IEEJ Outlook 2026

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

Overview

Yasuhisa ABE
Hiroshi AKIE
Matthieu CHAZAL
CHEN Yi-Chun
Naoko DOI
Seiya ENDO
Ryou ETOU
Tatsuya HAGITA
Hiroshi HASHIMOTO
Rino HIROSE
KIM Songhee
Kenji KIMURA
Kei KOBASHI
Yoshikazu KOBAYASHI
Souji KOIKARI
Kan KOTEGAWA
Ken KOYAMA
Taichi KUSAYANAGI
Ichiro KUTANI
Mas MANSOR
Tomoko MATSUMOTO
Tetsuo MORIKAWA
Soichi MORIMOTO
Tomoko MURAKAMI
Yu NAGATOMI
Yuto NAKANO
Yasushi NINOMIYA
Junya NISHI
Hideaki OBANE
Junichi OGASAWARA
Asamu OGAWA
Nanako OGAWA
Hiroyuki OKAWA
Yoshihiko OMORI
Kenichi ONISHI
Shun OTSU
Toshiyuki SAKAMOTO
Arina SATO
Keita SATO
Yoshiaki SHIBATA
Tohru SHIMIZU
Kei SHIMOGORI
Wataru SUGINO
Takahiko TAGAMI
Yoshiaki TAKAHASHI
Atsutaka YAMADA
Yukari YAMASHITA
Akira YANAGISAWA

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.

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

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

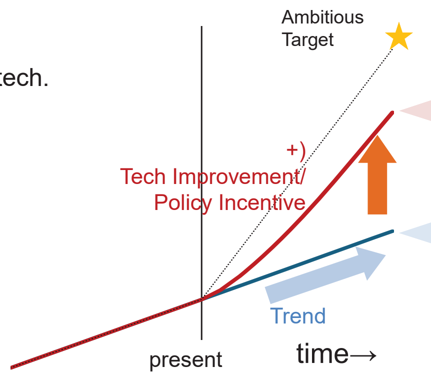
What is IEEJ Outlook?

■ 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

Substantial Increase in Power Demand, in addition to Data Centres

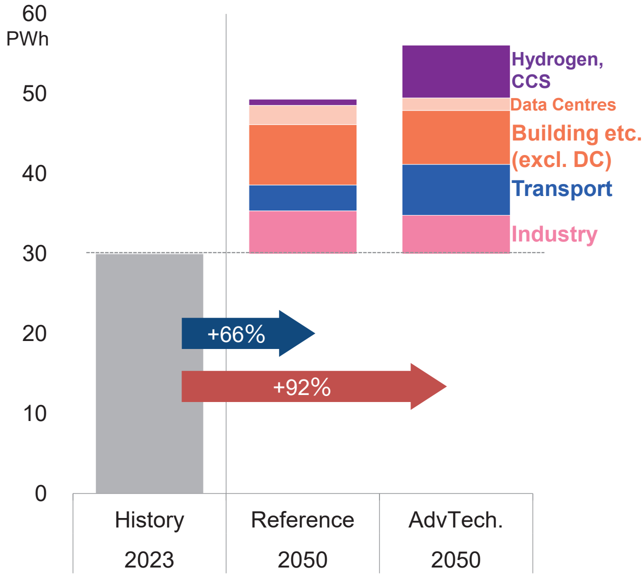
Historical Data Trend [Global]

- 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

Generation growth centred on solar PV and wind, but expansion of other sources is also necessary

