	-1.0	-1.6	-0.8
India	215 (3.4)	443 (5.0)	632 (6.3)	804 (7.7)	912 (9.2)	979 (10.7)	3.5	2.7	1.3	0.7	1.5
Japan	290 (4.7)	314 (3.6)	267 (2.7)	243 (2.3)	202 (2.0)	170 (1.8)	-0.3	-1.1	-1.8	-1.7	-1.6
Korea	65 (1.0)	158 (1.8)	182 (1.8)	180 (1.7)	163 (1.6)	143 (1.6)	3.4	-0.1	-1.0	-1.3	-0.8
Chinese Taipei	32 (0.5)	75 (0.8)	79 (0.8)	79 (0.8)	73 (0.7)	64 (0.7)	3.0	0.0	-0.9	-1.3	-0.7
ASEAN	171 (2.7)	377 (4.3)	446 (4.4)	564 (5.4)	628 (6.3)	646 (7.0)	3.1	2.6	1.1	0.3	1.3
Indonesia	79 (1.3)	148 (1.7)	152 (1.5)	186 (1.8)	214 (2.2)	231 (2.5)	2.1	2.2	1.4	0.7	1.4
Malaysia	13 (0.2)	42 (0.5)	56 (0.6)	77 (0.7)	80 (0.8)	76 (0.8)	4.7	3.6	0.4	-0.5	1.1
Myanmar	9 (0.2)	13 (0.1)	18 (0.2)	18 (0.2)	18 (0.2)	19 (0.2)	2.2	-0.5	0.2	0.8	0.2
Philippines	19 (0.3)	25 (0.3)	35 (0.3)	48 (0.5)	59 (0.6)	62 (0.7)	2.0	3.4	2.1	0.6	2.0
Singapore	5 (0.1)	15 (0.2)	19 (0.2)	20 (0.2)	20 (0.2)	20 (0.2)	4.4	0.7	0.0	-0.3	0.2
Thailand	29 (0.5)	84 (1.0)	94 (0.9)	104 (1.0)	107 (1.1)	103 (1.1)	3.9	1.1	0.3	-0.4	0.3
Viet Nam	16 (0.3)	48 (0.5)	69 (0.7)	110 (1.0)	129 (1.3)	134 (1.5)	4.9	5.3	1.6	0.4	2.3
North America	1 452 (23.3)	1 697 (19.2)	1 731 (17.2)	1 641 (15.6)	1 388 (14.0)	1 180 (12.9)	0.6	-0.6	-1.7	-1.6	-1.3
United States	1 294 (20.7)	1 513 (17.1)	1 540 (15.3)	1 453 (13.8)	1 225 (12.4)	1 041 (11.3)	0.6	-0.6	-1.7	-1.6	-1.3
Latin America	344 (5.5)	569 (6.4)	574 (5.7)	635 (6.0)	634 (6.4)	618 (6.7)	1.7	1.1	0.0	-0.3	0.3
Advanced Europe	1 142 (18.3)	1 289 (14.6)	1 255 (12.4)	1 140 (10.8)	926 (9.4)	760 (8.3)	0.3	-1.1	-2.1	-2.0	-1.7
European Union	995 (15.9)	1 070 (12.1)	1 023 (10.1)	928 (8.8)	753 (7.6)	612 (6.7)	0.1	-1.1	-2.1	-2.0	-1.8
Other Europe/Eurasia	1 057 (16.9)	711 (8.1)	802 (8.0)	754 (7.2)	680 (6.9)	601 (6.6)	-0.9	-0.7	-1.0	-1.2	-1.0
Africa	286 (4.6)	495 (5.6)	614 (6.1)	609 (5.8)	569 (5.7)	576 (6.3)	2.5	-0.1	-0.7	0.1	-0.2
Middle East	157 (2.5)	451 (5.1)	568 (5.6)	686 (6.5)	711 (7.2)	703 (7.7)	4.2	2.1	0.4	-0.1	0.7
Oceania	66 (1.1)	90 (1.0)	92 (0.9)	96 (0.9)	86 (0.9)	75 (0.8)	1.1	0.4	-1.1	-1.3	-0.7
Advanced Economies	3 058 (49.0)	3 644 (41.3)	3 632 (36.0)	3 406 (32.4)	2 864 (28.9)	2 418 (26.4)	0.6	-0.7	-1.7	-1.7	-1.4
Emerging Market and Developing Economies	2 981 (47.8)	4 824 (54.6)	6 135 (60.9)	6 640 (63.2)	6 527 (65.9)	6 227 (67.9)	2.4	0.9	-0.2	-0.5	0.1

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

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

Table A50 | Final energy consumption, industry [Advanced Technologies Scenario]

(Mtoe)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	1 797 (100)	2 643 (100)	3 037 (100)	3 246 (100)	3 119 (100)	2 717 (100)	1.7	0.7	-0.4	-1.4	-0.4
Asia	508 (28.3)	1 405 (53.1)	1 750 (57.6)	1 882 (58.0)	1 786 (57.2)	1 511 (55.6)	4.1	0.8	-0.5	-1.7	-0.5
China	234 (13.0)	924 (35.0)	1 129 (37.2)	1 080 (33.3)	900 (28.9)	652 (24.0)	5.2	-0.5	-1.8	-3.2	-1.9
India	59 (3.3)	158 (6.0)	247 (8.1)	363 (11.2)	405 (13.0)	382 (14.1)	4.7	4.4	1.1	-0.6	1.5
Japan	108 (6.0)	92 (3.5)	80 (2.6)	74 (2.3)	64 (2.1)	54 (2.0)	-1.0	-0.9	-1.4	-1.8	-1.4
Korea	19 (1.1)	45 (1.7)	47 (1.6)	49 (1.5)	45 (1.4)	36 (1.3)	2.9	0.5	-1.0	-2.1	-0.9
Chinese Taipei	13 (0.7)	24 (0.9)	27 (0.9)	28 (0.9)	26 (0.8)	21 (0.8)	2.4	0.5	-0.8	-1.9	-0.8
ASEAN	41 (2.3)	120 (4.6)	162 (5.3)	209 (6.4)	241 (7.7)	243 (9.0)	4.5	2.9	1.4	0.1	1.4
Indonesia	17 (1.0)	49 (1.9)	56 (1.9)	72 (2.2)	90 (2.9)	102 (3.8)	3.9	2.8	2.3	1.2	2.1
Malaysia	6 (0.3)	15 (0.6)	19 (0.6)	24 (0.7)	27 (0.9)	25 (0.9)	4.0	2.9	1.0	-0.9	0.9
Myanmar	0 (0.0)	1 (0.0)	3 (0.1)	4 (0.1)	5 (0.2)	6 (0.2)	7.0	3.0	2.7	1.2	2.2
Philippines	4 (0.2)	6 (0.2)	7 (0.2)	10 (0.3)	12 (0.4)	12 (0.4)	1.6	3.9	1.9	0.1	1.9
Singapore	1 (0.0)	5 (0.2)	7 (0.2)	7 (0.2)	7 (0.2)	6 (0.2)	8.1	0.8	-0.5	-1.5	-0.4
Thailand	9 (0.5)	26 (1.0)	30 (1.0)	35 (1.1)	37 (1.2)	34 (1.2)	4.1	1.7	0.5	-0.8	0.4
Viet Nam	5 (0.3)	17 (0.7)	40 (1.3)	56 (1.7)	62 (2.0)	59 (2.2)	7.3	3.9	1.0	-0.5	1.4
North America	331 (18.4)	313 (11.8)	324 (10.7)	326 (10.0)	302 (9.7)	258 (9.5)	-0.1	0.1	-0.8	-1.6	-0.8
United States	284 (15.8)	270 (10.2)	278 (9.2)	278 (8.6)	258 (8.3)	220 (8.1)	-0.1	0.0	-0.8	-1.6	-0.8
Latin America	114 (6.3)	179 (6.8)	169 (5.6)	197 (6.1)	210 (6.7)	203 (7.5)	1.3	1.7	0.6	-0.3	0.6
Advanced Europe	330 (18.4)	296 (11.2)	305 (10.1)	301 (9.3)	268 (8.6)	221 (8.2)	-0.3	-0.1	-1.2	-1.9	-1.1
European Union	313 (17.4)	247 (9.3)	246 (8.1)	246 (7.6)	219 (7.0)	180 (6.6)	-0.8	0.0	-1.1	-1.9	-1.1
Other Europe/Eurasia	391 (21.8)	205 (7.8)	211 (7.0)	204 (6.3)	194 (6.2)	174 (6.4)	-2.0	-0.4	-0.5	-1.1	-0.7
Africa	53 (3.0)	84 (3.2)	90 (3.0)	106 (3.3)	127 (4.1)	139 (5.1)	1.7	1.8	1.8	0.9	1.5
Middle East	47 (2.6)	134 (5.1)	160 (5.3)	200 (6.2)	205 (6.6)	186 (6.8)	4.0	2.5	0.2	-0.9	0.5
Oceania	23 (1.3)	26 (1.0)	27 (0.9)	29 (0.9)	27 (0.9)	23 (0.9)	0.5	0.9	-0.6	-1.4	-0.4
Advanced Economies	826 (46.0)	803 (30.4)	817 (26.9)	815 (25.1)	739 (23.7)	620 (22.8)	0.0	0.0	-1.0	-1.7	-0.9
Emerging Market and Developing Economies	970 (54.0)	1 840 (69.6)	2 219 (73.1)	2 431 (74.9)	2 380 (76.3)	2 096 (77.2)	2.7	1.0	-0.2	-1.3	-0.2

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

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

Table A51 | Final energy consumption, transport [Advanced Technologies Scenario]

(Mtoe)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	1 578 (100)	2 430 (100)	2 690 (100)	2 896 (100)	2 567 (100)	2 343 (100)	1.7	0.8	-1.2	-0.9	-0.5
Asia	189 (12.0)	493 (20.3)	719 (26.7)	823 (28.4)	773 (30.1)	732 (31.2)	4.4	1.5	-0.6	-0.6	0.1
China	30 (1.9)	195 (8.0)	346 (12.9)	396 (13.7)	340 (13.3)	291 (12.4)	8.2	1.5	-1.5	-1.6	-0.6
India	21 (1.3)	65 (2.7)	102 (3.8)	129 (4.5)	155 (6.0)	187 (8.0)	5.3	2.7	1.8	1.9	2.1
Japan	72 (4.6)	79 (3.2)	63 (2.4)	54 (1.9)	35 (1.4)	27 (1.1)	-0.4	-1.7	-4.1	-2.9	-3.0
Korea	15 (0.9)	30 (1.2)	36 (1.3)	31 (1.1)	22 (0.9)	17 (0.7)	2.9	-1.5	-3.5	-2.8	-2.6
Chinese Taipei	7 (0.5)	13 (0.5)	13 (0.5)	11 (0.4)	7 (0.3)	5 (0.2)	1.8	-1.5	-4.1	-3.3	-3.0
ASEAN	33 (2.1)	86 (3.6)	120 (4.5)	158 (5.4)	162 (6.3)	148 (6.3)	4.3	3.1	0.3	-0.9	0.7
Indonesia	11 (0.7)	30 (1.2)	51 (1.9)	64 (2.2)	65 (2.5)	59 (2.5)	5.2	2.5	0.1	-1.0	0.4
Malaysia	5 (0.3)	15 (0.6)	17 (0.6)	23 (0.8)	20 (0.8)	16 (0.7)	4.2	3.3	-1.7	-2.3	-0.4
Myanmar	0 (0.0)	1 (0.0)	2 (0.1)	3 (0.1)	4 (0.1)	4 (0.2)	4.4	5.0	3.1	2.0	3.3
Philippines	5 (0.3)	8 (0.3)	11 (0.4)	18 (0.6)	24 (0.9)	23 (1.0)	2.9	5.6	2.9	-0.2	2.6
Singapore	1 (0.1)	2 (0.1)	2 (0.1)	2 (0.1)	1 (0.1)	1 (0.0)	1.7	-1.2	-3.3	-2.4	-2.3
Thailand	9 (0.6)	19 (0.8)	25 (0.9)	26 (0.9)	23 (0.9)	19 (0.8)	3.3	0.6	-1.2	-2.2	-1.0
Viet Nam	1 (0.1)	10 (0.4)	11 (0.4)	21 (0.7)	26 (1.0)	26 (1.1)	6.8	7.7	2.1	0.2	3.1
North America	531 (33.6)	655 (26.9)	660 (24.5)	594 (20.5)	418 (16.3)	313 (13.4)	0.7	-1.2	-3.4	-2.9	-2.5
United States	488 (30.9)	596 (24.5)	604 (22.4)	540 (18.7)	381 (14.8)	284 (12.1)	0.7	-1.2	-3.4	-2.9	-2.6
Latin America	104 (6.6)	197 (8.1)	205 (7.6)	230 (8.0)	215 (8.4)	202 (8.6)	2.2	1.3	-0.7	-0.6	0.0
Advanced Europe	269 (17.0)	335 (13.8)	338 (12.6)	286 (9.9)	179 (7.0)	130 (5.5)	0.7	-1.8	-4.5	-3.2	-3.2
European Union	220 (13.9)	279 (11.5)	274 (10.2)	229 (7.9)	144 (5.6)	103 (4.4)	0.7	-2.0	-4.5	-3.3	-3.3
Other Europe/Eurasia	170 (10.8)	145 (6.0)	156 (5.8)	132 (4.5)	106 (4.1)	82 (3.5)	-0.3	-1.9	-2.2	-2.6	-2.2
Africa	38 (2.4)	87 (3.6)	122 (4.6)	148 (5.1)	168 (6.5)	182 (7.8)	3.8	2.2	1.2	0.8	1.4
Middle East	51 (3.2)	121 (5.0)	140 (5.2)	181 (6.3)	169 (6.6)	148 (6.3)	3.3	2.9	-0.7	-1.3	0.2
Oceania	24 (1.5)	35 (1.4)	35 (1.3)	35 (1.2)	29 (1.1)	23 (1.0)	1.2	0.2	-2.1	-2.0	-1.4
Advanced Economies	921 (58.3)	1 151 (47.3)	1 149 (42.7)	1 016 (35.1)	694 (27.0)	516 (22.0)	0.7	-1.4	-3.7	-2.9	-2.7
Emerging Market and Developing Economies	455 (28.8)	918 (37.8)	1 227 (45.6)	1 414 (48.8)	1 363 (53.1)	1 295 (55.3)	3.3	1.6	-0.4	-0.5	0.2

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

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

Table A52 | Final energy consumption, buildings, etc. [Advanced Technologies Scenario]

(Mtoe)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/2021	2021/2030	2030/2040	2040/2050	2021/2050
World	2 390 (100)	2 968 (100)	3 360 (100)	3 271 (100)	3 001 (100)	2 796 (100)	1.1	-0.3	-0.9	-0.7	-0.6
Asia	721 (30.2)	977 (32.9)	1 222 (36.4)	1 280 (39.1)	1 280 (42.6)	1 278 (45.7)	1.7	0.5	0.0	0.0	0.2
China	351 (14.7)	413 (13.9)	629 (18.7)	682 (20.8)	685 (22.8)	668 (23.9)	1.9	0.9	0.0	-0.3	0.2
India	122 (5.1)	187 (6.3)	228 (6.8)	236 (7.2)	246 (8.2)	270 (9.7)	2.0	0.4	0.4	0.9	0.6
Japan	78 (3.2)	108 (3.6)	94 (2.8)	86 (2.6)	73 (2.4)	61 (2.2)	0.6	-1.0	-1.5	-1.8	-1.5
Korea	24 (1.0)	44 (1.5)	46 (1.4)	44 (1.4)	40 (1.3)	35 (1.2)	2.0	-0.3	-1.0	-1.4	-0.9
Chinese Taipei	7 (0.3)	12 (0.4)	13 (0.4)	13 (0.4)	12 (0.4)	10 (0.4)	2.0	-0.1	-0.9	-1.5	-0.9
ASEAN	86 (3.6)	130 (4.4)	110 (3.3)	119 (3.6)	131 (4.4)	145 (5.2)	0.8	0.8	1.0	1.0	0.9
Indonesia	44 (1.8)	59 (2.0)	38 (1.1)	39 (1.2)	46 (1.5)	54 (1.9)	-0.5	0.5	1.6	1.5	1.2
Malaysia	2 (0.1)	8 (0.3)	9 (0.3)	12 (0.4)	13 (0.4)	13 (0.5)	4.8	2.8	0.8	0.3	1.2
Myanmar	8 (0.4)	10 (0.3)	13 (0.4)	10 (0.3)	8 (0.3)	8 (0.3)	1.4	-2.6	-2.0	-0.2	-1.6
Philippines	10 (0.4)	11 (0.4)	16 (0.5)	17 (0.5)	19 (0.6)	22 (0.8)	1.5	1.2	1.1	1.2	1.2
Singapore	1 (0.0)	2 (0.1)	3 (0.1)	3 (0.1)	3 (0.1)	3 (0.1)	3.0	0.7	-0.5	-0.9	-0.3
Thailand	11 (0.5)	20 (0.7)	16 (0.5)	16 (0.5)	16 (0.5)	16 (0.6)	1.2	0.4	-0.1	-0.4	0.0
Viet Nam	10 (0.4)	18 (0.6)	16 (0.5)	20 (0.6)	25 (0.8)	29 (1.1)	1.5	2.5	2.2	1.8	2.1
North America	456 (19.1)	572 (19.3)	570 (17.0)	536 (16.4)	473 (15.8)	409 (14.6)	0.7	-0.7	-1.2	-1.4	-1.1
United States	403 (16.9)	511 (17.2)	504 (15.0)	472 (14.4)	416 (13.9)	360 (12.9)	0.7	-0.7	-1.3	-1.4	-1.2
Latin America	100 (4.2)	148 (5.0)	166 (4.9)	170 (5.2)	165 (5.5)	162 (5.8)	1.6	0.2	-0.3	-0.2	-0.1
Advanced Europe	442 (18.5)	544 (18.3)	506 (15.0)	445 (13.6)	372 (12.4)	305 (10.9)	0.4	-1.4	-1.8	-2.0	-1.7
European Union	374 (15.7)	447 (15.0)	408 (12.1)	360 (11.0)	299 (10.0)	244 (8.7)	0.3	-1.4	-1.8	-2.0	-1.8
Other Europe/Eurasia	431 (18.0)	281 (9.5)	331 (9.8)	314 (9.6)	269 (9.0)	228 (8.1)	-0.9	-0.6	-1.5	-1.6	-1.3
Africa	184 (7.7)	306 (10.3)	380 (11.3)	329 (10.1)	242 (8.1)	217 (7.7)	2.4	-1.6	-3.0	-1.1	-1.9
Middle East	40 (1.7)	118 (4.0)	160 (4.8)	172 (5.3)	176 (5.9)	176 (6.3)	4.6	0.8	0.2	0.0	0.3
Oceania	15 (0.6)	23 (0.8)	25 (0.7)	25 (0.8)	24 (0.8)	22 (0.8)	1.7	0.2	-0.6	-0.8	-0.4
Advanced Economies	1 025 (42.9)	1 310 (44.1)	1 260 (37.5)	1 156 (35.3)	1 001 (33.3)	847 (30.3)	0.7	-0.9	-1.4	-1.6	-1.4
Emerging Market and Developing Economies	1 365 (57.1)	1 658 (55.9)	2 101 (62.5)	2 115 (64.7)	2 001 (66.7)	1 949 (69.7)	1.4	0.1	-0.6	-0.3	-0.3

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

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

Table A53 | Final energy consumption, electricity [Advanced Technologies Scenario]

(TWh)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/2021	CAGR (%) 2021/2030	CAGR (%) 2030/2040	CAGR (%) 2040/2050	CAGR (%) 2021/2050
World	9 699 (100)	17 880 (100)	24 150 (100)	30 814 (100)	37 694 (100)	43 310 (100)	3.0	2.7	2.0	1.4	2.0
Asia	1 823 (18.8)	6 677 (37.3)	11 896 (49.3)	16 326 (53.0)	19 928 (52.9)	22 655 (52.3)	6.2	3.6	2.0	1.3	2.2
China	454 (4.7)	3 450 (19.3)	7 580 (31.4)	10 247 (33.3)	11 538 (30.6)	11 661 (26.9)	9.5	3.4	1.2	0.1	1.5
India	212 (2.2)	718 (4.0)	1 206 (5.0)	2 149 (7.0)	3 381 (9.0)	4 810 (11.1)	5.8	6.6	4.6	3.6	4.9
Japan	765 (7.9)	1 035 (5.8)	932 (3.9)	950 (3.1)	998 (2.6)	976 (2.3)	0.6	0.2	0.5	-0.2	0.2
Korea	94 (1.0)	449 (2.5)	536 (2.2)	610 (2.0)	652 (1.7)	643 (1.5)	5.8	1.4	0.7	-0.1	0.6
Chinese Taipei	77 (0.8)	218 (1.2)	264 (1.1)	302 (1.0)	314 (0.8)	295 (0.7)	4.1	1.5	0.4	-0.6	0.4
ASEAN	130 (1.3)	601 (3.4)	1 018 (4.2)	1 527 (5.0)	2 137 (5.7)	2 879 (6.6)	6.9	4.6	3.4	3.0	3.6
Indonesia	28 (0.3)	147 (0.8)	286 (1.2)	446 (1.4)	709 (1.9)	1 090 (2.5)	7.8	5.1	4.7	4.4	4.7
Malaysia	20 (0.2)	111 (0.6)	155 (0.6)	224 (0.7)	286 (0.8)	335 (0.8)	6.8	4.1	2.5	1.6	2.7
Myanmar	2 (0.0)	6 (0.0)	17 (0.1)	33 (0.1)	58 (0.2)	92 (0.2)	7.6	7.9	5.9	4.7	6.1
Philippines	21 (0.2)	55 (0.3)	87 (0.4)	143 (0.5)	221 (0.6)	333 (0.8)	4.7	5.6	4.5	4.2	4.7
Singapore	13 (0.1)	42 (0.2)	53 (0.2)	61 (0.2)	63 (0.2)	60 (0.1)	4.7	1.4	0.3	-0.5	0.4
Thailand	38 (0.4)	149 (0.8)	191 (0.8)	244 (0.8)	299 (0.8)	354 (0.8)	5.3	2.8	2.1	1.7	2.2
Viet Nam	6 (0.1)	87 (0.5)	223 (0.9)	371 (1.2)	495 (1.3)	608 (1.4)	12.3	5.8	2.9	2.1	3.5
North America	3 051 (31.5)	4 265 (23.9)	4 362 (18.1)	4 855 (15.8)	5 621 (14.9)	6 048 (14.0)	1.2	1.2	1.5	0.7	1.1
United States	2 633 (27.1)	3 788 (21.2)	3 838 (15.9)	4 259 (13.8)	4 934 (13.1)	5 308 (12.3)	1.2	1.2	1.5	0.7	1.1
Latin America	516 (5.3)	1 125 (6.3)	1 375 (5.7)	1 749 (5.7)	2 253 (6.0)	2 782 (6.4)	3.2	2.7	2.6	2.1	2.5
Advanced Europe	2 248 (23.2)	3 106 (17.4)	3 151 (13.0)	3 502 (11.4)	3 890 (10.3)	4 084 (9.4)	1.1	1.2	1.1	0.5	0.9
European Union	1 887 (19.5)	2 510 (14.0)	2 487 (10.3)	2 776 (9.0)	3 073 (8.2)	3 220 (7.4)	0.9	1.2	1.0	0.5	0.9
Other Europe/Eurasia	1 448 (14.9)	1 193 (6.7)	1 349 (5.6)	1 533 (5.0)	1 923 (5.1)	2 338 (5.4)	-0.2	1.4	2.3	2.0	1.9
Africa	256 (2.6)	543 (3.0)	696 (2.9)	1 107 (3.6)	1 776 (4.7)	2 492 (5.8)	3.3	5.3	4.8	3.4	4.5
Middle East	199 (2.0)	719 (4.0)	1 066 (4.4)	1 433 (4.6)	1 950 (5.2)	2 519 (5.8)	5.6	3.3	3.1	2.6	3.0
Oceania	158 (1.6)	252 (1.4)	255 (1.1)	309 (1.0)	354 (0.9)	391 (0.9)	1.6	2.1	1.4	1.0	1.5
Advanced Economies	6 429 (66.3)	9 410 (52.6)	9 600 (39.7)	10 636 (34.5)	11 940 (31.7)	12 543 (29.0)	1.3	1.1	1.2	0.5	0.9
Emerging Market and Developing Economies	3 270 (33.7)	8 469 (47.4)	14 551 (60.3)	20 178 (65.5)	25 753 (68.3)	30 767 (71.0)	4.9	3.7	2.5	1.8	2.6

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

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

Table A54 | Electricity generated [Advanced Technologies Scenario]

(TWh)

							CAGR (%)				
	1990	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	11 837 (100)	21 538 (100)	28 402 (100)	36 128 (100)	45 879 (100)	57 517 (100)	2.9	2.7	2.4	2.3	2.5
Asia	2 237 (18.9)	7 992 (37.1)	13 664 (48.1)	18 866 (52.2)	23 006 (50.1)	26 570 (46.2)	6.0	3.6	2.0	1.5	2.3
China	621 (5.2)	4 197 (19.5)	8 560 (30.1)	11 633 (32.2)	13 029 (28.4)	13 184 (22.9)	8.8	3.5	1.1	0.1	1.5
India	289 (2.4)	972 (4.5)	1 635 (5.8)	2 831 (7.8)	4 208 (9.2)	5 755 (10.0)	5.7	6.3	4.0	3.2	4.4
Japan	862 (7.3)	1 164 (5.4)	1 040 (3.7)	1 057 (2.9)	1 131 (2.5)	1 171 (2.0)	0.6	0.2	0.7	0.4	0.4
Korea	105 (0.9)	497 (2.3)	608 (2.1)	689 (1.9)	750 (1.6)	792 (1.4)	5.8	1.4	0.8	0.6	0.9
Chinese Taipei	87 (0.7)	244 (1.1)	287 (1.0)	328 (0.9)	353 (0.8)	364 (0.6)	3.9	1.5	0.7	0.3	0.8
ASEAN	154 (1.3)	675 (3.1)	1 107 (3.9)	1 687 (4.7)	2 438 (5.3)	3 566 (6.2)	6.6	4.8	3.8	3.9	4.1
Indonesia	33 (0.3)	170 (0.8)	309 (1.1)	492 (1.4)	811 (1.8)	1 365 (2.4)	7.5	5.3	5.1	5.3	5.3
Malaysia	23 (0.2)	125 (0.6)	180 (0.6)	259 (0.7)	344 (0.8)	474 (0.8)	6.9	4.1	2.9	3.3	3.4
Myanmar	2 (0.0)	9 (0.0)	20 (0.1)	61 (0.2)	110 (0.2)	186 (0.3)	6.9	13.3	6.2	5.4	8.1
Philippines	26 (0.2)	68 (0.3)	106 (0.4)	172 (0.5)	266 (0.6)	398 (0.7)	4.6	5.5	4.5	4.1	4.7
Singapore	16 (0.1)	46 (0.2)	56 (0.2)	64 (0.2)	66 (0.1)	48 (0.1)	4.2	1.4	0.3	-3.1	-0.5
Thailand	44 (0.4)	159 (0.7)	177 (0.6)	220 (0.6)	284 (0.6)	402 (0.7)	4.6	2.5	2.6	3.6	2.9
Viet Nam	9 (0.1)	95 (0.4)	253 (0.9)	414 (1.1)	551 (1.2)	685 (1.2)	11.5	5.6	2.9	2.2	3.5
North America	3 685 (31.1)	4 957 (23.0)	4 997 (17.6)	5 547 (15.4)	6 688 (14.6)	7 941 (13.8)	1.0	1.2	1.9	1.7	1.6
United States	3 203 (27.1)	4 354 (20.2)	4 354 (15.3)	4 822 (13.3)	5 756 (12.5)	6 708 (11.7)	1.0	1.1	1.8	1.5	1.5
Latin America	623 (5.3)	1 406 (6.5)	1 726 (6.1)	2 151 (6.0)	3 084 (6.7)	4 726 (8.2)	3.3	2.5	3.7	4.4	3.5
Advanced Europe	2 695 (22.8)	3 623 (16.8)	3 637 (12.8)	4 026 (11.1)	4 850 (10.6)	5 872 (10.2)	1.0	1.1	1.9	1.9	1.7
European Union	2 256 (19.1)	2 955 (13.7)	2 885 (10.2)	3 404 (9.4)	4 137 (9.0)	4 755 (8.3)	0.8	1.9	2.0	1.4	1.7
Other Europe/Eurasia	1 856 (15.7)	1 689 (7.8)	1 867 (6.6)	2 073 (5.7)	2 493 (5.4)	2 902 (5.0)	0.0	1.2	1.9	1.5	1.5
Africa	309 (2.6)	686 (3.2)	885 (3.1)	1 391 (3.9)	2 448 (5.3)	3 973 (6.9)	3.4	5.2	5.8	5.0	5.3
Middle East	244 (2.1)	888 (4.1)	1 316 (4.6)	1 702 (4.7)	2 703 (5.9)	4 343 (7.6)	5.6	2.9	4.7	4.9	4.2
Oceania	187 (1.6)	298 (1.4)	310 (1.1)	372 (1.0)	607 (1.3)	1 191 (2.1)	1.6	2.1	5.0	7.0	4.8
Advanced Economies	7 666 (64.8)	10 867 (50.5)	10 972 (38.6)	12 123 (33.6)	14 486 (31.6)	17 420 (30.3)	1.2	1.1	1.8	1.9	1.6
Emerging Market and Developing Economies	4 171 (35.2)	10 671 (49.5)	17 430 (61.4)	24 005 (66.4)	31 393 (68.4)	40 097 (69.7)	4.7	3.6	2.7	2.5	2.9

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

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

Table A55 | Primary energy consumption per capita [Advanced Technologies Scenario]

(toe/person)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	1.66	1.85	1.87	1.81	1.60	1.43	0.4	-0.4	-1.2	-1.2	-0.9
Asia	0.71	1.24	1.50	1.58	1.45	1.29	2.5	0.6	-0.8	-1.2	-0.5
China	0.77	1.90	2.65	2.78	2.43	1.92	4.1	0.6	-1.4	-2.3	-1.1
India	0.32	0.54	0.67	0.80	0.85	0.87	2.4	2.0	0.5	0.3	0.9
Japan	3.54	3.90	3.18	3.14	2.88	2.70	-0.3	-0.2	-0.8	-0.7	-0.6
Korea	2.17	5.05	5.64	5.71	5.45	5.07	3.1	0.1	-0.5	-0.7	-0.4
Chinese Taipei	2.50	5.13	5.22	5.03	4.63	4.08	2.4	-0.4	-0.8	-1.3	-0.8
ASEAN	0.54	0.93	1.04	1.29	1.43	1.52	2.1	2.4	1.0	0.6	1.3
Indonesia	0.54	0.84	0.86	1.16	1.42	1.63	1.5	3.4	2.0	1.4	2.2
Malaysia	1.21	2.52	2.83	3.34	3.19	2.98	2.8	1.8	-0.5	-0.7	0.2
Myanmar	0.27	0.28	0.40	0.45	0.49	0.58	1.3	1.2	1.0	1.6	1.3
Philippines	0.43	0.44	0.54	0.63	0.69	0.68	0.7	1.8	0.9	-0.2	0.8
Singapore	3.78	4.76	6.46	6.46	6.35	6.11	1.7	0.0	-0.2	-0.4	-0.2
Thailand	0.77	1.73	1.81	2.01	2.08	2.18	2.8	1.2	0.3	0.5	0.6
Viet Nam	0.27	0.67	0.98	1.42	1.64	1.69	4.3	4.2	1.5	0.3	1.9
North America	7.67	7.20	6.56	5.79	4.73	4.14	-0.5	-1.4	-2.0	-1.3	-1.6
United States	7.67	7.16	6.44	5.65	4.57	3.99	-0.6	-1.5	-2.1	-1.4	-1.6
Latin America	1.07	1.35	1.26	1.27	1.24	1.23	0.5	0.1	-0.3	0.0	-0.1
Advanced Europe	3.25	3.29	2.92	2.53	2.21	2.03	-0.4	-1.6	-1.3	-0.9	-1.2
European Union	3.43	3.46	3.10	2.78	2.43	2.22	-0.3	-1.2	-1.3	-0.9	-1.1
Other Europe/Eurasia	4.50	3.35	3.59	3.44	3.31	3.13	-0.7	-0.5	-0.4	-0.6	-0.5
Africa	0.63	0.67	0.63	0.54	0.46	0.42	0.0	-1.7	-1.7	-1.0	-1.4
Middle East	1.67	2.95	3.07	3.14	3.01	2.87	2.0	0.3	-0.4	-0.5	-0.2
Oceania	4.85	5.46	4.87	4.21	3.55	3.30	0.0	-1.6	-1.7	-0.7	-1.3
Advanced Economies	4.48	4.70	4.29	3.87	3.33	3.01	-0.1	-1.2	-1.5	-1.0	-1.2
Emerging Market and Developing Economies	0.95	1.23	1.39	1.40	1.27	1.13	1.2	0.1	-1.0	-1.1	-0.7

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

Note: World includes international bunkers.

Table A56 | Primary energy consumption per GDP [Advanced Technologies Scenario]

(toe/$2015 million)

							CAGR (%)				
	1990	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	244	198	171	140	102	75	-1.1	-2.2	-3.1	-3.0	-2.8
Asia	312	268	217	173	115	76	-1.2	-2.5	-4.0	-4.0	-3.5
China	850	336	237	175	103	58	-4.0	-3.3	-5.2	-5.6	-4.7
India	590	426	339	256	164	108	-1.8	-3.1	-4.3	-4.1	-3.9
Japan	124	118	90	79	62	50	-1.0	-1.4	-2.3	-2.1	-2.0
Korea	231	198	172	142	109	83	-0.9	-2.1	-2.7	-2.7	-2.5
Chinese Taipei	315	256	186	146	109	80	-1.7	-2.6	-2.9	-3.1	-2.9
ASEAN	317	275	225	197	151	116	-1.1	-1.5	-2.6	-2.6	-2.3
Indonesia	365	310	221	205	164	129	-1.6	-0.8	-2.2	-2.4	-1.8
Malaysia	284	312	268	229	166	124	-0.2	-1.7	-3.2	-2.9	-2.6
Myanmar	1 489	318	323	292	212	166	-4.8	-1.1	-3.2	-2.4	-2.3
Philippines	249	182	161	125	95	72	-1.4	-2.8	-2.8	-2.6	-2.7
Singapore	163	98	98	83	70	58	-1.6	-1.8	-1.7	-1.7	-1.8
Thailand	294	340	296	250	184	139	0.0	-1.9	-3.0	-2.7	-2.6
Viet Nam	397	330	286	246	174	120	-1.0	-1.7	-3.4	-3.7	-3.0
North America	200	139	109	85	60	45	-1.9	-2.7	-3.5	-2.7	-3.0
United States	195	135	104	81	56	42	-2.0	-2.8	-3.6	-2.8	-3.1
Latin America	180	163	154	133	101	80	-0.5	-1.6	-2.7	-2.4	-2.2
Advanced Europe	141	109	86	64	49	39	-1.6	-3.2	-2.7	-2.2	-2.7
European Union	158	118	95	72	55	44	-1.6	-3.0	-2.7	-2.2	-2.6
Other Europe/Eurasia	826	532	466	379	291	221	-1.8	-2.3	-2.6	-2.7	-2.5
Africa	424	343	320	235	149	104	-0.9	-3.4	-4.5	-3.5	-3.8
Middle East	245	314	311	271	220	178	0.8	-1.5	-2.1	-2.1	-1.9
Oceania	150	118	95	73	52	42	-1.5	-2.9	-3.2	-2.3	-2.8
Advanced Economies	164	126	101	79	58	45	-1.6	-2.7	-3.0	-2.5	-2.8
Emerging Market and Developing Economies	470	318	262	205	138	94	-1.9	-2.7	-3.9	-3.7	-3.5

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

Note: World includes international bunkers.

Table A57 | Energy-related carbon dioxide emissions [Advanced Technologies Scenario]

(Mt)

	1990	2010	2021	2030	2040	2050	CAGR (%) 1990/ 2021	2021/ 2030	2030/ 2040	2040/ 2050	2021/ 2050
World	20 522 (100)	30 703 (100)	33 568 (100)	31 010 (100)	23 137 (100)	14 704 (100)	1.6	-0.9	-2.9	-4.4	-2.8
Asia	4 700 (22.9)	13 032 (42.4)	16 776 (50.0)	16 331 (52.7)	12 109 (52.3)	6 812 (46.3)	4.2	-0.3	-2.9	-5.6	-3.1
China	2 195 (10.7)	8 110 (26.4)	10 649 (31.7)	9 930 (32.0)	6 281 (27.1)	2 178 (14.8)	5.2	-0.8	-4.5	-10.0	-5.3
India	531 (2.6)	1 588 (5.2)	2 279 (6.8)	2 657 (8.6)	2 585 (11.2)	2 299 (15.6)	4.8	1.7	-0.3	-1.2	0.0
Japan	1 056 (5.1)	1 137 (3.7)	998 (3.0)	706 (2.3)	466 (2.0)	272 (1.8)	-0.2	-3.8	-4.1	-5.2	-4.4
Korea	208 (1.0)	528 (1.7)	559 (1.7)	472 (1.5)	354 (1.5)	150 (1.0)	3.2	-1.9	-2.8	-8.2	-4.4
Chinese Taipei	109 (0.5)	254 (0.8)	267 (0.8)	244 (0.8)	169 (0.7)	49 (0.3)	2.9	-1.0	-3.6	-11.7	-5.7
ASEAN	350 (1.7)	1 069 (3.5)	1 517 (4.5)	1 762 (5.7)	1 625 (7.0)	1 277 (8.7)	4.8	1.7	-0.8	-2.4	-0.6
Indonesia	131 (0.6)	397 (1.3)	557 (1.7)	652 (2.1)	619 (2.7)	495 (3.4)	4.8	1.8	-0.5	-2.2	-0.4
Malaysia	50 (0.2)	185 (0.6)	226 (0.7)	261 (0.8)	219 (0.9)	156 (1.1)	5.0	1.6	-1.7	-3.3	-1.3
Myanmar	4 (0.0)	8 (0.0)	28 (0.1)	52 (0.2)	70 (0.3)	87 (0.6)	6.4	7.3	3.0	2.2	4.0
Philippines	35 (0.2)	75 (0.2)	132 (0.4)	156 (0.5)	165 (0.7)	143 (1.0)	4.3	1.9	0.6	-1.4	0.3
Singapore	29 (0.1)	51 (0.2)	46 (0.1)	46 (0.1)	32 (0.1)	15 (0.1)	1.5	0.2	-3.7	-7.3	-3.8
Thailand	80 (0.4)	223 (0.7)	235 (0.7)	227 (0.7)	176 (0.8)	117 (0.8)	3.5	-0.4	-2.5	-4.0	-2.4
Viet Nam	16 (0.1)	122 (0.4)	285 (0.8)	360 (1.2)	337 (1.5)	258 (1.8)	9.6	2.6	-0.7	-2.6	-0.3
North America	5 126 (25.0)	5 698 (18.6)	5 055 (15.1)	3 895 (12.6)	2 119 (9.2)	1 011 (6.9)	0.0	-2.9	-5.9	-7.1	-5.4
United States	4 740 (23.1)	5 204 (17.0)	4 549 (13.6)	3 452 (11.1)	1 793 (7.7)	794 (5.4)	-0.1	-3.0	-6.3	-7.8	-5.8
Latin America	867 (4.2)	1 524 (5.0)	1 453 (4.3)	1 391 (4.5)	1 271 (5.5)	1 119 (7.6)	1.7	-0.5	-0.9	-1.3	-0.9
Advanced Europe	3 944 (19.2)	3 823 (12.5)	3 242 (9.7)	2 113 (6.8)	1 346 (5.8)	770 (5.2)	-0.6	-4.6	-4.4	-5.4	-4.8
European Union	3 464 (16.9)	3 135 (10.2)	2 579 (7.7)	1 473 (4.8)	934 (4.0)	515 (3.5)	-0.9	-6.0	-4.5	-5.8	-5.4
Other Europe/Eurasia	3 878 (18.9)	2 511 (8.2)	2 584 (7.7)	2 240 (7.2)	1 760 (7.6)	1 290 (8.8)	-1.3	-1.6	-2.4	-3.1	-2.4
Africa	524 (2.6)	1 008 (3.3)	1 218 (3.6)	1 335 (4.3)	1 297 (5.6)	1 168 (7.9)	2.8	1.0	-0.3	-1.0	-0.1
Middle East	569 (2.8)	1 553 (5.1)	1 862 (5.5)	1 987 (6.4)	1 663 (7.2)	1 188 (8.1)	3.9	0.7	-1.8	-3.3	-1.5
Oceania	279 (1.4)	421 (1.4)	392 (1.2)	295 (1.0)	182 (0.8)	104 (0.7)	1.1	-3.1	-4.7	-5.4	-4.5
Advanced Economies	10 784 (52.5)	11 954 (38.9)	10 593 (31.6)	7 809 (25.2)	4 697 (20.3)	2 393 (16.3)	-0.1	-3.3	-5.0	-6.5	-5.0
Emerging Market and Developing Economies	9 102 (44.4)	17 615 (57.4)	21 990 (65.5)	21 779 (70.2)	17 050 (73.7)	11 069 (75.3)	2.9	-0.1	-2.4	-4.2	-2.3

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

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

Table A58 | World [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	8 754	10 026	12 850	14 759	15 389	14 666	13 802	100	100	100	1.7	0.5	-0.5	-0.2
Coal	2 223	2 318	3 662	4 016	3 485	2 532	1 575	25	27	11	1.9	-1.6	-3.9	-3.2
Oil	3 237	3 684	4 155	4 352	4 321	3 545	2 704	37	29	20	1.0	-0.1	-2.3	-1.6
Natural gas	1 662	2 068	2 734	3 487	3 541	3 432	3 044	19	24	22	2.4	0.2	-0.8	-0.5
Nuclear	526	675	719	732	988	1 257	1 450	6.0	5.0	11	1.1	3.4	1.9	2.4
Hydro	184	225	296	369	419	471	527	2.1	2.5	3.8	2.3	1.4	1.2	1.2
Geothermal	34	52	62	111	227	306	367	0.4	0.8	2.7	3.9	8.3	2.4	4.2
Solar, wind, etc.	2.5	8.2	48	291	903	1 781	2 848	0.0	2.0	21	16.5	13.4	5.9	8.2
Biomass and waste	885	994	1 173	1 397	1 502	1 339	1 289	10	9.5	9.3	1.5	0.8	-0.8	-0.3
Hydrogen	-	-	-	-	-	-1.4	-3.5	-	-	-0.0	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	6 242	7 012	8 829	10 082	10 513	9 900	9 176	100	100	100	1.6	0.5	-0.7	-0.3
Industry	1 797	1 869	2 643	3 037	3 246	3 119	2 717	29	30	30	1.7	0.7	-0.9	-0.4
Transport	1 578	1 966	2 430	2 690	2 896	2 567	2 343	25	27	26	1.7	0.8	-1.1	-0.5
Buildings, etc.	2 390	2 561	2 968	3 360	3 271	3 001	2 796	38	33	30	1.1	-0.3	-0.8	-0.6
Non-energy use	477	616	788	995	1 099	1 213	1 320	7.6	9.9	14	2.4	1.1	0.9	1.0
Coal	751	542	1 061	913	799	659	509	12	9.1	5.6	0.6	-1.5	-2.2	-2.0
Oil	2 608	3 130	3 621	3 926	3 981	3 339	2 636	42	39	29	1.3	0.2	-2.0	-1.4
Natural gas	945	1 120	1 344	1 710	1 701	1 457	1 097	15	17	12	1.9	-0.1	-2.2	-1.5
Electricity	834	1 087	1 538	2 077	2 650	3 242	3 725	13	21	41	3.0	2.7	1.7	2.0
Heat	336	248	275	347	346	307	246	5.4	3.4	2.7	0.1	-0.1	-1.7	-1.2
Hydrogen	-	-	-	-	0.2	86	261	-	-	2.8	n.a.	n.a.	43.3	n.a.
Renewables	768	886	990	1 109	1 036	810	702	12	11	7.6	1.2	-0.8	-1.9	-1.6

Electricity generation

	(TWh)							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	11 837	15 423	21 538	28 402	36 128	45 879	57 517	100	100	100	2.9	2.7	2.4	2.5
Coal	4 430	5 995	8 674	10 252	8 854	5 671	2 468	37	36	4.3	2.7	-1.6	-6.2	-4.8
Oil	1 317	1 184	963	723	453	287	161	11	2.5	0.3	-1.9	-5.0	-5.0	-5.0
Natural gas	1 748	2 772	4 856	6 556	6 833	7 661	8 119	15	23	14	4.4	0.5	0.9	0.7
Nuclear	2 013	2 591	2 756	2 808	3 792	4 824	5 565	17	9.9	9.7	1.1	3.4	1.9	2.4
Hydro	2 139	2 611	3 447	4 293	4 871	5 482	6 128	18	15	11	2.3	1.4	1.2	1.2
Geothermal	36	52	68	96	201	264	313	0.3	0.3	0.5	3.2	8.6	2.2	4.2
Solar PV	0.1	0.8	32	1 020	4 642	9 798	16 458	0.0	3.6	29	35.1	18.3	6.5	10.1
Wind	3.9	31	342	1 864	4 955	9 318	14 214	0.0	6.6	25	22.0	11.5	5.4	7.3
CSP and marine	1.2	1.1	2.2	16	147	374	676	0.0	0.1	1.2	8.6	28.3	7.9	13.9
Biomass and waste	130	163	362	735	1 341	1 600	1 830	1.1	2.6	3.2	5.7	6.9	1.6	3.2
Hydrogen	-	-	-	-	-	562	1 545	-	-	2.7	n.a.	n.a.	n.a.	n.a.
Others	20	22	35	39	39	39	39	0.2	0.1	0.1	2.2	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	35 916	48 229	64 773	86 438	109 746	144 034	184 046	2.9	2.7	2.6	2.6
Population (million)	5 286	6 135	6 960	7 877	8 511	9 155	9 680	1.3	0.9	0.6	0.7
CO_2 emissions (Mt)	20 522	23 175	30 703	33 568	31 010	23 137	14 704	1.6	-0.9	-3.7	-2.8
GDP per capita ($2015 thousand)	6.8	7.9	9.3	11	13	16	19	1.6	1.8	2.0	1.9
Primary energy consump. per capita (toe)	1.7	1.6	1.8	1.9	1.8	1.6	1.4	0.4	-0.4	-1.2	-0.9
Primary energy consumption per GDP*2	244	208	198	171	140	102	75	-1.1	-2.2	-3.1	-2.8
CO_2 emissions per GDP*3	571	481	474	388	283	161	80	-1.2	-3.5	-6.1	-5.3
CO_2 per primary energy consumption*4	2.3	2.3	2.4	2.3	2.0	1.6	1.1	-0.1	-1.3	-3.1	-2.6

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A59 | Asia [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	2 088	2 867	4 803	6 439	7 127	6 815	6 173	100	100	100	3.7	1.1	-0.7	-0.1
Coal	789	1 038	2 416	3 142	2 951	2 146	1 248	38	49	20	4.6	-0.7	-4.2	-3.1
Oil	618	918	1 172	1 491	1 522	1 347	1 096	30	23	18	2.9	0.2	-1.6	-1.1
Natural gas	116	233	455	722	906	904	684	5.5	11	11	6.1	2.5	-1.4	-0.2
Nuclear	77	132	152	189	377	531	645	3.7	2.9	10	3.0	7.9	2.7	4.3
Hydro	32	41	92	157	182	216	251	1.5	2.4	4.1	5.3	1.7	1.6	1.6
Geothermal	8.2	23	31	64	140	202	246	0.4	1.0	4.0	6.8	9.2	2.9	4.8
Solar, wind, etc.	1.3	2.1	16	142	424	853	1 331	0.1	2.2	22	16.4	12.9	5.9	8.0
Biomass and waste	448	480	469	530	623	591	584	21	8.2	9.5	0.5	1.8	-0.3	0.3
Hydrogen	-	-	-	-	0.0	25	87	-	-	1.4	n.a.	n.a.	54.2	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 534	1 976	3 166	4 131	4 487	4 397	4 130	100	100	100	3.2	0.9	-0.4	0.0
Industry	508	654	1 405	1 750	1 882	1 786	1 511	33	42	37	4.1	0.8	-1.1	-0.5
Transport	189	323	493	719	823	773	732	12	17	18	4.4	1.5	-0.6	0.1
Buildings, etc.	721	818	977	1 222	1 280	1 280	1 278	47	30	31	1.7	0.5	0.0	0.2
Non-energy use	115	181	291	439	501	558	608	7.5	11	15	4.4	1.5	1.0	1.1
Coal	423	373	897	762	666	549	426	28	18	10	1.9	-1.5	-2.2	-2.0
Oil	465	743	993	1 343	1 387	1 238	1 020	30	33	25	3.5	0.4	-1.5	-0.9
Natural gas	46	89	201	392	434	389	290	3.0	9.5	7.0	7.1	1.1	-2.0	-1.0
Electricity	157	279	574	1 023	1 404	1 714	1 948	10	25	47	6.2	3.6	1.7	2.2
Heat	14	30	69	157	167	149	117	0.9	3.8	2.8	8.1	0.7	-1.8	-1.0
Hydrogen	-	-	-	-	0.0	13	44	-	-	1.1	n.a.	n.a.	41.1	n.a.
Renewables	429	462	433	454	428	345	285	28	11	6.9	0.2	-0.6	-2.0	-1.6

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	2 237	3 971	7 992	13 664	18 866	23 006	26 570	100	100	100	6.0	3.6	1.7	2.3
Coal	868	1 984	4 780	7 824	7 670	5 001	1 894	39	57	7.1	7.4	-0.2	-6.8	-4.8
Oil	433	381	260	130	80	74	59	19	1.0	0.2	-3.8	-5.3	-1.5	-2.7
Natural gas	237	566	1 096	1 466	2 182	2 700	2 310	11	11	8.7	6.1	4.5	0.3	1.6
Nuclear	294	505	582	727	1 446	2 037	2 474	13	5.3	9.3	3.0	7.9	2.7	4.3
Hydro	368	478	1 072	1 825	2 121	2 514	2 921	16	13	11	5.3	1.7	1.6	1.6
Geothermal	8.4	20	22	30	84	122	151	0.4	0.2	0.6	4.2	12.1	3.0	5.7
Solar PV	0.1	0.4	5.2	560	2 435	5 199	8 434	0.0	4.1	32	33.6	17.7	6.4	9.8
Wind	0.0	2.4	70	761	2 115	4 278	6 507	0.0	5.6	24	38.1	12.0	5.8	7.7
CSP and marine	0.0	0.0	0.0	2.5	15	35	83	0.0	0.0	0.3	20.8	22.1	9.0	12.9
Biomass and waste	9.0	15	82	315	695	872	1 047	0.4	2.3	3.9	12.2	9.2	2.1	4.2
Hydrogen	-	-	-	-	-	152	667	-	-	2.5	n.a.	n.a.	n.a.	n.a.
Others	20	20	21	23	23	23	23	0.9	0.2	0.1	0.5	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	6 690	10 397	17 895	29 673	41 194	59 070	80 738	4.9	3.7	3.4	3.5
Population (million)	2 955	3 454	3 874	4 284	4 507	4 686	4 772	1.2	0.6	0.3	0.4
CO_2 emissions (Mt)	4 700	6 817	13 032	16 776	16 331	12 109	6 812	4.2	-0.3	-4.3	-3.1
GDP per capita ($2015 thousand)	2.3	3.0	4.6	6.9	9.1	13	17	3.7	3.1	3.1	3.1
Primary energy consump. per capita (toe)	0.7	0.8	1.2	1.5	1.6	1.5	1.3	2.5	0.6	-1.0	-0.5
Primary energy consumption per GDP[*2]	312	276	268	217	173	115	76	-1.2	-2.5	-4.0	-3.5
CO_2 emissions per GDP[*3]	703	656	728	565	396	205	84	-0.7	-3.9	-7.4	-6.3
CO_2 per primary energy consumption[*4]	2.3	2.4	2.7	2.6	2.3	1.8	1.1	0.5	-1.4	-3.6	-2.9

