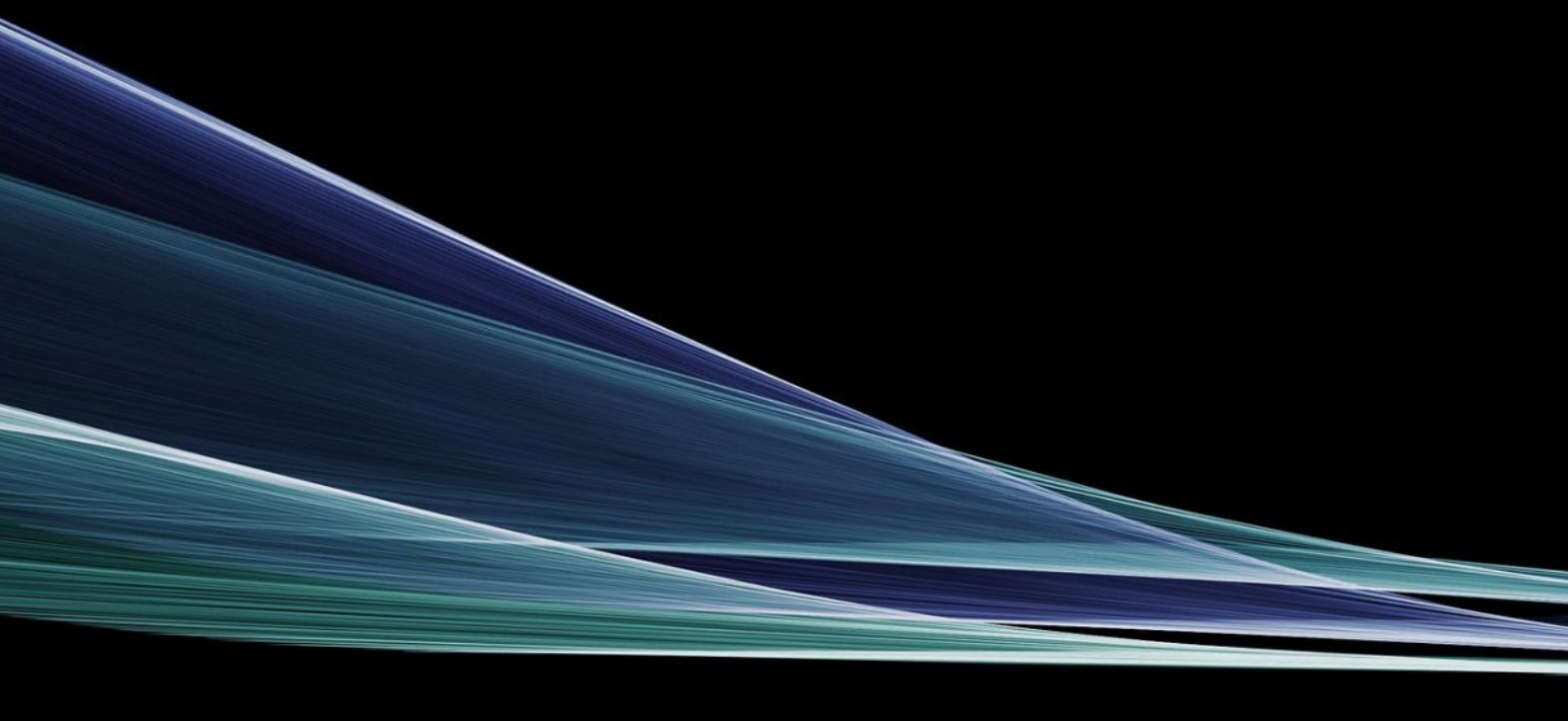
IEEJ Outlook 2026

Deepening uncertainties surrounding the challenges of energy transition:
a widening gap between the ideal and the reality



IEEJ Outlook 2026

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Summary

Global energy supply and demand outlook to 2050

Energy demand will continue to rise until 2050 under current conditions.

- This Outlook analyses global energy supply and demand projections through 2050 under two scenarios. Under the Reference Scenario, which assumes current policy and technological trends continue, global primary energy consumption will continue to grow steadily, primarily driven by Emerging and Developing Economies, increasing by 14% by 2050 compared to 2023 levels.
- On the other hand, under the 'Advanced Technologies Scenario'—which assumes the maximum deployment of various energy technologies to advance energy security and decarbonisation—emissions peak around 2030 before gradually declining, reaching a 6% reduction by 2050 compared to 2023 levels.

Under the Advanced Technologies Scenario, global CO_2 emissions will be reduced by 59% of current levels.

- Projections for carbon dioxide (CO_2) emissions vary significantly between the scenarios. Under the Reference Scenario, global emissions remain largely unchanged from current levels until 2050. This is because emissions reductions in Advanced Economies are largely offset by increased emissions associated with economic growth in Emerging and Developing Economies.
- Meanwhile, under the Advanced Technologies Scenario, global CO_2 emissions in 2050 would be reduced by 59% compared to 2023 levels. However, electrification remains challenging in non-power sectors, particularly industry (high-temperature heat) and transport (long-distance haulage), making decarbonisation in these sectors a major hurdle towards overall net-zero. Hydrogen and synthetic fuels represent promising alternatives, but high costs remain a challenge. Further technological advancement and cost reduction are essential going forward.

Significant increase in electricity demand and challenges to stable supply

- Global electricity generation continues to increase substantially under both scenarios. The Reference Scenario projects a 66% increase compared to 2023 levels, while the Advanced Technologies Scenario anticipates nearly double the increase, driven by electrification and expanding demand for hydrogen and carbon capture and storage (CCS). This growth stems from the rapid expansion of data centres, currently attracting global attention, alongside industry sector growth centred on Emerging and Developing Economies and rising space heating and cooling demand in residential sector.
- To meet this substantial increase in demand and ensure stable electricity supply, securing sufficient power generation capacity is essential. Solar photovoltaics and wind are expected to account for a large proportion of the overall increase in electricity generated. However, from around 2030, constraints such as a shortage of suitable sites and rising integration costs to manage supply fluctuations will become apparent. Consequently, investment in other

power sources such as thermal, nuclear and other renewable energies will also be indispensable.

Fossil fuel demand varies considerably depending on the scenario.

- The future of fossil fuel demand is subject to significant uncertainty. Oil demand varies considerably depending on the extent of electric vehicle (EV) penetration and efficiency improvements. Under the Reference Scenario, it continues to increase until 2050, whereas under the Advanced Technologies Scenario, it declines substantially. Consequently, among the three fossil fuels, oil exhibits the greatest variation depending on the scenario.
- Natural gas demand remains robust under both scenarios, with demand levels in 2050 remaining comparable to current levels even under the Advanced Technologies Scenario.
- Coal primarily supports power generation demand in Emerging and Developing Economies, but demand could decline significantly if the expansion of renewables progresses.
- Nevertheless, fossil fuels will continue to account for the bulk of energy consumption. Even under the Advanced Technologies Scenario, fossil fuels will constitute 54% of global primary energy consumption. Therefore, ensuring a stable supply of fossil fuels remains a critical challenge even as the energy transition progresses.

India and ASEAN: surging demand and supply-side constraints

- As energy demand declines in Advanced Economies and China, Emerging and Developing Economies—notably India and the Association of Southeast Asian Nations (ASEAN)—will drive new growth. India's annual income per capita is projected to approach $10 000 by 2050, with final energy consumption expected to nearly double from current levels under the Reference Scenario. ASEAN countries will also see sustained consumption growth alongside rising incomes and industrialisation.
- In India, driven by expanding demand in buildings and industry sectors, the Reference Scenario projects that electricity generated will more than triple over the next 25 years. While solar photovoltaics deployment is expected to increase, competition with agricultural land poses a challenge, making it difficult for solar photovoltaics alone to meet all electricity demand. Furthermore, addressing the social issue of improving transmission and distribution losses is also required.
- In Malaysia, one of the ASEAN members, the Reference Scenario projects a roughly 2.5-fold increase in electricity generated by 2050, driven by factors such as expanding data centre demand. An increase in natural gas-fired power generation utilising domestic resources is anticipated. To reduce CO_2 emissions, strengthening the power grid interconnection between the densely populated Malay Peninsula and Borneo Island—where suitable sites for renewables are concentrated—will be key.

Rising import dependence in Asia and its impact on the international energy market

- Increased domestic demand in India and ASEAN will heighten dependence on oil and natural gas imports. Furthermore, by 2050, 85% of crude oil interregional trade will be destined for Asia, with over half of this destined for South and Southeast Asia. Consequently, Asia will further enhance its presence in international energy trade.
- The CO_2 emissions reduction potential (the difference in emissions under the Reference and Advanced Technologies Scenarios) for India, ASEAN and other Emerging and Developing Asia combined is comparable to that of all Advanced Economies or China. The investment

required to realise reductions in these three regions amounts to approximately $240 billion annually. This represents 80% of the total funding target for all emerging and developing countries agreed at the 29th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP29) ($300 billion per annum). Mobilising private capital is essential to achieve investment on this scale.

The potential of variable renewable electricity considering integration costs

Expectations and challenges for variable renewable energy

- Significant increases in carbon-free energy sources are required to achieve decarbonisation. Expectations are particularly high for the continued expansion of variable renewable energy (VRE) sources such as solar photovoltaics and wind, which have seen substantial growth until recently. The IEEJ Outlook 2026 projects that under the Reference Scenario, VRE power generation will increase approximately fivefold from current levels to 2050, rising to approximately sevenfold under the Advanced Technologies Scenario.
- As the output of VRE fluctuates significantly depending on natural conditions such as solar radiation and wind speed, the expansion of VRE will have a major impact on the stability of the electricity supply-demand balance. For instance, as already observed in some countries and regions (such as the Kyushu region in Japan), instances occur where output from some generation facilities is curtailed during periods of surplus electricity supply from VRE. Furthermore, when VRE power generation suddenly drops due to natural conditions, and if the thermal power plants serving as backup experience unplanned outages, instances of tight electricity supply and demand are also frequently observed.
- With the expansion of VRE certain to continue into the future, it is essential to build a power system capable of responding to VRE fluctuations. This requires not only accurate forecasting of VRE power generation but also flexible operation of power generation facilities, the introduction of storage batteries and grid enhancement.

Volume of VRE deployment and integration costs

- As a cost assessment for the energy transition era premised on the expansion of VRE, analysis focusing on the overall costs of the energy (particularly electricity) system is gaining attention. This analysis considers the costs required for grid integration to accommodate the supply fluctuations of VRE (integration costs).
- In analysing integration costs, emphasis is placed on comprehensively and holistically assessing the expenses required for introducing the necessary technologies for the new energy transition. This is achieved by considering factors such as the costs of introducing new equipment like storage batteries and grid upgrades, as well as the costs associated with flexible facility operation (such as maintaining and operating thermal power plants as backup).
- As an example of analysis concerning integrated costs in Japan, the Agency for Natural Resources and Energy's Working Group on Power Generation Cost Verification has conducted a factor decomposition of the difference between the levelised cost of electricity (LCOE) and the levelised cost of electricity adjusted for some integrated costs (LCOE*). This analysis indicates that charging and discharging losses and the impact of output curtailment

are significant factors. Furthermore, the analysis of the energy mix (power generation mix) for fiscal year 2040 within the Seventh Strategic Energy Plan also incorporates considerations of integrated costs.

Changes in system costs according to VRE deployment levels (ASEAN analysis example)

- IEEJ Outlook 2026 analysed the deployment volume and integration costs of VRE up to 2060 for ASEAN, as an analysis considering integration costs.
- This analysis indicates that for ASEAN, the VRE share minimising energy system costs will be approximately 30% in 2060. Increasing VRE beyond this cost-minimising share leads to the replacement of conventional power generation sources such as thermal. This reduces the capital costs and fuel expenses associated with conventional power generation. Conversely, the costs associated with introducing VRE increase, alongside rising integration costs for measures such as battery storage. These additional costs exceed the savings from conventional power generation, resulting in an overall increase in total costs.
- In ASEAN, if the share of VRE in electricity generated reaches approximately 80%, this would result in cumulative additional costs of around $1.3 trillion between 2030 and 2060, compared to the cost-minimising share of approximately 30%.
- Regarding the promotion of energy transition towards decarbonisation in ASEAN, strengthening national efforts alongside collaboration and cooperation at the ASEAN level is essential. On the other hand, concerning enhanced measures through the expansion of VRE, it is necessary to note that additional costs may vary significantly between countries. This stems from differences in geographical and natural conditions, as well as the state of infrastructure development, meaning the scope for additional VRE varies considerably across ASEAN countries.
- Furthermore, the capacity to bear additional costs varies depending on economic circumstances and national scale. To further utilise VRE, transnational cooperation is essential, alongside diverse decarbonisation pathways tailored to each country's specific circumstances.

The importance of climate change targets and adaptation grounded in reality

Recent developments concerning the 1.5°C target

- The Paris Agreement (2015) stipulates the global temperature rise mitigation target as well below 2°C and to pursue efforts to limit the increase to 1.5°C. Subsequently, driven by successive net-zero declarations from major nations around 2020, the pursuit of the 1.5°C target and the associated goal of net-zero greenhouse gas (GHG) emissions became the global trend. However, in reality, global GHG emissions continue to rise, making the prospects for achieving the 1.5°C target increasingly challenging. Against this backdrop, new realities illustrating the difficulty of realising the 1.5°C target are becoming apparent worldwide.
- For example, the Group of Seven (G7) excluding Japan and the European Union (EU) are currently exceeding the emissions pathway required to achieve net zero by 2050 from current levels. Furthermore, Canada's new 2035 Nationally Determined Contribution (NDC) target exceeds the emissions pathway required to achieve net zero by 2050 from current levels.

- Coal-fired power generation trends in China and India also merit attention. In China, final investment decisions (FID) were made for 100 GW of new coal-fired power plants in 2024 alone. This represents the largest scale in the past decade. Meanwhile, coal-fired power plant decommissioning over the past five years averaged just 4.7 GW annually. Similarly, India saw FIDs for 15 GW of new coal-fired power plants in 2024, again the largest scale in the past decade. The current reality presents a challenging situation for achieving net-zero GHG emissions.

Comparison of the Advanced Technologies Scenario and the 2°C target

- The remaining carbon budget[1] required to limit global temperature rise to 1.5°C with a 50% probability is rapidly diminishing with each year's emissions. Specifically, the Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report had estimated this budget at 500 $GtCO_2$ after 2020. However, the latest assessment by Indicators of Global Climate Change (IGCC) shows a significant reduction to 130 $GtCO_2$ after 2025. This figure represents less than four years' worth of current emissions. Under a simple calculation assuming linear emissions reductions, this implies the world would need to achieve net-zero by 2032. Given the latest remaining carbon budget assessment, the 1.5°C target can be considered effectively unattainable. Consequently, setting a 2°C target appears realistic as a goal consistent with the Paris Agreement. This does not necessarily signify a retreat but rather a return to the original objective of the Paris Agreement.

- The overall CO_2 emissions pathway estimated based on energy-related CO_2 emissions up to 2050 from the IEEJ Outlook 2026 Advanced Technologies Scenario achieves net zero in 2073. Furthermore, the cumulative emissions from 2025 onwards until net-zero is achieved would total 906 $GtCO_2$, a level comparable to the latest remaining carbon budget (1 050–1 110 $GtCO_2$) and sufficient to limit global temperature rise to 2°C with 50% probability. However, to meet the 2°C target with the highest possible probability, it remains crucial to explore and pursue reduction potentials exceeding those of the Advanced Technologies Scenario.

Adaptation

- Climate change countermeasures are broadly categorised into 'mitigation' and 'adaptation'. 'Mitigation' involves reducing GHG emissions and expanding sinks to prevent increased GHG emissions from exacerbating climate change. Adaptation, on the other hand, refers to the processes of adjustment and response to climate change and its impacts, aimed at reducing the effects and damage caused by climate change. The primary approach is to mitigate the impacts of climate change through mitigation; if this proves difficult, it becomes crucial to combine it with adaptation. With the 1.5°C target now effectively unattainable, the importance of adaptation will only continue to grow.

- However, according to the United Nations Environment Programme's "Adaptation Gap Report 2024", there is an 8 to 14-fold gap between the finances required for adaptation and the current level of finance provision. The adaptation finance gap is substantial, and closing this gap is a priority.

- Breaking down the climate finance provided and mobilised by advanced economies reveals that mitigation finance accounted for 72% of the total in 2016 and 60% in 2022. Meanwhile, the proportion allocated to adaptation has increased, rising from 17% in 2016 to 28% in 2022.

[1] The total amount of CO_2 emissions permitted globally going forward to achieve a target

Article 9, paragraph 4 of the Paris Agreement aims for a 'balance' between adaptation and mitigation finances, which can be understood as striving for a ratio close to one-to-one between adaptation and mitigation finances. However, the current situation remains far from balanced, necessitating efforts to achieve equilibrium between adaptation and mitigation finances.

- When examining the primary areas of adaptation in terms of finance requirements and modelled costs, the sectors with the highest finance needs are 'agriculture and fisheries', 'water and floods' and 'infrastructure, energy and settlement'. Other important sectors include 'coastal and marine resources', 'forests and ecosystems' and 'human health'. It is necessary to consider which areas of adaptation should be prioritised, considering both current and future needs.

The future of AI and energy demand

The relationship between AI and energy

- The close interrelationship between artificial intelligence (AI) and energy is attracting global attention. A symbolic example of this is the recent expansion in the use of generative AI and advances in digitalisation, which have led to a significant increase in data centres. Locally, this has raised future concerns that the pace of constructing power supply facilities may not keep up with the pace of building data centres.

- Meanwhile, AI is anticipated to deliver significant benefits within the energy demand sector. It holds the potential to fundamentally transform energy usage itself by enhancing productivity and enabling energy savings across industry, transport and buildings. Through demand forecasting, AI can guide optimal factory operations, thereby improve productivity and enhance ultimately the energy efficiency of facilities such as factories. In transport, autonomous driving achieves energy savings through improved fuel efficiency via optimised vehicle spacing and route selection, alongside reduced travel distances. In buildings, energy savings are realised by optimising the operation of air conditioning and other systems while maintaining comfort levels. Thus, the future of AI and energy will be closely intertwined.

Data centre electricity demand and energy saving potential

- Global data centre electricity demand is projected to expand by a factor of 2.1, rising from 497 TWh in 2025 to 1 080 TWh in 2035 under the IEEJ Outlook 2026 Reference Scenario. Data volumes over the same period are expected to increase by a factor of 2.9, growing from 230 Zettabytes (ZB) in 2025 to 660 ZB in 2035. AI computation-related electricity consumption in data centres will drive this increase in electricity demand, with its share doubling from the current 14% to 30% by 2035. Meanwhile, the pace of growth in data centre electricity consumption, which averaged 17.5% annually between 2020 and 2024, will moderate slightly to 8.1% between 2025 and 2035.

- Global data centre electricity demand could potentially be saved by approximately 20% by 2035 compared to the Reference Scenario under the Advanced Technologies Scenario, indicating significant energy-saving potential. Contributing factors include improvements in power usage effectiveness (PUE) through the adoption of high-efficiency cooling technologies in new data centres (4.5% savings), efficiency enhancements in information and communication technology (ICT) equipment (14.2% savings) and computational efficiency gains (1.3% savings). How to achieve this represents a key challenge for the future.

- In any case, how to supply the increasing demand for electricity under the new information revolution in a stable manner and at competitive prices will become one of the most critical issues in the world's energy challenges.

AI-based energy savings potential in the demand side

- AI is expected to deliver significant energy savings through its application in the demand sector. This study estimated the additional energy-saving potential achievable beyond the Advanced Technologies Scenario through AI-driven optimisation. In the industry sector, an additional 2% to 6% energy-saving potential is projected for 2035 compared to the Advanced Technologies Scenario. In the short to medium term (2025–2035), the primary focus will be on retrofitting existing equipment with AI for optimisation and efficiency improvements. By sector, the greatest benefits are expected from non-energy-intensive industries, including machinery manufacturing, yielding 68 million tonnes of oil equivalent (Mtoe). This is followed by chemicals at 26 Mtoe and steel at 21 Mtoe.
- By 2035, the additional energy-saving potential from AI-enabled autonomous driving for passenger cars, buses and lorries will amount to 36.5 Mtoe. In Advanced Economies, the additional energy-saving potential from the Advanced Technologies Scenario is approximately 2.9%, while China's is 2.6%. Conversely, the adoption of autonomous driving in other Emerging and Developing Economies will not progress significantly; consequently, the additional energy-saving potential from the Advanced Technologies Scenario will be around 0.9% to 1.8%.
- The additional energy-saving potential for space cooling and heating, ventilation and lighting in the commercial sector in 2035 amounts to 8.8 Mtoe (102 TWh) compared to the Advanced Technologies Scenario. This is equivalent to reducing the electricity demand of data centres in 2035 by approximately 10%. The energy-saving potential of AI in Advanced Economies in 2035 is 4.3 Mtoe, while China's is 2.6 Mtoe.
- The additional energy-saving potential of AI-equipped space heating and cooling and water heating appliances in the residential sector is estimated at 1.5 Mtoe in Advanced Economies (a 2.3% reduction compared to the Advanced Technologies Scenario) and 0.9 Mtoe in Emerging and Developing Economies (a 1.5% reduction) by 2035.

Towards future expansion and adoption

- The utilisation of AI on the demand side holds significant energy-saving potential. However, various challenges exist in achieving its widespread adoption and realising these savings. The primary issues include a shortage of personnel capable of leveraging AI and insufficient awareness of its benefits. Furthermore, to realise AI's full potential, data standardisation and the establishment of input rules are necessary. Additionally, operational considerations such as ensuring cybersecurity are required during AI deployment.
- The energy-saving potential of data centres is significantly influenced by improvements in ICT efficiency. Consequently, alongside the traditional focus on enhancing cooling efficiency, measures and strategies aimed at improving the efficiency of ICT equipment are required. This necessitates additional metrics for evaluating data centre energy savings, such as ICT efficiency (beyond PUE). Furthermore, collaboration is vital not only by data centre operators but also with diverse stakeholders, including semiconductor manufacturers and IT-related equipment manufacturers.

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 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 US 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.

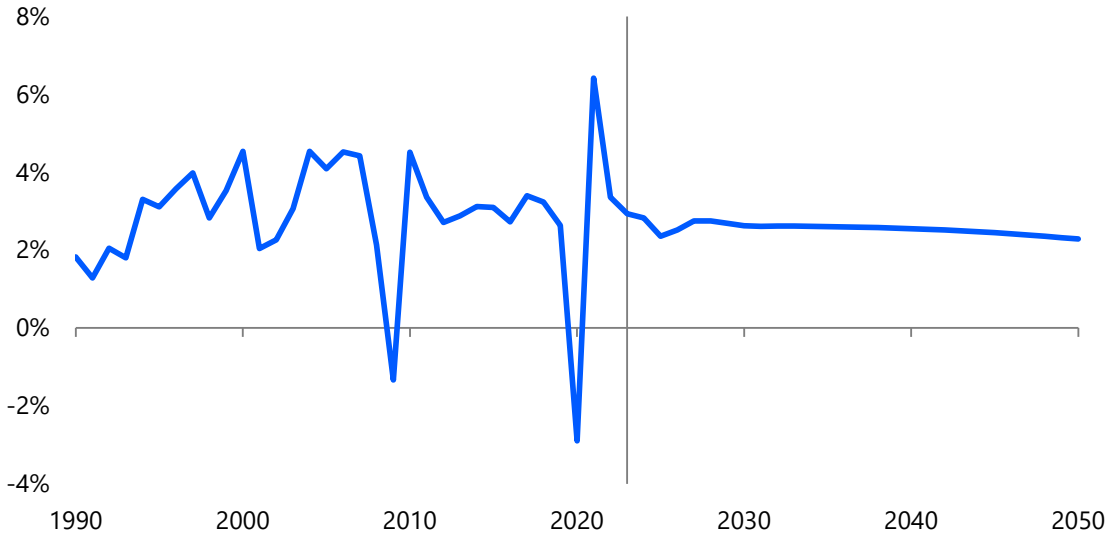
Assumptions for the future

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 US tariff policies. The growth rate will recover over the next

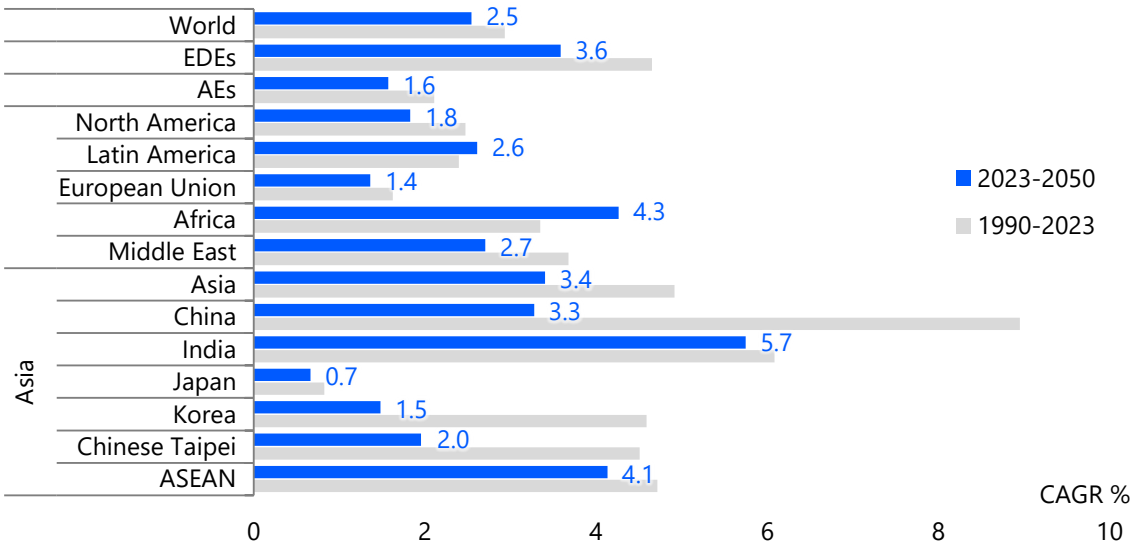
few years, but is expected to gradually decline towards 2050, transitioning from the upper to the lower 2% range (Figure 1-3). Russia's prolonged invasion of Ukraine will not cause significant damage to the global economy as a whole, although it will have localised and short-term effects. Meanwhile, concerns are growing over rising costs and market contraction resulting from supply chain restructuring driven by US 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

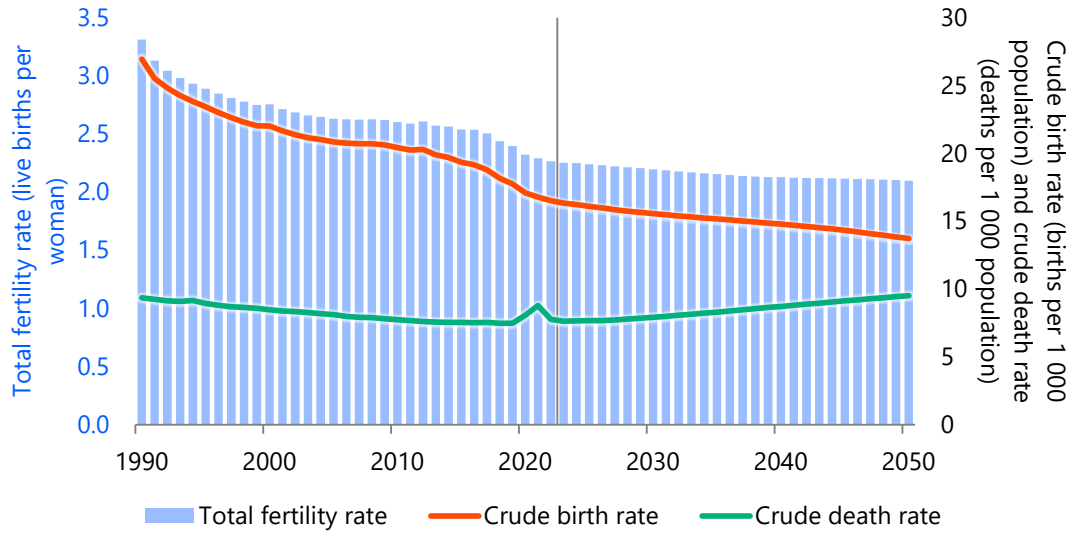


Notes: AEs stands for Advanced Economies. EDEs stands for Emerging and Developing Economies.

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).

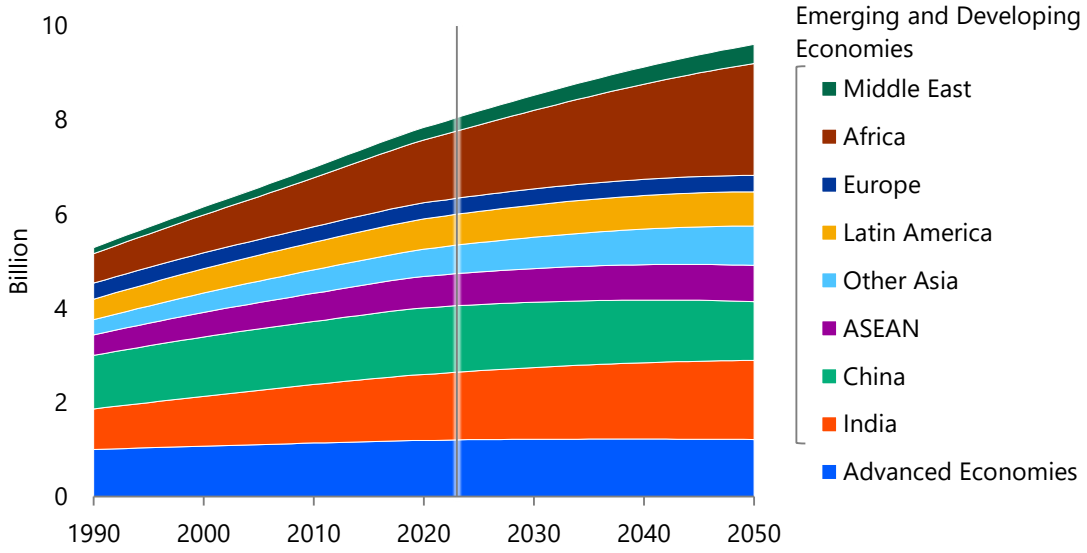
Figure 1-5 | World total fertility rate, crude birth rate and crude death rate



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

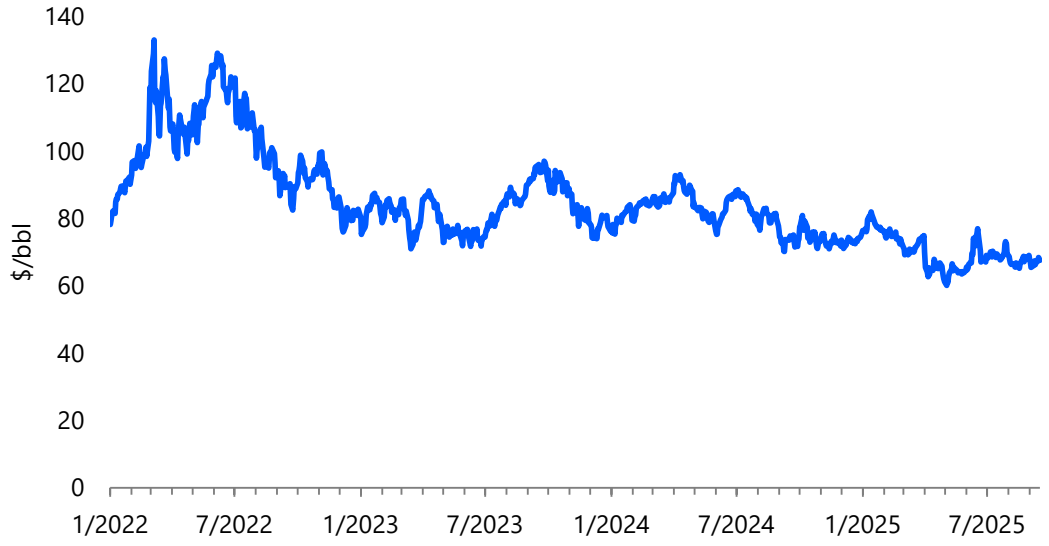
Recent situation

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.

2. Energy demand

2.1 Primary energy consumption

Whilst improvements in energy consumption per unit of GDP are being made from the perspective of climate change countermeasures and energy security, the volume continues to increase.

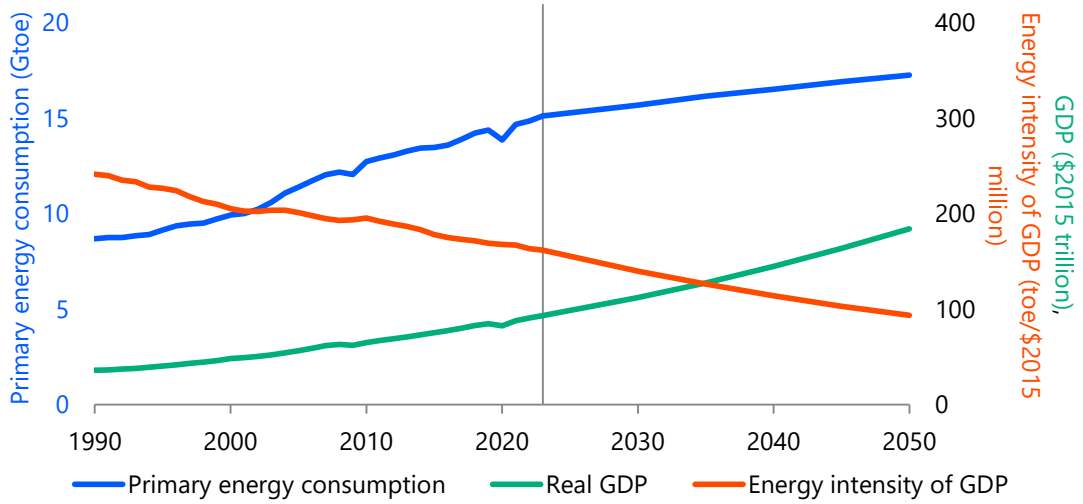
Even in 2025, the effects of climate change have been evident, with extreme wildfires in California in January, extreme heat waves in India and Pakistan since April, and the worst wildfires on record across Europe, covering an area of over 1 million hectares in the summer. To mitigate the impacts of climate change, each country has set greenhouse gas (GHG) emission reduction targets, and at the 29th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP29), held in Baku, Azerbaijan in November 2024, it was planned to conduct a follow-up, from 2025 until COP33, on the results of the Global Stocktake, which assessed global progress on GHG reductions and was completed at COP28. However, some developing economies claimed that there was no need for monitoring or follow up, while major advanced economies and small island nations called for confirmation of the implementation status of the agreement. This led to a sharp confrontation between the two sides, and further discussions were postponed. In 2025, US President Donald Trump directed the withdrawal of the United States from the Paris Agreement and related international climate commitments, with the withdrawal scheduled to take effect in January 2026, one year after notification. The framework for the 2050 net-zero target is losing momentum, with major banks withdrawing from the Net Zero Banking Alliance (NZBA), an international coalition aiming for decarbonisation, following pressure from some US Republican lawmakers. The European Union (EU) has also been proceeding with an ambitious proposal to reduce emissions by 90% compared with 1990 levels by 2040, but there are moves to allow the use of credits from afforestation and renewable energy deployment outside the European Union to achieve national targets, as well as to delay a final decision due to opposition from member states.

Furthermore, amid heightened tensions in the Middle East, Iran proposed a blockade of the Strait of Hormuz in June 2025. In August, escalating hostilities in Ukraine led to Ukrainian attacks on Russia's Druzhba crude oil pipeline facilities. Additionally, large-scale power outages occurred in Spain and Portugal in May. These developments have heightened concerns regarding energy supply stability and price stabilisation. On the energy demand side, there are growing uncertainties, including potential increased electricity consumption associated with digital transformation driven by generative artificial intelligence (AI) and other technologies. Consequently, while acknowledging diverse energy transition pathways, countries are strengthening policies to promote economic growth and a stable supply through enhanced energy efficiency and reduced fossil fuel dependence via clean technologies.

Global primary energy intensity per gross domestic product (GDP) from 2023 to 2050 will decline faster than from 1990 to 2022 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). Although COP28 set a target to double the annual rates of energy efficiency improvement from 2% to 4% until 2030, the actual improvement is expected to reach only 2.1% annually from 2023 to 2030, decline to 2.0% by 2035 and remain at 2.0% up to 2050. As global GDP will grow faster than improvements in energy intensity, primary energy consumption will continue to rise. Energy consumption growth, which was 1.7% per year from 1990 to 2023, will

slow to 0.5% per year from 2023 to 2035 due to continued progress in energy conservation and will remain at the same annual pace through 2050. As a result, global energy consumption will increase by 9% relative to 2023 levels by 2035, reaching 16 164 million tonnes of oil equivalent (Mtoe) and by 16% by 2050, to 17 298 Mtoe. It will be difficult to satisfy the new demand simply by increasing the supply of non-fossil fuels such as nuclear and renewable energies. Therefore, countries must enhance energy efficiency further to reduce global fossil fuel consumption with an eye towards the goals set at COP28.

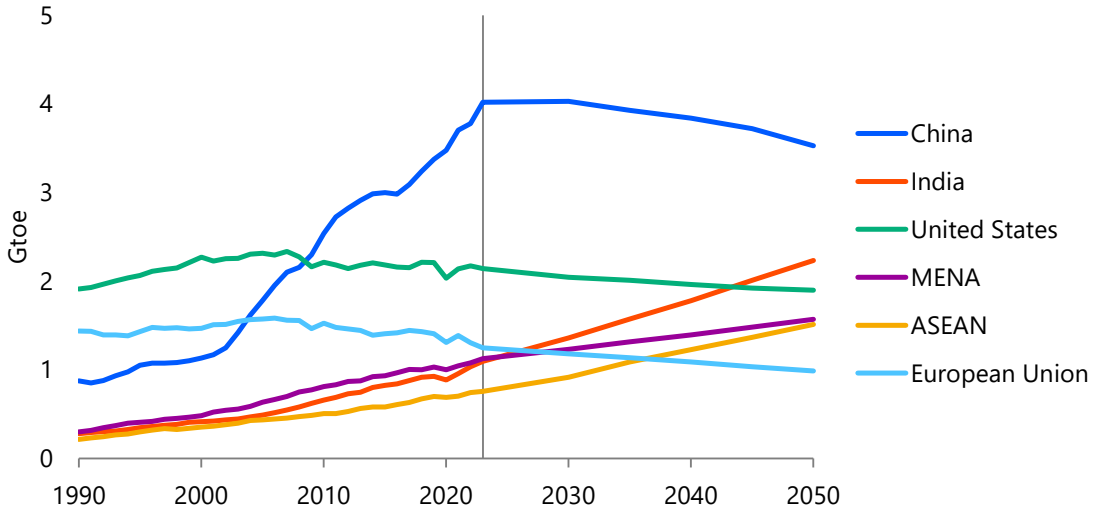
Figure 2-1 | Global primary energy consumption, real GDP and energy intensity of GDP [Reference Scenario]



By region, primary energy consumption in China, which has driven the global increase since 2000, will peak in the early 2030s and begin to decline due to slower economic growth as well as progress in energy efficiency, such as a shift towards services industries and the penetration of electric vehicles (EVs). Meanwhile, primary energy consumption in India, the Association of Southeast Asian Nations (ASEAN) and the Middle East and North Africa (MENA) will continue to increase in line with their rapid economic expansion, despite some progress in energy efficiency. The increase in these three countries/regions will account for 97% of the increase in the world's consumption from 2023 to 2035 and 110% from 2023 to 2050, pushing up global energy consumption, with their share growing from 20% in 2023 to 25% in 2035 and 31% in 2050 (Figure 2-2). Therefore, beyond the need to accelerate energy consumption reductions in Advanced Economies and China, the ability of India, ASEAN and MENA to moderate their energy consumption will determine global consumption trends and ultimately the success of climate change and energy security measures.

India, ASEAN and MENA, respectively, will increase their primary energy consumption by 2.7%, 1.2% and 2.6% per annum from 2023 to 2050 and account for 13%, 9% and 9% of global energy consumption in 2050. This is because their GDP will continue to grow at high annual rates of 5.7%, 4.1% and 3.0% through 2050. From the perspective of curbing global energy consumption, decoupling economic growth from energy consumption in these countries/regions represents a critical global challenge.

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



Advanced Economies, including the United States, the European Union and Japan, as well as China, must continue reducing their energy consumption in light of climate change and energy security concerns. However, in the United States, President Trump has suspended funding allocations under the Inflation Reduction Act and revoked environmental executive orders issued under the previous Biden administration, such as the target for electric vehicles to account for 50% of annual new car sales by 2030. In the European Union, regulations for automotive manufacturers continue to be relaxed through the postponement of targets and increased flexibility, treating the 2025 carbon dioxide (CO_2) emission standards as a three-year average from 2025 to 2027, reflecting the difficulty of achieving them. China's 14th Five-Year Plan, announced in 2021, set a goal of reducing CO_2 emissions per GDP by 18% between 2021 and 2025 compared with 2020 levels, but by 2023, emissions had increased from the previous year, resulting in only a 2% reduction relative to 2020. The United States, Europe, Japan and China will account for 40% and 21% of global GDP in 2035 and 35% and 23% in 2050, respectively, and will continue to hold large shares of energy consumption, at 22% and 24% in 2035 and 18% and 20% in 2050. To restrain global energy consumption in support of climate change and energy security measures, these economies should accelerate their reduction of energy consumption while contributing to stable global economic growth through sustained consumption and investment.

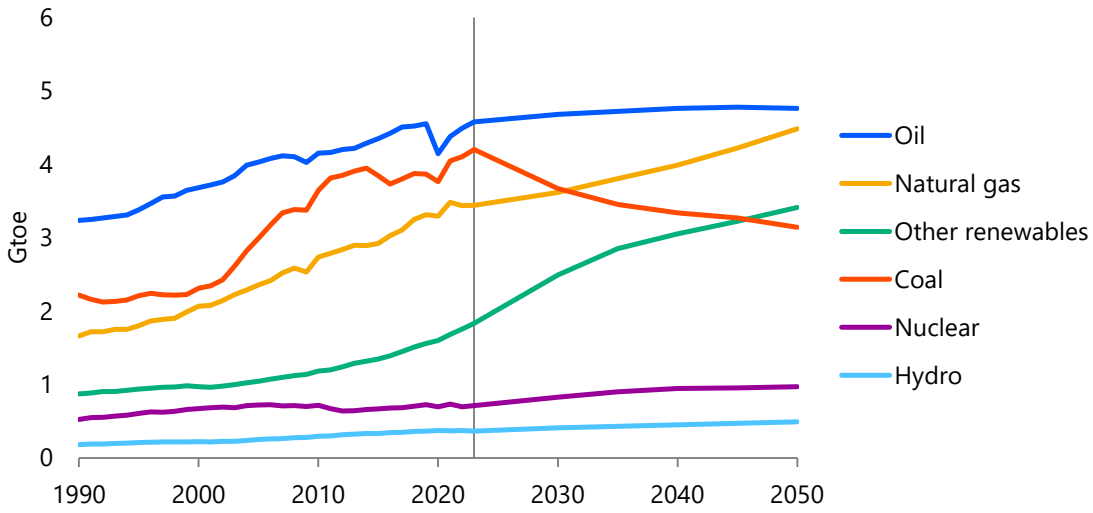
Further reducing global energy consumption will require enhanced international cooperation between advanced economies and emerging and developing economies, as well as among emerging and developing economies, alongside strengthened national policies. Advanced economies such as the United States, Europe and Japan must facilitate efficient technology transfer and support emerging and developing economies to achieve economic growth while limiting energy consumption by utilising Article 6 of the Paris Agreement, adhering to the new joint numerical targets on climate finance agreed at the 29th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP29), and addressing energy security concerns, particularly regarding fossil fuel supply instability.

Fossil fuel consumption continues to expand, with natural gas seeing particularly strong growth, continues to expand amid growing concerns about climate change and energy security.

In addition to the global trend towards carbon neutrality, Russia's invasion of Ukraine has heightened concerns about the stable supply of fossil fuels, particularly in Europe. As part of climate change mitigation efforts, COP28 established ambitious targets to triple global renewable energy installed capacity by 2030 compared with 2022 levels and triple global nuclear power generation installed capacity by 2050 compared with 2020 levels.

However, under current plans, nuclear will only reach 1.4 times the 2020 level by 2050 on a primary energy basis. Although renewables will sustain the growth observed during the 2020s, they will increase by only 1.4 times between 2022 and 2030. Growth will further slow after 2030 due to land availability and grid integration constraints, resulting in a 1.5-fold increase by 2035 and 1.8-fold by 2050 (Figure 2-3). Additionally, the adoption of hydrogen and ammonia will remain limited, as demand is not yet sufficient to justify their high costs.

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



Fossil fuel consumption declined significantly in 2020, partly due to the economic downturn and voluntary home confinement (or lockdowns) amid the COVID-19 pandemic. However, consumption rebounded as economies recovered from the pandemic, with coal and oil reaching a record high in 2023. Until 2030, overall fossil fuel consumption will decrease, as a significant reduction in coal offsets increases in oil and natural gas. After 2030, due to a larger increase in natural gas, fossil fuel consumption will resume growth, rising by 1.4% by 2050 compared with 2023 levels. Although the supply concerns have heightened due to Russia's invasion of Ukraine, natural gas, which emits the least carbon among fossil fuels, will be the most actively utilised fossil fuel to support climate change mitigation. Natural gas consumption will grow at an average annual rate of 1.0% through 2050, reaching 1.3 times its 2023 level, primarily driven by demand in the power generation sector. Oil will increase until the mid-2040s due to greater movement of people and goods and expanded use of petrochemical feedstocks. It will then begin to decrease slightly as the penetration of electrified vehicles increases and fuel efficiency improves in the road sector. This marks a departure from the IEEJ Outlook 2025, which projected that oil consumption on a calorie basis would continue to increase throughout the projection period. However, it is essential to recognize that consumption levels in 2050 will remain comparable to current levels

and may even exceed them on a volume basis (p.28). Whilst coal will increase in India and ASEAN, where electricity demand is expanding, due to its low cost, it will generally decline due to climate change mitigation measures, mainly in Advanced Economies, and air pollution, mainly in China. Coal will decline at an annual rate of 1.1% by 2050 and will be lower than that of renewable energy sources excluding hydro in the late 2040s.

While non-fossil energy sources will increase, overall energy demand will grow even faster. As a result, non-fossil sources alone will not be sufficient to meet total energy demand over the next three decades. Through 2050, it will remain realistic for the world, especially Emerging 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 [2023–2050, Reference Scenario]

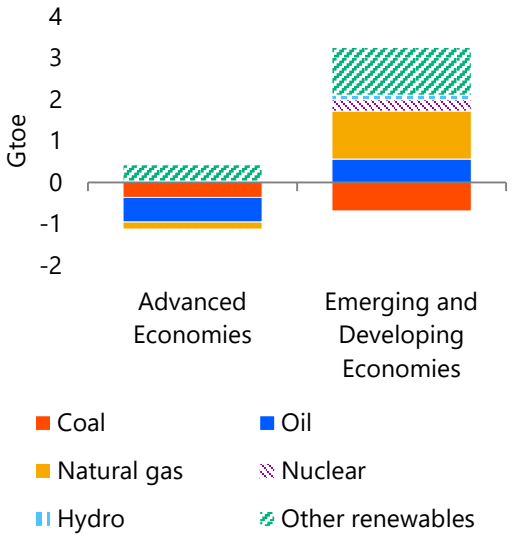
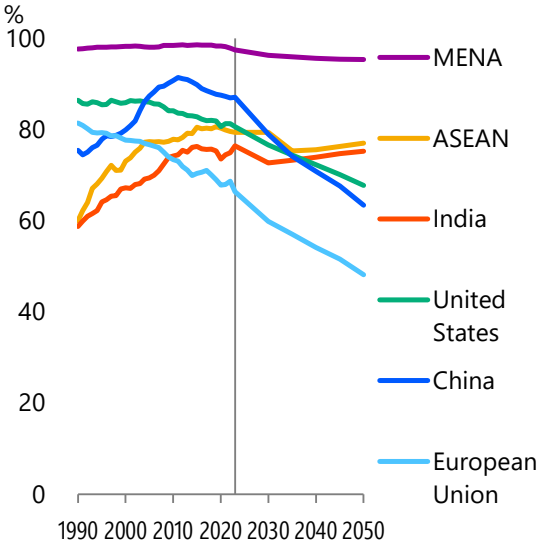


Figure 2-5 | Dependence on fossil fuels in selected economies/regions [Reference Scenario]



Dependence rates on fossil fuels will decrease from 81% in 2023 to 72% by 2050. The United States, the European Union and Japan will see their dependence rates decline from 81%, 66% and 85% in 2023 to 68%, 48% and 64% in 2050, respectively, as the adoption of non-fossil energy sources advances amid declining total energy consumption (Figure 2-5). Meanwhile, Emerging and Developing Economies excluding China will see their dependence rates remain high. Fossil fuel dependence rates in India, ASEAN and MENA will remain high at 75%, 77% and 95%, respectively, due to increasing total energy consumption, with fossil fuels continuing to meet much of this rising demand.

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

Among sectors, industry will experience the highest energy consumption growth, primarily in Emerging and Developing Economies, followed by the transport sector, the buildings sector and the other transformation sector, with similar increases (Figure 2-6). In the industry sector, production in secondary industries, such as machinery, will expand significantly in Emerging and Developing Economies. The transport sector will see increased consumption by motor vehicles as incomes rise in Emerging and Developing Economies, while consumption by air and sea transport will also grow substantially due to increased passenger movement and

international trade. Energy consumption growth in the buildings sector will also be significant. In India, ASEAN and MENA, the continued development of tertiary industries, including global call centres and improved household access to energy will drive demand growth. Rising living standards in these economies will further push up energy consumption in the buildings sector. Given these factors, it will be challenging for these economies to curb energy demand while maintaining economic growth. Furthermore, some point out that data centres are driving up electricity demand globally, including in Advanced Economies.

Figure 2-6 | Contributions to global primary energy consumption changes [Reference Scenario]

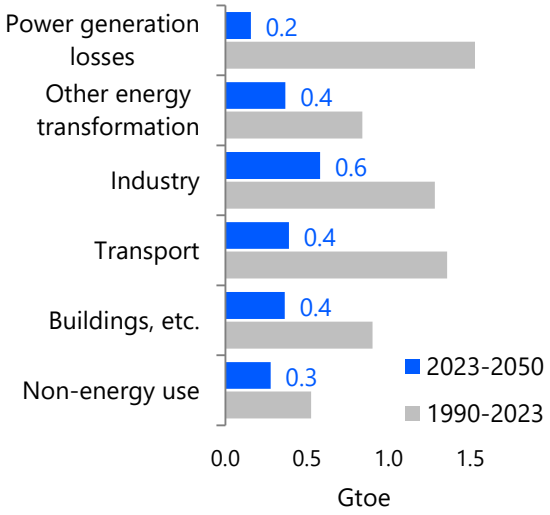
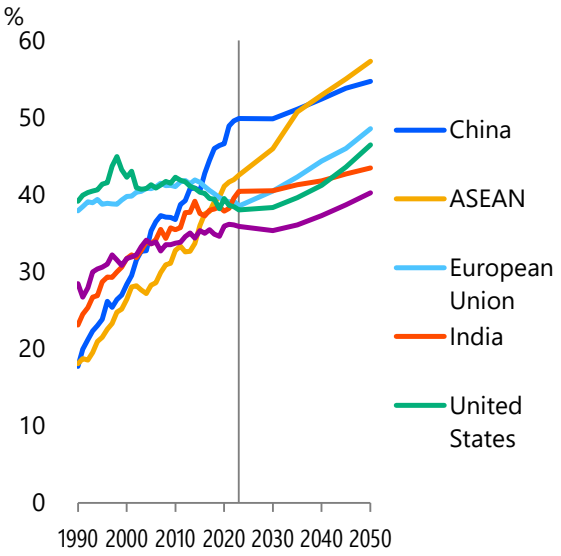


Figure 2-7 | Electrification rates on the supply side in selected economies/regions [Reference Scenario]

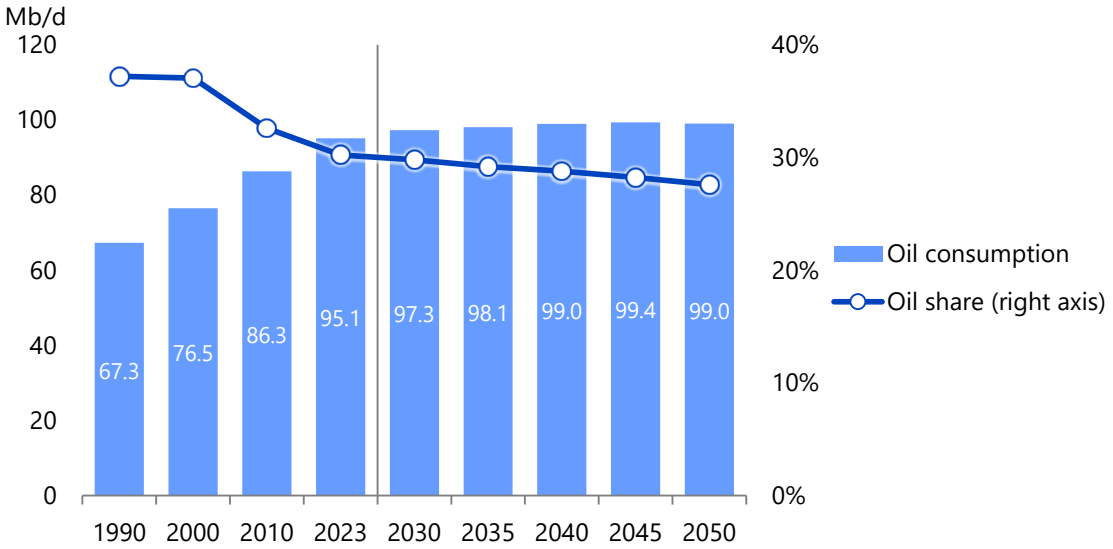


Energy consumption (losses) in the power generation sector will increase due to higher electricity generation resulting from rising electrification rates, although improvements in fossil fuel-fired power generation efficiency and a shift towards non-fossil power sources, which are assumed to have 100% efficiency (no losses), will partly offset this increase (Figure 2-7). As incomes rise and infrastructure development progresses in currently unelectrified regions, electricity consumption in Emerging and Developing Economies will continue to increase due to its convenience and widespread adoption. Furthermore, electricity demand will continue to grow, not only in Emerging and Developing Economies, but also in Advanced Economies, where digitalisation is increasing energy needs. Although the share of non-fossil energy sources is expected to grow, they will likely be insufficient to fully meet the rising electricity demand.

Oil consumption will peak in the late 2040s, while its share of primary energy consumption will decline gradually.

Global oil consumption, which stood at 95.1 million barrels per day (Mb/d) in 2023, will increase gradually, peaking in the mid-2040s before accounting for 99.0 Mb/d in 2050 (Figure 2-8). The oil share of primary energy consumption will continue to decline slightly from 30% in 2023 to 28% by 2050. This rate of decline will remain comparable to that observed between 2010 and 2023. Oil will remain the world's most widely used energy source through 2050.

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



In Advanced Economies, oil consumption has already peaked (Figure 2-9). Since reaching its peak in 2005, oil consumption has declined at an annual rate of 1.2%, but from 2023 to 2050, the decline will accelerate at an annual rate of 1.5%. The main factor driving this decline in Advanced Economies is the reduction in automobile fuel consumption, supported by fuel efficiency improvements and the adoption of electrified vehicles, including hybrid vehicles. By contrast, oil consumption in India, ASEAN and MENA will steadily increase at an annual rate of 1.5% from 2023 to 2050. The oil consumption of these economies will grow mainly in the transport, non-energy use and buildings sectors.

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

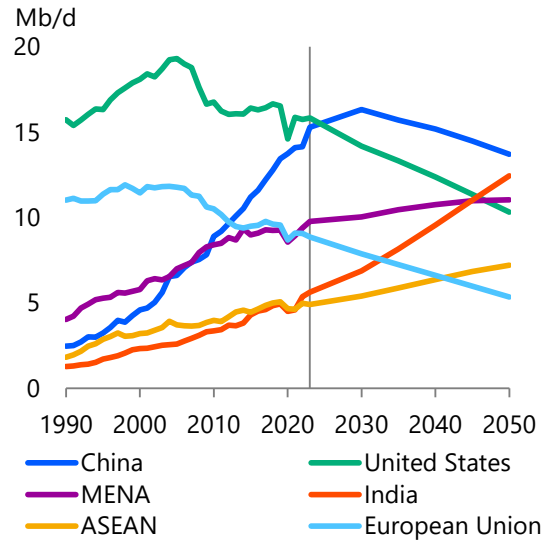
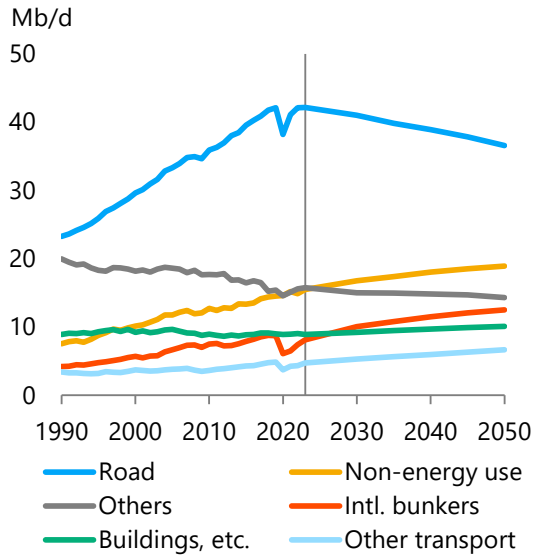


Figure 2-10 | Global oil consumption [Reference Scenario]



By sector, oil consumption in the road sector, which has the largest share, will peak in the 2020s and then decline, as the effects of fuel efficiency improvements and the expansion of electrified

vehicles outweigh the impact of increasing vehicle ownership (Figure 2-10). Meanwhile, oil consumption in the other transport sector, including international bunkers, domestic aviation and domestic navigation, is difficult to replace through means such as electrification. Rising trade and passenger mobility will drive growth in this area.

In India, ASEAN and MENA, oil consumption for automobiles will rise from 8.8 Mb/d in 2023 to 13.7 Mb/d in 2050. Vehicle ownership in these countries/regions will increase by 3.4-fold from current levels, supported by rising incomes and improvements in transport infrastructure, such as roads and bridges. To curb oil consumption, it will be necessary to actively promote a transition to electric vehicles and others. In Emerging and Developing Economies, the initial cost of electric vehicles may remain higher compared with conventional cars even in 2050, restricting sales to high-income consumers unless strong climate policies and financial incentives are implemented.

Oil consumption in the non-energy use sector, primarily for petrochemicals, will increase by 2.3 Mb/d from 2023 to 2050 in India, ASEAN and MENA, accounting for 68% of global growth in the 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. This means that both supply-side and demand-side factors will drive oil consumption growth in this sector. To suppress consumption in the sector, regulations on plastics consumption will need to be toughened. However, even from the perspective of addressing plastic waste issues, the reality is that establishing an international prevention treaty, as called for by the United Nations Environment Assembly in 2022, remains as difficult as climate change measures, with the 2025 intergovernmental negotiations failing to reach agreement.

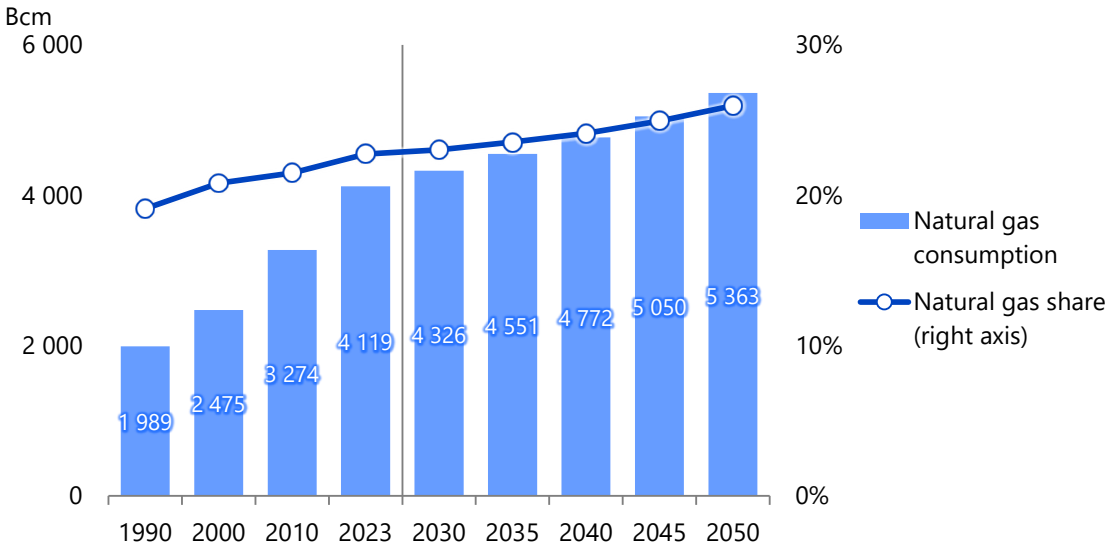
Oil consumption in the buildings sector of India, ASEAN and MENA will increase by 1.5 Mb/d from 2023 to 2050, accounting for 119% of the net global increase in this sector. As incomes rise, consumers in these countries/regions will shift from coal and solid biomass to oil, which is a relatively cleaner alternative 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 0.5 Mb/d during the same period. In those countries, the high initial investment required to switch to and operate electricity or city gas for water heating and cooking leads consumers to choose liquefied petroleum gas for that purpose.

China's oil consumption is expected to increase mainly in the non-energy use sector, peaking at 16.3 Mb/d around 2030, before declining to 13.7 Mb/d in 2050 due to a decline in the road sector driven by the increase in electric vehicles. Accelerating the reduction of oil consumption in China will be critical to achieving deeper global reductions in oil use.

Demand for natural gas for power generation continues to grow in India, ASEAN and MENA.

Natural gas consumption will see the largest increase of all energy sources through 2050. Global consumption will grow at an annual rate of 1.0%, rising from 4 119 billion cubic metres (Bcm) in 2023 to 5 363 Bcm in 2050 (Figure 2-11). As a result, natural gas will expand its share of primary energy consumption from 23% in 2023 to 26% in 2050, making it the second most consumed energy source after oil. As the European Union reduces its dependence on Russian natural gas and increases imports from other regions, particularly liquefied natural gas (LNG), the question of how to limit global natural gas demand growth remains critical.

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



India, ASEAN and MENA will account for 77% of the total global increase in natural gas consumption, adding a combined 1 245 Bcm between 2023 and 2050 (Figure 2-12). By 2050, natural gas consumption will reach 215 Bcm in India, 1 134 Bcm in ASEAN and 590 Bcm in MENA. The Middle East is expected to increase domestic natural gas consumption while continuing to prioritise cost-competitive oil exports to generate foreign currency. India and ASEAN will expand natural gas consumption primarily for the power generation sector to meet their rising electricity demand. China will see an increase of 42 Bcm by 2050, driven primarily in the power generation sector, although its level will fall below ASEAN levels in the 2040s. In contrast, the European Union will accelerate its transition away from natural gas, reducing its consumption by 131 Bcm by 2050, falling below India's level.

By sector, natural gas consumption in the buildings sector will decline due to increasing electrification and energy efficiency improvements (Figure 2-13). In contrast, consumption in Emerging and Developing Economies, including China, will rise, particularly in the power generation and industry sectors. In the power generation sector, natural gas demand will remain largely stable until 2030 due to the expansion of renewables and other energy sources. After 2030, demand is expected to rise again as the deployment of alternative power sources fails to keep pace with growing electricity needs. Natural gas consumption for power generation in Emerging and Developing Economies will increase at an annual rate of 2.7% from 2023 to 2050, accounting for 109% of global growth in the sector. This trend is driven by natural gas's lower CO_2 emissions compared with other fossil fuels, its relatively high flexibility in adjusting supply in response to fluctuations in demand, and its ability to support large-scale power generation at lower integration costs than renewables.

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

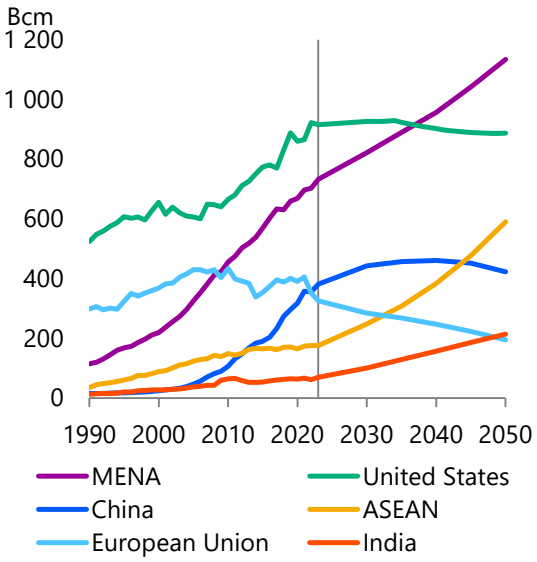
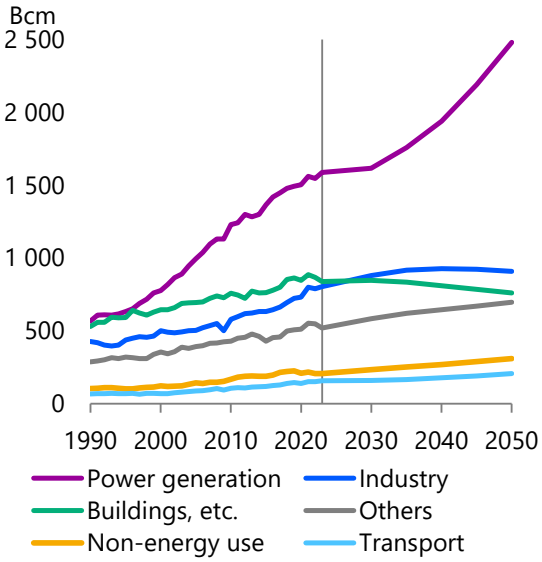


Figure 2-13 | Global natural gas consumption [Reference Scenario]



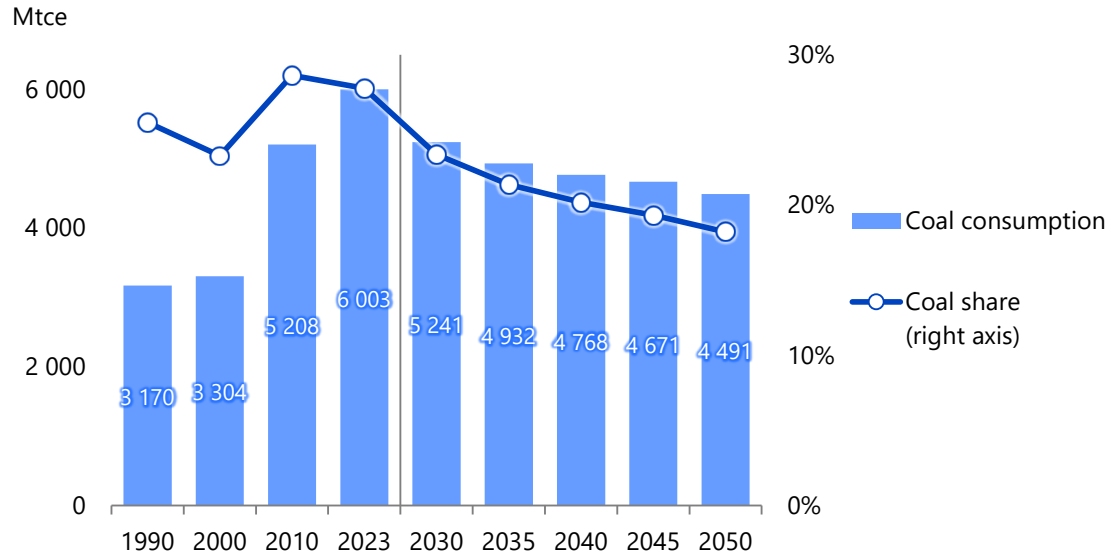
In the industry sector, natural gas consumption in Advanced Economies will decline, while demand in Emerging and Developing Economies will grow at an annual rate of 1.0%, contributing 149% of net global growth. Many industries will shift from oil and coal to natural gas due to its economic and environmental advantages. In the buildings sector, natural gas consumption is expected to decline due to increasing electrification and energy efficiency measures. China will be the primary driver of demand growth as it rapidly transitions from solid fuels such as coal and fuelwood to natural gas to improve air quality and public health.

As India, ASEAN, MENA and China drive the growth in natural gas consumption, they should adopt and widely implement high-efficiency technologies. For example, the power generation sector should fully utilise natural gas-fired combined cycle plants to optimise energy use and reduce consumption.

Coal consumption will peak in the 2020s due to environmental measures.

Global coal consumption, which stood at 6 003 million tonnes of coal equivalent (Mtce) in 2023, will decline at an annual rate of 1.1% due to the impact of environmental policies (Figure 2-14). Coal's share of primary energy consumption will decrease from 28% in 2023 to 18% in 2050. It will cede its position as the second-largest energy source to natural gas in the early 2030s, following oil, and will fall below renewables excluding hydro by the late 2040s.

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



In 2023, China accounted for 58% of global coal consumption, while India and ASEAN together made up 17%. The United States, Europe and Japan collectively accounted for 10%. By 2050, coal consumption in China and these three Advanced Economies will decline to 39% and 5% of the global total, respectively, while India and ASEAN will see their combined share rise to 39%, matching China's level (Figure 2-15).

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

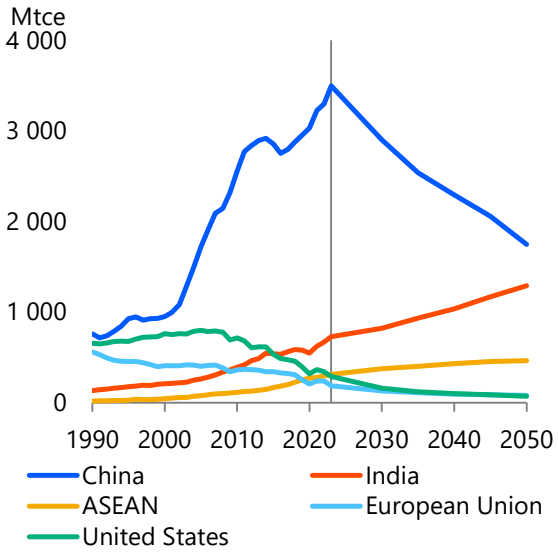
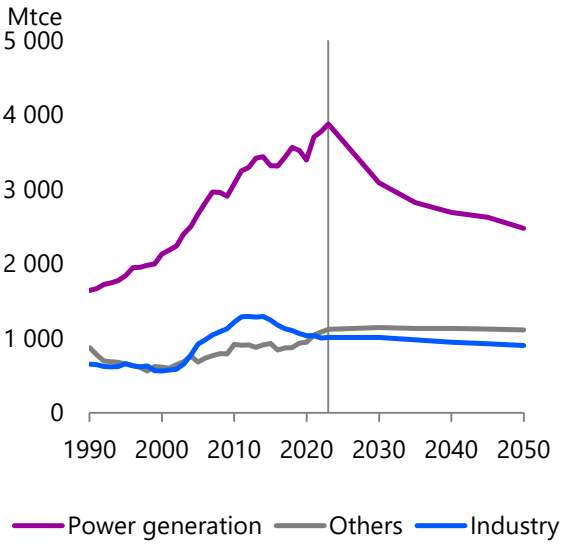


Figure 2-16 | Global coal consumption [Reference Scenario]



In China, coal consumption for industry has been declining since peaking in 2012, while that for power generation will decrease after peaking in the early 2020s due to measures against climate change and air pollution, which will result in a 50% overall decline in coal consumption by 2050. Coal consumption in the United States, Europe and Japan will continue falling in both the power generation and industry sectors, posting a 65% drop by 2050. In contrast, coal consumption in

India and ASEAN will continue to grow. By 2050, coal use for power generation will increase 1.6 times in India and 1.4 times in ASEAN. Industrial coal consumption will expand even more, rising by 2.0 times in India and 1.5 times in ASEAN. Note that MENA consumes limited coal due to the large number of oil- and gas-producing countries.

With growing pressure to address climate change, coal consumption has come under increasing scrutiny worldwide. At the 2024 meeting of environment ministers from the Group of Seven (G7), member countries agreed to phase out coal-fired power plants that lack emission reduction measures by 2035. In Europe, stricter regulations have raised the economic burden on coal-fired power plants while further tightening limits on CO_2 and mercury emissions. As such, restrictions on coal use are being strengthened in both the power generation and industry sectors. Meanwhile, in the United States, the Trump administration is promoting the use of coal to revitalise the domestic coal industry from the perspective of 'energy dominance'. While governments and financial institutions in Advanced Economies have been actively promoting coal divestment, an increasing number of financial institutions have been changing their policies since the Trump administration took office. Furthermore, many Emerging and Developing Asian Economies, including India and ASEAN, continue to rely on coal as an affordable domestic energy source to support energy self-sufficiency. These countries do not impose particularly strict restrictions on coal consumption. To curb coal consumption, Advanced Economies must accelerate their phase-out efforts, while China, India and ASEAN should prioritise switching from coal to natural gas and to hydrogen and ammonia, for both power generation and industrial use.

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

As more countries pursue carbon neutrality, expectations for the expansion of non-fossil energy sources continue to rise. In conjunction with COP28, participating nations declared that they would triple the world's renewable power generation capacity by 2030. Separately, another declaration was issued to triple the world's nuclear power generation capacity by 2050 compared with 2020 levels.

Non-fossil energy consumption for power generation centred on nuclear and hydro will grow 2.2 times, rising from 1 753 Mtoe in 2023 to 3 864 Mtoe in 2050 (Figure 2-17).

The most rapid growth will come from solar photovoltaics, wind and other renewable sources, which will expand 4.9 times over the same period. In contrast, nuclear and hydro will see slower growth due to policy constraints, environmental concerns and social considerations. Consequently, the share of nuclear and hydro in non-fossil energy for power generation will decline from 62% in 2023 to 38% in 2050.

Meanwhile, non-fossil energy consumption for heating will remain largely reliant on traditional solid biomass, such as fuelwood and manure, which are widely used in rural areas of Emerging and Developing Economies. From 957 Mtoe in 2023, non-fossil energy consumption for heating will decrease to 696 Mtoe by 2050 (Figure 2-18). 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 transport and heating, along with biogas, will grow 1.7 times by 2050, though they will still make up only 23% of total non-fossil energy consumption for heating.-

Non-fossil energy consumption will dramatically increase towards 2050. However, its share of total primary energy consumption will not increase as significantly, since overall energy demand will continue to rise. The share will only increase from 19% in 2023 to 28% in 2050.

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

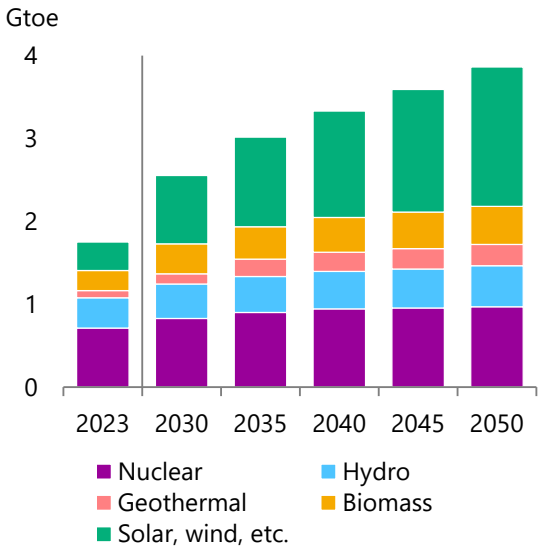
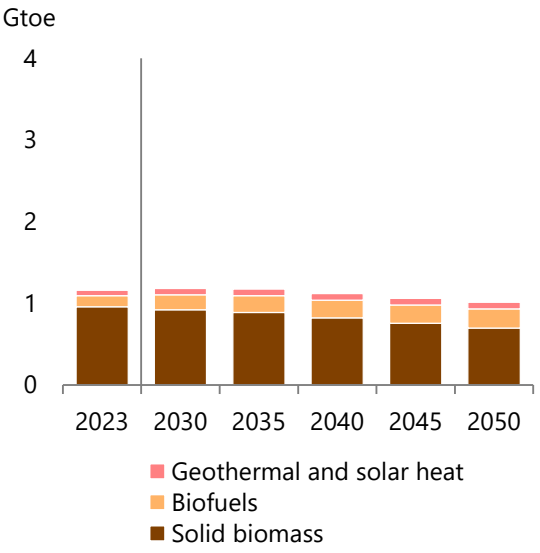


Figure 2-18 | Global non-fossil energy consumption for heating [Reference Scenario]



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

Asia will account for 54% of global energy consumption growth as its share of the global economy increases from 35% in 2023 to 44% in 2050 in real terms (Figure 2-19). China, India and ASEAN will be the primary drivers of this global economic expansion. While these economies share some similarities in energy consumption trends, they also exhibit distinct differences. Energy consumption in China will peak in the late 2020s, whereas in India and ASEAN, it will continue to rise (Figure 2-20). These differences stem from variations in economic and population growth.

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

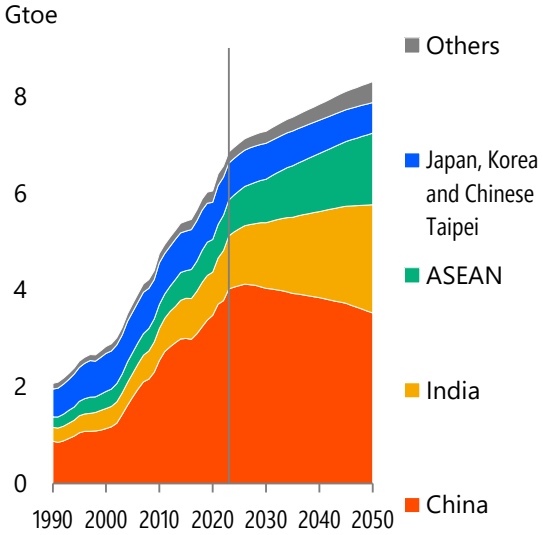
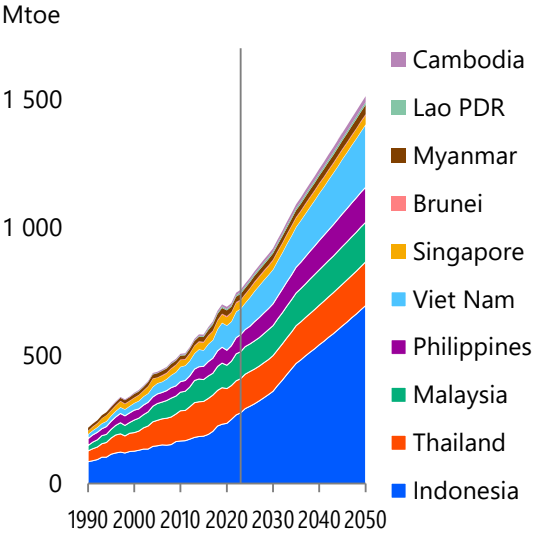


Figure 2-20 | ASEAN's primary energy consumption [Reference Scenario]



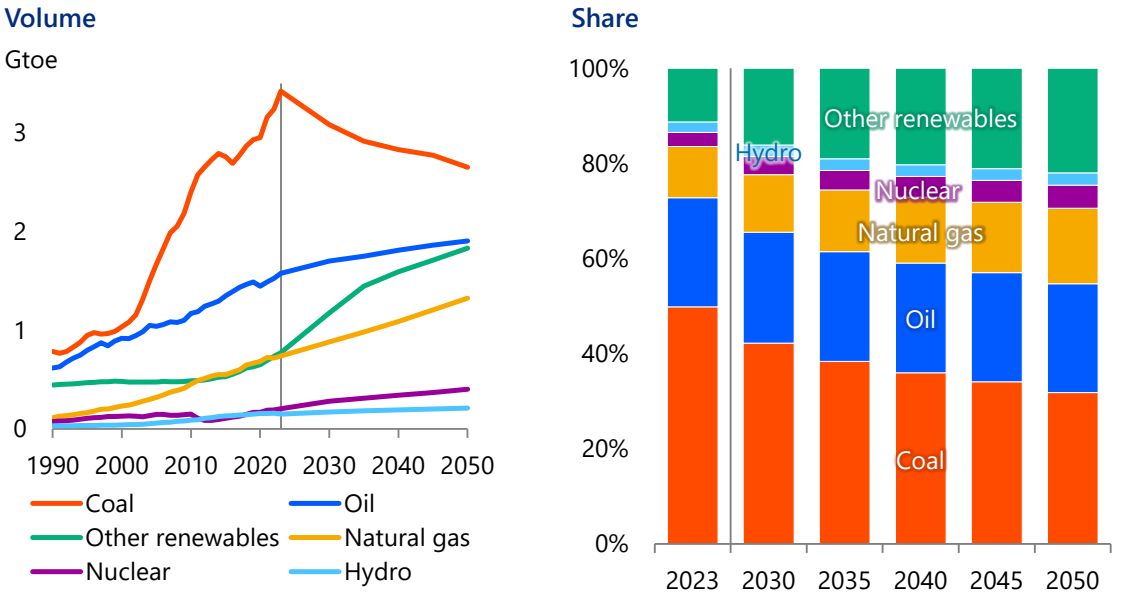
China's economy expanded 16.9-fold, from 1 trillion dollars in 1990 to $17.6 trillion in 2023 and will grow another 2.4-fold to $42 trillion by 2050. In the meantime, its population grew from 1.14 billion in 1990 to a peak of 1.41 billion in 2021 but will decline to below the 1999 level of 1.25 billion by 2050. Under the 14th Five-Year Plan (2021–2025), China has positioned the transition to a green economy as a key growth strategy. From the early 2020s, energy consumption will decline even as economic growth continues, similar to trends observed in advanced economies, driven primarily by energy conservation efforts in industry. After increasing at an average annual rate of 4.7% from 1990 to 2023, China's energy consumption is projected to decline at an annual rate of 0.5% from 2023 to 2050. By 2050, energy consumption will fall below 2023 levels, despite real GDP per capita exceeding $33 000. This marks China's transition to a mature economy, increasingly focused on carbon neutrality. China's share of Asian energy consumption rose from 42% in 1990 to 59% in 2023 but will decline to 42% by 2050.

India's economy expanded 7.0-fold, from $500 billion in 1990 to $3.3 trillion in 2023 and will grow 4.5-fold to $15 trillion in 2050. Its population rose from 860 million in 1990 to 1.44 billion in 2023, surpassing that of China. It will continue growing to reach 1.68 billion by 2050. Consequently, real GDP per capita will rise from $500 in 1990 to $9 000 in 2050, improving incomes and living standards. Although India has committed to achieving carbon neutrality by 2070, its energy consumption will continue growing at an annual rate of 2.7% from 2023 to 2050. As a result, climate change mitigation and energy security measures will become increasingly critical. India's share of Asian energy consumption will surge from 14% in 1990 and 16% in 2023 to 27% by 2050.

ASEAN's economy, valued at $740 billion in 1990, grew to $3.4 trillion in 2023 and will reach $10.1 trillion by 2050. Its population will expand from 440 million in 1990 to 770 million by 2050. As a result, real GDP per capita, which stood at $1 700 in 1990 and $4 900 in 2023, will rise to $13 000 by 2050, further improving income levels. ASEAN's energy consumption will continue to rise at an annual rate of 2.6% from 2023 to 2050, with Asia's share expanding from 11% in 2023 to 18% by 2050. Of that increase in consumption, 60% will be accounted for by Indonesia, which has declared its intention to achieve carbon neutrality by 2060. Within ASEAN, countries that have previously been fossil fuel exporters are facing declining supply capacity due to increased consumption and resource depletion, making energy security measures as important as climate change countermeasures.

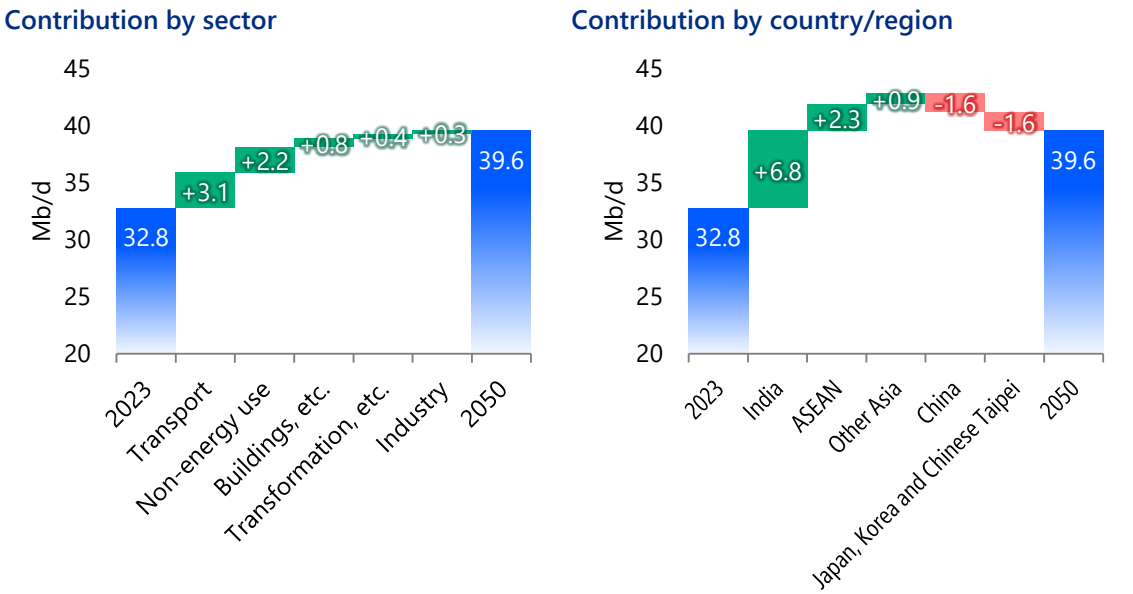
Even by 2050, while energy consumption in India and ASEAN will still be increasing, Asia will remain reliant on fossil fuels. Although this dependency will decrease from 84% in 2023, it will still account for 70% of its energy mix (Figure 2-21). Oil and natural gas consumption will continue to grow, driven primarily by demand from the transport and power generation sectors. Reducing Asia's dependence on fossil fuels will be essential for ensuring global energy stability and meeting climate goals.

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



Asia's oil consumption growth will slow from an annual rate of 2.9% between 1990 and 2023 to 0.7% from 2023 to 2050. The transport sector will drive 46% of this growth by 2050, while the non-energy use sector and the buildings sector will contribute 33% and 11%, respectively (Figure 2-22). By region, India will account for 100% and ASEAN for 34%. The share of India and ASEAN combined exceeds 100% because Japan, Korea and China will cut consumption. To curb oil demand, India and ASEAN must prioritise fuel efficiency improvements in the automobile sector, including vehicle electrification. Given that Asia will account for 175% of global oil consumption growth, developments in the region will significantly impact global oil trends.

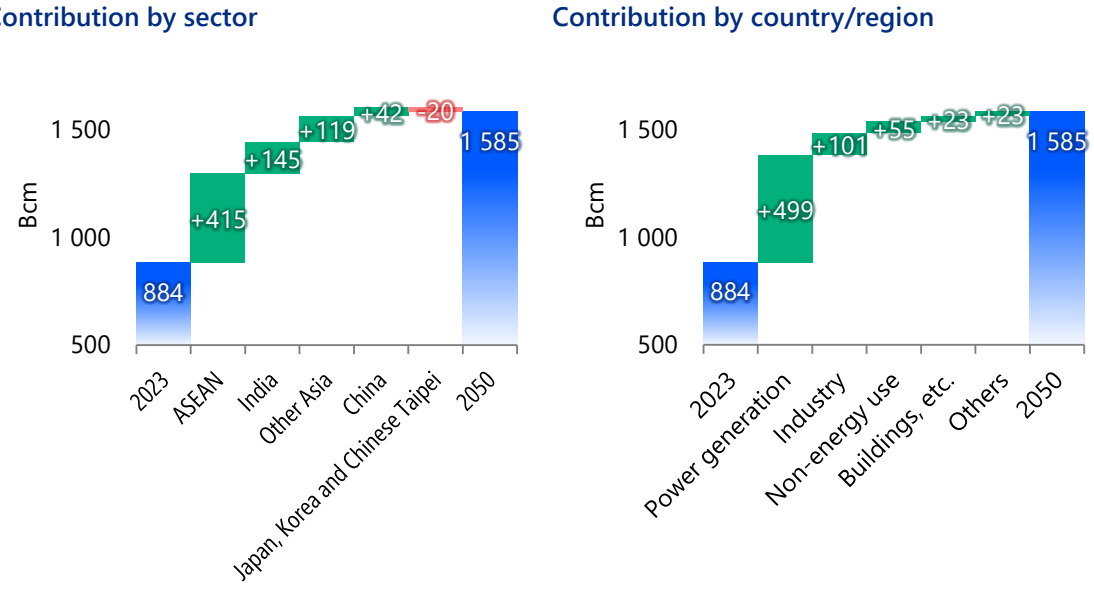
Figure 2-22 | Asian oil consumption [Reference Scenario]



To ensure stable oil supplies while addressing environmental concerns, Asian economies must accelerate the transition to alternative energy sources and enhance oil consumption efficiency.

Asia's natural gas consumption grew at an annual rate of 5.8% between 1990 and 2023 but will slow to 2.2% per year from 2023 to 2050. Of this growth by 2050, the power generation sector will account for 71%, the industry sector for 14% and the non-energy use sector for 8% (Figure 2-23). ASEAN will contribute 59% of the increase, followed by India at 21% and China at 6%. To curb natural gas consumption, China, India and ASEAN will need to improve efficiency, reduce electricity transmission and distribution losses and promote hydrogen co-firing in power generation. Additionally, enhancing insulation and efficiency measures in the buildings sector will be crucial. As Asia's natural gas consumption growth will account for 56% of global growth, limiting demand in these countries/regions will have a direct impact on global natural gas trends.

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



Although natural gas emits less CO_2 than oil and coal, it is still a fossil fuel that emits CO_2 when combusted. Therefore, it is essential for emerging and developing economies to maximise efficiency in natural gas use. This can be achieved by improving skills in equipment operation and maintenance, encouraging the mandatory adoption of natural gas-fired combined cycle systems and hydrogen co-firing in the power generation sector.

LNG imports will play a critical role in meeting Asia's natural gas demand. The region's LNG consumption is expected to rise from 279 million tonnes in 2024 to a 1.4-fold increase reaching 379 Mt in 2035 and further to 591 Mt in 2050, a 2.1-fold increase. Japan and Korea were among the earliest and largest LNG importers, but in 2021 and 2023, China surpassed Japan to become the world's largest LNG importer. In 2024, Japan, Korea and Chinese Taipei combined accounted for 49% of Asia's LNG imports, while China, India, ASEAN and South Asia together accounted for 51%. By 2050, this distribution will shift significantly, with the former group's share falling to 21% and the latter's rising to 79%. Consequently, India, ASEAN and China will play increasingly important roles in securing a stable LNG supply for the region.

Unlike oil or natural gas consumption, coal consumption in Asia will peak in the 2020s before beginning a long-term decline, driven primarily by reductions in coal-fired power generation.

Between 1990 and 2023, coal consumption grew rapidly at an annual rate of 4.6%, but it will decline at an annual rate of 1.0% from 2023 to 2050. Concerns over climate change and air pollution have led to growing global criticism of coal-fired power plants. Across Asia, the adoption of renewable energy is advancing, leading to a decline in coal consumption for power generation. However, coal will remain Asia's dominant energy source in 2050, accounting for 32% of the region's total energy mix. India and Indonesia, among others, will continue expanding coal-fired power generation to meet rising electricity demand. Asian economies must strive to reduce environmental burdens while advancing the effective utilisation of Asia's abundant coal resources. To achieve this, they must avoid constructing new or expanding inefficient coal-fired power plants, and instead pursue the introduction of carbon capture, utilisation and storage (CCUS) involving advanced economies, alongside ammonia co-firing.

Although Asia's non-fossil energy consumption remains lower in volume than oil or natural gas consumption, it will grow at an annual rate of 2.9% from 2023 to 2050. Renewables, excluding traditional biomass, will account for 96% of the region's non-fossil energy consumption growth between 2023 and 2050, followed by nuclear at 15%, while traditional biomass use will decline by 11%. China will account for 54% of the growth in renewable energy consumption (excluding traditional biomass), ASEAN 15% and India 25%. In nuclear, China will account for 62% of the increase, while ASEAN and India will contribute 9% and 24%, respectively. Asia's share of global non-fossil energy consumption will rise by 11 percentage points from 2023 levels, reaching 50% in 2050.

In 2020, China announced its goal of achieving carbon neutrality by 2060, setting a policy to curb fuels with higher CO_2 intensity, such as oil and coal, while promoting the use of natural gas and non-fossil energy sources through 2050. Additionally, China has been advancing industrial policies focused on renewable energy, battery storage and electric vehicles, strengthening its global position in decarbonisation technologies. However, given China's substantial fossil fuel consumption, significant improvements in energy efficiency and decarbonisation efforts will be required. Meanwhile, India, which will drive most of Asia's incremental energy consumption through 2050, has pledged to achieve carbon neutrality by 2070. Many ASEAN nations, including Indonesia, have also committed to carbon neutrality. Under its 'Make in India' initiative, India is promoting domestic solar photovoltaic power generation and the adoption of EVs. In ASEAN, Indonesia has integrated energy conservation and green industry development into its medium-term national development plan. To accelerate energy efficiency and decarbonisation, Asia must take a proactive approach, leveraging continued and enhanced technical and financial assistance from Japan, Korea, China and other economies. These commitments by China, India and ASEAN to address climate change will also contribute to the stability of energy supplies, including LNG.

2.2 Final energy consumption

Global final energy consumption in 2050 will increase 1.2-fold from 2023.

In the Reference Scenario, global final energy consumption will increase 1.2-fold, from 10 249 million tonnes of oil equivalent (Mtoe) in 2023 to 11 857 Mtoe in 2050, representing an average annual growth of 0.5%. The following key trends will define this change in global final consumption between 2023 and 2050.

First, India, the Association of Southeast Asian Nations (ASEAN) and the Middle East and North Africa (MENA) will be the primary drivers of global final energy consumption growth through 2050. As a result, any major developments affecting energy demand in these countries/regions will significantly influence global consumption trends. Therefore, particular attention should be

paid to the factors that cause fluctuations in final energy consumption in these countries/regions. Those fluctuating factors include economic growth, the details and strengths of their energy-related policies, the technological development and diffusion of energy-using equipment.

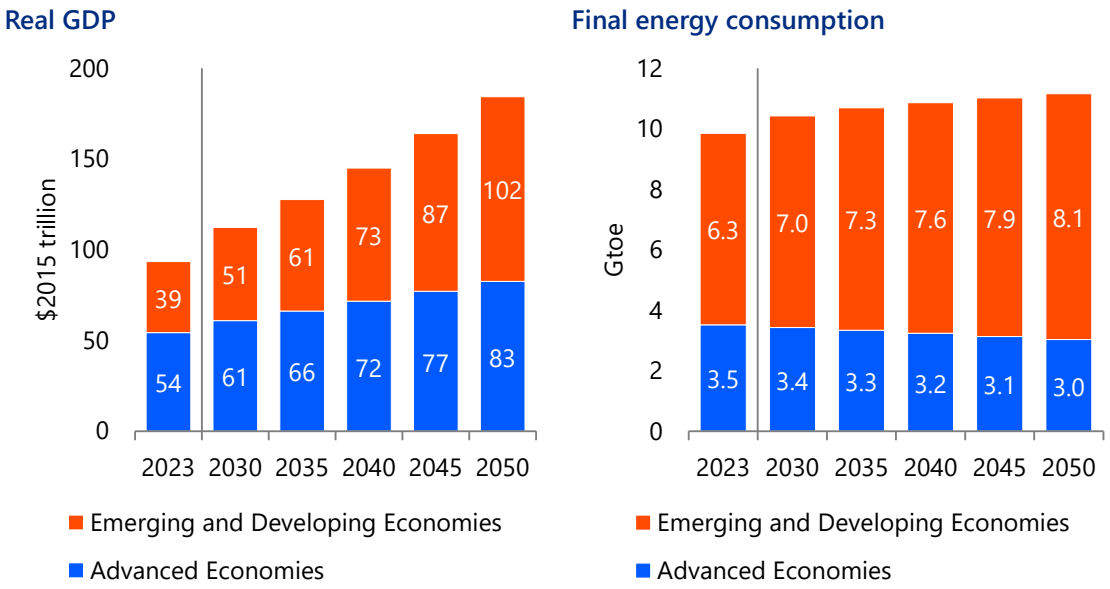
Second, all major energy sources will continue to play a role in global final energy consumption in 2050. While coal consumption will decline from the late 2020s and renewable energy consumption will decline from the 2030s, neither will reach an absolute minimum by 2050. While climate change is a critical global issue, if climate policies and investment strategies aimed at addressing it become overly biased towards specific energy sources, there is a risk of disrupting the overall energy supply-demand balance in the medium to long term. Therefore, it is essential to establish a market where each energy source can be supplied stably in response to demand, while taking into account trends in demand changes and the impact of climate change.

The following provides insights on final energy consumption changes in the Reference Scenario by economy group, region, sector and energy source between 2023 and 2050.

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

The increase in global final energy consumption from 2023 to 2050 will be driven primarily by Emerging and Developing Economies (Figure 2-24). While final energy consumption in Advanced Economies will decline over the same period, steady growth in Emerging and Developing Economies will more than offset this reduction, leading to an overall increase in global final energy consumption through 2050.

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



In Emerging and Developing Economies, final energy consumption is projected to reach 8 123 Mtoe in 2050, a 1.3-fold increase from 2023 (0.9% per year), driven by economic growth and population increase. These economies will follow a growth trajectory in the medium to long term. Improvements in energy efficiency and the expansion of service sectors will slow the rate of increase in final energy consumption. Final energy consumption growth will be significantly lower than real gross domestic product (GDP) growth (3.6% per annum).

In contrast, Advanced Economies will see final energy consumption decline to 3 039 Mtoe by 2050, a 10% reduction from 2023 levels. Even in those economies, real GDP will grow from 2023 to 2050 (1.6% per annum). However, in contrast to the upward trend in real GDP, final energy consumption will continue its downward trend, decreasing at an annual rate of 0.5%. This decline follows a trend that has been evident since the late 2000s, driven by accelerated energy conservation efforts and a structural shift towards service-based economies. As a result, the final energy consumption elasticity against GDP[4] in Advanced Economies will shift from 0.20 between 1990 and 2023 to −0.35 between 2023 and 2050[5].

Improving energy efficiency remains a key strategy for decarbonisation. Both advanced economies and emerging and developing economies will need to implement measures to enhance energy efficiency across all final energy consumption sectors.

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

Between 2023 and 2050, final energy consumption growth will be driven primarily by India, ASEAN and MENA (Figure 2-25 and Figure 2-26). Together, these countries/regions will account for more than 70% of the global increase in final energy consumption during this period.

Figure 2-25 | Global final energy consumption and contribution by country/region [Reference Scenario, 2023–2050]

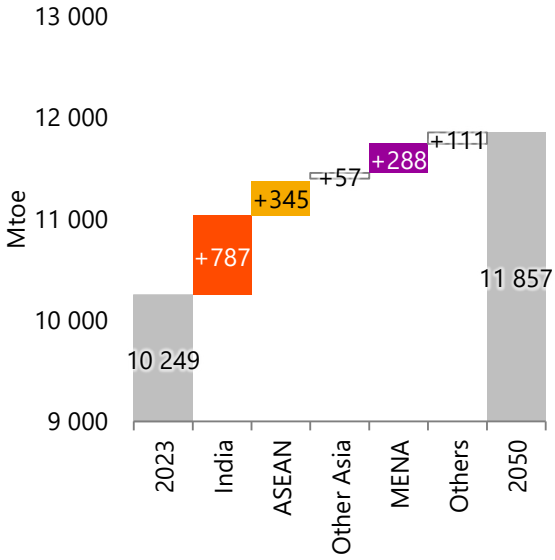
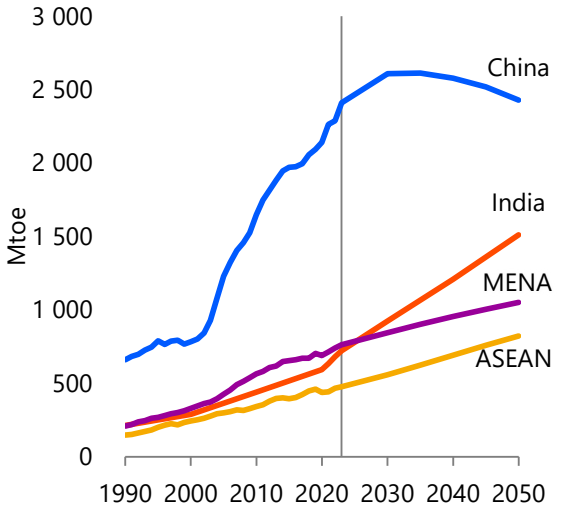


Figure 2-26 | Final energy consumption in China, India, MENA and ASEAN [Reference Scenario]



As a result of the strong demand growth in India and ASEAN, Asia's share of global final energy consumption will widen from 42% in 2023 to 46% in 2050. In the future, Asia will become an even more significant energy consumption centre.

India, which became the world's most populous country in 2022, will see its population exceed 1.6 billion and approach 1.7 billion by 2050. With GDP growing at an annual rate of 5.7% between 2023 and 2050, driven by urbanisation and other factors, India's GDP per capita will increase 3.9-

[4] Final energy consumption elasticity against GDP = final energy consumption growth rate ÷ real GDP growth rate.

[5] Nevertheless, higher economic growth does not necessarily mean less energy consumption.

fold. Backed by population and GDP growth, India's final energy consumption will grow 2.1-fold (2.8% per year) from 724 Mtoe in 2023 to 1 511 Mtoe in 2050. India alone will account for 60% of Asia's incremental final energy consumption, underscoring its rising significance not only within Asia but also globally. India's share of global final energy consumption will expand from 7.1% in 2023 to 12.7% in 2050, highlighting its growing influence on global energy demand.

In ASEAN, final energy consumption will grow at an annual rate of 2.0%, increasing from 477 Mtoe in 2023 to 822 Mtoe in 2050, largely driven by Indonesia and Viet Nam. Of the total 345 Mtoe increase in ASEAN's final energy consumption, Indonesia will contribute 142 Mtoe and Viet Nam 80 Mtoe. This growth reflects both countries' rising populations and expanding economies. In 2023, Indonesia and Viet Nam had populations of 281 million (the largest in ASEAN) and 100 million (the third largest), respectively, with continued growth expected. Between 2023 and 2050, GDP per capita will increase 2.9-fold in Indonesia and 3.6-fold in Viet Nam. Against this backdrop, Indonesia's final energy consumption will surpass that of Japan by the late 2030s.

China's final energy consumption will increase modestly, from 2 410 Mtoe in 2023 to 2 430 Mtoe in 2050. While China will remain the world's largest final energy consumer during this period, its energy demand will begin to decline after the 2030s. This pattern will differ from the constant uptrend in India and ASEAN. A key factor behind China's stabilisation and eventual decline in final energy consumption is the industry sector. The energy-intensive steel and cement industries, in particular, will see significant reductions in energy demand. The impact of efforts to eliminate excess capacity has already begun to materialise, with cement production peaking in the mid-2010s and crude steel production peaking in 2020 before shifting to a downward trend.

Final energy consumption in MENA will increase at an annual rate of 1.4% from 764 Mtoe in 2023 to 1 052 Mtoe in 2050 mainly in Iran, North Africa and Saudi Arabia. They will account for most of the region's total growth of 288 Mtoe. Specifically, Iran's final energy consumption will rise by 62 Mtoe, North Africa's by 86 Mtoe and Saudi Arabia's by 58 Mtoe. Population growth in these economies—at an annual rate of 0.9%—will outpace that of India and ASEAN, while GDP per capita will increase 2.0-fold in North Africa, 1.6-fold in Iran and 1.4-fold in Saudi Arabia.

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

Between 2023 and 2050, global final energy consumption will increase across all sectors, driven primarily by Emerging and Developing Economies. In contrast, final energy consumption in Advanced Economies will decline in all sectors except for the non-energy use sector (Figure 2-27).

In the transport sector, final energy consumption will grow at an annual rate of 0.5%, rising from 2 936 Mtoe in 2023 to 3 324 Mtoe in 2050, supported by growth in the road sector of Emerging and Developing Economies. The increase will reach 388 Mtoe, capturing 24% of the overall global rise in final energy consumption. Economic growth in these economies will lead to a significant expansion of automobile ownership over the same period (Figure 2-28). Consequently, final energy consumption in the transport sector of Emerging and Developing Economies will grow at an annual rate of 1.1%. In contrast, Advanced Economies will see an increase in electricity consumption due to the policy-driven adoption of electric vehicles. However, oil consumption in the road sector will decline significantly due to improvements in fuel efficiency and a reduction in internal combustion vehicle ownership. As a result, final energy consumption in the transport sector of Advanced Economies will decline at an annual rate of 1.5%.

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

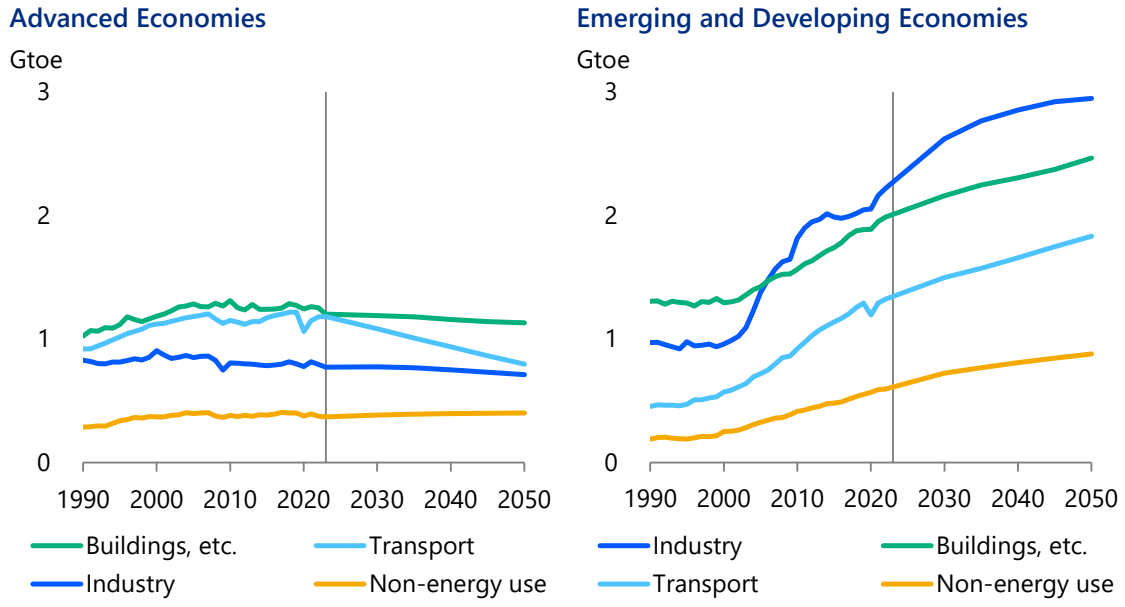
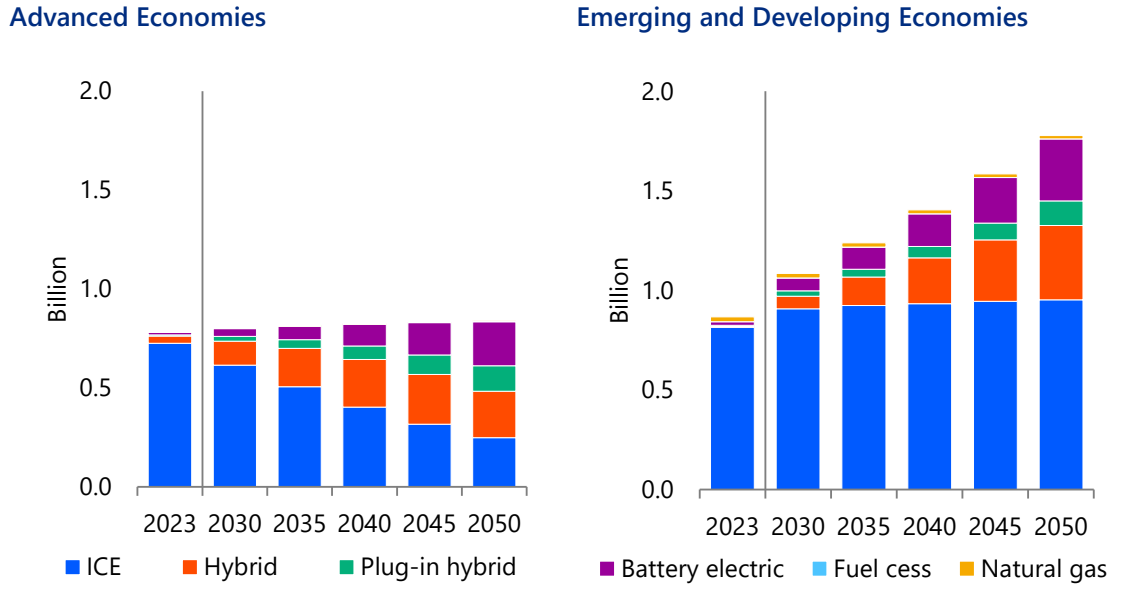


Figure 2-28 | Automobile ownership [Reference Scenario]



In the industry sector, final energy consumption will grow at an annual rate of 0.6%, increasing from 3 080 Mtoe in 2023 to 3 659 Mtoe in 2050. This growth will be driven primarily by increased electricity and natural gas consumption in manufacturing industries of Emerging and Developing Economies. The sector's total consumption growth will reach 580 Mtoe, accounting for 36% of the overall rise in final energy consumption. In general, however, there is a strong incentive in the industry sector, including manufacturing, to reduce the energy consumption of businesses to enhance the cost competitiveness of products. As a result, the growth in final energy

consumption in the global industry sector will be slower than the 2.3% annual growth in the value added of the global secondary sector from 2023 to 2050.

In the buildings sector, final energy consumption will grow at an annual rate of 0.4%, increasing from 3 232 Mtoe in 2023 to 3 595 Mtoe in 2050. The growth will be driven by increased consumption of electricity, city gas and petroleum products in the commercial and residential sectors of Emerging and Developing Economies. However, as Advanced Economies increasingly adopt electricity-consuming appliances, the consumption of city gas and petroleum products in the commercial and residential sectors will trend downward worldwide. The total increase in final energy consumption in the buildings sector will reach 363 Mtoe, representing 23% of the overall rise in final energy consumption. As living standards improve in Emerging and Developing Economies, access to modern energy and energy-efficient appliances will increase. In Africa, the share of traditional biomass (fuelwood and manure) in the buildings sector's energy consumption will decline from 73% in 2023 to 32% in 2050, while in Asia, where the share has already fallen to 18%, it will further decline to 5%.

In the non-energy use sector, final energy consumption is expected to grow at an annual rate of 0.9%, increasing from 1 002 Mtoe in 2023 to 1 279 Mtoe in 2050, mainly due to rising oil and natural gas consumption in Emerging and Developing Economies. The sector's total consumption growth will amount to 277 Mtoe, accounting for 17% of the overall rise in final energy consumption. In Emerging and Developing Economies, demand for petrochemical products, including plastics, will increase as living standards improve. In Advanced Economies, consumption will rise slightly between 2023 and 2050. In North America, the petrochemical industry's non-energy use will increase due to the expansion of shale gas production, which enables cost-effective procurement of feedstocks. 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.

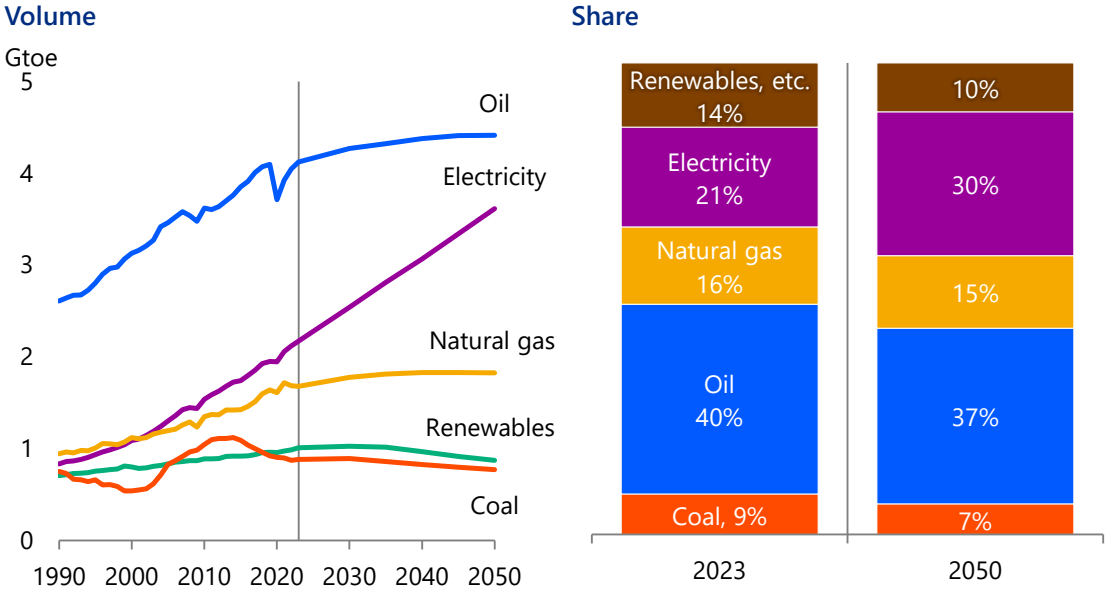
By energy source: Demand for all energy sources will remain.

Changes in global final energy consumption from 2023 to 2050 can be categorised into two trends: energy sources with an increasing share and those with a declining share (Figure 2-29).

While electricity's share of global final energy consumption will rise, the shares of oil, coal, natural gas and other renewables (dominated by the direct use of biomass) will decrease. Despite this shift, demand for coal and renewables and especially natural gas will remain significant in 2050. Fossil fuels (coal, oil and natural gas) will see their combined share of global final energy consumption fall from 65% in 2023 to 59% in 2050, yet they will continue to represent more than half of total consumption.

Final oil consumption will increase at a rate of 0.3% per year from 4 122 Mtoe in 2023 to 4 413 Mtoe in 2050, led by growth in the transport sector including the road sector in Emerging and Developing Economies. While the decline in Advanced Economies is expected to be 525 Mtoe, the increase in Emerging and Developing Economies will be 595 Mtoe. In Asia, where motorisation is accelerating, including in India and ASEAN, oil consumption in the road sector will increase by 151 Mtoe. The non-energy use sector will post the second-highest growth in oil consumption, following transport. In this sector, oil consumption will expand in Asia and the Middle East, where abundant local resources support petrochemical industry development.

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



Final electricity consumption will grow at an annual rate of 1.9%, increasing from 2 171 Mtoe in 2023 to 3 615 Mtoe in 2050. This growth will be driven by increased electricity use in the buildings and industry sectors. Electricity is the only energy source that will post consumption growth also in Advanced Economies. While the primary drivers of global electricity demand growth will be China, India and ASEAN, the consumption will increase also in North America and Europe. Generally, as people's incomes rise, electricity is preferred for its convenience. Additionally, the increasing penetration of digitalisation will expand the use of electricity-consuming devices and machinery. Electricity's share of global final energy consumption will rise from 21% in 2023 to 30% in 2050. As economies and societies become more reliant on electricity, the consequences of supply disruptions will grow. While decarbonising power sources is a significant issue, it is also important to ensure a stable supply system of electricity from the viewpoint of energy security.

Final natural gas consumption will grow at an annual rate of 0.3%, rising from 1 680 Mtoe in 2023 to 1 827 Mtoe in 2050. Growth will be concentrated in the industry and non-energy use sectors of Emerging and Developing Economies. In India, ASEAN and MENA, where manufacturing industries are expanding, demand for natural gas will increase, particularly for processing and assembly industries. In the non-energy use sector, India and ASEAN, with their growing demand for chemicals, and the Middle East, which is seeking to expand its petrochemical industry using natural gas, will drive the growth of global natural gas consumption.

Final coal consumption will decline at an annual rate of 0.5%, falling from 882 Mtoe in 2023 to 772 Mtoe in 2050, due primarily to reductions in China's industry and buildings sectors. As mentioned in the regional perspective, China's coal-intensive steel and cement manufacturing industries will contract in the medium to long term. By 2050, coal consumption in China's industry sector will be less than half of its 2023 level. In addition, China has pledged its '3060 Goal', which aims to reach peak carbon dioxide (CO_2) emissions by 2030 and become carbon neutral by 2060. Based on this goal, China plans to reduce coal consumption from 2025. This will accelerate the shift to electricity in the industry sector and to natural gas and electricity in the buildings sector.

Final renewable energy consumption will decline at an annual rate of 0.5%, decreasing from 1 009 Mtoe in 2023 to 875 Mtoe in 2050. This decline will be primarily driven by the ongoing energy transition in Emerging and Developing Economies in Asia and Africa. One area of renewable energy in final consumption gaining attention is liquid biofuels for use in automobiles and aircraft. However, traditional biomass, including fuelwood and manure used in Emerging and Developing Economies, accounted for the largest share at 68% in 2023, followed by 14% for fuelwood mainly for space heating in Europe and North America, 13% for liquid biofuels and 4% for others. As mentioned in the perspective by sector, the use of modern energy is gradually replacing the use of traditional biomass in Emerging and Developing Economies in Asia and Africa. As a result, global final consumption of renewables will gradually decline from the 2030s.

3. Energy supply

3.1 Crude oil

Crude oil supply in recent years

Crude oil supply trends since the coronavirus disease 2019 (COVID-19 pandemic have been shaped by factors such as rising geopolitical risks, production cuts by OPEC[6] Plus and increased production by non-OPEC Plus.

Geopolitical risks have persisted and continue to pose serious threats to oil supplies, including the war in Ukraine, attacks on oil tankers in the Middle East and attacks on Iran by Israel and the United States, but large-scale supply disruptions have been avoided as of November 2025. Western countries have imposed sanctions, including embargoes, price caps and the blocking of financing and insurance for tankers and import-export companies, to reduce Russia's and Iran's oil export revenues. Despite these sanctions, however, oil exports from Russia and Iran have remained resilient.

OPEC Plus, which began production cuts in 2017, agreed as a group to reduce output by 2.0 million barrels per day in October 2022. Furthermore, eight additional countries voluntarily agreed to reduce production by 1.66 Mb/d in April 2023 and by 2.2 Mb/d in November 2023, continuing to strengthen production cuts. However, from April 2025, they began to ease their voluntary production cuts, shifting to a strategy of expanding market share. In the meantime, non-OPEC Plus supply has been increasing, particularly in the Americas.

Despite these diverse risks, oil supply has been expanding at a pace that exceeds demand in 2025. According to the International Energy Agency (IEA), liquid fuel supply (including biofuels) in the second quarter of 2025 is projected to reach 105.0 Mb/d, exceeding demand for the same period by 1.8 Mb/d.

Non-OPEC production will decline after 2030, with OPEC's share expanding.

In the Reference Scenario, global oil demand will increase, mainly in Emerging and Developing Economies, such as India, the Association of Southeast Asian Nations (ASEAN) and Africa. However, global demand will remain largely flat from around 2040 onwards, affected by the continued decline in demand in Advanced Economies and the peaking of Chinese demand around 2030. As a result, the demand growth rate between 2023 and 2050 will only be 0.1% per annum.

Production from non-OPEC countries will be sustained until around 2030, underpinned by increased output in the Americas. Meanwhile, production in North America, mainly the United States, will peak around 2030. Production in Europe and Eurasia will not grow, as Russian production, which had remained solid despite sanctions from Western countries, will begin to decline, albeit slowly, with European production also continuing to decline. Production increases in Latin America will be sustained, though output in Africa will remain flat, while production declines will continue in Asia and Oceania. Against this backdrop, production in non-OPEC countries will begin to decline from 2030 onwards.

Meanwhile, OPEC production will remain roughly flat until around 2030, as production levels in non-OPEC countries are maintained. From 2030 onwards, however, production from non-OPEC

[6] The Organization of the Petroleum Exporting Countries

countries will decline, while production from cost-competitive OPEC countries will increase. As a result, the share of OPEC crude oil in the world oil supply will expand from 34% in 2023 to 40% in 2050.

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

(Mb/d)

	2023	2030	2040	2050	2023-2050	
					Changes	CAGR
Crude oil production	96.3	96.8	99.1	98.6	2.3	0.1%
OPEC	33.9	33.9	38.5	40.0	6.1	0.6%
Middle East	26.7	27.3	31.8	33.4	6.7	0.8%
Others	7.1	6.6	6.8	6.6	-0.6	-0.3%
Non-OPEC	62.4	62.9	60.6	58.6	-3.8	-0.2%
North America	24.0	26.1	25.2	23.7	-0.3	0.0%
Latin America	9.0	9.3	10.0	10.0	1.0	0.4%
Europe and Eurasia	17.6	16.6	15.2	14.6	-3.0	-0.7%
Middle East	2.9	3.3	3.7	4.4	1.5	1.6%
Africa	1.5	1.4	1.4	1.4	0.0	-0.1%
Asia and Oceania	7.5	6.3	5.2	4.4	-3.1	-1.9%
Processing gains	2.4	2.4	2.4	2.4	0.1	0.1%
Oil supply	98.6	99.2	101.6	101.0	2.3	0.1%

Note: Crude oil includes natural gas liquids (NGLs).

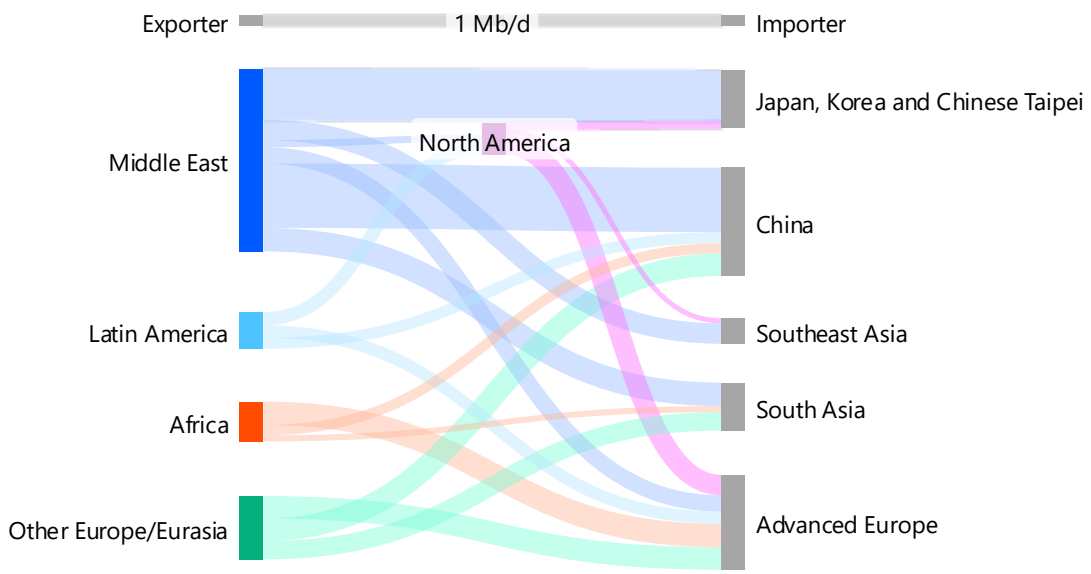
Asia's growing dependence on Middle Eastern crude oil

In 2024, global interregional crude oil trade totalled 43 Mb/d. The Middle East remained the largest exporting region, accounting for approximately 18 Mb/d, or 43% of global exports, followed by North America at 8 Mb/d and Other Europe/Eurasia, which is led by Russia, at 7 Mb/d. Asia is the primary destination for Middle Eastern crude oil, receiving 80% of the region's exports.

In Other Europe/Eurasia, 60% of exports were directed to Asia, largely due to Russia increasing shipments to China and India in response to Western embargoes. North American crude oil trade is predominantly intra-regional, with flows between the United States and Canada making up 50% of total exports. Of the remaining exports, 20% are shipped to Europe and another 20% to Asia.

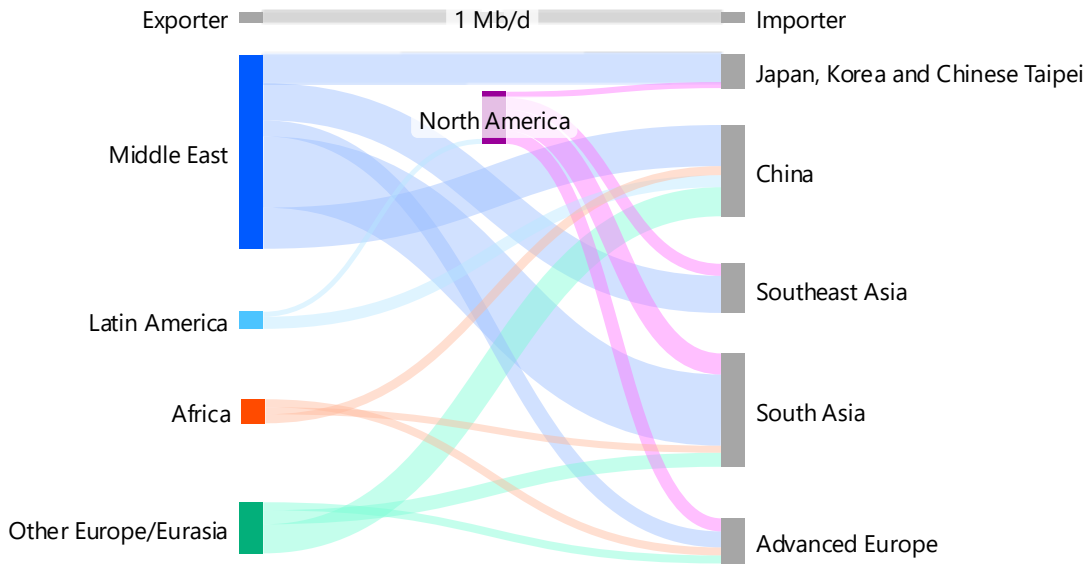
As for imports, Asia is by far the largest importing region with about 25 Mb/d, of which China, the world's largest importer, accounts for about 10 Mb/d. Advanced Europe's imports are also large, at 10 Mb/d. The largest supplier for Asia is the Middle East, with a 60% dependency rate for Asia as a whole. Since the onset of the war in Ukraine, Africa has emerged as the leading crude oil supplier to Advanced Europe, as the region moves away from Russian crude oil. North America and the Middle East have also expanded their exports to Advanced Europe, reducing Advanced Europe's dependence on crude oil from Other Europe/Eurasia. Before the invasion of Ukraine, Advanced Europe sourced 40% of its crude oil imports from this region. By 2024, this dependence had fallen to 24% (with the European Union's reliance on Russian crude oil dropping from 30% to just 4%).

Figure 3-1 | Major interregional crude oil trade flows [2024]



Note: Flows of 0.5 Mb/d or more are covered.
Sources: Energy Institute "Statistical Review of World Energy 2025", 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.

Interregional crude oil trade volume in 2050 will increase due to growing demand and declining regional production in Southeast Asia and South Asia, despite decreased imports from Advanced

Europe and Northeast Asia. There will be a notable decline in exports from Russia and Other Europe/Eurasia and Africa to Advanced Europe, as well as from the Middle East to Northeast Asia. Meanwhile, exports from the Middle East and North America to South Asia and Southeast Asia will grow. Overall, Asia's import dependence will continue to rise, with the Middle East remaining the largest supplier to Asia.

3.2 Natural gas

The liquefied natural gas market is finally entering a major expansion phase, with logistics continuing to fluctuate between east and west.

The year 2025 is characterised by accelerated investment decisions, engineering work, marketing activities to secure long-term sales contracts and financing, alongside increased liquefied natural gas (LNG) shipments coinciding with the completion and start-up of LNG projects currently under construction.

The United States has been central to global LNG production growth over the past eight years or so, and with the commencement of operations at new and expanded LNG production facilities and an increase in export volumes, investment decisions and development activities are accelerating following the end of the pause on export authorisation discussed below. Particularly notable is the advancement of additional facilities and expansion projects by LNG production project developers, who have established a firm foothold in the global LNG market over the past few years. Of the 46 million tonnes per year of final investment decisions (FIDs) on LNG export projects announced globally through September 2025, US projects accounted for 40 Mt.

Also in North America, an export project on the west coast of Canada began operations in mid-2025. Based on cost-competitive Canadian gas sources and direct access to Pacific markets, the project has the potential to become a game-changer in the Asian LNG market. LNG supplies are expected to expand on the west coast of North America, including projects under construction on the west coast of Mexico.

In the first half of 2025, global LNG trade exceeded 200 Mt, following the same period in 2023 and 2024. While the growth rate was modest compared with the same period the previous year, it marked the third record high for a January–June six-month period. However, contrary to the shift from the Atlantic to the Pacific in 2024, LNG imports in Asia, particularly China, decreased, while those in the European Union and the United Kingdom combined increased by around 20%. As a result, the ratio of LNG imports east and west of Suez shifted from 70:30 for the full year 2024 to 64:36 for the first half of 2025, with the Atlantic market gaining greater prominence.

Japan imported 32 Mt, slightly down from the same period in the previous year, for the second consecutive year. China's LNG imports remained at 30 Mt, down 20% year-on-year. In the first half of 2025, Japan was the world's largest LNG importer. China's total imports of pipeline gas and LNG were 60 Mt, down 8% from the same period in the previous year, but it remained the world's largest importer of natural gas. China produced 130.8 billion cubic metres of natural gas in the first half of 2025, up 5.8% year on year. On the other hand, consumption reached 211.97 Bcm, down 0.9% year-on-year. Southeast Asia's LNG imports remained at 11 Mt, down 10% year-on-year.

On the LNG export side, the United States, Qatar and Australia ranked highest, as in the same period from 2022 to 2024. Among these, the United States increased its exports by 8% compared with the same period in the previous year, exceeding 50 Mt for the first time in a six-month period.

Russia, ranked fourth as in the previous year, saw an 8% decrease compared with the same period the previous year.

Since 2022, a combination of the European Union's avoidance of using Russian fossil fuels and Russia's deliberate reduction in energy exports has led to a decline in Russian pipeline gas supply to the European Union. Monthly supply fell from just over 8 Mt in LNG equivalent in December 2021 to below 2 Mt after December 2022. At the beginning of 2025, supplies via Ukraine ceased, with monthly volumes remaining below 1 Mt. On the other hand, the supply of Russian LNG to the European Union increased slightly after 2022, marking a record high of 17 Mt in 2024. However, beyond 2025, alongside the remaining Russian pipeline gas supplies, there are uncertainties surrounding the supply trends for Russian LNG.

Depending on future trends in spot gas prices in Asia and Europe, the ratio of US LNG exports to each region will fluctuate. The ratio of US LNG exports to the European Union and the United Kingdom surged from around 30% in 2021 to over 60% in 2022–2023, then decreased to just under 50% in 2024, but rapidly rebounded to nearly 70% in the first half of 2025. Meanwhile, the share of US LNG exports to Asia declined from nearly half in 2021 to about a quarter from 2022 to 2023, before rising to just over 30% in 2024 and dropping to below 20% in the first half of 2025.

In the LNG market in 2022, the shutdown and postponed restart of a US LNG facility following a fire became a major factor in the decline in supply and the uncertain future outlook. In late 2023, labour disputes at large LNG production facilities in Australia caused market volatility, although they did not lead to supply disruptions. From 2024 to early 2025, restrictions on major LNG marine transport routes resulted in detours and longer shipping distances. If there are any additional troubles with large LNG production facilities or disruptions to transport routes, the market could be significantly disrupted. From late 2025 to 2027, the timely and stable commissioning of new LNG projects in Canada, Mexico, the United States, Australia and Qatar will also be major factors that affect the market.

In the United States, which became the world's largest LNG exporter in 2023, the administration suspended the non-free-trade-agreement (FTA) LNG export authorisation process in late January 2024, and the Department of Energy conducted a study on the economic and environmental impacts of LNG exports that same year. The pause on the LNG export authorisation process has caused delays and uncertainty for some LNG projects while calling into question the reliability of the United States as a long-term, stable LNG supplier. China, the fastest-growing natural gas and LNG market in recent years, experienced a decline in natural gas consumption in 2022 for the first time in the recorded history of China's natural gas market (−1.7% year-on-year), whereas its LNG imports fell by nearly 20% year-on-year. However, natural gas consumption rebounded in 2023 and in 2024, LNG imports, pipeline gas imports and domestic natural gas consumption and production all increased. Natural gas consumption declined slightly again in the first half of 2025. Meanwhile, both pipeline gas imports and domestic natural gas production increased, leading to a significant decrease in LNG imports.

India, another rapidly expanding natural gas market, saw demand recover from a 5% year-on-year decline in 2022 to a 15.5% increase in 2023. In 2024, it increased by 10.1% but dropped by 6.9% in the first half of 2025. While natural gas production by state-owned enterprises declined, private sector production rose by 16% in 2022, 20% in 2023 and 9% in 2024. In the first half of 2025, private sector production fell by 6.4% compared with the same period in the previous year, and overall domestic natural gas production also decreased by 3.8%.

In Southeast Asia and South Asia (excluding India), the impact of price and supply-demand fluctuations in the global LNG market has been varied in recent years. In Southeast Asia, LNG

imports increased by 32% year-on-year in 2022, 27% in 2023 and 16% in 2024, reaching 23.83 Mt in 2024. In the first half of 2025, however, imports fell sharply to 11.30 Mt, a 10.3% year-on-year decrease. Southeast Asia contains both LNG-exporting and LNG-importing countries, with varying degrees of impact. In 2023, the Philippines and Viet Nam joined the list of LNG importers, leading to a further increase in LNG imports in Southeast Asia. Bangladesh and Pakistan, on the other hand, significantly reduced LNG imports for natural gas-fired power generation in 2022, with a combined decline of 15% year-on-year. Their imports, however, increased by 8.8% in 2023 and 9.2% in 2024 to reach 13.51 Mt. In the first half of 2025, imports accounted for 6.83 Mt, with a year-on-year increase of 2.4%.

LNG market expansion history and current development status

Since the oil crisis half a century ago, natural gas and LNG have emerged as the cleanest and most essential energy sources among fossil fuels. Today, natural gas accounts for roughly a quarter of global and Japanese primary energy consumption. 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, especially in Asia, where LNG accounts for a major part of the natural gas supply. Seaborne LNG trade has increased by more than 60% in the 13 years since 2011. In 2022–2023, Germany, the Philippines, Hong Kong, Viet Nam and Mauritania 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. How Russian natural gas will be handled after the conflict is resolved will also have a major impact on global natural gas supply and demand.

For the time being, the United States will play a pivotal role in LNG supply, particularly through projects with the highest likelihood of being realised based on future investment decisions. Unlike traditional LNG projects in other regions, LNG projects in the United States do not necessarily have upstream gas fields supplying feedstock gas that are vertically integrated. These projects have been developed with relatively loose commitments on LNG purchasing, meaning that final consumption destinations are not always predetermined. However, since 2021, long-term contracts that specify the end-users have gained traction once again, leading to increasing diversity in project structures as global LNG volumes grow.

The rise of US LNG in the global market has driven structural changes in LNG trade. In 2019, the full-scale supply of US LNG to Japan demonstrated its advantage when oil-indexed prices were high, a feature that had previously been the mainstream in trading contracts with the main suppliers of LNG to Asia. On the other hand, in 2020, it demonstrated flexibility in absorbing fluctuations in supply volumes during a period of depressed global natural gas prices and short-term demand weakness. In 2021, as global natural gas prices surged, US LNG reinforced its competitive pricing and adaptability, solidifying its role as a key supplier to various regions. In 2022, the United States became the largest source of additional natural gas for Europe. In 2023 and 2024, it became the world's largest LNG exporter. A further phase of expansion is accelerating from 2025 onwards.

Table 3-2 | Changes in the role of LNG

Major periods and incidents	LNG's roles
Late 20th century Oil crises air pollution	Expanded as an alternative, clean energy source (Japan and Korea) Alternative source of supply for pipeline gas (Europe) Expanded its share among primary energy sources and helped ease the impact of the oil crises
2010s Addressed the nuclear power crisis Increased energy demand	Demonstrated flexibility to respond quickly to baseload power source shortages The number of participating companies across each element of the value chain has broadened, reducing the difficulty of liquefaction, maritime transport and vaporisation operations worldwide and expanding its use. Remarkable flexibility in emergencies
2021–2022 Rebound in post-pandemic energy demand Russian war, natural gas shortages	LNG imports made up for the reduced supply of Russian pipeline gas in Europe compared with before the invasion of Ukraine Decrease in Russian pipeline gas imports due to the crisis and pipeline explosion offset by increase in LNG imports, mainly from the United States
Towards the future Realistic solution for the uncertainties surrounding the energy transition	A core supply source for energy security Underpins economic growth in emerging markets and a stable energy supply in mature markets Combination with new and clean energy sources and transition Could be utilised permanently if LNG can become clean

The growing presence of the United States in the global LNG market has begun to influence LNG procurement contract negotiations, not only for US suppliers but also other LNG-producing countries. Meanwhile, Australia completed the final phase of its LNG production capacity expansion in 2019 and subsequently boosted output in 2020 and 2021, surpassing Qatar—which had been the world's largest LNG exporter since 2006. At the same time, Russia has expanded LNG production from its Arctic region, increasing its share of the European natural gas market despite ongoing geopolitical challenges.

Changing development models for LNG production

Historically, large-scale LNG projects have required four to five years from the investment decision to the start of exports. However, efforts to shorten construction timelines through standardisation and modularisation of engineering and assembly processes are yielding results. In addition, some of the emerging project companies have announced the completion of 1.4 Mt/year floating LNG (FLNG) production facilities in one to two years, which is significantly shorter than conventional methods.

New LNG developments are emerging in frontier regions across East and West Africa, where natural gas production is expanding. For offshore or small and medium-sized natural gas fields,

floating LNG production facilities are increasingly seen as viable options. Floating LNG production started in 2018 offshore Cameroon in West Africa, in 2022 offshore Mozambique in East Africa, in 2024 offshore the Republic of the Congo, and in 2025 offshore Senegal and Mauritania in West Africa. Large LNG players with global marketing capabilities have made commitments to take delivery of all LNG produced under these projects to promote them.

Mozambique 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. However, construction has been suspended since 2021, due to the deteriorating local security situation. As of mid-2025, coordination among stakeholders is underway to resume construction. 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. Tanzania also possesses abundant natural gas resources, which could lead to LNG exports.

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

The future role of LNG needs to be clarified

LNG and natural gas are expected to play a vital role as a realistic solution for resolving uncertainties in the energy transition. LNG's role has grown with the needs of the times. It will also play a role as a key energy source in energy transitions, contributing to energy security. It will underpin economic growth in emerging markets and stable energy supply in mature markets and contribute to the energy transition of the world in combination with new energy sources. Making LNG and natural gas clean will be a prerequisite.

Both the Reference Scenario and the Advanced Technologies Scenario foresee strong demand for LNG and natural gas mainly in the emerging markets in Southeast Asia. The demand could rise even further if energy efficiency does not improve as anticipated by these scenarios.

In Southeast Asia, regional consumption of natural gas has grown since the 1970s alongside the development of LNG export projects. Natural gas utilisation will continue and expand in traditional gas producer countries, namely Indonesia, Malaysia and Thailand.

Since 2011, seven countries have begun to import LNG, and LNG imports from outside the region, as well as mutual LNG trade within the region, are growing. The share of LNG in Southeast Asia's natural gas consumption is expected to grow from the current one-sixth to around one-third in 2050. There is a particularly large potential for expanding infrastructure for LNG use in the coastal regions and islands.

In the Southeast Asian market, natural gas will play a particularly important role in reducing emissions from the industry sector and in balancing the supply and demand of electricity. It may serve as an economically rational fuel for reducing emissions in the transitional period. Ensuring a stable natural gas market and expanding the supply capability to do so will help reduce energy transition costs.

Recent LNG market trends underline the importance of LNG's role and the long-term stability and security of the market. LNG is providing the flexibility necessary for responding to energy

crises, and the recent destabilisation of the supply-demand balance and prices is affirming the importance of taking long-term market stability measures.

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 emerging and developing economies, and the demand-side trend towards 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 natural gas demand reductions in Europe and the trend of natural gas demand recovery 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, increased volatility continues 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, for measuring, reporting and verifying (MRV) greenhouse gas (GHG) emissions, and for equipment for clean measures at the government and international levels.

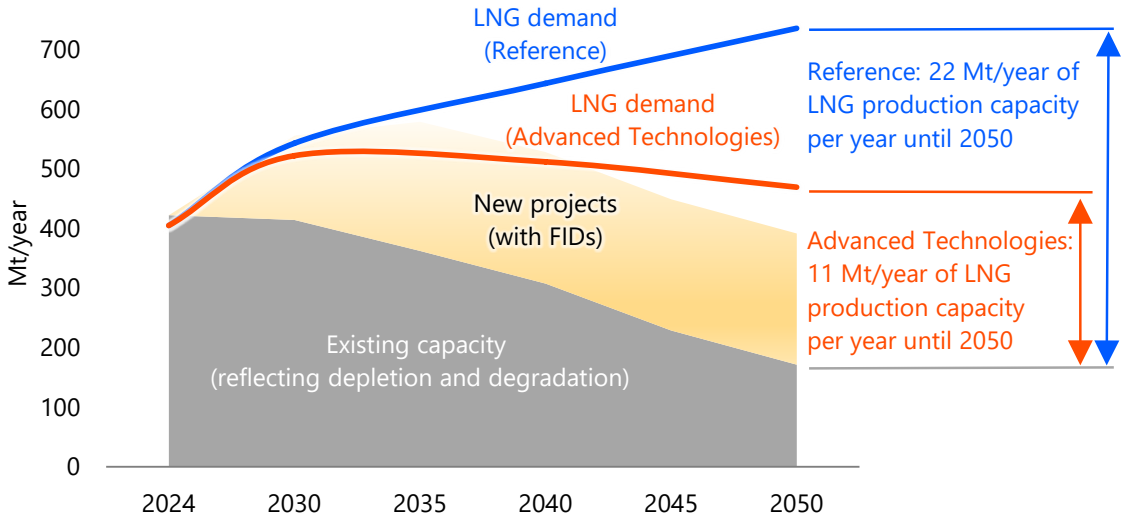
In this regard, the discussion at the 2025 LNG Producer-Consumer Conference on strengthening cooperation among governments and relevant organisations to stabilise the LNG market and promote cleaner LNG production represents progress.

Ongoing investments in LNG and natural gas are required for a stable supply

The LNG production sector needs additional capacity of 11 to 22 Mt/year up to 2050. These figures are based on the difference between the estimated LNG demand and decreased production capacity due to ageing. They include: 1/ investments in new projects, 2/ investments in new gas fields as alternative supplies (backfill), 3/ compensation for declining production in feedstock gas fields, and 4/ rejuvenation and renovation of existing LNG liquefaction facilities and other infrastructure.

The total capacity of new construction decisions in the past four years (projects in FID status) exceeds this amount. However, even the implementation of FID projects is not completely certain, and attention should be paid to the possibility of delays or cancellation. Causes for delay that have emerged include growing uncertainty over new Russian projects, continued suspension of construction in Africa due to political unrest, failure in project owner-contractor negotiations due to increased engineering, procurement and construction (EPC) costs in the United States, and a court decision to halt construction licensing stemming from a US environmental litigation.

Figure 3-3 | Global LNG demand and production capacity



Cost increases alongside technological innovations and evolving development models

Addressing development obstacles for LNG production projects will be key to the long-term use of LNG.

LNG supply has increased rapidly since the 2010s, with supply centres shifting from Qatar to Australia and then to the United States. In the process, the development costs for LNG production projects have been on the rise. In parallel, cost reduction efforts through floating LNG production, small- and medium-sized liquefaction facilities and modular systems have also been made.

The start of LNG exports in the North American west coast, namely in Canada and Mexico, and the progress of LNG development in East Africa are expected to be game changers that diversify supply sources and resolve bottlenecks in marine LNG transport to the Asian market in terms of distance and routes. Among these, LNG exports started from Canada's west coast in 2025.

Long-term commitment from buyers has been key to the steady stream of projects reaching FID in the past few years. In particular, the FID for the 2025 US project was supported by long-term LNG purchase agreements with buyers, including Japanese companies.

While steady growth in production capacity is expected in the medium term, construction delays are becoming a norm. There are views that LNG supply capacity will be in excess around 2030, but forecasts of excess could also spur additional demand. Due to the reasons on both the supply and demand sides, 'excess supply' will likely be an illusion.

Major LNG exporting regions have issues as well as resource potential. Australia's LNG export development has matured, and maintaining stable production through brownfield projects will be a challenge. Qatar is factoring in clean measures into its mega expansion plan, and whether it will be completed as planned is the key concern. East Africa has high resource potential, but full-scale expansion is at a standstill. Russia's supply is currently strong, but the country faces challenges and new development projects are growing even more uncertain.

LNG transport bottlenecks and production equipment problems

With the geographical expansion of the LNG market, ensuring smooth marine transport and stable LNG production is becoming ever more important as long-term challenges. Bottlenecks in

key LNG shipping routes, if they occur, are likely to cause serious disruptions when supply is tight. There is a need to establish a long-term LNG transportation strategy.

With the diversification of LNG supply sources, transportation routes and distances vary depending on the source and consumption areas. The completion of expansion of the Panama Canal in 2016 made it possible for LNG carriers to pass through, improving the convenience of transporting US LNG to Asia. Since the shale revolution, the canal has also contributed to increased shipments of liquefied petroleum gas (LPG) to Asia, alongside natural gas. The increase in traffic is causing long waiting times and detours. While passage and reservation systems are being rationalised, drops in water level caused by droughts have led to restrictions on the number of large vessels that can pass through. In 2024 and 2025, it is becoming a norm for US LNG bound for Northeast Asia to go around the Cape of Good Hope. Similarly, Middle Eastern LNG bound for Europe is also routinely shipped via the Cape of Good Hope. Constraints on LNG transportation are growing. Meanwhile, the start of full-scale LNG exports from the North American west coast and East Africa will be a game changer for rationalising and optimising LNG transportation.

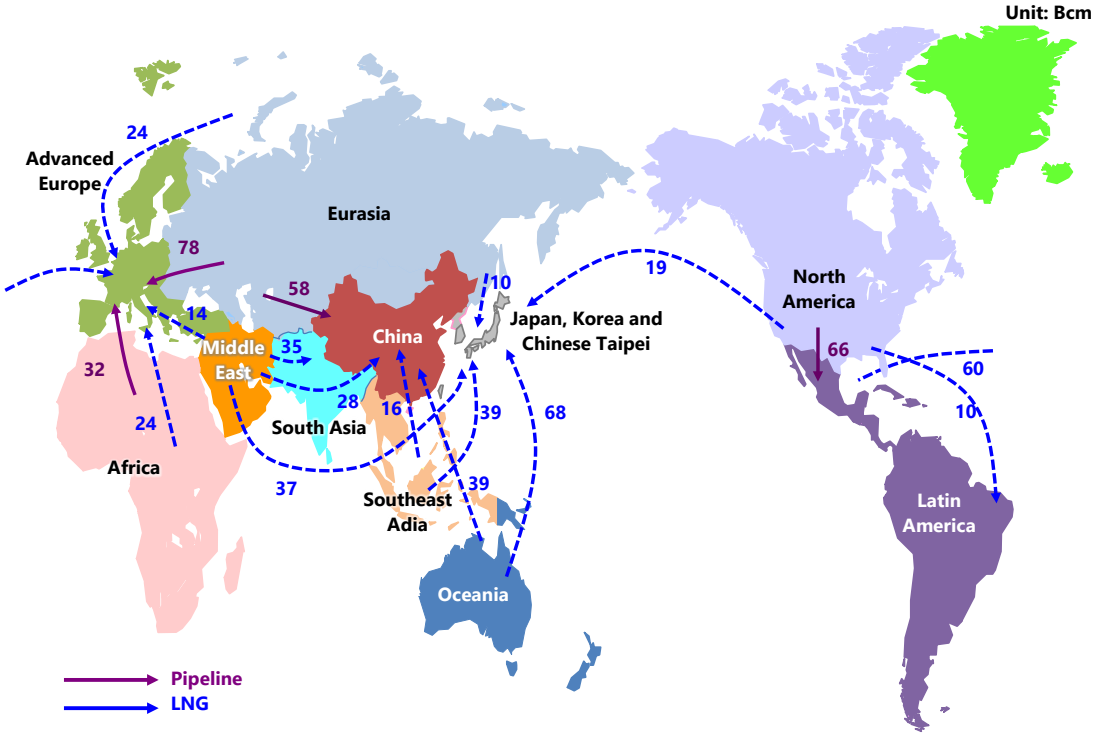
Unplanned shutdowns of LNG production facilities are increasing and are likely to cause serious problems when the supply-demand balance is tight. One example is a large US LNG export facility that shut down for extended periods after a fire in 2022, which coincided with relatively long unplanned shutdowns in other producer countries. Because this occurred when the market balance was tight, it pushed up the already high spot LNG and gas prices.

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

(Bcm)

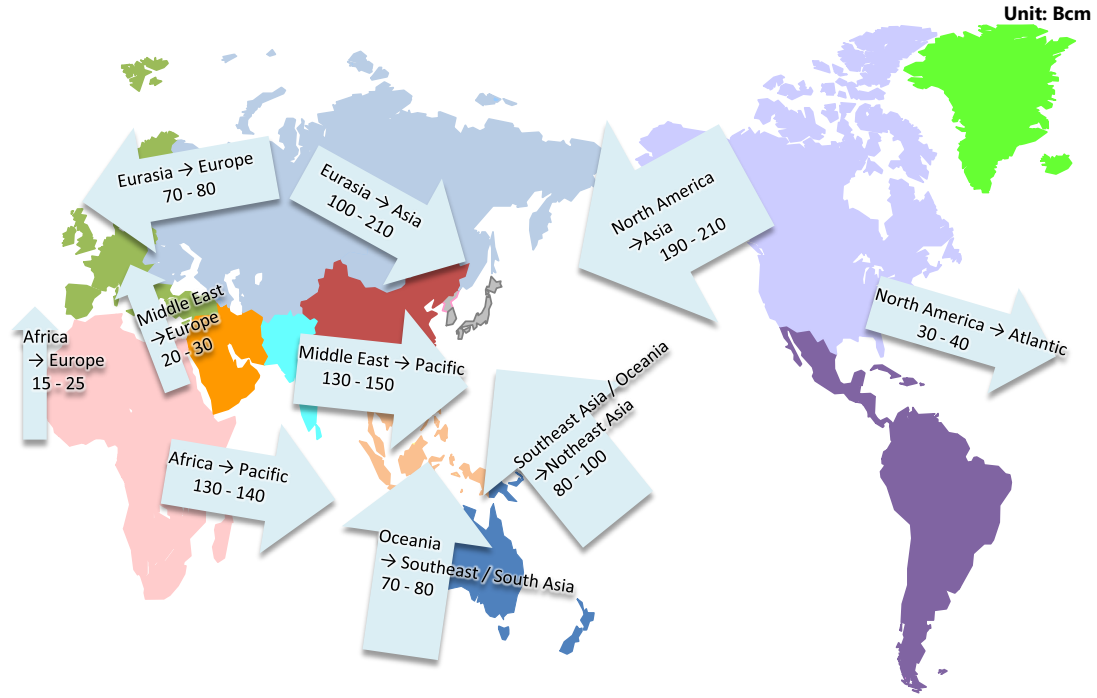
	2023	2030	2040	2050	2023-2050	
					Changes	CAGR
World	4 222	4 322	4 775	5 386	1 165	0.9%
North America and Mexico	1 280	1 292	1 385	1 365	85	0.2%
Latin America excl. Mexico	199	234	289	356	156	2.2%
Europe	196	136	132	106	-90	-2.2%
Eurasia	856	820	839	909	52	0.2%
Russia	638	600	600	609	-29	-0.2%
Middle East	732	770	827	1 049	318	1.3%
Africa	253	256	380	614	361	3.3%
Asia	538	650	738	784	246	1.4%
China	232	260	276	242	10	0.1%
India	36	55	87	90	54	3.5%
ASEAN	204	229	241	252	48	0.8%
Oceania	167	165	185	204	37	0.7%

Figure 3-4 | Major interregional natural gas trade flows [2024]



Note: Major interregional trade flows are indicated.

