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 incorporates the International Energy Agency's (IEA) energy balance tables, along with economic indicators, population data, vehicle ownership statistics, basic materials production and other energy-related information. We divided the world into 44 regions[2] plus international bunkers, as shown in Figure 1-1. We developed a detailed supply and demand analysis model for each region.

Figure 1-1 | Geographical coverage

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

We considered two main scenarios for the projections.

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 policy for a low-carbon transition deviating from past trends will be adopted.

Carbon capture and storage (CCS) is one of the most cutting-edge technologies, and support systems are being established for its commercialisation, primarily in advanced economies. Therefore, the IEEJ Outlook 2026 assumes the introduction of CCS in the relatively near future, around 2030, focusing on projects that are already in operation or under construction. Regarding hydrogen, which is expected to be a clean energy source, it is assumed that its use in power

[2] See Table A1 for a detailed definition.

generation will gradually increase, taking into account the commencement of hydrogen-ammonia co-fired power generation. However, its use in industry and transport is limited.

Advanced Technologies Scenario

In this scenario, all economies in the world are assumed to strongly implement energy and environmental policies contributing to securing stable energy supplies and strengthening measures against climate change and air pollution. These policies are assumed to achieve maximum effectiveness. Specifically, this scenario assumes widespread global implementation of advanced energy technologies as outlined in Figure 1-2, considering both their adoption potential and societal acceptance.

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

Introduction and enhancement of environmental regulations and national

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

Promoting technology development and international technology cooperation

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

Demand-side technologies

Industry

Global deployment of 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

Next-generation power transmission and distribution technologies

Low-loss substation equipment and voltage regulators

Note: SC stands for supercritical thermal power generation, USC for ultra-supercritical thermal power generation, A-USC for advanced ultra-supercritical thermal power generation, 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 influenced not only by the above-mentioned energy utilisation technologies and energy and environmental policies, but also by population, economic growth, other social and economic factors, and energy prices. The following economic growth

and population assumptions are common to both the Reference and Advanced Technologies Scenarios.

Economy

Recent situation

In 2024, despite concerns about stagflation and recession due to rapid global inflation in 2022, the global economy demonstrated solid growth. As we enter 2025, the growth momentum is slowing somewhat due to the growing impact of uncertainty on corporate investment and household consumption, caused by factors such as U.S. trade policies and rising geopolitical risks. The pace of economic recovery remains uneven across regions.

In the United States, with the inflation rate approaching the target of 2% through 2024, the Federal Reserve Board (FRB) announced a 0.5 percentage point cut to the policy interest rate in September 2024, followed by an additional rate cut towards the end of the year. In 2025, the economy has been buffeted by the policies of the new Trump administration. In response to the 'curious balance' of low levels of employment and layoffs (Federal Reserve Chairman Powell) caused by signs of an economic slowdown and increased crackdowns on illegal immigration, the FRB lowered interest rates for the first time in six months in September 2025. So far, the impact of the significant tariff hikes has not been as apparent as previously anticipated. However, this situation is not expected to last forever, and uncertainty remains regarding the future economy.

In Europe, inflation rates, which had remained high, have fallen to target levels. After lowering its policy interest rate in June 2024, the European Central Bank (ECB) implemented a total of eight rate cuts by June 2025, while the Swiss National Bank returned to a zero-interest rate policy in the same month. While the largest economy, Germany, is struggling with economic sluggishness, consumer sentiment is gradually improving in some countries where delayed economic recovery is finally progressing. However, significant risks remain, such as the prolonged Russian invasion of Ukraine and uncertainty surrounding energy supplies, necessitating caution regarding the future.

In China, under the government's 'high-quality development' strategy announced in 2024, exports of high-tech products such as electric vehicles (EVs) and semiconductors are increasing, while also creating trade friction, including over other goods. Nevertheless, growth is slowing due to sluggish domestic demand and a stagnant real estate market. The government continues to implement monetary easing measures, such as cuts to the reserve requirement ratio and the loan prime rate, but these have failed to improve consumer sentiment. Amid structural challenges such as population decline and deflationary pressures, growth is expected to continue slowing.