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A60 | China [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/2021	2021/2030	2030/2050	2021/2050
Total[*1]	874	1 133	2 536	3 738	3 908	3 317	2 510	100	100	100	4.8	0.5	-2.2	-1.4
Coal	531	668	1 790	2 266	2 062	1 316	518	61	61	21	4.8	-1.0	-6.7	-5.0
Oil	119	221	428	678	639	502	364	14	18	14	5.8	-0.6	-2.8	-2.1
Natural gas	13	21	89	299	396	332	110	1.5	8.0	4.4	10.7	3.2	-6.2	-3.4
Nuclear	-	4.4	19	106	170	238	305	-	2.8	12	n.a.	5.3	3.0	3.7
Hydro	11	19	61	112	121	135	145	1.2	3.0	5.8	7.8	0.9	0.9	0.9
Geothermal	-	1.7	3.6	24	28	28	24	-	0.6	1.0	n.a.	1.9	-0.7	0.1
Solar, wind, etc.	0.0	1.0	12	111	294	563	822	0.0	3.0	33	29.9	11.5	5.3	7.2
Biomass and waste	200	198	133	144	199	205	222	23	3.9	8.9	-1.1	3.7	0.6	1.5
Hydrogen	-	-	-	-	-0.0	-0.0	1.6	-	-	0.1	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	658	781	1 645	2 317	2 384	2 160	1 846	100	100	100	4.1	0.3	-1.3	-0.8
Industry	234	302	924	1 129	1 080	900	652	36	49	35	5.2	-0.5	-2.5	-1.9
Transport	30	83	195	346	396	340	291	4.6	15	16	8.2	1.5	-1.5	-0.6
Buildings, etc.	351	339	413	629	682	685	668	53	27	36	1.9	0.9	-0.1	0.2
Non-energy use	43	58	113	212	226	234	236	6.5	9.2	13	5.3	0.7	0.2	0.4
Coal	311	274	712	542	416	291	194	47	23	10	1.8	-2.9	-3.7	-3.5
Oil	85	180	369	619	586	465	344	13	27	19	6.6	-0.6	-2.6	-2.0
Natural gas	8.9	12	73	223	227	168	84	1.3	9.6	4.6	11.0	0.2	-4.8	-3.3
Electricity	39	89	297	652	881	992	1 003	5.9	28	54	9.5	3.4	0.6	1.5
Heat	13	26	62	147	157	140	109	2.0	6.4	5.9	8.1	0.7	-1.8	-1.0
Hydrogen	-	-	-	-	0.0	8.5	30	-	-	1.6	n.a.	n.a.	47.8	n.a.
Renewables	200	199	132	133	116	95	83	30	5.8	4.5	-1.3	-1.5	-1.7	-1.6

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	621	1 356	4 197	8 560	11 633	13 029	13 184	100	100	100	8.8	3.5	0.6	1.5
Coal	441	1 060	3 240	5 417	5 363	3 053	328	71	63	2.5	8.4	-0.1	-13.0	-9.2
Oil	50	47	15	11	9.8	4.5	0.3	8.1	0.1	0.0	-4.7	-1.7	-15.5	-11.4
Natural gas	2.8	5.8	78	268	701	764	142	0.4	3.1	1.1	15.9	11.3	-7.7	-2.2
Nuclear	-	17	74	408	651	912	1 169	-	4.8	8.9	n.a.	5.3	3.0	3.7
Hydro	127	222	711	1 300	1 406	1 566	1 684	20	15	13	7.8	0.9	0.9	0.9
Geothermal	0.1	0.1	0.1	0.1	2.1	2.6	2.7	0.0	0.0	0.0	2.6	36.5	1.3	11.1
Solar PV	0.0	0.0	0.7	327	1 399	2 754	4 068	0.0	3.8	31	47.3	17.5	5.5	9.1
Wind	0.0	0.6	45	656	1 689	3 431	5 083	0.0	7.7	39	50.6	11.1	5.7	7.3
CSP and marine	0.0	0.0	0.0	2.0	5.9	19	50	0.0	0.0	0.4	20.0	12.7	11.2	11.7
Biomass and waste	-	2.4	34	170	407	503	597	-	2.0	4.5	n.a.	10.2	1.9	4.4
Hydrogen	-	-	-	-	-	19	60	-	-	0.5	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/2021	2021/2030	2030/2050	2021/2050
GDP ($2015 billion)	1 027	2 770	7 554	15 802	22 368	32 274	43 522	9.2	3.9	3.4	3.6
Population (million)	1 135	1 263	1 338	1 412	1 404	1 367	1 305	0.7	-0.1	-0.4	-0.3
CO_2 emissions (Mt)	2 195	3 209	8 110	10 649	9 930	6 281	2 178	5.2	-0.8	-7.3	-5.3
GDP per capita ($2015 thousand)	0.9	2.2	5.6	11	16	24	33	8.4	4.0	3.8	3.8
Primary energy consump. per capita (toe)	0.8	0.9	1.9	2.6	2.8	2.4	1.9	4.1	0.6	-1.8	-1.1
Primary energy consumption per GDP[*2]	850	409	336	237	175	103	58	-4.0	-3.3	-5.4	-4.7
CO_2 emissions per GDP[*3]	2 137	1 158	1 074	674	444	195	50	-3.7	-4.5	-10.3	-8.6
CO_2 per primary energy consumption[*4]	2.5	2.8	3.2	2.8	2.5	1.9	0.9	0.4	-1.3	-5.2	-4.0

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A61 | India [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	280	418	667	944	1 217	1 365	1 464	100	100	100	4.0	2.9	0.9	1.5
Coal	93	146	279	421	472	443	407	33	45	28	5.0	1.3	-0.7	-0.1
Oil	61	112	162	223	272	299	288	22	24	20	4.3	2.2	0.3	0.9
Natural gas	11	23	54	55	98	126	138	3.8	5.8	9.4	5.5	6.6	1.7	3.2
Nuclear	1.6	4.4	6.8	12	49	91	119	0.6	1.3	8.1	6.8	16.6	4.5	8.1
Hydro	6.2	6.4	11	14	22	33	49	2.2	1.5	3.3	2.7	5.0	4.1	4.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	0.0	0.2	2.0	15	74	177	294	0.0	1.5	20	26.3	19.9	7.1	10.9
Biomass and waste	108	126	152	204	231	196	166	39	22	11	2.1	1.4	-1.6	-0.7
Hydrogen	-	-	-	-	-0.0	1.1	3.5	-	-	0.2	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	215	290	443	632	804	912	979	100	100	100	3.5	2.7	1.0	1.5
Industry	59	85	158	247	363	405	382	27	39	39	4.7	4.4	0.3	1.5
Transport	21	32	65	102	129	155	187	9.6	16	19	5.3	2.7	1.9	2.1
Buildings, etc.	122	147	187	228	236	246	270	57	36	28	2.0	0.4	0.7	0.6
Non-energy use	13	27	34	55	76	105	139	6.2	8.8	14	4.7	3.6	3.1	3.2
Coal	38	33	87	107	127	135	126	18	17	13	3.4	2.0	-0.1	0.6
Oil	50	94	138	205	253	279	269	23	32	28	4.6	2.4	0.3	0.9
Natural gas	6.1	12	19	38	54	68	71	2.8	6.0	7.3	6.1	4.1	1.4	2.2
Electricity	18	32	62	104	185	291	414	8.5	16	42	5.8	6.6	4.1	4.9
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	1.9	5.3	-	-	0.5	n.a.	n.a.	n.a.	n.a.
Renewables	102	119	138	179	185	136	93	48	28	9.5	1.8	0.4	-3.4	-2.2

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	289	561	972	1 635	2 831	4 208	5 755	100	100	100	5.7	6.3	3.6	4.4
Coal	189	387	658	1 170	1 274	1 017	805	65	72	14	6.1	1.0	-2.3	-1.3
Oil	13	25	19	4.5	1.2	-	-	4.3	0.3	-	-3.2	-13.7	-100	-100
Natural gas	10.0	56	107	62	209	342	441	3.4	3.8	7.7	6.1	14.5	3.8	7.0
Nuclear	6.1	17	26	47	188	348	455	2.1	2.9	7.9	6.8	16.6	4.5	8.1
Hydro	72	74	125	162	251	385	566	25	9.9	9.8	2.7	5.0	4.1	4.4
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	0.0	0.1	76	611	1 561	2 607	-	4.6	45	n.a.	26.2	7.5	13.0
Wind	0.0	1.7	20	77	209	429	710	0.0	4.7	12	28.6	11.7	6.3	8.0
CSP and marine	-	-	-	-	5.1	11	22	-	-	0.4	n.a.	n.a.	7.6	n.a.
Biomass and waste	-	0.2	17	37	82	115	150	-	2.3	2.6	n.a.	9.3	3.0	4.9
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	475	817	1 567	2 782	4 761	8 307	13 614	5.9	6.2	5.4	5.6
Population (million)	870	1 060	1 241	1 408	1 514	1 613	1 674	1.6	0.8	0.5	0.6
CO_2 emissions (Mt)	531	892	1 588	2 279	2 657	2 585	2 299	4.8	1.7	-0.7	0.0
GDP per capita ($2015 thousand)	0.5	0.8	1.3	2.0	3.1	5.1	8.1	4.2	5.3	4.9	5.0
Primary energy consump. per capita (toe)	0.3	0.4	0.5	0.7	0.8	0.8	0.9	2.4	2.0	0.4	0.9
Primary energy consumption per GDP*2	590	512	426	339	256	164	108	-1.8	-3.1	-4.2	-3.9
CO_2 emissions per GDP*3	1 119	1 092	1 013	819	558	311	169	-1.0	-4.2	-5.8	-5.3
CO_2 per primary energy consumption*4	1.9	2.1	2.4	2.4	2.2	1.9	1.6	0.8	-1.1	-1.6	-1.5

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A62 | Japan [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	437	516	500	400	375	324	283	100	100	100	-0.3	-0.7	-1.4	-1.2
Coal	77	97	115	109	69	51	33	18	27	12	1.1	-5.0	-3.6	-4.0
Oil	249	253	201	151	122	84	59	57	38	21	-1.6	-2.3	-3.6	-3.2
Natural gas	44	66	86	87	63	53	24	10	22	8.5	2.2	-3.5	-4.7	-4.3
Nuclear	53	84	75	18	64	59	58	12	4.6	21	-3.3	14.9	-0.5	4.1
Hydro	7.6	7.2	7.2	6.8	8.0	8.5	8.8	1.7	1.7	3.1	-0.4	1.8	0.5	0.9
Geothermal	1.6	3.1	2.4	2.7	4.7	6.0	6.8	0.4	0.7	2.4	1.8	6.2	1.9	3.2
Solar, wind, etc.	1.2	0.9	1.1	8.4	16	24	34	0.3	2.1	12	6.4	7.8	3.7	4.9
Biomass and waste	4.2	5.0	11	17	27	30	34	1.0	4.2	12	4.6	5.5	1.0	2.4
Hydrogen	-	-	-	-	0.0	7.5	25	-	-	8.9	n.a.	n.a.	40.0	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	290	336	314	267	243	202	170	100	100	100	-0.3	-1.1	-1.8	-1.6
Industry	108	103	92	80	74	64	54	37	30	32	-1.0	-0.9	-1.6	-1.4
Transport	72	89	79	63	54	35	27	25	24	16	-0.4	-1.7	-3.5	-3.0
Buildings, etc.	78	108	108	94	86	73	61	27	35	36	0.6	-1.0	-1.7	-1.5
Non-energy use	32	36	35	30	30	29	29	11	11	17	-0.2	-0.2	-0.2	-0.2
Coal	27	21	23	20	17	13	9.5	9.3	7.5	5.6	-1.0	-1.9	-2.8	-2.6
Oil	180	205	166	132	112	77	53	62	49	32	-1.0	-1.8	-3.6	-3.1
Natural gas	14	21	29	28	25	19	12	4.7	11	6.9	2.4	-1.2	-3.8	-3.0
Electricity	66	84	89	80	82	86	84	23	30	49	0.6	0.2	0.1	0.2
Heat	0.2	0.5	0.6	0.5	0.5	0.4	0.3	0.1	0.2	0.2	3.1	-1.1	-2.6	-2.1
Hydrogen	-	-	-	-	0.0	1.2	5.0	-	-	3.0	n.a.	n.a.	29.0	n.a.
Renewables	3.8	4.1	6.1	6.5	6.3	5.9	5.9	1.3	2.4	3.4	1.8	-0.4	-0.4	-0.4

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	862	1 055	1 164	1 040	1 057	1 131	1 171	100	100	100	0.6	0.2	0.5	0.4
Coal	125	228	317	322	151	87	27	14	31	2.3	3.1	-8.1	-8.2	-8.1
Oil	250	133	91	39	6.7	2.9	-	29	3.8	-	-5.8	-17.8	-100	-100
Natural gas	168	255	332	359	235	235	103	19	35	8.8	2.5	-4.6	-4.0	-4.2
Nuclear	202	322	288	71	247	225	224	23	6.8	19	-3.3	14.9	-0.5	4.1
Hydro	88	84	84	79	93	99	103	10	7.6	8.8	-0.4	1.8	0.5	0.9
Geothermal	1.7	3.3	2.6	3.0	5.3	6.9	7.9	0.2	0.3	0.7	1.8	6.5	2.0	3.4
Solar PV	0.1	0.4	3.5	86	136	182	226	0.0	8.3	19	26.0	5.2	2.6	3.4
Wind	-	0.1	4.0	9.4	54	99	165	-	0.9	14	n.a.	21.3	5.8	10.4
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	8.1	9.2	21	53	111	136	159	0.9	5.1	14	6.2	8.6	1.8	3.9
Hydrogen	-	-	-	-	-	40	138	-	-	12	n.a.	n.a.	n.a.	n.a.
Others	20	20	21	18	18	18	18	2.3	1.7	1.5	-0.3	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	3 510	3 987	4 219	4 435	4 744	5 178	5 607	0.8	0.8	0.8	0.8
Population (million)	123	127	128	126	120	112	105	0.1	-0.6	-0.7	-0.6
CO_2 emissions (Mt)	1 056	1 161	1 137	998	706	466	272	-0.2	-3.8	-4.7	-4.4
GDP per capita ($2015 thousand)	28	31	33	35	40	46	54	0.7	1.3	1.5	1.4
Primary energy consump. per capita (toe)	3.5	4.1	3.9	3.2	3.1	2.9	2.7	-0.3	-0.2	-0.7	-0.6
Primary energy consumption per GDP[*2]	124	129	118	90	79	62	50	-1.0	-1.4	-2.2	-2.0
CO_2 emissions per GDP[*3]	301	291	270	225	149	90	48	-0.9	-4.5	-5.5	-5.2
CO_2 per primary energy consumption[*4]	2.4	2.3	2.3	2.5	1.9	1.4	1.0	0.1	-3.1	-3.3	-3.2

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A63 | Korea [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	93	187	250	292	293	269	233	100	100	100	3.8	0.0	-1.1	-0.8
Coal	25	40	73	75	63	49	23	27	26	9.9	3.6	-1.9	-4.9	-4.0
Oil	50	99	95	112	105	86	71	54	38	30	2.6	-0.7	-1.9	-1.6
Natural gas	2.7	17	39	54	49	42	11	2.9	19	4.6	10.1	-1.3	-7.3	-5.4
Nuclear	14	28	39	41	58	58	46	15	14	20	3.6	3.8	-1.1	0.4
Hydro	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.6	0.1	0.1	-2.3	1.7	0.0	0.5
Geothermal	-	-	0.0	0.3	0.4	0.4	0.4	-	0.1	0.2	n.a.	4.8	-0.1	1.4
Solar, wind, etc.	0.0	0.0	0.2	2.8	8.7	13	21	0.0	0.9	9.0	19.9	13.6	4.5	7.2
Biomass and waste	0.7	1.4	3.5	6.3	9.3	11	14	0.8	2.2	6.0	7.2	4.4	2.0	2.8
Hydrogen	-	-	-	-	0.0	9.3	47	-	-	20	n.a.	n.a.	71.3	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	65	127	158	182	180	163	143	100	100	100	3.4	-0.1	-1.1	-0.8
Industry	19	38	45	47	49	45	36	30	26	25	2.9	0.5	-1.6	-0.9
Transport	15	26	30	36	31	22	17	22	20	12	2.9	-1.5	-3.1	-2.6
Buildings, etc.	24	37	44	46	44	40	35	38	25	24	2.0	-0.3	-1.2	-0.9
Non-energy use	6.7	25	38	53	55	57	56	10	29	39	6.9	0.4	0.1	0.2
Coal	12	9.1	9.5	7.1	6.1	4.7	3.1	18	3.9	2.1	-1.6	-1.6	-3.4	-2.8
Oil	44	80	82	97	91	76	63	67	54	44	2.6	-0.7	-1.8	-1.5
Natural gas	0.7	11	21	22	20	15	7.5	1.0	12	5.2	11.9	-0.7	-4.9	-3.6
Electricity	8.1	23	39	46	52	56	55	13	25	39	5.8	1.4	0.3	0.6
Heat	-	3.3	4.3	5.5	5.2	4.6	3.7	-	3.0	2.6	n.a.	-0.7	-1.6	-1.3
Hydrogen	-	-	-	-	0.0	0.8	2.8	-	-	1.9	n.a.	n.a.	48.7	n.a.
Renewables	0.7	1.3	2.7	3.9	4.7	5.8	7.7	1.1	2.1	5.4	5.5	2.2	2.5	2.4

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	105	289	497	608	689	750	792	100	100	100	5.8	1.4	0.7	0.9
Coal	18	111	219	208	167	116	10	17	34	1.3	8.3	-2.4	-13.1	-9.9
Oil	19	35	19	8.2	3.8	-	-	18	1.3	-	-2.7	-8.3	-100	-100
Natural gas	9.6	29	103	190	169	176	25	9.1	31	3.1	10.1	-1.3	-9.2	-6.8
Nuclear	53	109	149	158	221	222	176	50	26	22	3.6	3.8	-1.1	0.4
Hydro	6.4	4.0	3.7	3.1	3.6	3.6	3.6	6.0	0.5	0.4	-2.3	1.7	0.0	0.5
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	0.0	0.0	0.8	23	78	110	168	0.0	3.8	21	38.3	14.4	3.9	7.0
Wind	-	0.0	0.8	3.2	19	35	64	-	0.5	8.0	n.a.	21.8	6.3	10.9
CSP and marine	-	-	-	0.5	3.8	6.0	11	-	0.1	1.4	n.a.	26.6	5.5	11.6
Biomass and waste	-	0.1	1.1	8.6	18	23	28	-	1.4	3.5	n.a.	8.8	2.1	4.1
Hydrogen	-	-	-	-	-	53	303	-	-	38	n.a.	n.a.	n.a.	n.a.
Others	-	-	0.3	4.7	4.7	4.7	4.7	-	0.8	0.6	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	402	799	1 261	1 694	2 060	2 479	2 817	4.8	2.2	1.6	1.8
Population (million)	43	47	50	52	51	49	46	0.6	-0.1	-0.5	-0.4
CO_2 emissions (Mt)	208	399	528	559	472	354	150	3.2	-1.9	-5.6	-4.4
GDP per capita ($2015 thousand)	9.4	17	25	33	40	50	61	4.1	2.3	2.1	2.2
Primary energy consump. per capita (toe)	2.2	4.0	5.0	5.6	5.7	5.5	5.1	3.1	0.1	-0.6	-0.4
Primary energy consumption per GDP[*2]	231	234	198	172	142	109	83	-0.9	-2.1	-2.7	-2.5
CO_2 emissions per GDP[*3]	517	499	418	330	229	143	53	-1.4	-4.0	-7.0	-6.1
CO_2 per primary energy consumption[*4]	2.2	2.1	2.1	1.9	1.6	1.3	0.6	-0.5	-1.9	-4.5	-3.7

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A64 | Chinese Taipei [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	51	90	119	123	119	108	90	100	100	100	2.9	-0.3	-1.4	-1.0
Coal	11	30	42	43	39	28	12	23	35	14	4.4	-1.1	-5.6	-4.2
Oil	28	42	49	44	41	34	27	56	36	30	1.4	-0.8	-2.0	-1.6
Natural gas	1.6	6.2	15	26	27	22	3.0	3.1	21	3.3	9.4	0.4	-10.4	-7.2
Nuclear	8.6	10	11	7.2	4.3	6.8	6.8	17	5.9	7.5	-0.5	-5.7	2.3	-0.2
Hydro	0.5	0.4	0.3	0.3	0.4	0.4	0.4	1.1	0.2	0.5	-2.2	4.9	0.2	1.6
Geothermal	0.0	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0
Solar, wind, etc.	0.0	0.1	0.2	1.0	6.1	10	15	0.0	0.8	17	13.4	22.9	4.6	10.0
Biomass and waste	0.0	0.9	1.8	1.7	1.9	2.5	3.6	0.1	1.4	4.0	12.0	1.2	3.4	2.7
Hydrogen	-	-	-	-	-	4.6	22	-	-	24	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	32	54	75	79	79	73	64	100	100	100	3.0	0.0	-1.1	-0.7
Industry	13	21	24	27	28	26	21	40	34	33	2.4	0.5	-1.4	-0.8
Transport	7.3	12	13	13	11	7.4	5.3	23	16	8.3	1.8	-1.5	-3.7	-3.0
Buildings, etc.	6.9	11	12	13	13	12	10	22	16	16	2.0	-0.1	-1.2	-0.9
Non-energy use	4.9	9.5	25	27	28	28	27	15	34	43	5.6	0.3	0.0	0.1
Coal	3.5	5.3	6.4	5.5	4.9	3.8	2.6	11	7.0	4.1	1.5	-1.3	-3.1	-2.5
Oil	21	32	45	43	41	35	29	65	55	45	2.4	-0.6	-1.7	-1.4
Natural gas	1.0	1.8	2.4	5.1	5.1	3.9	2.1	3.1	6.4	3.3	5.4	0.0	-4.3	-3.0
Electricity	6.6	14	19	23	26	27	25	21	29	40	4.1	1.5	-0.1	0.4
Heat	-	0.0	1.6	2.1	2.0	1.7	1.4	-	2.6	2.2	n.a.	-0.5	-1.7	-1.4
Hydrogen	-	-	-	-	-	0.3	1.0	-	-	1.5	n.a.	n.a.	n.a.	n.a.
Renewables	0.0	0.4	0.7	0.5	0.8	1.4	2.5	0.1	0.7	3.8	11.2	4.0	6.1	5.5

Electricity generation

	(TWh)							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	87	181	244	287	328	353	364	100	100	100	3.9	1.5	0.5	0.8
Coal	24	88	122	129	111	68	1.8	28	45	0.5	5.5	-1.6	-18.7	-13.7
Oil	22	31	11	5.3	3.8	1.3	-	26	1.9	-	-4.5	-3.6	-100	-100
Natural gas	1.2	18	60	108	118	105	4.1	1.4	38	1.1	15.6	1.0	-15.4	-10.6
Nuclear	33	39	42	28	16	26	26	38	9.7	7.1	-0.5	-5.7	2.3	-0.2
Hydro	6.2	4.6	3.9	3.1	4.8	4.9	5.0	7.1	1.1	1.4	-2.2	4.9	0.2	1.6
Geothermal	0.0	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0
Solar PV	-	-	0.0	8.0	23	34	54	-	2.8	15	n.a.	12.6	4.3	6.8
Wind	-	0.0	1.0	2.2	47	81	122	-	0.8	33	n.a.	40.5	4.9	14.8
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	0.2	1.8	3.4	3.8	3.8	4.1	4.3	0.2	1.3	1.2	9.8	0.0	0.6	0.4
Hydrogen	-	-	-	-	-	28	147	-	-	40	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	161	307	463	658	812	990	1 137	4.7	2.4	1.7	1.9
Population (million)	20	22	23	23	24	23	22	0.5	0.1	-0.3	-0.2
CO_2 emissions (Mt)	109	215	254	267	244	169	49	2.9	-1.0	-7.7	-5.7
GDP per capita ($2015 thousand)	7.9	14	20	28	34	43	51	4.2	2.3	2.0	2.1
Primary energy consump. per capita (toe)	2.5	4.0	5.1	5.2	5.0	4.6	4.1	2.4	-0.4	-1.0	-0.8
Primary energy consumption per GDP[*2]	315	293	256	186	146	109	80	-1.7	-2.6	-3.0	-2.9
CO_2 emissions per GDP[*3]	677	701	548	406	300	171	43	-1.6	-3.3	-9.3	-7.4
CO_2 per primary energy consumption[*4]	2.1	2.4	2.1	2.2	2.0	1.6	0.5	0.0	-0.7	-6.4	-4.7

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A65 | ASEAN [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	231	378	536	678	901	1 055	1 153	100	100	100	3.5	3.2	1.2	1.9
Coal	12	31	85	178	189	185	169	5.3	26	15	9.0	0.7	-0.6	-0.2
Oil	88	153	189	222	278	272	222	38	33	19	3.0	2.6	-1.1	0.0
Natural gas	30	74	125	135	195	216	239	13	20	21	5.0	4.2	1.0	2.0
Nuclear	-	-	-	-	12	46	73	-	-	6.4	n.a.	n.a.	9.6	n.a.
Hydro	2.3	4.1	6.1	14	19	22	25	1.0	2.0	2.2	5.8	3.6	1.5	2.1
Geothermal	6.6	18	25	37	97	156	205	2.9	5.4	18	5.7	11.4	3.8	6.1
Solar, wind, etc.	-	-	0.0	4.0	17	53	119	-	0.6	10	n.a.	17.8	10.2	12.5
Biomass and waste	92	97	106	87	92	99	109	40	13	9.4	-0.2	0.6	0.9	0.8
Hydrogen	-	-	-	-	-0.0	2.3	-11	-	-	-0.9	n.a.	n.a.	45.5	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	171	269	377	446	564	628	646	100	100	100	3.1	2.6	0.7	1.3
Industry	41	74	120	162	209	241	243	24	36	38	4.5	2.9	0.8	1.4
Transport	33	62	86	120	158	162	148	19	27	23	4.3	3.1	-0.3	0.7
Buildings, etc.	86	112	130	110	119	131	145	50	25	22	0.8	0.8	1.0	0.9
Non-energy use	11	21	40	54	78	95	110	6.5	12	17	5.2	4.2	1.7	2.5
Coal	5.4	13	40	54	65	68	61	3.2	12	9.5	7.7	2.0	-0.3	0.4
Oil	67	123	163	198	250	249	207	39	44	32	3.6	2.6	-1.0	0.1
Natural gas	7.5	17	29	44	63	72	71	4.4	9.8	11	5.8	4.1	0.6	1.7
Electricity	11	28	52	88	131	184	248	6.5	20	38	6.9	4.6	3.2	3.6
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	0.1	0.4	-	-	0.1	n.a.	n.a.	n.a.	n.a.
Renewables	81	88	93	62	54	55	59	47	14	9.2	-0.8	-1.4	0.4	-0.1

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	154	370	675	1 107	1 687	2 438	3 566	100	100	100	6.6	4.8	3.8	4.1
Coal	28	79	185	492	504	492	486	18	44	14	9.7	0.3	-0.2	0.0
Oil	66	72	59	13	16	12	5.1	43	1.2	0.1	-5.1	2.2	-5.5	-3.2
Natural gas	26	154	336	330	571	684	862	17	30	24	8.5	6.3	2.1	3.4
Nuclear	-	-	-	-	45	178	282	-	-	7.9	n.a.	n.a.	9.6	n.a.
Hydro	27	47	71	158	217	258	291	18	14	8.2	5.8	3.6	1.5	2.1
Geothermal	6.6	16	19	27	65	100	129	4.3	2.4	3.6	4.6	10.4	3.5	5.6
Solar PV	-	-	0.0	37	120	456	1 105	-	3.4	31	n.a.	13.8	11.8	12.4
Wind	-	-	0.1	8.6	80	158	281	-	0.8	7.9	n.a.	28.2	6.5	12.8
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	41	70	89	106	0.4	3.7	3.0	14.6	6.1	2.1	3.3
Hydrogen	-	-	-	-	-	12	19	-	-	0.5	n.a.	n.a.	n.a.	n.a.
Others	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	728	1 167	1 947	3 011	4 570	6 979	9 916	4.7	4.7	3.9	4.2
Population (million)	427	507	578	650	697	736	760	1.4	0.8	0.4	0.5
CO_2 emissions (Mt)	350	680	1 069	1 517	1 762	1 625	1 277	4.8	1.7	-1.6	-0.6
GDP per capita ($2015 thousand)	1.7	2.3	3.4	4.6	6.6	9.5	13	3.3	3.9	3.5	3.6
Primary energy consump. per capita (toe)	0.5	0.7	0.9	1.0	1.3	1.4	1.5	2.1	2.4	0.8	1.3
Primary energy consumption per GDP*2	317	324	275	225	197	151	116	-1.1	-1.5	-2.6	-2.3
CO_2 emissions per GDP*3	481	583	549	504	386	233	129	0.2	-2.9	-5.3	-4.6
CO_2 per primary energy consumption*4	1.5	1.8	2.0	2.2	2.0	1.5	1.1	1.3	-1.5	-2.8	-2.4

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A66 | Indonesia [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	99	156	204	235	339	437	519	100	100	100	2.8	4.1	2.1	2.8
Coal	3.5	12	32	71	80	88	94	3.6	30	18	10.2	1.3	0.8	1.0
Oil	33	58	67	68	83	78	55	34	29	11	2.3	2.3	-2.0	-0.7
Natural gas	16	27	39	34	54	70	92	16	14	18	2.5	5.4	2.6	3.5
Nuclear	-	-	-	-	3.7	7.3	7.3	-	-	1.4	n.a.	n.a.	3.5	n.a.
Hydro	0.5	0.9	1.5	2.1	2.9	3.4	4.0	0.5	0.9	0.8	4.8	3.4	1.7	2.2
Geothermal	1.9	8.4	16	27	82	140	187	2.0	12	36	8.9	13.0	4.2	6.9
Solar, wind, etc.	-	-	0.0	0.1	2.0	16	46	-	0.0	8.8	n.a.	49.7	16.8	26.2
Biomass and waste	44	50	48	33	31	34	40	44	14	7.8	-0.9	-0.4	1.3	0.7
Hydrogen	-	-	-	-	-0.0	-0.7	-7.1	-	-	-1.4	n.a.	n.a.	50.5	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	79	120	148	152	186	214	231	100	100	100	2.1	2.2	1.1	1.4
Industry	17	30	49	56	72	90	102	22	37	44	3.9	2.8	1.7	2.1
Transport	11	21	30	51	64	65	59	14	34	25	5.2	2.5	-0.5	0.4
Buildings, etc.	44	59	59	38	39	46	54	55	25	23	-0.5	0.5	1.6	1.2
Non-energy use	7.4	9.8	10	7.0	9.3	13	16	9.3	4.6	7.1	-0.1	3.1	2.9	2.9
Coal	1.5	4.6	17	21	26	30	29	1.9	14	12	8.9	2.3	0.5	1.1
Oil	27	48	55	66	81	77	57	34	43	25	2.9	2.3	-1.7	-0.5
Natural gas	6.0	12	16	16	22	27	28	7.6	11	12	3.3	3.3	1.3	1.9
Electricity	2.4	6.8	13	25	38	61	94	3.1	16	41	7.8	5.1	4.6	4.7
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	42	49	48	25	19	19	23	53	16	10.0	-1.7	-3.1	1.1	-0.2

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	33	93	170	309	492	811	1 365	100	100	100	7.5	5.3	5.2	5.3
Coal	9.8	34	68	190	210	240	289	30	61	21	10.0	1.1	1.6	1.5
Oil	15	18	34	8.7	9.0	5.7	0.7	47	2.8	0.0	-1.8	0.4	-12.3	-8.5
Natural gas	0.7	26	40	52	124	191	314	2.2	17	23	14.7	10.2	4.8	6.4
Nuclear	-	-	-	-	14	28	28	-	-	2.1	n.a.	n.a.	3.5	n.a.
Hydro	5.7	10	17	25	33	40	46	17	8.0	3.4	4.8	3.4	1.7	2.2
Geothermal	1.1	4.9	9.4	16	48	81	109	3.4	5.2	8.0	8.9	13.0	4.2	6.9
Solar PV	-	-	0.0	0.2	13	155	460	-	0.1	34	n.a.	59.0	19.8	30.8
Wind	-	-	0.0	0.4	11	32	71	-	0.1	5.2	n.a.	43.4	9.6	19.2
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	0.0	0.1	17	31	39	46	-	5.7	3.4	n.a.	6.4	2.1	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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	270	395	658	1 066	1 657	2 664	4 013	4.5	5.0	4.5	4.7
Population (million)	182	214	244	274	292	309	318	1.3	0.7	0.4	0.5
CO_2 emissions (Mt)	131	255	397	557	652	619	495	4.8	1.8	-1.4	-0.4
GDP per capita ($2015 thousand)	1.5	1.8	2.7	3.9	5.7	8.6	13	3.2	4.3	4.1	4.1
Primary energy consump. per capita (toe)	0.5	0.7	0.8	0.9	1.2	1.4	1.6	1.5	3.4	1.7	2.2
Primary energy consumption per GDP*2	365	394	310	221	205	164	129	-1.6	-0.8	-2.3	-1.8
CO_2 emissions per GDP*3	484	647	604	522	393	232	123	0.2	-3.1	-5.6	-4.9
CO_2 per primary energy consumption*4	1.3	1.6	1.9	2.4	1.9	1.4	1.0	1.9	-2.3	-3.4	-3.1

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A67 | Malaysia [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	21	48	72	95	123	126	123	100	100	100	5.0	2.9	0.0	0.9
Coal	1.4	2.3	15	23	22	18	11	6.4	24	9.3	9.5	-0.3	-3.3	-2.4
Oil	11	19	25	26	33	27	19	54	27	15	2.6	2.9	-2.9	-1.1
Natural gas	6.8	25	31	43	61	66	63	32	45	52	6.1	4.0	0.2	1.4
Nuclear	-	-	-	-	1.8	3.8	8.9	-	-	7.2	n.a.	n.a.	8.2	n.a.
Hydro	0.3	0.6	0.6	2.7	3.0	3.4	3.5	1.6	2.8	2.9	6.8	1.2	0.8	0.9
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.2	0.6	6.1	18	-	0.2	14	n.a.	14.2	18.7	17.3
Biomass and waste	1.2	1.2	0.8	1.2	1.2	2.3	3.7	5.8	1.3	3.0	0.0	-0.1	5.7	3.8
Hydrogen	-	-	-	-	-0.0	-0.5	-4.5	-	-	-3.7	n.a.	n.a.	52.3	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	13	29	42	56	77	80	76	100	100	100	4.7	3.6	-0.1	1.1
Industry	5.5	12	15	19	24	27	25	41	33	32	4.0	2.9	0.1	0.9
Transport	4.9	11	15	17	23	20	16	36	31	20	4.2	3.3	-2.0	-0.4
Buildings, etc.	2.1	4.3	8.2	9.1	12	13	13	16	16	17	4.8	2.8	0.6	1.2
Non-energy use	0.8	2.2	3.7	11	18	21	23	6.3	19	30	8.6	5.8	1.3	2.6
Coal	0.5	1.0	1.8	0.6	0.7	0.6	0.5	3.8	1.1	0.7	0.6	1.0	-1.1	-0.5
Oil	9.3	18	24	23	30	25	18	70	42	23	3.0	2.9	-2.6	-0.9
Natural gas	1.1	3.9	6.3	18	26	28	26	8.2	32	34	9.4	4.4	0.0	1.4
Electricity	1.7	5.3	9.5	13	19	25	29	13	24	38	6.8	4.1	2.0	2.7
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	0.7	0.7	0.2	0.8	0.8	1.7	2.9	5.6	1.5	3.7	0.3	0.0	6.4	4.4

Electricity generation

	(TWh)							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	23	69	125	180	259	344	474	100	100	100	6.9	4.1	3.1	3.4
Coal	2.9	7.7	43	86	82	60	32	13	48	6.8	11.5	-0.6	-4.5	-3.3
Oil	11	3.6	3.7	1.0	0.8	0.2	-	46	0.6	-	-7.3	-2.9	-100	-100
Natural gas	5.5	51	71	58	127	157	158	24	32	33	7.9	9.0	1.1	3.5
Nuclear	-	-	-	-	7.0	15	34	-	-	7.2	n.a.	n.a.	8.2	n.a.
Hydro	4.0	7.0	6.5	31	35	39	41	17	17	8.6	6.8	1.2	0.8	0.9
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	2.0	6.7	71	206	-	1.1	43	n.a.	14.2	18.7	17.3
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	1.2	1.2	2.0	2.8	-	0.7	0.6	n.a.	0.0	4.2	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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	75	148	233	355	535	756	992	5.2	4.7	3.1	3.6
Population (million)	18	23	29	34	37	39	41	2.1	1.0	0.6	0.7
CO_2 emissions (Mt)	50	108	185	226	261	219	156	5.0	1.6	-2.5	-1.3
GDP per capita ($2015 thousand)	4.3	6.5	8.1	11	15	19	24	3.0	3.6	2.5	2.9
Primary energy consump. per capita (toe)	1.2	2.1	2.5	2.8	3.3	3.2	3.0	2.8	1.8	-0.6	0.2
Primary energy consumption per GDP*2	284	326	312	268	229	166	124	-0.2	-1.7	-3.0	-2.6
CO_2 emissions per GDP*3	674	731	797	636	487	290	157	-0.2	-2.9	-5.5	-4.7
CO_2 per primary energy consumption*4	2.4	2.2	2.6	2.4	2.1	1.7	1.3	0.0	-1.2	-2.5	-2.1

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A68 | Myanmar [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/2021	2021/2030	2030/2050	2021/2050
Total[*1]	11	13	14	22	25	29	35	100	100	100	2.3	1.9	1.6	1.7
Coal	0.1	0.3	0.4	1.1	2.9	4.3	6.0	0.6	5.2	17	9.5	11.3	3.6	6.0
Oil	0.7	2.0	1.3	5.7	7.3	9.0	9.1	6.8	26	26	6.8	2.9	1.1	1.7
Natural gas	0.8	1.2	1.3	3.4	8.6	12	16	7.1	16	46	5.0	10.8	3.2	5.5
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	0.1	0.2	0.5	0.8	1.3	1.7	2.0	1.0	3.8	5.9	6.9	5.3	2.3	3.2
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	-	0.0	0.1	1.7	5.0	-	0.0	14	n.a.	47.7	25.8	32.2
Biomass and waste	9.0	9.2	10	11	6.9	3.4	1.8	84	49	5.3	0.5	-4.8	-6.4	-5.9
Hydrogen	-	-	-	-	-	-0.6	-2.2	-	-	-6.4	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	9.4	11	13	18	18	18	19	100	100	100	2.2	-0.5	0.5	0.2
Industry	0.4	1.2	1.3	3.2	4.1	5.4	6.1	4.2	17	31	7.0	3.0	1.9	2.2
Transport	0.4	1.2	0.8	1.7	2.6	3.6	4.4	4.7	9.3	23	4.4	5.0	2.6	3.3
Buildings, etc.	8.5	9.1	10	13	10	8.4	8.3	90	71	43	1.4	-2.6	-1.1	-1.6
Non-energy use	0.1	0.1	0.1	0.4	0.4	0.5	0.6	1.0	2.2	3.3	4.8	0.8	1.8	1.5
Coal	0.1	0.3	0.2	0.2	0.2	0.2	0.2	0.5	1.1	0.9	4.7	0.0	-1.0	-0.7
Oil	0.6	1.5	1.0	5.6	7.1	8.7	8.9	6.2	31	46	7.6	2.7	1.1	1.6
Natural gas	0.2	0.3	0.6	0.5	0.6	0.6	0.6	2.4	2.8	2.9	2.7	1.0	-0.1	0.3
Electricity	0.1	0.3	0.5	1.4	2.8	5.0	7.9	1.6	7.8	41	7.6	7.9	5.3	6.1
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	8.4	9.0	10	11	6.8	3.4	1.8	89	58	9.3	0.8	-4.8	-6.5	-5.9

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	2.5	5.1	8.6	20	61	110	186	100	100	100	6.9	13.3	5.8	8.1
Coal	0.0	-	0.6	2.1	12	20	31	1.6	11	17	13.7	21.4	4.8	9.7
Oil	0.3	0.7	0.0	0.1	0.5	0.6	0.7	11	0.6	0.4	-2.7	17.1	1.8	6.4
Natural gas	1.0	2.5	1.8	7.9	32	50	73	39	40	39	7.0	16.9	4.2	8.0
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	1.2	1.9	6.2	9.5	15	19	24	48	48	13	6.9	5.3	2.3	3.2
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	0.0	0.5	18	52	-	0.1	28	n.a.	45.7	25.9	31.8
Wind	-	-	-	0.0	0.1	1.7	5.9	-	0.0	3.2	n.a.	146	25.1	54.4
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	2021	2030	2040	2050	1990/2021	2021/2030	2030/2050	2021/2050
GDP ($2015 billion)	7.2	14	43	67	87	137	209	7.5	3.0	4.5	4.0
Population (million)	40	46	49	54	57	59	60	1.0	0.7	0.3	0.4
CO_2 emissions (Mt)	4.0	9.5	8.1	28	52	70	87	6.4	7.3	2.6	4.0
GDP per capita ($2015 thousand)	0.2	0.3	0.9	1.2	1.5	2.3	3.5	6.4	2.4	4.2	3.6
Primary energy consump. per capita (toe)	0.3	0.3	0.3	0.4	0.4	0.5	0.6	1.3	1.2	1.3	1.3
Primary energy consumption per GDP[*2]	1 489	942	318	323	292	212	166	-4.8	-1.1	-2.8	-2.3
CO_2 emissions per GDP[*3]	564	700	188	415	598	512	416	-1.0	4.1	-1.8	0.0
CO_2 per primary energy consumption[*4]	0.4	0.7	0.6	1.3	2.0	2.4	2.5	4.0	5.3	1.0	2.3

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A69 | Philippines [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	27	39	42	61	82	100	107	100	100	100	2.7	3.3	1.4	2.0
Coal	1.3	4.6	7.0	19	18	19	18	4.7	31	17	9.1	-0.8	0.2	-0.1
Oil	9.7	16	14	18	27	32	26	36	30	24	2.1	4.6	-0.3	1.2
Natural gas	-	0.0	3.1	2.8	5.1	9.5	18	-	4.6	17	n.a.	6.6	6.7	6.7
Nuclear	-	-	-	-	2.2	6.6	6.6	-	-	6.1	n.a.	n.a.	5.6	n.a.
Hydro	0.5	0.7	0.7	0.8	1.1	1.2	1.4	2.0	1.3	1.4	1.3	3.4	1.5	2.1
Geothermal	4.7	10	8.5	9.2	15	16	17	18	15	16	2.2	5.5	0.7	2.2
Solar, wind, etc.	-	-	0.0	0.2	3.1	5.2	8.9	-	0.4	8.3	n.a.	33.3	5.4	13.3
Biomass and waste	10	7.6	8.7	11	10	10	11	39	18	9.8	0.1	-0.6	0.1	-0.1
Hydrogen	-	-	-	-	-	0.0	-0.1	-	-	-0.1	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	19	23	25	35	48	59	62	100	100	100	2.0	3.4	1.4	2.0
Industry	4.1	4.6	5.9	6.8	9.6	12	12	22	19	19	1.6	3.9	1.0	1.9
Transport	4.5	8.3	8.0	11	18	24	23	24	31	37	2.9	5.6	1.3	2.6
Buildings, etc.	10.0	9.9	11	16	17	19	22	52	44	35	1.5	1.2	1.1	1.2
Non-energy use	0.4	0.4	0.2	1.6	2.6	3.9	5.6	2.1	4.7	9.0	4.7	5.1	4.0	4.3
Coal	0.7	0.8	1.9	2.2	2.7	2.8	2.5	3.7	6.2	4.0	3.7	2.3	-0.3	0.5
Oil	8.1	13	11	18	26	31	25	43	50	39	2.5	4.3	-0.3	1.1
Natural gas	-	-	0.1	0.0	0.0	0.1	0.1	-	0.0	0.2	n.a.	62.8	7.0	21.9
Electricity	1.8	3.1	4.8	7.5	12	19	29	9.6	21	46	4.7	5.6	4.3	4.7
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	8.4	6.4	6.9	7.7	6.7	6.2	6.5	44	22	10	-0.3	-1.6	-0.1	-0.6

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	26	45	68	106	172	266	398	100	100	100	4.6	5.5	4.3	4.7
Coal	1.9	17	23	62	56	66	72	7.3	58	18	11.8	-1.1	1.3	0.5
Oil	12	9.2	7.1	1.6	3.2	3.3	2.9	47	1.5	0.7	-6.4	7.8	-0.5	2.0
Natural gas	-	0.0	20	19	36	74	153	-	18	38	n.a.	7.5	7.5	7.5
Nuclear	-	-	-	-	8.4	25	25	-	-	6.3	n.a.	n.a.	5.6	n.a.
Hydro	6.1	7.8	7.8	9.2	12	14	17	23	8.7	4.2	1.3	3.4	1.5	2.1
Geothermal	5.5	12	9.9	11	17	19	20	21	10	5.1	2.2	5.5	0.7	2.2
Solar PV	-	-	0.0	1.5	19	29	52	-	1.4	13	n.a.	32.9	5.2	13.1
Wind	-	-	0.1	1.3	17	31	51	-	1.2	13	n.a.	33.7	5.6	13.6
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	0.4	-	0.0	1.2	2.3	3.3	3.5	1.6	1.1	0.9	3.3	8.0	2.1	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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	107	143	229	379	654	1 057	1 479	4.2	6.2	4.2	4.8
Population (million)	62	78	95	114	130	145	158	2.0	1.4	1.0	1.1
CO_2 emissions (Mt)	35	65	75	132	156	165	143	4.3	1.9	-0.4	0.3
GDP per capita ($2015 thousand)	1.7	1.8	2.4	3.3	5.0	7.3	9.3	2.1	4.7	3.1	3.6
Primary energy consump. per capita (toe)	0.4	0.5	0.4	0.5	0.6	0.7	0.7	0.7	1.8	0.3	0.8
Primary energy consumption per GDP[*2]	249	272	182	161	125	95	72	-1.4	-2.8	-2.7	-2.7
CO_2 emissions per GDP[*3]	330	454	327	349	239	157	97	0.2	-4.1	-4.4	-4.3
CO_2 per primary energy consumption[*4]	1.3	1.7	1.8	2.2	1.9	1.7	1.3	1.6	-1.4	-1.8	-1.6

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A70 | Thailand [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	42	73	118	130	145	148	149	100	100	100	3.7	1.3	0.1	0.5
Coal	3.8	7.7	16	16	12	9.7	7.0	9.0	12	4.7	4.7	-2.8	-2.7	-2.8
Oil	18	32	45	56	58	54	46	43	43	31	3.7	0.4	-1.1	-0.6
Natural gas	5.0	17	33	34	39	31	28	12	26	19	6.3	1.7	-1.6	-0.6
Nuclear	-	-	-	-	-	3.9	9.0	-	-	6.0	n.a.	n.a.	n.a.	n.a.
Hydro	0.4	0.5	0.5	0.4	0.9	1.0	1.1	1.0	0.3	0.7	-0.2	9.2	1.1	3.5
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	-3.9	3.2	1.0
Solar, wind, etc.	-	-	0.0	0.7	2.3	9.2	18	-	0.6	12	n.a.	13.1	11.0	11.7
Biomass and waste	15	15	23	21	29	35	37	35	16	25	1.1	3.7	1.2	2.0
Hydrogen	-	-	-	-	-0.0	-0.5	-3.2	-	-	-2.2	n.a.	n.a.	49.7	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	29	51	84	94	104	107	103	100	100	100	3.9	1.1	-0.1	0.3
Industry	8.7	17	26	30	35	37	34	30	32	33	4.1	1.7	-0.2	0.4
Transport	9.2	15	19	25	26	23	19	32	26	18	3.3	0.6	-1.7	-1.0
Buildings, etc.	11	14	20	16	16	16	16	37	17	15	1.2	0.4	-0.2	0.0
Non-energy use	0.4	5.8	18	24	27	31	35	1.5	25	34	13.8	1.3	1.4	1.3
Coal	1.3	3.6	9.2	8.1	7.8	7.1	5.4	4.6	8.6	5.2	6.0	-0.3	-1.9	-1.4
Oil	15	29	43	54	56	53	46	52	57	44	4.2	0.4	-1.0	-0.6
Natural gas	0.1	1.1	4.6	5.4	5.4	5.7	5.5	0.5	5.7	5.3	12.5	0.0	0.1	0.1
Electricity	3.3	7.6	13	16	21	26	30	11	17	30	5.3	2.8	1.9	2.2
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	9.3	9.4	14	11	14	16	16	32	11	15	0.4	3.0	0.7	1.4

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	44	96	159	177	220	284	402	100	100	100	4.6	2.5	3.1	2.9
Coal	11	18	30	35	21	13	9.7	25	20	2.4	3.8	-5.8	-3.7	-4.3
Oil	10	10.0	1.1	0.7	-	-	-	23	0.4	-	-8.5	-100	n.a.	-100
Natural gas	18	62	120	110	135	102	91	40	62	23	6.1	2.3	-2.0	-0.6
Nuclear	-	-	-	-	-	15	34	-	-	8.6	n.a.	n.a.	n.a.	n.a.
Hydro	5.0	6.0	5.6	4.7	10	12	13	11	2.6	3.2	-0.2	9.2	1.1	3.5
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	-3.9	3.2	1.0
Solar PV	-	-	0.0	5.0	20	94	189	-	2.8	47	n.a.	16.6	11.9	13.3
Wind	-	-	-	3.6	5.9	12	22	-	2.0	5.6	n.a.	5.9	6.8	6.5
CSP and marine	-	-	-	-	0.1	0.2	0.5	-	-	0.1	n.a.	n.a.	8.8	n.a.
Biomass and waste	-	0.5	3.4	18	28	36	43	-	10	11	n.a.	5.3	2.1	3.1
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	144	221	347	438	582	805	1 066	3.7	3.2	3.1	3.1
Population (million)	55	63	68	72	72	71	68	0.8	0.1	-0.3	-0.2
CO_2 emissions (Mt)	80	151	223	235	227	176	117	3.5	-0.4	-3.3	-2.4
GDP per capita ($2015 thousand)	2.6	3.5	5.1	6.1	8.1	11	16	2.8	3.1	3.4	3.3
Primary energy consump. per capita (toe)	0.8	1.2	1.7	1.8	2.0	2.1	2.2	2.8	1.2	0.4	0.6
Primary energy consumption per GDP*2	294	328	340	296	250	184	139	0.0	-1.9	-2.9	-2.6
CO_2 emissions per GDP*3	557	683	644	535	390	218	110	-0.1	-3.4	-6.2	-5.3
CO_2 per primary energy consumption*4	1.9	2.1	1.9	1.8	1.6	1.2	0.8	-0.1	-1.6	-3.4	-2.8

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A71 | Viet Nam [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	18	29	59	95	146	174	182	100	100	100	5.5	4.8	1.1	2.3
Coal	2.2	4.4	15	47	53	46	31	12	49	17	10.3	1.5	-2.7	-1.4
Oil	2.7	7.8	18	23	43	48	45	15	24	25	7.1	7.2	0.2	2.3
Natural gas	0.0	1.1	8.1	6.3	15	17	15	0.0	6.6	8.4	28.4	10.2	0.0	3.1
Nuclear	-	-	-	-	4.0	25	42	-	-	23	n.a.	n.a.	12.4	n.a.
Hydro	0.5	1.3	2.4	6.8	9.5	11	13	2.6	7.1	7.1	9.0	3.9	1.5	2.3
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	-	-	0.0	2.7	9.0	14	23	-	2.8	13	n.a.	14.4	4.9	7.8
Biomass and waste	12	14	15	9.7	11	12	13	70	10	7.0	-0.8	1.5	0.7	1.0
Hydrogen	-	-	-	-	-0.0	-0.0	-0.8	-	-	-0.4	n.a.	n.a.	39.5	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	16	25	48	69	110	129	134	100	100	100	4.9	5.3	1.0	2.3
Industry	4.5	7.9	17	40	56	62	59	28	57	44	7.3	3.9	0.2	1.4
Transport	1.4	3.5	10	11	21	26	26	8.7	15	20	6.8	7.7	1.1	3.1
Buildings, etc.	10	13	18	16	20	25	29	63	23	22	1.5	2.5	2.0	2.1
Non-energy use	0.0	0.1	2.3	2.9	13	16	19	0.2	4.2	14	16.2	18.2	1.8	6.7
Coal	1.3	3.2	9.8	22	27	28	24	8.3	31	18	9.4	2.5	-0.6	0.3
Oil	2.3	6.5	17	19	37	42	40	15	27	30	7.0	7.5	0.4	2.6
Natural gas	-	0.0	0.5	1.7	6.8	8.4	9.1	-	2.5	6.8	n.a.	16.5	1.4	5.9
Electricity	0.5	1.9	7.5	19	32	43	52	3.3	28	39	12.3	5.8	2.5	3.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	12	13	14	7.6	7.7	8.4	8.4	74	11	6.3	-1.4	0.1	0.4	0.3

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	8.7	27	95	253	414	551	685	100	100	100	11.5	5.6	2.6	3.5
Coal	2.0	3.1	20	115	122	91	50	23	45	7.2	14.0	0.6	-4.4	-2.9
Oil	1.3	4.5	3.4	0.3	2.1	1.5	0.8	15	0.1	0.1	-4.7	24.1	-4.8	3.4
Natural gas	0.0	4.4	44	26	55	57	45	0.1	10	6.6	31.1	8.5	-0.9	1.9
Nuclear	-	-	-	-	15	95	160	-	-	23	n.a.	n.a.	12.4	n.a.
Hydro	5.4	15	28	79	111	133	150	62	31	22	9.0	3.9	1.5	2.3
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	-	28	59	85	141	-	11	21	n.a.	8.6	4.5	5.8
Wind	-	-	0.1	3.3	46	82	131	-	1.3	19	n.a.	33.8	5.4	13.5
CSP and marine	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Biomass and waste	-	-	0.1	2.1	4.7	5.9	7.1	-	0.8	1.0	n.a.	9.4	2.1	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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	45	94	177	332	591	1 000	1 521	6.7	6.6	4.8	5.4
Population (million)	67	79	87	97	103	106	107	1.2	0.6	0.2	0.3
CO_2 emissions (Mt)	16	42	122	285	360	337	258	9.6	2.6	-1.6	-0.3
GDP per capita ($2015 thousand)	0.7	1.2	2.0	3.4	5.7	9.4	14	5.4	6.0	4.6	5.0
Primary energy consump. per capita (toe)	0.3	0.4	0.7	1.0	1.4	1.6	1.7	4.3	4.2	0.9	1.9
Primary energy consumption per GDP[*2]	397	307	330	286	246	174	120	-1.0	-1.7	-3.5	-3.0
CO_2 emissions per GDP[*3]	365	444	689	857	609	337	170	2.8	-3.7	-6.2	-5.4
CO_2 per primary energy consumption[*4]	0.9	1.4	2.1	3.0	2.5	1.9	1.4	3.9	-2.1	-2.7	-2.5