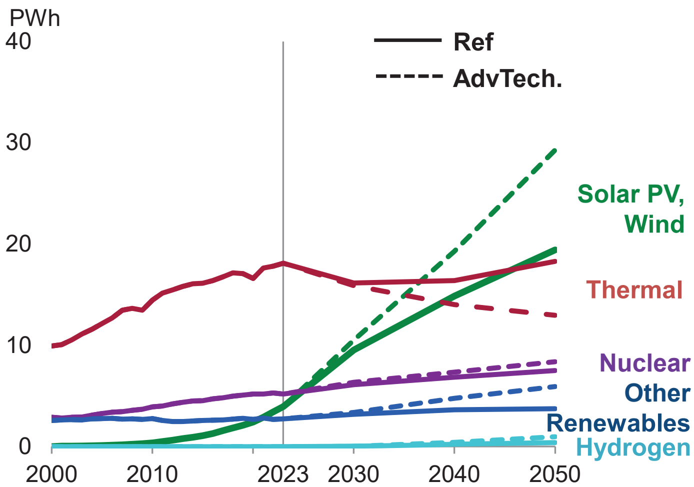
Historical Data Trend [Global]

- 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)

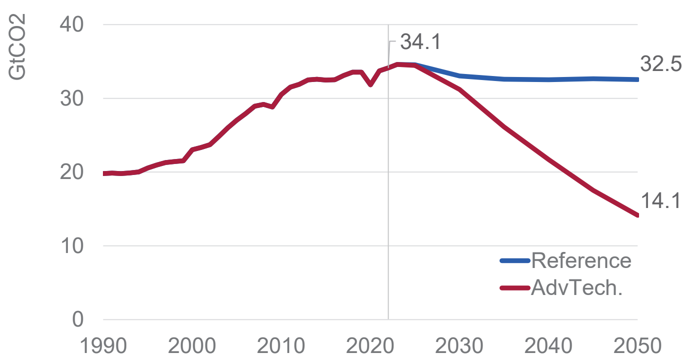


*Energy Institute, Statistical Review of World Energy (2025)

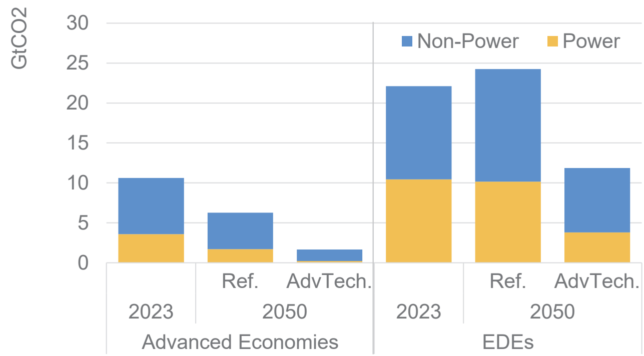
Non-Power Demand in EDEs : Major Challenge for Emission Reductions

- **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)



CO_2 Emission** (Regional, Sectoral)



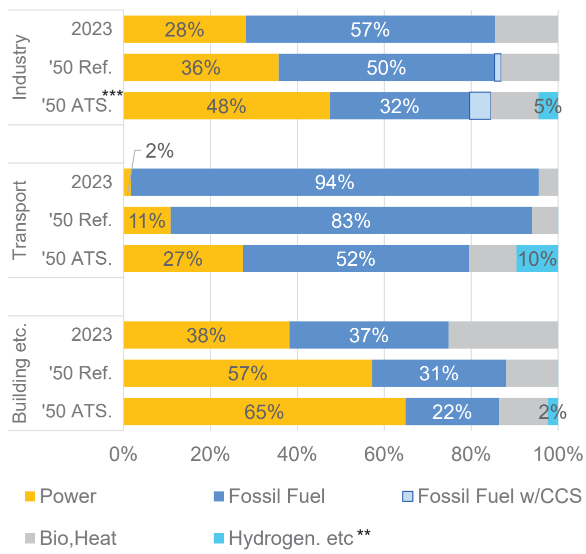
*Energy-related emissions minus offsets from CDR (BECCS/DACCS)

**EDEs: Emerging and Developing Economies

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".