India has maintained a relatively high economic growth rate, supported by strong private consumption, a recovery in exports, higher value added in services, and expanded infrastructure investments. Partly due to high tariffs imposed by the United States, India is trying to boost growth by simplifying its value-added tax, effectively lowering the tax rate. With its population growth and progress in digitalisation, India is expected to further strengthen its position as a growth engine for the global economy.

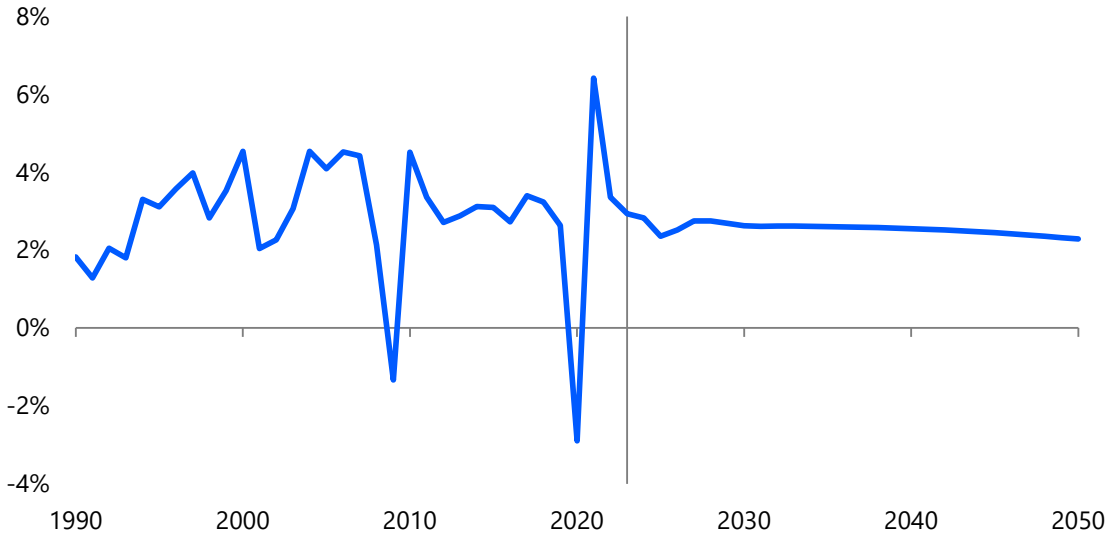
Assumptions for the future

Based on country-by-country economic development plans and economic outlooks prepared by think tanks around the world, we assume economic growth as follows:

The global economy will slow to a growth rate of 2.4% in 2025, the lowest since the COVID-19 pandemic, driven by factors such as U.S. tariff policies. The growth rate will recover over the next