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A72 | North America [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	2 126	2 525	2 473	2 429	2 244	1 916	1 721	100	100	100	0.4	-0.9	-1.3	-1.2
Coal	484	565	525	264	114	24	20	23	11	1.2	-1.9	-8.9	-8.3	-8.5
Oil	833	958	901	859	732	459	239	39	35	14	0.1	-1.8	-5.4	-4.3
Natural gas	493	622	632	840	782	607	491	23	35	29	1.7	-0.8	-2.3	-1.8
Nuclear	179	227	242	236	226	227	215	8.4	9.7	13	0.9	-0.5	-0.2	-0.3
Hydro	49	53	53	55	62	64	65	2.3	2.3	3.8	0.4	1.4	0.2	0.6
Geothermal	14	13	8.4	9.4	12	14	15	0.7	0.4	0.9	-1.3	2.9	1.0	1.6
Solar, wind, etc.	0.3	2.1	11	53	183	390	531	0.0	2.2	31	17.9	14.8	5.5	8.3
Biomass and waste	73	86	101	115	134	146	157	3.5	4.7	9.1	1.5	1.7	0.8	1.1
Hydrogen	-	-	-	-	-0.0	-15	-12	-	-	-0.7	n.a.	n.a.	37.1	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 452	1 728	1 697	1 731	1 641	1 388	1 180	100	100	100	0.6	-0.6	-1.6	-1.3
Industry	331	386	313	324	326	302	258	23	19	22	-0.1	0.1	-1.2	-0.8
Transport	531	640	655	660	594	418	313	37	38	27	0.7	-1.2	-3.2	-2.5
Buildings, etc.	456	528	572	570	536	473	409	31	33	35	0.7	-0.7	-1.3	-1.1
Non-energy use	134	173	158	177	185	195	201	9.2	10	17	0.9	0.5	0.4	0.4
Coal	59	36	30	16	14	11	8.4	4.1	0.9	0.7	-4.2	-1.3	-2.5	-2.1
Oil	749	870	850	818	709	467	281	52	47	24	0.3	-1.6	-4.5	-3.6
Natural gas	346	413	364	421	385	288	171	24	24	14	0.6	-1.0	-4.0	-3.1
Electricity	262	338	367	375	418	483	520	18	22	44	1.2	1.2	1.1	1.1
Heat	2.8	6.1	7.1	6.2	5.5	4.9	4.1	0.2	0.4	0.3	2.6	-1.2	-1.5	-1.4
Hydrogen	-	-	-	-	0.1	20	75	-	-	6.3	n.a.	n.a.	42.9	n.a.
Renewables	33	64	80	95	110	114	121	2.3	5.5	10	3.5	1.6	0.5	0.8

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	3 685	4 632	4 957	4 997	5 547	6 688	7 941	100	100	100	1.0	1.2	1.8	1.6
Coal	1 782	2 247	2 074	1 026	396	11	9.6	48	21	0.1	-1.8	-10.0	-17.0	-14.9
Oil	147	133	56	40	21	6.3	0.2	4.0	0.8	0.0	-4.1	-7.1	-21.8	-17.5
Natural gas	391	668	1 070	1 711	1 493	565	194	11	34	2.4	4.9	-1.5	-9.7	-7.2
Nuclear	685	871	930	904	867	871	827	19	18	10	0.9	-0.5	-0.2	-0.3
Hydro	570	612	614	636	722	744	757	15	13	9.5	0.4	1.4	0.2	0.6
Geothermal	16	15	18	19	25	29	31	0.4	0.4	0.4	0.6	3.1	1.1	1.7
Solar PV	0.0	0.2	3.3	154	772	1 840	2 545	0.0	3.1	32	41.9	19.6	6.1	10.2
Wind	3.1	5.9	104	418	1 063	2 033	2 668	0.1	8.4	34	17.2	10.9	4.7	6.6
CSP and marine	0.7	0.6	0.9	3.2	84	208	307	0.0	0.1	3.9	5.0	43.9	6.7	17.1
Biomass and waste	91	80	82	80	99	134	154	2.5	1.6	1.9	-0.4	2.5	2.2	2.3
Hydrogen	-	-	-	-	-	243	442	-	-	5.6	n.a.	n.a.	n.a.	n.a.
Others	-	-	6.8	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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	10 626	14 918	17 783	22 210	26 292	32 069	38 016	2.4	1.9	1.9	1.9
Population (million)	277	313	343	370	388	405	416	0.9	0.5	0.4	0.4
CO_2 emissions (Mt)	5 126	6 085	5 698	5 055	3 895	2 119	1 011	0.0	-2.9	-6.5	-5.4
GDP per capita ($2015 thousand)	38	48	52	60	68	79	91	1.5	1.4	1.5	1.5
Primary energy consump. per capita (toe)	7.7	8.1	7.2	6.6	5.8	4.7	4.1	-0.5	-1.4	-1.7	-1.6
Primary energy consumption per GDP[*2]	200	169	139	109	85	60	45	-1.9	-2.7	-3.1	-3.0
CO_2 emissions per GDP[*3]	482	408	320	228	148	66	27	-2.4	-4.7	-8.2	-7.1
CO_2 per primary energy consumption[*4]	2.4	2.4	2.3	2.1	1.7	1.1	0.6	-0.5	-2.0	-5.3	-4.3

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A73 | United States [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	1 914	2 273	2 216	2 139	1 958	1 650	1 475	100	100	100	0.4	-1.0	-1.4	-1.3
Coal	460	533	501	254	111	22	18	24	12	1.2	-1.9	-8.8	-8.6	-8.7
Oil	757	871	807	764	645	400	202	40	36	14	0.0	-1.9	-5.7	-4.5
Natural gas	438	548	556	723	658	487	390	23	34	26	1.6	-1.0	-2.6	-2.1
Nuclear	159	208	219	211	204	203	192	8.3	9.9	13	0.9	-0.4	-0.3	-0.3
Hydro	23	22	23	22	27	27	28	1.2	1.0	1.9	-0.2	2.3	0.2	0.9
Geothermal	14	13	8.4	9.4	12	14	15	0.7	0.4	1.0	-1.3	2.9	1.0	1.6
Solar, wind, etc.	0.3	2.1	11	49	175	371	489	0.0	2.3	33	17.6	15.1	5.3	8.2
Biomass and waste	62	73	89	103	122	134	146	3.3	4.8	9.9	1.6	1.9	0.9	1.2
Hydrogen	-	-	-	-	-0.0	-12	-8.0	-	-	-0.5	n.a.	n.a.	35.3	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 294	1 546	1 513	1 540	1 453	1 225	1 041	100	100	100	0.6	-0.6	-1.7	-1.3
Industry	284	332	270	278	278	258	220	22	18	21	-0.1	0.0	-1.2	-0.8
Transport	488	588	596	604	540	381	284	38	39	27	0.7	-1.2	-3.2	-2.6
Buildings, etc.	403	473	511	504	472	416	360	31	33	35	0.7	-0.7	-1.3	-1.2
Non-energy use	119	153	135	154	162	170	177	9.2	10.0	17	0.8	0.5	0.4	0.5
Coal	56	33	27	14	12	10	7.4	4.3	0.9	0.7	-4.5	-1.3	-2.4	-2.0
Oil	683	793	762	735	631	410	242	53	48	23	0.2	-1.7	-4.7	-3.8
Natural gas	303	360	322	370	337	253	151	23	24	14	0.6	-1.0	-3.9	-3.0
Electricity	226	301	326	330	366	424	457	18	21	44	1.2	1.2	1.1	1.1
Heat	2.2	5.3	6.6	5.6	5.0	4.4	3.6	0.2	0.4	0.3	3.1	-1.3	-1.6	-1.5
Hydrogen	-	-	-	-	0.1	18	68	-	-	6.5	n.a.	n.a.	42.5	n.a.
Renewables	23	54	70	85	101	106	113	1.8	5.5	11	4.3	1.8	0.6	1.0

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	3 203	4 026	4 354	4 354	4 822	5 756	6 708	100	100	100	1.0	1.1	1.7	1.5
Coal	1 700	2 129	1 994	992	394	8.3	7.8	53	23	0.1	-1.7	-9.8	-17.8	-15.4
Oil	131	118	48	36	17	4.0	0.2	4.1	0.8	0.0	-4.1	-7.8	-21.1	-17.2
Natural gas	382	634	1 018	1 634	1 374	396	15	12	38	0.2	4.8	-1.9	-20.1	-14.9
Nuclear	612	798	839	812	784	781	737	19	19	11	0.9	-0.4	-0.3	-0.3
Hydro	273	253	262	253	311	319	324	8.5	5.8	4.8	-0.2	2.3	0.2	0.9
Geothermal	16	15	18	19	25	29	31	0.5	0.4	0.5	0.6	3.1	1.1	1.7
Solar PV	0.0	0.2	3.1	148	756	1 803	2 458	0.0	3.4	37	41.7	19.9	6.1	10.2
Wind	3.1	5.7	95	383	988	1 850	2 269	0.1	8.8	34	16.8	11.1	4.2	6.3
CSP and marine	0.7	0.5	0.9	3.2	84	208	307	0.0	0.1	4.6	5.2	43.9	6.7	17.1
Biomass and waste	86	72	73	69	85	118	136	2.7	1.6	2.0	-0.7	2.3	2.4	2.3
Hydrogen	-	-	-	-	-	236	417	-	-	6.2	n.a.	n.a.	n.a.	n.a.
Others	-	-	3.7	4.7	4.7	4.7	4.7	-	0.1	0.1	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	9 811	13 754	16 383	20 529	24 289	29 608	35 085	2.4	1.9	1.9	1.9
Population (million)	250	282	309	332	347	361	370	0.9	0.5	0.3	0.4
CO_2 emissions (Mt)	4 740	5 611	5 204	4 549	3 452	1 793	794	-0.1	-3.0	-7.1	-5.8
GDP per capita ($2015 thousand)	39	49	53	62	70	82	95	1.5	1.4	1.5	1.5
Primary energy consump. per capita (toe)	7.7	8.1	7.2	6.4	5.6	4.6	4.0	-0.6	-1.5	-1.7	-1.6
Primary energy consumption per GDP[*2]	195	165	135	104	81	56	42	-2.0	-2.8	-3.2	-3.1
CO_2 emissions per GDP[*3]	483	408	318	222	142	61	23	-2.5	-4.8	-8.8	-7.6
CO_2 per primary energy consumption[*4]	2.5	2.5	2.3	2.1	1.8	1.1	0.5	-0.5	-2.1	-5.8	-4.6

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A74 | Latin America [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	467	610	788	821	884	904	923	100	100	100	1.8	0.8	0.2	0.4
Coal	21	28	39	39	30	25	23	4.6	4.7	2.5	2.0	-2.8	-1.3	-1.8
Oil	241	313	365	333	339	292	236	52	41	26	1.0	0.2	-1.8	-1.2
Natural gas	71	118	178	207	193	215	229	15	25	25	3.5	-0.8	0.9	0.3
Nuclear	3.2	5.3	7.2	9.8	21	36	44	0.7	1.2	4.7	3.6	9.1	3.6	5.3
Hydro	33	50	63	60	72	77	82	7.1	7.3	8.9	1.9	2.0	0.7	1.1
Geothermal	5.1	6.5	6.4	6.2	13	17	19	1.1	0.8	2.0	0.7	8.8	1.7	3.9
Solar, wind, etc.	0.0	0.2	0.9	17	51	103	212	0.0	2.0	23	22.2	13.1	7.4	9.2
Biomass and waste	93	90	128	149	165	155	142	20	18	15	1.6	1.1	-0.7	-0.2
Hydrogen	-	-	-	-	0.0	-16	-64	-	-	-6.9	n.a.	n.a.	n.a.	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	344	442	569	574	635	634	618	100	100	100	1.7	1.1	-0.1	0.3
Industry	114	143	179	169	197	210	203	33	29	33	1.3	1.7	0.2	0.6
Transport	104	140	197	205	230	215	202	30	36	33	2.2	1.3	-0.6	0.0
Buildings, etc.	100	122	148	166	170	165	162	29	29	26	1.6	0.2	-0.2	-0.1
Non-energy use	26	38	45	34	38	44	50	7.6	5.9	8.1	0.9	1.1	1.5	1.4
Coal	8.2	11	15	13	13	12	9.7	2.4	2.2	1.6	1.4	0.5	-1.5	-0.9
Oil	178	235	284	271	288	256	210	52	47	34	1.4	0.7	-1.6	-0.9
Natural gas	38	54	74	63	70	67	55	11	11	8.9	1.6	1.2	-1.2	-0.5
Electricity	44	68	97	118	150	194	239	13	21	39	3.2	2.7	2.3	2.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	2.9	15	-	-	2.5	n.a.	n.a.	38.6	n.a.
Renewables	75	74	99	109	113	103	89	22	19	14	1.2	0.4	-1.2	-0.7

Electricity generation

	(TWh)							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	623	1 009	1 406	1 726	2 151	3 084	4 726	100	100	100	3.3	2.5	4.0	3.5
Coal	24	44	75	84	49	29	26	3.8	4.9	0.6	4.2	-5.9	-3.1	-4.0
Oil	130	197	188	143	72	39	31	21	8.3	0.7	0.3	-7.3	-4.1	-5.1
Natural gas	58	142	326	492	408	655	929	9.3	29	20	7.1	-2.1	4.2	2.2
Nuclear	12	20	28	38	82	138	167	2.0	2.2	3.5	3.6	9.1	3.6	5.3
Hydro	386	584	731	700	833	896	952	62	41	20	1.9	2.0	0.7	1.1
Geothermal	5.9	8.0	9.9	9.2	19	24	26	1.0	0.5	0.6	1.4	8.6	1.5	3.7
Solar PV	0.0	0.0	0.1	48	237	450	955	0.0	2.8	20	41.6	19.3	7.2	10.8
Wind	0.0	0.3	4.7	127	328	719	1 487	0.0	7.3	31	46.1	11.2	7.8	8.9
CSP and marine	-	-	-	0.2	0.1	0.1	0.1	-	0.0	0.0	n.a.	-0.4	-1.3	-1.0
Biomass and waste	7.4	13	44	82	119	130	141	1.2	4.8	3.0	8.1	4.2	0.8	1.9
Hydrogen	-	-	-	-	-	2.2	8.7	-	-	0.2	n.a.	n.a.	n.a.	n.a.
Others	-	0.4	0.5	2.4	2.4	2.4	2.4	-	0.1	0.0	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	2 597	3 524	4 830	5 348	6 670	8 934	11 587	2.4	2.5	2.8	2.7
Population (million)	438	518	586	652	694	729	748	1.3	0.7	0.4	0.5
CO_2 emissions (Mt)	867	1 195	1 524	1 453	1 391	1 271	1 119	1.7	-0.5	-1.1	-0.9
GDP per capita ($2015 thousand)	5.9	6.8	8.2	8.2	9.6	12	15	1.1	1.8	2.4	2.2
Primary energy consump. per capita (toe)	1.1	1.2	1.3	1.3	1.3	1.2	1.2	0.5	0.1	-0.2	-0.1
Primary energy consumption per GDP[*2]	180	173	163	154	133	101	80	-0.5	-1.6	-2.5	-2.2
CO_2 emissions per GDP[*3]	334	339	315	272	209	142	97	-0.7	-2.9	-3.8	-3.5
CO_2 per primary energy consumption[*4]	1.9	2.0	1.9	1.8	1.6	1.4	1.2	-0.2	-1.3	-1.3	-1.3

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A75 | Advanced Europe [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	1 644	1 759	1 833	1 698	1 489	1 303	1 182	100	100	100	0.1	-1.4	-1.1	-1.2
Coal	450	331	301	204	90	74	64	27	12	5.4	-2.5	-8.7	-1.7	-3.9
Oil	617	654	605	530	426	267	159	38	31	13	-0.5	-2.4	-4.8	-4.1
Natural gas	267	396	473	447	296	200	106	16	26	8.9	1.7	-4.5	-5.0	-4.9
Nuclear	210	247	239	201	203	231	258	13	12	22	-0.1	0.1	1.2	0.9
Hydro	39	47	48	49	50	52	53	2.4	2.9	4.5	0.8	0.2	0.3	0.2
Geothermal	4.9	7.1	11	22	32	38	38	0.3	1.3	3.2	5.0	4.3	0.8	1.9
Solar, wind, etc.	0.4	2.9	18	64	173	226	288	0.0	3.8	24	18.3	11.6	2.6	5.3
Biomass and waste	56	72	137	178	217	191	170	3.4	10	14	3.8	2.2	-1.2	-0.2
Hydrogen	-	-	-	-	0.1	24	54	-	-	4.6	n.a.	n.a.	41.3	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 142	1 235	1 289	1 255	1 140	926	760	100	100	100	0.3	-1.1	-2.0	-1.7
Industry	330	325	296	305	301	268	221	29	24	29	-0.3	-0.1	-1.5	-1.1
Transport	269	318	335	338	286	179	130	24	27	17	0.7	-1.8	-3.9	-3.2
Buildings, etc.	442	477	544	506	445	372	305	39	40	40	0.4	-1.4	-1.9	-1.7
Non-energy use	101	114	113	106	107	106	104	8.9	8.5	14	0.1	0.1	-0.1	-0.1
Coal	124	62	55	43	35	25	16	11	3.4	2.2	-3.4	-2.1	-3.7	-3.2
Oil	528	573	538	493	403	261	171	46	39	23	-0.2	-2.2	-4.2	-3.6
Natural gas	205	269	285	292	248	173	88	18	23	12	1.1	-1.8	-5.1	-4.1
Electricity	193	234	267	271	301	334	351	17	22	46	1.1	1.2	0.8	0.9
Heat	45	42	53	50	45	40	31	3.9	4.0	4.1	0.3	-1.1	-1.8	-1.6
Hydrogen	-	-	-	-	0.1	15	44	-	-	5.9	n.a.	n.a.	38.6	n.a.
Renewables	48	56	91	106	107	79	58	4.2	8.5	7.7	2.6	0.0	-3.0	-2.0

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	2 695	3 236	3 623	3 637	4 026	4 850	5 872	100	100	100	1.0	1.1	1.9	1.7
Coal	1 030	968	873	535	77	45	46	38	15	0.8	-2.1	-19.4	-2.5	-8.1
Oil	209	180	81	43	7.3	3.4	0.4	7.8	1.2	0.0	-4.9	-18.0	-13.9	-15.2
Natural gas	176	514	857	769	191	163	182	6.5	21	3.1	4.9	-14.4	-0.2	-4.9
Nuclear	804	948	916	769	778	886	990	30	21	17	-0.1	0.1	1.2	0.9
Hydro	450	547	559	575	586	602	617	17	16	11	0.8	0.2	0.3	0.2
Geothermal	3.6	6.2	11	23	36	44	44	0.1	0.6	0.8	6.2	5.2	1.0	2.3
Solar PV	0.0	0.1	23	184	807	1 058	1 376	0.0	5.0	23	35.2	17.9	2.7	7.2
Wind	0.8	22	153	485	1 130	1 491	1 883	0.0	13	32	23.1	9.9	2.6	4.8
CSP and marine	0.5	0.5	1.2	5.7	7.7	10	15	0.0	0.2	0.2	8.1	3.4	3.3	3.3
Biomass and waste	21	48	146	241	399	429	448	0.8	6.6	7.6	8.2	5.8	0.6	2.2
Hydrogen	-	-	-	-	-	111	264	-	-	4.5	n.a.	n.a.	n.a.	n.a.
Others	0.3	1.5	4.6	6.7	6.7	6.7	6.7	0.0	0.2	0.1	10.0	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	11 682	14 633	16 894	19 669	23 173	26 699	30 170	1.7	1.8	1.3	1.5
Population (million)	505	528	557	582	589	589	583	0.5	0.1	-0.1	0.0
CO_2 emissions (Mt)	3 944	3 916	3 823	3 242	2 113	1 346	770	-0.6	-4.6	-4.9	-4.8
GDP per capita ($2015 thousand)	23	28	30	34	39	45	52	1.2	1.7	1.4	1.5
Primary energy consump. per capita (toe)	3.3	3.3	3.3	2.9	2.5	2.2	2.0	-0.4	-1.6	-1.1	-1.2
Primary energy consumption per GDP[*2]	141	120	109	86	64	49	39	-1.6	-3.2	-2.4	-2.7
CO_2 emissions per GDP[*3]	338	268	226	165	91	50	26	-2.3	-6.4	-6.2	-6.2
CO_2 per primary energy consumption[*4]	2.4	2.2	2.1	1.9	1.4	1.0	0.7	-0.7	-3.2	-3.8	-3.6

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A76 | Other Europe/Eurasia [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	1 514	988	1 112	1 225	1 171	1 125	1 061	100	100	100	-0.7	-0.5	-0.5	-0.5
Coal	365	209	211	212	179	160	141	24	17	13	-1.7	-1.9	-1.2	-1.4
Oil	459	199	216	251	218	173	127	30	20	12	-1.9	-1.5	-2.7	-2.3
Natural gas	596	481	566	611	578	555	512	39	50	48	0.1	-0.6	-0.6	-0.6
Nuclear	55	61	76	90	127	158	186	3.6	7.4	18	1.6	3.9	1.9	2.5
Hydro	22	23	26	30	30	32	33	1.5	2.4	3.2	0.9	0.1	0.6	0.4
Geothermal	0.0	0.1	0.6	0.2	0.3	0.3	0.3	0.0	0.0	0.0	7.7	0.9	0.1	0.3
Solar, wind, etc.	-	0.0	0.2	3.2	8.4	17	32	-	0.3	3.0	n.a.	11.1	6.9	8.2
Biomass and waste	17	15	19	31	33	31	31	1.1	2.5	2.9	1.9	1.0	-0.4	0.0
Hydrogen	-	-	-	-	-0.0	-3.2	-9.2	-	-	-0.9	n.a.	n.a.	57.8	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 057	647	711	802	754	680	601	100	100	100	-0.9	-0.7	-1.1	-1.0
Industry	391	205	205	211	204	194	174	37	26	29	-2.0	-0.4	-0.8	-0.7
Transport	170	110	145	156	132	106	82	16	19	14	-0.3	-1.9	-2.4	-2.2
Buildings, etc.	431	285	281	331	314	269	228	41	41	38	-0.9	-0.6	-1.6	-1.3
Non-energy use	65	47	80	104	105	111	118	6.2	13	20	1.5	0.0	0.6	0.4
Coal	113	36	41	52	44	36	27	11	6.4	4.5	-2.5	-1.9	-2.4	-2.2
Oil	275	144	174	214	193	155	118	26	27	20	-0.8	-1.2	-2.4	-2.0
Natural gas	258	200	233	265	237	192	144	24	33	24	0.1	-1.2	-2.4	-2.1
Electricity	125	86	103	116	132	165	201	12	14	33	-0.2	1.4	2.1	1.9
Heat	274	170	147	135	128	113	94	26	17	16	-2.3	-0.5	-1.6	-1.2
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Renewables	13	11	14	21	21	18	18	1.2	2.6	3.0	1.6	0.4	-0.9	-0.5

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	1 856	1 415	1 689	1 867	2 073	2 493	2 902	100	100	100	0.0	1.2	1.7	1.5
Coal	429	338	396	372	353	349	323	23	20	11	-0.5	-0.6	-0.4	-0.5
Oil	252	69	22	22	13	9.6	6.8	14	1.2	0.2	-7.5	-6.2	-3.1	-4.0
Natural gas	707	504	671	735	761	933	1 076	38	39	37	0.1	0.4	1.8	1.3
Nuclear	209	234	289	345	488	608	714	11	18	25	1.6	3.9	1.9	2.5
Hydro	259	267	306	345	347	373	389	14	18	13	0.9	0.1	0.6	0.4
Geothermal	0.0	0.1	0.5	0.5	0.6	0.6	0.6	0.0	0.0	0.0	9.9	0.7	0.0	0.2
Solar PV	-	-	0.0	15	48	93	159	-	0.8	5.5	n.a.	13.8	6.1	8.4
Wind	-	0.0	1.2	21	46	106	209	-	1.1	7.2	n.a.	9.4	7.8	8.3
CSP and marine	-	-	-	-	0.1	0.4	0.9	-	-	0.0	n.a.	n.a.	13.4	n.a.
Biomass and waste	0.0	2.6	3.3	10	16	20	24	0.0	0.5	0.8	18.9	5.2	1.9	2.9
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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	1 832	1 264	2 089	2 628	3 085	3 867	4 805	1.2	1.8	2.2	2.1
Population (million)	337	335	332	342	340	340	339	0.0	0.0	0.0	0.0
CO_2 emissions (Mt)	3 878	2 339	2 511	2 584	2 240	1 760	1 290	-1.3	-1.6	-2.7	-2.4
GDP per capita ($2015 thousand)	5.4	3.8	6.3	7.7	9.1	11	14	1.1	1.8	2.3	2.1
Primary energy consump. per capita (toe)	4.5	3.0	3.4	3.6	3.4	3.3	3.1	-0.7	-0.5	-0.5	-0.5
Primary energy consumption per GDP[*2]	826	782	532	466	379	291	221	-1.8	-2.3	-2.7	-2.5
CO_2 emissions per GDP[*3]	2 116	1 850	1 202	983	726	455	268	-2.4	-3.3	-4.9	-4.4
CO_2 per primary energy consumption[*4]	2.6	2.4	2.3	2.1	1.9	1.6	1.2	-0.6	-1.1	-2.2	-1.9

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A77 | European Union [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	1 441	1 471	1 527	1 388	1 246	1 085	972	100	100	100	-0.1	-1.2	-1.2	-1.2
Coal	393	285	252	166	77	61	50	27	12	5.2	-2.7	-8.2	-2.1	-4.0
Oil	531	550	506	437	349	221	133	37	32	14	-0.6	-2.5	-4.7	-4.0
Natural gas	250	309	363	340	235	163	87	17	24	9.0	1.0	-4.0	-4.8	-4.6
Nuclear	190	224	223	191	199	216	226	13	14	23	0.0	0.5	0.6	0.6
Hydro	24	30	32	30	30	31	31	1.7	2.2	3.2	0.7	0.0	0.2	0.2
Geothermal	3.2	4.6	5.5	6.8	8.0	8.3	8.1	0.2	0.5	0.8	2.5	1.8	0.1	0.6
Solar, wind, etc.	0.3	2.5	16	52	136	178	229	0.0	3.8	24	18.0	11.2	2.6	5.2
Biomass and waste	47	65	128	163	195	169	149	3.3	12	15	4.1	2.0	-1.3	-0.3
Hydrogen	-	-	-	-	0.0	18	38	-	-	3.9	n.a.	n.a.	40.7	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	995	1 027	1 070	1 023	928	753	612	100	100	100	0.1	-1.1	-2.1	-1.8
Industry	313	274	247	246	246	219	180	31	24	29	-0.8	0.0	-1.5	-1.1
Transport	220	262	279	274	229	144	103	22	27	17	0.7	-2.0	-3.9	-3.3
Buildings, etc.	374	391	447	408	360	299	244	38	40	40	0.3	-1.4	-1.9	-1.8
Non-energy use	88	100	98	94	94	90	85	8.9	9.2	14	0.2	0.0	-0.5	-0.4
Coal	109	47	37	28	24	17	11	11	2.8	1.8	-4.2	-2.1	-3.7	-3.2
Oil	445	479	448	406	330	217	144	45	40	24	-0.3	-2.3	-4.1	-3.5
Natural gas	185	220	231	227	196	138	72	19	22	12	0.7	-1.6	-4.9	-3.9
Electricity	162	189	216	214	239	264	277	16	21	45	0.9	1.2	0.7	0.9
Heat	55	43	52	47	43	38	30	5.5	4.6	4.8	-0.5	-1.1	-1.8	-1.6
Hydrogen	-	-	-	-	0.1	11	33	-	-	5.5	n.a.	n.a.	38.4	n.a.
Renewables	39	50	86	101	97	68	45	4.0	9.8	7.4	3.1	-0.4	-3.8	-2.7

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	2 256	2 630	2 955	2 885	3 404	4 137	4 755	100	100	100	0.8	1.9	1.7	1.7
Coal	844	846	755	453	99	55	42	37	16	0.9	-2.0	-15.6	-4.2	-7.9
Oil	189	173	82	47	11	5.3	0.6	8.4	1.6	0.0	-4.4	-14.7	-13.5	-13.9
Natural gas	188	331	589	552	178	161	155	8.3	19	3.3	3.5	-11.8	-0.7	-4.3
Nuclear	729	860	854	732	763	829	867	32	25	18	0.0	0.5	0.6	0.6
Hydro	284	350	372	348	349	357	364	13	12	7.7	0.7	0.0	0.2	0.2
Geothermal	3.2	4.8	5.6	6.5	12	15	15	0.1	0.2	0.3	2.3	7.1	1.0	2.8
Solar PV	0.0	0.1	22	159	709	877	973	0.0	5.5	20	34.8	18.1	1.6	6.5
Wind	0.8	21	140	387	943	1 392	1 770	0.0	13	37	22.2	10.4	3.2	5.4
CSP and marine	0.5	0.5	1.2	5.7	8.0	11	16	0.0	0.2	0.3	8.1	3.9	3.5	3.6
Biomass and waste	19	42	129	191	328	350	364	0.8	6.6	7.7	7.7	6.2	0.5	2.3
Hydrogen	-	-	-	-	-	80	183	-	-	3.9	n.a.	n.a.	n.a.	n.a.
Others	0.2	1.4	4.4	5.0	5.0	5.0	5.0	0.0	0.2	0.1	10.8	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	9 107	11 262	12 897	14 681	17 280	19 827	22 275	1.6	1.8	1.3	1.4
Population (million)	420	429	442	447	449	446	437	0.2	0.0	-0.1	-0.1
CO_2 emissions (Mt)	3 464	3 265	3 135	2 579	1 473	934	515	-0.9	-6.0	-5.1	-5.4
GDP per capita ($2015 thousand)	22	26	29	33	38	45	51	1.3	1.8	1.4	1.5
Primary energy consump. per capita (toe)	3.4	3.4	3.5	3.1	2.8	2.4	2.2	-0.3	-1.2	-1.1	-1.1
Primary energy consumption per GDP*2	158	131	118	95	72	55	44	-1.6	-3.0	-2.5	-2.6
CO_2 emissions per GDP*3	380	290	243	176	85	47	23	-2.5	-7.7	-6.3	-6.8
CO_2 per primary energy consumption*4	2.4	2.2	2.1	1.9	1.2	0.9	0.5	-0.8	-4.9	-3.9	-4.2

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A78 | Africa [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	390	495	685	853	901	926	998	100	100	100	2.6	0.6	0.5	0.5
Coal	74	90	109	105	93	81	68	19	12	6.8	1.1	-1.3	-1.6	-1.5
Oil	85	100	161	195	223	230	222	22	23	22	2.7	1.5	0.0	0.4
Natural gas	30	47	88	141	199	272	299	7.6	17	30	5.2	3.9	2.1	2.6
Nuclear	2.2	3.4	3.2	3.2	7.3	24	37	0.6	0.4	3.7	1.2	9.5	8.4	8.8
Hydro	4.8	6.4	9.4	13	17	25	36	1.2	1.5	3.6	3.2	3.0	3.9	3.6
Geothermal	0.3	0.4	0.9	4.3	23	31	44	0.1	0.5	4.4	9.2	20.6	3.2	8.3
Solar, wind, etc.	0.0	0.0	0.3	4.3	26	88	206	0.0	0.5	21	33.9	22.0	11.0	14.3
Biomass and waste	194	245	312	387	312	190	133	50	45	13	2.2	-2.4	-4.2	-3.6
Hydrogen	-	-	-	-	-0.0	-15	-46	-	-	-4.6	n.a.	n.a.	51.1	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	286	366	495	614	609	569	576	100	100	100	2.5	-0.1	-0.3	-0.2
Industry	53	58	84	90	106	127	139	19	15	24	1.7	1.8	1.3	1.5
Transport	38	54	87	122	148	168	182	13	20	32	3.8	2.2	1.0	1.4
Buildings, etc.	184	239	306	380	329	242	217	64	62	38	2.4	-1.6	-2.1	-1.9
Non-energy use	11	15	19	21	25	31	38	3.8	3.4	6.6	2.1	1.9	2.2	2.1
Coal	20	19	18	21	21	20	17	7.0	3.5	3.0	0.2	-0.5	-0.8	-0.7
Oil	70	89	137	170	198	216	217	24	28	38	2.9	1.7	0.5	0.8
Natural gas	8.6	14	27	45	54	59	59	3.0	7.3	10	5.5	1.9	0.5	0.9
Electricity	22	31	47	60	95	153	214	7.7	9.7	37	3.3	5.3	4.1	4.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	1.2	7.0	-	-	1.2	n.a.	n.a.	47.3	n.a.
Renewables	166	213	267	317	241	119	61	58	52	11	2.1	-3.0	-6.6	-5.5

Electricity generation

	(TWh)							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	309	439	686	885	1 391	2 448	3 973	100	100	100	3.4	5.2	5.4	5.3
Coal	164	208	259	246	224	190	154	53	28	3.9	1.3	-1.0	-1.9	-1.6
Oil	35	34	64	55	51	22	0.9	11	6.2	0.0	1.5	-0.9	-18.2	-13.2
Natural gas	45	106	234	371	622	993	1 255	15	42	32	7.0	5.9	3.6	4.3
Nuclear	8.4	13	12	12	28	91	142	2.7	1.4	3.6	1.2	9.5	8.4	8.8
Hydro	56	75	110	151	196	285	419	18	17	11	3.2	3.0	3.9	3.6
Geothermal	0.3	0.4	1.1	5.0	27	36	51	0.1	0.6	1.3	9.2	20.6	3.2	8.3
Solar PV	-	0.0	0.4	14	106	454	1 121	-	1.6	28	n.a.	25.0	12.5	16.2
Wind	-	0.2	2.4	23	101	274	601	-	2.6	15	n.a.	17.6	9.3	11.9
CSP and marine	-	-	-	2.9	29	94	219	-	0.3	5.5	n.a.	28.9	10.7	16.0
Biomass and waste	0.5	1.4	2.4	2.2	5.2	6.8	8.2	0.2	0.2	0.2	5.0	10.1	2.4	4.7
Hydrogen	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Others	-	0.1	1.9	1.6	1.6	1.6	1.6	-	0.2	0.0	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	920	1 208	1 998	2 663	3 830	6 227	9 596	3.5	4.1	4.7	4.5
Population (million)	620	794	1 021	1 346	1 652	2 024	2 405	2.5	2.3	1.9	2.0
CO_2 emissions (Mt)	524	652	1 008	1 218	1 335	1 297	1 168	2.8	1.0	-0.7	-0.1
GDP per capita ($2015 thousand)	1.5	1.5	2.0	2.0	2.3	3.1	4.0	0.9	1.8	2.8	2.4
Primary energy consump. per capita (toe)	0.6	0.6	0.7	0.6	0.5	0.5	0.4	0.0	-1.7	-1.4	-1.4
Primary energy consumption per GDP[*2]	424	410	343	320	235	149	104	-0.9	-3.4	-4.0	-3.8
CO_2 emissions per GDP[*3]	569	540	504	458	349	208	122	-0.7	-3.0	-5.1	-4.5
CO_2 per primary energy consumption[*4]	1.3	1.3	1.5	1.4	1.5	1.4	1.2	0.2	0.4	-1.2	-0.7

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A79 | Middle East [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	223	381	649	829	965	1 040	1 087	100	100	100	4.3	1.7	0.6	0.9
Coal	3.0	8.1	9.8	8.1	7.3	6.5	4.8	1.3	1.0	0.4	3.3	-1.2	-2.0	-1.8
Oil	146	226	324	331	372	343	291	66	40	27	2.7	1.3	-1.2	-0.4
Natural gas	72	145	311	478	531	589	589	32	58	54	6.3	1.2	0.5	0.7
Nuclear	-	-	-	3.4	27	50	65	-	0.4	6.0	n.a.	25.6	4.6	10.7
Hydro	1.0	0.7	1.5	1.9	2.0	2.2	2.3	0.5	0.2	0.2	2.0	0.4	0.8	0.7
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar, wind, etc.	0.4	0.7	1.3	2.7	22	63	154	0.2	0.3	14	6.2	26.2	10.3	15.0
Biomass and waste	0.5	0.4	1.0	1.1	2.4	3.2	5.4	0.2	0.1	0.5	3.0	8.6	4.1	5.5
Hydrogen	-	-	-	-	-0.0	-19	-27	-	-	-2.5	n.a.	n.a.	40.5	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	157	261	451	568	686	711	703	100	100	100	4.2	2.1	0.1	0.7
Industry	47	71	134	160	200	205	186	30	28	26	4.0	2.5	-0.4	0.5
Transport	51	75	121	140	181	169	148	32	25	21	3.3	2.9	-1.0	0.2
Buildings, etc.	40	74	118	160	172	176	176	25	28	25	4.6	0.8	0.1	0.3
Non-energy use	20	41	77	108	132	161	194	12	19	28	5.7	2.3	1.9	2.1
Coal	0.2	0.5	1.2	3.2	3.4	3.4	2.8	0.1	0.6	0.4	9.6	0.8	-1.0	-0.5
Oil	108	162	240	254	316	310	280	69	45	40	2.8	2.5	-0.6	0.3
Natural gas	31	65	146	218	242	219	174	20	38	25	6.5	1.1	-1.6	-0.8
Electricity	17	32	62	92	123	168	217	11	16	31	5.6	3.3	2.9	3.0
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	7.6	26	-	-	3.6	n.a.	n.a.	66.1	n.a.
Renewables	0.7	1.0	2.2	1.6	1.6	2.3	4.2	0.5	0.3	0.6	2.6	0.0	4.8	3.3

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	244	472	888	1 316	1 702	2 703	4 343	100	100	100	5.6	2.9	4.8	4.2
Coal	11	30	35	21	18	15	11	4.3	1.6	0.2	2.2	-1.5	-2.7	-2.3
Oil	108	189	286	283	207	133	62	44	22	1.4	3.2	-3.4	-5.8	-5.1
Natural gas	114	246	549	956	1 130	1 622	2 162	47	73	50	7.1	1.9	3.3	2.9
Nuclear	-	-	-	13	103	193	251	-	1.0	5.8	n.a.	25.6	4.6	10.7
Hydro	12	8.0	18	22	23	25	27	4.9	1.7	0.6	2.0	0.4	0.8	0.7
Geothermal	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Solar PV	-	-	0.1	16	151	509	1 411	-	1.2	32	n.a.	27.9	11.8	16.6
Wind	0.0	0.0	0.2	3.0	59	133	213	0.0	0.2	4.9	29.4	39.4	6.6	15.9
CSP and marine	-	-	-	1.2	11	26	52	-	0.1	1.2	n.a.	28.1	8.0	13.9
Biomass and waste	-	0.0	0.1	0.0	1.1	1.4	1.6	-	0.0	0.0	n.a.	51.5	1.9	15.3
Hydrogen	-	-	-	-	-	45	152	-	-	3.5	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	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	910	1 377	2 064	2 664	3 563	4 727	6 120	3.5	3.3	2.7	2.9
Population (million)	133	171	220	270	307	345	379	2.3	1.5	1.0	1.2
CO_2 emissions (Mt)	569	948	1 553	1 862	1 987	1 663	1 188	3.9	0.7	-2.5	-1.5
GDP per capita ($2015 thousand)	6.8	8.0	9.4	9.9	12	14	16	1.2	1.8	1.7	1.7
Primary energy consump. per capita (toe)	1.7	2.2	2.9	3.1	3.1	3.0	2.9	2.0	0.3	-0.4	-0.2
Primary energy consumption per GDP[*2]	245	277	314	311	271	220	178	0.8	-1.5	-2.1	-1.9
CO_2 emissions per GDP[*3]	625	689	752	699	558	352	194	0.4	-2.5	-5.1	-4.3
CO_2 per primary energy consumption[*4]	2.6	2.5	2.4	2.2	2.1	1.6	1.1	-0.4	-1.0	-3.1	-2.5

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A80 | Oceania [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	99	125	144	150	141	128	125	100	100	100	1.4	-0.7	-0.6	-0.6
Coal	36	49	52	42	21	15	6.2	36	28	4.9	0.5	-7.4	-5.9	-6.4
Oil	35	40	48	49	48	34	20	35	33	16	1.1	-0.2	-4.4	-3.1
Natural gas	19	24	31	40	39	32	23	19	27	18	2.5	-0.1	-2.7	-1.9
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	3.2	3.5	3.3	3.4	3.7	3.8	3.9	3.2	2.2	3.1	0.1	1.2	0.2	0.5
Geothermal	1.5	2.0	3.3	4.9	5.0	4.9	4.9	1.5	3.2	3.9	3.9	0.2	0.0	0.0
Solar, wind, etc.	0.1	0.1	0.9	5.2	17	42	95	0.1	3.5	76	12.8	14.3	8.8	10.5
Biomass and waste	4.7	6.0	5.9	5.8	6.2	6.0	5.5	4.7	3.8	4.4	0.7	0.8	-0.6	-0.2
Hydrogen	-	-	-	-	-0.0	-9.5	-33	-	-	-26	n.a.	n.a.	52.6	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	66	82	90	92	96	86	75	100	100	100	1.1	0.4	-1.2	-0.7
Industry	23	28	26	27	29	27	23	34	29	31	0.5	0.9	-1.0	-0.4
Transport	24	30	35	35	35	29	23	36	38	31	1.2	0.2	-2.1	-1.4
Buildings, etc.	15	19	23	25	25	24	22	22	27	29	1.7	0.2	-0.7	-0.4
Non-energy use	4.6	6.1	5.9	6.4	6.6	6.7	6.7	6.9	7.0	8.9	1.1	0.3	0.1	0.2
Coal	5.2	4.7	3.1	3.2	3.1	2.7	1.9	7.9	3.5	2.5	-1.5	-0.4	-2.4	-1.8
Oil	33	40	45	47	46	36	25	50	51	34	1.2	-0.2	-3.0	-2.1
Natural gas	10	14	14	15	15	11	7.0	16	16	9.2	1.1	-0.2	-3.6	-2.6
Electricity	14	18	22	22	27	30	34	21	24	45	1.6	2.1	1.2	1.5
Heat	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydrogen	-	-	-	-	0.0	0.9	3.4	-	-	4.5	n.a.	n.a.	50.2	n.a.
Renewables	3.8	5.2	5.3	5.0	5.1	4.6	4.0	5.8	5.5	5.4	0.9	0.2	-1.2	-0.8

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	187	249	298	310	372	607	1 191	100	100	100	1.6	2.1	6.0	4.8
Coal	122	176	182	144	67	31	5.5	65	46	0.5	0.5	-8.1	-11.8	-10.7
Oil	3.6	1.8	6.1	4.7	2.1	-	-	1.9	1.5	-	0.9	-8.4	-100	-100
Natural gas	20	26	54	55	47	30	11	11	18	0.9	3.3	-1.6	-7.1	-5.4
Nuclear	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
Hydro	37	41	38	39	43	44	45	20	13	3.8	0.1	1.2	0.2	0.5
Geothermal	2.1	2.9	5.9	8.4	8.6	8.6	8.6	1.1	2.7	0.7	4.5	0.2	0.0	0.1
Solar PV	-	0.0	0.4	28	85	194	457	-	9.0	38	n.a.	13.2	8.8	10.1
Wind	-	0.2	6.7	27	113	284	646	-	8.8	54	n.a.	17.1	9.1	11.5
CSP and marine	-	-	0.0	0.0	0.1	0.1	0.2	-	0.0	0.0	n.a.	29.1	6.5	13.1
Biomass and waste	1.6	2.0	3.5	4.1	5.4	6.1	6.7	0.9	1.3	0.6	3.1	3.0	1.0	1.6
Hydrogen	-	-	-	-	-	8.7	11	-	-	0.9	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	-1.2	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	658	908	1 220	1 583	1 939	2 441	3 015	2.9	2.3	2.2	2.2
Population (million)	20	23	26	31	33	36	38	1.3	0.9	0.6	0.7
CO_2 emissions (Mt)	279	359	421	392	295	182	104	1.1	-3.1	-5.1	-4.5
GDP per capita ($2015 thousand)	32	40	46	51	58	68	79	1.5	1.3	1.6	1.5
Primary energy consump. per capita (toe)	4.9	5.5	5.5	4.9	4.2	3.6	3.3	0.0	-1.6	-1.2	-1.3
Primary energy consumption per GDP[*2]	150	138	118	95	73	52	42	-1.5	-2.9	-2.8	-2.8
CO_2 emissions per GDP[*3]	424	396	345	248	152	74	35	-1.7	-5.3	-7.1	-6.6
CO_2 per primary energy consumption[*4]	2.8	2.9	2.9	2.6	2.1	1.4	0.8	-0.2	-2.4	-4.5	-3.9

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A81 | Advanced Economies [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total*1	4 471	5 234	5 357	5 139	4 711	4 096	3 681	100	100	100	0.5	-1.0	-1.2	-1.1
Coal	1 090	1 116	1 114	741	402	246	164	24	14	4.4	-1.2	-6.6	-4.4	-5.1
Oil	1 827	2 071	1 920	1 771	1 502	988	595	41	34	16	-0.1	-1.8	-4.5	-3.7
Natural gas	827	1 135	1 285	1 508	1 269	966	664	19	29	18	2.0	-1.9	-3.2	-2.8
Nuclear	463	596	606	503	555	581	584	10	9.8	16	0.3	1.1	0.3	0.5
Hydro	100	111	112	115	125	129	132	2.2	2.2	3.6	0.5	0.9	0.3	0.5
Geothermal	22	25	25	39	54	63	65	0.5	0.8	1.8	1.9	3.7	0.9	1.7
Solar, wind, etc.	2.1	6.1	31	134	404	705	984	0.0	2.6	27	14.4	13.0	4.5	7.1
Biomass and waste	139	172	261	324	397	389	386	3.1	6.3	10	2.8	2.3	-0.1	0.6
Hydrogen	-	-	-	-	0.1	28	113	-	-	3.1	n.a.	n.a.	46.4	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	3 058	3 579	3 644	3 632	3 406	2 864	2 418	100	100	100	0.6	-0.7	-1.7	-1.4
Industry	826	906	803	817	815	739	620	27	22	26	0.0	0.0	-1.4	-0.9
Transport	921	1 121	1 151	1 149	1 016	694	516	30	32	21	0.7	-1.4	-3.3	-2.7
Buildings, etc.	1 025	1 185	1 310	1 260	1 156	1 001	847	34	35	35	0.7	-0.9	-1.5	-1.4
Non-energy use	286	367	380	407	419	430	434	9.4	11	18	1.1	0.3	0.2	0.2
Coal	230	138	127	95	80	61	42	7.5	2.6	1.7	-2.8	-1.8	-3.2	-2.8
Oil	1 561	1 812	1 739	1 646	1 419	965	637	51	45	26	0.2	-1.6	-3.9	-3.2
Natural gas	578	732	717	784	700	511	287	19	22	12	1.0	-1.3	-4.4	-3.4
Electricity	553	715	809	826	915	1 027	1 079	18	23	45	1.3	1.1	0.8	0.9
Heat	48	52	66	64	58	51	41	1.6	1.8	1.7	0.9	-1.0	-1.8	-1.5
Hydrogen	-	-	-	-	0.2	38	132	-	-	5.5	n.a.	n.a.	40.0	n.a.
Renewables	89	131	185	217	234	211	200	2.9	6.0	8.3	2.9	0.8	-0.8	-0.3

Electricity generation

	(TWh)							Shares (%)			1990/	2021/	2030/	2021/
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	2021	2030	2050	2050
Total	7 666	9 705	10 867	10 972	12 123	14 486	17 420	100	100	100	1.2	1.1	1.8	1.6
Coal	3 129	3 837	3 812	2 378	991	378	119	41	22	0.7	-0.9	-9.3	-10.1	-9.8
Oil	667	539	274	142	45	14	0.7	8.7	1.3	0.0	-4.9	-12.0	-19.0	-16.9
Natural gas	766	1 528	2 527	3 269	2 327	1 341	562	10.0	30	3.2	4.8	-3.7	-6.9	-5.9
Nuclear	1 776	2 288	2 324	1 930	2 130	2 230	2 243	23	18	13	0.3	1.1	0.3	0.5
Hydro	1 158	1 293	1 302	1 335	1 452	1 497	1 531	15	12	8.8	0.5	0.9	0.3	0.5
Geothermal	23	27	37	54	75	89	92	0.3	0.5	0.5	2.7	3.9	1.0	1.9
Solar PV	0.1	0.7	31	484	1 905	3 422	4 831	0.0	4.4	28	32.1	16.4	4.8	8.3
Wind	3.8	29	269	944	2 425	4 024	5 547	0.1	8.6	32	19.4	11.1	4.2	6.3
CSP and marine	1.2	1.1	2.1	9.3	95	224	333	0.0	0.1	1.9	6.9	29.5	6.4	13.1
Biomass and waste	121	142	257	392	641	736	804	1.6	3.6	4.6	3.9	5.6	1.1	2.5
Hydrogen	-	-	-	-	-	496	1 324	-	-	7.6	n.a.	n.a.	n.a.	n.a.
Others	20	22	33	35	35	35	35	0.3	0.3	0.2	1.8	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	27 230	35 871	42 356	50 940	59 864	70 870	81 906	2.0	1.8	1.6	1.7
Population (million)	998	1 070	1 140	1 197	1 218	1 228	1 222	0.6	0.2	0.0	0.1
CO_2 emissions (Mt)	10 784	12 220	11 954	10 593	7 809	4 697	2 393	-0.1	-3.3	-5.7	-5.0
GDP per capita ($2015 thousand)	27	34	37	43	49	58	67	1.4	1.6	1.6	1.6
Primary energy consump. per capita (toe)	4.5	4.9	4.7	4.3	3.9	3.3	3.0	-0.1	-1.2	-1.2	-1.2
Primary energy consumption per GDP*2	164	146	126	101	79	58	45	-1.6	-2.7	-2.8	-2.8
CO_2 emissions per GDP*3	396	341	282	208	130	66	29	-2.1	-5.0	-7.2	-6.5
CO_2 per primary energy consumption*4	2.4	2.3	2.2	2.1	1.7	1.1	0.7	-0.5	-2.4	-4.6	-3.9

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Table A82 | Emerging Market and Developing Economies [Advanced Technologies Scenario]

Primary energy consumption

	Mtoe							Shares (%)			CAGR (%)			
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
Total[*1]	4 081	4 516	7 132	9 306	10 211	10 060	9 590	100	100	100	2.7	1.0	-0.3	0.1
Coal	1 133	1 201	2 548	3 275	3 083	2 286	1 411	28	35	15	3.5	-0.7	-3.8	-2.9
Oil	1 208	1 338	1 873	2 267	2 379	2 159	1 796	30	24	19	2.1	0.5	-1.4	-0.8
Natural gas	835	933	1 449	1 979	2 255	2 407	2 269	20	21	24	2.8	1.5	0.0	0.5
Nuclear	62	79	113	229	433	676	866	1.5	2.5	9.0	4.3	7.3	3.5	4.7
Hydro	84	113	184	254	294	343	395	2.1	2.7	4.1	3.6	1.6	1.5	1.5
Geothermal	12	27	36	72	172	243	302	0.3	0.8	3.1	5.9	10.2	2.8	5.1
Solar, wind, etc.	0.5	2.1	17	157	499	1 076	1 864	0.0	1.7	19	20.4	13.7	6.8	8.9
Biomass and waste	747	823	913	1 072	1 096	925	842	18	12	8.8	1.2	0.2	-1.3	-0.8
Hydrogen	-	-	-	-	-0.1	-55	-163	-	-	-1.7	n.a.	n.a.	49.1	n.a.