Figure 3-5 | Major interregional natural gas trade flows [Reference Scenario, 2050]



Notes: Major interregional trade flows are indicated, not encompassing all trade volumes. Supplies from Eurasia, Africa and the Middle East include those through pipelines in addition to LNG.

3.3 Coal

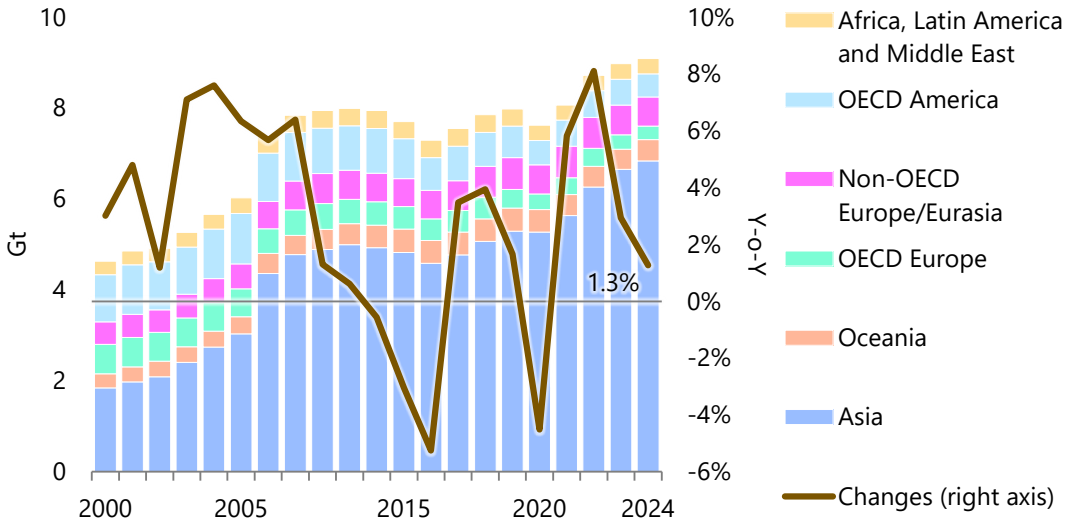
Overview of global supply and demand

In 2024, global coal production hit a record high of 9.1 Gt (Figure 3-6). This was mainly due to increased production in the three major coal-producing countries: China, India and Indonesia. Domestic circumstances, safety measures and export trends in each country contributed to the record-breaking results.

China maintained production at around 4.6 Gt in 2024. Although production in Shanxi Province declined due to strengthened safety management, increased production in the Inner Mongolia and Xinjiang regions more than compensated for this, contributing to sustaining nationwide production levels. Coal production continues to be ramped up as a pillar of the government's energy security strategy centred on domestic coal supply. In India, production increased 5% from the previous year to 1 090 Mt. Coal India Limited (CIL) and other captive (for self-consumption) and private mines also expanded output. Coal production in Indonesia recorded an 8% increase from the previous year to 830 Mt, thanks to expanded domestic demand and increased exports to China. Australia produced 470 Mt of coal, a 7% year-on-year increase, despite heavy rainfall at the start of the year, as operations proceeded smoothly thereafter. Both countries are adapting to weather risks while maintaining their positions as major exporters. Mongolia has also significantly increased production, supported by rising exports to China. South Africa succeeded in maintaining production levels despite the impact of power outages.

The record coal production in 2024 demonstrates that coal remains a central component of the current energy supply and economic activity. Meanwhile, environmental issues such as air pollution and greenhouse gas emissions continue to pose significant challenges. Going forward, greater attention is expected to focus on technological development and policy adjustments aimed at achieving both a stable supply and reduced environmental impact.

Figure 3-6 | Global coal production



Notes: Figures for 2024 are provisional.
Source: International Energy Agency "World Energy Balances July 2025"

Global coal production is expected to reach 9.2 Gt in 2025, recording a new high. By country, China recorded a 6% year-on-year rise in the first half of the year. This growth rate is largely

driven by a rebound effect following the large-scale production adjustments implemented in Shanxi Province in 2024. However, domestic inventories remain at high levels and prices are on a downward trajectory, particularly in the northern region. Although the market recovered during the summer, demand is expected to slow in the latter half of the year, raising concerns about potential impacts on production volumes.

In India, the government's drive to boost domestic coal production is expected to strengthen supply capacity for coal-fired power plants. Specifically, government measures to promote mining investment and reforms to the allocation system have borne fruit, leading to increased private sector participation. Production is forecast to reach the 1.1 Gt range, a 3% year-on-year increase. Although domestic demand remains resilient, particularly in the electricity and cement industries, concerns persist that high coal prices will push up power generation costs.

In Indonesia, coal production decreased by 8% year-on-year in the first half of the year. This was affected by low export prices to China as well as operational shutdowns caused by floods and heavy rains. For the full year, production is forecast to fall by 10% to 760 Mt, below the previous year. Attention must also be paid to limited shipping capacity at major ports and the restructuring of mines that fall below the break-even point. Price recovery and progress in infrastructure development are considered key to a production recovery in the latter half of the year and beyond.

In Australia, production is forecast to decline year-on-year to approximately 430 Mt due to operational stoppages caused by coal mine accidents and flood damage. While maintaining its position as a major exporter, there are concerns over its export competitiveness, due to increased vessel layover days caused by reduced supply, and Queensland's royalties being among the highest globally. Amid mounting pressure on coal operations following a period of environmental policy prioritisation, there is uncertainty about the future of coal supply and declining business predictability.

In the United States, production is increasing, thanks in part to policy support for the coal industry under the Trump administration. Demand has also been rising as coal-fired power generation has maintained a price advantage over natural gas-fired power generation. With the price impact on the natural gas market expected to ease in the second half of the year, demand is expected to remain at around 480 Mt overall.

In Russia, a slight production cut is expected due to continued sanctions, while uncertainty remains high and forecasts are fluid, with the possibility of a significant decline. By 2024, more than half of producers were expected to record losses, and the government plans to introduce rail transport subsidies from May 2025. Maintaining exports is key to sustaining production volumes. Going forward, Russia's strategy to shift to markets outside Europe, particularly Asia, will determine the success or failure of its exports.

Mongolia is expected to see a slight decrease in production due to limited railway capacity to China and a decline in demand within China, while South Africa will see a slight increase due to stable growth in domestic demand, mainly for electricity. Colombia is expected to face the risk of a significant decline in production due to labour disputes and changes in tax policy.

Supply and demand balance due to China and India's domestic coal production increase policies

Global coal demand increased by 1.5% compared with 2023, reaching a record high of 8.79 Gt. The growth rate has slowed compared with 2022 (4.4%) and 2023 (2.3%), but the upward trend continues. This growth was driven by Asian emerging economies, with China and India experiencing increases of 82 Mt and 45 Mt, respectively, from the previous year, and Indonesia

and Viet Nam also seeing expanded demand. Meanwhile, in advanced economies, demand continues to decline due to reductions in coal-fired power generation, with the European Union declining by 40 Mt and the United States by 14 Mt. As such, China, India and the Association of Southeast Asian Nations (ASEAN) account for 77% of global coal demand. This is more than double the share in the early 21st century, highlighting Asia's growing influence in the global coal market. The increase in coal-fired power generation in Asia is notable, reaching a record high of 10 766 TWh in 2024. Meanwhile, demand for coking coal for steelmaking has remained broadly flat or declined slightly in recent years. China accounts for 50% of global coal demand, with its power generation sector alone accounting for one-third of global coal consumption. As such, global coal demand trends have been heavily influenced by China's policies and electricity demand.

Global coal demand declined slightly in the first half of 2025. While fuel diversification and renewable energy adoption are gradually progressing, the situation is becoming more complex across regions. The coal market is in constant flux, with short-term economic fluctuations and seasonal factors intertwining.

Although China did not experience severe cold during the winter, high temperatures persisted in the summer, accelerating demand for thermal power generation. Annual coal demand for thermal power generation, however, is expected to decrease compared with the previous year. Sluggish electricity consumption and the expanded use of renewable energy will continue to weigh on coal use.

In India as well, demand stagnated in the first half of the year. The earlier-than-normal rainy season and extreme heat in 2024 caused thermal power generation demand to fall by 2.1%. On the other hand, strong demand from the iron and steel industry is boosting coking coal consumption, which is expected to be higher than the previous year on a full-year basis.

In East Asia, Japan's coal demand is gradually declining due to economic uncertainty, while Korea recorded a significant decline in the first half but recovered in the second half and full-year demand is ultimately forecast to be on par with the previous year. In Chinese Taipei, natural gas is filling the gap left by the nuclear phase-out, while coal consumption is expected to decrease in the power generation sector and decline slightly in the non-power-generation sector, resulting in a total decrease compared with the previous year. Meanwhile, Indonesia is performing strongly, with growth expected, primarily in power generation, but also in refining, steelmaking and self-generation.

Both the United States and the European Union expanded their coal consumption in the first half of the year. In the United States, surging natural gas prices and increased electricity demand are boosting production, which is expected to increase by 12% year-on-year in the first half and by 7% for the full year, to reach the 400 Mt range. In the European Union, the electricity sector relied on coal-fired power generation due to sluggish hydro and wind power output, leading to a 5% increase in coal-fired power generation in the first quarter. However, with the trend towards structural decarbonisation remaining unshaken, full-year coal-fired power generation is expected to decline compared with the previous year. The market for coking coal for steelmaking is also facing challenges. The global economic slowdown and sluggish infrastructure investment have dampened demand, while uncertainty over the future flow of steel products and components following the introduction of US tariffs is also contributing to market stagnation. Amid these mixed trends, global coal demand is expected to ultimately remain roughly flat compared with the previous year.

Coal trade

In 2024, global coal trade volume reached a new record high, exceeding 1.5 Gt for the first time. In particular, the trade volume of steam coal reached 1.18 Gt. Import demand in Asia is driving this increase. China, in particular, expanded its imports by 14% from the previous year to 550 Mt, the first time imports exceeded 500 Mt in a single year. China's imports are roughly twice those of India, the world's second-largest importer. As for exports, Indonesia increased its shipments by 6% to 550 Mt, led by those to China. Australia saw modest growth of 3% to 209 Mt. Russia's exports have dropped significantly due to Western sanctions, logistical disruptions and deteriorating profitability.

Meanwhile, global trade of coking coal is also expected to reach a record high of 370 Mt in 2024. Australia remained stable at the same level as the previous year, Mongolia exported its entire 56 Mt to China, recording a 5% increase, the United States saw a slight rise, while Canada experienced a decline.

Global steam coal trade is projected to decrease in 2025 compared with the previous year. China's imports are expected to decline due to slowing demand, robust domestic production and increased inventories. India's dependence on imports will decrease as domestic production expands. Japan and Korea are expected to see a decline in imports due to the recovery of nuclear power generation and economic uncertainty. Viet Nam is expected to increase its imports supported by rising domestic electricity demand. As for trends among major exporting countries, Indonesia is expected to reduce its steam coal exports by at least 10% to act as a supply balancer for Asian markets, including China and India. Colombia's exports will decline due to a worsening market and labour-management issues. South Africa will see a slight increase in trade volume due to tight supply and demand in Europe (low wind power output as backup). Meanwhile, coking coal trade will also decline in volume, reflecting weaker global steel demand. The primary driver is the slowdown in steel demand in China. In particular, exports from Mongolia, which is highly dependent on China, will fall significantly. Australia is also expected to see a slight decrease due to bad weather, while Russia faces a decrease caused by deteriorating corporate finances.

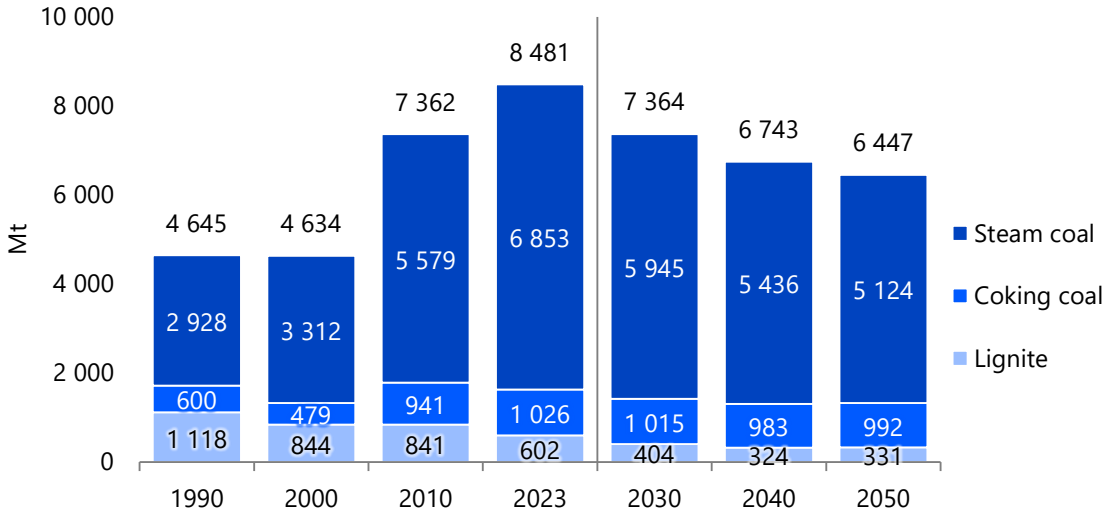
Maintaining a supply system that meets demand

Advanced economies, including the United States and Europe, have been accelerating their decarbonisation efforts, while emerging and developing economies have also declared their commitment to carbon neutrality. Consequently, many countries now share a recognition of the need to strictly limit fossil fuel consumption and production, particularly coal. Coal consumption in Europe and the United States has already been steadily declining. In such an environment, President Donald Trump, who returned to power in the United States in 2025, reversed policies implemented by the previous administration and introduced the 'Energy Dominance' strategy, which emphasises fossil fuels and deregulation. This has also led to the US coal industry receiving substantial support through an executive order dubbed 'Beautiful Clean Coal', making its future trajectory a subject of keen interest. Meanwhile, in China, India and emerging Asian economies, energy demand continues to rise alongside economic development, with coal continuing to play a central role in meeting this demand. However, resource majors have continued to withdraw from, downsize, or restructure their upstream coal operations in alignment with decarbonisation trends. Notably, amid this movement, companies backed by Asian businesses and conglomerates, whose demand continues to grow, have stepped in to bid for the coal assets being divested.

Given the energy situation in each country and current coal demand, the global phase-out of coal is expected to be a long-term effort in practice. Coal consumption in 2024 increased year-on-year, reaching a record high of 8.79 Gt. This surge was driven primarily by emerging Asian economies, including China and India. Looking at global coal demand in the short to medium term, demand will expand in Asia (including China, India and ASEAN countries) and Africa, in line with economic growth. In the long term, demand will increase in Asia (including India and ASEAN, excluding China) and Africa. Traditional upstream coal investment and financing for new mine development and the maintenance and renewal of existing operations have been significantly reduced or restricted amid decarbonisation efforts, raising concerns about future supply capacity. In this context, the aforementioned participation of Asian companies in coal projects is noteworthy. Attention is also focused on how the Trump administration's fossil fuel support policies will influence countries outside the United States.

Global coal production will increase until the late 2020s, then begin to decline in line with demand. Production volume will decrease from 8.481 Gt in 2023 to 7.364 Gt in 2030 and to 6.447 Gt in 2050 (Figure 3-7).

Figure 3-7 | Global coal production [Reference Scenario]



By coal type, steam coal production will peak in the late 2020s and then begin to decline in line with decreasing demand for power generation. Production volume will decrease from 6.853 Gt in 2023 to 5.945 Gt in 2030 and to 5.124 Gt in 2050. Consequently, China will rapidly shift its power sources from coal to renewable energies from the present until around 2030. As a result, coal demand will rapidly decline until around 2030, followed by a slower reduction towards 2050. Meanwhile, production of coking coal, mainly for steelmaking, will gradually decline from 1 026 Mt in 2023 to 992 Mt in 2050. Production of lignite, a locally produced and consumed energy resource, will gradually decrease from 620 Mt in 2023 to 331 Mt in 2050 alongside the decommissioning of existing lignite-fired power plants.

In the future, coal-supplying countries will produce in response to export demand (the international coal market) after meeting their domestic requirements. Conversely, countries that both produce and consume substantial amounts of coal, such as China and India, will expand domestic production to meet internal demand and import any shortfall from other supplying

countries. Countries such as Japan, where coal resources are limited and production is not economical, will depend entirely on imports.

Examining 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 increasingly difficult to develop new coal mines, expand production at existing operations, or invest in transportation infrastructure. In Australia, domestic consumption and export of coal remain a divisive public issue. The federal government is set to strengthen existing greenhouse gas measures following the change of government in 2022, which will significantly affect future production of fossil fuels, including coal. Coal-producing state governments are increasingly seeking alternative sources of foreign currency beyond coal exports while complying with climate change policies. Major importers of Australian coal, such as India and ASEAN, continue to experience increasing coal demand; however, competition from Indonesian exports may constrain supply depending on Indonesian domestic priority policies. Although supplies from Australia (especially steam coal) could potentially expand, this may prove difficult given the current policy and investment environment. The status of mergers and acquisitions of Australian coal assets should be closely monitored.

In Colombia, which has served as a supplier of coal mainly for Europe, companies from advanced economies are withdrawing from coal production. The country is unlikely to increase production significantly in the medium to long term as its political situation grows more unstable. South Africa, whose main markets are domestic supply and India, is also witnessing a transformation of its coal industry, including the withdrawal of companies from advanced economies. Reserves in existing coalfields are being depleted, necessitating a shift to new coalfields. Indonesia, a major exporter of steam coal, has expanded production primarily to meet remarkably strong export demand. Meanwhile, the government has established a basic policy of curbing production and prioritising domestic supply to protect coal resources. However, the coal production quotas announced annually by the government are set to allow for significant production increases, and currently there are no major disruptions to production for either domestic use or export. The rapid expansion of domestic self-generation demand in Indonesia, combined with increased domestic coal production in China and India, has led to a noticeable decline in coal import demand this year. Greater attention must therefore be paid to the government's future actions.

China and India have been increasing domestic coal production alongside their efforts to build new coal-fired power plants. Looking ahead, demand in China will peak in the late 2020s and then decline, while demand in India will grow towards 2050. Both countries have worked to secure supply capacity by increasing domestic coal production but have also utilised imported coal as a valve to adjust domestic supply and demand. The effects of increased production are beginning to be seen, and caution is required regarding the impact on the international market as demand for imported coal declines.

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

(Mt)

	2023	2030	2040	2050	2023-2050	
					Changes	CAGR
World	6 962	5 945	5 436	5 124	-1 838	-1.1%
North America	454	214	138	100	-354	-5.4%
United States	391	206	131	95	-296	-5.1%
Latin America	64	55	46	44	-20	-1.4%
Colombia	56	47	39	37	-19	-1.5%
OECD Europe	45	23	16	9	-35	-5.6%
Non-OECD Europe/Eurasia	368	330	298	304	-64	-0.7%
Russia	247	220	191	190	-57	-1.0%
Middle East	0	0	0	0	0	-0.5%
Africa	249	225	238	269	19	0.3%
South Africa	245	201	202	219	-26	-0.4%
Asia	5 529	4 886	4 519	4 233	-1 296	-1.0%
China	3 903	3 092	2 435	1 862	-2 041	-2.7%
India	839	1 002	1 296	1 564	725	2.3%
Indonesia	681	659	642	648	-33	-0.2%
Oceania	252	210	181	165	-87	-1.6%
Australia	251	210	180	164	-87	-1.6%

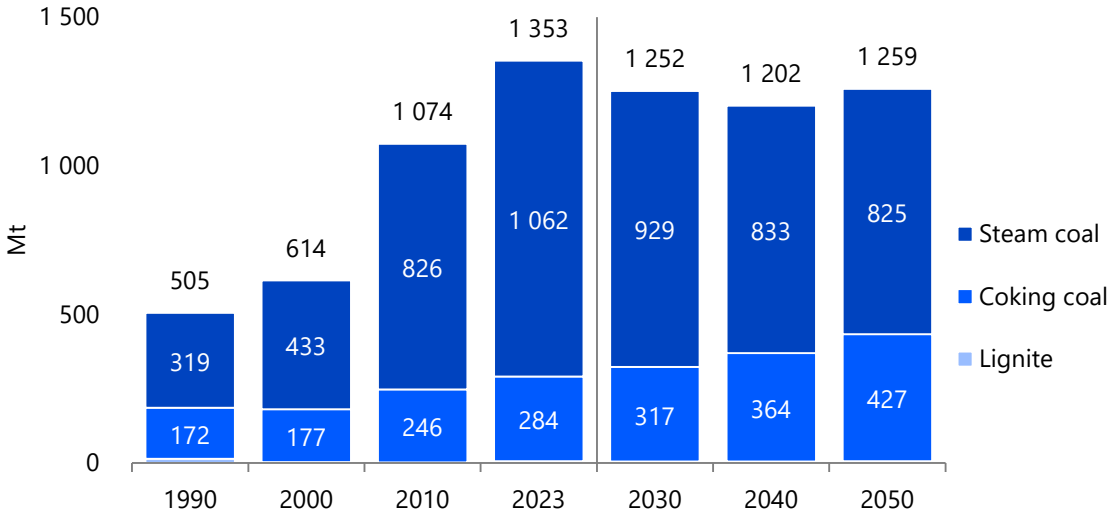
Table 3-5 | Coking coal production [Reference Scenario]

(Mt)

	2023	2030	2040	2050	2023-2050	
					Changes	CAGR
World	1 021	1 015	983	992	-29	-0.1%
North America	77	63	66	71	-6	-0.3%
United States	52	45	47	50	-2	-0.2%
Latin America	10	10	13	18	8	2.1%
Colombia	9	9	12	17	8	2.5%
OECD Europe	14	13	14	15	1	0.2%
Non-OECD Europe/Eurasia	110	103	108	115	5	0.2%
Russia	105	97	101	109	4	0.1%
Middle East	2	2	3	3	1	1.6%
Africa	8	19	28	38	30	5.8%
Mozambique	4	15	22	32	27	7.6%
Asia	641	621	541	482	-159	-1.1%
China	554	521	408	309	-245	-2.1%
India	57	68	99	136	80	3.3%
Mongolia	24	25	25	25	1	0.1%
Oceania	158	184	212	250	91	1.7%
Australia	157	183	211	249	91	1.7%

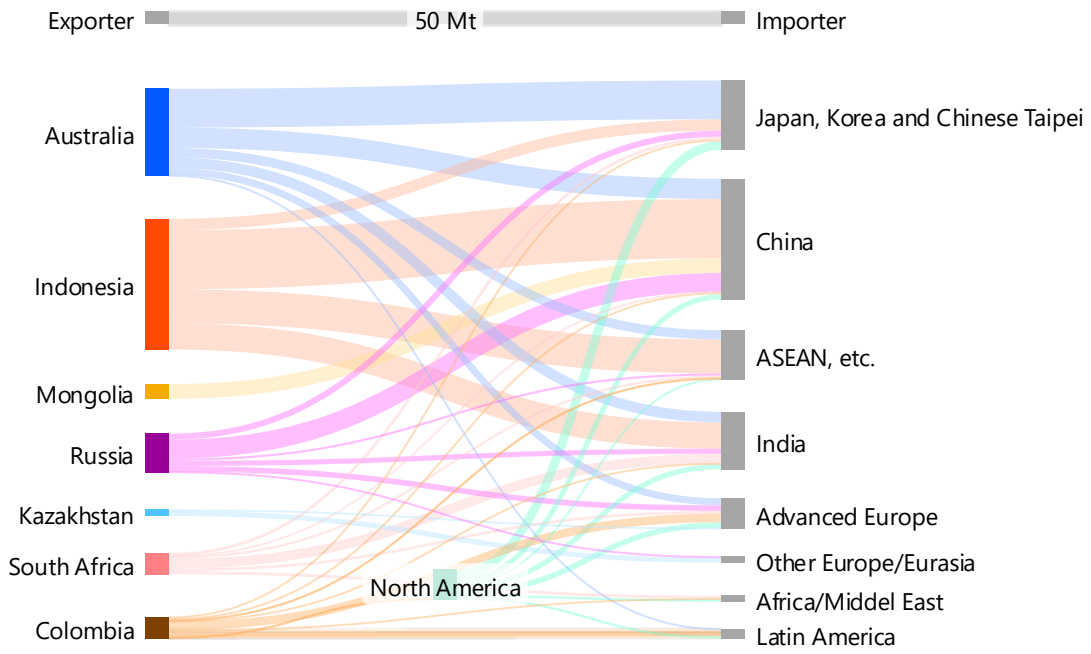
Coal trade volume will decrease from 1 353 Mt in 2023 to 1 202 Mt in 2040 but will then increase slightly to 1 259 Mt in 2050. By type of coal, trade of steam coal will decline significantly from 1 062 Mt in 2023 to 825 Mt in 2050, as China's imports peak in the late 2020s followed by a decline amid decarbonisation efforts. Conversely, demand for coking coal will gradually decrease due to declining steel demand in the European Union, Japan and China, but increasing steel demand in Emerging and Developing Economies, particularly India, will offset these declines, and trade volume will increase from 284 Mt in 2023 to 427 Mt in 2050.

Figure 3-8 | Global coal trade (import volume) [Reference Scenario]



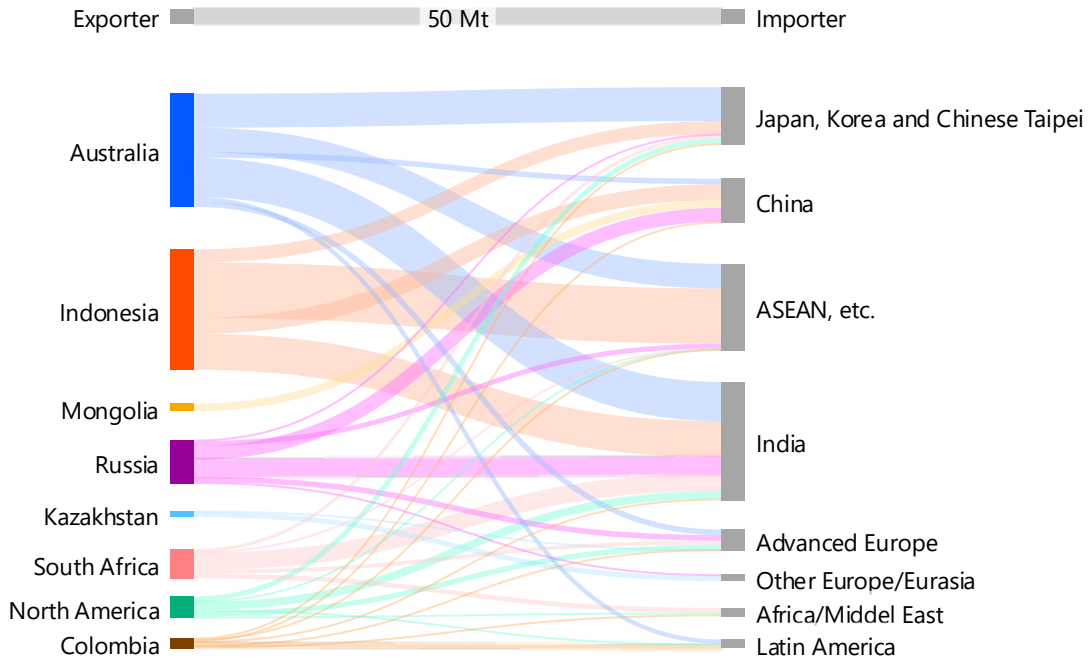
By major exporters, Australia will maintain the current level, but the volume balance will shift in line with demand changes, with steam coal decreasing and coking coal increasing. Indonesia will tend to reduce its export volume while maintaining production to meet increasing domestic demand. This will not significantly impact the market in the near term, partly due to reduced demand in China, but from the 2030s, it may affect the Asian market, depending on the supply balance between domestic and export markets. Russia's exports, following a decline in the short to medium term due to embargoes imposed by the European Union and Japan, will remain flat.

Figure 3-9 | Major interregional coal trade flows [2024]



Notes: Sum of steam coal and coking coal. 2 Mt or more listed. South Africa includes Mozambique.
Source: Estimated based on IEA "Coal Information 2025", TEX Report, etc.

Figure 3-10 | Major interregional coal trade flows [Reference Scenario, 2050]



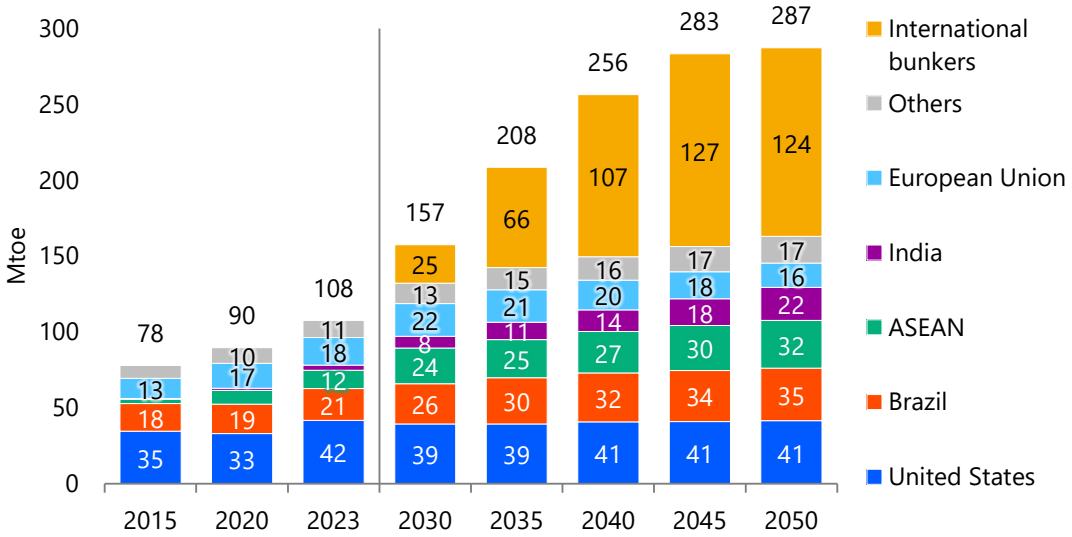
Notes: Sum of steam coal and coking coal. 2 Mt or more listed. South Africa includes Mozambique.

3.4 Biofuels for transport

The penetration of liquid biofuels including bioethanol and biodiesel has progressed as part of measures on climate change, energy security and agriculture promotion. Currently, biofuel use in automobiles is concentrated in the United States, Brazil, Southeast Asia and the European Union.

While biofuel consumption has increased substantially since the 1990s, investment in biofuels has remained stagnant since 2010. The increased introduction of low-cost electric vehicles (EVs), including those made in China, will pose a headwind for the use of liquid biofuels in automobiles. However, the number of internal combustion engine vehicles (ICEs) and hybrid electric vehicles (HEVs) using biofuels will also increase (Figure 2-28), leading to a gradual rise in overall demand[7] (Figure 3-11).

Figure 3-11 | Biofuel consumption for transportation [Reference Scenario]



Note: International bunkers include sustainable aviation fuel (SAF) and marine biofuel.

By region, demand for both liquid fuels and biofuels will grow in emerging and developing economies. In countries producing biofuel feedstocks such as sugarcane, including Brazil, demand for liquid fuels for motor vehicles will remain robust. Increasing liquid fuel demand will be met by raising the ethanol blending ratio. Biofuel demand in the Association of Southeast Asian Nations (ASEAN) will increase sharply but will not reach levels comparable to those in the United States or Brazil. In advanced economies, the introduction of regulations aimed at decarbonisation will reduce demand for liquid fuels, but a certain level of biofuel demand is expected to continue due to policy guidance, such as the setting of phased targets and introduction goals tailored to the circumstances of each country. In the European Union, which is proactive in taking measures against climate change, including the Renewable Energy Directive (RED III), a certain number of vehicles currently in operation will remain. As a result, demand for biofuels at a comparable scale is expected to persist beyond 2030, owing to stockpiles and other factors.

[7] It should be noted that the outlook in terms of calorific value differs from that based on volume because estimates are performed on the basis of the blending ratio (by volume) for liquid fuels such as gasoline and diesel.

Beyond automobiles, biofuel consumption for international aviation and marine transport, currently minimal, will expand in the future. The European Union adopted a bill to promote clean aviation fuel, 'ReFuelEU Aviation', in 2023, and is implementing regulations requiring operators supplying jet fuel to airports in the region to incorporate a certain percentage of sustainable aviation fuel (SAF) in their total fuel supply. While there are prospects for SAF derived from renewable energy or hydrogen, at the current stage, biofuel-derived SAF remains price-competitive. However, it is difficult at this point to foresee the comparative rationality of other decarbonisation measures, such as operational efficiency and the use of credits, and the volume of SAF introduced will depend on factors such as demand-side acceptance of price increases attributable to SAF and the degree of progress in achieving broad societal acceptance.

Regarding biofuels for marine use, while demand for liquid biofuels is expected in the near term, the long-term outlook points to the introduction of hydrogen-based liquid fuels such as ammonia and methanol, as well as hydrogen-based fuels including e-methane derived from liquefied natural gas (LNG) and gaseous biofuels. This shift is expected to align with progress in international regulatory trends, technological development and the advancement of societal implementation, including port infrastructure development. Consequently, liquid biofuels are expected to reach a peak around a transition point in 2040. In the longer term, the proportion of liquid biofuels used in shipping will therefore decrease.

On the supply side, there are growing concerns in some regions about the environmental impact of first-generation biofuels and their competition with food. Initiatives to develop next-generation biofuels, including second-generation cellulosic biofuels and third-generation algae-derived fuels, and to reduce their cost, will be strengthened.

3.5 Power generation

Recent trends

Increase in power generation accelerated in 2024 due to strong demand for data centres.

Total global electricity generated in 2024 amounted to 31.3 PWh, representing a 4.0% increase from the previous year[8]. This growth rate far exceeded the average of 2.6% per year over the past decade. The main factors behind this include continued economic growth and a surge in demand from power-hungry data centres. In particular, the United States, which leads in artificial intelligence (AI) development, saw its power generation growth rate rise by 2.2%, a significant increase compared with the average of 0.6% over the past decade.

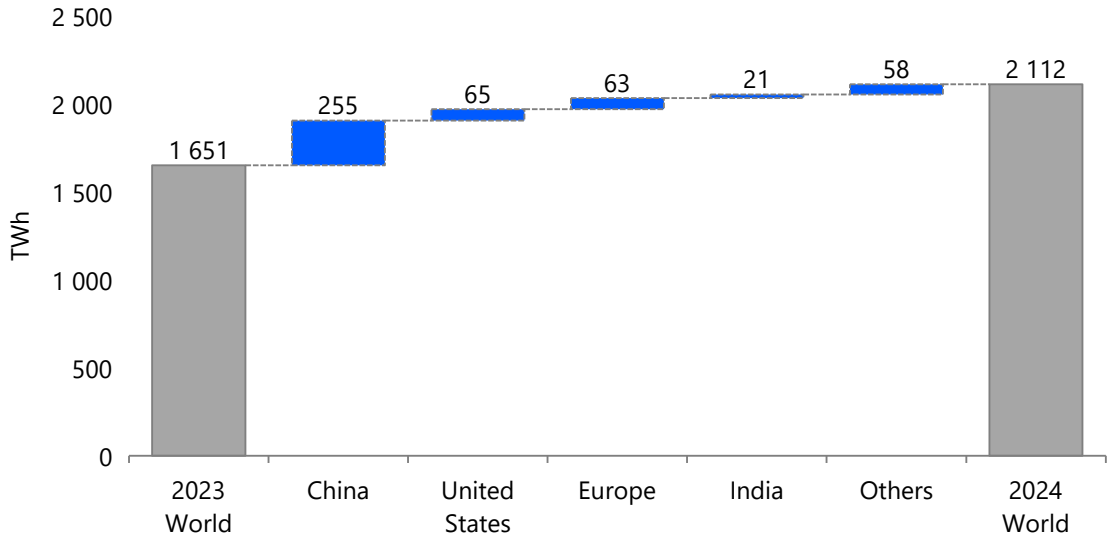
Solar photovoltaics continue to expand drastically, especially in China.

To meet this significant increase in demand, electricity generated from all power sources, including natural gas, coal, nuclear, hydro and other renewables, increased compared with the previous year in 2024. The increase in solar photovoltaics was particularly notable, with power generation reaching 2 112 TWh (up 27.6% year-on-year), exceeding the previous record of 2023.

China has been a strong driver of solar photovoltaic growth to date, and this trend continued into 2024. China alone accounted for 55% of the global increase in solar photovoltaic power generation. Of the remaining 45%, the United States, Europe and other regions each accounted for roughly one-third.

[8] Energy Institute "Statistical Review of World Energy" (2025)

Figure 3-12 | Year-on-year change in solar photovoltaic power generation [2024]

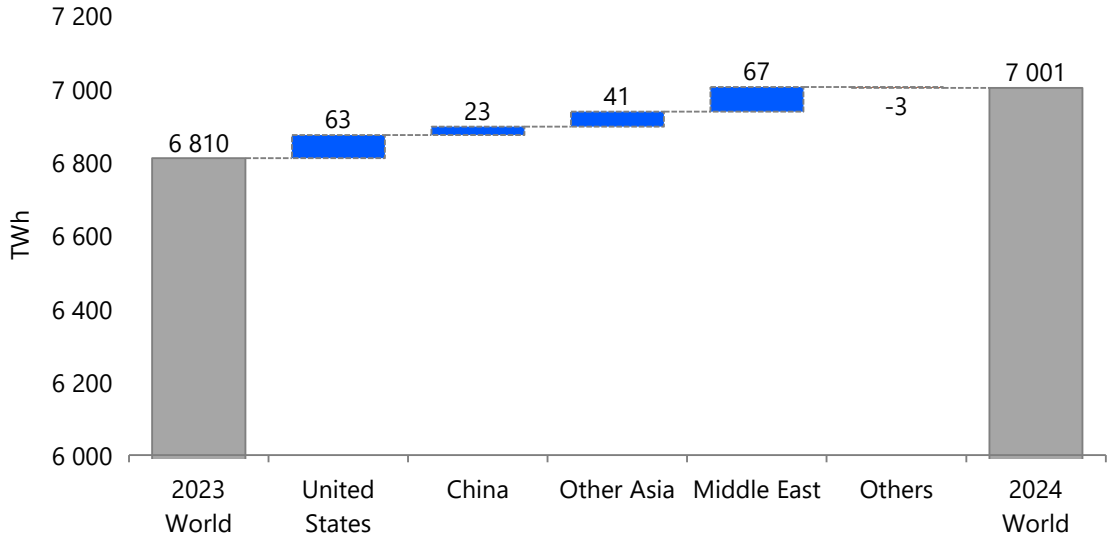


Source: Energy Institute "Statistical Review of World Energy" (2025)

Natural gas-fired power generation increased in the United States, Asia and the Middle East.

Following solar photovoltaics, the sectors that saw significant growth in 2024 were hydro and natural gas-fired power generation. Natural gas-fired power generation increased 2.8% to 7 001 TWh, accounting for 22.4% of total electricity generated. By region, there was a decrease in Europe, while a notable increase was seen in the United States, Asia and the Middle East. In the United States, natural gas is meeting the rapidly increasing demand for electricity from data centres along with renewable energy and is expected to maintain its position as a major power source under President Donald Trump's policy of promoting fossil fuels. In Asia, whilst it declines in Japan, new construction of natural gas-fired plants is steadily progressing in emerging and developing economies such as China, India and Indonesia, increasing its importance as a power source that combines emission reduction with load-following capability.

Figure 3-13 | Year-on-year change in natural gas-fired power generation [2024]



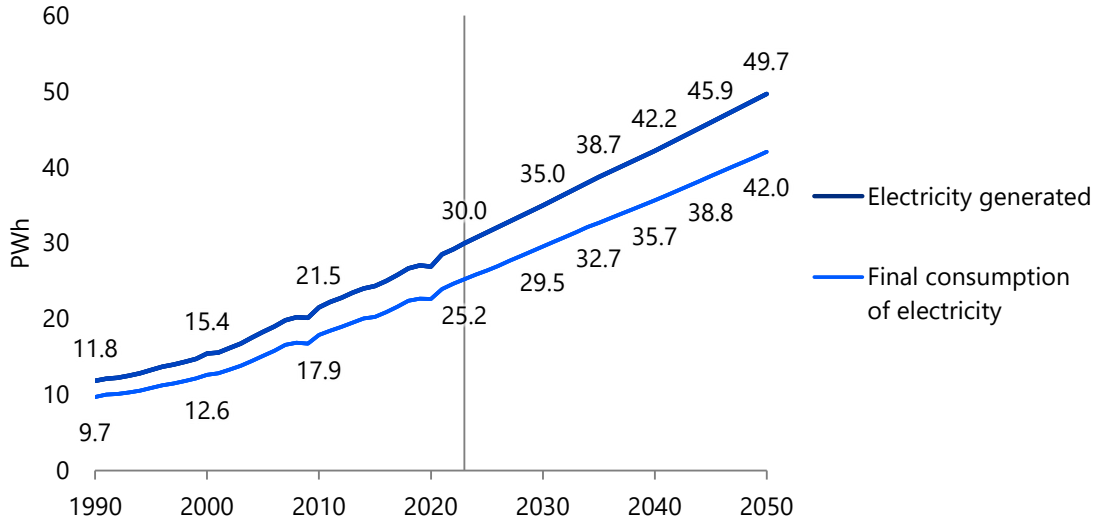
Source: Energy Institute "Statistical Review of World Energy" (2025)

Outlook

Electricity generated: Rapidly expanding in Asia and Africa while continuing to increase in Advanced Economies

Global electricity consumption will continue expanding at an annual rate of 1.8% until 2050, driven by conventional factors such as continued economic growth and ownership of electricity-consuming devices due to improved living standards, particularly in emerging and developing economies, as well as by factors such as recent accelerating electrification as a result of climate change countermeasures and increased consumption due to digital technology. This will result in global electricity generated increasing to 49 701 TWh in 2050, a 1.7-fold rise from the 2023 level (Figure 3-14). Of the 19 723 TWh increase, 82% will derive from Emerging and Developing Economies, with demand growth being particularly significant in India and the Association of Southeast Asian Nations (ASEAN). Furthermore, even in Advanced Economies where overall energy demand is declining, power generation will continue to increase at an annual rate of 1.0%, making new investment in power generation and transmission facilities a major challenge worldwide.

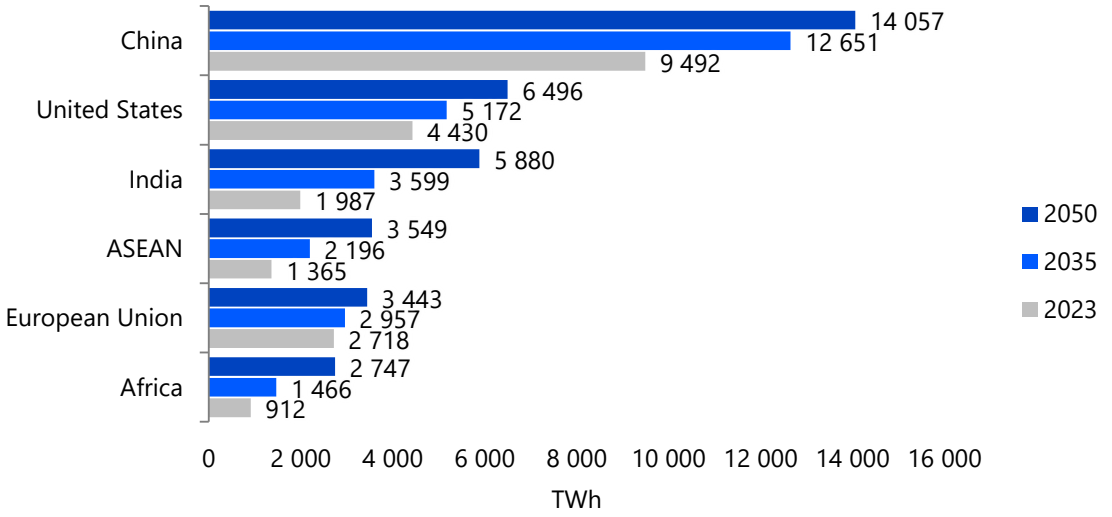
Figure 3-14 | Global electricity generated and final consumption of electricity [Reference Scenario]



Electricity generated in rapidly growing Asia will expand at an annual rate of 2.1% from 15 098 TWh in 2023 to 26 633 TWh in 2050, accounting for about half of the global total. China, which has expanded its electricity generated at a remarkable pace, will continue increasing its demand, albeit at a slower pace, and will account for 28% of the global electricity generated in 2050, the largest in the world (Figure 3-15).

Moreover, just as China increased its electricity generated alongside its economic growth in the past, India and ASEAN, both experiencing rapid economic expansion, are projected to see their electricity generated rise by 3.0 times and 2.6 times, respectively, by 2050. India will significantly surpass the European Union, while ASEAN's electricity generated will grow to a level comparable to that of the European Union. Similarly, electrification in Africa will progress significantly, with electricity generated in 2050 exceeding three times that of 2023.

Figure 3-15 | Electricity generated in selected countries/regions [Reference Scenario]

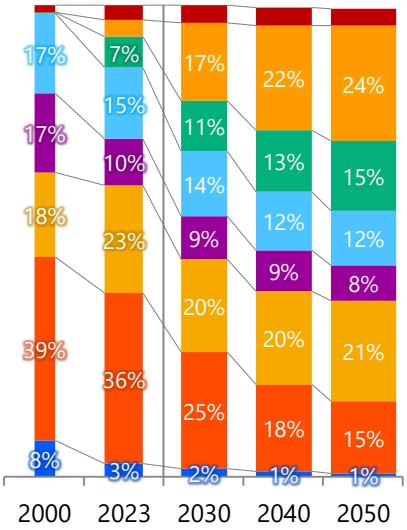


Power generation mix: Natural gas will become the largest power source.

Coal dominated the global power generation mix in 2023, accounting for 36% of electricity generated. Towards 2050, coal's share will continue to decline, with solar photovoltaics taking its place as the largest power source (Figure 3-16). Solar photovoltaics has recently been introduced at an overwhelming pace of over 20% per year, primarily in China, and is expected to account for 17% of electricity generated in 2030 and 24% in 2050. Meanwhile, wind will see significant expansion, accounting for 15% of electricity generated by 2050.

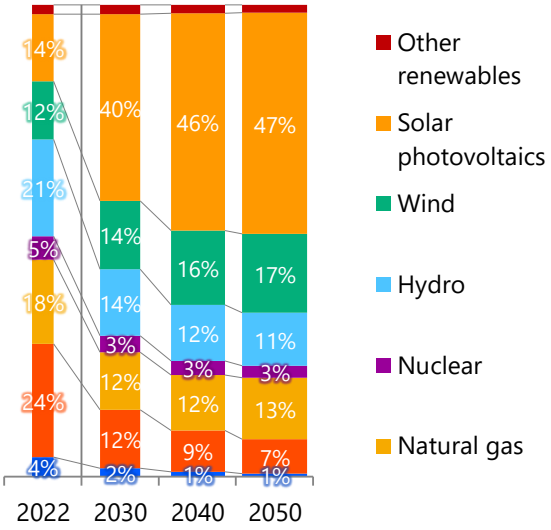
Figure 3-16 | Global power generation mix [Reference Scenario]

Electricity generated



Note: Bar widths are proportionate to total electricity generated.

Installed capacity



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

Natural gas, which will have the second-largest share after solar photovoltaics in 2050, is expected to see its share increase again through 2050 as the market stabilises following the significant price spike in 2022 and its high load-following capability allows it to serve as a backup power source for solar photovoltaics and wind. In Southeast Asia, it serves as a transitional stable power source to replace coal, while in the United States and the Middle East, underpinned by overwhelmingly low costs, it forms the core of power generation. Securing affordable and stable natural gas supplies will remain an important medium- to long-term priority for both advanced economies and emerging and developing economies.

Regarding coal, in addition to the United Kingdom, which phased out coal-fired power generation in 2024, advanced economies including Italy, Canada, France and Germany have announced plans to phase out coal-fired power generation, while others have committed to eliminating low-efficiency coal-fired power plants. These policies are generally expected to be achieved close to their target dates. In recent years, emerging and developing economies have also begun setting limits on new coal-fired power generation capacity and shifting to alternatives such as natural gas, solar photovoltaics and wind to address climate change and air pollution. Given this global trend, coal's share will decline, but it will continue to serve as an affordable and stable power source, particularly in emerging and developing economies, with about 70% of current electricity generated levels remaining by 2050. The United States and Europe, which are currently moving towards decarbonisation, have seen a sharp decline in coal-fired power generation. By contrast, the pace of new coal-fired power plant construction in China and India has been remarkable, with the increase in power generation in China and India in 2024 being greater than the decrease recorded in Europe and the United States.

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.

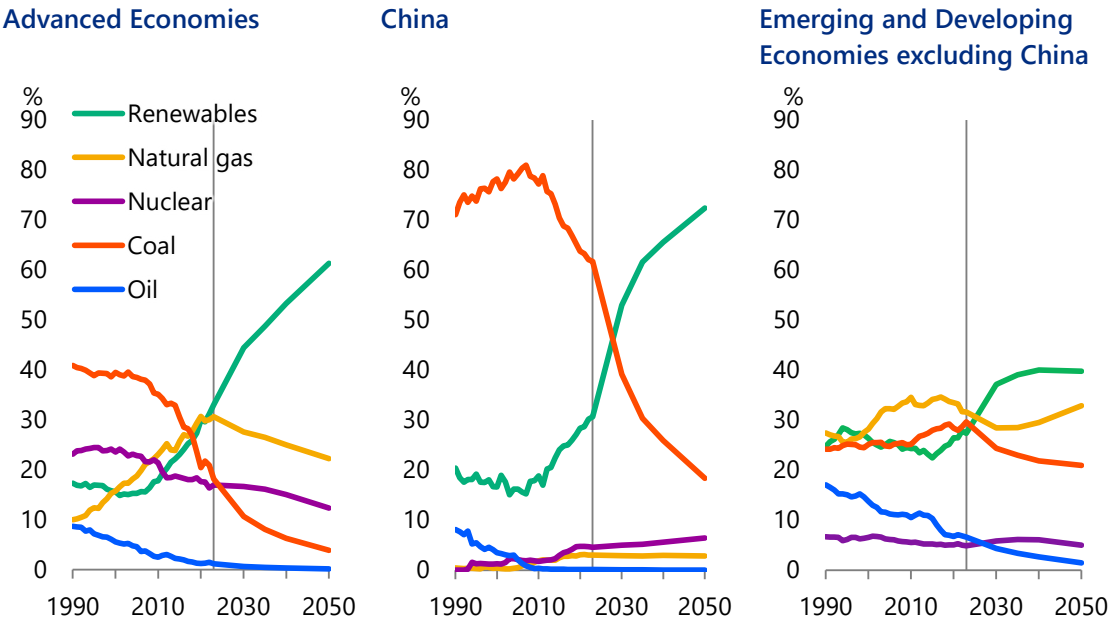
Power generation mix (overview by region)

In Advanced Economies, the shift from existing thermal power generation to renewables, primarily solar photovoltaics and wind, is already underway, and this trend is expected to continue in the future. However, given that suitable locations are limited and that measures to address output fluctuations require greater integration costs as the share of variable renewable energy in power sources increases, the current pace of deployment is likely to slow slightly after 2030. Nevertheless, variable-output solar photovoltaics and wind will account for 44% of electricity generated in 2050, making them potential future mainstay power sources. Addressing output fluctuations and expanding grid infrastructure to connect suitable generation areas with demand centres will become challenges that must be overcome as renewables strengthen their presence. As part of this, natural gas-fired power generation, in particular, will maintain a certain share, even as its volume decreases.

Even among Emerging and Developing Economies, the situation in China differs significantly from that in other regions. In China, where renewables have been actively developed, they will surpass coal to become the largest power source by 2030, keeping the recent rapid pace of adoption due to low costs. They are expected to continue increasing through 2050, albeit at a slower pace, to account for approximately 70% of the electricity generated. Of this, variable solar photovoltaics and wind will account for 58% and, as in Advanced Economies, measures to address output fluctuations will become an increasingly important issue.

In Emerging and Developing Economies excluding China, renewables, including wind, will increase and replace coal and natural gas as the largest power source by around 2030. However, a major difference from Advanced Economies is that their share will remain in the high 30% range, with thermal power generation maintaining a certain proportion. To meet the rapidly increasing demand for electricity, coal will account for approximately 22% of electricity generated in 2050, with natural gas accounting for 33%. To achieve both a stable supply of electricity and a reduction in carbon dioxide (CO_2) emissions, it is important to invest in efficient grid operation and high-efficiency equipment in the short term, and to explore options such as co-firing with hydrogen and ammonia, and carbon capture and storage (CCS) in the long term. Variable renewable energy is a promising power source that can simultaneously address the strong increase in electricity demand in Emerging and Developing Economies and the reduction of carbon dioxide emissions. Meanwhile, it is necessary to secure a certain amount of dispatchable thermal and hydro power sources, which are essential for an environment where electricity demand continues to grow against the backdrop of rapid economic growth, thus requiring the maintenance and expansion of installed capacity.

Figure 3-17 | Power generation mix in Advanced Economies and in Emerging and Developing Economies [Reference Scenario]

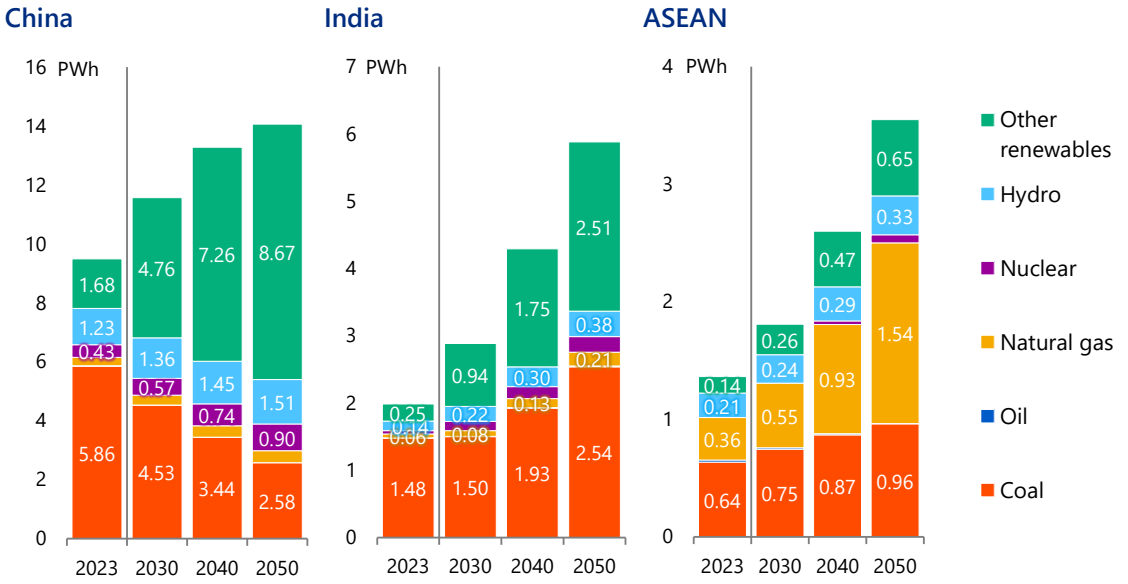


Diverging prospects for coal and renewable energies in three emerging areas in Asia

Across Asia, coal-fired power generation accounted for the largest share of electricity generation in 2023 in China, India and ASEAN. Going forward, a shift to natural gas and renewables will progress, reducing coal's share from 57% of power generated in 2023 to 25% by 2050. However, this power source transition varies significantly across countries and regions (Figure 3-18).

In China, renewable energy capacity has been rapidly expanding in recent years, as stated above, and electricity generated from solar photovoltaics, wind and other sources will increase more than fivefold from 2023 levels by 2050, establishing renewables as the dominant power generation source. Nevertheless, China continued to build new coal-fired power plants even in 2024, and despite its decreasing share, coal-fired power generation will be comparable to that of India by 2050.

Figure 3-18 | Chinese, Indian and ASEAN power generation mix [Reference Scenario]



India is also expanding its renewable power generation from both solar photovoltaics and wind, which is projected to overtake coal as the largest power source by 2050. However, unlike China, coal-fired power generation will continue to increase in the future and is expected to increase 1.7-fold compared with 2023. To meet the strong growth in electricity demand, a key issue will be how to mobilise a variety of options, including nuclear, hydro and natural gas, to satisfy the demand expansion that is expected to nearly triple compared with 2023.

In contrast to these two countries, ASEAN is substantially expanding its use of natural gas, which will reclaim its position as the largest power source alongside growing renewable energies. The situation varies considerably across ASEAN countries. In Thailand, strong public and private sector movements to phase out coal-fired power generation are driving a shift towards natural gas and renewables. Meanwhile, Indonesia and the Philippines are expected to continue to rely on coal as their main power source due to a rapidly increasing electricity demand. Another feature of the ASEAN region is the diverse range of supply forms, such as Lao People's Democratic Republic advancing the decarbonisation of power sources through the development of abundant hydro, and Viet Nam leveraging its potential for variable renewable energy, including offshore wind. Maintaining low-cost and stable electricity supply in this region, where demand continues to soar, presents significant challenges and necessitates diverse approaches tailored to each country's supply and demand characteristics.

Renewable power generation

In recent years, renewable energies have been increasingly adopted worldwide from the perspectives of stable supply and economic efficiency. Particularly in Europe, the Ukraine crisis that began in early 2022 has created strong pressure to reduce dependence on Russian natural gas. The use of renewable energy is now positioned as an urgent priority, with active deployment being pursued.

Meanwhile, in the United States, the second Donald Trump administration, which took office in January 2025, continues to shift policies from the previous administration. This turning point has led to market instability, causing the review and postponement of planned projects. The impact

will not be limited to the United States, and some European businesses and manufacturers may be temporarily affected. However, China remains the current driver of the rapid expansion of global installed capacity. China has been introducing solar photovoltaics and wind at an accelerated pace since 2022 and is expected to lead the way in renewable energy deployment going forward.

From 2015 to 2019, global renewable power generation capacity increased by just under 200 GW annually, but this figure exceeded 250 GW in 2020 and 300 GW in 2022 and ultimately surpassed 570 GW in 2024. This growth will peak towards 2030 (a simple average of approx. 700 GW per year).

Among them, solar photovoltaics, which have achieved substantially lower generation costs, have shown particularly remarkable growth and are expected to maintain their position accounting for 70% of new renewable power generation capacity additions. Moreover, as naturally variable power sources, including solar photovoltaics and wind, represent more than 90% of new renewable power generation capacity additions, their impact on electricity grids will inevitably increase.

Although the installation costs of solar panels and wind turbines have temporarily risen due to higher resource prices since 2021, the International Renewable Energy Agency (IRENA) estimates that the global weighted average levelised cost of electricity (LCOE) fell to $43/MWh for solar photovoltaics in 2024 and $34/MWh for onshore wind power. This is 41% lower for solar photovoltaics and 53% lower for onshore wind than the cheapest new fossil fuel power sources, maintaining their relative economic viability as new power sources. Furthermore, as thermal power generation costs are susceptible to fluctuations in fuel prices, as well as emissions regulations, carbon costs and environmental investment, making overall cost reductions difficult, the relative economic advantage of solar photovoltaics and onshore wind is expected to persist from the perspective of new construction.

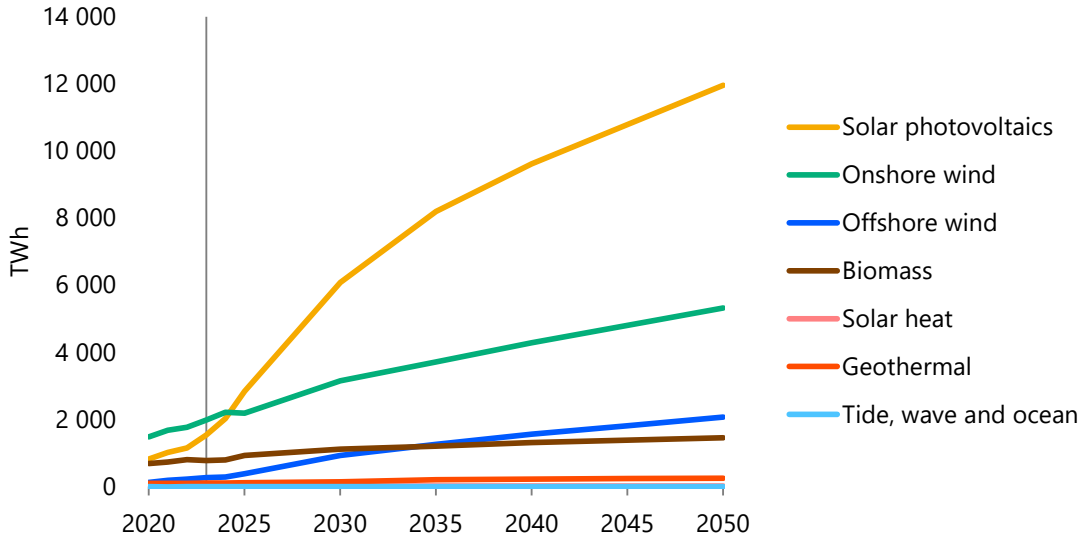
Beyond economic benefits, an increasing number of countries and regions are committing to renewable energy introduction targets (Table 3-6). Whilst regional variations in deployment approaches may emerge in response to developments such as the second Donald Trump administration, the overall global growth rate is expected to remain largely unchanged, partly due to China's strong role as a growth driver.

Table 3-6 | Renewable energy policies and targets in selected countries and regions

Country or region	Main policies and targets
United States	Announcement of a rollback of energy policies from the Joe Biden administration. Not setting decarbonisation targets, prioritising affordable and reliable energy through strengthened regulations for solar photovoltaics and wind power generation. Declaring a National Energy Emergency in January 2025 (The White House). One Big Beautiful Bill Act, July 2025 (Public Law No:119-21).
European Union	42.5% share of renewables in final energy consumption by 2030 (45% as an effort target). Renewable Energy Directive III (issued in November 2023) (European Parliament, Council of the European Union).
Japan	40% to 50% share of renewables in total electricity generated by 2040. The Seventh Strategic Energy Plan, Cabinet Decision in February 2025 (Ministry of Economy, Trade and Industry).
China	Share of non-fossil fuels in primary energy consumption to 25% by 2030 (including installed capacity of wind and solar photovoltaic power generation of 1 200 GW). 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 the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (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 renewable power generation up to 2050. Solar photovoltaics will increase nearly six-fold from 2 030 TWh in 2024 to 11 960 TWh in 2050. Wind (both onshore and offshore) will expand 3.0-fold from 2 500 TWh in 2024 to 7 390 TWh in 2050. As a result, variable renewables will significantly increase their share of global electricity generated from 13.1% in 2023 to 39.0% in 2050, strengthening their presence in the electricity system.

Figure 3-19 | Global renewable power generation excluding hydro [Reference Scenario]



China, Europe, the United States and India currently account for 80% of the cumulative installed wind (both onshore and offshore) power generation capacity, and this trend is expected to continue (Figure 3-20). Among these, China's share will continue to grow. The share will expand to the level above 50% by 2040 and its intense concentration in China will be even more pronounced than for solar photovoltaics, 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 remains a relatively large amount of room for expansion in China.

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

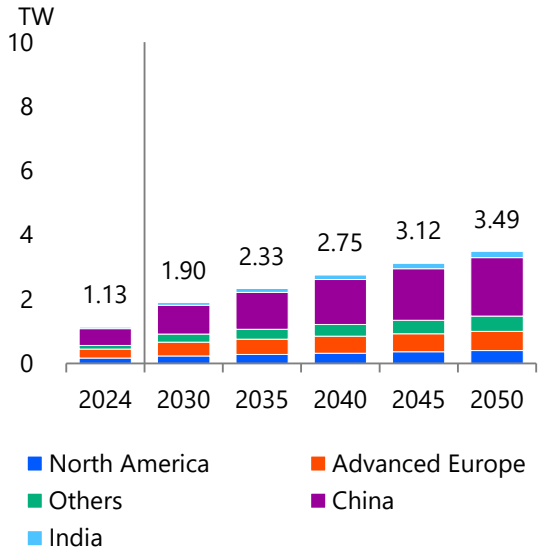
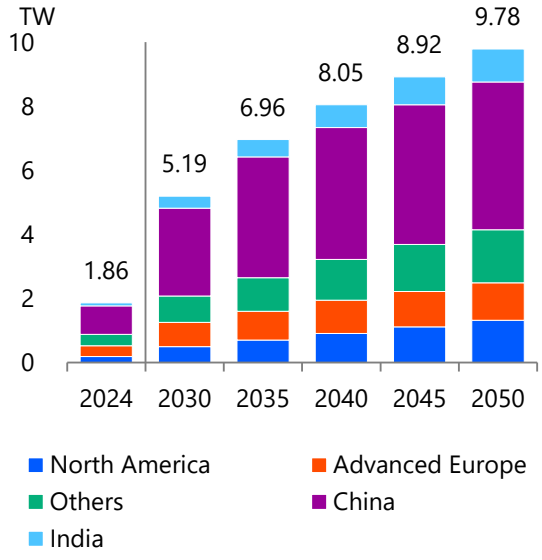


Figure 3-21 | Global installed solar photovoltaic power generation capacity [Reference Scenario]



Onshore wind power generation will grow relatively slowly towards 2050 compared with solar photovoltaics and offshore wind, primarily due to early-emerging site and grid constraints, such as limited suitable land for development. By 2050, installed capacity of onshore wind power

generation will reach 2 850 GW, representing only about 2.7 times the 2024 capacity of 1 050 GW. Nevertheless, the cumulative installed capacity in 2050 will remain 4.4 times larger than offshore wind, maintaining its significant presence in renewables.

In contrast, offshore wind, although inferior to onshore wind in scale, is expected to grow at an extremely high rate. Installed capacity of offshore wind power generation worldwide increased drastically from 3 GW in 2010 to 79 GW in 2024. Europe is the world's most mature offshore wind power generation market, with supply chains developed for wind farms. However, China has accelerated large-scale project development since 2020, and by the end of 2023, China's cumulative generation capacity of 37 GW surpassed Europe's 34 GW. This establishes China as one of the world's two largest offshore wind markets, alongside Europe, both nominally and in practice. China's further expansion is projected towards 2050.

The United States has minimal offshore wind capacity, though the former Joe Biden administration had actively promoted offshore wind projects, including a policy targeting 30 GW of offshore wind power generation capacity by 2030. However, following the inauguration of the second Donald Trump administration in January 2025, there has been a growing trend towards planning revisions, including development delays or cancellations, making the introduction of offshore wind power highly uncertain. In July 2025, the One Big Beautiful Bill Act (OBBBA) will partially reduce the tax credits for renewable energy, including wind, that were introduced in the Inflation Reduction Act (IRA). Further slowdown in introduction is expected in the future due to policy changes.

Asia other than China will hold offshore wind markets formed in Chinese Taipei, Korea and Viet Nam. In Japan, the Act on the Utilization of Marine Renewable Energy of 2019 has taken effect, and in 2025, the law was amended to allow project development including in exclusive economic zones (EEZs). As such, further efforts are being made to promote the introduction of offshore wind. The Japanese government has explicitly committed to supporting not only project development but also the expansion of domestic supply chains and industry development. With this policy support, global offshore wind power generation capacity is projected to grow approximately eight-fold from 79 GW in 2024 to 640 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, which experienced early adoption, but also all over the world, benefiting from significant reduction in power generation costs (Figure 3-21). China will maintain and expand its dominant position, representing 48% of global cumulative installed capacity in 2024, and is projected to remain so by 2050. However, compared with wind, the share of solar photovoltaics in the United States, Europe, India and others is relatively high, with somewhat less concentration on China. This reflects the versatility of solar photovoltaic power generation, which can produce electricity wherever sufficient sunlight exists, whereas wind power generation is geographically constrained by specific wind conditions.

Global installed capacity of solar photovoltaic power generation is projected to increase approximately eight-fold from 1 859 GW in 2024 to 9 785 GW in 2050. However, from 2030 onwards, grid constraints and the impact of the increasing share of variable power sources on power system stability will become increasingly apparent. Consequently, the net increment of global installed capacity of solar photovoltaic power generation, estimated to reach 4 490 GW in the decade from 2020 to 2030, will gradually decrease to 2 860 GW from 2030 to 2040 and 1 730 GW in the following decade. To overcome this slowing trend and maintain high growth in renewable power generation capacity through 2050, it will be critically important to integrate

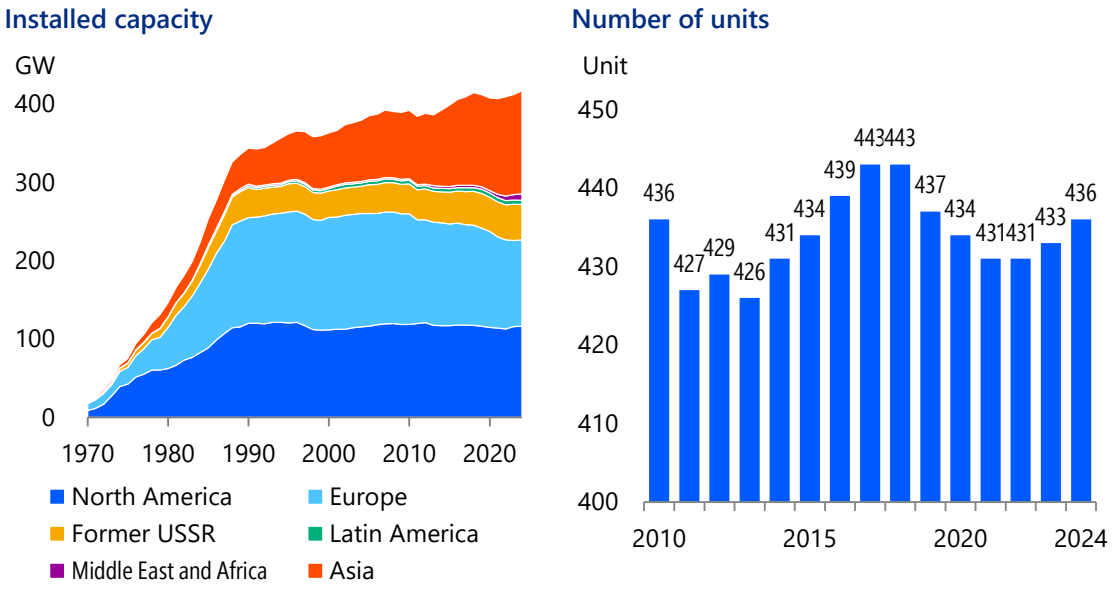
variable power sources, address grid constraints appropriately, and overcome location limitations through technological innovation. The Advanced Technologies Scenario described below assumes a situation where these challenges have been partially, though not completely, alleviated through policy measures addressing location constraints, integration technologies for variable power sources and grid development.

Nuclear

Recent trends: Movements towards expanded use of nuclear underway in various countries

The installed capacity of global nuclear power generation shows a long-term upward trend. After declining for three consecutive years from 2019 to 2021, capacity has been increasing through 2024 (Figure 3-22). From the 1970s to the 1980s, Japan and Western countries built numerous nuclear power plants, resulting in a rapid increase in cumulative installed capacity, but new constructions subsequently decelerated.

Figure 3-22 | Global nuclear power generation capacity and number of units



In recent years, however, as many countries have established ambitious greenhouse gas emission reduction targets, nuclear's role as a low-carbon baseload power source has gained renewed attention. Following the rise in global energy prices since 2021 and Russia's invasion of Ukraine in 2022, the importance of affordable, fossil fuel-free energy for energy security has increased, with nuclear increasingly recognised as a means to achieve this. In recent years, various organisations have begun forecasting that the growing proliferation of data centres and other facilities may lead to higher demand for electricity than previously anticipated, and in response, some countries and companies have taken steps to secure additional power sources. Against this background, there have been both moves to construct new nuclear reactors and to make effective use of existing reactors over the long term.

While ageing management and safety assurance remain prerequisites, the long-term operation of existing nuclear reactors is positioned as a low-carbon power source option with high economic efficiency and is being actively pursued, particularly in Western countries with numerous ageing reactors.

In the United States, reactors that have operated for more than 40 years have been permitted by the Nuclear Regulatory Commission (NRC) to operate for a further 20 years, extending their total operational lifespan to 60 years. Some reactors have received approval for a second extension, allowing them to operate for 80 years. Additionally, there have been recent initiatives to restart reactors previously scheduled for closure. Examples include the Palisades Nuclear Plant in Michigan and Three Mile Island Unit 1 in Pennsylvania. The latter is a prime example of the relationship between nuclear power and data centre electricity demand, as it was a power purchase agreement signed with Microsoft, a major information and communication technology (ICT) company, that led to its efforts to restart the plant.

Belgium, which had planned to complete nuclear phasing-out by 2025, announced in 2022 a 10-year extension for two reactors, Doel Unit 4 and Tihange Unit 3, and reached a final agreement with the owner, Engie S.A. In May 2025, the Parliament passed a resolution to repeal the nuclear phase-out policy. Similarly, in Sweden, the owner of the Forsmark and Ringhals nuclear power plants announced in June 2024 the decision to extend their operating periods from 60 to 80 years. These extensions will enable the country to supply low-carbon electricity until the 2060s.

In Japan, the 'GX Decarbonisation Power Source Act' enacted in May 2023 and enforced in June 2025 allows nuclear power plants' operating periods to be extended by excluding prolonged shutdown periods following the Fukushima Daiichi Nuclear Power Station accident from the prescribed operating timeframe. However, regardless of this provision, plants must undergo a Nuclear Regulation Authority review of ageing management measures every 10 years after their 30th year of operation to receive continued operation approval. As various scenarios emerge for different plants, tracking both the chronological age since startup and the actual operational lifetime of each facility will become increasingly important from a safety perspective.

As such, moves towards the effective utilisation of existing reactors are under way in various countries, while there are moves to construct new plants in some countries. China is particularly active, with Zhangzhou Unit 1 beginning commercial operation in January 2025. Further development is also proceeding, with the construction of about four units starting between February and August 2024. Furthermore, with the State Council's approval of plans to build a total of 10 reactors at five sites in April 2025, the expanded use of nuclear in China is likely to continue. In the United States, President Donald Trump signed several executive orders regarding nuclear in May 2025. Among these was a highly ambitious goal of increasing nuclear power generation capacity from approximately 100 GW in 2024 to 400 GW by 2050. Regardless of whether this goal is achievable, it can be said that the United States' policy towards the expanded use of nuclear has become even clearer. In France as well, progress is underway to build a total of six new reactors at three existing sites, while in the United Kingdom, the government made a final investment decision on the Sizewell C construction plan in July 2025. Both countries are also taking steps to increase the feasibility of new construction, such as nationalising power companies and amending laws to accelerate licensing procedures (France) and introducing an investment recovery scheme known as the Regulated Asset Base (RAB) model (the United Kingdom). In Sweden, where location restrictions were abolished through legal reform, a new support system for new construction was established in May 2025, combining low-interest loans and contracts for difference (CfD). In Europe and the United States, where new construction had stagnated for a long period, several recent new construction projects have seen significant delays compared with their initial schedules. It will be necessary to fully utilise lessons learned from these construction projects to avoid similar delays in the future.

Russia continues to dominate the global nuclear market. Russia has started building nuclear reactors in countries such as China, Turkey, Iran, India, Bangladesh and Egypt, holding a significant share of the export market. Furthermore, in June 2025, Kazakhstan, a uranium-producing country, selected Russia's state-owned nuclear company, Rosatom, as the prime contractor for the construction of the country's first nuclear power station. One reason for this is that Russia not only builds power plants but also provides comprehensive services including fuel supply and the collection of spent fuel, which meets the needs of emerging and developing economies. Meanwhile, Western countries have also been moving towards nuclear exports. In June 2025, Korea Hydro & Nuclear Power (KHNP) awarded an order for an expansion project (two reactors) at the Dukovany Nuclear Power Station in the Czech Republic. The United States is also pursuing exports to Bulgaria and India. In February 2025, Indian Prime Minister Narendra Modi visited the United States and issued a joint statement with President Donald Trump, in which the two leaders announced their intention to build US-made nuclear reactors in India. India is also reviewing its Civil Liability for Nuclear Damage Act (CLNDA) to mitigate uncertainty over the entry of private US operators.

Attention must also be maintained on developments beyond conventional large-scale light water reactors, including small modular reactors (SMRs) and Generation IV reactors. In the United States, both Republican and Democratic Parties have implemented aggressive support measures, with numerous private companies initiating advanced reactor development. In Canada, the regulatory authority issued a construction permit in April 2025 to Ontario Power, which is pursuing plans to introduce a light-water reactor SMR manufactured by GE Vernova Hitachi Nuclear Energy. Several other countries, including Korea, Bulgaria, Romania and Estonia, are also moving towards introducing SMRs. Concerning Generation IV reactors in the United States, X-energy, which is developing the high-temperature gas-cooled reactor 'Xe-100', applied to regulators in March 2025 for a construction licence in Texas alongside major chemical manufacturer Dow. Furthermore, in May of the same year, Kairos Power commenced full-scale construction of the 'Hermes' fluoride salt-cooled high-temperature demonstration reactor in Tennessee. Amazon is supporting the introduction and commercialisation of Xe-100, and Google plans to purchase electricity from Kairos Power's fluoride salt-cooled high-temperature reactor (a power generation reactor succeeding Hermes) in the future to supply its own data centres.

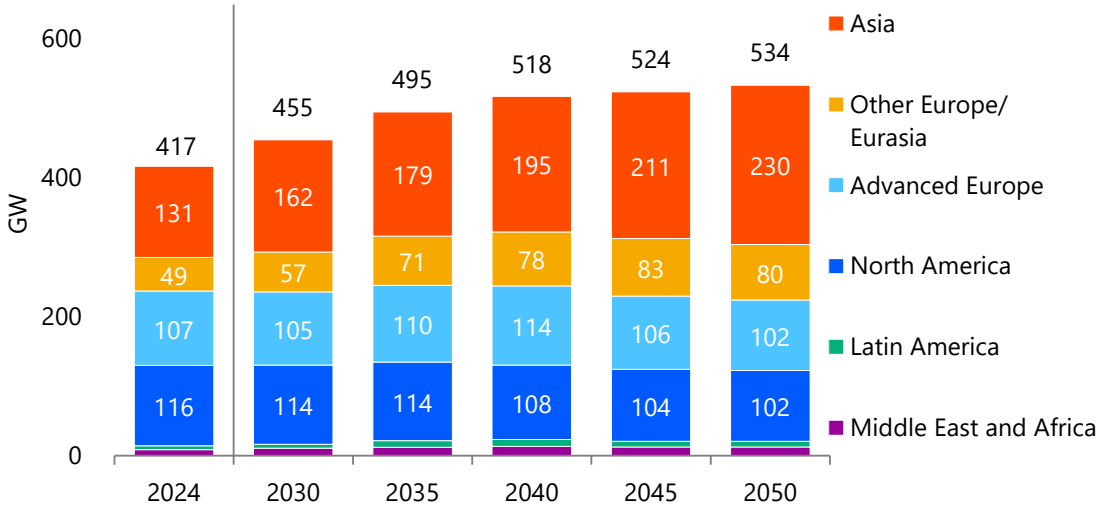
Thus, efforts are under way in many countries towards expanded use of nuclear as its role attracts increasing attention. However, in many cases, the final success or failure of the introduction will depend not only on governments' policies, but also on developers' ability to offer customers acceptable conditions in terms of costs and other factors. Customer responses to various nuclear initiatives worldwide merit close observation.

Outlook: Nuclear will increase particularly in Asia and reaffirm its role in Europe and the United States

The Fukushima Daiichi Nuclear Power Station accident changed public perception about nuclear, and some construction expertise has been lost during the subsequent hiatus in new projects. Consequently, Japan, Europe and the United States now face greater challenges in constructing new nuclear reactors as originally planned. With existing reactors built in the 1970s or 1980s approaching closure, nuclear power generation may decline in many countries. Nevertheless, recognising nuclear's value as a competitive, low-carbon baseload power source that enhances energy security and provides valuable business assets for electric utilities, these countries will maintain a significant nuclear presence. Meanwhile, several countries including China are actively expanding their nuclear power generation capacity, and some nations may introduce

nuclear for the first time. As a result, global installed nuclear power generation capacity will increase through 2050, reaching 534 GW (Figure 3-23).

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



The United States, still the world's largest user of nuclear energy with 94 reactors as of 2024, includes states where economic considerations have led to decisions for early closure of existing reactors. Market liberalisation has exposed nuclear to direct competition from natural gas-fired power generation and renewable power generation. As a result, the installed capacity will decrease by 2050. However, the United States will maintain its policy of treating nuclear as a strategic energy source. With both major political parties recognising nuclear's significance, substantial policy shifts are unlikely. Furthermore, due to rising demand for low-carbon, stable power sources, power purchase agreements are increasingly being concluded, either preventing closures for economic reasons or enabling plants to pursue restarts after closure. Against this backdrop, maintaining existing reactors and some new construction will continue, contingent upon favourable market conditions and investment climate.

In France, Europe's foremost nuclear advocate, the Energy Transition Law of July 2015 originally aimed to reduce nuclear's share of power generation to 50% (approximately 75% in 2015) by 2025. In view of its greenhouse gas (GHG) emission reduction goal, however, France concluded that it was difficult to attain this reduced target for nuclear, and the target year was later extended to 2035. In addition, the target itself was dropped by a law promulgated in June 2023. France announced plans in February 2022 to construct at least six new reactors (with the possibility of eight more) and has identified three construction sites (Penly, Gravelines and Bugey), which are all locations of existing reactors. Given these developments, the installed capacity in France will either be maintained at its current level or decline slightly for the time being. After 2035, decommissioning of ageing reactors will accelerate, continuing the overall downward trend. However, with initiatives underway to extend operational lifespans, utilities will optimise their nuclear–renewable balance and maintain nuclear power generation capacity where profitability permits.

In the United Kingdom, despite government support for nuclear, total installed power generation capacity will decline until the 2030s due to the decommissioning of older reactors. However, new construction plans aligned with the energy security strategy are in development, supported by

measures to enhance the business environment, such as the Regulated Asset Base (RAB) model, which offers greater investment return certainty. If this supportive approach continues, the temporary decline in installed capacity will reverse, recovering to approximately current levels in the late 2030s, before increasing thereafter.

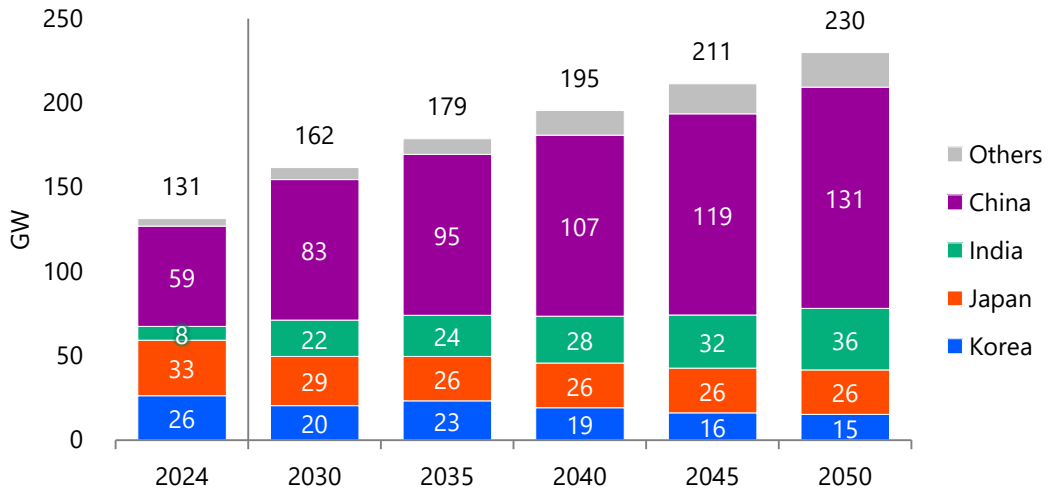
Switzerland has clearly established nuclear phase-out plans following the Fukushima Daiichi Nuclear Power Station accident and will cease nuclear power generation by 2035 under the government's decommissioning schedule. Belgium had originally planned to close all reactors by 2025, but following the reversal of its nuclear phase-out policy, it will maintain a certain number of reactors until 2050. Germany completed its nuclear phase-out in April 2023 with the closure of its last three reactors. The country is not expected to resume nuclear power generation under current circumstances. Other European OECD[9] countries will experience reduced installed capacity through 2050, despite some new construction initiatives, as economically unviable reactors are decommissioned.

Russia has committed to proactively utilise nuclear both domestically and internationally. Its domestic installed nuclear power generation capacity will increase to approximately 40 GW by 2035. Around 2030, Russia will overtake Japan as the world's fourth-largest nuclear power generation capacity holder. Given its aggressive reactor export strategy, Russia's influence in the global nuclear market will exceed that suggested by its domestic capacity alone. Beyond promoting its existing large light-water reactors, Russia has introduced the world's first floating nuclear power station and possesses a demonstration sodium-cooled fast reactor. Possessing such diverse technologies is important to enhance the infrastructure of the nuclear industry.

Asia, particularly China and India, will continue to increase its nuclear prominence. Emerging and developing economies in Asia, experiencing substantial economic growth, are highly motivated to deploy nuclear as a low-carbon, stable large-scale power source. China will expand its installed nuclear power generation capacity to 107 GW by 2040, surpassing the United States to become the world's largest nuclear user. Asia's total installed nuclear power generation capacity will exceed the combined capacity of OECD Europe and North America around 2040, reaching 230 GW by 2050. China and India together will account for more than 70% of this capacity (Figure 3-24).

[9] Organisation for Economic Co-operation and Development

Figure 3-24 | Asia's installed nuclear power generation capacity [Reference Scenario]



3.6 Hydrogen, etc

Hydrogen and low-carbon fuels made from hydrogen (such as ammonia, synthetic methane and synthetic fuels [e-fuels]) could be effective means of decarbonisation in hard-to-abate sectors including steel and chemicals, where alternative technologies such as electrification are limited, as well as in the transport sector and for fuel substitution in thermal power generation, which primarily serves as a balancing power source. In recent years, efforts have been made worldwide to set goals, provide policy support, and develop projects to expand hydrogen use.

Recently, there have been moves to cancel or postpone some projects on hydrogen, mainly due to difficulties in reducing costs, raising funds and securing markets (off-takers). While some view the movement towards hydrogen utilisation as stalling, support and legal frameworks are being developed, particularly in Europe, and the number of projects that have passed the final investment decision (FID) is steadily increasing. Therefore, the trend towards expanding hydrogen use appears set to continue. At present, projects that have secured economic viability and reliable off-takers, including government support, are proceeding. The question going forward is whether these challenges can be overcome through appropriate market design that accounts for policies and environmental values, alongside technological development and cost reduction.

Below is an overview of hydrogen support trends in each country. The European Union is increasingly promoting the use of renewable energy-derived hydrogen (green hydrogen) as part of its shift away from Russia since the Ukraine crisis. REPowerEU announced in March 2022 that it had set a target of supplying 10 Mt/year of renewable energy-derived hydrogen through domestic production and 10 Mt/year through imports by 2030. In addition, the European Union established the European Hydrogen Bank (EHB), a mechanism designed to support the intra-EU distribution and import of renewable-derived hydrogen. Following the first round of bidding, six projects signed grant agreements in October 2024, with a total expected support of 720 million euros. The second round of bidding closed in February 2025, with grant agreements expected to be signed by November 2025. In the United Kingdom, support for bridging the price gap between hydrogen and existing fuels (CfD support) has been promoted, with the total amount of CfD

expected to be 2.3 billion pounds over 15 years. Round 1 was completed, with five contracts signed in October 2024. Completion of the Round 2 review and the start of Round 3 are planned for 2025. In July 2024, Germany announced the results of the first tender for H2Global[10], an international hydrogen and hydrogen-derived fuel procurement mechanism. Germany launched its second bidding round in February 2025.

The United States launched a 10-year tax credit for clean hydrogen production through the Inflation Reduction Act (IRA), which was passed in August 2022. In addition, with a $7 billion support scheme under the Bipartisan Infrastructure Law, the United States selected seven Regional Clean Hydrogen Hubs (H2Hubs) aiming to create a clean hydrogen network encompassing hydrogen production and use. However, since President Donald Trump took office, support for hydrogen has become more uncertain. Amendments to the Inflation Reduction Act (IRA) also show moves to scale back support, such as limiting hydrogen production tax credits to projects that begin construction before 2027, rather than before 2032. Future developments warrant close monitoring.

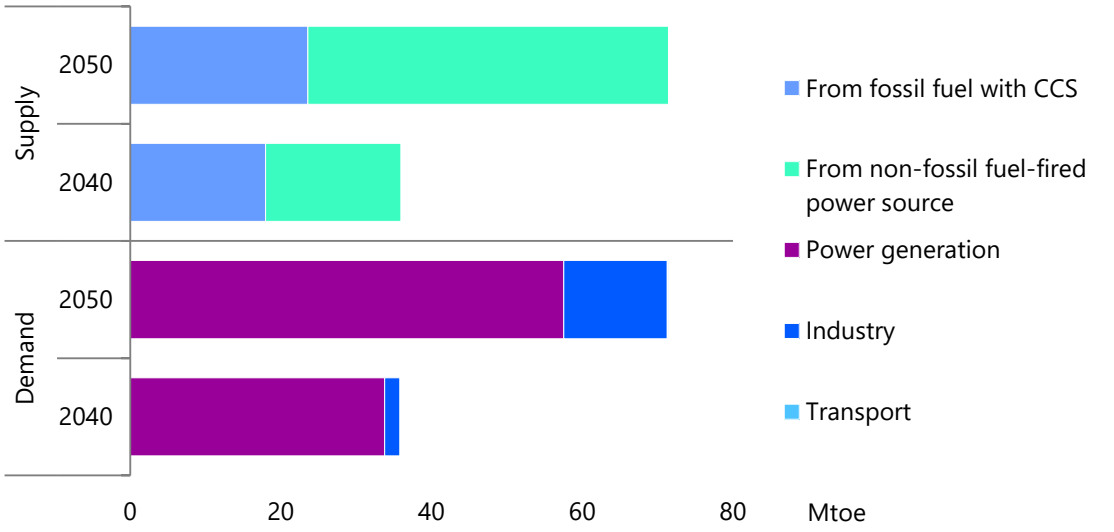
China has become the world's largest consumer of hydrogen. Its hydrogen production and consumption in 2024 were reported to be 36.5 Mt. China announced its 'Medium- and Long-Term Development Plan for the Hydrogen Energy Industry' in March 2022, with the goal of producing 100 kt/year–200 kt/year of renewables-derived hydrogen and holding 50 thousand fuel cell vehicles by 2025. As of 2025, green hydrogen production projects with a capacity of 20 kt/year have already begun operation, and sales of fuel cell vehicles, primarily commercial vehicles, are rapidly increasing (at a pace of more than 10 thousand units in two years), indicating that the social implementation of hydrogen is progressing rapidly. 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.

In Japan, based on the Hydrogen Society Promotion Act enacted in May 2024, preparations are underway to provide price-differential support and hub development support for clean hydrogen and ammonia. Regarding price-differential support, 27 project applications have been submitted by the March 2025 deadline and are expected to be reviewed in fiscal 2025. In addition, in the long-term decarbonised power source auction, a total of 920 MW of ammonia and hydrogen co-firing has been won in the first and second rounds. Through this support, hydrogen and ammonia use is expected to expand.

In the Reference Scenario, it is assumed that the current trend of ammonia co-firing in power generation will expand at a similar pace. In this scenario, hydrogen use is expected to remain at a limited level in power generation, industry and parts of the transport sector. However, for hydrogen to be widely used across various sectors in the future, policy support, appropriate market design and technological development, including cost reduction, will need to advance further. These assumptions will be reflected in the Advanced Technologies Scenario.

[10] The winning bid was for the export of green ammonia produced in Egypt to the Netherlands, with a contract price of €1 000/t.

Figure 3-25 | Supply and demand of clean hydrogen [Reference Scenario]



3.7 Carbon capture and storage

Carbon capture and storage (CCS) is a technology that captures carbon dioxide (CO_2) from a variety of emission sources and stores it in underground formations. This technology has already been widely commercialised in the United States, Canada, Norway, Australia and others, and has attracted much attention in recent years as a technology that can greatly contribute to future decarbonisation. CCS does not simply capture CO_2 generated from fossil fuel use; it is also an essential enabling technology for so-called carbon dioxide removal technologies such as direct air capture and carbon storage (DACCS). CCS is thus indispensable for keeping atmospheric CO_2 concentrations stable over the long term.

Aiming to achieve net-zero emissions by mid-century, advanced economies are developing support systems for CCS. In the United States, companies implementing CCS previously received a tax credit of $20 per tonne of CO_2 captured and stored, but the Inflation Reduction Act enacted in 2022 increased this to $85/t. Subsequently, under the Donald Trump administration that took office in 2025, while decarbonisation policies introduced under the Biden administration were abolished or scaled back across the board, tax incentives for CCS have been maintained. Canada, Australia and others provide subsidies for initial CCS investments as well as emissions trading credits for the CO_2 captured and stored. In the United Kingdom, although no commercial CCS projects exist yet, four sites have been identified as potential hubs for the intensive implementation of CCS. To achieve this, a system has been introduced whereby the government compensates for the difference between CCS implementation costs and the emission credit price that would apply without CCS.

In this context, in June 2025, the Japanese government presented a proposed support framework for CCS commercialisation. As in the UK system, the government will cover the difference between CCS implementation costs and the emissions credit price, based on the annual average price of the emissions trading scheme (GX-ETS) scheduled for introduction from fiscal year 2026. Specific budgetary measures will be taken in due course, and the extent to which projects may qualify remains uncertain. However, it is expected to become a major driving force for CCS commercialisation in Japan. The government aims to commercialise domestic CCS projects by

FY2030, with a decision on support under this system expected as early as fiscal 2026. The CCS projects currently undergoing feasibility studies with government support in Japan comprise two types: those transporting captured CO_2 via pipeline to storage sites and those transporting it by ship (Table 3-7). However, this support framework applies only to pipeline-based projects. A framework for ship-based projects is expected to follow.

Table 3-7 | Selected advanced CCS projects

Storage location	Storage amount (kt/year, approximate)	Capture source	Major transport means
Tomakomai region, Japan (marine aquifers)	1 500–2 000	Refinery, thermal power plants in Tomakomai region	Pipeline
Tohoku region along the Sea of Japan, Japan (marine aquifers)	1 500–1 900	Steel mills, cement plants, local emitters	Ships
East Niigata region, Japan (existing oil and gas fields)	1 400	Chemical plants, paper mills, power plants	Pipeline
Capital region, Japan (marine aquifers)	1 400	Steel mills, etc.	Pipeline
Western Kyushu, Japan (marine aquifers)	1 700	Refineries, thermal power plants	Ships
North off the coast of the Malay Peninsula, Malaysia (depleted oil and gas fields)	3 000	Steel, chemicals, oil refining, etc.	Ships
Off the coast of Sarawak, Malaysia (offshore depleted oil and gas fields)	1 900–2 900	Steel mills, power plants, chemical plants, etc.	Ships
South off the coast of the Malay Peninsula, Malaysia (Offshore declining oil and gas fields, aquifers)	5 000	Power generation, chemicals, cement, oil refining, etc.	Ships
Oceania (Offshore declining oil and gas fields, aquifers)	2 000	Steel mills, etc.	Ships

Source: Ministry of Economy, Trade and Industry

Nine projects are currently undergoing feasibility studies in Japan, while in Europe and the United States, investment and construction are already underway for commercial CCS projects that have passed final investment decisions (FID) (Table 3-8).

Table 3-8 | Ongoing CCS business investment projects in Europe and the United States

Project	Country	Annual storage amount (kt-CO_2)	Start of operation
Longship	Norway	750	2025 (Under construction)
Aramis	Netherlands	Expanded to 22 000	2029 (FID scheduled for 2026)
Greensand	Denmark	Expanded to 400–8 000	2026 (FID completed)
Teesside	United Kingdom	Expanded to 4 000–23 000	2028 (FID completed)
Eastern Louisiana	United States	5 000	2028 (Under construction)
Yazoo	United States	500	2028 (Under construction)

Source: Created based on press releases from each company

In terms of storage scale, some of the larger projects are expected to store more than 10 Mt per year, and if realised, they would represent highly effective emission reduction measures. The Norwegian and Dutch projects envisage capturing and storing CO_2 from industrial emission sources, whereas the US project targets ammonia production and the UK project targets natural gas-fired power stations, indicating that a diverse range of capture sources is being considered.

Regarding CCS in the Reference Scenario, near-term implementation volume, up to around 2030, is based on projects already in operation or those for which investment decisions have been made and construction has begun. As CCS represents a purely additional cost for operators, its deployment will not progress without sufficient government support. Therefore, it is assumed that even after 2030, deployment will progress mainly in developed countries where CCS support systems are already in place.

CCS is anticipated to become more widespread in so-called 'hard-to-abate sectors', such as industries that generally require high-temperature heat and where emissions reduction through electrification is difficult. However, given the comparatively easier recovery of additional costs in the power generation sector, a certain level of deployment is also anticipated there. Therefore, it is assumed that CCS will be introduced not only in the industry sector but also in the power generation sector. Among the industry sectors, the steelmaking sector is expected to see increased adoption, as CO_2 can be captured intensively from blast furnaces. On the other hand, in the cement sector, factories are geographically dispersed, making it difficult to transport captured CO_2, while in the chemical sector, multiple emission sources exist. Therefore, adoption is expected to remain limited in these sectors.

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 societal acceptability. 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]

2023 → 2050 (Reference, 2050)

	Advanced Economies	Emerging and Developing Economies
Thermal power generation	Developing an initial investment finance scheme	
	Installing CCS for new plants from 2030 (Countries with carbon storage potential excluding aquifers)	
[Natural gas-fired efficiency (stock basis)]	50.0% → 66.1% (54.5%)	37.8% → 51.8% (40.5%)
[Coal-fired efficiency (stock basis)]	36.8% → 43.9%[11] (41.2%)	33.3% → 38.5% (37.5%)
[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]	281 GW → 359 (245) GW	125 GW → 492 (289) GW

[11] 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.

2023 → 2050 (Reference, 2050)

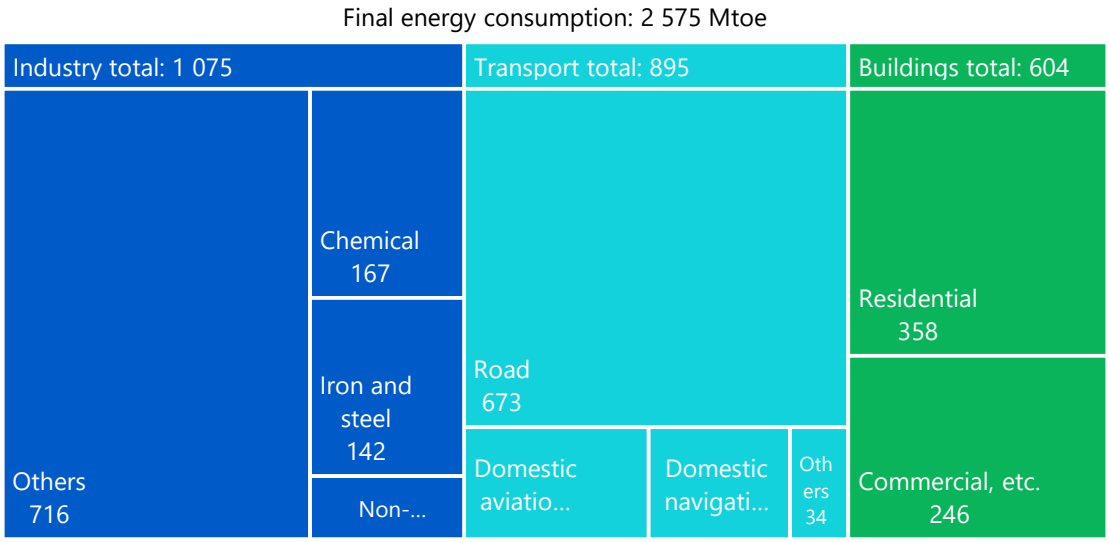
	Advanced Economies	Emerging and Developing Economies
Renewables power generation	System cost reduction	
	Grid stabilisation technology cost reduction	Low-cost finance
	Efficient grid operation	Advancing power systems
[Wind installed capacity]	421 GW → 1 807 (1 134) GW	541 GW → 3 277 (2 356) GW
[Solar photovoltaics installed capacity]	490 GW → 3 534 (2 996) GW	618 GW → 7 668 (6 789) GW
Biofuels for automobiles	Developing next-generation biofuels	Biofuel cost reduction
	Expanded use of flexible-fuel vehicles (FFVs)	Agricultural policy position
[Consumption]	69 Mtoe → 88 (65) Mtoe	43 Mtoe → 114 (92) Mtoe
Industry	100% penetration of the best available technology (BAT) in 2050	
Transport	Reducing fuel-efficient vehicle costs Doubling zero-emission vehicle (ZEV) travel distances	
[New passenger car fuel efficiency]	19.0 km/L → 53.5 (37.7) km/L	16.6 km/L → 41.6 (26.7) km/L
[ZEV share of new passenger car sales]	9.0% → 94.0% (58.8%)	11.6% → 74.4% (36.8%)
Buildings	1.6 times faster improvement in appliance and equipment efficiency and insulation efficiency on a stock basis (approx. 22% improvement in 2050 relative to the Reference Scenario). Electrifying space/water heating and cooking equipment, clean cooking	

Note: IGCC stands for integrated coal gasification combined cycle.

Energy efficiency

Final energy consumption in the Advanced Technologies Scenario will be 355 million tonnes of oil equivalent (Mtoe) or 3% less in 2030 and 2 575 Mtoe or 22% less in 2050 than in the Reference Scenario. These savings in 2050 are equivalent to 25% of final energy consumption in 2023. Of the energy savings, the industry sector will account for 1 075 Mtoe, the transport sector for 895 Mtoe, and the buildings sector for 604 Mtoe (Figure 4-1).

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



The road sector will be responsible for 673 Mtoe in the transport sector and the residential sector for 358 Mtoe in the buildings sector. This is because vehicles and energy-consuming home appliances offer huge potential for improving energy efficiency. The Emerging 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 and Developing Economies realise the potential energy savings is key to the progress of global energy savings.

By employing already available highly efficient technologies for steel, cement, chemicals, pulp and paper, and other energy-intensive industries, these sectors will improve their energy intensity in 2030 by several percentage points compared with the Reference Scenario (Table 4-2). Furthermore, by accelerating the adoption of highly efficient technologies, energy intensity will improve by more than 20% by 2050. Through these energy intensity improvements, the industry sector in Emerging and Developing Economies will reduce energy consumption by 872 Mtoe compared with the Reference Scenario. Asia, where raw materials industries account for a large share of production, will contribute to about 80% of the global energy savings. These technologies will contribute significantly to improving energy efficiency in Emerging and Developing Economies. The global development and proactive dissemination of energy efficiency improvement technologies, particularly in Emerging and Developing Economies, are therefore essential.

Table 4-2 | World energy indicators

		2023	Reference 2030	Reference 2050	Advanced Technologies 2030	Advanced Technologies 2050
Industry	Intensity (2023=100)					
	Iron and steel	100	100.4	97.9	96.7	74.3
	Non-metallic minerals	100	93.8	77.5	92.0	67.5
	Chemical	100	98.2	66.9	91.0	42.3
	Paper and pulp	100	95.9	88.0	92.5	69.6
	Others	100	98.4	75.5	94.1	50.5
Transport	New passenger vehicle fuel efficiency (km/L)	19.7	22.4	37.7	30.4	53.5
	ZEV's share of new vehicle sales	8.4%	15%	56%	44%	92%
	Natural gas's share in intl. marine bunkers	0.4%	3.7%	22%	5.9%	40%
	Biofuel's share of intl. aviation bunkers	0.1%	1.5%	5.2%	4.5%	42%
Buildings	Overall energy efficiency (2023 = 100)					
	Residential	100	90.7	66.9	88.1	55.2
	Commercial	100	99.0	64.3	97.8	52.3
	Electrification rate					
	Residential	29%	32%	47%	34%	55%
	Commercial	55%	58%	70%	59%	77%

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

In the transport sector, fuel efficiency and vehicle fleet mix changes make further progress. By type of vehicle, in addition to hybrid vehicles, electric vehicles (EVs), plug-in hybrid vehicles (PHEVs) and fuel cell vehicles will diffuse further. These zero-emission vehicles (ZEVs) will increase their share of new vehicle sales by 29 percentage points in 2030 and 36 percentage points in 2050 compared with the Reference Scenario. Due to changes in vehicle fleet composition and fuel efficiency improvements, the global average new vehicle fuel efficiency in 2050 will improve by 15.7 km/L from the Reference Scenario to 53.5 km/L (1.9 L/100 km). The transport sector will see the largest energy savings among sectors in the Advanced Economies as the share of ZEVs in those economies increases faster than in Emerging and Developing Economies. International bunkers will make progress in energy conservation through technological innovation and operational improvements. At the same time, given the significant potential for fuel switching, natural gas will account for 5.9% of international marine bunkers in 2030 and 40% in 2050. In international aviation, biofuel will comprise 4.5% of fuel use in 2030 and 42% in 2050.

It is more challenging for energy conservation incentives to work in the buildings sector than in the industry sector, where economic considerations drive energy conservation awareness. Consequently, the buildings sector presents significant potential for reducing energy consumption. The overall global residential energy efficiency will improve by 3% in 2030 and by 17% in 2050 compared with the Reference Scenario. Similarly, the overall efficiency of the commercial sector will improve by 1% in 2030 and 19% in 2050. Energy efficiency improvements for space and water heating systems in cold regions and enhanced insulation in Emerging and Developing Economies will contribute substantially to energy savings. 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 use, including inefficient fuelwood and manure, will see the greatest reduction through increased electrification and the adoption of modern cooking equipment in rural areas. Electricity consumption will decline substantially as energy efficiency improvements across various applications such as space cooling, power, and lighting more than offset the impact of appliance electrification.

Renewable energies

In the Advanced Technologies Scenario, variable renewables such as wind and solar photovoltaics will be introduced at a faster pace. The share of variable renewables in total global electricity generated will expand from 13.1% in 2023 to 51.9% 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 time variability of wind and solar photovoltaic power generation include rapid output fluctuations (frequency fluctuations), surplus electricity, and extreme generation shortfalls during cloudy or windless periods that occur 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[12], as well as the negative impacts on the natural environment, ecosystems and economic activities around renewable power source locations. Such impacts include adverse effects of large-scale solar photovoltaic facilities on forest development, those of onshore wind power facilities on birds, and the increasingly severe impact of offshore wind power generation on fishing.

Considering these challenges, technological, institutional, and political measures will be required to integrate variable renewable power sources into the electricity system. The Advanced Technologies Scenario 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 storage hydro and batteries), output adjustments by backup power sources, power supply adjustments using EVs, grid enhancement, and interregional power supply and smart grid systems combining these with information and communication technologies. For these technologies to diffuse, policies and legal systems to promote the harmony of power sources with the environment and the regional acceptance of renewables will be required to support their sustainable deployment.

Installed capacity for onshore and offshore wind power generation will increase in all regions faster than in the Reference Scenario, reaching 2 230 GW in 2030 and 5 080 GW in 2050 (Figure 4-2). Onshore wind power generation will expand remarkably in China and India as enhanced power transmission infrastructure and cost reduction for energy storage technologies ease the spatial and temporal unevenness of wind resource distribution. Offshore wind power generation will increase in China, Chinese Taipei, and Japan, as well as in Europe, which has so far led the world in offshore power generation. In particular, the increase in China will be significant. 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 processes based on better understanding with 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 45% of the world's installed capacity in 2030 and 50%

[12] Synchronous power sources with rotation energy have the inertial power of rotating turbines, as well as a synchronising power 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.

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 presence in 2050 will not differ significantly from the Reference Scenario.

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

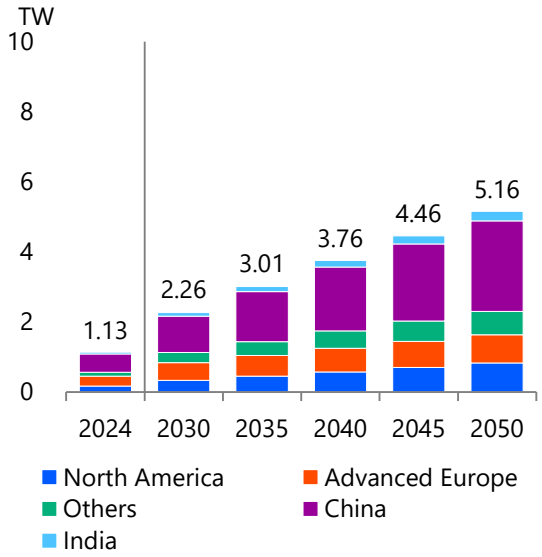
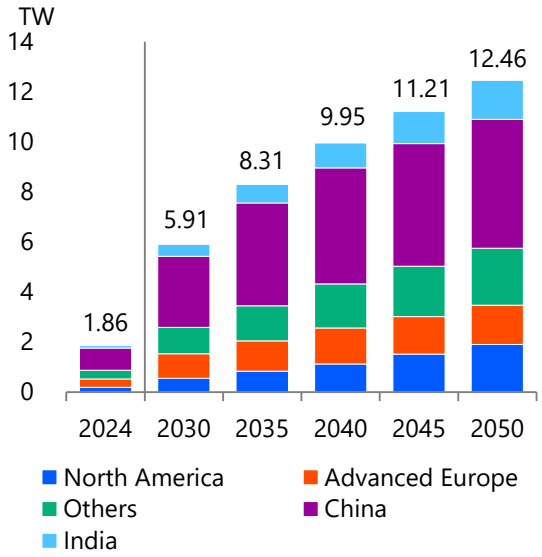


Figure 4-3 | Global installed solar photovoltaic power generation capacity [Advanced Technologies Scenario]



Solar photovoltaic power generation is also being introduced ambitiously, with global installed capacity reaching 5 850 GW in 2030 and 12 460 GW in 2050 (Figure 4-3). As a result of technological advances, which have, to a certain extent, overcome grid constraints and the effects of variable power sources on grid stability, as well as location constraints, wind and solar photovoltaics will increase by 1.5 times and 1.3 times, respectively, in 2050, compared with the Reference Scenario. While the current major solar photovoltaic power generation markets are dominated by China, Europe and the United States, India's presence will grow as a solar photovoltaic power generator due to falling costs for solar panels 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. In the Advanced Technologies Scenario, while solar photovoltaics show a 1.3-fold increase compared with the Reference Scenario in Europe, there is a 1.5-fold increase in India and a 1.4-fold increase in countries and regions other than China, North America and Europe (i.e. Middle East, Africa, Latin America, etc.), with no significant differences among them. This suggests that technological advances could make solar photovoltaic markets even more promising in countries and regions that are not currently major markets. As mentioned in the Reference Scenario, in the United States, the introduction of renewable energies such as wind and solar photovoltaics is expected to slow down due to policy changes under the second administration of Donald Trump, which was inaugurated in January 2025.

Meanwhile, initiatives towards a carbon-neutral society will continue to progress globally, and the current surge in electricity demand in the artificial intelligence (AI) industry could dramatically change the electricity supply and demand situation. Looking towards the middle of

this century, it remains crucial to select technologies aligned with the large-scale introduction of variable renewables, as envisaged in the Advanced Technologies Scenario.

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. Recent market trends indicate that batteries utilising lithium iron phosphate (LFP), which offer greater safety and longer-term usability than lithium-ion batteries, are becoming increasingly mainstream. Since they do not use nickel or cobalt, reductions in procurement costs are also expected. Meanwhile, long-term storage 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. Nuclear power generation in the Advanced Technologies Scenario will therefore expand 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. Additionally, advanced reactor types, such as small module reactors (SMRs) and Generation IV reactors, which have been actively developed in recent years, will also benefit from strong policy measures supporting their commercialisation. Despite decades of development, these advanced reactors have yet to be put into practical use on a commercial scale; however, in recent years, specific potential users in the United States, Europe and other countries are moving forward with introducing them, with many countries around the world expressing interest. Consequently, the future deployment of these advanced reactors will depend on whether planned or current demonstration reactor projects sufficiently satisfy the requirements of potential users worldwide.

Efforts in non-power sectors will also be important for substantial decarbonisation throughout society. As a result, 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 used primarily as a baseload power source, and this will not change even in 2050, as large amounts of energy demand will continue to be electrified. The effective use of surplus electricity and heat will be considered only after nuclear's primary role of supplying electricity is fulfilled.

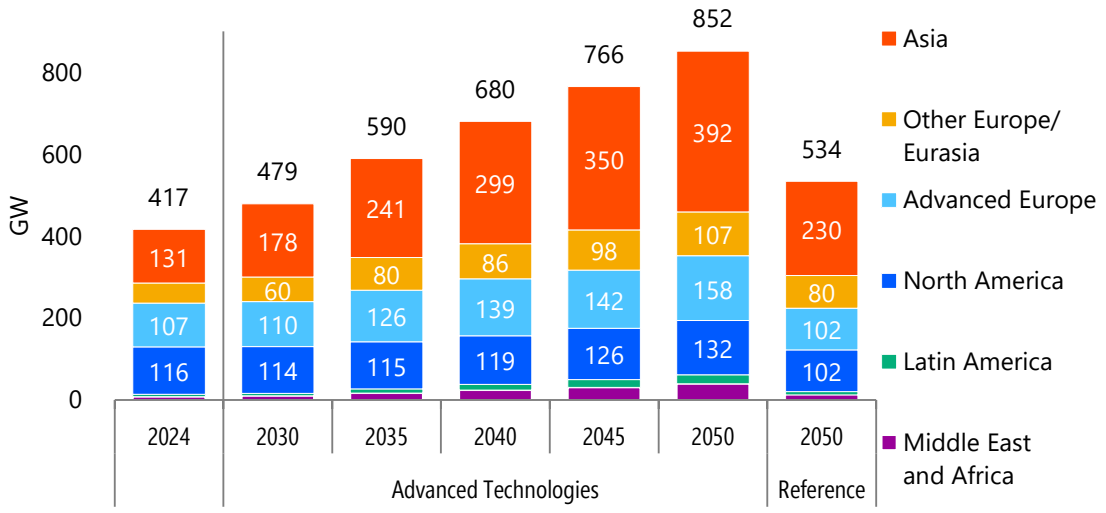
Among countries that have proactively promoted nuclear power generation, the United States and France will see their nuclear power generation capacity decline towards 2050 in the Reference Scenario as most existing reactors become outdated. In the Advanced Technologies Scenario where climate change measures will be implemented more powerfully, more new nuclear power

plant construction projects than in the Reference Scenario will be realised to narrow the reduction in France while the projects will even increase in the United States. In the United Kingdom, even in the Reference Scenario, new nuclear power generation capacity exceeding its current level will be added by 2050, but in the Advanced Technologies Scenario, new construction will be even greater. Some of the countries that announced nuclear phase-out policies following 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 and Developing Economies will expand nuclear power generation 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 and Developing Economies with remote territories such as islands are expected to introduce small nuclear reactors for small grids in these areas.

In the Advanced Technologies Scenario under these assumptions, global installed nuclear power generation capacity will increase from 417 GW in 2024 to 852 GW in 2050 (Figure 4-4). This is equivalent to approximately 1.6 times the amount of 534 GW in the Reference Scenario.

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



In North America, installed capacity will decline slightly from 2025 to 2030, but will increase to around 132 GW in 2050, through long-term operation of existing reactors and construction of new reactors. In the United States, both Democratic and Republican administrations have shown a commitment to nuclear, and policies have been implemented by the federal government and some state governments to support new construction and maintenance of existing reactors. In the Advanced Technologies Scenario, it is assumed that these policies will be maximally successful; thus, installed capacity will remain above that of the Reference Scenario. In addition, information and communication technology (ICT) companies that own data centres are expected to more actively secure nuclear-derived electricity and invest in development of advanced reactors. However, the impact of SMRs on those countries' total installed capacity will be limited due to the small capacity per unit.

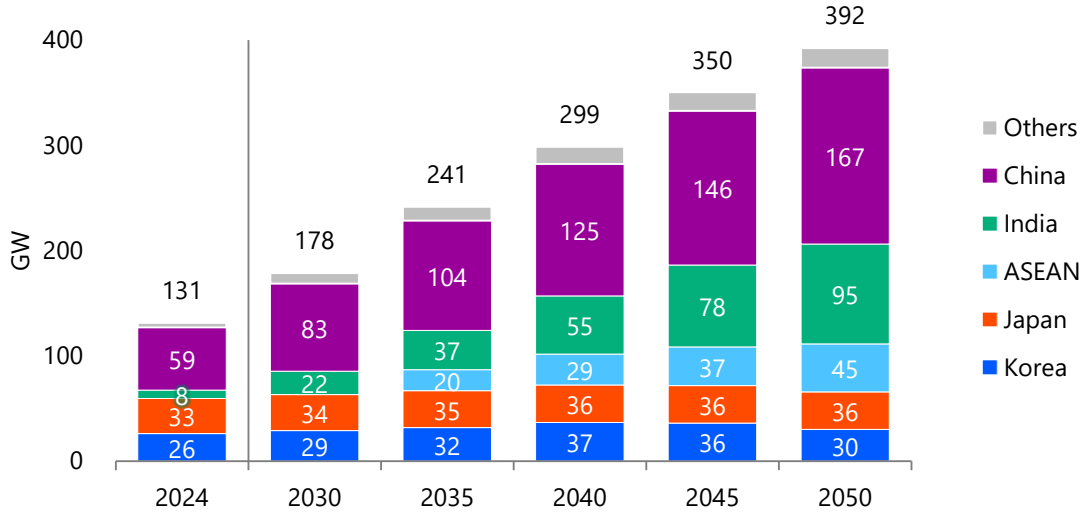
In Advanced Europe, countries aiming at ambitious targets for reducing greenhouse gas (GHG) emissions will politically promote the construction of additional nuclear power plants and the replacement of outdated reactors. As a result, installed nuclear power generation capacity will expand from 107 GW in 2024 to 158 GW in 2050. In France, the largest nuclear user in Europe, installed nuclear power generation capacity will decline more slowly than in the Reference Scenario through 2050, as the number of nuclear power 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-scale light-water (Generation III+) 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 operators. This will drive the expansion of nuclear power generation capacity.

Russia will accelerate construction of new nuclear power plants, continuing to expand its installed capacity from 29 GW in 2024 to 54 GW in 2050. Furthermore, Russian exports will actively proceed against the backdrop of economic growth and growing energy demand in Emerging and Developing Economies. Russia has already been promoting cooperative relations with many Emerging and Developing Economies to help them develop nuclear and other industrial infrastructure, as well as 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 energy markets, will commence operation of new reactors from around 2030 and steadily expand installed nuclear power generation capacity thereafter. As of 2024, the total installed capacity in these regions is approximately 14 GW but is projected to reach 62 GW by 2050.

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 OECD Europe and North America around 2035 and reach 392 GW in 2050 (Figure 4-5). 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 capacity as they require stable and economically efficient low-carbon power sources to meet their growing power 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, the Association of Southeast Asian Nations (ASEAN)'s installed capacity, though zero as of 2024, will reach 45 GW in 2050 as commercial nuclear power generation starts after 2030. That figure will exceed Japan's installed capacity of 36 GW at that year.

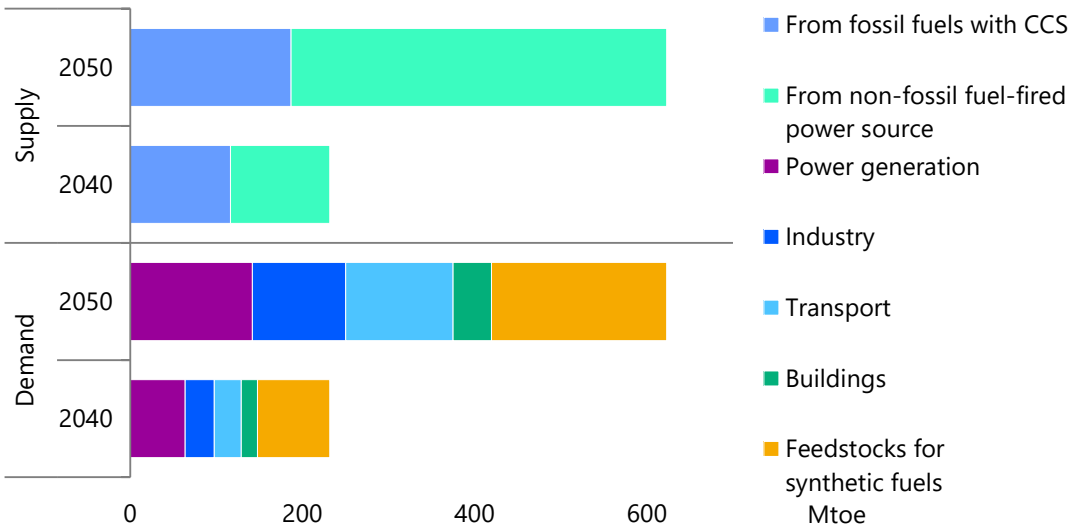
Figure 4-5 | Asia's installed nuclear power generation capacity [Advanced Technologies Scenario]



Hydrogen, etc.

In the Advanced Technologies Scenario, it is assumed that policy support, appropriate market design and technological development will progress steadily, with hydrogen and other technologies being used effectively as a means of decarbonisation. Specific uses of hydrogen include the power generation sector, the industry sector, the transport sector, and the buildings sector, encompassing its use as synthetic methane (e-methane) and synthetic fuels (e-fuels) (Figure 4-6). Uses of hydrogen and other technologies in each sector are described below.

Figure 4-6 | Supply and demand for clean hydrogen [Advanced Technologies Scenario]



In the power generation sector, the total amount of thermal power generation will decrease due to the expansion of renewable energy; however, remaining thermal power generation will be decarbonised by adding CCS or using fuels such as hydrogen. These power sources will provide adjustment capacity and contribute to CO_2 reduction in countries and regions with relatively little

renewable energy potential. In the transport sector, hydrogen is currently used mainly in fuel cell passenger vehicles; however, over time, its primary application will shift to commercial vehicles such as buses and trucks that have high annual mileage and present electrification challenges. Hydrogen and hydrogen-derived products including ammonia, synthetic methanol (e-methanol), and synthetic kerosene (e-kerosene) will serve as critical options for decarbonising shipping and aviation. Another application of hydrogen and hydrogen-derived low-carbon fuels will be in the industrial sector, especially for high-temperature heat demand, where electrification is difficult. In some regions, synthetic methane will increasingly replace part of the current natural gas demand. Regarding steelmaking, which accounts for a relatively large share of CO_2 emissions, current hydrogen-based technologies, such as blast furnace reduction and direct reduction using hydrogen, are still at the demonstration stage, but their introduction will proceed in 2050 as an important means of decarbonisation. In the buildings sector, hydrogen will be used only to a limited extent as an alternative to current fossil fuels. It will be introduced in areas where it is relatively easy to develop distribution infrastructure such as hydrogen pipelines and piping. Furthermore, as in the industry sector, some of the natural gas demand will be replaced by synthetic methane.

For hydrogen production, fossil fuel-derived hydrogen with CCS (blue hydrogen) will advance in the short term in light of its price competitiveness. However, future cost reductions in renewable power generation and water electrolysis systems will enhance hydrogen derived from non-fossil power sources such as renewable energy (green hydrogen). By 2050, green hydrogen will account for approximately 70% of clean hydrogen supply. 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.

The Advanced Technologies Scenario assumes the establishment of a supply chain capable of importing and exporting hydrogen. For long-distance hydrogen transport by ship, hydrogen needs to be converted into a hydrogen carrier. As large-scale capital investment and additional energy inputs are required, it is desirable for hydrogen production and demand to be geographically close to each other. However, for countries or regions such as Europe, Japan and Korea, where demand for hydrogen is large, but the supply potential of inexpensive clean hydrogen seems limited, long-distance transport of hydrogen from abroad will be necessary. To establish an economical international supply chain, it is necessary to significantly reduce the cost of hydrogen carriers, such as liquefied hydrogen, methylcyclohexane (MCH), ammonia, synthetic methane and synthetic fuels.

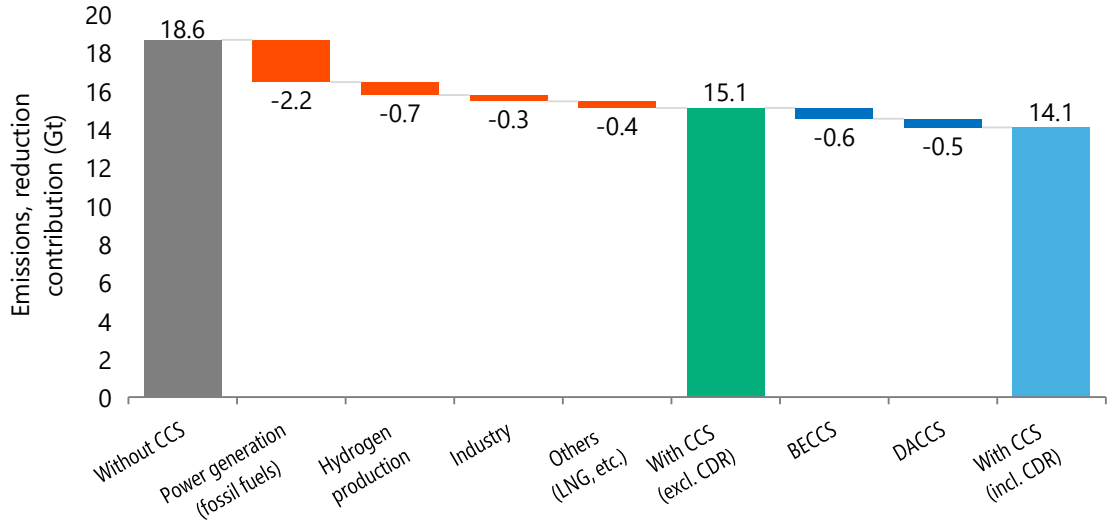
Carbon capture and storage

As stated in Section 3.7, CCS is expected to play a major role in sectors where decarbonisation through electrification is difficult, as the world moves towards decarbonisation. In the Reference Scenario, we assumed that CCS would be increasingly introduced primarily in advanced economies where policy support systems are already in place. However, in the Advanced Technologies Scenario, we envisioned a picture where CCS would be introduced to the maximum extent possible, including in emerging economies where CCS can be implemented relatively inexpensively.

First, in the power generation sector in Advanced Economies, CCS is expected to be applied to all newly built coal- and liquefied natural gas (LNG)-fired power plants that are not expecting ammonia or hydrogen co-firing, while in Emerging and Developing Economies, CCS is expected

to be increasingly applied to thermal power plants in China, India, Southeast Asia, the Middle East and other regions where CO_2 storage reservoirs and companies capable of implementing CCS exist. In the industry sector, also in Advanced Economies and some Emerging and Developing Economies, CCS is assumed to be actively applied in the steel, cement and chemical sectors where electrification is difficult. Furthermore, in the fossil fuel production sector, it was assumed that all new LNG projects will be equipped with facilities to capture and store the CO_2 generated during production.

Figure 4-7 | Amount of CCS implemented [Advanced Technologies Scenario, 2050]

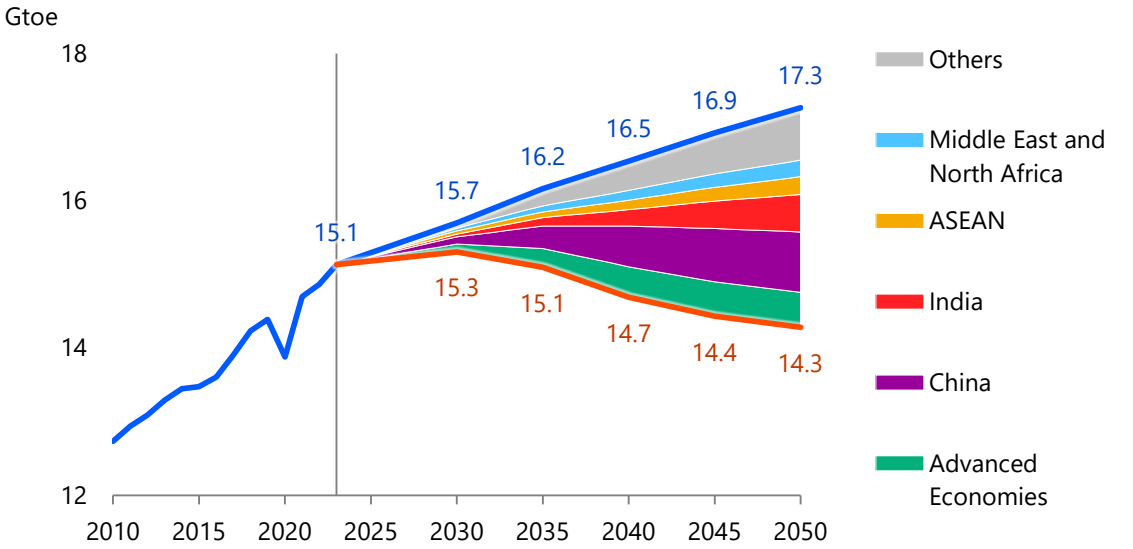


4.2 Energy supply and demand

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 higher improvements in the energy efficiency and climate change countermeasures. Primary energy consumption will increase until 2030, partly due to increased power demand in data centres and the time required to replace energy-saving equipment and technologies (Figure 4-8). However, it will begin to decline after 2030 as energy-saving equipment becomes more widely used. In 2035, primary energy consumption in the Advanced Technologies Scenario will be 1 065 million tonnes of oil equivalent (Mtoe) lower (−6.6%) than in the Reference Scenario but will remain nearly flat compared with 2023 at −36 Mtoe (−0.2%). Although the pace of decline will gradually slow after 2040 due to energy demand increases in carbon capture and storage (CCS), the decline will continue until 2050, resulting in a reduction in primary energy consumption of 2 984 Mtoe (20.1%) compared with the Reference Scenario. Cumulative energy savings by 2050 will be 38.3 Gtoe due to progress in energy efficiency improvement. Emerging and Developing Economies such as India, the Association of Southeast Asian Nations (ASEAN), and the Middle East and North Africa (MENA) will play a crucial role in realising the Advanced Technologies Scenario, as they have significant potential to save energy and expand the use of non-fossil energy sources.

Figure 4-8 | Global primary energy consumption and energy savings (relative to Reference Scenario) [Advanced Technologies Scenario]

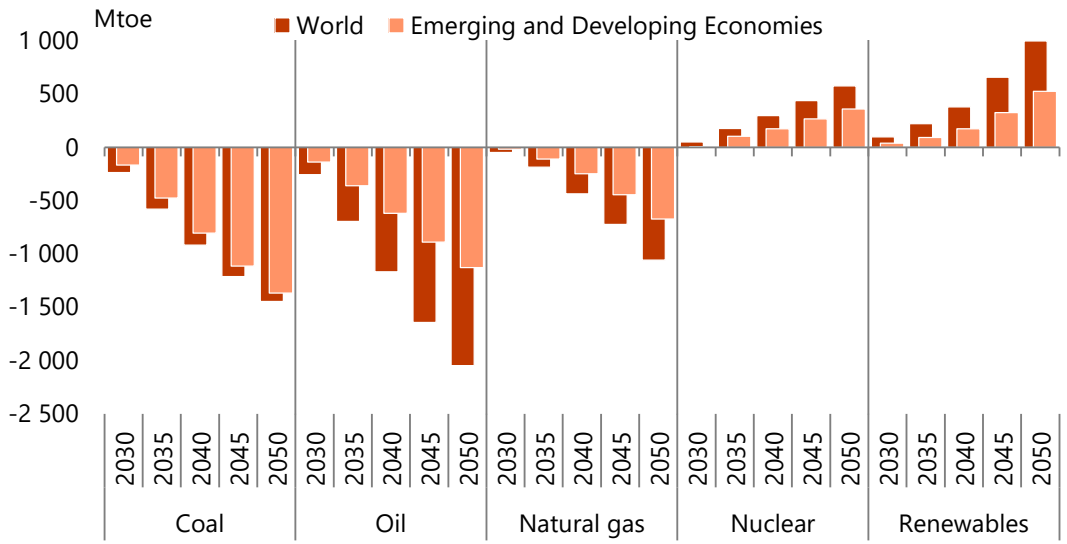


Emerging and Developing Economies will account for 80% of global energy savings in the Advanced Technologies Scenario in 2050. In particular, India, ASEAN and MENA will account for a combined share of 33%. Extraordinary efforts to boost energy efficiency and decarbonisation will be key to global energy security and climate change countermeasures.

By energy source, fossil fuels will decrease by only 4.6 Gtoe (37%) in 2050 compared with the Reference Scenario, with a cumulative reduction of 54.2 Gtoe (Figure 4-9), partly because fuel switching will also progress. Coal for power generation is being replaced in Emerging and Developing Economies, with these economies accounting for 80% in 2035 and 90% in 2050. Led by the spread of electrified vehicles, oil consumption will decrease by 0.7 Gtoe in 2035 and by 2.0 Gtoe in 2050, achieving the highest energy savings. Natural gas consumption will decline by only 0.2 Gtoe in 2035 and 1.1 Gtoe in 2050. The small saving in natural gas consumption in 2050, however, might partly result from increased use of feedstock for hydrogen production. Non-fossil energy consumption will increase by 0.4 Gtoe in 2035 and by 1.6 Gtoe in 2050. Nuclear and renewable energy consumption will rise by 59% and 26%, respectively, from the Reference Scenario in 2050. Even in the Advanced Technologies Scenario featuring strong growth in non-fossil energy consumption, the world will not be able to maintain or improve economic, social and living conditions without fossil fuels.

Realisation of the Advanced Technologies Scenario is challenging. Emerging and Developing Economies will account for 95% of the coal consumption savings in 2050, with India, ASEAN and MENA accounting for a combined 41%. Emerging and Developing Economies will account for 62% and 53% of the growth of nuclear and renewables, respectively, with India, ASEAN and MENA accounting for 31% and 25%, respectively. The Advanced Technologies Scenario thus requires Emerging and Developing Economies to achieve such reductions in coal consumption and growth in nuclear and renewables consumption within less than 30 years. During the process of realising the Advanced Technologies Scenario, the Emerging and Developing Economies will need to implement their energy transition far faster than the Advanced Economies did in the past.

Figure 4-9 | Primary energy consumption changes (relative to Reference Scenario) [Advanced Technologies Scenario]

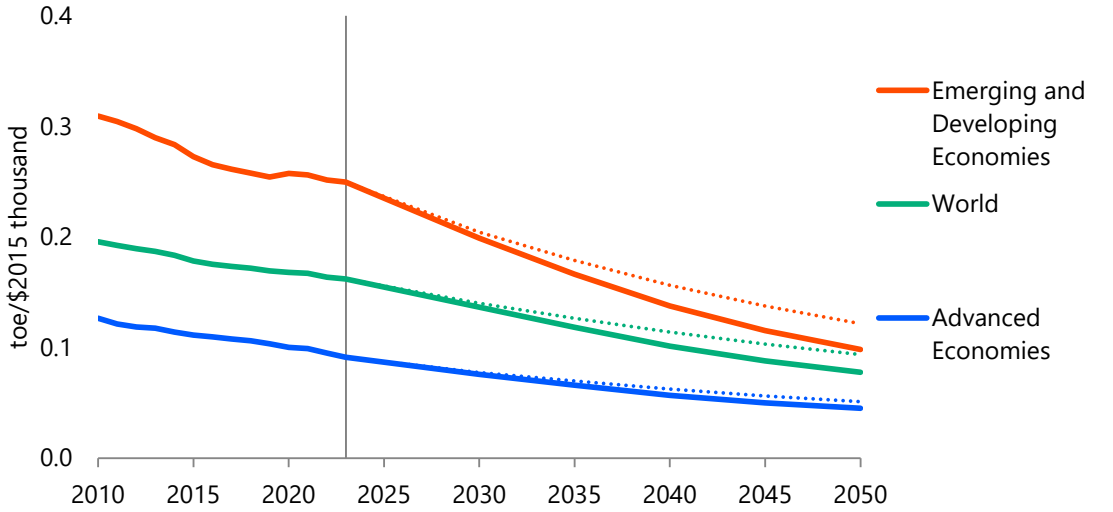


For the world to achieve the 1.5°C target, an average annual improvement in energy efficiency of more than 4% is necessary by 2030. However, in the Advanced Technologies Scenario, energy intensity per unit of gross domestic product (GDP) declines by an average of 2.6% per year in Advanced Economies and 3.2% in Emerging and Developing Economies from 2023 to 2030, which are not sufficient (Figure 4-10). In 2050, the Advanced Economies will post a decline of 55% in energy intensity from 2023 to 2050, compared with a fall of 62% for the Emerging and Developing Economies which have greater potential to improve energy efficiency. The global energy intensity per unit of GDP will have to decrease by 78% from 2023 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[13] to achieve carbon neutrality. The decrease would be far steeper than the declines in the Emerging and Developing Economies and in China, demonstrating the considerable difficulty of achieving global carbon neutrality by 2050.

If the Advanced Technologies Scenario is realised and further carbon dioxide (CO_2) emission reductions are made, both the Advanced Economies and the Emerging and Developing Economies will need to improve energy efficiency at a high pace and promote the decarbonisation of energy sources. This will require Advanced Economies to develop energy efficiency technologies, transfer them to Emerging and Developing Economies, enhance international fundraising capabilities, and eliminate barriers to energy savings, including insufficient awareness. Each country will need to adopt appropriate energy conservation and decarbonisation approaches tailored to urban and rural areas, while introducing incentives for energy-efficient appliances accessible to low-income households focused on day-to-day survival. Improving national and regional education programmes will also be essential to raise long-term awareness of energy efficiency.

[13] Hydrogen produced by decomposing fossil fuels and capturing carbon dioxide emitted in the process

Figure 4-10 | Primary energy intensity per GDP [Advanced Technologies Scenario]



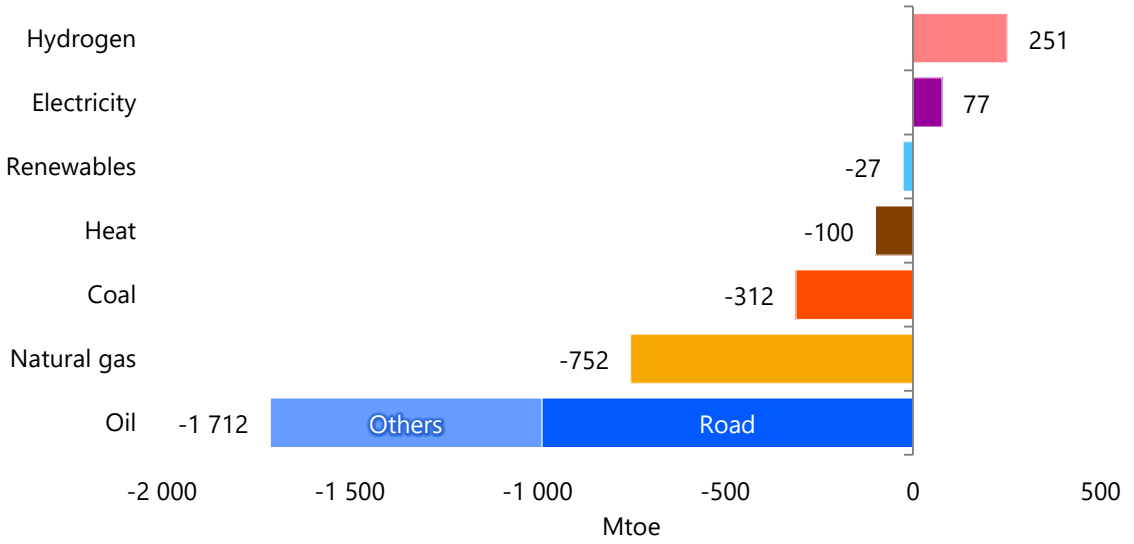
Note: Dotted lines represent the Reference Scenario.

All policy tools must be mobilised to plan and implement these CO_2 emission reduction measures, including subsidies, taxes, regulations and other public policies that can be leveraged by private businesses. Success will require Advanced Economies' bilateral cooperation with Emerging and Developing Economies, multilateral cooperation through frameworks such as the ASEAN+3, Asia-Pacific Economic Cooperation (APEC) forums, and Asia Zero Emission Community (AZEC) in Asia, as well as support from international financial institutions such as the International Monetary Fund (IMF) and the World Bank.

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

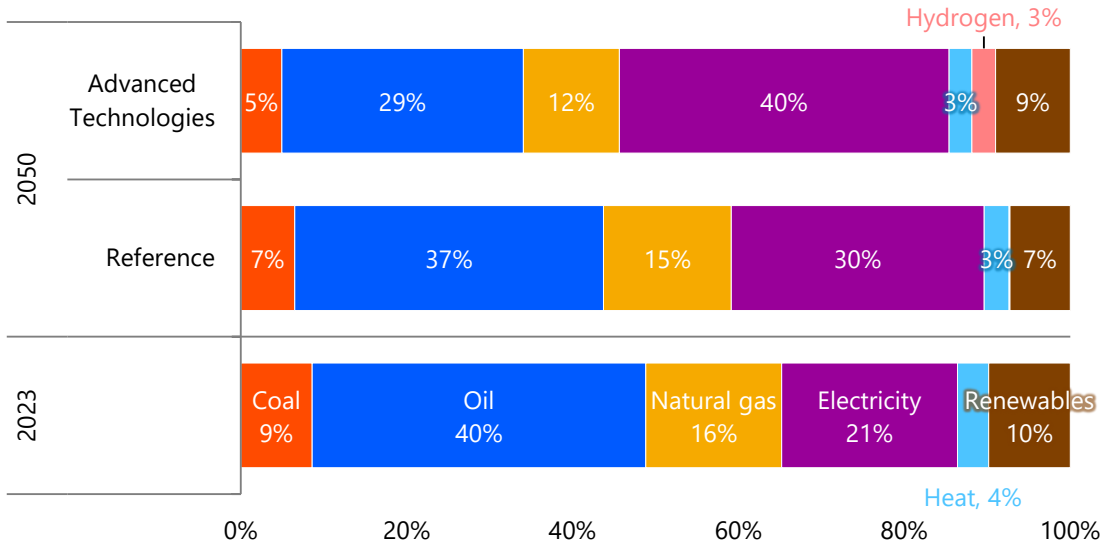
In the Advanced Technologies Scenario, oil will account for about 70% of net final energy consumption savings in 2050 (Figure 4-11). Factors behind oil consumption savings include a decrease in the road sector's oil consumption due to vehicle fuel efficiency improvements and fleet mix changes. Steady implementation is one of the key elements for bringing final energy consumption closer to the path of the Advanced Technologies Scenario. 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 4-11 | Global final energy consumption changes (relative to Reference Scenario) [Advanced Technologies Scenario, 2050]



The final energy consumption in the Advanced Technologies Scenario will be reduced compared with 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 due to promoted electrification with the aim of saving energy and reducing CO_2 emissions through high-efficiency and low-carbon electricity. In 2050, the share of electricity will be 9 percentage points higher than in the Reference Scenario (Figure 4-12). Hydrogen, expected to be a low-carbon solution for applications where electrification is difficult, is barely introduced in the Reference Scenario but will experience the greatest proportional increase among energy sources in the transition to the Advanced Technologies Scenario. Renewable energy volumes will decline as traditional biomass such as firewood and livestock manure is replaced with cleaner alternatives, but at a slower rate than fossil fuels, resulting in a share 2 percentage points higher than in the Reference Scenario. Despite these variations from the Reference Scenario, demand will persist for all major energy sources even in the Advanced Technologies Scenario. Therefore, also in this scenario, ensuring stable supply of each energy source will remain important as in the Reference Scenario.

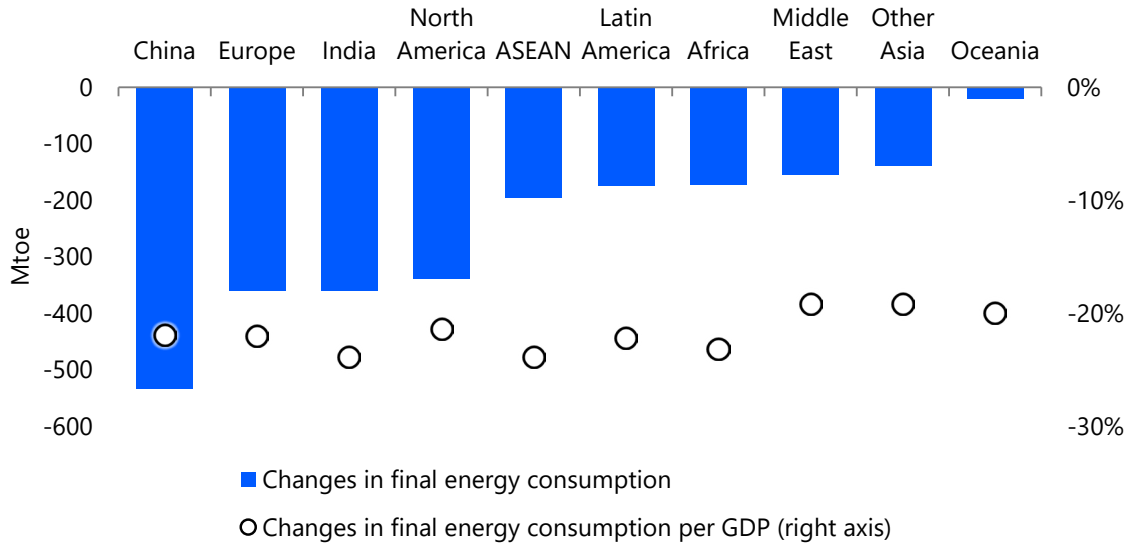
Figure 4-12 | Global final energy consumption mix



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

Asia, including China and India, will account for the largest share of final energy consumption savings in 2050, followed by North America, Europe and Africa (Figure 4-13). Steady progress in energy efficiency improvements in China, India, the United States, Europe 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 4-13 | 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 1 229 Mtoe, accounting for as much as 48% of global savings. China with 533 Mtoe in savings and India with 360 Mtoe will account for a combined 30% of global savings, highlighting their significant influence. Progress in these two countries' energy savings will affect not only the countries themselves but also global climate

change and energy security in other regions. They will substantially reduce oil consumption in the road sector, and coal and natural gas consumption in the industry sector, reflecting the effects of various technologies assumed in the Advanced Technologies Scenario. Achieving steady progress in energy efficiency improvements in these two countries through various measures, such as the transfer of highly efficient technologies from Advanced Economies, will be essential.

Final energy consumption savings in Europe will total 361 Mtoe, accounting for 14% of global savings. Notably, the buildings sector will account for 33% of these savings. Led primarily by the Organisation for Economic Co-operation and Development (OECD) countries, more efficient equipment for household and commercial use will be actively deployed, resulting in significant reductions in natural gas consumption. Final energy consumption savings in North America will total 340 Mtoe, accounting for 13% of global savings. The decline in oil consumption, primarily in the road sector, will account for approximately 60% of its savings. As automobiles are frequently used for mobility and transportation in North America, the combined oil demand in the road sector in the United States and Canada is the second largest in the world after Asia. Consequently, oil consumption in the road sector will decline substantially, driven by improvements in vehicle fuel efficiency and changes in vehicle fleet composition.

Africa presents unique characteristics in terms of sectoral savings. Of Africa's 173 Mtoe net final energy consumption savings, about 20% will come from reduced renewable energy consumption in the residential sector, leading to a 23% decline in final energy consumption per GDP—the largest reduction in energy consumption across all countries and regions. The savings in renewable energy consumption will be driven by the modernisation of energy use and the adoption of highly efficient appliances. To steadily implement residential sector energy savings, it will be essential to make highly efficient energy-consuming appliances available at affordable prices to a wider range of consumers and to develop infrastructure for supplying modern energy sources.

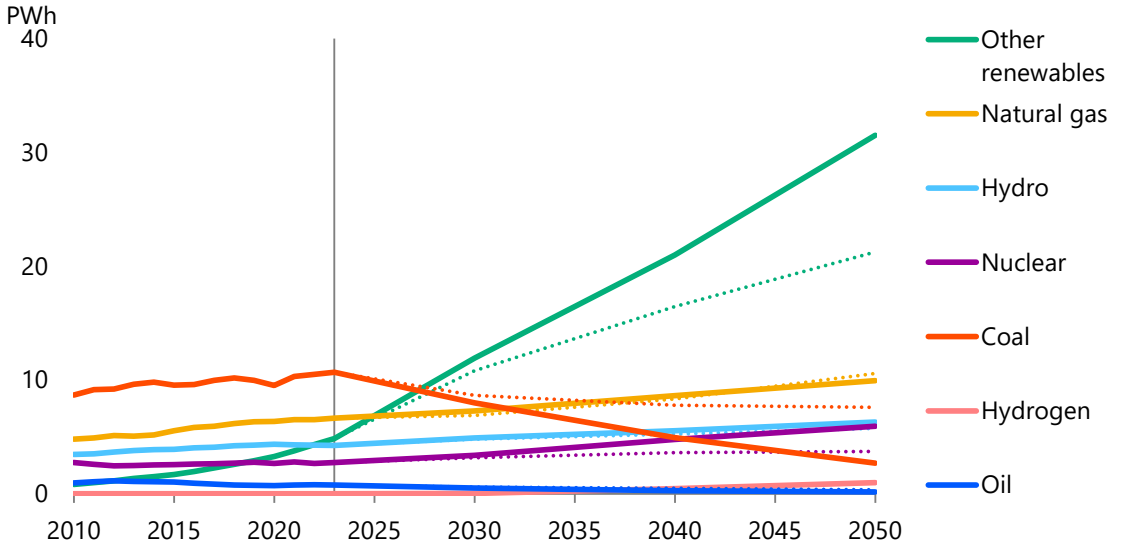
Power generation mix

In the Advanced Technologies Scenario, factors reducing electricity demand—such as maximisation of energy efficiency improvements—coexist with factors increasing demand, including accelerated electrification as a climate change countermeasure and additional electricity consumption arising from hydrogen production and CCS. As a result, electricity generated in 2050 will be 57 579 TWh, 14% higher than in the Reference Scenario. Although there is uncertainty about how global climate change countermeasures will progress, the electricity generated in 2050 under either scenario will be 1.7 to 2 times higher than the current level. Securing continuous investment in power generation facilities and transmission and distribution infrastructure that support this enormous increase in demand will be an unavoidable challenge for future energy supply.