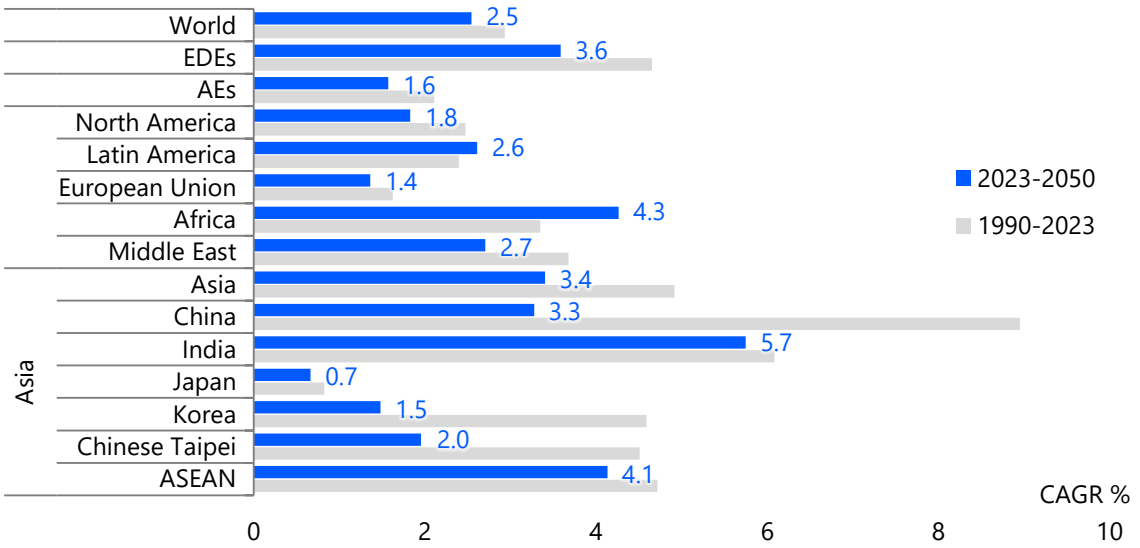
few years, but is expected to gradually decline towards 2050, transitioning from the upper to the lower 2% range (Figure 1-3). Russia's prolonged invasion of Ukraine will not cause significant damage to the global economy as a whole, although it will have localised and short-term effects. Meanwhile, concerns are growing over rising costs and market contraction resulting from supply chain restructuring driven by U.S. policy. For many economies to achieve sustained economic growth, it is essential to enhance productivity, promote technological innovation, implement appropriate fiscal, monetary and redistribution policies, strengthen international cooperation and ensure security.

Figure 1-3 | World economic growth



Advanced Economies will experience slightly weaker growth compared to historical trends, maintaining a growth rate of 1.6% per annum (Figure 1-4). Emerging and Developing Economies will also slow down, but their growth rate will be more than double that of Advanced Economies, at 3.6%. India, in particular, will achieve one of the world's highest growth rates at 5.7%, albeit a slowdown from its post-1990 performance (6.1%). China's slowdown will continue, with the growth rate at 3.3%, below the average for Emerging and Developing Economies. Both Africa and the Association of Southeast Asian Nations (ASEAN) will achieve growth in the low 4% range.

Figure 1-4 | Economic growth in the world and selected economies/regions

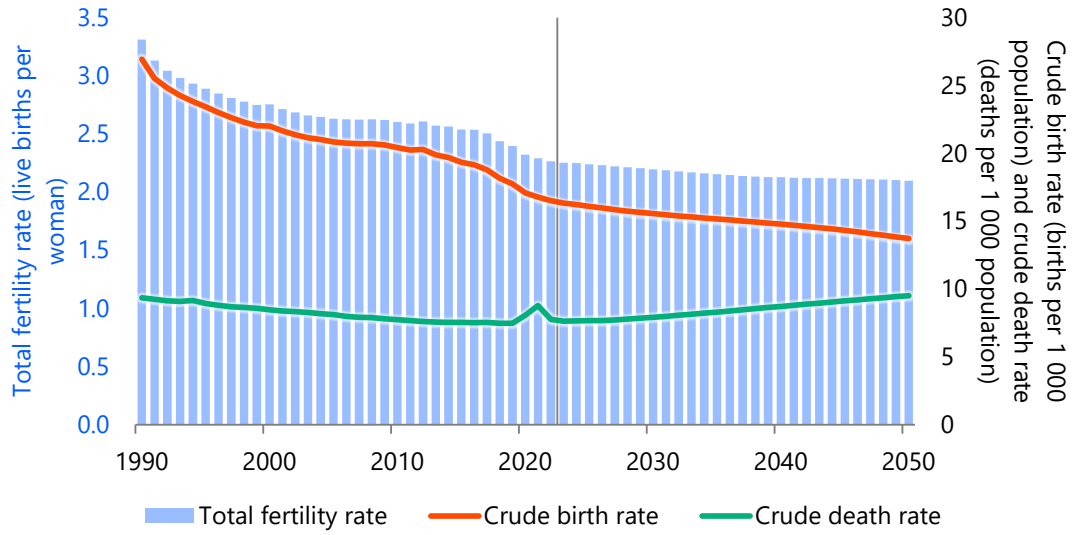


Notes: AEs stands for Advanced Economies. EDEs stands for Emerging and Developing Economies.