Final energy consumption

	Mtoe							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	2 981	3 158	4 824	6 135	6 640	6 527	6 227	100	100	100	2.4	0.9	-0.3	0.1
Industry	970	963	1 840	2 219	2 431	2 380	2 096	33	36	34	2.7	1.0	-0.7	-0.2
Transport	455	569	918	1 227	1 414	1 363	1 295	15	20	21	3.3	1.6	-0.4	0.2
Buildings, etc.	1 365	1 377	1 658	2 101	2 115	2 001	1 949	46	34	31	1.4	0.1	-0.4	-0.3
Non-energy use	191	249	408	589	680	783	886	6.4	9.6	14	3.7	1.6	1.3	1.4
Coal	521	404	934	818	719	598	467	17	13	7.5	1.5	-1.4	-2.1	-1.9
Oil	844	1 043	1 521	1 965	2 122	1 975	1 685	28	32	27	2.8	0.9	-1.1	-0.5
Natural gas	367	388	627	926	983	887	700	12	15	11	3.0	0.7	-1.7	-1.0
Electricity	281	372	728	1 251	1 735	2 215	2 646	9.4	20	42	4.9	3.7	2.1	2.6
Heat	288	196	209	283	287	256	205	9.7	4.6	3.3	-0.1	0.2	-1.7	-1.1
Hydrogen	-	-	-	-	0.0	22	83	-	-	1.3	n.a.	n.a.	46.7	n.a.
Renewables	679	755	805	892	794	574	440	23	15	7.1	0.9	-1.3	-2.9	-2.4

Electricity generation

	(TWh)							Shares (%)			1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
	1990	2000	2010	2021	2030	2040	2050	1990	2021	2050				
Total	4 171	5 718	10 671	17 430	24 005	31 393	40 097	100	100	100	4.7	3.6	2.6	2.9
Coal	1 301	2 158	4 862	7 874	7 863	5 293	2 350	31	45	5.9	6.0	0.0	-5.9	-4.1
Oil	650	645	689	580	408	273	160	16	3.3	0.4	-0.4	-3.8	-4.6	-4.3
Natural gas	982	1 244	2 329	3 287	4 505	6 320	7 557	24	19	19	4.0	3.6	2.6	2.9
Nuclear	236	303	432	878	1 662	2 594	3 322	5.7	5.0	8.3	4.3	7.3	3.5	4.7
Hydro	981	1 319	2 145	2 958	3 419	3 985	4 597	24	17	11	3.6	1.6	1.5	1.5
Geothermal	13	25	31	42	126	175	221	0.3	0.2	0.6	3.9	13.0	2.9	5.9
Solar PV	0.0	0.1	1.4	536	2 737	6 376	11 628	0.0	3.1	29	47.7	19.9	7.5	11.2
Wind	0.0	2.8	73	920	2 530	5 294	8 667	0.0	5.3	22	38.7	11.9	6.4	8.0
CSP and marine	0.0	0.0	0.0	6.3	51	150	344	0.0	0.0	0.9	24.5	26.2	10.0	14.8
Biomass and waste	8.5	21	105	343	700	864	1 026	0.2	2.0	2.6	12.7	8.3	1.9	3.9
Hydrogen	-	-	-	-	-	66	221	-	-	0.6	n.a.	n.a.	n.a.	n.a.
Others	-	0.5	2.4	4.3	4.3	4.3	4.3	-	0.0	0.0	n.a.	0.0	0.0	0.0

Energy and economic indicators

	1990	2000	2010	2021	2030	2040	2050	1990/ 2021	2021/ 2030	2030/ 2050	2021/ 2050
GDP ($2015 billion)	8 685	12 357	22 418	35 497	49 883	73 163	102 141	4.6	3.9	3.6	3.7
Population (million)	4 288	5 065	5 820	6 681	7 293	7 927	8 457	1.4	1.0	0.7	0.8
CO_2 emissions (Mt)	9 102	10 092	17 615	21 990	21 779	17 050	11 069	2.9	-0.1	-3.3	-2.3
GDP per capita ($2015 thousand)	2.0	2.4	3.9	5.3	6.8	9.2	12	3.2	2.8	2.9	2.9
Primary energy consump. per capita (toe)	1.0	0.9	1.2	1.4	1.4	1.3	1.1	1.2	0.1	-1.0	-0.7
Primary energy consumption per GDP[*2]	470	365	318	262	205	138	94	-1.9	-2.7	-3.8	-3.5
CO_2 emissions per GDP[*3]	1 048	817	786	619	437	233	108	-1.7	-3.8	-6.7	-5.8
CO_2 per primary energy consumption[*4]	2.2	2.2	2.5	2.4	2.1	1.7	1.2	0.2	-1.1	-3.0	-2.4

*1 Trade of electricity and heat are not shown, *2 toe/$2015 million,
*3 t/$2015 million, *4 t/toe

Slides

The 445th Forum on Research Work

IEEJ Outlook 2024

Energy, Environment and Economy

Complexity of achieving the energy transition under multiple pathways

Tokyo, 20 October 2023

The Institute of Energy Economics, Japan

IEEJ Outlook 2024

－Complexity of achieving the energy transition under multiple pathways－

Part 1 : Global Energy Supply and Demand Outlook to 2050

Seiya Endo
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What is IEEJ Outlook 2024 ?

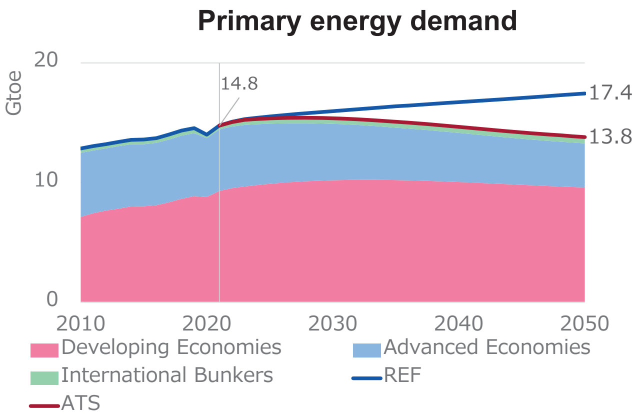
- Quantitative outlook of energy supply and demand in the world, toward 2050.

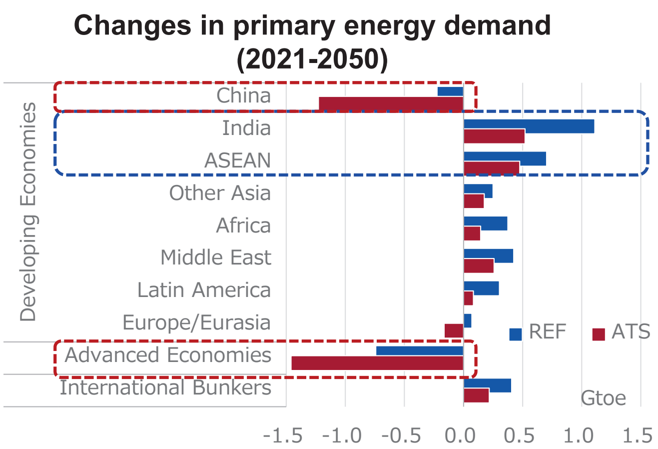
- Has two scenarios;

REF: (Reference Scenario)	ATS: (Advanced Technologies Scenario)
the prevailing changes will continue against the backdrop of current energy and environmental policies	Energy/environmental technologies are introduced to the maximum extent possible to ensure a stable supply of energy and strengthen measures against climate change

- **Forecast** analysis using econometric and other models.

Part 1: Global Outlook
Demand will grow significantly in Asia, Middle East, and Africa

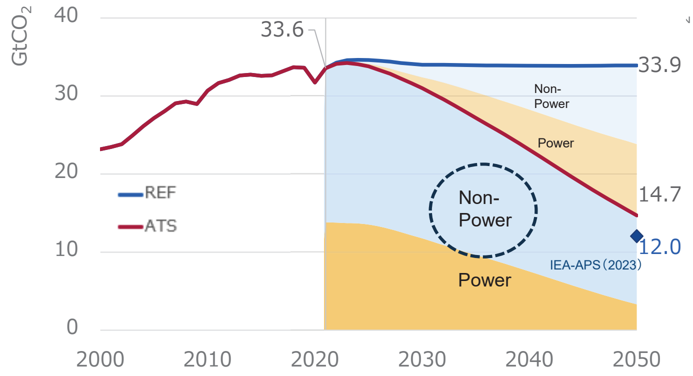




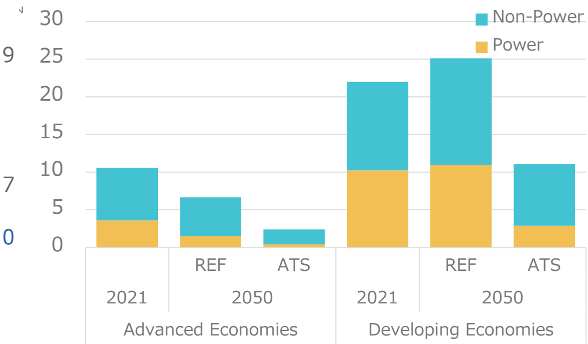
- (**REF**) Demand continues to increase with the current trend, reaching 1.2 times the current level by 2050.
- (**ATS**) Global demand peaks before 2030, however, India, ASEAN, the Middle East, and Africa will continue their demand growth.

Part1: Global Outlook Power generation moves closer to CN. Decarbonization of non-power is a challenge.

Energy-related CO_2 emissions



CO_2 emissions by region



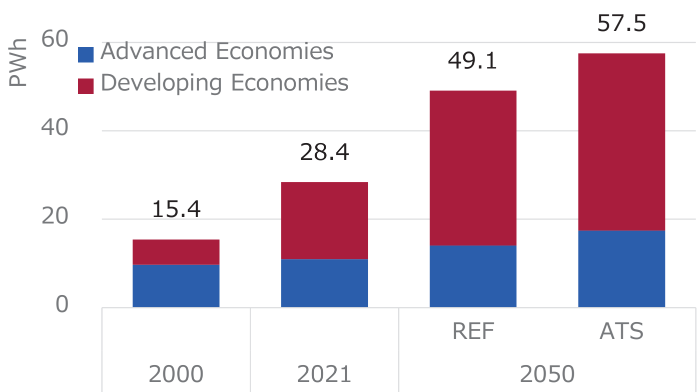
- (**REF**) CO2 emissions are nearly flat as increased demand is offset by lower CO2 intensity.
- (**ATS**) The emission peaks out before 2030 and decline to 14.7 $GtCO_2$ in 2050 (56% below 2021).

It is still far from carbon neutrality, and decarbonization in the non-power sector and emerging and developing countries are significant challenges.

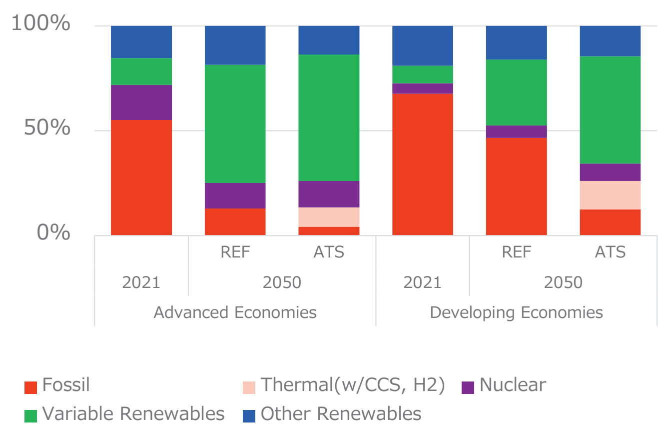
*IEA-APS: Announced Pledges Scenario from IEA “World Energy Outlook 2023”

Part 1: Global Outlook Power generation will be 1.7 to 2 times. Among them, renewable increase significantly.

Power Generation



Share in Power Generation



- (**REF**) Power generation increases 1.7 times from current levels. Most of the increase is in developing countries, but also in developed countries as electrification progresses.
- (**ATS**) Power generation doubles the current level. In addition to electrification progress, demand for green hydrogen is boosting demand. About 85% of power sources are decarbonized.

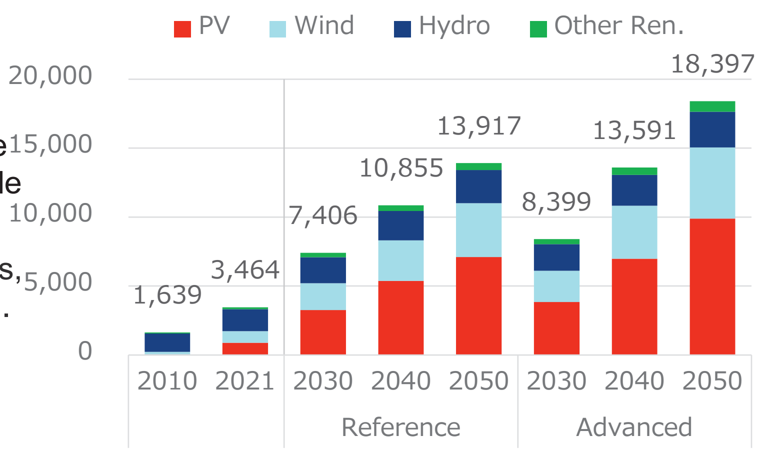
Part 1: Global Outlook　Renewable energy capacity will more than double by 2030 and continue the expansion.

- Remarkable penetration of renewables continues. The installed capacity of renewable energy in 2030 is expected to be 2.0~2.4 times that of 2021.
- Increases will continue after 2030 under both scenarios;
- **(REF)** The expansion will slightly slow down due to higher system costs and a decrease in suitable locations.

  (ATS) Renewable energy installation accelerates, increasing capacity to 5.4 times the current level.

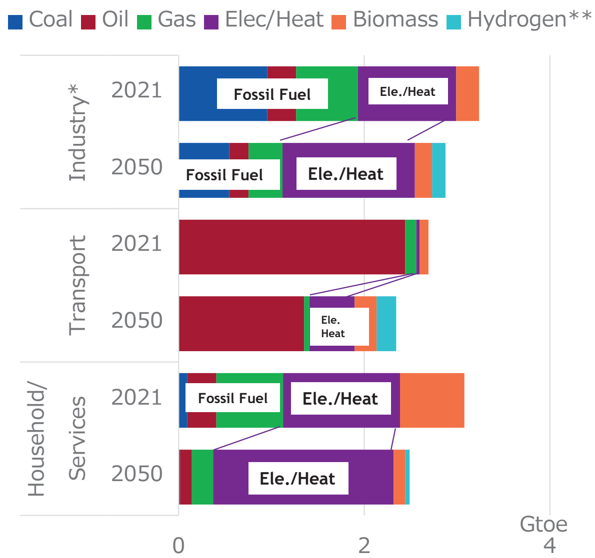
Particularly, solar PV and wind will be nearly 10 times the current capacity. Both daily and seasonal storage will be essential for a stable power supply.

Renewable capacity[GW]



Part 1: Global Outlook　While electrification and hydrogenation proceed rapidly, the role of fossil fuels remains

Final Energy Demands (ATS)



**Hydrogen includes ammonia and synthetic fuel from H_2.

- Industry

Fossil fuels remain due to the difficulty of substitution in heat demand at higher temperatures. (especially for steel and cement).

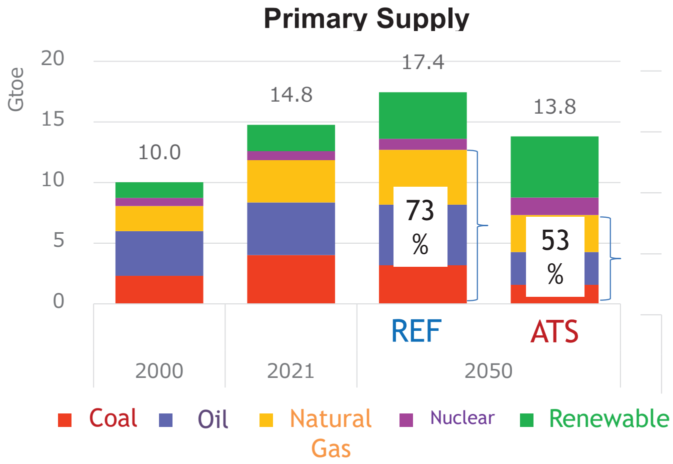
- Transport

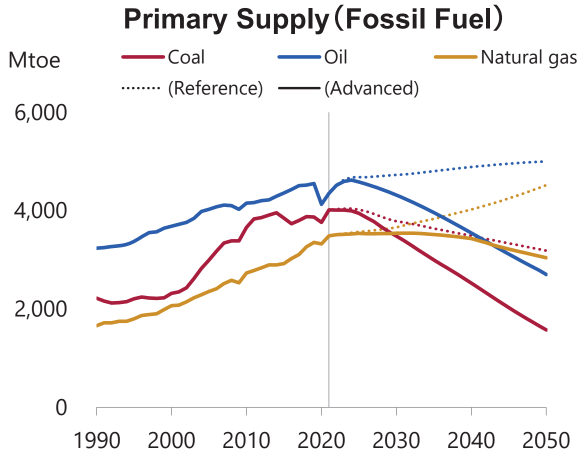
ZEVs (EVs + H_2 FCVs) are largely penetrating in the automobile subsector. They account for 60% of the passenger cars fleet and 47% of the trucks and buses.

- Others (Household and Services)

Significant electrification of both service subsectors and homes (often substituting from traditional biomass).

Primary oil and gas supply increases in Reference, and decreases in Advanced Tech..





- **(REF)** Primary supply in 2050 increases 1.2 times that of 2021, 73% of which will be fossil fuels. Oil demand increases 1.2 times and gas 1.3 times, while coal decreases 0.8 times.
- **(ATS)** Half of the primary supply is fossil fuels, and the other half is renewable and nuclear.

Oil and coal supply peaks in the 2020s because of a decrease in transportation demand for oil and power generation demand for coal. Gas supplies remains flat until the 2030s and begin to decline before 2040.

Part 1: Global Outlook
Conclusion

- India, ASEAN, Middle East, and Africa will be the center of demand growth in both scenarios.
- Emissions in the Reference scenario remains flat, and those from the Advanced Technologies scenario are halfway from reaching carbon neutrality. The remaining emissions are mainly from the non-power sector and the developing countries. To further cut emissions will remain a difficult challenge.
- Power generation doubles in the next three decades due to factors such as economic growth, electrification, and demand for green hydrogen. As variable renewable covers a large part of electricity, storage and dispatchable power are key to a stable electricity supply.
- In 2050, fossil fuels account for 73% of primary supply in Reference scenario and 53% in Advanced Technologies scenario. The effort for a stable supply of fossil fuels must be continued.

Part 2 (Topic)
ASEAN's Pathways towards Energy Transition

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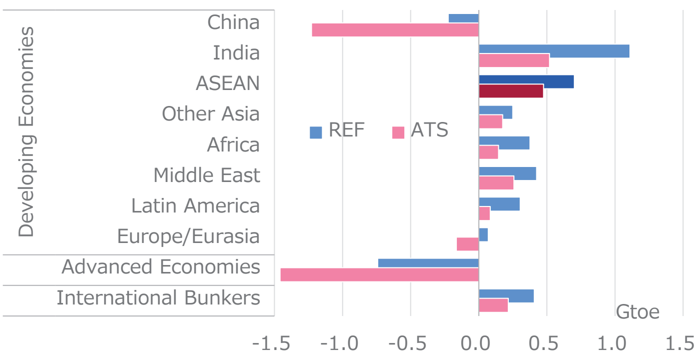
Part 2: ASEAN's Pathways towards Energy Transition
Demand growth in ASEAN is significant; net zero is a significant challenge.

Change in Primary Energy (2021-2050)

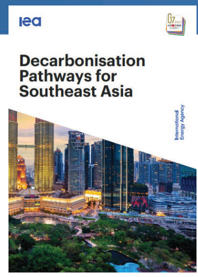


Pledges of ASEAN Countries

	Most recent developments
Brunei	N.A.
Cambodia	CN by 2050 (L/T Strategy, Dec. 2021)
Indonesia	NZ by 2060 or sooner (L/T Strategy, July 2021)
Lao PDR	NZ by 2050 (Climate Ambition Alliance)
Malaysia	CN by 2050 (PM expressed in Sept. 2021)
Myanmar	NZ by 2050 (Climate Ambition Alliance,)
Philippines	N.A.
Singapore	NZ by 2050 (updated L/T Strategy, Nov. 2022)
Thailand	CN by 2050 & NZ by 2065 (PM expressed at COP26)
Vietnam	CN by 2050 (PM expressed at COP26)

- As ASEAN continues to achieve significant economic growth, the region will be the center of energy demand growth in the world.
- Since COP26, eight countries have announced carbon-neutral targets by 2050 or 2060.
- Reducing CO2 emissions while expanding energy supply is a significant challenge.

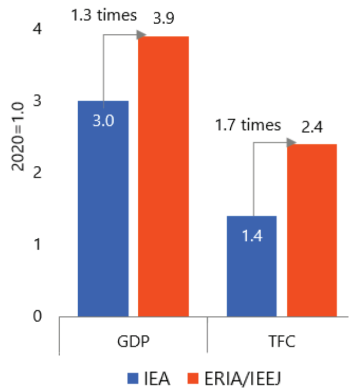
Part 2: ASEAN
IEA G7 Report: comparison of IEA and ERIA/IEEJ pathways



Source) IEA

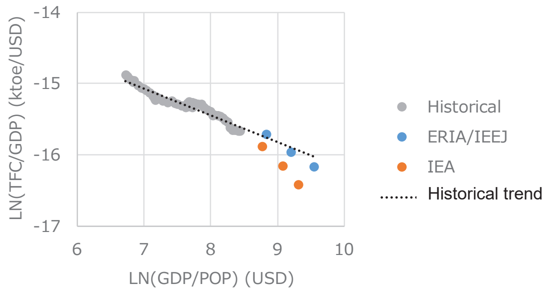
- Future energy demand significantly differs, depending on assumptions of economic growth and energy efficiency improvement.

Growth of ASEAN's GDP and TFC toward 2050



Source: produced from IEA, Decarbonization Pathways for Southeast Asia(2023)

ASEAN's Energy Efficiency Improvement (past five decades and future)



Source: produced from IEA, Decarbonization Pathways for Southeast Asia(2023) and IEA, World Energy Balances

Part 2: ASEAN
IEA G7 Report: comparison of IEA and ERIA/IEEJ pathways

- <u>The optimal energy mix in the future will change depending on the scale of demand.</u>

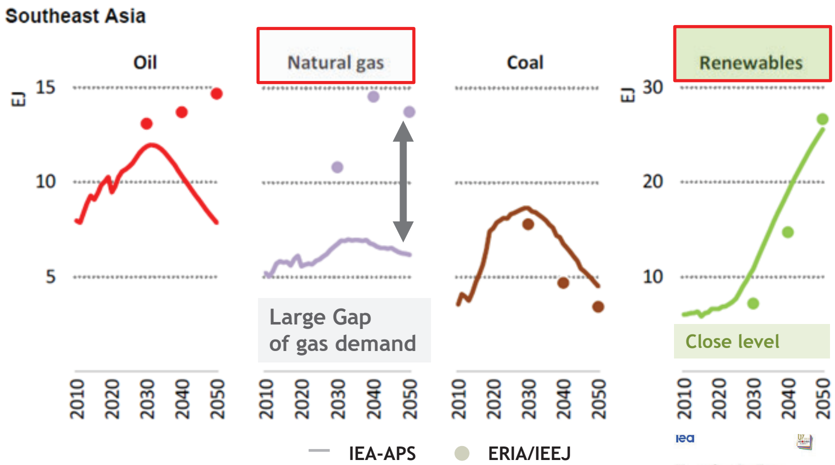
<u>IEA</u>

- The <u>low demand level</u> enables <u>renewable energy and electrification</u> while reducing the supply of natural gas.
- Renewable energy accounts for about <u>80%</u> of the total power generation in 2050.

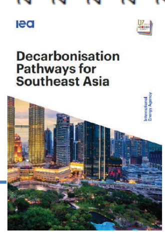
<u>ERIA/IEEJ</u>

- To meet the <u>high demand level</u>, <u>not only renewable</u> energy in the same amount as the IEA; (1) fossil fuels expansion (especially <u>natural gas</u>) (2) decarbonization by <u>hydrogen</u> and <u>CCS, CO2 removal by DACCS and BECCS</u> are required.
- The renewable energy share is about <u>60%</u>.

ASEAN Primary Energy Demand (IEA, ERIA/IEEJ comparison)



source: IEA, Decarbonization Pathways for Southeast Asia,(2023)



Source) IEA

Part 2: ASEAN
Analysis Framework：Cost-optimal energy mix

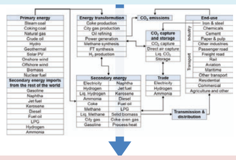
- **Optimal Case** is the energy mix that can meet the net-zero target of each ASEAN country at the lowest cost while meeting the demand of ERIA/IEEJ.
- Under the same demand growth, three cases are simulated; **RE40**: lower penetration of renewable energy, **RE80**: higher penetration of renewable energy, and **gas-cap**: gas supply constraint.

Case Assumptions

Cases	Renewable share in power	Primary supply of gas	CN Year
Optimal	**No limitation** (60% as a result)	No limitation	2050/2060
Gas-Cap	No limitation	Same as 2019	
RE40	40%	No limitation	
RE80	80%	No limitation	

IEEJ-NE　Model
(Bottom-up Optimization model)

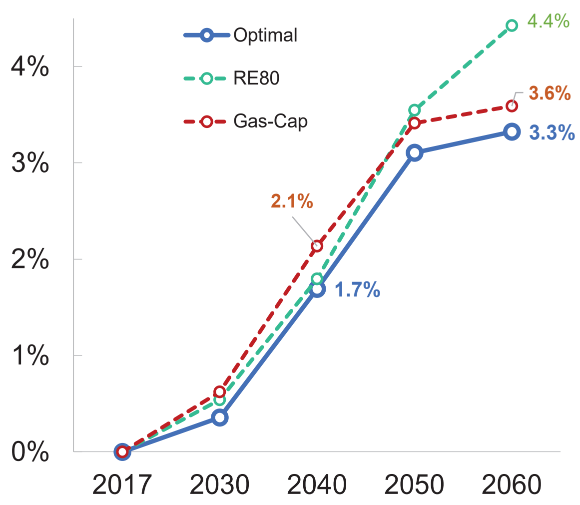
Input:
- CO_2 Reduction Target　- Energy Demands
- Tech. Information (Cost, Efficiency, etc.)



Output :
Cost-minimum energy mix which achieve the CO2 reduction target

Part 2: ASEAN　RE80 increases costs in the long term, while Gas-Cap increases costs in the mid-term.

Total CO_2 reduction cost* (ASEAN, per GDP)

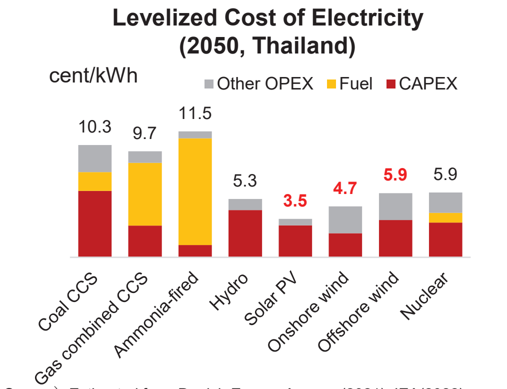


- The total CO2 reduction (abatement) cost to achieve 2060 net zero is US$570 billion/year, equivalent to 3.3% of GDP, in the **optimal case**.
- If the optimal energy mix is not realized, the abatement cost rises further;
  - **RE80** : Cost in 2060 rises to 4.4% of the GDP. The increase in 2050-2060 is especially significant.
  - **Gas-Cap** : The costs during the 2030-2040 are particularly large.

  In other words, the expansion of natural gas supply during the transition period will contribute significantly to cost reductions.

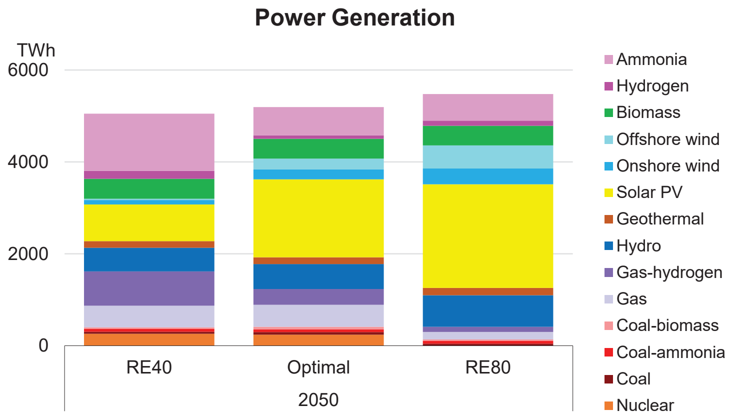
＊ The cost difference between the total cost of energy supply (capital, fuel, O&M, etc.) , compared to the baseline case without emission reductions. The future GDP is estimated from “Energy Outlook and Energy Saving Potential in East Asia 2020”(ERIA, 2021). 2017 Constant USD.

Part 2: ASEAN　Although LCOE of renewable will decrease over time, massive penetration requires additional cost



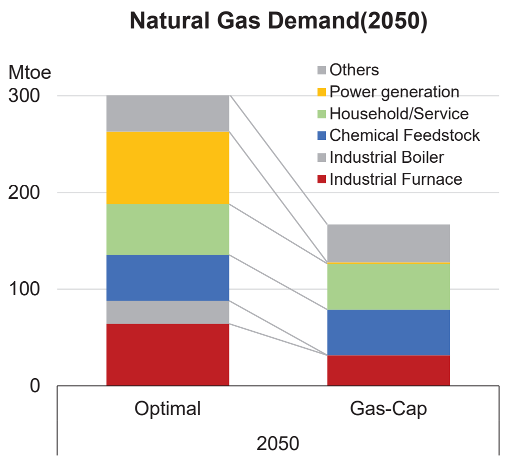
Source）Estimated from Danish Energy Agency (2021), IEA(2022)

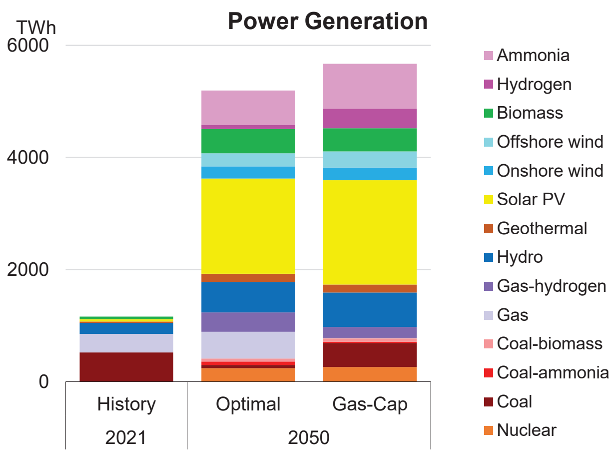
*Costs inside power generation facilities alone; which does not include integration costs.



- The generation cost of renewable energy itself (LCOE) is expected to be relatively low among zero-emission power in 2050. Therefore, if the installation is low, the average power generation cost would increase.[RE40]
- On the other hand, if variable renewable energy (solar and wind) is increased to the level of [RE80], it will be necessary to introduce them to areas with worse weather conditions, and integration costs for dealing with output fluctuations (batteries, etc.) will increase, leading to higher overall system costs.

Part 2: ASEAN　Gas plays an important role in heat demand and power generation, during the transition period

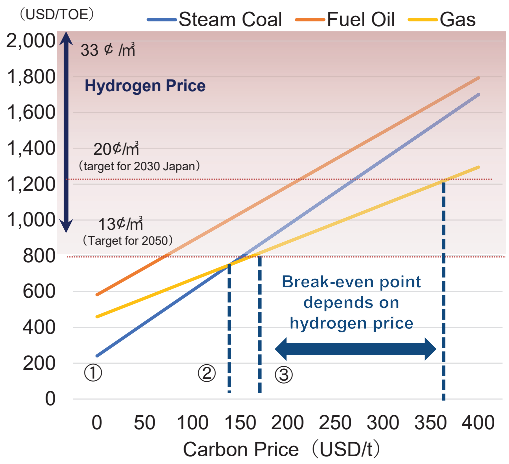




- In the **optimal case**, natural gas is primarily a fuel for industrial furnaces, which are difficult to electrify. In the **gas-cap** case, the shortage must be offset by oil and coal, which have higher emission factors.
- In the optimal case, gas-fired power generation is introduced to balance supply and demand.

Part 2: ASEAN
On the way to net-zero, gas is competitive among fossil fuels

Fuel Price
(Includes Carbon Price)



Source) Advanced Technologies Scenario, 2050

- In demand sectors where electrification is difficult, fossil fuel use is expected to continue until a low-cost hydrogen supply is realized.
- The cost advantages among fuels will change as follows.

(1) **<u>Coal has the smallest price</u>** per calorific value of fuel alone.

(2) As ASEAN moves toward net zero, some external cost is expected to be attached to CO_2 emissions.

If the carbon price increases to around $100/t, **<u>gas would be affordable</u>**.

(3) If the carbon price increases significantly and the hydrogen price is reduced to about 13 cents/m3, the **<u>H_2 price may fall below the gas price</u>**.

<u>Gas could become competitive where the carbon price falls between (2) and (3).</u>

* The MAC (marginal abatement cost*) calculated from this analysis is around 200$/t-$CO_2$ in 2040 and 370$/t in 2050, a level at which gas use has some advantage.

Part 2: ASEAN's Pathways towards Energy Transition
Conclusion

- For ASEAN, with its remarkable economic development, **<u>cost efficiency of energy transition is essential</u>** to achieve both economic growth and CN.
- Depending on future assumptions for growth and energy efficiency improvements, there will be significant differences in the outlook of future energy demand. It is not sufficient to simply focus on the share of renewable energy, as the **<u>optimal energy mix will vary depending on the total amount of demand</u>**.
- **<u>The cost of renewable energy is expected to be low</u>** among zero-emission power sources, making it a promising power source. However, it should be noted that suitable sites are limited, and the **<u>integration cost may increase when variable renewable covers a large part</u>** of the electricity supply.
- **<u>Gas will mainly play a role in reducing industrial emissions</u>** (especially hard-to-abate sectors) and **<u>in dispatchable power generation</u>**. It can be an important energy source for emission reductions, especially during the transition toward zero emissions.

An IEEJ Outlook 2024 Discussion Topic
To Achieve the Important Role of LNG and Natural Gas

November 2023
The Institute of Energy Economics, Japan - IEEJ

Hiroshi Hashimoto
Senior Fellow, Energy Security Unit

Abstract

- ✓ **Additional investment is required to ensure stable supply of LNG and natural gas**
  - Amount of required investment in natural gas production (from 2022 to 2050)
    Reference Scenario (REF): USD 9.8 trillion; Advanced Technology Scenario: USD 7.0 trillion
  - Significant addition of LNG production is required
  - Uncertainty remains over realization of LNG production projects with potential suspensions and delays
- ✓ **Trend of LNG production project costs and issues of LNG procurement**
  - Upward trends due to supply-chain disruptions, the Russian war, and inflation
  - On the other hand, innovations are underway to contain cost increases, including small and mid-scale liquefaction trains, modularization
  - To meet Japan's LNG requirement after 2030, joint procurement and partnerships between national and international companies, portfolio strategies for Japanese larger LNG buyers and trading houses, and optimisation of mixtures of LNG procurement (long-term and short-term contracts and spot purchases) should be further considered
- ✓ **Longer LNG transportation distances and needs of transportation optimisation**
  - While the expansion of the Panama Canal has provided significant merits with some bottlenecks and the market has seen longer shipping distances, streamlining LNG transportation is important
- ✓ **G7 and LNG Producer Consumer Conference emphasize the role of LNG and supply security**
  - Importance to define "abated" LNG compatible to energy transition
  - Enhancing gas security through dialogues involving IEA as well as its non-member countries
- ✓ **Toward LNG market stabilisation - long-term challenges**
  - Securing appropriate LNG supply through long-term commitment
  - Variety of financial measures should be developed to meet diversified needs of LNG production projects
  - As the market expands including emerging buyers, collaboration between buyers of different markets is also effective

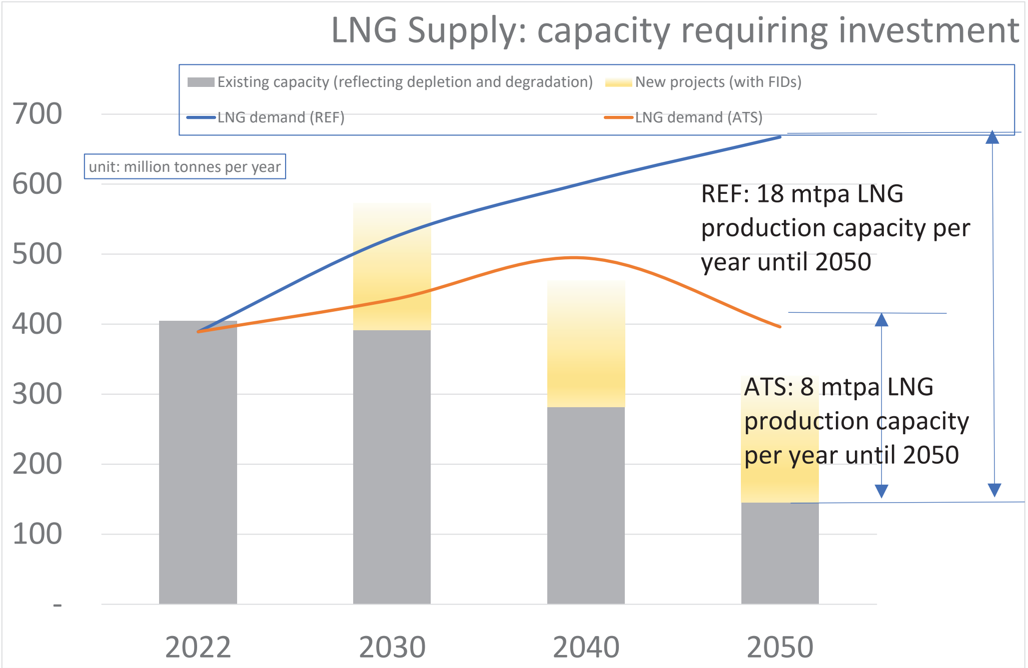
Investment is needed to meet incremental LNG demand, as well as replace depleting existing LNG production capacity

Investment is needed in 8 - 18 mtpa LNG production capacity per year until 2050

Required additional capacity investment means the gap between projected LNG demand and decreasing existing production capacity, to be filled by the followings:

1. Greenfield project investment
2. Alternative new field development (backfill) investment (the yellow stack indicates already sanctioned projects)
3. Investment in existing fields to offset production decline
4. Rejuvenation of existing liquefaction facilities

✓ *Those projects already greenlighted (included in the yellow stacks) may entails uncertainty with possible delays and failures to materialise

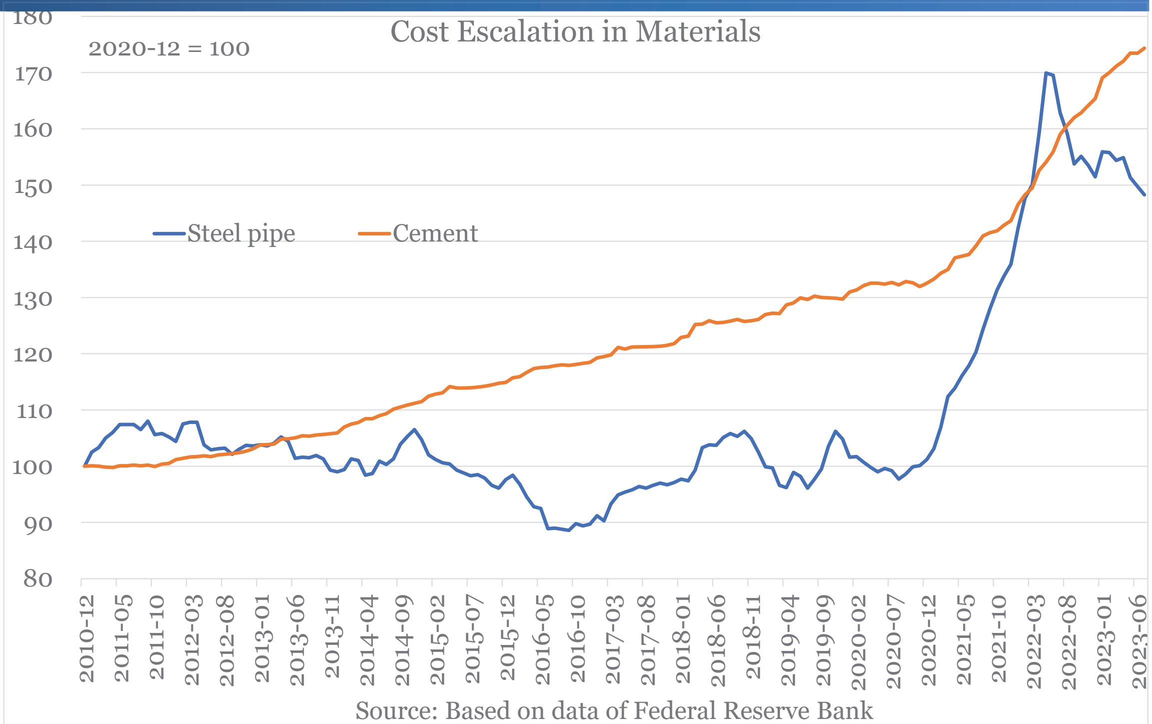


Trends of LNG production projects - development and costs

	Major trends	Factors to promote projects and cost reductions
2010-2014	• Responding to Northeast Asian LNG demand surge, Australian LNG production projects proliferated, leading to concentration of construction activities and cost escalarions	• Cost escalations in Australia stimulated LNG production development activities in other regions
2015-2020	• LNG production project development activities shifted to the United States with moderated cost escalations in both upstream and liquefaction sectors • As feedgas supply for the U.S. LNG shares the same network as the U.S. gas consuming market, the gas is not necessarily cheap but is expected to be stable on the long-term basis	• Conversion of underutilised LNG receiving infrastructure into LNG export facilities is a factor leading to overall cost reductions in the United States • Separated gas production and transportation sectors in the United States have led to lower risks and costs for individual players • Floating liquefaction (FLNG) has become a competitive options to develop remote gas sources
2021-2023	• Logistical constraints caused by the pandemic delayed construction acrtiviities, leading to cost overruns • The Russia-Ukraine war has led to general cost escalations • Instability in those countries where LNG production projects have been sanctioned has caused delays	• Innovative small and mid-scale liquefaction applications bring cost reductions • Modular and design-one-and-build-many strategies lead to cost reductions • The phasing out from Russian gas has stimulated LNG production development activities in other regions
	• Prices of steel, concrete, and other materials are on the rise (as well as an end of zero-interest) • CCS and electrification (renewables) add costs	• LNG production developers competing for market windows in the late 2020s pursue cost reductions

Higher material costs likely result in increases in LNG production project construction costs

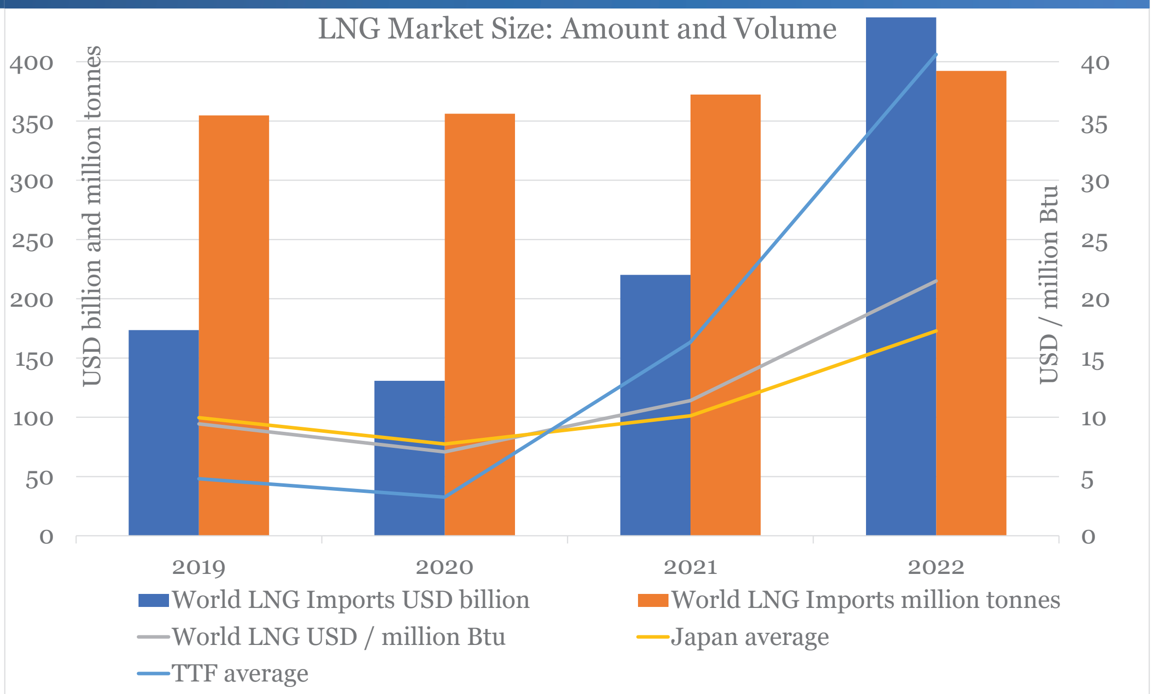
- ✓ Cost escalations have accelerated since late 2021 in steel, cement and other construction materials
- ✓ The higher material costs likely result in increase in LNG production project construction costs



Source: Based on data of Federal Reserve Bank

The rapid rise in prices resulted in a more significant expansion of the LNG market in terms of the total amount than the volume

- ✓ The LNG market experienced a steady growth in the volume wise in 2022
- ✓ The paid amount doubled in 2022, in a stark contrast against 2020 when the amount decreased significantly
- ✓ The economic value of the market is expected to shrink in 2023 due to lower LNG prices



Source: based on data of GIIGNL, Global Trade Atlas, Trade Statistics, and ICE

Selected Cases of Risks Facing LNG Production Projects After FIDs

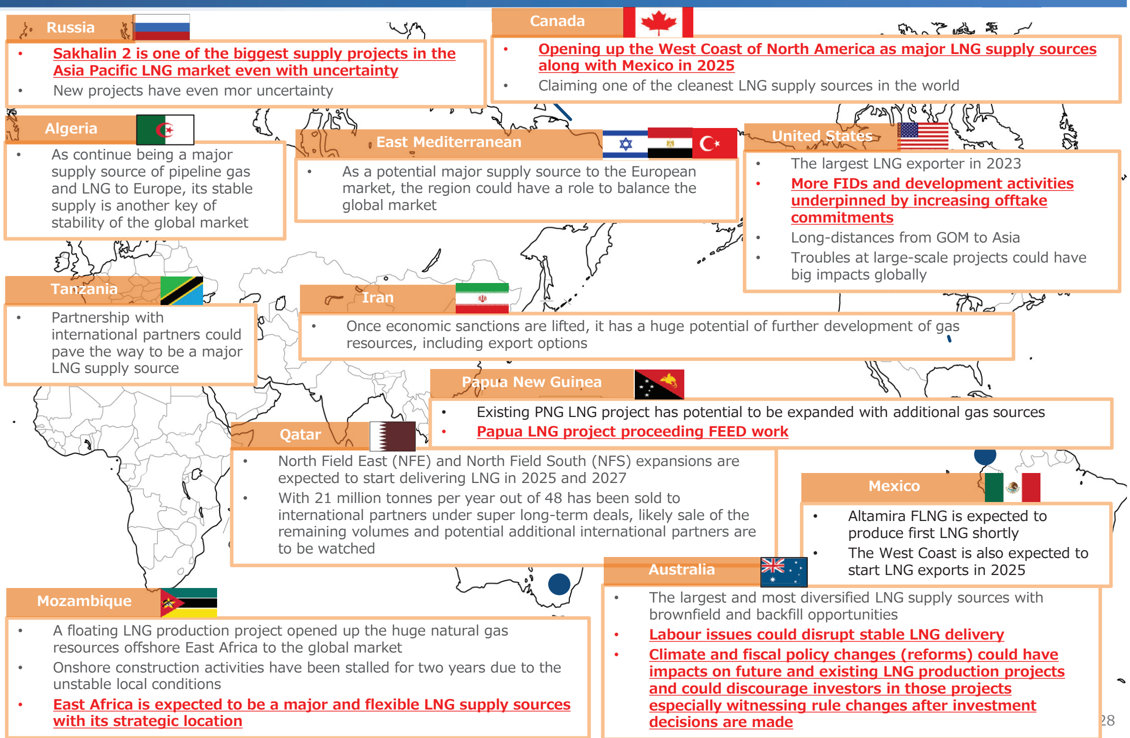
	Current status	What to watch
Mozambique	• FLNG started exports in 2022 • The first onshore project suspended construction due to instability, facing a delay of more than 2 years	• The first onshore project needs security in the area and faces potential additional costs - negotiation continues with contractors
Russia's Arctic LNG 2	• After the first module completion, uncertainty persists on the second and third modules	• Economic sanctions impose difficulties in technological and logistical aspects
Mauritania's and Senegal's offshore Greater Tortue Ahmeyim FLNG	• The delayed delivery of FLNG unit pushes back commercial operation to 1Q 2024	• Cost pressures due to the delay
Australia's Barossa development	• Resumption of drilling activities in 2023 should enable 2025 start of gas supply • The operator maintains cost estimates	• A delay in the resumption of activities could prolong suspension of Darwin LNG • Costs may be higher even if the schedule is maintained
Australia's Scarborough development	• The operator maintains cost estimates and production target of 2026 • Environmentalists challenge procedures	• Pipeline laying may be delayed due to procedural issues of environmental permit
Australia's other LNG projects	• Uncertainty over the implementation of the safeguard mechanism • Labour relation issues at the operating projects	• The day-one GHG net-zero requirement may pose difficulties on greenfield projects • LNG production projects may need to measures to avoid labour disputes

Securing greener LNG production projects

	Electrification and greener power sources	CCS
General Trends	• Electrification of liquefaction processes • Higher reliability and lower maintenance costs • More efficient liquefaction, better GHG management, and less gas consumption	• Capturing CO2 native to feedgas and generated from compression and liquefaction processes • Integrating CO2 captured in neighbouring industrial facilities could enhance economics
Challenges	• Securing greener power sources • Securing baseload and backup power supply • Installing renewable power sources within vicinity of the LNG production site • Securing flexibility in load and supply management of renewable power, with neighbouring industrial facilities, if there are any • Likely larger initial investment amount	• Securing suitable carbon storage sites in the neighbourhood • Creating sizable CO2 demand sources • Likely larger initial investment amount • Required time for integrating existing LNG facilities • Ensuring stable operation of the CCS • Greater technical challenges to capture CO2 from the process than from feedgas
U.S. Gulf Region	• Gradual progress has been observed in electrification with greener power sources partly as measures to reduce air pollutions	• CCS projects are developed by LNG production project developers partly helped by preferential tax treatment
Canada's West Coast	• Utilization of hydro-power from the grid	
Qatar	• In parallel with the NFE and NFS expansion projects solar power sources are developed	• CCS plans are combined with the NFE and NFS • A jetty boil-off gas recovery facility recovers BOG and reliquefy BOG

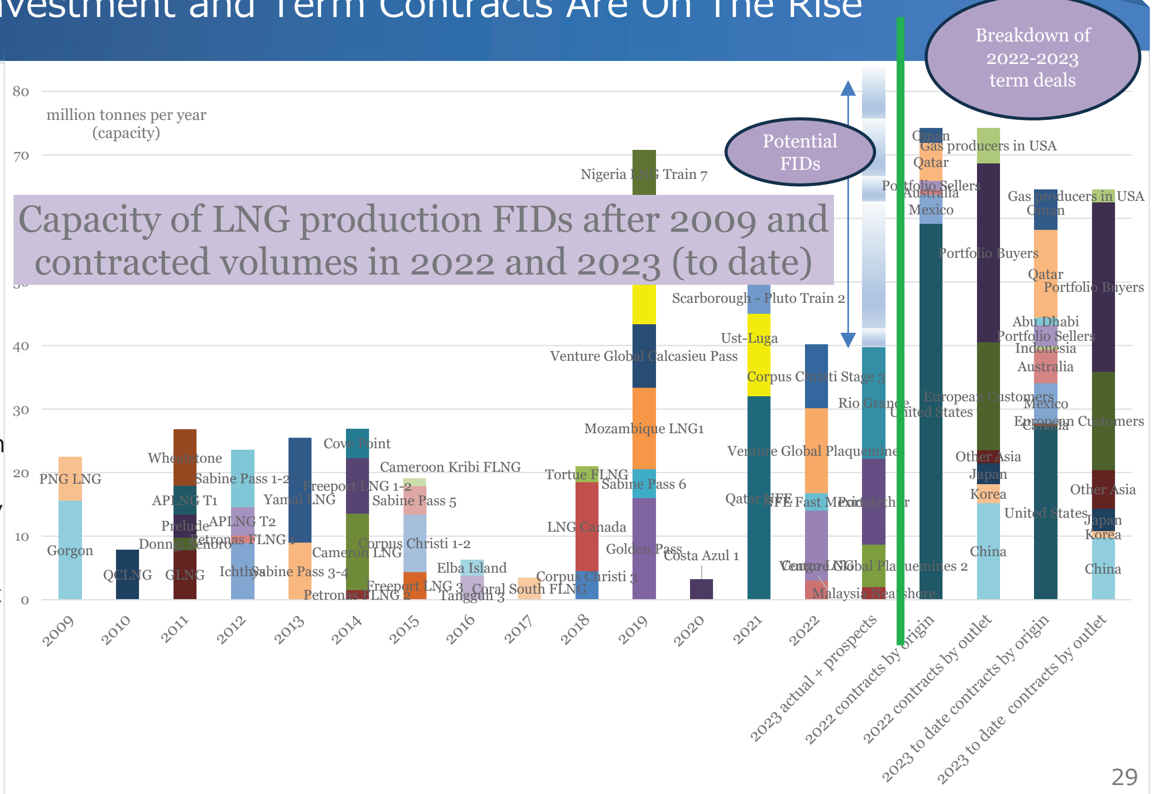
Major Current and Future LNG Supply Sources