The power generation mix will greatly change from the current one. Regarding coal, as Advanced Economies take the lead in promoting policies to phase it out, coal-fired power generation will decline substantially from the present to about a quarter of the current level in 2050 (Figure 4-14). In contrast, renewables including solar photovoltaics, wind, and biomass will become the largest power source. In the Reference Scenario, the pace of renewable energy growth will slow after 2030 due to land constraints and the difficulty of addressing output fluctuations. In the Advanced Technologies Scenario, the current pace of rapid deployment will be maintained. This outcome, however, cannot be achieved through deployment alone. It will be possible only with appropriate institutional design to harness the potential anticipated in the Advanced Technologies Scenario across the world, continuous cost reductions and support for measures to address output

fluctuations, such as thermal power generation, storage batteries and demand-side load adjustment (demand response).

Figure 4-14 | Global electricity generated [Advanced Technologies Scenario]



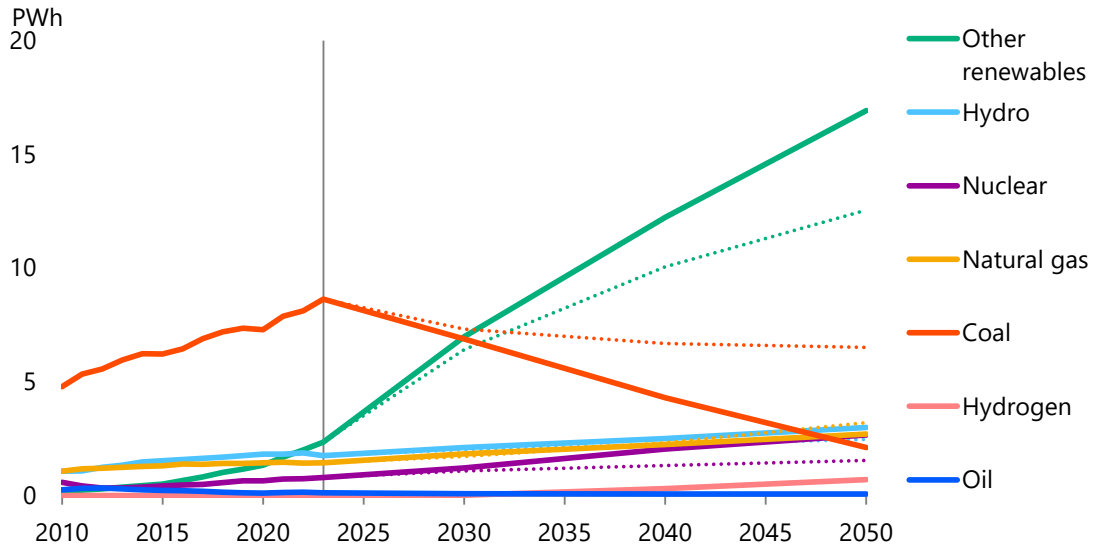
Note: Dotted lines represent the Reference Scenario.

As part of these efforts, to substitute for coal- and natural gas-fired power plants, thermal power generation equipped with CCS as well as hydrogen/ammonia-fired power plants will be introduced in earnest from around 2040. In policy formulation, rather than making a binary choice between thermal power and renewable energy, it is desirable to combine both options at appropriate scales tailored to regional circumstances, thereby achieving both supply stability and environmental objectives. In addition, storage batteries for both grid and consumer use will expand rapidly, contributing to the adjustment of the balance between electricity supply and demand alongside demand response measures utilising electric vehicles.

In Asia, coal, currently the largest power source, will begin declining, yielding its position as the largest power source to renewables (other than hydro) by around 2030 (Figure 4-15). This decline will be seen in Advanced Economies such as Japan and Korea, as well as in China, where renewable energy is already growing significantly. In Emerging and Developing Economies, a certain number of coal-fired power plants will be constructed. 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 strong 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 dispatchable renewables such as hydro and geothermal, as well as nuclear and emissions-controlled thermal power.

In Asia, natural gas-fired power generation will increase steadily until 2050 in both scenarios, serving as a key tool for managing fluctuations in renewable energy output. Hydrogen-fired power generation will also be introduced in earnest after 2040, progressing from Advanced Economies to Emerging and Developing Economies, supporting supply-demand balance adjustments in a manner similar to natural gas.

Figure 4-15 | 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. Oil demand will peak by 2030 and reach 57.8 million barrels per day (Mb/d) in 2050, 43% less than in the Reference Scenario. This decline in demand will cause non- Organization of the Petroleum Exporting Countries (OPEC) production to fall by 2030, with OPEC production also beginning to decline by 2040. However, the OPEC countries in the Middle East, which are more cost competitive, will maintain production at 24.2 Mb/d in 2050. As a result, OPEC's market share will increase slightly from the Reference Scenario, reaching 42% in 2050.

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

(Mb/d)

	2023	2030	2040	2050	2023-2050	
					Changes	CAGR
Crude oil production	96.3	91.6	74.4	56.2	-40.1	-2.0%
OPEC	33.9	33.9	29.4	24.2	-9.6	-1.2%
Middle East	26.7	27.5	24.7	20.9	-5.8	-0.9%
Others	7.1	6.4	4.7	3.3	-3.8	-2.8%
Non-OPEC	62.4	57.7	45.0	31.9	-30.5	-2.5%
North America	24.0	24.2	19.2	14.6	-9.4	-1.8%
Latin America	9.0	8.3	7.4	5.4	-3.6	-1.9%
Europe and Eurasia	17.6	14.6	10.5	6.4	-11.2	-3.7%
Middle East	2.9	3.1	3.0	2.7	-0.2	-0.2%
Africa	1.5	1.3	1.1	0.8	-0.7	-2.2%
Asia and Oceania	7.5	6.2	3.8	2.1	-5.4	-4.7%
Processing gains	2.4	2.3	1.8	1.4	-1.0	-2.0%
Oil supply	98.6	93.8	76.2	57.6	-41.1	-2.0%

Note: Crude oil includes natural gas liquids (NGLs).

Natural gas supply

As improvements in energy efficiency and other energy utilisation technologies reduce natural gas consumption in the Advanced Technologies Scenario, natural gas production will be 12% lower in 2040 and 25% lower in 2050 than in the Reference Scenario. However, better management of greenhouse gas (GHG) emissions may lead to a greater proportion of greener natural gas production capacity.

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

(Bcm)

	2023	2030	2040	2050	2023-2050	
					Changes	CAGR
World	4 222	4 259	4 223	4 067	-154	-0.1%
North America and Mexico	1 280	1 221	1 153	1 006	-274	-0.9%
Latin America excl. Mexico	199	214	243	222	23	0.4%
Europe	196	94	71	63	-133	-4.1%
Eurasia	856	840	776	724	-132	-0.6%
Russia	638	590	525	465	-173	-1.2%
Middle East	732	777	810	938	207	0.9%
Africa	253	330	425	412	159	1.8%
Asia	538	593	559	517	-21	-0.1%
China	232	230	160	87	-145	-3.6%
India	36	54	42	23	-13	-1.6%
ASEAN	204	203	243	253	49	0.8%
Oceania	167	190	185	185	18	0.4%

There will be a wide production gap between the Reference and Advanced Technologies Scenarios in North America which has a large production scale. The region's natural gas production in 2050 in the Advanced Technologies Scenario will be nearly 30% less than in the Reference Scenario. Production in Eurasia, including Russia, will be 20% lower than in the Reference Scenario. In the Middle East, Qatar and Iran will see large increases in production even in the Advanced Technologies Scenario, but production in the region in 2050 will be 10%–20% lower than in the Reference Scenario.

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 transportation.

Net natural gas-importing regions will reduce their imports by 40%–70% from the Reference Scenario in 2050. Among net natural gas-exporting regions, Eurasia including Russia will cut exports slightly while the Middle East will reduce its net exports (excluding intra-regional trade) by about 50% from the Reference Scenario. In North America, production will be lower than in the Reference Scenario, but demand will also decline significantly. Despite declining international prices, net exports in 2050 will remain only 20% below 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 in marine transportation). For LNG transportation in particular, relevant parties will be able to reduce transportation costs, transportation distances and GHG footprints while maintaining equivalent transport volumes through cooperation optimisation measures, including destination changes and cargo swapping.

Policy and securing investment issues leading to stabilisation of the LNG market and measures to make LNG cleaner

As a realistic solution to address the uncertainties of energy transition, it is necessary to set clear roles for LNG, as well as to establish clear LNG standards to fulfil those roles. At the company level, the key will be strengthening countermeasures and setting targets for methane and GHG emissions, as well as disclosing such information accurately and promptly. International forums such as the Group of Seven (G7) have recognised the importance of natural gas and LNG; however, it is also essential to establish standards defining which types of LNG are acceptable in the energy transition. The importance of strengthening methane and GHG emission measurement and international standardisation, as well as of international cooperation in emission reduction measures, is increasingly being recognised. In this regard, it is significant that the LNG Producer-Consumers Conference in June 2025 agreed on further cooperative efforts among governments and relevant international organisations to reduce and manage methane emissions.

Table 4-5 | Challenges to clean LNG production

	Electrification by clean electricity	CCS
Summary Benefit	Electrification of LNG production process Improvement of operational reliability and reduction of maintenance cost Improvement of GHG control and reduced natural gas consumption in the process	Capture of CO_2 in feedstock gas and in the process Improvement of economy through collaboration with surrounding industrial facilities
Challenge	Securing appropriate clean electricity Securing backup electricity Load fluctuation adjustment with neighbouring industrial facilities	Securing suitable site for CCS Cost and time required for integration in case of existing LNG facilities More difficult to capture CO_2 in the process than in feedstock gas

These planned LNG projects are increasingly adopting CCS to reduce GHG emissions and electric drivers powered by renewable energy. In the Advanced Technologies Scenario, the incorporation of these measures is expected to increase in both new LNG projects and existing LNG production facilities. Such incorporation will highlight the economic and environmental advantages of LNG projects, leading to the development of various financial instruments that meet the financing needs of LNG project development.

In the Advanced Technologies Scenario, building links between domestic and foreign buyers, including joint procurement arrangements, will be effective for securing clean LNG during market transitions. This approach considers the demand for flexibility and shorter contract terms by buyers, including those in developing economies, and the expanding base of buyers with relatively lower credit ratings. Such collaboration will also help Japan secure its required LNG supply stability, 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)
Clarification of LNG's role during the transition and beyond
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 crude oil-indexed pricing to more natural gas hub pricing, more complex composite factors, etc.
Development of financing methods also taking into account the trend of shortened contracts (addressing the gap between the requirements for shorter contracts and needs 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 increase the efficiency of coal use are enhanced towards carbon neutrality, initiatives to minimise coal use will progress in various sectors including power generation, steelmaking, and other industries. Coal's share in the power generation mix will decline in many countries as the proportions 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. Additionally, some coal-fired power generation will be required for economic reasons in countries and regions where renewable energy implementation is challenging.

Advanced Economies will suspend or terminate inefficient coal-fired power plants. Even when some coal-fired power plants are replaced, technologies to minimise coal consumption will be adopted, such as high-thermal-efficiency technologies like integrated coal gasification combined cycle (IGCC) and co-firing with ammonia or hydrogen. The installation of CCS equipment is also being examined commercially. By improving the efficiency of coal use at individual power plants and industrial facilities, CO_2 emissions intensity will be reduced.

Emerging 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 8.481 Gt in 2023 to 3.336 Gt in 2050 (Figure 4-16). By coal type, steam coal production will decline from 6.853 Gt in 2023 to 2.324 Gt in 2050, coking coal production from 1.026 Gt to 0.811 Gt, and lignite production from 620 Mt to 210 Mt. Compared with the Reference Scenario, overall coal production will decrease by 3.110 Gt in 2050. By coal type, steam coal will decrease by 2.8 Gt, coking coal by 181 Mt and lignite by 130 Mt.

Figure 4-16 | Global coal production [Advanced Technologies Scenario]

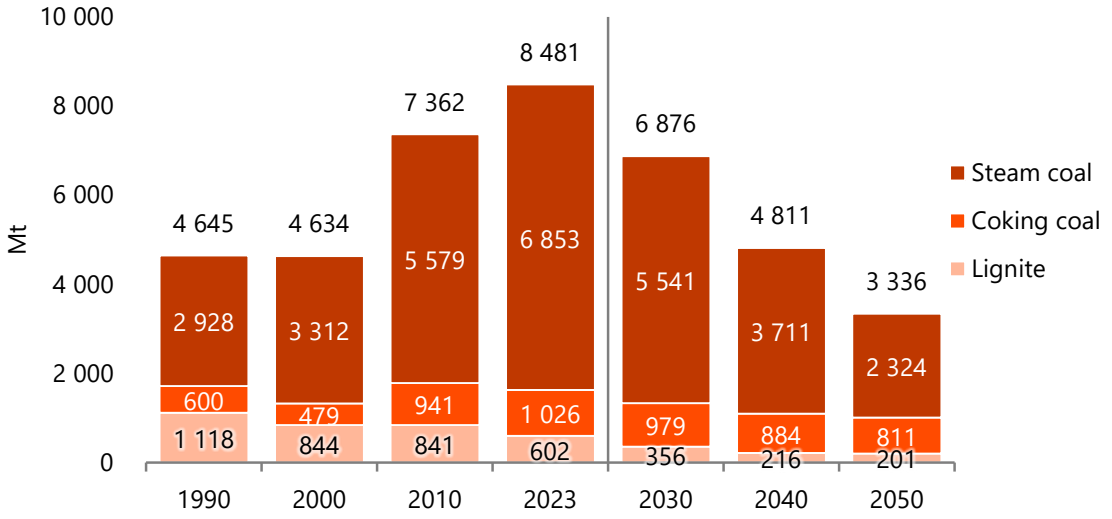


Table 4-7 | Steam coal production [Advanced Technologies Scenario]

(Mt)

	2023	2030	2040	2050	2023-2050	
					Changes	CAGR
World	6 962	5 541	3 711	2 324	-4 638	-4.0%
North America	454	156	48	42	-412	-8.5%
United States	391	149	43	38	-353	-8.3%
Latin America	64	47	24	17	-47	-4.8%
Colombia	56	40	20	12	-44	-5.5%
OECD Europe	45	21	9	5	-40	-7.6%
Non-OECD Europe/Eurasia	368	302	217	177	-191	-2.7%
Russia	247	199	133	102	-145	-3.2%
Middle East	0	0	0	0	0	-2.2%
Africa	249	206	163	132	-117	-2.3%
South Africa	245	185	141	110	-136	-2.9%
Asia	5 529	4 612	3 114	1 846	-3 683	-4.0%
China	3 903	2 961	1 662	735	-3 168	-6.0%
India	839	932	917	689	-151	-0.7%
Indonesia	681	594	421	304	-377	-2.9%
Oceania	252	197	137	105	-147	-3.2%
Australia	251	196	136	104	-146	-3.2%

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

(Mt)

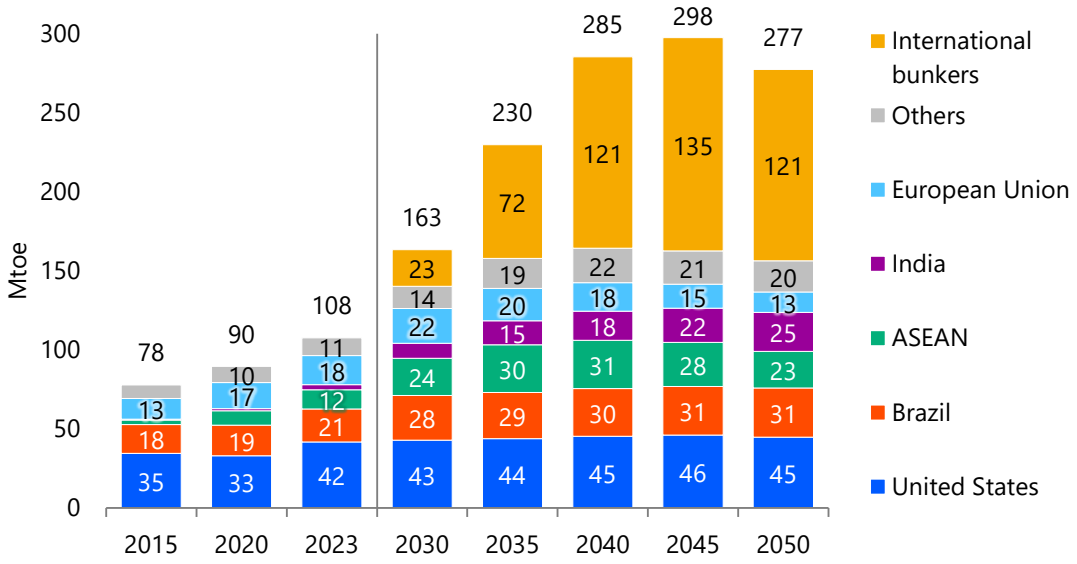
	2023	2030	2040	2050	2023-2050	
					Changes	CAGR
World	1 021	979	884	811	-210	-0.8%
North America	77	61	61	61	-16	-0.8%
United States	52	43	43	43	-9	-0.7%
Latin America	10	10	12	16	5	1.6%
Colombia	9	9	12	15	6	2.0%
OECD Europe	14	13	14	15	0	0.0%
Non-OECD Europe/Eurasia	110	96	86	80	-30	-1.2%
Russia	105	90	81	74	-31	-1.3%
Middle East	2	2	2	3	1	1.4%
Africa	8	17	21	24	15	4.0%
Mozambique	4	12	16	18	14	5.4%
Asia	641	601	490	395	-246	-1.8%
China	554	505	376	268	-286	-2.7%
India	57	64	83	98	41	2.0%
Mongolia	24	24	23	21	-3	-0.5%
Oceania	158	180	198	218	60	1.2%
Australia	157	179	197	217	60	1.2%

Most countries will see coal production decline, partly due to falling demand. For steam coal in particular, production in 2050 will be reduced compared with 2023 due to decreased domestic demand, with China, the United States and Australia experiencing the largest declines. India will also see a decline in steam coal production. On the other hand, coking coal production will decrease in China and the United States but increase in India, as steel demand varies greatly from country to country. In Australia and Mozambique, where exports dominate coal transactions, production will increase along with expanded exports due to increased steel production in Emerging and Developing Economies.

Biofuels for transport

In the Advanced Technologies Scenario, although electrification of the road sector will progress, demand for biofuels will increase beyond the Reference Scenario due to the spread of flexible-fuel vehicles (FFVs) that can run on high biofuel blends (Figure 4-17). Furthermore, if large-scale, low-cost supply of feedstocks, including advanced biofuels such as third-generation algae-based fuels, can be achieved, demand for biofuels is expected to increase not only in the United States and Brazil but also in India and ASEAN. I In contrast, Europe is expected to see little change in its electrification trajectory. Regulations on conventional biofuels, which are currently available, are anticipated to be maintained or strengthened from sustainability and environmental protection perspectives such as land use change (LUC) and indirect land use change (ILUC). Consequently, biofuel demand is not expected to increase as much as it would in the Reference Scenario. Based on these factors, the share of biofuels in total road sector energy demand will be approximately 15% by 2050.

Figure 4-17 | Biofuel consumption for transport [Advanced Technologies Scenario]



In the aviation sector, the use of bio-based sustainable aviation fuels (SAFs) will increase significantly, reaching 25% to 30% of global aviation fuel in 2050. There is little difference between the two scenarios in the amount of SAF introduced in 2050, but in the transition period leading up to that point, the Advanced Technologies Scenario will see greater deployment due to cost improvements and increased supply. On the other hand, bunker oil use for ships will fall below the Reference Scenario as hydrogen-based liquid and gaseous fuels are actively introduced through technological innovation under the Advanced Technologies Scenario.

4.3 India and ASEAN

This section focuses on India, a key driver of growth in global final energy consumption, and Malaysia, which will serve as the chair of the Association of Southeast Asian Nations (ASEAN) in 2025, to outline their efforts to achieve both decarbonisation and economic development, as well as future prospects.

Pursuing both economic development and decarbonisation

India

Having set 'Viksit Bharat 2047' (Developed India 2047) as its national vision, India aims to become one of the advanced economies by 2047 (the 100th anniversary of its independence). Viksit Bharat 2047 outlines multiple strategic pillars—economic growth and development, infrastructure development, social progress, governance and security, innovation, science and technology, environmental sustainability, and India in the world. In particular, regarding economic growth and development, it sets an ambitious goal of raising gross domestic product (GDP) to over $30 trillion by 2047, stating that achieving this goal will require maintaining an average growth rate of 7% to 10% over the coming decades[14].

Meanwhile, regarding decarbonisation, India declared at the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26), held in November 2021, that it will aim to achieve carbon neutrality by 2070. In the Nationally Determined Contribution (NDC) announced in August 2022, India has committed to reducing greenhouse gas (GHG) emissions per unit of GDP by 45% compared with 2005 levels by 2030. It also set a conditional target of increasing cumulative installed power generation capacity from non-fossil fuel-based energy sources to approximately 50% by 2030[15]. The goal of increasing non-fossil fuel power generation capacity to 500 GW by 2030, announced by Prime Minister Narendra Modi at COP26, was not included in the text of the NDC, but continues to be mentioned in Indian government documents. India had installed 242.8 GW of non-fossil fuel power generation capacity by June 2025 (233.99 GW from renewables and 8.8 GW from nuclear). This accounts for 50.07% of the total installed capacity (484.82 GW), achieving the goal announced at COP26 five years ahead of schedule[16]. The long-term strategy, announced at COP27 in November 2022, focuses on seven areas (electricity, transport, adaptation in urban design, industry, carbon removal, forests and vegetation, and finance), outlining the elements that should be addressed to achieve low-carbon development in each area.

In terms of simultaneous achievement of economic development and decarbonisation, India has been implementing the National Action Plan on Climate Change (NAPCC), a comprehensive framework, since 2008. The NAPCC consists of national missions in eight areas (solar photovoltaics, energy efficiency, living environment, water resources, Himalayan ecosystems, forests and other ecosystems, agriculture, and strategic knowledge dissemination on climate

[14] Viksit India, "Viksit India: Bold Vision. Brighter Future", https://viksitindia.com/

[15] Government of India, "India's Updated First Nationally Determined Contribution Under Paris Agreement (2021–2030)", August 2022. https://unfccc.int/sites/default/files/NDC/2022-08/India%20Updated%20First%20Nationally%20Determined%20Contrib.pdf

[16] Press Information Bureau, Government of India, "The Solar Surge: India's Bold Leap Toward a Net Zero Future", 19 August 2025. https://www.pib.gov.in/PressNoteDetails.aspx?id=155063&NoteId=155063&ModuleId=3

change), which are being reviewed to align with the NDCs[17]. The government is implementing sectoral policies in line with the NAPCC strategy while supporting each state and union territories (UTs) in formulating the State Action Plans for Climate Change (SAPCCs).

Malaysia

In terms of economic development, Malaysia has set a goal of achieving an average annual GDP growth rate of 4.5% to 5.5% between 2026 and 2030 in its 3rd Five-Year Plan (13MP), with development expenditure of approximately $130 billion[18]. Through this economic growth, Malaysia aims to become one of the high-income countries, ranking among the world's top 30 economies by 2030.

Regarding decarbonisation, Malaysia's NDC was submitted in 2021 and reaffirmed at COP29. The country pledged to reduce its GHG emissions intensity by 45% by 2030 from 2005 levels, with the goal of achieving net-zero emissions by 2050[19].

Malaysia's energy transition is driven by the National Energy Transition Roadmap (NETR) and the Malaysia Renewable Energy Roadmap (MyRER), which promote energy efficiency, renewable energies, green mobility, hydrogen, bioenergy, and carbon capture. While the clean energy transition is still in its early stages, Malaysia is progressing towards its goal of increasing the share of renewable energies in installed capacity to 40% by 2035 and 70% by 2050[20]. As of 2022, renewables accounted for 24% (9 GW) of installed power generation capacity. This is primarily due to hydro and solar photovoltaics (e.g. large-scale solar photovoltaics and rooftop solar photovoltaics).

Malaysia's MADANI economic framework integrates climate change measures with inclusive development, innovation and infrastructure development. Making use of green finance and carbon market mechanisms, the National Decarbonisation Committee oversees the implementation of the framework. This strategy reflects a balanced and pragmatic approach to energy security, economic competitiveness, and sustainability, and lays the foundations for a fair and low-carbon society.

Outlook

In both the Reference Scenario and the Advanced Technologies Scenario, energy consumption in Emerging and Developing Economies will continue to grow steadily, with India and ASEAN seeing particularly large increases in energy consumption due to robust economic growth. As shown in Figure 4-18, India's average income will approach $10 000, and energy consumption per capita will nearly double from the current level by 2050. Malaysia's GDP per capita is at the same level as China's, and robust growth and rising demand are expected to continue.

In China, from the 1990s to the 2000s, there was an explosive increase in energy demand, due partly to the rapid expansion of the secondary industry. Although a similar pace of

[17] Press Information Bureau, Government of India, "National Action Plan on Climate Change (NAPCC)", 1 December 2021. https://static.pib.gov.in/WriteReadData/specificdocs/documents/2021/dec/doc202112101.pdf

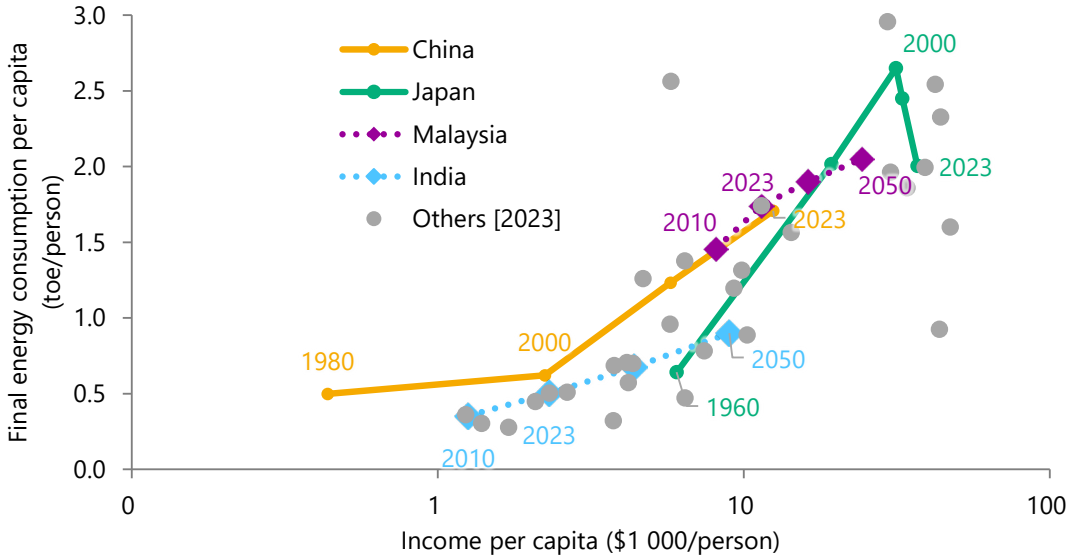
[18] Ministry of Economy, "Thirteenth Malaysia Plan 2026-2030", https://rmk13.ekonomi.gov.my/wp-content/uploads/2025/09/120925-Main-Document-e-Book.pdf

[19] UNFCCC, "Malaysia's Update of its First Nationally Determined Contribution", 30 July 2021. https://unfccc.int/sites/default/files/NDC/2022-06/Malaysia%20NDC%20Updated%20Submission%20to%20UNFCCC%20July%202021%20final.pdf

[20] Ministry of Economy, "National Energy Transition Roadmap", https://www.investmalaysia.gov.my/media/w1la4c2k/national-energy-transition-roadmap.pdf

industrialisation is unlikely in India or Malaysia, steady growth in demand is expected in the industry sector. This is because India continues to promote industrialisation as a policy direction, while Malaysia is expected to maintain a high industrialisation ratio by upgrading its industrial sector and strengthening its industrial base, thereby expanding into more advanced activities such as semiconductor design and cloud services. In addition, rising energy demand in non-industry sectors, such as the buildings and transport sectors, in both countries cannot be ignored.

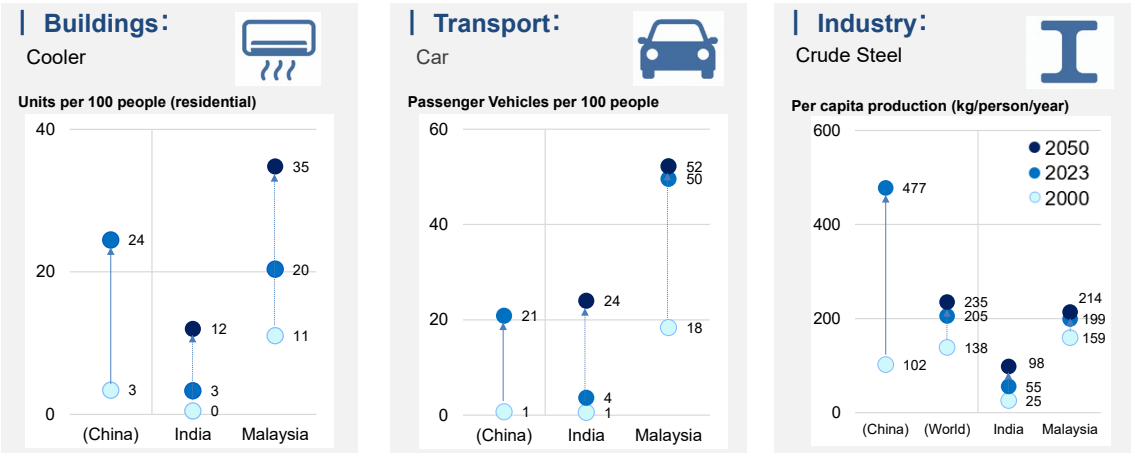
Figure 4-18 | Annual income and final energy consumption per capita



Note: Income per capita is in real terms, at 2015 prices.

Typical examples of energy consumption in each sector include the so-called '3Cs', that is, air conditioning (coolers), passenger cars (cars) and crude steel production (crude steel). Rising income levels among the population directly lead to an increase in air conditioning and passenger cars owned, while causing demand for materials, such as crude steel, to grow. Such trends can be observed in the spread of the '3Cs' in Japan in the 1960s and China in the 2000s, and a similar change is now occurring in Malaysia. Going forward, India is also expected to see progress in stimulating energy consumption in the industry, transport, and buildings sectors through the '3Cs'.

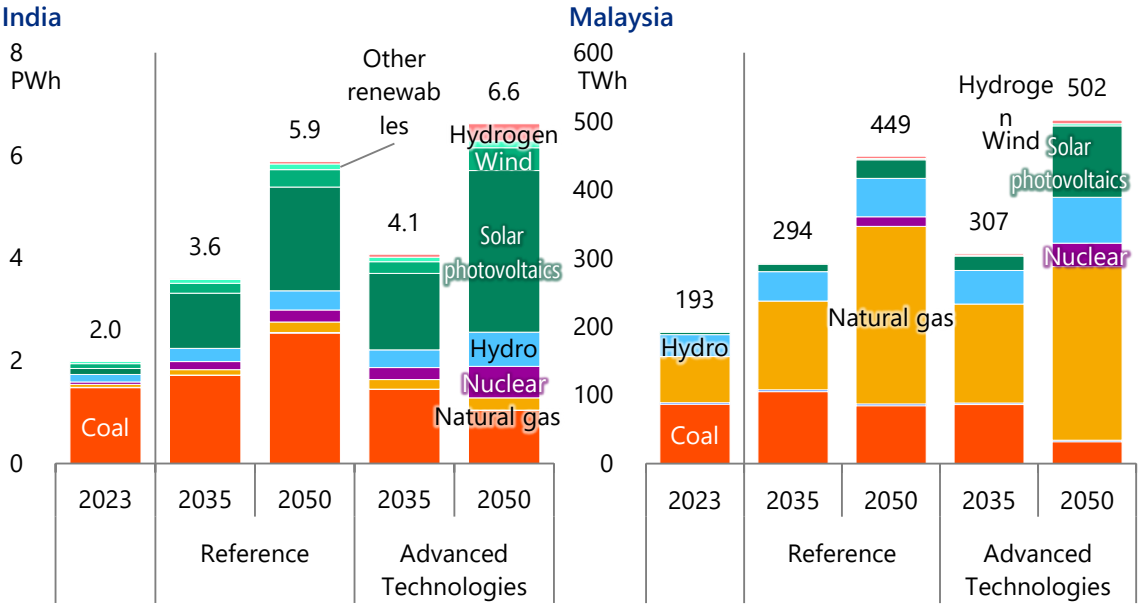
Figure 4-19 | Number of units owned and crude steel production per capita



Due to the significant expansion of energy consumption, the electricity generation required in 2050 will increase sharply, to more than triple the current level in India and to approximately 2 to 2.5 times the current level in Malaysia.

India is expected to see a notably large increase in solar photovoltaic power generation, reaching 17 times the current level (2 020 TWh) under the Reference Scenario in 2050 and 27 times (3 146 TWh) under the Advanced Technologies Scenario. While India has great potential for solar photovoltaics, competition with agricultural land is a major challenge for large-scale development. Coal currently plays an important role in India's power generation sector, and in the Reference Scenario, coal-fired power generation will continue to increase, accounting for 43% of electricity generated in 2050. Although coal-fired power generation will decrease in the Advanced Technologies Scenario, it will still account for 16% of electricity generated in 2050. As shown in Figure 4-20, it will be necessary to expand the power supply system that utilises a variety of power sources, not only coal and renewable energy.

Figure 4-20 | Power generation mix in India and Malaysia



In Malaysia, natural gas will continue to play a dominant role in the country's electricity supply. The share of natural gas-fired power generation in electricity generated in 2050 will remain high at 58% in the Reference Scenario and 51% in the Advanced Technologies Scenario. In the Advanced Technologies Scenario, solar photovoltaics will increase dramatically to 30 times the current level (104 TWh). To achieve its decarbonisation goals, Malaysia is aiming to significantly expand its solar photovoltaic installations through its Large-Scale Solar (LSS) programme and rooftop solar photovoltaics. However, with little potential for renewables (solar photovoltaics and hydro) on the Malay Peninsula, connecting power lines to Borneo will be a key issue for large-scale deployment.

Implication

To further utilise India's abundant renewable energy potential (particularly solar photovoltaics), it will be necessary to develop transmission and distribution infrastructure and resolve land constraints, such as competition with agricultural land and complex land acquisition. Regarding the former, in addition to securing sufficient investment, infrastructure development plans must

be formulated that balance local production and consumption of renewables with interregional exchange, taking into account the difficulty of building a power grid to cover India's vast territory, the world's seventh largest. On the other hand, as for the latter, it is necessary, while taking into account trends in changes to the agricultural population accompanying economic growth (shifts to other industries), to undertake long-term efforts such as simplifying regulations on land acquisition, harmonising systems across states, and increasing administrative involvement in negotiations with landowners, which present significant hurdles for private companies. As India's coal-fired power generation is believed to continue to play an important role in 2050, the gradual decarbonisation of existing coal-fired power plants through the co-firing of ammonia and biomass, and the decarbonisation of coal through carbon capture, utilisation and storage (CCUS) will likely become important options. India is currently developing a comprehensive policy on CCUS, and its early formulation and concrete implementation are expected. Given the large number of mining workers in the country, achieving a fair transition is a major challenge. As India continues to grow its economy and develop its infrastructure, it is necessary to assess the long-term and broad impact of this on whether new industries can adequately absorb employment from traditional industries.

In Malaysia, natural gas-fired power generation will continue to play a pivotal role in electricity supply. Against this backdrop, carbon capture and storage (CCS) is expected to play a significant role in achieving both decarbonisation and economic development. Furthermore, the development of an interconnector linking the Malay Peninsula and Sarawak will be an important component of the ASEAN Power Grid and will also contribute to the decarbonisation and stable supply of energy systems across Malaysia by utilising Sarawak's abundant renewable energy potential, such as hydro and solar photovoltaics. This will also be important in terms of regional economic development. At the same time, from a land use perspective, thorough examination will be needed to determine to what extent Sarawak's potential can actually be utilised. After the 13MP was submitted, the Ministry of Energy Transition and Water Transformation launched a feasibility study on nuclear power generation led by MyPower, a subsidiary of the ministry. Considering the development of nuclear, including small modular reactors, to complement renewable energy and natural gas-fired power sources, is an important option as a carbon dioxide (CO_2)-free power source that can meet rapidly expanding electricity demand, diversify energy sources and reduce emissions.

5. Carbon dioxide emissions

5.1 Current trends: Correcting the course of climate change measures and strengthening the competitiveness of Europe and the United States

In recent years, global efforts to combat climate change and reduce carbon dioxide emissions have reached a turning point. In particular, the announcement by the second Donald Trump administration, which took office in January 2025, to withdraw from the Paris Agreement, has triggered a backlash against US climate change policies. This sudden change in policy not only shook the domestic policy foundations but also seriously impacted the international cooperative system, casting uncertainty over policy decisions in various countries and the future direction of markets. Therefore, this section will focus on the current situation in the United States since the inauguration of the second Trump administration, as well as policy trends in the United States and Europe, and developments in climate change countermeasures.

On 20 January 2025, Mr Trump took office as president and signed an executive order that included withdrawing from the Paris Agreement[21]. The order covered five items, including: 1/ unleashing US energy; 2/ declaring a national energy emergency; and 3/ placing the United States first in international environmental agreements. One consequence of signing this executive order is that the United States, which had been contributing approximately $11 billion[22] annually to the United Nations Framework Convention on Climate Change (UNFCCC), will cease these contributions. Furthermore, the US withdrawal has made it even more difficult to provide developing countries with at least $300 billion a year in climate finance (public and private) by 2035 as funding for global warming countermeasures, as agreed at the 29th Conference of the Parties to the UNFCCC (COP29).

Within the United States, since the inauguration of the second Trump administration, the Environmental Protection Agency announced on 12 March that it would ease 31 regulations to advance President Trump's first executive order. This deregulation includes a reconsideration of power plant regulations, a reconsideration of motor vehicle regulations, and a reconsideration of the 2009 endangerment finding and regulations and actions that rely on that finding. Mr Trump also signed the executive order 'Protecting American Energy From State Overreach' on 8 April. The document declared that 'state overreach in energy regulation would undermine the economy and national security of the United States' and called for suspending enforcement of domestic emissions trading systems and carbon taxes (the so-called Superfund Act). Following this signing, the U.S. Department of Justice set a 7 July deadline for filing lawsuits against states participating in these initiatives, but no lawsuits have been filed.

In July, the Inflation Reduction Act (IRA)/Infrastructure Investment and Jobs Act (IIJA) tax credit funding suspension (including the suspension of wind and solar photovoltaic tax credits) was enacted. In addition, the bill rescinded the 2009 Endangerment Finding, which found that greenhouse gas (GHG) emissions have adverse effects on health and welfare, and proposed the repeal of automobile GHG emission standards. The government also plans to propose the

[21] The White House, "Putting America First In International Environmental Agreements", 20 January 2025. https://www.whitehouse.gov/presidential-actions/2025/01/putting-america-first-in-international-environmental-agreements/

[22] U.S. Department of State, "COP 29 Update: U.S. International Public Climate Finance", 18 November 2024. https://2021-2025.state.gov/cop-29-update-u-s-international-public-climate-finance/

complete abolition of GHG emission criteria, on the grounds that GHGs from thermal power plants do not contribute to air pollution.

Table 5-1 | Major energy and environment-related policies of the United States and the European Union

	United States	European Union
September 2024		Publication of Draghi Report (highlighting lack of investment, high energy costs and strategic dependency as key issues)
January 2025	Mr Trump took office as the 47th President of the United States. Direction to review energy regulations and speed up and licensing procedures. National energy emergency declared Withdrawal from and review of international environmental agreements (the Paris Agreement, etc.) directed.	Indication of the path to improving Europe's competitiveness presented
February 2025		Investments that boost both clean manufacturing and competitiveness. Simplification proposed for the Corporate Sustainability Reporting Directive (CSRD), the Corporate Sustainability Due Diligence Directive (CSDDD) and the Carbon Border Adjustment Mechanism (CBAM) (Omnibus Simplification).
March 2025	Review of the legal basis for GHG regulations commenced	
April 2025	Judicial decisions on state carbon pricing and emissions trading systems (ETS) supported	
May 2025		Amendments adopted to postpone compliance with vehicle GHG emission criteria until 2027
July 2025	Reduction of renewable energy tax credits and support for fossil fuels (One Big Beautiful Bill Act passed). Proposal to abolish Endangerment Finding + Proposal to abolish automobile GHG emission regulations.	

Such sceptical movements regarding climate change in the United States are affecting all areas of markets, policy and diplomacy outside the country. Particularly notable were the gains made by

right-wing and centre-right parties in elections across various countries, as well as the increase in policies prioritising the international competitiveness of domestic industries.

Meanwhile, on 9 January 2025, the European Union announced its Competitiveness Compass[23], outlining three priority areas, including decarbonising the EU economy, and five cross-cutting support policies, including deregulation. It pledged to simplify regulations and support clean industries to address the stagnation of innovation and hollowing out of manufacturing within the region. Furthermore, on 26 February, the European Union proposed the 'Omnibus Package'[24] to simplify the Corporate Sustainability Reporting Directive (CSRD), the Corporate Sustainability Due Diligence Directive (CSDDD), and the Carbon Border Adjustment Mechanism (CBAM). The package aims to reduce the compliance burden on businesses, such as European Sustainability Reporting Standards (ESRS) disclosure and supply chain audits, by reducing the number of target businesses. This is intended to enhance the Union's international competitiveness and is seen as a response to investment competition with the United States and China. Additionally, on 27 May, the European Union announced the relaxation of automobile exhaust gas regulations (changing the target value achievement from a single year in 2025 to an average over the period from 2025 to 2027)[25].

Examples of specific policies and documents calling for strengthening competitiveness in the European Union include the Clean Industrial Deal[26] and the Draghi Report[27]. The Clean Industrial Deal is a comprehensive package announced by the European Commission on 26 February to make decarbonisation an engine for 'industrial competitiveness'. It aims to address high energy costs and global competition by simultaneously advancing industry electrification and the renewable energy transition while reducing costs. The main pillars include: 1/ an affordable energy action plan (developing power grids and promoting electrification); 2/ creating demand for clean products (introducing sustainability and European resilience standards into procurement rules); 3/ mobilising funds (channelling more than €100 billion through an industrial decarbonisation bank and innovation fund); 4/ resource circulation and joint procurement of critical minerals; 5/ skills development; and 6/ simplifying regulations. The background to these developments is the Draghi Report, published in September 2024, in which former European Central Bank (ECB) President Mario Draghi summarised 'The Future of European Competitiveness' at the request of the European Commission. Taking into account the future transition costs of energy-intensive industries, the report analyses factors such as lack of investment in growth, persistently high energy prices, and lack of competitiveness. Thus, within the European Union as well, the need to enhance competitiveness across multiple fronts is being asserted, and these phenomena—which can be seen as actions based on such assertions—represent a gradual shift away from the previous overemphasis on climate change countermeasures.

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[23] European Commission, "Competitiveness compass", https://commission.europa.eu/topics/eu-competitiveness/competitiveness-compass_en. Retrieved 20 August 2025

[24] European Commission, "Commission simplifies rules on sustainability and EU investments, delivering over €6 billion in administrative relief", 6 February 2025

[25] European Union, "CO_2 emissions in cars: Council gives final approval to additional flexibility for carmakers", https://www.consilium.europa.eu/en/press/press-releases/2025/05/27/co2-emissions-in-cars-council-gives-final-approval-to-additional-flexibility-for-carmakers/pdf/, 27 May 2025

[26] European Commission, "Clean Industrial Deal", https://commission.europa.eu/topics/eu-competitiveness/clean-industrial-deal_en, Retrieved 8 August 2025

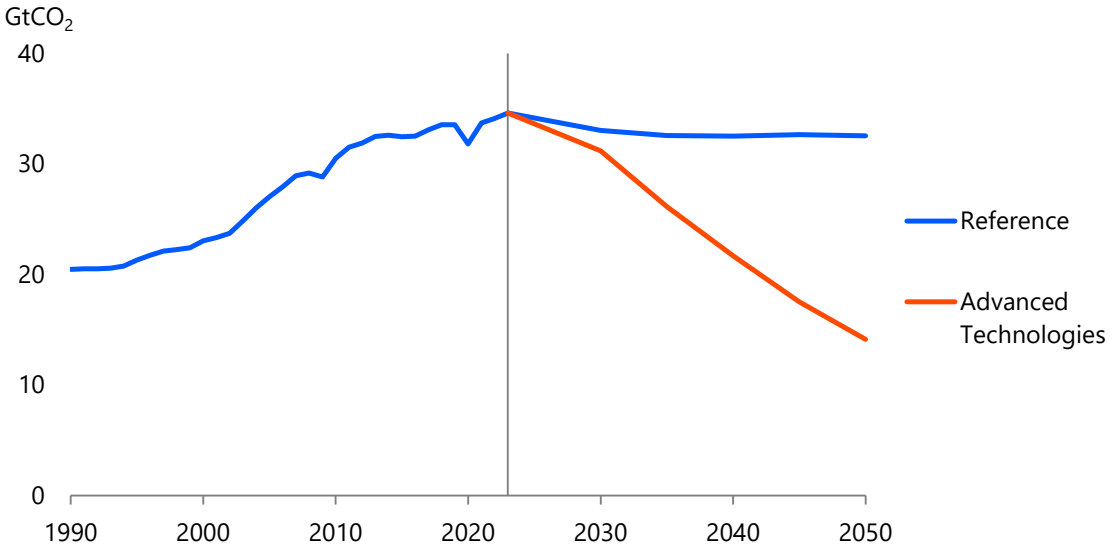
[27] European Commission, "The Draghi report on EU competitiveness", https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en, Retrieved 8 August 2025

Compared with the past, climate change measures have clearly shown a softening trend since around the start of the second Trump administration. On the other hand, renewable energies, particularly solar photovoltaics and wind, will likely see increased adoption in line with market principles as power generation costs fall.

5.2 Outlook for emissions

Figure 5-1 shows the world's carbon dioxide (CO_2) emissions[28]. In the Reference Scenario, emissions will peak in the mid-2020s, followed by a continuous decline towards 2035. However, the rate of decline will slow from 2035 onwards and remain roughly flat until 2050. On the other hand, in the Advanced Technologies Scenario, emission reductions will proceed smoothly towards 2050. Comparing CO_2 emissions between the two scenarios, the Advanced Technologies Scenario shows a significant reduction of 22% in 2035, 35% in 2040, and 57% in 2050 compared with the Reference Scenario. Meanwhile, according to the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report (AR6), to achieve the 1.5°C target, greenhouse gas (GHG) emissions need to be reduced by 43% by 2030 compared with 2019 levels, 60% by 2035, and 69% by 2040. However, the reductions under the Advanced Technologies Scenario will be only 7% in 2030, 22% in 2035, 35% in 2040 and 58% in 2050. This comparison reveals a significant gap with the 1.5°C target, highlighting that current measures alone are far from sufficient and that additional actions are essential. In addition, the latest assessment shows that the carbon budget has shrunk significantly since AR6, making the 1.5°C target unrealistic and necessitating a more realistic target of 2°C. This point is discussed in Section 9.2

Figure 5-1 | Global CO_2 emissions

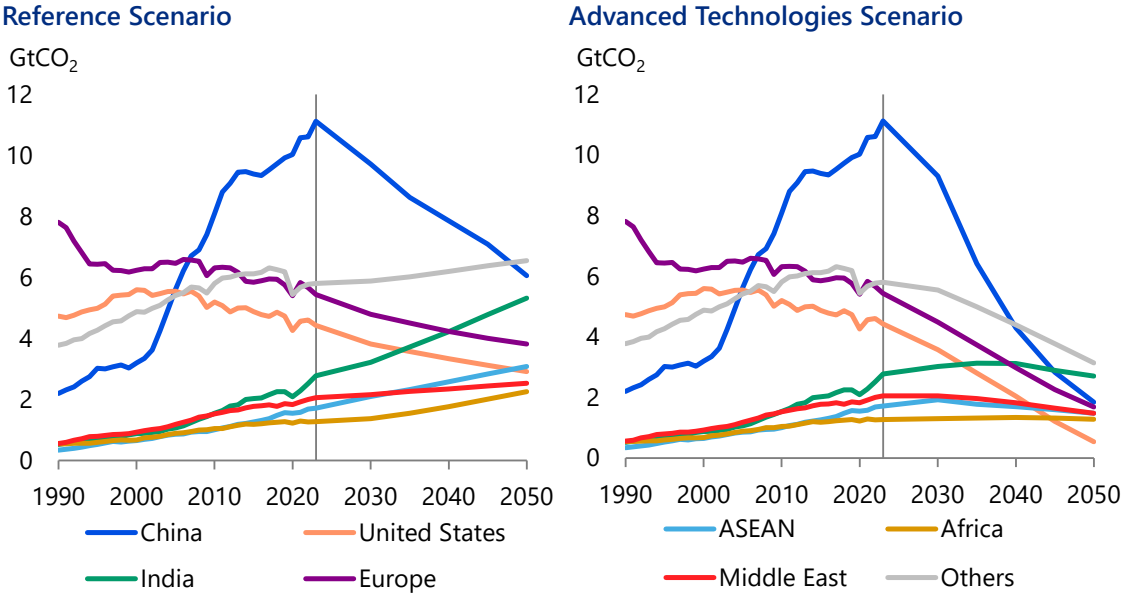


In 2023, China accounted for 32% of CO_2 emissions and the United States for 13%, with these two countries accounting for roughly half of global emissions. Looking at future emissions by region, emissions in the Reference Scenario will continue to decline in China, the United States and Europe (Figure 5-2). Emissions will continue to increase in India, the Association of Southeast

[28] Energy-related CO_2 emissions minus removals by direct air capture and carbon storage (DACCS). The same applies throughout this chapter.

Asian Nations (ASEAN), Africa and the Middle East, while in the Advanced Technologies Scenario, emissions will decrease in all eight countries/regions.

Figure 5-2 | CO_2 emissions

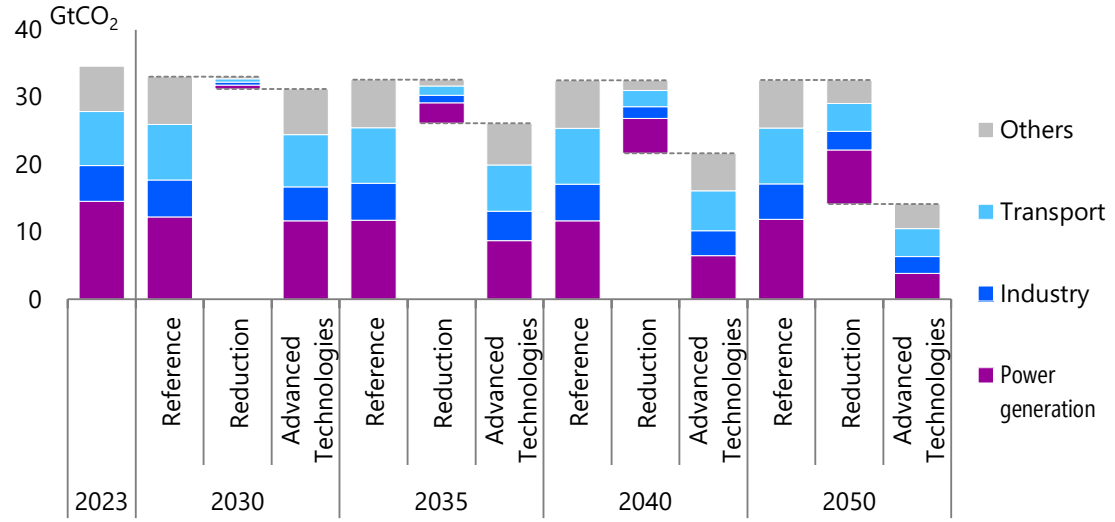


In the Advanced Technologies Scenario for 2050, the largest reduction from the Reference Scenario will be achieved by the United States (82% reduction), followed by China (70% reduction). These outstanding reductions by the two countries, as shown in Figure 3-12, will be attributable to the marked decrease in carbon emissions intensity in the power generation sector due to the expanded introduction of solar photovoltaics and wind. Emissions reductions in ASEAN and India will be around 50% compared with the Reference Scenario, while reductions in Africa and the Middle East will remain in the low 40% range. As stated above, while overall carbon emissions intensity in China and the United States is relatively low, intensity levels in the power generation sector remain high in ASEAN, India, the Middle East and Africa. This is attributable to significant increases in gross domestic product (GDP) in ASEAN and India, coupled with persistently high energy consumption per unit of GDP (indicating that economic growth and environmental impacts will not be decoupled).

In the Advanced Technologies Scenario, India's emissions decline only slowly from 2040 to 2050, and at this rate, it will be difficult for the Indian government to achieve its target of net zero by 2070. Therefore, policies and investments that contribute to emissions reduction, along with the promotion of clean power sources, are required.

The sectoral share of global CO_2 emissions in 2023 was approximately 42% for power generation, 15% for industry, and 23% for transport (Figure 5-3). In the Reference Scenario, CO_2 emissions from the power generation, industry, and transport sectors will decline only marginally between 2023 and 2030. From 2030 onwards, each sector will experience a slight decrease or stagnation, followed by no significant change in emission shares in 2050. On the other hand, in the Advanced Technologies Scenario, emissions from the power generation sector will decrease year by year, falling sharply to 26% by 2050 compared with 2023. Similarly, emissions from the industry and transport sectors will continue to decline, with the former reducing emissions by 46% and the latter by 52% in 2050 compared with 2023.

Figure 5-3 | Global CO_2 emissions



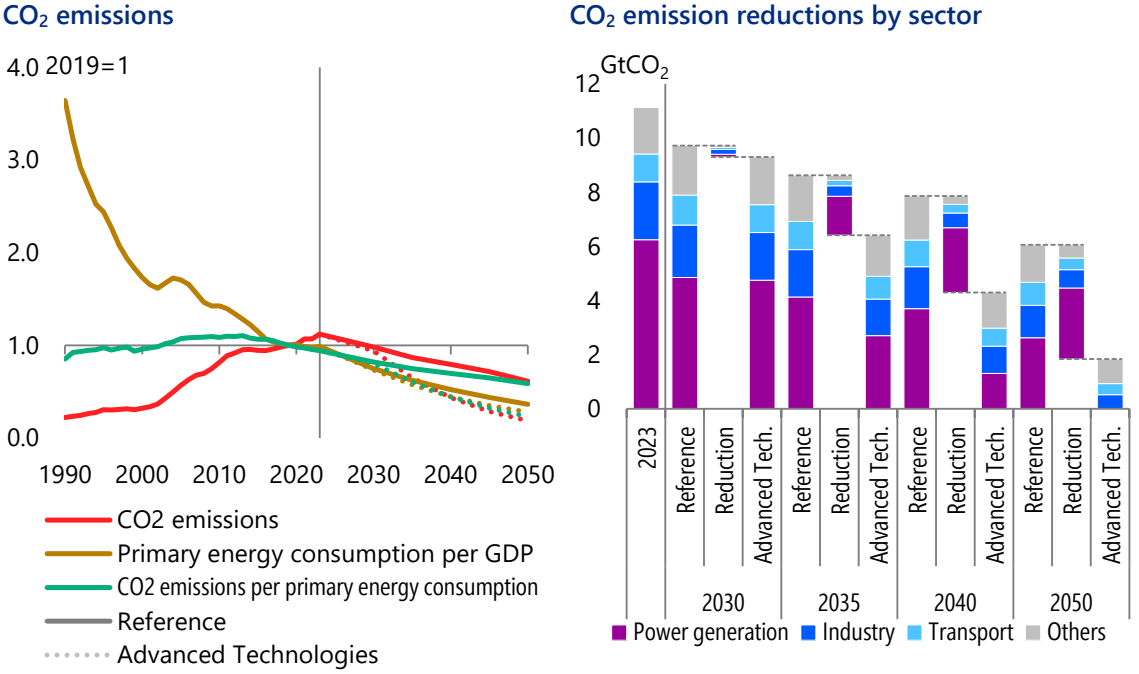
Note: Removals through the direct air capture and storage (DACCS) and bioenergy with carbon capture and storage (BECCS) are excluded from Other and Power Generation, respectively.

In the decomposition of factors affecting CO_2 emissions, two key indicators are considered: the reduction in CO_2 emissions per unit of primary energy consumption (CO_2 emissions/primary energy consumption) and the reduction in primary energy consumption per unit of GDP (primary energy consumption/GDP). Taking these factors into account, China, ASEAN, India, and the United States, where future CO_2 emissions are projected to fluctuate significantly, are analysed. Figure 5-4 to Figure 5-7 show the breakdown of CO_2 emissions, primary energy consumption per unit of GDP, CO_2 emissions per unit of primary energy consumption and CO_2 emission reductions by sector.

China's CO_2 emissions will peak in the mid-2020s in both the Reference Scenario and the Advanced Technologies Scenario, before continuing to decline. CO_2 emissions per unit of primary energy consumption reached their peak in 2013 and have been on a downward trend since then. One of the reasons for this decline was the introduction of renewable energies. As shown in Table A25, as of 2013, renewables accounted for only a small portion of China's power generation mix, with coal-fired power generation accounting for the majority. However, the introduction of renewables continued to expand, increasing their share by 2023.

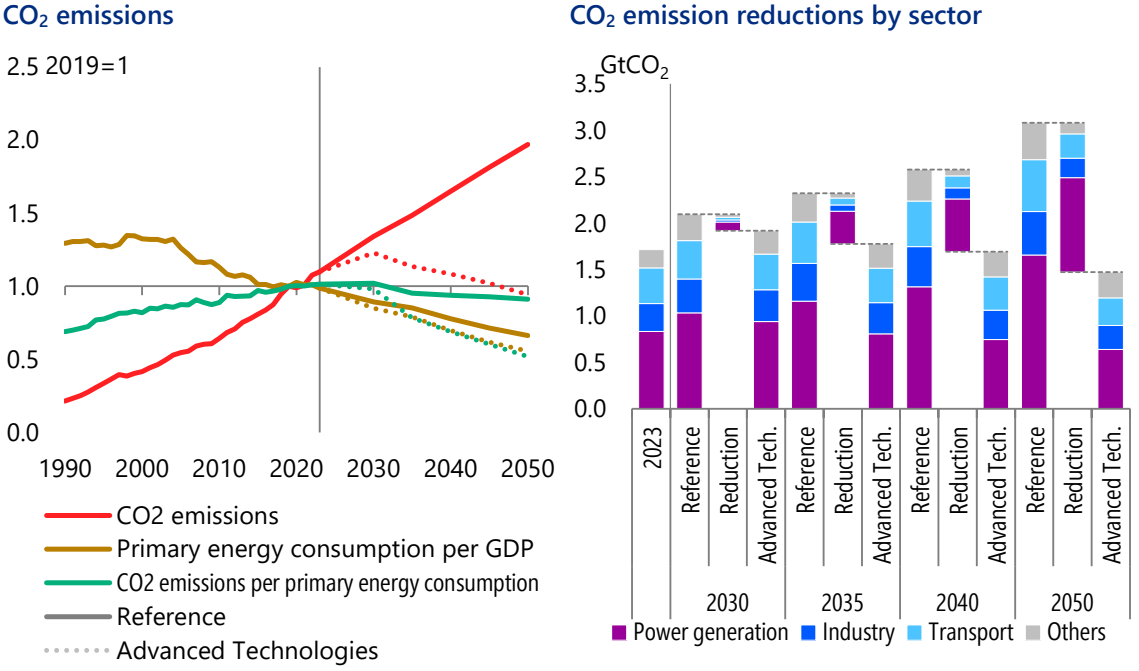
Even after 2023, the introduction of solar photovoltaics and wind continues. In the Advanced Technologies Scenario, in particular, solar photovoltaics and wind will account for approximately 70% of total electricity generated in 2050, a proportion that is extremely high even by international standards. Looking at CO_2 emissions by sector, those from the power generation sector will decrease year-on-year in both the Reference Scenario and the Advanced Technologies Scenario. In addition, primary energy consumption per unit of GDP has been declining every year since 1990, with the exception of certain periods. The downward trend will continue from 2023 onwards, with emissions by 2050 projected to be 64% lower than 2019 levels in the Reference Scenario and 72% lower in the Advanced Technologies Scenario.

Figure 5-4 | Primary energy consumption per GDP and emission reductions in China



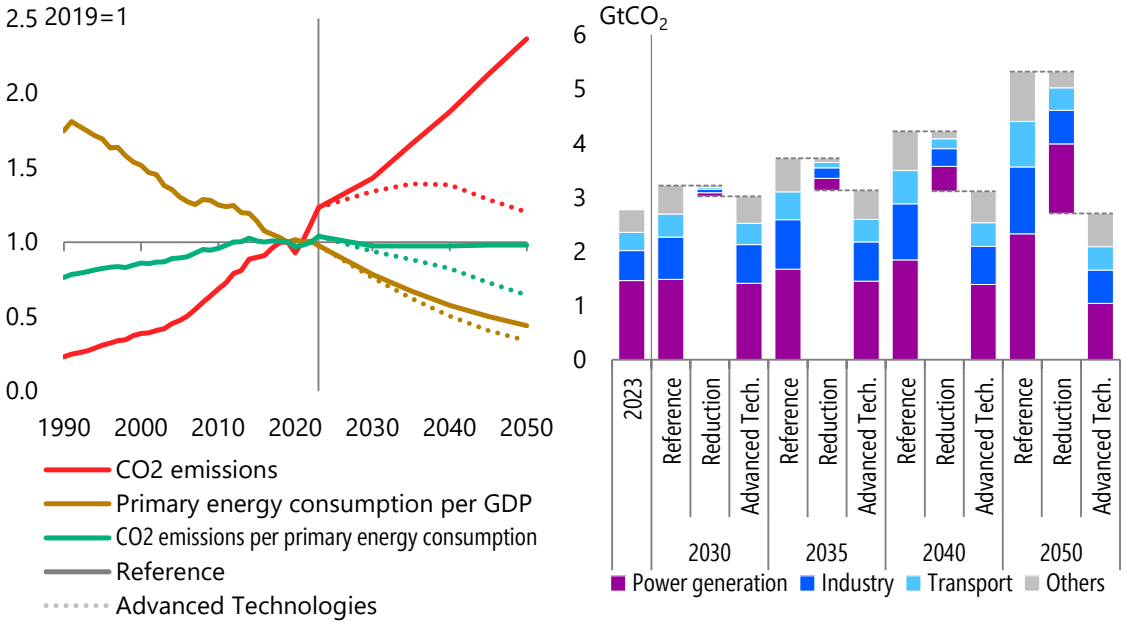
In ASEAN, CO_2 emissions keep increasing along with economic growth and will continue to grow due to strong growth in the future. In the Reference Scenario, CO_2 emissions will increase year by year towards 2050, while in the Advanced Technologies Scenario, they will peak around 2030. During the same period (2030), CO_2 emissions per unit of primary energy consumption will reverse their previous stagnant trend and begin to decline. Furthermore, primary energy consumption per unit of GDP, which was almost stagnant until 2004, began to decline, followed by a year-on-year decrease from 2023 onwards. On the other hand, in terms of CO_2 emissions by sector in 2050, they will double in the power generation sector compared with 2023 levels, increase 1.5 times in the industry sector, and increase approximately 1.5 times in the transport sector. In the Advanced Technologies Scenario, emissions will fall by 20% in the power generation sector, by 14% in the industry sector, and by 20% in the transport sector. Thus, to reduce CO_2 emissions during economic growth, both primary energy consumption per unit of GDP and CO_2 emissions per unit of primary energy consumption must be lowered, presenting significant hurdles on the path towards decarbonisation and carbon neutrality.

Figure 5-5 | Primary energy consumption per GDP and emission reductions in ASEAN



India will follow a path very similar to that of ASEAN, although the scale of its emissions may differ. However, even in the Advanced Technologies Scenario, CO_2 emissions will peak in 2040, and given that CO_2 emissions in 2050 are roughly equivalent to those in 2023, achieving a decarbonised society is becoming increasingly challenging.

Figure 5-6 | Primary energy consumption per GDP and emission reductions in India

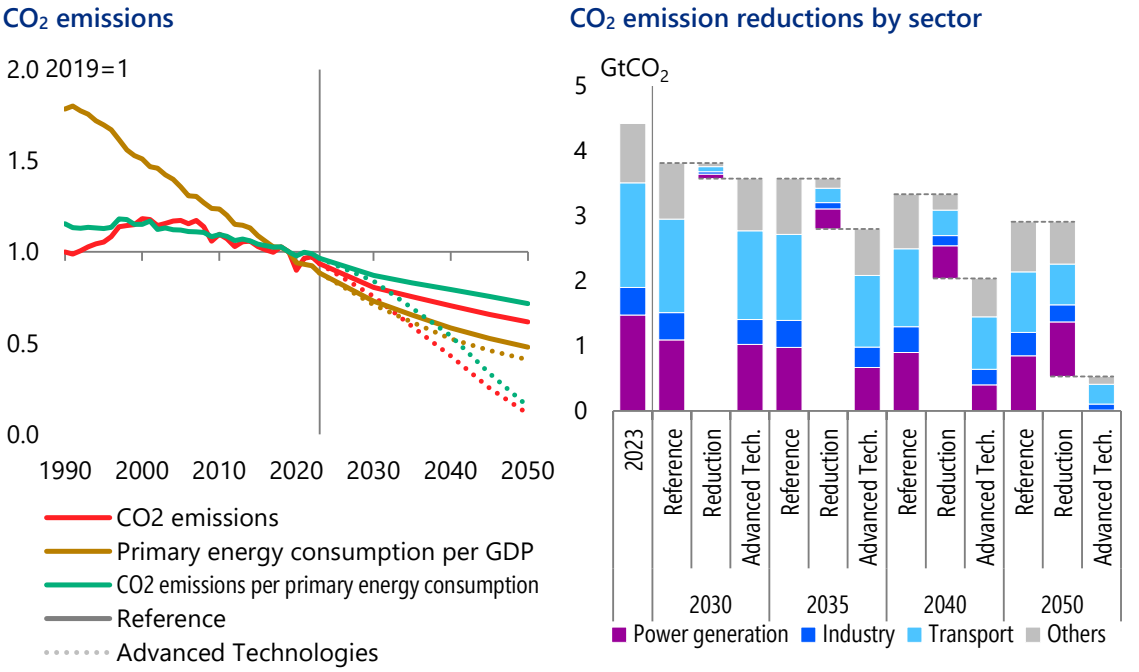


In the United States, CO_2 emissions, which already peaked in the 2000s, will decline in the long term under both the Reference Scenario and the Advanced Technologies Scenario. However, it is necessary to closely monitor the situation as the pace of decline may slow depending on future policy trends. On the other hand, CO_2 emissions per unit of primary energy consumption and primary energy consumption per unit of GDP show a broadly decreasing trend under both scenarios. In 2050, CO_2 emissions from the transport and power generation sectors will decline by 42% compared with 2023 levels in the Reference Scenario, while they will decrease by 81% in the transport sector and by 99% in the power generation sector in the Advanced Technologies Scenario. Unlike China, India and ASEAN, the United States has a large transport sector, which accounts for a substantial share of its CO_2 emissions. However, as mentioned above, in the Advanced Technologies Scenario, significant decarbonisation is also achieved in the transport sector, necessitating technology transfer to other countries.

In the Advanced Technologies Scenario, as stated above, China and the United States will have made significant reductions in emissions from their current levels by 2050, while the reduction rates of ASEAN and India will fall short of those of China and the United States. Comparing these two groups, it is notable that China and the United States will achieve near-zero emissions from the power generation sector. At the same time, CO_2 emissions per unit of primary energy consumption will decline substantially. As shown in Table A25, Table A26, Table A30 and Table A38,

China and the United States will significantly expand the introduction of renewable energies and power sources with carbon capture and storage (CCS) (including bioenergy with CCS [BECCS]). In other words, promoting the transfer of these technologies to developing countries such as ASEAN and India is essential for decarbonising the entire world.

Figure 5-7 | Primary energy consumption per GDP and emission reductions in the United States



6. Energy-related investments

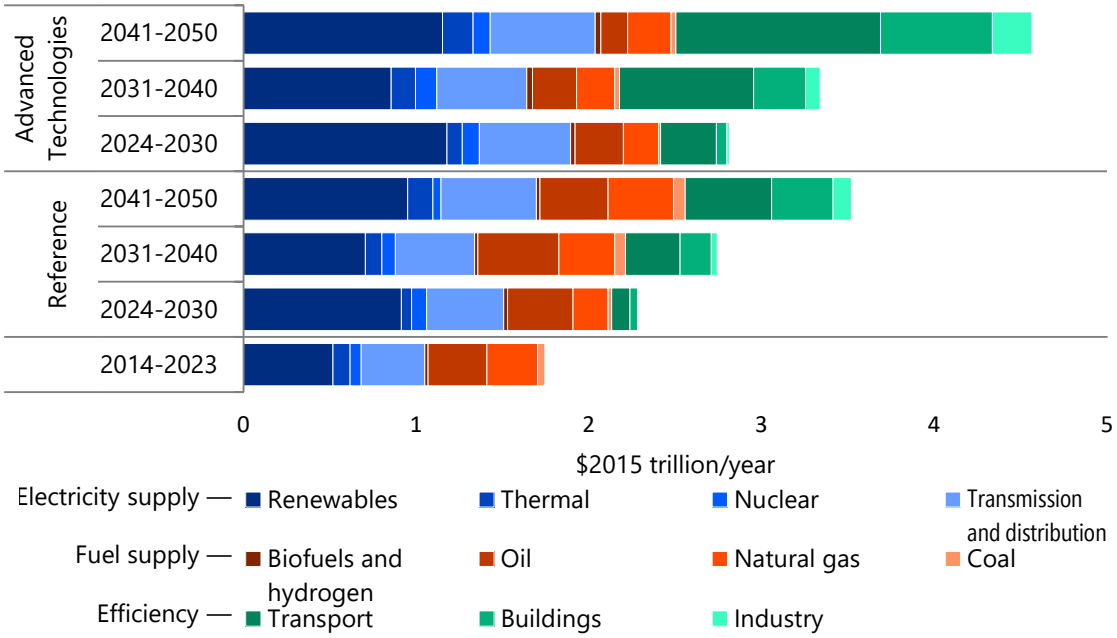
6.1 Recent trends and outlook

Most energy-related investments are made in oil production, natural gas production, and renewables. In the last decade (2014–2023, same hereafter), investments have targeted primarily electricity infrastructure such as renewables and transmission and distribution facilities, followed by facilities related to oil and natural gas production. From the 2020s (2024–2030, same hereafter), accelerated moves towards carbon neutrality will lead to significantly lower capital costs (unit prices) for renewable energy facilities, thus encouraging investments in renewables. In particular, at the 29th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP29), pledges were put forward to expand power grids and energy storage facilities in pursuit of the international goal of tripling global renewable energy capacity by 2030, with over 60 countries endorsing these commitments. Such international agreements are expected to further accelerate the expansion of renewable energy investments. Investments in energy-saving facilities will also increase to break away from dependence on fossil fuels. However, investment in fossil fuels will still need to continue to ensure stable supplies, not only in the Reference Scenario, where demand increases in Emerging and Developing Economies, but also in the Advanced Technologies Scenario.

In the Reference Scenario, energy-related investments[29] will double from an annual average of $1.8 trillion (2015 real prices, same hereafter) in the last 10 years to an annual average of $3.5 trillion in the 2040s (Figure 6-1). 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 average annual investment in the 2040s reaching $4.6 trillion, up $2.8 trillion from the last 10 years. As a result, cumulative global energy investments required by 2050 will reach $98.7 trillion.

[29] 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.

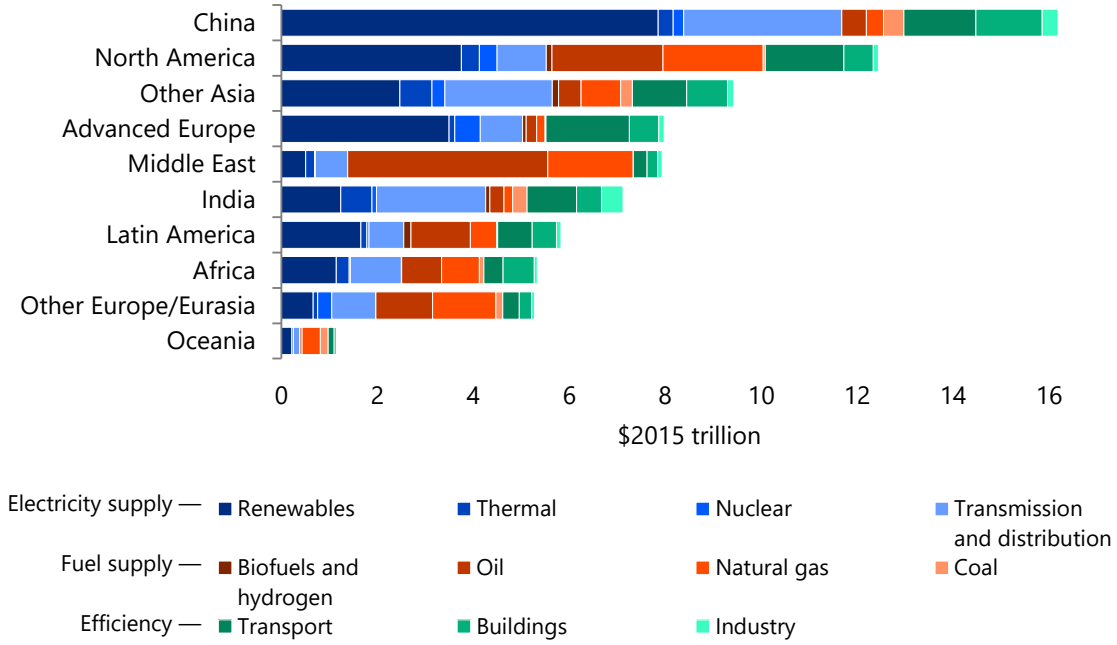
Figure 6-1 | Global energy-related investments



Note: Values of 2014–2023 are estimates.

The amount of energy-related investment varies by region (Figure 6-2).

Figure 6-2 | Energy-related investments [Reference Scenario, cumulative total for 2024–2050]



In Advanced Europe, which is moving away from dependence on fossil fuels, investments in renewables and energy efficiency will account for more than 70% of total investment. On the other

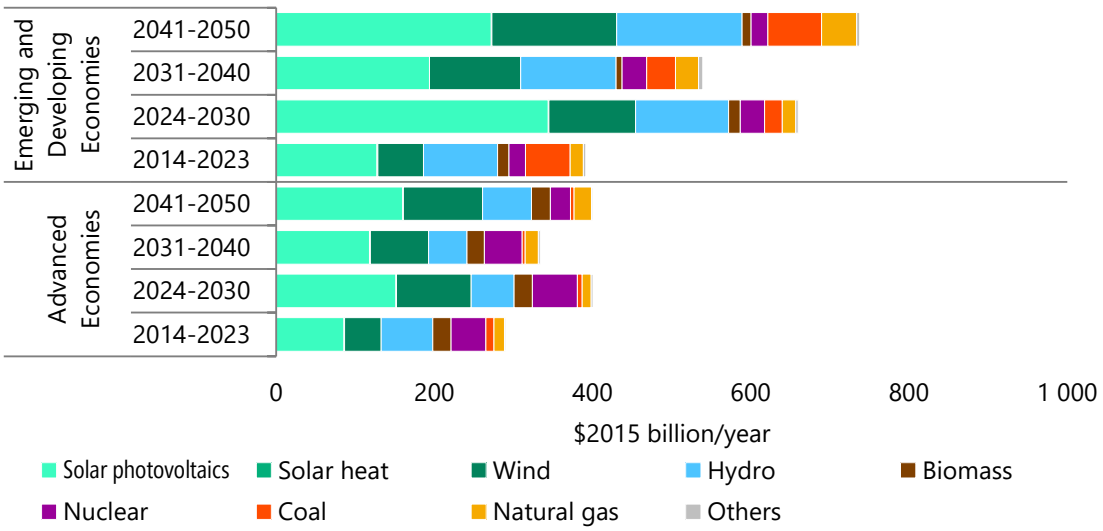
hand, in Oceania, which is also a fossil fuel supply region among other Advanced Economies, investments in oil and natural gas will account for about half of total investment, with renewable energy investments remaining at less than 20%. In the Middle East, another fossil fuel supply region, investments in oil and natural gas production will exceed 70%, while investments in renewables and energy efficiency will account for around 10%. In North America, investments in renewables will account for 30% of total investment, 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, as China aims to achieve the '3060 Target', a national strategy to reach peak carbon dioxide (CO_2) emissions by 2030 and achieve carbon neutrality by 2060. In addition, China is investing heavily in power transmission and distribution, making its cumulative investment the largest of any country or region. India, a fast-growing country, will have the largest share of investment in power transmission and distribution due to the installation of new networks to meet the growing demand for electricity, while investment in energy efficiency will be under 30% and renewables will be under 20%.

6.2 Electricity investments

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

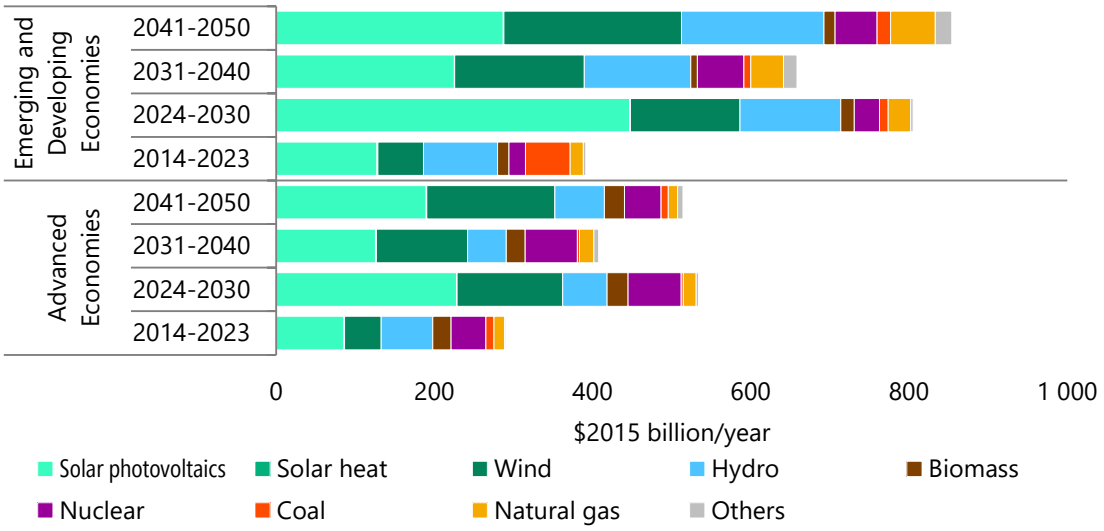
Of the investments in power generation equipment, those in renewable energy facilities account for the largest share (Figure 6-3 and Figure 6-4).

Figure 6-3 | Power generation equipment investment [Reference Scenario]



Note: Values of 2014–2023 are estimates.

Figure 6-4 | Power generation equipment investment [Advanced Technologies Scenario]



Note: Values of 2014–2023 are estimates.

In the last decade, feed-in tariffs and net metering systems contributed to active investments in renewable energy facilities in many regions. From the 2020s onwards, investments in Emerging and Developing Economies will increase significantly in both the Reference and Advanced Technologies Scenarios.

In the Reference Scenario, investments after the 2020s will be higher than in the last 10 years, both in Advanced Economies and Emerging and Developing Economies. In the 2020s, countries will continue to expand investment, particularly in renewables such as solar photovoltaics and wind, to achieve their Nationally Determined Contributions (NDCs). As a result, the average annual investment will increase significantly compared with the last 10 years, approximately 1.4 times in Advanced Economies and 1.7 times in Emerging and Developing Economies. In the 2030s, the average annual investment will decline in both Advanced Economies and Emerging and Developing Economies due to lower capital costs, such as cheaper solar panels and larger wind turbines, but will begin to increase again in the 2040s as more capacity is installed. Advanced Economies will mainly invest in solar photovoltaics, wind, and nuclear. Among fossil fuel power sources, the average annual investment in natural gas-fired power generation will continue to expand through the 2040s. Emerging and Developing Economies will continue to invest in hydro in addition to solar photovoltaics and wind. Among fossil fuel power sources, investment in coal-fired power generation will be notable, exceeding that in natural gas-fired power generation in average annual terms in the 2040s.

In the Advanced Technologies Scenario, solar photovoltaics and wind will be more actively introduced compared with the Reference Scenario. In addition, there will be a marked increase in nuclear in Advanced Economies, while nuclear and natural gas will be actively introduced in Emerging and Developing Economies. Increased investment in these areas will drive the overall increase in average annual investment under the Advanced Technologies Scenario.

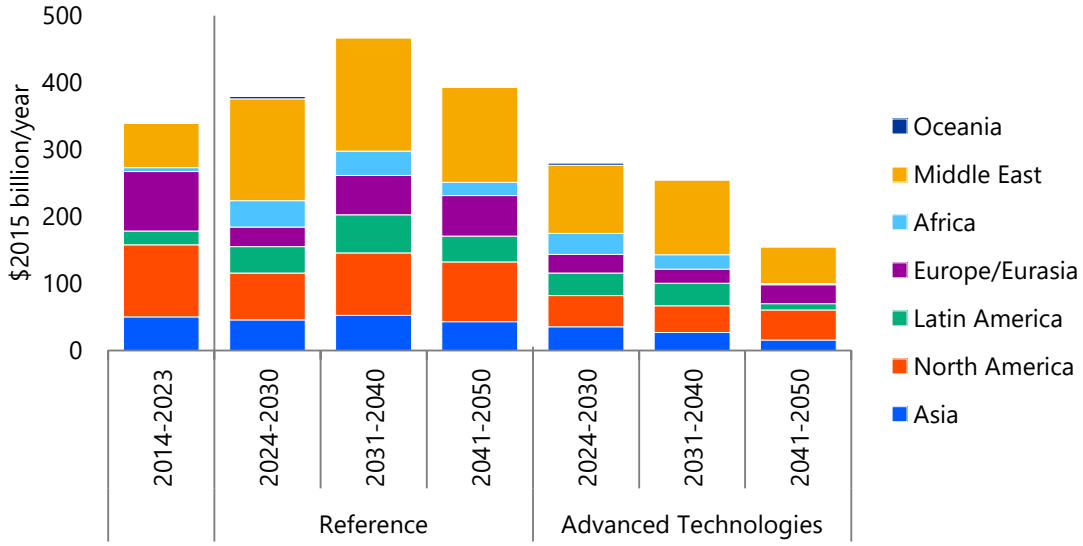
6.3 Investments in oil and natural gas

Although there are moves towards carbon neutrality and a shift from dependence on certain regions (such as Russia for fossil fuel supply), investments in oil and natural gas will not

necessarily decline, particularly as demand continues to increase in Emerging and Developing Economies.

In the Reference Scenario, average annual investment in oil will increase in the Middle East and North America due to expanding demand, reaching about 1.4 times the level of the past 10 years in the 2030s. Although declining in the 2040s, average annual investment will remain higher than in the last decade due to persistent demand, especially from Emerging and Developing Economies (Figure 6-5). In contrast, in the Advanced Technologies Scenario, progress in transportation fuel efficiency and accelerated energy substitution with biofuels and other sources will result in average annual investment from the 2020s falling below the level of the past 10 years and continuing to drop. As a result, investments in the 2040s will be about half of those in the last 10 years.

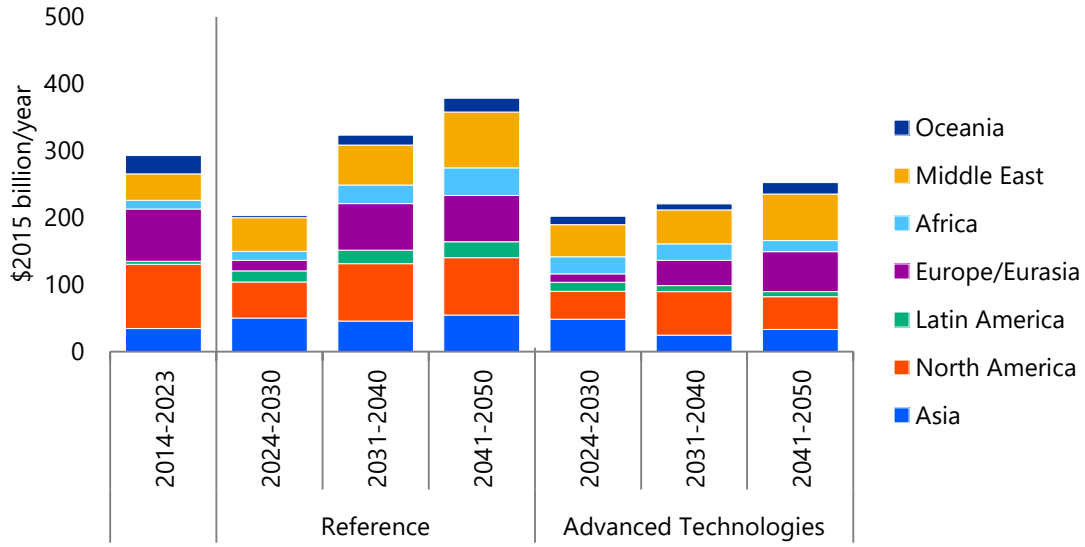
Figure 6-5 | Investment in the oil sector



Note: Values of 2014–2023 are estimates.

In the Reference Scenario, average annual investment in natural gas will continue to expand in light of growing demand, primarily in North America, the Middle East, Russia and Europe/Eurasia, and will increase by approximately 1.3 times in the 2040s compared with the most recent decade (Figure 6-6). However, in the Advanced Technologies Scenario, where renewables and nuclear increase further, from the 2020s, the average annual investment will remain lower than in the most recent decade. Even after this initial decline, a gradual increase will continue until the 2040s due to expanded demand in Emerging and Developing Economies, with investments in North America, the Middle East and Europe/Eurasia driving the increase.

Figure 6-6 | Investment in the natural gas sector

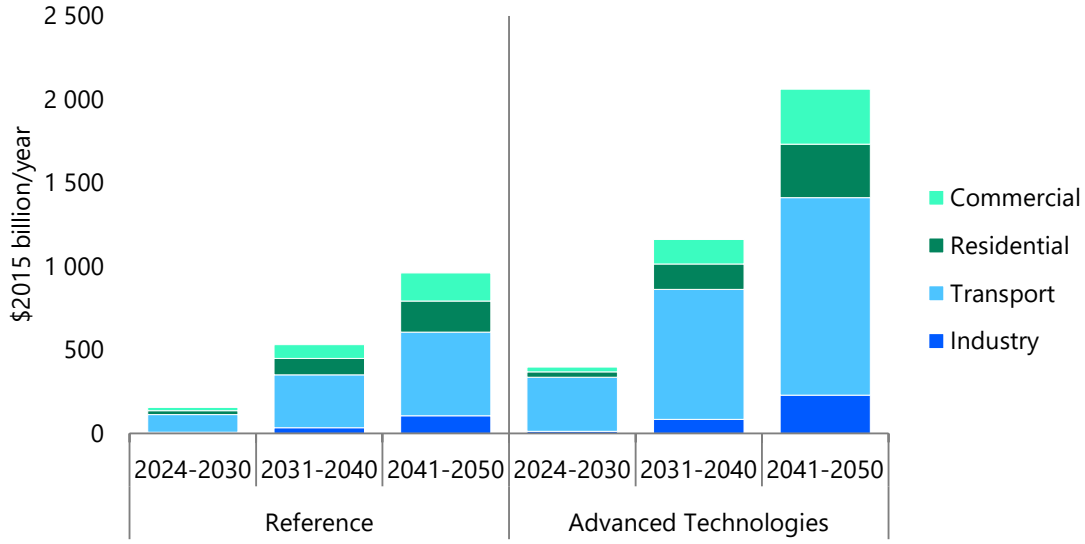


Note: Values of 2014-2023 are estimates.

6.4 Energy efficiency investments

In terms of average annual investment for introducing energy-efficient[30] equipment on the demand side, the transport sector will account for more than half, followed by the buildings sector with about 30% (Figure 6-7).

Figure 6-7 | Global energy efficiency investments



In the Reference Scenario, the transport sector will see increased average annual investment 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

[30] Energy efficiency levels in 2023 are considered as the baseline.

Scenario, average annual investment will increase due to accelerated electrification driven by the expanded use of electric vehicles and the introduction of fuel cell vehicles that use hydrogen.

In the buildings sector, investments in the commercial sector will exceed those in the residential sector. Furthermore, particularly in the Advanced Technologies Scenario, the average annual investment will increase due to accelerating improvements in the efficiency of newly installed home appliances and equipment and their insulation performance, as well as the shift to electrifying space- and water-heating and cooking equipment and clean cooking solutions.

Part II

Deepening uncertainties surrounding the challenges of energy transition: a widening gap between the ideal and the reality

7. Various pathways for decarbonising the road transport sector in the Global South

—Efforts and challenges towards BEV and biofuels deployment—

It is undeniable that the battery electric vehicle (BEV) plays a key role in decarbonising the road transport sector while delivering secondary benefits such as reducing air pollution and oil imports. Many countries and regions are enhancing their BEV production policies to strengthen their industrial competitiveness for the future. However, the decarbonisation pathways of countries and regions vary greatly depending on their individual circumstances, and the road transport sector is no exception. From this perspective, IEEJ Outlook 2025[31] compared various types of vehicles with different powertrains (internal combustion engine vehicles [ICVs], hybrid electric vehicles [HEVs], plug-in hybrid vehicles [PHEVs] and BEVs) in terms of their greenhouse gas (GHG) emissions and total cost of ownership (TCO) using life cycle assessments (LCAs) for different regions (Advanced Europe, Brazil, Association of Southeast Asian Nations [ASEAN] and India), to demonstrate that the optimal powertrain for decarbonisation varies depending on the individual circumstances of countries and regions.

IEEJ Outlook 2026 takes a more comprehensive approach to optimal decarbonisation pathways in the road transport sector by focusing on the diverse pathways taken by key Global South countries, namely Indonesia, Brazil and India. Specifically, the report uses a case study of Indonesia to analyse various social challenges hampering the spread of BEVs, including environmental burdens from the production and use of BEVs, infrastructure upgrades necessary for their wider adoption, and the impact on critical mineral supply and demand. It likewise uses case studies of Brazil and India to evaluate the secondary policy effects, potential and challenges of biofuels as a promising fuel option for decarbonisation.

7.1 Indonesia's initiatives for wider domestic production and use of BEVs

Indonesian government policies

Indonesia is the second-largest car producer in ASEAN (1.197 million in 2024) only after Thailand and has the largest unit sales of new vehicles in ASEAN (866 thousand in 2024)[32]. Indonesia also produces 51% of the global supply of nickel, a mineral essential for BEV batteries (as of 2023) and is striving to become the global hub for BEV production. In 2022, the Indonesian government withdrew its domestic low-emission vehicle production target that had been set in 2020 (BEVs, PHEVs, HEVs and FCEVs) and set a fresh, BEV-only target to produce 1 million domestically in 2035 (Table 7-1).

[31] https://eneken.ieej.or.jp/data/12092.pdf

[32] "Automobile production and sales trends in major countries and regions" by Japan External Trade Organization (2025) https://www.jetro.go.jp/ext_images/_Reports/01/6f831adb699b3451/20250016.pdf

Table 7-1 | Indonesia's domestic BEV production: actuals and targets

(1 000 units)

	2024 actual	2050 target	2030 target	2035 target
BEV production volume	42	400	600	1 000
[Reference] Previous target				
Total domestic production volume	1 197	2 000	3 000	4 000
Of which: LCEVs only	112	400	750	1 200

Note: LCEV stands for low carbon emission vehicle (BEV, PHEV, HEV and FCEV).
Source: The target for BEVs is based on Indonesia's Ministry of Industry Regulation of 2022 and the targets for total production volume and LCEVs are based on that for 2020; the actuals are from the Association of Indonesia Automotive Industries (GAIKINDO).

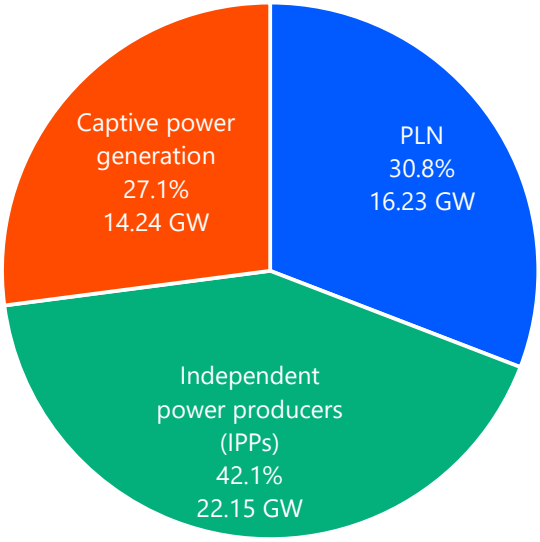
The targets for domestic BEV ownership are 2 million four-wheel vehicles in 2030 (passenger and commercial vehicles, at around 76 thousand as of the end of 2024) and 13 thousand for motorcycles. This can be seen as an ambitious industrial policy that leverages critical mineral reserves as well as the existing domestic industrial infrastructure.

Evaluation of environmental aspects

As described above, Indonesia is working on expanding the domestic production and use of BEVs by leveraging its abundant nickel resources. Meanwhile, the energy used in the nickel refining process comes mostly from coal (as a heat source) and coal-fired captive power generation, which is said to be increasing carbon dioxide (CO_2) emissions. In 2021, the Indonesian government declared that it would halt new coal-fired power plant construction from 2023, but with exceptions that include allowing new coal-fired captive power plant construction for nickel refiners and industrial complexes. Coal-fired captive power generation is also exempt from the early retirement support project for coal-fired power plants led by the Just Energy Transition Partnership (JETP), of which Japan is a member. In fact, coal-fired captive power plants account for 30% of Indonesia's coal-fired power plant capacity in operation but two-thirds of the coal-fired power capacity in the construction and planning stages (Figure 7-1 and Table 7-2).

Furthermore, in Indonesia's nickel refining sector, alongside deforestation associated with mining and ongoing impacts on marine ecosystems, there is a risk of local air pollution unless appropriate emission regulations are introduced to control the sulphur dioxide (SO_2) emissions from processing nickel sulphide ores into nickel sulphate.

Figure 7-1 | Composition of Indonesia's operating coal-fired power plants by supplier [July 2025]



Note: The figures for PLN include power plants wholly owned by PLN as subsidiaries.
Source: Created based on the Global Coal Plant Tracker and the RUPTL electricity supply business plan (2025–2034).

Table 7-2 | Characteristics of Indonesia's coal-fired power plants by suppliers

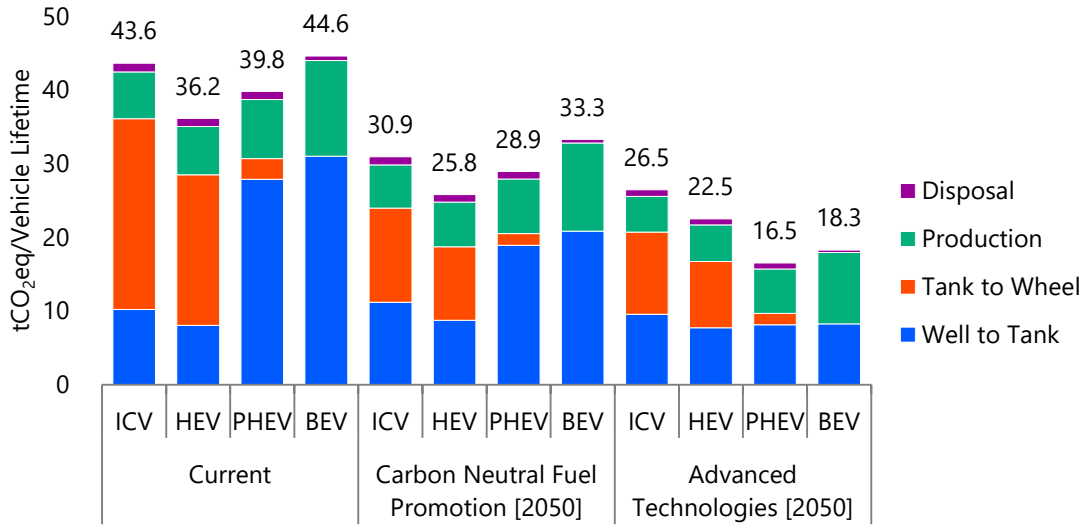
	PLN	Independent power producers (IPPs)	Captive power generation
In operation (GW)	16.2	22.1	14.2
In construction/ planning (GW)	1.7	4.2	11.7
Suspended (since 2021 or later) (GW)	7.0	12.0	4.1
Purpose	Supply to consumers	Sell to PLN	Power supply for the industry
Ownership/ management	State-owned	Domestic companies,	Local smelters, Chinese companies, etc.
Applicability of policy/ regulation	Early retirement and freeze on new builds by JETP apply	Early retirement and freeze on new builds by JETP apply	JETP does not apply

The current situation is thought to be due mostly to the influence of Chinese companies. The Indonesian government has been driving a policy to limit nickel ore exports and promote refining in the country. As a result, Chinese and other companies have begun planning and operating numerous refineries domestically, and approximately three-fourths of Indonesia's nickel refining capacity is said to belong to Chinese companies. These refineries are built on remote islands in conjunction with small, low-efficiency coal-fired power plants. The Chinese government announced that it would end support for new coal-fired power plant construction outside China

in 2021, but this does not apply to captive power plants of industrial complexes related to the Belt and Road Initiative. BEVs, by nature, are a countermeasure against climate change and air pollution, but there will be little point if CO_2 emissions from producing BEVs increase and generate other environmental burdens, particularly for the benefit of Chinese companies. The environmental burden should be considered on a comprehensive basis that includes entire supply chains.

Are BEVs' GHG emissions smaller than the emissions of other powertrains on an LCA basis in Indonesia? As of 2023, coal-fired power generation accounts for two-thirds of Indonesia's power supply, driving up the country's carbon emission factor for electricity to 829 gCO_2/kWh, 1.4 times as large as the global average of 575 gCO_2/kWh. As such, a BEV has higher emissions than an ICV on an LCA basis, and this trend will not change in the future (2050) unless electricity is decarbonised as seen in the Advanced Technologies Scenario (Figure 7-2).

Figure 7-2 | GHG emissions from vehicles in Indonesia on an LCA basis



Note: The Carbon Neutral Fuel Promotion Case is a combination of the Reference Scenario and the carbon neutral fuel ratio of the Advanced Technologies Scenario.

The former Joko Widodo administration greatly expanded the country's power generation capacity, mainly using coal-fired power generation, in its first term through a capacity expansion project called the 35-Gigawatt Power Plant Project. As electricity demand did not grow as many as expected, Indonesia's coal-fired power generation capacity is currently said to be in overcapacity[33]. Indonesia's carbon emission factor for electricity, described earlier, is an all-day average of all power sources, and CO_2 emissions could rise further if BEVs spread and drive up the operation of coal-fired power capacity currently in excess.

The impact of the increase in BEVs greatly depends on the regional power generation mix and charging behaviour (Table 7-3).

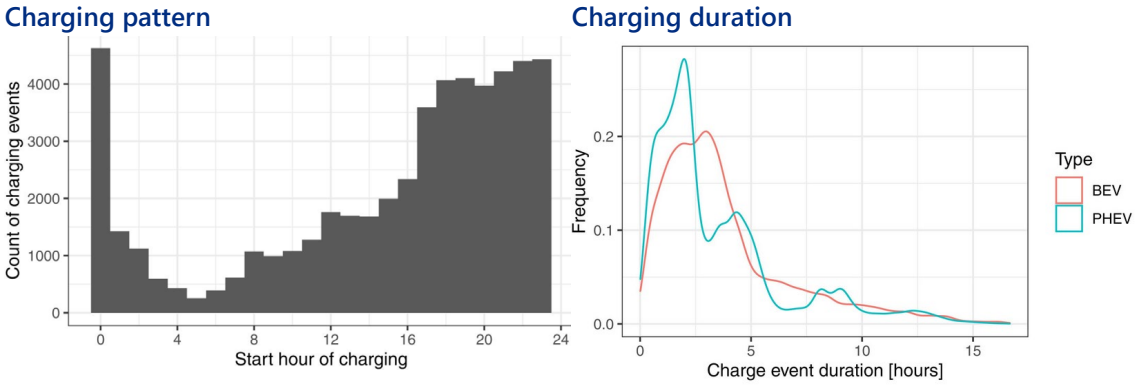
[33] https://www.transitionzero.org/insights/indonesia-net-zero-curve

Table 7-3 | BEV charging hour patterns and impact on the annual demand curve

BEV charging hour pattern	Impact (annual demand curve)	Implications on the grid and power sources
Charging at night-time after 10 p.m. is the most common	The valleys in night-time demand in winter and summer will rise	The utilisation of wind and baseload power source will improve. Additional power by thermal power generation will be needed during shortages
Charging soars from around 5 p.m. when people come home	Summer and winter evening peaks will rise further	Grid burden will increase as excess thermal power plants go into operation
Daytime charging	Day-time demand will rise from spring through autumn	Beneficial for absorbing solar photovoltaics

For example, in Norway, where BEVs are the most widespread in the world, electricity demand did increase due to BEVs, but this has led to effective use of baseload power sources, as more than 90% of Norway's power generation mix consists of hydro. Meanwhile, in California, the United States, where BEVs are spreading rapidly, charging mostly starts around 5 p.m., when people come home, usually takes two to three hours and thus tends to overlap with the evening peak demand hours (Figure 7-3). The state's solar photovoltaic-dependent power generation mix carries a risk of increased CO_2 emissions due to BEVs because while solar photovoltaics often produce excess electricity in the daytime, additional demand arising during night-time is supplied using thermal power generation.

Figure 7-3 | California, the United States: charging pattern and duration



Source: Alan J., Jake H., (2022) Distribution grid impacts of electric vehicles: A California case study, iScience 25 1-16.

Solar photovoltaics may become a key power source in Indonesia in the future as well, if the decarbonisation of electricity is pursued. However, even if the all-day average carbon emission factor for all power sources decreases, cheap coal-fired power plants may continue to operate as a marginal power source, limiting the emissions reduction effect. As a result, the BEV's well-to-tank emissions shown in Figure 7-2 may increase by 1.3 times currently and by 1.8 to 3.6 times by 2050. As such, it is essential to urgently decarbonise coal-fired power generation and introduce renewable energy. Moreover, considering the characteristics of renewables and consistency with

BEV charging times, BEV owners should be encouraged to charge their cars during the daytime when electricity generated by solar photovoltaics is available, or during off-peak hours. Specifically, appropriate policy design—such as shifting charging hours through time-based tariffs and promoting smart charging technologies, is essential. If this is achieved, BEVs may become flexible grid-balancing resources rather than a source of increased CO_2 emissions.

Estimation of infrastructure costs

To put more BEVs on the road, it is essential to meet the resulting increase in electricity demand by securing power sources and reinforcing transmission networks. In particular, the spread of rapid chargers, while improving user convenience, is expected to raise peak demand and increase transmission network loads in cities where demand is concentrated. If BEVs increase to meet the Indonesian government's 2030 BEV target (2 million four-wheel vehicles) and adoption accelerates thereafter to reach 10 million in 2040, and half of these BEVs are charged between 4 p.m. and 10 p.m., this can generate at least 15 GW of additional electricity demand. The Indonesian government is planning to increase installed power generation capacity from 106 GW in 2025 to around 242 GW in 2040; however, an additional demand of 15 GW is by no means negligible. Furthermore, reinforcement of battery storage, power generation facilities and transmission infrastructure will likely be necessary to address regions and seasons with tight electricity supply. Unless smart charging is widely adopted, substantial additional infrastructure investment will be required.

Development of charger infrastructure calls for national budget allocation. Indonesia plans to install one charger for every 15 BEVs by 2030 and sets a goal to boost the number of chargers from the current 3 202 medium-speed chargers to 62 918 chargers by 2030 (30 796 medium-speed, 19 538 high-speed and 12 584 ultra-high-speed). This is estimated to cost 23 trillion rupiah (approx. 200 billion yen) in total over the next six years, which, at a 50% government subsidy rate, would equal 0.05% of Indonesia's national budget. Japan has a similar plan to install 300 000 chargers by 2030, which is estimated to cost 0.03% of the national budget under comparable assumptions, and given that the cost of BEV chargers is broadly similar worldwide, the costs represent a relatively larger burden for developing economies.

Needless to say, introducing BEVs requires certain policy costs alongside infrastructure costs. These policy costs include:

1. Incentives for BEV buyers (in Indonesia, value-added tax reduction (from 11% to 1%, applicable to models with a domestic production rate of 40% or higher), exemption from luxury goods sales tax (around 15%)),
2. Reduction of running costs for BEV owners (in Indonesia, 30% discount on electricity tariffs for BEV owners from 10 p.m. to 5 a.m.), and
3. Incentives for BEV producers (in Indonesia, corporate tax reduction for BEV, BEV battery and motor producers, etc.).

While it is difficult to accurately estimate total fiscal costs, measures 1 and 2 above are estimated to require a national budget allocation of Rp5 trillion–Rp6 trillion (¥43 billion–¥52 billion) annually.

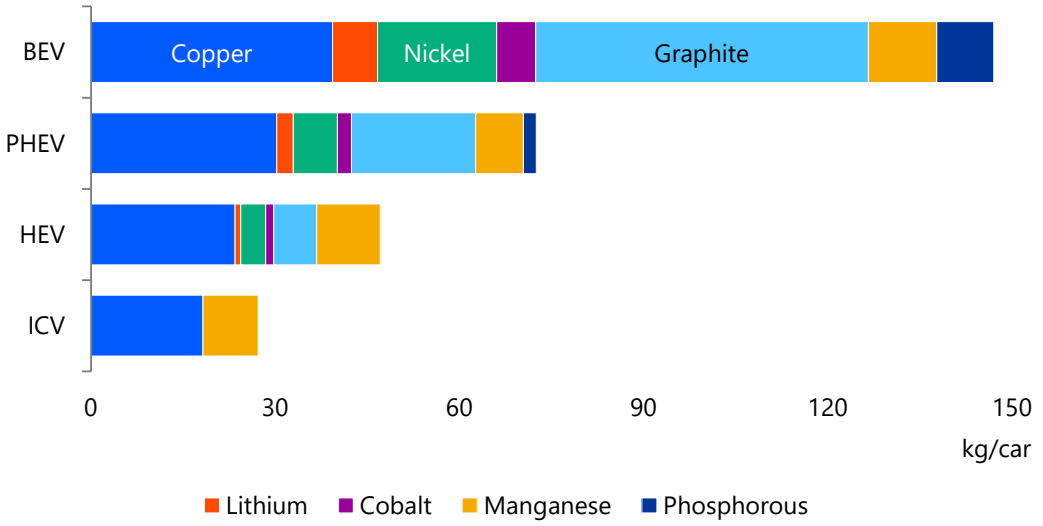
Other

It is also important to note the temperature-related deterioration of battery performance in tropical countries. A survey that collected data from 30 000 BEVs shows a 17%–18% drop in a

BEV's driving range at a temperature of 100°F (37.8°C) relative to ideal conditions[34], and a difference of 5%–6% in remaining battery capacity was observed after four-year use between moderate- and high-temperature regions[35]. Many original equipment manufacturers (OEMs) also advise users to avoid parking their BEVs at high temperatures with a full battery or charging at high or low temperatures.

Another issue for BEVs is their extensive use of critical minerals, which may affect the supply-demand balance of those minerals as BEV adoption increases, pushing up BEV prices. Also, the supply of critical mineral products depends heavily on China and is subject to the risk of supply disruptions triggered by export controls. BEVs are estimated to consume five times more critical minerals than ICVs, three times more than HEVs, and twice as much as PHEVs (Figure 7-4). Compared with the analysis in IEEJ Outlook 2024[36], the gap between BEVs and other powertrains has narrowed thanks to the wider adoption of lithium iron phosphate (LFP) batteries; nevertheless, the impact of the spread of BEVs must continue to be monitored.

Figure 7-4 | Critical mineral usage per passenger car



With the spread of BEVs, decreasing gasoline tax revenues are becoming an issue in various countries. In the United States, for example, a draft of the One Big Beautiful Bill Act (OBBBA) that passed the House of Representatives proposed imposing a surcharge of $250 per year on BEV owners. The proposal was ultimately removed from the final OBBBA, but many states do impose an annual surcharge of around $100–$200 on BEV owners. This issue is expected to be discussed in many countries, including Japan, going forward.

7.2 Use of bioethanol in Brazil

Brazil is the world leader in blending bioethanol into gasoline. The blending ratio, which had already been high at 27%, was raised to 30% in August 2025. This blending ratio in gasoline is a

[34] Blake Hough and Liz Najman, How Hot Summer Weather Affects EV Range, Recurrent, June 2025. https://www.recurrentauto.com/research/what-a-c-does-to-your-range

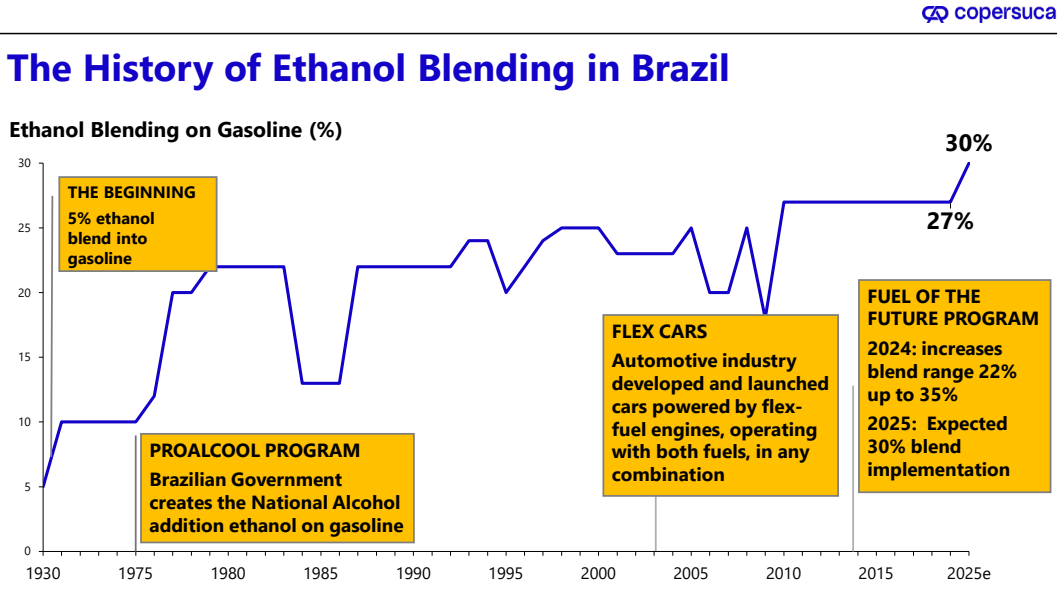
[35] Charlotte Argue, How long do electric car batteries last? What analysing 10,000 EVs tells us..., GEOTAB, July 2025. https://www.geotab.com/blog/ev-battery-health/

[36] https://eneken.ieej.or.jp/data/11380.pdf

regulatory threshold, and in fact, a ratio as high as 45% has been achieved. This has been made possible by the following historical background, in addition to the spread of flex-fuel cars, which can run on gasoline with any bioethanol blend from 0% to 100% (they accounted for 78.4% of new cars sold in Brazil in 2023) and government subsidies for bioethanol fuels.

Blending bioethanol into gasoline has a long history in Brazil and goes back about 100 years to 1931, when a 5% blend was introduced. Before climate change became a major policy issue, bioethanol was initially used in the transport sector as a means to support the sugarcane industry. Full-fledged production of bioethanol eventually began during World War II to conserve crude oil, and the blending ratio was raised to 10%. The blending ratio was raised further to 20% during the oil crises in the 1970s, and from the 2000s onwards, progress was made in the development and introduction of flex-fuel cars, leading to the present situation (Figure 7-5).

Figure 7-5 | History of bioethanol blending in Brazil



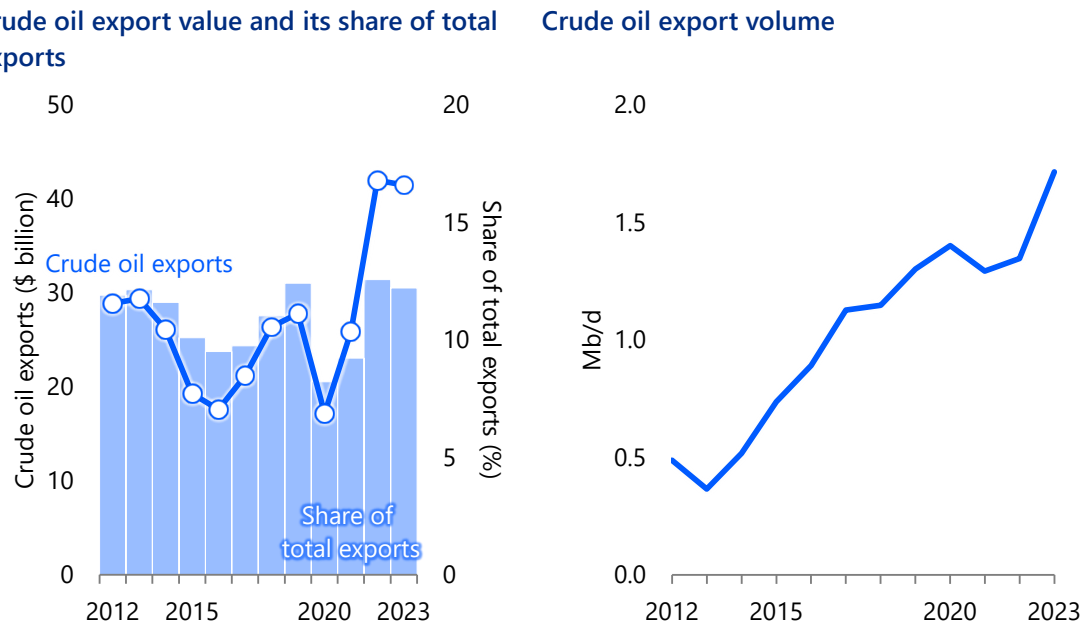
Source: Copersucar

Bioethanol production has made a major contribution to the country's energy security to date. Brazil's energy self-sufficiency rate reached 116% in 2023, and biofuels, including ethanol, account for 33% of the country's primary energy supply. Brazil is an oil producer, but it is reducing domestic gasoline consumption through bioethanol blending to help increase oil exports. Specifically, Brazil's oil exports have grown fourfold in the last 10 years and now account for 12%–13% of total exports, contributing to the country's foreign currency earnings (Figure 7-6). Domestic energy consumption grew by 470 PJ in 2023, of which crude oil accounted for 110 PJ and biofuels 320 PJ. The growth in Brazil's oil exports of 550 PJ (250 kb/d) that year would not have been possible without an increase in biofuel production.

Brazil's bioethanol policy is also helping to make its automobile industry competitive. As mentioned earlier, around 80% of the 2.5 million new cars sold each year in Brazil are flex-fuel cars, and the share of domestically produced vehicles in total new-car sales remains at 80%–90%, suggesting that the widespread use of flex-fuel cars, which are unique to the Brazilian market, is helping to maintain this high domestic share. The share of workers on sugarcane farms in

agriculture has also increased from 4% to 8% in the 2000s, indicating that bioethanol is playing a role in agricultural development and job creation in the region.

Figure 7-6 | Brazil's crude oil exports



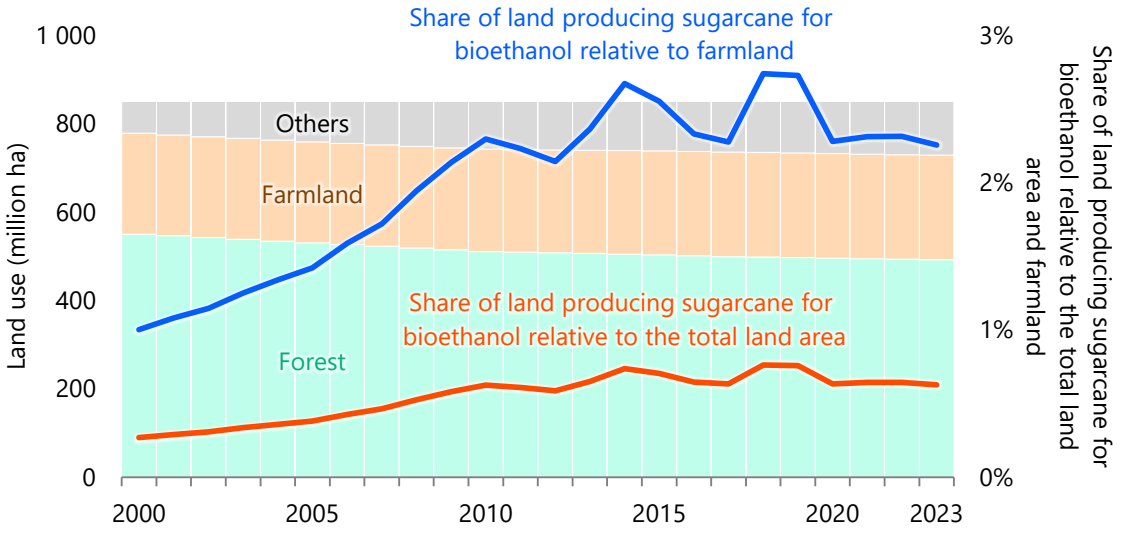
Source: Created based on data from Trendeconomy, the Organisation for Economic Co-operation and Development (OECD) and Federal Reserve Economic Data.

On the other hand, issues have been noted with utilising bioethanol, not only in Brazil, but also in any country. One of the persistent concerns about the expanded use of biofuels is land-use change, which may lead to deforestation through the expansion of arable land. However, as far as Brazil is concerned, the percentage of land producing sugarcane for bioethanol has remained stable relative to the total land area and farmland, and the impact of land-use change appears limited, at least for the time being (Figure 7-7).

Brazil's sugarcane industry is also working to reduce the carbon footprint (CFP) associated with bioethanol production. IEEJ's field study in 2024 also noted innovative efforts such as the production of biogas from bioethanol by-products for transport trucks, use as fertilisers, double-cropping sugarcane with maize, use of sugarcane residue (bagasse) for second-generation bioethanol production and power generation, and even consideration of introducing BECCS[37]. While working to expand bioethanol exports, Brazil is aware that reducing the CFP is essential for competitiveness in international markets. Brazil's challenges going forward include improving the transparency and credibility of CFP calculation and advancing related technologies.

[37] Bioenergy with carbon capture and storage. This is the capture and storage of CO_2 from biomass power generation and is one of the negative emission technologies.

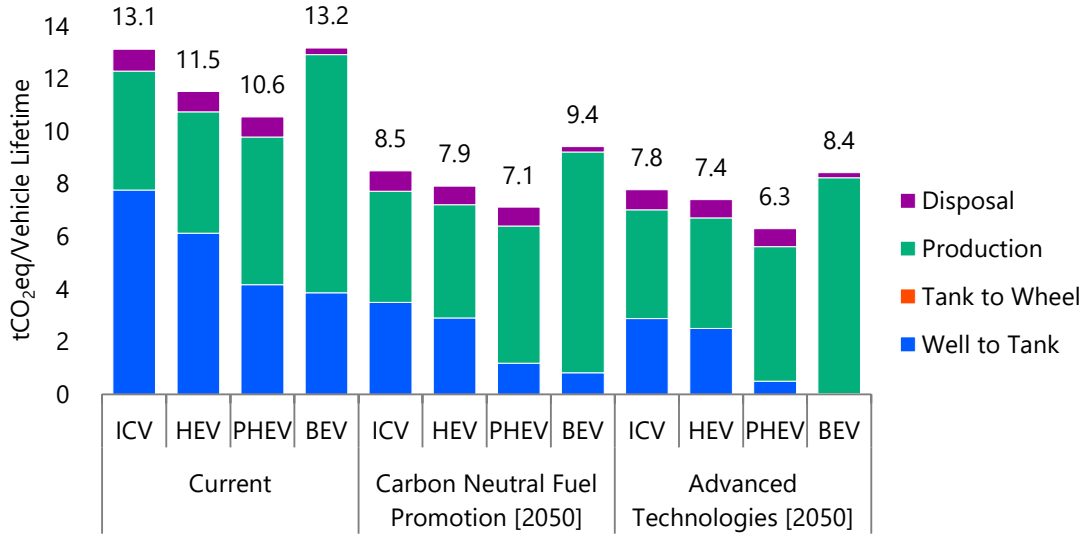
Figure 7-7 | Use of land in Brazil and share of sugarcane farmland for bioethanol



Source: Created based on the World Bank database.

An cycle assessment (LCA) of greenhouse gas (GHG) emissions in Brazil showed that compared with battery electric vehicles (BEVs), which generate high carbon dioxide (CO_2) emissions in the battery production phase, the CFP of internal combustion engine vehicles (ICVs), hybrid electric vehicles (HEVs) and plug-in hybrid vehicles (PHEVs) that run on 100% bioethanol fuel is lower than that of BEVs, and this ranking is not expected to change in the future (Figure 7-8). Brazil's carbon emission factor for electricity is extremely low at 79 gCO_2/kWh relative to the global average of 576 gCO_2/kWh, as its power generation mix consists mainly of hydro, which gives the country a significant advantage for BEVs; but even then, bioethanol was shown to be lower in carbon than BEVs on an LCA basis.

Figure 7-8 | Automobile GHG emissions on an LCA basis in Brazil



Note: The Carbon Neutral Fuel Promotion Case is a combination of the Reference Scenario and the carbon neutral fuel ratio of the Advanced Technologies Scenario.

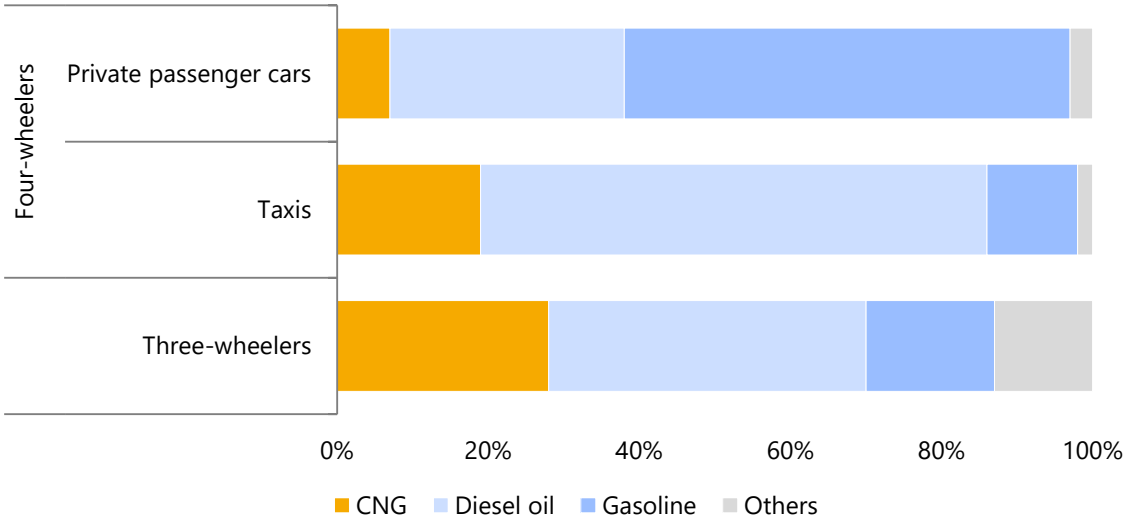
As described above, the expanded use of bioethanol in Brazil is being pursued from a wide range of perspectives including climate change, energy and economic security policies, as well as industrial policies such as automotive and agricultural policies, all while leveraging the country's abundant bioresources. Bioethanol is considered to have higher environmental performance than BEVs when combined with HEVs and PHEVs and can be seen as an excellent example of diverse decarbonisation pathways for the road transport sector.

In April 2024, the leaders of Japan and Brazil launched the Initiative for Sustainable Fuel and Mobility or ISFM, which combines sustainable fuels such as biofuels with high-performance mobility equipment such as HEVs, and in September 2025, the two countries co-hosted the first Ministerial Meeting on Sustainable Fuels in the Kansai region of Japan. There are high expectations for expanding bilateral cooperation into multilateral international cooperation.

7.3 Utilisation of biogas in India

India is also actively promoting the use of bioethanol, raising its ethanol blending ratio over the past decade from just 1.5% in 2014 to the current 20%. Meanwhile, what is even more noteworthy is that, to the extent identified in our study, it is the only country with a mandated blending ratio of biogas in compressed natural gas (CNG). In India, the use of CNG vehicles is widespread to address air pollution and because of low fuel costs, and CNG vehicles have an extremely high share of 28%, 19% and 7%, respectively, for three-wheelers, taxis and private passenger cars, respectively (Figure 7-9).

Figure 7-9 | Composition of registered vehicles in India by fuel type



Source: Created based on data from the Energy and Resource Institute (TERI).

In India, biogas policies have been reinforced to utilise abundant domestic bioresources such as agricultural residues, livestock manure and other wastes, as well as to draw on the vehicle composition described above, aiming to promote the agricultural and livestock industries, reduce liquefied natural gas (LNG) imports, save foreign currencies and contribute to a circular economy. Specifically, the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative was launched in 2018, introducing voluntary biogas blending targets that would be made mandatory and gradually raised from 2025 (Table 7-4). This initiative is also part of the measures to promote agriculture.

Table 7-4 | Biofuel blending ratio targets in India

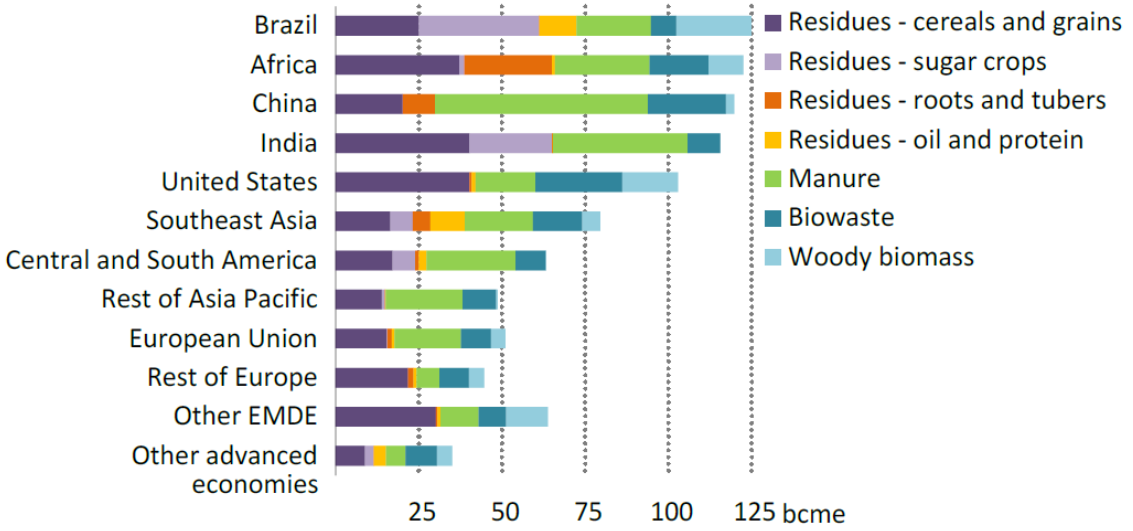
	Target year	Blending ratio
Bioethanol	2025	20%
Biodiesel	2030	5%
SAF	2028	2%

	Target year	Blending ratio
Biogas	Through 2024	Not specified
	From 2025	1%
	From 2026	3%
	From 2027	4%
	From 2028	5%

Source: Ministry of Petroleum and Natural Gas

According to the International Energy Agency (IEA), biogas production in India is built on its agricultural sector, which accounts for 18% of its gross domestic product (GDP) and 45% of employment and has a history of more than 100 years. India's biogas potential is among the world's largest, alongside Brazil and China (Figure 7-10), and its biogas policy, underpinned by this long history and abundant domestic resources, has no equivalent in any other country. It is also interesting that the title of the initiative stresses affordability as well as sustainability.

Figure 7-10 | Biogas potential of major countries and regions

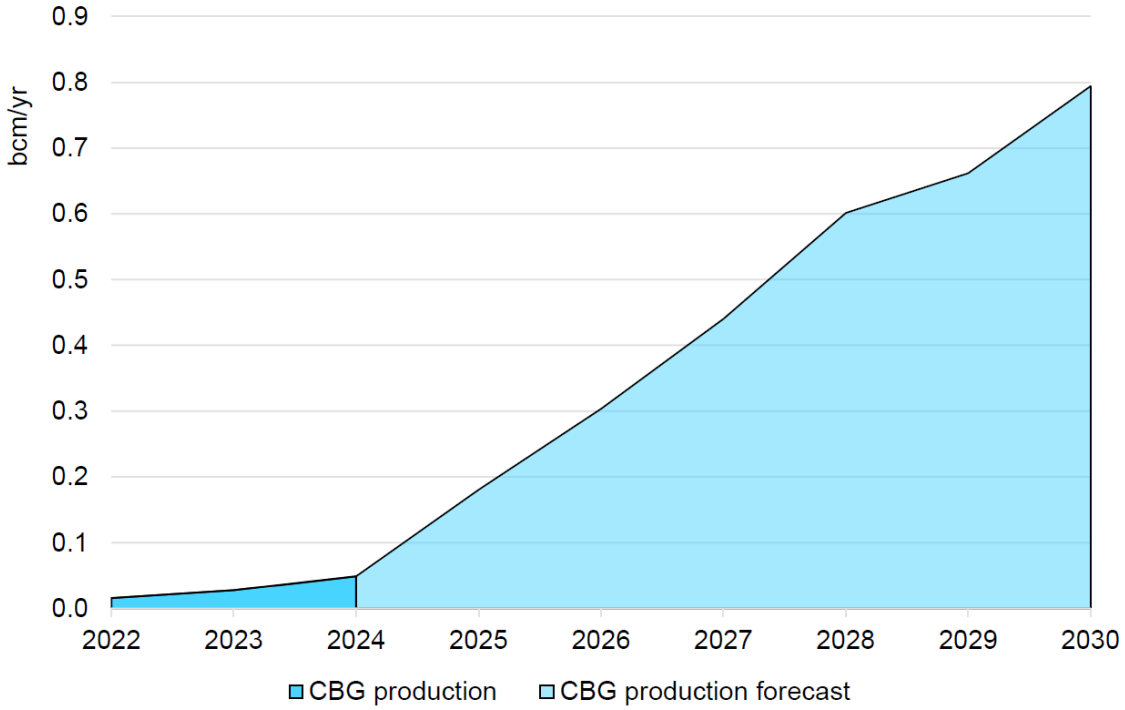


Source: IEA "Outlook for Biogas and Biomethane"

According to the IEA, India is still utilising only 5% of its vast biogas potential and a major production expansion (16 times the level by 2030) is expected (Figure 7-11).

Expanding the use of biogas in India has its challenges, as with the rollout of BEVs in Indonesia and bioethanol in Brazil. First is procuring biofeedstock, including managing seasonal fluctuations such as the concentration of agricultural residue generation immediately after harvesting, and the underdeveloped logistics infrastructure for feedstock collection in rural and other areas. Difficulty in investment decisions and financing due to non-transparent pricing and insufficient development of human resources and certification systems is also a challenge. Due partly to these challenges, according to the IEA, there are only 90 biogas production plants as of September 2024, compared with the SATAT target of 5 000 by 2024.

Figure 7-11 | Outlook for compressed biogas production volume towards 2030 in India



Source: IEA "India Gas Market Report Outlook to 2030"

As with Brazil's bioethanol, India's biogas utilisation has benefits such as reducing dependence on imported LNG and promoting agriculture, as well as contributing to carbon neutrality, and can be seen as one of the diverse decarbonisation pathways for the road transport sector that vary depending on the circumstances in each country. Suzuki Motor Corporation, a Japanese automaker, is also working with local dairy farmers to establish five biogas production plants in the state of Gujarat starting in 2025. However, we cannot say that India's biogas utilisation is supported by sufficient private-sector business incentives, unlike Indonesia's nickel refining and Brazil's bioethanol production. It is necessary to offer more carrots (support measures) alongside the stick (blending ratio regulations). While intergovernmental cooperation on climate change tends to lack variety and to focus on expanding renewable power sources and the early retirement of coal-fired power plants, going forward, it will be important to provide international assistance for more grass-rooted initiatives of this kind. With respect to Japan, utilising the bilateral Joint Crediting Mechanism (JCM) might be an option.

7.4 Conclusion

Key Global South countries such as Indonesia, Brazil and India are engaged in decarbonising the road transport sector by drawing on their regional resources and industrial strengths, from a broad perspective that transcends climate change and encompasses industrial policy and energy security. While all three countries are pursuing electrification and the broad adoption of biofuels, there are major differences in their priorities. There are a few insights we can draw from the above case analyses. First, the decarbonisation of power sources is a prerequisite for countries pursuing electrification of their road transport sector and battery electric vehicle (BEV) production. Reducing the environmental burden of production and other processes, shifting peak power demand and developing social infrastructure should follow. Biofuels provide an alternative

decarbonisation pathway alongside electrification and also contribute to agricultural development. Furthermore, blending biofuels into conventional fuels may reduce the costs of developing new infrastructure. In summary, the cases of the three Global South countries clearly show that not only electrification but also diverse pathways must be examined from a comprehensive perspective when decarbonising the road transport sector.

8. Variable renewable electricity: challenges and integration costs

Decarbonisation requires adding vast amounts of non-carbon emitting power sources. In particular, solar photovoltaics (PV) and wind have been expanding significantly in recent years as their costs have come down considerably with progress in technology and economies of scale. Expectations for continued expansion of solar PV and wind remain high, and IEEJ Outlook 2026 projects that electricity generated from variable renewable energy will expand by about five times between now and 2050 in its Reference Scenario and by about seven times in its Advanced Technologies Scenario.

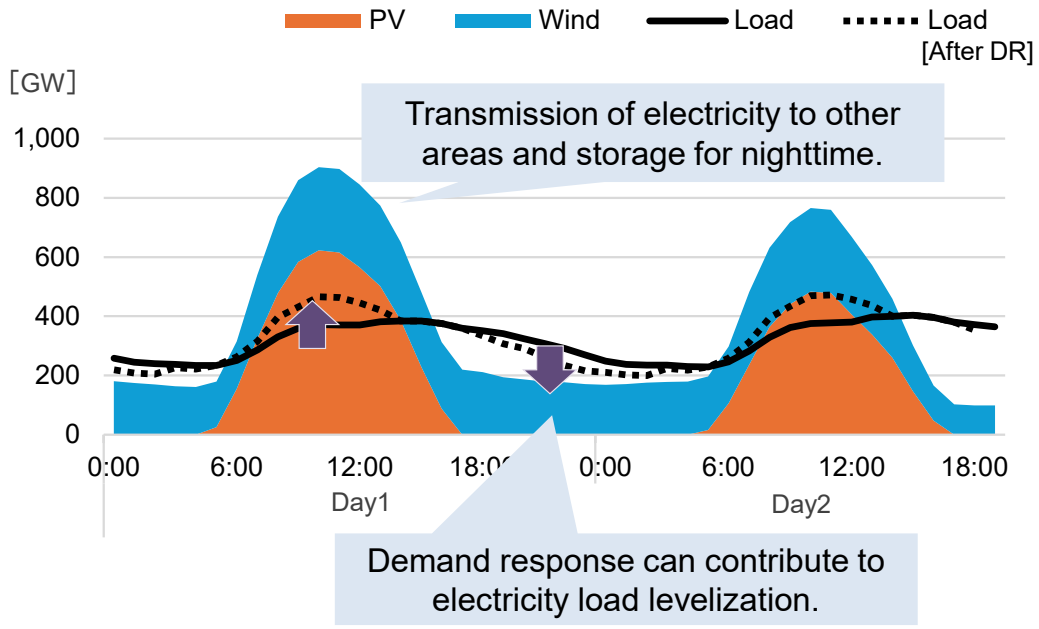
Solar PV and wind are sometimes referred to as variable renewable energy (VRE) as their power output is affected by natural conditions. As VRE deployment increases, there is a need for the electricity and energy systems to adapt to the increase in VRE. The costs necessary for this adaptation are called integration costs. This chapter describes the idea of integration costs as a challenge associated with the expansion of VRE and presents examples of analysis.

8.1 Challenges of VRE expansion

Response to output fluctuations and stable supply of electricity

As the power output from VRE fluctuates based on natural conditions, it is important to predict output and respond to changes in real time to maintain a stable supply of electricity. For example, in some countries and regions today (such as the Kyushu region of Japan), some power plants are subject to output curtailment during periods when VRE electricity supply is in surplus. Occasional electricity supply-demand tightness has also occurred when natural conditions caused VRE output to plunge and backup thermal power plants experienced unplanned shutdowns. As such, when introducing large amounts of VRE, it is essential to operate conventional power sources like thermal power generation flexibly to ensure the stable functioning of the power system. In addition, the use of technologies capable of instantly restoring the power supply-demand balance, such as power interchanges with other regions via transmission networks, demand-side load balancing (demand response) and storage batteries is being considered (Figure 8-1).

Figure 8-1 | An illustrative example of mass introduction of VRE and response by power systems



Source: IEEJ Outlook 2025

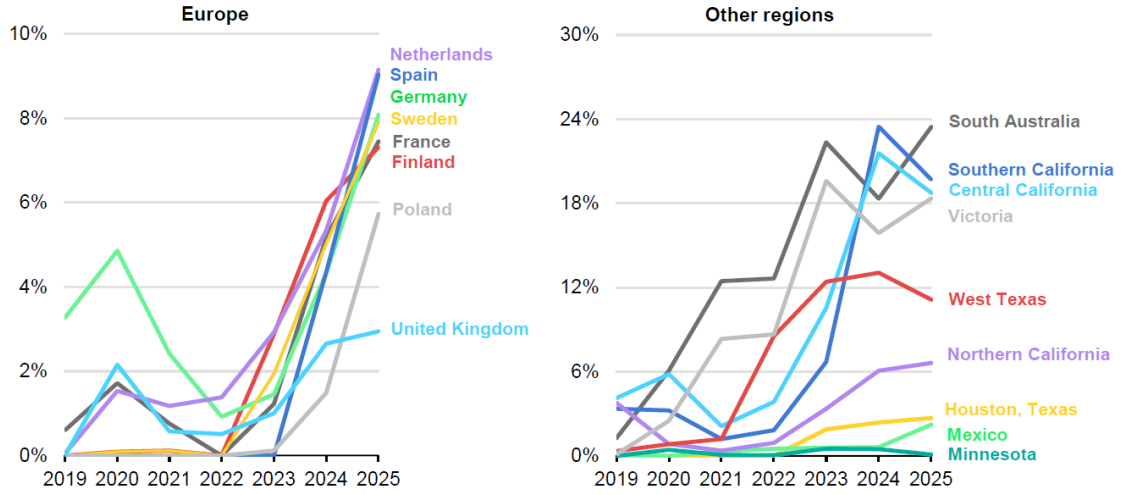
Shortage of power system flexibility and impact on the electricity market

One impact of VRE expansion is the effect on the electricity market. A notable example is negative pricing, in which wholesale electricity market prices become negative. According to the International Energy Agency (IEA) (2025), negative prices in wholesale electricity markets are still relatively rare on a global basis but have been increasing in some regions in recent years.

For example, in South Australia, which had an annual VRE share of around 65% in 2023, prices were negative for around 25% of the annual trading time in the wholesale electricity market. Similarly, in Texas, where the annual share of VRE was around 33% in 2023, prices were negative for around 10% of the annual trading time. While negative market prices do spur electricity consumption and urge consumers to utilise load balancing in situations of excess electricity supply, they are also known to worsen market revenues and in turn negatively impact investments in power sources.

IEA (2025) noted that negative prices are a result of wider fluctuation ranges in wholesale prices caused by insufficient system flexibility. It also noted that to respond to VRE output fluctuations, it is important to ensure power system flexibility by utilising thermal power generation and demand-side load balancing.

Figure 8-2 | Cases of negative prices in the wholesale electricity markets around the world



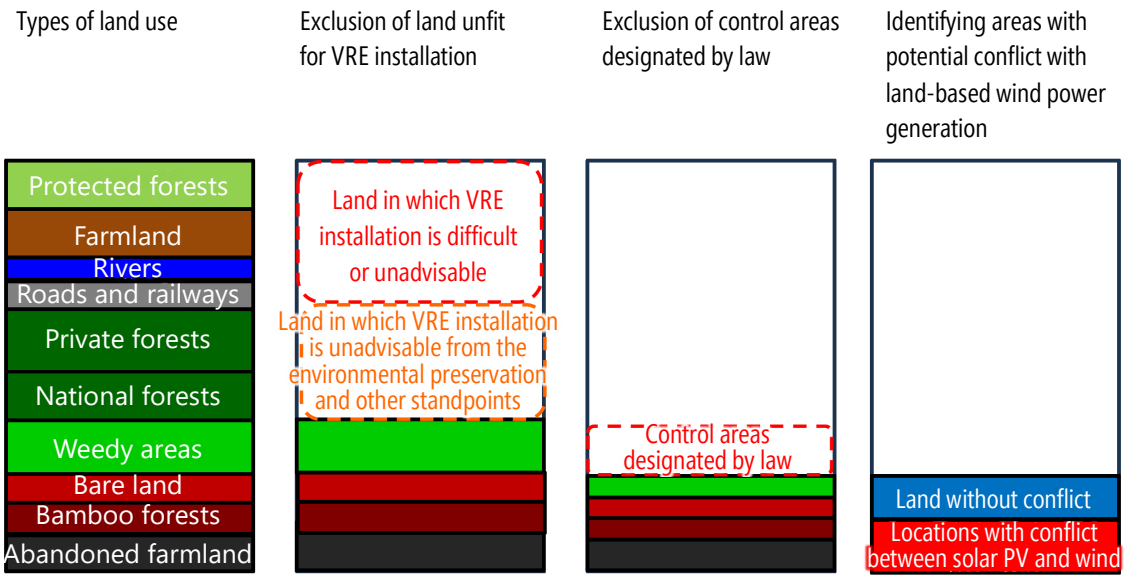
Source: IEA (2025), *Electricity Mid-Year Update 2025*, IEA, Paris https://www.iea.org/reports/electricity-mid-year-update-2025, Licence: CC BY 4.0

Constraints on resource development and land use

The availability of renewables, not limited to VRE, is affected by natural and land conditions. Regions with favourable conditions and a high energy supply potential tend to be concentrated in nature-rich areas. For instance, much of the supply potential for wind power generation is found in mountainous regions and offshore areas with favourable wind conditions that are often located far away from demand centres such as cities. This makes it necessary to build new power systems when developing these resources.

Furthermore, because developing this supply potential can disrupt harmony with the natural environment and other land uses (Figure 8-3), these factors must be considered when assessing supply potential to achieve sustainable renewable energy development. Renewable energy development usually starts in locations that are relatively easy to access from a regulatory perspective, and such sites become scarcer as projects advance. As a result, additional costs, such as those for power grid construction and environmental protection, tend to increase with time.

Figure 8-3 | Sample method for evaluating VRE plant locations



Source: 67th meeting of the Large-scale Renewable Energy Introduction and the Next-Generation Power Network, Committee on Energy Efficiency and Renewable Energy/Electricity and Gas Industry Committee, Advisory Committee for Natural Resources and Energy, Material 3; explanatory material by the IEEJ/Yokohama National University (2024)

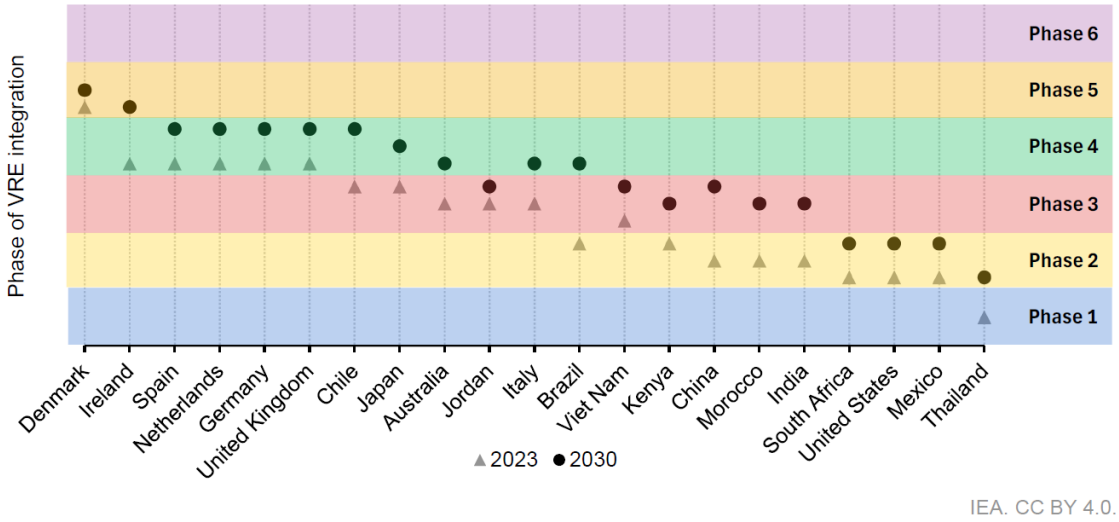
VRE grid integration challenges

IEA (2024) classifies countries by phase based on their progress in introducing VRE and other renewables, taking into account the stable supply capability of their power systems, market impact and other factors. For example, Denmark is categorised in Phase 5, an advanced phase of VRE introduction, because it can cover its electricity demand with VRE (especially wind) for almost all hours of the year. Meanwhile, Japan is lower than Denmark in Phase 3 and is expected to move up to Phase 4 in 2030 as more VRE is introduced.

The IEA expects that countries will move up in phases and notes that the measures required for their power systems will change depending on the phase.

In addition to technological and institutional measures, cost-related measures will be important going forward. The costs required for integrating a power source into the power system are essential, and these costs are referred to as integration costs. In introducing VRE, it is important to identify the integration costs as a metric that accounts for the nature of each power source, and integration costs are increasingly recognised as a challenge for the wider adoption of VRE.

Figure 8-4 | Phases of variable renewable energy introduction



Note: The phase assessments for 2030 are based, among other factors, on VRE forecasts that will be presented in the upcoming Renewables 2024 report.

Source: IEA (2024), *Integrating Solar and Wind*, IEA, Paris https://www.iea.org/reports/integrating-solar-and-wind, Licence: CC BY 4.0

8.2 Integration costs

Power system integration costs

In addition to the costs associated with power sources themselves, the Organisation for Economic Co-operation and Development (OECD)[38] notes that the following integration costs will be necessary.

- **Profile costs**: The costs for changing the operations of dispatchable power stations to address a supply-demand mismatch resulting from a deviation of power station output from the plan.
- **Balancing costs**: The costs arising from operating dispatchable power stations in grid-balancing mode to address brief output prediction errors lasting for a few seconds to a few minutes and brief output fluctuations.
- **Grid-related costs**: The costs for building core transmission networks connecting power plant locations and demand areas, and for installing power cables connecting power plants with the electric power grid.

Various approaches are being studied for analysing the power system integration costs based on these cost classifications, as shown in Table 8-1. The approaches have different focuses, such as the change in overall costs of the power system and the value of a power source in the market, thereby ensuring that integration costs are assessed from a variety of perspectives.

[38] OECD/NEA (2018) "The Full Cost of Electricity Provision"

Table 8-1 | Integration cost-related indicators and examples of analysis methods

Indicator	Description	Example of analysis
Integration cost, system cost	The cost obtained by subtracting the amount proportional to the levelised cost of electricity (LCOE) from the total cost of the power sector. There are many cases of evaluation for various regions around the world.	
System value	An indicator for evaluating the contribution of each power source to the power market. It is advocated in the IEA report "Next Generation Wind and Solar Power" (2016).	IEA
Levelised avoided cost of electricity (LACE)	An indicator proposed by the U.S. Department of Energy (DOE) and the Energy Information Administration (EIA). LACE indicates the economic advantage of a certain technology by considering the costs that would be avoided when a certain power source is introduced into the power system.	U.S. DOE/EIA, Levelized Costs of New Generation Resources in the Annual Energy Outlook (annual editions)
Enhanced levelized cost/wider system impact	This indicator expands the traditional LCOE to incorporate the marginal costs of a power source. Rather than a simple cost comparison, it enables evaluations that incorporate the impact on the power market.	Department for Business, Energy and Industrial Strategy (BEIS), Electricity Generation Costs 2020, etc.
System LCOE	This indicator is based on the marginal cost of each power source and is known to be effective for evaluating the impact of increasing new renewable capacities on the power market. By adding on the difference between marginal unit prices of each power source and demand to LCOE, the impact on the overall power system is incorporated more accurately.	Hirth et al., 2016 and others
Marginal system LCOE	This is an indicator that is based on the marginal cost of each power source and is used to compare and analyse certain power sources. It is used especially to compare two types of technologies in terms of relative economic efficiency.	Ueckerdt et al., 2013; Reichenberg et al., 2018 and others

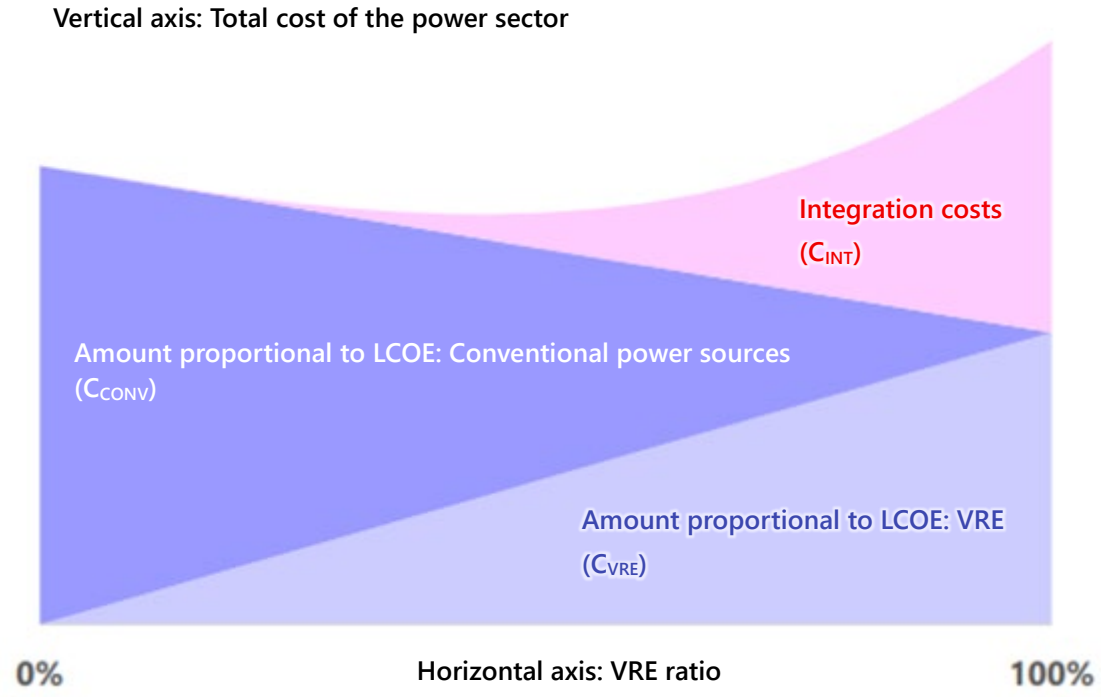
Indicator	Description	Example of analysis
Relative marginal system LCOE/ average system LCOE	This indicator evaluates the integrability of a power source and its value in the market based on its marginal cost and average cost.	Matsuo and Komiyama, 2021

Source: Created based on Matsuo (2021), Assessment of costs by power source with a focus on OECD/NEA and IEA reports

Optimal power generation mix integration costs

In considering the future power generation mix and evaluating its economic efficiency, it is important to assess total system costs including integration costs, in addition to the costs of each power source itself. Matsuo (2025) notes that when including the costs for integrating a power source into the power system (integration cost) in the evaluation, there is an optimal combination of power sources in terms of costs (Figure 8-5).