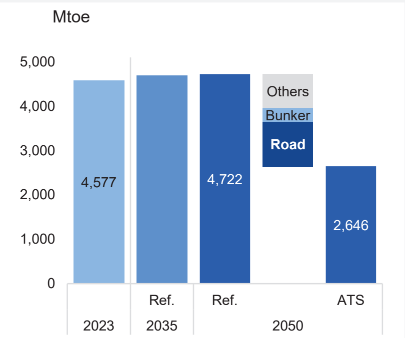
Fossil Fuel Consumption Shows a Wide Range Between the Scenarios

- 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)

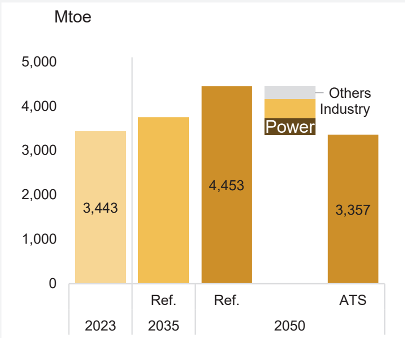
Oil

- Largest gap (**Ref** vs. **AdvTech**) among fossil fuels.
- Most uncertainty stems from road transport.



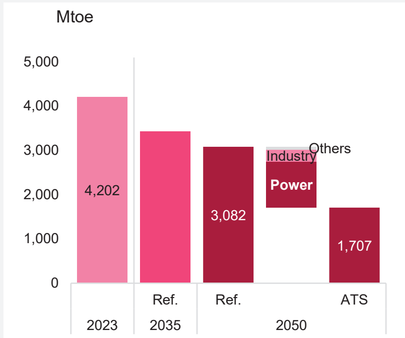
Natural Gas

- Relatively small range between **Ref** and **AdvTech**.; robust demand is expected.



Coal

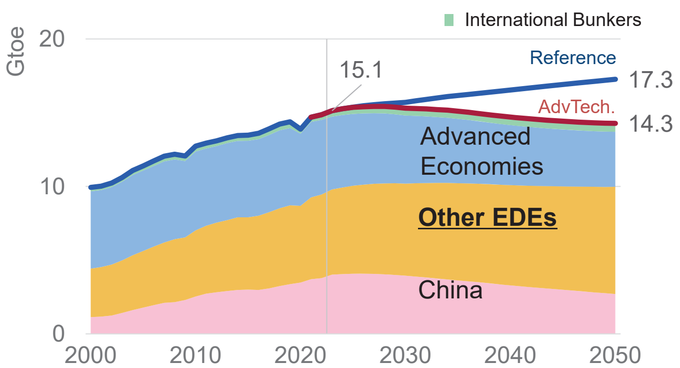
- High uncertainty in power generation in the future.
- **AdvTech**.: Renewable substitution reduces coal demand, including EDEs.



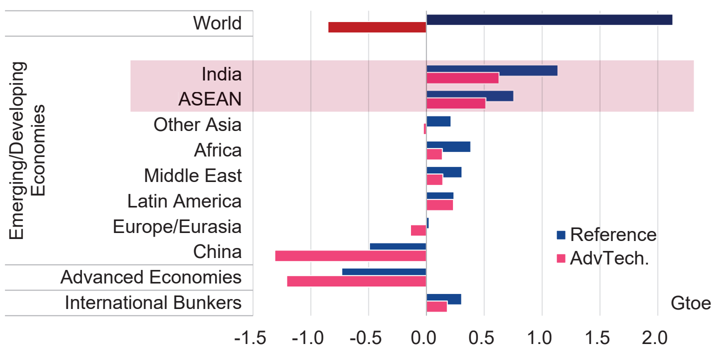
India and ASEAN Drive Energy Consumption Growth