- ✓Projects advance around the world to increase LNG supply
- ✓Risks are here and there with development
- ✓Projects become more difficult in frontier areas as relatively accessible ones have been already developed
- ✓Expansion at existing sites (brownfield) and feedgas supply replacement projects (backfill) are considered economically advantageous



LNG Production Investment and Term Contracts Are On The Rise

- ✓ LNG FIDs and construction activities are on the rise after the Ukraine war
- ✓ The project boom leads to construction cost escalation
- ✓ A clear definition of "abated LNG" is required to encourage investment under the long-term perspective of energy transition
- ✓ Russian projects, even though they have been with FIDs, are uncertain
- ✓ The United States as supply sources, China, other Asia, Europe, and portfolio players as buyers represent majority of term-contract parties in 2022 and 2023

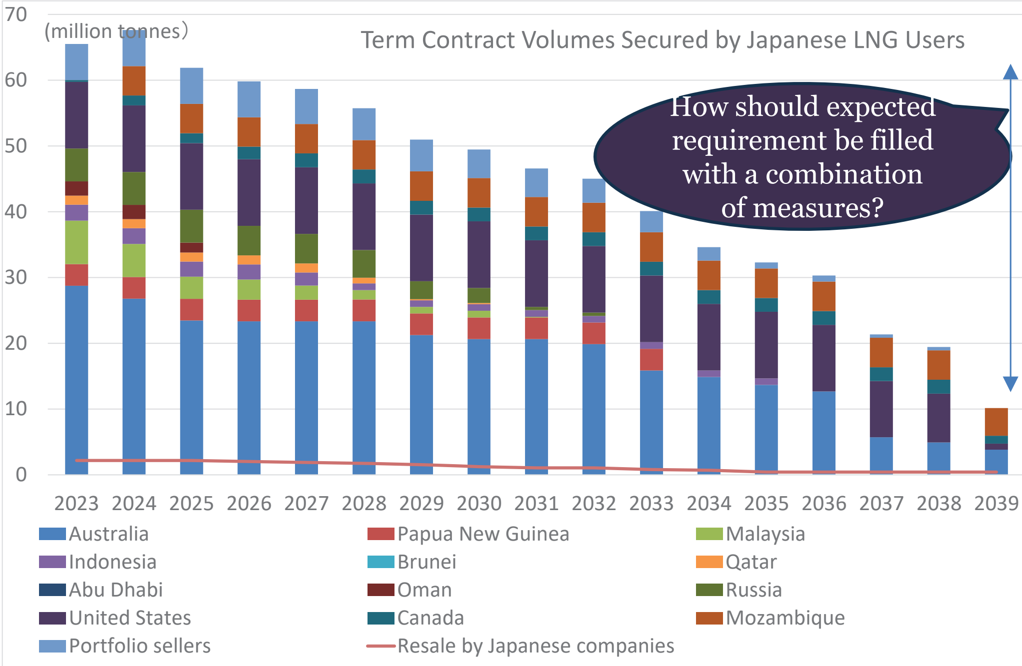


Japanese LNG Procurement Tends to Rely on Partnerships and Portfolio Players

- ✓ Volumes procured so far go down from 60 million tonnes of 2025 to 50 million tonnes by 2030
- ✓ Requirement is expected to maintain the 60 million tonnes per year level until 2050 according to the IEEJ's Reference Scenario
- ✓ For future procurement:
  - ➢ Large volumes under long-term contracts are difficult for individual buyers
  - ➢ Share of short-term and spot procurement grows

↓

- ✓ Cooperation between companies and the government and policy supports are essential
  - ➢ Procurement from portfolio players of Japan and other international portfolio players
  - ➢ Encouragement for Japanese larger buyers and trading houses to undertake portfolio activities
  - ➢ Partnerships with international companies, including joint procurement and optimization
  - ➢ Partnerships between fellow companies – including joint purchase



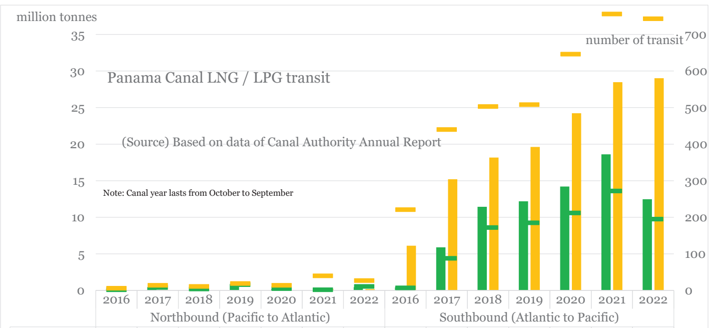
Huge Benefit of the Panama Canal - As Well As Bottlenecks

<Benefit of the expanded canal>

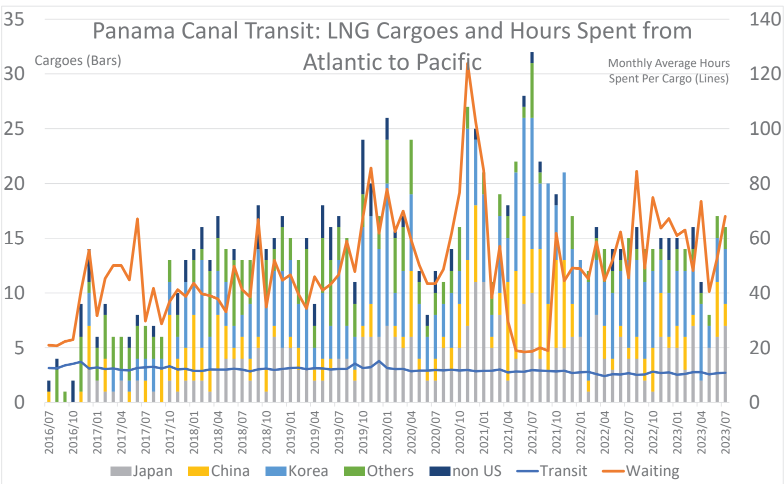
- ✓ As 2016 expansion of the Panama Canal enabled transit of LNG carriers, more LNG can be transported from the United States mostly the Gulf of Mexico to Northeast Asia
- ✓ Thanks to the shale revolution, more LLPG is also transported through the canal

<challenges>

- ✓ Due to larger volumes transported, waiting times are longer to transit
- ✓ Drought lowers water levels leading to restrictions of number of large vessels to transit



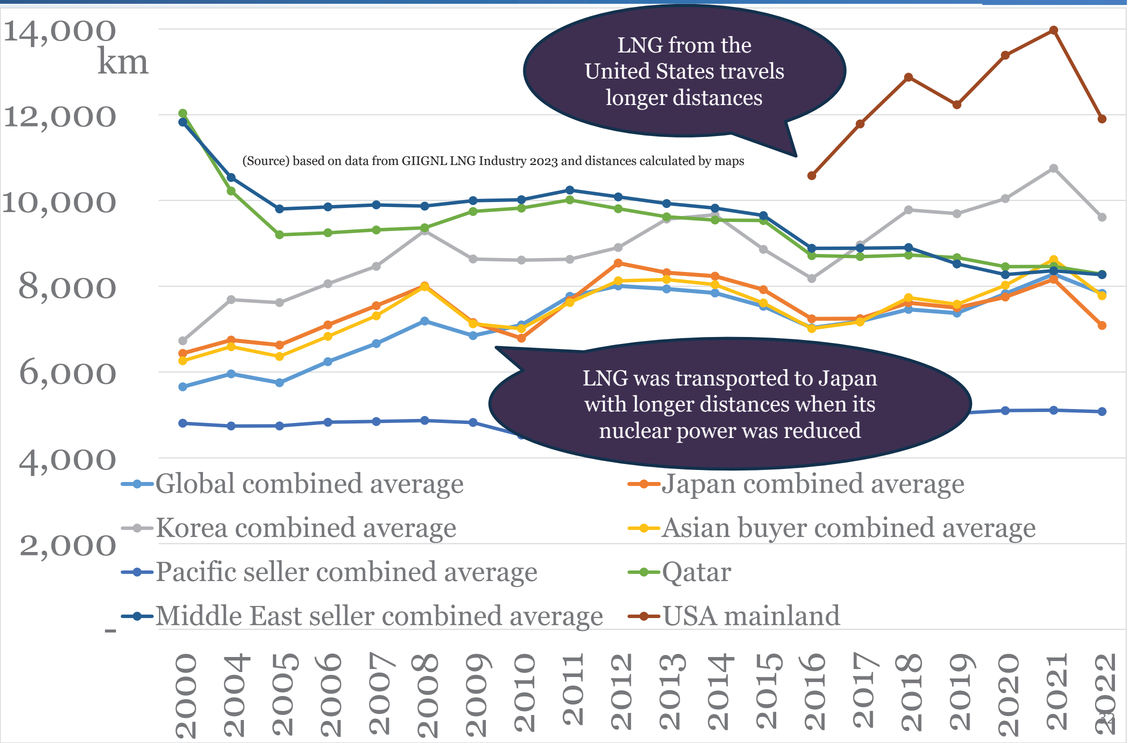
	Northbound 2016	2017	2018	2019	2020	2021	2022	Southbound 2016	2017	2018	2019	2020	2021	2022
LNG Tonnes	0.12	0.46	0.06	0.87	0.15	0.02	0.45	0.43	6	11	12	14	19	12
LPG Tonnes	0.05	0.08	0.06	0.05	0.06	0.20	0.17	6	15	18	20	24	28	29
LNG Transit	2	8	4	16	5	2	11	7	88	172	185	212	272	195
LPG Transit	6	14	11	19	14	40	27	221	440	503	508	646	756	743



(Source) based on data from ICIS LNG Edge

Longer Transportation Distances and Bottlenecks Make Optimization Essential

- ✓ Along with supply sources, transportation routes and distances are diversified
- ✓ Distances have been longer when LNG demand surged in Japan and Asia unexpectedly
- ✓ Long-distance transportation has increased notably from the U.S. Gulf Coast to Northeast Asia
- ✓ In 2022, the shift of U.S. LNG to Europe lowered the overall average transportation distance
- ✓ The West Coast of North America and East Africa are expected to contribute to optimization of LNG transportation



G7 Ministerial Communique Underwrites Importance of Natural Gas

Relevant articles related to LNG and natural gas	Note
49. Energy security and clean energy transitions: . . . commitment. . . to accelerate the **phase-out of unabated fossil fuels**	Definition of "abated" will be the key
61. Methane: . . . **an internationally aligned approach for measurement, monitoring, reporting, and verification of methane and other GHG** emissions to create an international market that minimizes GHG emissions across oil, gas, and coal value chains, including by minimizing flaring and venting, and adopting best available leak detection and repair solutions and standards.	International standards of emission measurement and international cooperation are important
69. Natural gas and LNG . . . **investment in the gas sector can be appropriate** to help address potential market shortfalls provoked by the crisis, subject to clearly defined national circumstances, and **if implemented in a manner consistent with our climate objectives** and without creating lock-in effects, for example by ensuring that projects are integrated into national strategies for the development of low-carbon and renewable hydrogen.	Great recognition of the importance of natural gas and LNG Also important is to establish the standard of transition compatible LNG

Outcomes of the LNG Producer Consumer Conference 2023

- ✓IEA member, LNG-producing and -consuming countries expressed respective approaches of LNG utilization toward net-zero goals and expectations on LNG and natural gas in their energy security
- ✓Japan emphasized the importance of green transition. It also pointed the necessity of securing emergency reserves and mutual cooperation. Japan also presented its plans of SBL (Strategic Buffer LNG) and support of LNG trading. Japan also expressed its support for abolishing destination restrictions.
- ✓Japan and EU announced cooperation in the LNG area, including enhancement of LNG supply security, cooperation with international organisations (specifically IEA), transparency of the LNG market information, and cooperation in methane emission mitigation measures

LNG Supply Security To Be Enhanced Through International Cooperation

- ✓Provisions and transparency of gas market information by IEA, covering member and non-member countries, and its advisory functions should be enhanced as indicated in the Chair's summary of the LNG Producer Consumer Conference 2023
- ✓To ensure sufficient supply, stable procurement and deliveries of LNG and natural gas, enhanced mutual dialogues and cooperations between producing and consuming countries, as well as among consuming countries are necessary, paving the way toward smooth energy transition and energy security.

Toward Long-Term Stability and Further Growth of the LNG Markets

	Notable issues to be considered from the perspective of LNG consumers
Supply issues	Steady realisation of LNG projects in the United States as the mainstay supply sources Maintain stability and enable expansion of LNG production in Australia, Canada and Mexico Realization of LNG production projects in Africa's frontier regions Effective utilisation of existing - amortised - LNG production projects in enhancing flexibility of the global LNG market
Demand issues	As LNG demand centers shift to developing economies, support from traditional LNG consuming countries may be effective As flexibility in the LNG market is valued, efforts are needed between the public and private sectors to secure stable demand and enable some forms of long-term commitments. Demand aggregation, utilization of portfolio players and joint procurement are necessary
Pricing issues	Increasingly greater fluctuation of prices due to increasing volatility and increasing gas-on-gas pricing make it important to consider appropriate balances between different pricing arrangements
Climate change challenges	Clarification of LNG project standards that are compatible with decarbonized energy transition (methane and GHG emission mitigation measures) is necessary Promoting CC(U)S and green electricity in LNG liquefaction contributes to greening LNG
Financial challenges	Financing arrangements that can accommodate shorter LNG sale contracts are needed As the market expands, it is also important to ensure the creditworthiness of new buyers entering the market

Significance and the roles of Negative Emissions Technologies (NETs)

The Institute of Energy Economics, Japan

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Executive Analyst, Clean Energy Unit

Summary

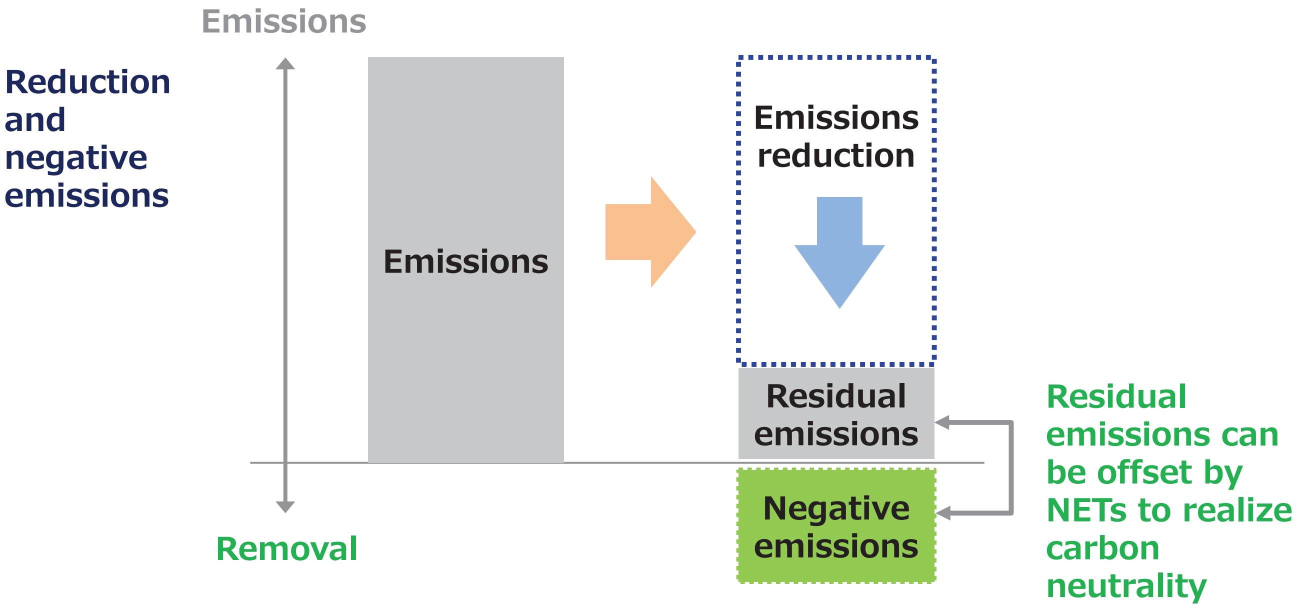
- It is very difficult to realize carbon neutrality without negative emissions technologies (NETs). The Roles and contributions of NETs should be more clearly specified in the long-term emissions reduction plan.

- Various types of NETs exist with different degrees of technological maturity. Understanding the potential of carbon removal volume each NETs, establishment of the methods to accurately measure the removal volume, cost reduction, and assessment to potential impacts to ecosystem by NETs need to be pursued as immediate actions.

- International cooperation is also important. Based on the shared understanding about the values and the roles of NETs in various pathways toward carbon neutrality, countries need to cooperate to establish internationally acceptable MRVs system, certification system, and removal credit system.

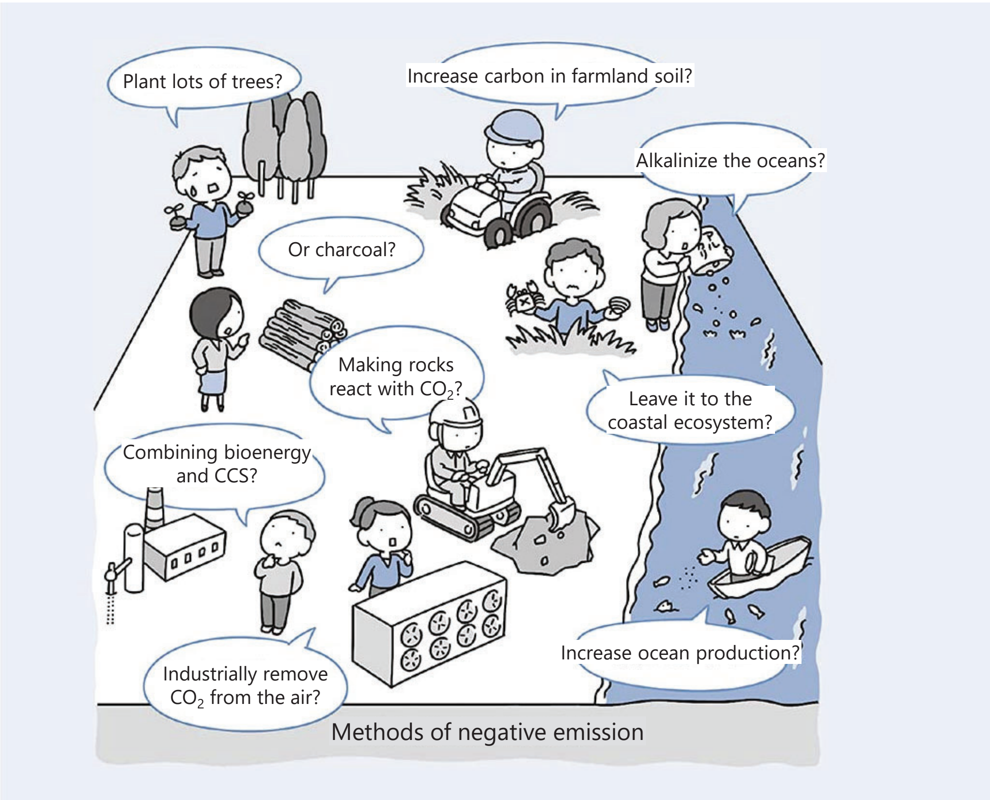
What is negative emissions technologies?

- Negative emissions technologies (NETs) : technologies that capture greenhouse gas from the atmosphere and store it for a long term.
  - NETs is a means of carbon dioxide removal (CDR).
- NETs can offset the residual emissions that cannot be eliminated to realize carbon neutrality.



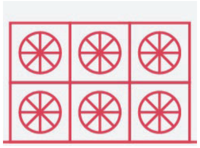
Various types of NETs

- Various NETs can be deployed to capture CO2 and store it.



Source: Institute of Applied Energy (2021)

Various types of NETs (cont.)

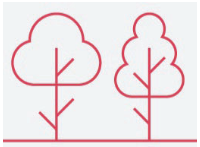


Direct Air Carbon Dioxide Capture and Storage(DACCS)

Capture CO2 directly from the atmosphere and store it underground

Bioenergy with carbon dioxide capture and storage (BECCS)

Capture CO2 emitted from bio-energy and store it underground



Afforestation and forest management

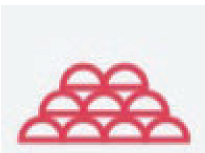
CO2 absorption by forests through large-scale afforestation, reforestation, adoption of agroforestry methods, and active prevention of deforestation.

Soil carbon sequestration

Promote carbon storage in the soil through no-till cultivation, growing crops that cover the soil surface, and using compos。

Sources: Institute of Applied Energy (2021); J Wilcox, B Kolosz, & J Freeman (2021) CDR Primer

Various types of NETs (cont.)



Bio char

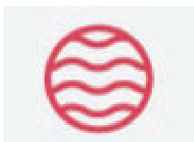
Carbon contained in biomass is fixed for a long period of time by carbonizing biomass through pyrolysis or other means.

Enhanced weathering

CO2 from the atmosphere is absorbed and fixed (mineralized) by reacting with materials such as basalt, peridotite, and serpentinite.

Blue carbon

Promote carbon storage by improving vegetation and soil in coastal areas, and CO2 absorption by large-scale seaweed cultivation



Ocean alkalization

The amount of CO2 absorbed at the sea surface is increased by increasing the alkalinity of seawater by adding calcium carbonate and other substances.

Sources: Institute of Applied Energy (2021); J Wilcox, B Kolosz, & J Freeman (2021) CDR Primer

Various negative emissions technologies (NETs)

- NETs can be broadly divided into two categories: technology-based and nature-based ones.
- While each NET has its own advantages and disadvantages, DACCS and BECCS (both of which utilize CCS) have relatively high technological maturity, large removal potential, easy measurement of removal volume, and long CO2 fixation periods.

Overview of major NETs

NETs	Type	TRL*	Removal cost (US$/tCO2)	Removal potential (GtCO2/yr)
DACCS	Technology	6	100-300	5-40
BECCS	Technology	5-6	15-400	0.5-11
Afforestation/Forest managemnet	Nature	8-9	0-240	0.5-10
Soil carbon sequestration	Nature	8-9	-45-100**	0.6-9.3
Bio char	Nature	6-7	10-345	0.3-6.6
Weathering enhancement	Nature	3-4	50-200	2-4
Blue carbon	Nature	2-3	N/A	<1
Ocean alkalization	Nature	1-2	40-260	1-100

＊TRL (Technology Readiness Level) is a measure to type of measurement system used to assess the maturity level of a particular technology. TRL9 is closest to commercialization.
** Soil carbon sequestration can generate profits (negative cost) by improving the soil productivity.
Source：Babiker *et al.* (2022) Cross-sectoral Perspectives.

Policy actions for NETs introduction

- Incentives such as tax credits, setting introduction targets for individual NETs, and integrating removal credits into existing emissions trading systems are being considered for NETs introduction by major countries.
- In Japan, R&D for DAC technologies are provided by the government, and policy options to create the market for NETs are being discussed.

Country	Incentives	Numerical target	Credit
US	• Tax benefit (130-180$/t-$CO_2$) for DAC project • 3.5$ billion is provided for 4 DAC hub developments	• Carbon dioxide removal by giga-ton scale • Cost reduction to below 100$/t-$CO_2$	-
UK	• 100 million GBP provided for R&D of NETs incl. DACCS	• 5 million t-CO_2 removal by 2030 and 75 to 80 million t-CO_2 removal by 2050 through technology-based NETs	• Integration of removal credit to the UK-ETS
EU	• Plan to expand incentive for NETs (details are under discussion)	• 310 million t-CO_2 removal by LULUCF and 5 million t-CO_2 removal by tech-based NETs by 2030.	• Integration of removal credit to the EU-ETS

Japan's policy actions

- In May 2023, the Study Group on Market Creation for Negative Emissions Technologies released a summary framework, which provides the following seven options for market creation of NETs.
  - Which options will be adopted will be discussed at the Study Group.

Option	Outline
Compensation	The government compensate if a reference price linked to market will be below a strike price based on cost plus margin.
Public procurement	The government procure negative emission arrangement made by business actors at a specific price.
Purchase of excess credit	The government purchase surplus removal credit which a business actor could not sell at market.
Tax benefit	The government provides tax benefits for adoption of NETs
Support for CAPEX and Pilot Tests	The government supports pilot testing, FS, FEED, project development, and EPC
R&D support	The government supports R&D of NETs to reduce costs.
Allocation of obligatory purchase	The government obliges high-emission sectors to purchase removal credit for a certain volume.

Source : METI (2023) "Summary framework for market creation of negative emissions technologies"

Expected carbon removal by NETs in major countries

- Carbon neutrality scenarios made by government / research institute in major countries assume that 10% to 20% of the existing emissions will be offset by carbon removal, necessitating NETs as a means to achieve carbon neutrality.

	Reference year	LULUCF	Other NETs	Total	Removal volume (mil t-CO_2e)
Japan	2015	No assumption	14%	—	185
China	2020	6%	6%	12%	1,553
EU	2020	13%	6%	19%	593
Germany	2018	No assumption	9%	9%	72
France	2015	14%	3%	18%	78
UK	2020	4%	12%	16%	64

Scenarios colored by yellow are those made by the government.
LULUCF: Land Use, Land Use Change, and Forestry

Carbon neutral scenarios by governments and research institutes

■ References of each country's scenario in the previous slide

Country	Source	Remarks	Base year
Japan	Research Institute of Innovative Technology for the Earth (RITE) (2021), "Scenario Analysis of Carbon Neutrality in 2050 (Interim report)," Advisory Committee on Energy Resources, Sub-Committee on Basic Energy Policy	Reference case	2015
China	Project Report Editorial Team (2020) "China's Long-Term Low Carbon Development Strategy and Transformation Pathway Research Report", *China Population, Resources and Environment*, Vol. 30, No. 11 (Analysis by a team led by Tsinghua University)	1.5℃ scenario	2020
EU	European Commission (2020), Stepping up Europe's 2030 climate ambition.	Average of four scenarios	2015
Germany	Prognos, Öko-Institut, Wuppertal-Institut (2020), Klimaneutrales Deutschland (Agora Energiewende, Agora Verkehrswende und Stiftung Klimaneutralität). Prognos, Öko-Institut, Wuppertal-Institut (2021), *Klimaneutrales Deutschland 2045* (Stiftung Klimaneutralität, Agora Energiewende und Agora Verkehrswende).（CN2045の分析）		2018
France	Direction Générale de l'Energie et du Climat (2020), *Synthèse du scénario de référence de la stratégie française pour l'énergie et le climat*.)	Additional Measures Scenario (AMS)	2015
UK	Committee on Climate Change (2020), The Sixth Carbon Budget .	Balance Net Zero Path Scenario	2020

Roles of NETs in the pathways to carbon neutrality

■ It is very difficult to achieve carbon neutrality without NETs.

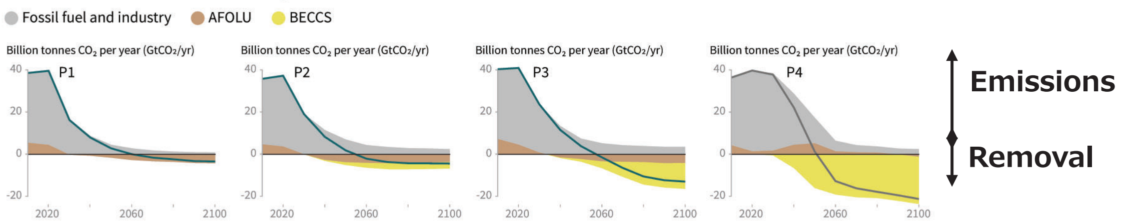
- Adoption of NETs is assumed in almost all scenarios referenced in the IPCC report.

■ The use of NETs should be more clearly and concretely positioned in long-term emission reduction plans by each country.

Characteristics of four illustrative model pathways

Different mitigation strategies can achieve the net emissions reductions that would be required to follow a pathway that limits global warming to 1.5°C with no or limited overshoot. All pathways use Carbon Dioxide Removal (CDR), but the amount varies across pathways, as do the relative contributions of Bioenergy with Carbon Capture and Storage (BECCS) and removals in the Agriculture, Forestry and Other Land Use (AFOLU) sector. This has implications for emissions and several other pathway characteristics.

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Source: IPCC (2018), Special Report: Global Warming of 1.5 ºC. Figure SPM 3b.

R&D for NETs

- Existing actions to develop DAC technologies and to secure domestic CO2 storage sites by the Japanese government should be accelerated.
  - The possibility to combine biomass fuel (including co-firing at thermal power) with CCS should alto be explored as a type BECCS operation.
- For nature-based solutions, the first goal is to achieve the forest absorption targets set forth in the current NDC. The possibility of soil carbon sequestration and biochar then should be examined.

NETs	Type	Major challenges
DACCS	Technology -based	• Cost reduction (CO2 capturing, energy input) • CCS capacity development (transport infrastructure, storage capacity, etc.)
BECCS	Technology -based	• Ensuring stable supply sources of biomass • Maximization of co-benefits (such as power supply) • CCS capacity development
Afforestation / Forest management	Nature-based	• Securing sites to adopt NETs • Promoting the logging of aging forest • Utilization of wood products by cut-down trees
Soil carbon sequestration	Nature-based	• Potential impacts to the existing agricultural activities • Accurate measurement of carbon removal volume • Maximization of co-benefits

R&D for NETs (cont.)

- Some nature-based solutions such as blue carbon and enhanced weathering are suitable for Japan’s geographical conditions, and actions for these NETs, such as establishment of methods for measuring the removal volume and securing application sites) should be promoted.

NETs	Type	Major challenges
Bio char	Nature-based	• Securing sites for the NETs application • Accurate measurement methods for the volume and duration of removed volume • Value chain development from production to utilization • Management of the impact to the atmosphere and water
Enhanced weathering	Nature-based	• Pilot testing and data accumulation • Securing proper sites (including public acceptance) • Value chain development
Blue carbon	Nature-based	• Accurate measurement methods for the volume and duration of removed volume • Securing proper sites (including public acceptance) • Cost reduction
Ocean alkalization	Nature-based	• Pilot testing and data accumulation • Accurate measurement methods • Management of the impacts on ecosystem

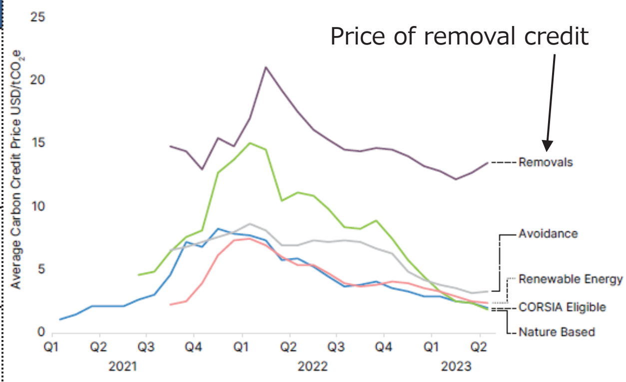
Development of removal credit system

- Offsetting residual emissions by NETs requires removal credit system.
- Removal credit has different characteristics from reduction credit.
  - Removal credit is already traded in the voluntary credit market at a higher price than reduction credit.
- MRV system of removed volume, certification system of carbon dioxide removal, and transaction rules for removal credit need to be established.

Reduction credit and removal credit

	Reduction credit	Removal credit
Traded CO_2	Reduced CO_2 volume from base case or pre-determined emissions quota	Reduced CO_2 volume from base case
Characteristic of traded CO_2	CO_2 that will be emitted	CO_2 that already exist in the atmosphere
Major means to generate credit	Efficiency improvement, renewable, nuclear	NETs
Time horizon	Relatively short-term	Relatively long-term

Price of different credits

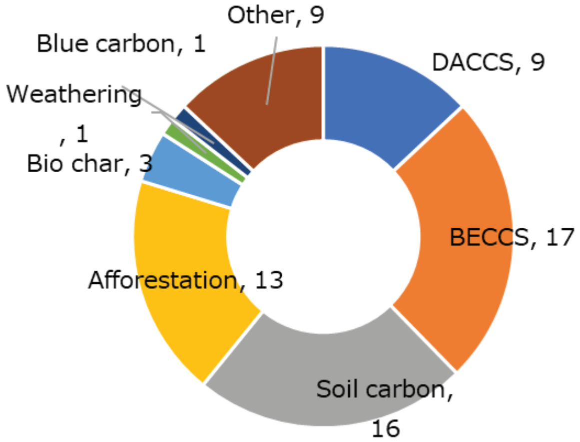


Source: World Bank, State and Trends of Carbon Pricing 2023

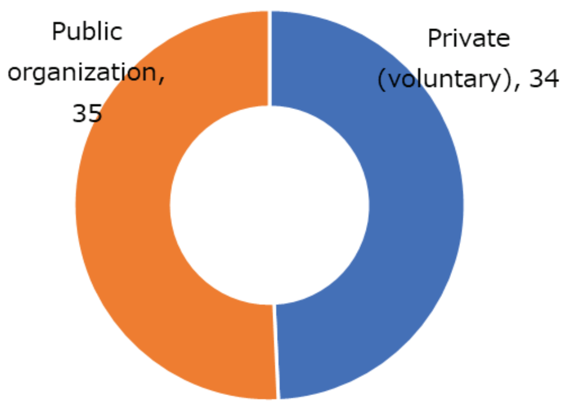
Measurement, Reporting, and Verification

- Currently, various MRV procedures for NETs coexist.
  - As of May 2023, there are 69 MRV procedures related to NETs worldwide.
- Establishment of MRV methods that are shared internationally is still a long way off, and future multilateral efforts (e.g., setting minimum standards, understanding the amount of removal over the lifecycle, etc.) are needed.

Number of MRV procedures by NETs



Number of MRV procedures by its owner



Note : "Other" includes Peatland rewetting, Wetland restoration, Woody biomass burial, and Bio oil.
Source : Leo Mercer and Josh Burke (2023) Strengthening MRV standards for greenhouse gas removals to improve climate change governance.

International Cooperation

- Shared international recognition of the values and the roles for NETs
  - Currently, only afforestation/forest management and BECCS are listed as NETs in the IPCC report.
  - Common understanding and the method of measuring the removal volume and the carbon fixation period of each NET need to be established.
- Development of MRV system
  - Accumulation and sharing of data on removal effect of each NET
  - Standardization of MRV methods (or agreement on minimum conditions)
  - Development of a method for measuring removal effect on life cycle basis
- Development of international certification and credit systems
  - Development of certification systems for carbon removal in each country and integration into international certification systems
  - Establishment of a cross-border removal credit system
  - Development of a mechanism to enable the counting of removal volume toward NDC
- Formation and promotion of international NETs projects
  - Pursue opportunities to apply low-cost NETs overseas and count the removal volume to NDCs
  - Establishment of rules for the use of NETs in the ocean

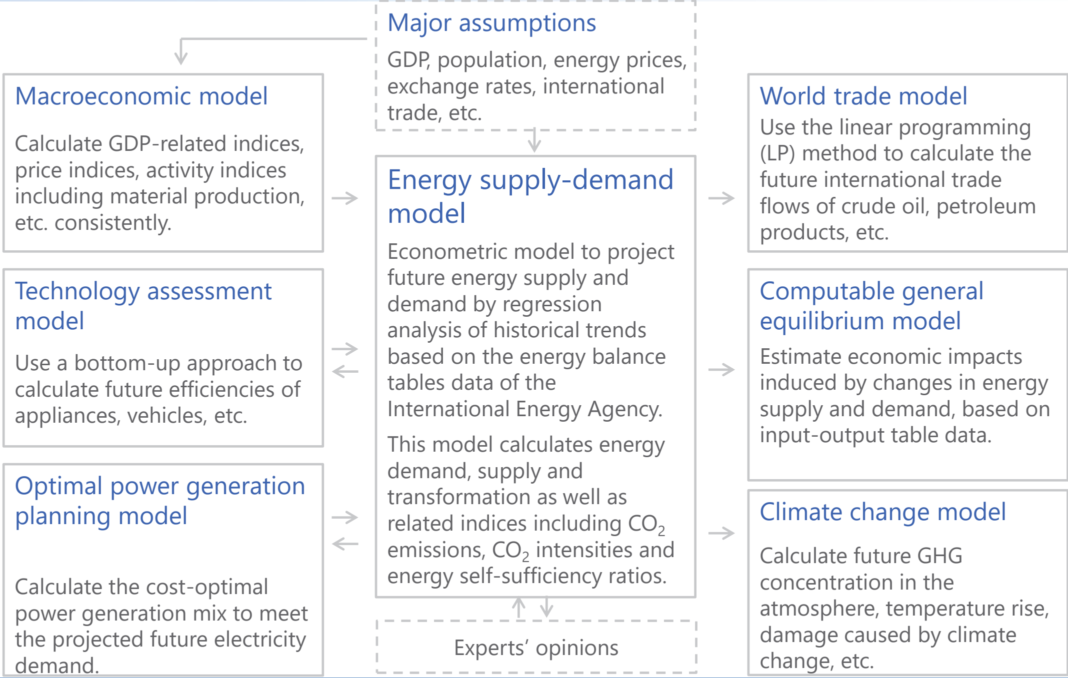
Reference materials

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 eight regions.

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

Modelling framework

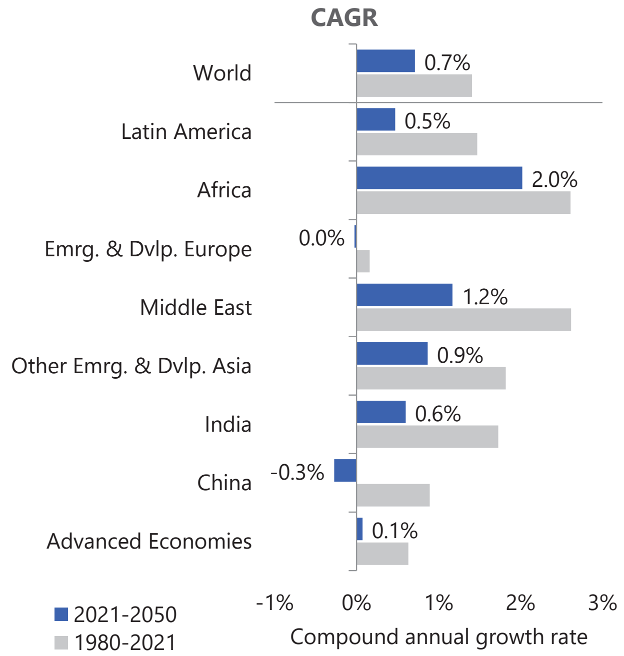


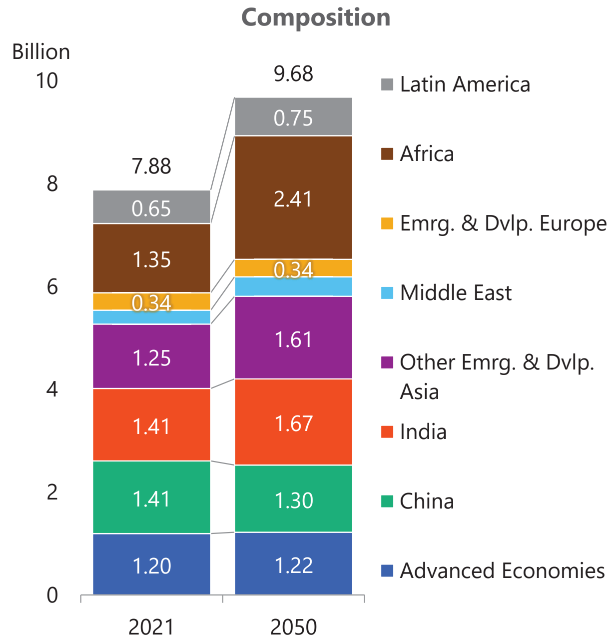
Basic scenarios in IEEJ Outlook

	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** price decreases due to request for decarbonization.	All prices decrease along with decrease in demand due to progress in energy saving and request for decarbonization
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

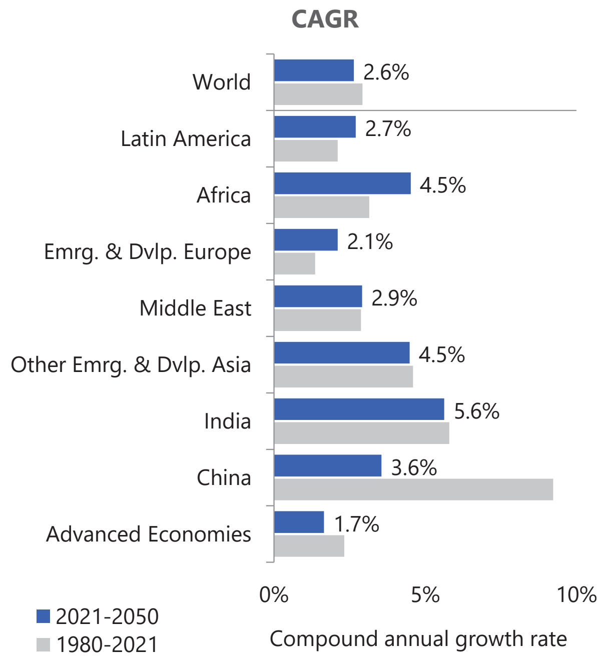
Population

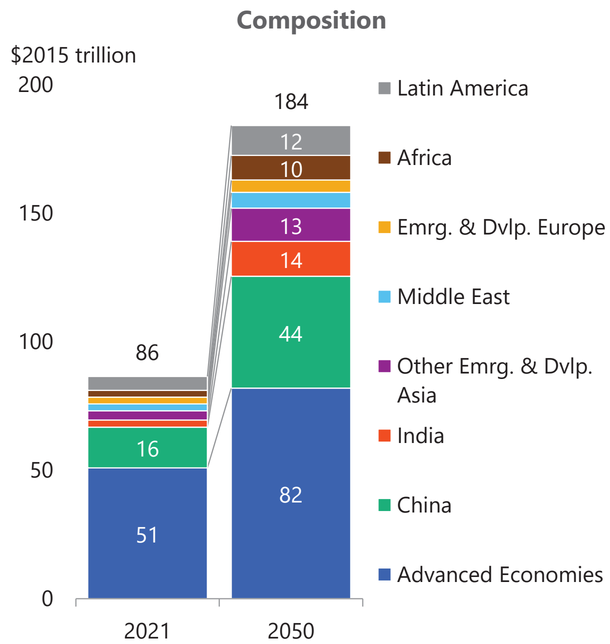




Assumptions

Real GDP



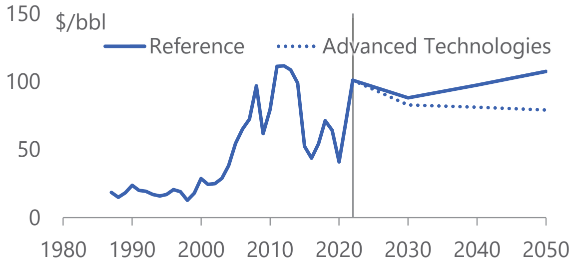


Assumptions

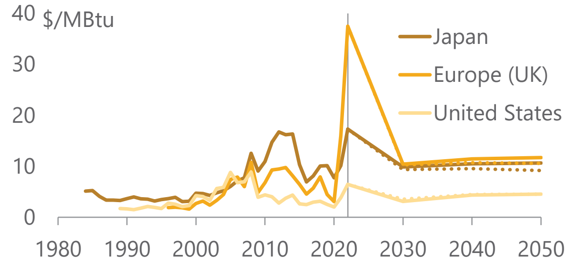
International energy prices

Reference : ——
Advanced Technologies : ··········

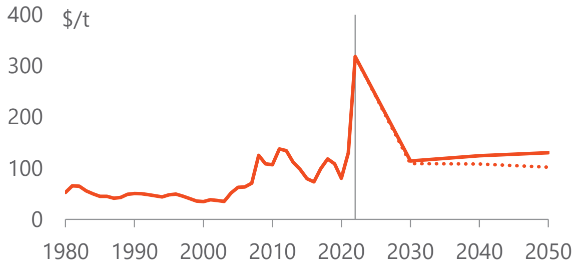
Crude oil



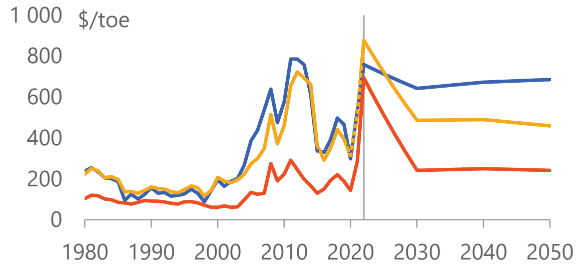
Natural gas



Coal



CIF import prices for Japan



Note: Historical prices are nominal. Assumed future prices as real in $2022.

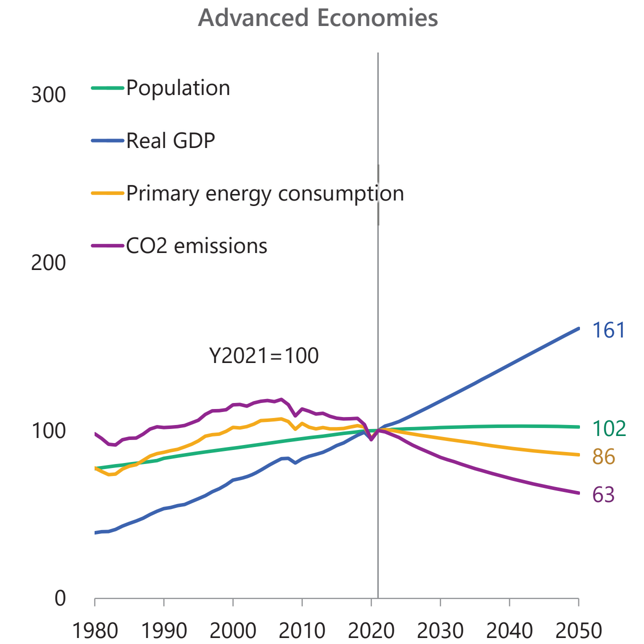
Assumptions

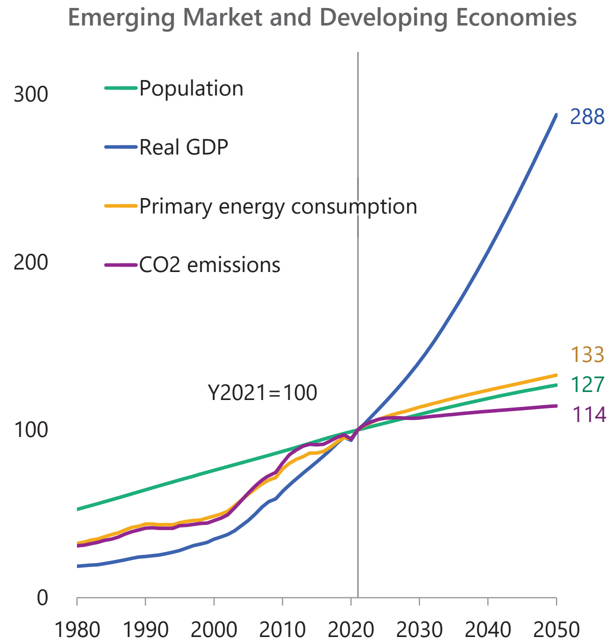
Energy and environmental technology

			2021	2050 Reference	2050 Advanced Technologies	Assumptions for Advanced Technologies Scenario
Improving energy efficiency	Industry	Intensity in steel industry (ktoe/kt)	0.261	0.254	0.202	100% penetration of Best Available Technology by 2050.
		Intensity in non-metallic minerals industry	0.091	0.070	0.055	
	Transport	Electrified vehicle share in passenger car sales	12%	66%	96%	Cost reduction of electrified vehicles. Promotion measures including fuel supply infrastructure. *electrified vehicle includes hybrid vehicle, plug-in hybrid vehicle, electric vehicle and fuel-cell vehicle
		Average fuel efficiency in new passenger car (km/L)	15.0	27.4	46.6	
	Buildings	Residential total efficiency (Y2021=100)	100	154	202	Efficiency improvement at twice the speed for newly installed appliance, equipment and insulation.
		Commercial total efficiency	100	153	204	Electrification in space heating, water heater and cooking (clean cooking in developing regions).
	Power	Thermal generation efficiency (Power transmission end)	37%	44%	49%	Financial scheme for initial investment in high-efficient thermal power plant.
Penetrating low-carbon technology	Biofuels for transport (Mtoe)		94	138	236	Development of next generation biofuel with cost reduction. Relating to agricultural policy in developing regions.
	Nuclear power generation capacity (GW)		429	506	802	Appropriate price in wholesale electricity market. Framework for financing initial investment in developing regions.
	Wind power generation capacity (GW)		842	3 904	5 170	Further reduction of generation cost. Cost reduction of grid stabilization technology.
	Solar PV power generation capacity		883	7 104	9 883	Efficient operation of power system.
	Thermal power generation capacity with CCS (GW)		0	0	1 110	Installing CCS after 2030 (regions which have storage potential except for aquifer).
	Zero-emission generation ratio (incl. CCS)		38%	59%	88%	Efficient operation of power system including international power grid.