Figure 8-5 | Conceptual diagram of power generation costs (LCOE) and integration costs



Source: First meeting of the Power Generation Cost Verification Working Group, Material 1, Material 5 Overview of Assessment by Power Generation Cost Verification Working Group (material submitted by Committee Member Matsuo (2024)

With technological progress, the generation cost of renewables per 1 kWh of output (LCOE) is now lower than that of conventional power sources. As such, there are high expectations for replacing conventional power sources with new renewable capacities on cost-competitiveness grounds. This means that C_{CONV} will be gradually replaced by C_{VRE} as shown in Figure 8-5.

Meanwhile, additional costs for installing battery systems and reinforcing the grid will arise as VRE is introduced in large amounts. As a result, costs represented by C_{INT} in Figure 8-5 will be necessary for some power sources in addition to their development costs.

8.3 Power generation including integration costs

Assessing the power generation mix with integration costs

To analyse the integration costs with incremental amounts of variable renewable energy (VRE), we identified the power generation mix that produces the smallest energy system costs for the Association of Southeast Asian Nations (ASEAN) as a whole using a model that analyses the entire energy system.

For the analysis, the NE_ASEAN model[39], a linear planning model co-developed by the IEEJ and the Otsuki Group at Yokohama National University based on the NE_Japan model developed by the Otsuki Group, was used. The amount of VRE capacity to be introduced by 2060 and its integration costs were analysed based on the assumption that each country will reduce greenhouse gas (GHG) emissions in line with the Nationally Determined Contributions (NDCs).

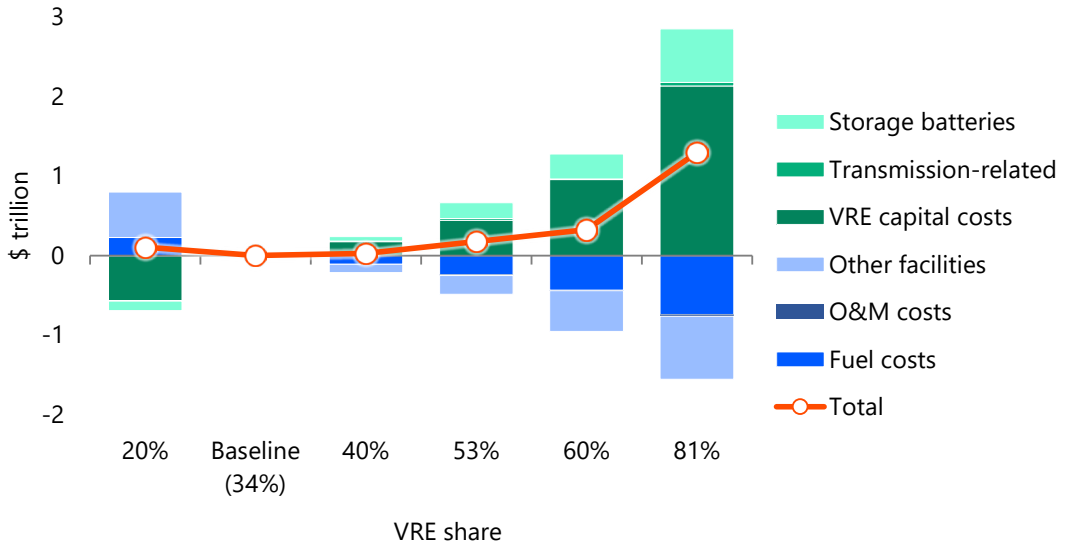
Analysis of power generation mixes including integration costs

For nations to reduce their GHG emissions in line with their NDCs, introducing decarbonised energies is essential. Based on the conditions of this estimation, ASEAN's energy system costs are estimated to be the lowest in 2060 when the VRE share is around 30%. Using this result as the baseline, we charted the system costs for higher and lower shares of VRE.

Facility and fuel costs for conventional power generation decrease as VRE increases from the baseline. On the other hand, the costs for introducing VRE itself increase, along with additional costs for integration, such as those for storage batteries (Figure 8-6). For example, when the share of VRE is raised to 60% for ASEAN as a whole, the costs would increase by 300 billion dollars between 2030 and 2060, as opposed to a much greater increase of $1.3 trillion if the share is raised to 80%.

[39] The IEEJ-NE_ASEAN model analyses the combination of energy technologies, including power generation and storage facilities, that minimises the overall cost of the energy system. See below for an overview of the model and an example analysis. IEA (2023), Decarbonisation Pathways for Southeast Asia, IEA, Paris https://www.iea.org/reports/decarbonisation-pathways-for-southeast-asia, Licence: CC BY 4.0

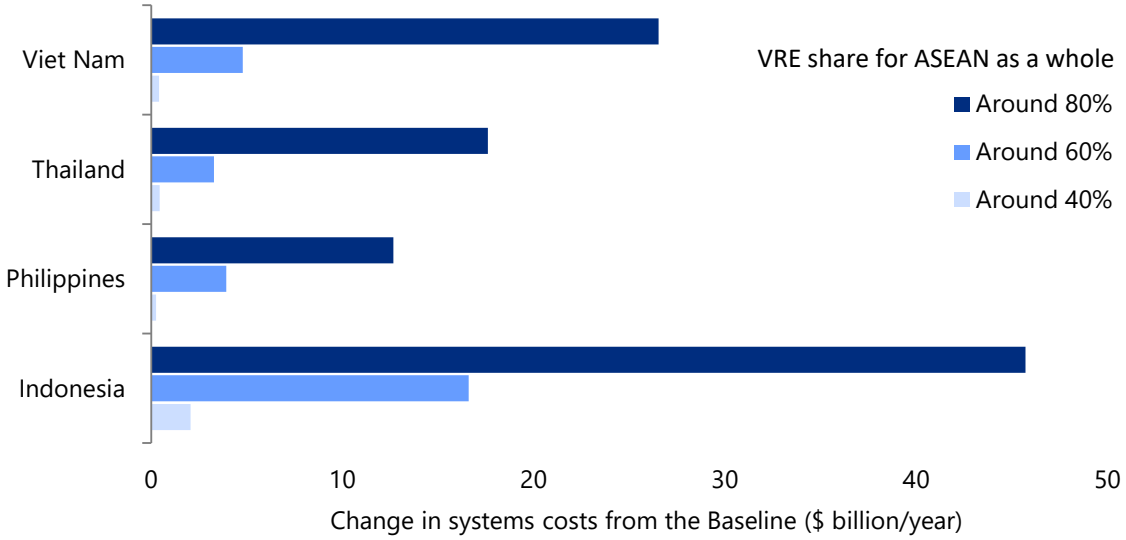
Figure 8-6 | VRE shares and system costs in ASEAN [total for 2030–2060]



Notes: The assumptions for international and other key transmission lines are based on the maximum scale of grid development being considered under the ASEAN Power Grid initiative. All numbers are in real terms; 2017 prices.

To promote the energy transition required to decarbonise the ASEAN region, ASEAN-wide collaboration and cooperation are essential, alongside strengthening efforts within each country. Meanwhile, attention must be paid to the potentially significant differences in additional costs between countries. Behind these gaps lie variations in geographical and natural conditions and the availability of infrastructure, between the ASEAN nations, resulting in major disparities in their abilities to add more VRE (Figure 8-7). The impact of the cost increase associated with adding VRE is particularly significant in Indonesia, Viet Nam and Thailand, which have large populations and economies.

Figure 8-7 | VRE shares and system costs in ASEAN [2060]



Notes: The assumptions for international and other key transmission lines are based on the maximum scale of grid development being considered under the ASEAN Power Grid initiative. All numbers are in real terms; 2017 prices.

Here we present an analysis of different shares of VRE and integration costs. Some ASEAN nations are rich in non-VRE renewables, such as hydro and geothermal resources. Meanwhile, the ability to bear additional costs associated with reaching carbon neutrality varies between nations depending on their economic circumstances and national scale. To utilise VRE and other renewable energies even further, alongside cross-border cooperation, it is essential for each country to decarbonise through a pathway that suits its individual circumstances.

9. Importance of reality-based climate targets and adaptation

—Advanced Technologies Scenario as a pathway for reaching the 2°C climate target—

The 2015 Paris Agreement sets a target to limit global warming to well below 2°C above pre-industrial levels and encourages 'efforts' to stay below 1.5°C. In other words, the target of the Paris Agreement is 2°C and 1.5°C can be seen as an additional, non-binding target. However, following the issuance of the Special Report on Global Warming of 1.5°C by the Intergovernmental Panel on Climate Change (IPCC) (2018) and the declaration of net-zero emissions targets by a number of key nations around 2020, the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26) held in 2021 passed a 'resolution' that contains special language highlighting the significance of efforts to stay below 1.5°C on its own, rather than in tandem with the 2°C target. At present, the Group of Seven (G7) countries including Japan are explicitly committed to the 1.5°C target (except the US Trump administration). In July 2025, the International Court of Justice issued an advisory opinion stating that the Nationally Determined Contributions (NDCs) of the parties to the Paris Agreement must be aligned with the 1.5°C temperature target of the Agreement.

However, in reality, the world's greenhouse gas emissions continue to rise, and the prospects for achieving the 1.5°C target are becoming increasingly challenging. This chapter analyses the current status of major nations and others regarding the 1.5°C target, and it demonstrates that the 1.5°C target is no longer achievable based on the remaining carbon budget and that the Advanced Technologies Scenario of the IEEJ Outlook 2026 provides a pathway for reaching the alternative 2°C target. The increasing significance of adaptation in efforts to achieve the 2°C target is also discussed.

9.1 Recent developments regarding the 1.5°C target

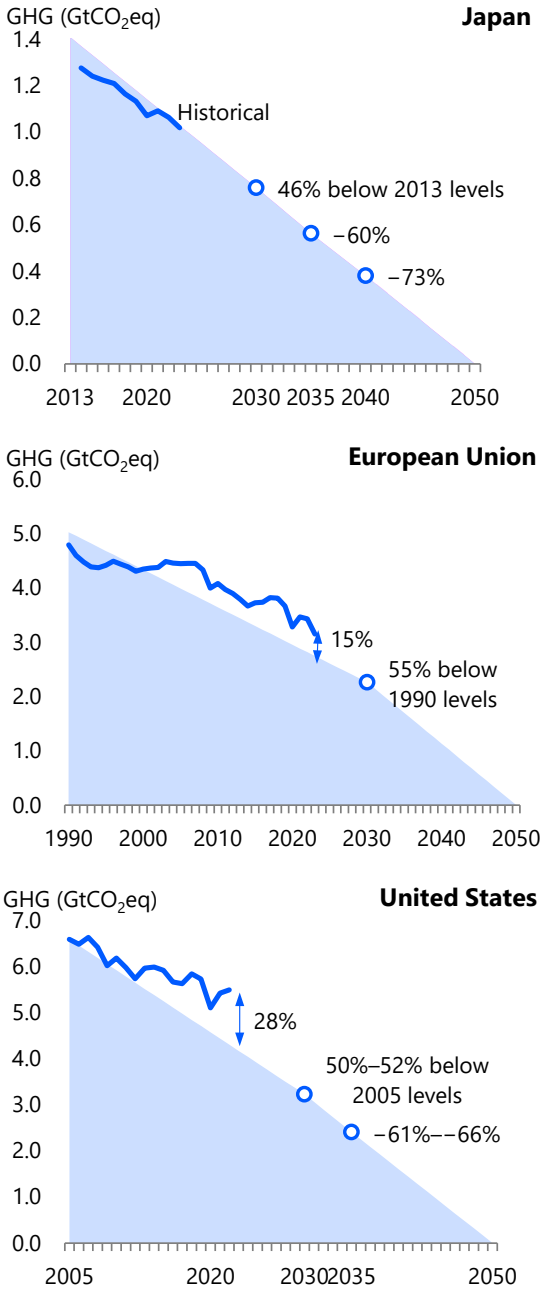
Moves in advanced economies

As mentioned earlier, advanced economies, particularly the G7 countries (excluding the United States; see Section 5.1 for the situation in the United States) are committed to the 1.5°C target. However, the GHG emissions of no country other than Japan are on track to meet the 2030 targets, and emissions remain above the required levels (Figure 9-1)[40].

While all countries need to reinforce their emissions reduction measures to reach net-zero in 2050, unlike around 2020, when climate action was a top policy priority, energy security and the need to ensure affordable energy supply have gained much greater weight in recent years. As a result, the G7 countries have faced considerably more difficulty in managing their policies.

[40] As Italy has not set its own reduction targets, a strict comparison is not possible; however, when compared to the European Union-wide targets, it is still not on track.

Figure 9-1 | Emission reduction pathways of G7 nations and their progress



	Latest GHG emissions ($MtCO_2$)	Deviation from the 2030 target pathway ($MtCO_2$, %)
Japan	1 017	−9.3 (−0.9%)
European Union	3 152	406 (14.8%)
United States	5 489	1 186 (27.6%)
Germany	741	143 (24.0%)
France	339	40 (14%)
United Kingdom	389	30 (8%)
Canada	670	143 (27%)

The Parties to the Paris Agreement were required to submit their 2035 NDCs by February 2025. However, only 52 countries, including nine advanced economies, have done so as of the end of September 2025. To meet the 1.5°C target, countries were encouraged to set a reduction target of 60% from 2019 levels for their 2035 NDCs based on the global stocktake at COP28 (2023). However, the only advanced economy governments that have met this target are a small number of non-EU European countries such as the United Kingdom, as well as Australia (Table 9-1). Most advanced economies remain committed to the 1.5°C target but are assumed to be taking more realistic actions regarding the 2035 target.

Table 9-1 | 2035 targets in the new NDCs of advanced economies

	2030	2035
Japan	46% reduction from 2013 levels	60% reduction from 2013 levels (54% reduction from 2019 levels)
European Union	55% reduction from 1990 levels	66.25%–72.5% reduction from 1990 levels*1 (54%–62% reduction from 2019 levels)
United Kingdom	68% reduction from 1998 levels	81% reduction from 1990 levels (66% reduction from 2019 levels)
Switzerland	50% reduction from 1990 levels	65% reduction from 1990 levels (60% reduction from 2019 levels)
United States (under the Biden administration)	50%–52% reduction from 2005 levels	61%–66% reduction from 2005 levels (55%–61% reduction from 2019 levels)
Canada	40%–45% reduction from 2005 levels	45%–50% reduction from 2005 levels (44%–49% reduction from 2019 levels)
New Zealand	50% reduction from 2005 levels	51%–55% reduction from 2005 levels (50%–54% reduction from 2019 levels)
Norway	55% reduction from 1990 levels	70%–75% reduction from 1990 levels (70%–75% reduction from 2019 levels)
Australia	43% reduction from 2005 levels	62%–70% reduction from 2005 levels (53%–63% reduction from 2019 levels)
Iceland	41% reduction from 2005 levels	50%–55% reduction from 2005 levels (48%–53% reduction from 2019 levels)
Russia	30% reduction from 1990 levels	33%–35% reduction from 1990 levels (39%–44% reduction from 2019 levels)

*1: The next NDC is yet to be released as the IEEJ Outlook 2026 is being written. The information is based on the State of Intent released on 18 September 2025.

Under such circumstances, the leader of the UK Conservative Party, Kemi Badenoch, made a noteworthy comment in March 2025 that 'Net zero by 2050 is impossible. I don't say that with pleasure. I want a better future, a better environment for our children. But we have to get real'. The Tories were the ruling party when the United Kingdom hosted COP26. It was the current leader of that same party who stated that net zero is impossible, not for the world, but for the United Kingdom.

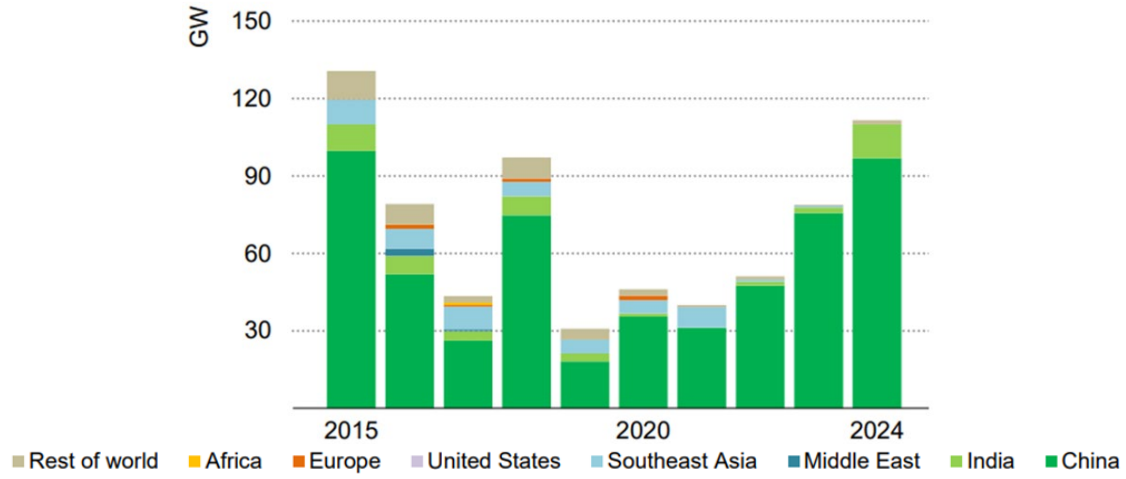
There are moves to revise the 1.5°C target in the private sector as well. The Net-Zero Banking Alliance (NZBA) was launched at COP26 to align the GHG emissions financed by financial institutions with the 1.5°C target. However, with the withdrawal of six key US banks at the end of 2024, and subsequent withdrawals by Japanese banks, the NZBA revised its policy in April 2025 to also recognise the 2°C target.

Moves in emerging economies

One of the reasons for the continued increase in the world's energy-related carbon dioxide (CO2) emissions is the ongoing growth in coal consumption in China and India. As of 2024, China and India account for 56% and 15%, respectively, of global coal consumption, ranking as the world's first and second largest consumers.

According to the International Energy Agency (IEA), in China, final investment decisions (FIDs) for building 100 GW of coal-fired power plants were made in 2024 alone (Figure 9-2). FIDs for new coal-fired power plants in China decreased to about 30 GW in 2019 but subsequently increased, reaching 100 GW in 2024, the highest level in the last decade.

Figure 9-2 | Final investment decisions for new coal-fired power plants



Source: IEA "World Energy Investment 2025"

It goes without saying that existing coal-fired power plants are being retired as new ones are built. However, only 4.7 GW/year of plant capacity has been scrapped in the last five years, resulting in a significant net increase in coal-fired power generation capacity in China. The installed capacity of renewables has also grown significantly, with 341 GW of solar photovoltaic power generation capacity and 80 GW of wind power generation capacity newly constructed in 2024. However, based on the capacity factor of these renewable power sources in China, the output from new coal-fired capacity would match that of new solar photovoltaic and wind capacity even if the capacity factor of the coal capacities is around 50%. Therefore, building 100 GW of new coal-fired power plants per year would have an immeasurable impact on China's CO_2 emissions.

At the Climate Summit held on the margins of the United Nations General Assembly in New York on 24 September 2025, Chinese leader Xi Jinping announced China's next NDC to 'reduce GHG emissions by 7% to 10% from peak levels by 2035'. European think-tanks estimate that China is actually capable of reducing its CO_2 emissions by at least 30% from 2023 levels by 2035 and staying on track to meet the 1.5°C target, and the view that China's next NDC is insufficient is becoming increasingly widespread.

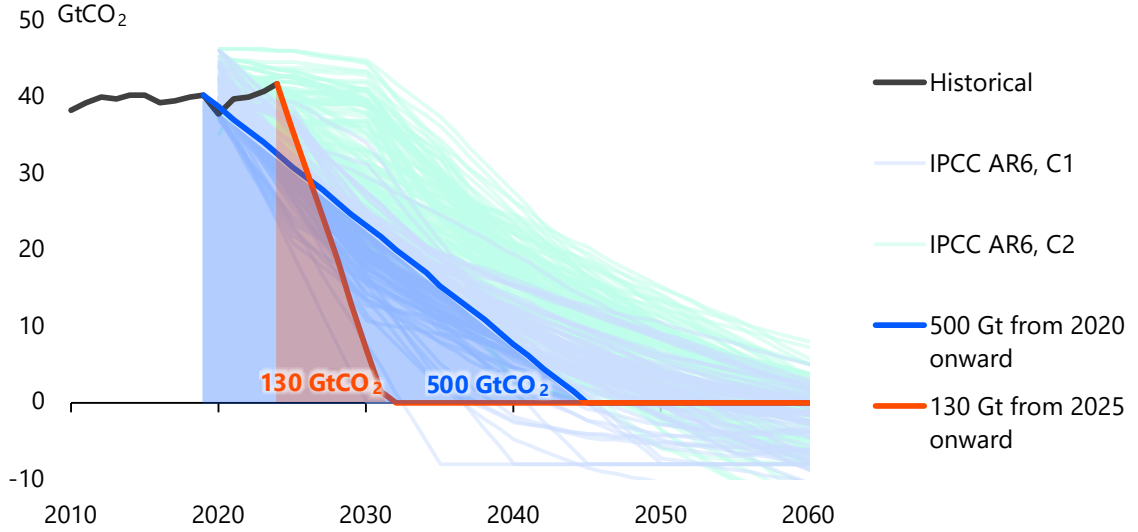
According to the IEA, in India, FIDs for building 15 GW of coal-fired power plants were made in 2024, again the largest in the last decade. The world's largest coal company, Coal India Limited, which supplies three-fourths of India's coal demand, announced in June 2025 that it would reopen 32 of its defunct coal mines and develop five new ones, citing the inability of renewables to meet the growing demand. The share of coal-fired power generation, which is currently over 70% of the total electricity generated, will still be 50% in 2031–2032, according to the Indian government, indicating that coal will remain in use in the future.

9.2 Comparison of the Advanced Technologies Scenario and the 2°C target

The viability of the climate target was quantitatively evaluated based on the carbon budget[41]. As mentioned in previous IEEJ Outlook[42], the remaining carbon budget needed to keep the increase in global temperature below 1.5°C with a 50% probability is quickly decreasing from the level reported at the time of the Sixth Assessment Report (AR6) Synthesis Report (SYR) of the Intergovernmental Panel on Climate Change (IPCC) due to annual emissions. Specifically, IPCC AR6 SYR estimated the remaining carbon budget to be 500 $GtCO_2$ from 2020 onwards. However, the latest estimate from the Indicators of Global Climate Change (IGCC)[43] (IGCC 2024)[44] shows a significant decline to 130 $GtCO_2$ from 2025 onwards. This value is barely four years' worth of emissions at current levels, and, based on a simple calculation using a linear decrease in emissions, the world will need to go net-zero in 2032 (Figure 9-3). According to the IGCC 2024, the difference from the level of 500 $GtCO_2$ as of IPCC AR6 SYR consists of a decrease of 200 $GtCO_2$ due to emissions in 2020–2024, a decrease of a little over 100 $GtCO_2$ due to an upward revision of warming associated with a reduction of cooling aerosols, and a decline of about 40 $GtCO_2$ due to the rise in estimated warming based on the high temperatures observed in recent years. Given this estimated value, the 1.5°C target is already effectively unattainable. Therefore, the realistic option would be to pursue 2°C as the target aligned with the Paris Agreement. This is not necessarily a step back, but rather represents a return to the original target of the Paris Agreement.

[41] The carbon budget is the maximum value of cumulative net CO_2 emissions artificially achieved to keep temperature rise below a certain threshold with a given probability. The residual carbon budget is the amount remaining after subtracting the quantity already emitted in the past.
[42] IEEJ Outlook 2024 and IEEJ Outlook 2025
[43] IGCC is an international research project that publishes the residual carbon budget annually. A similar initiative is the Global Carbon Budget (GCB).
[44] Forster et al., "Indicators of Global Climate Change 2024: annual update of key indicators of the state of the climate system and human influence", ESSD, 17, 2641–2680, 2025. https://essd.copernicus.org/articles/17/2641/2025/

Figure 9-3 | Carbon dioxide emission pathway consistent with the 1.5°C target



Notes: 'Historical' was obtained from Global Carbon Budget 2024[45]. Including emissions from cement production processes, flaring, land use, land use change and forestry sector. 'IPCC AR6, C1' includes 97 scenarios that fall under 'C1: limiting warming to 1.5°C (>50%) with no or limited overshoot', while 'IPCC AR6 C2' includes 131 scenarios that fall under 'C2: returning to 1.5°C (>50%) after a high overshoot'[46].

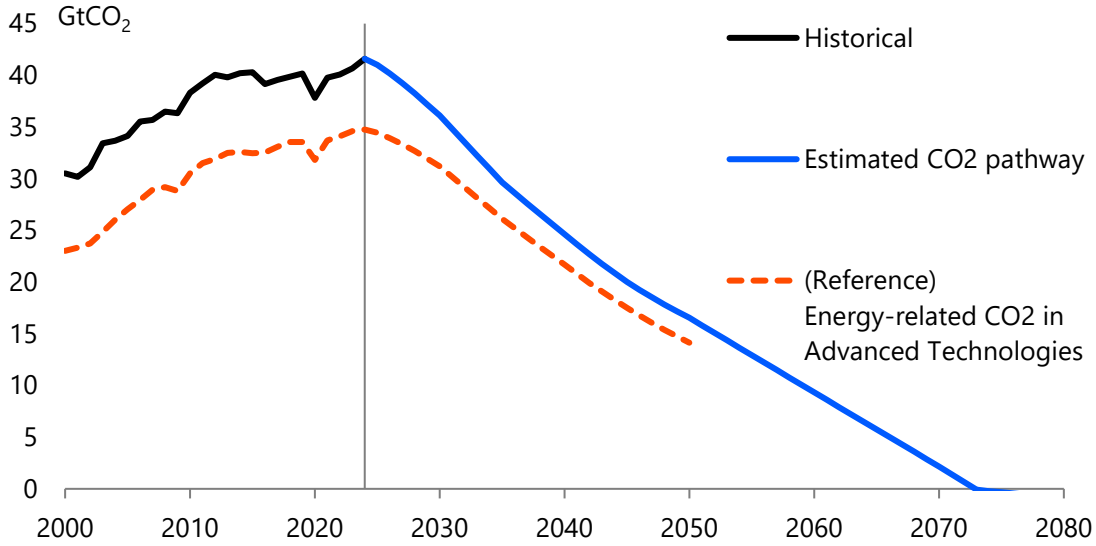
We used the carbon budget concept again to see whether the carbon dioxide (CO_2) emission pathway of the Advanced Technologies Scenario of the IEEJ Outlook 2026 is consistent with the 2°C target. To do so, it is necessary to extend the energy-related CO_2[47] emission pathway of the Advanced Technologies Scenario, which ends in 2050, into a pathway that continues until anthropogenic CO_2 emissions, including non-energy-related emissions, reach net-zero. For this purpose, we roughly estimated energy-related CO_2 emissions for 2051 onwards, assuming that the pace of reduction in 2050 (−0.61 $GtCO_2$/year) will continue thereafter. We assumed that emissions would be flat after reaching net-zero. Next, we set the amounts of non-energy-related CO_2 emissions (land-use change, cement process, cement absorption, flaring, etc.) by referring to the Illustrative Mitigation Pathways (IMPs) in the IPCC AR6 Working Group 3 (WG3) report. Among the IMPs with various mitigation levels, for non-energy-related CO_2 emissions, we referred to the Moderate Action (ModAct) aligned with the climate policies based on the Nationally Determined Contributions (NDCs) submitted in 2020, to adopt a slightly conservative assumption. Lastly, non-energy-related CO_2 emissions and energy-related CO_2 emissions were aggregated to obtain an estimated CO_2 pathway.

The estimated CO_2 pathway reaches net-zero in 2073, as shown in Figure 9-4. As the IPCC AR6 WG3 report assumes that the 2°C CO_2 emission pathway reaches net-zero around 2070–2080 (with a 67% probability)[48], the estimated pathway appears broadly consistent with the 2°C target.

[45] Global Carbon Budget, "GCB 2024". https://globalcarbonbudget.org/gcb-2024/.
[46] Byers et al., "AR6 Scenarios Database hosted by IIASA", International Institute for Applied Systems Analysis, 2022. https://data.ene.iiasa.ac.at/ar6/#/login?redirect=%2Fworkspaces.
[47] The amount removed via Direct Air Capture and Storage (DACCS) has been taken into account.
[48] IPCC, "Summary for Policymakers. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change", 2022, Figure SPM.5.
https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf

However, our estimate must be compared with the latest remaining carbon budget for accuracy. The total CO_2 emissions along the pathway from 2025 until net-zero is reached are 906 $GtCO_2$, which is a level capable of limiting the global temperature increase to within 2°C (50% probability) based on the latest remaining carbon budget (Table 9-2). However, total emissions slightly exceed the remaining carbon budget of IGCC 2024 for the 2°C target (67% probability).

Figure 9-4 | Estimated anthropogenic CO_2 emission pathway until reaching net-zero, created by extending the energy-related CO_2 emission pathway of the Advanced Technologies Scenario to 2050



Notes: 'Historical' was obtained from Global Carbon Budget 2024[49]. '(Reference) Advanced Technologies Scenario' is the energy-related CO_2 emission pathway of the Advanced Technologies Scenario. 'Estimated pathway' is the estimated anthropogenic CO_2 emission pathway until reaching net-zero, created by extending the energy-related CO_2 emission pathway of the Advanced Technologies Scenario to 2050.

[49] Global Carbon Budget, "GCB 2024". https://globalcarbonbudget.org/gcb-2024/.

Table 9-2 | Comparison of cumulative CO_2 emissions from the estimated pathway and the remaining carbon budget

Scenario		Cumulative CO_2 from 2025 onwards ($GtCO_2$)
Estimated pathway (cumulative total till net-zero is reached)		906
2°C (50% probability)	IPCC AR6 SYR (start year adjusted)	1 150
	GCB 2024	1 110
	IGCC 2024	1 050
2°C (67% probability)	IPCC AR6 SYR (start year adjusted)	950
	GCB 2024	Not specified
	IGCC 2024	870
2°C (50% probability)	IGCC 2024	490

Note: As the remaining carbon budget in IPCC AR6 SYR is for the period starting from 2020, the emissions for the five years from 2020 to 2024 (200 $GtCO_2$) have been removed to obtain the values in the table.

Given the uncertainty of the estimated energy-related CO_2 pathway and remaining carbon budget in this analysis, and to maximise the probability of achieving the 2°C target, it is important to continue exploring possibilities for deeper emissions reductions beyond those in the Advanced Technologies Scenario.

9.3 Adaptation

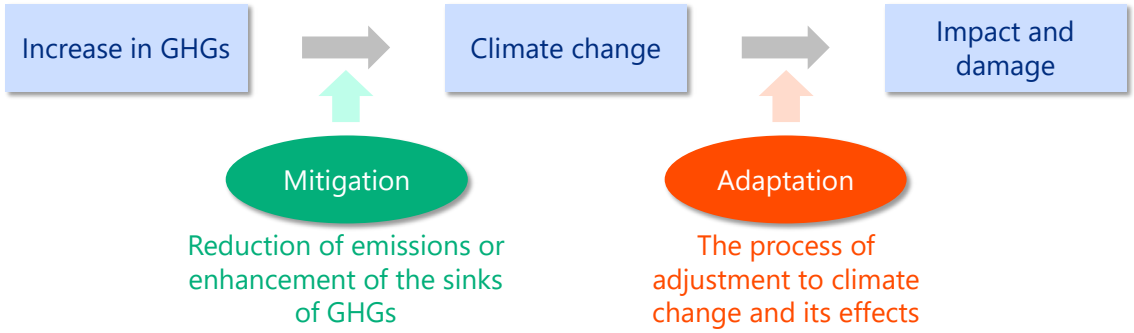
What is adaptation?

Mitigation (reduction) actions have not reached the scale or degree necessary to limit the increase in average global temperature in line with the long-term target of the Paris Agreement, and the temperatures are rapidly approaching and, in some cases, surpassing 1.5°C above pre-industrial levels. The unprecedented frequency and intensity of recent climate impacts underscore their scale and the challenge of adapting to them. Effective and appropriate adaptation actions are needed more urgently than ever.

Measures to address climate change can be divided into ‘mitigation’ and ‘adaptation’. 'Mitigation' means reducing greenhouse gases (GHGs) and expanding sinks to prevent climate change from worsening. On the other hand, ‘adaptation’ is the process of adjusting to and responding to climate change and its impacts to reduce the damage (Figure 9-5).

It is important to first alleviate the impacts of climate change through mitigation, and, where this proves insufficient, implement adaptation measures as well. With the 1.5°C target becoming effectively unachievable, adaptation will increase in importance going forward.

Figure 9-5 | What is adaptation?



How large is the adaptation finance gap?

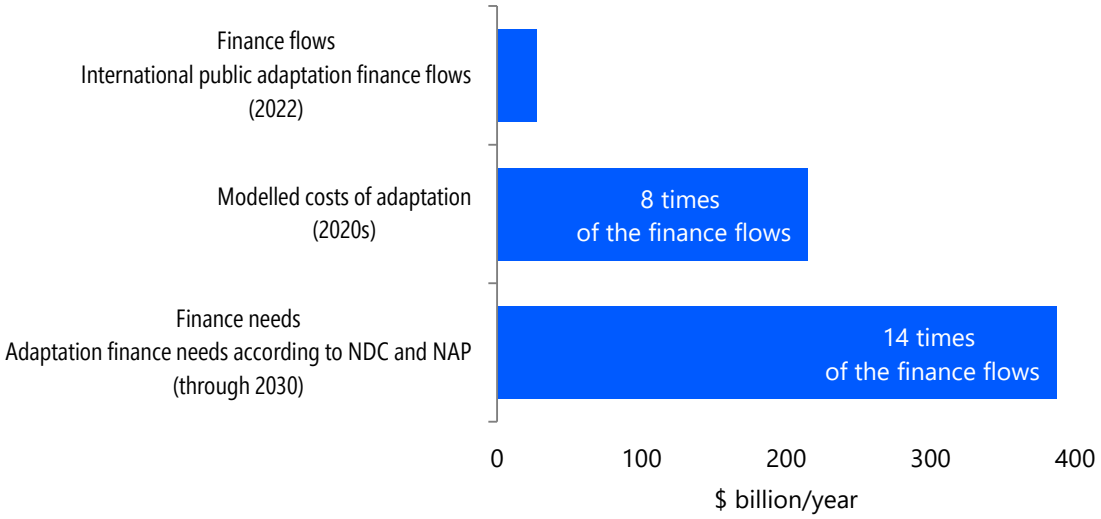
On the demand for adaptation financing, the Adaptation Gap Report 2023[50] of the United Nations Environment Programme (UNEP) describes the method for estimating adaptation financing needs and modelled adaptation costs, as well as their results. Adaptation financing needs were estimated by evaluating and analysing those presented in the National Adaptation Plans (NAPs) and the Nationally Determined Contributions (NDCs), by extrapolating the results to all countries including those that have not submitted their NAPs or NDCs. Modelled adaptation costs estimate the economic impacts of climate change and evaluate the costs required to reduce those impacts. It should be noted that the modelled costs and financing needs do not include private sector adaptation needs such as those for private infrastructure, increased air-conditioning demand and impacts on labour productivity due to rising temperatures.

UNEP's Adaptation Gap Report 2024[51] presents updated estimates. For adaptation needs, the modelled costs of adaptation amounted to 215 billion dollars per year and the financing needs to $387 billion per year, while merely $28 billion were provided to developing countries via international public adaptation finance flows in 2022 (Figure 9-6). We can see there still lies an extremely large gap if we compare the adaptation needs and the international public finance flows in 2022. There is still an extremely large gap between the adaptation needs and the international public finance flows in 2022. The finance needed for adaptation is 8 to 14 times the amount currently available. The priority is to bridge this significant gap in adaptation finance.

For adaptation finance and mitigation finance, Article 9.4 of the Paris Agreement stipulates that 'the provision of scaled-up financial resources should aim to achieve a balance between adaptation and mitigation'. This is understood to mean that the ratio of adaptation to mitigation finance should be brought to 1:1.

[50] https://www.unep.org/resources/adaptation-gap-report-2023
[51] https://www.unep.org/resources/adaptation-gap-report-2024

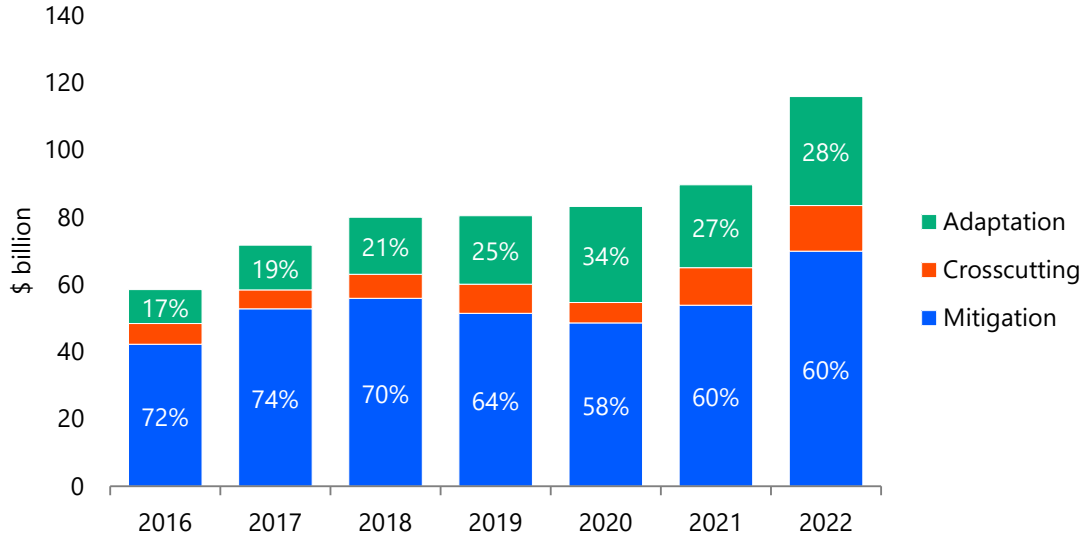
Figure 9-6 | Adaptation finance gap



Source: Created based on UNEP (2024) Adaptation Gap Report 2024.

If we compare the amounts of adaptation and mitigation finance within the climate finance provided and mobilised by advanced economies, mitigation finance accounted for 72% and 60% in 2016 and 2022, respectively (Figure 9-7). On the other hand, adaptation finance accounted for 17% and 28% in those same years, remaining far short of the amount of mitigation finance. It is necessary to take measures to ensure a balance between adaptation and mitigation finance.

Figure 9-7 | Climate finance provided and mobilised by area (including private sector finance)



Source: Created based on Organisation for Economic Co-operation and Development (OECD) (2024), Climate Finance Provided and Mobilised by Developed Countries in 2013–2022.

Various areas of adaptation

UNEP's Adaptation Gap Report gives the following as the key areas and sectors for adaptation: 'infrastructure, energy and settlement', 'water and floods', 'agriculture and fisheries', 'coastal and

marine resources', 'forests and ecosystems', 'extreme weather and disaster risk' and 'human health'. These areas and sectors are described in detail in Table 9-3.

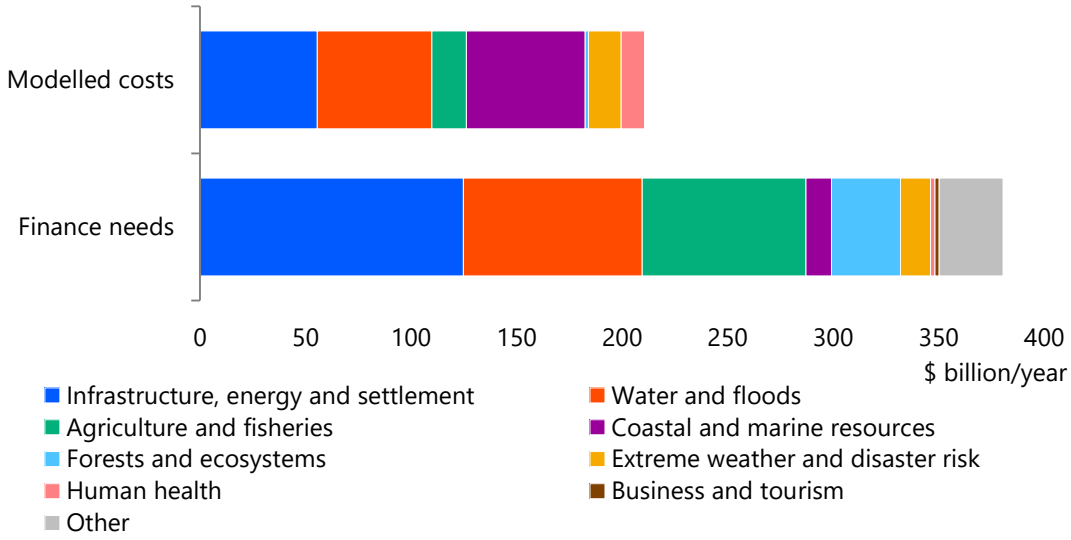
Table 9-3 | Key areas with adaptation needs

Area/sector	Description
Infrastructure, energy and settlement	Making infrastructure resilient in the energy and transportation subsectors
Water and floods	River flood protection (structures)
Agriculture and fisheries	Agricultural research and development, water management and infrastructure to address the impact of climate change on chronic hunger Addressing changes in fish catch potential, improving marine and coastal ecosystems (expanding marine protected areas) and safety at sea (responding to hazards from tropical windstorms, etc.)
Coastal and marine resources	Coastal protection (to address flood risks using dikes, etc.) and beach nourishment (to reduce erosion)
Forests and ecosystems	Expanding protected areas
Extreme weather and disaster risk	Weather and climate services (early warning systems, etc.) and social protection (funding for shock (climate extremes) response programs)
Human health	Disease control to address increase in malaria, dengue and diarrhoeal diseases, heat-alert schemes and supporting health sector responses to address increased heat-related mortality, disease surveillance and making future water, sanitation and hygiene (WASH) investment resilient

Source: Created based on UNEP (2023) Adaptation Gap Report 2023.

The key adaptation areas with high financing needs are 'agriculture and fisheries', 'water and floods' and 'infrastructure, energy and settlement', while those with high modelled costs are 'water and floods', 'infrastructure, energy and settlement' and 'coastal and marine resources' (Figure 9-8). Other areas that make up a large portion are 'forests and ecosystems' in terms of high financing needs and 'human health' with high modelled costs. It is necessary to consider which areas to prioritise for adaptation based on actual and future needs.

Figure 9-8 | Finance needs and modelled costs



Source: Created based on UNEP (2023/2024) Adaptation Gap Report 2023 and 2024.

10. Future of artificial intelligence and energy demand

The close interrelationship between artificial intelligence (AI) and energy is at the centre of global attention. As a symbolic example, in recent years, the growth in the use of generative AI and digitalisation has triggered a major increase in the number of data centres, raising concerns that electricity supply facilities may fail to keep up with the pace of data centre construction in some places in the future.

There are also high expectations for AI to bring significant benefits to energy-use-related demand sectors. AI has the potential to transform energy use itself by improving productivity and saving energy in industry, transport and buildings. AI is expected to enable optimal plant operation by forecasting demand, improving productivity, and thereby enhancing the energy efficiency of plants. In the transport sector, AI will save energy through autonomous driving, namely by improving fuel efficiency through optimising the spacing between cars and route selection, and by shortening travel distances. For buildings, AI will save energy by optimising air-conditioning operations while maintaining comfort. In this way, the futures of AI and energy are closely interconnected.

This chapter provides an overview of the relationship between AI and energy, examines the energy savings potential of data centres, and assesses the current status and provides a future outlook, focusing on the role that AI can play in energy saving.

10.1 Relationship between AI and energy

Factors behind the soaring electricity consumption of data centres in recent years

AI is an area of computer science that refers to technologies for building machines and computers capable of simulating the cognitive functions associated with human intelligence. There are various types of AI, but when we focus on analytical techniques, they can be classified into 'rule-based AI', 'machine learning', 'deep learning' and 'generative AI'.

- **Rule-based AI**: AIs operate based on the rules given by humans.
- **Machine learning**: This is a method that enables computers to realise a mechanism equivalent to human learning. Based on a certain algorithm, the computer discovers patterns and rules from input data, and it applies these patterns to new data to identify and predict what they are.
- **Deep learning**: Machine learning performed using multi-layer artificial neural networks. An artificial neural network simulates the neural network of the human brain and enables higher accuracy than machine learning.
- **Generative AI**: Based on deep learning technology, generative AI generates new content using massive amounts of learning data.

With the advent of generative AI in recent years, increases in data centres and their electricity consumption are raising the risk of local capacity constraints in transmission networks and electricity supply shortages at peak demand.

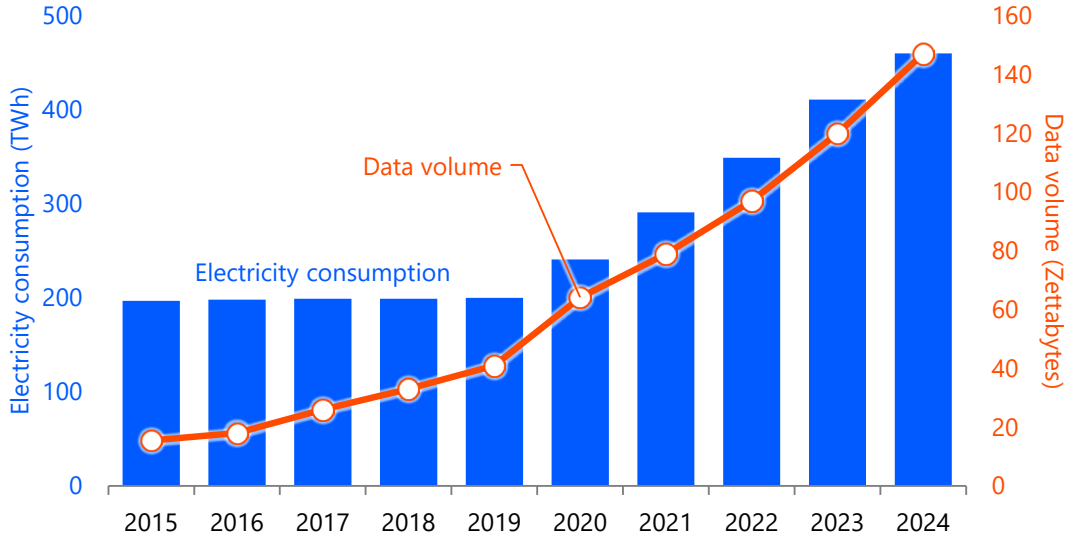
Currently, AI-related workload is estimated to account for 14% of the electricity consumption of data centres worldwide, cloud computing 54%, and conventional business-related workload

from email and storage 32%[52]. AI uses significant amounts of electricity during the training and inference processes.

Meanwhile, if we look at the historical trends of data centres, electricity consumption remained mostly unchanged from 2015 through 2019, while the global data volume increased by a factor of 2.6 from 15.5 zettabytes. This was due to 1/ improved efficiency of servers, storage, networking, infrastructure and other devices; 2/ the transition from small-scale data centres to large-scale cloud and hyperscale data centres; and 3/ improved efficiency of the graphics processing unit (GPU) that processes images and videos.

However, global electricity consumption of data centres, which had previously remained stable, increased by 70% in the three years between 2020 and 2023. The factors behind it included the expansion in the use of generative AI and progress in digitalisation, the spread of remote work and workation during the pandemic, and the full-fledged development of the fifth-generation mobile communication system (5G) including in regions previously without coverage[53]. All these factors spread faster than improvements in the efficiency of data centre equipment and facilities.

Figure 10-1 | Global electricity consumption and data volume of data centres



Sources: Masanet et al. (2020), Cisco, International Energy Agency, Goldman Sachs Research

Improving the hardware and software efficiency of AI

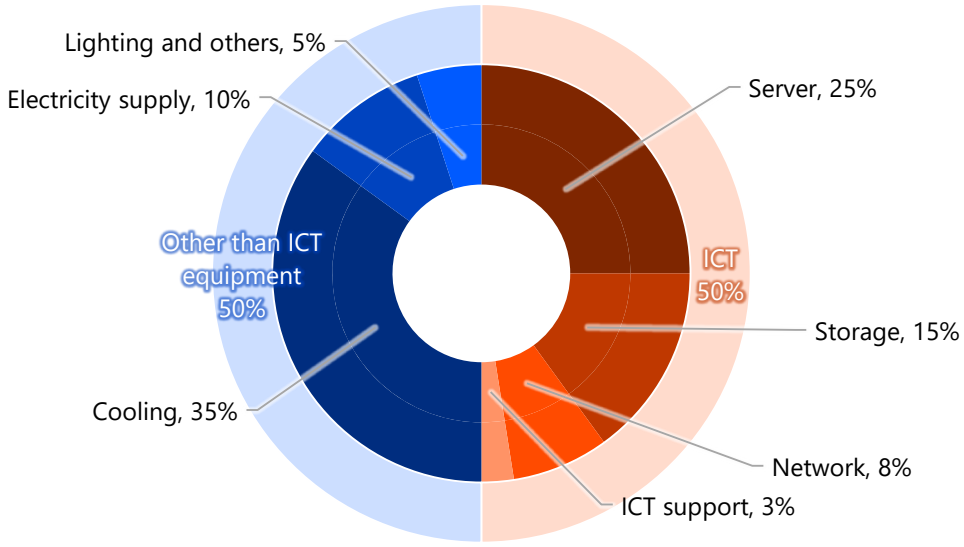
In looking at the relationship between AI and energy, it is necessary to consider both the hardware and software aspects for future efficiency improvements. Specifically, 1/ the hardware aspects represent the performance of data centre information and communication technology (ICT) equipment that conducts computational tasks, and that of auxiliary facilities such as cooling; and 2/ the software aspects include differences in electricity consumption between computational methods and improvements in the efficiency of AI models.

[52] https://www.goldmansachs.com/insights/articles/ai-to-drive-165-increase-in-data-center-power-demand-by-2030

[53] https://www.jaif.or.jp/en/news/7022#:~:text=Among%20other%20things%2C%20it%20showed,/%20floor%20area)%20as%20parameters

Data centre efficiency performance is often measured by power usage effectiveness (PUE). PUE is obtained by dividing the total electricity consumption of a data centre by the electricity consumption of its ICT equipment, and the energy efficiency is higher the closer the PUE is to 1. Data centre performance varies greatly depending on the scale, but the global average PUE is around 1.5. When PUE is 2, ICT equipment accounts for 50% of the total electricity consumption, followed by cooling, which accounts for around 35% (Figure 10-2). Often located near cities, data centres are experiencing rising ICT equipment density per rack for efficient land use. In some cases, efficiency is deteriorating due to operating air conditioners at full capacity to cool the heat emitted from ICT equipment.

Figure 10-2 | Breakdown of data centre electricity consumption (when PUE=2)



Source: Hongyu Zhu et. Al. (2023) "Future data center energy-conservation and emission-reduction technologies in the context of smart and low-carbon city construction. Sustainable Cities and Society" | VOL 89 | 2023 |

A generative AI system must conduct massive amounts of computation depending on the model (such as a large language model [LLM]) and data volume (several billion web pages). Learning is conducted over several weeks using supercomputers installed in data centres, sometimes with massive energy consumption.

According to an analysis of electricity demand for generative AI use by Dutch researcher Alex de Vries, ChatGPT may consume 564 MWh of electricity per day to operate. According to the analysis, if Google were to use AI to conduct about 9 billion searches a day, 29.2 TWh of electricity would be needed per year, which is equivalent to the annual electricity consumption of Ireland.

Meanwhile, the generative AI tool Gemini, which Google released in 2025, consumes just 0.24 Wh per prompt, which is almost the same as the electricity consumption of a common search. Considering that a generative AI search was said to be 10 times as electricity intensive as a common search, electricity savings have made rapid progress.

Table 10-1 | Relationship between data centres, AI and energy: present and future

		Present	Future
Hardware (data centre)	ICT equipment Server, storage and ICT auxiliary equipment	ICT equipment is the most electricity-intensive and accounts for 50% of the total data centre electricity consumption. Often located near cities, data centres are seeing rising ICT equipment density per rack for efficient land use. In some cases, efficiency is deteriorating due to putting air conditioners in full operation for cooling.	Optimise rack layout. Shift from company data centres to hyperscalers. Migrate to edge computing for some purposes. Optimal use of servers such as shifting from GPU to CPU. Improve the efficiency of integrated circuits and storage.
	Auxiliary facilities Cooling, backup electricity supplies, lighting, etc.	Cooling demand is rising as computation volume soars and ICT equipment density rises. Cooling-related electricity consumption accounts for around 35% of the total.	Improve efficiency by switching from air cooling to rear door cooling, liquid cooling and immersion cooling.
Software	Computation Generative AI, Data processing, Software	Computation by generative AI consumes 10 times as much electricity as common search operations. However, a search operation by the latest generative AI only consumes almost as much electricity as a common search operation.	Reduce energy demand per task through innovative algorithms. Models are 'optimised in scale' to match different tasks.

10.2 Efforts of tech firms

Hyperscalers that own many large-scale data centres necessary for using artificial intelligence (AI) are setting ambitious net-zero targets (Table 10-2). Among the efforts to reach those targets, all companies set energy efficiency improvements that directly affect operating costs as their priority and are implementing various unique initiatives.

Table 10-2 | Efforts of tech firms

Hyperscaler	Net-zero target	Efforts to achieve net-zero		
		Data centre efficiency improvement	Supply chain decarbonisation	Electricity source development and support, carbon dioxide removal (CDR)
Amazon (Amazon Web Services)	2040 (Amazon as a whole)	Improve power usage effectiveness (PUE) by introducing efficient cooling systems. Develop efficient semiconductor chips.	Use low-carbon construction materials (steel, concrete). Utilise low-carbon fuels (sustainable aviation fuels (SAFs), renewable diesel).	Invest in renewable energies; electricity purchase agreements (PPAs). PPAs with battery systems, actively utilise proprietary systems. Nuclear power generation PPAs, support for the development of small modular reactors (SMRs).
Microsoft (Microsoft Azure)	2030 (Microsoft as a whole; hourly matching)	Use of energy-saving operations such as standby mode. Develop advanced cooling technologies.	Use low-carbon construction materials (steel, concrete, wood, etc.) Utilise low-carbon fuels (SAFs, renewable diesel). Cooperation with suppliers (requiring the use of decarbonised electricity).	Invest in renewable energies; PPAs. Nuclear PPAs (including nuclear restarts). Provide support for implementing decarbonised energies using proprietary technologies.
Google (Google Cloud Platform)	2030 (Google as a whole; hourly matching)	Optimise cooling systems by utilising machine learning. DR through task shifting. Optimise data centre design.	Cooperation with suppliers (requiring the use of decarbonised electricity). Utilise low-carbon construction materials.	Invest in renewable energies; PPAs. Provide support for implementation of decarbonised energies using proprietary technologies.
Meta	2030	Monitor workload and optimise electricity profile. Highly energy-efficient hardware design. Improve cooling efficiency using outdoor air and direct evaporative cooling.	Cooperation with suppliers (aim to have at least two-thirds of all suppliers set emission targets by 2026). Utilise decarbonised fuels (SAFs, biofuels)	Invest in renewable energies and batteries; PPAs. Provide support for developing CDR technologies.

Efforts to achieve net-zero (cross-company efforts)

iMasons Climate Accord (ICA): a framework to decarbonise the digital infrastructure run by industrial group iMasons, which consists of digital infrastructure firms, mainly big tech firms.

Semiconductor Climate Consortium (SCC): a framework for decarbonising the semiconductor industry.

ZEROgrid: A framework consisting mainly of large-scale users to decarbonise electricity grids and improve their reliability.

To lower the power usage effectiveness (PUE) by improving the efficiency of non-information and communication technology (ICT) equipment such as cooling systems and the facilities as a whole, efforts to raise operating temperatures to reduce the amount of necessary cooling are in progress, alongside efforts to improve cooling systems using innovative technologies and AI. Improvements in data centre efficiency through data centre design optimisation, strengthened workload monitoring, and AI utilisation are also underway. In addition, measures to improve data centre flexibility, such as task shifting, though not directly linked to improving the energy intensity, are receiving attention as they contribute to demand response (in which electricity consumption is adjusted depending on the balance between grid electricity supply and demand), and in turn help decarbonise the grid.

To improve the efficiency of central processing units (CPUs), graphics processing units (GPUs) and other ICT equipment that perform computations, alongside efforts such as offloading CPU computations and energy-saving operations such as a standby mode, big tech companies are developing their own AI-specific semiconductor chips, such as Amazon Web Services' Trainium, Google's TPU, Meta's MTIA and Microsoft's Maia 100.

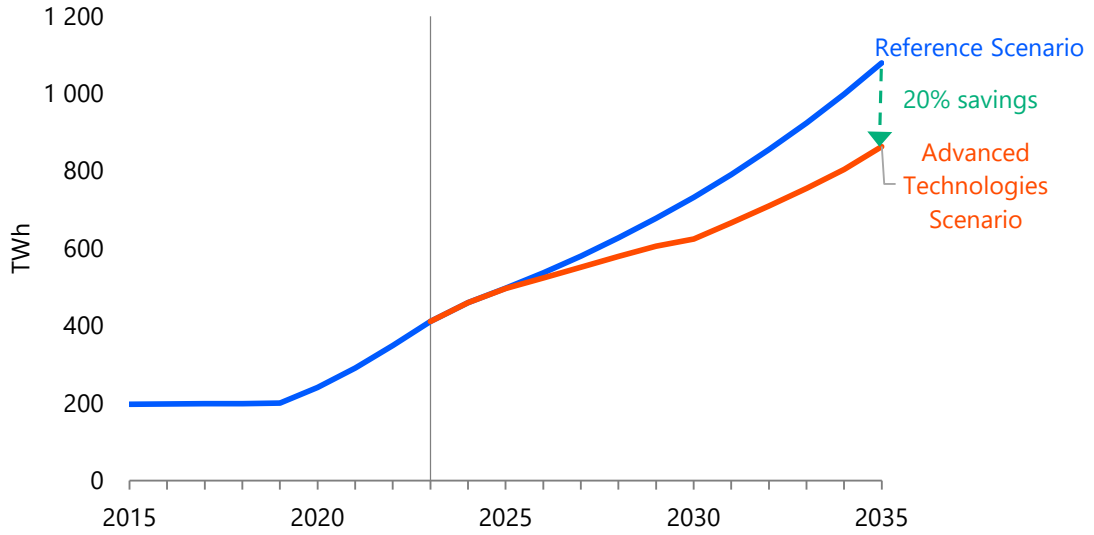
10.3 Electricity demand and energy savings potential of data centres

Based on the Reference Scenario, the electricity demand of data centres worldwide will increase by 2.1 times from 497 TWh in 2025 to 1 080 TWh in 2035 (Figure 10-3). The amount of data will grow by 2.9 times from 230 zettabytes (ZB) to 660 ZB in the same period.

The growth is driven by electricity consumption for artificial intelligence (AI) computations at data centres, which will double from the current 14% to 30% of the data centre total in 2035. Meanwhile, the pace of increase in data centre electricity consumption will ease somewhat from 17.5% per year in 2020–2024 to 8.1% in 2025–2035. Recently, electricity consumption soared as AI learned new data from scratch over weeks for large language models. However, as AI systems will learn more efficiently by shifting to differential learning and only learning updates, or by updating only some parameters, the increase in data centre electricity consumption is expected to ease in the future.

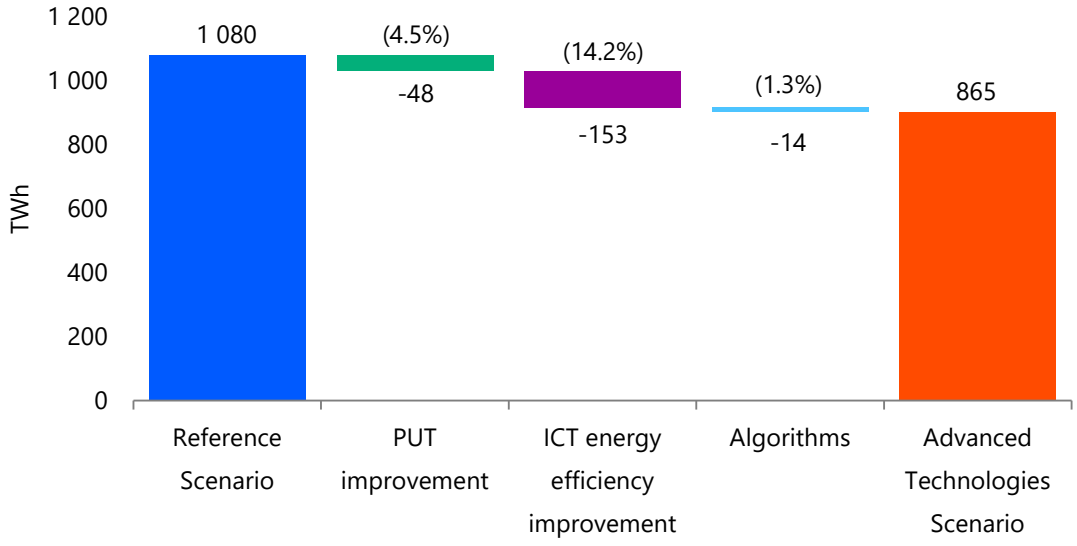
Based on the Advanced Technologies Scenario, data centre electricity consumption will be 20% lower than that of the Reference Scenario in 2035. This saving is due to improvements in power usage effectiveness (PUE) through the introduction of high-efficiency cooling technologies in new data centres, and improvements in the efficiency of information and communication technology (ICT) equipment and computations.

Figure 10-3 | Electricity demand and energy savings potential of data centres



The current average global PUE of data centres is estimated to be 1.5. This will improve to 1.38 in 2035 based on the Reference Scenario, and further to 1.28 based on the Advanced Technologies Scenario thanks to the wider adoption of liquid cooling and immersion cooling (an electricity saving of 4.5% from the Reference Scenario). ICT has an even greater energy savings potential, and the Advanced Technologies Scenario can save 14.2% more electricity than the Reference Scenario. Efficiency is improved by various technological factors such as more efficient central processing units (CPUs) and graphics processing units (GPUs), non-von Neumann computers, more efficient storage equipment, shorter transmission pathways between memory and processors, and the replacement of some volatile memory functions with non-volatile memory (that can retain data when electricity is cut off).

Figure 10-4 | Electricity demand and energy savings potential of data centres (comparison with the Reference Scenario) [Advanced Technologies Scenario, 2035]



An electricity saving of about 1.3% can be expected from improvements in computation efficiency (by 2035). The number of searches by generative AI is expected to more than double by 2035 from the current 3 trillion searches a year, but higher-efficiency models are likely to be adopted to some extent.

10.4 Energy saving using artificial intelligence (current state analysis)

Overview

There are concerns that the widespread use of artificial intelligence (AI) will drive up data centre electricity consumption and trigger national, regional and local electricity supply shortages. Meanwhile, AI is also expected to bring various benefits to the energy sector, such as an expanded use of renewables through weather forecasts, optimal electricity grid operation, energy savings and efficiency improvements in other demand sectors and the development of new materials. As demand sectors have greater energy consumption than data centres, the application of AI to these sectors can result in greater net energy savings overall.

AI can play various roles in the demand sectors. These roles can be summarised based on four keywords: 'detection', 'prediction', 'simulation' and 'optimisation'.

One possible application is to optimise the processes from sourcing to production, not for one manufacturing plant but for the whole company or even several companies, thus optimising and planning the production for the entire supply chain. Weather forecasting by electricity retailers and the optimal supply of renewable energy have been put into practice. It is also possible to guide users to control the timing of heat storage by heat pumps and the discharge of electric vehicles (EVs) to match the supply of variable renewable electricity.

The following sections focus on AI's contribution to energy savings in each sector, provide an overview of its roles, discuss the potential and challenges, and forecast the future.

Industry

The use of AI technology is already underway in the industry sector for applications such as failure detection, production management and demand forecasting. For example, it can forecast optimal production capacity while allowing for demand fluctuations and optimise energy consumption across entire supply chains.

AI also plays an essential role in energy saving. It can produce additional energy savings of a few percent in the industry sector without special facility upgrades. Facility upgrades are needed, however, if further energy savings are to be explored. The industry sector is a so-called 'hard-to-abate' sector, and even a contribution of a few percent from AI would be valuable for reducing remaining heat demand, as well as supporting electrification.

Conventional digital control was performed based on the difference between the target and actual values. For example, when controlling the heat temperature in a factory, control operations stop when a target temperature is reached. This causes a gradual deviation from the target temperature over time and the need for a correction.

Figure 10-5 | Energy saving using AI in the industry sector

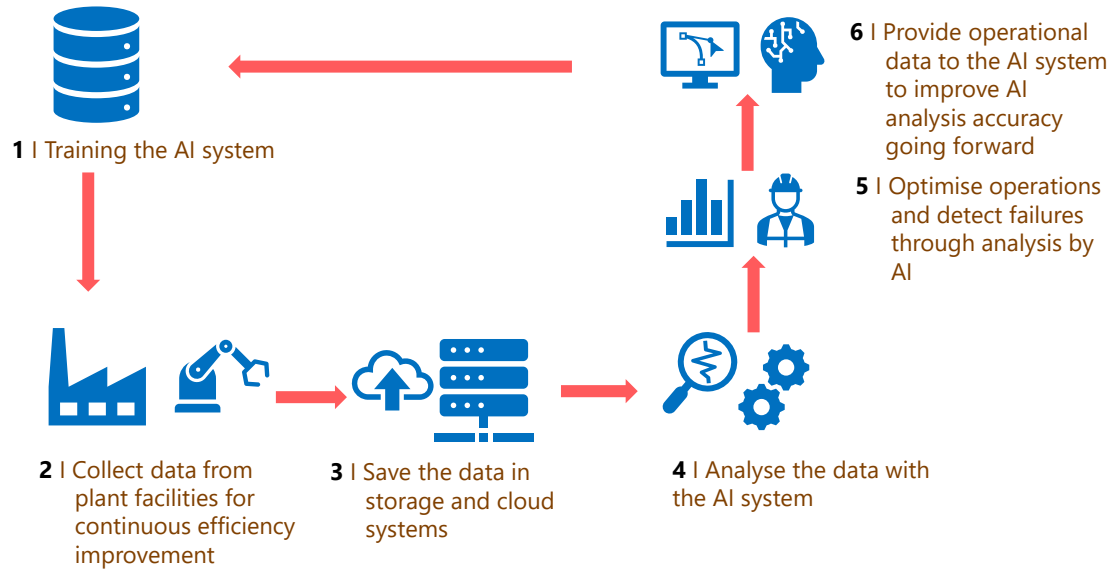
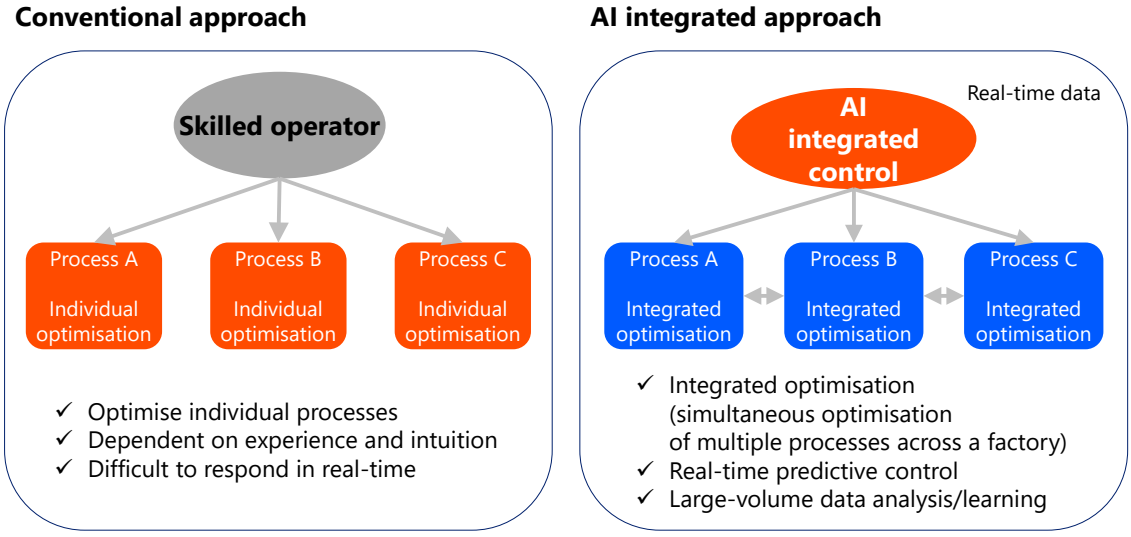


Figure 10-6 | Energy saving in the industry sector: Comparison between the conventional approach and AI integration approach



AI control learns from past operational data and performs a control operation before a deviation occurs. For heat temperature control, once the target temperature is reached, control is performed focusing on 'what kind of control is needed to avoid deviating from the target value'.

AI can achieve greater energy savings as it is capable of not only optimising the operations of a single facility but also optimising multiple processes simultaneously across a factory, performing dynamic control based on real-time forecasts, deriving optimal solutions from large amounts of data, and coordinating approaches among several factories.

One example of energy saving using AI is the case of Toshiba. There are multiple boilers, turbines, generators and chillers operating in one factory, and it is necessary to supply electricity, steam and cold and hot water. Toshiba provides a digital platform for optimising plant operations and

minimising costs by using a mathematical model, which is built based on demand forecasts generated by AI using outdoor temperatures and production plans[54].

Azbil Corporation provides technologies for updating models for factory control[55]. The accuracy of advanced factory control depends on how accurately plant operations are modelled. Meanwhile, a model's error can widen after implementation due to changes in the plant's operational characteristics, such as ageing, facility repairs and modifications, and can affect the model's performance related to control and optimal operation. The company provides technologies for updating models so that models remain up to date with changes in the plant.

Iron and steel

The iron and steel industry is an energy-intensive sector that accounts for 8% of the world's final energy consumption and 7% of the carbon dioxide (CO_2) emissions of the energy sector, and its production processes are hard to decarbonise[56]. By collecting and analysing data using AI, benefits can be expected, including improving product quality, reducing raw material costs and enabling preventive maintenance of equipment, which in turn leads to reduced energy use and lower CO_2 emissions, as well as improving production efficiency.

The major European steel company ArcelorMittal is working on saving energy at its plants using Energiency's industrial energy performance software. This software platform evaluates the energy performance of plants in real-time using AI algorithms. With the help of Energiency, Luxembourg's Belval plant has reduced its energy consumption by 9 GWh, saving 150 000 euros or over 3% in electricity tariffs[57]. Belgium's Geel plant is also aiming to cut its annual energy consumption by at least 5%[58].

Japan's JFE Steel has built a cyber-physical system (CPS) that reproduces the status of the steel mills' blast furnaces in virtual space. CPS visualises the status of blast furnaces using real-time image data from inside the furnaces, in addition to temperature and pressure data collected with sensors. Optimal controls are performed by forecasting the future using AI and conducting analysis with various models[59]. Digital twin technology is a core component of CPS and is being used to optimise incineration in parts of the furnaces. This technology has been implemented at the company's West Japan Works and has reduced fuel use by 5% and CO_2 emissions by 6 600 t/year compared with previous levels[60].

Cement

The cement industry is an energy-intensive sector that accounts for 8% of the global CO_2 emissions and 4.5% those of Japan[61]. The uses of AI related to cement proposed to date include

[54] "Optimisation of private power generation facilities": Toshiba Energy Systems & Solutions Corporation (2021) https://www.global.toshiba/jp/company/energy/topics/digital-transformation/dx008-210324.html

[55] "Plant model automatic update technology using parameter probability distribution": Azbil Corporation, https://www.azbil.com/jp/corporate/pr/library/review/pdf/Review2025_05.pdf

[56] https://www.iea.org/reports/iron-and-steel-technology-roadmap, https://unece.org/climate-change/press/cop27-un-report-shows-pathways-carbon-neutrality-energy-intensive-steel

[57] https://innoenergy.com/uploads/2023/01/success-story-arcelormittal-energiency-eng.pdf

[58] https://belgium.arcelormittal.com/en/arcelormittal-chooses-energiencys-artificial-intelligence-to-save-energy-in-steel-coils-processing/

[59] https://www.jfe-steel.co.jp/products/solution/data-science/01-blast-furnace.html

[60] https://www.jfe-steel.co.jp/release/2023/07/230710.html

[61] Takafumi Noguchi 'The Challenge of Concrete for Achieving Carbon Neutrality by 2050', Japan Institute of Country-ology and Engineering, September 2022

heat optimisation using sensors during clinker production[62] and optimising concrete mixes (ratio of cement, sand, water, fly ash, etc.)[63].

Carbon Re, a venture from Cambridge University, is optimising the heat of plant operations during clinker production. The company creates a high-accuracy digital twin based on cement plant operation data to realise real-time process optimisation and reduce fuel use in the preheater and kiln (baking) processes. The digital twin technology can be added to existing plants and can be linked with advanced process control (APC) systems such as ABB's Expert Optimizer and FLSmidth's ECS/ProcessExpert, allowing operations to be adjusted automatically by AI. The Mokra plant of Heidelberg Materials has reduced its energy-related CO2 emissions by 2% by introducing this AI on a trial basis.

Paper

The paper industry mainly produces paper and paperboard using wood (pulp) and recycled paper as raw materials and is an energy-intensive sector that requires large amounts of electricity and heat from steam during the manufacturing process. The manufacturing process is divided into the pulping process for producing the raw materials and the papermaking process, in which pulp is processed into paper.

Paper and paperboard production requires substantial amounts of steam heat and electricity. Paper mills around the world are starting to introduce AI to reduce energy consumption and CO_2 emissions. AI is expected to be used in a variety of areas such as improving the efficiency of drying processes, optimising shipping plans for raw material purchases and predictive maintenance.

One best-practice example in the paper industry shows that electricity costs were cut by 5% per year and CO_2 emissions by 20 kt by switching to load-levelling operations suggested by AI[64].

Chemicals

The chemicals industry is divided largely into the petrochemical, polymer chemical and inorganic chemical industries. Among these, the petrochemical industry is particularly energy-intensive, as it involves high-temperature processes such as thermal cracking using naphtha obtained from crude oil as feedstock. Energy consumption in chemical processes occurs mainly in the reaction (such as thermal decomposition), separation and purification (such as distillation), drying and concentration, transport and mixing and other processes (such as auxiliary facilities), and the reaction and separation and purification processes are particularly energy-intensive. For example, the decomposition furnace, which is the core facility of an ethylene plant, accounts for the majority of the total energy consumption[65, 66].

In the petrochemical industry, energy-saving initiatives including catalyst improvements to increase low-temperature activity and selectivity, waste heat recovery and reuse, heat integration, and high-efficiency furnaces and distillation columns have been implemented. Previously, operations used to be based mainly on static optimisation assuming an as-designed, steady state and rely on the experience and knowledge of skilled operators. However, combining operations

[62] Carbon Re, https://carbonre.com/. Retrieved 19 August 2025
[63] Meta, 16 July 2025. https://engineering.fb.com/2025/07/16/data-center-engineering/ai-make-lower-carbon-faster-curing-concrete/
[64] https://newji.ai/supplier/manufacturing-industry/paper-industry-dx-strategies-and-ai-iot-application-examples/
[65] https://research-portal.uu.nl/files/691692/NWS-E-2006-3.pdf
[66] https://www.sciencedirect.com/science/article/abs/pii/S0360544218309083

with AI has made possible an integrated approach that can optimise multiple processes simultaneously across a factory, dynamic control based on real-time forecasting and data-driven operation that derives the optimal solution from vast amounts of data, raising the likelihood of simultaneously achieving stable quality and higher yield while saving energy.

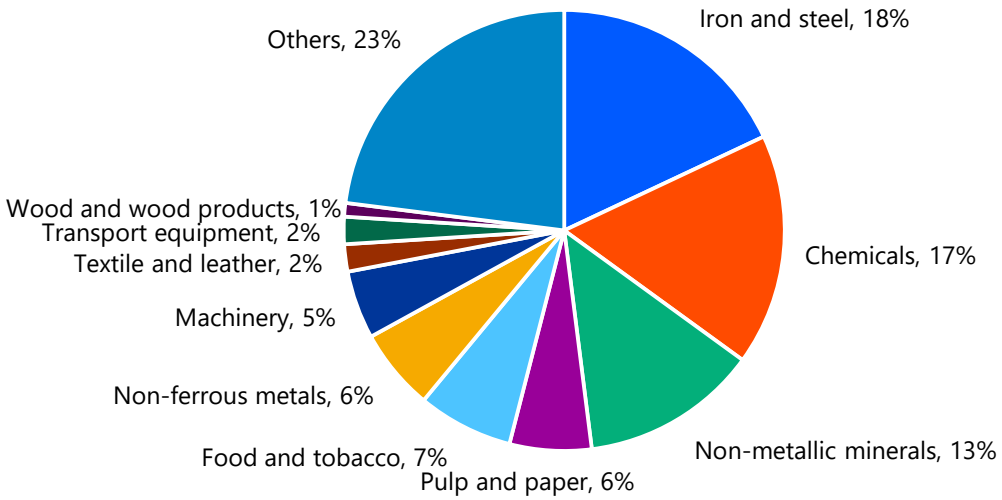
Published case studies report energy savings of a few percent [67] through unit-to-plant optimisation, with certain units (such as rotary kilns) indicating savings in the high double digits (for example, 4%[68] fuel savings for chemical manufacturers and 15%–30%[69] fuel savings for rotary kilns). However, the effect varies significantly depending on the scope of introduction, operational conditions, and the baseline. While this is a limited case, a petrochemical ethylene plant has reported a 40% reduction in fuel consumption through visualisation and optimal control achieved by combining internet of things (IoT) sensors with AI[70].

Other industries

So far, we have discussed energy-intensive industries such as steel, cement, paper and petrochemicals. Meanwhile, there are also other industries that consume significant amounts of energy. Among such industries are food and tobacco, non-ferrous metals and machinery manufacturing[71].

In the final energy consumption of the manufacturing sector, electricity accounts for 30%, while heat and other uses account for 70%[72].

Figure 10-7 | Final energy consumption of the global manufacturing sector



Source: International Energy Agency (2024) "World Energy Balances"

[67] https://www.mckinsey.com/industries/metals-and-mining/our-insights/the-potential-of-advanced-process-controls-in-energy-and-materials
[68] https://c3.ai/wp-content/uploads/2024/05/C3-AI-Case-Study-Chemical-Manufacturer-Energy-Efficiency.pdf
[69] https://imubit.com/oxbow-case-study/
[70] Yokogawa Electric Corporation, https://www.yokogawa.co.jp/news/press-releases/2023/2023-03-30-ja/
[71] International Energy Agency (2024) "World Energy Balances"
[72] International Energy Agency (2024) "World Energy Balances"

As an example of the energy-saving effects of AI utilisation in factories, Yokogawa Electric reduced energy consumption by 3.3%. This was done by using a manufacturing data analysis AI to establish energy-saving metrics, then combining these with a general-purpose AI that performs optimisation and control[73]. Fuji Electric states that by utilising AI to optimise the operation of electricity and heat supply equipment, energy savings of 5% to 7% can be expected[74, 75]. Similar initiatives are underway at overseas companies; Schneider Electric Industries SAS says that by employing AI for analysis and proposal generation, energy consumption in the utilities sector can be reduced by 10% to 15%[76].

Residential

Energy savings using AI are achieved in the residential sector by having AI learn and analyse each household's energy usage patterns and human activity levels, so that appliances and devices can operate with optimal energy efficiency. By using AI controls to conduct upward and downward demand response (DR) based on the electricity prices and the share of renewable electricity sources, it is possible to use the resources within the residential sector as grid-balancing capacities. Various cases of AI use in the residential sector include savings of 14% for air conditioning[77], 15% to 35% for water heating[78] and 21% for washing and drying[79].

[73] Agency for Natural Resources and Energy (Yokogawa Digital Corporation), "The hearing materials in Document 4 for the 48th Energy Efficiency and Conservation Subcommittee of the Committee on Energy Efficiency and Renewable Energy, Advisory Committee for Natural Resources and Energy", https://www.meti.go.jp/shingikai/enecho/shoene_shinene/sho_energy/pdf/048_04_00.pdf

[74] Kyushu Renewable Energy and Environmental Industry Promotion Association (2024), "148th Eco School: Energy-saving solutions that create competitiveness: Introducing an energy management system that utilises DX and AI technologies (Fuji Electric Co., Ltd.)", https://k-rip.gr.jp/wp/wp-content/uploads/2024/06/3e78a0a6d967afb90ef0174efdcd55c7.pdf

[75] Fuji Electric Co., Ltd., "AI Technology Solutions List", https://www.fujielectric.co.jp/products/blue_navigation/energy_conservation/solution_list_energy_conservation_ai.html

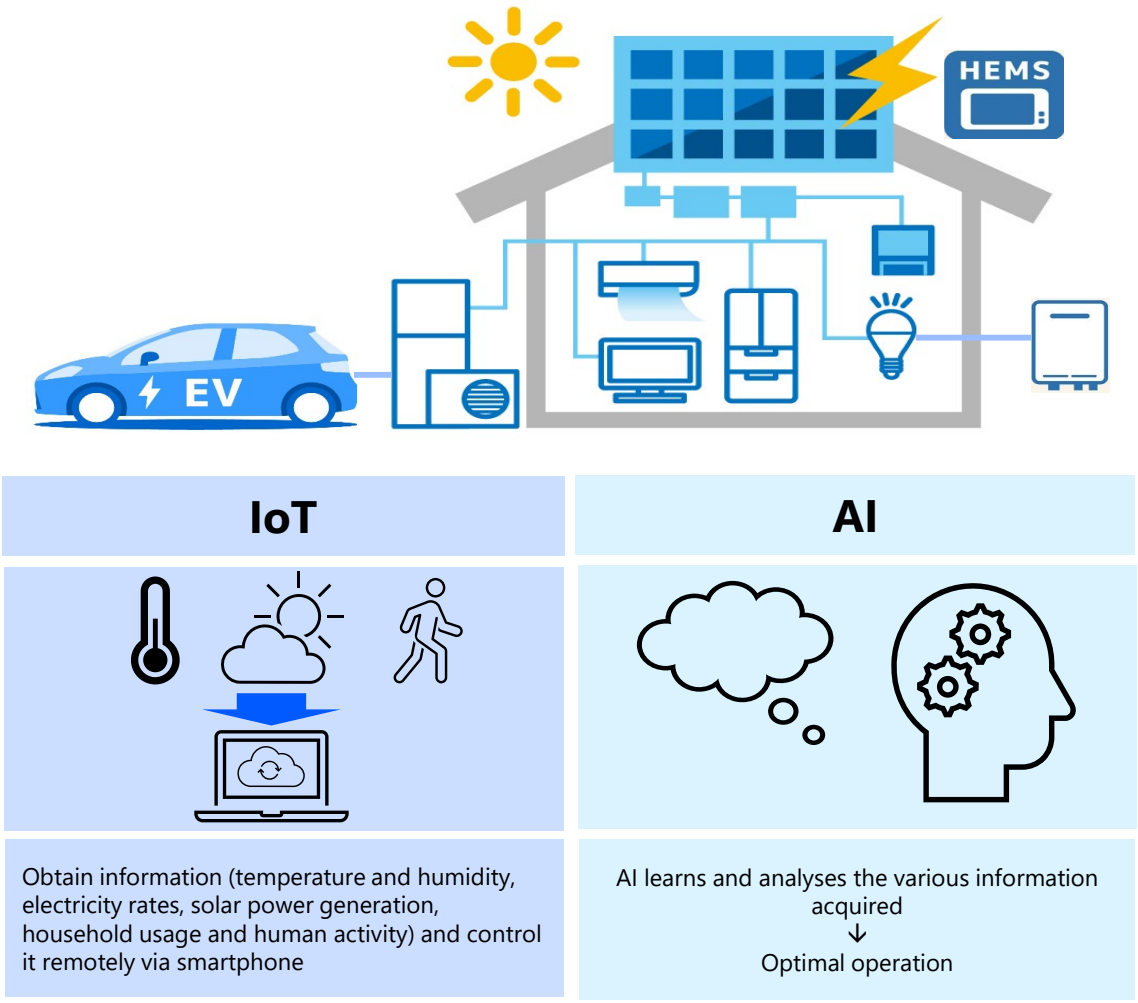
[76] Schneider Electric Industries SAS (2024) "EcoStruxureTM Industrial Advisor - Predictive Energy", https://download.schneider-electric.com/files?p_Doc_Ref=PEB_99823549329&p_enDocType=Brochure&p_File_Name=EcoStruxure+Industrial+Advisor+-+Predictive+Energy+e-brochure.pdf

[77] When comparing the power consumption of Sharp air conditioners with and without AIoT control. Sharp Corporation 'More energy savings with AIoT!' https://jp.sharp/aircon/aiot-saving/ (Accessed on 13 August 2025)

[78] Case studies featuring Panasonic's AI EcoNavi-equipped water heaters and wood pellet water heaters from ÖkoFEN (Austria). 'AI EcoNavi' by Panasonic https://sumai.panasonic.jp/hp/2point/2_11.html (Accessed on 13 August 2025), ÖkoFEN (2025) "Product catalogue pellet heating" https://www.oekofen.com/assets/download/DeutschMA/Drucksorten/Drucksorten_aktuell_EN/oekofen_catalogue_pellets_2025.pdf (Accessed on 13 August 2025)

[79] Case studies featuring Panasonic's AI EcoNavi-equipped washing machine. 'AI EcoNavi' by Panasonic https://panasonic.jp/wash/feature/LX/econavi.html (Accessed on 13 August 2025)

Figure 10-8 | An illustrative example of AI-driven energy savings in the residential sector



With air conditioners, AI assesses factors such as lifestyle and ambient temperature to automatically regulate settings, maintaining comfort while achieving energy savings. For instance, by learning the time to wake up or to come home, as well as the room thermal characteristics, the air conditioner learns to start up gradually, reducing the electricity consumption during startup. It can also reduce electricity consumption by automatically adjusting the temperature based on when occupants are leaving the house and proactively controlling the temperature based on weather information collected by AI. These AI-based controls reduce electricity consumption by 14% compared to systems without AI.

For water heaters, energy can be saved mainly by detecting people entering and leaving the bathroom when the bath is in automatic reheating mode and by reducing the energy consumption for automatic reheating when no one is bathing. Furthermore, by learning bathing patterns, AI can heat bath water at the optimal time. This can save energy by up to 35% compared with systems without AI.

Washing machines and laundry dryers can save energy by having AI determine the optimal operating conditions based on the water temperature, load size and fabric type detected by sensors. For instance, when the water temperature is high or the load size is small, the washing

time is automatically shortened to save energy. When drying, the drying time is reduced to save electricity when there are many items that dry quickly. There are reports that AI control has reduced electricity consumption by up to 8% for washing alone and by up to 21% for the combined washing and drying cycle.

AI can be utilised not only in individual appliances but also in Home Energy Management Systems (HEMS) to reduce energy consumption. This mechanism involves using AI to predict solar photovoltaic power generation and electricity usage, control appliances within the home, and thereby reduce electricity consumption.

By connecting to the internet, IoT appliances support functions such as remote on/off switching via smartphone, remote monitoring of usage status and operation according to preset schedules, temperatures and other parameters. AI-equipped appliances learn from collected data and optimise operations more autonomously.

For example, they can perform more precise control by collecting past usage data using the sensors in the IoT appliances, transferring the data to the cloud or servers for storage, and then having AI learn and analyse this data by cross-referencing it with weather data and other information.

However, while these AI-equipped appliances and devices are technically capable of saving energy, their widespread adoption remains a challenge. AI-equipped devices tend to be more expensive than conventional products, which can be a barrier to adoption.

Commercial

Energy conservation in the commercial sector primarily focuses on improving the efficiency of installed equipment, and the energy savings effect can be limited depending on the actual operating conditions after installation. However, a combination of factors, including recent progress in AI technology, the falling costs of networked sensors and cloud computing, and innovations in construction and building materials, could drive a significant improvement in energy conservation in the commercial sector.

Energy efficiency in the commercial sector should be approached in stages. First, at the building design stage, with AI technology, it will be possible to utilise large amounts of historical data to create more efficient designs, beyond just fulfilling the current energy efficiency standards. At the operation stage, it will be possible to optimise lighting, air conditioning and power control using data on the flow of people and the weather collected via sensors, and to simultaneously achieve efficient energy use and comfort for the whole building. Furthermore, through integration with the surrounding buildings, energy savings can be expected at the community level.

There are several instances of AI-driven energy-saving initiatives like these. First, Daikin Industries implemented an initiative in which it used a Building Energy Management System (BEMS) to visualise the energy usage of a Yamaha office building, and it then used AI to analyse the accumulated data and save energy by 21% through optimisation[80]. In a similar example, NTT

[80] Daikin Industries (2025) "Achieving energy savings in air conditioning through artificial intelligence (AI) | Automatic energy tuning using heat load prediction" https://www.daikin.co.jp/tic/topics/feature/2025/20250507#:~:text=%E2%80%95%E2%80%95%E3%83%A4%E3%83%9E%E3%83%8F%E6%A7%98%E3%81%A7%E3%81%AF21%EF%BC%85%E3%80%81BMW%EF%BC%88%E3%82%BF%E3%82%A4%EF%BC%89%E6%A7%98%E3%81%A7%E3%81%AF16%EF%BC%85%E3%81%AE%E7%9C%81%E3%82%A8%E3%83%8D%E6%80%A7%E8%83%BD%E3%82%92%20%E7%99%BA%E6%8F%AE (Accessed on 13 August 2025)

Data (2025) applied NTT's computing technology for optimal air conditioning control scenarios to the office lobby of JR Shinjuku Miraina Tower and demonstrated a 50% reduction in energy consumption in the summer[81]. Additionally, Zhao et al. (2023) have demonstrated that the winter heating energy consumption of the Osaka University campus can be reduced by at least 30% through automatic air-conditioning control using AI. Similarly, outside of Japan, Vattenfall (2023) has demonstrated a 30% reduction in the energy consumption of residential buildings by using AI to analyse their energy consumption and optimise their operation[82].

Even when a building energy-saving plan is created, it is difficult to adjust the discrepancy between the target and actual results daily. Mitsubishi Electric's system uses AI-based control to achieve planned targets, saving energy without the involvement of building managers[83]. The key point of this system is that it uses machine learning to analyse the incoming electricity and energy demand patterns for air conditioning, estimate energy-saving effects, and on that basis, sets targets and manages energy savings.

Even with AI control, results for air-conditioning temperature can deviate from targets depending on weather conditions; any such deviations are carried over to the next day's target to achieve annual performance targets. Compared with the electricity consumption of the previous year, energy savings of 1% to 5% have been achieved.

AI control can contribute to the energy management of not only individual buildings but also entire regions. Taisei Corporation is developing a cloud-based Community Energy Management System (CEMS)[84]. In this system, AI creates optimal operation plans based on weather forecasts, building usage and past operational data. The system is deployed through the installation of data collection devices in buildings. Furthermore, because it can control multiple buildings, it can be used not only to save energy but also as a grid-balancing capacity, such as by shifting demand to another building depending on the grid's supply-demand balance.

Meanwhile, digitising buildings for higher efficiency may not produce results that match the anticipated savings potential because of the installation of numerous networked sensors, higher on-site energy consumption for processing the collected data, or increased demand for data centres. Responses to possible sensor failures and events such as electricity outages must also be considered.

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[81] NTT DATA Japan Corporation (2021) "Demonstrating the simultaneous achievement of energy savings and comfortable environments through feedforward AI air conditioning control using small-scale learning" https://www.nttdata.com/global/ja/news/release/2021/110100/ (Accessed on 13 August 2025)

[82] Vattenfall (2023) "Yes, AI will improve energy efficiency—Essentially all buildings can benefit from this technology" https://group.vattenfall.com/press-and-media/newsroom/2023/yes-ai-will-improve-energy-efficiency--essentially-all-buildings-can-benefit-from-this-technology#:~:text=The%20properties%27%20heating%20system%20is,total%20of%20about%2030%20percent (Accessed on 13 August 2025)
https://www.taisei.co.jp/about_us/wn/2025/250711_10553.html

[83] Mitsubishi Electric Corporation (2023) 'An automated energy-saving solution for building air-conditioning systems "Smart Energy-Saving Assist"'
https://www.giho.mitsubishielectric.co.jp/giho/pdf/2023/2311106.pdf

[84] "Japan's first introduction of cloud-based CEMS utilising AI in an existing high-rise complex.": Taisei Corporation (2025)

Transport

Road

One area where AI can improve energy efficiency in road transport is the optimisation of services such as parcel delivery, where large volumes of packages are delivered using numerous trucks. The issue is route optimisation, in other words, how multiple delivery operations should be connected and what routes should be taken to maximise energy efficiency for delivering packages from an unspecified number of senders to their respective receivers. This is a complex problem, particularly in urban areas with well-developed road networks, where numerous options exist; using AI increases the likelihood of selecting a better route. By considering factors such as traffic congestion predictions, in addition to the length and slope of the road and the speed limit, an optimal route with a greater energy-saving impact can be selected. Such efforts to use AI to improve the efficiency of truck transport networks are already underway in Japan by Yamato Transport[85] and other companies.

Furthermore, for long-distance truck transport, fuel consumption is an issue not only during delivery but also when empty trucks travel after delivery. For higher energy efficiency, it is desirable for trucks to carry loads on both outbound and return trips, to reduce the number of empty trucks and increase delivery efficiency. Energy efficiency can also be improved by loading as many packages as possible to minimise empty spaces in the loading compartment while trucks are in transit. It is desirable to combine multiple delivery jobs with overlapping or nearby delivery routes and transport them together on a single truck. Such energy-saving efforts are already underway at companies such as Kao[86] and Lion[87]. In addition, the New Energy and Industrial Technology Development Organization (NEDO) is working on a programme called 'Program to Develop and Promote the Commercialization of Energy Conservation Technologies to Realize a Decarbonized Society', in which the Air Business Club and the University of Shiga Prefecture are studying ways to improve transportation efficiency using AI, including mixed-load trucks[88].

The above are examples related to planning freight transport, but AI can also optimise the operation of individual vehicles, that is, enabling eco-driving. For example, new types of 'connected and automated vehicles' (CAVs) that can communicate with surrounding vehicles and nearby traffic lights are being proposed and considered. CAVs monitor the surrounding road conditions through communications and use this information to optimise their driving speed and adjust the electricity distribution of their drivetrain (for example, adjusting the balance between the engine and motor). This reduces energy consumption and achieves eco-driving. Not all control technologies installed in CAVs are AI applications, but the knowledge and algorithms obtained through machine learning are expected to be useful, for example, when incorporating traffic light conditions into vehicle control[89].

[85] Yamato Transport Co., Ltd., https://www.yamato-hd.co.jp/news/2021/newsrelease_20210803_1.html
[86] Kao Corporation, https://www.kao.com/jp/newsroom/news/release/2025/20250122-001/
[87] Lion Corporation, https://doc.lion.co.jp/uploads/tmg_block_page_image/file/10377/20241225_02.pdf
[88] NEDO, https://www.nedo.go.jp/koubo/DA3_100318.html
[89] Paper on CAV, https://doi.org/10.1016/j.rser.2023.114025

Table 10-3 | Energy saving in the road sector using AI

Purpose	Energy conservation through AI in the road sector
Demand forecast	The loading efficiency and passenger efficiency of cargo trucks, taxis, etc. are improved based on weather and traffic information.
Route decision	Through machine learning, AI suggests optimal routes considering the driver's travel preferences and, for cargo trucks, delivery efficiency.
Maintain distance between vehicles	By keeping a constant distance between vehicles through autonomous driving, vehicles can move without congestion, improving fuel efficiency. Platooning also reduces air resistance, contributing to improved fuel efficiency.

Aviation, shipping and railways

Air, sea and rail transport face challenges similar to road transport. First, they must reduce the energy consumption of aircraft, ships and vehicles during flight, navigation and operation—in other words, optimise their operation, akin to eco-driving in automobiles. Furthermore, airlines and shipping companies with large fleets operating air and sea transport networks need to combine operations and develop plans for efficient transport across multiple airports and ports. This problem is structurally similar to that of vehicle transport, and AI is expected to improve efficiency. In fact, in the aviation industry, Alaska Airlines is using AI to optimise flight routes[90], and in the shipping industry, Cosmo Oil is using AI to plan domestic vessel allocations, reducing fuel consumption[91].

10.5 Scenario analysis related to energy savings using artificial intelligence

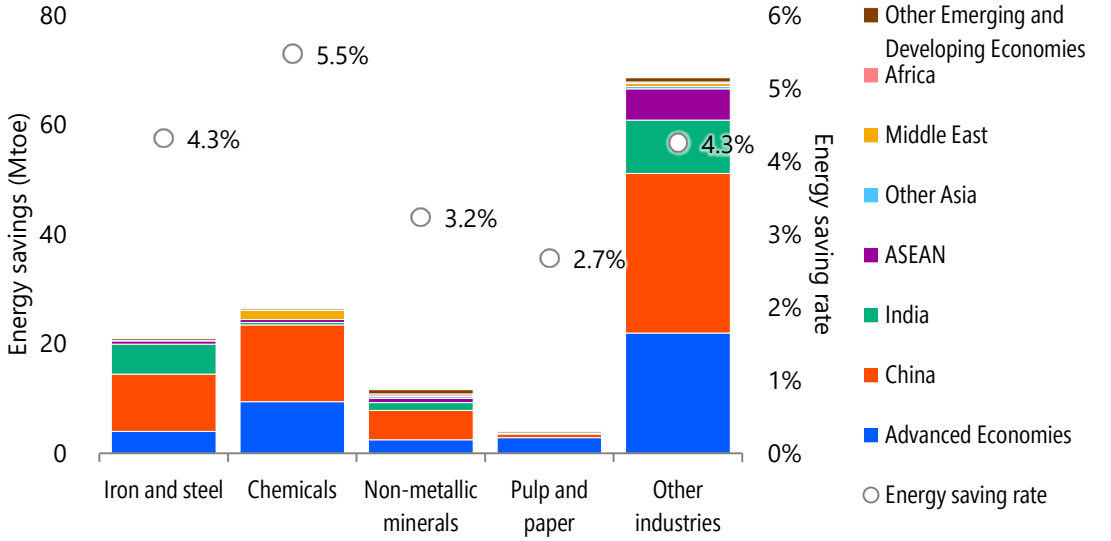
Energy savings potential of artificial intelligence in the industry sector

The energy savings potential of artificial intelligence (AI) in the industry sector will be equivalent to 2% to 6% under the Advanced Technologies Scenario in 2035 (Figure 10-9). In the short to medium term (2025 to 2035), the introduction of AI will be primarily focused on retrofitting existing facilities to optimise operations and improve efficiency.

By industry, the energy savings in the chemical industry will be the largest at 26 Mtoe, followed by the steel, cement and paper industries at 21 Mtoe, 11.5 Mtoe and 4 Mtoe, respectively. In addition to these, there will be a 68 Mtoe effect in non-energy-intensive industries such as the machinery industry.

[90] Alaska Airlines, https://www.alaskakouku.com/2021/06/airspace-intelligenceai.html
[91] Cosmo Oil Co., Ltd., https://www.cosmo-energy.co.jp/ja/information/press/2025/250415-01.html

Figure 10-9 | Energy savings potential of using AI in the industry sector (compared with the Advanced Technologies Scenario) [2035]



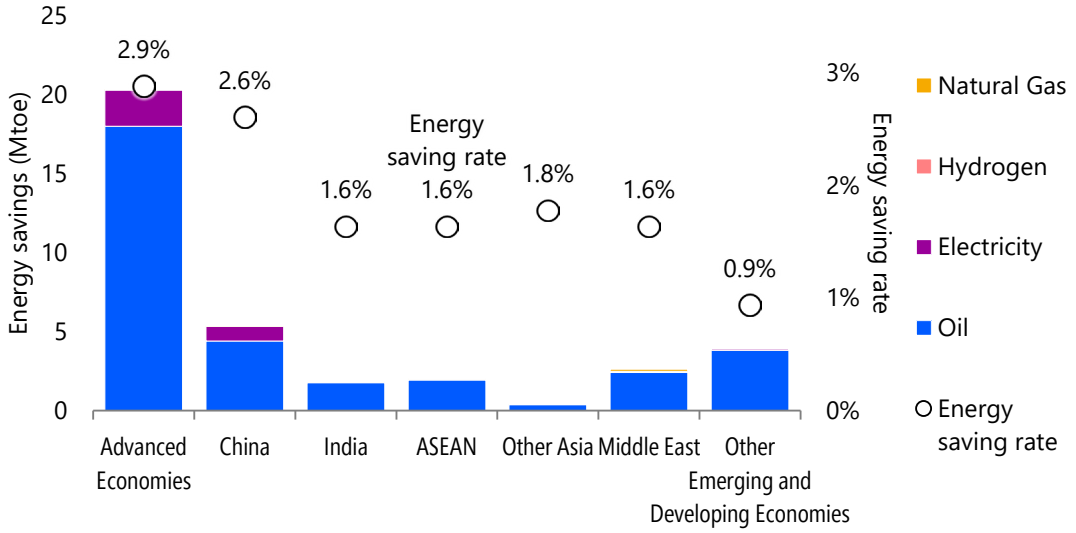
By region, AI will be adopted from early on in the Organisation for Economic Co-operation and Development (OECD) countries thanks to their abundant capital and digital infrastructure. China will see a high rate of AI adoption from the early stages, driven by its national strategy to actively promote digitalisation, as well as new builds and large-scale expansions. India, the Association of Southeast Asian Nations (ASEAN), other Asian countries, Africa and other Emerging and Developing Economies will initially lag behind, but adoption will accelerate due to rapid industrial development and the need to improve cost competitiveness. From 2035 onwards, they are expected to benefit from their late-comer advantage and introduce the latest AI more efficiently when expanding facilities or building new ones.

Energy savings potential of AI for road transport

The energy savings achieved by autonomous driving using AI in passenger cars, buses and trucks will reach 36.5 Mtoe in 2035 (Figure 10-10). The energy savings effect will be around 2.9% higher than that under the Advanced Technologies Scenario in Advanced Economies and 2.6% in China. Meanwhile, in other Emerging and Developing Economies, autonomous driving will not see significant progress in the short to medium term (2025 to 2035), and the energy savings will be around 0.9% to 1.8%.

Autonomous driving technology is not limited to electric vehicles (EVs) and can be applied to internal combustion engine vehicles (ICVs) as well. There are expectations that autonomous driving will spread to trucks, buses, taxis and other commercial vehicles, for which EVs are considered more difficult to deploy widely. This can lead to energy savings by improving loading efficiency and passenger efficiency based on weather and traffic information. Furthermore, transportation distances will be shortened by avoiding traffic congestion and selecting optimal routes. Autonomous driving will also improve fuel efficiency by maintaining a consistent distance between vehicles.

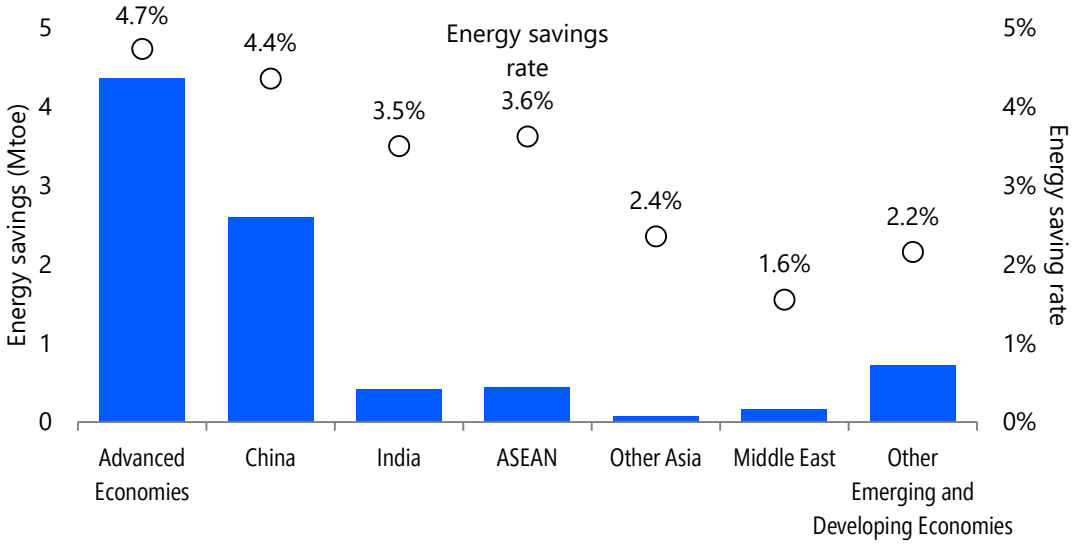
Figure 10-10 | Energy savings potential of AI for road transport (compared with the Advanced Technologies Scenario) [2035]



Energy savings potential of AI in the commercial sector

The energy savings potential of AI for heating, cooling, ventilation and lighting in 2035 is 8.8 Mtoe (102 TWh) compared with the Advanced Technologies Scenario (Figure 10-11). This is roughly a 10% reduction in data centre electricity demand in 2035. The energy savings potential of AI is 4.3 Mtoe in Advanced Economies and 2.6 Mtoe in China. In Emerging and Developing Economies, the adoption of AI will be limited to the latest buildings in the short to medium term.

Figure 10-11 | Energy savings potential of AI in the commercial sector (compared with the Advanced Technologies Scenario) [2035]



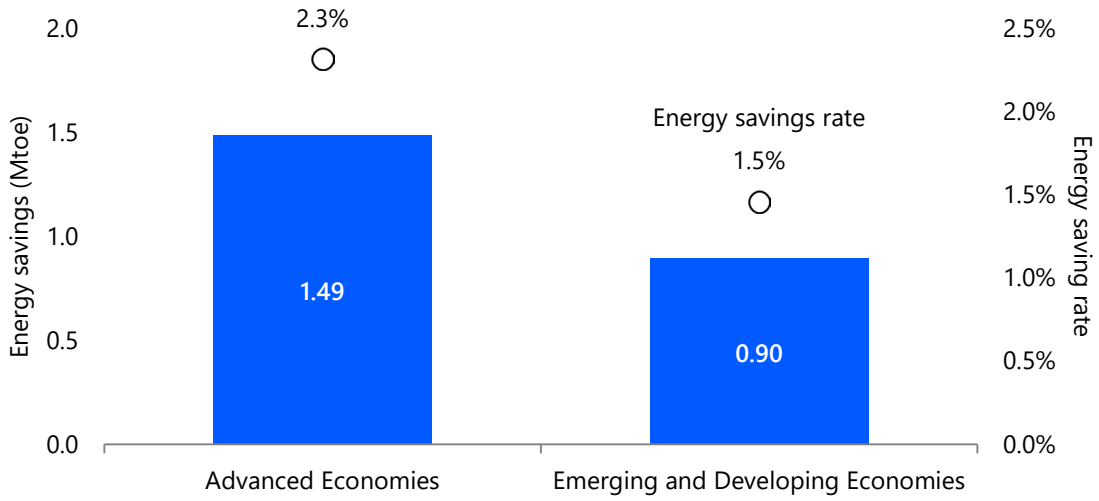
In Advanced Economies, digital control using Building Energy Management System (BEMS) has already become standard in large buildings of over 10 000 m². BEMS manages a building's energy based on predefined rules. By adding AI learning and prediction functions to this mechanism, more autonomous management of a building's energy will be possible. AI can improve the

energy efficiency of an entire building without upgrading existing equipment, namely by installing sensors to collect data on the movement of people, temperature, and so on, and maintaining comfort through optimal control of lighting, air conditioning and power. In Emerging and Developing Economies, AI is expected to spread in the long run (after 2035), after first going through a stage of digitalisation.

Energy savings potential of AI in the residential sector

The energy savings potential of AI-equipped air conditioners and water heaters is 1.5 Mtoe compared with the Advanced Technologies Scenario (a 2.3% saving) for Advanced Economies and 0.9 Mtoe (a 1.5% reduction) for Emerging and Developing Economies in 2035 (Figure 10-12). Since AI-enabled technologies are high-end products that require a high initial investment, their adoption rate will be relatively low compared with that in other sectors in the short to medium term. AI air conditioners, for example, can save energy while maintaining comfort by performing proactive control that takes weather forecasts and human behaviour into account. For wider adoption of AI, it is necessary to promote understanding of its benefits.

Figure 10-12 | Energy savings potential of AI in the residential sector (compared with the Advanced Technologies Scenario) [2035]



For further widespread adoption

The use of AI on the demand side has many possibilities, including improving productivity and achieving energy savings in the industry sector, improving fuel efficiency and reducing travel distances for automobiles, and improving energy efficiency while maintaining comfort in the buildings sector. By 2035, an additional energy savings potential of several percent compared with the Advanced Technologies Scenario can be expected.

However, there are many obstacles to the introduction of AI in the energy demand sectors. First is the shortage of skilled personnel who can utilise AI in the industrial, commercial, road and other sectors. For example, factory equipment operators often rely on their experience. It is essential to raise awareness among factory workers about what AI can do.

Another issue is the lack of data that can be used. The more data there is, the higher the accuracy of predictions, which in turn enables more efficient operations. In other words, data preparation is essential before AI can be put into operation.

On the other hand, we must be careful of rebound effects, such as increases in energy consumption due to higher productivity. Efforts are currently underway to mitigate the rebound effects by having AI learn human behaviour and energy use patterns and apply predictive control. Sharing efforts like these is also important to promote the use of AI in the demand sectors.

Policy measures that need to be taken include sharing best practices to develop human resources and raise awareness and providing incentives to promote widespread adoption. To maximise the impact of AI, it is also necessary to standardise data and establish rules for data input and interoperability. Measures must also be implemented during the operation of AI, such as ensuring cybersecurity.

The energy savings potential of data centres depends significantly on improvements in information and communication technology (ICT) efficiency. Therefore, in addition to improving cooling efficiency, which has traditionally been the focus, measures and strategies to improve the efficiency of ICT equipment are needed. This will require additional evaluation of ICT efficiency as an indicator of data centre energy efficiency (in addition to power usage effectiveness [PUE]). It will also be important to cooperate not only with data centre operators but also with various stakeholders such as semiconductor manufacturers and ICT-related manufacturers.

Annex

The EDMC Energy Databank provides even more data to its members.

Table A1 | Regional groupings

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

		United Kingdom	
		Others	Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Iceland, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and Republic of Türkiye
	Other Europe/Eurasia	Russian Federation	
		Other Former Soviet Union	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Republic of 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	South Africa (Republic of)		
	North Africa	Algeria, Egypt, Libya, Morocco, and Tunisia	
	Other Africa	Angola, Benin, Botswana, Cameroon, Republic of the Congo, Democratic Republic of Congo, Côte d'Ivoire, Eritrea, Kingdom of 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	Islamic Republic of Iran		
	Iraq		
	Kuwait		
	Oman		
	Qatar		
	Saudi Arabia		
	United Arab Emirates		

	Other Middle East	Bahrain, Israel, Jordan, Lebanon, Syrian Arab Republic, and Yemen
Oceania	Australia	
	New Zealand	
International bunkers		
European Union	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, and Sweden	
Advanced Economies	Advanced Europe, Hong Kong, Japan, Korea, North America, Oceania, Singapore, and Chinese Taipei	
Emerging and Developing Economies	Africa, Brunei Darussalam, Cambodia, People's Republic of China, India, Indonesia, Lao People's Democratic Republic, Latin America, Malaysia, Middle East, Myanmar, Other Europe/Eurasia, Other Asia, Philippines, Thailand, and Viet Nam	
Group of Seven	Canada, France, Germany, Italy, Japan, United Kingdom, and United States	
Organization of the Petroleum Exporting Countries (OPEC)	Algeria, Republic of the Congo, Equatorial Guinea, Gabon, Islamic Republic of Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, United Arab Emirates, and Bolivarian Republic of Venezuela	

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

Table A2 | 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

(Intentionally blank)

Table A3 | Population

	(Million)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	5 292	6 153	6 991	8 054	8 526	8 838	9 126	9 385	9 606
Asia	2 954	3 461	3 891	4 350	4 500	4 589	4 656	4 700	4 718
China	1 135	1 263	1 338	1 411	1 387	1 362	1 332	1 295	1 250
India	865	1 058	1 243	1 438	1 525	1 579	1 623	1 656	1 680
Japan	123	127	128	125	120	116	112	109	105
Korea	43	47	50	52	51	50	49	47	45
Chinese Taipei	20	22	23	23	23	22	21	20	19
ASEAN	439	526	603	689	721	740	756	767	773
Indonesia	184	216	246	281	296	305	312	317	321
Malaysia	18	23	29	35	38	40	42	43	44
Myanmar	40	45	49	54	56	57	58	59	59
Philippines	63	80	96	115	121	126	130	132	134
Singapore	3.0	4.0	5.1	5.9	6.2	6.3	6.3	6.3	6.2
Thailand	55	63	69	72	71	71	70	68	66
Viet Nam	66	77	87	100	104	107	108	110	110
North America	277	313	343	377	391	400	408	415	420
United States	250	282	309	337	349	356	363	369	373
Latin America	438	517	585	655	684	701	714	722	727
Brazil	149	174	194	211	216	218	219	219	217
Advanced Europe	507	529	558	587	587	586	583	580	574
Other Europe/Eurasia	338	336	333	339	343	343	344	345	346
Russia	148	147	143	144	140	138	137	136	135
Africa	625	805	1 038	1 430	1 667	1 843	2 022	2 201	2 378
Middle East	131	168	217	284	320	342	364	384	404
Oceania	20	23	26	32	34	35	36	37	39
International Bunkers	-	-	-	-	-	-	-	-	-
Advanced Economies	1 000	1 072	1 140	1 209	1 219	1 223	1 223	1 221	1 215
Group of Seven	652	699	741	781	791	795	798	800	800
Emerging and Developing Economies	4 291	5 081	5 851	6 845	7 307	7 616	7 903	8 164	8 391
Emerging and Developing Asia	2 759	3 255	3 678	4 137	4 293	4 387	4 461	4 511	4 536
Non-Asia	2 337	2 692	3 101	3 704	4 026	4 250	4 470	4 684	4 888
European Union	421	429	442	449	446	442	438	433	427

Source: United Nations "World Population Prospects 2024", World Bank "World Development Indicators"
Note: Same value for Reference Scenario and Advanced Technologies Scenario

CAGR (%)				
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.3	0.8	0.7	0.5	0.7
1.2	0.5	0.3	0.1	0.3
0.7	-0.2	-0.4	-0.6	-0.4
1.6	0.8	0.6	0.3	0.6
0.0	-0.6	-0.6	-0.6	-0.6
0.6	-0.2	-0.4	-0.8	-0.5
0.4	-0.5	-0.6	-0.9	-0.7
1.4	0.7	0.5	0.2	0.4
1.3	0.7	0.5	0.3	0.5
2.1	1.1	0.9	0.7	0.9
0.9	0.6	0.3	0.1	0.3
1.8	0.8	0.7	0.4	0.6
2.0	0.6	0.3	-0.2	0.2
0.8	-0.1	-0.2	-0.5	-0.3
1.3	0.5	0.4	0.1	0.3
0.9	0.5	0.4	0.3	0.4
0.9	0.5	0.4	0.3	0.4
1.2	0.6	0.4	0.2	0.4
1.1	0.3	0.1	-0.1	0.1
0.4	0.0	-0.1	-0.2	-0.1
0.0	0.2	0.0	0.1	0.1
-0.1	-0.4	-0.3	-0.2	-0.2
2.5	2.2	1.9	1.6	1.9
2.4	1.7	1.3	1.0	1.3
1.4	0.9	0.7	0.6	0.7
n.a.	n.a.	n.a.	n.a.	n.a.
0.6	0.1	0.0	-0.1	0.0
0.5	0.2	0.1	0.0	0.1
1.4	0.9	0.8	0.6	0.8
1.2	0.5	0.4	0.2	0.3
1.4	1.2	1.1	0.9	1.0
0.2	-0.1	-0.2	-0.3	-0.2

Table A4 | GDP

	($2015 billion)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	36 016	48 379	65 081	93 506	112 250	127 708	145 013	164 008	184 245
Asia	6 719	10 478	18 086	32 734	42 276	50 161	59 295	69 593	80 766
China	1 041	2 825	7 712	17 612	23 232	27 323	31 895	36 873	42 032
India	475	817	1 567	3 333	5 148	6 930	9 163	11 880	15 058
Japan	3 510	3 987	4 219	4 601	4 764	4 942	5 131	5 317	5 500
Korea	402	799	1 261	1 764	1 997	2 175	2 343	2 495	2 623
Chinese Taipei	161	307	463	688	826	913	999	1 083	1 159
ASEAN	739	1 180	1 975	3 377	4 537	5 645	6 955	8 443	10 075
Indonesia	270	395	658	1 179	1 649	2 085	2 606	3 221	3 929
Malaysia	75	148	233	401	533	646	775	920	1 076
Myanmar	7.1	14	44	67	74	90	113	140	172
Philippines	107	143	229	430	646	853	1 087	1 324	1 535
Singapore	71	141	248	392	468	522	571	615	656
Thailand	144	221	347	459	531	625	738	862	995
Viet Nam	45	94	177	379	545	711	924	1 186	1 496
North America	10 663	14 881	17 739	23 868	27 532	30 218	33 051	35 972	38 929
United States	9 785	13 718	16 339	22 063	25 520	28 022	30 663	33 387	36 146
Latin America	2 636	3 592	4 885	5 757	6 834	7 874	9 029	10 261	11 544
Brazil	917	1 186	1 703	1 961	2 315	2 688	3 111	3 567	4 044
Advanced Europe	11 667	14 676	16 969	20 871	23 040	24 837	26 651	28 479	30 246
Other Europe/Eurasia	1 797	1 233	2 050	2 706	3 211	3 558	3 936	4 353	4 800
Russia	1 161	780	1 251	1 545	1 724	1 860	2 015	2 187	2 370
Africa	967	1 233	2 040	2 865	3 742	4 682	5 843	7 227	8 845
Middle East	911	1 378	2 092	3 000	3 661	4 200	4 791	5 446	6 167
Oceania	656	907	1 220	1 704	1 953	2 177	2 417	2 676	2 950
International Bunkers	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Advanced Economies	27 250	35 877	42 387	54 216	60 965	66 212	71 633	77 139	82 582
Group of Seven	21 501	27 927	31 987	40 084	44 720	48 450	52 410	56 468	60 526
Emerging and Developing Economies	8 766	12 502	22 694	39 290	51 285	61 496	73 380	86 869	101 663
Emerging and Developing Asia	2 455	5 066	11 628	24 961	33 837	41 182	49 782	59 581	70 308
Non-Asia	29 297	37 900	46 995	60 772	69 974	77 547	85 718	94 415	103 479
European Union	9 094	11 284	12 931	15 477	17 038	18 344	19 670	21 003	22 287

Source: World Bank "World Development Indicators", etc. (historical)
The Institute of Energy Economics, Japan (assumption)
Note: Same value for Reference Scenario and Advanced Technologies Scenario

CAGR (%)				
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
2.9	2.6	2.6	2.4	2.5
4.9	3.7	3.4	3.1	3.4
8.9	4.0	3.2	2.8	3.3
6.1	6.4	5.9	5.1	5.7
0.8	0.5	0.7	0.7	0.7
4.6	1.8	1.6	1.1	1.5
4.5	2.7	1.9	1.5	2.0
4.7	4.3	4.4	3.8	4.1
4.6	4.9	4.7	4.2	4.6
5.2	4.1	3.8	3.3	3.7
7.0	1.5	4.3	4.3	3.6
4.3	6.0	5.3	3.5	4.8
5.3	2.6	2.0	1.4	1.9
3.6	2.1	3.3	3.0	2.9
6.7	5.3	5.4	4.9	5.2
2.5	2.1	1.8	1.7	1.8
2.5	2.1	1.9	1.7	1.8
2.4	2.5	2.8	2.5	2.6
2.3	2.4	3.0	2.7	2.7
1.8	1.4	1.5	1.3	1.4
1.2	2.5	2.1	2.0	2.1
0.9	1.6	1.6	1.6	1.6
3.3	3.9	4.6	4.2	4.3
3.7	2.9	2.7	2.6	2.7
2.9	2.0	2.2	2.0	2.1
n.a.	n.a.	n.a.	n.a.	n.a.
2.1	1.7	1.6	1.4	1.6
1.9	1.6	1.6	1.5	1.5
4.7	3.9	3.6	3.3	3.6
7.3	4.4	3.9	3.5	3.9
2.2	2.0	2.1	1.9	2.0
1.6	1.4	1.4	1.3	1.4

Table A5 | GDP per capita

	($2015 thousand/person)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	6.8	7.9	9.3	12	13	14	16	17	19
Asia	2.3	3.0	4.6	7.5	9.4	11	13	15	17
China	0.9	2.2	5.8	12	17	20	24	28	34
India	0.5	0.8	1.3	2.3	3.4	4.4	5.6	7.2	9.0
Japan	28	31	33	37	40	43	46	49	52
Korea	9.4	17	25	34	39	43	48	53	58
Chinese Taipei	7.9	14	20	29	37	41	47	53	60
ASEAN	1.7	2.2	3.3	4.9	6.3	7.6	9.2	11	13
Indonesia	1.5	1.8	2.7	4.2	5.6	6.8	8.4	10	12
Malaysia	4.2	6.5	8.1	11	14	16	19	21	24
Myanmar	0.2	0.3	0.9	1.2	1.3	1.6	1.9	2.4	2.9
Philippines	1.7	1.8	2.4	3.7	5.3	6.8	8.4	10.0	11
Singapore	23	35	49	66	76	83	90	98	106
Thailand	2.6	3.5	5.1	6.4	7.5	8.9	11	13	15
Viet Nam	0.7	1.2	2.0	3.8	5.2	6.7	8.5	11	14
North America	38	48	52	63	70	76	81	87	93
United States	39	49	53	66	73	79	84	91	97
Latin America	6.0	6.9	8.4	8.8	10.0	11	13	14	16
Brazil	6.1	6.8	8.8	9.3	11	12	14	16	19
Advanced Europe	23	28	30	36	39	42	46	49	53
Other Europe/Eurasia	5.3	3.7	6.1	8.0	9.4	10	11	13	14
Russia	7.8	5.3	8.8	11	12	13	15	16	18
Africa	1.5	1.5	2.0	2.0	2.2	2.5	2.9	3.3	3.7
Middle East	6.9	8.2	9.6	11	11	12	13	14	15
Oceania	32	40	46	53	58	62	67	71	76
International Bunkers	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Advanced Economies	27	33	37	45	50	54	59	63	68
Group of Seven	33	40	43	51	57	61	66	71	76
Emerging and Developing Economies	2.0	2.5	3.9	5.7	7.0	8.1	9.3	11	12
Emerging and Developing Asia	0.9	1.6	3.2	6.0	7.9	9.4	11	13	16
Non-Asia	13	14	15	16	17	18	19	20	21
European Union	22	26	29	34	38	41	45	48	52

Source: World Bank "World Development Indicators", International Energy Agency "World Energy Balances", etc. (historical)
The Institute of Energy Economics, Japan (assumption)
Note: Same value for Reference Scenario and Advanced Technologies Scenario

CAGR (%)				
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.6	1.8	1.9	1.9	1.9
3.7	3.2	3.1	3.0	3.1
8.2	4.3	3.6	3.5	3.7
4.5	5.5	5.3	4.7	5.1
0.8	1.1	1.4	1.4	1.3
4.0	1.9	2.1	2.0	2.0
4.1	3.1	2.5	2.4	2.6
3.3	3.6	3.9	3.5	3.7
3.2	4.1	4.1	3.9	4.0
3.1	3.0	2.9	2.7	2.8
6.0	0.9	4.0	4.2	3.3
2.4	5.1	4.7	3.1	4.2
3.2	2.0	1.7	1.6	1.7
2.7	2.2	3.6	3.5	3.2
5.3	4.8	5.0	4.8	4.9
1.5	1.5	1.4	1.4	1.4
1.6	1.6	1.4	1.4	1.5
1.2	1.8	2.4	2.3	2.2
1.3	2.1	2.8	2.7	2.6
1.3	1.4	1.5	1.4	1.5
1.2	2.3	2.0	1.9	2.1
1.0	1.9	1.8	1.8	1.8
0.8	1.6	2.6	2.6	2.3
1.3	1.1	1.4	1.5	1.4
1.5	1.1	1.5	1.4	1.3
n.a.	n.a.	n.a.	n.a.	n.a.
1.5	1.6	1.6	1.5	1.6
1.4	1.4	1.5	1.4	1.4
3.2	2.9	2.8	2.7	2.8
6.0	3.9	3.5	3.3	3.6
0.8	0.8	1.0	1.0	0.9
1.4	1.5	1.6	1.5	1.6

Table A6 | Primary energy consumption

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	8 701	9 938	12 735	15 135	15 702	16 164	16 538	16 922	17 266
Asia	2 073	2 839	4 758	6 869	7 301	7 595	7 865	8 137	8 340
China	878	1 134	2 541	4 022	4 032	3 930	3 842	3 722	3 528
India	280	418	661	1 098	1 361	1 574	1 781	2 010	2 234
Japan	437	516	500	378	358	339	320	305	293
Korea	90	186	244	276	263	261	252	242	232
Chinese Taipei	51	90	118	111	117	116	114	111	108
ASEAN	217	355	506	757	919	1 090	1 229	1 369	1 513
Indonesia	85	127	166	276	360	470	542	615	695
Malaysia	21	48	73	106	118	128	138	147	155
Myanmar	11	14	14	22	23	25	28	32	36
Philippines	27	39	42	67	85	100	115	127	137
Singapore	12	19	25	31	34	35	35	36	36
Thailand	42	73	118	133	139	146	155	163	170
Viet Nam	18	29	59	102	134	158	184	214	245
North America	2 126	2 525	2 476	2 437	2 329	2 292	2 240	2 191	2 158
United States	1 914	2 273	2 216	2 143	2 046	2 012	1 965	1 925	1 900
Latin America	467	611	791	867	925	976	1 023	1 068	1 112
Brazil	141	188	268	313	331	355	376	396	413
Advanced Europe	1 644	1 759	1 834	1 548	1 456	1 409	1 353	1 287	1 229
Other Europe/Eurasia	1 514	988	1 113	1 160	1 161	1 167	1 167	1 175	1 183
Russia	879	619	693	791	778	776	773	771	769
Africa	354	437	610	813	898	985	1 047	1 115	1 196
Middle East	223	380	647	899	978	1 036	1 088	1 148	1 206
Oceania	99	125	145	150	154	152	151	149	148
International Bunkers	202	274	361	391	500	551	603	652	695
Advanced Economies	4 467	5 233	5 355	4 943	4 722	4 613	4 474	4 330	4 210
Group of Seven	3 490	4 024	3 945	3 555	3 365	3 270	3 161	3 050	2 974
Emerging and Developing Economies	4 032	4 430	7 020	9 800	10 481	10 999	11 461	11 941	12 361
Emerging and Developing Asia	1 475	2 015	3 859	6 062	6 519	6 835	7 135	7 435	7 665
Non-Asia	6 427	6 825	7 617	7 875	7 901	8 018	8 070	8 134	8 231
European Union	1 441	1 471	1 528	1 248	1 182	1 139	1 091	1 036	987

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.7	0.5	0.5	0.4	0.5	15 305	15 099	14 691	14 435	14 282	0.2	-0.4	-0.3	-0.2
3.7	0.9	0.7	0.6	0.7	7 112	7 053	6 882	6 745	6 631	0.5	-0.3	-0.4	-0.1
4.7	0.0	-0.5	-0.8	-0.5	3 935	3 625	3 290	3 001	2 710	-0.3	-1.8	-1.9	-1.5
4.2	3.1	2.7	2.3	2.7	1 324	1 459	1 558	1 636	1 725	2.7	1.6	1.0	1.7
-0.4	-0.8	-1.1	-0.9	-0.9	355	326	296	278	263	-0.9	-1.8	-1.2	-1.3
3.5	-0.7	-0.4	-0.8	-0.6	262	253	241	227	209	-0.7	-0.8	-1.4	-1.0
2.4	0.8	-0.3	-0.6	-0.1	115	109	102	95	90	0.5	-1.2	-1.2	-0.8
3.9	2.8	2.9	2.1	2.6	875	1 013	1 101	1 183	1 271	2.1	2.3	1.4	1.9
3.6	3.9	4.2	2.5	3.5	345	444	503	557	613	3.2	3.8	2.0	3.0
5.0	1.6	1.6	1.2	1.4	111	117	120	122	124	0.8	0.8	0.3	0.6
2.2	0.5	1.9	2.6	1.8	21	21	22	25	27	-0.7	0.6	1.9	0.7
2.8	3.6	3.0	1.8	2.7	82	97	105	112	117	2.9	2.6	1.0	2.1
3.1	1.2	0.4	0.2	0.5	34	34	34	33	32	1.0	0.0	-0.4	0.1
3.5	0.6	1.1	1.0	0.9	135	137	139	140	142	0.2	0.3	0.3	0.3
5.4	4.0	3.2	2.9	3.3	123	137	150	166	185	2.7	2.0	2.1	2.2
0.4	-0.6	-0.4	-0.4	-0.4	2 271	2 157	2 021	1 926	1 853	-1.0	-1.2	-0.9	-1.0
0.3	-0.7	-0.4	-0.3	-0.4	1 991	1 889	1 766	1 685	1 624	-1.0	-1.2	-0.8	-1.0
1.9	0.9	1.0	0.8	0.9	901	916	919	923	935	0.5	0.2	0.2	0.3
2.5	0.8	1.3	0.9	1.0	322	329	331	332	335	0.4	0.3	0.1	0.3
-0.2	-0.9	-0.7	-1.0	-0.9	1 416	1 328	1 225	1 165	1 149	-1.3	-1.4	-0.6	-1.1
-0.8	0.0	0.1	0.1	0.1	1 154	1 127	1 085	1 051	1 022	-0.1	-0.6	-0.6	-0.5
-0.3	-0.2	-0.1	-0.1	-0.1	772	744	711	680	652	-0.3	-0.8	-0.9	-0.7
2.6	1.4	1.6	1.3	1.4	853	882	898	921	950	0.7	0.5	0.6	0.6
4.3	1.2	1.1	1.0	1.1	950	972	983	1 011	1 040	0.8	0.3	0.6	0.5
1.3	0.3	-0.2	-0.2	-0.1	153	144	135	133	131	0.2	-1.2	-0.3	-0.5
2.0	3.5	1.9	1.4	2.2	496	521	543	560	572	3.4	0.9	0.5	1.4
0.3	-0.7	-0.5	-0.6	-0.6	4 614	4 359	4 061	3 863	3 734	-1.0	-1.3	-0.8	-1.0
0.1	-0.8	-0.6	-0.6	-0.7	3 279	3 075	2 854	2 701	2 612	-1.2	-1.4	-0.9	-1.1
2.7	1.0	0.9	0.8	0.9	10 195	10 219	10 088	10 011	9 977	0.6	-0.1	-0.1	0.1
4.4	1.0	0.9	0.7	0.9	6 337	6 323	6 202	6 106	6 030	0.6	-0.2	-0.3	0.0
0.6	0.0	0.2	0.2	0.2	7 697	7 525	7 267	7 130	7 079	-0.3	-0.6	-0.3	-0.4
-0.4	-0.8	-0.8	-1.0	-0.9	1 155	1 083	998	949	930	-1.1	-1.4	-0.7	-1.1

Table A7 | Primary energy consumption, coal

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	2 219	2 313	3 645	4 202	3 668	3 452	3 337	3 270	3 144
Asia	785	1 033	2 400	3 422	3 081	2 915	2 829	2 771	2 650
China	531	665	1 790	2 449	2 030	1 776	1 606	1 441	1 224
India	93	146	274	510	574	652	726	817	904
Japan	77	97	115	99	73	63	53	48	45
Korea	22	39	68	66	62	56	54	50	45
Chinese Taipei	11	30	42	38	37	35	32	29	26
ASEAN	12	31	79	218	262	282	301	317	325
Indonesia	3.5	12	25	98	119	124	132	137	136
Malaysia	1.4	2.3	15	24	26	26	24	22	19
Myanmar	0.1	0.3	0.4	0.9	1.1	1.3	1.5	1.7	2.0
Philippines	1.3	4.6	7.0	23	29	35	37	38	38
Singapore	0.0	-	0.0	0.3	0.3	0.3	0.3	0.3	0.2
Thailand	3.8	7.7	16	15	15	15	15	14	14
Viet Nam	2.2	4.4	15	51	63	71	80	92	103
North America	484	565	525	210	115	88	74	63	52
United States	460	533	501	202	111	84	70	60	49
Latin America	21	28	40	37	32	32	32	33	35
Brazil	9.7	13	14	14	13	13	14	15	15
Advanced Europe	450	331	301	168	118	102	85	76	67
Other Europe/Eurasia	365	209	211	218	191	183	180	181	186
Russia	191	120	106	143	125	121	116	114	116
Africa	74	90	109	103	99	104	111	122	131
Middle East	3.0	8.1	9.2	7.8	6.8	6.0	5.0	4.8	4.9
Oceania	36	49	52	36	26	23	21	19	18
International Bunkers	-	-	-	-	0.0	0.0	0.0	0.0	0.0
Advanced Economies	1 087	1 115	1 109	622	433	368	320	286	254
Group of Seven	787	811	776	367	221	178	148	132	118
Emerging and Developing Economies	1 133	1 198	2 536	3 581	3 235	3 084	3 018	2 984	2 890
Emerging and Developing Asia	669	863	2 168	3 214	2 907	2 759	2 689	2 643	2 533
Non-Asia	1 434	1 280	1 246	780	587	537	508	499	495
European Union	393	285	252	129	90	77	66	60	55

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
2.0	-1.9	-0.9	-0.6	-1.1	3 431	2 872	2 421	2 057	1 698	-2.9	-3.4	-3.5	-3.3
4.6	-1.5	-0.8	-0.7	-0.9	2 909	2 450	2 045	1 700	1 358	-2.3	-3.5	-4.0	-3.4
4.7	-2.6	-2.3	-2.7	-2.5	1 949	1 524	1 165	884	581	-3.2	-5.0	-6.7	-5.2
5.3	1.7	2.4	2.2	2.1	535	548	536	492	469	0.7	0.0	-1.3	-0.3
0.8	-4.3	-3.2	-1.5	-2.9	62	49	38	33	32	-6.6	-4.8	-1.8	-4.2
3.4	-1.0	-1.4	-1.9	-1.5	51	40	29	22	17	-3.8	-5.4	-5.0	-4.9
3.7	-0.5	-1.3	-1.9	-1.4	32	28	23	19	15	-2.5	-3.3	-4.0	-3.3
9.1	2.6	1.4	0.8	1.5	239	216	205	195	178	1.3	-1.5	-1.4	-0.8
10.6	2.7	1.1	0.3	1.2	111	100	97	90	76	1.7	-1.3	-2.4	-0.9
9.0	1.3	-0.5	-2.3	-0.7	24	22	18	13	8.2	0.3	-3.0	-7.5	-3.8
8.4	1.7	3.2	3.1	2.8	0.8	0.7	0.8	0.8	0.8	-3.3	0.3	0.9	-0.4
9.1	3.9	2.4	0.1	1.9	26	26	26	26	25	2.3	-0.2	-0.2	0.4
8.7	0.5	-1.5	-2.4	-1.3	0.3	0.3	0.2	0.2	0.2	-0.6	-2.8	-3.8	-2.6
4.3	-0.1	-0.1	-0.5	-0.3	14	13	11	10.0	8.9	-0.8	-2.4	-2.2	-1.9
9.9	3.3	2.4	2.6	2.7	54	46	43	45	49	0.9	-2.1	1.3	-0.1
-2.5	-8.3	-4.3	-3.4	-5.0	82	36	25	25	24	-12.6	-11.1	-0.8	-7.8
-2.5	-8.2	-4.4	-3.5	-5.1	79	33	23	22	21	-12.5	-11.7	-0.7	-8.0
1.7	-2.0	0.0	1.0	-0.2	29	26	24	25	27	-3.4	-1.8	1.2	-1.1
1.1	-1.2	0.9	1.1	0.4	12	11	11	11	11	-2.4	-0.5	0.3	-0.7
-2.9	-4.9	-3.2	-2.4	-3.3	106	82	63	55	53	-6.4	-5.1	-1.6	-4.2
-1.5	-1.9	-0.6	0.3	-0.6	181	161	150	139	131	-2.6	-1.9	-1.3	-1.9
-0.9	-1.9	-0.8	0.0	-0.8	120	110	100	91	85	-2.5	-1.8	-1.6	-1.9
1.0	-0.6	1.2	1.7	0.9	92	85	79	75	68	-1.7	-1.4	-1.5	-1.5
3.0	-2.0	-3.0	-0.1	-1.7	4.9	3.6	3.2	3.4	3.5	-6.4	-4.1	0.8	-2.9
0.0	-4.3	-2.4	-1.3	-2.5	27	29	31	35	34	-3.9	1.4	1.0	-0.2
n.a.	n.a.	-0.7	1.9	n.a.	0.0	0.0	0.0	0.0	0.0	n.a.	2.8	5.3	n.a.
-1.7	-5.0	-3.0	-2.3	-3.3	362	265	209	189	175	-7.4	-5.3	-1.7	-4.6
-2.3	-7.0	-3.9	-2.2	-4.1	173	107	84	77	74	-10.2	-7.0	-1.2	-5.7
3.5	-1.4	-0.7	-0.4	-0.8	3 069	2 608	2 211	1 869	1 523	-2.2	-3.2	-3.7	-3.1
4.9	-1.4	-0.8	-0.6	-0.9	2 762	2 332	1 955	1 626	1 293	-2.1	-3.4	-4.0	-3.3
-1.8	-4.0	-1.4	-0.3	-1.7	522	423	376	357	341	-5.6	-3.2	-1.0	-3.0
-3.3	-5.1	-3.1	-1.7	-3.1	80	61	49	44	42	-6.7	-4.8	-1.3	-4.0

Table A8 | Primary energy consumption, oil

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	3 237	3 682	4 153	4 577	4 682	4 720	4 762	4 780	4 764
Asia	618	918	1 171	1 576	1 702	1 750	1 810	1 863	1 903
China	119	221	428	736	785	756	730	697	659
India	61	112	162	271	331	392	460	530	599
Japan	249	253	201	141	128	118	107	97	86
Korea	50	99	95	101	96	92	88	83	78
Chinese Taipei	28	42	48	37	43	42	40	39	36
ASEAN	88	154	191	236	260	282	307	329	347
Indonesia	33	58	67	73	79	86	93	99	103
Malaysia	11	19	25	33	33	33	34	33	32
Myanmar	0.7	2.0	1.3	6.2	6.5	7.8	9.7	12	14
Philippines	9.9	16	14	20	27	33	39	45	50
Singapore	11	17	18	20	22	23	23	23	23
Thailand	18	32	45	54	54	55	57	58	59
Viet Nam	2.7	7.8	18	25	31	35	40	45	51
North America	833	958	901	858	764	719	668	613	558
United States	757	871	807	762	682	641	596	546	497
Latin America	241	314	367	356	360	370	379	382	380
Brazil	59	88	106	115	112	116	121	126	130
Advanced Europe	617	654	605	519	461	423	387	350	314
Other Europe/Eurasia	459	199	216	237	237	232	227	221	215
Russia	264	126	139	151	150	147	143	139	136
Africa	85	100	161	215	235	256	283	311	338
Middle East	146	224	323	372	377	391	399	405	406
Oceania	35	40	48	53	61	59	56	53	49
International Bunkers	202	274	361	390	484	520	554	581	602
Advanced Economies	1 827	2 070	1 919	1 733	1 577	1 477	1 371	1 258	1 145
Group of Seven	1 447	1 578	1 413	1 247	1 104	1 025	942	856	771
Emerging and Developing Economies	1 208	1 338	1 873	2 454	2 621	2 723	2 837	2 940	3 017
Emerging and Developing Asia	277	500	805	1 274	1 412	1 474	1 550	1 620	1 679
Non-Asia	2 417	2 490	2 621	2 611	2 495	2 449	2 398	2 336	2 259
European Union	531	550	506	426	379	348	318	287	257

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.1	0.3	0.2	0.0	0.1	4 425	4 025	3 593	3 135	2 715	-0.5	-2.1	-2.8	-1.9
2.9	1.1	0.6	0.5	0.7	1 615	1 521	1 427	1 324	1 223	0.3	-1.2	-1.5	-0.9
5.7	0.9	-0.7	-1.0	-0.4	751	664	584	509	445	0.3	-2.5	-2.7	-1.8
4.6	2.9	3.4	2.7	3.0	310	335	357	369	371	1.9	1.4	0.4	1.2
-1.7	-1.4	-1.8	-2.2	-1.8	120	101	82	65	53	-2.3	-3.8	-4.3	-3.6
2.2	-0.7	-0.9	-1.2	-0.9	93	84	74	64	56	-1.1	-2.3	-2.7	-2.1
0.8	1.9	-0.5	-1.1	-0.1	41	38	35	31	27	1.5	-1.8	-2.3	-1.1
3.0	1.4	1.7	1.2	1.4	243	237	233	222	207	0.4	-0.4	-1.2	-0.5
2.4	1.1	1.7	1.1	1.3	71	68	66	61	55	-0.3	-0.8	-1.8	-1.0
3.3	0.1	0.0	-0.4	-0.1	32	29	25	21	18	-0.6	-2.2	-3.5	-2.3
6.7	0.8	4.0	3.8	3.1	6.1	6.9	7.8	8.8	9.7	-0.1	2.5	2.2	1.7
2.1	4.4	4.0	2.4	3.5	25	29	31	31	28	3.8	2.1	-1.2	1.3
1.7	1.2	0.3	0.0	0.4	19	15	14	14	13	-1.1	-2.7	-0.6	-1.5
3.3	0.1	0.5	0.4	0.3	52	49	46	43	40	-0.4	-1.2	-1.5	-1.1
7.0	3.0	2.6	2.4	2.6	29	31	32	33	32	2.2	1.0	0.0	0.9
0.1	-1.6	-1.3	-1.8	-1.6	725	613	485	353	250	-2.4	-4.0	-6.4	-4.5
0.0	-1.6	-1.4	-1.8	-1.6	650	551	436	316	221	-2.2	-3.9	-6.6	-4.5
1.2	0.2	0.5	0.0	0.2	340	320	289	252	216	-0.6	-1.6	-2.9	-1.8
2.0	-0.4	0.8	0.7	0.4	103	100	96	90	85	-1.5	-0.8	-1.2	-1.1
-0.5	-1.7	-1.7	-2.1	-1.8	417	326	246	174	121	-3.1	-5.1	-6.9	-5.3
-2.0	0.0	-0.4	-0.6	-0.4	228	205	178	150	126	-0.6	-2.4	-3.4	-2.3
-1.7	0.0	-0.5	-0.5	-0.4	145	130	113	96	82	-0.6	-2.4	-3.2	-2.2
2.9	1.3	1.9	1.8	1.7	223	225	230	227	220	0.5	0.3	-0.4	0.1
2.9	0.2	0.6	0.2	0.3	351	328	298	272	254	-0.8	-1.6	-1.6	-1.4
1.3	1.8	-0.8	-1.3	-0.3	57	48	37	27	18	1.0	-4.2	-6.9	-3.9
2.0	3.2	1.4	0.8	1.6	467	438	402	357	288	2.6	-1.5	-3.3	-1.1
-0.2	-1.3	-1.4	-1.8	-1.5	1 475	1 226	974	728	540	-2.3	-4.1	-5.7	-4.2
-0.4	-1.7	-1.6	-2.0	-1.8	1 029	846	658	478	341	-2.7	-4.4	-6.4	-4.7
2.2	0.9	0.8	0.6	0.8	2 482	2 360	2 217	2 051	1 888	0.2	-1.1	-1.6	-1.0
4.7	1.5	0.9	0.8	1.0	1 340	1 281	1 222	1 150	1 072	0.7	-0.9	-1.3	-0.6
0.2	-0.6	-0.4	-0.6	-0.5	2 342	2 065	1 764	1 454	1 205	-1.5	-2.8	-3.7	-2.8
-0.7	-1.6	-1.7	-2.1	-1.9	343	269	204	145	103	-3.1	-5.1	-6.6	-5.1

Table A9 | Primary energy consumption, natural gas

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	1 662	2 069	2 737	3 443	3 616	3 804	3 989	4 221	4 483
Asia	116	234	454	739	884	983	1 089	1 206	1 325
China	13	21	89	319	370	382	386	378	354
India	11	23	54	58	84	108	132	156	179
Japan	44	66	86	80	72	70	64	60	57
Korea	2.7	18	38	51	52	51	54	55	54
Chinese Taipei	1.6	6.2	15	26	29	30	30	30	30
ASEAN	30	74	125	147	207	257	321	399	494
Indonesia	16	27	39	43	77	106	147	199	264
Malaysia	6.8	25	31	44	52	61	69	79	89
Myanmar	0.8	1.2	1.3	3.2	4.4	5.7	7.0	8.7	11
Philippines	-	0.0	3.1	2.6	4.6	7.0	11	16	21
Singapore	-	1.1	6.5	9.9	10	10	10	10	11
Thailand	5.0	17	33	35	41	44	45	47	49
Viet Nam	0.0	1.1	8.1	6.5	15	21	28	36	45
North America	493	622	635	885	896	895	883	870	867
United States	438	548	556	765	775	772	755	744	742
Latin America	71	118	178	207	215	232	254	283	314
Brazil	3.4	8.4	24	26	23	27	30	34	39
Advanced Europe	267	396	473	362	316	298	273	245	213
Other Europe/Eurasia	596	481	566	565	530	521	512	514	527
Russia	367	319	384	413	378	372	356	352	357
Africa	30	47	89	143	167	214	262	319	381
Middle East	72	145	311	501	563	604	644	694	748
Oceania	19	24	32	39	38	39	39	40	41
International Bunkers	-	-	-	0.8	8.4	19	33	50	68
Advanced Economies	827	1 136	1 287	1 457	1 417	1 398	1 358	1 316	1 277
Group of Seven	704	941	992	1 162	1 132	1 115	1 081	1 049	1 025
Emerging and Developing Economies	835	933	1 450	1 985	2 190	2 387	2 597	2 855	3 138
Emerging and Developing Asia	67	141	306	568	716	816	925	1 045	1 168
Non-Asia	1 547	1 834	2 283	2 703	2 724	2 802	2 867	2 966	3 090
European Union	250	309	363	272	238	224	206	186	163

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
2.2	0.7	1.0	1.2	1.0	3 566	3 617	3 552	3 497	3 423	0.5	0.0	-0.4	0.0
5.8	2.6	2.1	2.0	2.2	851	865	849	830	818	2.0	0.0	-0.4	0.4
10.2	2.2	0.4	-0.9	0.4	371	339	279	206	124	2.2	-2.8	-7.8	-3.4
5.3	5.5	4.5	3.1	4.3	88	105	115	116	118	6.2	2.6	0.3	2.7
1.8	-1.5	-1.1	-1.3	-1.3	62	53	42	34	22	-3.6	-3.8	-6.3	-4.7
9.4	0.2	0.4	0.1	0.2	46	44	38	33	32	-1.5	-2.0	-1.6	-1.7
8.9	1.5	0.3	0.0	0.5	27	25	23	21	18	0.2	-1.4	-2.7	-1.5
4.9	5.0	4.5	4.4	4.6	191	220	261	309	370	3.8	3.2	3.6	3.5
3.1	8.5	6.7	6.1	6.9	70	88	118	155	201	7.1	5.5	5.5	5.9
5.8	2.5	2.8	2.6	2.6	48	56	62	68	75	1.3	2.6	1.8	2.0
4.5	4.6	4.7	4.5	4.6	4.4	5.6	6.7	8.1	9.7	4.5	4.4	3.8	4.2
n.a.	8.7	9.2	6.7	8.1	4.0	5.3	8.1	13	17	6.4	7.4	7.6	7.2
n.a.	0.6	0.1	0.2	0.3	10	10	9.7	9.0	8.3	0.3	-0.4	-1.6	-0.7
6.1	2.3	1.0	0.7	1.2	39	39	38	38	38	1.4	-0.1	0.0	0.3
26.6	12.7	6.5	4.8	7.4	13	13	14	15	18	10.1	1.0	2.3	3.8
1.8	0.2	-0.1	-0.2	-0.1	896	886	818	745	649	0.2	-0.9	-2.3	-1.1
1.7	0.2	-0.3	-0.2	-0.1	772	763	698	632	548	0.1	-1.0	-2.4	-1.2
3.3	0.5	1.7	2.2	1.6	214	227	242	255	267	0.5	1.3	1.0	0.9
6.4	-1.7	2.5	2.6	1.4	22	22	21	20	18	-2.3	-0.5	-1.7	-1.4
0.9	-1.9	-1.4	-2.4	-1.9	296	249	181	128	92	-2.8	-4.8	-6.5	-4.9
-0.2	-0.9	-0.3	0.3	-0.3	529	505	487	465	447	-0.9	-0.8	-0.8	-0.9
0.4	-1.3	-0.6	0.0	-0.5	375	360	340	321	305	-1.4	-1.0	-1.1	-1.1
4.9	2.2	4.6	3.8	3.7	166	209	241	270	295	2.1	3.8	2.0	2.7
6.1	1.7	1.3	1.5	1.5	560	607	646	692	720	1.6	1.4	1.1	1.4
2.3	-0.5	0.3	0.4	0.1	39	38	36	35	34	0.0	-1.0	-0.4	-0.5
n.a.	39.7	14.8	7.4	17.8	14	31	53	77	100	49.5	14.6	6.6	19.5
1.7	-0.4	-0.4	-0.6	-0.5	1 381	1 311	1 152	1 009	859	-0.8	-1.8	-2.9	-1.9
1.5	-0.4	-0.5	-0.5	-0.5	1 112	1 066	949	839	711	-0.6	-1.6	-2.8	-1.8
2.7	1.4	1.7	1.9	1.7	2 172	2 276	2 348	2 411	2 464	1.3	0.8	0.5	0.8
6.7	3.4	2.6	2.4	2.7	702	728	732	729	735	3.1	0.4	0.0	1.0
1.7	0.1	0.5	0.8	0.5	2 701	2 722	2 651	2 590	2 505	0.0	-0.2	-0.6	-0.3
0.3	-1.9	-1.4	-2.3	-1.9	224	188	136	98	70	-2.8	-4.8	-6.4	-4.9

Table A10 | Primary energy consumption, nuclear

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	526	675	719	715	830	902	946	955	971
Asia	77	132	152	206	282	313	344	371	403
China	-	4.4	19	113	149	171	193	214	236
India	1.6	4.4	6.8	12	36	41	46	53	61
Japan	53	84	75	22	47	42	42	42	42
Korea	14	28	39	47	37	42	35	29	28
Chinese Taipei	8.6	10	11	4.6	-	-	-	-	-
ASEAN	-	-	-	-	-	2.2	7.9	14	18
Indonesia	-	-	-	-	-	-	-	-	-
Malaysia	-	-	-	-	-	-	1.8	3.7	3.7
Myanmar	-	-	-	-	-	-	-	-	-
Philippines	-	-	-	-	-	-	-	-	-
Singapore	-	-	-	-	-	-	-	-	-
Thailand	-	-	-	-	-	-	1.8	3.7	6.2
Viet Nam	-	-	-	-	-	2.2	4.2	6.4	8.6
North America	179	227	242	234	236	234	223	215	211
United States	159	208	219	211	214	214	209	204	204
Latin America	3.2	5.3	7.2	9.5	9.9	17	18	15	15
Brazil	0.6	1.6	3.8	3.8	4.0	6.9	6.9	5.6	5.6
Advanced Europe	210	247	239	171	181	190	198	184	177
Other Europe/Eurasia	55	61	76	81	103	126	140	148	142
Russia	31	34	45	57	65	75	94	97	88
Africa	2.2	3.4	3.2	2.2	5.6	7.8	10.0	8.8	8.8
Middle East	-	-	-	10	13	13	13	13	13
Oceania	-	-	-	-	-	-	-	-	-
International Bunkers	-	-	-	-	-	-	-	-	-
Advanced Economies	463	596	606	479	500	508	498	470	458
Group of Seven	370	485	482	356	397	395	380	351	346
Emerging and Developing Economies	62	79	113	236	330	393	448	484	513
Emerging and Developing Asia	1.7	9.3	27	133	199	229	266	299	334
Non-Asia	449	544	567	508	548	588	602	584	567
European Union	190	224	223	162	175	183	182	161	155

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
0.9	2.2	1.3	0.3	1.1	880	1 077	1 243	1 393	1 545	3.0	3.5	2.2	2.9
3.0	4.6	2.0	1.6	2.5	319	431	534	622	696	6.4	5.3	2.7	4.6
n.a.	4.0	2.6	2.0	2.7	149	187	225	263	300	4.0	4.2	2.9	3.7
6.4	16.4	2.5	2.7	6.0	37	62	92	130	158	16.7	9.6	5.5	9.9
-2.6	11.4	-0.9	0.0	2.5	62	63	65	65	65	16.0	0.5	0.0	4.1
3.8	-3.4	-0.6	-2.3	-2.0	53	58	67	65	55	1.6	2.4	-2.0	0.6
-1.8	-100	n.a.	n.a.	-100	5.0	5.0	5.0	5.0	5.0	1.0	0.0	0.0	0.3
n.a.	n.a.	n.a.	8.9	n.a.	-	37	54	67	83	n.a.	n.a.	4.5	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	-	15	15	15	15	n.a.	n.a.	0.0	n.a.
n.a.	n.a.	n.a.	7.1	n.a.	-	-	3.8	6.3	8.9	n.a.	n.a.	8.9	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	-	4.4	6.6	6.6	8.8	n.a.	n.a.	2.9	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	13.0	n.a.	-	1.8	3.9	6.4	9.0	n.a.	n.a.	8.8	n.a.
n.a.	n.a.	n.a.	7.4	n.a.	-	16	25	33	42	n.a.	n.a.	5.4	n.a.
0.8	0.1	-0.5	-0.5	-0.4	236	238	245	259	273	0.1	0.4	1.1	0.6
0.8	0.3	-0.2	-0.3	-0.1	214	214	222	236	250	0.3	0.3	1.2	0.6
3.3	0.6	6.2	-2.0	1.7	9.9	18	26	34	41	0.6	10.2	4.5	5.5
5.8	0.9	5.5	-2.1	1.4	4.0	7.9	12	16	19	0.9	11.3	5.1	6.2
-0.6	0.8	0.9	-1.1	0.1	189	218	241	248	277	1.4	2.5	1.4	1.8
1.2	3.3	3.1	0.2	2.1	107	142	153	174	189	4.0	3.6	2.1	3.2
1.8	1.9	3.8	-0.7	1.6	65	75	86	96	100	1.9	2.9	1.5	2.1
0.0	14.0	6.0	-1.3	5.2	5.6	14	22	32	45	14.0	14.7	7.4	11.7
n.a.	4.0	0.0	0.0	1.0	13	17	21	23	25	4.0	4.7	1.8	3.4
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
0.1	0.6	0.0	-0.8	-0.2	545	582	623	643	675	1.9	1.4	0.8	1.3
-0.1	1.6	-0.4	-0.9	-0.1	413	423	442	442	473	2.1	0.7	0.7	1.1
4.1	4.9	3.1	1.4	2.9	336	496	619	750	870	5.2	6.3	3.5	5.0
14.2	6.0	3.0	2.3	3.5	199	305	397	487	571	6.0	7.1	3.7	5.6
0.4	1.1	0.9	-0.6	0.4	561	647	709	771	849	1.4	2.4	1.8	1.9
-0.5	1.1	0.4	-1.6	-0.2	185	215	226	223	241	1.9	2.0	0.7	1.5

Table A11 | Primary energy consumption, hydro

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	184	225	297	366	413	433	453	473	494
Asia	32	41	92	151	174	184	194	203	212
China	11	19	61	106	117	121	124	127	130
India	6.2	6.4	11	12	19	22	25	29	33
Japan	7.6	7.2	7.2	6.5	7.2	7.3	7.4	7.5	7.5
Korea	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Chinese Taipei	0.5	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4
ASEAN	2.3	4.4	6.8	18	21	23	25	27	28
Indonesia	0.5	0.9	1.5	2.1	2.9	3.2	3.6	4.0	4.3
Malaysia	0.3	0.6	0.6	2.7	3.2	3.7	4.1	4.5	4.8
Myanmar	0.1	0.2	0.5	0.8	1.2	1.4	1.5	1.7	1.8
Philippines	0.5	0.7	0.7	0.9	1.3	1.5	1.8	2.1	2.5
Singapore	-	-	-	-	-	-	-	-	-
Thailand	0.4	0.5	0.5	0.6	1.0	1.1	1.1	1.2	1.2
Viet Nam	0.5	1.3	2.4	6.9	7.7	8.1	8.4	8.6	8.8
North America	49	53	53	52	61	62	63	63	64
United States	23	22	23	21	26	27	27	27	28
Latin America	34	51	64	66	73	76	79	82	85
Brazil	18	26	35	37	37	39	42	44	47
Advanced Europe	39	47	48	48	51	51	52	52	53
Other Europe/Eurasia	22	23	26	29	31	32	33	34	34
Russia	14	14	14	17	19	20	21	22	22
Africa	4.8	6.4	9.4	14	18	22	26	32	39
Middle East	1.0	0.7	1.5	1.7	2.4	2.5	2.6	2.7	2.8
Oceania	3.2	3.5	3.3	3.6	3.8	3.8	3.9	4.0	4.2
International Bunkers	-	-	-	-	-	-	-	-	-
Advanced Economies	100	111	112	111	123	125	127	128	130
Group of Seven	66	72	72	69	80	81	82	83	84
Emerging and Developing Economies	85	114	185	255	290	308	326	345	365
Emerging and Developing Asia	23	33	84	144	166	176	185	195	204
Non-Asia	153	184	205	215	240	249	259	270	282
European Union	24	30	32	28	30	30	31	31	31

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
2.1	1.8	0.9	0.9	1.1	422	448	477	509	544	2.1	1.2	1.3	1.5
4.8	2.0	1.1	0.9	1.3	181	198	216	236	258	2.7	1.8	1.8	2.0
7.1	1.5	0.6	0.4	0.8	119	124	129	135	140	1.6	0.9	0.8	1.0
2.1	6.3	3.0	2.5	3.7	23	30	37	47	58	9.2	5.0	4.4	5.9
-0.5	1.6	0.3	0.1	0.6	7.3	7.4	7.6	7.7	7.7	1.7	0.4	0.2	0.7
-1.6	-0.6	0.0	0.0	-0.2	0.3	0.3	0.3	0.3	0.3	-0.6	0.0	0.0	-0.2
-1.3	2.5	0.0	0.0	0.6	0.4	0.4	0.4	0.4	0.4	2.5	0.0	0.0	0.6
6.3	2.3	1.8	1.3	1.7	23	26	29	32	35	3.7	2.4	1.7	2.5
4.5	4.4	2.3	1.9	2.7	3.0	3.5	4.0	4.4	4.9	5.3	2.7	2.2	3.2
6.5	2.4	2.4	1.6	2.1	3.6	4.2	4.8	5.3	5.8	4.0	2.9	1.9	2.8
6.4	6.4	2.2	1.8	3.1	1.4	1.6	1.9	2.1	2.3	8.3	3.0	2.3	4.1
1.6	6.0	2.9	3.4	3.9	1.4	1.6	1.9	2.2	2.7	6.4	3.2	3.7	4.2
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
0.9	7.3	1.7	0.9	2.8	1.0	1.2	1.3	1.4	1.4	8.6	2.1	1.0	3.3
8.6	1.5	0.8	0.5	0.9	8.8	9.8	11	11	12	3.5	1.9	1.3	2.1
0.2	2.3	0.3	0.2	0.8	62	62	63	64	64	2.4	0.3	0.2	0.8
-0.3	3.2	0.2	0.2	1.0	26	27	27	27	28	3.2	0.2	0.2	1.0
2.1	1.4	0.8	0.7	0.9	73	77	80	84	88	1.5	0.9	0.9	1.0
2.2	0.2	1.2	1.2	0.9	37	40	43	47	50	0.3	1.4	1.5	1.2
0.7	0.7	0.2	0.2	0.4	51	51	52	52	53	0.7	0.2	0.2	0.4
0.8	0.9	0.7	0.4	0.6	31	32	33	34	34	0.9	0.7	0.4	0.6
0.6	1.8	0.8	0.5	0.9	19	20	21	22	22	1.8	0.8	0.5	0.9
3.3	3.5	3.9	4.0	3.8	18	22	26	32	39	3.5	3.9	4.0	3.8
1.5	5.4	0.8	0.6	1.9	2.4	2.5	2.6	2.7	2.8	5.4	0.8	0.6	1.9
0.4	0.4	0.4	0.7	0.5	3.8	3.9	4.0	4.2	4.4	0.6	0.6	0.9	0.7
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
0.3	1.5	0.3	0.2	0.6	124	126	127	129	130	1.6	0.3	0.2	0.6
0.2	2.1	0.2	0.2	0.7	81	82	83	84	84	2.2	0.3	0.2	0.7
3.4	1.9	1.2	1.1	1.3	298	323	350	380	413	2.3	1.6	1.7	1.8
5.7	2.1	1.1	0.9	1.3	173	190	208	228	249	2.7	1.8	1.8	2.1
1.0	1.6	0.8	0.9	1.0	240	250	261	273	286	1.6	0.8	0.9	1.1
0.5	0.8	0.3	0.2	0.4	30	30	31	31	31	0.8	0.3	0.2	0.4

Table A12 | Primary energy consumption, solar, wind, etc.