Population

For population assumptions, we referenced the United Nations' 'World Population Prospects'. In many Advanced Economies, the total fertility rate (TFR), which is the average number of children born to a woman during her lifetime, has fallen significantly below 1.7. Emerging and Developing Economies are also experiencing declining TFRs, corresponding to income growth and increased female participation in education and the workforce. Thanks to medical technology advancements and improved food and sanitary conditions, the rapid rise in mortality rates observed during the COVID-19 pandemic subsided by 2023, but the rates are expected to increase gradually in the medium to long-term due to the ageing population (Figure 1-5).

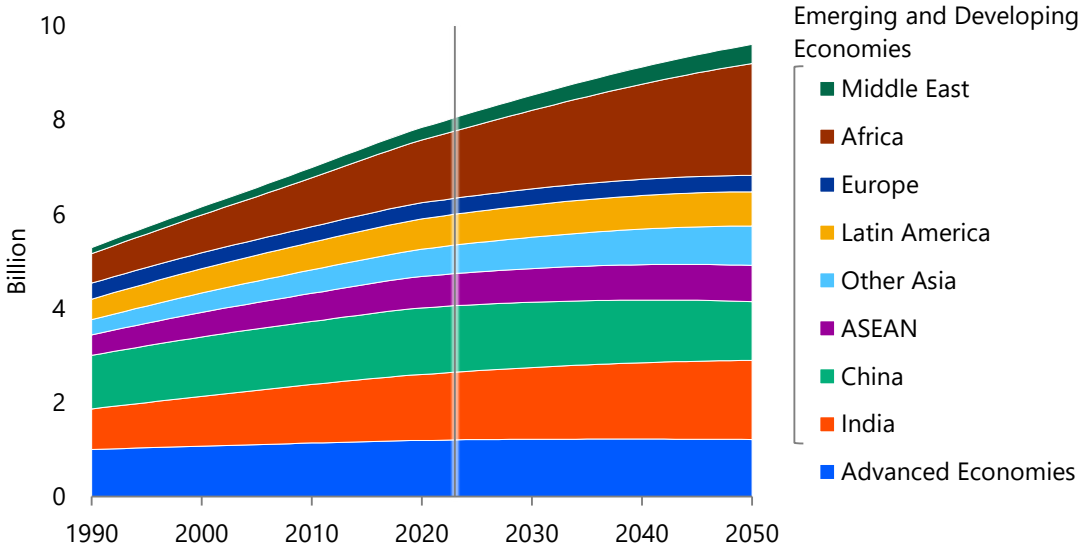
Figure 1-5 | World total fertility rate, crude birth rate and crude death rate



Source: United Nations 'World Population Prospects 2024'

As a result of this global trend toward declining birthrates and population ageing, population growth will continue, but the pace is expected to gradually slow, with the average annual growth rate at 0.7%. As a result, the world population, which was 5.3 billion in 1990 and 8.1 billion in 2023, will reach 9.5 billion by 2050 (Figure 1-6).

Figure 1-6 | Population



Among Advanced Economies, North America, particularly the United States, will experience relatively steady population growth due to substantial immigration and a comparatively high TFR, reaching 417 million by 2050[3]. However, the increase will be moderate, resulting in a slight decline in the United States' share of global population. The European Union's population will peak in the early 2020s, partly due to immigration resulting from the invasion of Ukraine, before beginning to decline, reaching 426 million by 2050. In Asia, Japan's population began decreasing in 2011 and will decline by approximately 15% from 2024 levels to 105 million by 2050. Korea's population, which began gradually declining in 2021, will decrease to 45 million by 2050.