Reference Scenario

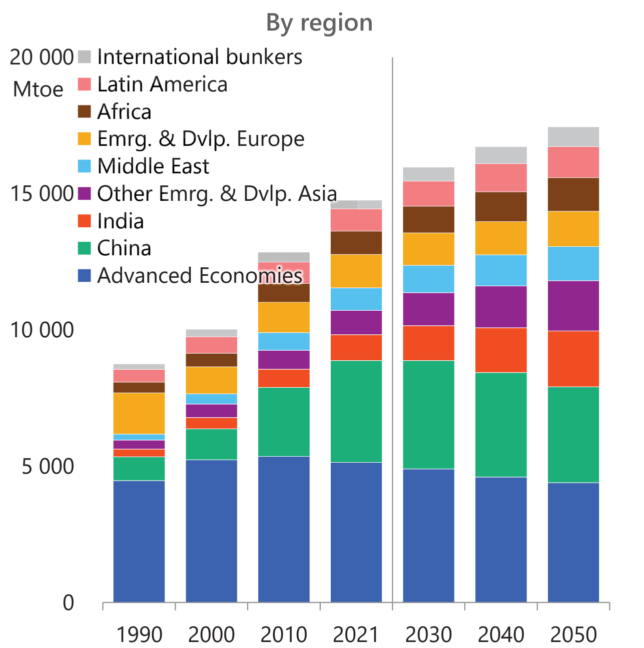
Population, GDP, energy and CO_2

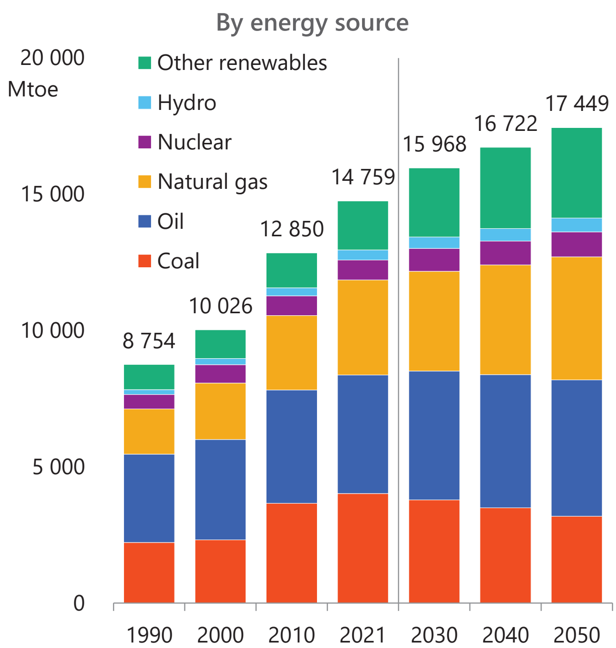




Reference Scenario

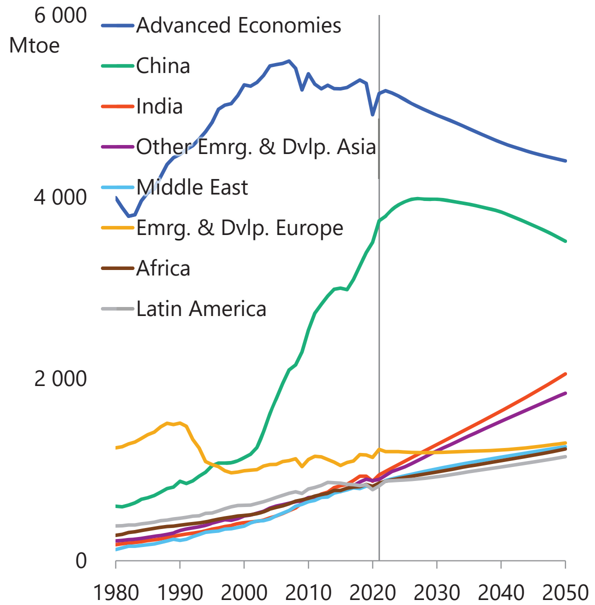
Primary energy consumption

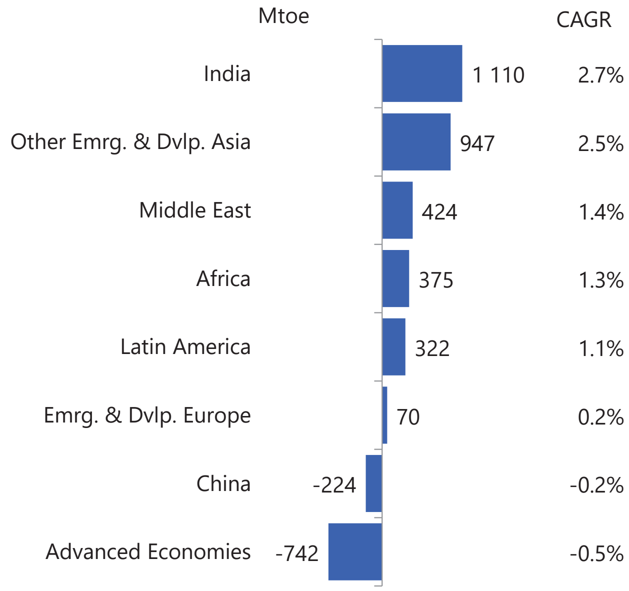




Reference Scenario

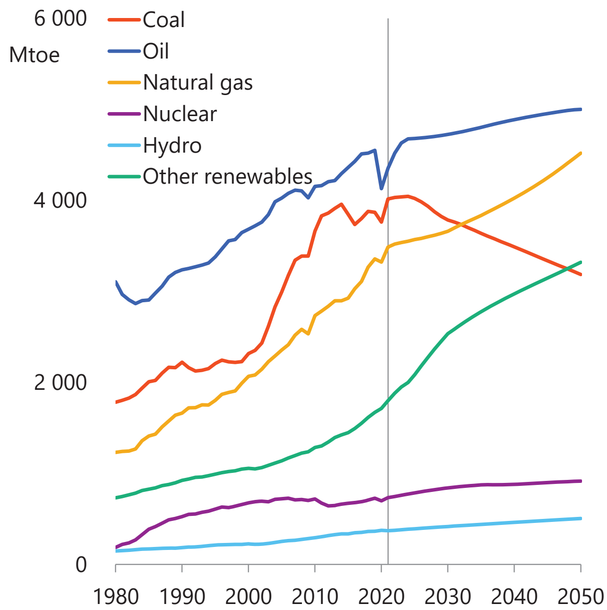
Primary energy consumption (by region)

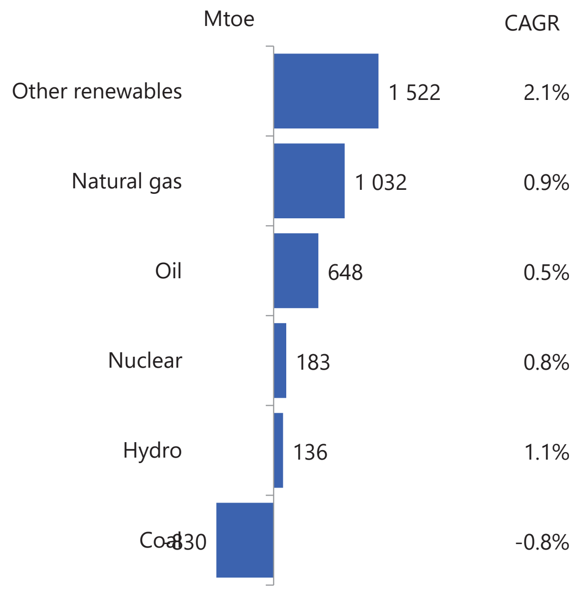




Reference Scenario

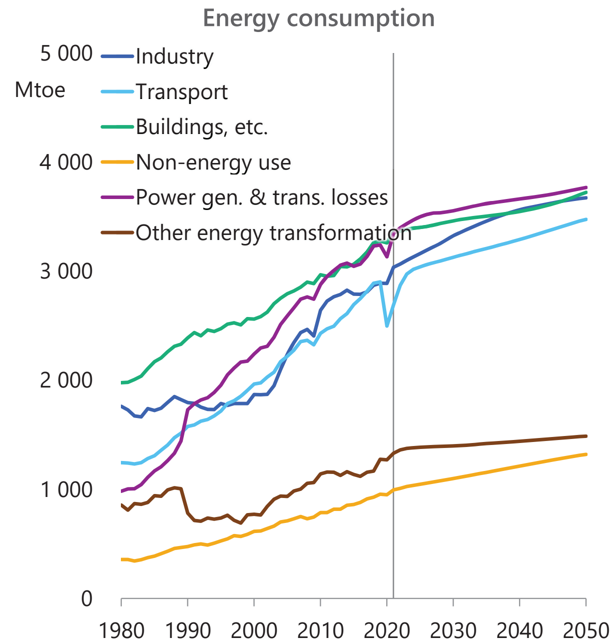
Primary energy consumption (by energy source)

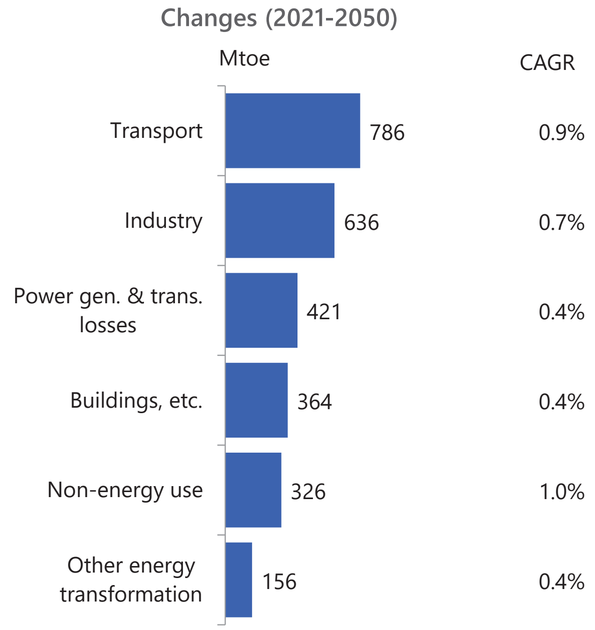




Reference Scenario

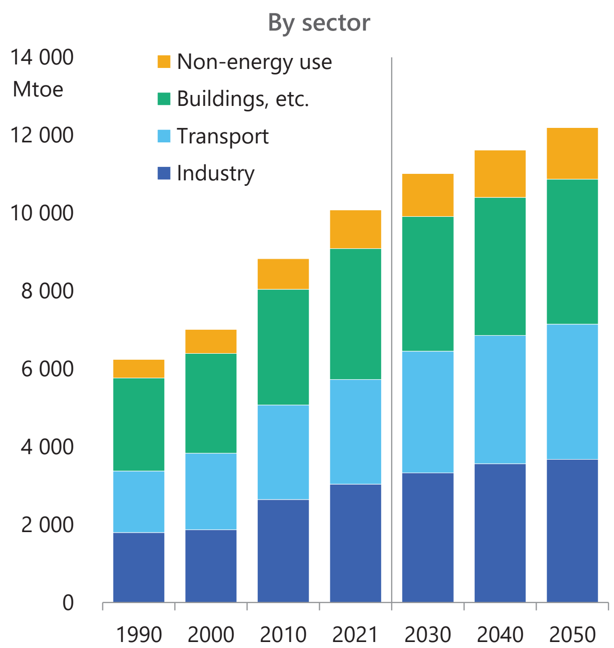
Primary energy consumption (by sector)

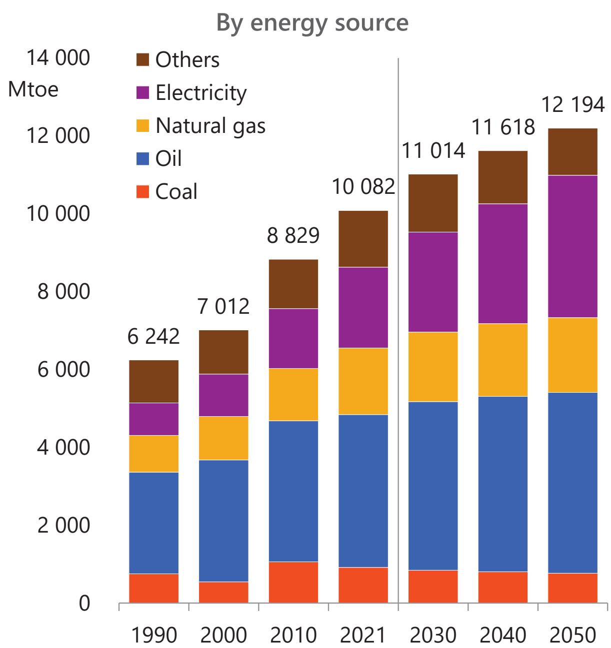




Reference Scenario

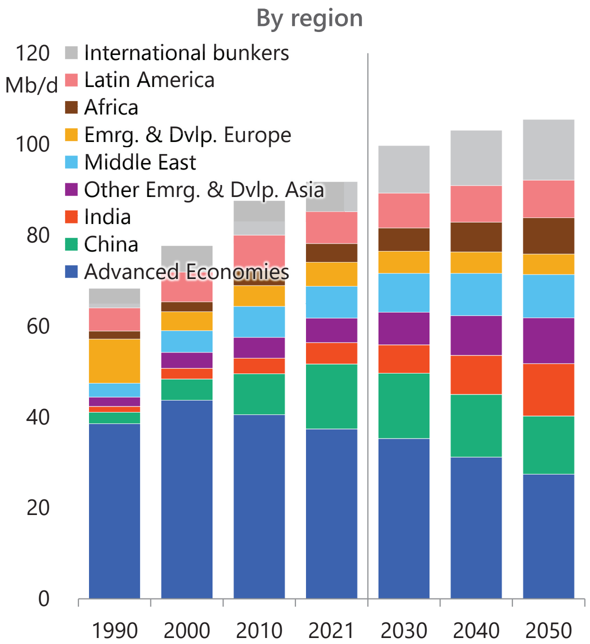
Final energy consumption

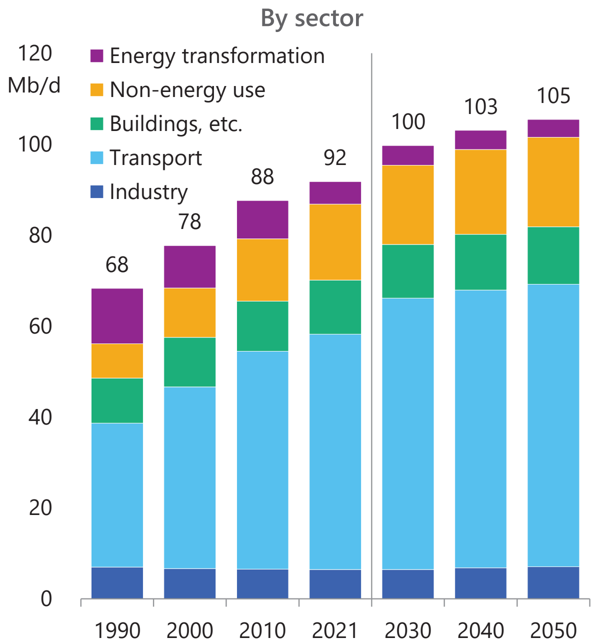




Reference Scenario

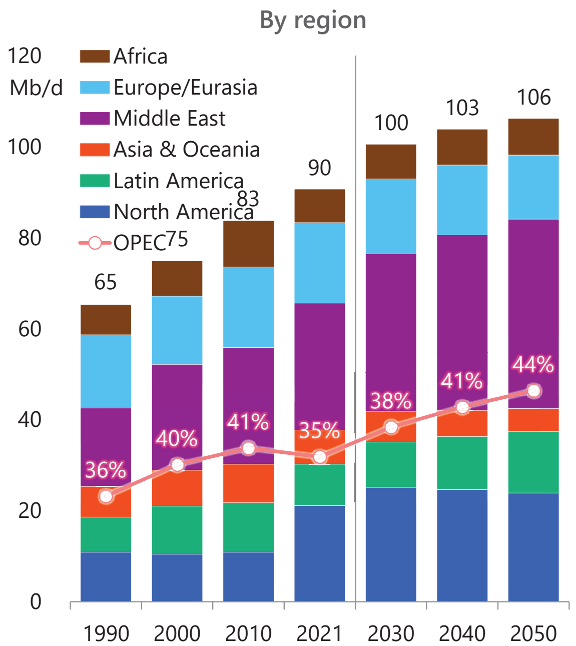
Oil consumption

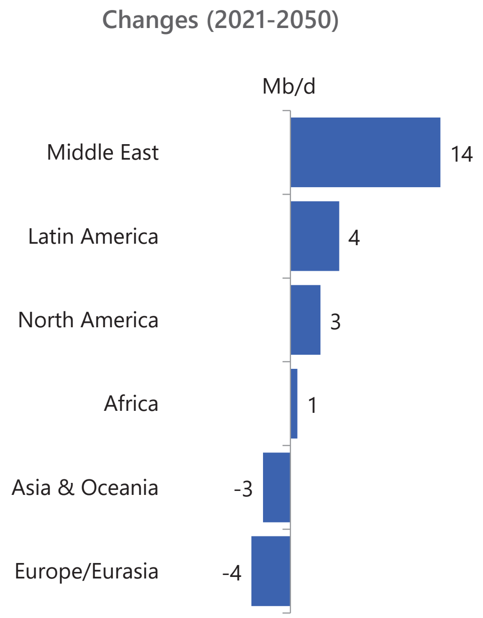




Reference Scenario

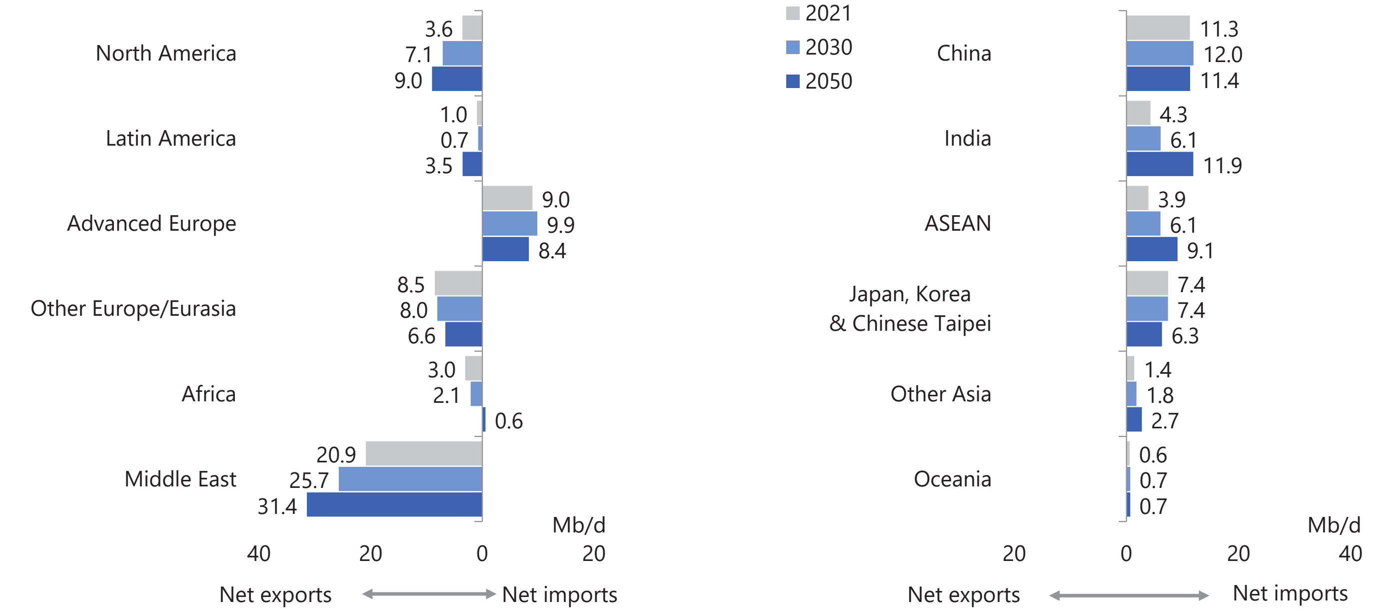
Crude oil production





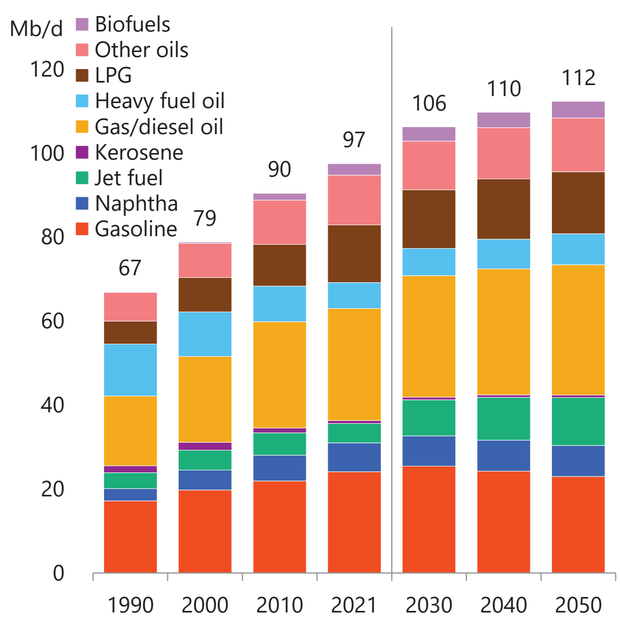
Reference Scenario

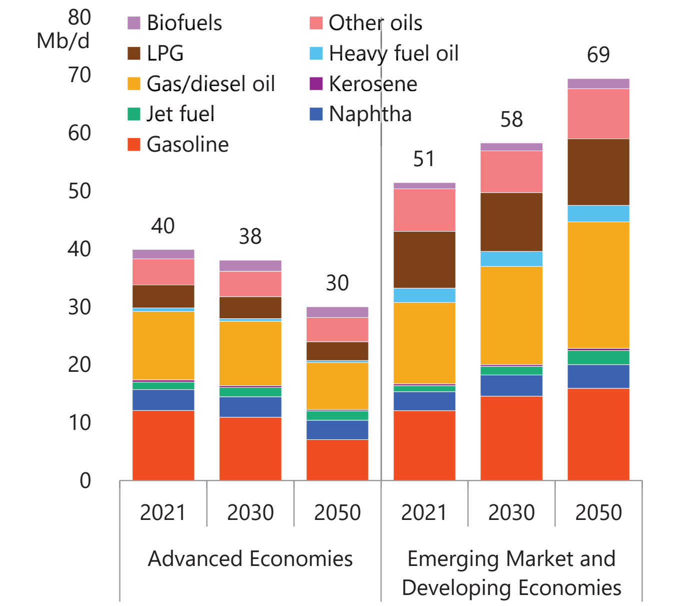
Net exports and imports of oil



Reference Scenario

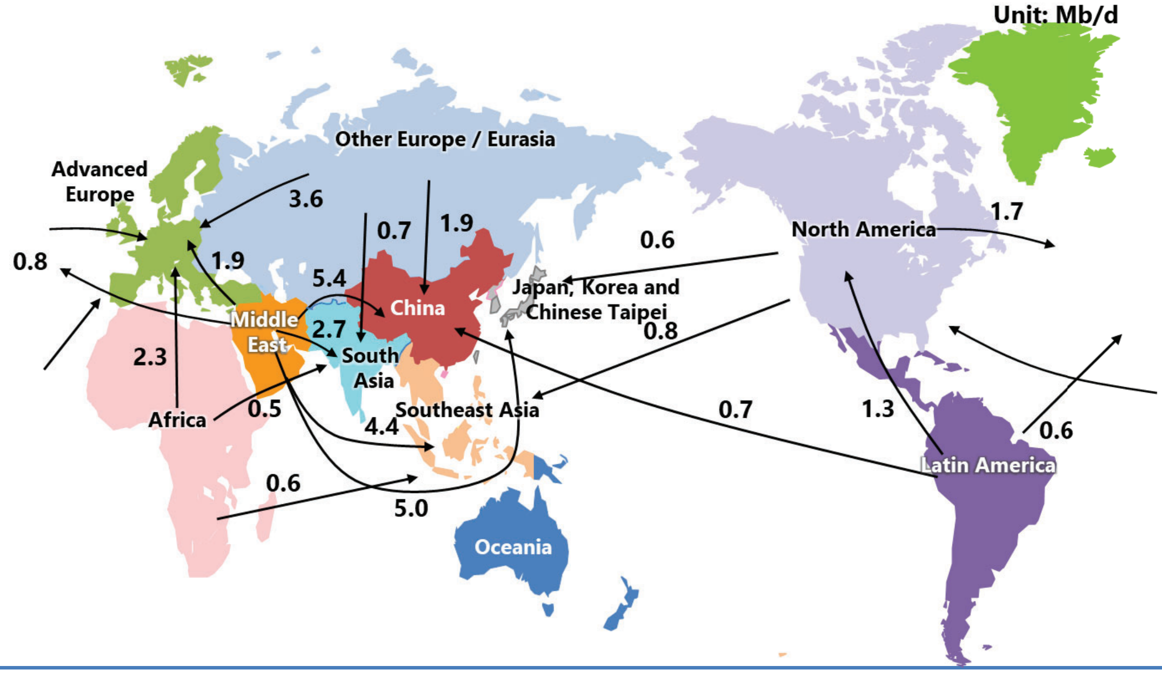
Petroleum product demand





Note: Other oils includes crude oil (direct consumption), asphalt, refinery gas, gas-liquefied oil [GTL], etc.

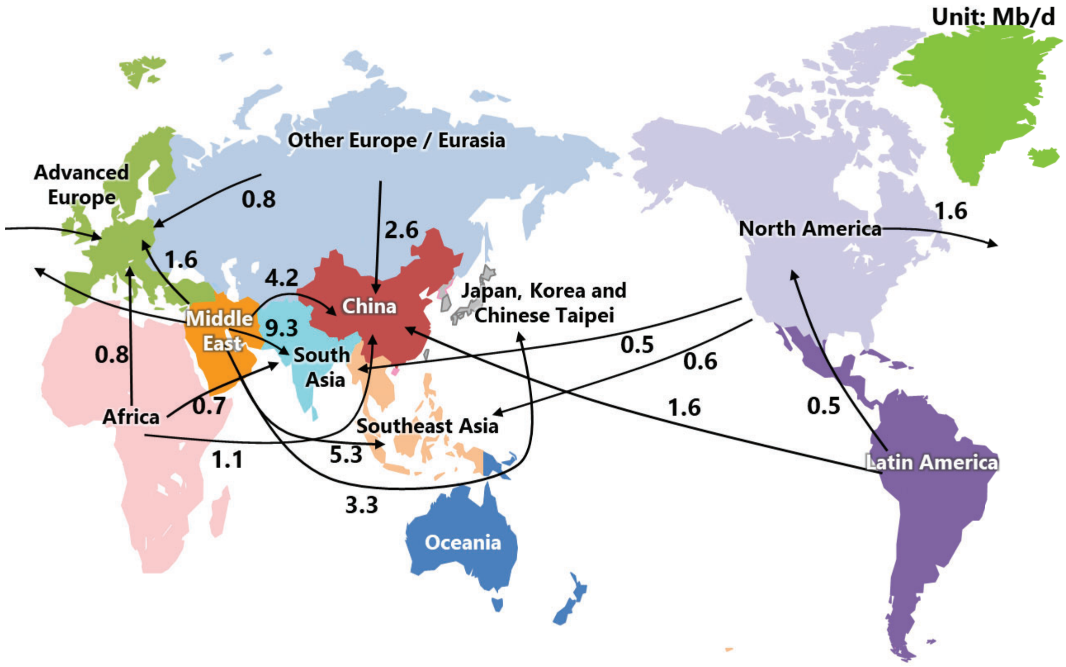
Major trade flows of crude oil (2022)



Note: 0.5 Mb/d or more are shown

Reference Scenario

Major trade flows of crude oil (2050)

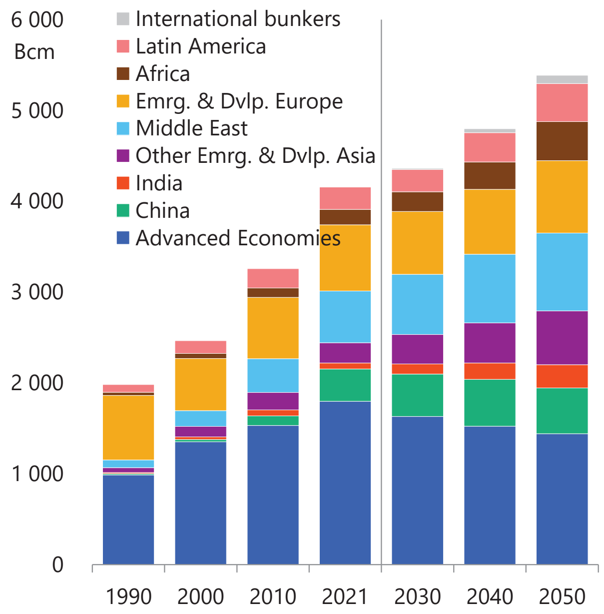


Note: 0.5 Mb/d or more are shown

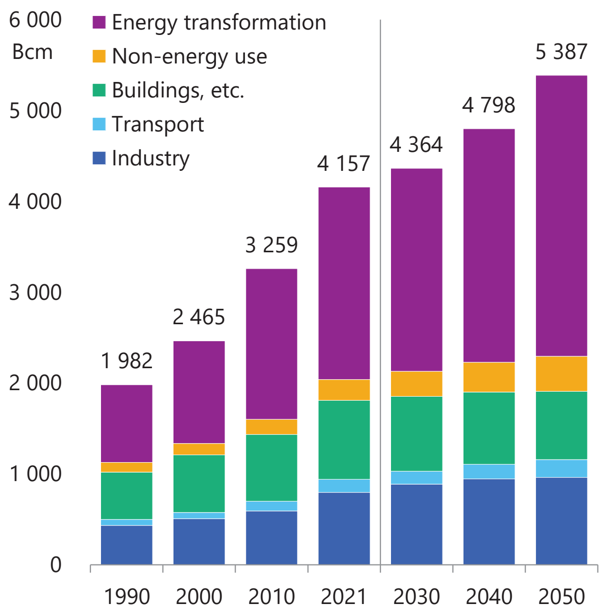
Reference Scenario

Natural gas consumption

By region



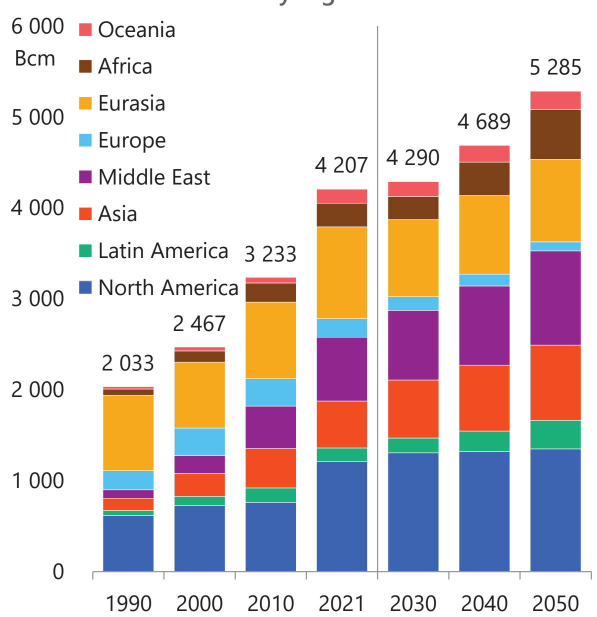
By sector



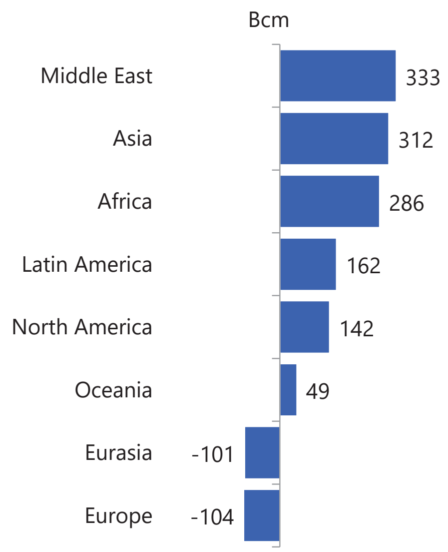
Reference Scenario

Natural gas production

By region

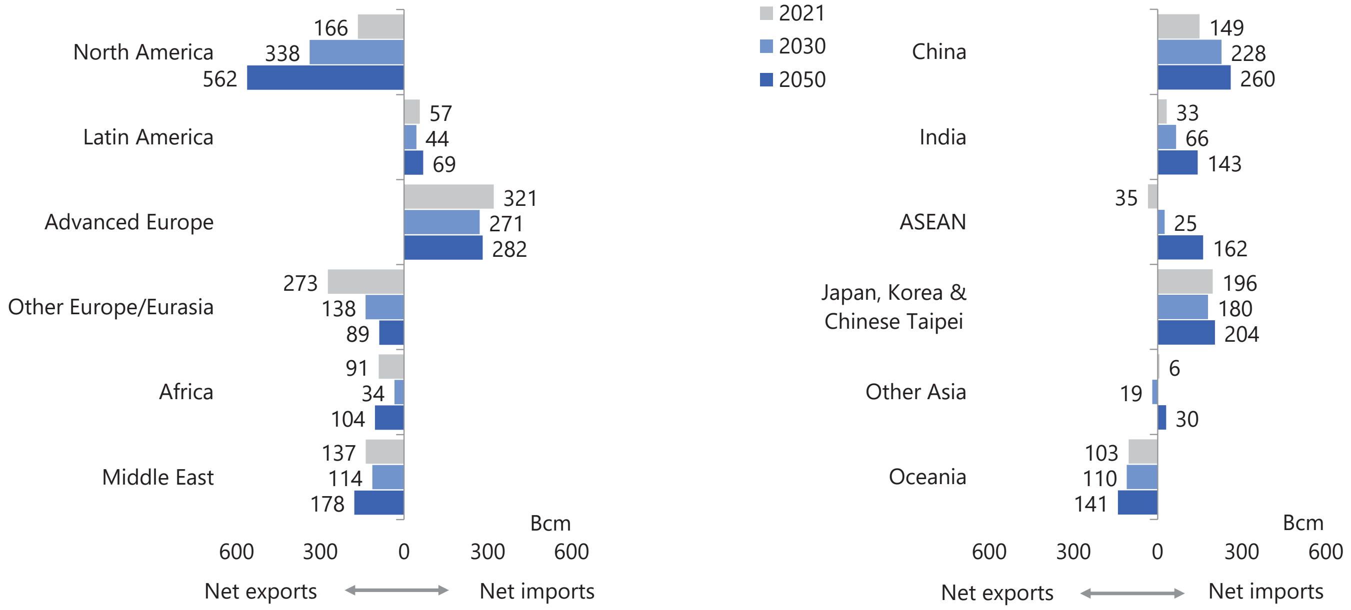


Changes (2021-2050)



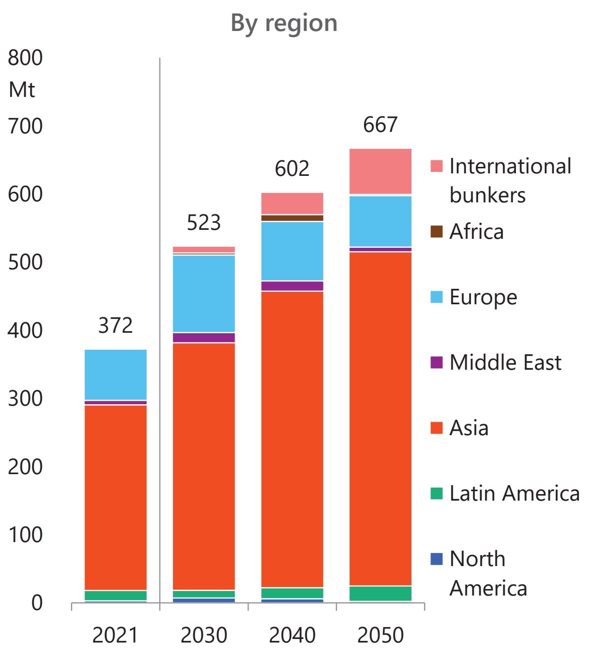
Reference Scenario

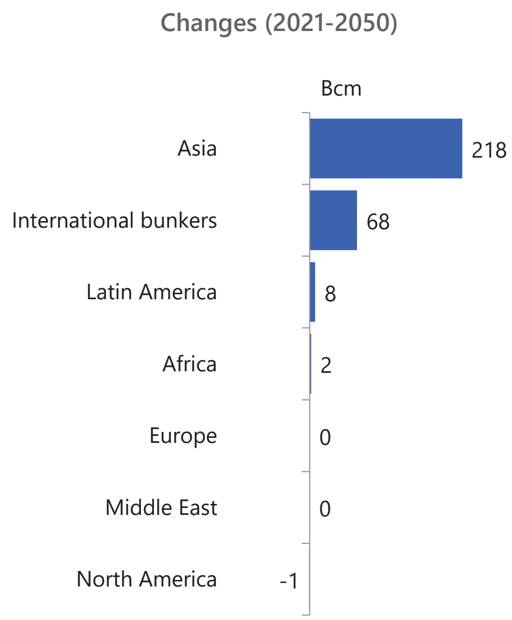
Net exports and imports of natural gas



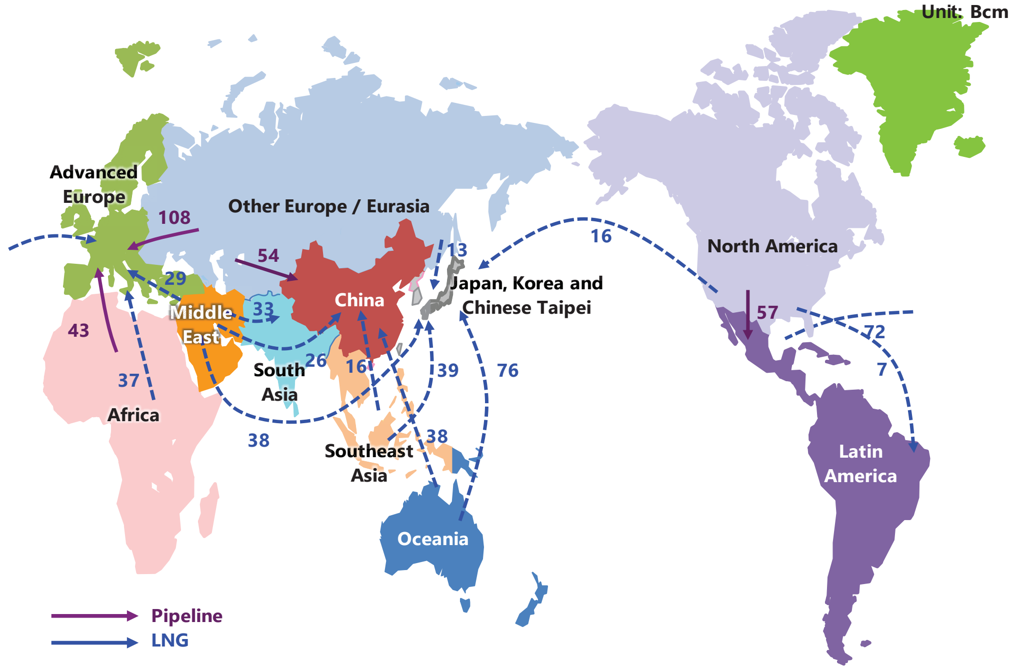
Reference Scenario

LNG demand





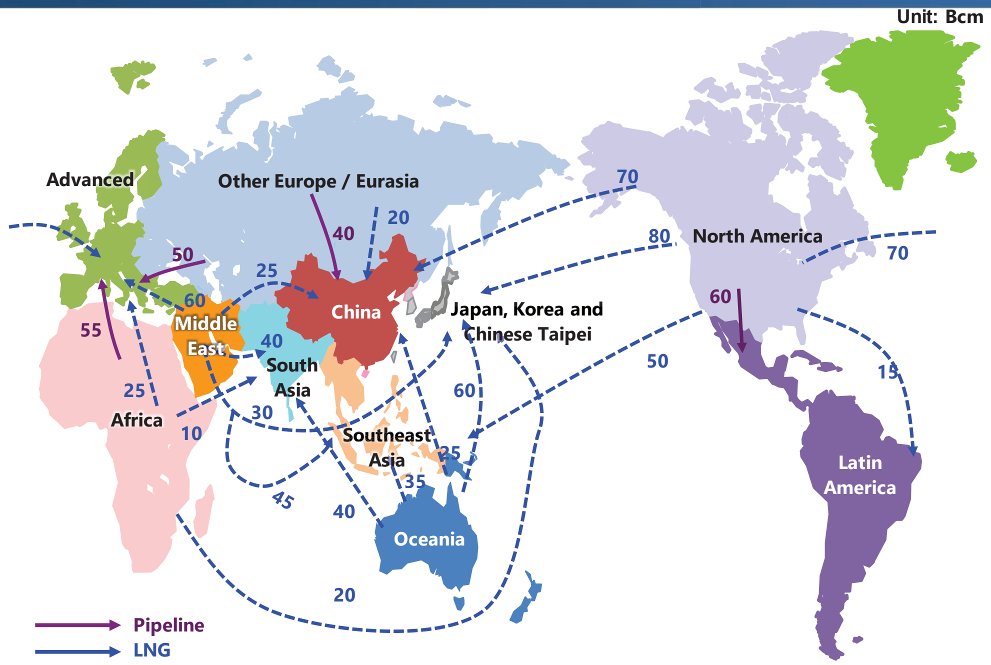
Major trade flows of natural gas (2022)



Note: This figure shows the main interregional trade and does not include the total trade volume. There is a possibility that some pipeline gas may be replaced by LNG.

Reference Scenario

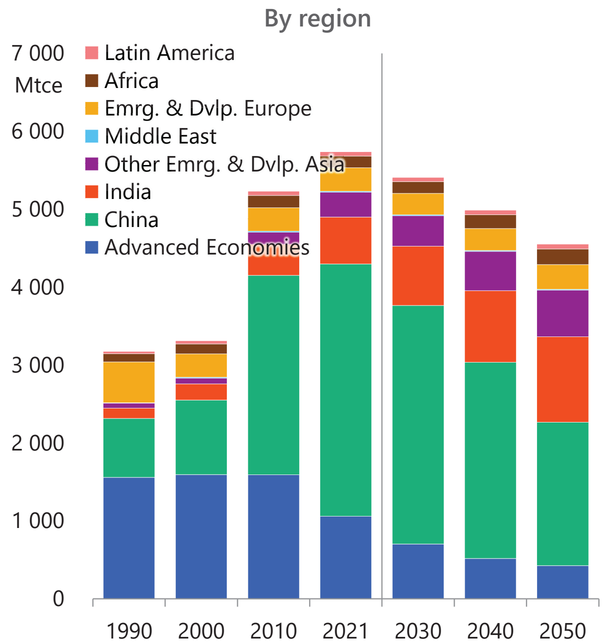
Major trade flows of natural gas (2050)

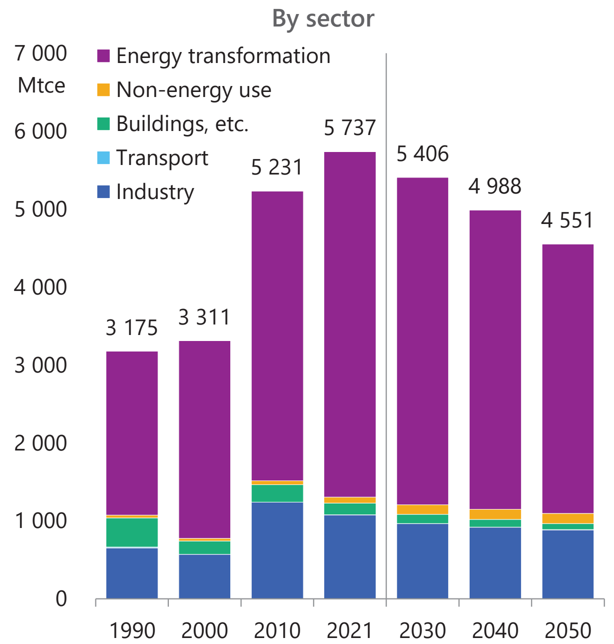


Note: This figure shows the main interregional trade and does not include the total trade volume. There is a possibility that some pipeline gas may be replaced by LNG.

Reference Scenario

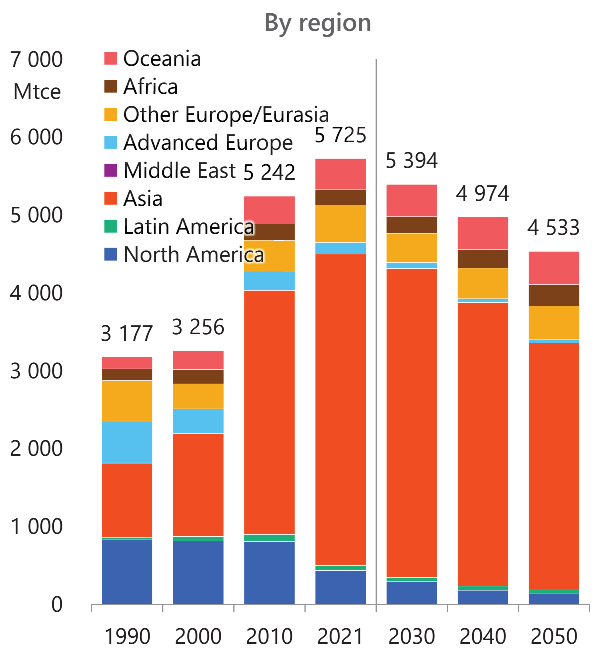
Coal consumption

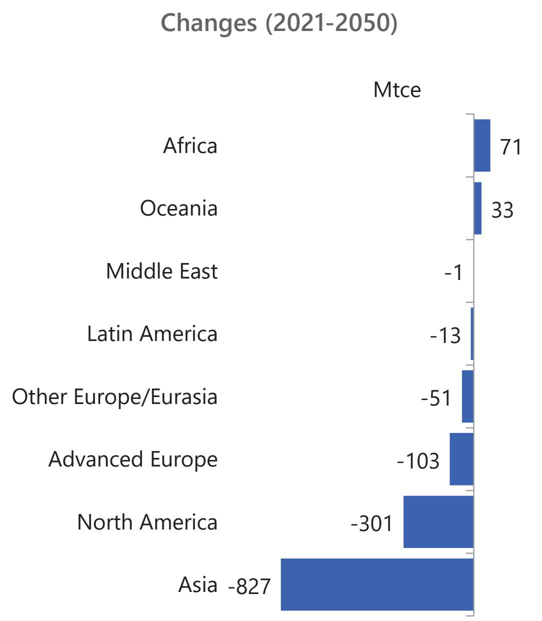




Reference Scenario

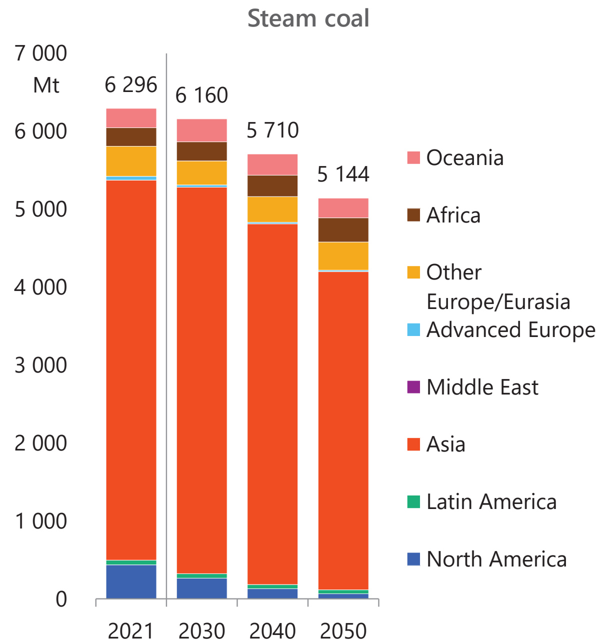
Coal production

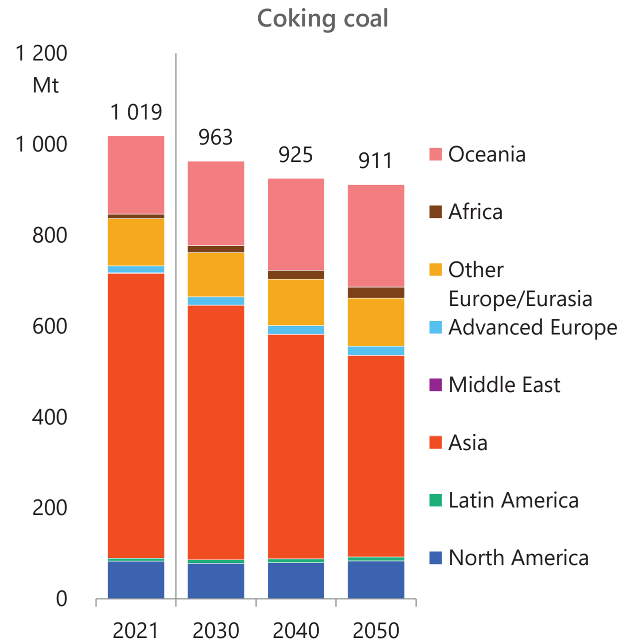




Reference Scenario

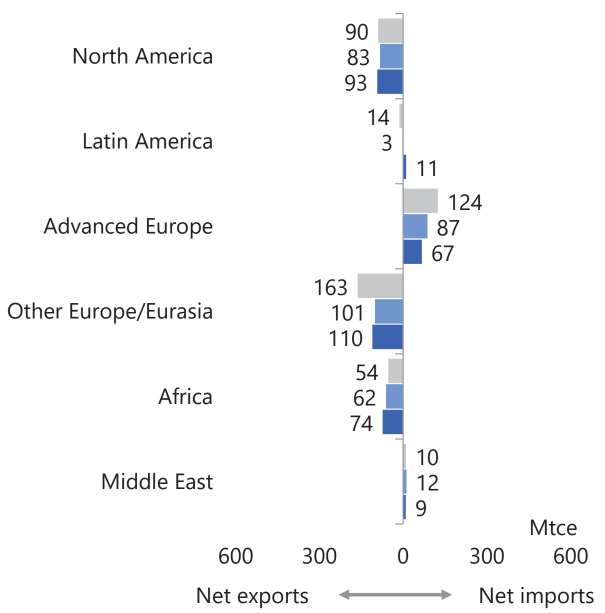
Coal production (steam and coking coal)

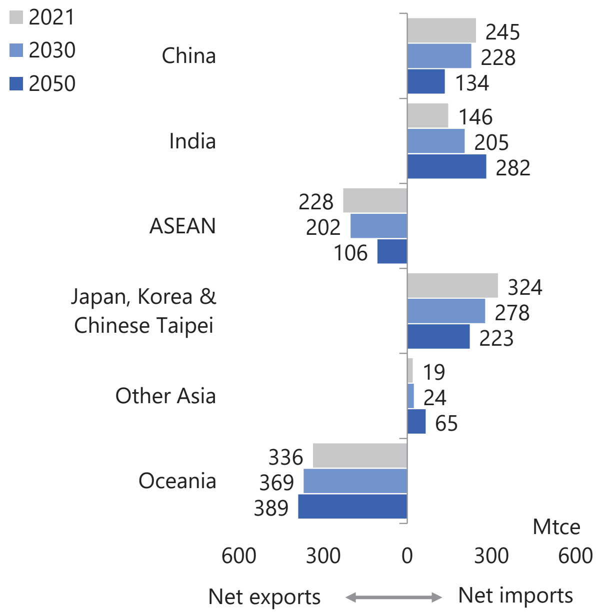




Reference Scenario

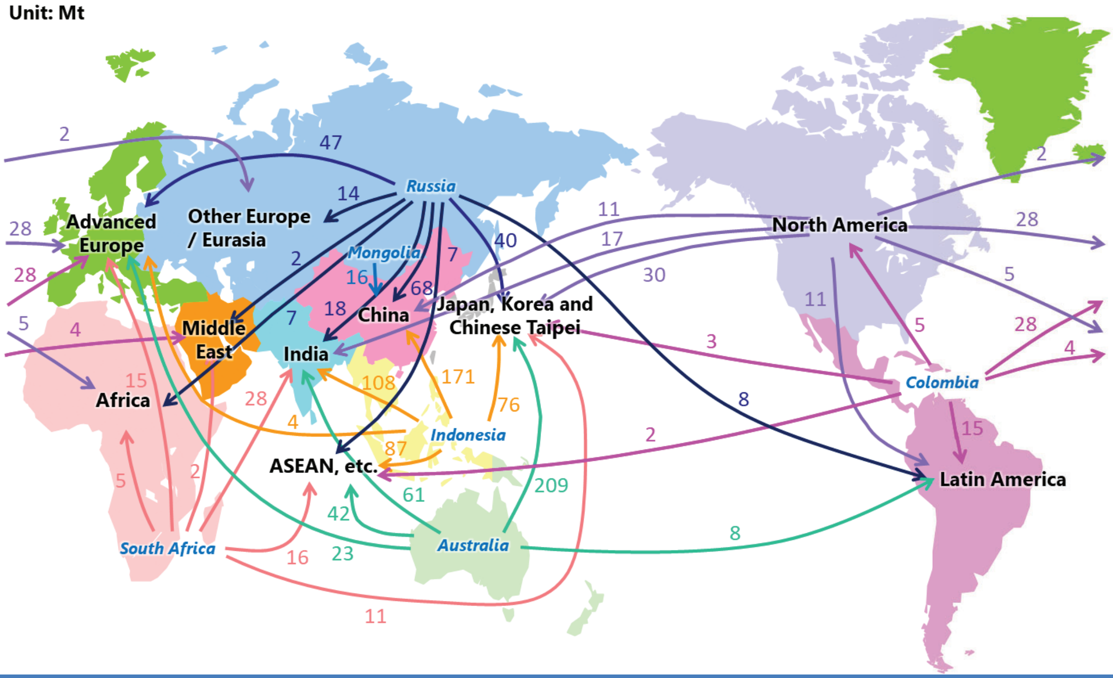
Net exports and imports of coal





Major trade flows of steam and coking coal (2022)

Unit: Mt

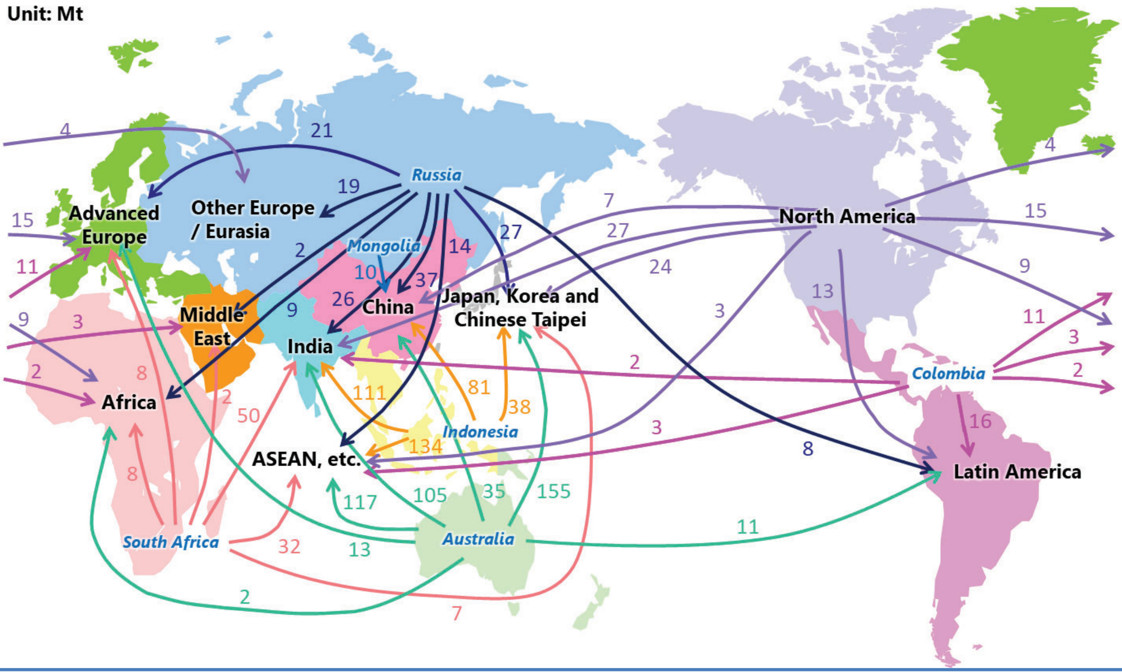


Notes: Total value of steam and coking coal. 2 Mt or more are shown. South Africa includes Mozambique.
Source: Estimated from IEA "Coal Information 2022", "TEX Report", etc.