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	2.5	8.2	48	385	867	1 127	1 328	1 526	1 729
Asia	1.3	2.1	16	195	533	715	830	932	1 036
China	0.0	1.0	12	154	408	541	609	666	725
India	0.0	0.2	2.0	20	77	111	144	175	206
Japan	1.2	0.9	1.1	9.3	14	18	22	25	27
Korea	0.0	0.0	0.2	3.3	7.4	9.1	11	13	15
Chinese Taipei	0.0	0.1	0.2	1.7	5.9	7.1	8.3	9.7	11
ASEAN	-	0.0	0.0	5.3	14	21	25	31	37
Indonesia	-	-	0.0	0.4	2.2	4.3	5.6	7.5	9.5
Malaysia	-	-	-	0.3	0.5	0.9	1.3	1.8	2.4
Myanmar	-	-	-	0.0	0.1	0.1	0.3	0.4	0.6
Philippines	-	-	0.0	0.3	1.7	2.3	2.6	3.1	3.6
Singapore	-	-	0.0	0.1	0.3	0.4	0.4	0.5	0.5
Thailand	-	-	0.0	0.8	2.0	3.0	3.9	4.9	5.9
Viet Nam	-	-	0.0	3.3	7.2	9.1	11	12	14
North America	0.3	2.1	11	63	121	159	196	234	274
United States	0.3	2.1	11	59	113	149	185	222	260
Latin America	0.0	0.2	0.9	24	45	56	69	81	93
Brazil	0.0	0.1	0.5	14	26	32	39	44	49
Advanced Europe	0.4	2.9	18	82	114	126	145	174	205
Other Europe/Eurasia	-	0.0	0.2	3.9	8.3	10	12	14	16
Russia	-	0.0	0.0	0.6	1.0	1.3	1.6	2.0	2.3
Africa	0.0	0.0	0.3	5.0	19	27	35	43	51
Middle East	0.4	0.7	1.3	4.5	14	18	23	27	30
Oceania	0.1	0.1	0.9	7.2	13	16	19	21	24
International Bunkers	-	-	-	-	-	-	-	-	-
Advanced Economies	2.1	6.1	31	167	275	335	401	477	556
Group of Seven	1.6	4.1	20	111	187	235	286	338	396
Emerging and Developing Economies	0.5	2.1	17	218	592	792	927	1 049	1 173
Emerging and Developing Asia	0.0	1.2	14	180	505	680	788	884	982
Non-Asia	1.3	6.0	33	191	335	412	499	595	693
European Union	0.3	2.5	16	68	93	102	121	146	171

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
16.4	12.3	4.4	2.7	5.7	950	1 352	1 702	2 125	2 584	13.8	6.0	4.3	7.3
16.4	15.4	4.5	2.2	6.4	573	829	1 007	1 188	1 394	16.7	5.8	3.3	7.6
29.2	14.9	4.1	1.8	5.9	419	594	697	786	895	15.3	5.2	2.5	6.7
25.7	21.4	6.4	3.7	9.1	97	151	197	255	314	25.4	7.4	4.8	10.8
6.4	5.8	4.8	2.1	4.0	15	22	28	33	37	7.2	6.4	2.9	5.3
19.2	12.1	3.9	3.2	5.7	9.0	12	15	19	23	15.4	5.3	4.1	7.4
14.6	19.2	3.4	2.9	7.1	6.8	8.7	11	13	16	21.5	4.8	3.8	8.5
n.a.	15.1	6.0	3.9	7.5	19	32	45	65	88	20.1	8.9	6.9	10.9
n.a.	28.7	9.5	5.5	12.6	3.9	8.6	13	20	29	39.3	12.9	8.2	17.3
n.a.	6.8	10.8	6.1	8.0	0.6	1.8	3.1	5.6	9.0	11.2	17.6	11.1	13.5
n.a.	23.3	16.1	7.9	14.7	0.1	0.4	0.9	2.0	3.2	32.2	25.6	13.0	22.4
n.a.	26.7	4.2	3.3	9.3	2.8	4.2	5.3	6.9	8.6	35.4	6.7	4.9	12.8
n.a.	15.1	3.3	1.4	5.5	0.4	0.5	0.6	0.6	0.7	17.6	4.5	1.5	6.6
n.a.	14.7	6.9	4.1	7.8	2.6	4.2	6.1	8.2	11	18.8	9.0	5.7	10.2
n.a.	11.7	4.0	2.4	5.4	8.7	12	15	20	26	14.7	5.8	5.2	7.8
17.3	9.7	4.9	3.4	5.6	127	184	244	332	428	10.5	6.7	5.8	7.3
17.1	9.7	5.0	3.5	5.6	119	172	228	308	395	10.5	6.7	5.6	7.3
22.1	9.2	4.3	3.0	5.1	49	70	96	136	187	10.5	6.9	6.9	7.8
22.7	9.6	4.1	2.5	4.9	28	36	43	50	60	10.9	4.2	3.5	5.6
17.9	4.8	2.4	3.5	3.4	131	168	216	285	340	6.9	5.1	4.7	5.4
n.a.	11.3	4.0	2.5	5.3	9.4	13	18	24	32	13.3	6.5	6.0	8.0
n.a.	6.8	4.9	3.3	4.8	1.1	1.4	1.8	2.1	2.3	7.9	5.0	2.8	4.9
32.2	21.4	6.2	3.8	9.0	27	41	57	75	94	27.2	7.9	5.0	11.5
7.5	17.4	5.0	3.0	7.3	20	30	42	57	74	23.3	8.0	5.6	10.9
13.1	8.7	3.7	2.5	4.5	14	17	22	29	36	9.4	5.0	5.0	6.1
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
14.3	7.4	3.8	3.3	4.6	303	412	536	710	880	8.9	5.9	5.1	6.3
13.6	7.8	4.3	3.3	4.8	206	290	379	511	646	9.2	6.3	5.5	6.7
20.3	15.3	4.6	2.4	6.4	647	940	1 166	1 415	1 704	16.8	6.1	3.9	7.9
28.7	15.8	4.5	2.2	6.5	542	786	952	1 123	1 318	17.0	5.8	3.3	7.6
16.4	8.4	4.1	3.3	4.9	377	523	695	937	1 190	10.2	6.3	5.5	7.0
17.7	4.6	2.7	3.6	3.5	107	137	179	235	282	6.8	5.2	4.7	5.4

Table A13 | Primary energy consumption, biomass and waste

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	836	912	1 075	1 338	1 468	1 483	1 458	1 420	1 391
Asia	435	456	444	518	558	580	597	609	620
China	205	203	140	127	146	155	166	171	176
India	108	126	151	215	240	246	246	248	249
Japan	4.2	5.0	11	17	14	14	17	17	17
Korea	0.7	1.4	3.5	6.8	8.4	8.7	9.0	9.1	9.2
Chinese Taipei	0.0	0.9	1.8	1.7	1.7	1.8	1.8	1.8	1.9
ASEAN	78	73	80	94	100	106	111	116	120
Indonesia	30	21	17	31	39	42	45	47	49
Malaysia	1.2	1.3	0.9	1.7	2.8	3.5	3.5	3.4	3.2
Myanmar	9.1	10.0	11	11	9.7	8.7	8.0	7.5	7.0
Philippines	10	7.6	8.7	11	10.0	9.7	9.5	9.2	9.0
Singapore	0.1	0.2	0.6	0.7	1.0	1.0	1.0	1.0	1.0
Thailand	15	15	23	25	23	26	28	31	33
Viet Nam	12	14	15	9.3	9.8	11	12	13	14
North America	73	86	101	126	125	122	121	119	117
United States	62	73	89	112	111	109	108	106	105
Latin America	91	89	128	160	178	180	180	180	179
Brazil	48	47	82	102	115	120	123	125	127
Advanced Europe	56	72	137	173	193	190	184	176	170
Other Europe/Eurasia	17	15	19	28	57	58	59	61	63
Russia	12	6.9	6.9	11	36	38	40	43	46
Africa	158	187	237	324	342	333	293	247	210
Middle East	0.5	0.5	1.0	1.4	1.6	1.7	1.7	1.8	1.9
Oceania	4.8	6.1	6.1	5.9	6.0	6.0	6.1	6.0	6.0
International Bunkers	-	-	-	1.1	7.3	12	16	21	25
Advanced Economies	139	172	262	331	349	344	339	330	321
Group of Seven	95	114	175	221	226	221	219	212	206
Emerging and Developing Economies	697	740	813	1 006	1 111	1 127	1 103	1 069	1 045
Emerging and Developing Asia	430	448	427	491	533	554	569	581	591
Non-Asia	400	456	631	819	903	892	845	790	746
European Union	47	65	129	155	174	171	164	157	151

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.4	1.3	-0.1	-0.5	0.1	1 477	1 446	1 406	1 391	1 415	1.4	-0.5	0.1	0.2
0.5	1.1	0.7	0.4	0.7	573	581	581	585	599	1.4	0.1	0.3	0.5
-1.4	2.0	1.3	0.6	1.2	154	168	184	199	215	2.8	1.8	1.6	2.0
2.1	1.6	0.2	0.1	0.5	234	226	211	202	199	1.3	-1.0	-0.6	-0.3
4.4	-3.4	2.0	0.0	-0.1	21	22	22	22	21	3.0	0.6	-0.4	0.8
7.0	3.2	0.7	0.3	1.2	9.0	9.6	11	12	13	4.2	1.6	2.2	2.5
11.3	0.1	0.4	0.3	0.3	1.8	2.1	2.6	3.1	3.7	0.8	3.3	3.8	2.8
0.6	0.9	1.1	0.8	0.9	104	111	112	113	113	1.5	0.7	0.1	0.7
0.1	3.6	1.4	0.9	1.8	45	50	51	51	50	5.6	1.3	-0.1	1.9
1.0	7.2	2.2	-0.7	2.4	2.9	3.3	3.6	3.8	3.9	7.9	2.2	0.8	3.1
0.6	-1.8	-2.0	-1.3	-1.7	8.4	6.0	4.8	4.1	3.4	-3.9	-5.4	-3.4	-4.3
0.3	-1.9	-0.5	-0.5	-0.9	10	9.9	9.5	9.1	8.8	-1.9	-0.5	-0.8	-1.0
7.2	5.0	0.1	0.3	1.4	1.1	1.2	1.3	1.5	1.7	7.0	1.6	2.8	3.4
1.6	-1.0	2.0	1.4	1.0	23	27	29	30	32	-1.0	2.2	1.1	0.9
-0.9	0.7	2.0	1.6	1.5	9.5	9.3	9.2	9.3	9.7	0.3	-0.3	0.5	0.1
1.6	-0.1	-0.3	-0.4	-0.3	133	134	139	144	148	0.8	0.4	0.6	0.6
1.8	-0.2	-0.3	-0.3	-0.3	119	121	126	132	137	0.8	0.6	0.8	0.7
1.7	1.5	0.1	-0.1	0.4	174	166	156	147	140	1.1	-1.1	-1.1	-0.5
2.3	1.6	0.7	0.3	0.8	114	110	106	101	96	1.5	-0.7	-0.9	-0.2
3.5	1.6	-0.5	-0.8	-0.1	201	191	179	167	157	2.2	-1.2	-1.3	-0.4
1.6	10.7	0.3	0.6	3.0	64	64	64	65	66	12.3	0.0	0.4	3.2
-0.4	19.2	1.1	1.4	5.6	44	46	47	50	53	22.8	0.7	1.1	6.1
2.2	0.8	-1.5	-3.3	-1.6	310	265	219	185	158	-0.6	-3.4	-3.2	-2.6
3.4	1.9	0.6	0.9	1.0	1.7	1.8	2.0	2.4	2.9	2.7	1.8	3.7	2.7
0.6	0.2	0.2	-0.1	0.1	6.0	5.8	5.6	5.4	5.3	0.3	-0.7	-0.6	-0.4
n.a.	30.4	8.2	4.7	12.2	15	38	60	90	139	44.9	14.7	8.8	19.5
2.7	0.8	-0.3	-0.5	-0.1	374	366	360	354	350	1.8	-0.4	-0.3	0.2
2.6	0.3	-0.3	-0.6	-0.3	249	244	243	242	242	1.7	-0.2	-0.1	0.3
1.1	1.4	-0.1	-0.5	0.1	1 088	1 042	986	947	926	1.1	-1.0	-0.6	-0.3
0.4	1.2	0.7	0.4	0.7	540	546	544	547	558	1.3	0.1	0.3	0.5
2.2	1.4	-0.7	-1.2	-0.3	889	827	764	715	678	1.2	-1.5	-1.2	-0.7
3.7	1.7	-0.6	-0.9	-0.1	181	172	160	148	139	2.3	-1.3	-1.4	-0.4

Table A14 | Final energy consumption

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	6 183	6 927	8 720	10 249	10 930	11 246	11 469	11 674	11 857
Asia	1 515	1 952	3 128	4 280	4 774	4 996	5 179	5 350	5 488
China	662	785	1 649	2 410	2 609	2 613	2 577	2 519	2 430
India	215	291	440	724	924	1 069	1 210	1 362	1 511
Japan	291	336	314	250	235	223	211	200	189
Korea	65	127	161	174	174	172	167	162	156
Chinese Taipei	32	54	74	69	81	81	80	78	76
ASEAN	149	245	343	477	559	624	692	759	822
Indonesia	57	91	106	161	196	223	250	277	303
Malaysia	13	29	42	61	70	76	81	87	91
Myanmar	9.5	12	13	20	20	21	23	25	28
Philippines	19	23	25	37	48	58	67	76	83
Singapore	5.0	8.3	15	18	20	20	21	21	21
Thailand	29	51	85	99	101	106	112	116	120
Viet Nam	16	25	48	69	87	101	116	132	149
North America	1 452	1 728	1 699	1 757	1 723	1 700	1 662	1 623	1 590
United States	1 294	1 546	1 513	1 561	1 533	1 514	1 482	1 449	1 421
Latin America	343	442	571	630	673	704	733	760	784
Brazil	112	154	212	253	271	288	305	320	333
Advanced Europe	1 142	1 235	1 289	1 154	1 093	1 044	994	946	903
Other Europe/Eurasia	1 057	647	709	769	769	763	753	745	739
Russia	625	418	447	520	509	500	490	481	473
Africa	247	307	421	564	629	676	698	716	747
Middle East	158	260	451	610	672	713	748	782	813
Oceania	66	82	90	95	98	99	99	99	99
International Bunkers	202	274	361	391	500	551	603	652	695
Advanced Economies	3 059	3 579	3 649	3 523	3 429	3 345	3 240	3 135	3 039
Group of Seven	2 378	2 737	2 676	2 558	2 457	2 389	2 308	2 229	2 159
Emerging and Developing Economies	2 922	3 074	4 710	6 334	7 002	7 349	7 627	7 887	8 123
Emerging and Developing Asia	1 116	1 418	2 557	3 762	4 258	4 494	4 694	4 885	5 042
Non-Asia	4 467	4 701	5 231	5 578	5 657	5 698	5 687	5 671	5 674
European Union	995	1 027	1 071	931	881	841	799	759	722

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.5	0.9	0.5	0.3	0.5	10 575	10 277	9 852	9 502	9 282	0.4	-0.7	-0.6	-0.4
3.2	1.6	0.8	0.6	0.9	4 609	4 554	4 433	4 322	4 260	1.1	-0.4	-0.4	0.0
4.0	1.1	-0.1	-0.6	0.0	2 510	2 368	2 191	2 029	1 897	0.6	-1.4	-1.4	-0.9
3.7	3.6	2.7	2.2	2.8	894	973	1 034	1 089	1 151	3.1	1.5	1.1	1.7
-0.5	-0.9	-1.0	-1.1	-1.0	227	205	182	165	153	-1.4	-2.2	-1.7	-1.8
3.0	0.0	-0.4	-0.7	-0.4	171	162	151	140	131	-0.3	-1.2	-1.4	-1.0
2.4	2.2	-0.1	-0.5	0.3	78	75	70	66	62	1.8	-1.1	-1.2	-0.4
3.6	2.3	2.2	1.7	2.0	542	574	595	611	626	1.8	0.9	0.5	1.0
3.2	2.8	2.5	1.9	2.4	190	206	217	224	231	2.4	1.3	0.7	1.4
4.7	1.9	1.6	1.1	1.5	68	69	68	66	65	1.4	0.1	-0.4	0.2
2.2	0.1	1.4	2.1	1.3	18	17	17	19	20	-1.4	-0.1	1.3	0.1
2.0	3.9	3.3	2.2	3.1	47	54	59	62	63	3.6	2.3	0.6	2.0
4.0	1.2	0.5	0.1	0.5	19	19	18	18	17	0.7	-0.4	-0.5	-0.2
3.8	0.4	1.0	0.7	0.7	100	100	100	99	98	0.2	0.0	-0.2	0.0
4.5	3.5	2.9	2.5	2.9	85	91	97	103	110	3.0	1.4	1.2	1.7
0.6	-0.3	-0.4	-0.4	-0.4	1 676	1 566	1 431	1 323	1 250	-0.7	-1.6	-1.3	-1.3
0.6	-0.3	-0.3	-0.4	-0.3	1 493	1 398	1 278	1 183	1 120	-0.6	-1.5	-1.3	-1.2
1.9	0.9	0.9	0.7	0.8	653	648	634	618	610	0.5	-0.3	-0.4	-0.1
2.5	1.0	1.2	0.9	1.0	263	265	264	263	262	0.6	0.1	-0.1	0.1
0.0	-0.8	-0.9	-0.9	-0.9	1 054	948	846	769	714	-1.3	-2.2	-1.7	-1.8
-1.0	0.0	-0.2	-0.2	-0.1	747	704	653	605	567	-0.4	-1.3	-1.4	-1.1
-0.6	-0.3	-0.4	-0.3	-0.4	493	459	422	389	363	-0.8	-1.5	-1.5	-1.3
2.5	1.6	1.0	0.7	1.0	590	583	572	570	574	0.7	-0.3	0.0	0.1
4.2	1.4	1.1	0.8	1.1	655	662	656	654	657	1.0	0.0	0.0	0.3
1.1	0.5	0.1	0.0	0.2	95	90	84	81	79	0.0	-1.3	-0.5	-0.7
2.0	3.5	1.9	1.4	2.2	496	521	543	560	572	3.4	0.9	0.5	1.4
0.4	-0.4	-0.6	-0.6	-0.5	3 326	3 070	2 787	2 565	2 411	-0.8	-1.8	-1.4	-1.4
0.2	-0.6	-0.6	-0.7	-0.6	2 380	2 185	1 974	1 811	1 701	-1.0	-1.9	-1.5	-1.5
2.4	1.4	0.9	0.6	0.9	6 753	6 685	6 522	6 376	6 299	0.9	-0.3	-0.3	0.0
3.8	1.8	1.0	0.7	1.1	4 108	4 088	4 007	3 929	3 892	1.3	-0.3	-0.3	0.1
0.7	0.2	0.1	0.0	0.1	5 470	5 202	4 876	4 619	4 451	-0.3	-1.1	-0.9	-0.8
-0.2	-0.8	-1.0	-1.0	-0.9	850	764	680	616	569	-1.3	-2.2	-1.8	-1.8

Table A15 | Final energy consumption, industry

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	1 797	1 864	2 620	3 080	3 393	3 533	3 604	3 652	3 659
Asia	512	654	1 396	1 811	2 055	2 151	2 195	2 223	2 212
China	238	301	923	1 166	1 226	1 200	1 139	1 063	962
India	59	85	157	287	413	491	553	614	664
Japan	107	103	91	73	66	63	60	57	54
Korea	20	38	48	46	47	47	46	45	43
Chinese Taipei	13	21	25	24	29	30	29	29	28
ASEAN	41	76	112	168	214	246	277	305	331
Indonesia	17	30	38	65	84	99	112	125	137
Malaysia	5.5	12	15	19	25	29	33	37	40
Myanmar	0.5	1.9	2.0	2.0	2.2	2.5	2.8	3.0	3.2
Philippines	4.1	4.6	5.9	7.0	11	14	16	18	19
Singapore	0.6	2.2	5.1	6.9	7.6	7.7	7.6	7.4	7.1
Thailand	8.7	17	27	30	33	36	38	40	42
Viet Nam	4.5	7.9	17	34	44	51	58	66	73
North America	331	386	312	324	328	329	326	320	314
United States	284	332	270	279	282	282	279	274	270
Latin America	114	143	180	181	201	218	234	247	259
Brazil	40	57	80	86	95	104	113	120	126
Advanced Europe	330	325	296	271	266	260	252	243	234
Other Europe/Eurasia	391	205	205	207	218	221	222	223	223
Russia	209	128	126	151	154	154	153	152	151
Africa	55	59	85	98	114	129	145	162	178
Middle East	42	64	119	160	183	194	200	205	209
Oceania	23	28	26	27	28	29	30	30	31
International Bunkers	-	-	-	-	-	-	-	-	-
Advanced Economies	827	905	805	772	773	767	751	731	711
Group of Seven	602	646	545	516	505	499	486	472	459
Emerging and Developing Economies	971	959	1 816	2 308	2 620	2 765	2 853	2 921	2 948
Emerging and Developing Asia	369	489	1 226	1 662	1 904	2 003	2 052	2 085	2 079
Non-Asia	1 285	1 210	1 224	1 268	1 338	1 381	1 409	1 429	1 448
European Union	313	274	247	217	214	210	204	197	190

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.6	1.4	0.6	0.2	0.6	3 243	3 128	2 921	2 722	2 585	0.7	-1.0	-1.2	-0.6
3.9	1.8	0.7	0.1	0.7	1 959	1 894	1 768	1 647	1 562	1.1	-1.0	-1.2	-0.5
4.9	0.7	-0.7	-1.7	-0.7	1 157	1 034	887	759	653	-0.1	-2.6	-3.0	-2.1
4.9	5.3	3.0	1.9	3.2	400	441	458	463	474	4.8	1.4	0.3	1.9
-1.2	-1.3	-0.9	-1.0	-1.1	63	56	49	44	40	-2.1	-2.4	-2.1	-2.2
2.5	0.5	-0.3	-0.8	-0.3	46	43	39	35	31	-0.1	-1.6	-2.1	-1.4
1.9	2.7	0.1	-0.3	0.6	28	26	24	22	20	2.0	-1.4	-1.7	-0.6
4.3	3.5	2.6	1.8	2.5	206	221	228	231	236	2.9	1.0	0.4	1.3
4.1	3.8	2.9	2.0	2.8	82	90	96	99	102	3.3	1.6	0.7	1.7
3.8	3.8	2.9	1.9	2.8	24	25	25	25	24	3.1	0.6	-0.3	0.9
4.5	1.7	2.1	1.6	1.8	1.8	1.8	1.9	2.0	2.1	-1.4	0.4	0.9	0.1
1.6	7.4	3.4	1.6	3.8	11	13	14	14	14	7.1	2.0	0.3	2.7
7.6	1.4	0.1	-0.6	0.1	7.1	6.8	6.1	5.4	4.8	0.6	-1.6	-2.4	-1.3
3.8	1.3	1.5	0.9	1.2	32	33	33	32	31	1.0	0.1	-0.4	0.2
6.3	3.8	2.8	2.2	2.8	43	45	46	47	50	3.3	0.7	0.9	1.4
-0.1	0.2	-0.1	-0.4	-0.1	316	293	262	234	213	-0.4	-1.8	-2.1	-1.6
-0.1	0.2	-0.1	-0.3	-0.1	271	251	224	199	181	-0.4	-1.9	-2.1	-1.6
1.4	1.5	1.5	1.0	1.3	194	197	194	190	189	1.0	0.0	-0.3	0.1
2.3	1.5	1.7	1.1	1.4	92	94	93	91	90	1.0	0.1	-0.3	0.2
-0.6	-0.3	-0.6	-0.7	-0.5	257	238	214	194	179	-0.8	-1.8	-1.8	-1.5
-1.9	0.8	0.2	0.0	0.3	209	197	182	168	158	0.2	-1.4	-1.4	-1.0
-1.0	0.3	0.0	-0.2	0.0	147	137	123	111	103	-0.3	-1.8	-1.8	-1.4
1.8	2.1	2.5	2.1	2.2	108	114	118	121	126	1.3	0.9	0.7	0.9
4.1	1.9	0.9	0.4	1.0	174	169	159	147	138	1.2	-0.9	-1.4	-0.5
0.5	0.8	0.6	0.2	0.5	27	26	24	22	21	0.1	-1.2	-1.5	-1.0
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
-0.2	0.0	-0.3	-0.5	-0.3	743	689	619	556	508	-0.5	-1.8	-1.9	-1.5
-0.5	-0.3	-0.4	-0.6	-0.4	485	445	396	353	320	-0.9	-2.0	-2.1	-1.8
2.7	1.8	0.9	0.3	0.9	2 500	2 439	2 302	2 166	2 076	1.1	-0.8	-1.0	-0.4
4.7	2.0	0.7	0.1	0.8	1 816	1 762	1 649	1 541	1 466	1.3	-1.0	-1.2	-0.5
0.0	0.8	0.5	0.3	0.5	1 284	1 234	1 153	1 075	1 022	0.2	-1.1	-1.2	-0.8
-1.1	-0.2	-0.5	-0.7	-0.5	206	191	172	155	142	-0.7	-1.8	-1.9	-1.6

Table A16 | Final energy consumption, transport

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	1 578	1 965	2 431	2 936	3 080	3 131	3 198	3 264	3 324
Asia	189	323	493	795	898	936	986	1 039	1 091
China	30	83	195	376	424	413	403	391	378
India	21	32	65	125	163	200	244	292	343
Japan	72	89	79	64	59	54	50	45	40
Korea	15	26	30	36	34	31	29	26	23
Chinese Taipei	7.3	12	13	13	12	12	11	9.6	8.4
ASEAN	33	62	88	148	168	184	201	219	235
Indonesia	11	21	30	58	67	73	78	84	90
Malaysia	4.9	11	15	23	23	23	23	22	21
Myanmar	0.4	1.2	0.8	4.7	5.2	6.5	8.2	10	12
Philippines	4.5	8.3	8.0	13	18	22	27	32	35
Singapore	1.4	1.8	2.4	2.2	2.2	2.1	2.0	1.9	1.7
Thailand	9.2	15	19	29	28	28	28	28	28
Viet Nam	1.4	3.5	10	15	20	23	26	30	34
North America	531	640	655	679	622	584	548	509	473
United States	488	588	596	619	569	535	502	467	434
Latin America	104	141	199	237	246	253	260	266	270
Brazil	33	47	70	94	96	100	104	108	112
Advanced Europe	269	318	335	347	312	285	260	236	215
Other Europe/Eurasia	170	110	145	161	156	152	149	146	143
Russia	116	74	96	107	103	100	99	98	96
Africa	38	54	87	131	142	158	176	194	212
Middle East	51	75	122	156	165	173	180	186	191
Oceania	24	30	35	38	39	38	37	36	34
International Bunkers	202	274	361	391	500	551	603	652	695
Advanced Economies	921	1 121	1 150	1 182	1 082	1 008	937	865	796
Group of Seven	768	915	909	913	828	770	715	659	606
Emerging and Developing Economies	456	570	919	1 362	1 498	1 571	1 658	1 748	1 832
Emerging and Developing Asia	92	189	366	677	788	836	894	955	1 017
Non-Asia	1 187	1 369	1 577	1 749	1 683	1 643	1 609	1 573	1 537
European Union	220	262	279	280	252	230	209	190	171

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.9	0.7	0.4	0.4	0.5	2 964	2 798	2 634	2 501	2 429	0.1	-1.2	-0.8	-0.7
4.4	1.7	0.9	1.0	1.2	856	825	796	774	766	1.1	-0.7	-0.4	-0.1
7.9	1.7	-0.5	-0.6	0.0	403	361	322	292	275	1.0	-2.2	-1.6	-1.1
5.6	3.8	4.1	3.5	3.8	155	175	196	217	235	3.1	2.4	1.8	2.4
-0.4	-1.1	-1.7	-2.2	-1.7	56	47	38	31	27	-1.9	-3.9	-3.4	-3.2
2.8	-1.1	-1.7	-2.1	-1.7	33	27	22	18	15	-1.5	-3.8	-3.7	-3.2
1.8	-0.9	-1.4	-2.4	-1.6	12	9.8	7.8	6.2	5.2	-1.6	-4.0	-3.9	-3.3
4.7	1.8	1.8	1.6	1.7	162	167	168	166	163	1.3	0.4	-0.3	0.4
5.2	2.1	1.6	1.4	1.6	64	66	65	63	61	1.6	0.1	-0.6	0.2
4.8	0.0	-0.1	-0.6	-0.3	22	20	18	16	14	-0.4	-1.9	-2.7	-1.8
7.4	1.4	4.8	4.1	3.6	5.0	5.9	7.1	8.3	9.5	0.8	3.5	3.0	2.6
3.2	4.6	4.4	2.7	3.8	17	21	24	25	24	4.3	3.2	0.3	2.4
1.5	-0.3	-0.7	-1.4	-0.9	1.9	1.5	1.3	1.2	1.1	-2.0	-4.0	-1.0	-2.4
3.5	-0.6	0.1	0.1	-0.1	27	25	24	21	20	-0.9	-1.4	-1.9	-1.5
7.5	3.8	2.8	2.6	3.0	19	20	22	22	23	3.2	1.3	0.6	1.5
0.7	-1.2	-1.3	-1.5	-1.3	598	519	440	374	335	-1.8	-3.0	-2.7	-2.6
0.7	-1.2	-1.2	-1.4	-1.3	549	479	407	346	310	-1.7	-2.9	-2.7	-2.5
2.5	0.5	0.5	0.4	0.5	237	228	216	205	197	0.0	-0.9	-0.9	-0.7
3.2	0.3	0.7	0.8	0.7	92	90	89	89	89	-0.2	-0.4	0.0	-0.2
0.8	-1.5	-1.8	-1.9	-1.8	290	234	189	158	142	-2.5	-4.2	-2.8	-3.3
-0.2	-0.5	-0.5	-0.4	-0.5	150	135	120	106	94	-1.1	-2.2	-2.4	-2.0
-0.3	-0.5	-0.4	-0.3	-0.4	97	88	78	70	63	-1.3	-2.2	-2.2	-1.9
3.8	1.2	2.1	1.9	1.8	138	146	152	157	163	0.8	1.0	0.7	0.8
3.5	0.8	0.9	0.6	0.8	160	156	149	142	137	0.3	-0.7	-0.8	-0.5
1.4	0.3	-0.5	-0.7	-0.4	37	33	30	26	24	-0.2	-2.3	-2.0	-1.6
2.0	3.5	1.9	1.4	2.2	496	521	543	560	572	3.4	0.9	0.5	1.4
0.8	-1.2	-1.4	-1.6	-1.5	1 030	873	728	615	550	-1.9	-3.4	-2.8	-2.8
0.5	-1.4	-1.5	-1.6	-1.5	787	666	555	469	420	-2.1	-3.4	-2.7	-2.8
3.4	1.4	1.0	1.0	1.1	1 437	1 403	1 362	1 326	1 307	0.8	-0.5	-0.4	-0.2
6.2	2.2	1.3	1.3	1.5	752	738	725	717	716	1.5	-0.4	-0.1	0.2
1.2	-0.6	-0.4	-0.5	-0.5	1 611	1 452	1 295	1 167	1 091	-1.2	-2.2	-1.7	-1.7
0.7	-1.5	-1.8	-2.0	-1.8	234	189	152	126	112	-2.5	-4.2	-3.0	-3.3

Table A17 | Final energy consumption, buildings, etc.

	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	2 330	2 478	2 874	3 232	3 347	3 424	3 462	3 513	3 595
Asia	697	787	942	1 185	1 252	1 312	1 374	1 447	1 529
China	351	338	412	584	624	659	691	724	758
India	122	147	184	254	275	290	310	335	366
Japan	77	107	108	87	85	81	78	74	71
Korea	24	38	44	44	43	42	41	40	39
Chinese Taipei	6.9	11	12	13	13	13	13	13	12
ASEAN	64	86	102	113	124	136	149	164	179
Indonesia	22	30	27	33	38	44	50	57	65
Malaysia	2.1	4.3	8.2	11	13	14	15	16	17
Myanmar	8.5	9.1	10	13	12	11	11	12	12
Philippines	10.0	9.9	11	16	17	19	21	23	25
Singapore	1.1	1.7	2.3	3.0	3.2	3.4	3.4	3.5	3.6
Thailand	11	14	20	17	17	17	17	18	18
Viet Nam	10	13	18	17	20	23	26	30	34
North America	456	528	572	573	585	594	592	593	599
United States	403	473	511	507	519	530	530	532	539
Latin America	99	121	147	176	187	192	196	201	207
Brazil	29	36	44	58	64	68	71	74	76
Advanced Europe	442	477	545	452	430	414	398	385	374
Other Europe/Eurasia	431	285	279	315	308	303	295	290	287
Russia	260	179	157	189	179	172	165	159	154
Africa	144	179	230	309	345	357	342	322	315
Middle East	47	82	136	198	215	226	237	247	257
Oceania	15	19	23	25	26	26	27	28	28
International Bunkers	-	-	-	-	-	-	-	-	-
Advanced Economies	1 024	1 185	1 311	1 201	1 188	1 178	1 156	1 140	1 130
Group of Seven	783	904	972	887	878	872	855	844	839
Emerging and Developing Economies	1 306	1 294	1 562	2 030	2 159	2 246	2 306	2 374	2 465
Emerging and Developing Asia	586	627	770	1 033	1 104	1 168	1 235	1 313	1 399
Non-Asia	1 633	1 691	1 932	2 047	2 095	2 113	2 088	2 066	2 067
European Union	374	391	447	362	342	328	314	301	291

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mtoe)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.0	0.5	0.3	0.4	0.4	3 259	3 195	3 093	3 035	2 991	0.1	-0.5	-0.3	-0.3
1.6	0.8	0.9	1.1	0.9	1 225	1 239	1 247	1 260	1 276	0.5	0.2	0.2	0.3
1.6	1.0	1.0	0.9	1.0	616	632	637	639	638	0.8	0.3	0.0	0.3
2.3	1.1	1.2	1.7	1.4	265	269	276	289	305	0.6	0.4	1.0	0.7
0.4	-0.4	-0.9	-0.8	-0.7	84	78	71	67	64	-0.6	-1.6	-1.1	-1.2
1.9	-0.3	-0.4	-0.7	-0.5	42	41	38	36	33	-0.5	-1.0	-1.5	-1.0
2.0	-0.2	-0.2	-0.5	-0.3	13	12	12	11	10	-0.4	-1.0	-1.4	-1.0
1.7	1.3	1.9	1.9	1.7	121	127	134	142	149	0.9	1.1	1.1	1.0
1.3	2.2	2.8	2.6	2.6	38	42	47	52	56	2.1	2.2	1.9	2.0
5.1	2.0	1.7	1.4	1.7	12	13	14	14	14	1.8	1.0	0.5	1.0
1.2	-0.7	-0.5	0.6	-0.2	11	8.9	8.2	8.1	8.1	-2.3	-2.6	-0.2	-1.6
1.4	1.4	1.9	1.6	1.7	17	18	19	20	20	1.1	1.1	0.8	1.0
3.0	1.1	0.7	0.4	0.7	3.2	3.2	3.2	3.1	3.0	1.0	0.0	-0.5	0.1
1.4	-0.3	0.5	0.5	0.2	16	16	16	15	15	-0.7	-0.4	-0.6	-0.5
1.6	2.4	2.9	2.6	2.7	19	22	24	26	29	2.1	2.2	1.8	2.0
0.7	0.3	0.1	0.1	0.2	575	562	532	514	498	0.1	-0.8	-0.7	-0.5
0.7	0.3	0.2	0.2	0.2	511	502	476	462	450	0.1	-0.7	-0.6	-0.4
1.8	0.9	0.5	0.5	0.6	184	183	181	178	177	0.6	-0.2	-0.2	0.0
2.1	1.4	1.0	0.7	1.0	63	65	65	65	64	1.2	0.3	-0.1	0.4
0.1	-0.7	-0.8	-0.6	-0.7	422	392	359	334	312	-1.0	-1.6	-1.4	-1.4
-0.9	-0.3	-0.4	-0.3	-0.3	301	284	264	246	229	-0.6	-1.3	-1.4	-1.2
-1.0	-0.8	-0.8	-0.6	-0.7	174	161	148	136	125	-1.1	-1.7	-1.6	-1.5
2.4	1.6	-0.1	-0.8	0.1	316	293	268	253	244	0.3	-1.6	-0.9	-0.9
4.5	1.2	1.0	0.8	1.0	212	216	217	223	227	1.0	0.3	0.4	0.5
1.6	0.5	0.5	0.5	0.5	25	25	25	27	29	0.3	-0.3	1.6	0.6
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
0.5	-0.2	-0.3	-0.2	-0.2	1 168	1 117	1 044	995	952	-0.4	-1.1	-0.9	-0.9
0.4	-0.1	-0.3	-0.2	-0.2	863	826	771	736	706	-0.4	-1.1	-0.9	-0.8
1.3	0.9	0.7	0.7	0.7	2 091	2 078	2 049	2 040	2 040	0.4	-0.2	0.0	0.0
1.7	1.0	1.1	1.3	1.1	1 079	1 101	1 119	1 141	1 164	0.6	0.4	0.4	0.4
0.7	0.3	0.0	-0.1	0.0	2 034	1 956	1 847	1 775	1 715	-0.1	-1.0	-0.7	-0.7
-0.1	-0.8	-0.9	-0.7	-0.8	336	311	284	264	246	-1.0	-1.7	-1.4	-1.4

Table A18 | Final energy consumption, electricity

	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	9 699	12 638	17 886	25 247	29 547	32 684	35 651	38 834	42 033
Asia	1 823	3 249	6 685	12 876	15 934	17 868	19 550	21 244	22 811
China	454	1 036	3 450	8 012	9 817	10 725	11 316	11 773	12 005
India	212	368	718	1 608	2 326	2 897	3 491	4 167	4 879
Japan	765	973	1 035	879	871	871	871	877	890
Korea	94	263	449	535	571	594	607	616	621
Chinese Taipei	77	160	218	258	291	301	308	314	319
ASEAN	130	321	613	1 248	1 645	1 973	2 334	2 731	3 164
Indonesia	28	79	155	412	561	693	846	1 021	1 220
Malaysia	20	61	111	182	231	270	312	357	403
Myanmar	1.7	3.4	6.5	21	32	40	48	58	70
Philippines	21	37	55	96	147	183	222	260	296
Singapore	13	27	42	55	61	65	67	69	70
Thailand	38	88	149	204	234	259	285	311	339
Viet Nam	6.2	22	87	246	338	413	496	587	688
North America	3 051	3 930	4 265	4 423	4 775	5 138	5 474	5 888	6 348
United States	2 633	3 499	3 788	3 894	4 211	4 542	4 847	5 231	5 661
Latin America	516	796	1 124	1 458	1 688	1 890	2 102	2 322	2 553
Brazil	211	321	438	580	685	780	873	965	1 053
Advanced Europe	2 248	2 717	3 106	2 978	3 041	3 127	3 232	3 371	3 523
Other Europe/Eurasia	1 449	1 001	1 193	1 331	1 483	1 599	1 714	1 835	1 966
Russia	826	608	727	837	903	965	1 024	1 085	1 148
Africa	256	361	544	738	951	1 198	1 510	1 877	2 287
Middle East	199	378	718	1 179	1 380	1 546	1 727	1 927	2 145
Oceania	158	207	252	263	295	318	343	370	400
International Bunkers	-	-	-	-	-	-	-	-	-
Advanced Economies	6 429	8 313	9 410	9 437	9 951	10 458	10 945	11 548	12 213
Group of Seven	5 062	6 373	6 904	6 701	7 039	7 425	7 796	8 269	8 800
Emerging and Developing Economies	3 270	4 326	8 476	15 810	19 596	22 226	24 707	27 286	29 820
Emerging and Developing Asia	851	1 790	4 898	11 103	14 095	15 993	17 654	19 325	20 868
Non-Asia	7 876	9 390	11 202	12 371	13 612	14 816	16 101	17 590	19 223
European Union	1 887	2 198	2 510	2 329	2 377	2 444	2 526	2 635	2 754

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(TWh)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
2.9	2.3	1.9	1.7	1.9	30 320	33 852	36 845	39 956	42 929	2.7	2.0	1.5	2.0
6.1	3.1	2.1	1.6	2.1	16 299	18 245	19 705	21 070	22 485	3.4	1.9	1.3	2.1
9.1	2.9	1.4	0.6	1.5	9 936	10 668	10 918	11 020	11 004	3.1	0.9	0.1	1.2
6.3	5.4	4.1	3.4	4.2	2 509	3 248	3 975	4 702	5 541	6.6	4.7	3.4	4.7
0.4	-0.1	0.0	0.2	0.0	880	884	882	900	910	0.0	0.0	0.3	0.1
5.4	0.9	0.6	0.2	0.6	571	594	605	607	600	0.9	0.6	-0.1	0.4
3.7	1.7	0.6	0.4	0.8	290	297	298	296	291	1.7	0.3	-0.2	0.5
7.1	4.0	3.6	3.1	3.5	1 680	2 006	2 340	2 693	3 084	4.3	3.4	2.8	3.4
8.5	4.5	4.2	3.7	4.1	585	736	898	1 071	1 259	5.2	4.4	3.4	4.2
6.9	3.4	3.1	2.6	3.0	234	271	305	336	366	3.7	2.7	1.8	2.6
7.9	6.1	4.3	3.8	4.6	34	44	53	64	77	6.9	4.8	3.7	4.9
4.7	6.3	4.2	2.9	4.3	148	185	225	269	317	6.5	4.2	3.5	4.5
4.5	1.5	0.9	0.5	0.9	62	66	67	65	63	1.6	0.7	-0.5	0.5
5.2	2.0	2.0	1.8	1.9	237	261	285	311	339	2.1	1.9	1.7	1.9
11.8	4.7	3.9	3.3	3.9	339	395	452	515	593	4.7	2.9	2.8	3.3
1.1	1.1	1.4	1.5	1.3	4 868	5 306	5 680	6 149	6 480	1.4	1.6	1.3	1.4
1.2	1.1	1.4	1.6	1.4	4 286	4 677	5 010	5 454	5 773	1.4	1.6	1.4	1.5
3.2	2.1	2.2	2.0	2.1	1 727	1 971	2 227	2 487	2 745	2.4	2.6	2.1	2.4
3.1	2.4	2.5	1.9	2.2	708	810	900	984	1 076	2.9	2.4	1.8	2.3
0.9	0.3	0.6	0.9	0.6	3 180	3 398	3 575	3 752	3 864	0.9	1.2	0.8	1.0
-0.3	1.6	1.5	1.4	1.5	1 528	1 677	1 816	1 949	2 083	2.0	1.7	1.4	1.7
0.0	1.1	1.3	1.1	1.2	935	1 013	1 077	1 131	1 186	1.6	1.4	1.0	1.3
3.3	3.7	4.7	4.2	4.3	993	1 285	1 606	1 943	2 307	4.3	4.9	3.7	4.3
5.5	2.3	2.3	2.2	2.2	1 423	1 641	1 880	2 194	2 502	2.7	2.8	2.9	2.8
1.6	1.7	1.5	1.6	1.6	301	329	356	412	463	2.0	1.7	2.7	2.1
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
1.2	0.8	1.0	1.1	1.0	10 198	10 917	11 503	12 221	12 708	1.1	1.2	1.0	1.1
0.9	0.7	1.0	1.2	1.0	7 229	7 764	8 195	8 749	9 119	1.1	1.3	1.1	1.1
4.9	3.1	2.3	1.9	2.4	20 123	22 935	25 341	27 735	30 221	3.5	2.3	1.8	2.4
8.1	3.5	2.3	1.7	2.4	14 452	16 360	17 812	19 162	20 583	3.8	2.1	1.5	2.3
1.4	1.4	1.7	1.8	1.6	14 021	15 608	17 140	18 886	20 444	1.8	2.0	1.8	1.9
0.6	0.3	0.6	0.9	0.6	2 486	2 654	2 791	2 934	3 029	0.9	1.2	0.8	1.0

Table A19 | Electricity generated

	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	11 850	15 425	21 523	29 978	34 966	38 716	42 170	45 921	49 664
Asia	2 244	3 970	7 975	15 098	18 676	21 005	22 891	24 838	26 621
China	621	1 356	4 197	9 492	11 567	12 651	13 279	13 796	14 057
India	289	561	972	1 987	2 886	3 599	4 291	5 075	5 880
Japan	862	1 055	1 164	993	983	983	983	991	1 006
Korea	109	288	472	607	648	673	688	700	706
Chinese Taipei	90	181	244	279	315	327	335	342	349
ASEAN	154	374	692	1 365	1 810	2 196	2 599	3 053	3 549
Indonesia	33	93	177	433	599	753	921	1 121	1 348
Malaysia	23	69	125	193	247	294	342	394	448
Myanmar	2.5	5.2	8.8	21	33	42	52	64	79
Philippines	26	45	68	118	180	226	269	314	355
Singapore	16	32	46	58	64	67	70	72	73
Thailand	44	96	159	196	229	257	285	315	347
Viet Nam	8.7	27	95	274	376	461	552	656	769
North America	3 686	4 632	4 958	5 063	5 460	5 881	6 285	6 781	7 331
United States	3 203	4 026	4 354	4 430	4 789	5 172	5 534	5 986	6 496
Latin America	624	1 008	1 405	1 796	2 071	2 318	2 594	2 872	3 168
Brazil	223	349	516	708	834	947	1 059	1 164	1 264
Advanced Europe	2 695	3 236	3 623	3 462	3 632	3 741	3 894	4 084	4 292
Other Europe/Eurasia	1 856	1 415	1 689	1 826	1 889	2 024	2 149	2 284	2 425
Russia	1 082	876	1 036	1 159	1 164	1 241	1 307	1 363	1 416
Africa	315	442	687	912	1 169	1 466	1 842	2 272	2 747
Middle East	244	472	888	1 502	1 713	1 898	2 103	2 344	2 600
Oceania	187	249	298	318	356	383	412	445	480
International Bunkers	-	-	-	-	-	-	-	-	-
Advanced Economies	7 673	9 704	10 843	10 818	11 496	12 092	12 704	13 450	14 272
Group of Seven	6 042	7 437	7 990	7 639	8 119	8 574	9 041	9 554	10 248
Emerging and Developing Economies	4 177	5 721	10 680	19 160	23 470	26 624	29 466	32 471	35 391
Emerging and Developing Asia	1 138	2 383	6 010	13 124	16 629	18 918	20 779	22 697	24 452
Non-Asia	9 606	11 455	13 548	14 880	16 290	17 711	19 279	21 083	23 043
European Union	2 256	2 630	2 955	2 718	3 387	3 592	3 741	3 729	3 747

Source: International Energy Agency "World Energy Balances" (historical)
The Institute of Energy Economics, Japan (projection)
Note: Excluding generation by pumped storage hydro

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(TWh)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
2.9	2.2	1.9	1.6	1.9	36 016	41 212	45 615	51 394	57 579	2.7	2.4	2.4	2.4
5.9	3.1	2.1	1.5	2.1	19 147	21 902	23 739	25 823	28 204	3.5	2.2	1.7	2.3
8.6	2.9	1.4	0.6	1.5	11 726	12 877	13 285	13 676	14 120	3.1	1.3	0.6	1.5
6.0	5.5	4.0	3.2	4.1	3 118	4 075	4 839	5 666	6 618	6.7	4.5	3.2	4.6
0.4	-0.1	0.0	0.2	0.0	994	1 009	1 016	1 053	1 081	0.0	0.2	0.6	0.3
5.3	0.9	0.6	0.3	0.6	649	687	708	727	741	1.0	0.9	0.5	0.7
3.5	1.8	0.6	0.4	0.8	315	326	332	342	352	1.7	0.5	0.6	0.9
6.8	4.1	3.7	3.2	3.6	1 854	2 291	2 740	3 312	3 971	4.5	4.0	3.8	4.0
8.1	4.7	4.4	3.9	4.3	628	823	1 031	1 291	1 586	5.4	5.1	4.4	4.9
6.7	3.6	3.3	2.8	3.2	252	307	360	426	502	3.9	3.6	3.4	3.6
6.7	6.6	4.8	4.2	5.0	35	50	67	90	120	7.7	6.6	6.0	6.7
4.7	6.2	4.1	2.8	4.2	183	234	285	350	419	6.4	4.5	3.9	4.8
4.0	1.5	0.8	0.5	0.9	65	70	73	73	71	1.6	1.1	-0.1	0.8
4.6	2.2	2.2	2.0	2.1	229	257	288	327	373	2.2	2.3	2.6	2.4
11.0	4.6	3.9	3.4	3.9	374	449	527	635	768	4.6	3.5	3.8	3.9
1.0	1.1	1.4	1.6	1.4	5 582	6 269	6 911	7 875	8 756	1.4	2.2	2.4	2.0
1.0	1.1	1.5	1.6	1.4	4 888	5 490	6 045	6 887	7 646	1.4	2.1	2.4	2.0
3.3	2.1	2.3	2.0	2.1	2 137	2 547	3 065	3 775	4 610	2.5	3.7	4.2	3.6
3.6	2.4	2.4	1.8	2.2	866	1 002	1 133	1 281	1 453	2.9	2.7	2.5	2.7
0.8	0.7	0.7	1.0	0.8	3 817	4 251	4 674	5 434	6 207	1.4	2.0	2.9	2.2
-0.1	0.5	1.3	1.2	1.1	1 957	2 155	2 331	2 526	2 729	1.0	1.8	1.6	1.5
0.2	0.1	1.2	0.8	0.7	1 210	1 315	1 386	1 428	1 466	0.6	1.4	0.6	0.9
3.3	3.6	4.7	4.1	4.2	1 225	1 606	2 031	2 509	3 029	4.3	5.2	4.1	4.5
5.7	1.9	2.1	2.1	2.1	1 786	2 073	2 406	2 886	3 382	2.5	3.0	3.5	3.1
1.6	1.6	1.5	1.5	1.5	365	410	460	565	662	2.0	2.3	3.7	2.7
n.a.	n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	n.a.
1.0	0.9	1.0	1.2	1.0	11 822	13 056	14 207	16 100	17 897	1.3	1.9	2.3	1.9
0.7	0.9	1.1	1.3	1.1	8 368	9 304	10 152	11 520	12 900	1.3	2.0	2.4	2.0
4.7	2.9	2.3	1.8	2.3	24 194	28 156	31 408	35 293	39 681	3.4	2.6	2.4	2.7
7.7	3.4	2.3	1.6	2.3	17 089	19 775	21 576	23 597	25 931	3.8	2.4	1.9	2.6
1.3	1.3	1.7	1.8	1.6	16 869	19 310	21 876	25 570	29 375	1.8	2.6	3.0	2.6
0.6	3.2	1.0	0.0	1.2	3 627	4 016	4 256	4 401	4 673	4.2	1.6	0.9	2.0

Table A20 | Primary energy consumption per capita

	Reference Scenario (Tonne of oil equivalent [toe]/person)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	1.6	1.6	1.8	1.9	1.8	1.8	1.8	1.8	1.8
Asia	0.7	0.8	1.2	1.6	1.6	1.7	1.7	1.7	1.8
China	0.8	0.9	1.9	2.9	2.9	2.9	2.9	2.9	2.8
India	0.3	0.4	0.5	0.8	0.9	1.0	1.1	1.2	1.3
Japan	3.5	4.1	3.9	3.0	3.0	2.9	2.8	2.8	2.8
Korea	2.1	4.0	4.9	5.3	5.1	5.2	5.2	5.1	5.1
Chinese Taipei	2.5	4.0	5.1	4.7	5.2	5.3	5.3	5.4	5.5
ASEAN	0.5	0.7	0.8	1.1	1.3	1.5	1.6	1.8	2.0
Indonesia	0.5	0.6	0.7	1.0	1.2	1.5	1.7	1.9	2.2
Malaysia	1.2	2.1	2.5	3.0	3.1	3.2	3.3	3.4	3.5
Myanmar	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6
Philippines	0.4	0.5	0.4	0.6	0.7	0.8	0.9	1.0	1.0
Singapore	3.8	4.6	4.9	5.3	5.5	5.5	5.6	5.6	5.8
Thailand	0.8	1.2	1.7	1.9	1.9	2.1	2.2	2.4	2.6
Viet Nam	0.3	0.4	0.7	1.0	1.3	1.5	1.7	1.9	2.2
North America	7.7	8.1	7.2	6.5	6.0	5.7	5.5	5.3	5.1
United States	7.7	8.1	7.2	6.4	5.9	5.6	5.4	5.2	5.1
Latin America	1.1	1.2	1.4	1.3	1.4	1.4	1.4	1.5	1.5
Brazil	0.9	1.1	1.4	1.5	1.5	1.6	1.7	1.8	1.9
Advanced Europe	3.2	3.3	3.3	2.6	2.5	2.4	2.3	2.2	2.1
Other Europe/Eurasia	4.5	2.9	3.3	3.4	3.4	3.4	3.4	3.4	3.4
Russia	5.9	4.2	4.9	5.5	5.5	5.6	5.7	5.7	5.7
Africa	0.6	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5
Middle East	1.7	2.3	3.0	3.2	3.1	3.0	3.0	3.0	3.0
Oceania	4.9	5.5	5.5	4.7	4.5	4.3	4.2	4.0	3.8
International Bunkers	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Advanced Economies	4.5	4.9	4.7	4.1	3.9	3.8	3.7	3.5	3.5
Group of Seven	5.3	5.8	5.3	4.6	4.3	4.1	4.0	3.8	3.7
Emerging and Developing Economies	0.9	0.9	1.2	1.4	1.4	1.4	1.5	1.5	1.5
Emerging and Developing Asia	0.5	0.6	1.0	1.5	1.5	1.6	1.6	1.6	1.7
Non-Asia	2.7	2.5	2.5	2.1	2.0	1.9	1.8	1.7	1.7
European Union	3.4	3.4	3.5	2.8	2.7	2.6	2.5	2.4	2.3

Source: World Bank "World Development Indicators", International Energy Agency "World Energy Balances", etc. (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(toe/person)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
0.4	-0.3	-0.2	-0.1	-0.2	1.8	1.7	1.6	1.5	1.5	-0.7	-1.1	-0.8	-0.9
2.5	0.4	0.4	0.5	0.4	1.6	1.5	1.5	1.4	1.4	0.0	-0.7	-0.5	-0.4
4.0	0.3	-0.1	-0.2	0.0	2.8	2.7	2.5	2.3	2.2	-0.1	-1.4	-1.3	-1.0
2.6	2.3	2.1	1.9	2.1	0.9	0.9	1.0	1.0	1.0	1.9	1.0	0.7	1.1
-0.5	-0.2	-0.5	-0.2	-0.3	3.0	2.8	2.6	2.6	2.5	-0.4	-1.2	-0.5	-0.7
2.9	-0.5	0.0	0.0	-0.1	5.1	5.0	4.9	4.8	4.6	-0.6	-0.4	-0.6	-0.5
2.0	1.3	0.3	0.3	0.6	5.1	5.0	4.8	4.7	4.6	1.0	-0.6	-0.3	-0.1
2.5	2.1	2.5	1.9	2.2	1.2	1.4	1.5	1.5	1.6	1.4	1.8	1.2	1.5
2.3	3.1	3.6	2.2	3.0	1.2	1.5	1.6	1.8	1.9	2.5	3.3	1.7	2.5
2.9	0.5	0.7	0.5	0.6	2.9	2.9	2.9	2.8	2.8	-0.4	-0.1	-0.3	-0.3
1.3	0.0	1.6	2.5	1.5	0.4	0.4	0.4	0.4	0.5	-1.3	0.3	1.8	0.4
0.9	2.8	2.3	1.5	2.1	0.7	0.8	0.8	0.8	0.9	2.1	1.9	0.7	1.5
1.0	0.6	0.1	0.4	0.3	5.4	5.4	5.3	5.2	5.2	0.4	-0.3	-0.2	-0.1
2.7	0.7	1.3	1.4	1.2	1.9	1.9	2.0	2.1	2.1	0.3	0.5	0.7	0.5
4.1	3.4	2.8	2.7	2.9	1.2	1.3	1.4	1.5	1.7	2.2	1.6	2.0	1.9
-0.5	-1.2	-0.8	-0.7	-0.8	5.8	5.4	5.0	4.6	4.4	-1.5	-1.6	-1.2	-1.4
-0.6	-1.2	-0.8	-0.6	-0.8	5.7	5.3	4.9	4.6	4.3	-1.5	-1.6	-1.1	-1.4
0.7	0.3	0.6	0.6	0.5	1.3	1.3	1.3	1.3	1.3	-0.1	-0.2	0.0	-0.1
1.4	0.5	1.1	1.0	0.9	1.5	1.5	1.5	1.5	1.5	0.1	0.1	0.2	0.1
-0.6	-0.9	-0.7	-0.8	-0.8	2.4	2.3	2.1	2.0	2.0	-1.3	-1.4	-0.5	-1.0
-0.8	-0.2	0.0	0.1	0.0	3.4	3.3	3.2	3.0	2.9	-0.2	-0.7	-0.7	-0.6
-0.2	0.1	0.2	0.1	0.1	5.5	5.4	5.2	5.0	4.8	0.0	-0.6	-0.7	-0.5
0.0	-0.8	-0.4	-0.3	-0.5	0.5	0.5	0.4	0.4	0.4	-1.5	-1.4	-1.1	-1.3
1.9	-0.5	-0.2	0.0	-0.2	3.0	2.8	2.7	2.6	2.6	-0.9	-0.9	-0.5	-0.8
-0.1	-0.5	-0.9	-0.8	-0.8	4.5	4.1	3.7	3.6	3.4	-0.7	-1.9	-0.9	-1.2
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
-0.3	-0.8	-0.6	-0.5	-0.6	3.8	3.6	3.3	3.2	3.1	-1.1	-1.3	-0.8	-1.1
-0.5	-1.0	-0.7	-0.6	-0.7	4.1	3.9	3.6	3.4	3.3	-1.3	-1.5	-0.9	-1.2
1.3	0.0	0.1	0.2	0.1	1.4	1.3	1.3	1.2	1.2	-0.4	-0.9	-0.7	-0.7
3.1	0.5	0.5	0.5	0.5	1.5	1.4	1.4	1.4	1.3	0.1	-0.6	-0.4	-0.4
-0.8	-1.1	-0.8	-0.7	-0.9	1.9	1.8	1.6	1.5	1.4	-1.5	-1.6	-1.1	-1.4
-0.6	-0.7	-0.6	-0.7	-0.7	2.6	2.4	2.3	2.2	2.2	-1.0	-1.3	-0.4	-0.9

Table A21 | Primary energy consumption per GDP

	Reference Scenario (Tonne of oil equivalent [toe]/$2015 million)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	242	205	196	162	140	127	114	103	94
Asia	309	271	263	210	173	151	133	117	103
China	843	401	330	228	174	144	120	101	84
India	590	511	422	329	264	227	194	169	148
Japan	124	129	118	82	75	69	62	57	53
Korea	223	233	193	156	132	120	108	97	88
Chinese Taipei	315	292	254	161	142	127	114	102	93
ASEAN	294	301	256	224	203	193	177	162	150
Indonesia	314	320	253	234	218	225	208	191	177
Malaysia	284	326	312	263	221	198	178	160	144
Myanmar	1 514	960	329	333	312	277	247	227	210
Philippines	251	272	182	155	132	118	106	96	90
Singapore	163	133	100	80	72	67	62	58	55
Thailand	294	328	340	289	261	234	210	189	171
Viet Nam	397	307	330	270	246	222	199	180	164
North America	199	170	140	102	85	76	68	61	55
United States	196	166	136	97	80	72	64	58	53
Latin America	177	170	162	151	135	124	113	104	96
Brazil	153	159	157	159	143	132	121	111	102
Advanced Europe	141	120	108	74	63	57	51	45	41
Other Europe/Eurasia	842	802	543	429	362	328	297	270	246
Russia	757	794	554	512	451	417	384	353	324
Africa	366	354	299	284	240	210	179	154	135
Middle East	244	276	309	300	267	247	227	211	195
Oceania	151	138	119	88	79	70	62	56	50
International Bunkers	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Advanced Economies	164	146	126	91	77	70	62	56	51
Group of Seven	162	144	123	89	75	68	60	54	49
Emerging and Developing Economies	460	354	309	249	204	179	156	137	122
Emerging and Developing Asia	601	398	332	243	193	166	143	125	109
Non-Asia	219	180	162	130	113	103	94	86	80
European Union	158	130	118	81	69	62	55	49	44

Source: World Bank "World Development Indicators", International Energy Agency "World Energy Balances", etc. (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(toe/$2015 million)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
-1.2	-2.1	-2.0	-1.9	-2.0	136	118	101	88	78	-2.4	-2.9	-2.6	-2.7
-1.2	-2.7	-2.6	-2.5	-2.6	168	141	116	97	82	-3.1	-3.6	-3.4	-3.4
-3.9	-3.8	-3.6	-3.5	-3.6	169	133	103	81	64	-4.2	-4.8	-4.6	-4.6
-1.7	-3.1	-3.0	-2.7	-2.9	257	211	170	138	115	-3.5	-4.1	-3.9	-3.8
-1.2	-1.3	-1.9	-1.6	-1.6	74	66	58	52	48	-1.4	-2.5	-1.9	-2.0
-1.1	-2.4	-2.0	-2.0	-2.1	131	116	103	91	80	-2.5	-2.4	-2.5	-2.5
-2.0	-1.8	-2.1	-2.0	-2.0	139	119	102	88	78	-2.1	-3.0	-2.7	-2.7
-0.8	-1.4	-1.4	-1.6	-1.5	193	179	158	140	126	-2.1	-2.0	-2.2	-2.1
-0.9	-1.0	-0.5	-1.6	-1.0	209	213	193	173	156	-1.6	-0.8	-2.1	-1.5
-0.2	-2.5	-2.1	-2.1	-2.2	209	180	155	133	115	-3.3	-2.9	-2.9	-3.0
-4.5	-0.9	-2.3	-1.6	-1.7	286	233	198	176	157	-2.1	-3.6	-2.3	-2.7
-1.4	-2.3	-2.2	-1.6	-2.0	126	113	97	84	76	-2.9	-2.6	-2.4	-2.6
-2.1	-1.4	-1.6	-1.2	-1.4	72	65	59	53	49	-1.5	-2.0	-1.8	-1.8
-0.1	-1.4	-2.2	-2.0	-1.9	254	220	188	163	143	-1.8	-3.0	-2.7	-2.6
-1.2	-1.3	-2.1	-1.9	-1.8	226	193	162	140	124	-2.5	-3.3	-2.7	-2.8
-2.0	-2.7	-2.2	-2.0	-2.2	82	71	61	54	48	-3.0	-3.0	-2.5	-2.8
-2.1	-2.7	-2.2	-2.0	-2.2	78	67	58	50	45	-3.1	-3.0	-2.5	-2.8
-0.5	-1.5	-1.8	-1.6	-1.6	132	116	102	90	81	-1.9	-2.5	-2.3	-2.3
0.1	-1.6	-1.7	-1.7	-1.6	139	122	106	93	83	-1.9	-2.6	-2.5	-2.4
-1.9	-2.3	-2.2	-2.2	-2.2	61	53	46	41	38	-2.7	-2.9	-1.9	-2.4
-2.0	-2.4	-2.0	-1.8	-2.0	360	317	276	242	213	-2.5	-2.6	-2.6	-2.6
-1.2	-1.8	-1.6	-1.7	-1.7	448	400	353	311	275	-1.9	-2.4	-2.5	-2.3
-0.8	-2.4	-2.9	-2.8	-2.7	228	188	154	127	107	-3.1	-3.9	-3.5	-3.5
0.6	-1.6	-1.6	-1.5	-1.6	259	231	205	186	169	-2.0	-2.3	-1.9	-2.1
-1.6	-1.6	-2.3	-2.1	-2.1	78	66	56	50	44	-1.7	-3.3	-2.3	-2.5
n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
-1.8	-2.3	-2.1	-2.0	-2.1	76	66	57	50	45	-2.6	-2.8	-2.2	-2.6
-1.8	-2.3	-2.2	-2.0	-2.2	73	63	54	48	43	-2.7	-2.9	-2.3	-2.6
-1.8	-2.8	-2.7	-2.5	-2.6	199	166	137	115	98	-3.2	-3.6	-3.3	-3.4
-2.7	-3.3	-2.9	-2.7	-2.9	187	154	125	102	86	-3.6	-4.0	-3.7	-3.8
-1.6	-1.9	-1.8	-1.7	-1.8	110	97	85	76	68	-2.3	-2.6	-2.1	-2.3
-2.0	-2.1	-2.2	-2.2	-2.2	68	59	51	45	42	-2.5	-2.8	-1.9	-2.4

Table A22 | Energy-related carbon dioxide emissions

	Reference Scenario (Mt)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
World	20 453	23 032	30 520	34 603	33 043	32 581	32 520	32 659	32 537
Asia	4 688	6 748	12 915	17 810	17 091	16 702	16 677	16 752	16 545
China	2 198	3 194	8 093	11 127	9 719	8 625	7 862	7 088	6 064
India	518	872	1 541	2 771	3 218	3 722	4 218	4 784	5 322
Japan	1 046	1 149	1 126	928	775	703	615	548	487
Korea	208	391	531	533	494	460	441	411	370
Chinese Taipei	108	213	252	257	253	243	229	212	195
ASEAN	334	649	1 006	1 716	2 098	2 323	2 578	2 837	3 080
Indonesia	125	239	346	672	858	949	1 071	1 194	1 312
Malaysia	48	102	177	240	264	279	289	296	301
Myanmar	4.0	9.3	7.6	28	32	39	49	60	73
Philippines	35	65	75	153	204	248	286	317	339
Singapore	23	36	45	44	47	48	47	46	46
Thailand	79	148	219	239	249	254	256	258	257
Viet Nam	17	42	123	293	379	434	498	576	656
North America	5 117	6 075	5 690	4 938	4 264	4 012	3 770	3 528	3 310
United States	4 729	5 599	5 193	4 426	3 815	3 575	3 338	3 114	2 914
Latin America	829	1 148	1 471	1 478	1 472	1 532	1 602	1 679	1 749
Brazil	191	294	372	416	384	403	427	453	474
Advanced Europe	3 948	3 916	3 823	2 924	2 429	2 207	1 976	1 757	1 536
Other Europe/Eurasia	3 859	2 324	2 494	2 510	2 357	2 298	2 257	2 251	2 282
Russia	2 101	1 379	1 449	1 622	1 510	1 473	1 414	1 393	1 404
Africa	542	672	1 039	1 270	1 366	1 547	1 756	2 007	2 254
Middle East	551	922	1 524	2 054	2 157	2 259	2 341	2 442	2 533
Oceania	280	360	422	383	357	340	324	310	296
International Bunkers	639	867	1 143	1 235	1 548	1 683	1 815	1 933	2 032
Advanced Economies	10 763	12 180	11 931	10 038	8 647	8 037	7 424	6 828	6 256
Group of Seven	8 377	9 354	8 791	7 248	6 137	5 687	5 241	4 828	4 450
Emerging and Developing Economies	9 050	9 984	17 446	23 330	22 847	22 861	23 281	23 897	24 250
Emerging and Developing Asia	3 269	4 919	10 919	16 017	15 494	15 225	15 324	15 518	15 432
Non-Asia	15 126	15 417	16 462	15 558	14 404	14 196	14 027	13 973	13 960
European Union	3 970	3 671	3 512	2 517	2 117	1 918	1 717	1 536	1 356

Source: International Energy Agency "World Energy Balances", etc. (historical)
The Institute of Energy Economics, Japan (projection)

Reference Scenario					Advanced Technologies Scenario								
CAGR (%)					(Mt)					CAGR (%)			
1990/ 2023	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050	2030	2035	2040	2045	2050	2023/ 2030	2030/ 2040	2040/ 2050	2023/ 2050
1.6	-0.7	-0.2	0.0	-0.2	31 201	26 128	21 684	17 523	14 135	-1.5	-3.6	-4.2	-3.3
4.1	-0.6	-0.2	-0.1	-0.3	16 099	12 915	10 443	8 445	6 987	-1.4	-4.2	-3.9	-3.4
5.0	-1.9	-2.1	-2.6	-2.2	9 303	6 419	4 296	2 835	1 839	-2.5	-7.4	-8.1	-6.4
5.2	2.2	2.7	2.4	2.4	3 016	3 132	3 115	2 894	2 705	1.2	0.3	-1.4	-0.1
-0.4	-2.5	-2.3	-2.3	-2.4	686	516	364	216	99	-4.2	-6.1	-12.2	-7.9
2.9	-1.1	-1.1	-1.7	-1.3	434	329	227	145	84	-2.9	-6.3	-9.4	-6.6
2.7	-0.2	-1.0	-1.6	-1.0	225	192	155	115	81	-1.9	-3.7	-6.3	-4.2
5.1	2.9	2.1	1.8	2.2	1 920	1 775	1 694	1 594	1 474	1.6	-1.2	-1.4	-0.6
5.2	3.6	2.2	2.0	2.5	790	734	715	674	615	2.3	-1.0	-1.5	-0.3
5.0	1.4	0.9	0.4	0.8	246	231	203	175	148	0.3	-1.9	-3.1	-1.8
6.0	2.1	4.3	4.1	3.6	30	35	41	47	54	1.1	3.1	2.8	2.5
4.5	4.2	3.4	1.7	3.0	187	186	186	182	168	2.9	-0.1	-1.0	0.3
2.0	1.2	-0.1	-0.3	0.2	39	24	16	8.1	1.8	-1.5	-8.8	-19.5	-11.2
3.4	0.6	0.3	0.0	0.3	236	214	194	172	152	-0.2	-1.9	-2.4	-1.7
9.1	3.7	2.8	2.8	3.0	330	287	271	264	261	1.7	-1.9	-0.4	-0.4
-0.1	-2.1	-1.2	-1.3	-1.5	4 012	3 170	2 340	1 432	692	-2.9	-5.2	-11.5	-7.0
-0.2	-2.1	-1.3	-1.3	-1.5	3 578	2 800	2 042	1 208	533	-3.0	-5.5	-12.6	-7.5
1.8	-0.1	0.9	0.9	0.6	1 399	1 316	1 195	1 047	894	-0.8	-1.6	-2.9	-1.8
2.4	-1.1	1.1	1.1	0.5	353	338	313	282	251	-2.3	-1.2	-2.2	-1.9
-0.9	-2.6	-2.0	-2.5	-2.4	2 191	1 691	1 163	662	287	-4.0	-6.1	-13.1	-8.2
-1.3	-0.9	-0.4	0.1	-0.4	2 296	2 043	1 820	1 594	1 400	-1.3	-2.3	-2.6	-2.1
-0.8	-1.0	-0.7	-0.1	-0.5	1 471	1 305	1 121	946	798	-1.4	-2.7	-3.3	-2.6
2.6	1.0	2.5	2.5	2.1	1 297	1 323	1 334	1 317	1 277	0.3	0.3	-0.4	0.0
4.1	0.7	0.8	0.8	0.8	2 055	1 958	1 819	1 646	1 476	0.0	-1.2	-2.1	-1.2
1.0	-1.0	-1.0	-0.9	-1.0	347	268	196	108	25	-1.4	-5.5	-18.5	-9.6
2.0	3.3	1.6	1.1	1.9	1 505	1 445	1 372	1 272	1 097	2.9	-0.9	-2.2	-0.4
-0.2	-2.1	-1.5	-1.7	-1.7	7 957	6 208	4 475	2 697	1 281	-3.3	-5.6	-11.8	-7.3
-0.4	-2.3	-1.6	-1.6	-1.8	5 663	4 398	3 169	1 865	823	-3.5	-5.6	-12.6	-7.7
2.9	-0.3	0.2	0.4	0.1	21 739	18 475	15 836	13 553	11 757	-1.0	-3.1	-2.9	-2.5
4.9	-0.5	-0.1	0.1	-0.1	14 691	11 836	9 668	7 950	6 711	-1.2	-4.1	-3.6	-3.2
0.1	-1.1	-0.3	0.0	-0.4	13 597	11 768	9 868	7 805	6 051	-1.9	-3.2	-4.8	-3.4
-1.4	-2.4	-2.1	-2.3	-2.3	1 900	1 449	1 002	594	289	-3.9	-6.2	-11.7	-7.7

Table A23 | World

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	8 701	9 938	12 735	15 135	15 702	16 164	16 538	16 922	17 266
Coal	2 219	2 313	3 645	4 202	3 668	3 452	3 337	3 270	3 144
Oil	3 237	3 682	4 153	4 577	4 682	4 720	4 762	4 780	4 764
Natural gas	1 662	2 069	2 737	3 443	3 616	3 804	3 989	4 221	4 483
Nuclear	526	675	719	715	830	902	946	955	971
Hydro	184	225	297	366	413	433	453	473	494
Geothermal	34	52	61	110	157	244	265	278	291
Solar, wind, etc.	2.5	8.2	48	385	867	1 127	1 328	1 526	1 729
Biomass and waste	836	912	1 075	1 338	1 468	1 483	1 458	1 420	1 391
Hydrogen	-	-	-	-	-	-	-	-	-

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	6 183	6 927	8 720	10 249	10 930	11 246	11 469	11 674	11 857
Coal	752	541	1 046	882	894	860	827	799	772
Oil	2 608	3 128	3 622	4 122	4 268	4 321	4 378	4 410	4 413
Natural gas	947	1 122	1 349	1 680	1 776	1 814	1 828	1 830	1 827
Electricity	834	1 087	1 538	2 171	2 541	2 811	3 066	3 340	3 615
Heat	336	249	276	385	425	423	404	381	356
Hydrogen	-	-	-	-	0.2	0.2	2.2	7.0	14
Renewables and waste	707	801	889	1 009	1 025	1 016	964	908	861
Industry	1 797	1 864	2 620	3 080	3 393	3 533	3 604	3 652	3 659
Transport	1 578	1 965	2 431	2 936	3 080	3 131	3 198	3 264	3 324
Buildings, etc.	2 330	2 478	2 874	3 232	3 347	3 424	3 462	3 513	3 595
Non-energy use	478	619	795	1 002	1 110	1 158	1 206	1 244	1 279

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	11 850	15 425	21 523	29 978	34 966	38 716	42 170	45 921	49 664
Coal	4 436	5 993	8 682	10 687	8 648	8 023	7 773	7 792	7 596
Oil	1 322	1 187	968	778	594	538	476	419	343
Natural gas	1 743	2 765	4 820	6 648	6 887	7 547	8 339	9 395	10 581
Nuclear	2 013	2 591	2 756	2 740	3 186	3 460	3 630	3 664	3 726
Hydro	2 143	2 619	3 456	4 252	4 809	5 035	5 264	5 499	5 746
Geothermal	36	52	68	98	137	204	222	236	249
Solar photovoltaics	0.1	0.8	32	1 605	5 781	7 909	9 361	10 743	12 149
Wind	3.9	31	342	2 333	3 732	4 608	5 496	6 408	7 355
Concentrated solar power and marine	1.2	1.1	2.2	16	17	17	18	19	20
Biomass and waste	130	163	364	773	1 110	1 201	1 308	1 379	1 450
Hydrogen	-	-	-	-	17	126	236	319	401
Others	20	22	34	47	47	47	47	47	47

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	20 453	23 032	30 520	34 603	33 043	32 581	32 520	32 659	32 537
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	36 016	48 379	65 081	93 506	112 250	127 708	145 013	164 008	184 245
Population (million)	5 292	6 153	6 991	8 054	8 526	8 838	9 126	9 385	9 606
GDP per capita ($2015 thousand)	6.8	7.9	9.3	12	13	14	16	17	19
Primary energy consumption per capita (toe/person)	1.6	1.6	1.8	1.9	1.8	1.8	1.8	1.8	1.8
Primary energy consumption per GDP (toe/$2015 million)	242	205	196	162	140	127	114	103	94
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	568	476	469	370	294	255	224	199	177
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.4	2.3	2.4	2.3	2.1	2.0	2.0	1.9	1.9

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
1.7	0.5	0.4	0.5	100	100	100	100	15 305	15 099	14 691	14 435	14 282	-0.2	-0.3	-0.2	100	100
2.0	-1.3	-0.6	-1.1	26	28	20	18	3 431	2 872	2 421	2 057	1 698	-3.2	-3.5	-3.3	16	12
1.1	0.2	0.0	0.1	37	30	29	28	4 425	4 025	3 593	3 135	2 715	-1.4	-2.8	-1.9	24	19
2.2	0.9	1.2	1.0	19	23	24	26	3 566	3 617	3 552	3 497	3 423	0.2	-0.4	0.0	24	24
0.9	1.7	0.3	1.1	6.0	4.7	5.7	5.6	880	1 077	1 243	1 393	1 545	3.3	2.2	2.9	8.5	11
2.1	1.3	0.9	1.1	2.1	2.4	2.7	2.9	422	448	477	509	544	1.6	1.3	1.5	3.2	3.8
3.6	5.3	0.9	3.7	0.4	0.7	1.6	1.7	154	261	298	328	359	6.0	1.9	4.5	2.0	2.5
16.4	7.5	2.7	5.7	0.0	2.5	8.0	10	950	1 352	1 702	2 125	2 584	9.1	4.3	7.3	12	18
1.4	0.5	-0.5	0.1	9.6	8.8	8.8	8.1	1 477	1 446	1 406	1 391	1 415	0.3	0.1	0.2	9.6	9.9
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
1.5	0.7	0.3	0.5	100	100	100	100	10 575	10 277	9 852	9 502	9 282	-0.2	-0.6	-0.4	100	100
0.5	-0.4	-0.7	-0.5	12	8.6	7.2	6.5	821	697	595	518	460	-2.3	-2.6	-2.4	6.0	5.0
1.4	0.4	0.1	0.3	42	40	38	37	4 066	3 757	3 404	3 048	2 702	-1.1	-2.3	-1.6	35	29
1.8	0.5	0.0	0.3	15	16	16	15	1 687	1 566	1 397	1 228	1 075	-1.1	-2.6	-1.6	14	12
2.9	2.1	1.7	1.9	13	21	27	30	2 608	2 911	3 169	3 436	3 692	2.2	1.5	2.0	32	40
0.4	0.3	-1.3	-0.3	5.4	3.8	3.5	3.0	396	368	329	290	255	-0.9	-2.5	-1.5	3.3	2.8
n.a.	n.a.	20.4	n.a.	-	-	0.0	0.1	0.3	36	84	147	265	n.a.	12.2	n.a.	0.9	2.9
1.1	-0.3	-1.1	-0.6	11	9.8	8.4	7.3	999	942	874	835	834	-0.8	-0.5	-0.7	8.9	9.0
1.6	0.9	0.2	0.6	29	30	31	31	3 243	3 128	2 921	2 722	2 585	-0.3	-1.2	-0.6	30	28
1.9	0.5	0.4	0.5	26	29	28	28	2 964	2 798	2 634	2 501	2 429	-0.6	-0.8	-0.7	27	26
1.0	0.4	0.4	0.4	38	32	30	30	3 259	3 195	3 093	3 035	2 991	-0.3	-0.3	-0.3	31	32
2.3	1.1	0.6	0.9	7.7	9.8	11	11	1 109	1 157	1 205	1 243	1 278	1.1	0.6	0.9	12	14

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
2.9	2.0	1.6	1.9	100	100	100	100	36 016	41 212	45 615	51 394	57 579	2.5	2.4	2.4	100	100
2.7	-1.9	-0.2	-1.3	37	36	18	15	7 996	6 339	4 946	3 822	2 704	-4.4	-5.9	-5.0	11	4.7
-1.6	-2.9	-3.2	-3.0	11	2.6	1.1	0.7	503	386	285	218	173	-5.7	-4.8	-5.4	0.6	0.3
4.1	1.3	2.4	1.7	15	22	20	21	7 277	8 125	8 629	9 346	9 956	1.5	1.4	1.5	19	17
0.9	1.7	0.3	1.1	17	9.1	8.6	7.5	3 379	4 135	4 769	5 345	5 929	3.3	2.2	2.9	10	10
2.1	1.3	0.9	1.1	18	14	12	12	4 907	5 215	5 548	5 915	6 322	1.6	1.3	1.5	12	11
3.0	4.9	1.2	3.5	0.3	0.3	0.5	0.5	137	227	256	281	306	6.1	1.8	4.5	0.6	0.5
34.5	10.9	2.6	7.8	0.0	5.4	22	24	6 608	9 791	12 323	15 044	17 905	12.7	3.8	9.3	27	31
21.4	5.2	3.0	4.3	0.0	7.8	13	15	3 883	5 343	6 877	9 060	11 537	6.6	5.3	6.1	15	20
8.3	0.5	1.3	0.8	0.0	0.1	0.0	0.0	19	21	25	31	37	2.4	4.2	3.1	0.1	0.1
5.5	3.1	1.0	2.4	1.1	2.6	3.1	2.9	1 235	1 348	1 464	1 567	1 670	3.8	1.3	2.9	3.2	2.9
n.a.	n.a.	5.5	n.a.	-	-	0.6	0.8	26	236	446	718	991	n.a.	8.3	n.a.	1.0	1.7
2.7	0.0	0.0	0.0	0.2	0.2	0.1	0.1	47	47	47	47	47	0.0	0.0	0.0	0.1	0.1

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
1.6	-0.4	0.0	-0.2	31 201	26 128	21 684	17 523	14 135	-2.7	-4.2	-3.3	
n.a.	n.a.	n.a.	n.a.	-	-	172	544	974	n.a.	18.9	n.a.	

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
2.9	2.6	2.4	2.5	112 250	127 708	145 013	164 008	184 245	2.6	2.4	2.5	
1.3	0.7	0.5	0.7	8 526	8 838	9 126	9 385	9 606	0.7	0.5	0.7	
1.6	1.9	1.9	1.9	13	14	16	17	19	1.9	1.9	1.9	
0.4	-0.2	-0.1	-0.2	1.8	1.7	1.6	1.5	1.5	-0.9	-0.8	-0.9	
-1.2	-2.0	-1.9	-2.0	136	118	101	88	78	-2.7	-2.6	-2.7	
-1.3	-2.9	-2.4	-2.7	278	205	150	107	77	-5.2	-6.5	-5.7	
-0.1	-0.9	-0.4	-0.7	2.0	1.7	1.5	1.2	1.0	-2.5	-3.9	-3.1	

Table A24 | Asia

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	2 073	2 839	4 758	6 869	7 301	7 595	7 865	8 137	8 340
Coal	785	1 033	2 400	3 422	3 081	2 915	2 829	2 771	2 650
Oil	618	918	1 171	1 576	1 702	1 750	1 810	1 863	1 903
Natural gas	116	234	454	739	884	983	1 089	1 206	1 325
Nuclear	77	132	152	206	282	313	344	371	403
Hydro	32	41	92	151	174	184	194	203	212
Geothermal	8.2	23	30	61	86	152	165	171	176
Solar, wind, etc.	1.3	2.1	16	195	533	715	830	932	1 036
Biomass and waste	435	456	444	518	558	580	597	609	620
Hydrogen	-	-	-	-	0.8	3.0	7.7	11	15

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	1 515	1 952	3 128	4 280	4 774	4 996	5 179	5 350	5 488
Coal	423	372	885	746	757	729	702	678	654
Oil	465	743	992	1 405	1 524	1 569	1 625	1 675	1 714
Natural gas	46	90	201	414	483	517	540	555	561
Electricity	157	279	575	1 107	1 370	1 537	1 681	1 827	1 962
Heat	14	30	70	204	249	252	240	224	205
Hydrogen	-	-	-	-	0.2	0.2	0.8	2.2	3.9
Renewables and waste	409	437	405	403	389	393	390	390	388
Industry	512	654	1 396	1 811	2 055	2 151	2 195	2 223	2 212
Transport	189	323	493	795	898	936	986	1 039	1 091
Buildings, etc.	697	787	942	1 185	1 252	1 312	1 374	1 447	1 529
Non-energy use	117	188	298	489	569	597	624	642	657

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	2 244	3 970	7 975	15 098	18 676	21 005	22 891	24 838	26 621
Coal	875	1 982	4 788	8 643	7 323	6 855	6 692	6 723	6 521
Oil	433	381	260	125	95	93	91	93	90
Natural gas	237	566	1 070	1 440	1 719	1 990	2 324	2 747	3 204
Nuclear	294	505	582	791	1 083	1 202	1 319	1 424	1 549
Hydro	368	478	1 072	1 754	2 021	2 138	2 251	2 359	2 465
Geothermal	8.4	20	22	31	43	81	90	94	98
Solar photovoltaics	0.1	0.4	5.2	888	3 854	5 399	6 185	6 877	7 582
Wind	0.0	2.4	70	1 022	1 963	2 537	3 080	3 574	4 078
Concentrated solar power and marine	0.0	0.0	0.0	2.5	2.8	2.8	2.9	2.9	3.0
Biomass and waste	9.0	15	83	382	545	605	681	726	771
Hydrogen	-	-	-	-	6.7	81	156	197	239
Others	20	20	21	20	20	20	20	20	20

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	4 688	6 748	12 915	17 810	17 091	16 702	16 677	16 752	16 545
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	6 719	10 478	18 086	32 734	42 276	50 161	59 295	69 593	80 766
Population (million)	2 954	3 461	3 891	4 350	4 500	4 589	4 656	4 700	4 718
GDP per capita ($2015 thousand)	2.3	3.0	4.6	7.5	9.4	11	13	15	17
Primary energy consumption per capita (toe/person)	0.7	0.8	1.2	1.6	1.6	1.7	1.7	1.7	1.8
Primary energy consumption per GDP (toe/$2015 million)	309	271	263	210	173	151	133	117	103
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	698	644	714	544	404	333	281	241	205
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.3	2.4	2.7	2.6	2.3	2.2	2.1	2.1	2.0

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
3.7	0.8	0.6	0.7	100	100	100	100	7 112	7 053	6 882	6 745	6 631	0.0	-0.4	-0.1	100	100
4.6	-1.1	-0.7	-0.9	38	50	36	32	2 909	2 450	2 045	1 700	1 358	-3.0	-4.0	-3.4	30	20
2.9	0.8	0.5	0.7	30	23	23	23	1 615	1 521	1 427	1 324	1 223	-0.6	-1.5	-0.9	21	18
5.8	2.3	2.0	2.2	5.6	11	14	16	851	865	849	830	818	0.8	-0.4	0.4	12	12
3.0	3.1	1.6	2.5	3.7	3.0	4.4	4.8	319	431	534	622	696	5.8	2.7	4.6	7.8	10
4.8	1.5	0.9	1.3	1.5	2.2	2.5	2.5	181	198	216	236	258	2.1	1.8	2.0	3.1	3.9
6.3	6.0	0.6	4.0	0.4	0.9	2.1	2.1	83	160	188	210	233	6.9	2.1	5.1	2.7	3.5
16.4	8.9	2.2	6.4	0.1	2.8	11	12	573	829	1 007	1 188	1 394	10.1	3.3	7.6	15	21
0.5	0.8	0.4	0.7	21	7.5	7.6	7.4	573	581	581	585	599	0.7	0.3	0.5	8.4	9.0
n.a.	n.a.	6.7	n.a.	-	-	0.1	0.2	6.2	18	34	48	53	n.a.	4.6	n.a.	0.5	0.8

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
3.2	1.1	0.6	0.9	100	100	100	100	4 609	4 554	4 433	4 322	4 260	0.2	-0.4	0.0	100	100
1.7	-0.4	-0.7	-0.5	28	17	14	12	699	596	510	444	394	-2.2	-2.6	-2.3	12	9.2
3.4	0.9	0.5	0.7	31	33	31	31	1 449	1 374	1 295	1 210	1 124	-0.5	-1.4	-0.8	29	26
6.9	1.6	0.4	1.1	3.1	9.7	10	10	453	432	389	342	301	-0.4	-2.5	-1.2	8.8	7.1
6.1	2.5	1.6	2.1	10	26	32	36	1 402	1 569	1 695	1 812	1 934	2.5	1.3	2.1	38	45
8.4	1.0	-1.6	0.0	0.9	4.8	4.6	3.7	224	207	181	155	132	-0.7	-3.1	-1.6	4.1	3.1
n.a.	n.a.	17.5	n.a.	-	-	0.0	0.1	0.1	5.7	14	26	50	n.a.	13.9	n.a.	0.3	1.2
0.0	-0.2	-0.1	-0.1	27	9.4	7.5	7.1	382	370	349	332	324	-0.8	-0.7	-0.8	7.9	7.6
3.9	1.1	0.1	0.7	34	42	42	40	1 959	1 894	1 768	1 647	1 562	-0.1	-1.2	-0.5	40	37
4.4	1.3	1.0	1.2	12	19	19	20	856	825	796	774	766	0.0	-0.4	-0.1	18	18
1.6	0.9	1.1	0.9	46	28	27	28	1 225	1 239	1 247	1 260	1 276	0.3	0.2	0.3	28	30
4.4	1.4	0.5	1.1	7.7	11	12	12	569	596	623	641	656	1.4	0.5	1.1	14	15

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
5.9	2.5	1.5	2.1	100	100	100	100	19 147	21 902	23 739	25 823	28 204	2.7	1.7	2.3	100	100
7.2	-1.5	-0.3	-1.0	39	57	29	24	6 892	5 556	4 301	3 208	2 116	-4.0	-6.8	-5.1	18	7.5
-3.7	-1.8	-0.1	-1.2	19	0.8	0.4	0.3	88	83	78	75	70	-2.7	-1.0	-2.1	0.3	0.2
5.6	2.9	3.3	3.0	11	9.5	10	12	1 832	2 067	2 248	2 471	2 707	2.7	1.9	2.4	9.5	9.6
3.0	3.1	1.6	2.5	13	5.2	5.8	5.8	1 224	1 653	2 048	2 388	2 670	5.8	2.7	4.6	8.6	9.5
4.8	1.5	0.9	1.3	16	12	9.8	9.3	2 110	2 304	2 513	2 744	2 999	2.1	1.8	2.0	11	11
4.1	6.4	0.9	4.3	0.4	0.2	0.4	0.4	43	93	111	126	141	7.7	2.4	5.7	0.5	0.5
33.2	12.1	2.1	8.3	0.0	5.9	27	28	4 263	6 375	7 677	8 890	10 231	13.5	2.9	9.5	32	36
36.7	6.7	2.8	5.3	0.0	6.8	13	15	2 040	2 894	3 663	4 551	5 626	7.8	4.4	6.5	15	20
19.5	0.8	0.3	0.6	0.0	0.0	0.0	0.0	3.5	3.7	3.9	4.3	4.7	2.6	1.9	2.3	0.0	0.0
12.0	3.5	1.3	2.6	0.4	2.5	3.0	2.9	617	691	765	838	911	4.2	1.8	3.3	3.2	3.2
n.a.	n.a.	4.4	n.a.	-	-	0.7	0.9	14	162	310	509	707	n.a.	8.6	n.a.	1.3	2.5
0.1	0.0	0.0	0.0	0.9	0.1	0.1	0.1	20	20	20	20	20	0.0	0.0	0.0	0.1	0.1

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
4.1	-0.4	-0.1	-0.3	16 099	12 915	10 443	8 445	6 987	-3.1	-3.9	-3.4	
n.a.	n.a.	n.a.	n.a.	-	-	82	191	313	n.a.	14.3	n.a.	

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
4.9	3.6	3.1	3.4	42 276	50 161	59 295	69 593	80 766	3.6	3.1	3.4
1.2	0.4	0.1	0.3	4 500	4 589	4 656	4 700	4 718	0.4	0.1	0.3
3.7	3.1	3.0	3.1	9.4	11	13	15	17	3.1	3.0	3.1
2.5	0.4	0.5	0.4	1.6	1.5	1.5	1.4	1.4	-0.4	-0.5	-0.4
-1.2	-2.7	-2.5	-2.6	168	141	116	97	82	-3.4	-3.4	-3.4
-0.8	-3.8	-3.1	-3.6	381	257	176	121	87	-6.4	-6.9	-6.6
0.4	-1.2	-0.7	-1.0	2.3	1.8	1.5	1.3	1.1	-3.1	-3.6	-3.3

Table A25 | China

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	878	1 134	2 541	4 022	4 032	3 930	3 842	3 722	3 528
Coal	531	665	1 790	2 449	2 030	1 776	1 606	1 441	1 224
Oil	119	221	428	736	785	756	730	697	659
Natural gas	13	21	89	319	370	382	386	378	354
Nuclear	-	4.4	19	113	149	171	193	214	236
Hydro	11	19	61	106	117	121	124	127	130
Geothermal	-	1.1	2.4	19	27	29	29	28	26
Solar, wind, etc.	0.0	1.0	12	154	408	541	609	666	725
Biomass and waste	205	203	140	127	146	155	166	171	176
Hydrogen	-	-	-	-	-0.1	0.1	1.1	0.9	0.8

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	662	785	1 649	2 410	2 609	2 613	2 577	2 519	2 430
Coal	311	274	712	526	480	426	377	334	295
Oil	85	180	369	676	714	688	667	639	605
Natural gas	8.9	12	73	242	274	278	273	260	242
Electricity	39	89	297	689	844	922	973	1 012	1 032
Heat	13	26	63	194	238	240	229	213	195
Hydrogen	-	-	-	-	0.0	0.0	0.4	1.2	2.1
Renewables and waste	205	202	135	83	59	58	58	58	58
Industry	238	301	923	1 166	1 226	1 200	1 139	1 063	962
Transport	30	83	195	376	424	413	403	391	378
Buildings, etc.	351	338	412	584	624	659	691	724	758
Non-energy use	43	62	120	285	335	341	345	340	331

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	621	1 356	4 197	9 492	11 567	12 651	13 279	13 796	14 057
Coal	441	1 060	3 240	5 857	4 528	3 837	3 440	3 116	2 574
Oil	50	47	15	9.1	6.2	4.7	3.6	2.8	1.9
Natural gas	2.8	5.8	78	283	336	359	390	418	400
Nuclear	-	17	74	435	574	656	741	822	904
Hydro	127	222	711	1 231	1 365	1 408	1 447	1 482	1 513
Geothermal	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Solar photovoltaics	0.0	0.0	0.7	584	2 781	3 855	4 192	4 469	4 750
Wind	0.0	0.6	45	886	1 625	2 097	2 549	2 942	3 341
Concentrated solar power and marine	0.0	0.0	0.0	2.1	1.9	2.0	2.0	2.0	2.1
Biomass and waste	-	2.4	34	206	351	391	431	457	482
Hydrogen	-	-	-	-	-	41	82	86	90
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	2 198	3 194	8 093	11 127	9 719	8 625	7 862	7 088	6 064
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	1 041	2 825	7 712	17 612	23 232	27 323	31 895	36 873	42 032
Population (million)	1 135	1 263	1 338	1 411	1 387	1 362	1 332	1 295	1 250
GDP per capita ($2015 thousand)	0.9	2.2	5.8	12	17	20	24	28	34
Primary energy consumption per capita (toe/person)	0.8	0.9	1.9	2.9	2.9	2.9	2.9	2.9	2.8
Primary energy consumption per GDP (toe/$2015 million)	843	401	330	228	174	144	120	101	84
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	2 111	1 131	1 049	632	418	316	247	192	144
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.5	2.8	3.2	2.8	2.4	2.2	2.0	1.9	1.7

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
4.7	-0.3	-0.8	-0.5	100	100	100	100	3 935	3 625	3 290	3 001	2 710	-1.2	-1.9	-1.5	100	100
4.7	-2.5	-2.7	-2.5	60	61	42	35	1 949	1 524	1 165	884	581	-4.3	-6.7	-5.2	35	21
5.7	0.0	-1.0	-0.4	14	18	19	19	751	664	584	509	445	-1.3	-2.7	-1.8	18	16
10.2	1.1	-0.9	0.4	1.5	7.9	10	10	371	339	279	206	124	-0.8	-7.8	-3.4	8.5	4.6
n.a.	3.2	2.0	2.7	-	2.8	5.0	6.7	149	187	225	263	300	4.1	2.9	3.7	6.9	11
7.1	1.0	0.4	0.8	1.2	2.6	3.2	3.7	119	124	129	135	140	1.2	0.8	1.0	3.9	5.2
n.a.	2.4	-0.8	1.2	-	0.5	0.7	0.7	24	26	24	22	20	1.5	-2.0	0.2	0.7	0.7
29.2	8.4	1.8	5.9	0.0	3.8	16	21	419	594	697	786	895	9.3	2.5	6.7	21	33
-1.4	1.6	0.6	1.2	23	3.2	4.3	5.0	154	168	184	199	215	2.2	1.6	2.0	5.6	7.9
n.a.	n.a.	-3.2	n.a.	-	-	0.0	0.0	-0.2	-0.1	2.2	-1.5	-8.8	n.a.	n.a.	n.a.	0.1	-0.3

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
4.0	0.4	-0.6	0.0	100	100	100	100	2 510	2 368	2 191	2 029	1 897	-0.6	-1.4	-0.9	100	100
1.6	-1.9	-2.4	-2.1	47	22	15	12	444	351	280	228	189	-3.6	-3.8	-3.7	13	10.0
6.5	-0.1	-1.0	-0.4	13	28	26	25	682	608	538	474	418	-1.3	-2.5	-1.8	25	22
10.5	0.7	-1.2	0.0	1.3	10	11	9.9	257	227	184	142	108	-1.6	-5.2	-3.0	8.4	5.7
9.1	2.1	0.6	1.5	5.9	29	38	42	854	917	939	948	946	1.8	0.1	1.2	43	50
8.5	1.0	-1.6	0.0	2.0	8.1	8.9	8.0	213	196	171	146	123	-0.7	-3.3	-1.7	7.8	6.5
n.a.	n.a.	18.9	n.a.	-	-	0.0	0.1	0.0	3.8	8.8	17	34	n.a.	14.5	n.a.	0.4	1.8
-2.7	-2.0	-0.1	-1.3	31	3.4	2.3	2.4	60	64	69	74	78	-1.1	1.3	-0.2	3.2	4.1
4.9	-0.1	-1.7	-0.7	36	48	44	40	1 157	1 034	887	759	653	-1.6	-3.0	-2.1	40	34
7.9	0.4	-0.6	0.0	4.6	16	16	16	403	361	322	292	275	-0.9	-1.6	-1.1	15	14
1.6	1.0	0.9	1.0	53	24	27	31	616	632	637	639	638	0.5	0.0	0.3	29	34
5.9	1.1	-0.4	0.6	6.5	12	13	14	334	340	344	339	330	1.1	-0.4	0.5	16	17

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
8.6	2.0	0.6	1.5	100	100	100	100	11 726	12 877	13 285	13 676	14 120	2.0	0.6	1.5	100	100
8.1	-3.1	-2.9	-3.0	71	62	26	18	4 376	3 183	2 128	1 322	394	-5.8	-15.5	-9.5	16	2.8
-5.0	-5.3	-6.4	-5.7	8.1	0.1	0.0	0.0	6.1	3.9	2.2	1.2	0.3	-7.9	-18.9	-12.1	0.0	0.0
15.1	1.9	0.2	1.3	0.4	3.0	2.9	2.8	460	475	418	297	102	2.3	-13.2	-3.7	3.1	0.7
n.a.	3.2	2.0	2.7	-	4.6	5.6	6.4	574	718	865	1 008	1 152	4.1	2.9	3.7	6.5	8.2
7.1	1.0	0.4	0.8	20	13	11	11	1 380	1 440	1 502	1 565	1 629	1.2	0.8	1.0	11	12
3.8	-2.6	0.0	-1.6	0.0	0.0	0.0	0.0	0.1	2.5	2.6	2.6	2.7	16.3	0.4	10.1	0.0	0.0
46.4	12.3	1.3	8.1	0.0	6.2	32	34	2 878	4 227	4 799	5 176	5 641	13.2	1.6	8.8	36	40
48.3	6.4	2.7	5.0	0.0	9.3	19	24	1 681	2 357	2 998	3 660	4 479	7.4	4.1	6.2	23	32
18.8	-0.2	0.4	0.0	0.0	0.0	0.0	0.0	2.5	2.6	2.7	2.9	3.1	1.6	1.3	1.5	0.0	0.0
n.a.	4.5	1.1	3.2	-	2.2	3.2	3.4	368	412	455	498	540	4.8	1.7	3.6	3.4	3.8
n.a.	n.a.	0.9	n.a.	-	-	0.6	0.6	-	56	112	145	177	n.a.	4.6	n.a.	0.8	1.3
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
5.0	-2.0	-2.6	-2.2	9 303	6 419	4 296	2 835	1 839	-5.4	-8.1	-6.4
n.a.	n.a.	n.a.	n.a.	-	-	53	113	181	n.a.	13.1	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
8.9	3.6	2.8	3.3	23 232	27 323	31 895	36 873	42 032	3.6	2.8	3.3
0.7	-0.3	-0.6	-0.4	1 387	1 362	1 332	1 295	1 250	-0.3	-0.6	-0.4
8.2	3.9	3.5	3.7	17	20	24	28	34	3.9	3.5	3.7
4.0	0.1	-0.2	0.0	2.8	2.7	2.5	2.3	2.2	-0.8	-1.3	-1.0
-3.9	-3.7	-3.5	-3.6	169	133	103	81	64	-4.6	-4.6	-4.6
-3.6	-5.4	-5.2	-5.3	400	235	135	77	44	-8.7	-10.6	-9.4
0.3	-1.8	-1.7	-1.7	2.4	1.8	1.3	0.9	0.7	-4.3	-6.3	-5.1

Table A26 | India

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	280	418	661	1 098	1 361	1 574	1 781	2 010	2 234
Coal	93	146	274	510	574	652	726	817	904
Oil	61	112	162	271	331	392	460	530	599
Natural gas	11	23	54	58	84	108	132	156	179
Nuclear	1.6	4.4	6.8	12	36	41	46	53	61
Hydro	6.2	6.4	11	12	19	22	25	29	33
Geothermal	-	-	-	-	-	-	-	-	0.0
Solar, wind, etc.	0.0	0.2	2.0	20	77	111	144	175	206
Biomass and waste	108	126	151	215	240	246	246	248	249
Hydrogen	-	-	-	-	-0.0	0.6	2.7	3.7	4.8

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	215	291	440	724	924	1 069	1 210	1 362	1 511
Coal	38	33	83	125	170	191	208	224	238
Oil	50	94	138	224	285	340	402	465	527
Natural gas	6.1	12	19	46	65	83	100	117	132
Electricity	18	32	62	138	200	249	300	358	420
Heat	-	-	-	-	-	-	-	-	0.0
Hydrogen	-	-	-	-	-	0.0	0.1	0.5	1.0
Renewables and waste	102	119	138	191	204	206	200	198	194
Industry	59	85	157	287	413	491	553	614	664
Transport	21	32	65	125	163	200	244	292	343
Buildings, etc.	122	147	184	254	275	290	310	335	366
Non-energy use	13	27	34	57	74	88	104	121	138

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	289	561	972	1 987	2 886	3 599	4 291	5 075	5 880
Coal	189	387	658	1 479	1 500	1 717	1 925	2 229	2 538
Oil	13	25	19	4.2	5.6	6.7	7.8	9.3	11
Natural gas	10.0	56	107	59	85	107	132	166	205
Nuclear	6.1	17	26	48	138	156	178	202	233
Hydro	72	74	125	144	220	258	296	337	379
Geothermal	-	-	-	-	-	-	-	-	-
Solar photovoltaics	-	0.0	0.1	119	726	1 072	1 402	1 710	2 020
Wind	0.0	1.7	20	93	145	191	234	285	337
Concentrated solar power and marine	-	-	-	-	0.3	0.3	0.3	0.3	0.3
Biomass and waste	-	0.2	17	41	67	78	89	100	112
Hydrogen	-	-	-	-	-	13	27	36	45
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	518	872	1 541	2 771	3 218	3 722	4 218	4 784	5 322
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	475	817	1 567	3 333	5 148	6 930	9 163	11 880	15 058
Population (million)	865	1 058	1 243	1 438	1 525	1 579	1 623	1 656	1 680
GDP per capita ($2015 thousand)	0.5	0.8	1.3	2.3	3.4	4.4	5.6	7.2	9.0
Primary energy consumption per capita (toe/person)	0.3	0.4	0.5	0.8	0.9	1.0	1.1	1.2	1.3
Primary energy consumption per GDP (toe/$2015 million)	590	511	422	329	264	227	194	169	148
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	1 092	1 067	983	831	625	537	460	403	353
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	1.9	2.1	2.3	2.5	2.4	2.4	2.4	2.4	2.4

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
4.2	2.9	2.3	2.7	100	100	100	100	1 324	1 459	1 558	1 636	1 725	2.1	1.0	1.7	100	100
5.3	2.1	2.2	2.1	33	46	41	40	535	548	536	492	469	0.3	-1.3	-0.3	34	27
4.6	3.2	2.7	3.0	22	25	26	27	310	335	357	369	371	1.6	0.4	1.2	23	21
5.3	4.9	3.1	4.3	3.8	5.3	7.4	8.0	88	105	115	116	118	4.1	0.3	2.7	7.4	6.9
6.4	8.0	2.7	6.0	0.6	1.1	2.6	2.7	37	62	92	130	158	12.5	5.5	9.9	5.9	9.2
2.1	4.3	2.5	3.7	2.2	1.1	1.4	1.5	23	30	37	47	58	6.7	4.4	5.9	2.4	3.3
n.a.	n.a.	n.a.	n.a.	-	-	-	0.0	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
25.9	12.4	3.7	9.1	0.0	1.8	8.1	9.2	97	151	197	255	314	14.5	4.8	10.8	13	18
2.1	0.8	0.1	0.5	38	20	14	11	234	226	211	202	199	-0.1	-0.6	-0.3	14	12
n.a.	n.a.	5.8	n.a.	-	-	0.2	0.2	-0.0	2.9	12	25	38	n.a.	12.1	n.a.	0.8	2.2

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
3.7	3.1	2.2	2.8	100	100	100	100	894	973	1 034	1 089	1 151	2.1	1.1	1.7	100	100
3.7	3.0	1.3	2.4	18	17	17	16	154	150	141	132	124	0.7	-1.3	0.0	14	11
4.6	3.5	2.7	3.2	23	31	33	35	266	289	309	322	324	1.9	0.5	1.4	30	28
6.3	4.7	2.9	4.0	2.8	6.3	8.2	8.8	63	73	78	81	82	3.2	0.4	2.2	7.6	7.1
6.3	4.7	3.4	4.2	8.5	19	25	28	216	279	342	404	477	5.5	3.4	4.7	33	41
n.a.	n.a.	n.a.	n.a.	-	-	-	0.0	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	24.0	n.a.	-	-	0.0	0.1	0.0	0.9	2.4	4.6	7.4	n.a.	11.7	n.a.	0.2	0.6
1.9	0.3	-0.3	0.0	48	26	17	13	195	181	161	145	136	-1.0	-1.6	-1.2	16	12
4.9	3.9	1.9	3.2	27	40	46	44	400	441	458	463	474	2.8	0.3	1.9	44	41
5.6	4.0	3.5	3.8	9.7	17	20	23	155	175	196	217	235	2.7	1.8	2.4	19	20
2.3	1.2	1.7	1.4	57	35	26	24	265	269	276	289	305	0.5	1.0	0.7	27	26
4.5	3.5	2.9	3.3	6.2	7.9	8.6	9.1	74	88	104	121	138	3.5	2.9	3.3	10	12

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
6.0	4.6	3.2	4.1	100	100	100	100	3 118	4 075	4 839	5 666	6 618	5.4	3.2	4.6	100	100
6.4	1.6	2.8	2.0	65	74	45	43	1 399	1 442	1 365	1 142	1 033	-0.5	-2.7	-1.3	28	16
-3.3	3.7	3.5	3.6	4.3	0.2	0.2	0.2	5.5	6.0	6.0	5.3	5.1	2.2	-1.6	0.7	0.1	0.1
5.5	4.9	4.5	4.7	3.4	3.0	3.1	3.5	136	185	221	226	243	8.1	0.9	5.4	4.6	3.7
6.4	8.0	2.7	6.0	2.1	2.4	4.1	4.0	141	237	355	499	608	12.5	5.5	9.9	7.3	9.2
2.1	4.3	2.5	3.7	25	7.2	6.9	6.4	267	344	436	544	671	6.7	4.4	5.9	9.0	10
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	15.6	3.7	11.1	-	6.0	33	34	947	1 486	1 981	2 560	3 146	18.0	4.7	12.9	41	48
27.4	5.5	3.7	4.9	0.0	4.7	5.4	5.7	147	228	262	348	443	6.2	5.4	5.9	5.4	6.7
n.a.	n.a.	0.1	n.a.	-	-	0.0	0.0	0.3	0.4	0.4	0.4	0.4	n.a.	0.4	n.a.	0.0	0.0
n.a.	4.6	2.4	3.8	-	2.1	2.1	1.9	76	91	106	122	138	5.7	2.7	4.6	2.2	2.1
n.a.	n.a.	5.3	n.a.	-	-	0.6	0.8	-	54	108	220	331	n.a.	11.8	n.a.	2.2	5.0
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
5.2	2.5	2.4	2.4	3 016	3 132	3 115	2 894	2 705	0.7	-1.4	-0.1
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
6.1	6.1	5.1	5.7	5 148	6 930	9 163	11 880	15 058	6.1	5.1	5.7
1.6	0.7	0.3	0.6	1 525	1 579	1 623	1 656	1 680	0.7	0.3	0.6
4.5	5.4	4.7	5.1	3.4	4.4	5.6	7.2	9.0	5.4	4.7	5.1
2.6	2.2	1.9	2.1	0.9	0.9	1.0	1.0	1.0	1.4	0.7	1.1
-1.7	-3.1	-2.7	-2.9	257	211	170	138	115	-3.8	-3.9	-3.8
-0.8	-3.4	-2.6	-3.1	586	452	340	244	180	-5.1	-6.2	-5.5
0.9	-0.4	0.1	-0.2	2.3	2.1	2.0	1.8	1.6	-1.4	-2.4	-1.7

Table A27 | Japan

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	437	516	500	378	358	339	320	305	293
Coal	77	97	115	99	73	63	53	48	45
Oil	249	253	201	141	128	118	107	97	86
Natural gas	44	66	86	80	72	70	64	60	57
Nuclear	53	84	75	22	47	42	42	42	42
Hydro	7.6	7.2	7.2	6.5	7.2	7.3	7.4	7.5	7.5
Geothermal	1.6	3.1	2.4	3.1	3.7	4.8	5.5	5.9	6.3
Solar, wind, etc.	1.2	0.9	1.1	9.3	14	18	22	25	27
Biomass and waste	4.2	5.0	11	17	14	14	17	17	17
Hydrogen	-	-	-	-	0.4	1.0	1.6	3.2	4.8

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	291	336	314	250	235	223	211	200	189
Coal	27	21	23	17	15	14	13	12	11
Oil	180	206	166	124	113	104	95	85	75
Natural gas	14	21	29	26	24	23	21	19	18
Electricity	66	84	89	76	75	75	75	75	77
Heat	0.2	0.5	0.6	0.7	0.7	0.6	0.5	0.5	0.4
Hydrogen	-	-	-	-	0.0	0.0	0.0	0.1	0.2
Renewables and waste	3.8	4.1	6.1	6.6	6.4	6.6	7.1	7.2	7.2
Industry	107	103	91	73	66	63	60	57	54
Transport	72	89	79	64	59	54	50	45	40
Buildings, etc.	77	107	108	87	85	81	78	74	71
Non-energy use	34	37	36	26	24	24	24	23	23

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	862	1 055	1 164	993	983	983	983	991	1 006
Coal	125	228	317	284	180	141	98	85	73
Oil	250	133	91	30	18	14	8.8	5.6	2.9
Natural gas	168	255	332	331	296	301	278	262	248
Nuclear	202	322	288	84	179	162	163	162	162
Hydro	88	84	84	75	84	85	86	87	87
Geothermal	1.7	3.3	2.6	3.4	4.2	5.4	6.2	6.7	7.2
Solar photovoltaics	0.1	0.4	3.5	96	123	160	202	224	247
Wind	-	0.1	4.0	10	37	47	54	61	68
Concentrated solar power and marine	-	-	-	-	-	-	-	-	-
Biomass and waste	8.1	9.2	21	63	43	44	59	59	59
Hydrogen	-	-	-	-	2.5	7.1	12	23	34
Others	20	20	21	16	16	16	16	16	16

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	1 046	1 149	1 126	928	775	703	615	548	487
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	3 510	3 987	4 219	4 601	4 764	4 942	5 131	5 317	5 500
Population (million)	123	127	128	125	120	116	112	109	105
GDP per capita ($2015 thousand)	28	31	33	37	40	43	46	49	52
Primary energy consumption per capita (toe/person)	3.5	4.1	3.9	3.0	3.0	2.9	2.9	2.8	2.8
Primary energy consumption per GDP (toe/$2015 million)	124	129	118	82	75	69	62	57	53
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	298	288	267	202	163	142	120	103	89
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.4	2.2	2.3	2.5	2.2	2.1	1.9	1.8	1.7

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
-0.4	-1.0	-0.9	-0.9	100	100	100	100	355	326	296	278	263	-1.4	-1.2	-1.3	100	100
0.8	-3.7	-1.5	-2.9	18	26	16	15	62	49	38	33	32	-5.5	-1.8	-4.2	13	12
-1.7	-1.6	-2.2	-1.8	57	37	34	29	120	101	82	65	53	-3.2	-4.3	-3.6	28	20
1.8	-1.2	-1.3	-1.3	10	21	20	19	62	53	42	34	22	-3.7	-6.3	-4.7	14	8.3
-2.6	4.0	0.0	2.5	12	5.8	13	14	62	63	65	65	65	6.6	0.0	4.1	22	25
-0.5	0.8	0.1	0.6	1.7	1.7	2.3	2.6	7.3	7.4	7.6	7.7	7.7	0.9	0.2	0.7	2.6	2.9
2.0	3.5	1.4	2.7	0.4	0.8	1.7	2.2	3.7	5.2	6.0	6.4	6.8	4.1	1.2	3.0	2.0	2.6
6.4	5.2	2.1	4.0	0.3	2.5	6.9	9.3	15	22	28	33	37	6.7	2.9	5.3	9.5	14
4.4	-0.2	0.0	-0.1	1.0	4.6	5.2	5.7	21	22	22	22	21	1.5	-0.4	0.8	7.6	8.2
n.a.	n.a.	11.7	n.a.	-	-	0.5	1.7	1.7	4.0	5.9	13	19	n.a.	12.3	n.a.	2.0	7.2

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
-0.5	-1.0	-1.1	-1.0	100	100	100	100	227	205	182	165	153	-1.8	-1.7	-1.8	100	100
-1.4	-1.5	-1.5	-1.5	9.3	6.7	6.1	5.9	13	11	8.7	7.3	6.3	-3.8	-3.2	-3.6	4.8	4.1
-1.1	-1.6	-2.2	-1.8	62	50	45	40	107	90	72	58	48	-3.1	-4.0	-3.5	40	31
2.0	-1.2	-1.6	-1.4	4.7	10	10	9.5	24	20	17	13	10.0	-2.6	-5.0	-3.5	9.2	6.5
0.4	-0.1	0.2	0.0	23	30	35	41	76	76	76	77	78	0.0	0.3	0.1	42	51
4.0	-1.6	-2.9	-2.1	0.1	0.3	0.3	0.2	0.7	0.6	0.5	0.5	0.4	-1.9	-2.8	-2.2	0.3	0.3
n.a.	n.a.	19.5	n.a.	-	-	0.0	0.1	0.0	0.4	0.9	1.9	4.1	n.a.	16.0	n.a.	0.5	2.7
1.7	0.4	0.1	0.3	1.3	2.6	3.3	3.8	6.3	7.0	7.1	6.8	6.2	0.5	-1.3	-0.2	3.9	4.1
-1.2	-1.1	-1.0	-1.1	37	29	29	29	63	56	49	44	40	-2.2	-2.1	-2.2	27	26
-0.4	-1.5	-2.2	-1.7	25	26	24	21	56	47	38	31	27	-3.1	-3.5	-3.2	21	17
0.4	-0.7	-0.8	-0.7	27	35	37	38	84	78	71	67	64	-1.2	-1.1	-1.2	39	42
-0.9	-0.4	-0.3	-0.4	12	10	11	12	24	24	24	23	23	-0.4	-0.3	-0.4	13	15

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
0.4	-0.1	0.2	0.0	100	100	100	100	994	1 009	1 016	1 053	1 081	0.1	0.6	0.3	100	100
2.5	-6.0	-2.9	-4.9	14	29	10	7.3	137	90	50	34	33	-9.8	-3.9	-7.6	4.9	3.1
-6.2	-7.0	-10.7	-8.4	29	3.0	0.9	0.3	12	8.9	4.8	2.7	1.0	-10.2	-14.4	-11.8	0.5	0.1
2.1	-1.0	-1.1	-1.1	19	33	28	25	238	208	167	145	93	-3.9	-5.7	-4.6	16	8.6
-2.6	4.0	0.0	2.5	23	8.5	17	16	238	243	250	249	249	6.6	0.0	4.1	25	23
-0.5	0.8	0.1	0.6	10	7.6	8.8	8.7	85	87	88	89	90	0.9	0.2	0.7	8.7	8.3
2.0	3.6	1.5	2.8	0.2	0.3	0.6	0.7	4.2	6.0	6.9	7.4	7.9	4.3	1.3	3.2	0.7	0.7
24.7	4.5	2.0	3.5	0.0	9.7	21	25	134	195	255	292	333	5.9	2.7	4.7	25	31
n.a.	10.1	2.3	7.1	-	1.1	5.5	6.7	40	58	72	86	102	12.0	3.6	8.8	7.0	9.4
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
6.4	-0.4	0.1	-0.2	0.9	6.3	6.0	5.9	80	82	84	86	88	1.8	0.4	1.3	8.3	8.1
n.a.	n.a.	11.4	n.a.	-	-	1.2	3.4	9.3	16	23	45	67	n.a.	11.4	n.a.	2.3	6.2
-0.6	0.0	0.0	0.0	2.3	1.6	1.6	1.6	16	16	16	16	16	0.0	0.0	0.0	1.6	1.5

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
-0.4	-2.4	-2.3	-2.4	686	516	364	216	99	-5.4	-12.2	-7.9	
n.a.	n.a.	n.a.	n.a.	-	-	14	44	79	n.a.	18.8	n.a.	

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
0.8	0.6	0.7	0.7	4 764	4 942	5 131	5 317	5 500	0.6	0.7	0.7
0.0	-0.6	-0.6	-0.6	120	116	112	109	105	-0.6	-0.6	-0.6
0.8	1.3	1.4	1.3	40	43	46	49	52	1.3	1.4	1.3
-0.5	-0.4	-0.2	-0.3	3.0	2.8	2.6	2.6	2.5	-0.8	-0.5	-0.7
-1.2	-1.6	-1.6	-1.6	74	66	58	52	48	-2.1	-1.9	-2.0
-1.2	-3.0	-3.0	-3.0	144	104	71	41	18	-6.0	-12.8	-8.5
0.1	-1.4	-1.4	-1.4	1.9	1.6	1.2	0.8	0.4	-4.0	-11.1	-6.7

Table A28 | Korea

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	90	186	244	276	263	261	252	242	232
Coal	22	39	68	66	62	56	54	50	45
Oil	50	99	95	101	96	92	88	83	78
Natural gas	2.7	18	38	51	52	51	54	55	54
Nuclear	14	28	39	47	37	42	35	29	28
Hydro	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Geothermal	-	-	0.0	0.3	0.4	0.4	0.4	0.4	0.4
Solar, wind, etc.	0.0	0.0	0.2	3.3	7.4	9.1	11	13	15
Biomass and waste	0.7	1.4	3.5	6.8	8.4	8.7	9.0	9.1	9.2
Hydrogen	-	-	-	-	0.4	0.7	1.0	1.7	2.5

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	65	127	161	174	174	172	167	162	156
Coal	12	8.3	13	8.0	7.9	7.4	6.7	6.1	5.6
Oil	44	80	82	88	86	82	79	75	70
Natural gas	0.9	11	21	22	21	21	20	19	18
Electricity	8.1	23	39	46	49	51	52	53	53
Heat	-	3.3	4.3	6.1	5.9	5.7	5.3	4.9	4.6
Hydrogen	-	-	-	-	0.0	0.0	0.1	0.1	0.2
Renewables and waste	0.7	1.3	2.7	3.9	4.1	4.0	4.0	4.0	3.9
Industry	20	38	48	46	47	47	46	45	43
Transport	15	26	30	36	34	31	29	26	23
Buildings, etc.	24	38	44	44	43	42	41	40	39
Non-energy use	6.7	25	38	48	50	51	51	52	51

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	109	288	472	607	648	673	688	700	706
Coal	21	110	220	205	200	179	177	167	148
Oil	19	35	19	7.3	5.6	3.9	2.7	1.2	-
Natural gas	9.7	30	78	161	187	190	213	228	230
Nuclear	53	109	149	180	142	161	134	113	106
Hydro	6.4	4.0	3.7	3.7	3.6	3.6	3.6	3.6	3.6
Geothermal	-	-	-	-	-	-	-	-	-
Solar photovoltaics	0.0	0.0	0.8	30	61	74	89	105	121
Wind	-	0.0	0.8	3.4	24	30	36	42	50
Concentrated solar power and marine	-	-	-	0.4	0.5	0.5	0.5	0.5	0.5
Biomass and waste	-	0.1	1.1	11	18	20	22	23	24
Hydrogen	-	-	-	-	2.7	4.9	7.1	13	18
Others	-	-	0.3	4.4	4.4	4.4	4.4	4.4	4.4

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	208	391	531	533	494	460	441	411	370
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	402	799	1 261	1 764	1 997	2 175	2 343	2 495	2 623
Population (million)	43	47	50	52	51	50	49	47	45
GDP per capita ($2015 thousand)	9.4	17	25	34	39	43	48	53	58
Primary energy consumption per capita (toe/person)	2.1	4.0	4.9	5.3	5.1	5.2	5.2	5.1	5.1
Primary energy consumption per GDP (toe/$2015 million)	223	233	193	156	132	120	108	97	88
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	517	489	421	302	248	212	188	165	141
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.3	2.1	2.2	1.9	1.9	1.8	1.8	1.7	1.6

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
3.5	-0.5	-0.8	-0.6	100	100	100	100	262	253	241	227	209	-0.8	-1.4	-1.0	100	100
3.4	-1.2	-1.9	-1.5	25	24	21	19	51	40	29	22	17	-4.8	-5.0	-4.9	12	8.3
2.2	-0.8	-1.2	-0.9	56	37	35	34	93	84	74	64	56	-1.8	-2.7	-2.1	31	27
9.4	0.3	0.1	0.2	3.0	18	21	23	46	44	38	33	32	-1.8	-1.6	-1.7	16	15
3.8	-1.7	-2.3	-2.0	15	17	14	12	53	58	67	65	55	2.1	-2.0	0.6	28	26
-1.6	-0.3	0.0	-0.2	0.6	0.1	0.1	0.1	0.3	0.3	0.3	0.3	0.3	-0.3	0.0	-0.2	0.1	0.1
n.a.	2.2	-0.5	1.2	-	0.1	0.2	0.2	0.4	0.4	0.4	0.4	0.4	2.5	-0.8	1.2	0.2	0.2
19.2	7.2	3.2	5.7	0.0	1.2	4.3	6.4	9.0	12	15	19	23	9.4	4.1	7.4	6.3	11
7.0	1.7	0.3	1.2	0.8	2.4	3.6	4.0	9.0	9.6	11	12	13	2.7	2.2	2.5	4.4	6.2
n.a.	n.a.	10.2	n.a.	-	-	0.4	1.1	1.2	4.2	6.8	10	13	n.a.	6.4	n.a.	2.8	6.1

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
3.0	-0.2	-0.7	-0.4	100	100	100	100	171	162	151	140	131	-0.8	-1.4	-1.0	100	100
-1.2	-1.0	-1.9	-1.3	18	4.6	4.0	3.6	7.1	5.7	4.5	3.6	3.0	-3.4	-4.1	-3.6	3.0	2.3
2.2	-0.7	-1.2	-0.9	67	51	47	45	84	77	68	61	54	-1.5	-2.3	-1.8	45	42
10.1	-0.3	-1.1	-0.6	1.4	12	12	12	20	18	15	12	9.0	-2.1	-5.1	-3.2	10	6.8
5.4	0.7	0.2	0.6	12	26	31	34	49	51	52	52	52	0.7	-0.1	0.4	35	39
n.a.	-0.8	-1.5	-1.0	-	3.5	3.2	2.9	5.8	5.4	4.9	4.3	3.7	-1.3	-2.6	-1.8	3.2	2.9
n.a.	n.a.	12.8	n.a.	-	-	0.0	0.1	0.1	0.5	1.0	1.8	3.0	n.a.	11.5	n.a.	0.7	2.3
5.2	0.2	-0.3	0.0	1.1	2.2	2.4	2.5	4.1	4.3	4.7	5.5	6.4	1.2	3.1	1.9	3.1	4.9
2.5	0.0	-0.8	-0.3	31	26	28	27	46	43	39	35	31	-1.0	-2.1	-1.4	26	24
2.8	-1.4	-2.1	-1.7	22	21	17	15	33	27	22	18	15	-2.9	-3.7	-3.2	15	12
1.9	-0.3	-0.7	-0.5	36	25	25	25	42	41	38	36	33	-0.8	-1.5	-1.0	26	25
6.1	0.4	0.0	0.3	10	27	31	33	50	51	51	52	51	0.4	0.0	0.3	34	39

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
5.3	0.7	0.3	0.6	100	100	100	100	649	687	708	727	741	0.9	0.5	0.7	100	100
7.1	-0.9	-1.8	-1.2	20	34	26	21	152	117	74	51	35	-5.8	-7.4	-6.4	11	4.7
-2.8	-5.8	-100	-100	17	1.2	0.4	-	4.5	2.9	1.4	0.5	-	-9.2	-100	-100	0.2	-
8.9	1.7	0.8	1.3	8.9	26	31	33	156	164	146	146	163	-0.6	1.1	0.1	21	22
3.8	-1.7	-2.3	-2.0	48	30	19	15	202	221	256	251	210	2.1	-2.0	0.6	36	28
-1.6	-0.3	0.0	-0.2	5.8	0.6	0.5	0.5	3.6	3.6	3.6	3.6	3.6	-0.3	0.0	-0.2	0.5	0.5
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
36.7	6.6	3.1	5.3	0.0	4.9	13	17	76	100	126	154	185	8.8	3.9	7.0	18	25
n.a.	14.9	3.3	10.5	-	0.6	5.3	7.1	28	38	49	61	76	17.0	4.5	12.2	6.9	10
n.a.	0.9	0.2	0.7	-	0.1	0.1	0.1	0.6	0.6	0.6	0.6	0.6	1.6	0.2	1.1	0.1	0.1
n.a.	4.1	1.2	3.0	-	1.8	3.2	3.5	19	22	24	27	29	4.7	1.8	3.6	3.4	3.9
n.a.	n.a.	10.0	n.a.	-	-	1.0	2.6	2.9	13	22	28	34	n.a.	4.3	n.a.	3.2	4.6
n.a.	0.0	0.0	0.0	-	0.7	0.6	0.6	4.4	4.4	4.4	4.4	4.4	0.0	0.0	0.0	0.6	0.6

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
2.9	-1.1	-1.7	-1.3	434	329	227	145	84	-4.9	-9.4	-6.6	
n.a.	n.a.	n.a.	n.a.	-	-	4.5	9.8	16	n.a.	13.2	n.a.	

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
4.6	1.7	1.1	1.5	1 997	2 175	2 343	2 495	2 623	1.7	1.1	1.5	
0.6	-0.3	-0.8	-0.5	51	50	49	47	45	-0.3	-0.8	-0.5	
4.0	2.0	2.0	2.0	39	43	48	53	58	2.0	2.0	2.0	
2.9	-0.2	0.0	-0.1	5.1	5.0	4.9	4.8	4.6	-0.5	-0.6	-0.5	
-1.1	-2.2	-2.0	-2.1	131	116	103	91	80	-2.4	-2.5	-2.5	
-1.6	-2.7	-2.8	-2.8	217	151	97	58	32	-6.5	-10.4	-8.0	
-0.6	-0.6	-0.9	-0.7	1.7	1.3	0.9	0.6	0.4	-4.1	-8.1	-5.6	

Table A29 | Chinese Taipei

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	51	90	118	111	117	116	114	111	108
Coal	11	30	42	38	37	35	32	29	26
Oil	28	42	48	37	43	42	40	39	36
Natural gas	1.6	6.2	15	26	29	30	30	30	30
Nuclear	8.6	10	11	4.6	-	-	-	-	-
Hydro	0.5	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4
Geothermal	0.0	-	-	0.0	0.1	0.1	0.1	0.1	0.1
Solar, wind, etc.	0.0	0.1	0.2	1.7	5.9	7.1	8.3	9.7	11
Biomass and waste	0.1	0.9	1.8	1.7	1.7	1.8	1.8	1.8	1.9
Hydrogen	-	-	-	-	0.2	0.4	0.5	0.9	1.4

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	32	54	74	69	81	81	80	78	76
Coal	3.5	5.4	6.5	4.3	4.9	4.7	4.5	4.1	3.8
Oil	21	32	44	35	41	41	40	38	36
Natural gas	1.0	1.8	2.4	5.3	6.1	6.0	5.9	5.8	5.7
Electricity	6.6	14	19	22	25	26	26	27	27
Heat	-	0.0	1.6	1.7	2.5	2.5	2.4	2.2	2.1
Hydrogen	-	-	-	-	-	-	0.0	0.1	0.1
Renewables and waste	0.0	0.4	0.7	0.4	0.6	0.6	0.7	0.7	0.8
Industry	13	21	25	24	29	30	29	29	28
Transport	7.3	12	13	13	12	12	11	9.6	8.4
Buildings, etc.	6.9	11	12	13	13	13	13	13	12
Non-energy use	4.9	9.4	23	19	26	27	27	27	27

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	90	181	244	279	315	327	335	342	349
Coal	27	87	122	119	110	101	91	80	69
Oil	22	31	11	3.8	2.9	2.2	1.5	0.9	0.3
Natural gas	1.2	18	60	112	124	130	134	134	133
Nuclear	33	39	42	18	-	-	-	-	-
Hydro	6.2	4.6	4.2	4.0	4.7	4.7	4.7	4.7	4.7
Geothermal	0.0	-	-	0.0	0.1	0.1	0.1	0.1	0.1
Solar photovoltaics	-	-	0.0	13	25	29	33	39	45
Wind	-	0.0	1.0	6.2	43	53	63	73	82
Concentrated solar power and marine	-	-	-	-	-	-	-	-	-
Biomass and waste	0.2	1.8	3.4	3.6	3.9	3.9	3.9	3.9	3.9
Hydrogen	-	-	-	-	1.5	2.8	4.0	7.2	10
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	108	213	252	257	253	243	229	212	195
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	161	307	463	688	826	913	999	1 083	1 159
Population (million)	20	22	23	23	23	22	21	20	19
GDP per capita ($2015 thousand)	7.9	14	20	29	37	41	47	53	60
Primary energy consumption per capita (toe/person)	2.5	4.0	5.1	4.7	5.2	5.3	5.4	5.4	5.5
Primary energy consumption per GDP (toe/$2015 million)	315	292	254	161	142	127	114	102	93
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	672	694	545	374	306	267	229	196	168
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.1	2.4	2.1	2.3	2.2	2.1	2.0	1.9	1.8

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
2.4	0.2	-0.6	-0.1	100	100	100	100	115	109	102	95	90	-0.5	-1.2	-0.8	100	100
3.7	-1.0	-1.9	-1.4	23	35	28	25	32	28	23	19	15	-3.0	-4.0	-3.3	22	17
0.8	0.5	-1.1	-0.1	56	34	36	34	41	38	35	31	27	-0.5	-2.3	-1.1	34	31
8.9	0.8	0.0	0.5	3.1	24	27	28	27	25	23	21	18	-0.8	-2.7	-1.5	23	20
-1.8	-100	n.a.	-100	17	4.2	-	-	5.0	5.0	5.0	5.0	5.0	0.4	0.0	0.3	4.9	5.5
-1.3	1.0	0.0	0.6	1.1	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	1.0	0.0	0.6	0.4	0.5
5.9	6.2	0.0	3.9	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	6.2	0.0	3.9	0.1	0.1
14.5	9.6	2.9	7.1	0.0	1.6	7.3	10	6.8	8.7	11	13	16	11.3	3.8	8.5	11	18
11.3	0.2	0.3	0.3	0.1	1.6	1.6	1.7	1.8	2.1	2.6	3.1	3.7	2.3	3.8	2.8	2.5	4.1
n.a.	n.a.	10.6	n.a.	-	-	0.4	1.3	0.3	1.4	2.3	3.7	4.7	n.a.	7.4	n.a.	2.3	5.2

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
2.4	0.8	-0.5	0.3	100	100	100	100	78	75	70	66	62	0.1	-1.2	-0.4	100	100
0.7	0.1	-1.5	-0.5	11	6.3	5.6	5.0	4.5	3.9	3.2	2.7	2.3	-1.7	-3.2	-2.3	4.6	3.7
1.6	0.7	-1.0	0.1	65	51	50	47	41	38	35	31	29	-0.1	-1.9	-0.7	49	46
5.2	0.7	-0.5	0.2	3.1	7.7	7.4	7.5	5.3	4.3	3.4	2.5	1.8	-2.6	-6.3	-4.0	4.8	2.8
3.7	1.0	0.4	0.8	21	32	33	36	25	26	26	25	25	0.9	-0.2	0.5	37	40
n.a.	2.0	-1.2	0.8	-	2.5	3.0	2.8	2.3	2.1	1.7	1.4	1.1	0.0	-4.0	-1.5	2.4	1.8
n.a.	n.a.	21.1	n.a.	-	-	0.0	0.2	-	0.1	0.3	0.6	1.0	n.a.	12.6	n.a.	0.4	1.6
9.8	2.7	1.0	2.1	0.1	0.6	0.9	1.0	0.7	1.0	1.4	1.9	2.5	7.0	6.1	6.7	2.0	4.0
1.9	1.2	-0.3	0.6	40	35	37	38	28	26	24	22	20	0.0	-1.7	-0.6	34	33
1.8	-1.2	-2.4	-1.6	23	19	13	11	12	9.8	7.8	6.2	5.2	-3.0	-3.9	-3.3	11	8.4
2.0	-0.2	-0.5	-0.3	22	19	16	16	13	12	12	11	10	-0.8	-1.4	-1.0	16	16
4.2	2.1	0.0	1.3	15	27	34	35	26	27	27	27	27	2.1	0.0	1.3	38	43

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
3.5	1.1	0.4	0.8	100	100	100	100	315	326	332	342	352	1.0	0.6	0.9	100	100
4.5	-1.5	-2.7	-2.0	30	43	27	20	90	72	53	37	23	-4.7	-8.0	-5.9	16	6.5
-5.2	-5.2	-16.2	-9.4	25	1.4	0.5	0.1	2.5	1.8	1.1	0.6	0.2	-6.8	-18.3	-11.2	0.3	0.0
14.7	1.1	0.0	0.7	1.3	40	40	38	115	118	114	107	95	0.1	-1.8	-0.6	34	27
-1.8	-100	n.a.	-100	36	6.4	-	-	19	19	19	19	19	0.4	0.0	0.3	5.8	5.4
-1.3	1.0	0.0	0.6	6.8	1.4	1.4	1.4	4.7	4.7	4.7	4.7	4.7	1.0	0.0	0.6	1.4	1.3
6.4	6.4	0.0	4.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	6.4	0.0	4.0	0.0	0.0
n.a.	5.7	3.2	4.7	-	4.6	9.8	13	29	36	43	53	64	7.4	4.0	6.1	13	18
n.a.	14.5	2.8	10.0	-	2.2	19	24	48	64	81	98	118	16.3	3.8	11.5	24	33
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
9.0	0.4	0.1	0.3	0.2	1.3	1.2	1.1	3.9	4.0	4.2	4.3	4.4	0.9	0.5	0.8	1.3	1.3
n.a.	n.a.	10.0	n.a.	-	-	1.2	3.0	1.6	6.7	12	18	24	n.a.	7.3	n.a.	3.5	6.7
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
2.7	-0.7	-1.6	-1.0	225	192	155	115	81	-2.9	-6.3	-4.2	
n.a.	n.a.	n.a.	n.a.	-	-	0.7	1.4	2.1	n.a.	11.8	n.a.	