The population of Emerging and Developing Economies will continue to increase substantially, driven by Africa and India. Africa's population will grow by nearly 60% from current levels to 2.378 billion in 2050, as lower mortality rates offset gradually declining birth rates. Nigeria, in particular, is expected to experience rapid population growth to become the third most populous country in the world by 2050. The Middle East's population will expand by 50%, reaching 404 million by 2050, supported by government financial incentives to increase the population and growing immigration from other regions. In Asia, India, which surpassed China in 2023 to become the world's most populous country, will maintain its high growth rate, reaching 1.68 billion in 2050. China's population, which peaked in 2021, has begun to decline and will decrease to approximately 1.250 billion by 2050. ASEAN's population will increase by 10% to 768 million by 2050.

[3] The United Nations' "World Population Prospects 2024" does not reflect the exclusionary policies of the Trump administration, which came into office in 2025.

International energy prices

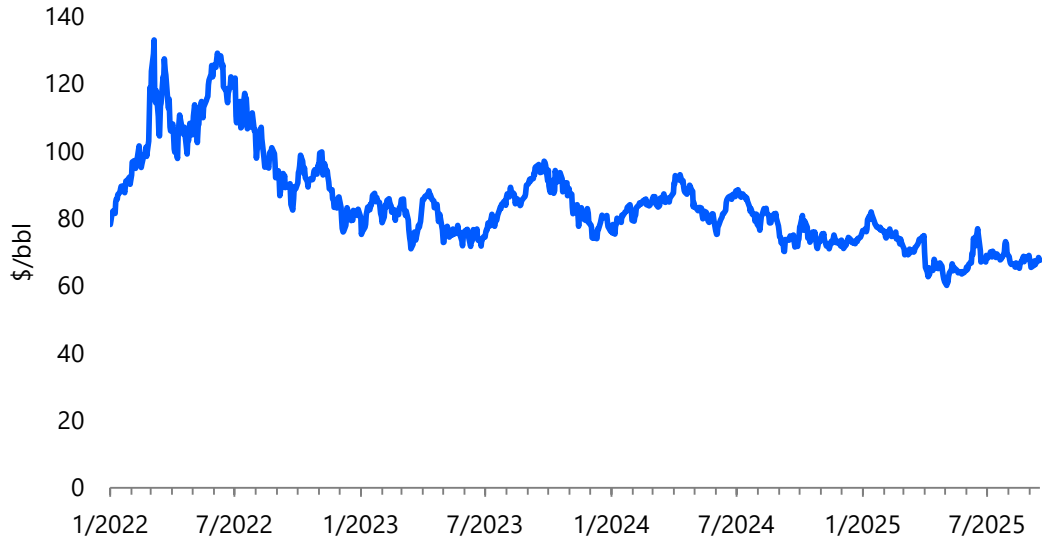
Recent situation

Brent crude oil prices surged to nearly $130 per barrel (bbl) in March 2022 following Russia's invasion of Ukraine. However, by the end of the year, the prices had declined to around $80/bbl, driven by sustained Russian exports despite sanctions and concerns over weakening global demand. In 2023, they temporarily approached $100/bbl at the end of September. Oil prices were influenced by several factors, including accelerating inflation in the United States and Europe, monetary tightening aimed at controlling inflation and additional production cuts by Organization of the Petroleum Exporting Countries (OPEC) plus members, including Saudi Arabia and Russia. Demand recovery, especially in China, also contributed to price fluctuations.

Thereafter, oil prices continued to decline, and by the end of December, had fallen below $80/bbl. In 2024, the prices rose to over $90/bbl in April as supply concerns grew due to continued production cuts by OPEC+ and attacks on merchant ships in the Red Sea. Oil prices gradually fell to $75/bbl by June and then rose to $85/bbl in July due to rising tensions between the Lebanese militant group Hezbollah and Israel. However, from August onwards, the prices began to decline due to increased production in non-OPEC countries such as the United States and Brazil, and slowing demand in China.