Reference Scenario

Major trade flows of steam and coking coal (2050)

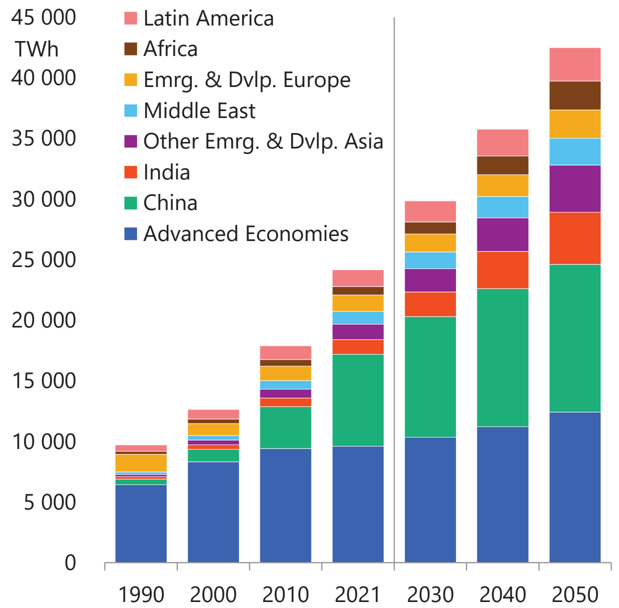
Unit: Mt



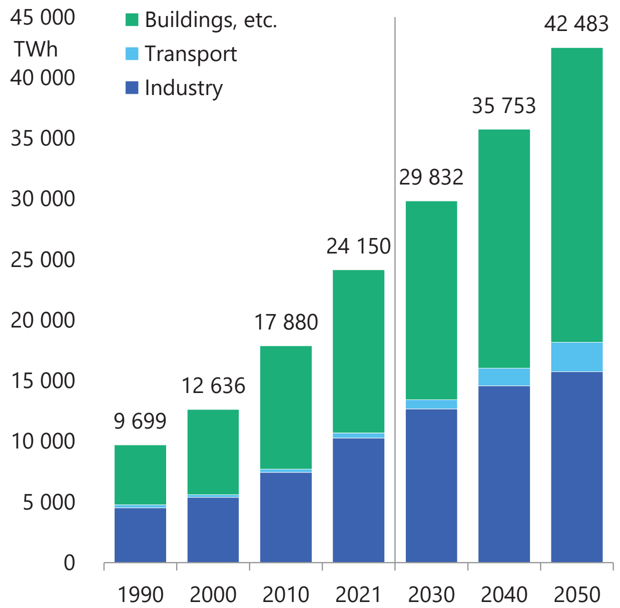
Notes: Total value of steam and coking coal. 2 Mt or more are shown. South Africa includes Mozambique.

Final consumption of electricity

By region

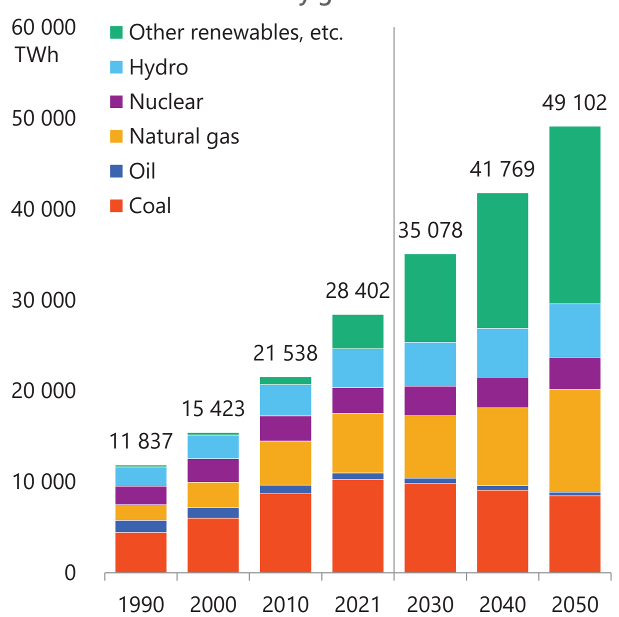


By sector

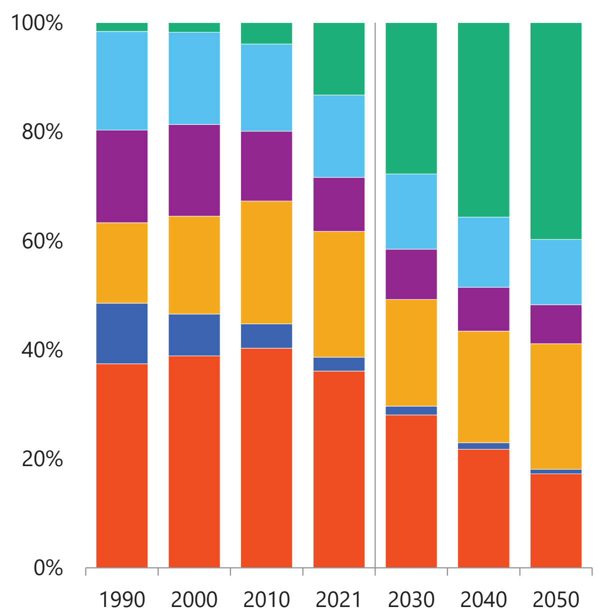


Power generation mix

Electricity generated

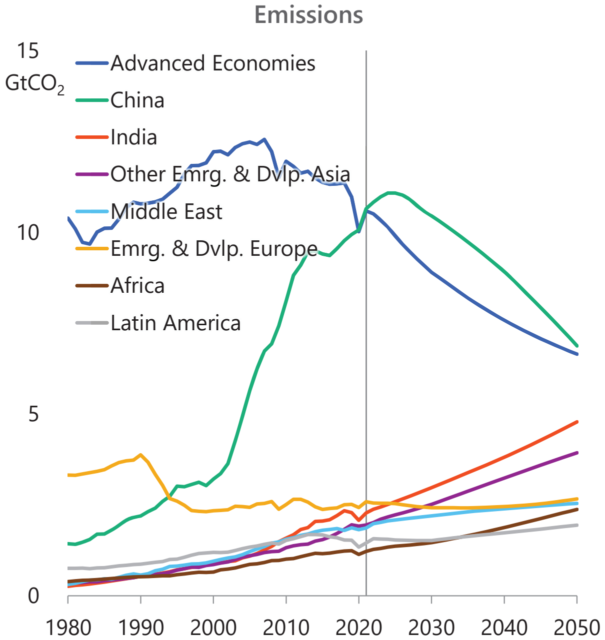


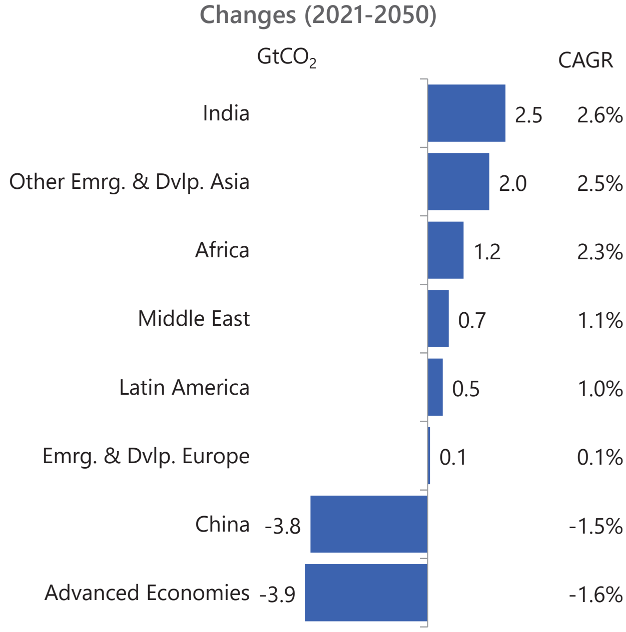
Shares



Reference Scenario

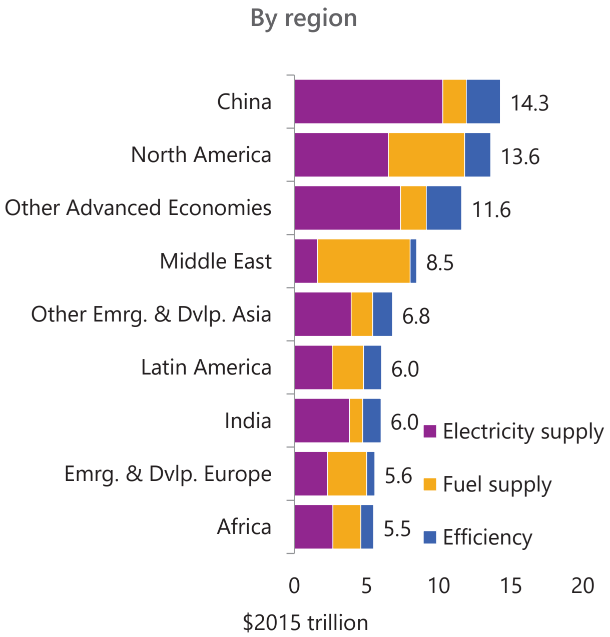
Energy-related CO_2 emissions

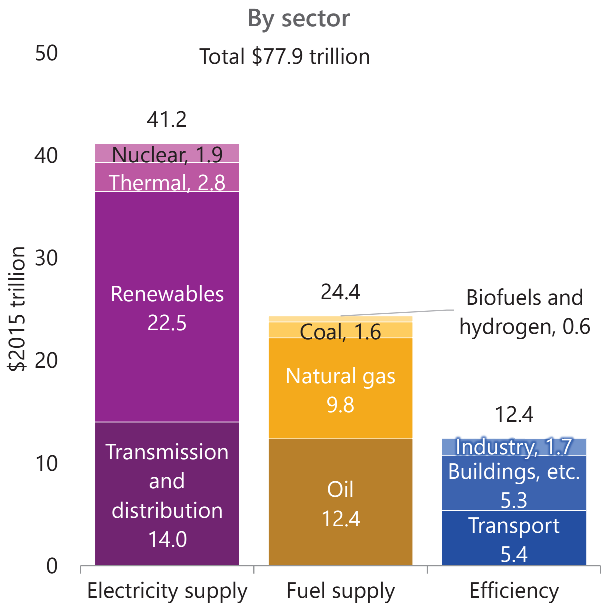




Reference Scenario

Energy-related investments (2022–2050)

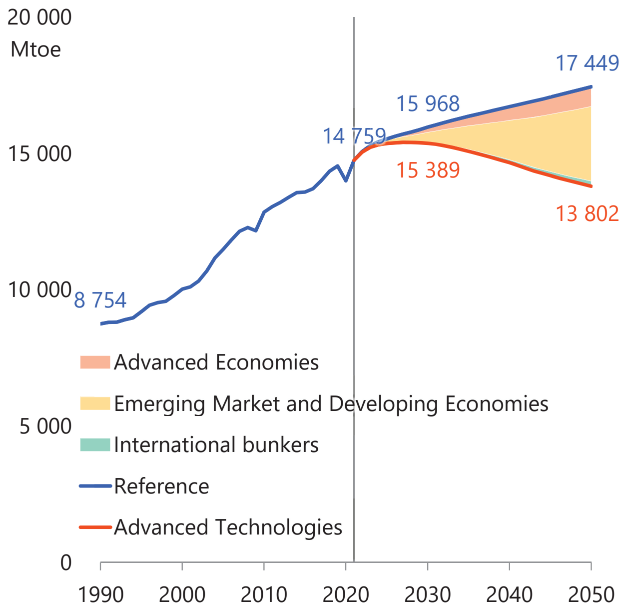




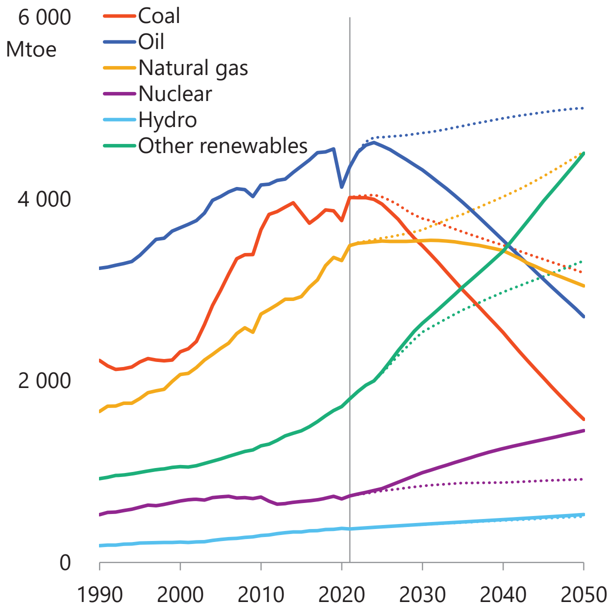
Advanced Technologies Scenario

Primary energy consumption

By region



By energy source

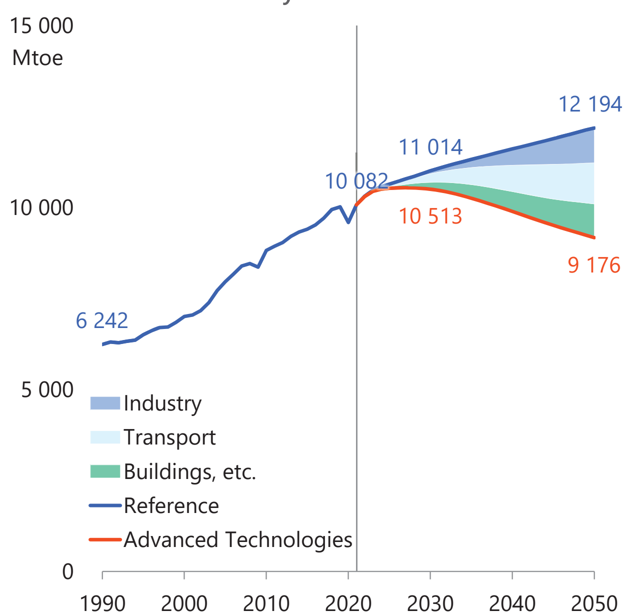


Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

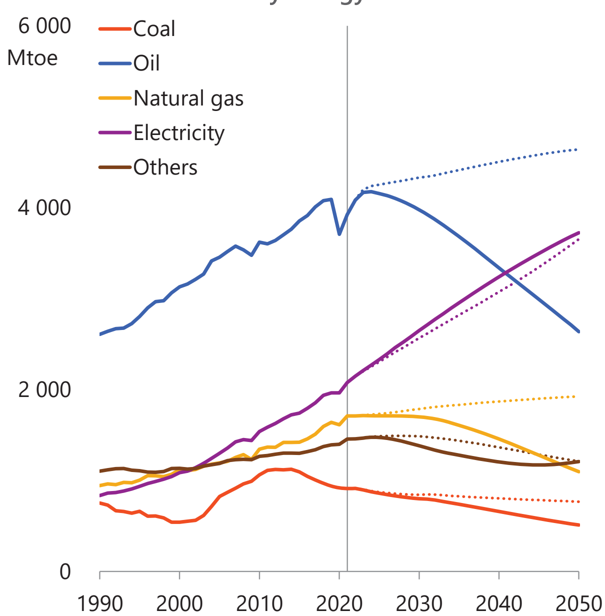
Advanced Technologies Scenario

Final energy consumption

By sector

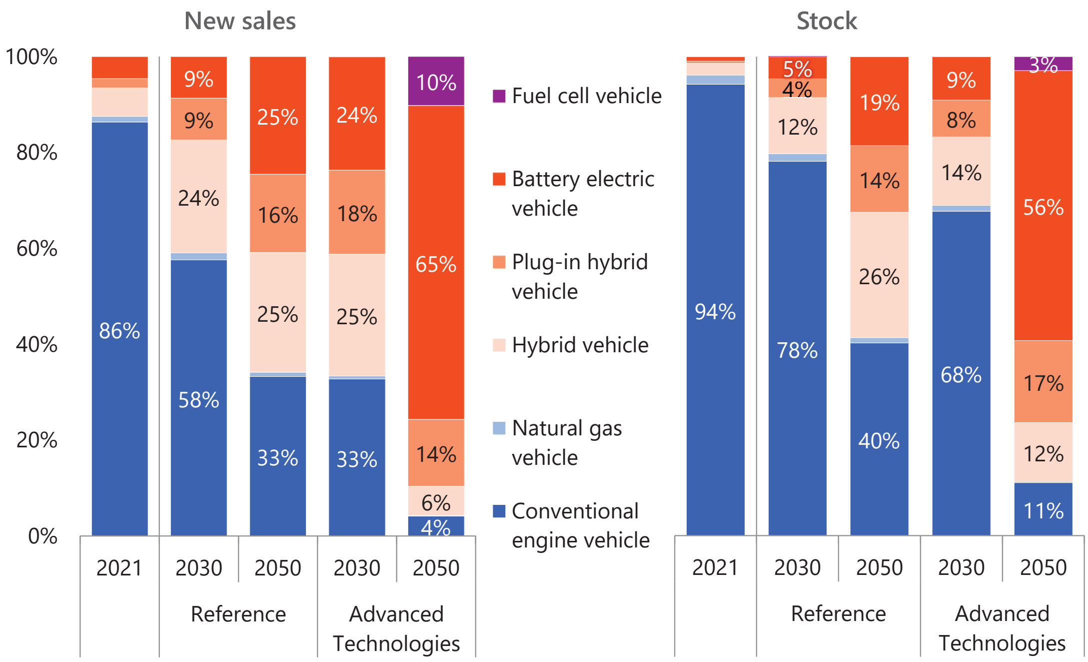


By energy



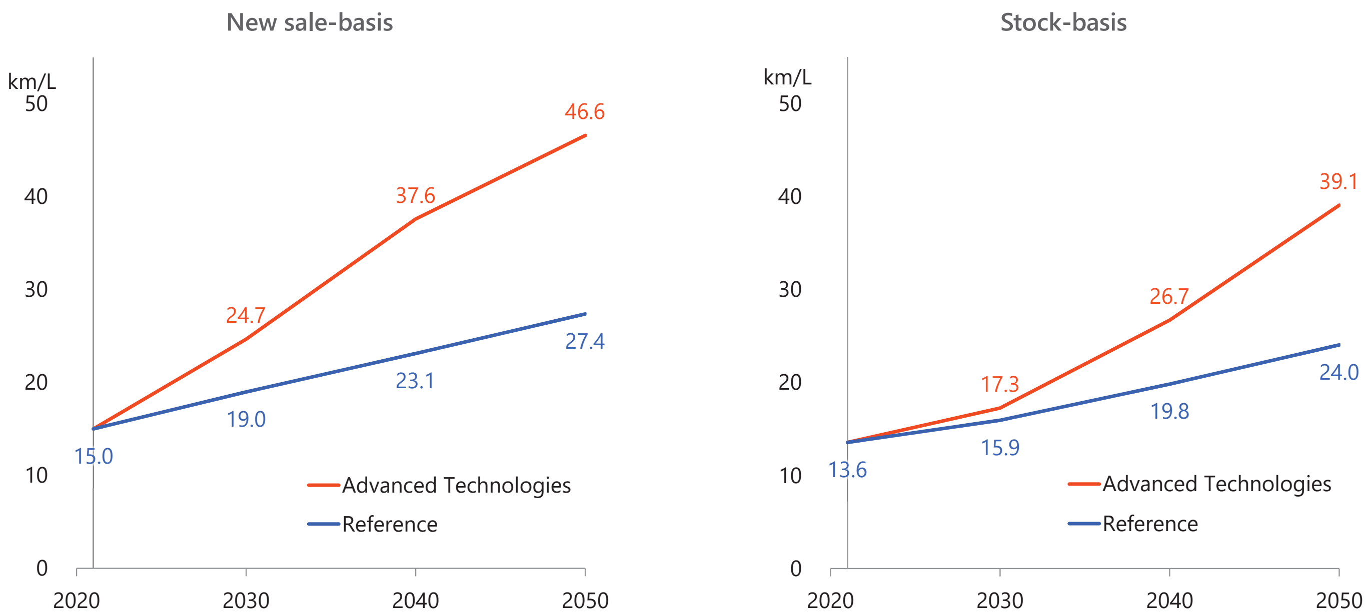
Advanced Technologies Scenario

Share of passenger vehicle



Advanced Technologies Scenario

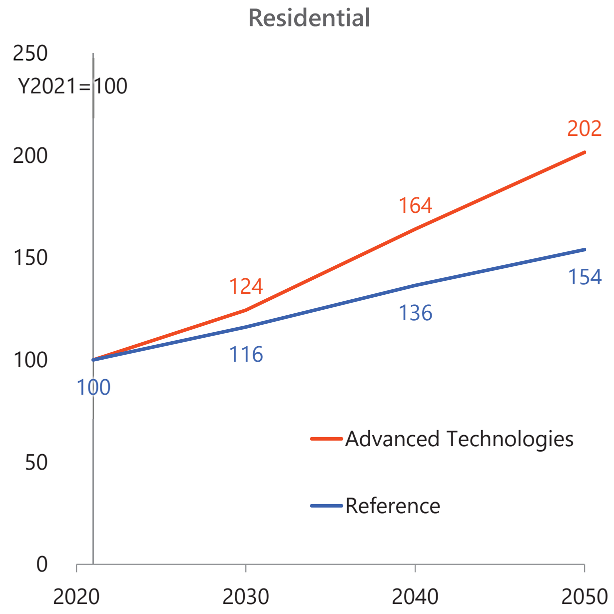
Fuel efficiency of passenger vehicle

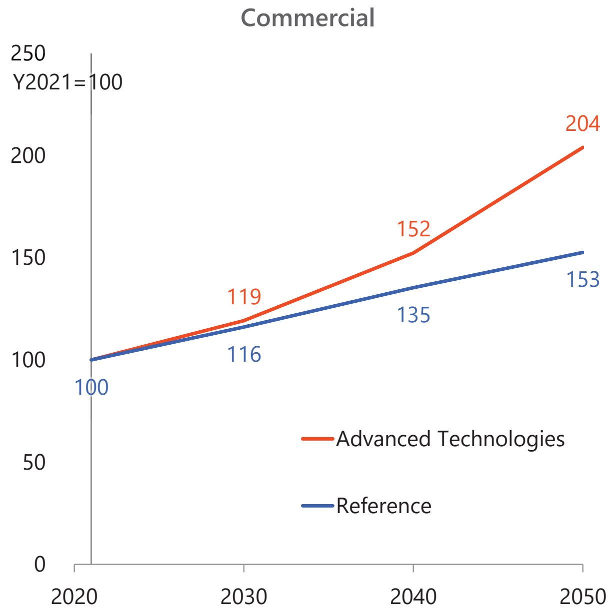


Note: Litres of gasoline equivalent

Advanced Technologies Scenario

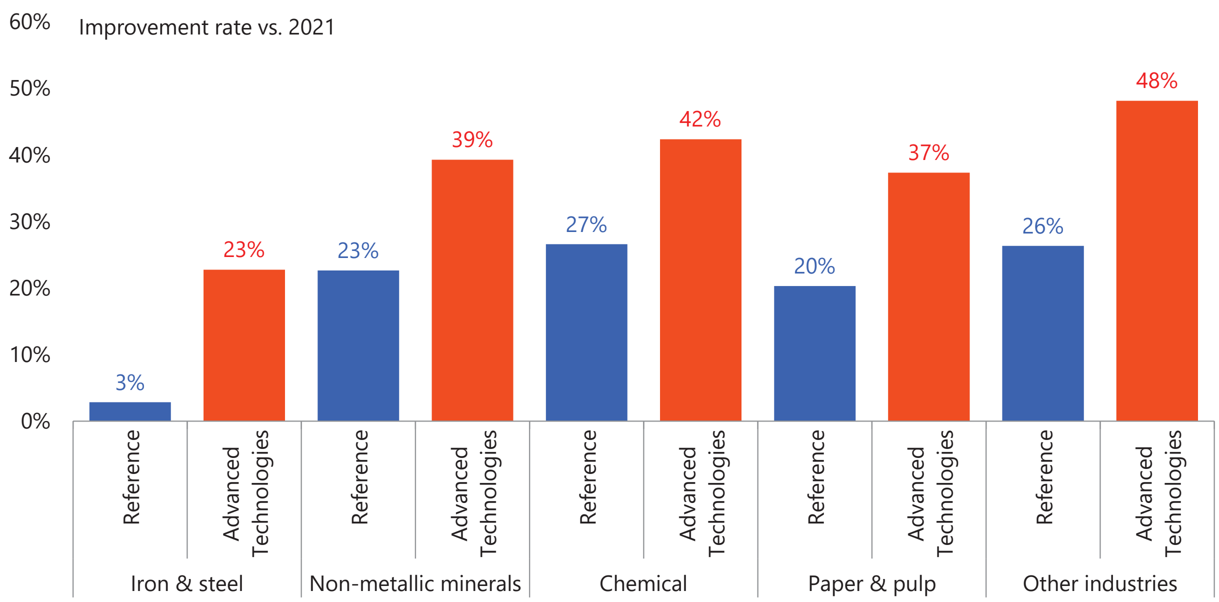
Energy efficiency in buildings sector



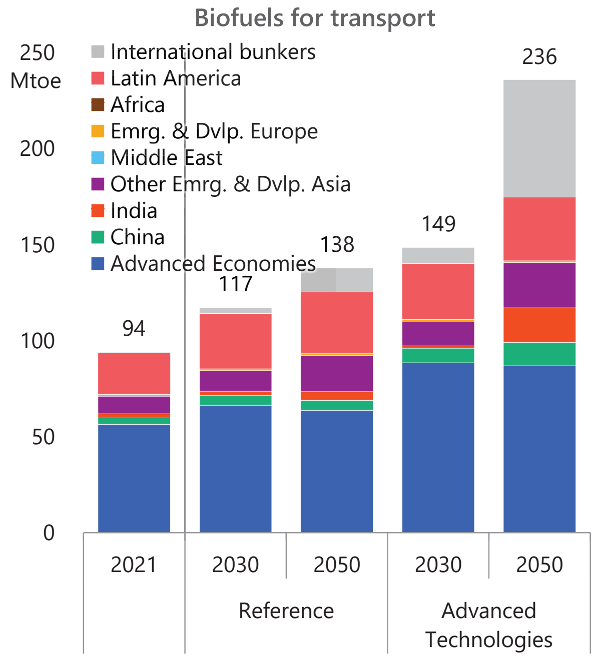


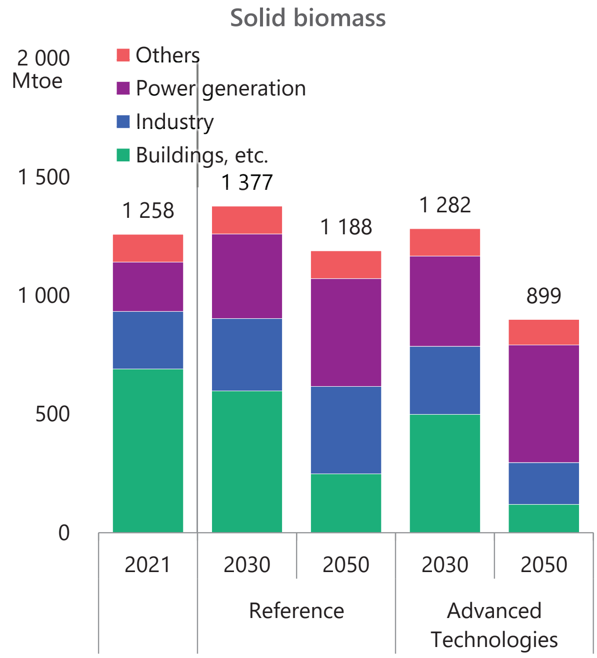
Advanced Technologies Scenario

Energy intensity improvement in industry sector

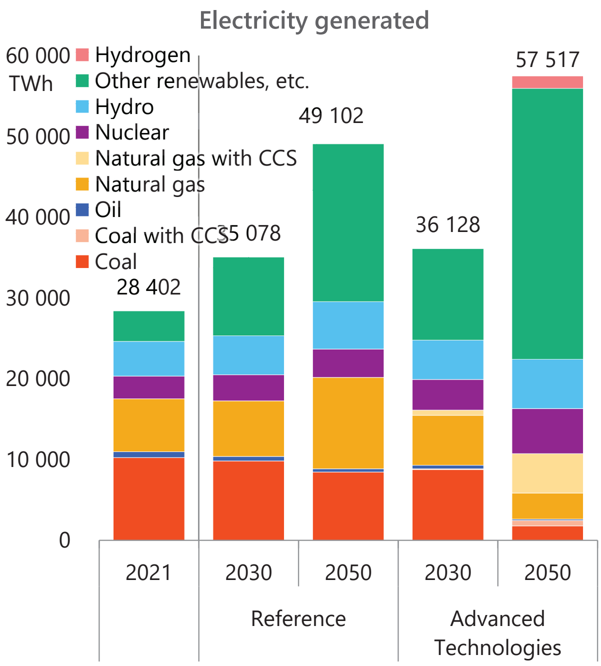


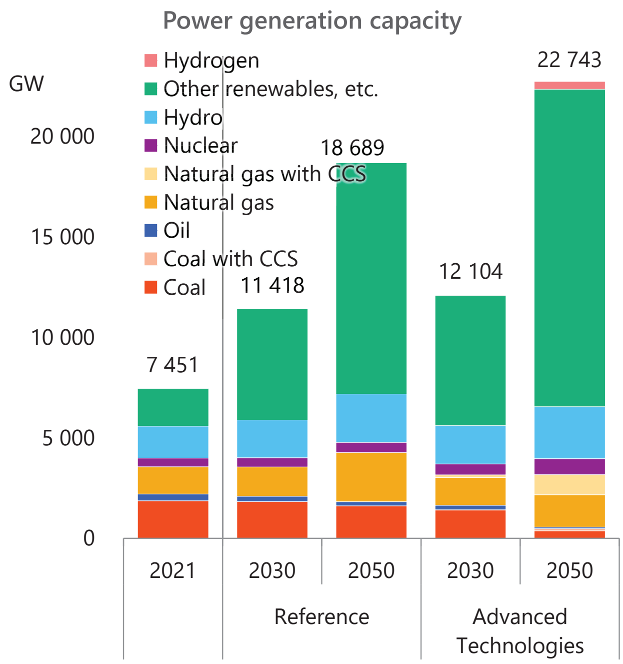
Biomass





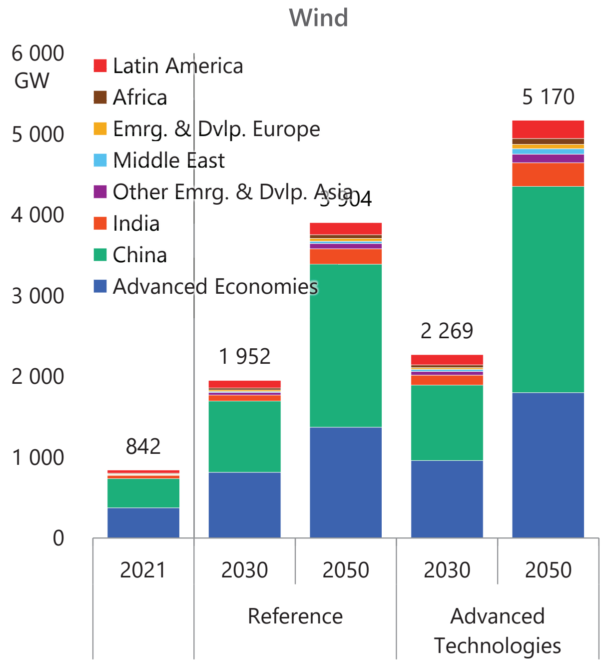
Power generation mix

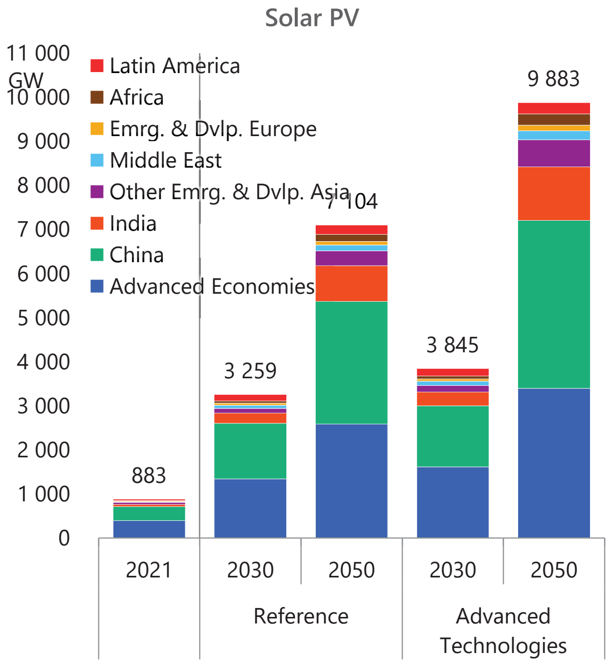




Advanced Technologies Scenario

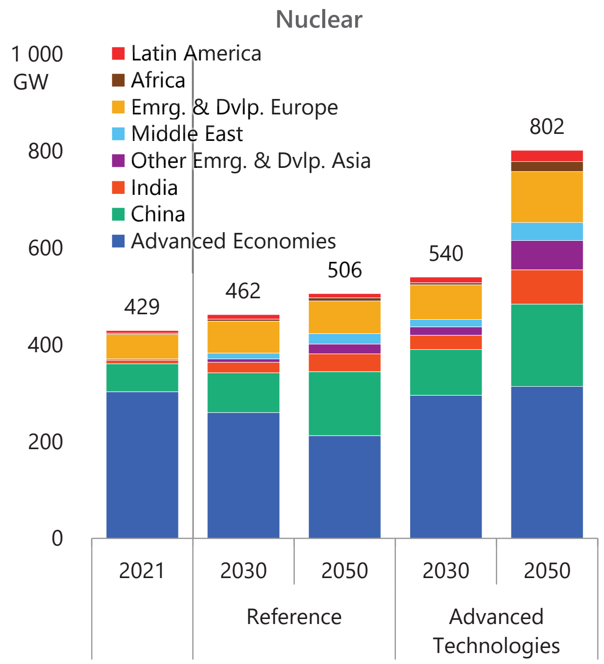
Wind and solar PV power generation capacity

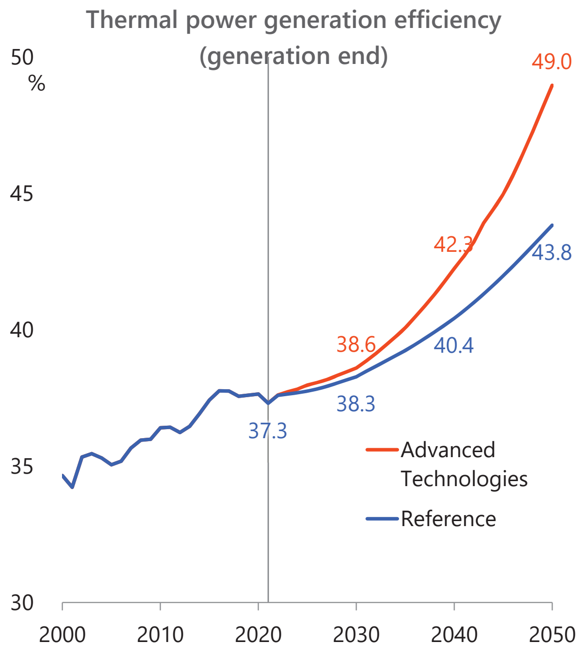




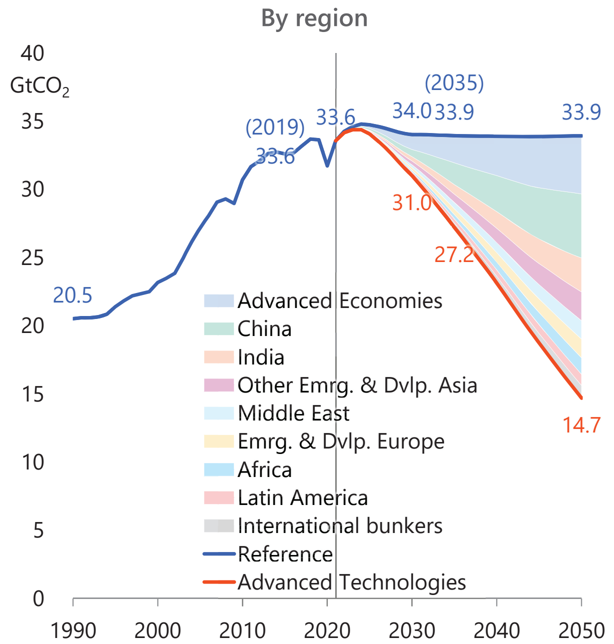
Advanced Technologies Scenario

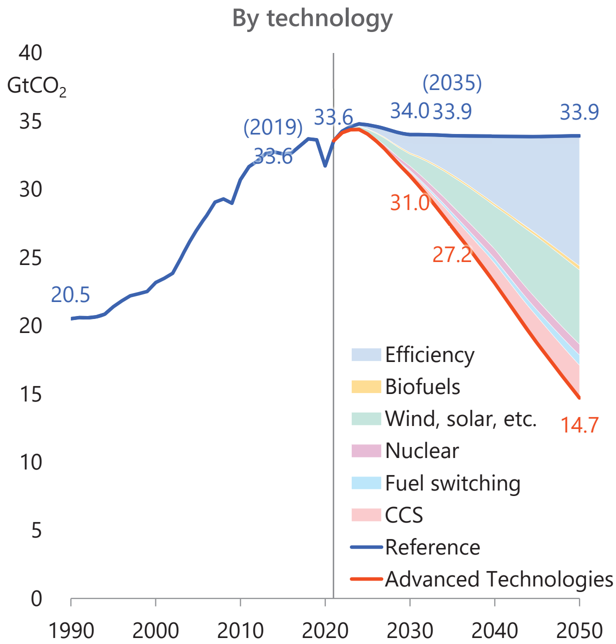
Nuclear power generation capacity and thermal power generation efficiency



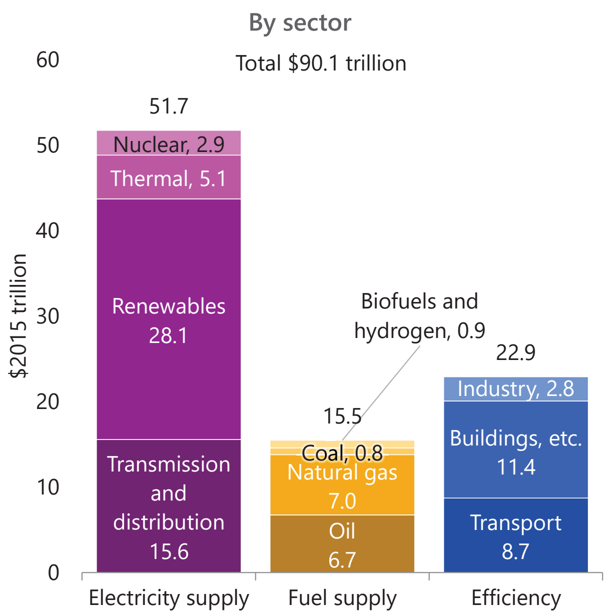


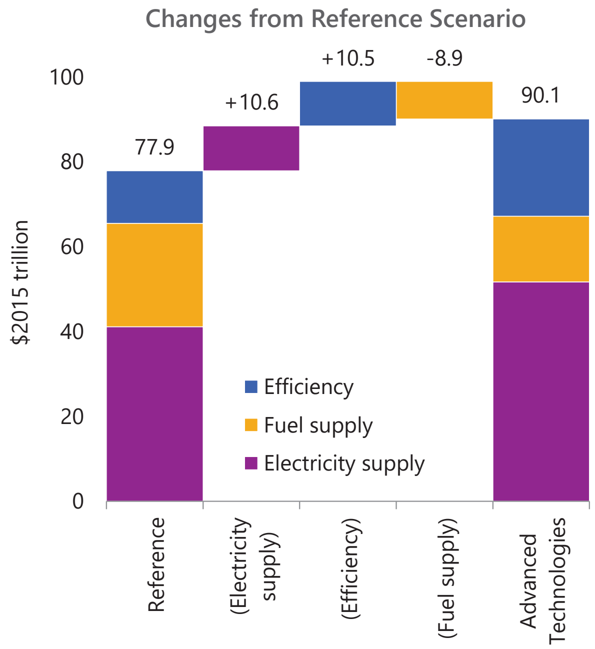
Energy-related CO_2 emissions





Energy-related investments (2022–2050)

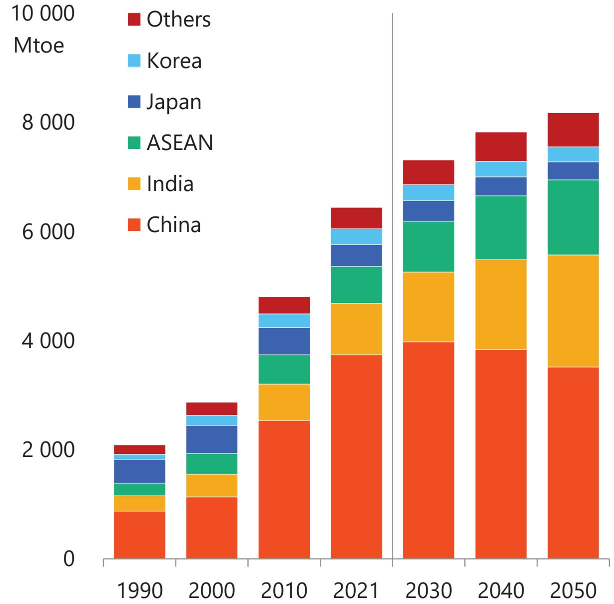




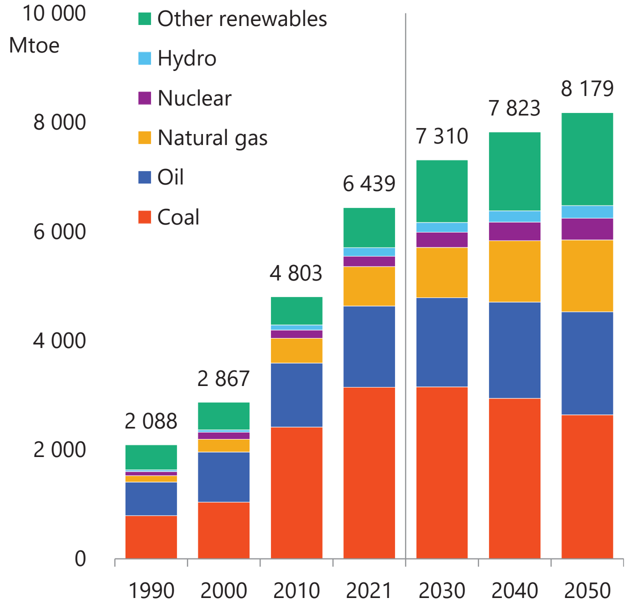
Asia Reference Scenario

Primary energy consumption

By region



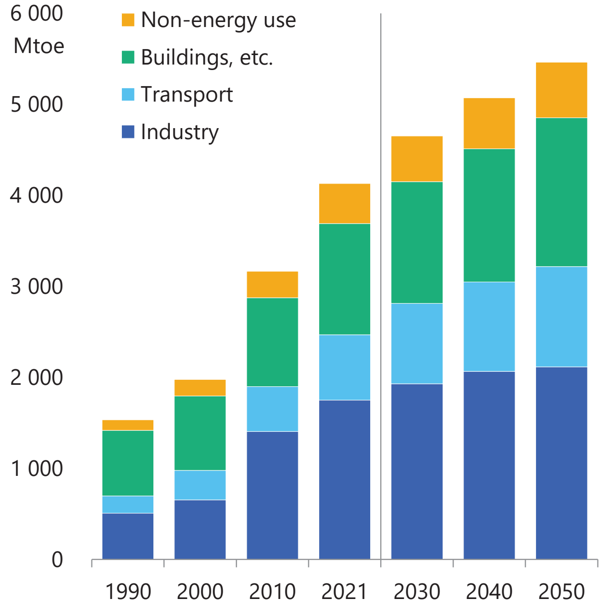
By energy source



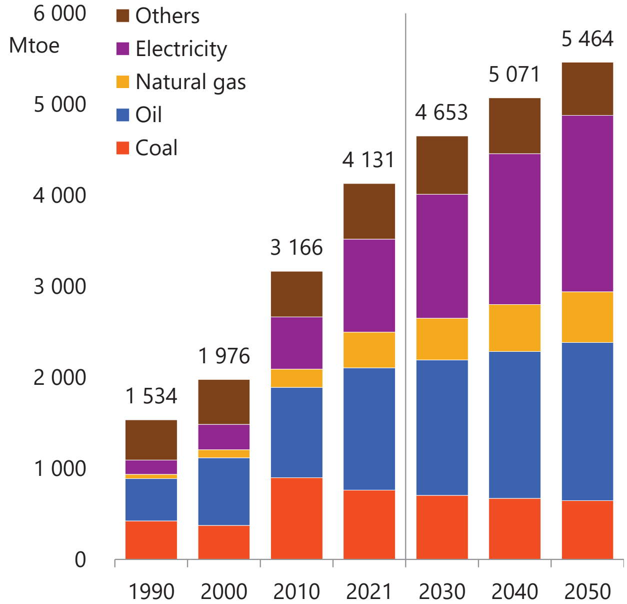
Asia Reference Scenario

Final energy consumption

By sector



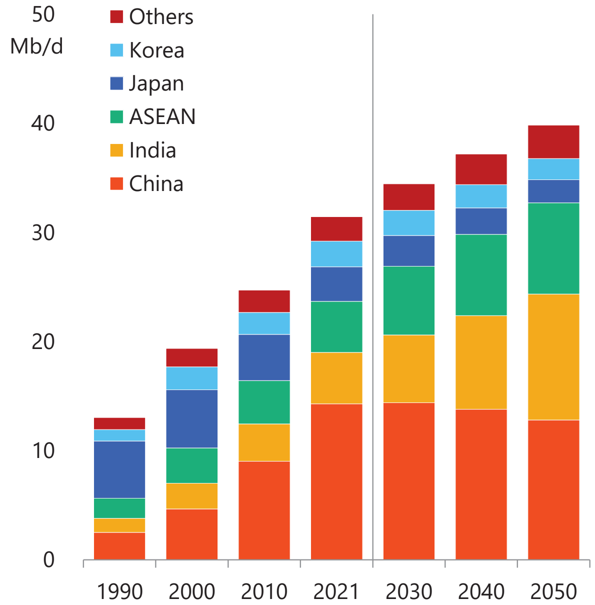
By energy source



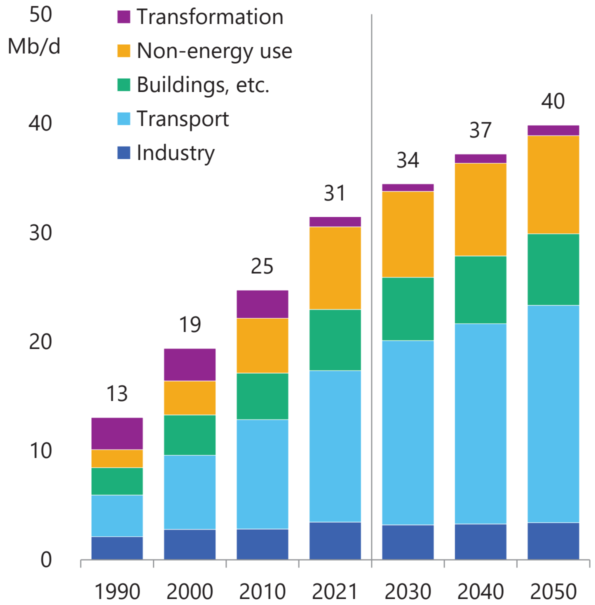
Asia | Reference Scenario

Oil consumption

By region



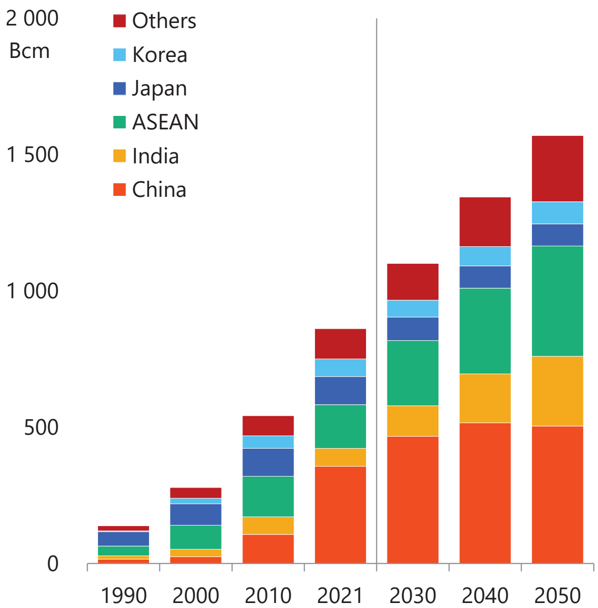
By sector



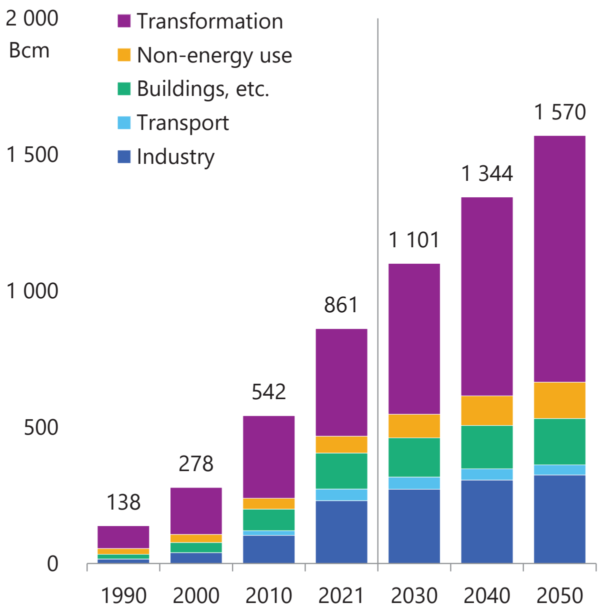
Asia | Reference Scenario

Natural gas consumption

By region

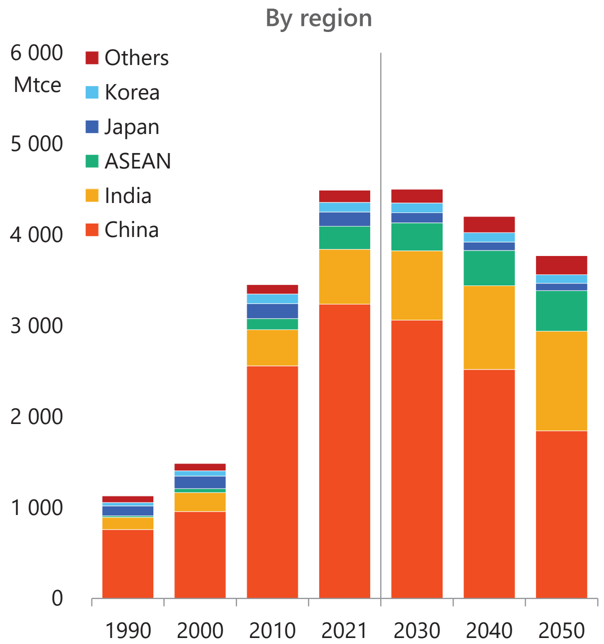


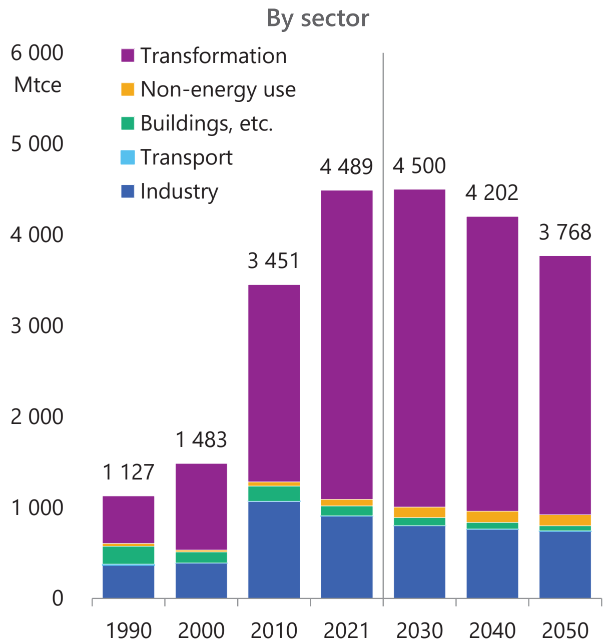
By sector



Asia | Reference Scenario

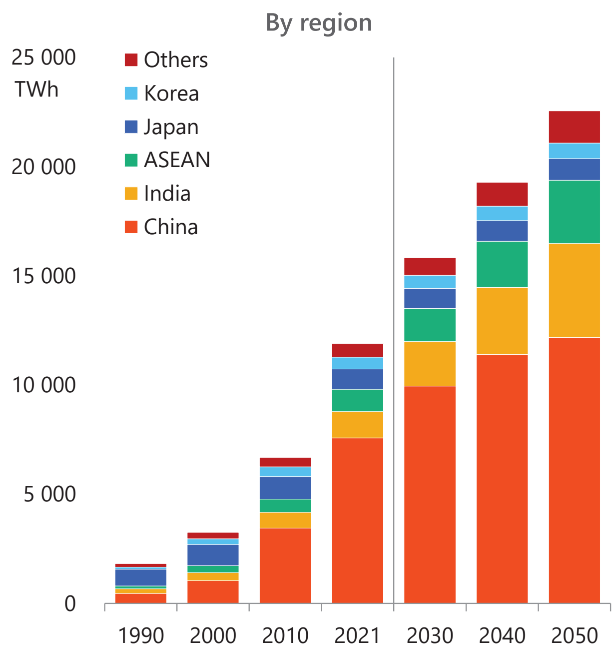
Coal consumption

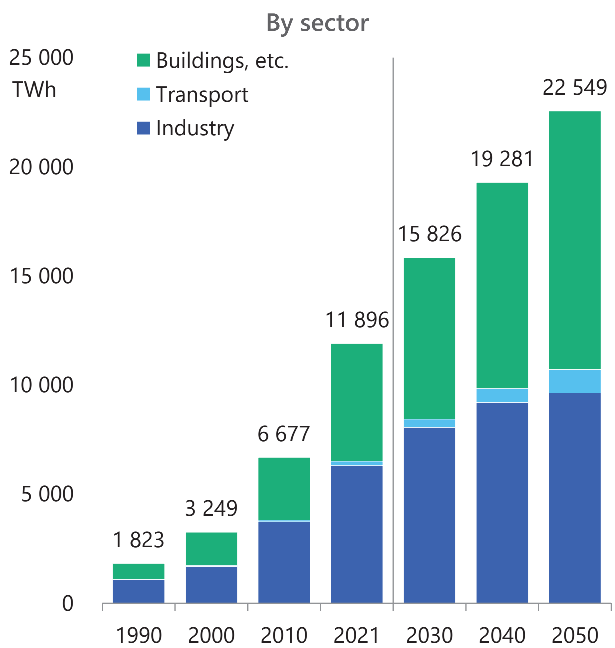




Asia | Reference Scenario

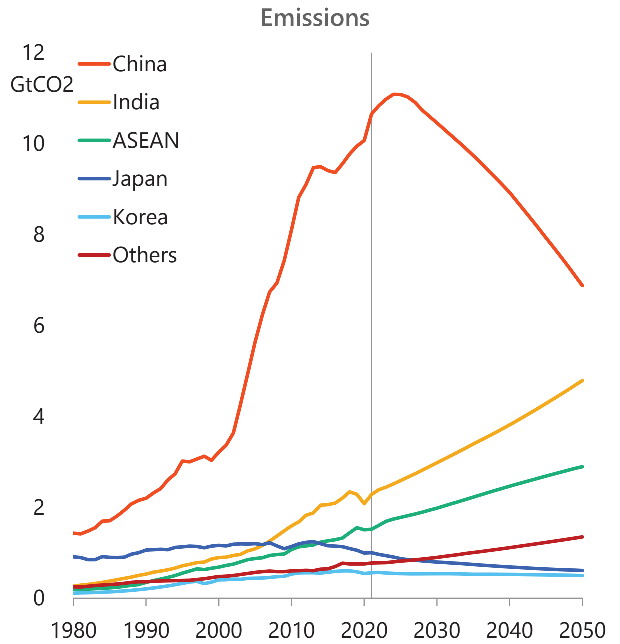
Final consumption of electricity

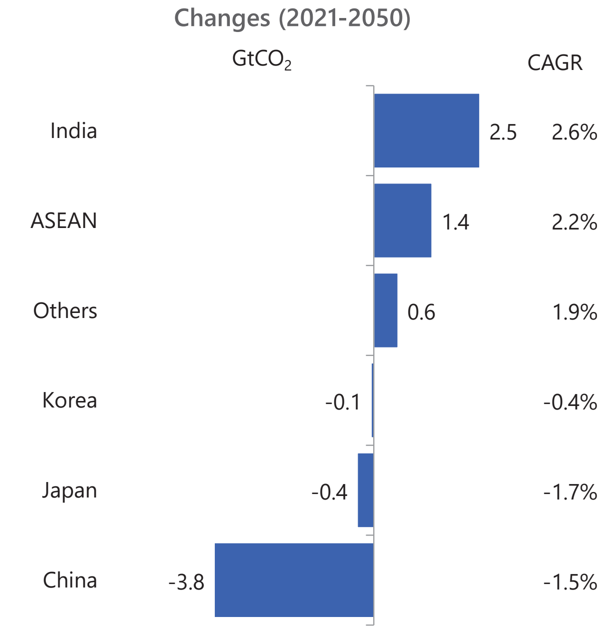




Asia Reference Scenario

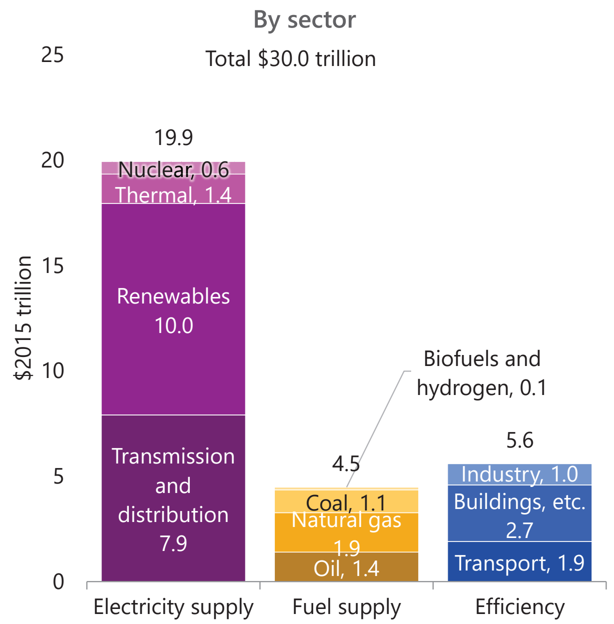
Energy-related CO_2 emissions

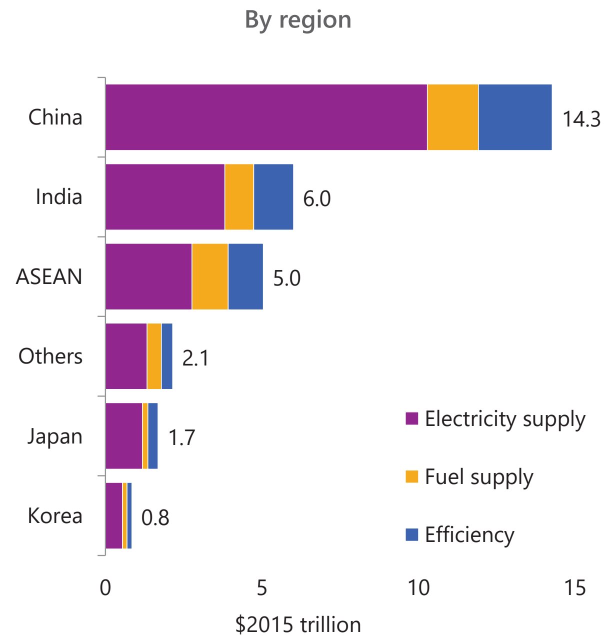




Asia Reference Scenario

Energy-related investments (2022–2050)