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
4.5	2.2	1.5	2.0	826	913	999	1 083	1 159	2.2	1.5	2.0
0.4	-0.5	-0.9	-0.7	23	22	21	20	19	-0.5	-0.9	-0.7
4.1	2.8	2.4	2.6	37	41	47	53	60	2.8	2.4	2.6
2.0	0.7	0.3	0.6	5.1	5.0	4.8	4.7	4.6	0.1	-0.3	-0.1
-2.0	-2.0	-2.0	-2.0	139	119	102	88	78	-2.6	-2.7	-2.7
-1.8	-2.8	-3.1	-2.9	272	211	155	106	70	-5.0	-7.7	-6.0
0.3	-0.8	-1.1	-0.9	2.0	1.8	1.5	1.2	0.9	-2.5	-5.1	-3.5

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Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	217	355	506	757	919	1 090	1 229	1 369	1 513
Coal	12	31	79	218	262	282	301	317	325
Oil	88	154	191	236	260	282	307	329	347
Natural gas	30	74	125	147	207	257	321	399	494
Nuclear	-	-	-	-	-	2.2	7.9	14	18
Hydro	2.3	4.4	6.8	18	21	23	25	27	28
Geothermal	6.6	18	25	38	54	117	129	136	142
Solar, wind, etc.	-	-	0.0	5.3	14	21	25	31	37
Biomass and waste	78	73	80	94	100	106	111	116	120
Hydrogen	-	-	-	-	-0.0	0.3	1.1	1.1	1.0

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	149	245	343	477	559	624	692	759	822
Coal	5.4	14	29	45	54	59	62	64	65
Oil	67	124	165	216	237	258	281	303	321
Natural gas	7.5	17	29	47	58	66	73	80	85
Electricity	11	28	53	107	142	170	201	235	272
Heat	-	-	-	-	0.0	0.0	0.1	0.1	0.1
Hydrogen	-	-	-	-	0.1	0.1	0.2	0.2	0.2
Renewables and waste	58	63	67	63	68	72	74	77	78
Industry	41	76	112	168	214	246	277	305	331
Transport	33	62	88	148	168	184	201	219	235
Buildings, etc.	64	86	102	113	124	136	149	164	179
Non-energy use	11	21	40	47	53	59	65	71	77

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	154	374	692	1 365	1 810	2 196	2 599	3 053	3 549
Coal	28	79	192	635	745	806	868	926	961
Oil	66	72	60	19	12	11	9.3	7.0	3.4
Natural gas	26	154	335	361	549	714	929	1 199	1 536
Nuclear	-	-	-	-	-	8.4	30	53	71
Hydro	27	51	80	207	244	268	290	311	330
Geothermal	6.6	16	19	28	38	75	83	86	90
Solar photovoltaics	-	0.0	0.0	42	103	158	202	253	308
Wind	-	-	0.1	17	58	76	89	105	122
Concentrated solar power and marine	-	-	-	-	0.0	0.0	0.0	0.0	0.0
Biomass and waste	0.6	1.1	6.4	56	60	67	74	81	87
Hydrogen	-	-	-	-	0.0	12	24	32	41
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	334	649	1 006	1 716	2 098	2 323	2 578	2 837	3 080
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	739	1 180	1 975	3 377	4 537	5 645	6 955	8 443	10 075
Population (million)	439	526	603	689	721	740	756	767	773
GDP per capita ($2015 thousand)	1.7	2.2	3.3	4.9	6.3	7.6	9.2	11	13
Primary energy consumption per capita (toe/person)	0.5	0.7	0.8	1.1	1.3	1.5	1.6	1.8	2.0
Primary energy consumption per GDP (toe/$2015 million)	294	301	256	224	203	193	177	162	150
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	452	550	510	508	462	412	371	336	306
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	1.5	1.8	2.0	2.3	2.3	2.1	2.1	2.1	2.0

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
3.9	2.9	2.1	2.6	100	100	100	100	875	1 013	1 101	1 183	1 271	2.2	1.4	1.9	100	100
9.1	1.9	0.8	1.5	5.7	29	24	21	239	216	205	195	178	-0.4	-1.4	-0.8	19	14
3.0	1.5	1.2	1.4	40	31	25	23	243	237	233	222	207	-0.1	-1.2	-0.5	21	16
4.9	4.7	4.4	4.6	14	19	26	33	191	220	261	309	370	3.4	3.6	3.5	24	29
n.a.	n.a.	8.9	n.a.	-	-	0.6	1.2	-	37	54	67	83	n.a.	4.5	n.a.	4.9	6.5
6.3	2.0	1.3	1.7	1.1	2.4	2.0	1.9	23	26	29	32	35	2.9	1.7	2.5	2.7	2.7
5.5	7.4	0.9	5.0	3.1	5.1	11	9.4	54	127	156	180	205	8.6	2.7	6.4	14	16
n.a.	9.6	3.9	7.5	-	0.7	2.1	2.5	19	32	45	65	88	13.4	6.9	10.9	4.1	6.9
0.6	1.0	0.8	0.9	36	12	9.1	8.0	104	111	112	113	113	1.0	0.1	0.7	10	8.9
n.a.	n.a.	-0.8	n.a.	-	-	0.1	0.1	2.7	6.1	5.3	0.2	-7.6	n.a.	n.a.	n.a.	0.5	-0.6

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
3.6	2.2	1.7	2.0	100	100	100	100	542	574	595	611	626	1.3	0.5	1.0	100	100
6.6	2.0	0.5	1.4	3.6	9.4	9.0	7.9	51	50	47	44	42	0.3	-1.1	-0.3	7.9	6.7
3.6	1.6	1.3	1.5	45	45	41	39	223	223	220	212	201	0.1	-0.9	-0.3	37	32
5.7	2.7	1.5	2.2	5.0	9.8	11	10	54	57	57	56	54	1.1	-0.5	0.5	9.6	8.7
7.1	3.8	3.1	3.5	7.5	22	29	33	145	173	201	232	265	3.8	2.8	3.4	34	42
n.a.	n.a.	5.0	n.a.	-	-	0.0	0.0	0.0	0.0	0.1	0.1	0.1	n.a.	4.3	n.a.	0.0	0.0
n.a.	n.a.	2.7	n.a.	-	-	0.0	0.0	0.0	0.0	0.1	0.2	0.3	n.a.	14.0	n.a.	0.0	0.0
0.2	1.0	0.6	0.8	39	13	11	9.5	69	72	70	67	64	0.6	-0.9	0.1	12	10
4.3	3.0	1.8	2.5	28	35	40	40	206	221	228	231	236	1.8	0.4	1.3	38	38
4.7	1.8	1.6	1.7	22	31	29	29	162	167	168	166	163	0.7	-0.3	0.4	28	26
1.7	1.6	1.9	1.7	43	24	22	22	121	127	134	142	149	1.0	1.1	1.0	23	24
4.5	1.9	1.8	1.9	7.4	9.9	9.4	9.4	53	59	65	71	77	1.9	1.8	1.9	11	12

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
6.8	3.9	3.2	3.6	100	100	100	100	1 854	2 291	2 740	3 312	3 971	4.2	3.8	4.0	100	100
10.0	1.9	1.0	1.5	18	47	33	27	682	593	556	518	456	-0.8	-2.0	-1.2	20	11
-3.7	-4.1	-9.6	-6.2	43	1.4	0.4	0.1	13	10	8.9	6.9	3.8	-4.4	-8.2	-5.8	0.3	0.1
8.3	5.7	5.2	5.5	17	26	36	43	568	695	888	1 143	1 464	5.4	5.1	5.3	32	37
n.a.	n.a.	8.9	n.a.	-	-	1.2	2.0	-	142	206	258	318	n.a.	4.5	n.a.	7.5	8.0
6.3	2.0	1.3	1.7	18	15	11	9.3	267	305	339	372	403	2.9	1.7	2.5	12	10
4.4	6.7	0.9	4.5	4.3	2.0	3.2	2.5	38	83	100	115	129	7.9	2.5	5.9	3.7	3.2
n.a.	9.7	4.3	7.7	-	3.1	7.8	8.7	155	266	382	539	719	13.9	6.5	11.1	14	18
n.a.	10.3	3.2	7.6	-	1.2	3.4	3.4	64	102	138	208	294	13.1	7.9	11.2	5.0	7.4
n.a.	n.a.	0.0	n.a.	-	-	0.0	0.0	0.1	0.2	0.3	0.4	0.7	n.a.	9.6	n.a.	0.0	0.0
14.7	1.7	1.6	1.7	0.4	4.1	2.8	2.5	68	78	88	99	109	2.7	2.1	2.5	3.2	2.7
n.a.	n.a.	5.5	n.a.	-	-	0.9	1.1	0.0	16	33	53	74	n.a.	8.5	n.a.	1.2	1.9
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
5.1	2.4	1.8	2.2	1 920	1 775	1 694	1 594	1 474	-0.1	-1.4	-0.6
n.a.	n.a.	n.a.	n.a.	-	-	10	22	35	n.a.	13.2	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
4.7	4.3	3.8	4.1	4 537	5 645	6 955	8 443	10 075	4.3	3.8	4.1
1.4	0.5	0.2	0.4	721	740	756	767	773	0.5	0.2	0.4
3.3	3.8	3.5	3.7	6.3	7.6	9.2	11	13	3.8	3.5	3.7
2.5	2.3	1.9	2.2	1.2	1.4	1.5	1.5	1.6	1.7	1.2	1.5
-0.8	-1.4	-1.6	-1.5	193	179	158	140	126	-2.0	-2.2	-2.1
0.4	-1.8	-1.9	-1.9	423	315	244	189	146	-4.2	-5.0	-4.5
1.2	-0.5	-0.3	-0.4	2.2	1.8	1.5	1.3	1.2	-2.3	-2.8	-2.4

Table A31 | Indonesia

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	85	127	166	276	360	470	542	615	695
Coal	3.5	12	25	98	119	124	132	137	136
Oil	33	58	67	73	79	86	93	99	103
Natural gas	16	27	39	43	77	106	147	199	264
Nuclear	-	-	-	-	-	-	-	-	-
Hydro	0.5	0.9	1.5	2.1	2.9	3.2	3.6	4.0	4.3
Geothermal	1.9	8.4	16	29	42	105	117	122	128
Solar, wind, etc.	-	-	-	0.4	2.2	4.3	5.6	7.5	9.5
Biomass and waste	30	21	17	31	39	42	45	47	49
Hydrogen	-	-	-	-	-0.0	-0.0	-	-	-

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	57	91	106	161	196	223	250	277	303
Coal	1.5	4.6	5.9	17	22	24	26	27	27
Oil	27	48	55	68	73	80	87	93	98
Natural gas	6.0	12	16	20	26	30	34	37	40
Electricity	2.4	6.8	13	35	48	60	73	88	105
Heat	-	-	-	-	-	-	-	-	-
Hydrogen	-	-	-	-	-	-	-	-	-
Renewables and waste	20	20	16	20	27	29	30	32	33
Industry	17	30	38	65	84	99	112	125	137
Transport	11	21	30	58	67	73	78	84	90
Buildings, etc.	22	30	27	33	38	44	50	57	65
Non-energy use	7.4	9.8	10	5.3	6.6	7.6	8.8	10	11

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	33	93	177	433	599	753	921	1 121	1 348
Coal	9.8	34	76	300	345	357	383	401	403
Oil	15	18	34	8.6	8.5	7.4	6.1	3.7	-
Natural gas	0.7	26	40	56	133	205	313	460	651
Nuclear	-	-	-	-	-	-	-	-	-
Hydro	5.7	10	17	25	33	37	42	46	50
Geothermal	1.1	4.9	9.4	17	25	61	68	71	75
Solar photovoltaics	-	-	0.0	0.7	17	37	49	67	86
Wind	-	-	0.0	0.5	4.8	8.7	11	16	21
Concentrated solar power and marine	-	-	-	-	-	-	-	-	-
Biomass and waste	-	0.0	0.1	27	32	35	38	41	43
Hydrogen	-	-	-	-	-	5.0	10.0	15	20
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	125	239	346	672	858	949	1 071	1 194	1 312
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	270	395	658	1 179	1 649	2 085	2 606	3 221	3 929
Population (million)	184	216	246	281	296	305	312	317	321
GDP per capita ($2015 thousand)	1.5	1.8	2.7	4.2	5.6	6.8	8.4	10	12
Primary energy consumption per capita (toe/person)	0.5	0.6	0.7	1.0	1.2	1.5	1.7	1.9	2.2
Primary energy consumption per GDP (toe/$2015 million)	314	320	253	234	218	225	208	191	177
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	462	606	526	570	520	455	411	371	334
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	1.5	1.9	2.1	2.4	2.4	2.0	2.0	1.9	1.9

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
3.6	4.0	2.5	3.5	100	100	100	100	345	444	503	557	613	3.6	2.0	3.0	100	100
10.6	1.8	0.3	1.2	4.2	36	24	20	111	100	97	90	76	-0.1	-2.4	-0.9	19	12
2.4	1.4	1.1	1.3	39	26	17	15	71	68	66	61	55	-0.6	-1.8	-1.1	13	8.9
3.1	7.5	6.1	6.9	19	16	27	38	70	88	118	155	201	6.1	5.5	5.9	24	33
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	15	15	15	15	n.a.	0.0	n.a.	2.9	2.4
4.5	3.2	1.9	2.7	0.6	0.8	0.7	0.6	3.0	3.5	4.0	4.4	4.9	3.8	2.2	3.2	0.8	0.8
8.6	8.5	1.0	5.6	2.3	11	22	18	42	111	140	164	187	9.7	3.0	7.1	28	31
n.a.	17.0	5.5	12.6	-	0.1	1.0	1.4	3.9	8.6	13	20	29	23.1	8.2	17.3	2.6	4.7
0.1	2.3	0.9	1.8	35	11	8.2	7.0	45	50	51	51	50	3.1	-0.1	1.9	10	8.2
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-0.1	-0.4	-0.5	-2.5	-5.5	n.a.	26.1	n.a.	-0.1	-0.9

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
3.2	2.6	1.9	2.4	100	100	100	100	190	206	217	224	231	1.8	0.7	1.4	100	100
7.7	2.4	0.5	1.7	2.6	11	10	8.9	20	19	18	16	15	0.1	-1.6	-0.5	8.2	6.5
2.8	1.5	1.2	1.4	48	42	35	32	66	65	62	59	54	-0.5	-1.5	-0.8	29	23
3.7	3.1	1.5	2.5	11	13	14	13	24	26	26	25	25	1.5	-0.6	0.7	12	11
8.5	4.3	3.7	4.1	4.3	22	29	35	50	63	77	92	108	4.7	3.4	4.2	36	47
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	0.0	0.0	0.0	n.a.	0.0	n.a.	0.0	0.0
0.1	2.4	0.9	1.8	35	13	12	11	30	33	33	32	30	2.9	-1.1	1.4	15	13
4.1	3.3	2.0	2.8	31	40	45	45	82	90	96	99	102	2.3	0.7	1.7	44	44
5.2	1.8	1.4	1.6	19	36	31	30	64	66	65	63	61	0.7	-0.6	0.2	30	27
1.3	2.5	2.6	2.6	38	20	20	21	38	42	47	52	56	2.1	1.9	2.0	22	24
-1.0	3.0	2.6	2.9	13	3.3	3.5	3.8	6.6	7.6	8.8	10	11	3.0	2.6	2.9	4.1	4.9

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
8.1	4.5	3.9	4.3	100	100	100	100	628	823	1 031	1 291	1 586	5.2	4.4	4.9	100	100
10.9	1.5	0.5	1.1	30	69	42	30	326	285	278	255	203	-0.4	-3.1	-1.4	27	13
-1.7	-2.0	-100	-100	47	2.0	0.7	-	8.5	6.6	5.4	3.2	-	-2.7	-100	-100	0.5	-
14.0	10.7	7.6	9.5	2.2	13	34	48	153	223	352	521	739	11.4	7.7	10.0	34	47
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	56	56	56	56	n.a.	0.0	n.a.	5.5	3.5
4.5	3.2	1.9	2.7	17	5.7	4.5	3.7	35	41	46	52	57	3.8	2.2	3.2	4.5	3.6
8.6	8.5	1.0	5.6	3.4	3.9	7.4	5.5	25	65	81	95	109	9.7	3.0	7.1	7.9	6.9
n.a.	28.3	5.7	19.4	-	0.2	5.4	6.4	35	71	106	147	192	34.2	6.1	23.0	10	12
n.a.	20.2	6.7	15.0	-	0.1	1.2	1.6	6.3	25	41	84	138	29.9	12.8	23.3	4.0	8.7
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	2.2	1.2	1.8	-	6.1	4.2	3.2	39	44	49	54	59	3.7	1.8	3.0	4.8	3.7
n.a.	n.a.	7.1	n.a.	-	-	1.1	1.5	-	7.3	15	24	33	n.a.	8.6	n.a.	1.4	2.1
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
5.2	2.8	2.0	2.5	790	734	715	674	615	0.4	-1.5	-0.3
n.a.	n.a.	n.a.	n.a.	-	-	10	22	34	n.a.	13.2	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
4.6	4.8	4.2	4.6	1 649	2 085	2 606	3 221	3 929	4.8	4.2	4.6
1.3	0.6	0.3	0.5	296	305	312	317	321	0.6	0.3	0.5
3.2	4.1	3.9	4.0	5.6	6.8	8.4	10	12	4.1	3.9	4.0
2.3	3.4	2.2	3.0	1.2	1.5	1.6	1.8	1.9	3.0	1.7	2.5
-0.9	-0.7	-1.6	-1.0	209	213	193	173	156	-1.1	-2.1	-1.5
0.6	-1.9	-2.1	-2.0	479	352	275	209	157	-4.2	-5.5	-4.7
1.5	-1.2	-0.5	-0.9	2.3	1.7	1.4	1.2	1.0	-3.1	-3.4	-3.2

Table A32 | Malaysia

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	21	48	73	106	118	128	138	147	155
Coal	1.4	2.3	15	24	26	26	24	22	19
Oil	11	19	25	33	33	33	34	33	32
Natural gas	6.8	25	31	44	52	61	69	79	89
Nuclear	-	-	-	-	-	-	1.8	3.7	3.7
Hydro	0.3	0.6	0.6	2.7	3.2	3.7	4.1	4.5	4.8
Geothermal	-	-	-	-	-	-	-	-	-
Solar, wind, etc.	-	-	-	0.3	0.5	0.9	1.3	1.8	2.4
Biomass and waste	1.2	1.3	0.9	1.7	2.8	3.5	3.5	3.4	3.3
Hydrogen	-	-	-	-	-0.0	0.0	0.1	-	-0.1

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	13	29	42	61	70	76	81	87	91
Coal	0.5	1.0	1.8	0.8	1.2	1.2	1.2	1.1	1.1
Oil	9.3	18	24	28	28	28	28	28	27
Natural gas	1.1	3.9	6.3	15	18	21	23	24	26
Electricity	1.7	5.3	9.5	16	20	23	27	31	35
Heat	-	-	-	-	-	-	-	-	-
Hydrogen	-	-	-	-	-	-	-	-	-
Renewables and waste	0.8	0.7	0.2	1.3	2.4	3.0	3.0	2.9	2.7
Industry	5.5	12	15	19	25	29	33	37	40
Transport	4.9	11	15	23	23	23	23	22	21
Buildings, etc.	2.1	4.3	8.2	11	13	14	15	16	17
Non-energy use	0.8	2.3	3.7	8.2	9.4	10	11	12	12

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	23	69	125	193	247	294	342	394	448
Coal	2.9	7.7	43	87	104	105	101	94	84
Oil	11	3.6	3.7	2.1	2.4	2.5	2.6	2.6	2.6
Natural gas	5.5	51	71	67	97	130	164	206	259
Nuclear	-	-	-	-	-	-	7.0	14	14
Hydro	4.0	7.0	6.5	32	38	43	48	52	56
Geothermal	-	-	-	-	-	-	-	-	-
Solar photovoltaics	-	-	-	3.4	5.4	11	15	21	27
Wind	-	-	-	-	-	-	-	-	-
Concentrated solar power and marine	-	-	-	-	-	-	-	-	-
Biomass and waste	-	-	1.0	1.3	1.3	1.4	1.5	1.6	1.7
Hydrogen	-	-	-	-	-	1.3	2.5	2.9	3.2
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	48	102	177	240	264	279	289	296	301
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	75	148	233	401	533	646	775	920	1 076
Population (million)	18	23	29	35	38	40	42	43	44
GDP per capita ($2015 thousand)	4.2	6.5	8.1	11	14	16	19	21	24
Primary energy consumption per capita (toe/person)	1.2	2.1	2.5	3.0	3.1	3.2	3.3	3.4	3.5
Primary energy consumption per GDP (toe/$2015 million)	284	326	312	263	221	198	178	160	144
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	637	687	761	598	496	431	373	322	279
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.2	2.1	2.4	2.3	2.2	2.2	2.1	2.0	1.9

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
5.0	1.6	1.2	1.4	100	100	100	100	111	117	120	122	124	0.8	0.3	0.6	100	100
9.0	0.2	-2.3	-0.7	6.4	22	18	13	24	22	18	13	8.2	-1.6	-7.5	-3.8	15	6.6
3.3	0.0	-0.4	-0.1	54	32	24	21	32	29	25	21	18	-1.6	-3.5	-2.3	21	14
5.8	2.7	2.6	2.6	32	42	50	58	48	56	62	68	75	2.0	1.8	2.0	52	60
n.a.	n.a.	7.1	n.a.	-	-	1.3	2.4	-	-	3.8	6.3	8.9	n.a.	8.9	n.a.	3.1	7.2
6.5	2.4	1.6	2.1	1.6	2.6	3.0	3.1	3.6	4.2	4.8	5.3	5.8	3.4	1.9	2.8	4.0	4.7
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	9.1	6.1	8.0	-	0.3	0.9	1.5	0.6	1.8	3.1	5.6	9.0	14.9	11.1	13.5	2.6	7.2
1.0	4.2	-0.7	2.4	5.8	1.6	2.5	2.1	2.9	3.3	3.6	3.8	3.9	4.5	0.8	3.1	3.0	3.2
n.a.	n.a.	n.a.	n.a.	-	-	0.1	-0.1	-0.0	-0.2	-0.5	-1.9	-3.9	n.a.	21.8	n.a.	-0.5	-3.1

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
4.7	1.7	1.1	1.5	100	100	100	100	68	69	68	66	65	0.6	-0.4	0.2	100	100
1.4	2.1	-0.4	1.2	3.8	1.3	1.4	1.2	1.1	0.9	0.8	0.7	0.7	0.1	-2.0	-0.7	1.2	1.0
3.4	0.0	-0.5	-0.2	70	46	34	29	27	24	21	17	14	-1.7	-3.7	-2.5	31	22
8.3	2.3	1.3	1.9	8.2	25	28	28	17	18	17	16	16	0.7	-0.9	0.1	25	24
6.9	3.2	2.6	3.0	13	26	33	38	20	23	26	29	31	3.1	1.8	2.6	39	48
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
1.7	5.1	-0.9	2.8	5.6	2.1	3.7	3.0	2.5	2.8	3.0	3.1	3.1	5.1	0.3	3.3	4.4	4.8
3.8	3.2	1.9	2.8	41	31	41	44	24	25	25	25	24	1.6	-0.3	0.9	37	37
4.8	0.0	-0.6	-0.3	36	37	28	23	22	20	18	16	14	-1.3	-2.7	-1.8	27	21
5.1	1.8	1.4	1.7	16	18	18	19	12	13	14	14	14	1.3	0.5	1.0	20	22
7.2	1.7	1.3	1.5	6.3	13	13	14	9.4	10	11	12	12	1.7	1.3	1.5	16	19

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
6.7	3.4	2.8	3.2	100	100	100	100	252	307	360	426	502	3.7	3.4	3.6	100	100
10.8	0.9	-1.8	-0.1	13	45	29	19	95	86	70	53	32	-1.2	-7.6	-3.6	20	6.4
-4.8	1.3	0.1	0.9	46	1.1	0.8	0.6	2.4	2.4	2.3	2.2	2.1	0.7	-1.1	0.0	0.6	0.4
7.9	5.4	4.7	5.1	24	35	48	58	105	144	174	212	254	5.7	3.8	5.0	48	51
n.a.	n.a.	7.1	n.a.	-	-	2.1	3.1	-	-	15	24	34	n.a.	8.9	n.a.	4.0	6.8
6.5	2.4	1.6	2.1	17	17	14	13	42	49	56	62	67	3.4	1.9	2.8	16	13
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	9.2	6.1	8.0	-	1.8	4.4	6.1	7.2	21	36	66	104	14.9	11.1	13.5	10	21
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	0.9	1.2	1.0	-	0.7	0.4	0.4	1.3	1.7	2.1	2.5	2.9	2.8	3.3	3.0	0.6	0.6
n.a.	n.a.	2.5	n.a.	-	-	0.7	0.7	-	2.0	4.0	4.7	5.3	n.a.	2.9	n.a.	1.1	1.1
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
5.0	1.1	0.4	0.8	246	231	203	175	148	-1.0	-3.1	-1.8
n.a.	n.a.	n.a.	n.a.	-	-	0.2	0.6	1.0	n.a.	14.8	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
5.2	3.9	3.3	3.7	533	646	775	920	1 076	3.9	3.3	3.7
2.1	1.0	0.7	0.9	38	40	42	43	44	1.0	0.7	0.9
3.1	2.9	2.7	2.8	14	16	19	21	24	2.9	2.7	2.8
2.9	0.6	0.5	0.6	2.9	2.9	2.9	2.8	2.8	-0.2	-0.3	-0.3
-0.2	-2.3	-2.1	-2.2	209	180	155	133	115	-3.1	-2.9	-3.0
-0.2	-2.7	-2.8	-2.8	461	357	262	190	138	-4.7	-6.2	-5.3
0.0	-0.5	-0.8	-0.6	2.2	2.0	1.7	1.4	1.2	-1.7	-3.4	-2.4

Table A33 | Myanmar

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	11	14	14	22	23	25	28	32	36
Coal	0.1	0.3	0.4	0.9	1.1	1.3	1.5	1.7	2.0
Oil	0.7	2.0	1.3	6.2	6.5	7.8	9.7	12	14
Natural gas	0.8	1.2	1.3	3.2	4.4	5.7	7.0	8.7	11
Nuclear	-	-	-	-	-	-	-	-	-
Hydro	0.1	0.2	0.5	0.8	1.2	1.4	1.5	1.7	1.8
Geothermal	-	-	-	-	0.0	0.0	0.0	0.1	0.1
Solar, wind, etc.	-	-	-	0.0	0.1	0.1	0.3	0.4	0.6
Biomass and waste	9.1	10.0	11	11	9.7	8.7	8.0	7.5	7.0
Hydrogen	-	-	-	-	-	-0.0	-0.1	-0.1	-0.2

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	9.5	12	13	20	20	21	23	25	28
Coal	0.1	0.3	0.2	0.7	0.6	0.7	0.7	0.7	0.8
Oil	0.6	1.5	1.0	5.9	6.2	7.5	9.2	11	13
Natural gas	0.2	0.3	0.6	0.4	0.4	0.4	0.5	0.5	0.6
Electricity	0.1	0.3	0.6	1.8	2.7	3.4	4.2	5.0	6.0
Heat	-	-	-	-	0.0	0.0	0.0	0.1	0.1
Hydrogen	-	-	-	-	0.0	0.0	0.0	0.0	0.0
Renewables and waste	8.5	9.7	11	11	9.6	8.6	7.9	7.4	6.9
Industry	0.5	1.9	2.0	2.0	2.2	2.5	2.8	3.0	3.2
Transport	0.4	1.2	0.8	4.7	5.2	6.5	8.2	10	12
Buildings, etc.	8.5	9.1	10	13	12	11	11	12	12
Non-energy use	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	2.5	5.2	8.8	21	33	42	52	64	79
Coal	0.0	-	0.6	1.1	2.0	2.9	4.0	5.3	7.2
Oil	0.3	0.7	0.0	0.1	0.2	0.2	0.3	0.3	0.3
Natural gas	1.0	2.5	1.8	10	16	22	28	35	44
Nuclear	-	-	-	-	-	-	-	-	-
Hydro	1.2	1.9	6.2	9.3	14	16	18	20	21
Geothermal	-	-	-	-	-	-	-	-	-
Solar photovoltaics	-	-	-	0.2	0.6	1.2	2.5	3.9	5.6
Wind	-	-	-	-	-	-	-	-	-
Concentrated solar power and marine	-	-	-	-	-	-	-	-	-
Biomass and waste	-	0.1	0.2	0.3	0.0	0.0	0.0	0.0	0.0
Hydrogen	-	-	-	-	-	-	-	-	-
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	4.0	9.3	7.6	28	32	39	49	60	73
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	7.1	14	44	67	74	90	113	140	172
Population (million)	40	45	49	54	56	57	58	59	59
GDP per capita ($2015 thousand)	0.2	0.3	0.9	1.2	1.3	1.6	1.9	2.4	2.9
Primary energy consumption per capita (toe/person)	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6
Primary energy consumption per GDP (toe/$2015 million)	1 514	960	329	333	312	277	247	227	210
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	567	653	172	415	433	436	432	429	421
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	0.4	0.7	0.5	1.2	1.4	1.6	1.7	1.9	2.0

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
2.2	1.3	2.6	1.8	100	100	100	100	21	21	22	25	27	0.0	1.9	0.7	100	100
8.4	2.6	3.1	2.8	0.6	4.3	5.2	5.5	0.8	0.7	0.8	0.8	0.8	-1.2	0.9	-0.4	3.5	3.1
6.7	2.7	3.8	3.1	6.8	28	35	39	6.1	6.9	7.8	8.8	9.7	1.4	2.2	1.7	35	36
4.5	4.7	4.5	4.6	7.1	14	25	30	4.4	5.6	6.7	8.1	9.7	4.4	3.8	4.2	30	36
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
6.4	3.9	1.8	3.1	1.0	3.6	5.5	5.1	1.4	1.6	1.9	2.1	2.3	5.1	2.3	4.1	8.4	8.7
n.a.	n.a.	5.4	n.a.	-	-	0.2	0.2	0.0	0.0	0.0	0.0	0.0	n.a.	3.1	n.a.	0.1	0.1
n.a.	18.8	7.9	14.6	-	0.1	0.9	1.5	0.1	0.4	0.9	2.0	3.2	28.1	13.0	22.3	4.2	12
0.6	-1.9	-1.3	-1.7	85	50	29	19	8.4	6.0	4.8	4.1	3.4	-4.8	-3.4	-4.3	21	13
n.a.	n.a.	11.8	n.a.	-	-	-0.2	-0.5	-0.0	-0.2	-0.6	-1.3	-2.2	n.a.	14.1	n.a.	-2.6	-8.2

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
2.2	0.9	2.1	1.3	100	100	100	100	18	17	17	19	20	-0.7	1.3	0.1	100	100
8.1	0.4	0.4	0.4	0.5	3.4	3.2	2.7	0.4	0.3	0.3	0.3	0.3	-5.1	-0.7	-3.5	1.6	1.3
7.3	2.6	3.8	3.1	6.2	30	41	48	5.9	6.6	7.6	8.6	9.4	1.5	2.2	1.7	43	47
1.6	1.6	1.8	1.7	2.4	1.9	2.2	2.1	0.3	0.3	0.3	0.4	0.4	-0.5	0.4	-0.2	2.0	1.8
7.9	5.0	3.8	4.6	1.6	9.3	18	22	2.9	3.8	4.6	5.5	6.6	5.6	3.7	4.9	26	33
n.a.	n.a.	5.4	n.a.	-	-	0.2	0.3	0.0	0.0	0.0	0.0	0.0	n.a.	3.1	n.a.	0.2	0.2
n.a.	n.a.	5.5	n.a.	-	-	0.1	0.2	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
0.7	-1.8	-1.3	-1.6	89	55	35	25	8.2	5.8	4.6	4.0	3.3	-4.8	-3.5	-4.3	27	16
4.5	1.9	1.6	1.8	4.9	10	12	12	1.8	1.8	1.9	2.0	2.1	-0.4	0.9	0.1	11	10
7.4	3.3	4.1	3.6	4.7	24	36	44	5.0	5.9	7.1	8.3	9.5	2.4	3.0	2.6	40	48
1.2	-0.6	0.6	-0.2	89	64	50	43	11	8.9	8.2	8.1	8.1	-2.5	-0.2	-1.6	47	40
2.9	1.0	1.8	1.3	1.0	1.2	1.3	1.2	0.2	0.3	0.3	0.3	0.3	1.0	1.8	1.3	1.6	1.7

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
6.7	5.5	4.2	5.0	100	100	100	100	35	50	67	90	120	7.0	6.0	6.7	100	100
10.6	7.7	6.1	7.1	1.6	5.3	7.6	9.1	1.7	2.3	2.7	3.1	3.5	5.3	2.7	4.3	4.0	2.9
-2.3	4.5	2.6	3.8	11	0.6	0.5	0.4	0.2	0.2	0.3	0.3	0.4	4.9	2.7	4.1	0.4	0.3
7.3	6.2	4.8	5.7	39	48	53	56	16	24	31	40	52	6.9	5.2	6.3	47	43
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
6.4	3.9	1.8	3.1	48	44	34	27	16	19	22	25	27	5.1	2.3	4.1	33	23
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	17.6	8.4	14.1	-	0.8	4.8	7.1	1.0	4.6	11	22	37	28.0	13.2	22.3	16	31
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	-16.3	0.0	-10.6	-	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-16.3	0.0	-10.6	0.0	0.0
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
6.0	3.4	4.1	3.6	30	35	41	47	54	2.3	2.8	2.5
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
7.0	3.1	4.3	3.6	74	90	113	140	172	3.1	4.3	3.6
0.9	0.4	0.1	0.3	56	57	58	59	59	0.4	0.1	0.3
6.0	2.7	4.2	3.3	1.3	1.6	1.9	2.4	2.9	2.7	4.2	3.3
1.3	0.9	2.5	1.5	0.4	0.4	0.4	0.4	0.5	-0.4	1.8	0.4
-4.5	-1.7	-1.6	-1.7	286	233	198	176	157	-3.0	-2.3	-2.7
-0.9	0.2	-0.3	0.1	404	387	360	336	311	-0.8	-1.5	-1.1
3.7	2.0	1.4	1.8	1.4	1.7	1.8	1.9	2.0	2.2	0.9	1.7

Table A34 | Philippines

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	27	39	42	67	85	100	115	127	137
Coal	1.3	4.6	7.0	23	29	35	37	38	38
Oil	9.9	16	14	20	27	33	39	45	50
Natural gas	-	0.0	3.1	2.6	4.6	7.0	11	16	21
Nuclear	-	-	-	-	-	-	-	-	-
Hydro	0.5	0.7	0.7	0.9	1.3	1.5	1.8	2.1	2.5
Geothermal	4.7	10	8.5	9.2	12	12	13	13	13
Solar, wind, etc.	-	-	0.0	0.3	1.7	2.3	2.6	3.1	3.6
Biomass and waste	10	7.6	8.7	11	10.0	9.7	9.5	9.2	9.0
Hydrogen	-	-	-	-	-0.0	0.1	0.3	0.3	0.3

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	19	23	25	37	48	58	67	76	83
Coal	0.7	0.8	1.9	2.0	3.2	3.5	3.7	3.8	3.6
Oil	8.1	13	11	19	26	32	38	44	48
Natural gas	-	-	0.1	-	0.0	0.1	0.1	0.1	0.2
Electricity	1.8	3.1	4.8	8.2	13	16	19	22	25
Heat	-	-	-	-	-	-	-	-	-
Hydrogen	-	-	-	-	-	-	-	-	-
Renewables and waste	8.4	6.4	6.9	7.9	6.7	6.4	6.1	5.9	5.6
Industry	4.1	4.6	5.9	7.0	11	14	16	18	19
Transport	4.5	8.3	8.0	13	18	22	27	32	35
Buildings, etc.	10.0	9.9	11	16	17	19	21	23	25
Non-energy use	0.4	0.4	0.2	1.4	2.0	2.5	3.0	3.7	4.3

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	26	45	68	118	180	226	269	314	355
Coal	1.9	17	23	74	100	122	134	140	139
Oil	12	9.2	7.1	1.3	1.0	0.5	-	-	-
Natural gas	-	0.0	20	17	29	43	66	93	124
Nuclear	-	-	-	-	-	-	-	-	-
Hydro	6.1	7.8	7.8	10	15	18	20	24	29
Geothermal	5.5	12	9.9	11	14	14	15	15	15
Solar photovoltaics	-	-	0.0	2.6	14	19	22	26	31
Wind	-	-	0.1	1.3	5.9	7.7	8.8	10	12
Concentrated solar power and marine	-	-	-	-	-	-	-	-	-
Biomass and waste	0.4	-	0.0	1.4	0.8	0.9	1.1	1.2	1.2
Hydrogen	-	-	-	-	-	1.3	2.7	3.3	4.0
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	35	65	75	153	204	248	286	317	339
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	107	143	229	430	646	853	1 087	1 324	1 535
Population (million)	63	80	96	115	121	126	130	132	134
GDP per capita ($2015 thousand)	1.7	1.8	2.4	3.7	5.3	6.8	8.4	10.0	11
Primary energy consumption per capita (toe/person)	0.4	0.5	0.4	0.6	0.7	0.8	0.9	1.0	1.0
Primary energy consumption per GDP (toe/$2015 million)	251	272	182	155	132	118	106	96	90
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	329	452	327	355	316	291	263	240	221
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	1.3	1.7	1.8	2.3	2.4	2.5	2.5	2.5	2.5

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
2.8	3.2	1.8	2.7	100	100	100	100	82	97	105	112	117	2.7	1.0	2.1	100	100
9.1	3.0	0.1	1.9	4.7	34	33	28	26	26	26	26	25	0.8	-0.2	0.4	25	22
2.1	4.2	2.4	3.5	37	30	34	36	25	29	31	31	28	2.8	-1.2	1.3	30	24
n.a.	9.0	6.7	8.1	-	3.8	9.6	15	4.0	5.3	8.1	13	17	7.0	7.6	7.2	7.6	14
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	4.4	6.6	6.6	8.8	n.a.	2.9	n.a.	6.3	7.5
1.6	4.1	3.4	3.9	1.9	1.3	1.5	1.8	1.4	1.6	1.9	2.2	2.7	4.5	3.7	4.2	1.8	2.3
2.1	1.9	0.4	1.4	18	14	11	9.6	12	16	16	17	17	3.4	0.5	2.3	16	15
n.a.	12.9	3.3	9.3	-	0.5	2.3	2.6	2.8	4.2	5.3	6.9	8.6	17.7	4.9	12.8	5.1	7.4
0.3	-1.1	-0.5	-0.9	39	17	8.2	6.6	10	9.9	9.5	9.1	8.8	-1.1	-0.8	-1.0	9.0	7.5
n.a.	n.a.	1.1	n.a.	-	-	0.3	0.2	-	0.1	0.3	0.5	0.6	n.a.	5.1	n.a.	0.3	0.5

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
2.0	3.6	2.2	3.1	100	100	100	100	47	54	59	62	63	2.8	0.6	2.0	100	100
3.2	3.8	-0.3	2.2	3.7	5.4	5.5	4.3	3.1	3.1	2.9	2.7	2.4	2.3	-2.0	0.7	5.0	3.8
2.6	4.3	2.4	3.5	43	51	57	58	25	29	31	31	28	3.0	-1.0	1.5	52	44
n.a.	n.a.	6.2	n.a.	-	-	0.1	0.2	0.0	0.0	0.1	0.1	0.1	n.a.	2.7	n.a.	0.1	0.1
4.7	5.1	2.9	4.3	9.6	22	28	31	13	16	19	23	27	5.1	3.5	4.5	33	43
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
-0.2	-1.5	-0.8	-1.2	44	21	9.1	6.8	6.7	6.5	6.1	5.6	5.3	-1.5	-1.3	-1.4	10	8.4
1.6	5.1	1.6	3.8	22	19	24	23	11	13	14	14	14	4.1	0.3	2.7	23	22
3.2	4.5	2.7	3.8	24	35	40	42	17	21	24	25	24	3.7	0.3	2.4	40	39
1.4	1.7	1.6	1.7	52	42	31	30	17	18	19	20	20	1.1	0.8	1.0	32	32
3.9	4.6	3.5	4.2	2.1	3.8	4.5	5.1	2.0	2.5	3.0	3.7	4.3	4.6	3.5	4.2	5.1	6.8

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
4.7	5.0	2.8	4.2	100	100	100	100	183	234	285	350	419	5.3	3.9	4.8	100	100
11.7	3.6	0.4	2.4	7.3	62	50	39	92	91	94	99	101	1.5	0.6	1.2	33	24
-6.6	-100	n.a.	-100	47	1.1	-	-	0.9	0.4	-	-	-	-100	n.a.	-100	-	-
n.a.	8.4	6.6	7.7	-	14	24	35	27	36	56	89	118	7.4	7.7	7.5	20	28
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	17	25	25	34	n.a.	2.9	n.a.	8.9	8.0
1.6	4.1	3.4	3.9	23	8.7	7.6	8.1	16	18	22	26	31	4.5	3.7	4.2	7.6	7.4
2.1	1.9	0.4	1.4	21	9.1	5.5	4.3	14	19	19	20	20	3.5	0.5	2.3	6.7	4.8
n.a.	13.4	3.5	9.6	-	2.2	8.1	8.6	26	40	52	67	84	19.4	4.9	13.8	18	20
n.a.	11.9	2.9	8.5	-	1.1	3.3	3.3	6.0	8.2	9.8	13	16	12.6	5.0	9.7	3.5	3.8
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
3.7	-1.6	1.3	-0.5	1.6	1.2	0.4	0.3	0.9	1.1	1.3	1.4	1.4	-0.4	0.8	0.1	0.5	0.3
n.a.	n.a.	4.0	n.a.	-	-	1.0	1.1	-	2.4	4.8	9.5	14	n.a.	11.4	n.a.	1.7	3.4
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
4.5	3.7	1.7	3.0	187	186	186	182	168	1.2	-1.0	0.3	
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
4.3	5.6	3.5	4.8	646	853	1 087	1 324	1 535	5.6	3.5	4.8
1.8	0.7	0.4	0.6	121	126	130	132	134	0.7	0.4	0.6
2.4	4.9	3.1	4.2	5.3	6.8	8.4	10.0	11	4.9	3.1	4.2
0.9	2.5	1.5	2.1	0.7	0.8	0.8	0.8	0.9	2.0	0.7	1.5
-1.4	-2.2	-1.6	-2.0	126	113	97	84	76	-2.7	-2.4	-2.6
0.2	-1.8	-1.7	-1.7	290	218	171	138	109	-4.2	-4.4	-4.3
1.7	0.5	-0.1	0.3	2.3	1.9	1.8	1.6	1.4	-1.5	-2.0	-1.7

Table A35 | Thailand

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	42	73	118	133	139	146	155	163	170
Coal	3.8	7.7	16	15	15	15	15	14	14
Oil	18	32	45	54	54	55	57	58	59
Natural gas	5.0	17	33	35	41	44	45	47	49
Nuclear	-	-	-	-	-	-	1.8	3.7	6.2
Hydro	0.4	0.5	0.5	0.6	1.0	1.1	1.1	1.2	1.2
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar, wind, etc.	-	-	0.0	0.8	2.0	3.0	3.9	4.9	5.9
Biomass and waste	15	15	23	25	23	26	28	31	33
Hydrogen	-	-	-	-	-0.0	-0.0	0.0	-0.0	-0.1

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	29	51	85	99	101	106	112	116	120
Coal	1.3	3.6	9.2	7.1	6.9	6.9	6.9	6.7	6.5
Oil	15	29	43	55	55	56	58	59	60
Natural gas	0.1	1.1	4.6	7.2	7.5	8.0	8.5	8.9	9.2
Electricity	3.3	7.6	13	18	20	22	24	27	29
Heat	-	-	-	-	-	-	-	-	-
Hydrogen	-	-	-	-	-	-	-	-	-
Renewables and waste	9.3	9.4	15	12	12	13	14	15	15
Industry	8.7	17	27	30	33	36	38	40	42
Transport	9.2	15	19	29	28	28	28	28	28
Buildings, etc.	11	14	20	17	17	17	17	18	18
Non-energy use	0.4	5.8	18	23	24	26	28	30	32

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	44	96	159	196	229	257	285	315	347
Coal	11	18	30	29	31	32	33	33	34
Oil	10	10.0	1.1	3.2	-	-	-	-	-
Natural gas	18	62	119	126	144	154	159	166	172
Nuclear	-	-	-	-	-	-	7.0	14	24
Hydro	5.0	6.0	5.6	6.8	11	12	13	14	14
Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar photovoltaics	-	-	0.0	5.3	15	26	36	46	56
Wind	-	-	-	3.5	7.8	8.9	9.9	11	12
Concentrated solar power and marine	-	-	-	-	0.0	0.0	0.0	0.0	0.0
Biomass and waste	-	0.5	3.8	23	20	23	26	30	33
Hydrogen	-	-	-	-	-	0.4	0.9	1.1	1.3
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	79	148	219	239	249	254	256	258	257
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	144	221	347	459	531	625	738	862	995
Population (million)	55	63	69	72	71	71	70	68	66
GDP per capita ($2015 thousand)	2.6	3.5	5.1	6.4	7.5	8.9	11	13	15
Primary energy consumption per capita (toe/person)	0.8	1.2	1.7	1.9	1.9	2.1	2.2	2.4	2.6
Primary energy consumption per GDP (toe/$2015 million)	294	328	340	289	261	234	210	189	171
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	547	670	632	520	469	406	347	299	258
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	1.9	2.0	1.9	1.8	1.8	1.7	1.7	1.6	1.5

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
3.5	0.9	1.0	0.9	100	100	100	100	135	137	139	140	142	0.3	0.3	0.3	100	100
4.3	-0.1	-0.5	-0.3	9.0	11	9.5	8.3	14	13	11	10.0	8.9	-1.7	-2.2	-1.9	8.1	6.3
3.3	0.3	0.4	0.3	43	40	37	35	52	49	46	43	40	-0.8	-1.5	-1.1	33	28
6.1	1.5	0.7	1.2	12	26	29	29	39	39	38	38	38	0.5	0.0	0.3	28	27
n.a.	n.a.	13.0	n.a.	-	-	1.2	3.6	-	1.8	3.9	6.4	9.0	n.a.	8.8	n.a.	2.8	6.3
0.9	4.0	0.9	2.8	1.0	0.4	0.7	0.7	1.0	1.2	1.3	1.4	1.4	4.7	1.1	3.3	0.9	1.0
0.0	4.2	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	2.6	0.0	0.0
n.a.	10.1	4.1	7.8	-	0.6	2.5	3.5	2.6	4.2	6.1	8.2	11	12.9	5.7	10.2	4.4	7.4
1.6	0.7	1.4	1.0	35	19	18	19	23	27	29	30	32	0.8	1.1	0.9	21	22
n.a.	n.a.	n.a.	n.a.	-	-	0.0	-0.0	0.1	0.1	-0.0	-0.1	-0.4	n.a.	40.4	n.a.	-0.0	-0.3

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
3.8	0.7	0.7	0.7	100	100	100	100	100	100	100	99	98	0.1	-0.2	0.0	100	100
5.2	-0.2	-0.5	-0.3	4.6	7.2	6.1	5.4	7.2	6.8	6.3	5.9	5.6	-0.7	-1.1	-0.9	6.3	5.7
4.0	0.3	0.3	0.3	52	56	52	50	53	50	48	45	43	-0.8	-1.2	-1.0	48	44
12.7	1.0	0.9	0.9	0.5	7.3	7.6	7.7	7.3	7.3	7.2	7.0	6.9	0.0	-0.5	-0.2	7.2	7.0
5.2	2.0	1.8	1.9	11	18	22	24	20	22	25	27	29	2.0	1.7	1.9	25	30
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
0.7	1.1	0.9	1.0	32	12	12	13	12	14	14	13	13	1.0	-0.2	0.5	14	14
3.8	1.4	0.9	1.2	30	30	34	35	32	33	33	32	31	0.5	-0.4	0.2	33	32
3.5	-0.2	0.1	-0.1	32	29	25	23	27	25	24	21	20	-1.2	-1.9	-1.5	24	20
1.4	0.1	0.5	0.2	37	17	16	15	16	16	16	15	15	-0.5	-0.6	-0.5	16	15
12.8	1.2	1.3	1.3	1.5	23	25	27	24	26	28	30	32	1.2	1.3	1.3	28	33

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
4.6	2.2	2.0	2.1	100	100	100	100	229	257	288	327	373	2.3	2.6	2.4	100	100
2.9	0.8	0.3	0.6	25	15	12	9.7	26	22	18	15	12	-2.9	-3.8	-3.2	6.1	3.2
-3.5	-100	n.a.	-100	23	1.7	-	-	-	-	-	-	-	-100	n.a.	-100	-	-
6.1	1.4	0.7	1.2	40	64	56	50	140	141	141	143	148	0.7	0.5	0.6	49	40
n.a.	n.a.	13.0	n.a.	-	-	2.5	6.9	-	7.0	15	25	34	n.a.	8.8	n.a.	5.1	9.2
0.9	4.0	0.9	2.8	11	3.4	4.6	4.2	12	14	15	16	16	4.7	1.0	3.3	5.1	4.4
0.0	4.2	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	2.6	0.0	0.0
n.a.	11.8	4.7	9.1	-	2.7	13	16	22	39	59	81	106	15.2	6.0	11.7	20	28
n.a.	6.2	2.0	4.6	-	1.8	3.5	3.5	7.9	9.3	11	13	16	6.9	3.6	5.7	3.8	4.2
n.a.	n.a.	0.0	n.a.	-	-	0.0	0.0	0.1	0.2	0.3	0.4	0.7	n.a.	9.6	n.a.	0.1	0.2
n.a.	0.9	2.4	1.4	-	12	9.2	9.6	21	25	29	33	37	1.4	2.7	1.9	9.9	10
n.a.	n.a.	3.9	n.a.	-	-	0.3	0.4	-	0.6	1.2	1.8	2.5	n.a.	8.1	n.a.	0.4	0.7
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
3.4	0.4	0.0	0.3	236	214	194	172	152	-1.2	-2.4	-1.7
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
3.6	2.8	3.0	2.9	531	625	738	862	995	2.8	3.0	2.9
0.8	-0.2	-0.5	-0.3	71	71	70	68	66	-0.2	-0.5	-0.3
2.7	3.0	3.5	3.2	7.5	8.9	11	13	15	3.0	3.5	3.2
2.7	1.1	1.4	1.2	1.9	1.9	2.0	2.1	2.1	0.4	0.7	0.5
-0.1	-1.9	-2.0	-1.9	254	220	188	163	143	-2.5	-2.7	-2.6
-0.2	-2.4	-2.9	-2.6	444	343	263	199	152	-3.9	-5.3	-4.4
-0.1	-0.5	-0.9	-0.7	1.7	1.6	1.4	1.2	1.1	-1.5	-2.7	-1.9

Table A36 | Viet Nam

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	18	29	59	102	134	158	184	214	245
Coal	2.2	4.4	15	51	63	71	80	92	103
Oil	2.7	7.8	18	25	31	35	40	45	51
Natural gas	0.0	1.1	8.1	6.5	15	21	28	36	45
Nuclear	-	-	-	-	-	2.2	4.2	6.4	8.6
Hydro	0.5	1.3	2.4	6.9	7.7	8.1	8.4	8.6	8.8
Geothermal	-	-	-	-	-	-	-	-	-
Solar, wind, etc.	-	-	0.0	3.3	7.2	9.1	11	12	14
Biomass and waste	12	14	15	9.3	9.8	11	12	13	14
Hydrogen	-	-	-	-	-0.0	0.1	0.3	0.3	0.3

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	16	25	48	69	87	101	116	132	149
Coal	1.3	3.2	9.8	16	20	21	23	24	25
Oil	2.3	6.5	17	23	29	33	37	42	47
Natural gas	-	0.0	0.5	2.0	3.2	4.0	5.0	6.0	7.0
Electricity	0.5	1.9	7.5	21	29	35	43	51	59
Heat	-	-	-	-	-	-	-	-	-
Hydrogen	-	-	-	-	-	-	-	-	-
Renewables and waste	12	13	14	6.9	6.9	7.7	8.6	9.4	10
Industry	4.5	7.9	17	34	44	51	58	66	73
Transport	1.4	3.5	10	15	20	23	26	30	34
Buildings, etc.	10	13	18	17	20	23	26	30	34
Non-energy use	0.0	0.1	2.3	2.7	3.5	4.3	5.3	6.4	7.7

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	8.7	27	95	274	376	461	552	656	769
Coal	2.0	3.1	20	123	131	150	171	205	243
Oil	1.3	4.5	3.4	3.5	0.1	-	-	-	-
Natural gas	0.0	4.4	44	26	68	98	135	174	220
Nuclear	-	-	-	-	-	8.4	16	25	33
Hydro	5.4	15	28	81	89	94	97	100	102
Geothermal	-	-	-	-	-	-	-	-	-
Solar photovoltaics	-	-	-	27	44	56	66	74	82
Wind	-	-	0.1	12	40	50	59	68	77
Concentrated solar power and marine	-	-	-	-	-	-	-	-	-
Biomass and waste	-	-	0.1	2.1	3.0	3.5	4.0	4.5	5.0
Hydrogen	-	-	-	-	-	2.3	4.6	6.1	7.6
Others	-	-	-	-	-	-	-	-	-

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	17	42	123	293	379	434	498	576	656
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	45	94	177	379	545	711	924	1 186	1 496
Population (million)	66	77	87	100	104	107	108	110	110
GDP per capita ($2015 thousand)	0.7	1.2	2.0	3.8	5.2	6.7	8.5	11	14
Primary energy consumption per capita (toe/person)	0.3	0.4	0.7	1.0	1.3	1.5	1.7	1.9	2.2
Primary energy consumption per GDP (toe/$2015 million)	397	307	330	270	246	222	199	180	164
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	367	448	693	773	695	611	539	485	439
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	0.9	1.5	2.1	2.9	2.8	2.8	2.7	2.7	2.7

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
5.4	3.5	2.9	3.3	100	100	100	100	123	137	150	166	185	2.3	2.1	2.2	100	100
9.9	2.7	2.6	2.7	12	50	44	42	54	46	43	45	49	-0.9	1.3	-0.1	29	27
7.0	2.8	2.4	2.6	15	25	22	21	29	31	32	33	32	1.5	0.0	0.9	22	18
26.2	9.0	4.8	7.4	0.0	6.3	15	18	13	13	14	15	18	4.7	2.3	3.8	9.4	9.5
n.a.	n.a.	7.4	n.a.	-	-	2.3	3.5	-	16	25	33	42	n.a.	5.4	n.a.	17	23
8.6	1.1	0.5	0.9	2.6	6.8	4.5	3.6	8.8	9.8	11	11	12	2.6	1.3	2.1	7.1	6.6
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	7.1	2.4	5.4	-	3.3	5.8	5.6	8.7	12	15	20	26	9.4	5.2	7.8	10	14
-0.9	1.5	1.6	1.5	70	9.1	6.5	5.7	9.5	9.3	9.2	9.3	9.7	-0.1	0.5	0.1	6.1	5.2
n.a.	n.a.	-0.5	n.a.	-	-	0.2	0.1	-0.1	-0.4	-0.9	-2.3	-4.3	n.a.	17.2	n.a.	-0.6	-2.3

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
4.5	3.1	2.5	2.9	100	100	100	100	85	91	97	103	110	2.0	1.2	1.7	100	100
7.8	2.1	0.9	1.7	8.3	23	19	17	19	19	18	17	17	0.8	-0.5	0.3	18	16
7.2	2.9	2.4	2.7	15	33	32	32	27	29	30	31	31	1.6	0.1	1.1	31	28
n.a.	5.4	3.5	4.7	-	3.0	4.3	4.7	3.1	3.7	4.2	4.7	5.2	4.4	2.1	3.5	4.4	4.8
11.8	4.2	3.3	3.9	3.3	31	37	40	29	34	39	44	51	3.6	2.8	3.3	40	47
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
-1.6	1.3	1.7	1.5	74	9.9	7.4	6.8	6.5	6.1	5.8	5.6	5.7	-1.0	-0.1	-0.7	5.9	5.2
6.3	3.2	2.2	2.8	28	50	50	49	43	45	46	47	50	1.8	0.9	1.4	48	46
7.5	3.2	2.6	3.0	8.7	22	22	23	19	20	22	22	23	2.1	0.6	1.5	22	21
1.6	2.7	2.6	2.7	63	24	23	23	19	22	24	26	29	2.1	1.8	2.0	25	26
14.8	4.2	3.9	4.0	0.2	3.9	4.6	5.2	3.5	4.3	5.3	6.4	7.7	4.2	3.9	4.0	5.5	7.1

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
11.0	4.2	3.4	3.9	100	100	100	100	374	449	527	635	768	3.9	3.8	3.9	100	100
13.3	2.0	3.6	2.6	23	45	31	32	104	69	54	55	63	-4.7	1.5	-2.4	10	8.2
3.1	-100	n.a.	-100	15	1.3	-	-	0.1	-	-	-	-	-100	n.a.	-100	-	-
28.9	10.1	5.0	8.2	0.1	9.6	24	29	64	60	67	72	88	5.6	2.8	4.6	13	11
n.a.	n.a.	7.4	n.a.	-	-	2.9	4.3	-	62	95	127	160	n.a.	5.4	n.a.	18	21
8.6	1.1	0.5	0.9	62	29	18	13	102	114	124	133	141	2.6	1.3	2.1	24	18
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	5.3	2.2	4.2	-	9.9	12	11	57	79	103	135	172	8.1	5.3	7.1	20	22
n.a.	10.1	2.7	7.3	-	4.2	11	10	44	59	75	99	125	11.7	5.1	9.2	14	16
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	3.9	2.4	3.3	-	0.8	0.7	0.6	3.3	3.7	4.1	4.8	5.4	4.1	2.8	3.6	0.8	0.7
n.a.	n.a.	5.1	n.a.	-	-	0.8	1.0	-	2.5	5.0	9.1	13	n.a.	10.2	n.a.	0.9	1.7
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
9.1	3.2	2.8	3.0	330	287	271	264	261	-0.4	-0.4	-0.4
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
6.7	5.4	4.9	5.2	545	711	924	1 186	1 496	5.4	4.9	5.2
1.3	0.5	0.1	0.3	104	107	108	110	110	0.5	0.1	0.3
5.3	4.9	4.8	4.9	5.2	6.7	8.5	11	14	4.9	4.8	4.9
4.1	3.1	2.7	2.9	1.2	1.3	1.4	1.5	1.7	1.8	2.0	1.9
-1.2	-1.8	-1.9	-1.8	226	193	162	140	124	-3.0	-2.7	-2.8
2.3	-2.1	-2.0	-2.1	605	403	293	223	174	-5.5	-5.1	-5.4
3.5	-0.3	-0.1	-0.2	2.7	2.1	1.8	1.6	1.4	-2.7	-2.5	-2.6

Table A37 | North America

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	2 126	2 525	2 476	2 437	2 329	2 292	2 240	2 191	2 158
Coal	484	565	525	210	115	88	74	63	52
Oil	833	958	901	858	764	719	668	613	558
Natural gas	493	622	635	885	896	895	883	870	867
Nuclear	179	227	242	234	236	234	223	215	211
Hydro	49	53	53	52	61	62	63	63	64
Geothermal	14	13	8.4	9.7	12	14	15	16	16
Solar, wind, etc.	0.3	2.1	11	63	121	159	196	234	274
Biomass and waste	73	86	101	126	125	122	121	119	117
Hydrogen	-	-	-	-	-0.2	-0.5	-0.7	-0.5	-0.0

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	1 452	1 728	1 699	1 757	1 723	1 700	1 662	1 623	1 590
Coal	59	36	30	14	13	13	12	11	11
Oil	749	870	851	823	754	713	667	617	567
Natural gas	346	413	364	423	433	426	409	388	369
Electricity	262	338	367	380	411	442	471	506	546
Heat	2.8	6.1	7.1	6.1	6.0	6.0	5.8	5.5	5.2
Hydrogen	-	-	-	-	0.0	0.0	0.5	1.8	3.6
Renewables and waste	33	64	80	110	105	100	97	93	89
Industry	331	386	312	324	328	329	326	320	314
Transport	531	640	655	679	622	584	548	509	473
Buildings, etc.	456	528	572	573	585	594	592	593	599
Non-energy use	134	173	160	181	187	192	197	201	204

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	3 686	4 632	4 958	5 063	5 460	5 881	6 285	6 781	7 331
Coal	1 782	2 247	2 074	766	376	267	213	169	125
Oil	147	133	56	38	28	25	23	21	19
Natural gas	391	668	1 070	1 962	1 952	2 003	2 031	2 116	2 228
Nuclear	685	871	930	897	904	899	856	824	811
Hydro	570	612	614	607	711	721	730	738	746
Geothermal	16	15	18	20	25	29	30	32	33
Solar photovoltaics	0.0	0.2	3.3	222	682	971	1 267	1 577	1 891
Wind	3.1	5.9	104	466	670	819	951	1 091	1 232
Concentrated solar power and marine	0.7	0.6	0.9	3.1	3.0	3.1	3.1	3.1	3.2
Biomass and waste	91	81	82	72	90	100	109	118	127
Hydrogen	-	-	-	-	7.8	33	59	82	105
Others	-	-	6.8	11	11	11	11	11	11

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	5 117	6 075	5 690	4 938	4 264	4 012	3 770	3 528	3 310
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	10 663	14 881	17 739	23 868	27 532	30 218	33 051	35 972	38 929
Population (million)	277	313	343	377	391	400	408	415	420
GDP per capita ($2015 thousand)	38	48	52	63	70	76	81	87	93
Primary energy consumption per capita (toe/person)	7.7	8.1	7.2	6.5	6.0	5.7	5.5	5.3	5.1
Primary energy consumption per GDP (toe/$2015 million)	199	170	140	102	85	76	68	61	55
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	480	408	321	207	155	133	114	98	85
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.4	2.4	2.3	2.0	1.8	1.8	1.7	1.6	1.5

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
0.4	-0.5	-0.4	-0.4	100	100	100	100	2 271	2 157	2 021	1 926	1 853	-1.1	-0.9	-1.0	100	100
-2.5	-6.0	-3.4	-5.0	23	8.6	3.3	2.4	82	36	25	25	24	-11.7	-0.8	-7.8	1.3	1.3
0.1	-1.5	-1.8	-1.6	39	35	30	26	725	613	485	353	250	-3.3	-6.4	-4.5	24	13
1.8	0.0	-0.2	-0.1	23	36	39	40	896	886	818	745	649	-0.5	-2.3	-1.1	40	35
0.8	-0.3	-0.5	-0.4	8.4	9.6	10.0	9.8	236	238	245	259	273	0.3	1.1	0.6	12	15
0.2	1.1	0.2	0.8	2.3	2.1	2.8	3.0	62	62	63	64	64	1.1	0.2	0.8	3.1	3.5
-1.1	2.6	0.7	1.9	0.7	0.4	0.7	0.7	12	15	16	17	17	3.1	0.8	2.2	0.8	0.9
17.3	6.9	3.4	5.6	0.0	2.6	8.7	13	127	184	244	332	428	8.3	5.8	7.3	12	23
1.6	-0.2	-0.4	-0.3	3.5	5.2	5.4	5.4	133	134	139	144	148	0.6	0.6	0.6	6.9	8.0
n.a.	n.a.	-26.0	n.a.	-	-	-0.0	-0.0	-2.9	-11	-14	-11	1.1	n.a.	n.a.	n.a.	-0.7	0.1

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
0.6	-0.3	-0.4	-0.4	100	100	100	100	1 676	1 566	1 431	1 323	1 250	-1.2	-1.3	-1.3	100	100
-4.2	-1.0	-1.1	-1.0	4.1	0.8	0.7	0.7	12	9.4	7.9	6.9	6.2	-3.4	-2.4	-3.0	0.6	0.5
0.3	-1.2	-1.6	-1.4	52	47	40	36	720	621	504	395	305	-2.8	-4.9	-3.6	35	24
0.6	-0.2	-1.0	-0.5	24	24	25	23	408	358	296	235	179	-2.1	-4.9	-3.1	21	14
1.1	1.3	1.5	1.3	18	22	28	34	419	456	488	529	557	1.5	1.3	1.4	34	45
2.4	-0.3	-1.0	-0.6	0.2	0.3	0.3	0.3	5.6	5.2	4.7	4.1	3.6	-1.5	-2.4	-1.9	0.3	0.3
n.a.	n.a.	21.2	n.a.	-	-	0.0	0.2	0.1	8.2	20	40	84	n.a.	15.2	n.a.	1.4	6.7
3.7	-0.7	-0.8	-0.8	2.3	6.2	5.8	5.6	112	108	109	113	115	0.0	0.5	0.2	7.6	9.2
-0.1	0.0	-0.4	-0.1	23	18	20	20	316	293	262	234	213	-1.2	-2.1	-1.6	18	17
0.7	-1.3	-1.5	-1.3	37	39	33	30	598	519	440	374	335	-2.5	-2.7	-2.6	31	27
0.7	0.2	0.1	0.2	31	33	36	38	575	562	532	514	498	-0.4	-0.7	-0.5	37	40
0.9	0.5	0.4	0.4	9.2	10	12	13	187	192	197	201	204	0.5	0.4	0.4	14	16

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
1.0	1.3	1.6	1.4	100	100	100	100	5 582	6 269	6 911	7 875	8 756	1.8	2.4	2.0	100	100
-2.5	-7.2	-5.2	-6.5	48	15	3.4	1.7	241	50	11	12	12	-22.1	0.6	-14.4	0.2	0.1
-4.0	-2.8	-2.0	-2.5	4.0	0.7	0.4	0.3	29	25	27	22	16	-2.0	-5.0	-3.1	0.4	0.2
5.0	0.2	0.9	0.5	11	39	32	30	2 118	2 267	2 150	1 988	1 653	0.5	-2.6	-0.6	31	19
0.8	-0.3	-0.5	-0.4	19	18	14	11	906	912	940	995	1 047	0.3	1.1	0.6	14	12
0.2	1.1	0.2	0.8	15	12	12	10	716	726	735	743	750	1.1	0.2	0.8	11	8.6
0.6	2.7	0.7	1.9	0.4	0.4	0.5	0.4	25	31	33	34	36	3.1	0.8	2.3	0.5	0.4
40.5	10.8	4.1	8.3	0.0	4.4	20	26	744	1 162	1 589	2 191	2 815	12.3	5.9	9.9	23	32
16.4	4.3	2.6	3.7	0.1	9.2	15	17	685	919	1 192	1 611	2 103	5.7	5.8	5.7	17	24
4.7	0.0	0.2	0.1	0.0	0.1	0.0	0.0	3.2	3.4	3.6	3.9	4.1	0.9	1.5	1.1	0.1	0.0
-0.7	2.5	1.5	2.1	2.5	1.4	1.7	1.7	96	113	130	140	150	3.5	1.4	2.7	1.9	1.7
n.a.	n.a.	6.0	n.a.	-	-	0.9	1.4	8.2	48	87	123	160	n.a.	6.3	n.a.	1.3	1.8
n.a.	0.0	0.0	0.0	-	0.2	0.2	0.2	11	11	11	11	11	0.0	0.0	0.0	0.2	0.1

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
-0.1	-1.6	-1.3	-1.5	4 012	3 170	2 340	1 432	692	-4.3	-11.5	-7.0	
n.a.	n.a.	n.a.	n.a.	-	-	25	132	263	n.a.	26.5	n.a.	

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
2.5	1.9	1.7	1.8	27 532	30 218	33 051	35 972	38 929	1.9	1.7	1.8	
0.9	0.5	0.3	0.4	391	400	408	415	420	0.5	0.3	0.4	
1.5	1.5	1.4	1.4	70	76	81	87	93	1.5	1.4	1.4	
-0.5	-1.0	-0.7	-0.8	5.8	5.4	5.0	4.6	4.4	-1.6	-1.2	-1.4	
-2.0	-2.4	-2.0	-2.2	82	71	61	54	48	-3.0	-2.5	-2.8	
-2.5	-3.4	-2.9	-3.2	146	105	71	40	18	-6.1	-12.9	-8.7	
-0.5	-1.1	-0.9	-1.0	1.8	1.5	1.2	0.7	0.4	-3.2	-10.7	-6.1	

Table A38 | United States

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	1 914	2 273	2 216	2 143	2 046	2 012	1 965	1 925	1 900
Coal	460	533	501	202	111	84	70	60	49
Oil	757	871	807	762	682	641	596	546	497
Natural gas	438	548	556	765	775	772	755	744	742
Nuclear	159	208	219	211	214	214	209	204	204
Hydro	23	22	23	21	26	27	27	27	28
Geothermal	14	13	8.4	9.7	12	14	15	15	16
Solar, wind, etc.	0.3	2.1	11	59	113	149	185	222	260
Biomass and waste	62	73	89	112	111	109	108	106	105
Hydrogen	-	-	-	-	-0.2	-0.3	-0.3	-0.2	-0.0

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	1 294	1 546	1 513	1 561	1 533	1 514	1 482	1 449	1 421
Coal	56	33	27	12	12	11	10	9.8	9.4
Oil	683	793	762	737	676	639	597	552	506
Natural gas	303	360	322	372	383	378	364	346	330
Electricity	226	301	326	335	362	391	417	450	487
Heat	2.2	5.3	6.6	5.4	5.4	5.4	5.2	5.0	4.7
Hydrogen	-	-	-	-	0.0	0.0	0.5	1.6	3.2
Renewables and waste	23	54	70	100	94	90	88	84	81
Industry	284	332	270	279	282	282	279	274	270
Transport	488	588	596	619	569	535	502	467	434
Buildings, etc.	403	473	511	507	519	530	530	532	539
Non-energy use	119	153	135	157	163	167	171	175	179

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	3 203	4 026	4 354	4 430	4 789	5 172	5 534	5 986	6 496
Coal	1 700	2 129	1 994	742	373	266	212	168	124
Oil	131	118	48	33	26	23	20	18	17
Natural gas	382	634	1 018	1 865	1 872	1 903	1 892	1 951	2 037
Nuclear	612	798	839	808	822	822	802	782	782
Hydro	273	253	262	247	308	312	316	320	324
Geothermal	16	15	18	20	24	29	30	31	32
Solar photovoltaics	0.0	0.2	3.1	214	665	949	1 241	1 545	1 855
Wind	3.1	5.7	95	426	596	734	853	978	1 105
Concentrated solar power and marine	0.7	0.5	0.9	3.1	3.0	3.0	3.1	3.1	3.1
Biomass and waste	86	72	73	61	80	88	97	105	112
Hydrogen	-	-	-	-	7.8	32	57	76	94
Others	-	-	3.7	11	11	11	11	11	11

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	4 729	5 599	5 193	4 426	3 815	3 575	3 338	3 114	2 914
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	9 785	13 718	16 339	22 063	25 520	28 022	30 663	33 387	36 146
Population (million)	250	282	309	337	349	356	363	369	373
GDP per capita ($2015 thousand)	39	49	53	66	73	79	84	91	97
Primary energy consumption per capita (toe/person)	7.7	8.1	7.2	6.4	5.9	5.6	5.4	5.2	5.1
Primary energy consumption per GDP (toe/$2015 million)	196	166	136	97	80	72	64	58	53
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	483	408	318	201	150	128	109	93	81
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.5	2.5	2.3	2.1	1.9	1.8	1.7	1.6	1.5

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
0.3	-0.5	-0.3	-0.4	100	100	100	100	1 991	1 889	1 766	1 685	1 624	-1.1	-0.8	-1.0	100	100
-2.5	-6.0	-3.5	-5.1	24	9.4	3.6	2.6	79	33	23	22	21	-12.0	-0.7	-8.0	1.3	1.3
0.0	-1.4	-1.8	-1.6	40	36	30	26	650	551	436	316	221	-3.2	-6.6	-4.5	25	14
1.7	-0.1	-0.2	-0.1	23	36	38	39	772	763	698	632	548	-0.5	-2.4	-1.2	39	34
0.8	0.0	-0.3	-0.1	8.3	9.8	11	11	214	214	222	236	250	0.3	1.2	0.6	13	15
-0.3	1.5	0.2	1.0	1.2	1.0	1.4	1.5	26	27	27	27	28	1.5	0.2	1.0	1.5	1.7
-1.1	2.4	0.7	1.8	0.7	0.5	0.7	0.8	12	15	16	16	17	2.9	0.8	2.1	0.9	1.0
17.1	6.9	3.5	5.6	0.0	2.8	9.4	14	119	172	228	308	395	8.3	5.6	7.3	13	24
1.8	-0.2	-0.3	-0.3	3.3	5.2	5.5	5.5	119	121	126	132	137	0.7	0.8	0.7	7.2	8.4
n.a.	n.a.	-20.7	n.a.	-	-	-0.0	-0.0	-2.3	-8.4	-10	-6.2	6.8	n.a.	n.a.	n.a.	-0.6	0.4

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
0.6	-0.3	-0.4	-0.3	100	100	100	100	1 493	1 398	1 278	1 183	1 120	-1.2	-1.3	-1.2	100	100
-4.5	-1.0	-1.0	-1.0	4.3	0.8	0.7	0.7	10	8.2	6.9	6.1	5.5	-3.3	-2.3	-2.9	0.5	0.5
0.2	-1.2	-1.6	-1.4	53	47	40	36	648	559	454	353	270	-2.8	-5.1	-3.7	35	24
0.6	-0.1	-1.0	-0.5	23	24	25	23	360	317	263	209	160	-2.0	-4.8	-3.1	21	14
1.2	1.3	1.6	1.4	18	21	28	34	369	402	431	469	496	1.5	1.4	1.5	34	44
2.8	-0.3	-1.0	-0.5	0.2	0.3	0.4	0.3	5.0	4.6	4.2	3.7	3.3	-1.5	-2.4	-1.9	0.3	0.3
n.a.	n.a.	21.2	n.a.	-	-	0.0	0.2	0.1	7.3	18	36	77	n.a.	15.4	n.a.	1.4	6.9
4.5	-0.7	-0.8	-0.7	1.8	6.4	5.9	5.7	101	99	101	105	108	0.1	0.7	0.3	7.9	9.7
-0.1	0.0	-0.3	-0.1	22	18	19	19	271	251	224	199	181	-1.3	-2.1	-1.6	18	16
0.7	-1.2	-1.4	-1.3	38	40	34	31	549	479	407	346	310	-2.4	-2.7	-2.5	32	28
0.7	0.3	0.2	0.2	31	32	36	38	511	502	476	462	450	-0.4	-0.6	-0.4	37	40
0.8	0.5	0.4	0.5	9.2	10	12	13	163	167	171	175	179	0.5	0.4	0.5	13	16

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
1.0	1.3	1.6	1.4	100	100	100	100	4 888	5 490	6 045	6 887	7 646	1.8	2.4	2.0	100	100
-2.5	-7.1	-5.2	-6.4	53	17	3.8	1.9	239	48	8.4	9.1	9.2	-23.2	1.0	-15.0	0.1	0.1
-4.1	-2.9	-1.8	-2.5	4.1	0.7	0.4	0.3	26	22	24	20	14	-1.8	-5.0	-3.0	0.4	0.2
4.9	0.1	0.7	0.3	12	42	34	31	2 030	2 153	2 009	1 822	1 476	0.4	-3.0	-0.9	33	19
0.8	0.0	-0.3	-0.1	19	18	14	12	822	822	851	905	958	0.3	1.2	0.6	14	13
-0.3	1.5	0.2	1.0	8.5	5.6	5.7	5.0	308	312	316	320	324	1.5	0.2	1.0	5.2	4.2
0.6	2.5	0.7	1.9	0.5	0.4	0.5	0.5	24	31	32	34	35	3.0	0.9	2.2	0.5	0.5
40.3	10.9	4.1	8.3	0.0	4.8	22	29	724	1 132	1 549	2 136	2 744	12.3	5.9	9.9	26	36
16.1	4.2	2.6	3.6	0.1	9.6	15	17	608	812	1 046	1 388	1 789	5.4	5.5	5.5	17	23
4.8	0.0	0.2	0.0	0.0	0.1	0.1	0.0	3.2	3.4	3.6	3.8	4.1	0.8	1.5	1.1	0.1	0.1
-1.0	2.7	1.5	2.3	2.7	1.4	1.7	1.7	83	99	115	124	133	3.8	1.5	2.9	1.9	1.7
n.a.	n.a.	5.1	n.a.	-	-	1.0	1.4	8.2	44	80	114	148	n.a.	6.3	n.a.	1.3	1.9
n.a.	0.0	0.0	0.0	-	0.2	0.2	0.2	11	11	11	11	11	0.0	0.0	0.0	0.2	0.1

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
-0.2	-1.6	-1.3	-1.5	3 578	2 800	2 042	1 208	533	-4.4	-12.6	-7.5	
n.a.	n.a.	n.a.	n.a.	-	-	23	127	256	n.a.	27.4	n.a.	

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
2.5	2.0	1.7	1.8	25 520	28 022	30 663	33 387	36 146	2.0	1.7	1.8
0.9	0.4	0.3	0.4	349	356	363	369	373	0.4	0.3	0.4
1.6	1.5	1.4	1.5	73	79	84	91	97	1.5	1.4	1.5
-0.6	-0.9	-0.6	-0.8	5.7	5.3	4.9	4.6	4.3	-1.6	-1.1	-1.4
-2.1	-2.4	-2.0	-2.2	78	67	58	50	45	-3.0	-2.5	-2.8
-2.6	-3.5	-3.0	-3.3	140	100	67	36	15	-6.3	-14.0	-9.2
-0.5	-1.1	-1.0	-1.1	1.8	1.5	1.2	0.7	0.3	-3.4	-11.8	-6.6

Table A39 | Latin America

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	467	611	791	867	925	976	1 023	1 068	1 112
Coal	21	28	40	37	32	32	32	33	35
Oil	241	314	367	356	360	370	379	382	380
Natural gas	71	118	178	207	215	232	254	283	314
Nuclear	3.2	5.3	7.2	9.5	9.9	17	18	15	15
Hydro	34	51	64	66	73	76	79	82	85
Geothermal	5.1	6.5	6.4	6.3	11	14	15	17	18
Solar, wind, etc.	0.0	0.2	0.9	24	45	56	69	81	93
Biomass and waste	91	89	128	160	178	180	180	180	179
Hydrogen	-	-	-	-	-0.1	-0.9	-2.9	-4.7	-6.9

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	343	442	571	630	673	704	733	760	784
Coal	8.3	11	15	12	13	13	13	14	14
Oil	179	236	286	306	314	323	332	338	339
Natural gas	38	54	74	67	71	74	77	80	84
Electricity	44	68	97	125	145	163	181	200	220
Heat	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen	-	-	-	-	-	-	0.1	0.6	1.3
Renewables and waste	74	73	99	119	129	131	129	128	126
Industry	114	143	180	181	201	218	234	247	259
Transport	104	141	199	237	246	253	260	266	270
Buildings, etc.	99	121	147	176	187	192	196	201	207
Non-energy use	26	38	45	36	38	41	43	46	48

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	624	1 008	1 405	1 796	2 071	2 318	2 594	2 872	3 168
Coal	24	44	75	83	55	53	52	51	55
Oil	130	196	188	110	84	78	71	60	42
Natural gas	54	134	317	439	424	487	578	705	837
Nuclear	12	20	28	36	38	66	69	57	57
Hydro	391	591	739	772	850	883	917	951	985
Geothermal	5.9	8.0	9.9	9.2	14	16	18	20	21
Solar photovoltaics	0.0	0.0	0.1	104	261	319	391	454	517
Wind	0.0	0.3	4.7	155	239	304	383	457	531
Concentrated solar power and marine	-	-	-	0.1	0.2	0.2	0.2	0.2	0.2
Biomass and waste	7.4	13	44	83	102	106	110	113	116
Hydrogen	-	-	-	-	-	-	-	-	-
Others	-	0.4	0.5	5.3	5.3	5.3	5.3	5.3	5.3

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	829	1 148	1 471	1 478	1 472	1 532	1 602	1 679	1 749
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	2 636	3 592	4 885	5 757	6 834	7 874	9 029	10 261	11 544
Population (million)	438	517	585	655	684	701	714	722	727
GDP per capita ($2015 thousand)	6.0	6.9	8.4	8.8	10.0	11	13	14	16
Primary energy consumption per capita (toe/person)	1.1	1.2	1.4	1.3	1.4	1.4	1.4	1.5	1.5
Primary energy consumption per GDP (toe/$2015 million)	177	170	162	151	135	124	113	104	96
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	315	320	301	257	215	195	177	164	152
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	1.8	1.9	1.9	1.7	1.6	1.6	1.6	1.6	1.6

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
1.9	1.0	0.8	0.9	100	100	100	100	901	916	919	923	935	0.3	0.2	0.3	100	100
1.7	-0.8	1.0	-0.2	4.6	4.2	3.1	3.2	29	26	24	25	27	-2.5	1.2	-1.1	2.6	2.9
1.2	0.4	0.0	0.2	52	41	37	34	340	320	289	252	216	-1.2	-2.9	-1.8	31	23
3.3	1.2	2.2	1.6	15	24	25	28	214	227	242	255	267	0.9	1.0	0.9	26	29
3.3	3.9	-2.0	1.7	0.7	1.1	1.8	1.3	9.9	18	26	34	41	6.2	4.5	5.5	2.9	4.4
2.1	1.0	0.7	0.9	7.2	7.7	7.7	7.6	73	77	80	84	88	1.1	0.9	1.0	8.7	9.4
0.6	5.4	1.6	4.0	1.1	0.7	1.5	1.6	11	16	18	19	20	6.3	1.1	4.3	1.9	2.1
22.1	6.3	3.0	5.1	0.0	2.8	6.8	8.4	49	70	96	136	187	8.4	6.9	7.8	10	20
1.7	0.7	-0.1	0.4	20	18	18	16	174	166	156	147	140	-0.2	-1.1	-0.5	17	15
n.a.	n.a.	9.0	n.a.	-	-	-0.3	-0.6	-0.2	-4.4	-13	-29	-51	n.a.	15.0	n.a.	-1.4	-5.5

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
1.9	0.9	0.7	0.8	100	100	100	100	653	648	634	618	610	0.0	-0.4	-0.1	100	100
1.2	0.5	0.4	0.5	2.4	1.9	1.8	1.8	12	9.8	8.7	7.9	7.3	-2.0	-1.7	-1.9	1.4	1.2
1.6	0.5	0.2	0.4	52	49	45	43	298	284	261	233	208	-0.9	-2.3	-1.4	41	34
1.7	0.8	0.8	0.8	11	11	10	11	68	65	61	56	51	-0.6	-1.8	-1.0	9.5	8.3
3.2	2.2	2.0	2.1	13	20	25	28	149	170	192	214	236	2.5	2.1	2.4	30	39
n.a.	1.6	0.0	1.0	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.7	1.3	0.0	0.0
n.a.	n.a.	24.1	n.a.	-	-	0.0	0.2	0.0	0.9	2.6	6.2	13	n.a.	17.7	n.a.	0.4	2.2
1.5	0.5	-0.2	0.2	21	19	18	16	126	119	110	101	95	-0.5	-1.5	-0.8	17	16
1.4	1.5	1.0	1.3	33	29	32	33	194	197	194	190	189	0.4	-0.3	0.1	31	31
2.5	0.5	0.4	0.5	30	38	35	34	237	228	216	205	197	-0.5	-0.9	-0.7	34	32
1.8	0.7	0.5	0.6	29	28	27	26	184	183	181	178	177	0.2	-0.2	0.0	28	29
0.9	1.1	1.1	1.1	7.6	5.6	5.9	6.1	38	41	43	46	48	1.1	1.1	1.1	6.8	7.9

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
3.3	2.2	2.0	2.1	100	100	100	100	2 137	2 547	3 065	3 775	4 610	3.2	4.2	3.6	100	100
3.9	-2.7	0.6	-1.5	3.8	4.6	2.0	1.7	49	46	41	47	53	-4.1	2.6	-1.7	1.3	1.1
-0.5	-2.6	-5.1	-3.5	21	6.1	2.7	1.3	77	65	52	38	24	-4.3	-7.5	-5.5	1.7	0.5
6.6	1.6	3.8	2.4	8.6	24	22	26	449	562	714	885	1 060	2.9	4.0	3.3	23	23
3.3	3.9	-2.0	1.7	2.0	2.0	2.7	1.8	38	69	101	132	156	6.2	4.5	5.5	3.3	3.4
2.1	1.0	0.7	0.9	63	43	35	31	854	892	932	975	1 022	1.1	0.9	1.0	30	22
1.3	4.1	1.6	3.2	1.0	0.5	0.7	0.7	14	19	21	22	23	9.0	1.2	6.0	0.7	0.5
41.9	8.1	2.8	6.1	0.0	5.8	15	16	294	411	555	754	999	10.3	6.1	8.7	18	22
43.6	5.5	3.3	4.7	0.0	8.6	15	17	249	363	525	792	1 138	7.5	8.0	7.7	17	25
n.a.	1.6	1.3	1.5	-	0.0	0.0	0.0	0.2	0.2	0.3	0.5	0.6	5.0	7.5	5.9	0.0	0.0
7.6	1.7	0.6	1.2	1.2	4.6	4.2	3.7	108	113	119	124	128	2.1	0.8	1.6	3.9	2.8
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	0.0	0.0	0.0	-	0.3	0.2	0.2	5.3	5.3	5.3	5.3	5.3	0.0	0.0	0.0	0.2	0.1

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
1.8	0.5	0.9	0.6	1 399	1 316	1 195	1 047	894	-1.2	-2.9	-1.8
n.a.	n.a.	n.a.	n.a.	-	-	7.3	15	22	n.a.	11.8	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
2.4	2.7	2.5	2.6	6 834	7 874	9 029	10 261	11 544	2.7	2.5	2.6
1.2	0.5	0.2	0.4	684	701	714	722	727	0.5	0.2	0.4
1.2	2.2	2.3	2.2	10.0	11	13	14	16	2.2	2.3	2.2
0.7	0.5	0.6	0.5	1.3	1.3	1.3	1.3	1.3	-0.2	0.0	-0.1
-0.5	-1.7	-1.6	-1.6	132	116	102	90	81	-2.3	-2.3	-2.3
-0.6	-2.1	-1.6	-1.9	205	167	132	102	77	-3.8	-5.2	-4.3
-0.1	-0.5	0.0	-0.3	1.6	1.4	1.3	1.1	1.0	-1.6	-3.0	-2.1

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Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	1 644	1 759	1 834	1 548	1 456	1 409	1 353	1 287	1 229
Coal	450	331	301	168	118	102	85	76	67
Oil	617	654	605	519	461	423	387	350	314
Natural gas	267	396	473	362	316	298	273	245	213
Nuclear	210	247	239	171	181	190	198	184	177
Hydro	39	47	48	48	51	51	52	52	53
Geothermal	4.9	7.1	11	23	28	36	37	37	37
Solar, wind, etc.	0.4	2.9	18	82	114	126	145	174	205
Biomass and waste	56	72	137	173	193	190	184	176	170
Hydrogen	-	-	-	-	-0.0	-0.4	-2.0	-3.2	-4.5

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	1 142	1 235	1 289	1 154	1 093	1 044	994	946	903
Coal	124	61	55	36	34	30	26	23	21
Oil	528	573	538	475	427	392	358	324	290
Natural gas	205	269	285	238	223	212	200	186	174
Electricity	193	234	267	256	262	269	278	290	303
Heat	45	42	53	43	42	40	38	36	34
Hydrogen	-	-	-	-	0.0	0.0	0.3	1.1	2.1
Renewables and waste	48	56	92	106	105	101	93	86	79
Industry	330	325	296	271	266	260	252	243	234
Transport	269	318	335	347	312	285	260	236	215
Buildings, etc.	442	477	545	452	430	414	398	385	374
Non-energy use	101	114	113	84	85	85	84	83	81

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	2 695	3 236	3 623	3 462	3 632	3 741	3 894	4 084	4 292
Coal	1 030	968	873	449	250	194	134	98	62
Oil	209	180	81	46	14	11	7.9	5.9	3.2
Natural gas	176	514	857	615	479	444	379	299	186
Nuclear	804	948	916	657	695	729	759	707	680
Hydro	450	547	559	558	588	595	602	609	616
Geothermal	3.6	6.2	11	23	29	40	41	41	42
Solar photovoltaics	0.0	0.1	23	281	577	664	803	980	1 162
Wind	0.8	22	153	598	675	721	808	966	1 147
Concentrated solar power and marine	0.5	0.5	1.2	5.6	4.7	5.1	5.4	6.3	7.0
Biomass and waste	21	48	146	220	311	323	335	341	348
Hydrogen	-	-	-	-	1.1	6.7	12	21	30
Others	0.3	1.5	4.6	8.7	8.7	8.7	8.7	8.7	8.7

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	3 948	3 916	3 823	2 924	2 429	2 207	1 976	1 757	1 536
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	11 667	14 676	16 969	20 871	23 040	24 837	26 651	28 479	30 246
Population (million)	507	529	558	587	587	586	583	580	574
GDP per capita ($2015 thousand)	23	28	30	36	39	42	46	49	53
Primary energy consumption per capita (toe/person)	3.2	3.3	3.3	2.6	2.5	2.4	2.3	2.2	2.1
Primary energy consumption per GDP (toe/$2015 million)	141	120	108	74	63	57	51	45	41
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	338	267	225	140	105	89	74	62	51
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.4	2.2	2.1	1.9	1.7	1.6	1.5	1.4	1.3

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
-0.2	-0.8	-1.0	-0.9	100	100	100	100	1 416	1 328	1 225	1 165	1 149	-1.4	-0.6	-1.1	100	100
-2.9	-3.9	-2.4	-3.3	27	11	6.3	5.5	106	82	63	55	53	-5.6	-1.6	-4.2	5.1	4.6
-0.5	-1.7	-2.1	-1.8	38	34	29	26	417	326	246	174	121	-4.3	-6.9	-5.3	20	11
0.9	-1.6	-2.4	-1.9	16	23	20	17	296	249	181	128	92	-4.0	-6.5	-4.9	15	8.0
-0.6	0.8	-1.1	0.1	13	11	15	14	189	218	241	248	277	2.0	1.4	1.8	20	24
0.7	0.4	0.2	0.4	2.4	3.1	3.8	4.3	51	51	52	52	53	0.4	0.2	0.4	4.2	4.6
4.8	2.8	0.0	1.8	0.3	1.5	2.7	3.0	28	38	39	39	39	3.1	0.0	1.9	3.2	3.4
17.9	3.4	3.5	3.4	0.0	5.3	11	17	131	168	216	285	340	5.8	4.7	5.4	18	30
3.5	0.4	-0.8	-0.1	3.4	11	14	14	201	191	179	167	157	0.2	-1.3	-0.4	15	14
n.a.	n.a.	8.4	n.a.	-	-	-0.1	-0.4	2.5	9.8	14	21	21	n.a.	3.7	n.a.	1.2	1.8

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
0.0	-0.9	-0.9	-0.9	100	100	100	100	1 054	948	846	769	714	-1.8	-1.7	-1.8	100	100
-3.7	-1.9	-2.1	-2.0	11	3.1	2.6	2.3	29	21	17	13	11	-4.4	-3.8	-4.2	2.0	1.6
-0.3	-1.6	-2.1	-1.8	46	41	36	32	390	311	243	192	153	-3.9	-4.5	-4.1	29	21
0.4	-1.0	-1.4	-1.2	18	21	20	19	213	183	149	115	85	-2.7	-5.5	-3.7	18	12
0.9	0.5	0.9	0.6	17	22	28	34	274	292	307	323	332	1.1	0.8	1.0	36	47
-0.2	-0.6	-1.3	-0.9	3.9	3.7	3.9	3.7	41	38	35	31	28	-1.2	-2.2	-1.6	4.1	3.9
n.a.	n.a.	20.8	n.a.	-	-	0.0	0.2	0.1	4.9	12	23	42	n.a.	13.5	n.a.	1.4	5.9
2.5	-0.8	-1.6	-1.1	4.2	9.2	9.4	8.8	107	97	84	72	63	-1.4	-2.9	-1.9	9.9	8.8
-0.6	-0.4	-0.7	-0.5	29	23	25	26	257	238	214	194	179	-1.4	-1.8	-1.5	25	25
0.8	-1.7	-1.9	-1.8	24	30	26	24	290	234	189	158	142	-3.5	-2.8	-3.3	22	20
0.1	-0.8	-0.6	-0.7	39	39	40	41	422	392	359	334	312	-1.3	-1.4	-1.4	42	44
-0.6	0.0	-0.3	-0.1	8.9	7.2	8.5	9.0	85	85	84	83	81	0.0	-0.3	-0.1	9.9	11

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
0.8	0.7	1.0	0.8	100	100	100	100	3 817	4 251	4 674	5 434	6 207	1.8	2.9	2.2	100	100
-2.5	-6.9	-7.4	-7.1	38	13	3.4	1.4	214	141	72	49	47	-10.2	-4.2	-8.0	1.5	0.8
-4.5	-9.9	-8.7	-9.4	7.8	1.3	0.2	0.1	11	7.5	3.2	1.3	0.6	-14.5	-15.3	-14.8	0.1	0.0
3.9	-2.8	-6.9	-4.3	6.5	18	9.7	4.3	444	371	183	100	82	-6.9	-7.7	-7.2	3.9	1.3
-0.6	0.8	-1.1	0.1	30	19	19	16	726	837	927	953	1 063	2.0	1.4	1.8	20	17
0.7	0.4	0.2	0.4	17	16	15	14	588	595	602	609	616	0.4	0.2	0.4	13	9.9
5.8	3.4	0.1	2.2	0.1	0.7	1.1	1.0	29	43	44	44	45	3.8	0.2	2.4	0.9	0.7
34.5	6.4	3.8	5.4	0.0	8.1	21	27	731	954	1 250	1 550	1 753	9.2	3.4	7.0	27	28
22.3	1.8	3.6	2.4	0.0	17	21	27	722	921	1 180	1 676	2 113	4.1	6.0	4.8	25	34
7.6	-0.3	2.8	0.8	0.0	0.2	0.1	0.2	5.1	6.0	7.9	12	15	2.0	6.7	3.7	0.2	0.2
7.4	2.5	0.4	1.7	0.8	6.4	8.6	8.1	337	348	361	369	377	2.9	0.4	2.0	7.7	6.1
n.a.	n.a.	9.3	n.a.	-	-	0.3	0.7	2.2	19	35	61	87	n.a.	9.4	n.a.	0.8	1.4
10.3	0.0	0.0	0.0	0.0	0.3	0.2	0.2	8.7	8.7	8.7	8.7	8.7	0.0	0.0	0.0	0.2	0.1

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
-0.9	-2.3	-2.5	-2.4	2 191	1 691	1 163	662	287	-5.3	-13.1	-8.2	
n.a.	n.a.	n.a.	n.a.	-	-	44	127	209	n.a.	16.8	n.a.	

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
1.8	1.4	1.3	1.4	23 040	24 837	26 651	28 479	30 246	1.4	1.3	1.4	
0.4	0.0	-0.2	-0.1	587	586	583	580	574	0.0	-0.2	-0.1	
1.3	1.5	1.4	1.5	39	42	46	49	53	1.5	1.4	1.5	
-0.6	-0.8	-0.8	-0.8	2.4	2.3	2.1	2.0	2.0	-1.3	-0.5	-1.0	
-1.9	-2.2	-2.2	-2.2	61	53	46	41	38	-2.8	-1.9	-2.4	
-2.6	-3.7	-3.7	-3.7	95	68	44	23	9.5	-6.6	-14.2	-9.5	
-0.7	-1.5	-1.5	-1.5	1.5	1.3	0.9	0.6	0.3	-4.0	-12.5	-7.2	

Table A41 | Other Europe/Eurasia

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	1 514	988	1 113	1 160	1 161	1 167	1 167	1 175	1 183
Coal	365	209	211	218	191	183	180	181	186
Oil	459	199	216	237	237	232	227	221	215
Natural gas	596	481	566	565	530	521	512	514	527
Nuclear	55	61	76	81	103	126	140	148	142
Hydro	22	23	26	29	31	32	33	34	34
Geothermal	0.0	0.1	0.6	0.2	0.3	0.3	0.3	0.3	0.3
Solar, wind, etc.	-	0.0	0.2	3.9	8.3	10	12	14	16
Biomass and waste	17	15	19	28	57	58	59	61	63
Hydrogen	-	-	-	-	-0.0	-0.1	-0.4	-0.8	-1.1

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	1 057	647	709	769	769	763	753	745	739
Coal	113	36	39	47	49	47	45	43	41
Oil	275	144	174	213	209	205	201	196	189
Natural gas	258	200	233	242	233	228	221	216	211
Electricity	125	86	103	114	127	138	147	158	169
Heat	274	170	147	132	129	125	120	115	112
Hydrogen	-	-	-	-	-	-	-	0.0	0.0
Renewables and waste	13	11	14	20	22	21	19	18	17
Industry	391	205	205	207	218	221	222	223	223
Transport	170	110	145	161	156	152	149	146	143
Buildings, etc.	431	285	279	315	308	303	295	290	287
Non-energy use	65	47	80	86	87	87	87	86	86

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	1 856	1 415	1 689	1 826	1 889	2 024	2 149	2 284	2 425
Coal	429	338	396	375	329	331	344	372	419
Oil	252	69	22	20	16	15	15	15	16
Natural gas	707	504	671	731	646	649	668	709	790
Nuclear	209	234	289	311	393	484	536	568	544
Hydro	259	267	306	335	358	371	382	391	398
Geothermal	0.0	0.1	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Solar photovoltaics	-	-	0.0	19	59	73	89	100	111
Wind	-	0.0	1.2	24	35	43	51	60	69
Concentrated solar power and marine	-	-	-	-	0.0	0.0	0.0	0.1	0.1
Biomass and waste	0.0	2.6	3.3	9.1	52	58	63	69	75
Hydrogen	-	-	-	-	-	-	-	-	-
Others	-	-	0.0	0.1	0.1	0.1	0.1	0.1	0.1

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	3 859	2 324	2 494	2 510	2 357	2 298	2 257	2 251	2 282
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	1 797	1 233	2 050	2 706	3 211	3 558	3 936	4 353	4 800
Population (million)	338	336	333	339	343	343	344	345	346
GDP per capita ($2015 thousand)	5.3	3.7	6.2	8.0	9.4	10	11	13	14
Primary energy consumption per capita (toe/person)	4.5	2.9	3.3	3.4	3.4	3.4	3.4	3.4	3.4
Primary energy consumption per GDP (toe/$2015 million)	842	802	543	429	362	328	297	270	246
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	2 147	1 885	1 217	928	734	646	573	517	475
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.5	2.4	2.2	2.2	2.0	2.0	1.9	1.9	1.9

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
-0.8	0.0	0.1	0.1	100	100	100	100	1 154	1 127	1 085	1 051	1 022	-0.4	-0.6	-0.5	100	100
-1.5	-1.1	0.3	-0.6	24	19	15	16	181	161	150	139	131	-2.2	-1.3	-1.9	14	13
-2.0	-0.3	-0.6	-0.4	30	20	19	18	228	205	178	150	126	-1.7	-3.4	-2.3	16	12
-0.2	-0.6	0.3	-0.3	39	49	44	45	529	505	487	465	447	-0.9	-0.8	-0.9	45	44
1.2	3.2	0.2	2.1	3.6	7.0	12	12	107	142	153	174	189	3.8	2.1	3.2	14	18
0.8	0.8	0.4	0.6	1.5	2.5	2.8	2.9	31	32	33	34	34	0.8	0.4	0.6	3.0	3.3
6.8	2.1	0.2	1.4	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	1.9	0.0	1.2	0.0	0.0
n.a.	7.0	2.5	5.3	-	0.3	1.1	1.3	9.4	13	18	24	32	9.2	6.0	8.0	1.6	3.1
1.6	4.5	0.6	3.0	1.1	2.4	5.1	5.3	64	64	64	65	66	4.9	0.4	3.2	5.9	6.5
n.a.	n.a.	10.3	n.a.	-	-	-0.0	-0.1	0.3	-0.1	-1.3	-3.2	-6.1	n.a.	17.1	n.a.	-0.1	-0.6

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
-1.0	-0.1	-0.2	-0.1	100	100	100	100	747	704	653	605	567	-1.0	-1.4	-1.1	100	100
-2.6	-0.3	-0.8	-0.5	11	6.1	5.9	5.6	45	38	31	27	23	-2.4	-3.1	-2.6	4.8	4.0
-0.8	-0.4	-0.6	-0.4	26	28	27	26	202	184	161	137	117	-1.7	-3.1	-2.2	25	21
-0.2	-0.5	-0.5	-0.5	24	32	29	29	223	203	179	159	141	-1.8	-2.4	-2.0	27	25
-0.3	1.5	1.4	1.5	12	15	20	23	131	144	156	168	179	1.8	1.4	1.7	24	32
-2.2	-0.6	-0.7	-0.6	26	17	16	15	125	117	108	99	92	-1.2	-1.6	-1.3	17	16
n.a.	n.a.	n.a.	n.a.	-	-	-	0.0	-	0.0	0.0	0.0	0.0	n.a.	0.0	n.a.	0.0	0.0
1.3	0.0	-1.4	-0.6	1.2	2.6	2.6	2.3	20	19	17	16	15	-0.9	-1.1	-1.0	2.6	2.7
-1.9	0.4	0.0	0.3	37	27	30	30	209	197	182	168	158	-0.7	-1.4	-1.0	28	28
-0.2	-0.5	-0.4	-0.5	16	21	20	19	150	135	120	106	94	-1.7	-2.4	-2.0	18	17
-0.9	-0.4	-0.3	-0.3	41	41	39	39	301	284	264	246	229	-1.0	-1.4	-1.2	40	40
0.9	0.0	0.0	0.0	6.2	11	11	12	87	87	87	86	86	0.0	0.0	0.0	13	15

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
-0.1	1.0	1.2	1.1	100	100	100	100	1 957	2 155	2 331	2 526	2 729	1.4	1.6	1.5	100	100
-0.4	-0.5	2.0	0.4	23	21	16	17	309	282	279	269	261	-1.7	-0.7	-1.3	12	9.6
-7.4	-1.8	0.9	-0.8	14	1.1	0.7	0.7	15	13	13	13	13	-2.4	-0.2	-1.6	0.6	0.5
0.1	-0.5	1.7	0.3	38	40	31	33	689	724	790	827	879	0.5	1.1	0.7	34	32
1.2	3.3	0.2	2.1	11	17	25	22	412	544	588	667	724	3.8	2.1	3.2	25	27
0.8	0.8	0.4	0.6	14	18	18	16	358	371	382	391	398	0.8	0.4	0.6	16	15
9.0	1.2	0.0	0.8	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.6	0.6	1.2	0.0	0.8	0.0	0.0
n.a.	9.4	2.3	6.7	-	1.1	4.1	4.6	71	102	141	195	259	12.4	6.3	10.1	6.1	9.5
n.a.	4.5	3.0	3.9	-	1.3	2.4	2.8	35	46	60	81	105	5.5	5.8	5.6	2.6	3.9
n.a.	n.a.	10.9	n.a.	-	-	0.0	0.0	0.1	0.2	0.3	0.5	0.6	n.a.	7.7	n.a.	0.0	0.0
17.2	12.0	1.9	8.2	0.0	0.5	2.9	3.1	66	71	76	82	88	13.3	1.5	8.8	3.3	3.2
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	0.0	0.0	0.0	-	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
-1.3	-0.6	0.1	-0.4	2 296	2 043	1 820	1 594	1 400	-1.9	-2.6	-2.1	
n.a.	n.a.	n.a.	n.a.	-	-	13	28	44	n.a.	12.8	n.a.	

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
1.2	2.2	2.0	2.1	3 211	3 558	3 936	4 353	4 800	2.2	2.0	2.1	
0.0	0.1	0.1	0.1	343	343	344	345	346	0.1	0.1	0.1	
1.2	2.1	1.9	2.1	9.4	10	11	13	14	2.1	1.9	2.1	
-0.8	-0.1	0.1	0.0	3.4	3.3	3.2	3.0	2.9	-0.5	-0.7	-0.6	
-2.0	-2.1	-1.8	-2.0	360	317	276	242	213	-2.6	-2.6	-2.6	
-2.5	-2.8	-1.9	-2.4	715	574	462	366	292	-4.0	-4.5	-4.2	
-0.5	-0.7	0.0	-0.4	2.0	1.8	1.7	1.5	1.4	-1.5	-2.0	-1.7	

Table A42 | European Union

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	1 441	1 471	1 528	1 248	1 182	1 139	1 091	1 036	987
Coal	393	285	252	129	90	77	66	60	55
Oil	531	550	506	426	379	348	318	287	257
Natural gas	250	309	363	272	238	224	206	186	163
Nuclear	190	224	223	162	175	183	182	161	155
Hydro	24	30	32	28	30	30	31	31	31
Geothermal	3.2	4.6	5.5	6.6	7.6	7.9	7.9	7.9	7.8
Solar, wind, etc.	0.3	2.5	16	68	93	102	121	146	171
Biomass and waste	47	65	129	155	174	171	164	157	151
Hydrogen	-	-	-	-	-0.0	-0.3	-1.5	-2.3	-3.2

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	995	1 027	1 071	931	881	841	799	759	722
Coal	109	47	37	23	22	19	17	15	14
Oil	445	479	448	388	349	320	293	264	236
Natural gas	185	220	231	182	171	162	152	142	132
Electricity	162	189	216	200	204	210	217	227	237
Heat	55	43	52	40	39	38	36	33	31
Hydrogen	-	-	-	-	0.0	0.0	0.2	0.8	1.6
Renewables and waste	39	50	87	97	96	91	84	77	71
Industry	313	274	247	217	214	210	204	197	190
Transport	220	262	279	280	252	230	209	190	171
Buildings, etc.	374	391	447	362	342	328	314	301	291
Non-energy use	88	100	98	72	73	73	72	71	69

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	2 256	2 630	2 955	2 718	3 387	3 592	3 741	3 729	3 747
Coal	844	846	755	346	188	145	101	82	63
Oil	189	173	82	48	-	-	-	-	-
Natural gas	188	331	589	459	363	337	292	237	158
Nuclear	729	860	854	620	672	701	699	618	593
Hydro	284	350	372	330	348	352	357	361	366
Geothermal	3.2	4.8	5.6	6.3	9.7	13	14	14	14
Solar photovoltaics	0.0	0.1	22	247	733	866	999	1 058	1 117
Wind	0.8	21	140	479	805	893	982	1 049	1 115
Concentrated solar power and marine	0.5	0.5	1.2	5.6	6.1	6.6	6.6	6.7	6.8
Biomass and waste	19	42	129	172	257	266	276	281	285
Hydrogen	-	-	-	-	0.9	5.3	9.6	17	24
Others	0.2	1.4	4.4	6.0	6.0	6.0	6.0	6.0	6.0

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	3 970	3 671	3 512	2 517	2 117	1 918	1 717	1 536	1 356
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	9 094	11 284	12 931	15 477	17 038	18 344	19 670	21 003	22 287
Population (million)	421	429	442	449	446	442	438	433	427
GDP per capita ($2015 thousand)	22	26	29	34	38	41	45	48	52
Primary energy consumption per capita (toe/person)	3.4	3.4	3.5	2.8	2.7	2.6	2.5	2.4	2.3
Primary energy consumption per GDP (toe/$2015 million)	158	130	118	81	69	62	55	49	44
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	437	325	272	163	124	105	87	73	61
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.8	2.5	2.3	2.0	1.8	1.7	1.6	1.5	1.4

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
-0.4	-0.8	-1.0	-0.9	100	100	100	100	1 155	1 083	998	949	930	-1.3	-0.7	-1.1	100	100
-3.3	-3.9	-1.7	-3.1	27	10	6.0	5.6	80	61	49	44	42	-5.6	-1.3	-4.0	4.9	4.6
-0.7	-1.7	-2.1	-1.9	37	34	29	26	343	269	204	145	103	-4.3	-6.6	-5.1	20	11
0.3	-1.6	-2.3	-1.9	17	22	19	17	224	188	136	98	70	-4.0	-6.4	-4.9	14	7.6
-0.5	0.7	-1.6	-0.2	13	13	17	16	185	215	226	223	241	2.0	0.7	1.5	23	26
0.5	0.5	0.2	0.4	1.7	2.3	2.8	3.2	30	30	31	31	31	0.5	0.2	0.4	3.1	3.4
2.2	1.0	-0.1	0.6	0.2	0.5	0.7	0.8	7.6	8.0	8.0	7.9	7.9	1.1	-0.1	0.6	0.8	0.8
17.7	3.5	3.6	3.5	0.0	5.4	11	17	107	137	179	235	282	5.9	4.7	5.4	18	30
3.7	0.4	-0.9	-0.1	3.3	12	15	15	181	172	160	148	139	0.2	-1.4	-0.4	16	15
n.a.	n.a.	8.0	n.a.	-	-	-0.1	-0.3	1.8	6.8	9.6	13	11	n.a.	1.8	n.a.	1.0	1.2

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
-0.2	-0.9	-1.0	-0.9	100	100	100	100	850	764	680	616	569	-1.8	-1.8	-1.8	100	100
-4.6	-1.8	-2.1	-1.9	11	2.5	2.1	1.9	19	14	11	8.9	7.4	-4.3	-3.8	-4.1	1.6	1.3
-0.4	-1.6	-2.1	-1.8	45	42	37	33	318	254	199	157	125	-3.8	-4.5	-4.1	29	22
-0.1	-1.0	-1.4	-1.2	19	20	19	18	163	140	114	88	65	-2.7	-5.4	-3.7	17	11
0.6	0.5	0.9	0.6	16	22	27	33	214	228	240	252	261	1.1	0.8	1.0	35	46
-1.0	-0.7	-1.4	-0.9	5.5	4.3	4.5	4.3	38	36	32	29	26	-1.3	-2.3	-1.7	4.8	4.5
n.a.	n.a.	20.8	n.a.	-	-	0.0	0.2	0.1	3.6	8.7	17	31	n.a.	13.4	n.a.	1.3	5.4
2.8	-0.9	-1.7	-1.2	4.0	10	10	9.8	98	87	75	64	54	-1.5	-3.2	-2.1	11	9.5
-1.1	-0.4	-0.7	-0.5	31	23	26	26	206	191	172	155	142	-1.4	-1.9	-1.6	25	25
0.7	-1.7	-2.0	-1.8	22	30	26	24	234	189	152	126	112	-3.5	-3.0	-3.3	22	20
-0.1	-0.8	-0.7	-0.8	38	39	39	40	336	311	284	264	246	-1.4	-1.4	-1.4	42	43
-0.6	0.0	-0.4	-0.2	8.9	7.8	9.0	9.6	73	73	72	71	69	0.0	-0.4	-0.2	11	12

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
0.6	1.9	0.0	1.2	100	100	100	100	3 627	4 016	4 256	4 401	4 673	2.7	0.9	2.0	100	100
-2.7	-7.0	-4.6	-6.1	37	13	2.7	1.7	156	98	54	41	41	-10.4	-2.8	-7.6	1.3	0.9
-4.0	-100	n.a.	-100	8.4	1.8	-	-	-	-	-	-	-	-100	n.a.	-100	-	-
2.7	-2.6	-6.0	-3.9	8.3	17	7.8	4.2	334	274	129	80	66	-7.2	-6.5	-6.9	3.0	1.4
-0.5	0.7	-1.6	-0.2	32	23	19	16	710	825	866	855	924	2.0	0.7	1.5	20	20
0.5	0.5	0.2	0.4	13	12	9.5	9.8	348	352	357	361	366	0.5	0.2	0.4	8.4	7.8
2.0	4.7	0.1	3.0	0.1	0.2	0.4	0.4	9.7	14	15	15	15	5.1	0.2	3.3	0.3	0.3
34.2	8.6	1.1	5.7	0.0	9.1	27	30	879	1 082	1 285	1 351	1 417	10.2	1.0	6.7	30	30
21.5	4.3	1.3	3.2	0.0	18	26	30	895	1 054	1 213	1 333	1 454	5.6	1.8	4.2	29	31
7.6	1.0	0.2	0.7	0.0	0.2	0.2	0.2	6.7	7.0	7.2	7.4	7.6	1.4	0.6	1.1	0.2	0.2
6.9	2.8	0.3	1.9	0.8	6.3	7.4	7.6	281	290	299	305	311	3.3	0.4	2.2	7.0	6.7
n.a.	n.a.	9.6	n.a.	-	-	0.3	0.6	1.7	13	25	46	67	n.a.	10.3	n.a.	0.6	1.4
10.7	0.0	0.0	0.0	0.0	0.2	0.2	0.2	6.0	6.0	6.0	6.0	6.0	0.0	0.0	0.0	0.1	0.1

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
-1.4	-2.2	-2.3	-2.3	1 900	1 449	1 002	594	289	-5.3	-11.7	-7.7	
n.a.	n.a.	n.a.	n.a.	-	-	34	99	165	n.a.	17.1	n.a.	

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
1.6	1.4	1.3	1.4	17 038	18 344	19 670	21 003	22 287	1.4	1.3	1.4
0.2	-0.1	-0.3	-0.2	446	442	438	433	427	-0.1	-0.3	-0.2
1.4	1.6	1.5	1.6	38	41	45	48	52	1.6	1.5	1.6
-0.6	-0.6	-0.7	-0.7	2.6	2.4	2.3	2.2	2.2	-1.2	-0.4	-0.9
-2.0	-2.2	-2.2	-2.2	68	59	51	45	42	-2.7	-1.9	-2.4
-2.9	-3.6	-3.5	-3.6	112	79	51	28	13	-6.6	-12.8	-8.9
-0.9	-1.4	-1.4	-1.4	1.6	1.3	1.0	0.6	0.3	-4.0	-11.1	-6.7

Table A43 | Africa

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	354	437	610	813	898	985	1 047	1 115	1 196
Coal	74	90	109	103	99	104	111	122	131
Oil	85	100	161	215	235	256	283	311	338
Natural gas	30	47	89	143	167	214	262	319	381
Nuclear	2.2	3.4	3.2	2.2	5.6	7.8	10.0	8.8	8.8
Hydro	4.8	6.4	9.4	14	18	22	26	32	39
Geothermal	0.3	0.4	0.9	5.2	13	22	27	32	37
Solar, wind, etc.	0.0	0.0	0.3	5.0	19	27	35	43	51
Biomass and waste	158	187	237	324	342	333	293	247	210
Hydrogen	-	-	-	-	-0.1	-0.3	-0.7	-0.9	-1.1

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	247	307	421	564	629	676	698	716	747
Coal	20	19	18	21	22	22	23	24	25
Oil	70	89	136	188	208	233	260	287	311
Natural gas	9.3	15	28	48	58	66	72	79	85
Electricity	22	31	47	64	82	103	130	161	197
Heat	-	-	-	-	-	-	0.0	0.0	0.0
Hydrogen	-	-	-	-	-	-	0.1	0.3	0.6
Renewables and waste	126	153	192	243	260	251	212	165	128
Industry	55	59	85	98	114	129	145	162	178
Transport	38	54	87	131	142	158	176	194	212
Buildings, etc.	144	179	230	309	345	357	342	322	315
Non-energy use	11	15	19	25	28	31	35	38	42

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	315	442	687	912	1 169	1 466	1 842	2 272	2 747
Coal	164	208	259	226	206	227	255	300	337
Oil	40	37	65	73	58	50	42	42	42
Natural gas	45	107	235	382	440	571	764	989	1 245
Nuclear	8.4	13	12	8.5	21	30	38	34	34
Hydro	56	75	110	164	209	252	306	372	453
Geothermal	0.3	0.4	1.1	6.0	15	25	31	37	44
Solar photovoltaics	-	0.0	0.3	17	141	213	288	360	434
Wind	-	0.2	2.4	29	70	88	108	127	147
Concentrated solar power and marine	-	-	-	3.0	3.2	3.3	3.4	3.5	3.6
Biomass and waste	0.5	1.5	2.4	2.4	3.9	4.4	4.8	5.3	5.8
Hydrogen	-	-	-	-	-	-	-	-	-
Others	-	0.1	0.6	1.5	1.5	1.5	1.5	1.5	1.5

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	542	672	1 039	1 270	1 366	1 547	1 756	2 007	2 254
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	967	1 233	2 040	2 865	3 742	4 682	5 843	7 227	8 845
Population (million)	625	805	1 038	1 430	1 667	1 843	2 022	2 201	2 378
GDP per capita ($2015 thousand)	1.5	1.5	2.0	2.0	2.2	2.5	2.9	3.3	3.7
Primary energy consumption per capita (toe/person)	0.6	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5
Primary energy consumption per GDP (toe/$2015 million)	366	354	299	284	240	210	179	154	135
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	560	544	509	443	365	331	301	278	255
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	1.5	1.5	1.7	1.6	1.5	1.6	1.7	1.8	1.9

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
2.6	1.5	1.3	1.4	100	100	100	100	853	882	898	921	950	0.6	0.6	0.6	100	100
1.0	0.4	1.7	0.9	21	13	11	11	92	85	79	75	68	-1.5	-1.5	-1.5	8.8	7.2
2.9	1.6	1.8	1.7	24	26	27	28	223	225	230	227	220	0.4	-0.4	0.1	26	23
4.9	3.6	3.8	3.7	8.4	18	25	32	166	209	241	270	295	3.1	2.0	2.7	27	31
0.0	9.2	-1.3	5.2	0.6	0.3	1.0	0.7	5.6	14	22	32	45	14.4	7.4	11.7	2.4	4.7
3.3	3.7	4.0	3.8	1.4	1.7	2.5	3.3	18	22	26	32	39	3.7	4.0	3.8	2.9	4.1
9.2	10.1	3.5	7.6	0.1	0.6	2.5	3.1	13	26	31	37	44	11.1	3.4	8.2	3.5	4.6
29.4	12.2	3.8	9.0	0.0	0.6	3.4	4.3	27	41	57	75	94	15.4	5.0	11.5	6.4	9.8
2.2	-0.6	-3.3	-1.6	45	40	28	18	310	265	219	185	158	-2.3	-3.2	-2.6	24	17
n.a.	n.a.	4.8	n.a.	-	-	-0.1	-0.1	-1.0	-4.9	-8.8	-12	-13	n.a.	3.9	n.a.	-1.0	-1.4

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
2.5	1.3	0.7	1.0	100	100	100	100	590	583	572	570	574	0.1	0.0	0.1	100	100
0.2	0.6	0.7	0.6	8.1	3.7	3.3	3.3	20	18	17	16	15	-1.2	-1.0	-1.1	3.0	2.7
3.0	1.9	1.8	1.9	28	33	37	42	202	213	220	222	220	0.9	0.0	0.6	38	38
5.1	2.4	1.6	2.1	3.8	8.6	10	11	55	58	59	58	57	1.1	-0.3	0.6	10	9.9
3.3	4.3	4.2	4.3	8.9	11	19	26	85	111	138	167	198	4.7	3.7	4.3	24	35
n.a.	n.a.	0.0	n.a.	-	-	0.0	0.0	-	-	0.0	0.0	0.0	n.a.	11.6	n.a.	0.0	0.0
n.a.	n.a.	24.0	n.a.	-	-	0.0	0.1	0.0	0.4	1.3	3.3	7.4	n.a.	18.7	n.a.	0.2	1.3
2.0	-0.8	-4.9	-2.3	51	43	30	17	228	183	137	103	76	-3.3	-5.8	-4.2	24	13
1.8	2.3	2.1	2.2	22	17	21	24	108	114	118	121	126	1.1	0.7	0.9	21	22
3.8	1.8	1.9	1.8	15	23	25	28	138	146	152	157	163	0.9	0.7	0.8	27	28
2.4	0.6	-0.8	0.1	58	55	49	42	316	293	268	253	244	-0.8	-0.9	-0.9	47	42
2.6	1.9	1.9	1.9	4.4	4.5	5.0	5.6	28	31	35	38	42	1.9	1.9	1.9	6.1	7.3

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
3.3	4.2	4.1	4.2	100	100	100	100	1 225	1 606	2 031	2 509	3 029	4.8	4.1	4.5	100	100
1.0	0.7	2.8	1.5	52	25	14	12	189	175	165	153	133	-1.8	-2.2	-2.0	8.1	4.4
1.8	-3.2	0.2	-2.0	13	8.0	2.3	1.5	40	25	21	15	5.2	-7.0	-13.2	-9.3	1.0	0.2
6.7	4.2	5.0	4.5	14	42	41	45	446	596	759	946	1 139	4.1	4.1	4.1	37	38
0.0	9.2	-1.3	5.2	2.7	0.9	2.1	1.2	21	55	84	121	171	14.4	7.4	11.7	4.1	5.7
3.3	3.7	4.0	3.8	18	18	17	17	209	252	306	372	453	3.7	4.0	3.8	15	15
9.2	10.1	3.5	7.6	0.1	0.7	1.7	1.6	15	30	36	43	51	11.1	3.4	8.2	1.8	1.7
n.a.	18.2	4.2	12.8	-	1.8	16	16	225	369	527	689	867	22.5	5.1	15.7	26	29
n.a.	8.1	3.1	6.2	-	3.2	5.8	5.3	71	94	120	155	195	8.8	5.0	7.4	5.9	6.4
n.a.	0.6	0.6	0.6	-	0.3	0.2	0.1	3.8	4.1	4.6	5.3	6.2	2.4	3.0	2.6	0.2	0.2
5.0	4.1	1.8	3.2	0.2	0.3	0.3	0.2	4.4	5.1	5.8	6.5	7.1	5.3	2.0	4.0	0.3	0.2
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	0.0	0.0	0.0	-	0.2	0.1	0.1	1.5	1.5	1.5	1.5	1.5	0.0	0.0	0.0	0.1	0.1

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
2.6	1.9	2.5	2.1	1 297	1 323	1 334	1 317	1 277	0.3	-0.4	0.0	
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	n.a.	n.a.	n.a.	

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
3.3	4.3	4.2	4.3	3 742	4 682	5 843	7 227	8 845	4.3	4.2	4.3	
2.5	2.1	1.6	1.9	1 667	1 843	2 022	2 201	2 378	2.1	1.6	1.9	
0.8	2.2	2.6	2.3	2.2	2.5	2.9	3.3	3.7	2.2	2.6	2.3	
0.0	-0.5	-0.3	-0.4	0.5	0.5	0.4	0.4	0.4	-1.4	-1.1	-1.3	
-0.8	-2.7	-2.8	-2.7	228	188	154	127	107	-3.5	-3.5	-3.5	
-0.7	-2.3	-1.6	-2.0	346	283	228	182	144	-3.8	-4.5	-4.1	
0.1	0.4	1.2	0.7	1.5	1.5	1.5	1.4	1.3	-0.3	-1.0	-0.6	

Table A44 | Middle East

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	223	380	647	899	978	1 036	1 088	1 148	1 206
Coal	3.0	8.1	9.2	7.8	6.8	6.0	5.0	4.8	4.9
Oil	146	224	323	372	377	391	399	405	406
Natural gas	72	145	311	501	563	604	644	694	748
Nuclear	-	-	-	10	13	13	13	13	13
Hydro	1.0	0.7	1.5	1.7	2.4	2.6	2.6	2.7	2.8
Geothermal	-	-	-	-	-	-	-	-	-
Solar, wind, etc.	0.4	0.7	1.3	4.5	14	18	23	27	30
Biomass and waste	0.5	0.5	1.0	1.4	1.6	1.7	1.7	1.8	1.9
Hydrogen	-	-	-	-	-0.3	-0.6	-0.9	-1.0	-1.0

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	158	260	451	610	672	713	748	782	813
Coal	0.2	0.5	0.6	2.8	3.1	3.0	3.0	2.9	2.8
Oil	108	160	238	272	298	317	333	348	359
Natural gas	32	66	149	231	250	258	261	262	261
Electricity	17	32	62	101	119	133	149	166	185
Heat	-	-	-	-	-	-	-	-	-
Hydrogen	-	-	-	-	0.0	0.0	0.3	1.0	2.1
Renewables and waste	0.8	1.0	2.2	2.0	2.1	2.1	2.2	2.2	2.3
Industry	42	64	119	160	183	194	200	205	209
Transport	51	75	122	156	165	173	180	186	191
Buildings, etc.	47	82	136	198	215	226	237	247	257
Non-energy use	19	38	75	96	110	120	131	143	155

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	244	472	888	1 502	1 713	1 898	2 103	2 344	2 600
Coal	11	30	35	17	11	6.9	2.6	1.7	2.0
Oil	108	189	290	362	296	262	224	180	128
Natural gas	114	246	545	1 026	1 178	1 351	1 543	1 775	2 031
Nuclear	-	-	-	39	51	51	52	51	51
Hydro	12	8.0	18	20	28	30	31	32	33
Geothermal	-	-	-	-	-	-	-	-	-
Solar photovoltaics	-	-	0.1	32	133	176	224	263	297
Wind	0.0	0.0	0.2	4.7	10	15	20	27	35
Concentrated solar power and marine	-	-	-	2.0	2.8	2.8	3.0	3.2	3.2
Biomass and waste	-	0.0	0.1	0.0	1.0	1.1	1.2	1.3	1.4
Hydrogen	-	-	-	-	-	1.1	2.3	10	18
Others	-	-	0.0	0.2	0.2	0.2	0.2	0.2	0.2

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	551	922	1 524	2 054	2 157	2 259	2 341	2 442	2 533
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	911	1 378	2 092	3 000	3 661	4 200	4 791	5 446	6 167
Population (million)	131	168	217	284	320	342	364	384	404
GDP per capita ($2015 thousand)	6.9	8.2	9.6	11	11	12	13	14	15
Primary energy consumption per capita (toe/person)	1.7	2.3	3.0	3.2	3.1	3.0	3.0	3.0	3.0
Primary energy consumption per GDP (toe/$2015 million)	244	276	309	300	267	247	227	211	195
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	605	669	728	685	589	538	489	448	411
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.5	2.4	2.4	2.3	2.2	2.2	2.2	2.1	2.1

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
4.3	1.1	1.0	1.1	100	100	100	100	950	972	983	1 011	1 040	0.5	0.6	0.5	100	100
3.0	-2.6	-0.1	-1.7	1.3	0.9	0.5	0.4	4.9	3.6	3.2	3.4	3.5	-5.1	0.8	-2.9	0.3	0.3
2.9	0.4	0.2	0.3	66	41	37	34	351	328	298	272	254	-1.3	-1.6	-1.4	30	24
6.1	1.5	1.5	1.5	32	56	59	62	560	607	646	692	720	1.5	1.1	1.4	66	69
n.a.	1.6	0.0	1.0	-	1.1	1.2	1.1	13	17	21	23	25	4.4	1.8	3.4	2.2	2.4
1.5	2.7	0.6	1.9	0.5	0.2	0.2	0.2	2.4	2.5	2.6	2.7	2.8	2.6	0.6	1.9	0.3	0.3
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
7.5	10.0	3.0	7.3	0.2	0.5	2.1	2.5	20	30	42	57	74	14.1	5.6	10.9	4.3	7.1
3.4	1.1	0.9	1.0	0.2	0.2	0.2	0.2	1.7	1.8	2.0	2.4	2.9	2.1	3.7	2.7	0.2	0.3
n.a.	n.a.	1.4	n.a.	-	-	-0.1	-0.1	-3.8	-18	-32	-41	-42	n.a.	2.6	n.a.	-3.3	-4.0

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
4.2	1.2	0.8	1.1	100	100	100	100	655	662	656	654	657	0.4	0.0	0.3	100	100
8.5	0.4	-0.4	0.1	0.1	0.5	0.4	0.3	2.1	1.6	1.5	1.5	1.4	-3.5	-0.5	-2.4	0.2	0.2
2.8	1.2	0.8	1.0	68	45	45	44	290	291	284	273	263	0.2	-0.8	-0.1	43	40
6.2	0.7	0.0	0.5	20	38	35	32	239	224	201	177	155	-0.8	-2.6	-1.5	31	24
5.5	2.3	2.2	2.2	11	17	20	23	122	141	162	189	215	2.8	2.9	2.8	25	33
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	22.1	n.a.	-	-	0.0	0.3	0.0	1.9	5.3	10	19	n.a.	13.4	n.a.	0.8	2.8
2.9	0.6	0.7	0.7	0.5	0.3	0.3	0.3	2.1	2.2	2.4	2.8	3.3	1.2	3.1	1.9	0.4	0.5
4.1	1.3	0.4	1.0	27	26	27	26	174	169	159	147	138	-0.1	-1.4	-0.5	24	21
3.5	0.8	0.6	0.8	32	26	24	24	160	156	149	142	137	-0.3	-0.8	-0.5	23	21
4.5	1.1	0.8	1.0	29	32	32	32	212	216	217	223	227	0.6	0.4	0.5	33	35
5.1	1.9	1.7	1.8	12	16	18	19	110	120	131	143	155	1.9	1.7	1.8	20	24

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
5.7	2.0	2.1	2.1	100	100	100	100	1 786	2 073	2 406	2 886	3 382	2.8	3.5	3.1	100	100
1.4	-10.5	-2.3	-7.5	4.3	1.1	0.1	0.1	7.0	2.9	1.4	1.8	2.2	-13.6	4.5	-7.3	0.1	0.1
3.7	-2.8	-5.4	-3.8	44	24	11	4.9	240	163	88	53	44	-8.0	-6.7	-7.5	3.7	1.3
6.9	2.4	2.8	2.6	47	68	73	78	1 245	1 478	1 720	2 047	2 342	3.1	3.1	3.1	72	69
n.a.	1.6	0.0	1.0	-	2.6	2.5	2.0	51	63	81	89	97	4.4	1.8	3.4	3.4	2.9
1.5	2.7	0.6	1.9	4.9	1.3	1.5	1.3	28	30	31	32	33	2.6	0.6	1.9	1.3	1.0
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	12.2	2.9	8.6	-	2.1	11	11	199	308	441	586	748	16.7	5.4	12.4	18	22
29.2	8.9	5.5	7.6	0.0	0.3	1.0	1.3	11	19	31	53	80	11.7	10.0	11.1	1.3	2.4
n.a.	2.3	0.8	1.7	-	0.1	0.1	0.1	3.0	3.5	3.9	4.7	5.6	4.0	3.6	3.8	0.2	0.2
n.a.	27.4	1.5	17.1	-	0.0	0.1	0.1	1.2	1.4	1.6	1.7	1.8	29.2	1.6	18.2	0.1	0.1
n.a.	n.a.	23.2	n.a.	-	-	0.1	0.7	-	2.9	5.8	17	28	n.a.	17.2	n.a.	0.2	0.8
n.a.	0.0	0.0	0.0	-	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
4.1	0.8	0.8	0.8	2 055	1 958	1 819	1 646	1 476	-0.7	-2.1	-1.2	
n.a.	n.a.	n.a.	n.a.	-	-	-	34	78	n.a.	n.a.	n.a.	

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
3.7	2.8	2.6	2.7	3 661	4 200	4 791	5 446	6 167	2.8	2.6	2.7	
2.4	1.5	1.0	1.3	320	342	364	384	404	1.5	1.0	1.3	
1.3	1.3	1.5	1.4	11	12	13	14	15	1.3	1.5	1.4	
1.9	-0.3	0.0	-0.2	3.0	2.8	2.7	2.6	2.6	-0.9	-0.5	-0.8	
0.6	-1.6	-1.5	-1.6	259	231	205	186	169	-2.2	-1.9	-2.1	
0.4	-2.0	-1.7	-1.9	561	466	380	302	239	-3.4	-4.5	-3.8	
-0.2	-0.4	-0.2	-0.3	2.2	2.0	1.9	1.6	1.4	-1.2	-2.6	-1.8	

Table A45 | Oceania

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	99	125	145	150	154	152	151	149	148
Coal	36	49	52	36	26	23	21	19	18
Oil	35	40	48	53	61	59	56	53	49
Natural gas	19	24	32	39	38	39	39	40	41
Nuclear	-	-	-	-	-	-	-	-	-
Hydro	3.2	3.5	3.3	3.6	3.8	3.8	3.9	4.0	4.2
Geothermal	1.5	2.0	3.3	4.9	6.3	6.3	6.3	6.3	6.3
Solar, wind, etc.	0.1	0.1	0.9	7.2	13	16	19	21	24
Biomass and waste	4.8	6.1	6.1	5.9	6.0	6.0	6.1	6.0	6.0
Hydrogen	-	-	-	-	-0.1	-0.1	-0.1	-0.1	0.0

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	66	82	90	95	98	99	99	99	99
Coal	5.2	4.7	3.1	3.0	3.2	3.1	2.9	2.8	2.6
Oil	33	40	45	49	49	48	47	44	42
Natural gas	10	14	14	14	15	15	15	15	15
Electricity	14	18	22	23	25	27	29	32	34
Heat	-	-	-	-	-	-	-	-	-
Hydrogen	-	-	-	-	-	-	0.0	0.1	0.2
Renewables and waste	3.8	5.2	5.3	5.4	5.3	5.4	5.3	5.3	5.2
Industry	23	28	26	27	28	29	30	30	31
Transport	24	30	35	38	39	38	37	36	34
Buildings, etc.	15	19	23	25	26	26	27	28	28
Non-energy use	4.6	6.1	5.9	5.6	5.7	5.7	5.7	5.7	5.7

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	187	249	298	318	356	383	412	445	480
Coal	122	176	182	129	100	89	80	77	74
Oil	3.6	1.8	6.1	4.9	3.5	3.0	2.5	2.2	1.9
Natural gas	20	26	54	53	49	51	52	56	60
Nuclear	-	-	-	-	-	-	-	-	-
Hydro	37	41	38	42	44	45	46	47	49
Geothermal	2.1	2.9	5.9	8.2	11	11	11	11	11
Solar photovoltaics	-	0.0	0.4	42	73	93	114	134	153
Wind	-	0.2	6.7	35	70	82	95	106	117
Concentrated solar power and marine	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass and waste	1.6	2.0	3.5	3.8	4.7	5.0	5.2	5.4	5.5
Hydrogen	-	-	-	-	1.3	4.0	6.7	7.5	8.4
Others	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	280	360	422	383	357	340	324	310	296
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	656	907	1 220	1 704	1 953	2 177	2 417	2 676	2 950
Population (million)	20	23	26	32	34	35	36	37	39
GDP per capita ($2015 thousand)	32	40	46	53	58	62	67	71	76
Primary energy consumption per capita (toe/person)	4.9	5.5	5.5	4.7	4.5	4.3	4.2	4.0	3.8
Primary energy consumption per GDP (toe/$2015 million)	151	138	119	88	79	70	62	56	50
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	426	397	345	225	183	156	134	116	100
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.8	2.9	2.9	2.5	2.3	2.2	2.2	2.1	2.0

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
1.3	0.0	-0.2	-0.1	100	100	100	100	153	144	135	133	131	-0.6	-0.3	-0.5	100	100
0.0	-3.2	-1.3	-2.5	36	24	14	12	27	29	31	35	34	-0.8	1.0	-0.2	23	26
1.3	0.3	-1.3	-0.3	35	36	37	33	57	48	37	27	18	-2.1	-6.9	-3.9	28	14
2.3	-0.1	0.4	0.1	19	26	26	27	39	38	36	35	34	-0.6	-0.4	-0.5	27	26
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
0.4	0.4	0.7	0.5	3.2	2.4	2.6	2.8	3.8	3.9	4.0	4.2	4.4	0.6	0.9	0.7	3.0	3.4
3.7	1.5	0.0	0.9	1.5	3.3	4.2	4.2	6.3	6.3	6.3	6.3	6.3	1.5	0.0	0.9	4.7	4.8
13.0	5.7	2.5	4.5	0.1	4.8	12	16	14	17	22	29	36	6.8	5.0	6.1	16	27
0.6	0.2	-0.1	0.1	4.9	3.9	4.0	4.1	6.0	5.8	5.6	5.4	5.3	-0.3	-0.6	-0.4	4.2	4.1
n.a.	n.a.	n.a.	n.a.	-	-	-0.1	0.0	-0.9	-4.0	-7.0	-8.7	-8.1	n.a.	1.5	n.a.	-5.2	-6.2

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
1.1	0.3	0.0	0.2	100	100	100	100	95	90	84	81	79	-0.7	-0.5	-0.7	100	100
-1.7	-0.2	-1.0	-0.5	7.9	3.2	2.9	2.6	2.8	2.2	1.7	1.4	1.2	-3.2	-3.6	-3.3	2.1	1.5
1.2	-0.4	-1.0	-0.6	50	52	47	42	47	41	35	28	23	-2.1	-3.9	-2.8	41	29
1.0	0.2	-0.3	0.0	16	15	15	15	14	13	11	9.1	7.1	-1.5	-4.3	-2.6	13	9.0
1.6	1.6	1.6	1.6	21	24	30	35	26	28	31	35	40	1.8	2.7	2.1	37	50
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
n.a.	n.a.	21.8	n.a.	-	-	0.0	0.2	0.0	0.3	0.8	1.7	3.6	n.a.	15.7	n.a.	1.0	4.5
1.1	-0.1	-0.2	-0.1	5.8	5.7	5.4	5.3	5.3	5.1	4.8	4.5	4.4	-0.7	-0.9	-0.8	5.8	5.5
0.5	0.6	0.2	0.5	34	28	30	31	27	26	24	22	21	-0.7	-1.5	-1.0	29	26
1.4	-0.2	-0.7	-0.4	36	40	37	35	37	33	30	26	24	-1.5	-2.0	-1.6	35	31
1.6	0.5	0.5	0.5	22	26	27	29	25	25	25	27	29	0.0	1.6	0.6	29	36
0.6	0.1	0.0	0.0	6.9	5.9	5.7	5.8	5.7	5.7	5.7	5.7	5.7	0.1	0.0	0.0	6.8	7.2

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
1.6	1.5	1.5	1.5	100	100	100	100	365	410	460	565	662	2.2	3.7	2.7	100	100
0.2	-2.7	-0.8	-2.0	65	40	20	15	96	86	76	82	81	-3.1	0.7	-1.7	16	12
1.0	-3.9	-2.6	-3.4	1.9	1.5	0.6	0.4	3.1	2.1	1.3	0.7	0.0	-7.5	-35.6	-19.1	0.3	0.0
3.0	-0.1	1.5	0.5	11	17	13	13	53	60	64	81	94	1.1	4.0	2.1	14	14
n.a.	n.a.	n.a.	n.a.	-	-	-	-	-	-	-	-	-	n.a.	n.a.	n.a.	-	-
0.4	0.4	0.7	0.5	20	13	11	10	44	45	47	49	51	0.6	0.9	0.7	10	7.7
4.2	1.5	0.0	1.0	1.1	2.6	2.6	2.2	11	11	11	11	11	1.5	0.0	1.0	2.3	1.6
n.a.	6.0	3.0	4.9	-	13	28	32	81	110	143	188	233	7.4	5.0	6.5	31	35
n.a.	6.1	2.1	4.6	-	11	23	24	71	86	105	140	176	6.8	5.3	6.2	23	27
n.a.	6.1	0.0	3.8	-	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	22.1	8.6	17.0	0.0	0.0
2.7	1.8	0.5	1.4	0.9	1.2	1.3	1.1	4.7	5.0	5.3	5.6	5.9	2.0	0.9	1.6	1.2	0.9
n.a.	n.a.	2.3	n.a.	-	-	1.6	1.7	1.4	4.2	7.0	7.9	8.8	n.a.	2.3	n.a.	1.5	1.3
-1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
1.0	-1.0	-0.9	-1.0	347	268	196	108	25	-3.9	-18.5	-9.6
n.a.	n.a.	n.a.	n.a.	-	-	0.3	18	45	n.a.	62.8	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
2.9	2.1	2.0	2.1	1 953	2 177	2 417	2 676	2 950	2.1	2.0	2.1
1.4	0.8	0.6	0.7	34	35	36	37	39	0.8	0.6	0.7
1.5	1.3	1.4	1.3	58	62	67	71	76	1.3	1.4	1.3
-0.1	-0.7	-0.8	-0.8	4.5	4.1	3.7	3.6	3.4	-1.4	-0.9	-1.2
-1.6	-2.0	-2.1	-2.1	78	66	56	50	44	-2.7	-2.3	-2.5
-1.9	-3.0	-2.9	-2.9	178	123	81	40	8.6	-5.8	-20.1	-11.4
-0.3	-1.0	-0.7	-0.9	2.3	1.9	1.5	0.8	0.2	-3.3	-18.3	-9.1

Table A46 | Advanced Economies

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	4 467	5 233	5 355	4 943	4 722	4 613	4 474	4 330	4 210
Coal	1 087	1 115	1 109	622	433	368	320	286	254
Oil	1 827	2 070	1 919	1 733	1 577	1 477	1 371	1 258	1 145
Natural gas	827	1 136	1 287	1 457	1 417	1 398	1 358	1 316	1 277
Nuclear	463	596	606	479	500	508	498	470	458
Hydro	100	111	112	111	123	125	127	128	130
Geothermal	22	25	25	41	51	62	64	65	66
Solar, wind, etc.	2.1	6.1	31	167	275	335	401	477	556
Biomass and waste	139	172	262	331	349	344	339	330	321
Hydrogen	-	-	-	-	0.7	1.2	0.7	2.7	5.0

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	3 059	3 579	3 649	3 523	3 429	3 345	3 240	3 135	3 039
Coal	230	137	130	82	79	72	65	60	55
Oil	1 561	1 812	1 740	1 610	1 486	1 396	1 300	1 197	1 095
Natural gas	578	732	717	730	725	705	673	636	600
Electricity	553	715	809	812	856	899	941	993	1 050
Heat	48	52	66	57	57	55	52	49	46
Hydrogen	-	-	-	-	0.1	0.1	1.0	3.3	6.5
Renewables and waste	89	131	186	232	226	218	207	196	186
Industry	827	905	805	772	773	767	751	731	711
Transport	921	1 121	1 151	1 182	1 082	1 008	937	865	796
Buildings, etc.	1 024	1 185	1 311	1 201	1 188	1 178	1 156	1 140	1 130
Non-energy use	288	368	382	369	385	391	396	399	401

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	7 673	9 704	10 843	10 818	11 496	12 092	12 704	13 450	14 272
Coal	3 136	3 835	3 813	1 965	1 224	979	798	677	553
Oil	667	539	274	131	74	59	47	37	28
Natural gas	766	1 528	2 501	3 312	3 170	3 206	3 175	3 186	3 177
Nuclear	1 776	2 288	2 324	1 837	1 919	1 951	1 912	1 806	1 759
Hydro	1 158	1 293	1 302	1 291	1 435	1 454	1 472	1 489	1 506
Geothermal	23	27	37	54	69	85	89	90	92
Solar photovoltaics	0.1	0.7	31	685	1 545	1 997	2 515	3 064	3 627
Wind	3.8	29	269	1 119	1 519	1 752	2 007	2 339	2 696
Concentrated solar power and marine	1.2	1.1	2.1	9.2	8.3	8.7	9.0	10.0	11
Biomass and waste	122	143	258	375	475	498	537	554	571
Hydrogen	-	-	-	-	17	60	104	158	212
Others	20	22	33	40	40	40	40	40	40

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	10 763	12 180	11 931	10 038	8 647	8 037	7 424	6 828	6 256
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	27 250	35 877	42 387	54 216	60 965	66 212	71 633	77 139	82 582
Population (million)	1 000	1 072	1 140	1 209	1 219	1 223	1 223	1 221	1 215
GDP per capita ($2015 thousand)	27	33	37	45	50	54	59	63	68
Primary energy consumption per capita (toe/person)	4.5	4.9	4.7	4.1	3.9	3.8	3.7	3.5	3.5
Primary energy consumption per GDP (toe/$2015 million)	164	146	126	91	77	70	62	56	51
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	395	339	281	185	142	121	104	89	76
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.4	2.3	2.2	2.0	1.8	1.7	1.7	1.6	1.5

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
0.3	-0.6	-0.6	-0.6	100	100	100	100	4 614	4 359	4 061	3 863	3 734	-1.2	-0.8	-1.0	100	100
-1.7	-3.8	-2.3	-3.3	24	13	7.1	6.0	362	265	209	189	175	-6.2	-1.7	-4.6	5.1	4.7
-0.2	-1.4	-1.8	-1.5	41	35	31	27	1 475	1 226	974	728	540	-3.3	-5.7	-4.2	24	14
1.7	-0.4	-0.6	-0.5	19	29	30	30	1 381	1 311	1 152	1 009	859	-1.4	-2.9	-1.9	28	23
0.1	0.2	-0.8	-0.2	10	9.7	11	11	545	582	623	643	675	1.6	0.8	1.3	15	18
0.3	0.8	0.2	0.6	2.2	2.2	2.8	3.1	124	126	127	129	130	0.8	0.2	0.6	3.1	3.5
1.9	2.7	0.3	1.8	0.5	0.8	1.4	1.6	51	65	68	69	70	3.0	0.3	2.0	1.7	1.9
14.3	5.3	3.3	4.6	0.0	3.4	9.0	13	303	412	536	710	880	7.1	5.1	6.3	13	24
2.7	0.1	-0.5	-0.1	3.1	6.7	7.6	7.6	374	366	360	354	350	0.5	-0.3	0.2	8.9	9.4
n.a.	n.a.	21.5	n.a.	-	-	0.0	0.1	5.1	12	16	36	58	n.a.	13.7	n.a.	0.4	1.6

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
0.4	-0.5	-0.6	-0.5	100	100	100	100	3 326	3 070	2 787	2 565	2 411	-1.4	-1.4	-1.4	100	100
-3.1	-1.4	-1.7	-1.5	7.5	2.3	2.0	1.8	69	53	43	35	30	-3.8	-3.4	-3.7	1.5	1.3
0.1	-1.3	-1.7	-1.4	51	46	40	36	1 403	1 190	969	777	624	-2.9	-4.3	-3.5	35	26
0.7	-0.5	-1.1	-0.7	19	21	21	20	686	599	492	388	292	-2.3	-5.1	-3.3	18	12
1.2	0.9	1.1	1.0	18	23	29	35	877	939	989	1 051	1 093	1.2	1.0	1.1	35	45
0.5	-0.5	-1.3	-0.8	1.6	1.6	1.6	1.5	55	52	47	41	37	-1.2	-2.4	-1.6	1.7	1.5
n.a.	n.a.	20.6	n.a.	-	-	0.0	0.2	0.3	14	36	69	138	n.a.	14.6	n.a.	1.3	5.7
3.0	-0.7	-1.1	-0.8	2.9	6.6	6.4	6.1	235	223	212	204	198	-0.5	-0.7	-0.6	7.6	8.2
-0.2	-0.2	-0.5	-0.3	27	22	23	23	743	689	619	556	508	-1.3	-1.9	-1.5	22	21
0.8	-1.4	-1.6	-1.5	30	34	29	26	1 030	873	728	615	550	-2.8	-2.8	-2.8	26	23
0.5	-0.2	-0.2	-0.2	33	34	36	37	1 168	1 117	1 044	995	952	-0.8	-0.9	-0.9	37	39
0.8	0.4	0.1	0.3	9.4	10	12	13	385	391	396	399	401	0.4	0.1	0.3	14	17

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
1.0	0.9	1.2	1.0	100	100	100	100	11 822	13 056	14 207	16 100	17 897	1.6	2.3	1.9	100	100
-1.4	-5.2	-3.6	-4.6	41	18	6.3	3.9	940	560	337	265	231	-9.9	-3.7	-7.6	2.4	1.3
-4.8	-5.8	-5.2	-5.6	8.7	1.2	0.4	0.2	63	49	39	29	18	-6.8	-7.3	-7.0	0.3	0.1
4.5	-0.2	0.0	-0.2	10.0	31	25	22	3 208	3 276	2 914	2 654	2 262	-0.7	-2.5	-1.4	21	13
0.1	0.2	-0.8	-0.2	23	17	15	12	2 090	2 232	2 392	2 467	2 589	1.6	0.8	1.3	17	14
0.3	0.8	0.2	0.6	15	12	12	11	1 441	1 461	1 481	1 499	1 516	0.8	0.2	0.6	10	8.5
2.6	2.9	0.4	2.0	0.3	0.5	0.7	0.6	69	91	94	97	99	3.3	0.5	2.2	0.7	0.6
31.2	7.9	3.7	6.4	0.0	6.3	20	25	1 801	2 563	3 415	4 438	5 392	9.9	4.7	7.9	24	30
18.8	3.5	3.0	3.3	0.1	10	16	19	1 593	2 087	2 679	3 674	4 688	5.3	5.8	5.4	19	26
6.4	-0.1	1.8	0.6	0.0	0.1	0.1	0.1	8.9	10	12	16	20	1.7	5.1	2.9	0.1	0.1
3.5	2.1	0.6	1.6	1.6	3.5	4.2	4.0	544	577	613	635	657	2.9	0.7	2.1	4.3	3.7
n.a.	n.a.	7.4	n.a.	-	-	0.8	1.5	26	108	190	288	385	n.a.	7.4	n.a.	1.3	2.2
2.2	0.0	0.0	0.0	0.3	0.4	0.3	0.3	40	40	40	40	40	0.0	0.0	0.0	0.3	0.2

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
-0.2	-1.8	-1.7	-1.7	7 957	6 208	4 475	2 697	1 281	-4.6	-11.8	-7.3	
n.a.	n.a.	n.a.	n.a.	-	-	89	332	615	n.a.	21.3	n.a.	

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
2.1	1.7	1.4	1.6	60 965	66 212	71 633	77 139	82 582	1.7	1.4	1.6
0.6	0.1	-0.1	0.0	1 219	1 223	1 223	1 221	1 215	0.1	-0.1	0.0
1.5	1.6	1.5	1.6	50	54	59	63	68	1.6	1.5	1.6
-0.3	-0.7	-0.5	-0.6	3.8	3.6	3.3	3.2	3.1	-1.2	-0.8	-1.1
-1.8	-2.2	-2.0	-2.1	76	66	57	50	45	-2.8	-2.2	-2.6
-2.3	-3.4	-3.1	-3.3	131	94	62	35	16	-6.2	-13.0	-8.8
-0.5	-1.2	-1.1	-1.2	1.7	1.4	1.1	0.7	0.3	-3.5	-11.0	-6.4

Table A47 | Group of Seven

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	3 490	4 024	3 945	3 555	3 365	3 270	3 161	3 050	2 974
Coal	787	811	776	367	221	178	148	132	118
Oil	1 447	1 578	1 413	1 247	1 104	1 025	942	856	771
Natural gas	704	941	992	1 162	1 132	1 115	1 081	1 049	1 025
Nuclear	370	485	482	356	397	395	380	351	346
Hydro	66	72	72	69	80	81	82	83	84
Geothermal	19	21	16	19	23	26	27	28	29
Solar, wind, etc.	1.6	4.1	20	111	187	235	286	338	396
Biomass and waste	95	114	175	221	226	221	219	212	206
Hydrogen	-	-	-	-	0.1	-0.0	-0.7	-0.2	0.5

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	2 378	2 737	2 676	2 558	2 457	2 389	2 308	2 229	2 159
Coal	146	76	68	42	38	36	33	30	28
Oil	1 238	1 395	1 294	1 175	1 062	990	916	837	759
Natural gas	495	613	568	583	578	560	533	502	473
Electricity	435	548	594	576	605	639	670	711	757
Heat	13	19	26	22	21	20	19	18	17
Hydrogen	-	-	-	-	0.0	0.0	0.7	2.4	4.8
Renewables and waste	51	85	126	160	152	144	137	128	121
Industry	602	646	545	516	505	499	486	472	459
Transport	768	915	909	913	828	770	715	659	606
Buildings, etc.	783	904	972	887	878	872	855	844	839
Non-energy use	226	272	250	243	245	248	251	254	255

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	6 042	7 437	7 990	7 639	8 119	8 574	9 041	9 554	10 248
Coal	2 506	2 963	2 844	1 206	618	446	330	272	217
Oil	553	373	189	92	61	50	40	32	25
Natural gas	647	1 236	1 845	2 624	2 489	2 520	2 493	2 520	2 564
Nuclear	1 419	1 862	1 849	1 367	1 524	1 516	1 459	1 348	1 327
Hydro	765	832	834	805	932	944	954	964	973
Geothermal	21	23	26	29	36	41	44	45	47
Solar photovoltaics	0.1	0.6	21	448	1 052	1 420	1 833	2 225	2 647
Wind	3.1	17	176	775	1 054	1 234	1 419	1 628	1 880
Concentrated solar power and marine	1.2	1.1	1.4	3.6	3.6	4.0	4.1	4.2	4.3
Biomass and waste	107	110	175	257	309	325	357	369	382
Hydrogen	-	-	-	-	11	43	76	113	151
Others	20	21	31	32	32	32	32	32	32

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	8 377	9 354	8 791	7 248	6 137	5 687	5 241	4 828	4 450
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	21 501	27 927	31 987	40 084	44 720	48 450	52 410	56 468	60 526
Population (million)	652	699	741	781	791	795	798	800	800
GDP per capita ($2015 thousand)	33	40	43	51	57	61	66	71	76
Primary energy consumption per capita (toe/person)	5.4	5.8	5.3	4.6	4.3	4.1	4.0	3.8	3.7
Primary energy consumption per GDP (toe/$2015 million)	162	144	123	89	75	68	60	54	49
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	390	335	275	181	137	117	100	86	74
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.4	2.3	2.2	2.0	1.8	1.7	1.7	1.6	1.5

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
0.1	-0.7	-0.6	-0.7	100	100	100	100	3 279	3 075	2 854	2 701	2 612	-1.3	-0.9	-1.1	100	100
-2.3	-5.2	-2.2	-4.1	23	10	4.7	4.0	173	107	84	77	74	-8.3	-1.2	-5.7	2.9	2.8
-0.4	-1.6	-2.0	-1.8	41	35	30	26	1 029	846	658	478	341	-3.7	-6.4	-4.7	23	13
1.5	-0.4	-0.5	-0.5	20	33	34	34	1 112	1 066	949	839	711	-1.2	-2.8	-1.8	33	27
-0.1	0.4	-0.9	-0.1	11	10	12	12	413	423	442	442	473	1.3	0.7	1.1	15	18
0.2	1.0	0.2	0.7	1.9	1.9	2.6	2.8	81	82	83	84	84	1.1	0.2	0.7	2.9	3.2
0.0	2.2	0.6	1.6	0.5	0.5	0.9	1.0	23	27	29	30	31	2.6	0.7	1.9	1.0	1.2
13.6	5.7	3.3	4.8	0.0	3.1	9.1	13	206	290	379	511	646	7.5	5.5	6.7	13	25
2.6	-0.1	-0.6	-0.3	2.7	6.2	6.9	6.9	249	244	243	242	242	0.5	-0.1	0.3	8.5	9.2
n.a.	n.a.	n.a.	n.a.	-	-	-0.0	0.0	-1.1	-6.4	-7.9	-1.1	11	n.a.	n.a.	n.a.	-0.3	0.4

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
0.2	-0.6	-0.7	-0.6	100	100	100	100	2 380	2 185	1 974	1 811	1 701	-1.5	-1.5	-1.5	100	100
-3.7	-1.4	-1.5	-1.4	6.1	1.6	1.4	1.3	34	27	22	19	17	-3.6	-3.0	-3.4	1.1	1.0
-0.2	-1.5	-1.9	-1.6	52	46	40	35	998	834	667	522	406	-3.3	-4.8	-3.9	34	24
0.5	-0.5	-1.2	-0.8	21	23	23	22	545	474	389	306	230	-2.4	-5.1	-3.4	20	14
0.9	0.9	1.2	1.0	18	23	29	35	622	668	705	752	784	1.2	1.1	1.1	36	46
1.6	-0.7	-1.3	-1.0	0.5	0.8	0.8	0.8	20	19	17	15	13	-1.4	-2.2	-1.7	0.9	0.8
n.a.	n.a.	20.9	n.a.	-	-	0.0	0.2	0.1	11	27	53	109	n.a.	14.9	n.a.	1.4	6.4
3.5	-0.9	-1.2	-1.0	2.1	6.3	5.9	5.6	161	152	147	144	142	-0.5	-0.3	-0.5	7.4	8.3
-0.5	-0.3	-0.6	-0.4	25	20	21	21	485	445	396	353	320	-1.5	-2.1	-1.8	20	19
0.5	-1.4	-1.6	-1.5	32	36	31	28	787	666	555	469	420	-2.9	-2.7	-2.8	28	25
0.4	-0.2	-0.2	-0.2	33	35	37	39	863	826	771	736	706	-0.8	-0.9	-0.8	39	42
0.2	0.2	0.2	0.2	9.5	9.5	11	12	245	248	251	254	255	0.2	0.2	0.2	13	15

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
0.7	1.0	1.3	1.1	100	100	100	100	8 368	9 304	10 152	11 520	12 900	1.7	2.4	2.0	100	100
-2.2	-7.3	-4.1	-6.2	41	16	3.6	2.1	425	164	81	68	68	-14.7	-1.8	-10.1	0.8	0.5
-5.3	-4.8	-4.6	-4.7	9.2	1.2	0.4	0.2	52	42	35	26	18	-5.5	-6.5	-5.9	0.3	0.1
4.3	-0.3	0.3	-0.1	11	34	28	25	2 587	2 675	2 414	2 180	1 780	-0.5	-3.0	-1.4	24	14
-0.1	0.4	-0.9	-0.1	23	18	16	13	1 584	1 625	1 696	1 697	1 816	1.3	0.7	1.1	17	14
0.2	1.0	0.2	0.7	13	11	11	9.5	937	950	962	972	980	1.1	0.2	0.7	9.5	7.6
1.0	2.4	0.7	1.8	0.3	0.4	0.5	0.5	36	44	47	49	50	2.8	0.8	2.1	0.5	0.4
30.1	8.6	3.7	6.8	0.0	5.9	20	26	1 195	1 796	2 421	3 227	4 033	10.4	5.2	8.5	24	31
18.2	3.6	2.9	3.3	0.1	10	16	18	1 127	1 505	1 916	2 635	3 403	5.5	5.9	5.6	19	26
3.4	0.9	0.4	0.7	0.0	0.0	0.0	0.0	4.2	4.6	4.9	5.3	5.7	1.9	1.6	1.8	0.0	0.0
2.7	1.9	0.7	1.5	1.8	3.4	3.9	3.7	371	396	423	440	456	3.0	0.8	2.1	4.2	3.5
n.a.	n.a.	7.1	n.a.	-	-	0.8	1.5	18	70	121	190	259	n.a.	7.9	n.a.	1.2	2.0
1.5	0.0	0.0	0.0	0.3	0.4	0.4	0.3	32	32	32	32	32	0.0	0.0	0.0	0.3	0.2

Reference Scenario				Advanced Technologies Scenario								
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050	
				2030	2035	2040	2045	2050				
-0.4	-1.9	-1.6	-1.8	5 663	4 398	3 169	1 865	823	-4.7	-12.6	-7.7	
n.a.	n.a.	n.a.	n.a.	-	-	69	269	499	n.a.	21.8	n.a.	