In September, the prices fell to around $70/bbl and remained at that level until December. In 2025, as OPEC+ began gradually lifting production cuts in March, oil prices gradually declined to $60/bbl by May. In June, a tanker collision near the Strait of Hormuz, possibly caused by radio interference, led to the prices temporarily rising to $75/bbl, but they have since fallen gradually. In September, eight OPEC+ member countries completed the lifting of their voluntary production cuts. Brent crude oil prices have fluctuated between $60/bbl and $80/bbl, influenced by macroeconomic conditions in major consuming countries, particularly China and the United States (Figure 1-7).

Figure 1-7 | Brent crude oil prices



Source: Intercontinental Exchange

Regarding natural gas prices, spot liquefied natural gas (LNG) and spot natural gas prices have been on a downward trajectory since late December 2022. The dominance of oil-linked long-term

LNG contracts in the Asian market has diminished, although this situation could fluctuate within a short period. The average Asian spot LNG price for 2022 was $35 per million British thermal unit (MBtu) while the European spot natural gas price (Title Transfer Facility [TTF], front-month delivery) was $43/MBtu. The 2023 average for both ranged from $13/MBtu to $14/MBtu, the 2024 average was also around $11/MBtu to $12/MBtu, with the average for the first half of 2025 ranging from $12/MBtu to $13/MBtu.

Spot LNG and spot natural gas prices (in Europe) have soared since the second half of 2021 after the slump in 2020, intensifying volatility. Under such circumstances, spot LNG and natural gas prices continually exceeded oil prices on a calorific value basis from August 2021 to April 2023. Although natural gas prices have generally remained at lower levels relative to oil prices in the second half of 2024 and have largely moved in line with oil prices, they remain above pre-2021 averages.

From April 2023 onwards, natural gas prices were expected to ease due to improving European supply conditions and stable LNG availability toward 2030. However, potential disruptions could reverse this trend. Factors such as further reductions in Russian pipeline gas to Europe, rising LNG demand from China and unexpected production outages could lead to renewed price volatility. For instance, in July 2024, both Asian spot LNG and European spot natural gas prices remained elevated for the Northern Hemisphere's summer season due to hurricane-induced LNG production halts in the United States.

Japan's average LNG import price reached a record high of $22.71/MBtu in September 2022, reflecting the surge in Japan's average oil prices through June 2022. It then fell below $13/MBtu in early 2024, partly due to the downward trend in oil prices since July 2022, then dropped to $11.45/MBtu in June 2025.

The steam coal market also experienced significant price volatility. Prices exceeded $400 per tonne (t) in 2022, a record high, driven by increased demand following the COVID-19 recovery, intensified efforts by the European Union, Japan and others to switch from Russian coal to alternative sources following Russia's invasion of Ukraine and supply constraints in major coal-producing countries due to adverse weather. Subsequently, coal prices fell as Russian coal was redirected to non-sanctioning countries such as China and India, weather conditions improved in key producing regions, and demand for energy and steel weakened.

From 2024 onward, the prices temporarily dipped below $100/t, but by August 2025, they have been hovering around $110/t. Although the prices remain significantly lower than the 2022 peak, they are still high compared to pre-pandemic levels. However, alongside declining profits from the coal business due to falling market prices, concerns exist over a reduction in supply capacity due to the difficulty of making coal investments amid the trend away from coal. In particular, uncertainty regarding future coal supplies is becoming apparent.

Reference Scenario

In the Reference Scenario, oil demand will continue to be driven by Asia; however, the centre of demand growth will shift from China to India and ASEAN. On the supply side, non-OPEC production will increase until around 2030, after which dependence on OPEC will rise. Oil demand is projected to expand continuously through 2050, with the breakeven oil price expected to rise over the medium to long term. The real oil price (2024 prices) is assumed to be $80/bbl in 2030 and $85/bbl in 2050 (Table 1-1).