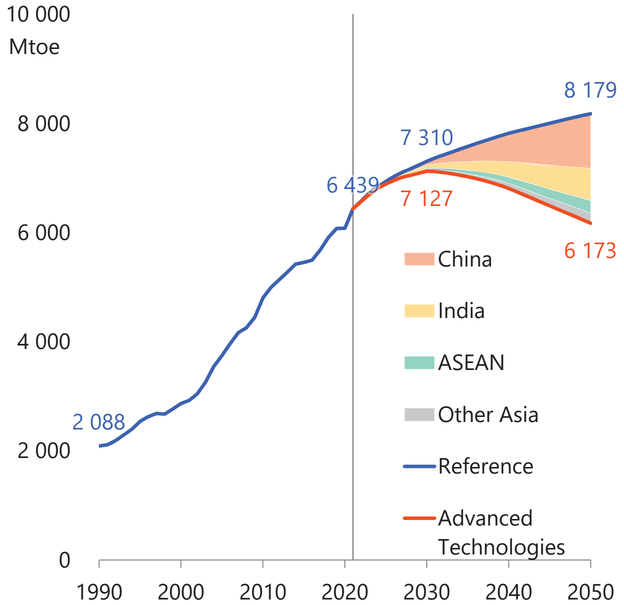




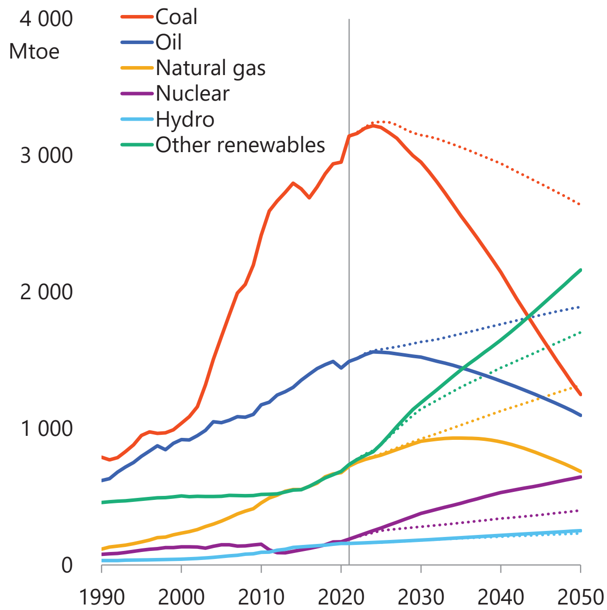
Asia | Advanced Technologies Scenario

Primary energy consumption

By region



By energy source

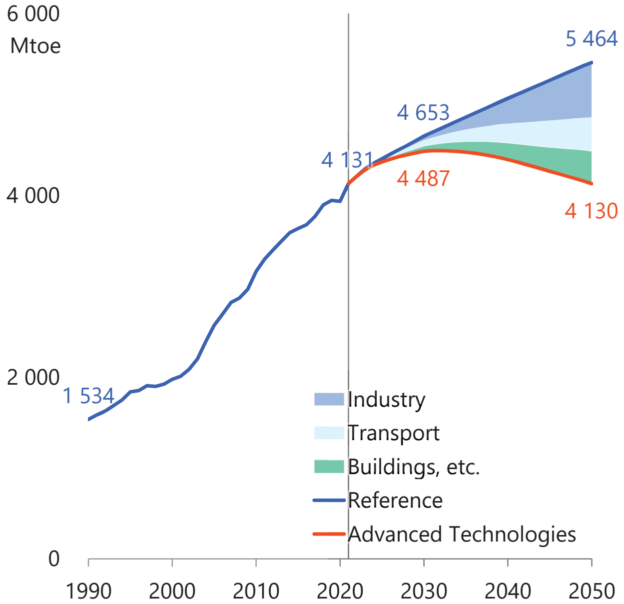


Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

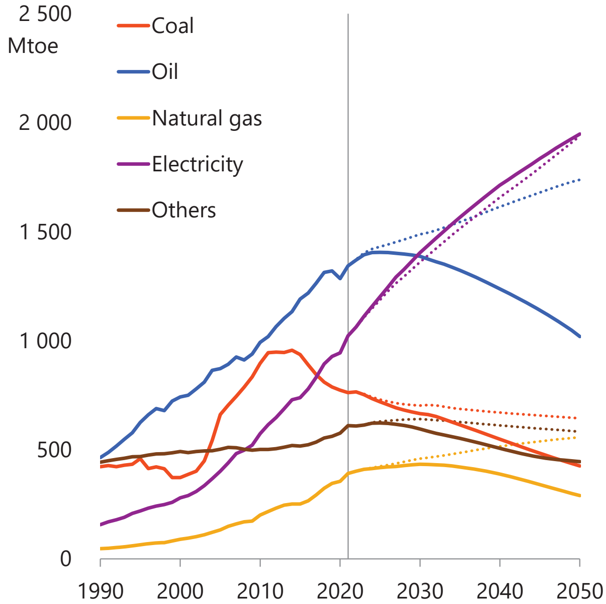
Asia | Advanced Technologies Scenario

Final energy consumption

By sector

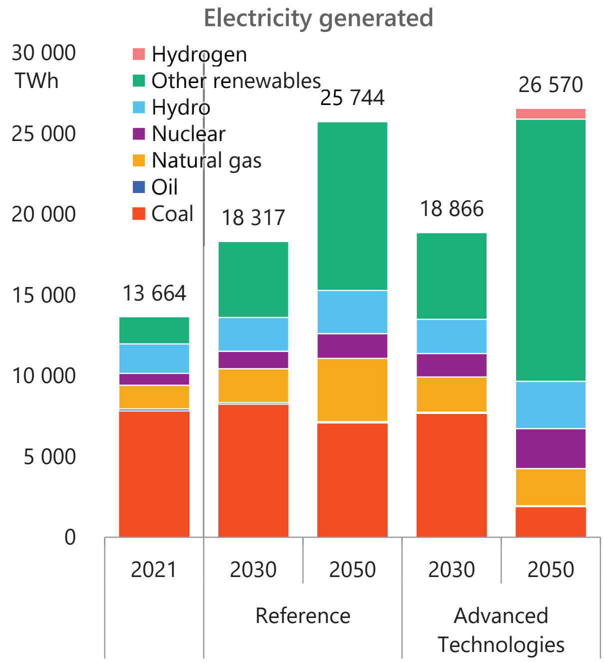


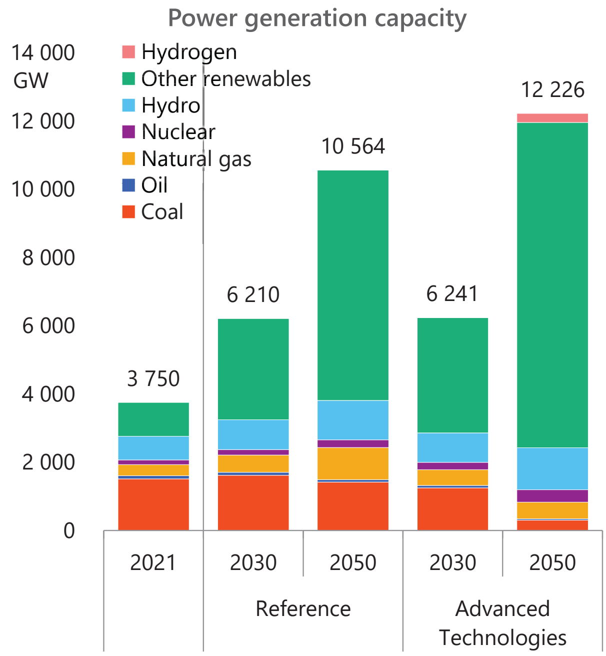
By energy source



Asia

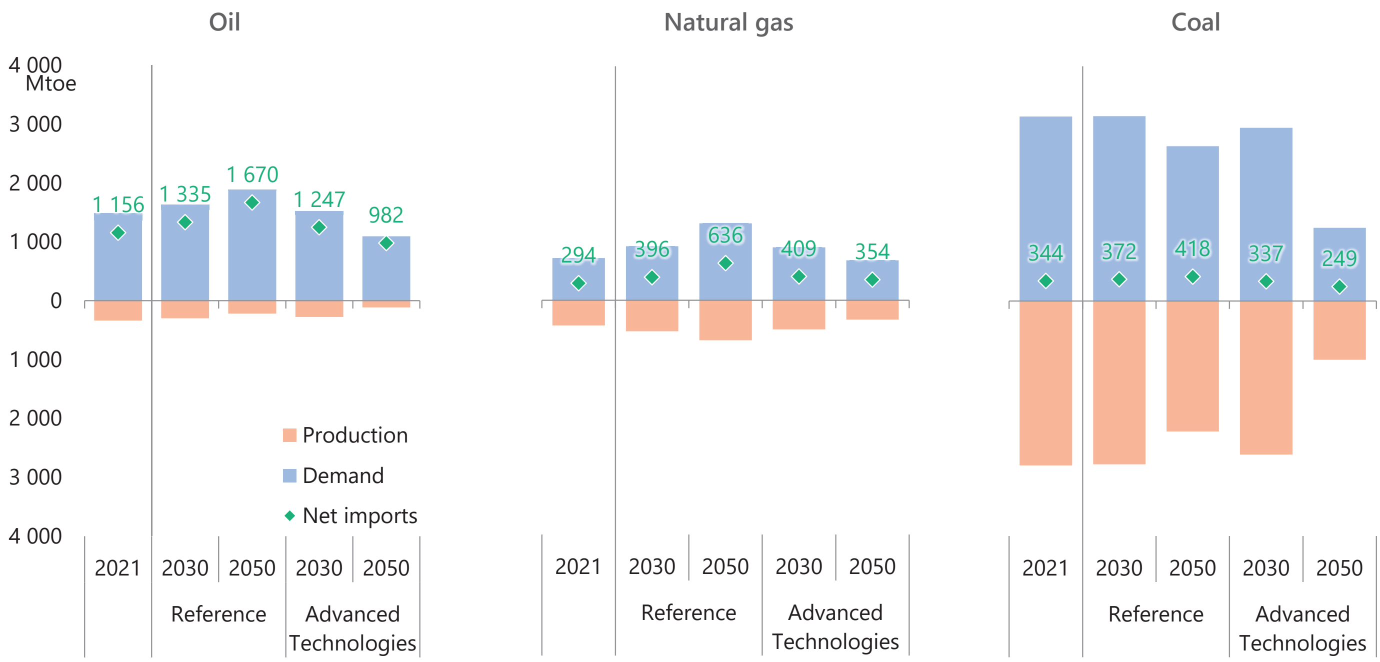
Power generation mix



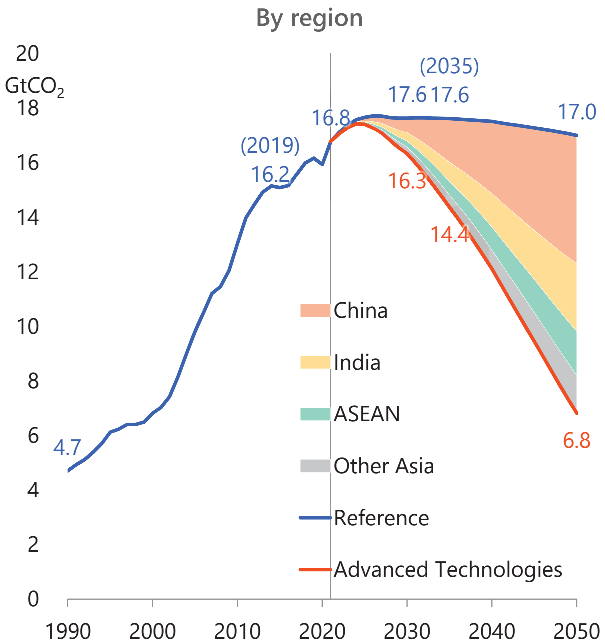


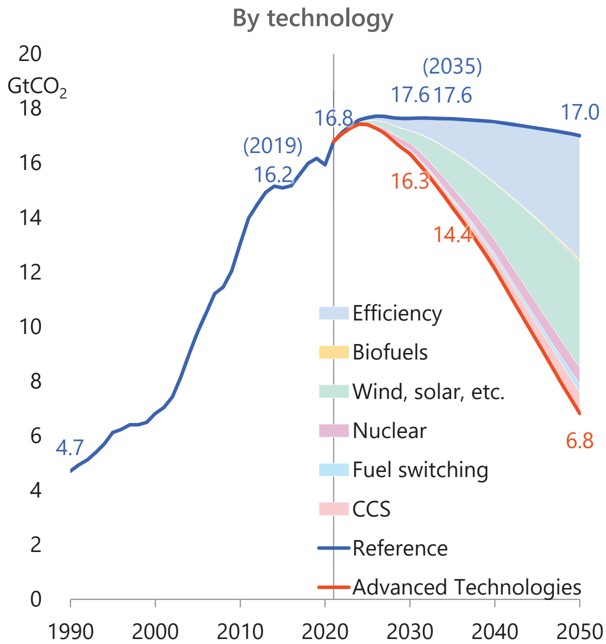
Asia

Supply and demand balance of fossil fuels

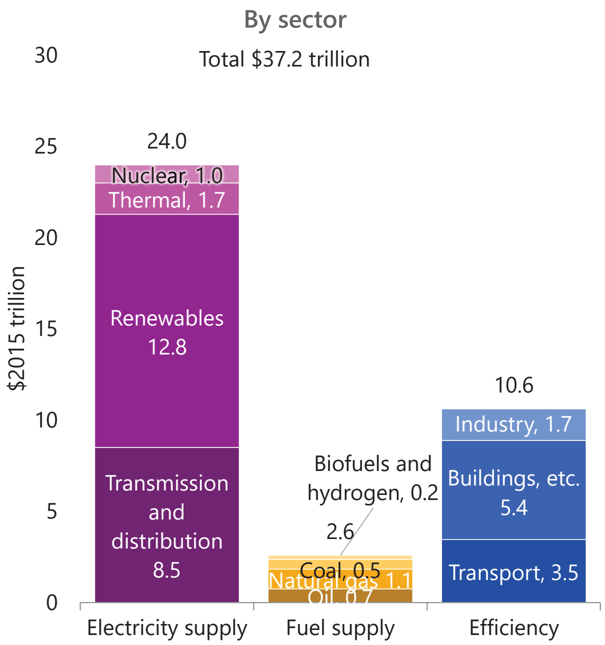


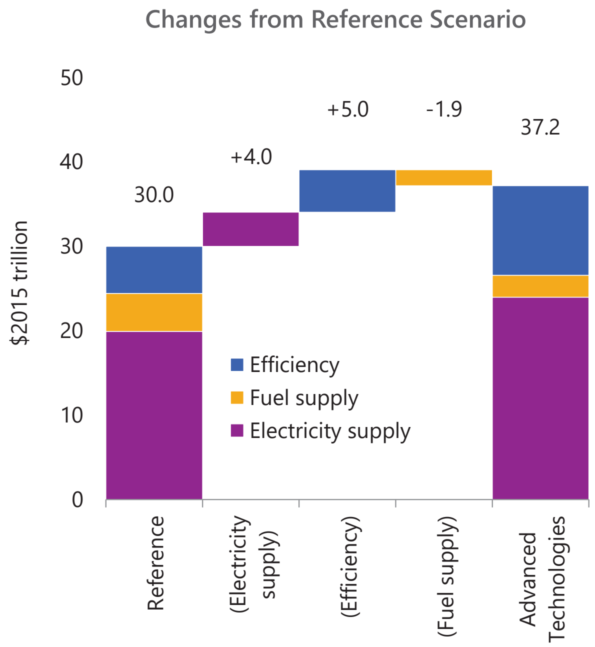
Energy-related CO_2 emissions





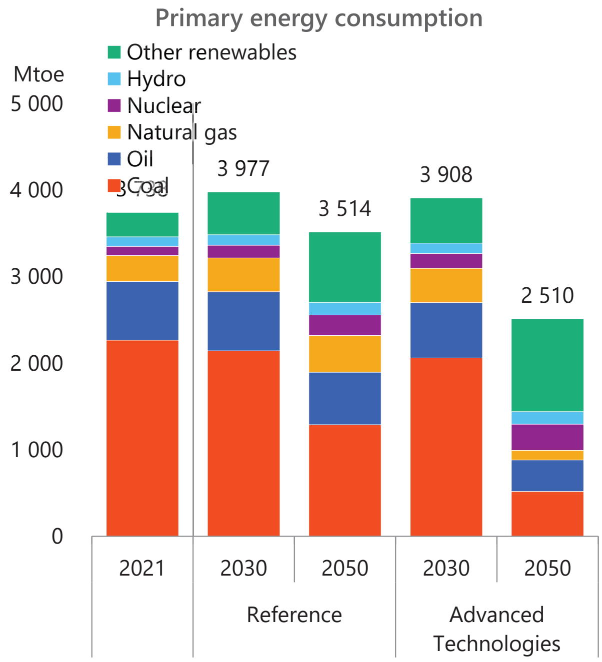
Energy-related investments (2022–2050)

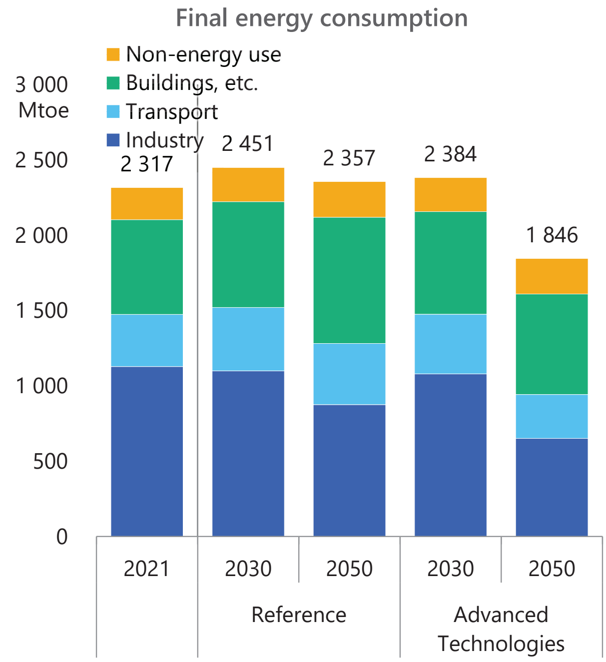




China

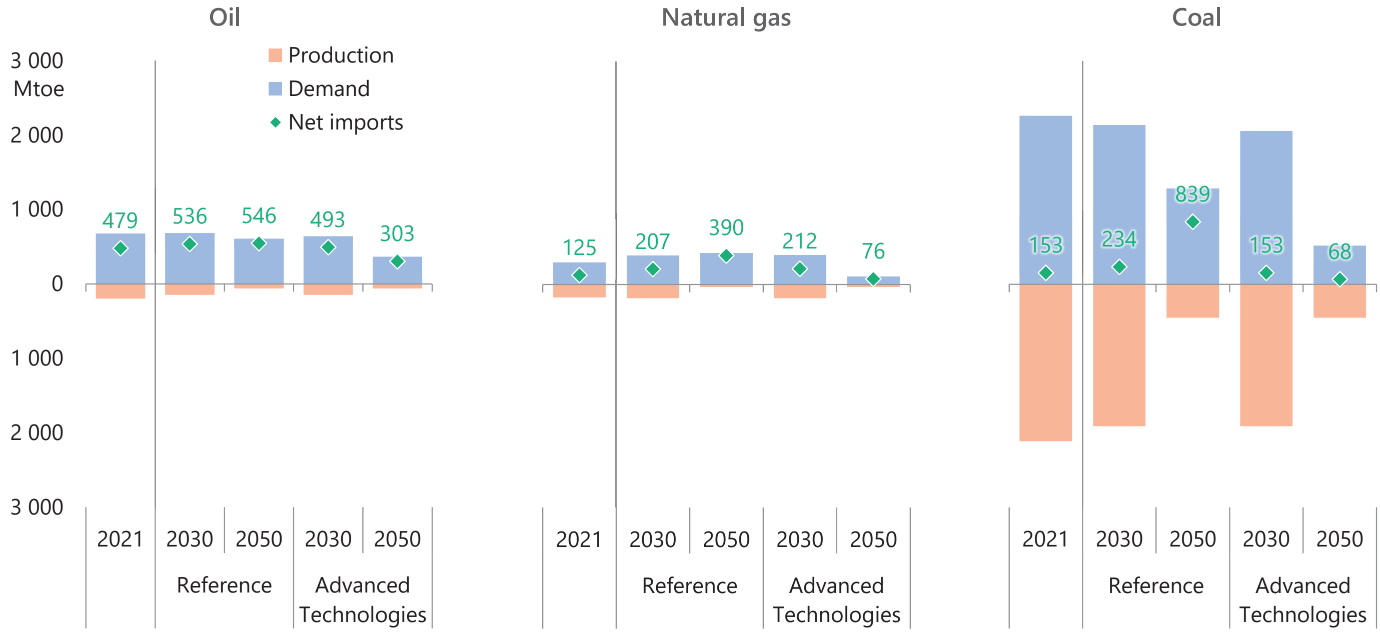
Energy consumption





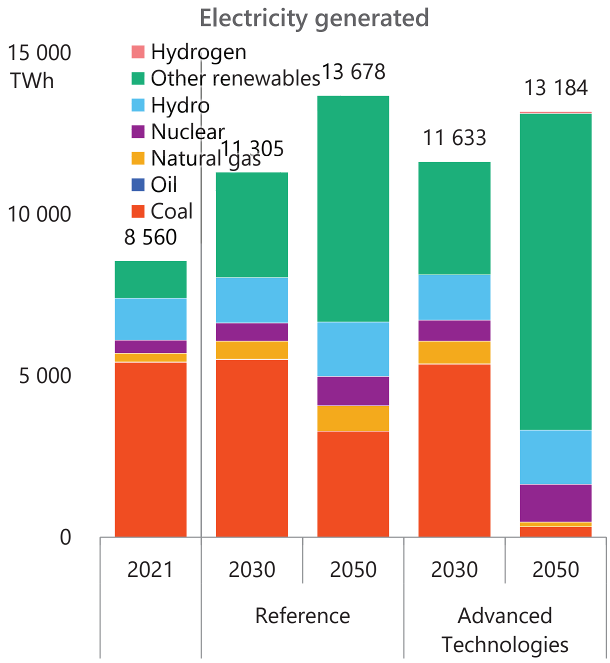
China

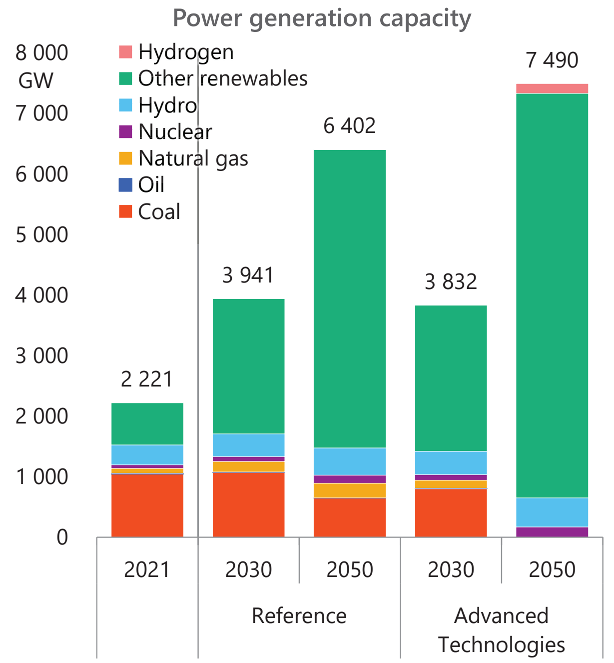
Supply and demand balance of fossil fuels



China

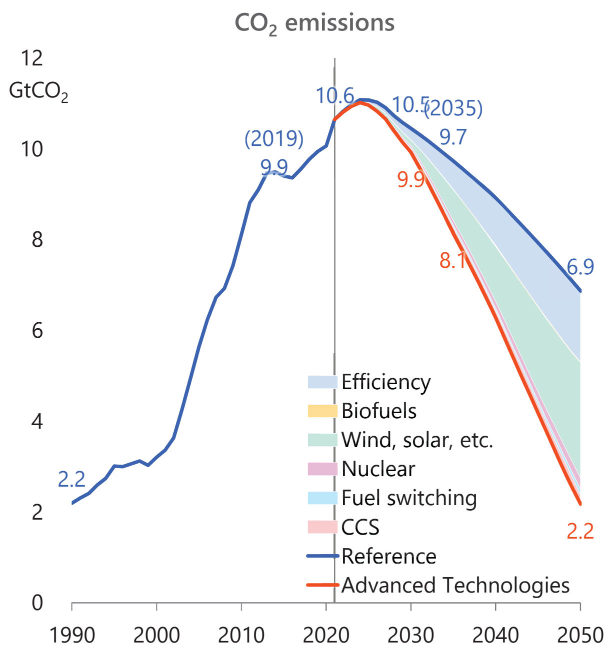
Power generation mix

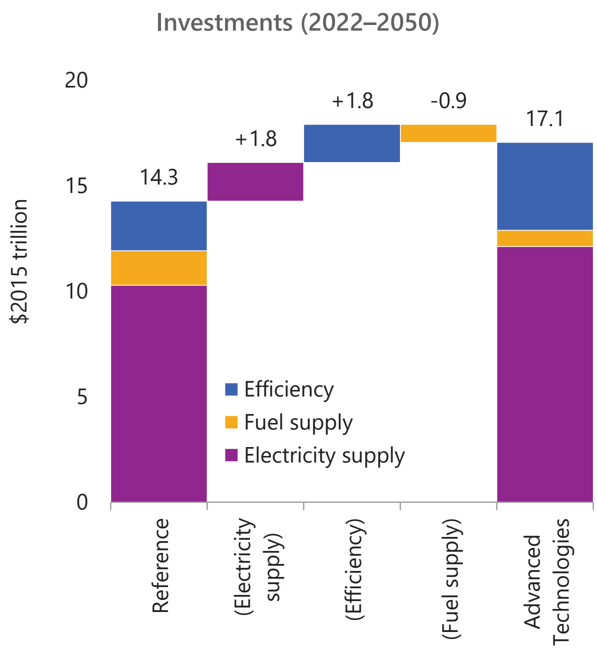




China

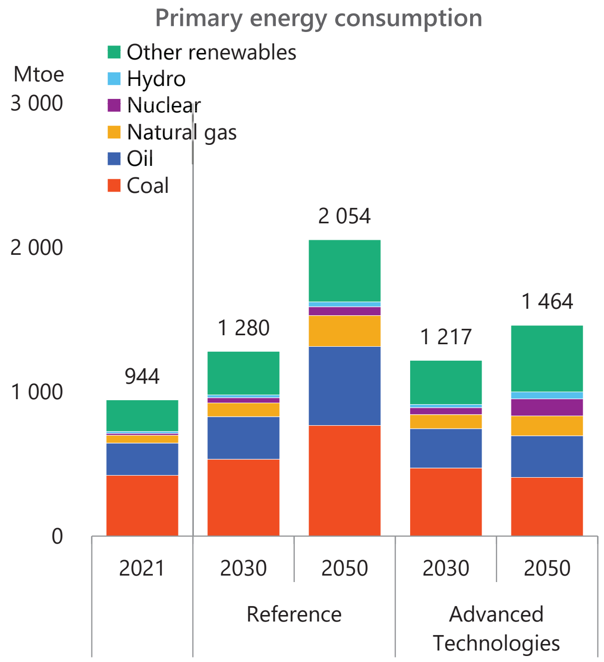
Energy-related CO_2 emissions and investments

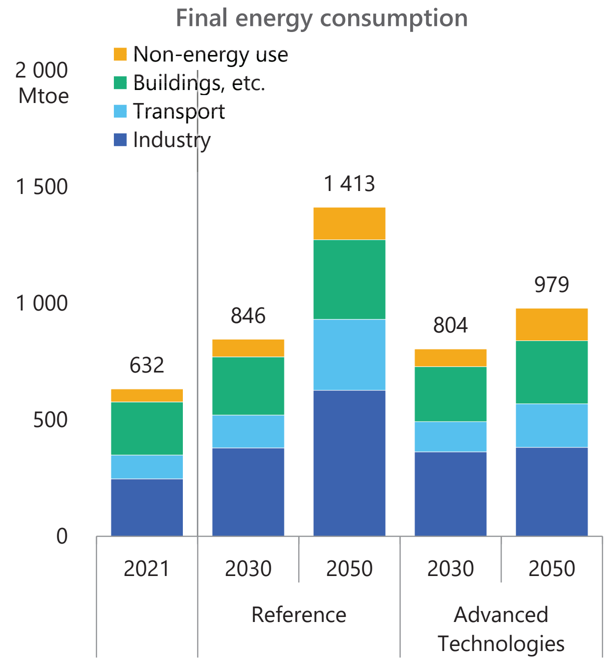




India

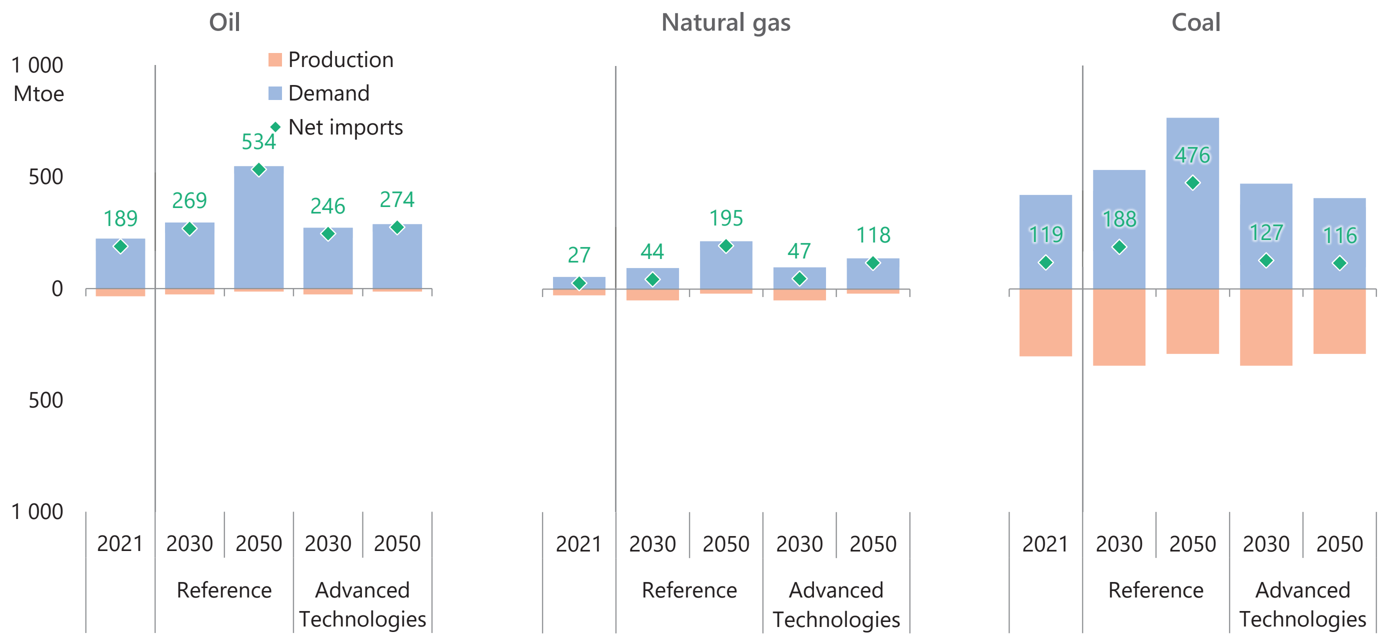
Energy consumption





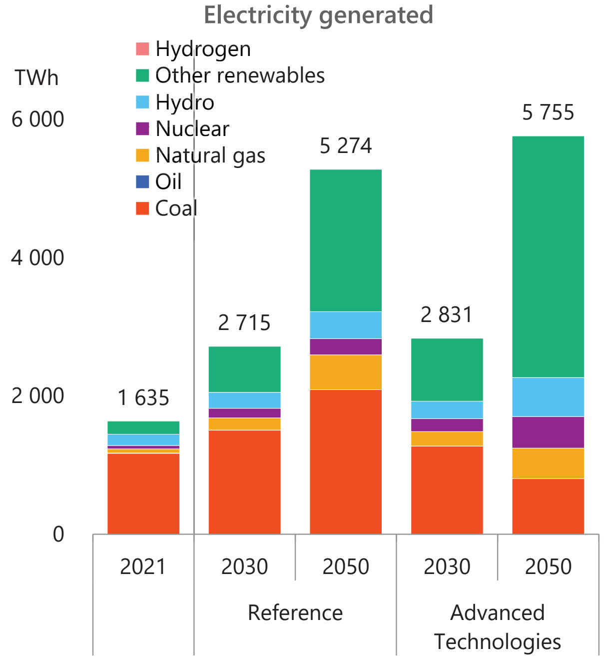
India

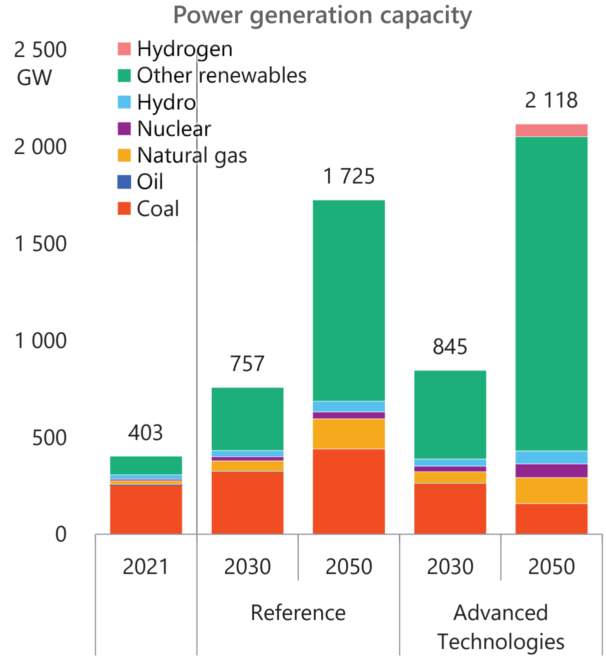
Supply and demand balance of fossil fuels



India

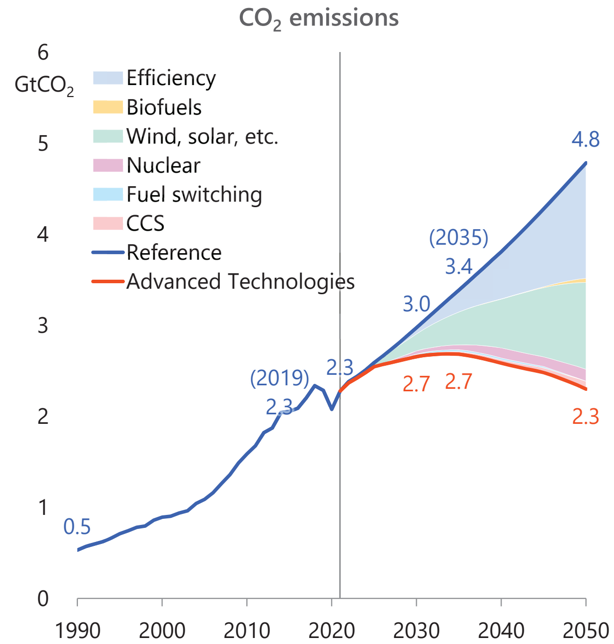
Power generation mix

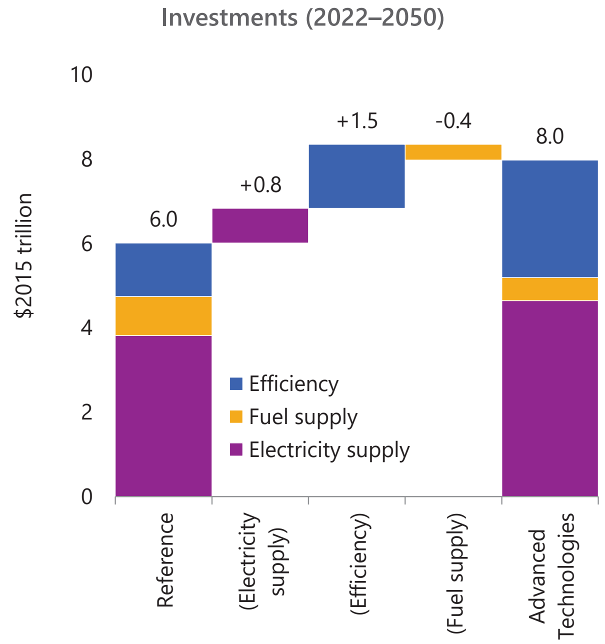




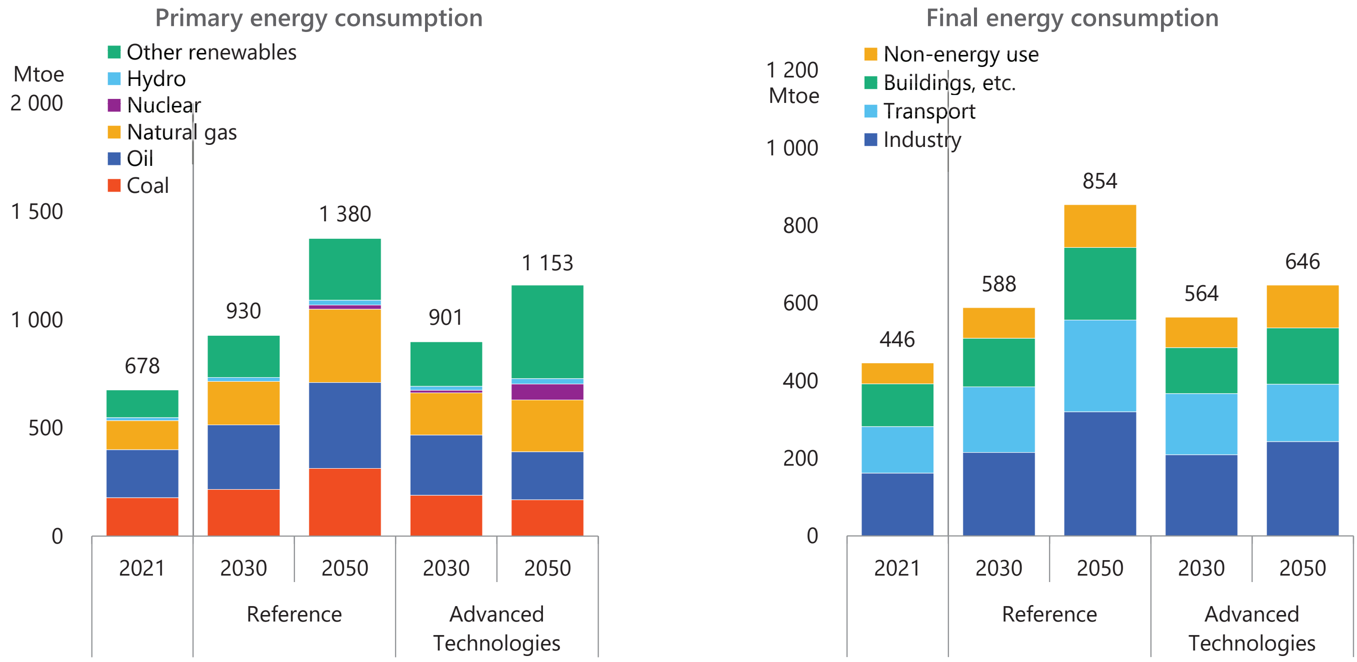
India

Energy-related CO_2 emissions and investments

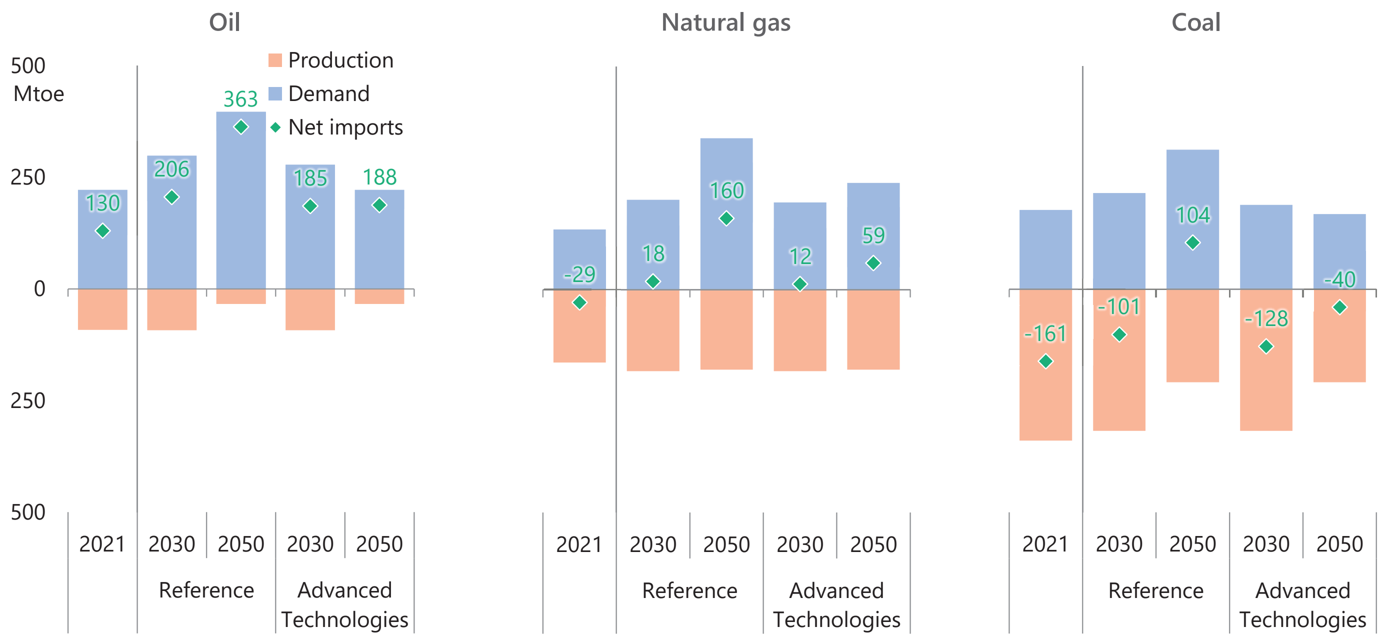




Energy consumption

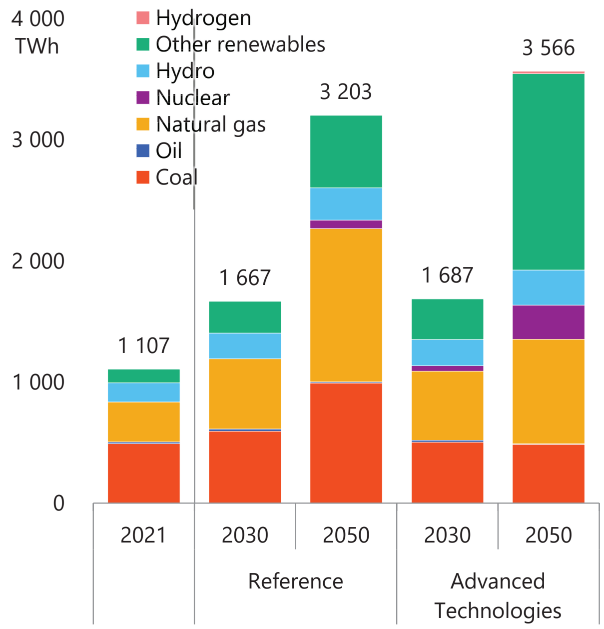


Supply and demand balance of fossil fuels

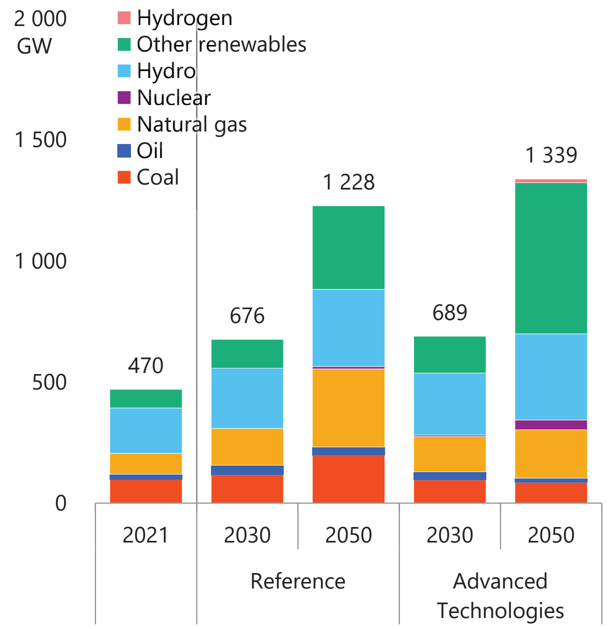


Power generation mix

Electricity generated

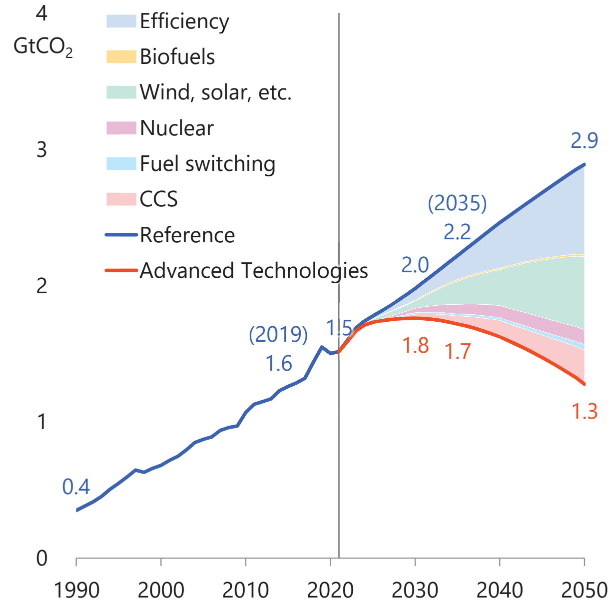


Power generation capacity

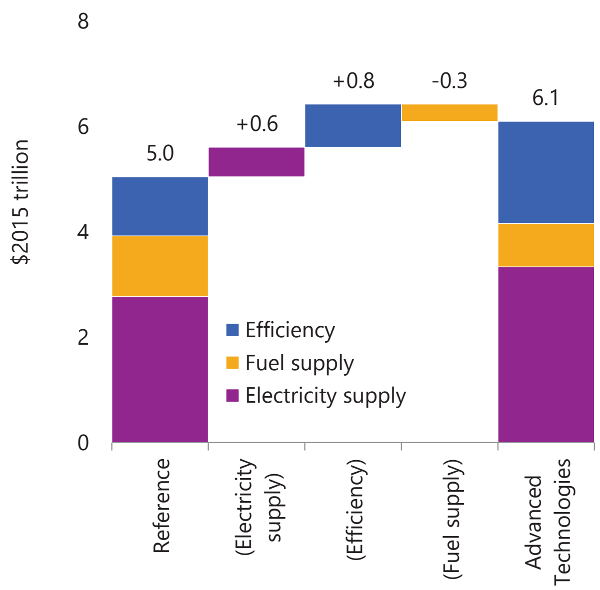


Energy-related CO_2 emissions and investments

CO_2 emissions



Investments (2022–2050)



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October 2023

The Institute of Energy Economics, Japan