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
1.9	1.6	1.5	1.5	44 720	48 450	52 410	56 468	60 526	1.6	1.5	1.5
0.5	0.1	0.0	0.1	791	795	798	800	800	0.1	0.0	0.1
1.4	1.5	1.4	1.4	57	61	66	71	76	1.5	1.4	1.4
-0.5	-0.8	-0.6	-0.7	4.1	3.9	3.6	3.4	3.3	-1.4	-0.9	-1.2
-1.8	-2.2	-2.0	-2.2	73	63	54	48	43	-2.8	-2.3	-2.6
-2.3	-3.4	-3.0	-3.3	127	91	60	33	14	-6.2	-13.9	-9.1
-0.5	-1.2	-1.0	-1.1	1.7	1.4	1.1	0.7	0.3	-3.5	-11.8	-6.7

Table A48 | Emerging and Developing Economies

Primary energy consumption	Reference Scenario (Million tonnes of oil equivalent [Mtoe])								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total[*1]	4 032	4 430	7 020	9 800	10 481	10 999	11 461	11 941	12 361
Coal	1 133	1 198	2 536	3 581	3 235	3 084	3 018	2 984	2 890
Oil	1 208	1 338	1 873	2 454	2 621	2 723	2 837	2 940	3 017
Natural gas	835	933	1 450	1 985	2 190	2 387	2 597	2 855	3 138
Nuclear	62	79	113	236	330	393	448	484	513
Hydro	85	114	185	255	290	308	326	345	365
Geothermal	12	26	35	69	106	182	201	213	225
Solar, wind, etc.	0.5	2.1	17	218	592	792	927	1 049	1 173
Biomass and waste	697	740	813	1 006	1 111	1 127	1 103	1 069	1 045
Hydrogen	-	-	-	-	-0.7	-1.2	-0.7	-2.7	-5.0

Final energy consumption	Reference Scenario (Mtoe)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	2 922	3 074	4 710	6 334	7 002	7 349	7 627	7 887	8 123
Coal	521	404	916	800	815	789	762	739	717
Oil	845	1 042	1 521	2 123	2 298	2 406	2 525	2 631	2 717
Natural gas	369	390	632	949	1 042	1 090	1 122	1 144	1 158
Electricity	281	372	729	1 360	1 685	1 911	2 125	2 347	2 565
Heat	288	197	210	328	369	368	352	332	310
Hydrogen	-	-	-	-	0.2	0.2	1.2	3.7	7.4
Renewables and waste	618	670	702	775	792	786	741	691	650
Industry	971	959	1 816	2 308	2 620	2 765	2 853	2 921	2 948
Transport	456	570	919	1 362	1 498	1 571	1 658	1 748	1 832
Buildings, etc.	1 306	1 294	1 562	2 030	2 159	2 246	2 306	2 374	2 465
Non-energy use	190	251	413	633	725	767	810	845	878

Electricity generated	Reference Scenario (TWh)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Total	4 177	5 721	10 680	19 160	23 470	26 624	29 466	32 471	35 391
Coal	1 301	2 158	4 869	8 723	7 424	7 044	6 975	7 115	7 043
Oil	656	648	694	647	520	478	428	382	315
Natural gas	977	1 237	2 318	3 336	3 717	4 341	5 164	6 210	7 404
Nuclear	236	303	432	904	1 267	1 509	1 718	1 859	1 967
Hydro	985	1 326	2 154	2 961	3 374	3 581	3 792	4 010	4 239
Geothermal	13	25	31	44	68	118	134	145	157
Solar photovoltaics	0.0	0.1	1.4	919	4 236	5 911	6 846	7 679	8 522
Wind	0.0	2.8	73	1 214	2 213	2 857	3 489	4 069	4 659
Concentrated solar power and marine	0.0	0.0	0.0	7.3	8.4	8.6	8.9	9.3	9.6
Biomass and waste	8.5	21	106	397	636	704	772	825	879
Hydrogen	-	-	-	-	-	66	132	161	189
Others	-	0.5	1.1	7.1	7.1	7.1	7.1	7.1	7.1

Carbon dioxide [CO_2]	Reference Scenario ($MtCO_2$)								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Energy-related CO_2 emissions[*2]	9 050	9 984	17 446	23 330	22 847	22 861	23 281	23 897	24 250
Avoidance by carbon dioxide removal [CDR]	-	-	-	-	-	-	-	-	-

Energy and economic indicators	Reference Scenario								
	1990	2000	2010	2023	2030	2035	2040	2045	2050
Gross domestic product [GDP] ($2015 billion)	8 766	12 502	22 694	39 290	51 285	61 496	73 380	86 869	101 663
Population (million)	4 291	5 081	5 851	6 845	7 307	7 616	7 903	8 164	8 391
GDP per capita ($2015 thousand)	2.0	2.5	3.9	5.7	7.0	8.1	9.3	11	12
Primary energy consumption per capita (toe/person)	0.9	0.9	1.2	1.4	1.4	1.4	1.5	1.5	1.5
Primary energy consumption per GDP (toe/$2015 million)	460	354	309	249	204	179	156	137	122
Energy-related CO_2 emissions per GDP[*2] (t/$2015 million)	1 032	799	769	594	445	372	317	275	239
Energy-related CO_2 per primary energy consumption[*2] (t/toe)	2.2	2.3	2.5	2.4	2.2	2.1	2.0	2.0	2.0

*1 The total and breakdown do not necessarily match since international exports/imports of electricity and heat are not shown.
*2 After avoidance by carbon dioxide removal [CDR].

Reference Scenario								Advanced Technologies Scenario									
CAGR (%)				Shares (%)				(Mtoe)					CAGR (%)			Shares (%)	
1990/2023	2023/2040	2040/2050	2023/2050	1990	2023	2040	2050	2030	2035	2040	2045	2050	2023/2040	2040/2050	2023/2050	2040	2050
2.7	0.9	0.8	0.9	100	100	100	100	10 195	10 219	10 088	10 011	9 977	0.2	-0.1	0.1	100	100
3.5	-1.0	-0.4	-0.8	28	37	26	23	3 069	2 608	2 211	1 869	1 523	-2.8	-3.7	-3.1	22	15
2.2	0.9	0.6	0.8	30	25	25	24	2 482	2 360	2 217	2 051	1 888	-0.6	-1.6	-1.0	22	19
2.7	1.6	1.9	1.7	21	20	23	25	2 172	2 276	2 348	2 411	2 464	1.0	0.5	0.8	23	25
4.1	3.8	1.4	2.9	1.5	2.4	3.9	4.1	336	496	619	750	870	5.8	3.5	5.0	6.1	8.7
3.4	1.5	1.1	1.3	2.1	2.6	2.8	2.9	298	323	350	380	413	1.9	1.7	1.8	3.5	4.1
5.4	6.5	1.1	4.5	0.3	0.7	1.8	1.8	103	196	231	260	289	7.3	2.3	5.4	2.3	2.9
20.3	8.9	2.4	6.4	0.0	2.2	8.1	9.5	647	940	1 166	1 415	1 704	10.4	3.9	7.9	12	17
1.1	0.5	-0.5	0.1	17	10	9.6	8.5	1 088	1 042	986	947	926	-0.1	-0.6	-0.3	9.8	9.3
n.a.	n.a.	21.5	n.a.	-	-	-0.0	-0.0	-5.1	-26	-44	-73	-103	n.a.	8.9	n.a.	-0.4	-1.0

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(Mtoe)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
2.4	1.1	0.6	0.9	100	100	100	100	6 753	6 685	6 522	6 376	6 299	0.2	-0.3	0.0	100	100
1.3	-0.3	-0.6	-0.4	18	13	10.0	8.8	752	643	553	482	429	-2.2	-2.5	-2.3	8.5	6.8
2.8	1.0	0.7	0.9	29	34	33	33	2 196	2 129	2 033	1 915	1 791	-0.3	-1.3	-0.6	31	28
2.9	1.0	0.3	0.7	13	15	15	14	987	936	852	763	683	-0.6	-2.2	-1.2	13	11
4.9	2.7	1.9	2.4	9.6	21	28	32	1 731	1 972	2 179	2 385	2 599	2.8	1.8	2.4	33	41
0.4	0.4	-1.3	-0.2	9.9	5.2	4.6	3.8	340	316	282	248	219	-0.9	-2.5	-1.5	4.3	3.5
n.a.	n.a.	20.2	n.a.	-	-	0.0	0.1	0.1	8.0	21	42	81	n.a.	14.7	n.a.	0.3	1.3
0.7	-0.3	-1.3	-0.7	21	12	9.7	8.0	748	681	602	541	497	-1.5	-1.9	-1.6	9.2	7.9
2.7	1.3	0.3	0.9	33	36	37	36	2 500	2 439	2 302	2 166	2 076	0.0	-1.0	-0.4	35	33
3.4	1.2	1.0	1.1	16	22	22	23	1 437	1 403	1 362	1 326	1 307	0.0	-0.4	-0.2	21	21
1.3	0.8	0.7	0.7	45	32	30	30	2 091	2 078	2 049	2 040	2 040	0.1	0.0	0.0	31	32
3.7	1.5	0.8	1.2	6.5	10	11	11	724	766	809	844	877	1.5	0.8	1.2	12	14

Reference Scenario								Advanced Technologies Scenario									
1990/2023	2023/2040	2040/2050	2023/2050	Shares (%)				(TWh)					2023/2040	2040/2050	2023/2050	Shares (%)	
				1990	2023	2040	2050	2030	2035	2040	2045	2050				2040	2050
4.7	2.6	1.8	2.3	100	100	100	100	24 194	28 156	31 408	35 293	39 681	3.0	2.4	2.7	100	100
5.9	-1.3	0.1	-0.8	31	46	24	20	7 057	5 779	4 610	3 557	2 474	-3.7	-6.0	-4.6	15	6.2
0.0	-2.4	-3.0	-2.6	16	3.4	1.5	0.9	440	336	245	189	155	-5.5	-4.5	-5.2	0.8	0.4
3.8	2.6	3.7	3.0	23	17	18	21	4 069	4 849	5 715	6 691	7 695	3.2	3.0	3.1	18	19
4.1	3.9	1.4	2.9	5.7	4.7	5.8	5.6	1 289	1 902	2 377	2 879	3 341	5.9	3.5	5.0	7.6	8.4
3.4	1.5	1.1	1.3	24	15	13	12	3 466	3 753	4 068	4 416	4 806	1.9	1.7	1.8	13	12
3.8	6.8	1.6	4.9	0.3	0.2	0.5	0.4	68	136	162	185	207	8.7	2.5	6.4	0.5	0.5
46.6	12.5	2.2	8.6	0.0	4.8	23	24	4 807	7 228	8 908	10 606	12 513	14.3	3.5	10.2	28	32
37.2	6.4	2.9	5.1	0.0	6.3	12	13	2 290	3 256	4 197	5 386	6 849	7.6	5.0	6.6	13	17
23.4	1.2	0.7	1.0	0.0	0.0	0.0	0.0	10	11	12	15	17	3.2	3.2	3.2	0.0	0.0
12.4	4.0	1.3	3.0	0.2	2.1	2.6	2.5	691	771	850	931	1 012	4.6	1.8	3.5	2.7	2.6
n.a.	n.a.	3.7	n.a.	-	-	0.4	0.5	-	128	256	431	605	n.a.	9.0	n.a.	0.8	1.5
n.a.	0.0	0.0	0.0	-	0.0	0.0	0.0	7.1	7.1	7.1	7.1	7.1	0.0	0.0	0.0	0.0	0.0

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050	($MtCO_2$)					2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
2.9	0.0	0.4	0.1	21 739	18 475	15 836	13 553	11 757	-2.3	-2.9	-2.5
n.a.	n.a.	n.a.	n.a.	-	-	83	212	360	n.a.	15.7	n.a.

Reference Scenario				Advanced Technologies Scenario							
1990/2023	2023/2040	2040/2050	2023/2050						2023/2040	2040/2050	2023/2050
				2030	2035	2040	2045	2050			
4.7	3.7	3.3	3.6	51 285	61 496	73 380	86 869	101 663	3.7	3.3	3.6
1.4	0.8	0.6	0.8	7 307	7 616	7 903	8 164	8 391	0.8	0.6	0.8
3.2	2.9	2.7	2.8	7.0	8.1	9.3	11	12	2.9	2.7	2.8
1.3	0.1	0.2	0.1	1.4	1.3	1.3	1.2	1.2	-0.7	-0.7	-0.7
-1.8	-2.7	-2.5	-2.6	199	166	137	115	98	-3.4	-3.3	-3.4
-1.7	-3.6	-2.8	-3.3	424	300	216	156	116	-5.8	-6.0	-5.9
0.2	-0.9	-0.3	-0.7	2.1	1.8	1.6	1.4	1.2	-2.4	-2.8	-2.6

Table A49 | Conversion factors

From \ To	Megajoule (MJ)	Kilowatt hour (kWh)	Kilocalorie (kcal)	Tonne of oil equivalent (toe)	British thermal unit (Btu)	Tonne of coal equivalent (tce)
MJ	1	2.77778×10^{-1}	2.38846×10^{2}	2.38846×10^{-5}	9.47817×10^{2}	3.41209×10^{-5}
kWh	3.60000	1	8.59845×10^{2}	8.59845×10^{-5}	3.41214×10^{3}	1.22835×10^{-4}
Kcal	4.18680×10^{-3}	1.16300×10^{-3}	1	1×10^{-7}	3.96832	1.42857×10^{-7}
Toe	4.18680×10^{4}	1.16300×10^{4}	1×10^{7}	1	3.96832×10^{7}	1.42857
Btu	1.05506×10^{-3}	2.93071×10^{-4}	2.51996×10^{-1}	2.51996×10^{-8}	1	3.59994×10^{-8}
Tce	2.93076×10^{4}	0.8141×10^{4}	0.7×10^{7}	0.7	2.77782×10^{7}	1

Crude oil is calculated as 1 million barrels per day (1 Mb/d) = 47.26 Mtoe, natural gas as 1 billion cubic metres (1 Bcm) = 0.8373 Mtoe, steam coal as 1 Mt = 0.5222 Mtoe, coking coal as 1 Mt = 0.6480 Mtoe, and liquid biofuels as 1 Mb/d = 35.34 Mtoe.

Slides

The 451st Forum on Research Work

IEEJ Outlook 2026

Deepening uncertainties surrounding the challenges of energy transition: a widening gap between the ideal and the reality

Tokyo, 17 October 2025

The Institute of Energy Economics, Japan

451st Regular Research Forum, October 17, 2025

IEEJ Outlook 2026

Global Energy Supply and Demand Outlook to 2050

The Institute of Energy Economics, Japan (IEEJ)

Seiya Endo
Senior Economist

Contents

- Global energy supply and demand outlook to 2050
- Economic growth in India and ASEAN and its global impact

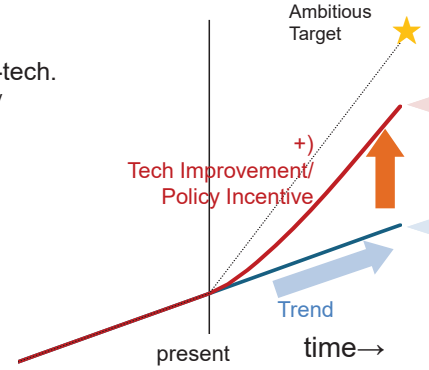
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What is IEEJ Outlook?

- Global energy supply and demand projections through 2050.
  - Compiled latest energy and socioeconomic data to estimate future energy demand and CO_2 emissions
  - 44 regions over the world + international bunkers are respectively evaluated.
- Two scenarios with different technology and policy development trajectories
  - Both are **forecast** scenarios asking "What if...?"
  - Unlike **backcast** scenarios emission reduction targets are not necessarily achieved.

Scenarios

↑Amount of low carbon-tech.
*e.g. Renewables, Efficiency



[Advanced Technologies] ("AdvTech.")
Maximum implementation of policies for energy security and climate action.
(considering feasibility and acceptance)

[Reference]("Ref")
Continuation of historical trends.
*Does not imply fixed current policies/technologies

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Substantial Increase in Power Demand, in addition to Data Centres

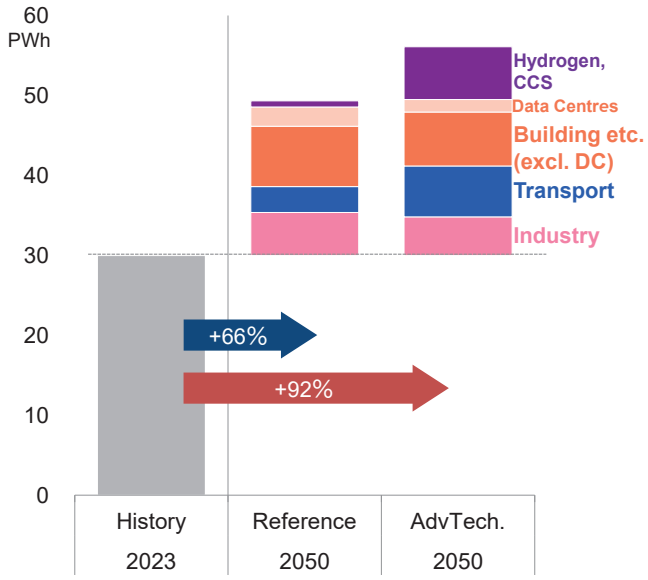
Historical Data Trend [Global]

- 2024 generation increased +4.0% from 2023*
  - ➢ accelerating from 10-year average (2.6%/year)。

Outlook toward 2050

- Continued substantial increase in generation across both scenarios
  - **Reference**: increase equivalent to 2/3 of 2023 generation levels, mainly from industrial sectors and residential heating/cooling
  - **Electricity demand growth is inevitable.**
- **AdvTech.**:Electrification, hydrogen/CCS drive demand.
  - **Increases:** Transportation (EV growth), hydrogen, and CCS demand
  - **Decreases:** Residential (including data centres) and industrial energy efficiency improvements

Required Generation Increase (World)



*Energy Institute, Statistical Review of World Energy (2025)

**Estimated by adding transmission and distribution losses to the electricity demand in each sector

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Generation growth centred on solar PV and wind, but expansion of other sources is also necessary

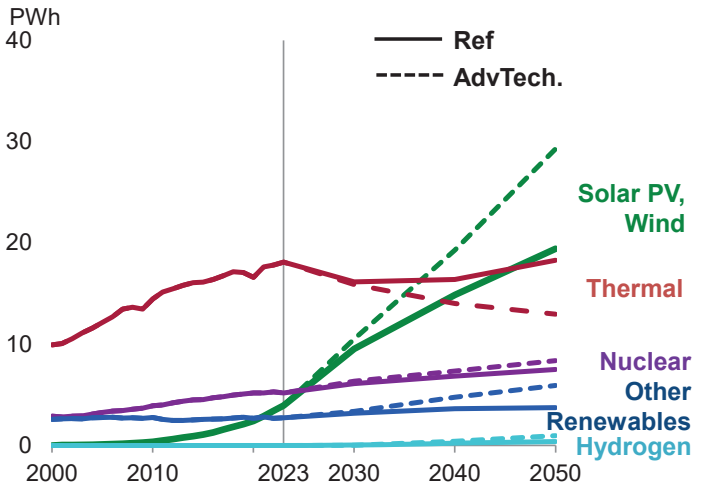
Historical Data Trend [Global]

- Solar PV generation continued to increase at the highest pace ever between 2022-2024.*
- Wind power grows but the pace is slowing due to high costs.

Outlook toward 2050

- **Reference**: Solar and wind dominate future expansion, but slow after 2030 due to several constraints.
  - land use, policy shifts, integration costs.
- **AdvTech.** :Overcomes these constraints, sustaining strong growth.
- Investment across other sources (Thermal/ Nuclear/ Other Renew.) remains essential.

Generation by Source (Global)



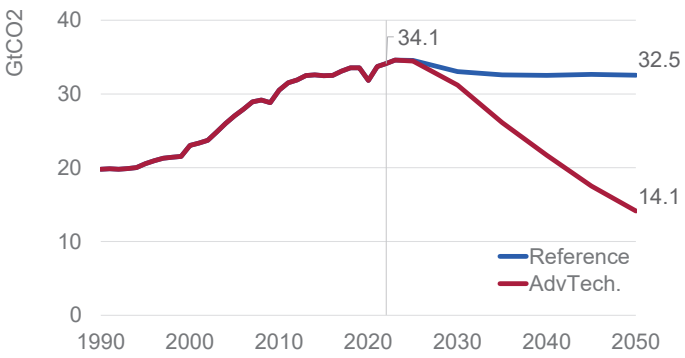
*Energy Institute, Statistical Review of World Energy (2025)

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Non-Power Demand in EDEs : Major Challenge for Emission Reductions

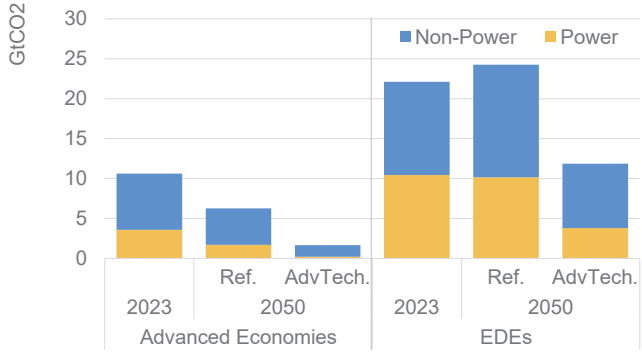
- **Reference**: Global emissions remain around current levels.
- **AdvTech.**: Emissions reduction accelerates after 2030, reaching –59.3% vs 2023.
  - Non-power sectors in EDEs is the most significant challenge for net zero, accounting for most remaining emissions.
  - Prioritizing power decarbonization and efficiency measures is essential.

CO_2 Emission*(World)



*Energy-related emissions minus offsets from CDR (BECCS/DACCS)

CO_2 Emission**(Regional, Sectoral)



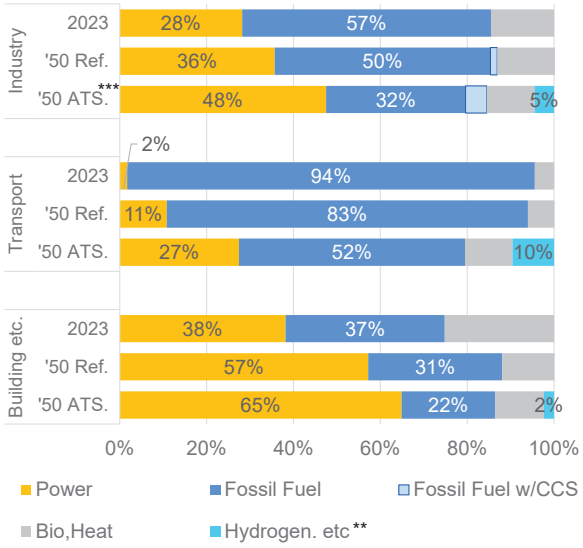
**EDEs: Emerging and Developing Economies

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Demand: Substantial Fossil Fuel Demand Remains

- Electrification is key for decarbonization, but the difficulties vary by sector.
  - **Industry** and **transport** : Hard to electrify; especially in High-temperature heat and long-distance transport.
  - **Residential**:** Relatively easy to electrify.
- Hydrogen etc.** could be play a role in Hard-to-Electrify sectors.
  - Many technologies are currently at demonstration stage, and high cost remains a challenge.

Final Energy Consumption (by sector)



"Industry" includes energy consumed in blast furnace conversion. *"Hydrogen etc." includes ammonia and synthetic fuels.
*** ATS shows "Advanced Technologies Scenario".

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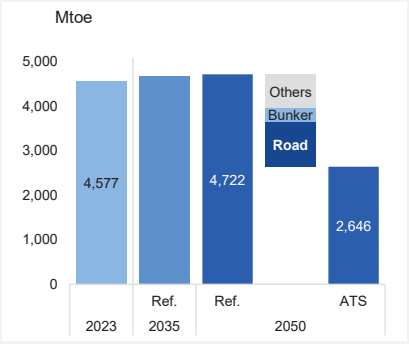
Fossil Fuel Consumption Shows a Wide Range Between the Scenarios

- Global fossil fuel consumption shows significant differences between scenarios.
  - Even in **AdvTech**., fossil fuels account for over half of primary energy consumption.

Primary Energy Consumption (Global)

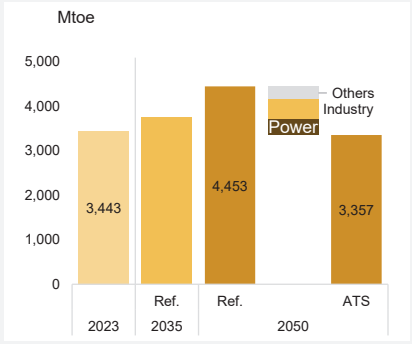
Oil

- Largest gap (**Ref** vs. **AdvTech**) among fossil fuels.
- Most uncertainty stems from road transport.



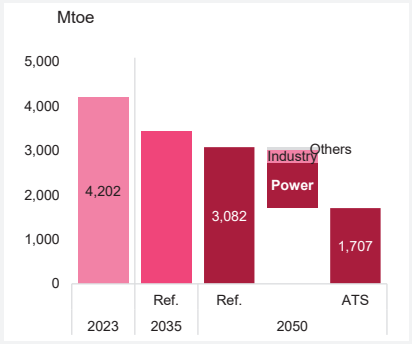
Natural Gas

- Relatively small range between **Ref** and **AdvTech**.; robust demand is expected.



Coal

- High uncertainty in power generation in the future.
- **AdvTech**.: Renewable substitution reduces coal demand, including EDEs.

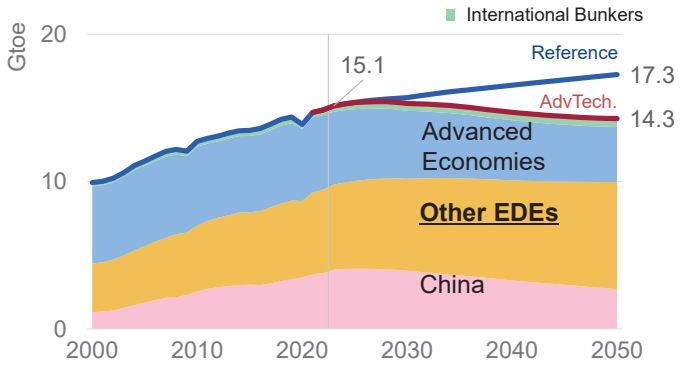


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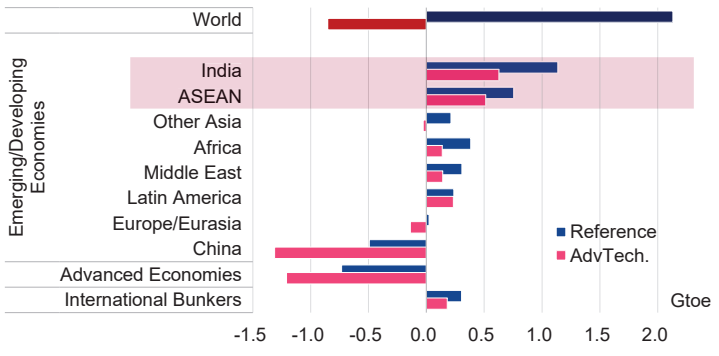
India and ASEAN Drive Energy Consumption Growth

- **Reference:** Primary energy consumption continues a steady increase, reaching 14% growth. (2050 vs. 2023)
- **AdvTech:** The consumption peaks around 2030, due to efficiency improvement.
  - Peaks before 2030 in both developed Economies and China.
  - Other EDEs (especially **India and ASEAN**), show significant consumption growth in both scenarios.

Primary Energy Consumption



Regional Changes (2023-2050)

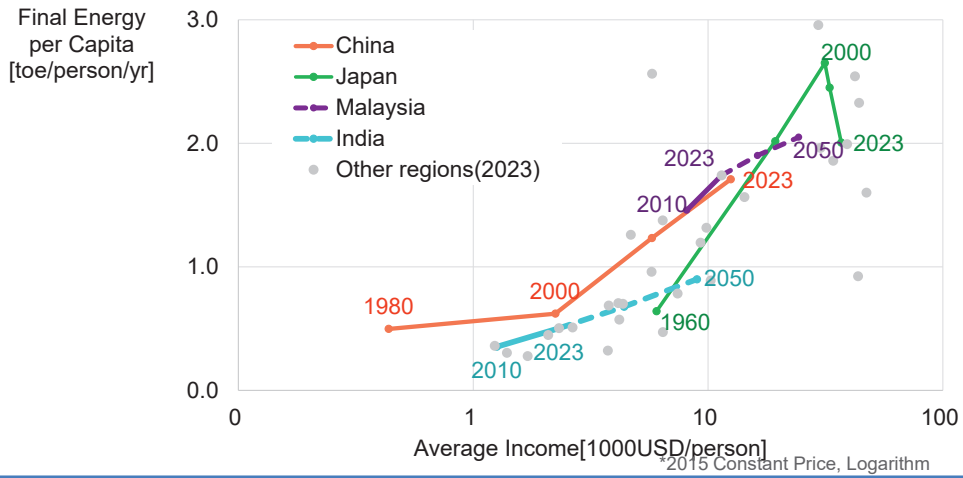


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Economic Growth Makes ASEAN and India Major Energy Consumers

- Japan and China have experienced energy growth with development. ASEAN and India follows in the next decades.
  - **Malaysia**: Average income is currently equivalent to China. Continued robust growth is expected.
  - **India**: Average income approaching $10,000 by 2050, with energy consumption per capita doubling.

Income and Final Energy Per Capita (Reference)



*2015 Constant Price, Logarithm

Source）History: IEA(2025), World Bank(2025), IEEJ（2025）. Future projections are from this outlook.

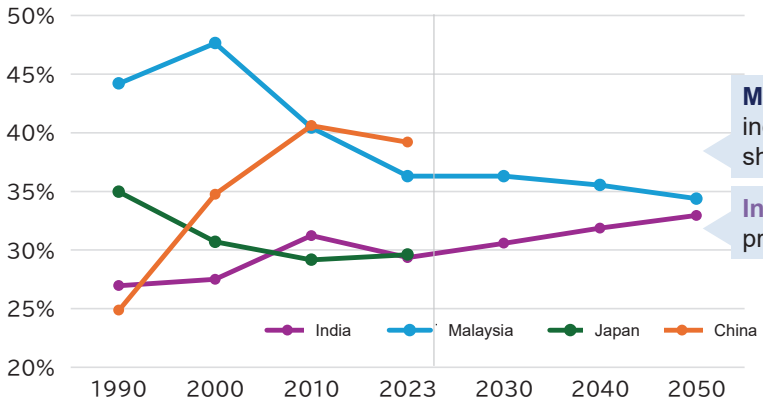
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Industrialization is progressing steadily in South/Southeast Asia

- Secondary industry consumes particularly high energy and drives energy demand.

Secondary Industry Share of Total GDP

China: Rapid secondary industry growth in 1990s-2000s.



Malaysia: Secondary industry maintains high share.

India: Industrialization is progressing steadily.

Source: Historical data from World Bank (2025). Projections based on this outlook.

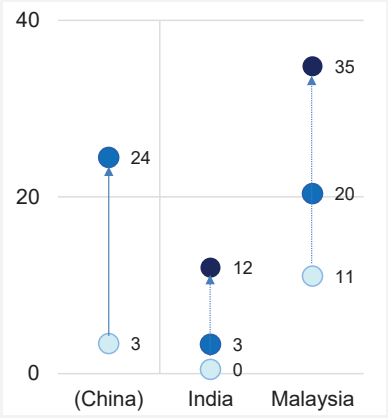
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Expanding "3C" Usage Stimulates Energy Consumption

- Rising income levels stimulate increase **especially in ownership of cooler, cars**, additionally crude steel production.
  (e.g.)Penetration of "3C" in 1960s Japan/economic growth in 2000s China

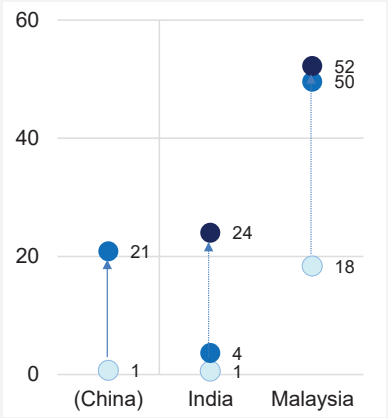
Buildings: Cooler

Units per 100 people (residential)



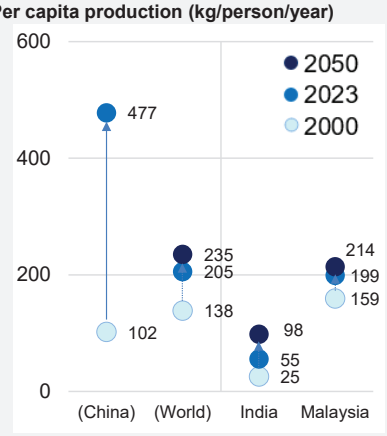
Transport: Car

Passenger Vehicles per 100 people



Industry: Crude Steel

Per capita production (kg/person/year)

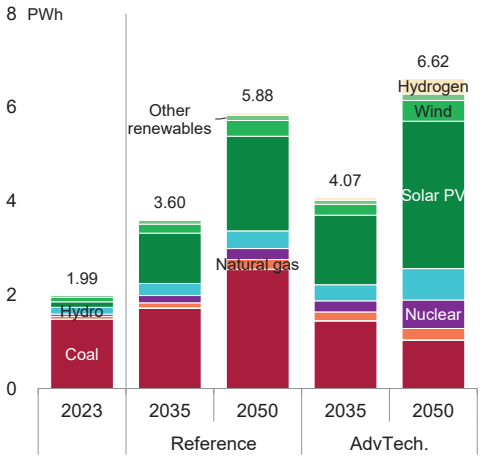


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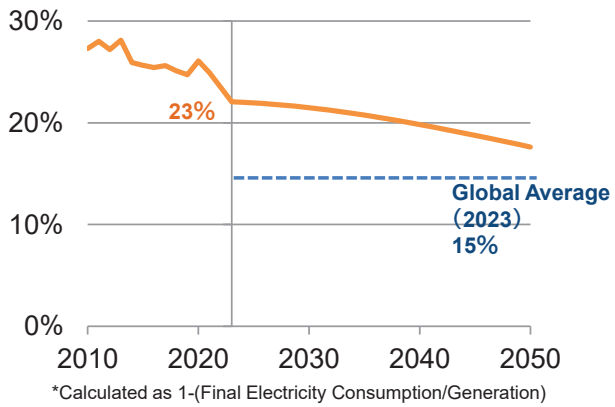
Challenges in Energy Supply and Demand (1): Rapid Increase in Power Generation (India)

- In next 27 years, required generation more than triple 2023 level.
  - Driven by rapid electricity demand growth in residential and industrial sectors.
  - Significant solar expansion expected, but competition with agricultural land is major challenge.
- Transmission and distribution loss is reducing but remains high.

Generation Mix (India)



Transmission and Distribution Loss Rate(Ref)



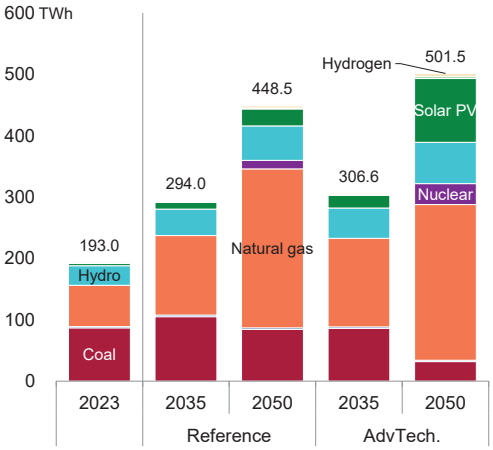
*Calculated as 1-(Final Electricity Consumption/Generation)

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Challenges in Energy Supply and Demand (1): Rapid Increase in Power Generation (Malaysia)

- **Ref:** Generation increases ×1.6 by 2035 and ×2.3 by 2050 (vs. 2023)
  - Residential cooling demand is expanding.
  - Data centres are growing, driving power demand growth.
- Natural gas-fired power remains central of power supply.
  - Sites for renewable is concentrated in Borneo Island. Strengthening grid connection with Malay Peninsula (where population centres are located) is necessary for large-scale deployment

Generation Mix (Malaysia)





出所：Flourish

Malay Peninsula: 3/4 of the population is concentrated

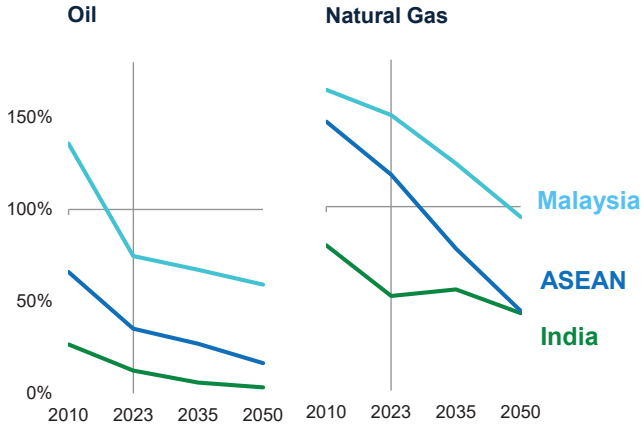
Borneo Island: Solar and hydro suitable sites are concentrated

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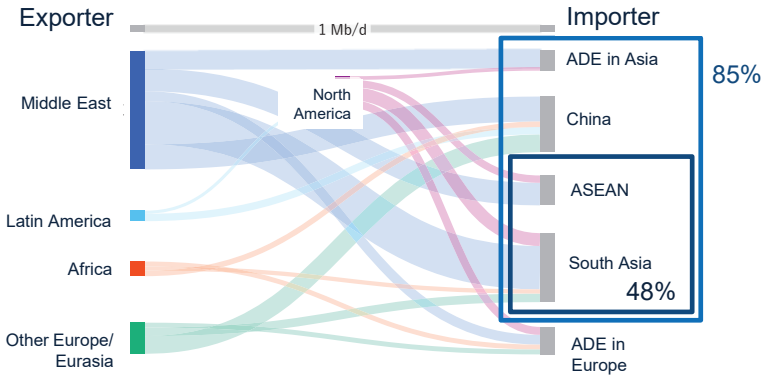
Challenges in Energy Supply and Demand (2): Rising Import Dependence on Fossil Fuel

- Oil and gas self-sufficiency declines in India and ASEAN;
  - Oil: Already import-dependent in both regions, and the dependency get deepen.
  - Gas: ASEAN becomes a net gas importer by 2035.
- Asia's share of global crude oil trade rises sharply.
  - By 2050, 85% of interregional flows head to Asia, over half to South/Southeast Asia.

Self-sufficiency rate(Ref)



Crude Oil Trade Flow (2050,Ref)



Note: Shows flows of 0.5 Mb/d or greater. Percentages represent share of total inter-regional trade volume.

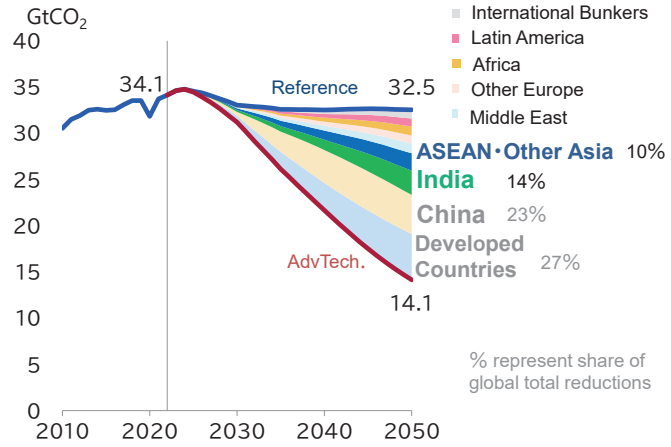
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Challenges in Energy Supply and Demand (3): Investment for CO_2 Reduction

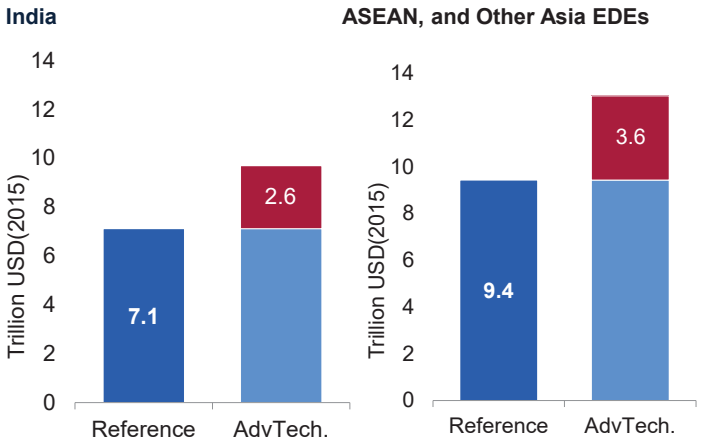
- Emission reduction potential (Reference – AdvTech.) in India, ASEAN, and Other Asia EDEs approaches scale of developed countries or China.
- On the other hand, substantial energy investment is required for AdvTech.
  - Additional investment needed for reductions in these three regions alone equals 80% of target amount agreed at COP29*.

*300B USD/year.
(Target for all EDEs. Includes adaptation)

CO_2 Emissions(Energy-related)



Energy Investments(Cumulative, 2024-2050)



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Summary

- - Global power demand surges through 2050, driven by economic growth, electrification, and expanding data centres.
  - AdvTech. sees +92% generation vs 2023 due to electrification, hydrogen and CCS.
- Fossil fuel use, particularly oil, diverges widely across scenarios; ensuring fuel supply stability remains essential, even in energy transition pathway.
- India and ASEAN are the centres of future demand growth, facing three significant challenges:
  - 1. Managing rapidly rising power demand.
  - 2. Declining fossil fuel self-sufficiency.
  - 3. Securing investment for CO_2 reduction.

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IEEJ Outlook 2026

Evaluating the Integration Costs and Deployment Potential of Variable Renewable Energy

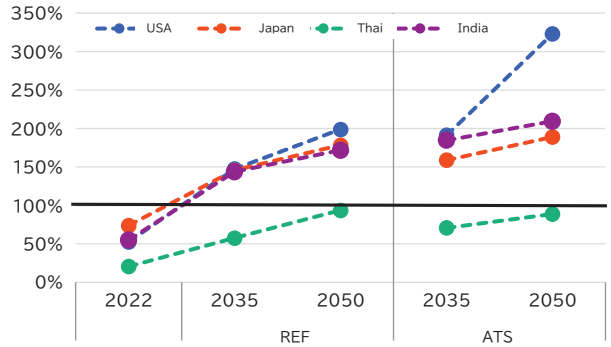
The Institute of Energy Economics, Japan

Yu NAGATOMI
Executive Analyst, Energy Data and Modelling Center
(Co-author: Hideaki OBANE, Seiya ENDO)

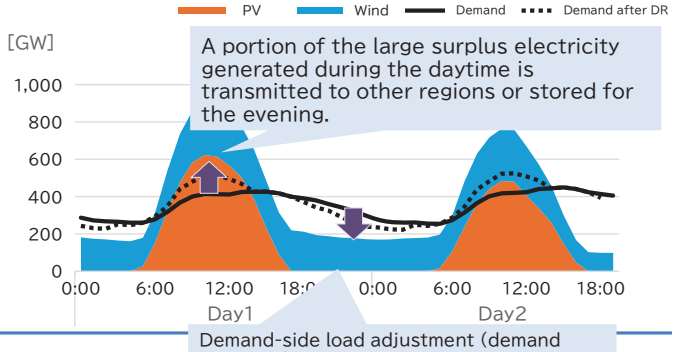
Rising VRE Penetration and the Changing Supply–Demand Balance in the Power System

- The IEEJ Outlook 2026 projects that under the Reference Scenario(REF), VRE power generation will increase approximately fivefold from current levels to 2050, rising to approximately sevenfold under the Advanced Technologies Scenario(ATS).
- As VRE scales toward decarbonization, the electricity supply–demand balance will shift significantly — as already seen in regions with high solar penetration, where daytime and nighttime conditions diverge sharply.
- Power systems must therefore be designed to manage VRE fluctuations through accurate forecasting, flexible operation of power generation, storage deployment, and grid reinforcement.

Ratio of Installed VRE Capacity to Average Annual Electric Load [GW]



Gap Between Solar/Wind Output and Power Demand (Illustrative)
ATS– India, 2050 (August)



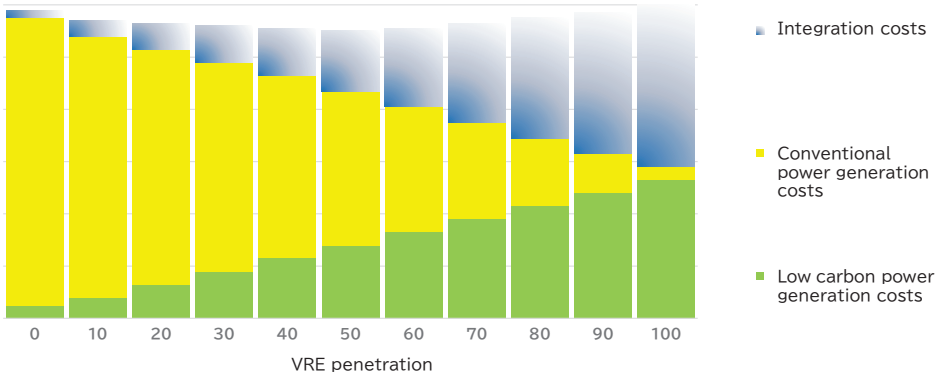
Source:IEEJ Outlook 2025

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VRE Deployment and the Evolution of Integration Costs

- When integrating a power source, additional system costs beyond its generation cost — known as integration costs — are incurred. These include expenses for grid reinforcement and storage.
- As VRE penetration rises, it is crucial to account for these growing integration costs and assess the total system cost to achieve an optimal balance.

Illustrative image: Growth in VRE deployment vs. system cost trajectory



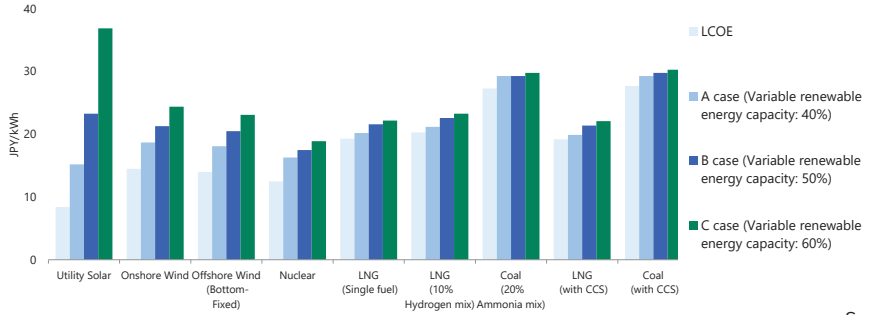
Source：Author, based on Matsuo (2021) and The Working Group on Power Generation Cost Verification (2025)

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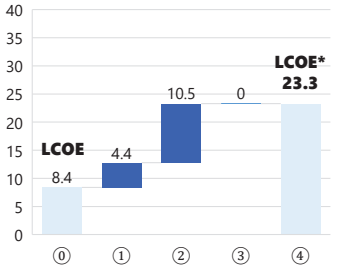
Example of the Study on Integration Cost: The Working Group on Power Generation Cost Verification (2025)

- The right-hand side figure decomposes the gap between generation cost (LCOE: Levelized Cost of Energy) and adjusted LCOE (LCOE*), which incorporates part of the integration costs, showing that charging/discharging losses and curtailment have the largest impact.
- As VRE penetration increases, curtailment and storage losses grow, while the capacity factor of balancing plants declines — resulting in a much steeper rise in LCOE* for VRE compared with nuclear and thermal power.

Comparison of Generation Cost vs. Adjusted Generation Cost (including part of the integration costs)



Breakdown of Utility-Scale Solar PV Cost



①Changes in the variable costs of balancing (dispatchable) power sources

② Changes in variable costs due to charging/discharging losses and renewable output curtailment

③ Changes in fixed costs resulting from the capacity factor (utilization rate) of added power sources

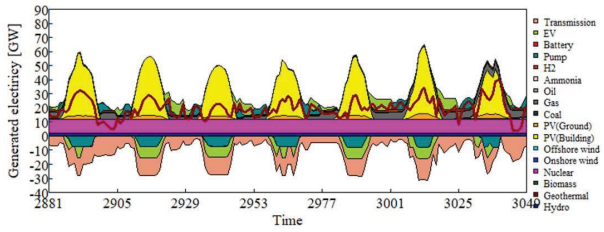
Source：Author, based on The Working Group on Power Generation Cost Verification (2025)

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Overview of the IEEJ Technology Selection Model (IEEJ-NE Model)

- Using the IEEJ-NE model, we analyze the least-cost technology mix for ASEAN under varying levels of VRE deployment.
- The analysis assumes each country follows its NDC targets and evaluates VRE deployment and integration costs through 2060.
- IEEJ-NE Model Framework
  - ✓ Simulates annual power and hydrogen supply–demand on a time-step basis
  - ✓ Calculates required capacity for power generation and storage
  - ✓ Considers grid reinforcement and energy storage for power system balancing

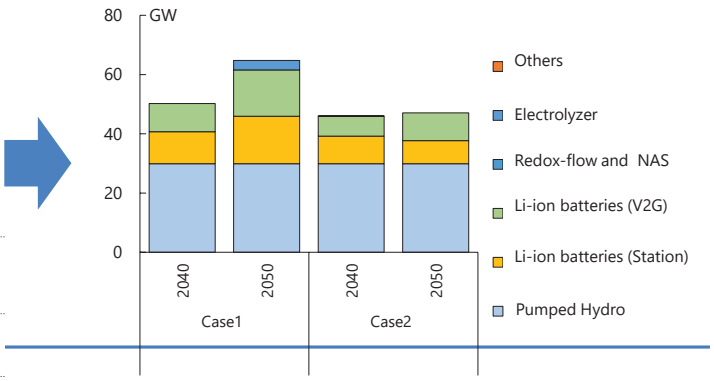
Example of Power Supply–Demand (hourly)



Technology list

Energy Storage	Pumped hydro, Li-ion batteries (grid-side and demand-side), NaS batteries, redox-flow batteries, hydrogen storage
(Demand Response)	Demand-side flexibility: EV charging, passenger EV V2G, and heat pump water heater load shifting

Required storage capacity estimated by area

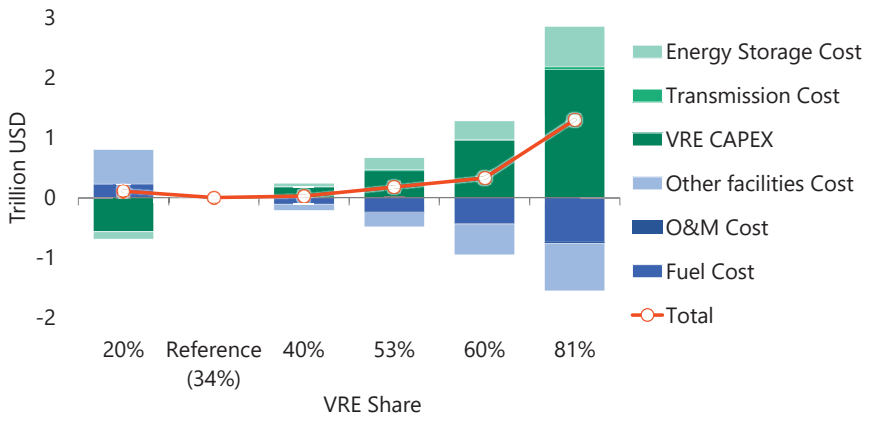


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VRE Deployment and Changes in System Cost

- In ASEAN, the least-cost VRE share in 2060 is estimated to be around 30% — used here as the reference.
- Increasing VRE beyond this reference reduces conventional generation capital and fuel costs, but raises VRE installation costs and integration costs such as storage.
- At 81% VRE, cumulative system cost rises by approximately USD 1.3 trillion over 2030–2060 compared with the reference.

Cumulative System Cost Change in ASEAN (2030–2060, vs. baseline)



Cost Increase: Energy Storage, Transmission, VRE CAPEX

Cost Decrease: Other facilities (mainly conventional; power plants), O&M, Fuel

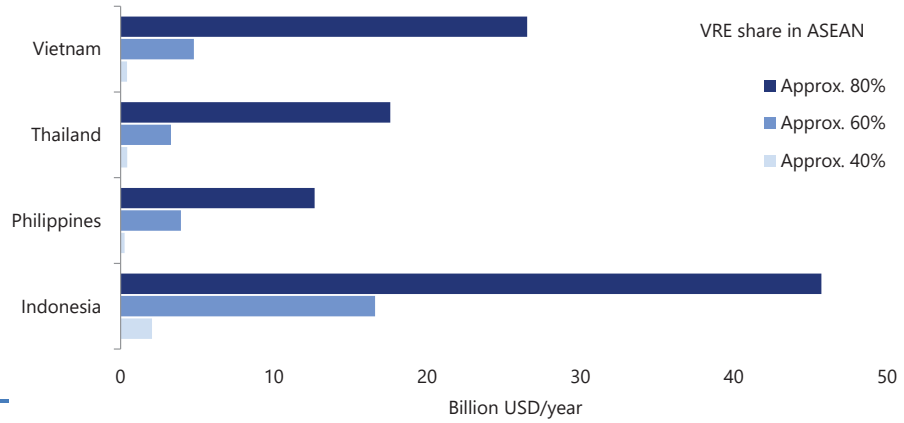
Note: Interconnection capacity is capped based on ASEAN Power Grid assumptions. Costs are shown in 2017 real USD.

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VRE Deployment and Country-Level System Cost Impacts

- The change in system cost from higher VRE deployment varies significantly by country.
- Indonesia, Vietnam, and Thailand — with large populations and economies — see the largest cost increases, including VRE capital costs.

Change in System Cost by Country in 2060 (vs. baseline)



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Summary

- As variable renewable energy (VRE) expands toward decarbonization, the future supply–demand balance of electricity will change significantly.
- In the decarbonization era, integration costs are increasingly seen as a key metric for evaluating energy costs, and a growing number of studies and analyses are focusing on them.
- This report analyzes VRE deployment and integration costs in ASEAN through 2060.
- When VRE is increased beyond the reference level, capital and fuel costs for conventional power are reduced — but VRE installation and integration costs rise, resulting in a net increase in total system cost.
- The cost and additional deployment potential of VRE vary by country, making it essential to pursue diverse and country-specific pathways to decarbonization.

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Appendix: Key Components of Integration Costs (Typical Classification)

Category	Item	Detailed item	Description	Considered in various analyses
Cost of managing forecast errors	Balancing costs		Short-term balancing costs from dispatchable plants responding to intra-day VRE fluctuations (seconds–minutes reserve).	
Grid reinforcement costs	Grid-related costs		Investment in transmission infrastructure and congestion management (e.g., redispatch) due to geographical mismatch between VRE generation and demand.	This study
Cost of supply–demand mismatch / adequacy	Profile costs/utilization costs	Cost of supply–demand mismatch / adequacy	Backup capacity required due to the low capacity value of VRE, especially during peak demand (e.g., thermal, flexible renewables, storage).	This study The Working Group on Power Generation Cost Verification
		Curtailment costs	Higher unit cost of electricity when VRE output exceeds demand and curtailment is needed.	This study、 The Working Group on Power Generation Cost Verification
		Reduced capacity factor of dispatchable plants	Increase in unit generation cost as baseload and mid-merit thermal plants operate fewer hours due to VRE.	The Working Group on Power Generation Cost Verification
		Increased cycling and start-up/shutdown costs	Additional costs from more frequent and unplanned ramping or cycling of dispatchable power plants.	The Working Group on Power Generation Cost Verification

Source: Author, based on Ueckerdt et al. (2013) and Matsuo (2021)

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IEEJ Outlook 2026

The importance of climate change targets and adaptation grounded in reality

~Advanced Technologies Scenario as a milestone for achieving the 2°C target~

The Institute of Energy Economics, Japan (IEEJ)

Climate Change & Energy Efficiency Unit
Soichi Morimoto, Takahiko Tagami, Toshiyuki Sakamoto

Recent developments concerning the 1.5°C target (Developed countries)

The Paris Agreement (2015) stipulates the global temperature rise mitigation target as well below 2°C and to pursue efforts to limit the increase to 1.5°C.

Subsequently, driven by successive net-zero declarations from major nations around 2020, the pursuit of the 1.5°C target and the associated goal of net-zero greenhouse gas (GHG) emissions became the global trend.

However, in reality, global GHG emissions continue to rise, making the prospects for achieving the 1.5°C target increasingly challenging. Against this backdrop, new realities illustrating the difficulty of realising the 1.5°C target are becoming apparent worldwide. In developed countries and industries,

- The United States has announced its withdrawal from the Paris Agreement and is also advancing domestic measures, including the early termination of tax credits under the Inflation Reduction Act (IRA), the revocation of the GHG endangerment finding, and the removal of emission regulations for automobiles and fossil-fuel power plants.
- The G7 excluding Japan and the EU are currently exceeding the emissions pathway required to achieve net-zero by 2050. Furthermore, Canada's new 2035 NDC target exceeds the emissions pathway required to achieve net-zero by 2050 from current levels.
- Kemi Badenoch, leader of the UK Conservative Party, stated in March 2025: “Net zero by 2050 is impossible. I don’t say that with pleasure. I want a better future and a better environment for our children. But we have to get real.” (The Conservative Party was in government when the UK hosted COP26.)
- The NZBA (Net-Zero Banking Alliance) changed its policy to allow the 2°C target in April this year, from its position of seeking to align the 1.5°C target of financed emissions in response to the withdrawal of six major U.S. banks at the end of last year and the subsequent withdrawal of Japanese banks.

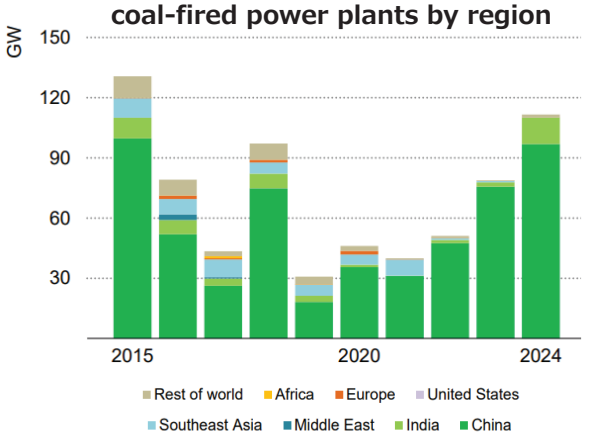
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Recent developments concerning the 1.5°C target (Emerging countries)

- In China, final investment decisions (FID) were made for the construction of 100 GW of new coal-fired power plants in 2024 alone. This represents the largest scale in the past decade. In comparison,
  - Coal-fired power plant decommissioning over the past five years averaged just 4.7 GW annually
  - In 2024, 341 GW of solar PV and 80 GW of wind power were newly installed, but their combined electricity generation is equivalent to that of 100 GW of newly built coal-fired power operating at a 50% capacity factor.

  Thus, the impact of 100 GW of new coal-fired power plants per year on China's CO_2 emissions is immeasurable.
- Similarly, India saw FIDs for 15 GW of new coal-fired power plants in 2024, again the largest scale in the past decade. Coal India, the world's largest coal company, announced the resumption of 32 dormant coal mines and the development of five new coal mines in June this year.
- The current reality presents a challenging situation for achieving net-zero GHG emissions.

Final investment decisions (FID) for new coal-fired power plants by region



(Source) IEA, World Energy Investment 2025

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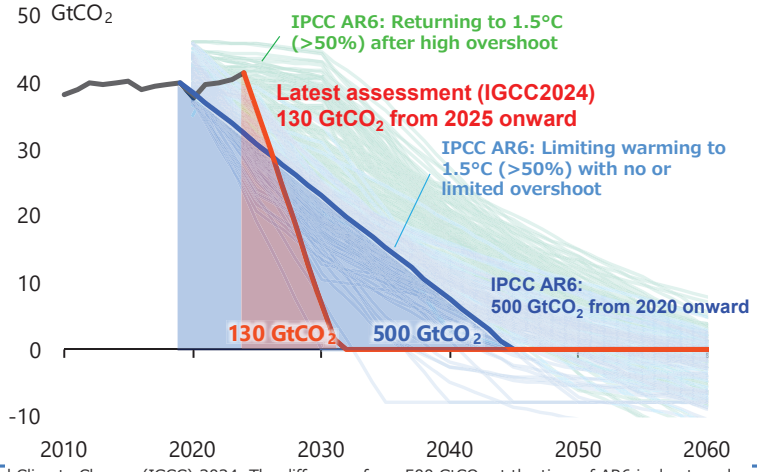
1.5°C target effectively unattainable

- Compared to the IPCC AR6, the remaining carbon budget*1 toward 1.5°C with a 50% probability is rapidly decreasing.

*1: The total amount of CO_2 emissions permitted globally going forward to achieve a target.

- The latest assessment is 130 $GtCO_2$*2 from 2025 onward, which is less than four years' worth of current emissions, and a simple calculation assuming linear emissions reductions requires net-zero by 2032. Given the latest remaining carbon budget assessment, the 1.5°C target can be considered effectively unattainable. → Need to assume a 2°C target. This does not necessarily signify a retreat but rather a return to the original objective of the Paris Agreement..

CO_2 emissions pathway consistent with the 1.5°C target



*2: According to the Indicators of Global Climate Change (IGCC) 2024. The difference from 500 $GtCO_2$ at the time of AR6 is due to a decrease of 200 $GtCO_2$ in emissions from 2020 to 2024, a decrease of just over 100 $GtCO_2$ due to an upward revision of global warming due to the reduction of aerosols with cooling effects, and a decrease of about 40 $GtCO_2$ due to an increase in global warming estimates due to high temperature observations over the past few years.

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Comparison of the Advanced Technologies Scenario and the 2°C target (Assumptions)

- Based on the energy-related CO_2 emission pathway to 2050 in the IEEJ Outlook 2026 Advanced Technologies Scenario, the total anthropogenic CO_2 emission pathway including non-energy by the year of achieving net-zero was estimated.

Indicators		Assumptions
Energy-related CO_2	–2050	IEEJ Outlook 2026 Advanced Technologies Scenario
	2051–	Assuming continuation of 2050 reduction rate (-0.61 $GtCO_2$/yr) Emissions flat after net-zero
Non energy-related CO_2 (Land-use change, cement emissions, cement absorption, flaring, and other sources)		Referencing the ModAct (Moderate Action) scenario—one of the Illustrative Mitigation Pathways (IMPs) in the IPCC AR6 WG3—which aligns with climate policies based on the NDCs submitted in 2020. (Although the IMPs encompass pathways with varying levels of mitigation ambition, non-energy CO_2 emissions are assumed somewhat conservatively.)

- Carbon budget comparison targets
  - IPCC 6th Assessment Report Synthesis Report (IPCC AR6 SYR)
  - Global Carbon Budget 2024（GCB 2024） : International research projects, updated annually
  - Indicators of Global Climate Change 2024（IGCC 2024） : Same above

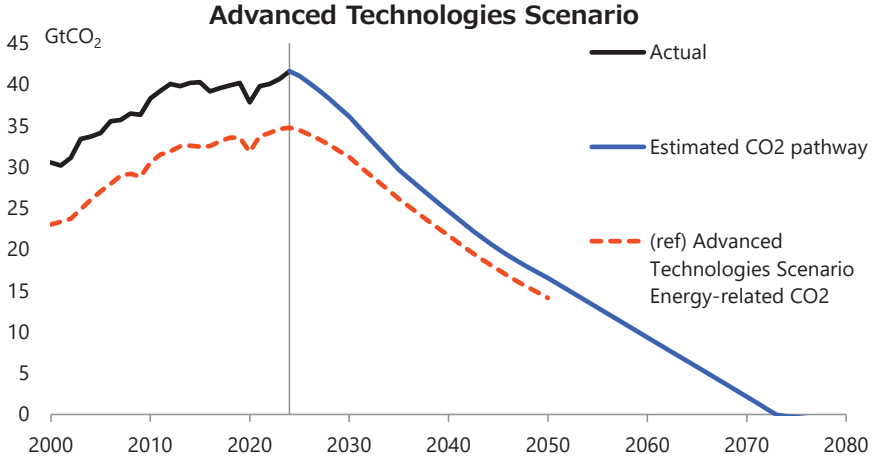
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GCB 2024 : https://essd.copernicus.org/articles/17/965/2025/essd-17-965-2025-discussion.html
IGCC 2024 : https://essd.copernicus.org/articles/17/2641/2025/

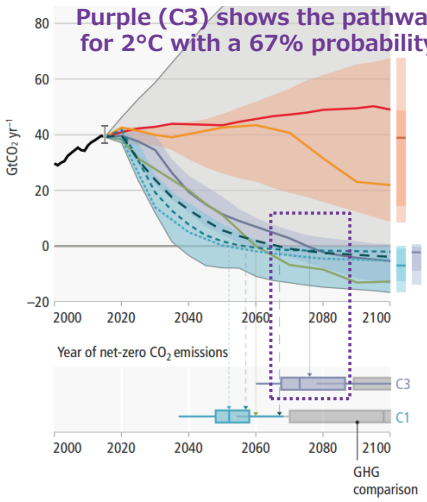
Comparison of the Advanced Technologies Scenario and the 2°C target (CO_2 emissions pathway)

- The estimated CO_2 emissions pathway achieves net-zero in 2073. The IPCC AR6 Working Group III (WG3) report states that the CO_2 emissions pathway for 2°C with a 67% probability (C3) achieves net-zero around 2070 to 2080, which is consistent with our estimates, but to be precise, it needs to be compared with the remaining carbon budget.

Estimated CO_2 emissions pathway based on the Advanced Technologies Scenario



CO_2 emissions pathways in IPCC AR6 WG3



Note: (Left) The estimated CO_2 pathway shows total CO_2. The Advanced Technologies Scenario shows energy-related CO_2.
(Right) IPCC AR6 WG3 SPM p.26

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Comparison of the Advanced Technologies Scenario and the 2°C target (Carbon budget)

- The cumulative emissions from 2025 onwards until net-zero is achieved in the estimated CO_2 emission pathway would total 906 $GtCO_2$, a level comparable to the latest remaining carbon budget and sufficient to limit global temperature rise to 2°C with 50% probability.
- However, it slightly exceeds the remaining carbon budget for the 2 °C target with a 67% probability according to IGCC 2024. → To meet the 2°C target with the highest possible probability, it remains crucial to explore and pursue reduction potentials exceeding those of the Advanced Technologies Scenario.

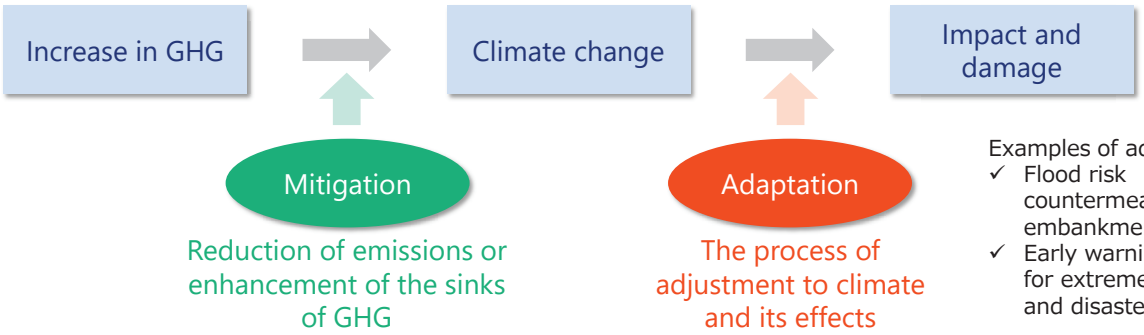
Scenarios		Cumulative CO_2 from 2025 onwards ($GtCO_2$)
Estimated pathway (cumulative to net-zero)		**906**
2°C with 50% probability	IPCC AR6 SYR (Starting point adjusted)	1,150
	GCB2024	1,110
	IGCC2024	1,050
2°C with 67% probability	IPCC AR6 SYR (Starting point adjusted)	950
	GCB2024	NA
	IGCC2024	870
1.7°C with 50% probability	IGCC2024	490

Note: Since the IPCC AR6 SYR budget starts in 2020, the value is listed after deducting 200 $GtCO_2$ emissions for 5 years from 2020 to 2024.

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What is adaptation?

- Current mitigation efforts are not sufficient in scale or level to keep the rise in global mean temperature within the Paris Agreement's long-term climate targets. As a result, global temperatures are rapidly approaching over 1.5 °C increase above pre-industrial levels. The growing frequency and intensity of climate impacts demonstrate how severe the challenges of climate impacts and adaptation have become. Effective and appropriate adaptation measures are now needed more urgently than ever.
- What is adaptation?



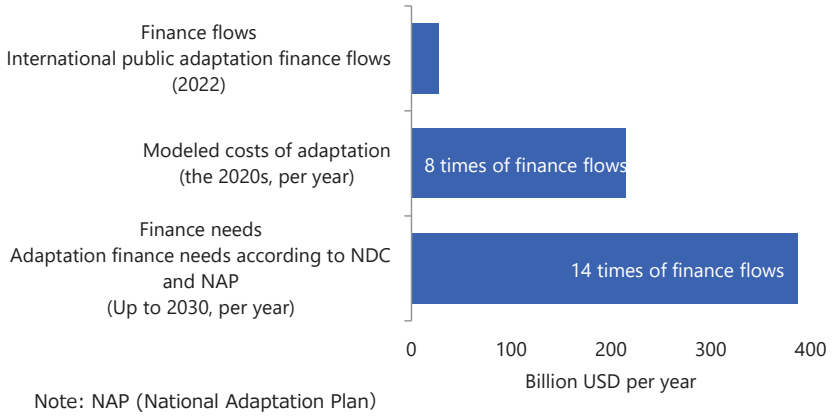
Examples of adaptations:
- ✓ Flood risk countermeasures by embankments
- ✓ Early warning system for extreme weather and disasters

- The primary approach is to mitigate the impacts of climate change through mitigation; if this proves difficult, it becomes crucial to combine it with adaptation. With the 1.5°C target now effectively unattainable, the importance of adaptation will only continue to grow.

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What is the gap in adaptation finance?

Adaptation finance gap



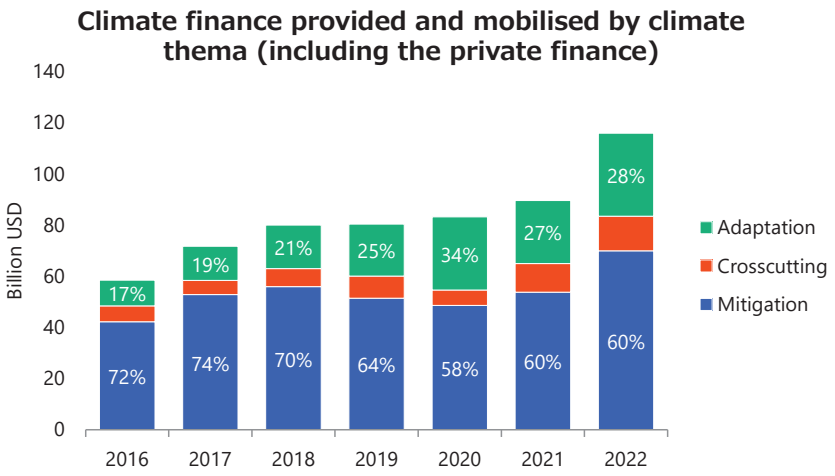
Note: NAP (National Adaptation Plan)

- Adaptation needs estimated by the United Nations Environment Program (UNEP) "Adaptation Gap Report" shows that the modeled costs of adaptation is $215 billion per year and the finance needs are $387 billion per year.
- Meanwhile, actual international public adaptation finance flows to developing countries were only $28 billion in 2022.
- Comparing adaptation needs with international public finance flows in 2022 shows that a huge adaptation finance gap still exists. There is an 8 to 14-fold gap between the finance required for adaptation and the current level of finance provision.
- The adaptation finance gap is substantial, and closing this gap is a priority.

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Source: Created from UNEP (2024), Adaptation Gap Report 2024.

Balance between adaptation and mitigation finance

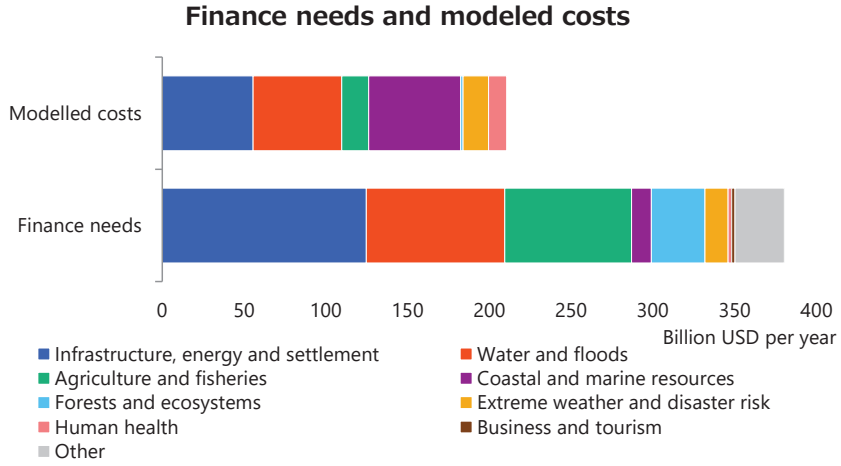


- Article 9, paragraph 4 of the Paris Agreement states, "The provision of scaled-up financial resources should aim to achieve a balance between adaptation and mitigation". This is likely to bring the ratio of adaptation and mitigation finances closer to 1:1.
- Breaking down the climate finance provided and mobilised by advanced economies reveals that mitigation finance accounted for 72% of the total in 2016 and 60% in 2022. Meanwhile, the proportion allocated to adaptation has increased, rising from 17% in 2016 to 28% in 2022, but still remains far from being balanced with mitigation finance.
- It is necessary to strike a balance between adaptation and mitigation finances

Source: Created from OECD (2024), Climate Finance Provided and Mobilised by Developed Countries in 2013–2022.

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Main areas that need adaptation



- The finance needs are large in "Agriculture and fisheries", "Water and floods" and "Infrastructure, energy and settlement".
- The modeled costs are large in "Water and floods" and "Infrastructure, energy and settlement". "Coastal and marine resources" is also large.
- In addition, "Forests and ecosystems" accounts for a large proportion of the finance needs, and "Human health" accounts for a large proportion of the modeled costs.
- It is necessary to consider which areas of adaptation should be prioritised, considering both current and future needs.

Source: Created from UNEP (2023/2024), Adaptation Gap Report 2023/2024.

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(Reference) Main areas that need to be adapted

Areas and sectors	Contents
Infrastructure, energy and Settlement	• Making infrastructure resilient in the energy and transportation subsectors
Water and floods	• River flood protection (structures)
Agriculture and fisheries	• Agricultural research and development, water management and infrastructure to address the impact of climate change on chronic hunger • Addressing changes in fish catch potential, improving marine and coastal ecosystems (expanding marine protected areas) and safety at sea (responding to hazards from tropical windstorms, etc.)
Coastal and marine resources	• Coastal protection (to address flood risks using dikes, etc.) and beach nourishment (to reduce erosion)
Forests and ecosystems	• Expansion of protected areas
Extreme weather and disaster risk	• Weather and climate services (early warning systems, etc.) and social protection (funding for shock (climate extremes) response programs)
Human health	• Disease control to address increase in malaria, dengue and diarrhoeal diseases, heat-alert schemes and supporting health sector responses to address increased heat-related mortality, disease surveillance, and making future water, sanitation and hygiene (WASH) investment resilient

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Source: Created from UNEP (2023), Adaptation Gap Report 2023.

Summary

- Developed countries continue to deviate from the emissions pathway to achieve the 1.5°C target, and there is even a trend of increasing coal use in developing countries. Some industries are also reviewing their efforts to align with the 1.5°C target.
- The remaining carbon budget to achieve the 1.5°C target is depleting, and it is time to take the 2°C target as a realistic target. This does not necessarily signify a retreat but rather a return to the original objective of the Paris Agreement.
- The Advanced Technologies Scenario is consistent with the 2°C target. Moreover, it is a forward-casting scenario and can serve as a milestone for future efforts grounded in reality.
- Adaptation will become more and more important in the future. Adaptation has a clearer effect than mitigation, but there is a large gap between the finance needed and provided. It is necessary to reconsider the balance of public financial support for adaptation and mitigation.

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IEEJ Outlook 2026

AI and the Future of Energy Demand

The Institute of Energy Economics, Japan

Naoko Doi, Asamu Ogawa, Songhee Kim, Taichi Kusayagi, Soji Koikari, Kagami Kotegawa, Kei Kobashi, Arina Sato, Toru Shimizu, Yi-chum Chen, Yu Nagatomi, Junya Nishi, Rino Hirose, Soichi Morimoto, and Atsutaka Yamada

Background and Study Objectives

Background

- **The close interrelationship between artificial intelligence (AI) and energy is attracting global attention.**
  - The growing use of generative AI and the advancement of digitalization will lead to a significant expansion of data centers.
  - Locally, there are concerns that the construction of power supply facilities will not keep up with the pace of data center construction.
- **AI is expected to bring significant benefits in key sectors related to energy use.**
  - Various energy-saving and CO2 emission reduction effects are expected
- **However, there are challenges to using AI on the demand side, such as a lack of awareness, human resources, and investment.**

Study Objectives

- **To analyze the future electricity demand in data centres and its energy-saving potential.**
- **To analyze the energy-saving effects of AI in demand sectors (industry, transportation, business, and households).**

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Electricity Consumption at Data Centres：Was 2020 a turning point？

Trends in Data Centres Electricity Consumption

2015-2019

Data center electricity consumption remained flat

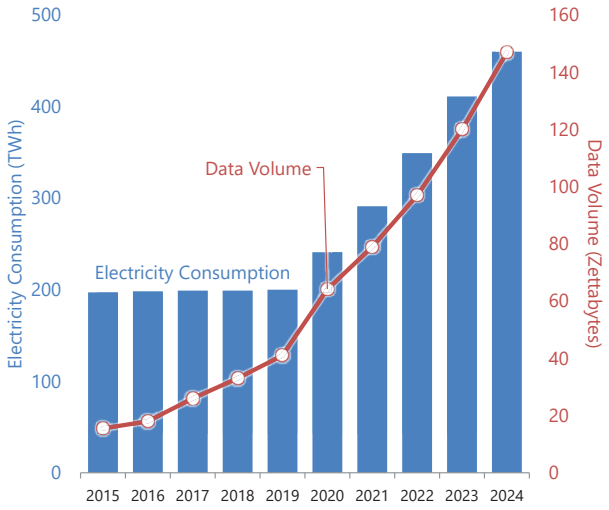
- Data volume triples
- Energy efficiency advances in servers, storage, networking, infrastructure, etc.
- Shift from small data centers to large cloud and hyperscale data centers
- Improved efficiency of Graphics Processing Units (GPUs) contributes

After 2020

Data center electricity consumption increased by 70%

- The emergence of ChatGPT-3 and the expansion of generative AI use
- Advancing digitalization
- Increased use of cloud services due to the establishment of remote work
- Preparation for the construction of high-speed 5G equipment to cover unserved areas is underway

Global Data Centre Electricity Consumption and Data Volume



Source : Masanet et al. (2020), Cisco, IEA, Goldman Sachs Research,

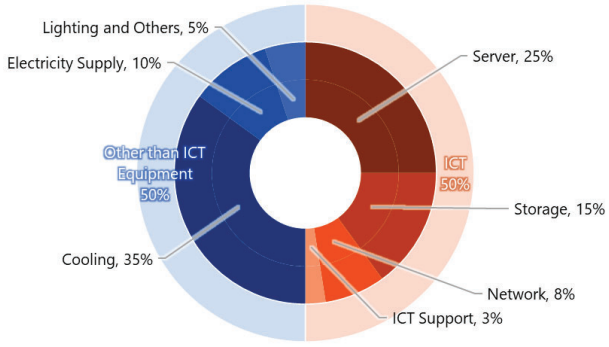
Source： https://www.goldmansachs.com/insights/articles/AI-poised-to-drive-160-increase-in-power-demand, https://explodingtopics.com/blog/data-generated-per-day
https://www.forbes.com/sites/siemens-smart-infrastructure/2023/03/13/how-data-centers-are-driving-the-renewable-energy-transition/?sh=1396b0fb4214
https://www.jaif.or.jp/en/news/7022#:~:text=Among%20other%20things%2C%20it%20showed,/%20floor%20area)%20as%20parameters.

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Data Centre Electricity Consumption：Technology Contributions

- Data centres accounted for approximately **1.6% of global electricity consumption (2023)**. A data centre efficiency is measured by **the Power Usage Effectiveness (PUE) index**, with **the global average being around 1.5**.
- **In addition to PUE, evaluation is also required using other indicators, such as ICT energy efficiency.**

Data Centre Electricity Consumption by Technology（PUE=2）



Note：PUE is a measure of data center energy efficiency, which can be calculated by dividing the total data center facility energy by the IT equipment energy consumption. The closer PUE gets to 1, the more efficient a data center is.

Toward Electricity Savings

Current

- Large-scale computation for AI applications
- Servers are installed to accommodate floor space constraints in urban areas and to enable **high-density computation per unit of floor space**.

✓ Increase in electricity consumption, waste heat and need for cooling

Future

- Improving the efficiency of ICT equipment
- Utilizing innovative cooling technologies
- Facility consolidation (hyper-scaling)
- Increasing computing efficiency
- Use of waste heat, and renewable generation

Source（Left Side Figure）：Hongyu Zhu et. Al. (2023). Future data center energy-conservation and emission-reduction technologies in the context of smart and low-carbon city construction . Sustainable Cities and Society | VOL 89 | 2023 |

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Data Centre, AI and Energy：Current and Future

		Current	Future
Hardware (Data Centre)	ICT  Servers, storage, and IT auxiliary equipment	• IT equipment accounts for the largest proportion of electricity consumption at **data centers, at around 50%.** • Data centers are often located near cities, and in order to make efficient use of land, **ICT equipment is being packed more densely per rack**, which can result in a decrease in efficiency when air conditioners are operating at full capacity. • The spread of **generative AI** is leading to an increase in data volume and increased electricity consumption.	• Optimizing **rack layout** • Shifting from company data centers to **hyperscalers** • Shifting to **edge computing** depending on the application • Optimizing server utilization, such as **shifting from GPUs to CPUs** • Increasing the efficiency of **integrated circuits and storage**
	Support Facility  Cooling, backup power, lighting, etc.	• The increase in computing volume and the increasing density of IT equipment are driving up demand for cooling. • In particular, related power consumption accounts for **approximately 35% of total electricity consumption of traditional data centres**. •	• High efficiency from air-cooled to **rear door air conditioning, liquid cooling**, and immersion cooling
Software	Algorithm  Generative AI、Data Volume、Software	• The electricity required for **generative AI calculations is 10 times that of a typical search**. • On the other hand, the electricity consumption per search by the **latest generative AI is equivalent to that of a typical search**.	• Reduced energy demand per task through **innovative algorithms Models are "right-sized" for a variety of tasks**

Source：IEEJ (2025).

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Hyperscalers ：Net Zero Roadmap

✓ Hyperscalers are undertaking various measures for meeting the ambitious net zero targets.

Hyperscaler	Net Zero Target	Measures for Net Zero		
		Data Centre	Supply Chain	Electricity Supply, CDR
Amazon (Amazon Web Services)	2040 (Amazon as a whole, hourly matching)	• Improve PUE by introducing efficient cooling systems • Develop efficient semiconductor chips	• Use of low-carbon building materials (steel, concrete) • Use of low-carbon fuels (SAF, renewable diesel)	• Renewable energy investments, PPAs • PPAs with battery systems, utilization of in-house systems • PPAs for nuclear power generation, support for SMR development
Microsoft (Microsoft Azure)	2030 (Microsoft as a whole, hourly matching)	• Energy-saving operation, such as standby mode Development of advanced cooling technology	• Use of low-carbon building materials (steel, concrete, wood, etc.) • Use of low-carbon fuels (SAF, renewable diesel) • Collaboration with suppliers (requesting the use of carbon-free electricity)	• Renewable energy investments and PPAs Nuclear power PPAs (including restarts) • Support for CDR technology development
Google (Google Cloud Platform)	2030 (Google as a whole, hourly matching)	• Cooling system optimization using machine learning • DR through task shifting • Data center design optimization	• Collaboration with suppliers (requesting the use of carbon-free electricity) • Use of low-carbon building materials	• Renewable energy investments and PPAs Support for the implementation of decarbonized energy using our own technology
META	2030	• Workload monitoring and power profile optimization • Energy-efficient hardware design • Efficient cooling using fresh air and direct evaporative cooling	• Collaboration with suppliers (aiming for more than two-thirds of suppliers to set emissions targets by 2026) Utilization of decarbonized fuels (SAF, biofuels)	• Investment in renewable energy batteries, PPA • Support for CDR technology development

Cross Company Approaches for Net Zero

- iMasons Climate Accord (ICA)：A framework aimed at decarbonizing digital infrastructure, organized by iMasons, an industry group comprised of digital infrastructure companies, primarily big tech companies.
- Semiconductor Climate Consortium (SCC)：Framework for decarbonization in the semiconductor industry
- ZEROgrid：A framework centered on large-scale consumers aimed at decarbonizing and improving the reliability of the power grid.

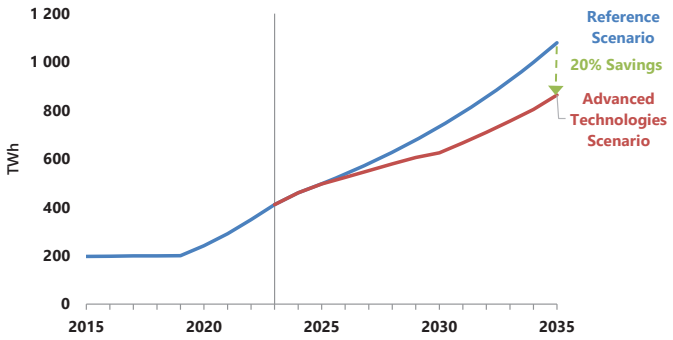
Source：From sustainability report of respective company.

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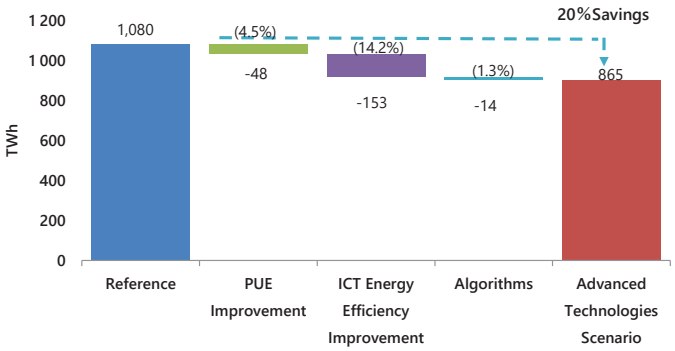
Data Centre Electricity Demand Outlook and Electricity Savings Potential（2035）

- Global data center (DC) electricity demand is expected to **more than double from the current level of 497 TWh to 1,080 TWh by 2035.**
- Improving PUE through the introduction of **high-efficiency cooling technology, ICT energy efficiency improvement** and **rationalization of algorithms** has the potential to **save electricity demand by 20% by 2035.**

Data Centre Electricity Demand Outlook（2025-2035）



Data Centre Electricity Savings Potential（2035）



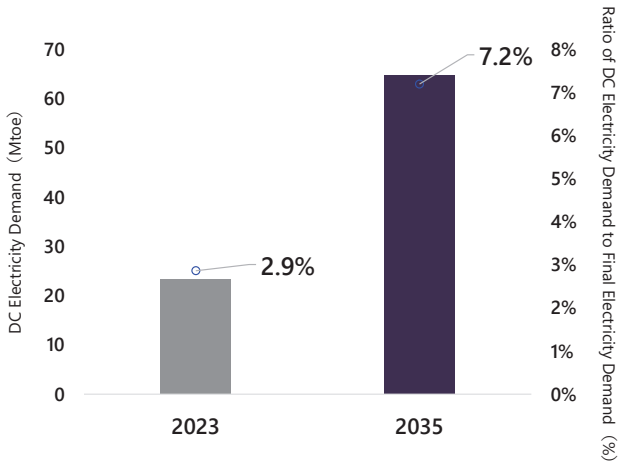
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Source：IEEJ (2025).

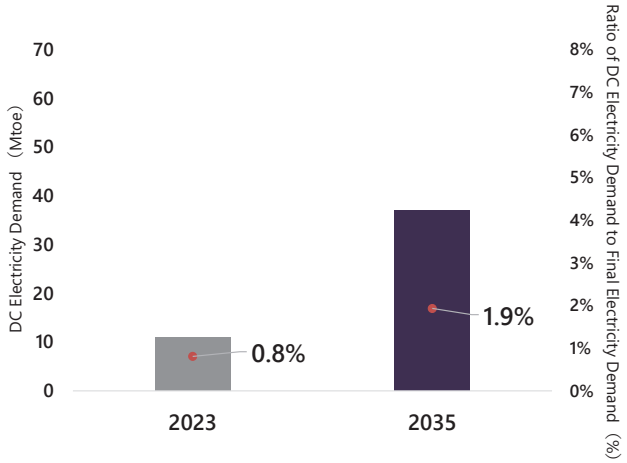
Data Centre Electricity Demand and Ratio to Final Electricity Demand (2023 and 2035)

- In **developed countries**, the share of electricity demand from data centers (DCs) in final electricity demand will **increase from 2.9% (2023) to 7.2% (2035).**
- In **emerging and developing countries**, the share will **increase from 0.8% (2023) to 1.9% (2035).**

Advanced Economies



Emerging and Developing Economies



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Source：IEEJ (2025).

Energy Savings Potential of AI for the Demand Sector

- This analysis examines **the energy savings potential of AI for the demand sector up to 2035.**

Cases

Reference Scenario	✓ The trend of change will continue against the backdrop of current energy and environmental policies. ✓ *This does not mean that the status quo of policies, technologies, etc. will remain unchanged.
Alternative Technologies Scenario (ATS)	✓ Policies for stable energy supply and strengthening climate change countermeasures will be vigorously implemented, and the introduction of low-carbon technologies such as renewable energy and high-efficiency equipment will be promoted to the maximum extent possible.
AI Advancement Scenario	✓ The introduction of AI for efficient energy use will advance energy conservation through the introduction of new technologies and improvements to stock operations, in addition to ATS.

Estimation of Technical Potential Energy Savings

Sector・Sub-sector・Technology

1. Industry
- Iron and Steel, Cement, Petrochemical, Paper and Pulp, and Other industry

2. Residential
- Cooling/Heating, and Hot Water

3. Commercial
- Cooling/Heating, Ventilation and Lighting

4. Road
- Passenger Vehicles, Buses・Trucks

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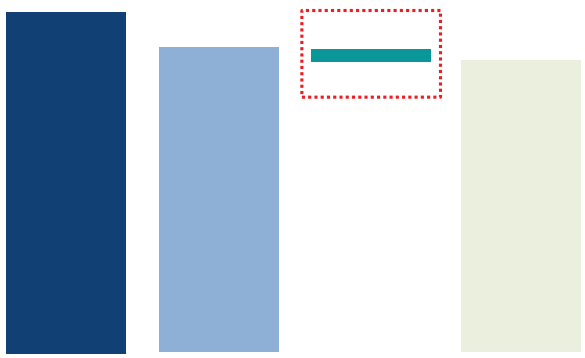
What contributions does AI can make to the energy sector?

- AI is expected various benefits to the energy sector.
- This study conducted **a quantitative analysis of the energy savings potential of AI for optimization of the demand sector.**

Examples

Detection	▪ Automatic detection of malfunctions and other issues, detection of methane leaks ▪ Remote sensing
Prediction	▪ Weather forecasting and renewable energy use ▪ Industrial production forecasting and building operation forecasting ▪ Transportation demand forecasting and vehicle route optimization
Optimization	▪ Optimizing industrial production processes ▪ Optimizing energy usage in buildings and equipment ▪ Improving fuel efficiency through autonomous driving ▪ Demand response through energy supply and demand optimization
Simulation	▪ Simulations related to identifying new materials and manufacturing new products ▪ Simulations of the effects of energy conservation and clean energy adoption

Image of Energy Savings Potential by AI



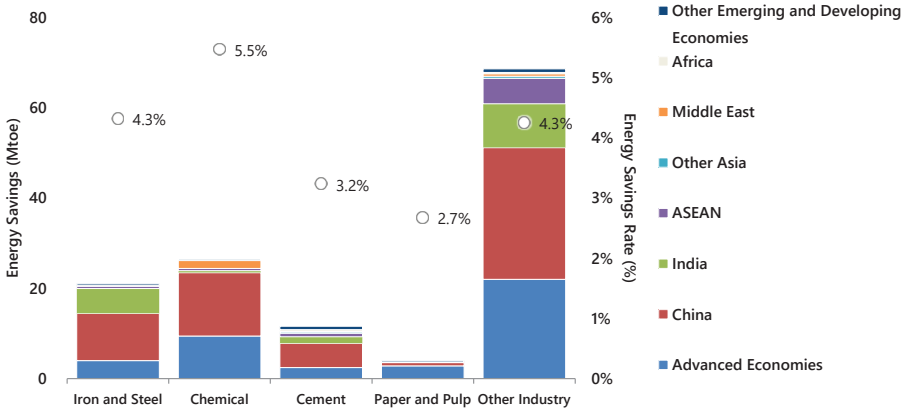
Source：ICEF（2024）他より作成。

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Industry: Energy Savings Potential of AI （Ratio to Alternative Technologies Scenario）

- Previously, **operational improvements were mainly based on the experience and knowledge of experienced operators**, but **by combining this with AI**, energy savings become possible through dynamic control based **on real-time predictions and an integrated approach that simultaneously optimizes multiple processes throughout the factory**.
- By 2035, **the use of AI has the potential to save 2-5%** in energy compared to **the Advanced Technologies Scenario**.

Energy Savings Potential of AI and Ratio to Alternative Technologies Scenario【2035】



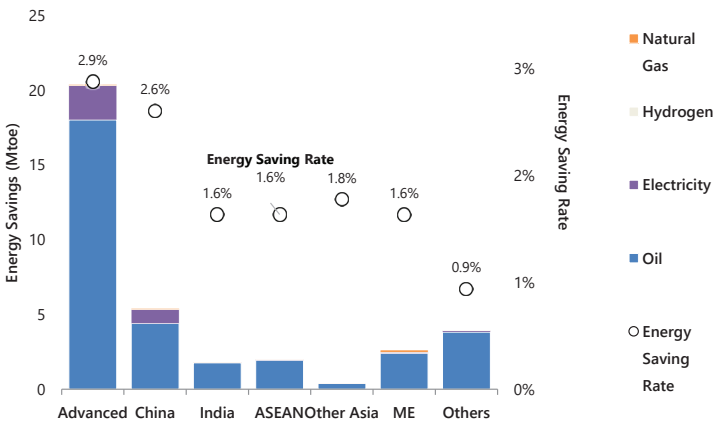
Source：IEEJ (2025).

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Road Transport: Energy Savings Potential of AI （Ratio to Alternative Technologies Scenario）

- ✓ Autonomous driving using AI is expected to improve fuel efficiency and optimize (shorten) travel routes.
- ✓ The energy saving potential of AI for **passenger cars, buses, and trucks is estimated to reach 36.5 Mtoe in 2035 (0.9%-2.9% compared to ATS).**

Energy Savings Potential of AI and Ratio to Alternative Technologies Scenario【2035】



Source：IEEJ (2025).

Examples for Energy Savings of AI in the Road Transport

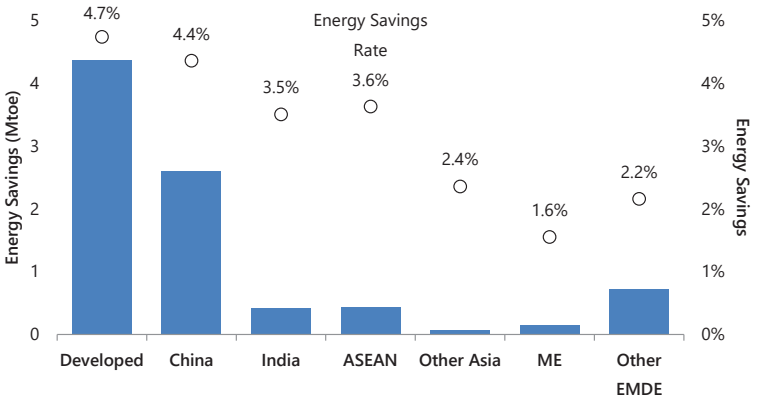
	Exampes
Demand Projection	The loading efficiency and passenger efficiency of cargo trucks, buses, taxis, etc. can be improved by taking into account weather and traffic information.
Route Optimization	Through machine learning, AI suggests route optimization that takes into account the driver's travel preferences and, in the case of cargo trucks, delivery efficiency.
Maintain distance between vehicles	By maintaining a constant distance between vehicles through autonomous driving, vehicles can move without congestion, contributing to improved fuel efficiency. Platooning also reduces air resistance, contributing to improved fuel efficiency.

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Commercial/Buildings: Energy Savings Potential of AI （Ratio to Alternative Technologies Scenario）

✓ The energy savings potential for heating, cooling, ventilation, and lighting in 2035 is 8.8 Mtoe (102 TWh), which is equivalent to a reduction of approximately 10% of the data center's electricity demand in 2035.

Energy Savings Potential of AI by Cooling/Heating/Ventilation/Lighting and Ratio to Alternative Technologies Scenario【2035】



Examples for Energy Savings of AI in the Commercial Sector

Design Phase	▪ Utilizing AI technology to leverage large amounts of accumulated past data, highly energy-efficient buildings can be designed for new construction and renovations. ▪ It is possible to simulate not only individual buildings but also improvements to the energy efficiency of the entire region.
Operational a Phase	▪ Sensors collect information on people flow and the weather, and optimally control lighting, air conditioning, and power throughout the building, achieving both efficient energy use and comfort. ▪ It is possible to improve the operation of not only individual buildings but also regional energy demand.

Source：IEEJ (2025).

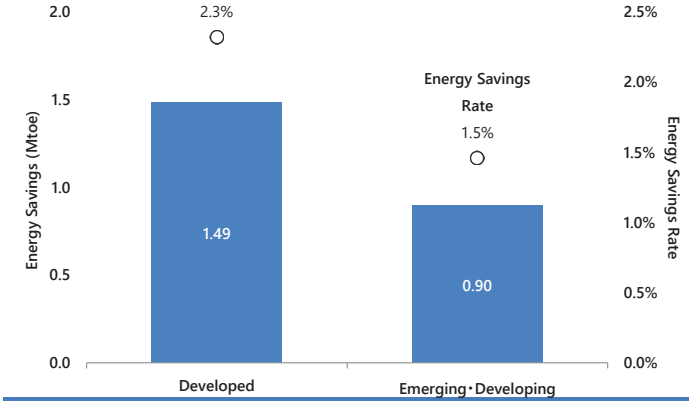
IEEJ © 2025

Residential : Energy Savings Potential of AI （Ratio to Alternative Technologies Scenario）

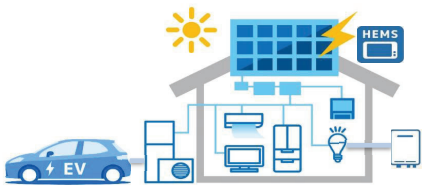
✓ Estimates of the energy savings potential for heating and cooling using AI suggest that in 2035, **it could reach 1.5 Mtoe in developed economies (a 2.3% savings compared to the Advanced Technologies Scenario)** and **0.9 Mtoe in emerging and developing economies (a 1.5% savings compared to the Advanced Technologies Scenario).**

✓ As AI-enabled technology is a high-end product that requires a high initial investment, there is a need to promote understanding of benefits and cost of AI-enabled technology.

Electricity Savings Potential of AI by Cooling/Heating/Hot Water Supply and Ratio to Alternative Technologies Scenario【2035】



Images for Energy Savings of AI in the Residential Sector



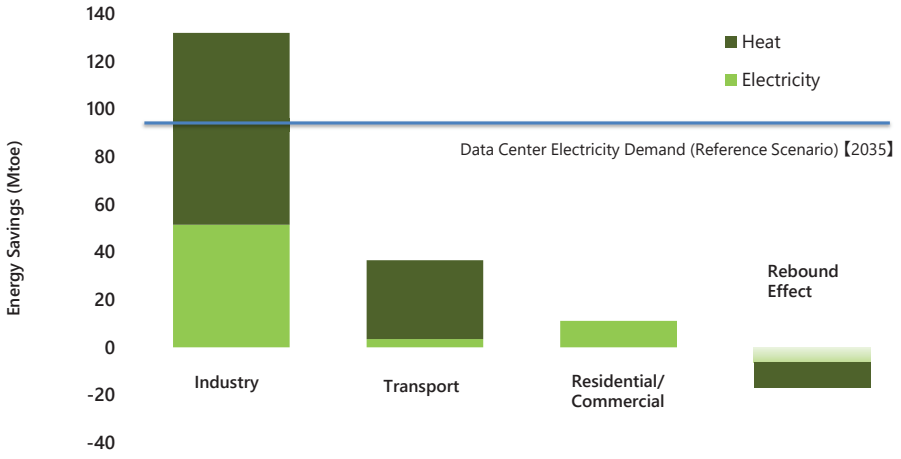
IoT	AI
Obtain information (temperature and humidity, electricity rates, solar power generation, household usage, and human activity), and control it remotely via smartphone	AI learns and analyzes the various information acquired ↓ Optimal operation

Source：IEEJ (2025).

IEEJ © 2025

Energy Savings Potential of AI at the Demand Side（2035）

- ✓ Demand-side energy savings using AI have **the technical potential to reach 178 Mtoe (2,088 TWh) in 2035.**
- ✓ By sector, the energy demand reduction effect is greatest in the industrial sector.



Source：IEEJ (2025).

IEEJ © 2025

Hurdles and Risks for AI in the Demand Side

	Hurdles	Risks
Residential and Commercial	▪ Low adoption of digital technology and shortage of digital-related human resources ▪ Increasing urbanization in emerging countries and a lack of consideration for digital technology in urban planning and institutional development ▪ Lack of market design for flexible supply and demand adjustment	▪ AI is a "high-end" method and may be outperformed by other methods, such as improved insulation performance. ▪ Possible rebound effect ▪ Operational risks (safety and security risks)
Industry	▪ Lack of investment in digitalization among small and medium-sized enterprises ▪ Lack of personnel with digital-related knowledge (energy management qualifications tend to emphasize experience, making it difficult to understand what can be done) ▪ Various types of coordination within large companies	▪ Increased energy consumption and CO2 emissions due to lack of AI maintenance ▪ Operational risks (safety and security risks) ▪ Increased energy consumption due to increased production speed in industrial production processes
Transport	▪ Lack of data ▪ Lack of standardized communication protocols ▪ Lack of human resources	▪ Risk of privacy information infringement ▪ Risk of increased energy consumption due to efficiency improvements
Measures	▪ Sharing data and best practices to promote understanding, developing human resources, and supporting implementation and promoting efforts to harmonize urban planning and digitalization.	

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Source：https://www.icef.go.jp/wp-content/themes/icef/pdf/2024/roadmap/08_ICEF2.0%20Buildings_stand%20alone.pdf

Implications

- The use of **AI on the demand side has great potential for energy savings**. By sector, the industry sector has the greatest impact on energy demand savings. However, **various challenges remain in its widespread adoption and energy savings**. By promoting the following through public-private collaboration, the use of AI can be expected to contribute to cost-effective energy savings.
  - **Human resource development and awareness building**
  - **Providing incentives for increased adoption**
  - **Data standardization**
  - **Cybersecurity measures**
- Considering the energy-saving potential of data centres, **the contribution of improving ICT efficiency is relatively large**. For this reason, **additional evaluations (other than PUE) are required, such as measuring ICT efficiency improvements** as an indicator of data center energy savings. In addition to improving cooling efficiency, which has traditionally been the central issue**, measures and methods are required to improve the efficiency of ICT equipment**. Furthermore, cooperation is important not only with data center operators, but also with a variety of stakeholders, such as semiconductor manufacturers and ICT-related manufacturers.

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Reference materials

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Geographical coverage

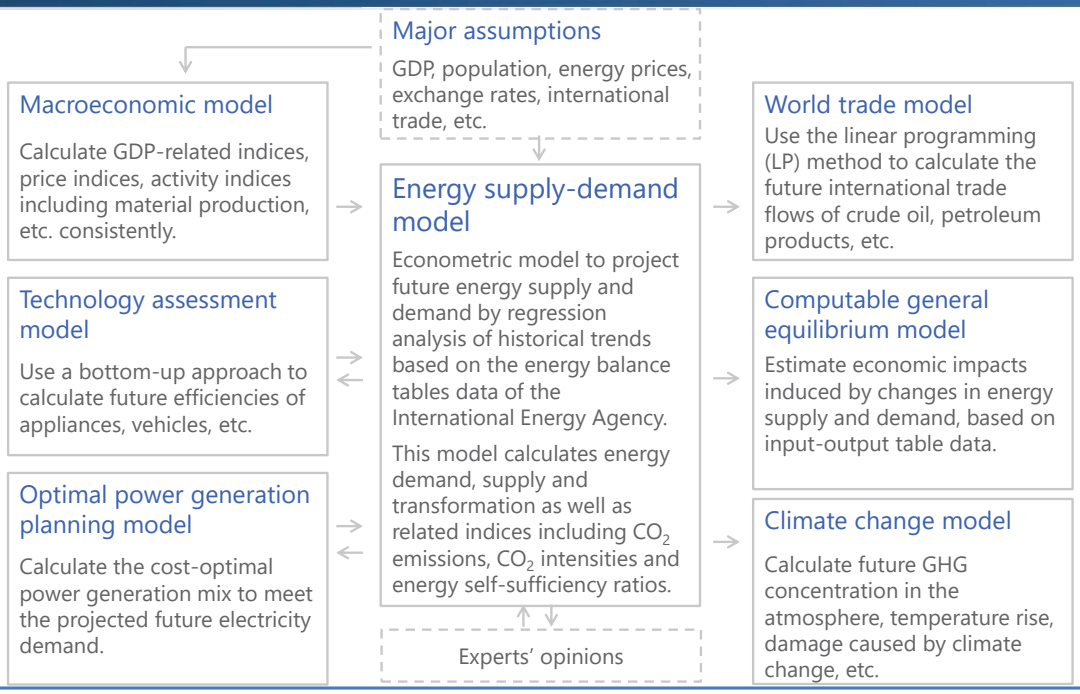
- Countries/regions in the world are geographically aggregated into 44 regions.
- Especially the Asian energy supply/demand structure is considered in detail, aggregating the area into 17 regions. That of the Middle East is also aggregated into eight regions.



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

IEEJ © 2025

Modelling framework



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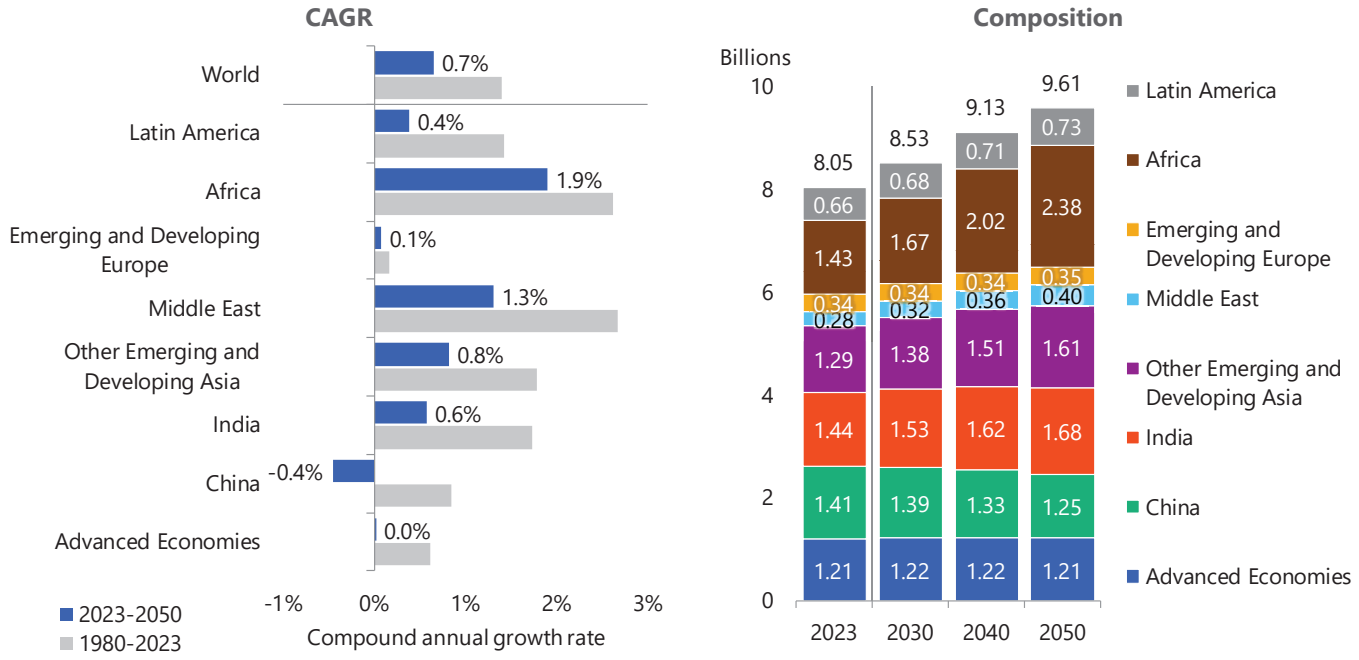
Basic scenarios in IEEJ Outlook

	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

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Assumptions

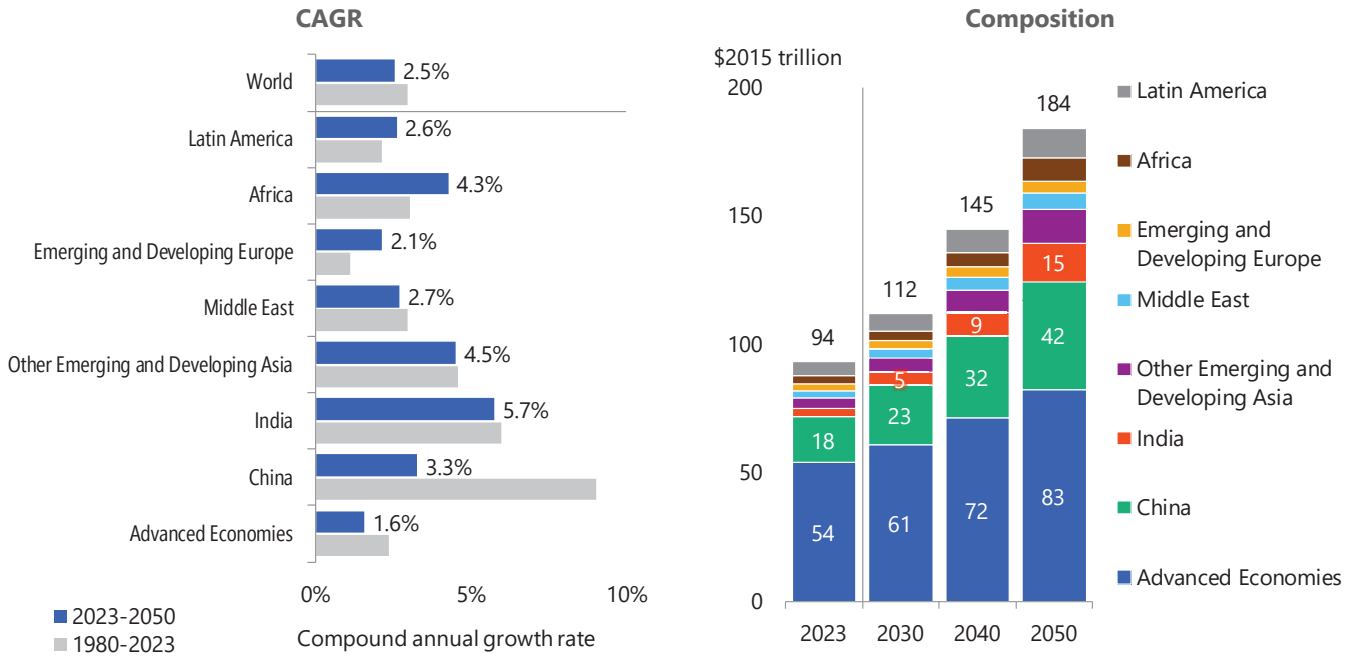
Population



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Assumptions

Real GDP



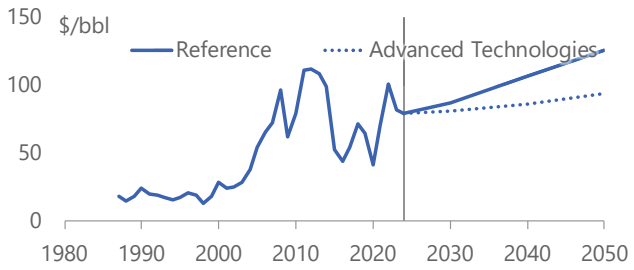
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Assumptions

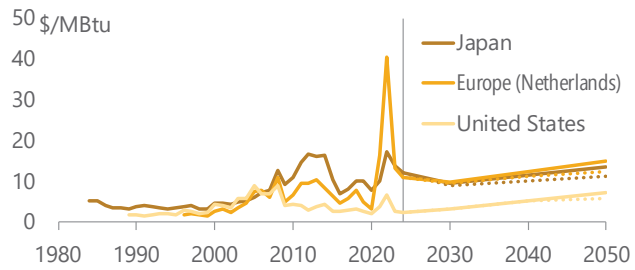
International energy prices

Reference :
Advanced Technologies :

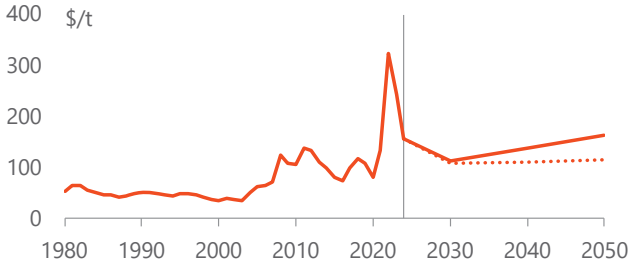
Crude oil



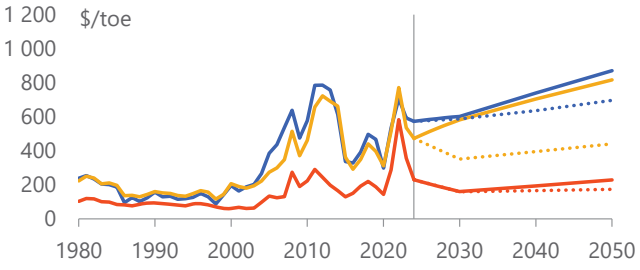
Natural gas



Coal



CIF import prices for Japan



Note: Historical prices are nominal. Assumed future prices are real in $2025.

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Assumptions

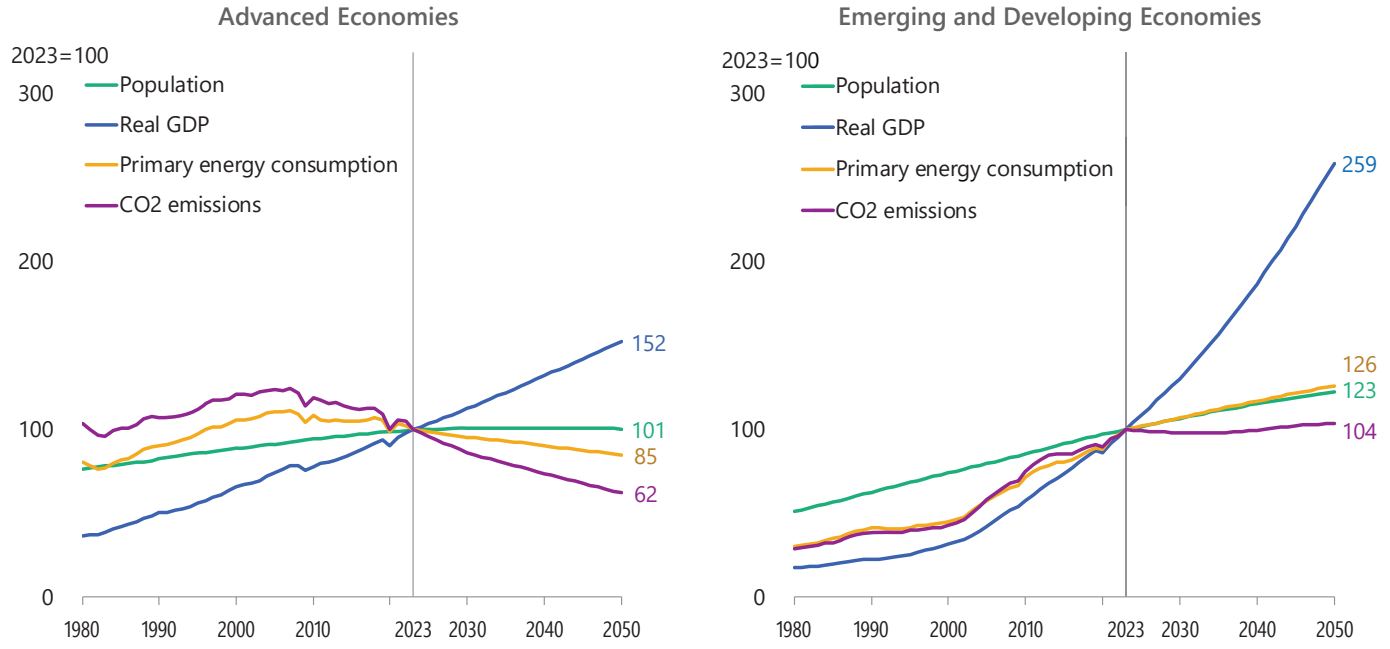
Energy and environmental technology

			2023	2050 Reference	2050 Advanced Technologies	Assumptions for Advanced Technologies Scenario
Improving energy efficiency	Industry	Intensity in steel industry (ktoe/kt)	0.273	0.268	0.203	100% penetration of Best Available Technology by 2050.
		Intensity in non-metallic minerals industry	0.095	0.073	0.064	
	Transport	Electrified vehicle share in passenger car sales	17%	65%	93%	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)	18.0	29.1	44.3	
	Buildings	Residential total efficiency (Y2022=100)	100	150	181	Efficiency improvement at 1.7 times the speed for installed appliance, equipment and insulation. Electrification in space heating, water heater and cooking (clean cooking in developing regions).
		Commercial total efficiency	100	115	142	
	Power generation	Thermal generation efficiency (Power transmission end)	37%	41%	47%	Financial scheme for initial investment in high-efficient thermal power plant.
Penetrating low-carbon technology	Biofuels for transport (Mtoe)		113	183	341	Development of next generation biofuel with cost reduction. Relating to agricultural policy in developing regions.
	Nuclear power generation capacity (GW)		407	534	852	Appropriate price in wholesale electricity market. Framework for financing initial investment in developing regions.
	Wind power generation capacity (GW)		1,077	3,490	5,084	Further reduction of generation cost. Cost reduction of grid stabilization technology. Efficient operation of power system.
	Solar PV power generation capacity		1,374	9,785	12,456	
	Thermal power generation capacity with CCS (GW)		0	22	1,287	Installing CCS after 2030 (regions which have storage potential except for aquifer).
	Zero-emission generation ratio (incl. CCS)		40%	62%	85%	Efficient operation of power system including international power grid.

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Reference Scenario

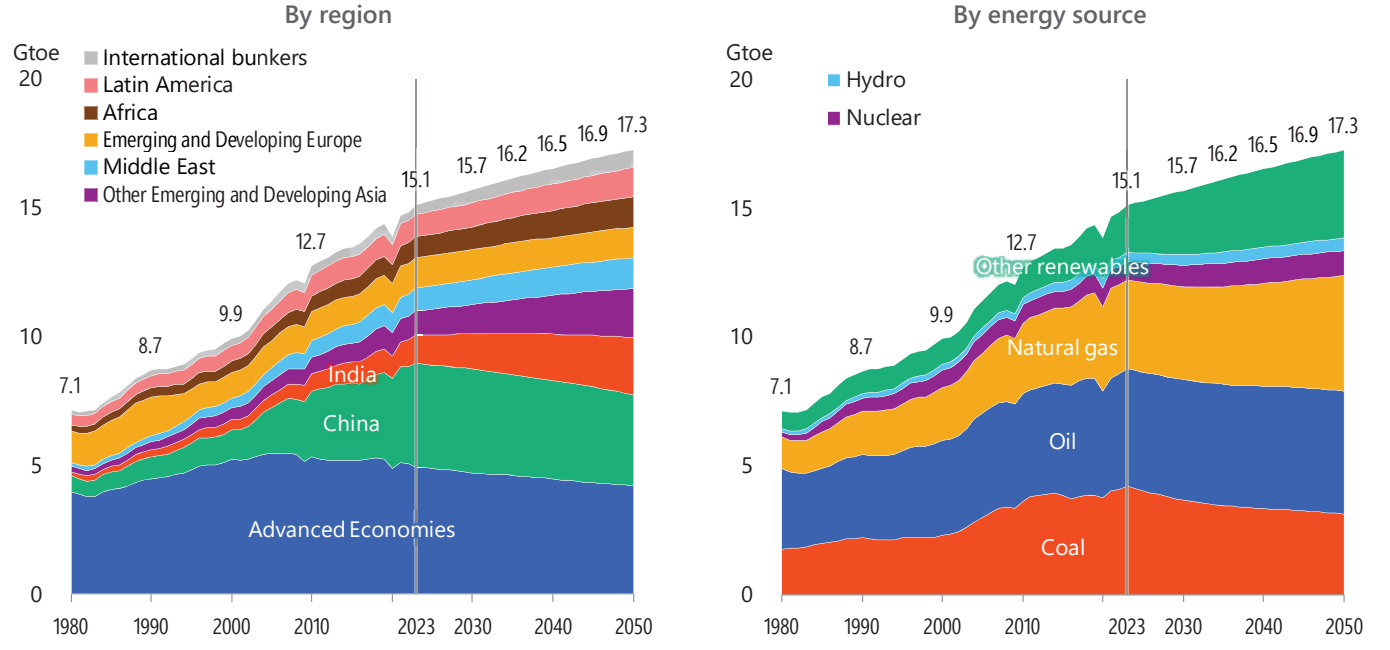
Population, GDP, energy and CO_2



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Reference Scenario

Primary energy consumption

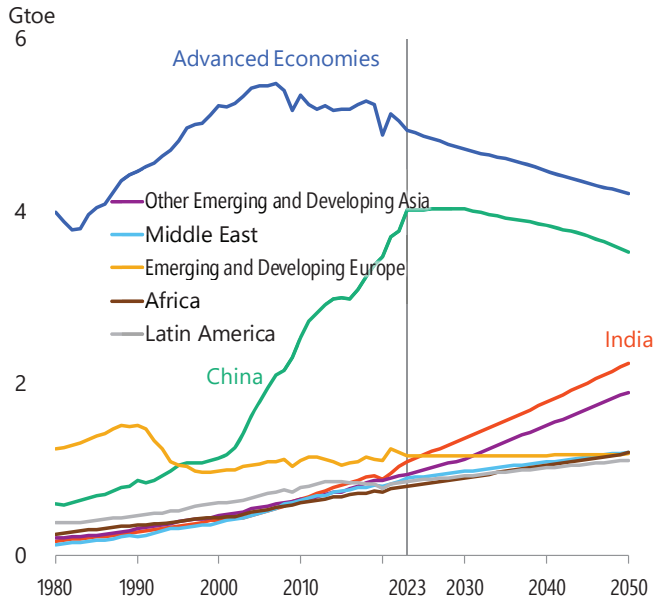


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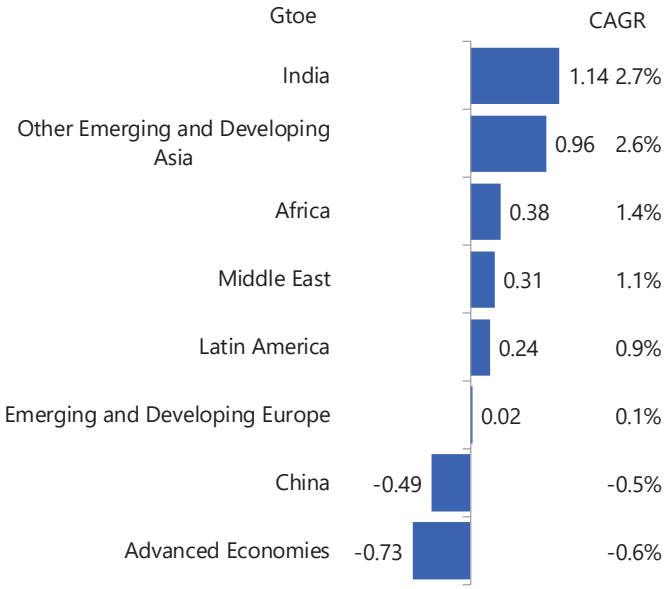
Reference Scenario

Primary energy consumption (by region)

Energy consumption



Changes (2023-2050)

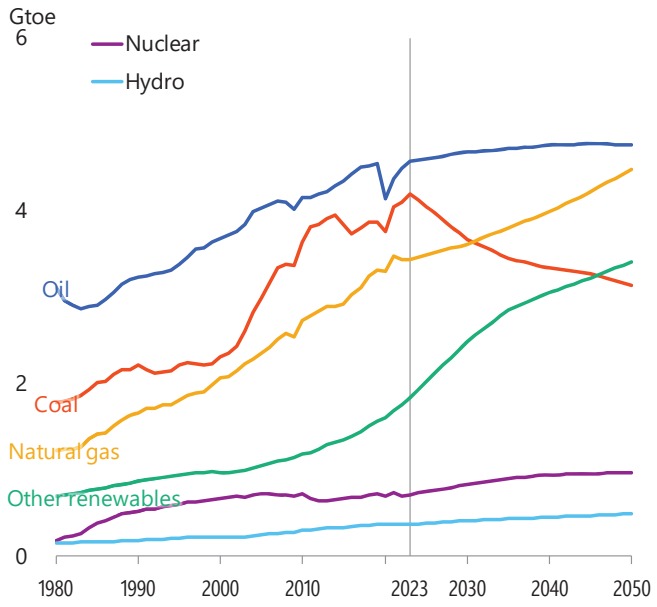


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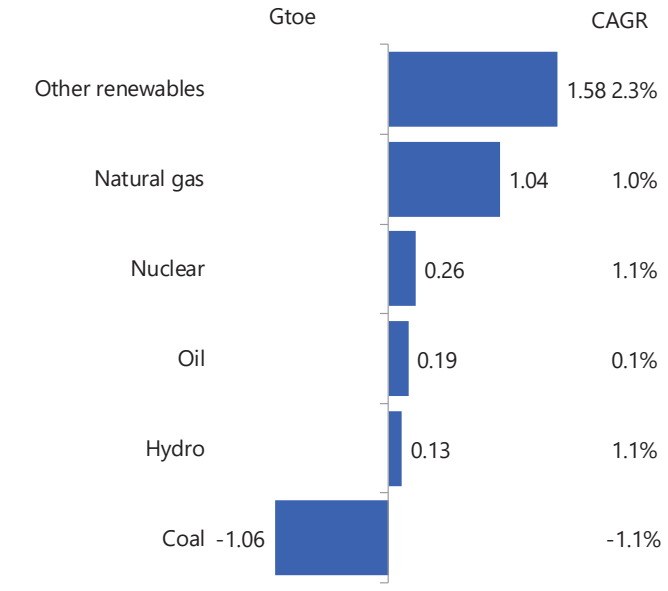
Reference Scenario

Primary energy consumption (by energy source)

Energy consumption



Changes (2023-2050)

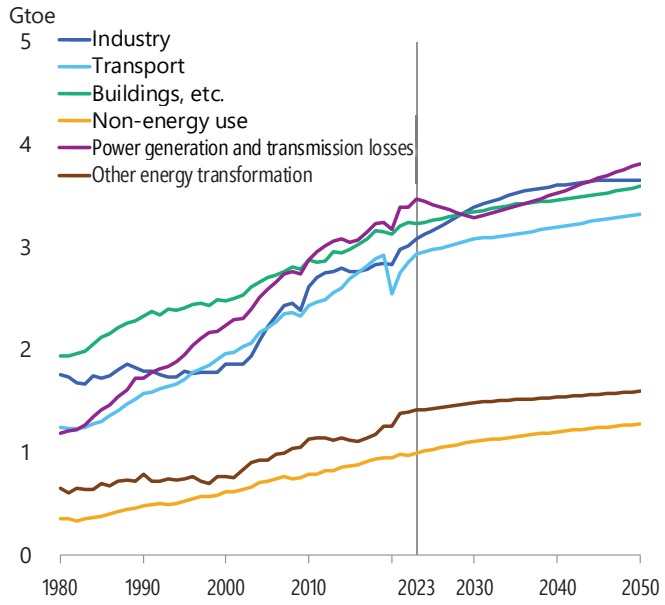


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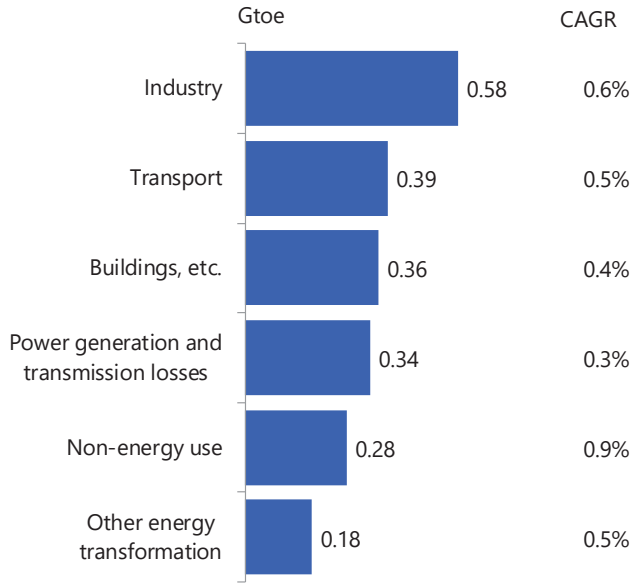
Reference Scenario

Primary energy consumption (by sector)

Energy consumption



Changes (2023-2050)

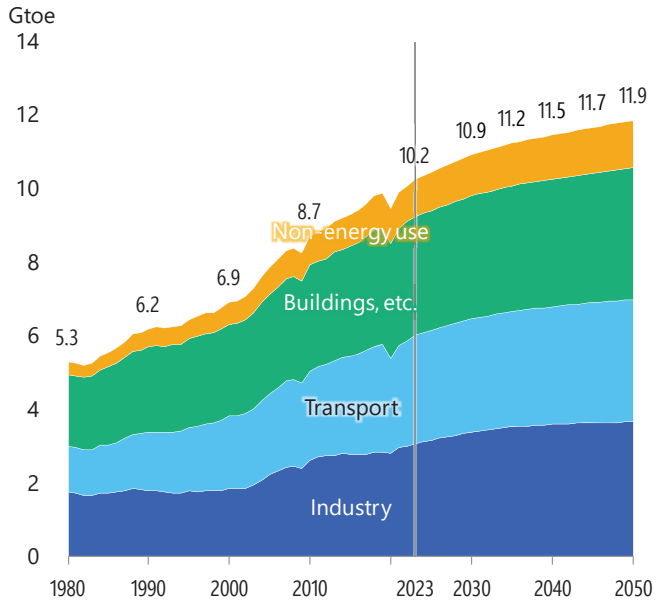


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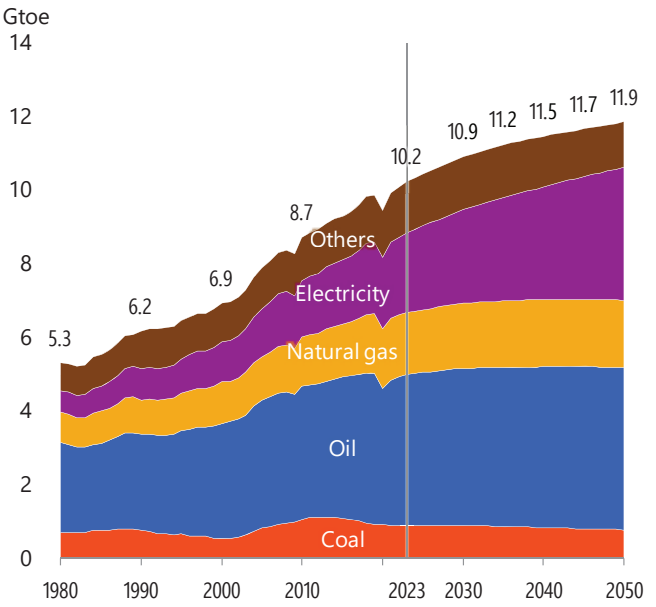
Reference Scenario

Final energy consumption

By sector



By energy source

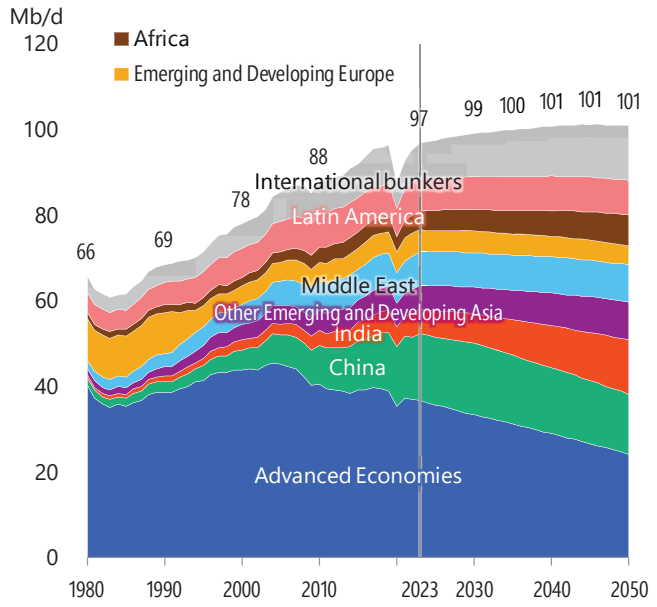


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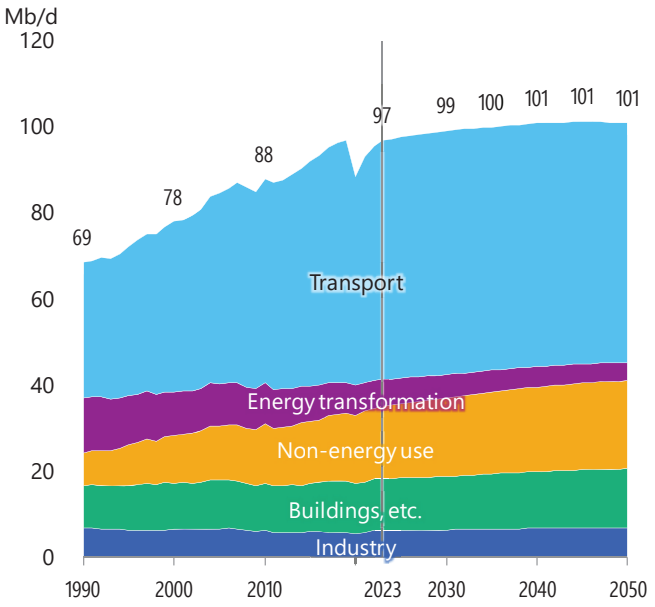
Reference Scenario

Oil consumption

By region



By sector

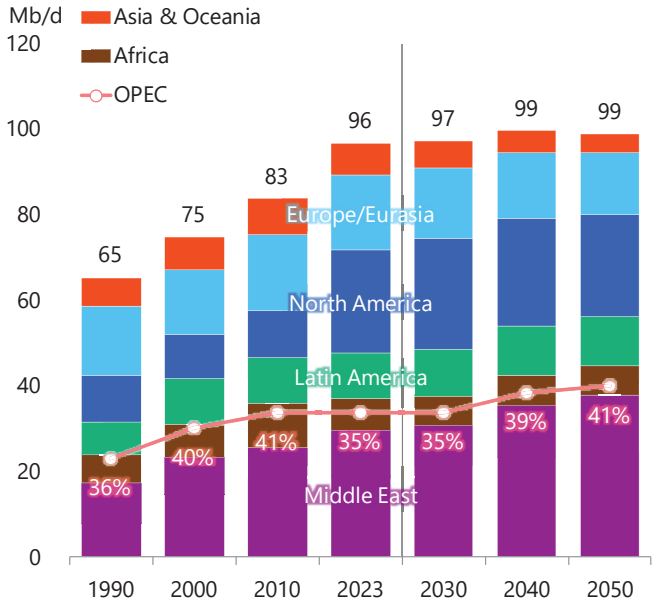


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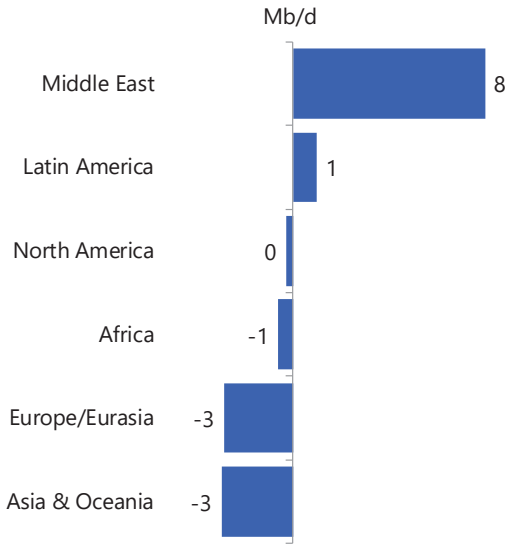
Reference Scenario

Crude oil production

By region



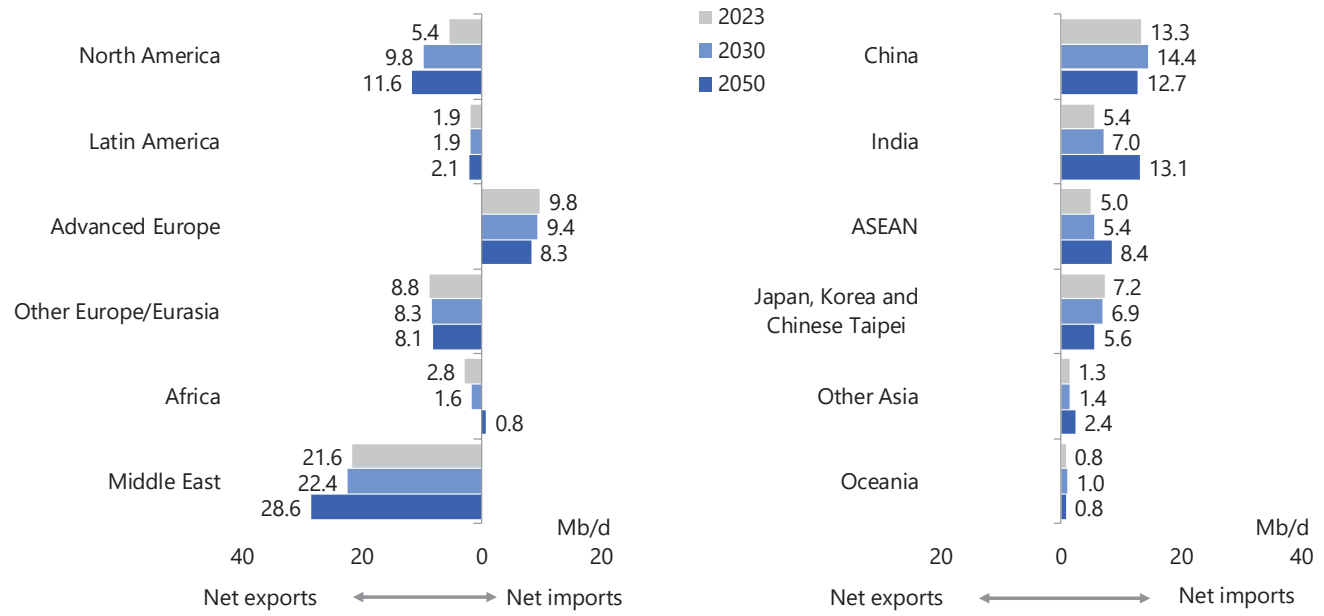
Changes (2023-2050)



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Reference Scenario

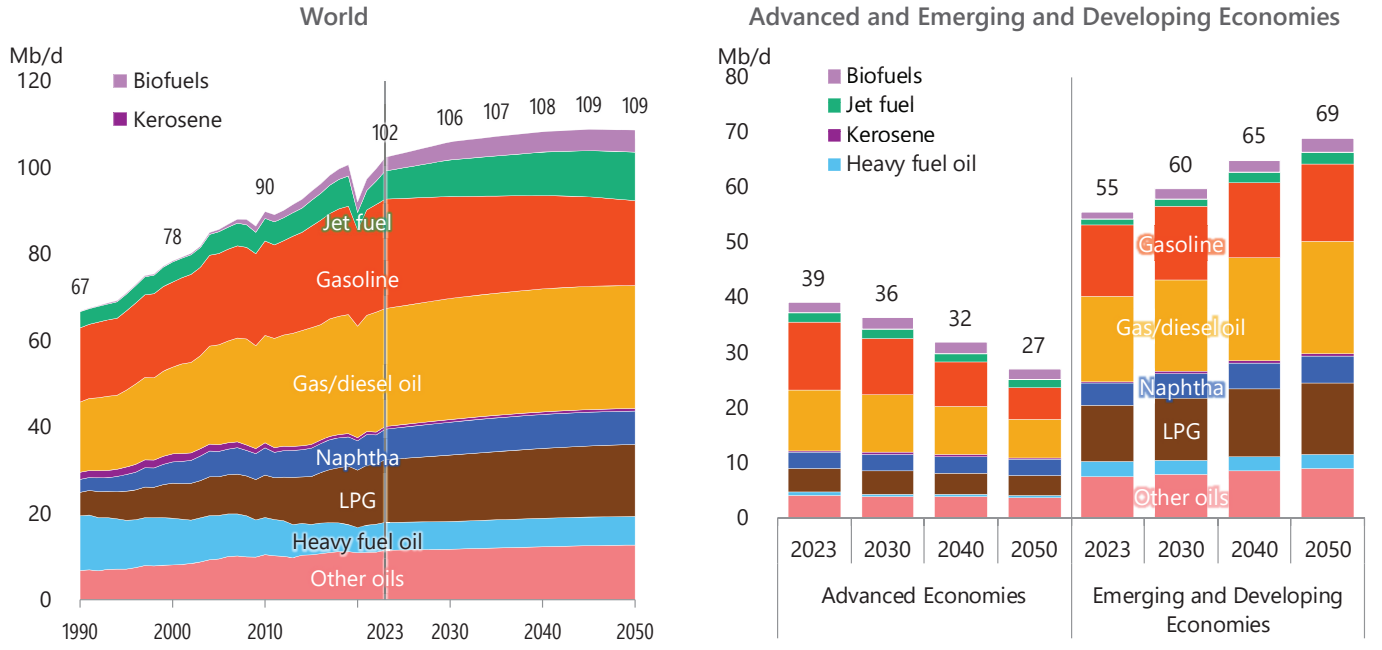
Net exports and imports of oil



IEEJ © 2025

Reference Scenario

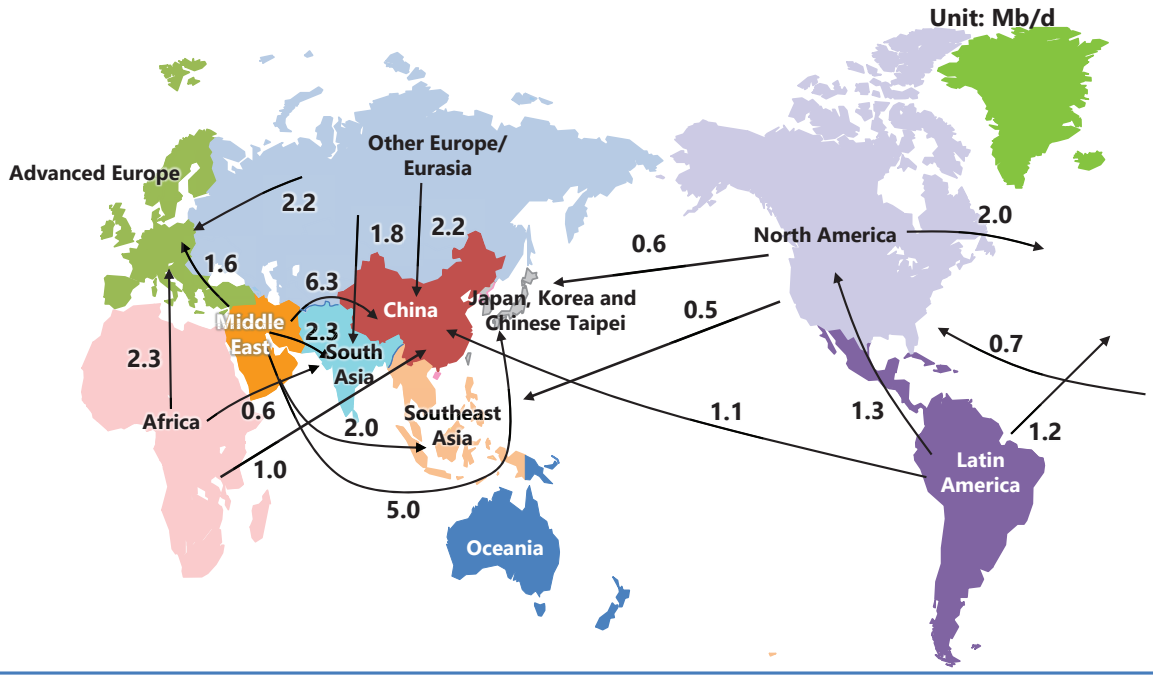
Petroleum product demand



IEEJ © 2025

Note: Other oils includes crude oil (direct consumption), asphalt, refinery gas, gas-liquefied oil [GTL], etc.