- **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



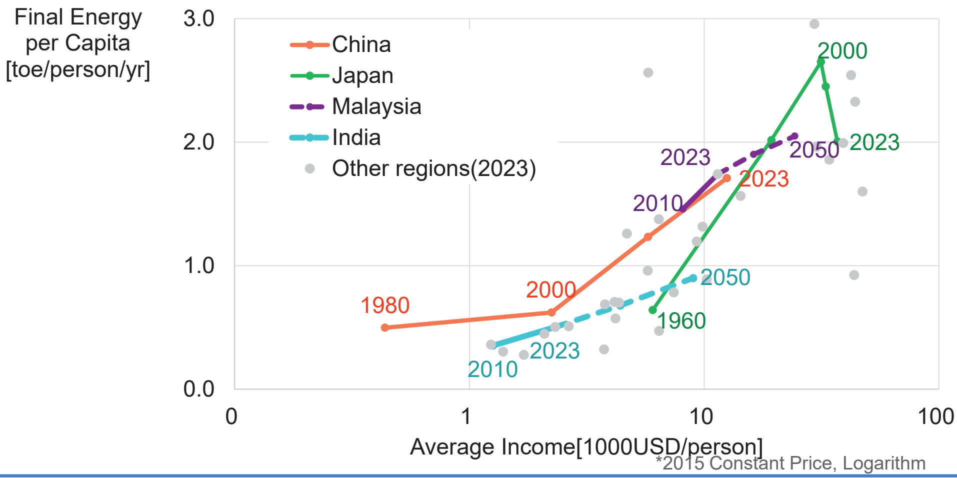
Regional Changes (2023-2050)



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)

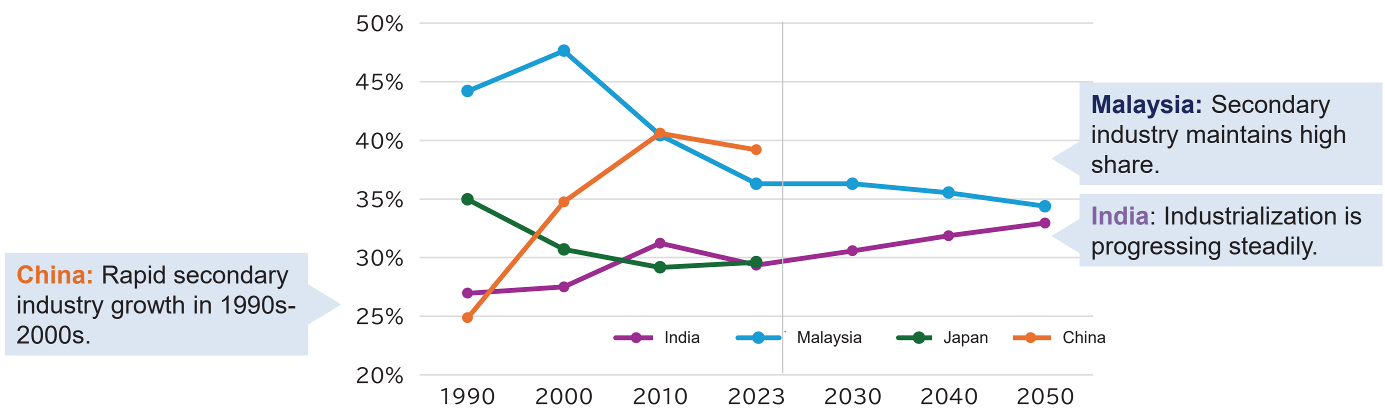


Source）History: IEA(2025), World Bank(2025), IEEJ（2025）. Future projections are from this outlook.

Industrialization is progressing steadily in South/Southeast Asia

- Secondary industry consumes particularly high energy and drives energy demand.