Table 1-1 | International energy prices

Real prices			Reference			Advanced Technologies		
		2024	2030	2040	2050	2030	2040	2050
Oil	$2024/bbl	79	80	85	85	75	70	65
Natural gas								
Japan	$2024/MBtu	12.1	8.8	9.2	9.1	8.3	8.1	7.6
Europe (Netherlands)	$2024/MBtu	11.0	8.9	9.8	9.9	8.7	9.0	8.6
United States	$2024/MBtu	2.4	3.0	4.2	4.7	3.0	4.1	4.0
Steam coal	$2024/t	157	105	110	110	100	90	80

Nominal prices			Reference			Advanced Technologies		
		2024	2030	2040	2050	2030	2040	2050
Oil	$/bbl	79	91	131	179	89	112	144
Natural gas								
Japan	$/MBtu	12.1	10.0	14.2	19.1	9.9	12.9	16.8
Europe (Netherlands)	$/MBtu	11.0	10.1	15.0	21.0	10.3	14.4	18.9
United States	$/MBtu	2.4	3.4	6.5	9.9	3.6	6.6	8.8
Steam coal	$/t	157	120	169	232	119	145	177

Note: The annual inflation rate is assumed at about 3%.

Assuming an annual inflation rate of approximately 3%, the nominal oil price would rise to $95/bbl by 2030 and $188/bbl by 2050.

Regarding Japan's natural gas prices, the coefficient of the oil price-sensitive portion of Japan's import prices linked to oil is expected to decline in line with the downward trend in oil consumption in Japan. The sustained increase in LNG exports from the United States is anticipated to diversify procurement sources and eliminate or ease destination restrictions, gradually shifting pricing away from oil-linked contracts. Additionally, Japan's natural gas prices are expected to mutually influence Asian markets, including those in emerging economies. Consequently, the ratio of oil price impact on Japan's import prices is set at 60% in 2030, decreasing to 50% by 2050. Meanwhile, the share of Japan's import prices mainly affected by US natural gas prices, rather than oil prices, will gradually increase from 40% in 2030 to 50% in 2050. In addition, a certain premium will also be applied by multiplying the United States Henry Hub price by a premium factor.

The Henry Hub price is based on projections from the U.S. Energy Information Administration's (EIA) 'Annual Energy Outlook 2025'. US prices will likely remain lower than those in other regions, supported by abundant domestic supply. Taking into account the current development situation, the price will rise gradually 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, followed by a gradual rise. In Europe, the portion of prices linked to oil is projected to decline, reflecting decreasing crude oil consumption. However, European natural gas prices are expected to remain elevated due to the phasing-out of Russian pipeline gas, which previously contributed to stable prices.

It is assumed that carbon capture and storage (CCS) and electrification will gradually be incorporated into new and existing LNG projects. However, the resulting increases in investment costs and their potential impact on LNG prices are not factored into this scenario. While discussions continue regarding the potential for a premium for cleaner LNG, some producers have stated they will not pass the additional costs of greenhouse gas (GHG) measures onto prices. At the same time, some consumers remain cautious about accepting such premiums.

Coal prices (free on board [FOB], steam coal from Newcastle, Australia) reached a record high in 2022 due to sanctions on Russian coal and supply disruptions. However, global supply concerns have eased, leading to price stabilisation. Over the long term, demand for coal is expected to decline, partly due to the global trend toward carbon neutrality. Nonetheless, as new investments in coal production decrease, supply and demand dynamics will gradually tighten, with the real price assumed to reach $110/t by 2040. 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 risk 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 from around 2030 because of more rapid improvements in energy efficiency and fuel switching to nuclear, renewables and hydrogen. As a result of the sluggish demand, fossil fuel prices generally will be lower compared to the Reference Scenario. 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 gradual decline. In Japan, the share of import LNG prices linked to oil will decrease further, aligned with reduced crude oil consumption in Japan. Specifically, the ratio affected by oil prices will decline to 50% in 2030 and 40% in 2050, which is lower than in the Reference Scenario. The portion of Japanese import prices influenced by factors other than oil, primarily US natural gas prices, will be 50% in 2030 and 60% in 2050. A premium will continue to be added by multiplying the Henry Hub price by a premium factor. Henry Hub prices assume continued abundant supply capacity, while also referencing the EIA's 'Annual Energy Outlook 2025'. The coefficient for the oil price-sensitive portion of European natural gas 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.