Major trade flows of crude oil (2025)

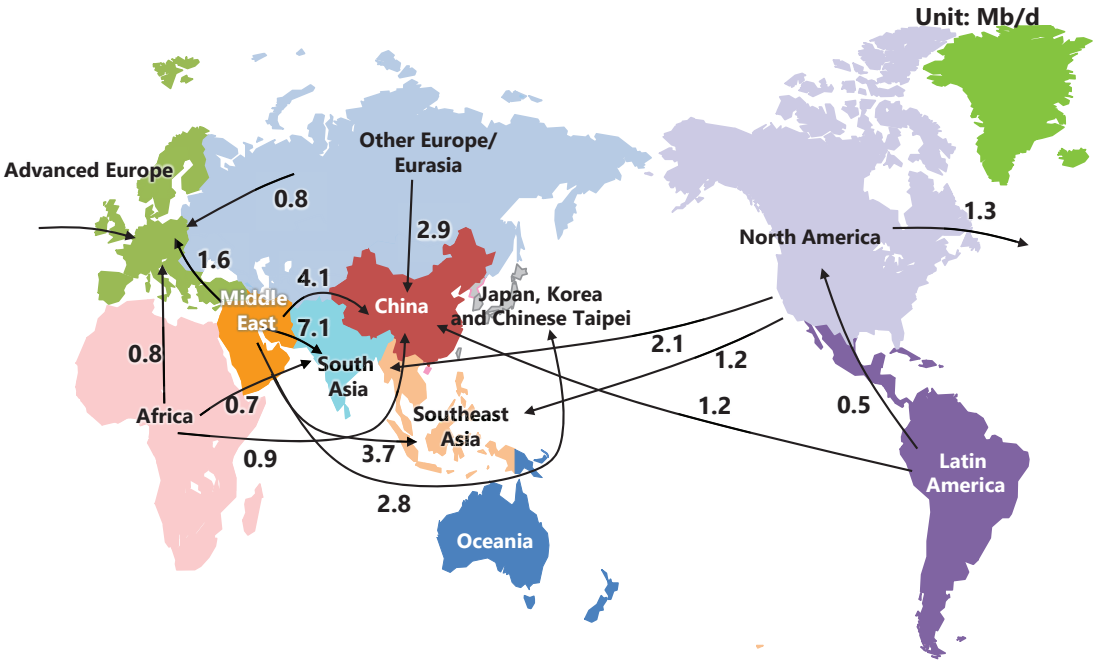


Note: 0.5 Mb/d or more are shown

IEEJ © 2025

Reference Scenario

Major trade flows of crude oil (2050)



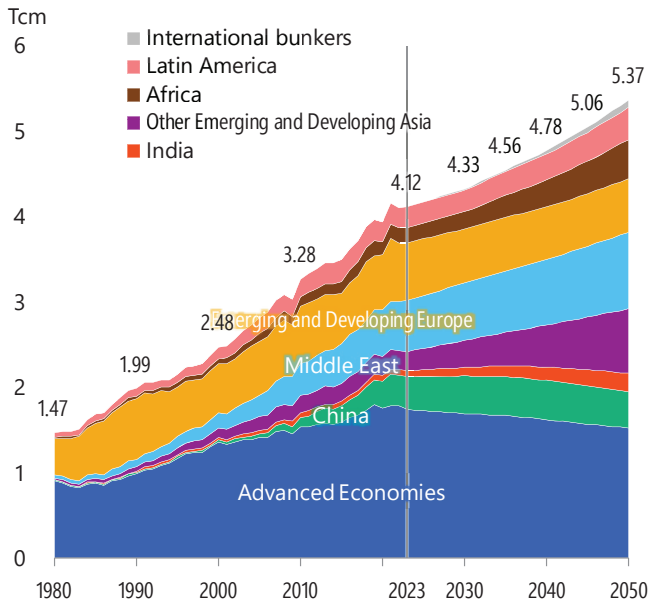
Note: 0.5 Mb/d or more are shown

IEEJ © 2025

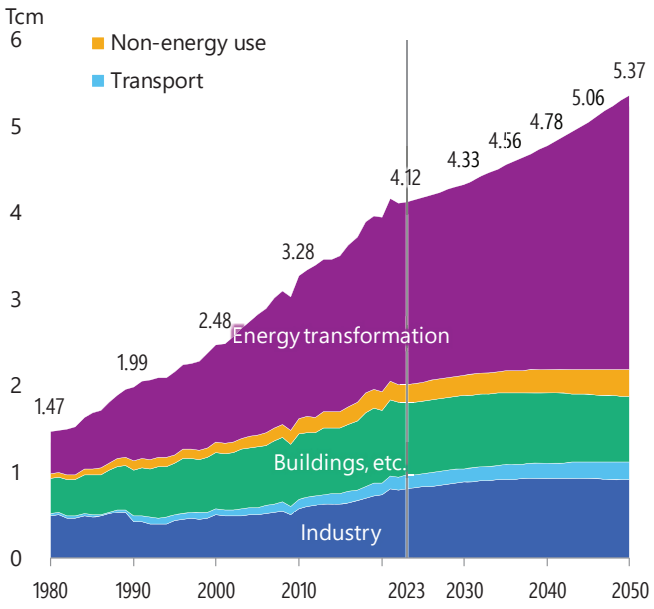
Reference Scenario

Natural gas consumption

By region



By sector

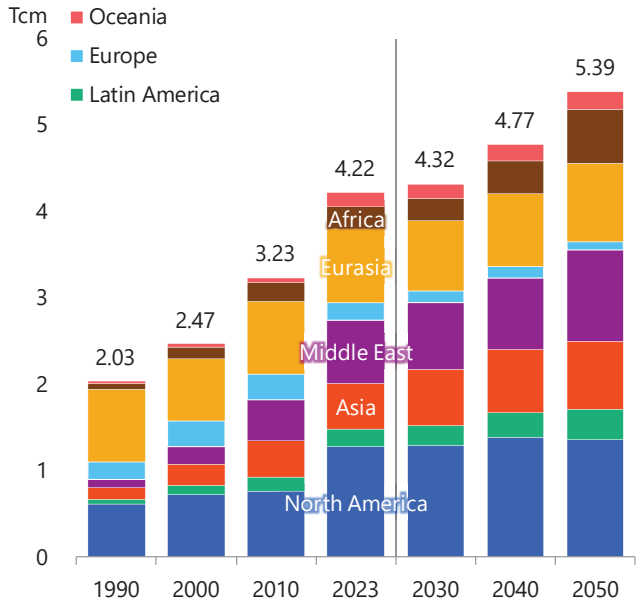


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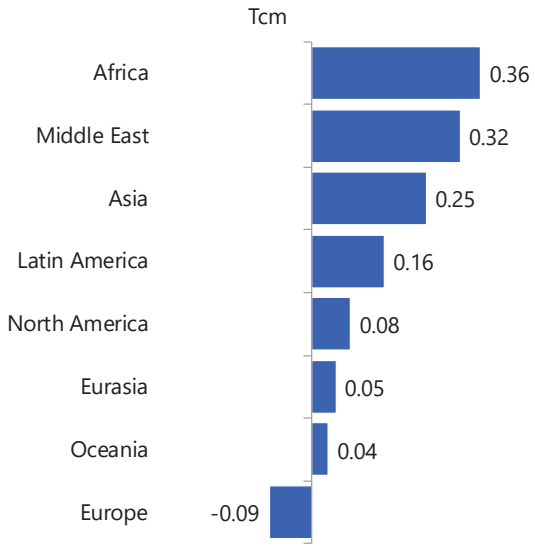
Reference Scenario

Natural gas production

By region



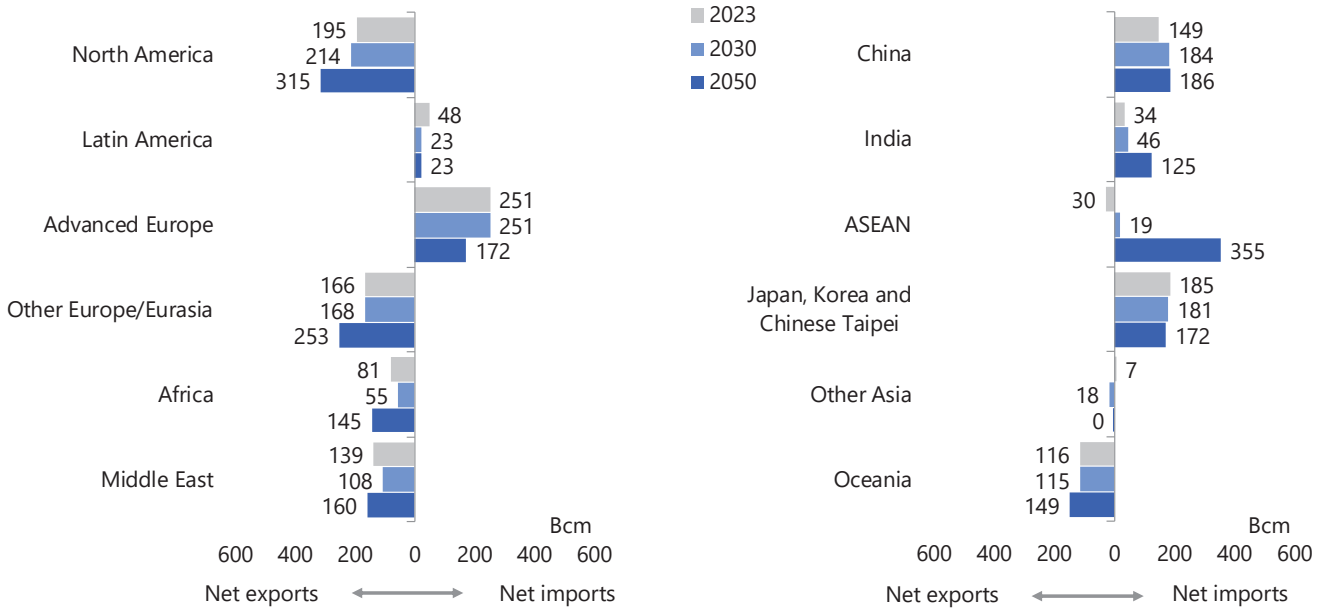
Changes (2023-2050)



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Reference Scenario

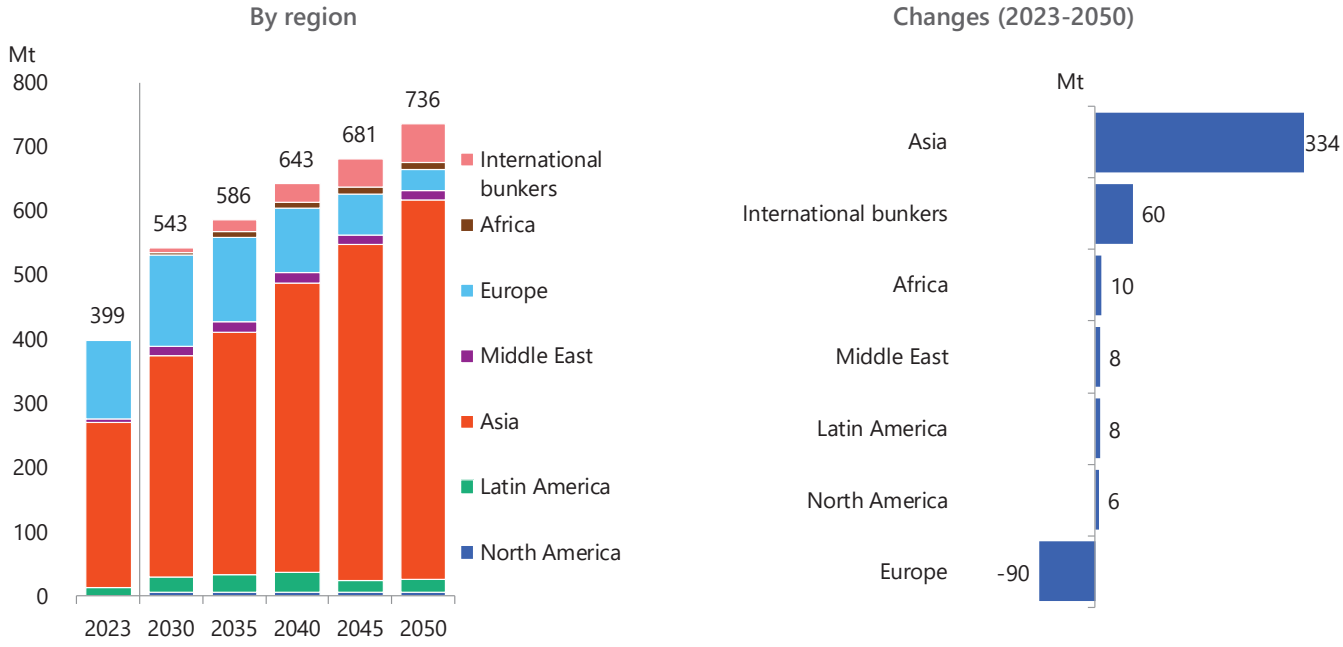
Net exports and imports of natural gas



IEEJ © 2025

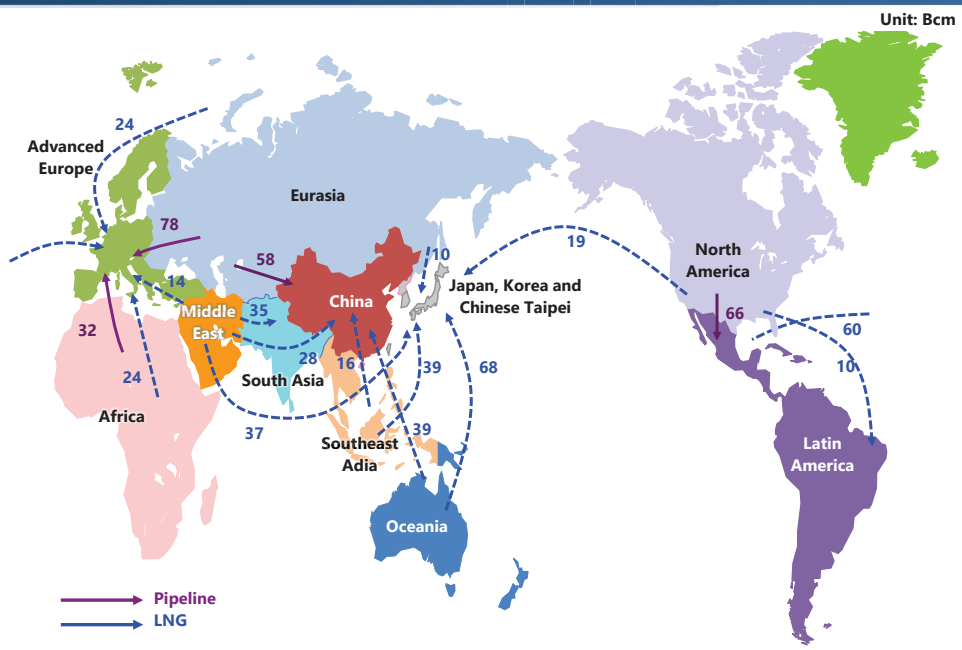
Reference Scenario

LNG demand



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Major trade flows of natural gas (2025)

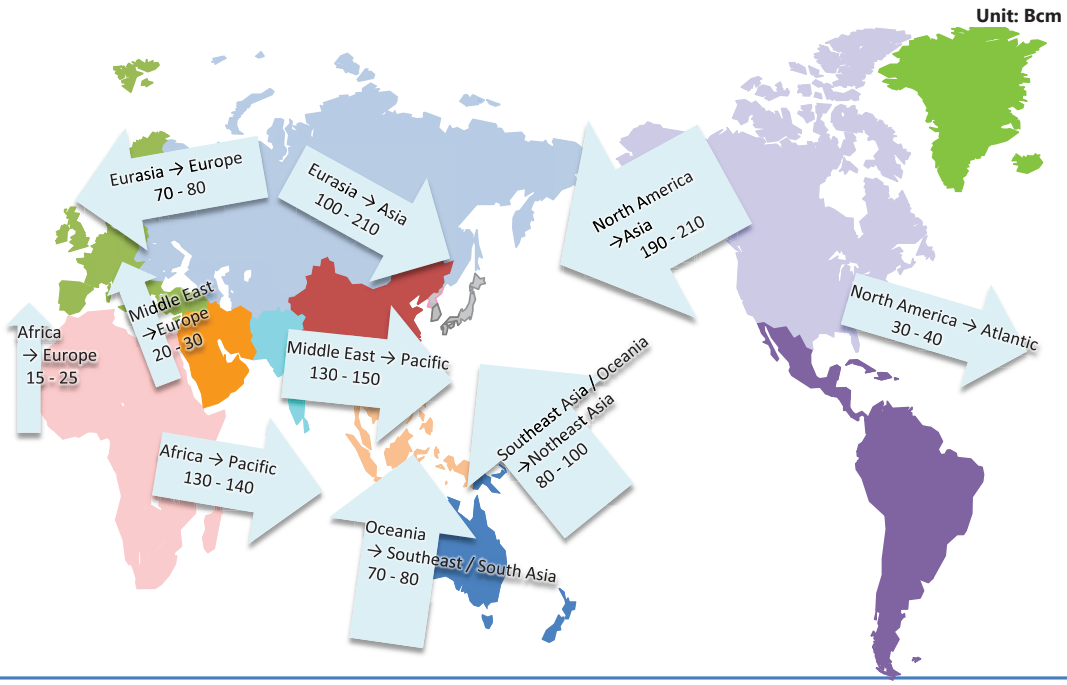


Note: This figure shows the main interregional trade and does not include the total trade volume.

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Reference Scenario

Major trade flows of natural gas (2050)



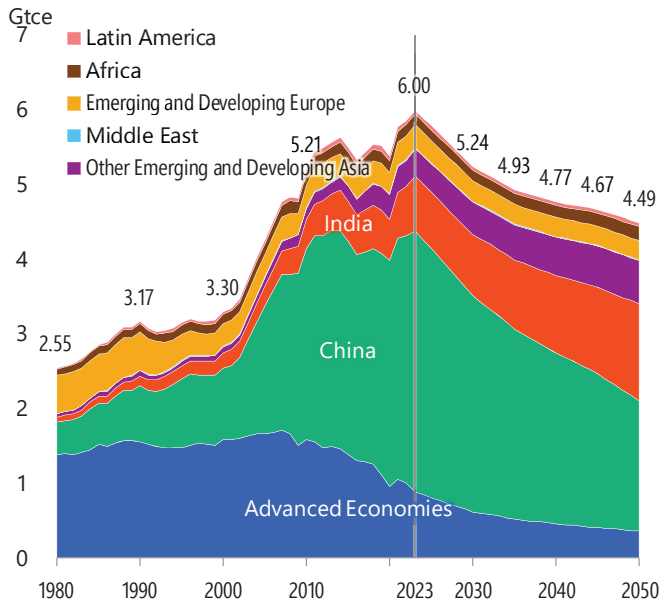
Note: This figure shows the main interregional trade and does not include the total trade volume.

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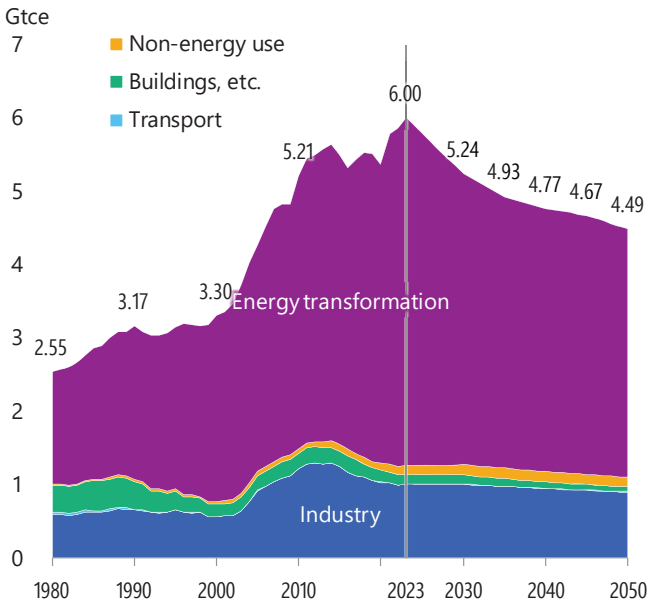
Reference Scenario

Coal consumption

By region



By sector

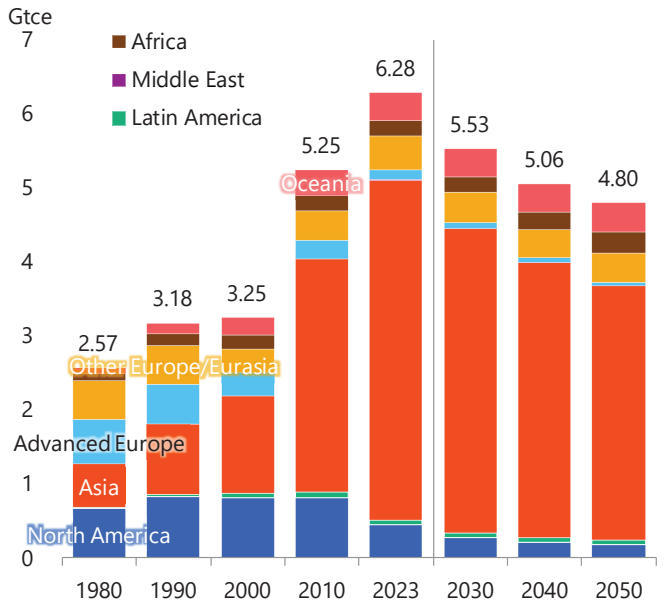


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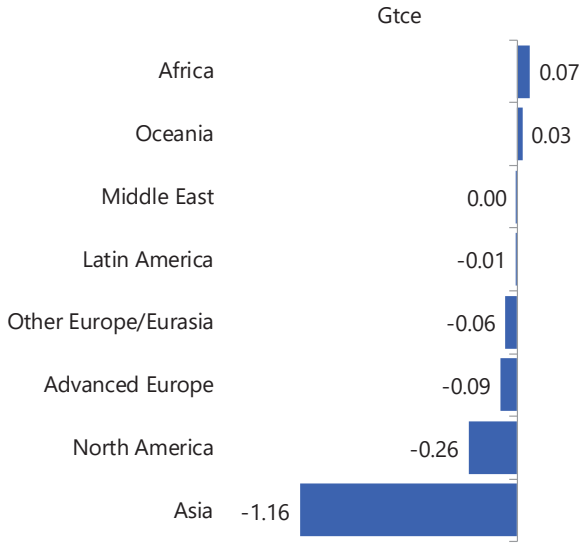
Reference Scenario

Coal production

By region



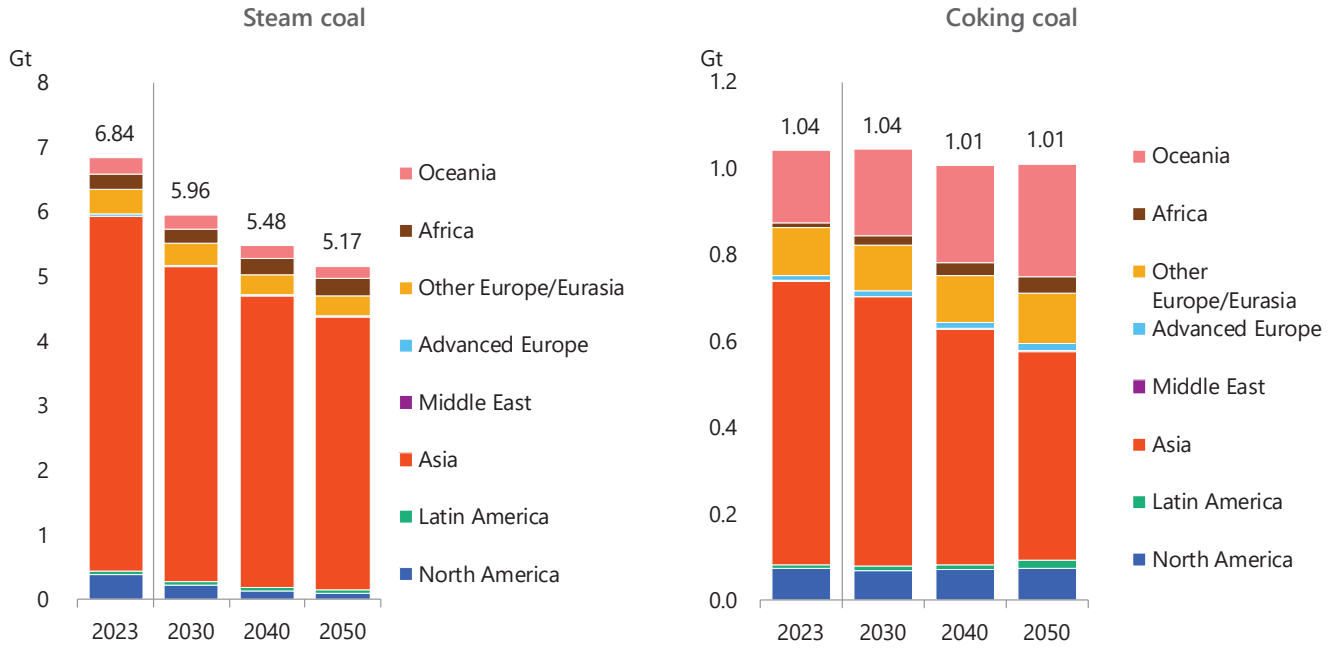
Changes (2023-2050)



IEEJ © 2025

Reference Scenario

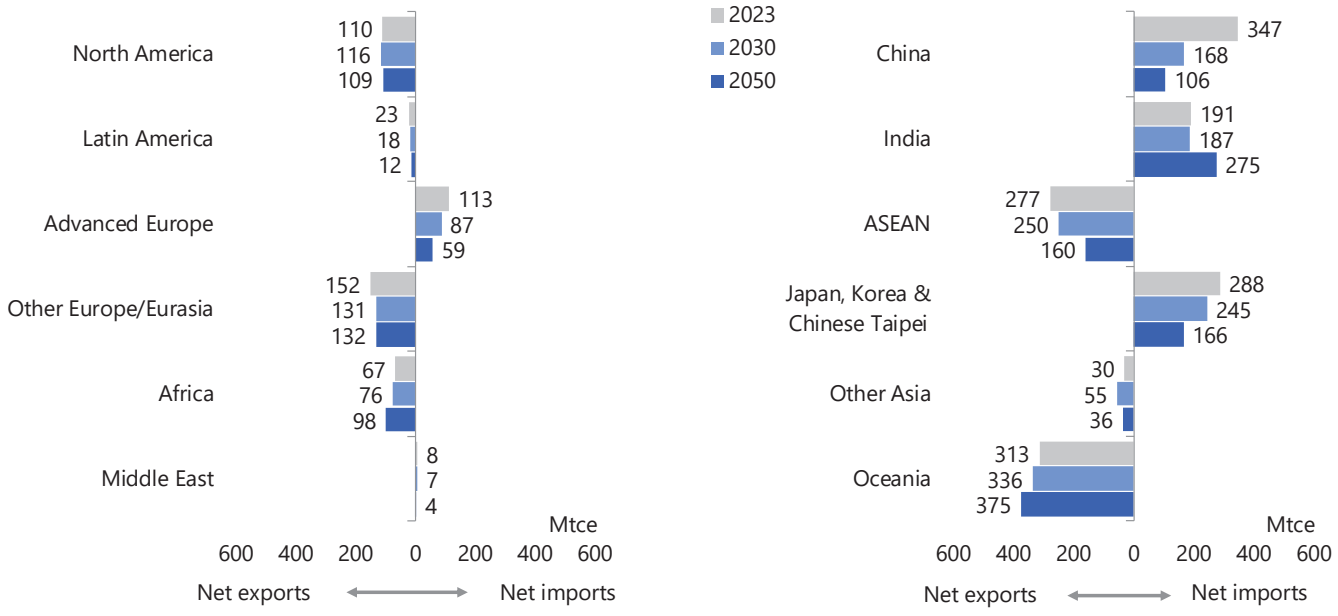
Coal production (steam and coking coal)



IEEJ © 2025

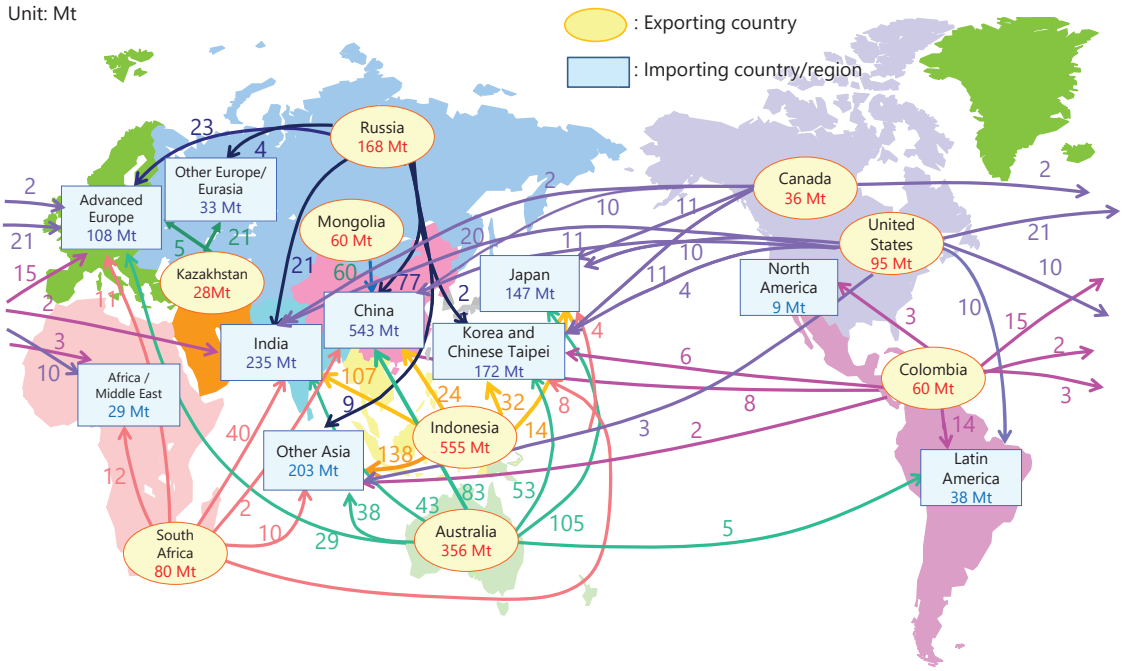
Reference Scenario

Net exports and imports of coal



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Major trade flows of steam and coking coal (2025)

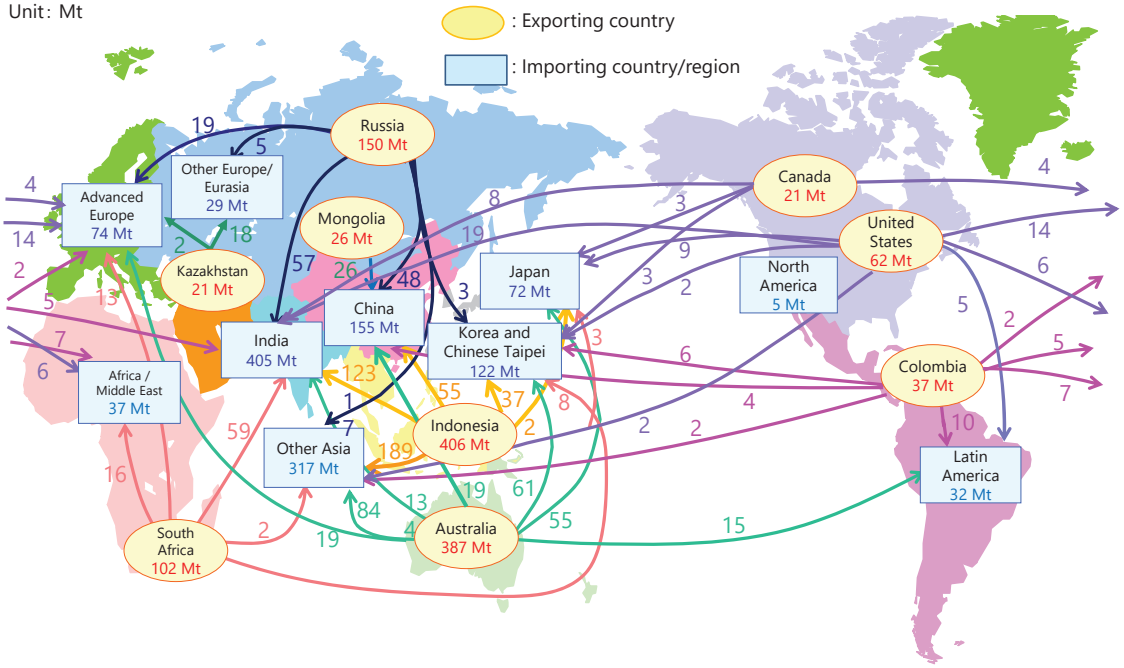


Notes: Total value of steam and coking coal. 2 Mt or more are shown. South Africa includes Mozambique. Source: Estimated from IEA "Coal Information 2025", "TEX Report", etc.

IEEJ © 2025

Reference Scenario

Major trade flows of steam and coking coal (2050)



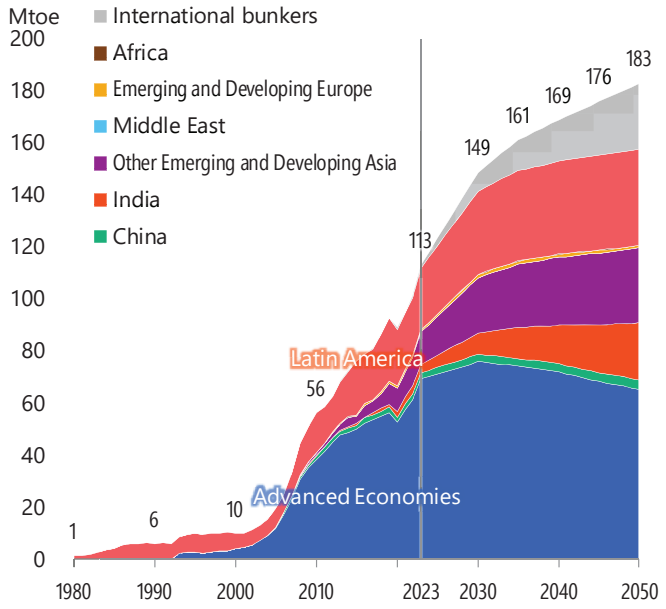
Notes: Total value of steam and coking coal. 2 Mt or more are shown. South Africa includes Mozambique.

IEEJ © 2025

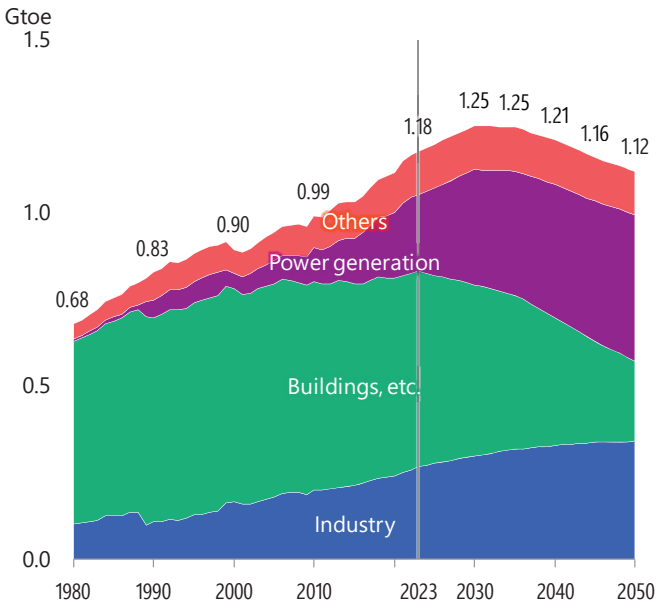
Reference Scenario

Biomass consumption

Biofuels for transport



Solid biomass

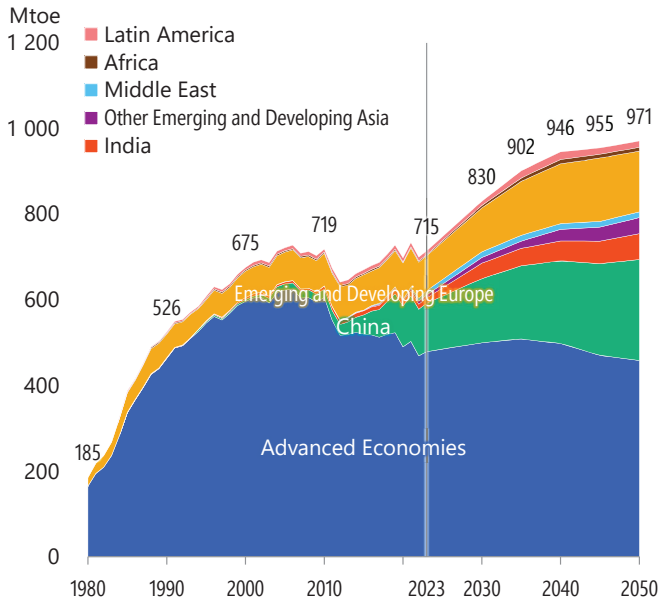


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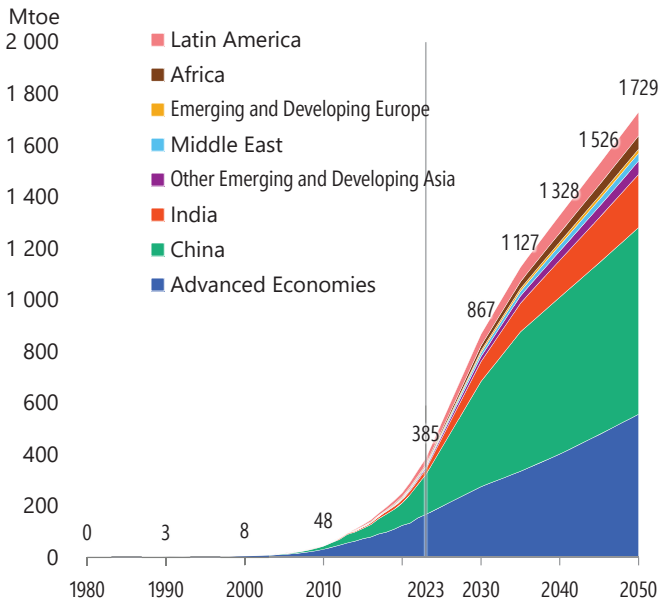
Reference Scenario

Consumption of nuclear and solar/wind/other

Nuclear



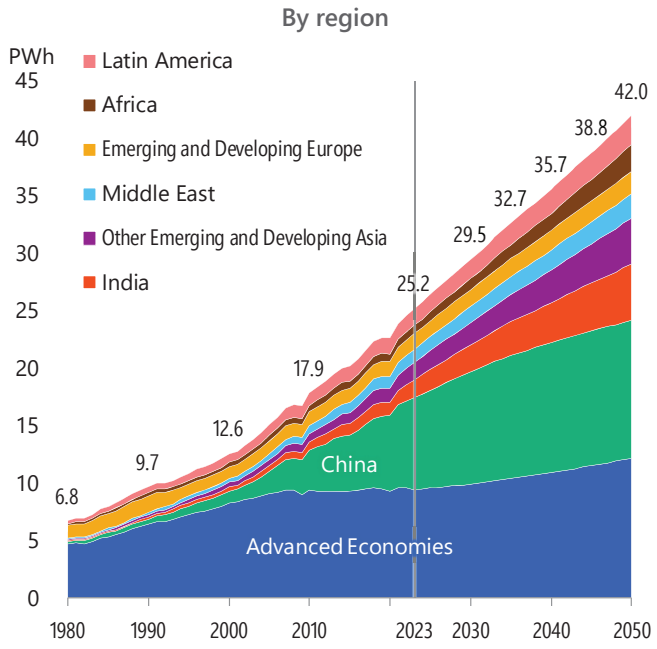
Solar/wind/other

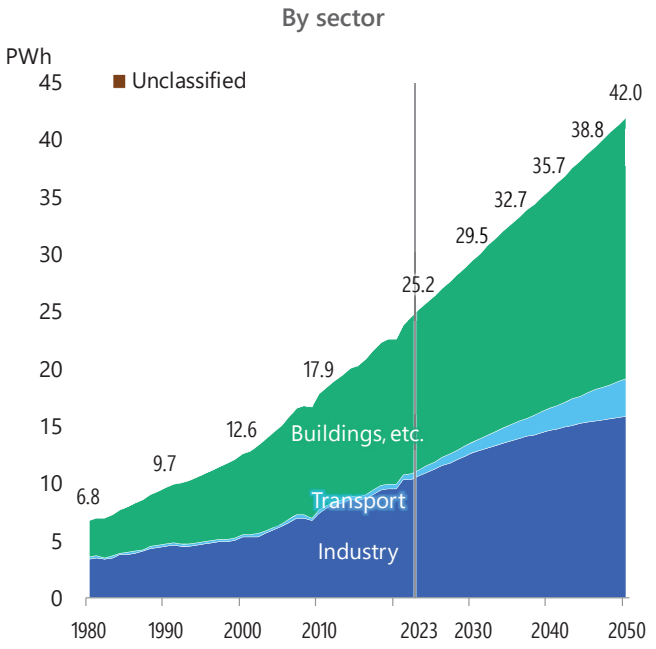


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Reference Scenario

Final consumption of electricity

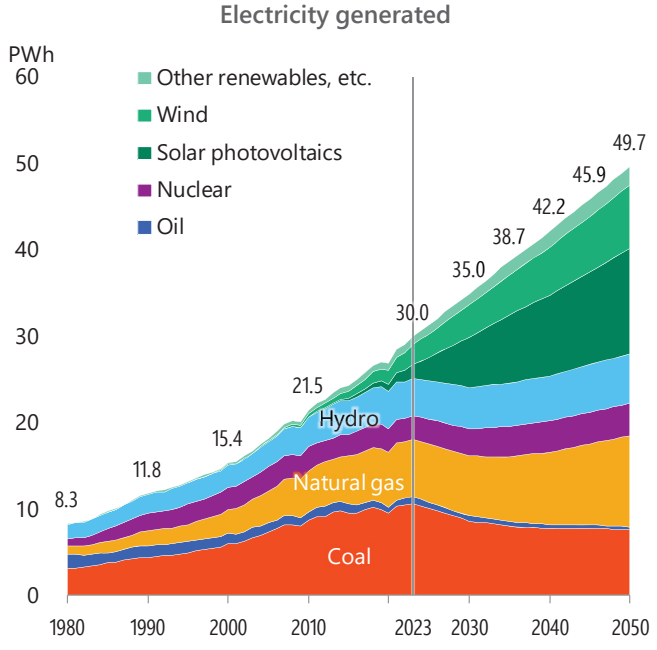


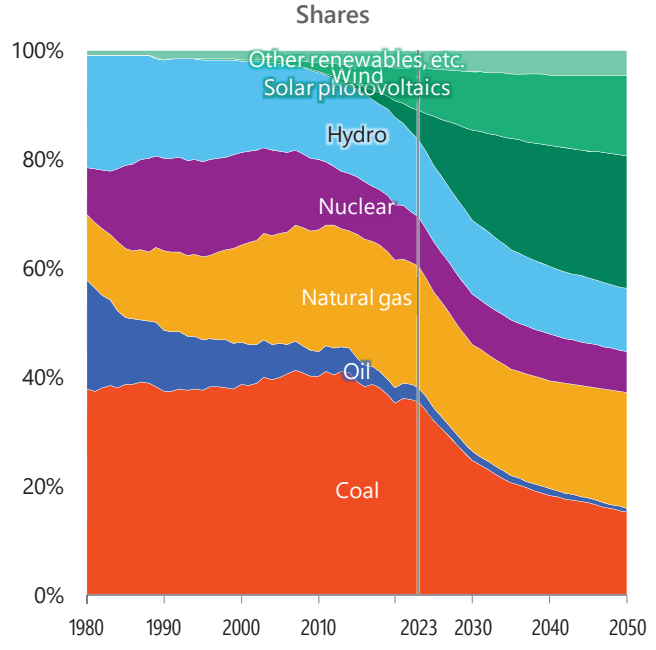


IEEJ © 2025

Reference Scenario

Power generation mix

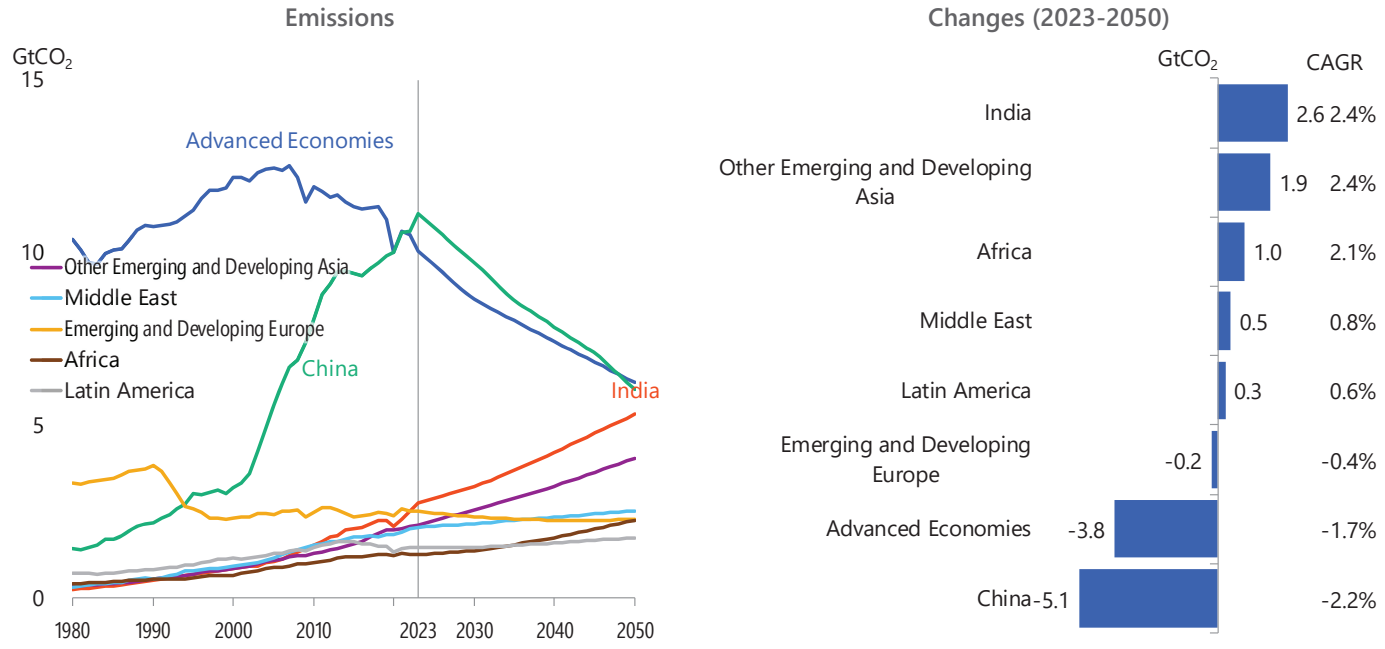




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Reference Scenario

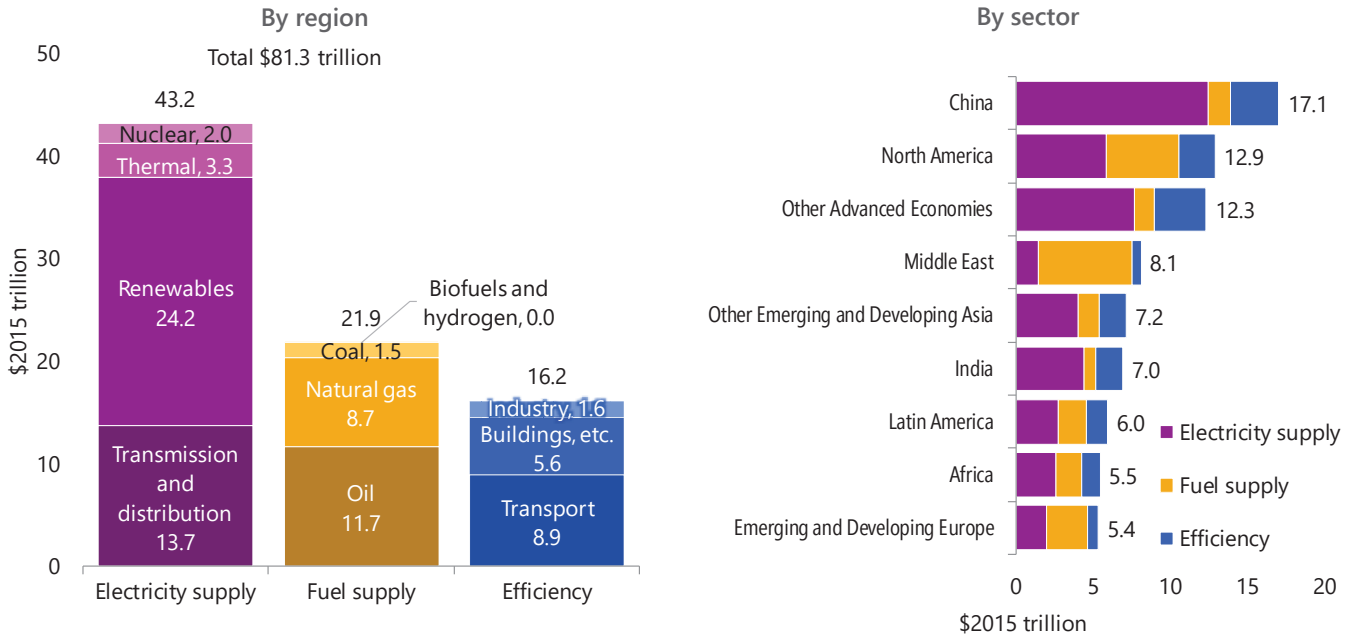
Energy-related CO_2 emissions



IEEJ © 2025

Reference Scenario

Energy-related investments (2025–2050)

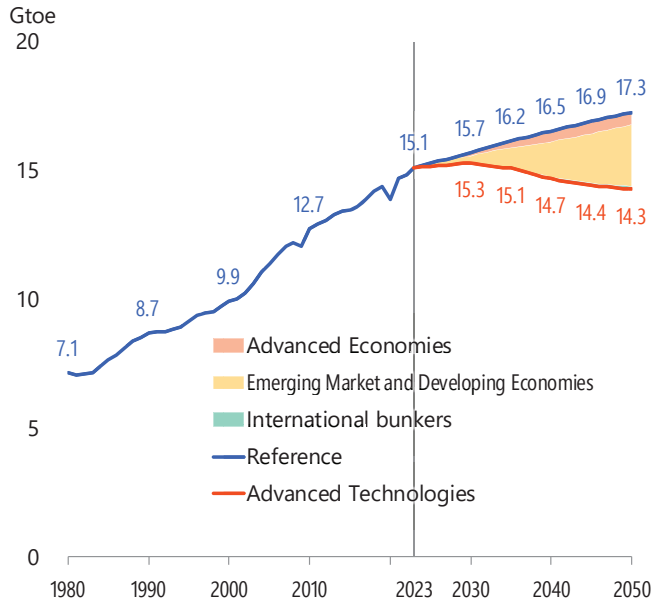


IEEJ © 2025

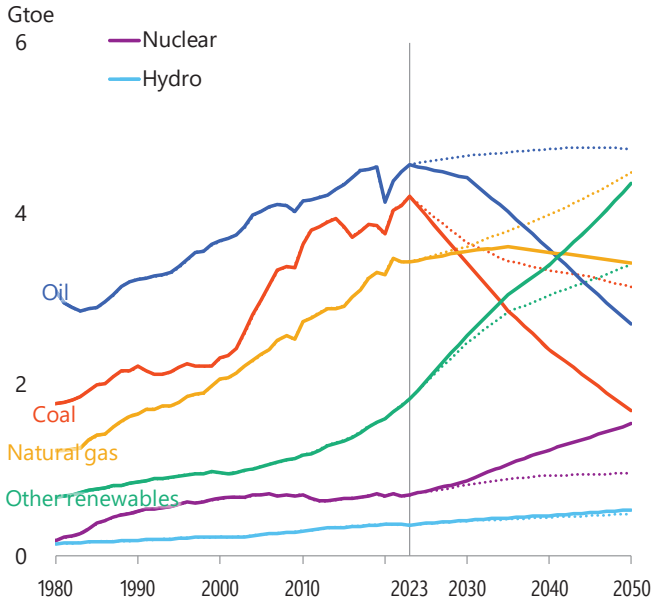
Advanced Technologies Scenario

Primary energy consumption

By region



By energy source



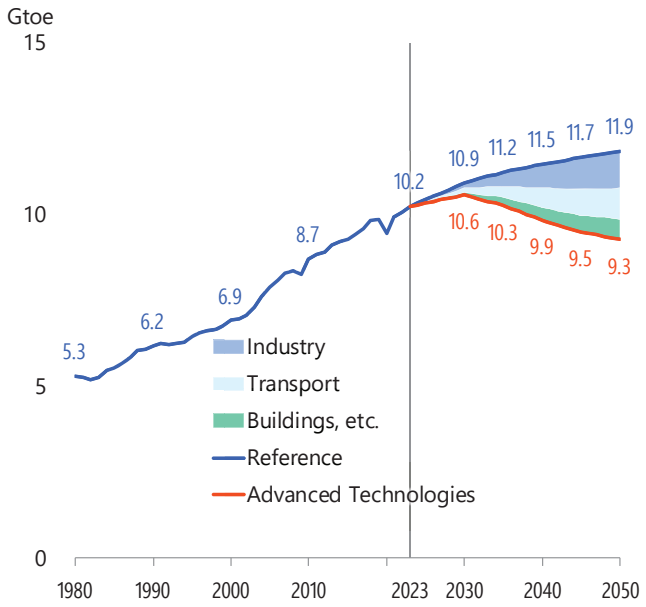
Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

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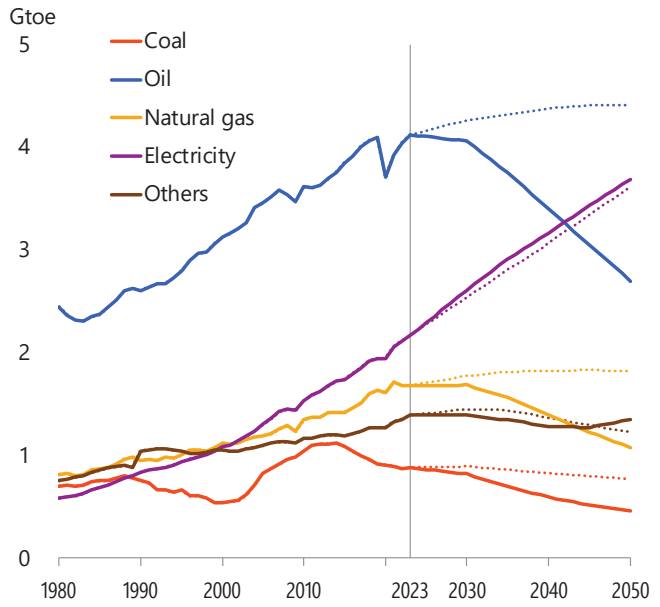
Advanced Technologies Scenario

Final energy consumption

By sector



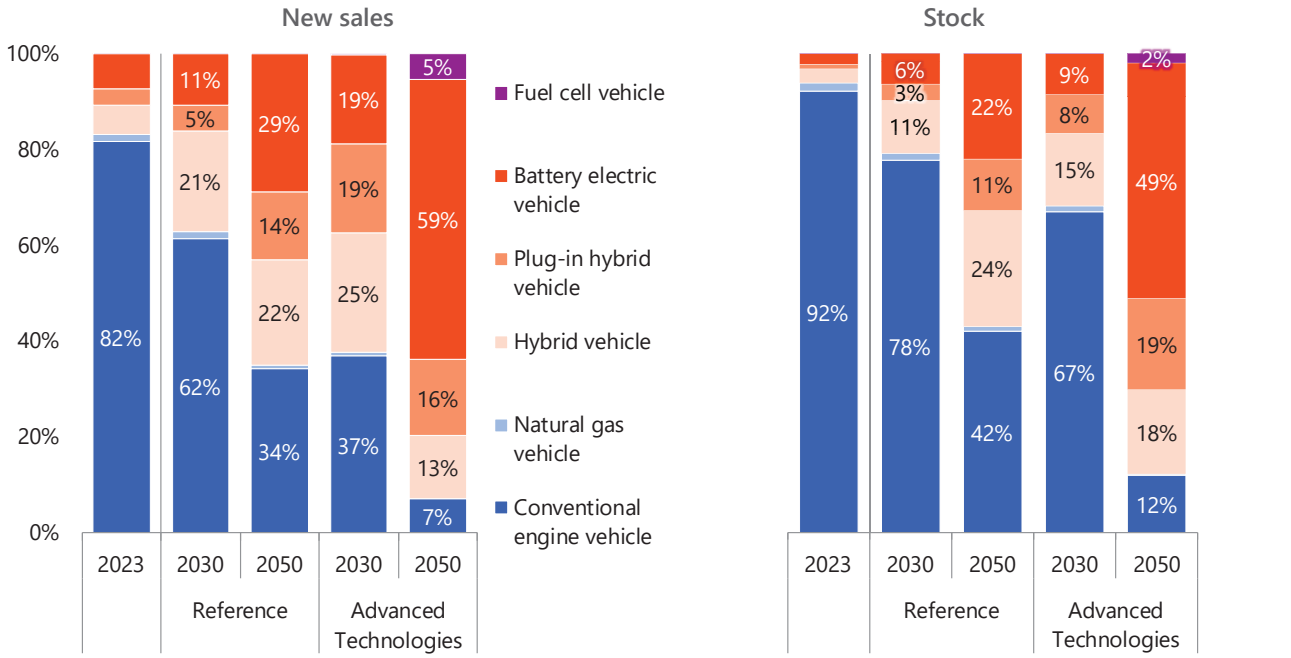
By energy



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Advanced Technologies Scenario

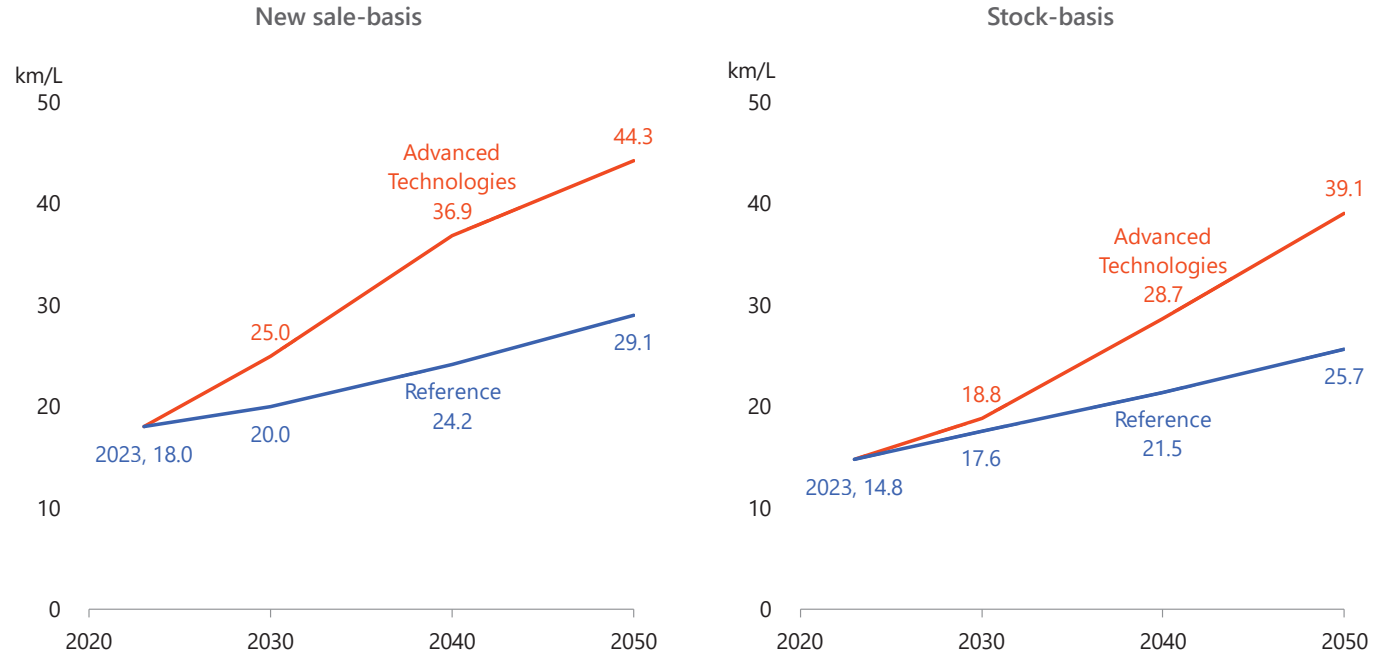
Share of passenger vehicle



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Advanced Technologies Scenario

Fuel efficiency of passenger vehicle

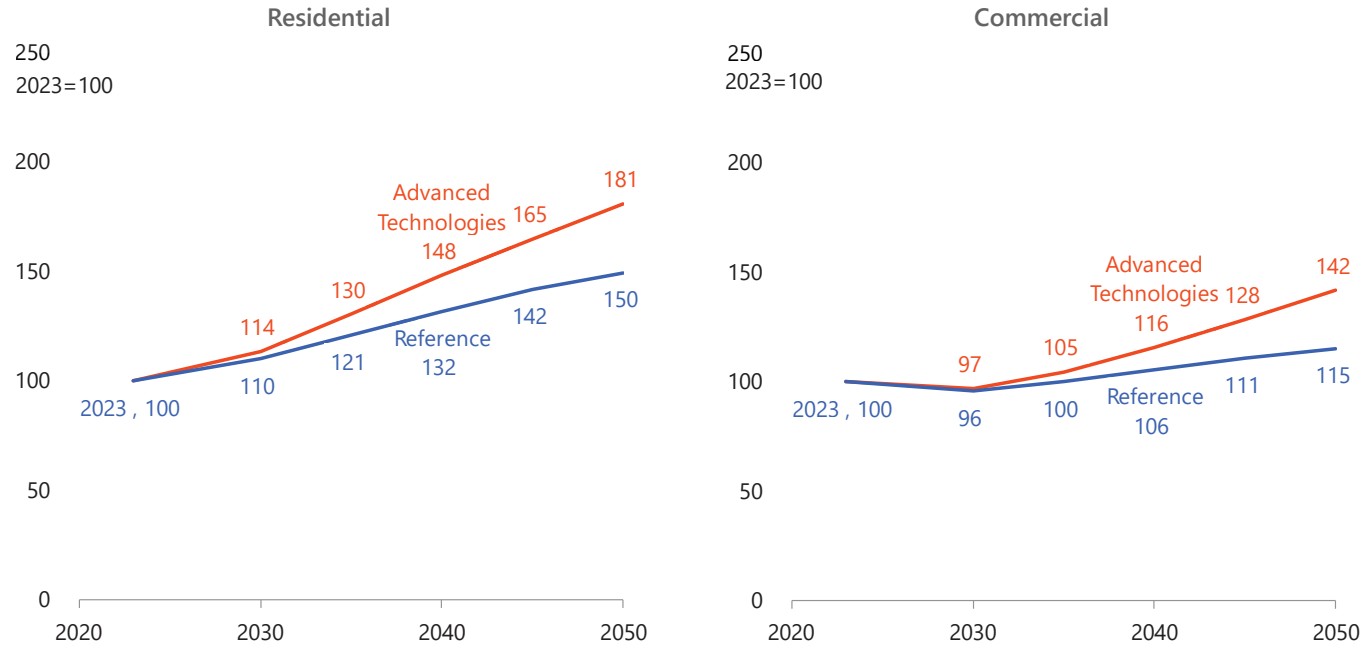


Note: Litres of gasoline equivalent

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Advanced Technologies Scenario

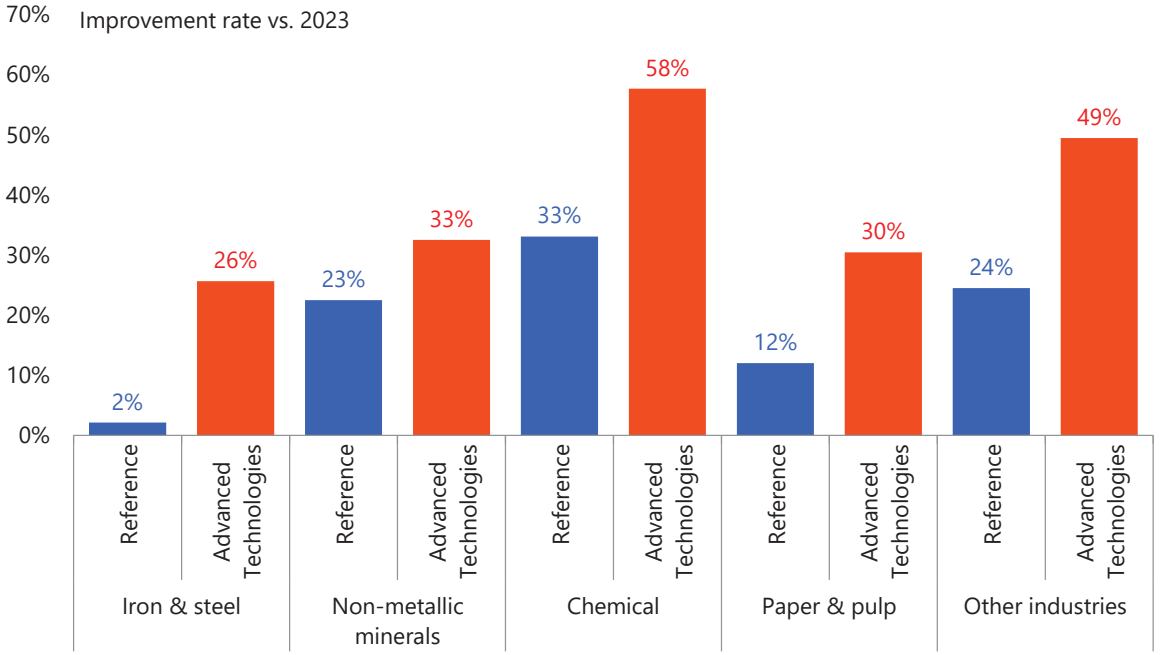
Energy efficiency in buildings sector



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Advanced Technologies Scenario

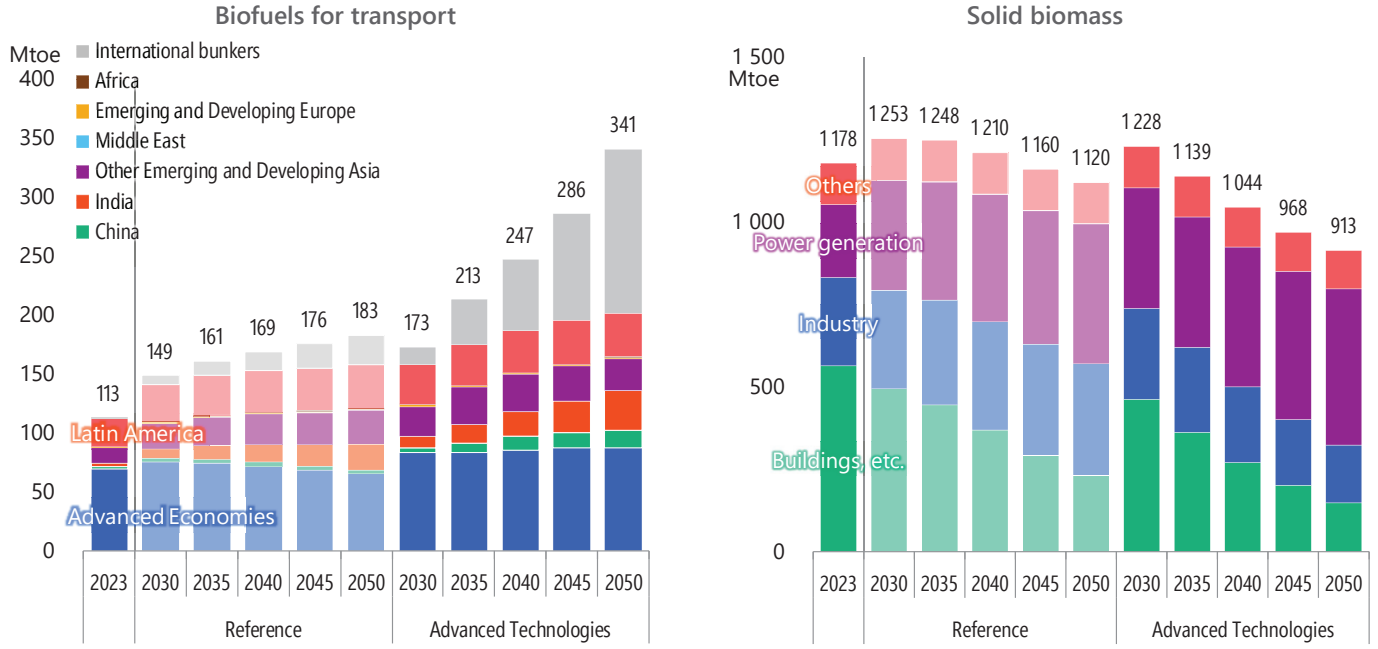
Energy intensity improvement in industry sector



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Advanced Technologies Scenario

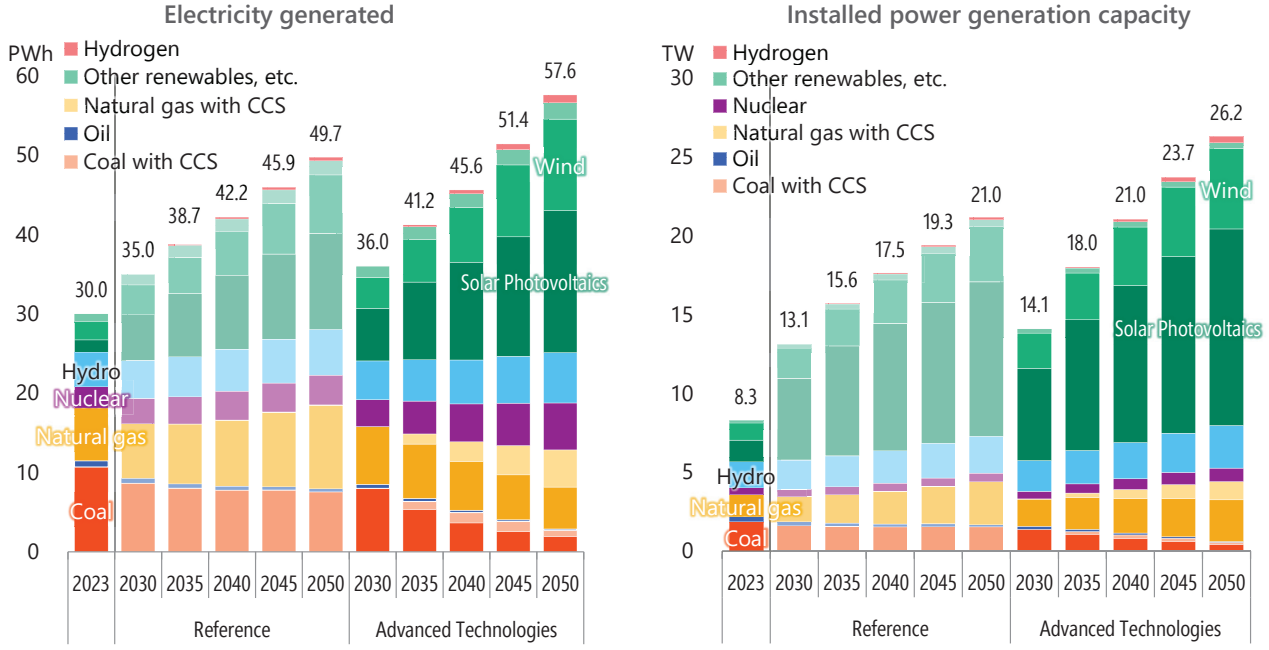
Biomass consumption



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Advanced Technologies Scenario

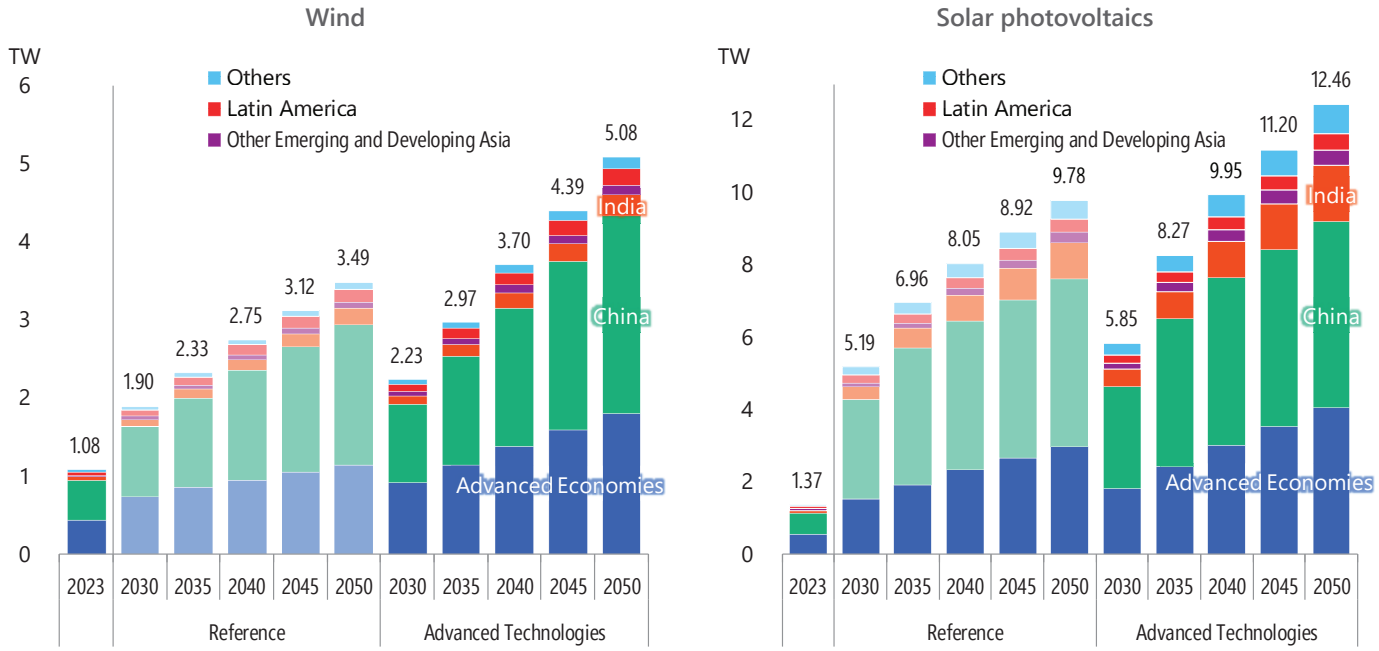
Power generation mix



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Advanced Technologies Scenario

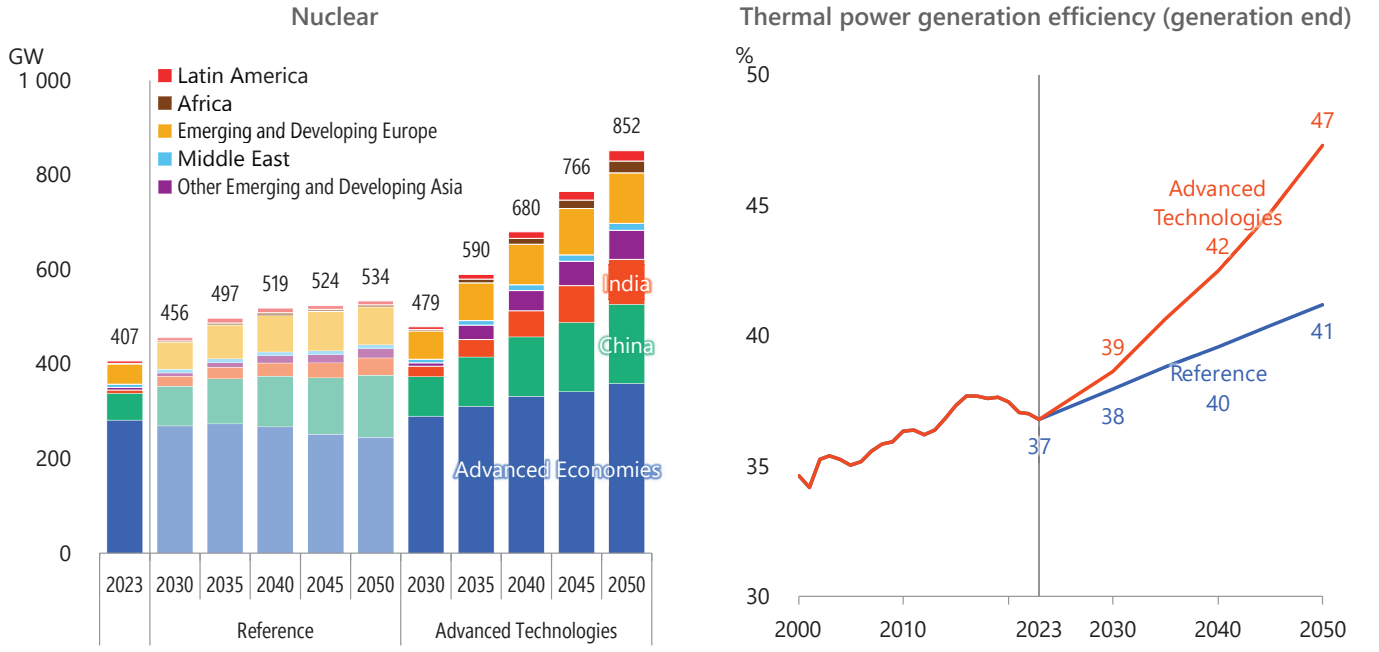
Installed wind and solar PV power generation capacity



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Advanced Technologies Scenario

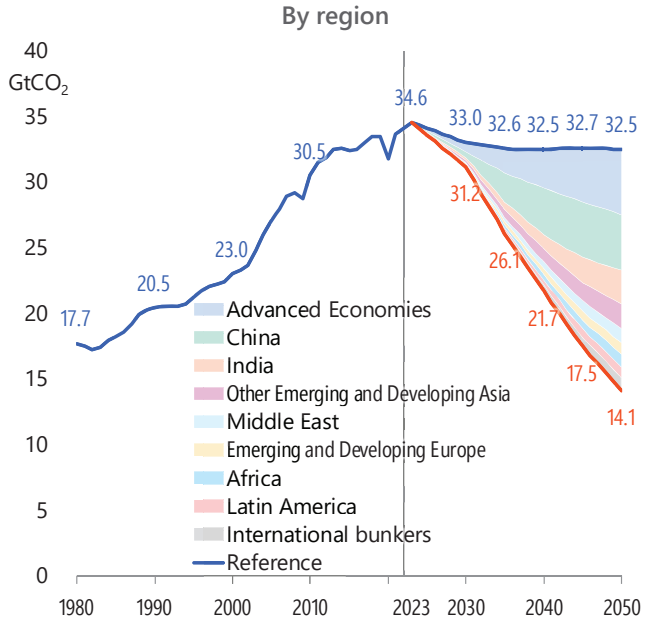
Installed nuclear power generation capacity and thermal power generation efficiency

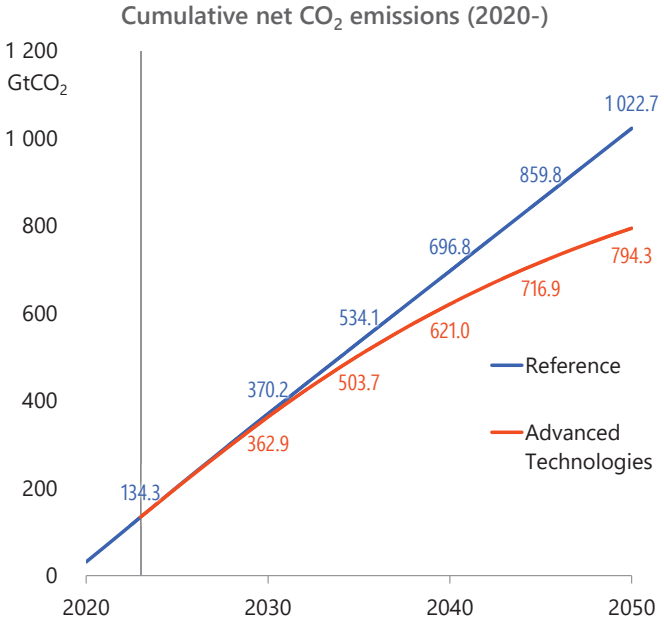


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Advanced Technologies Scenario

Energy-related CO_2 emissions

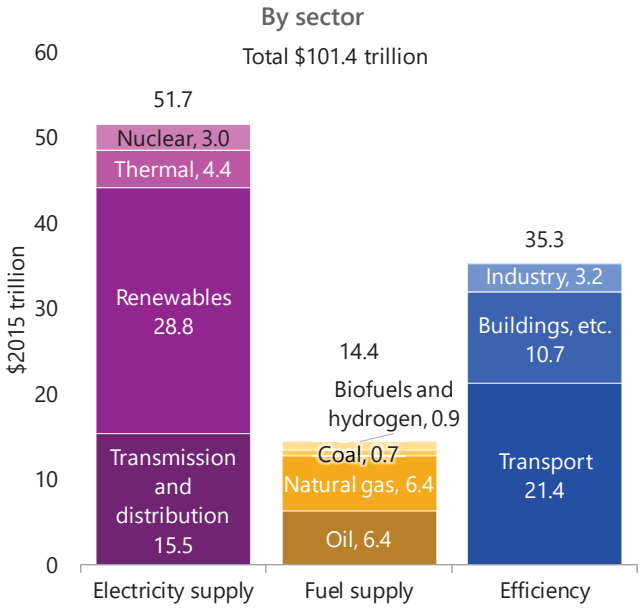


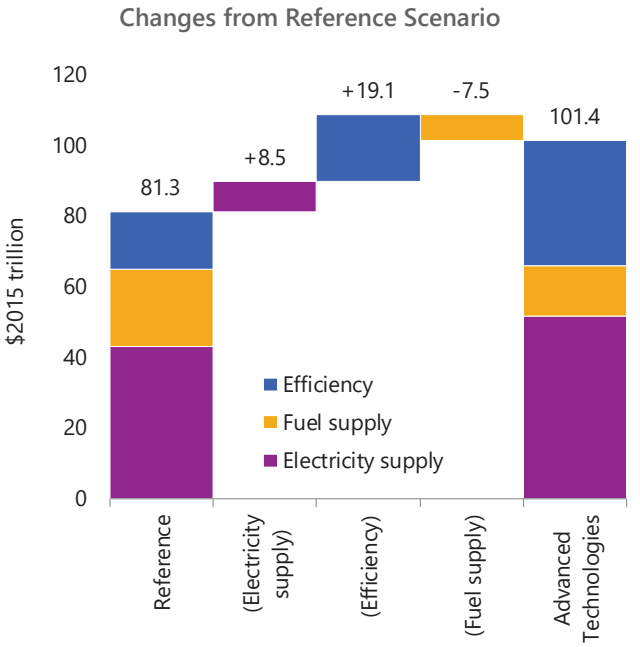


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Advanced Technologies Scenario

Energy-related investments (2025–2050)



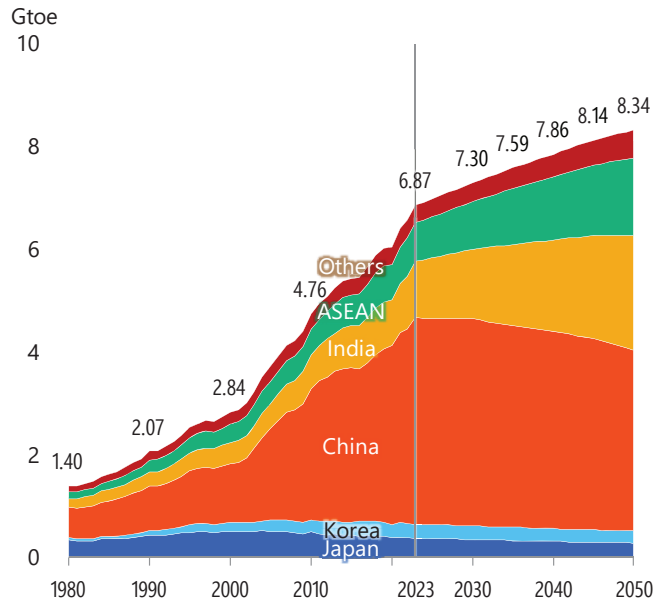


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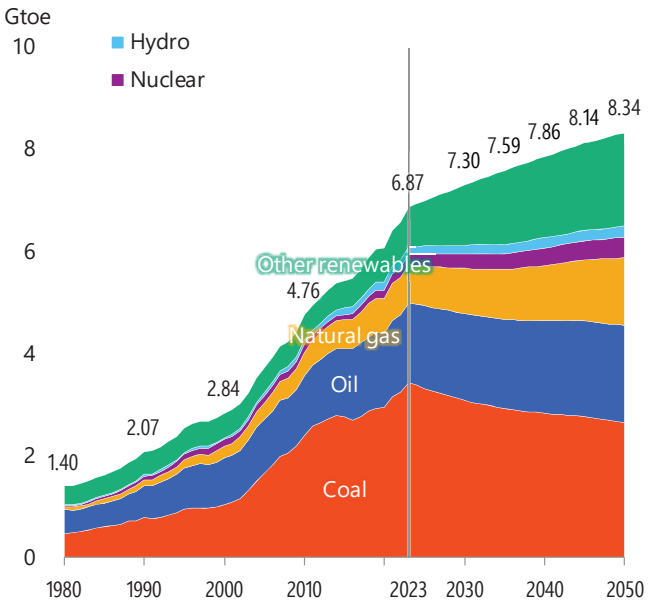
Asia | Reference Scenario

Primary energy consumption

By region



By energy source

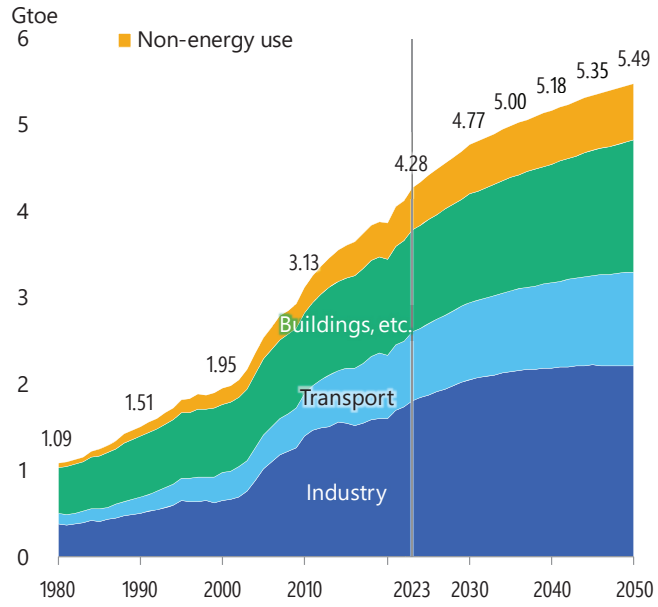


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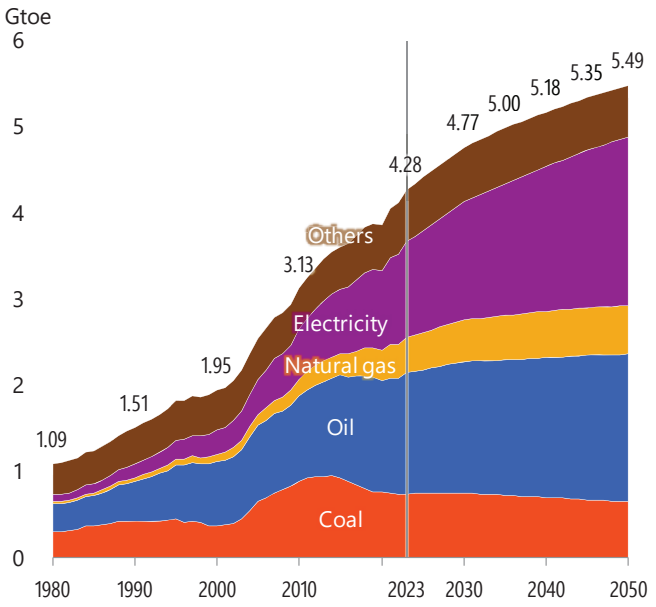
Asia | Reference Scenario

Final energy consumption

By sector



By energy source

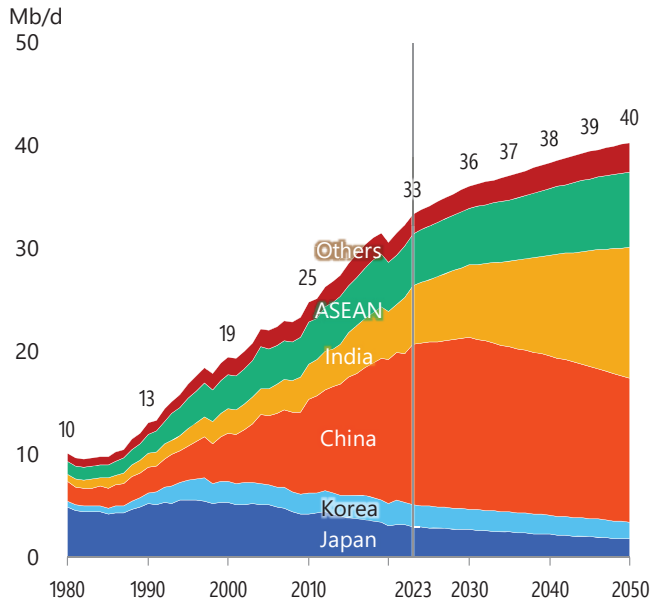


IEEJ © 2025

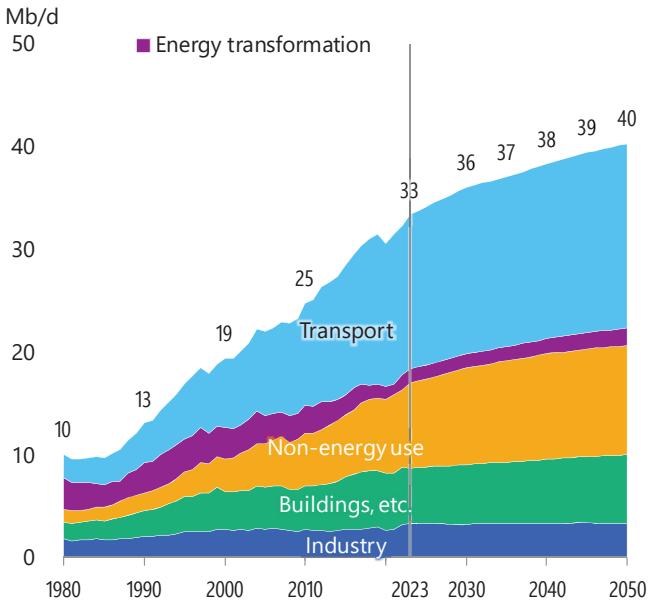
Asia | Reference Scenario

Oil consumption

By region



By sector

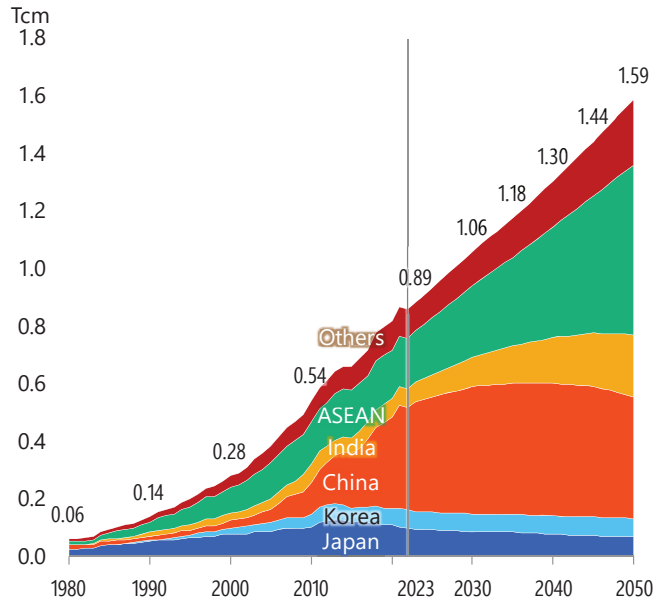


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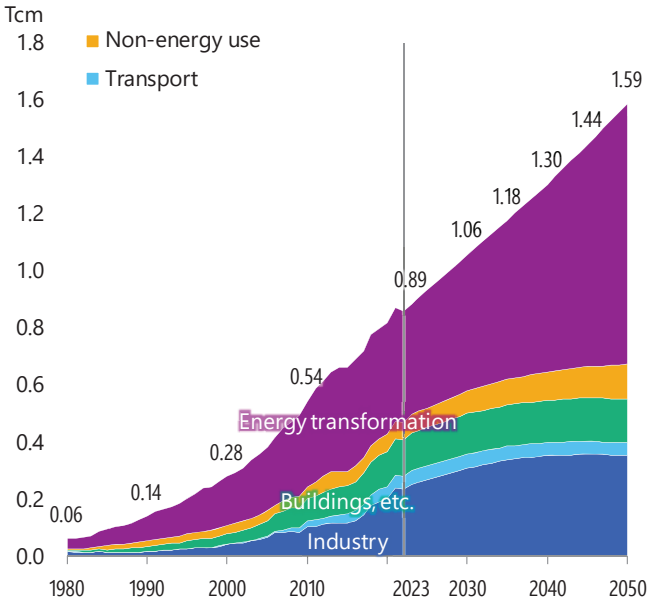
Asia | Reference Scenario

Natural gas consumption

By region



By sector

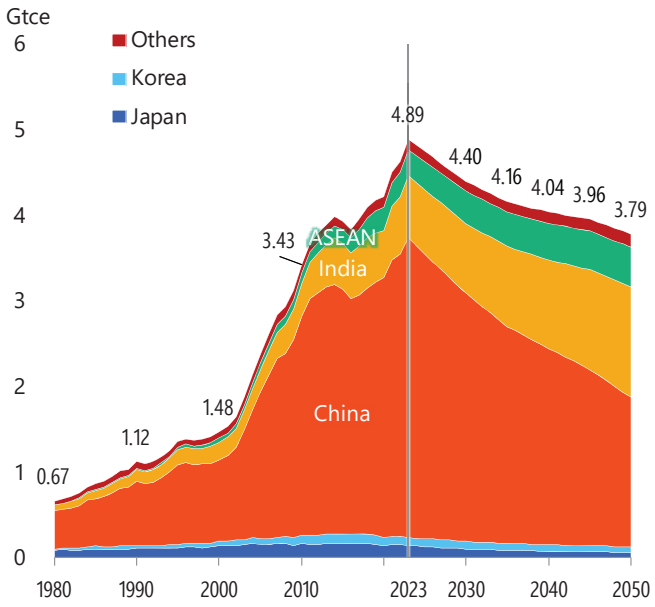


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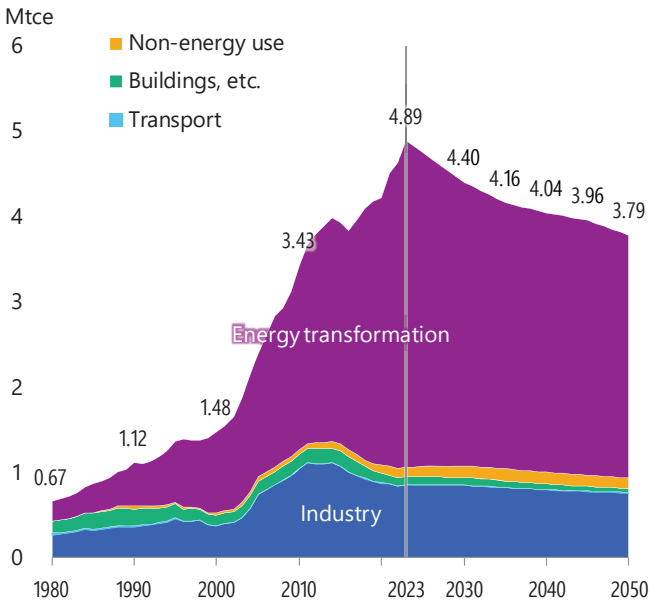
Asia | Reference Scenario

Coal consumption

By region



By sector

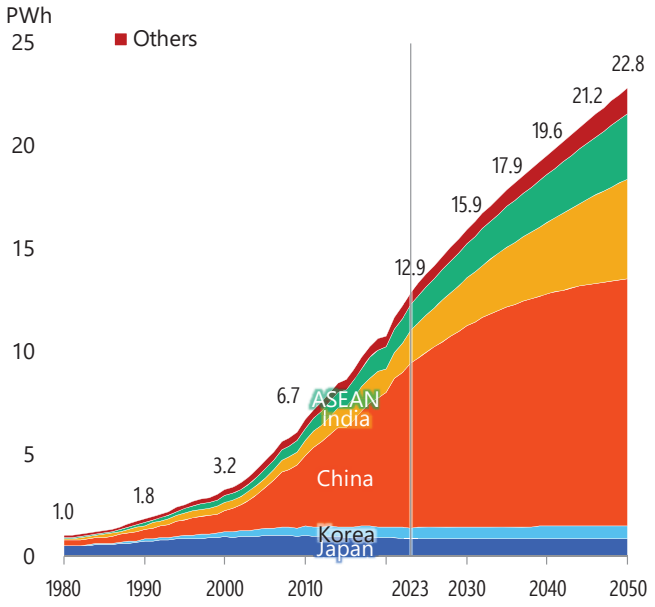


IEEJ © 2025

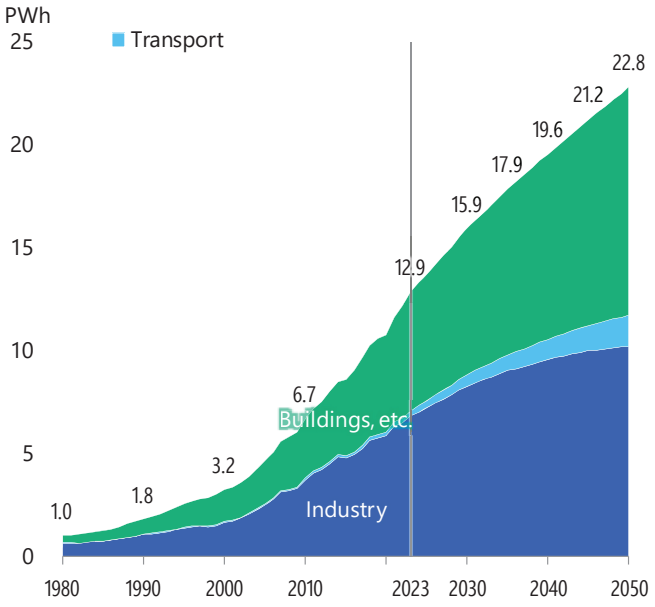
Asia | Reference Scenario

Final consumption of electricity

By region



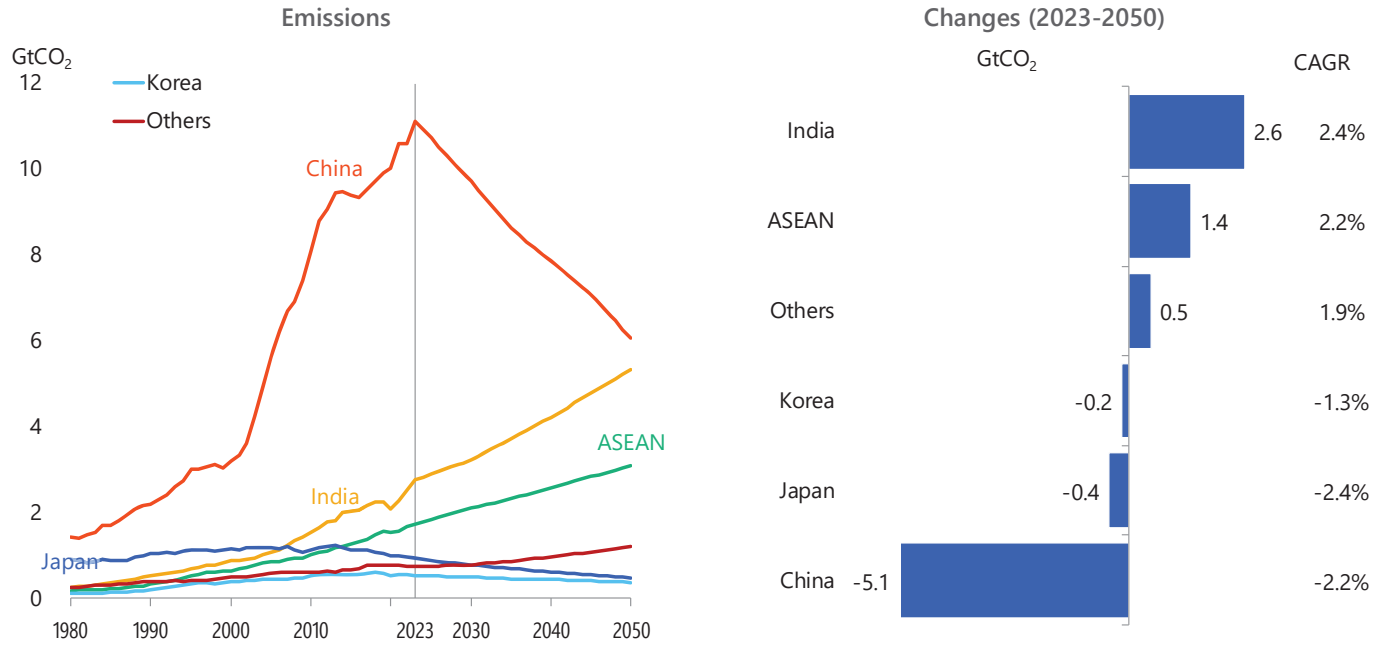
By sector



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Asia | Reference Scenario

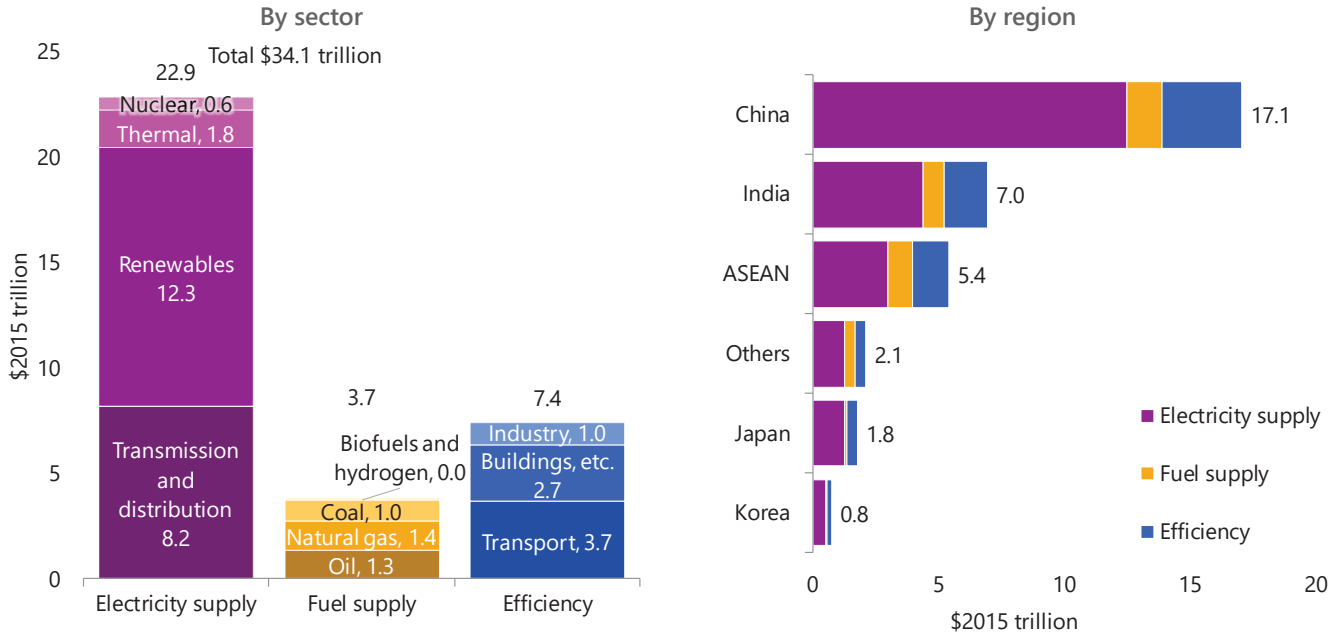
Energy-related CO_2 emissions



IEEJ © 2025

Asia | Reference Scenario

Energy-related investments (2025–2050)

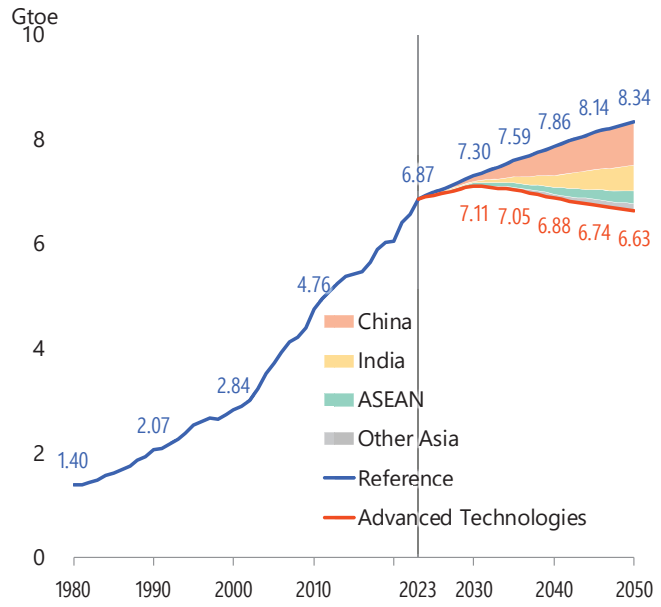


IEEJ © 2025

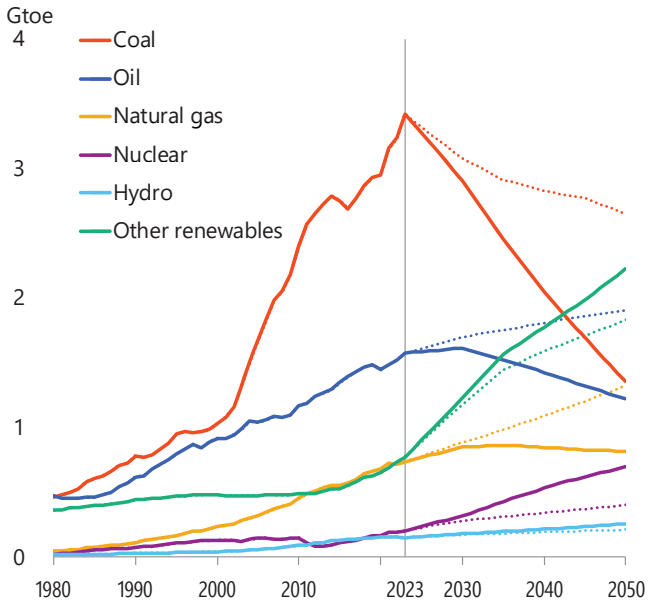
Asia | Advanced Technologies Scenario

Primary energy consumption

By region



By energy source



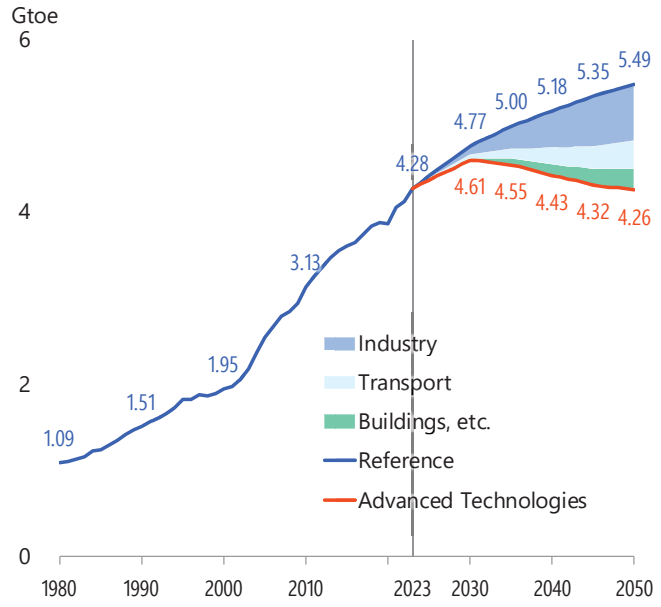
Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

IEEJ © 2025

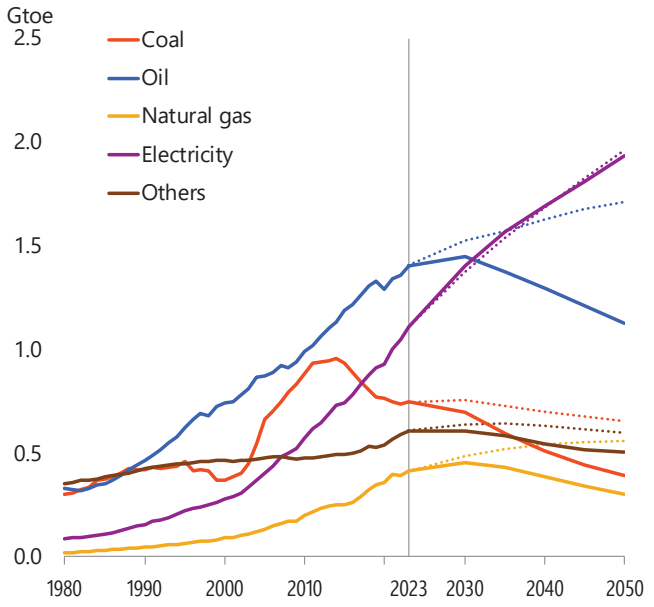
Asia | Advanced Technologies Scenario

Final energy consumption

By sector



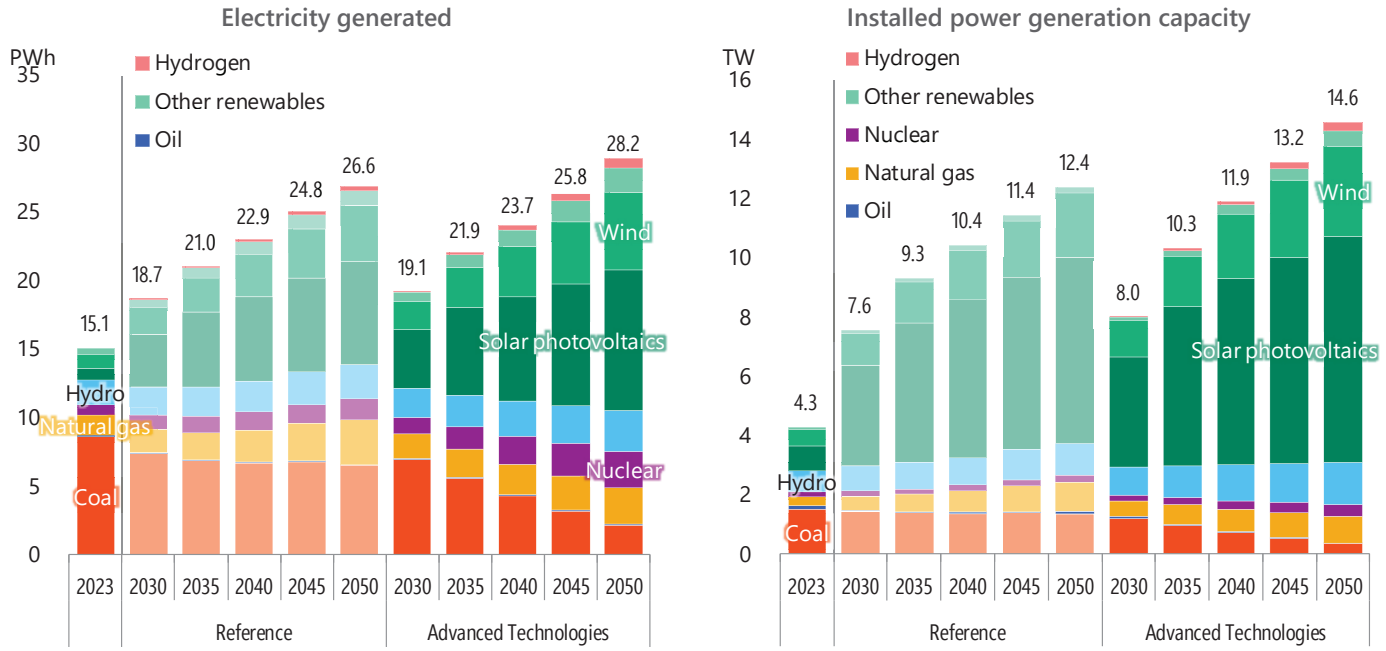
By energy source



IEEJ © 2025

Asia

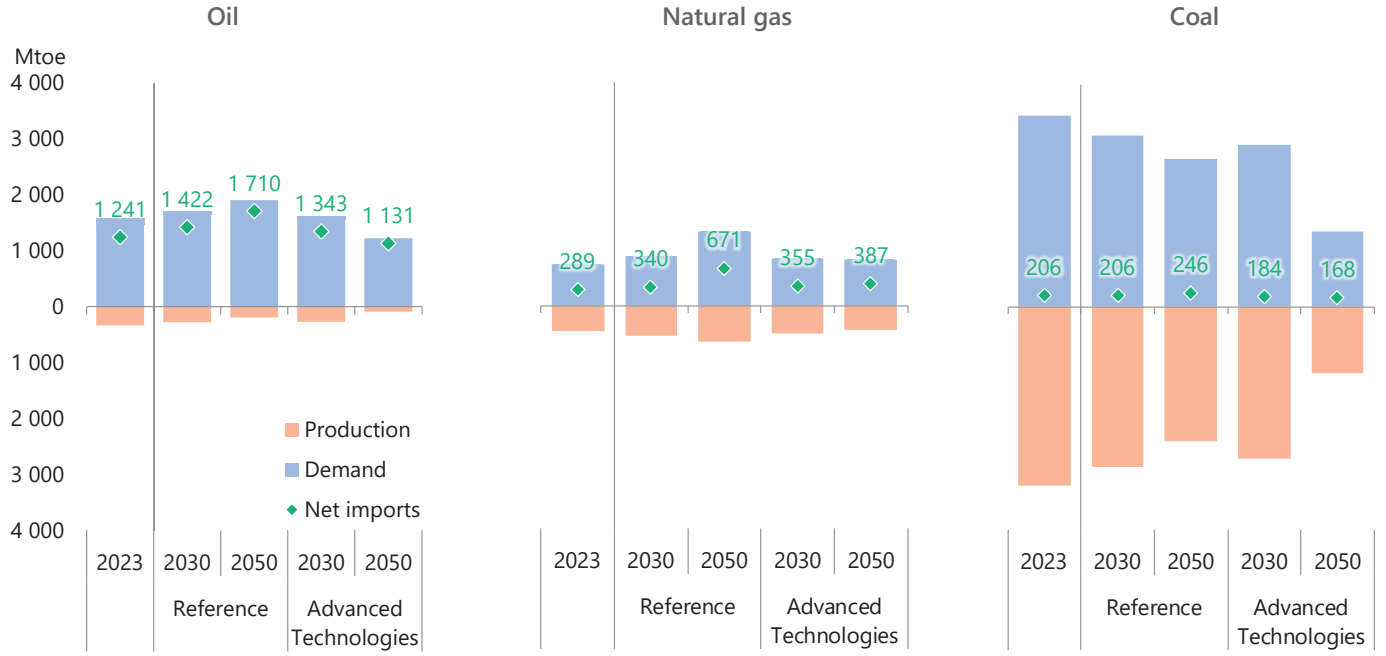
Power generation mix



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Asia

Supply and demand balance of fossil fuels

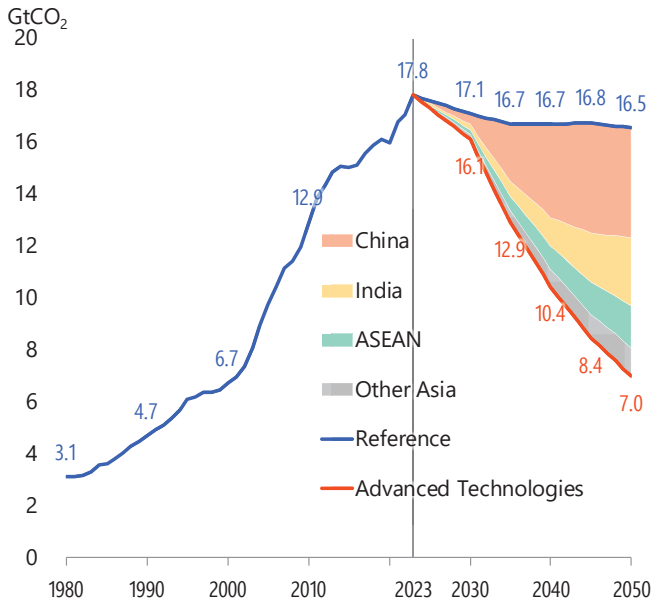


IEEJ © 2025

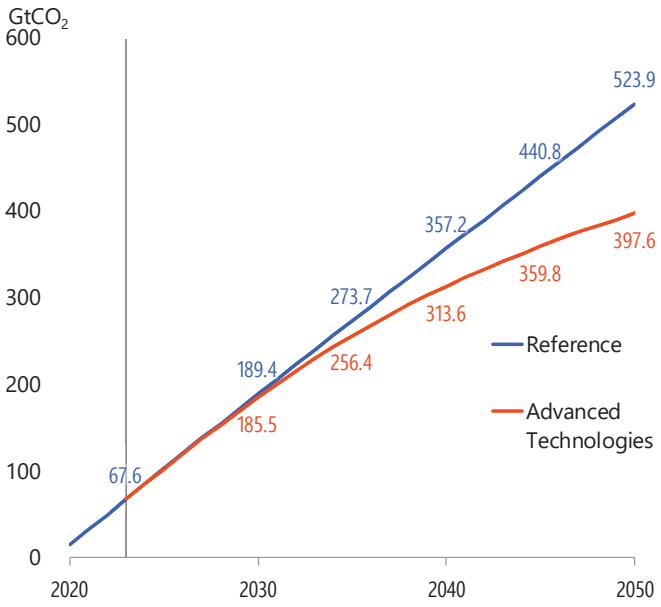
Asia | Advanced Technologies Scenario

Energy-related CO_2 emissions

By region



Cumulative net CO_2 emissions (2020-)

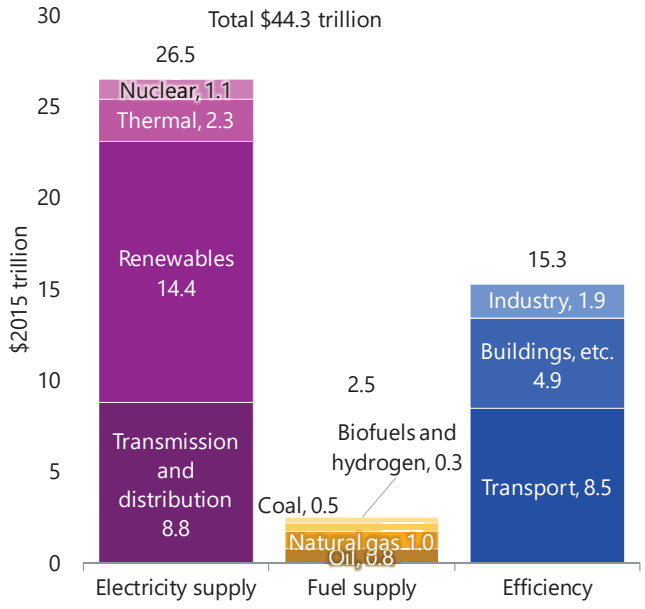


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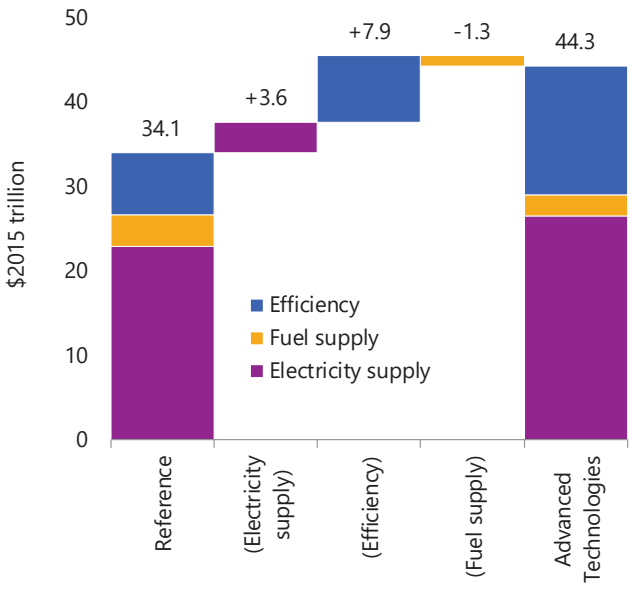
Asia | Advanced Technologies Scenario

Energy-related investments (2025–2050)

By sector



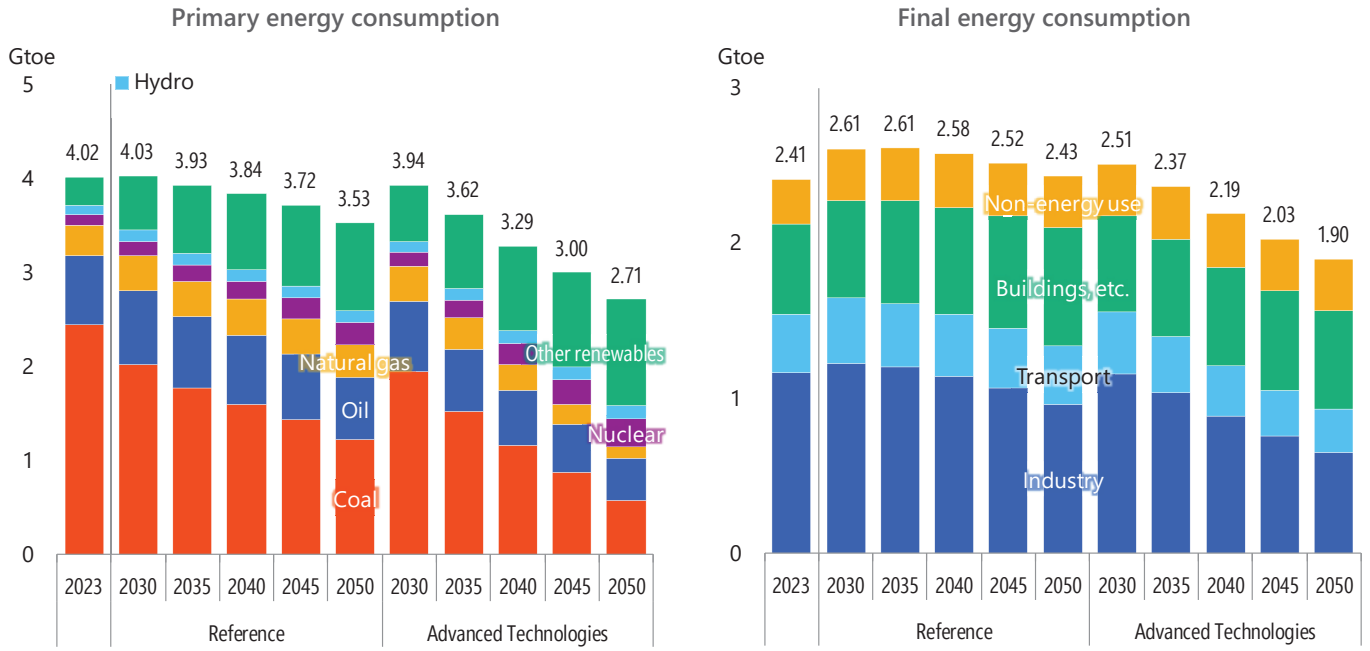
Changes from Reference Scenario



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China

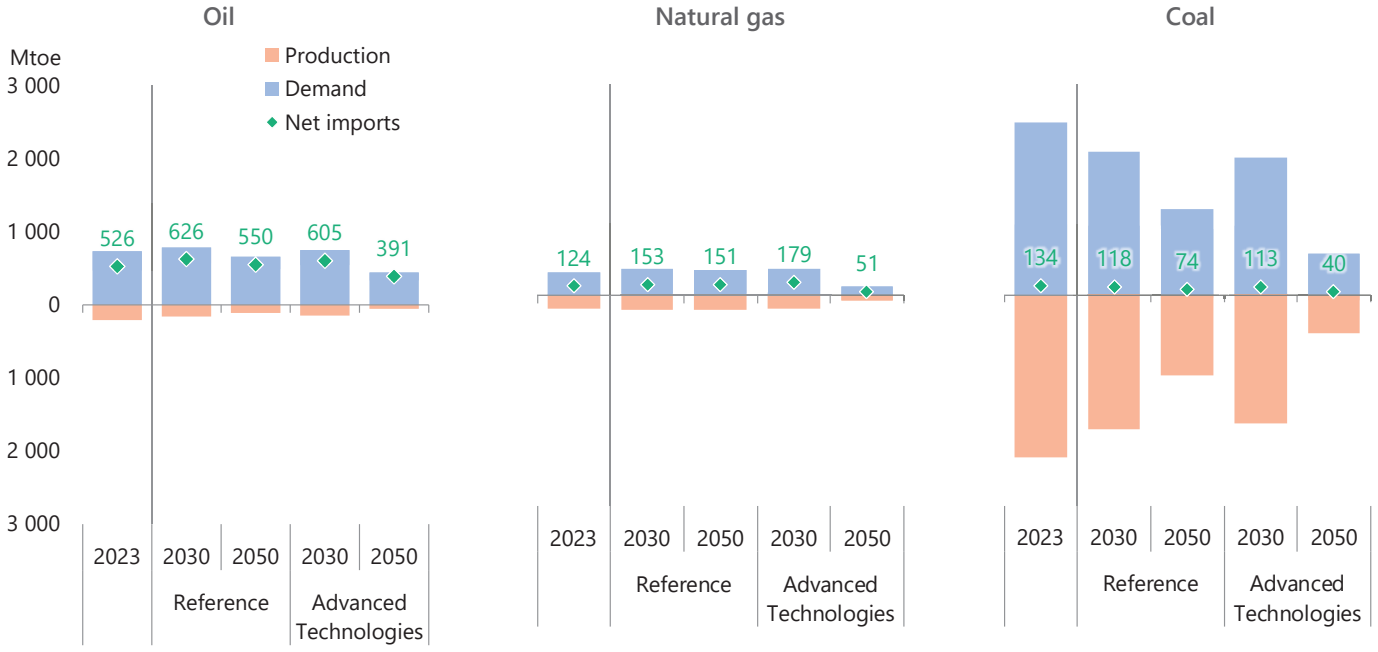
Energy consumption



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China

Supply and demand balance of fossil fuels

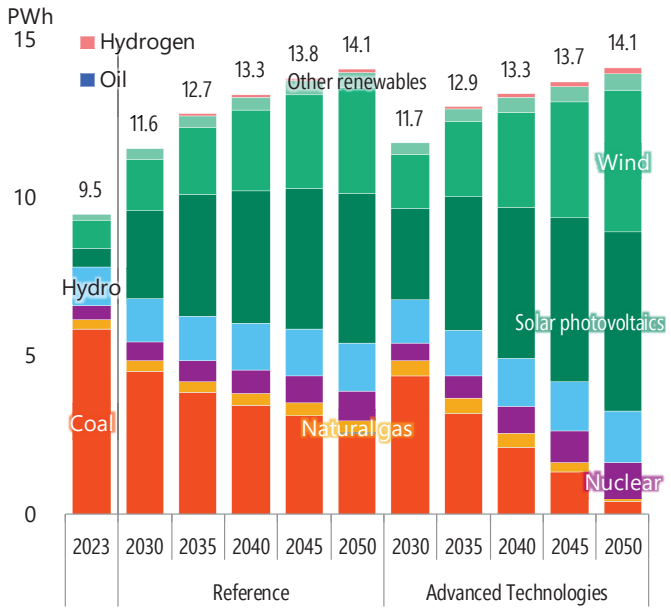


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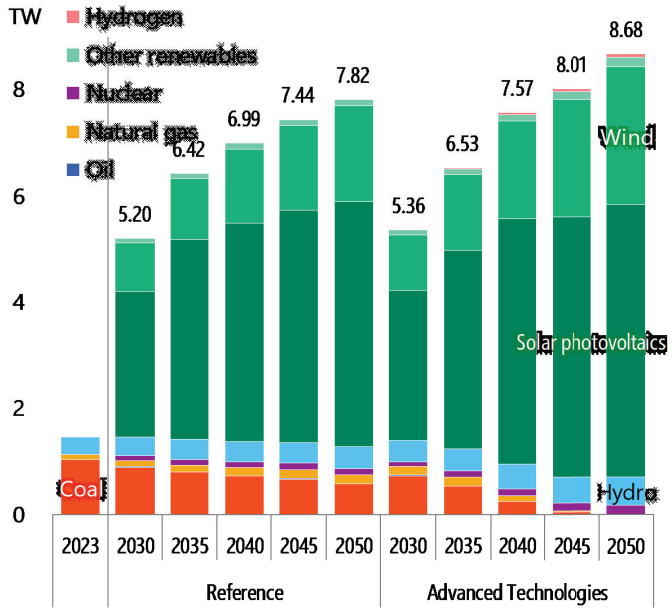
China

Power generation mix

Electricity generated



Installed power generation capacity

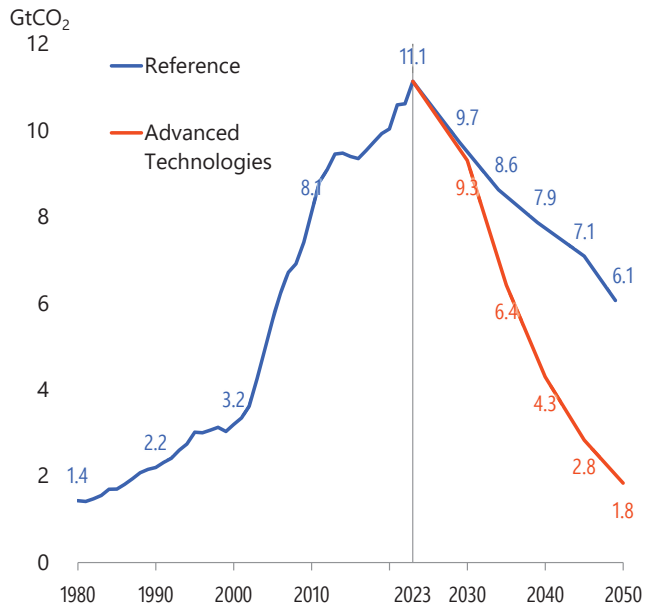


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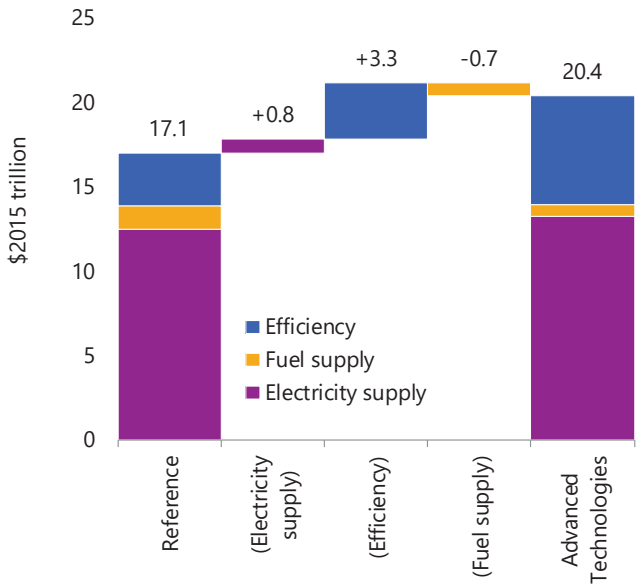
China

Energy-related CO_2 emissions and investments

CO_2 emissions



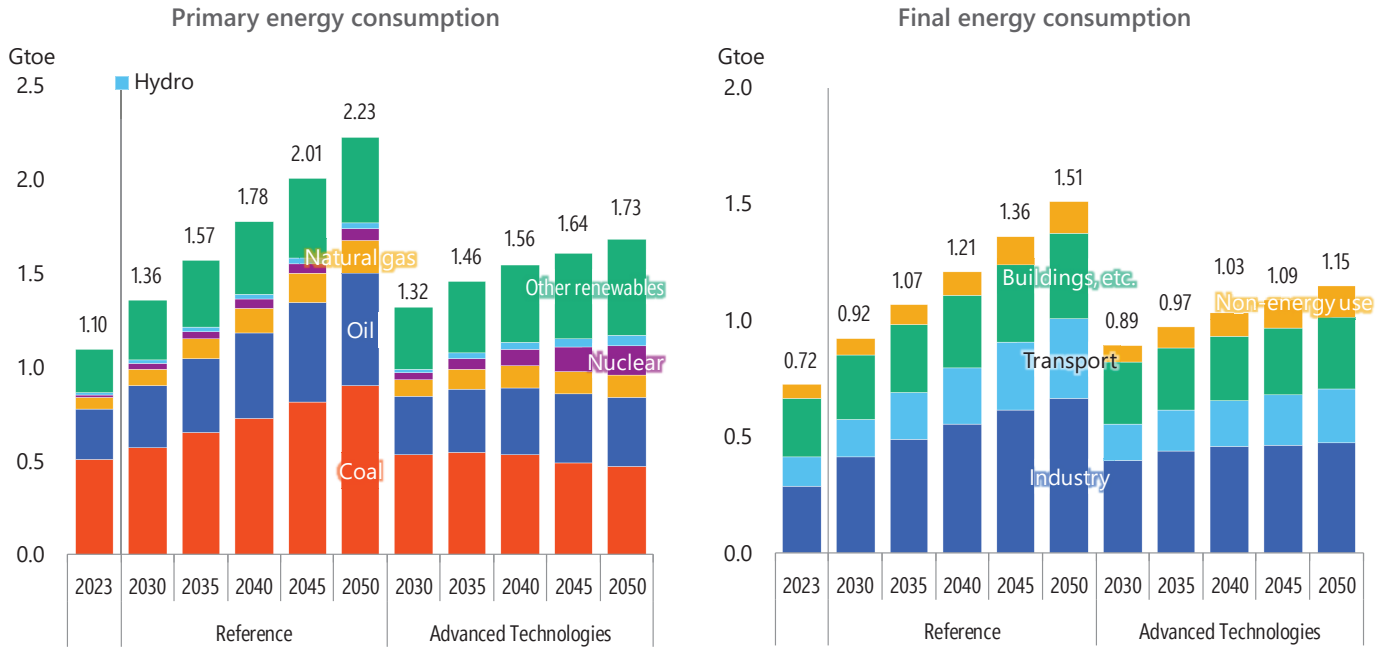
Investments (2025–2050)



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India

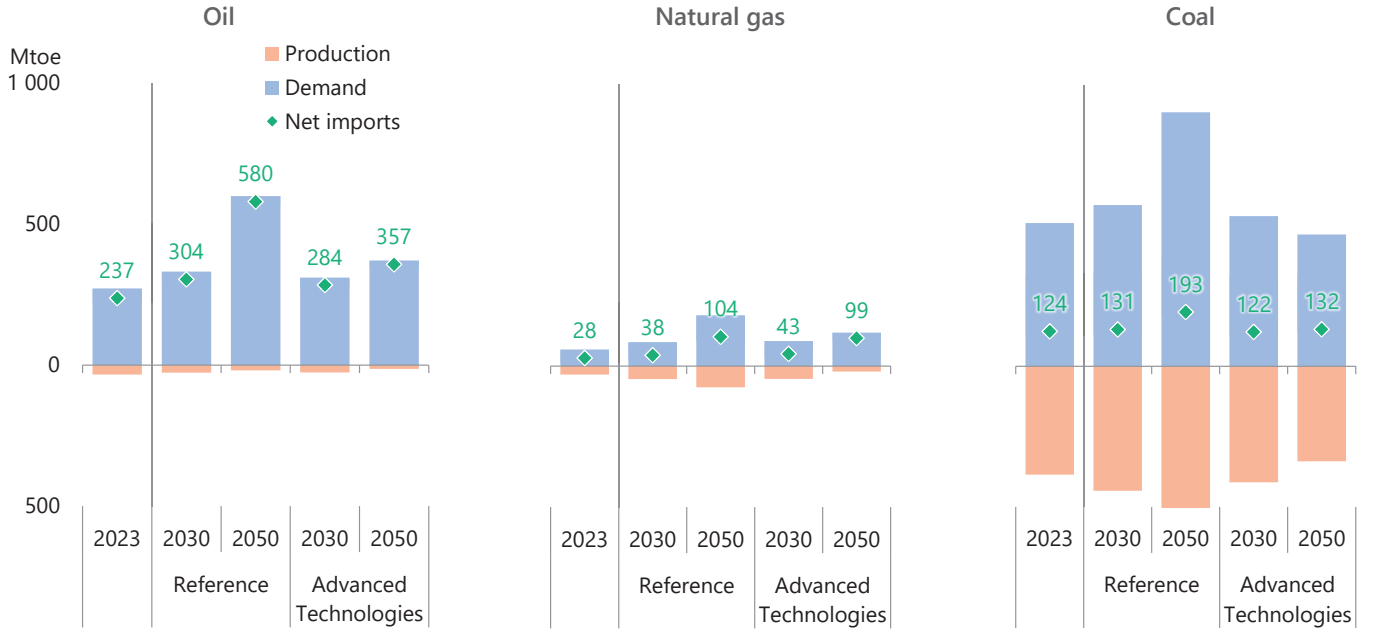
Energy consumption



IEEJ © 2025

India

Supply and demand balance of fossil fuels

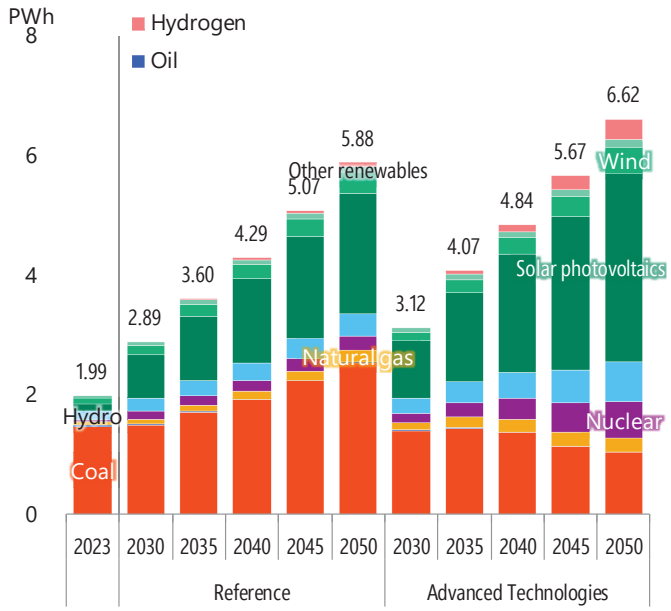


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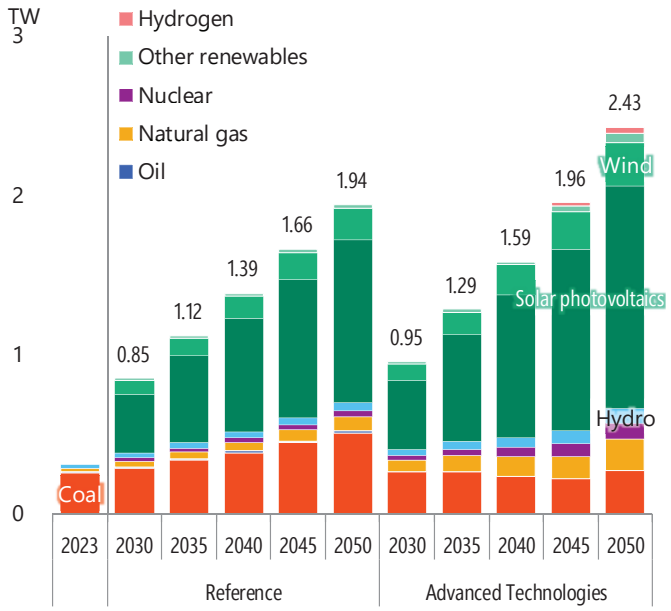
India

Power generation mix

Electricity generated



Installed power generation capacity

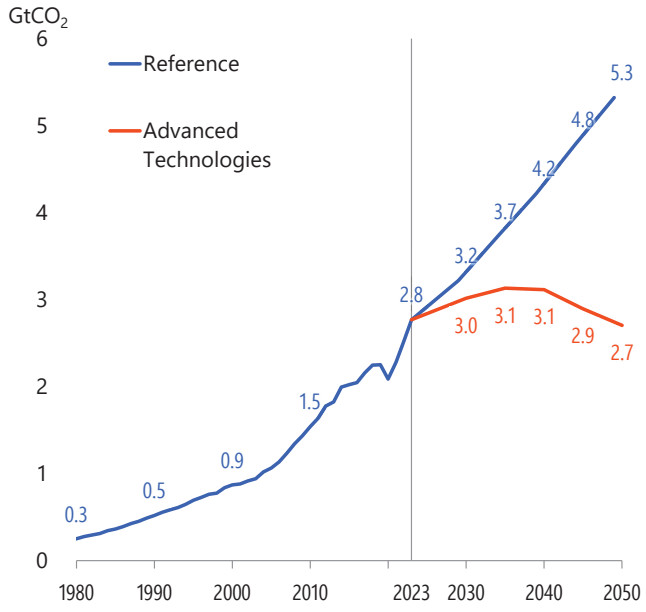


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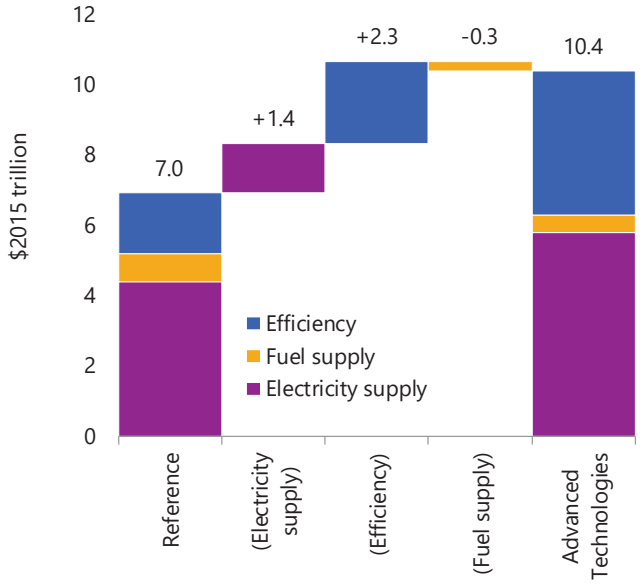
India

Energy-related CO_2 emissions and investments

CO_2 emissions



Investments (2025–2050)

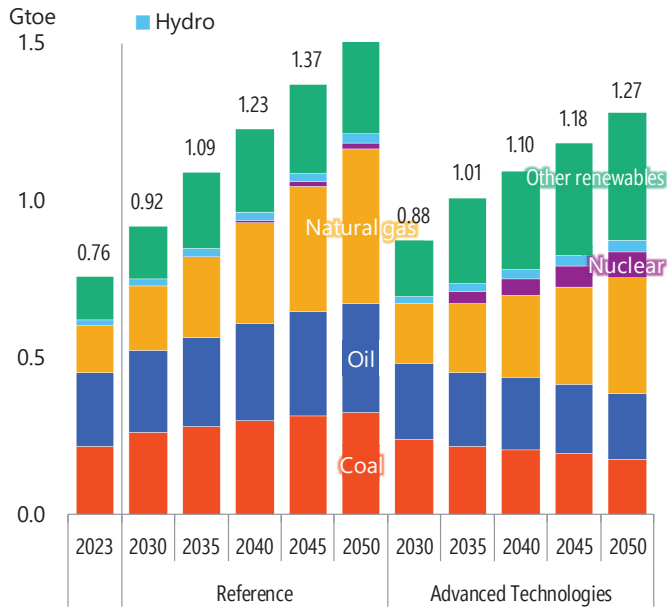


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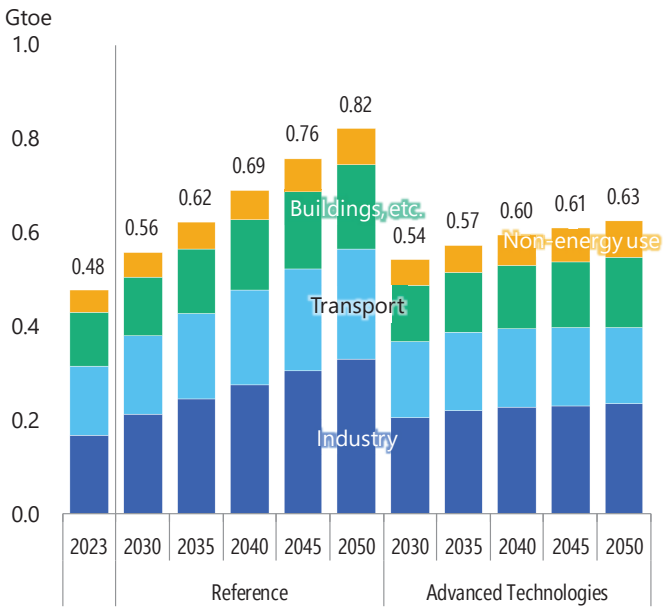
ASEAN

Energy consumption

Primary energy consumption



Final energy consumption

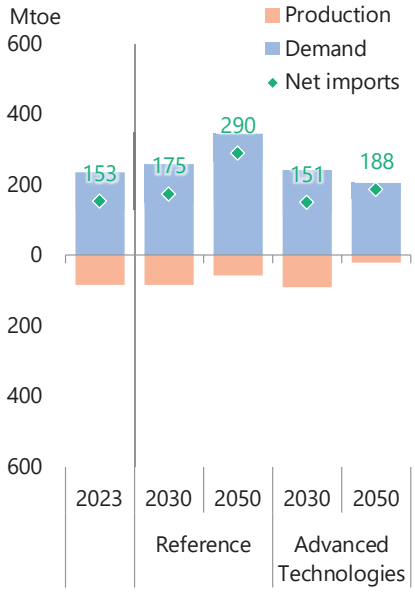


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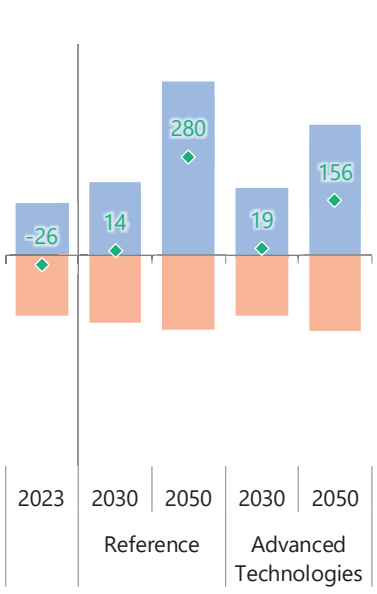
ASEAN

Supply and demand balance of fossil fuels

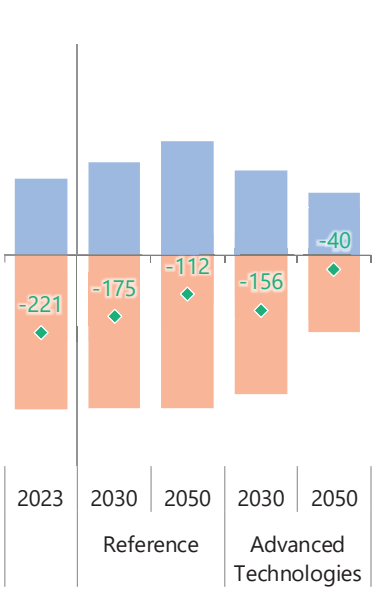
Oil



Natural gas



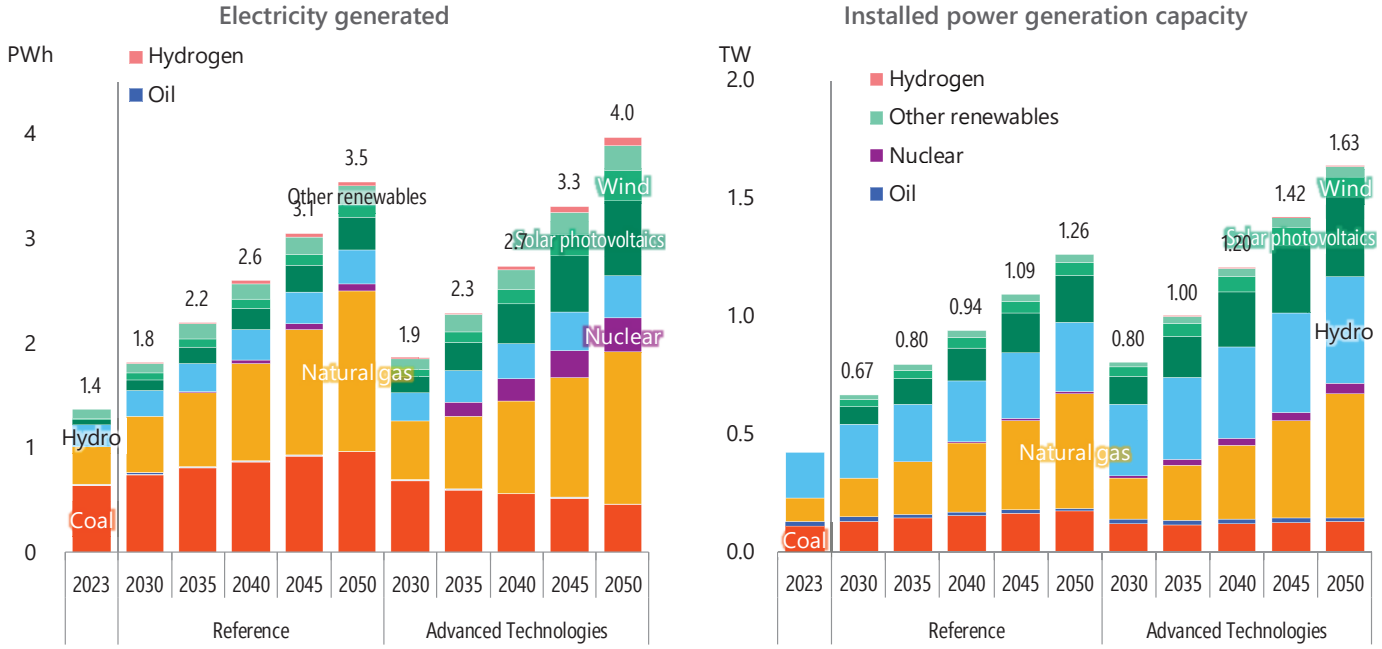
Coal



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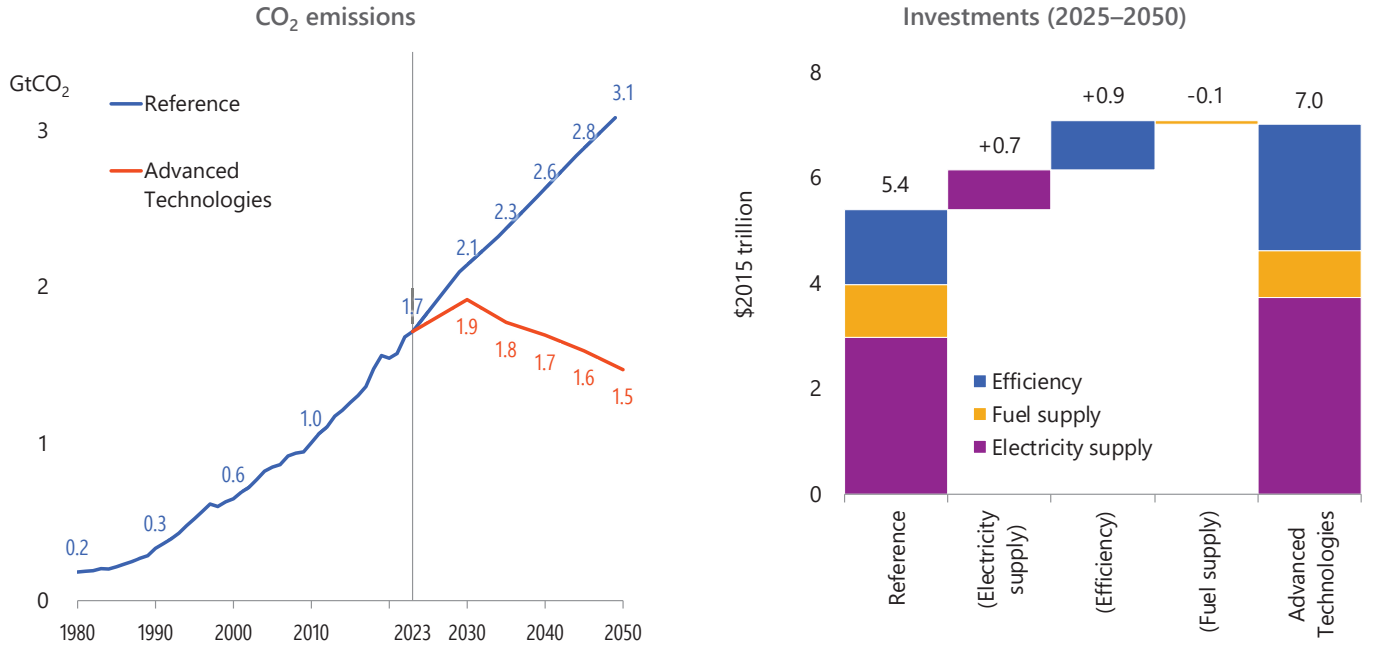
Power generation mix



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ASEAN

Energy-related CO_2 emissions and investments



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