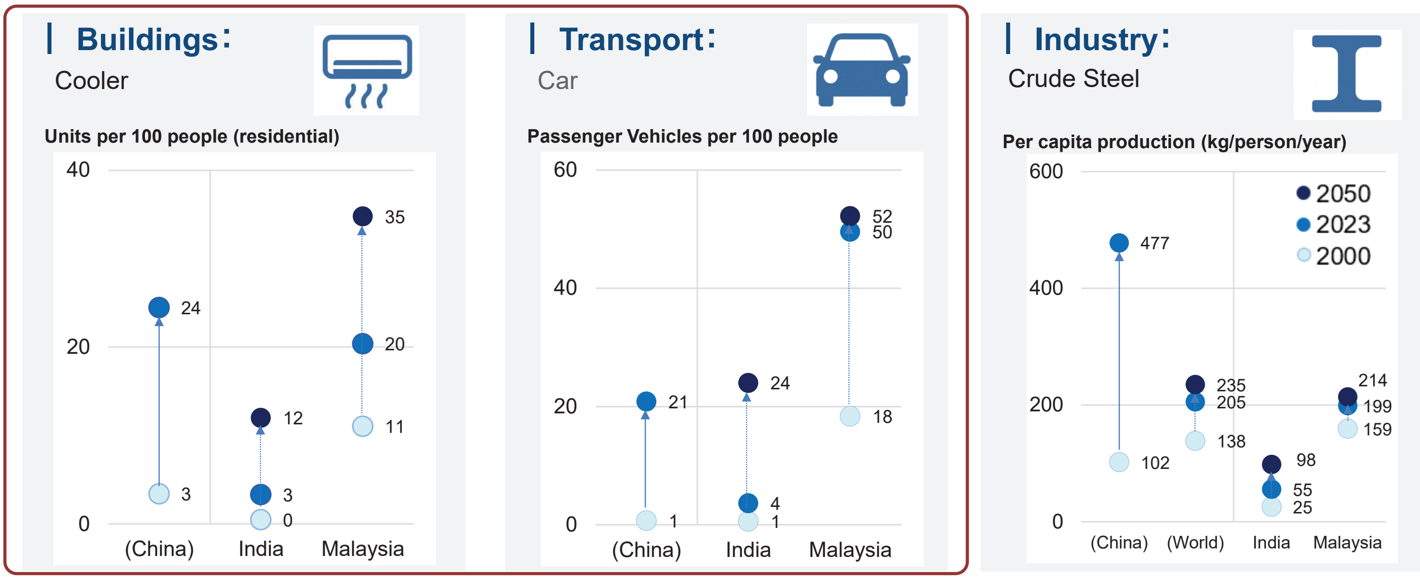
Secondary Industry Share of Total GDP



Source: Historical data from World Bank (2025). Projections based on this outlook.

Expanding "3C" Usage Stimulates Energy Consumption

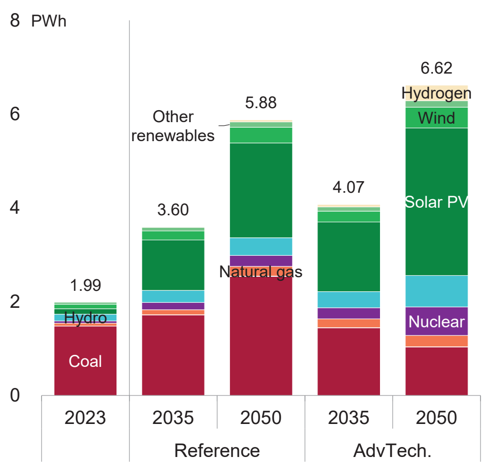
- Rising income levels stimulate increase **especially in ownership of cooler, cars**, additionally crude steel production.
  (e.g.)Penetration of "3C" in 1960s Japan/economic growth in 2000s China



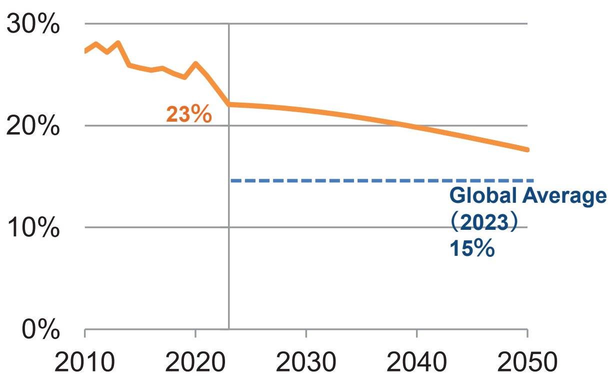
Challenges in Energy Supply and Demand (1): Rapid Increase in Power Generation (India)

- 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)

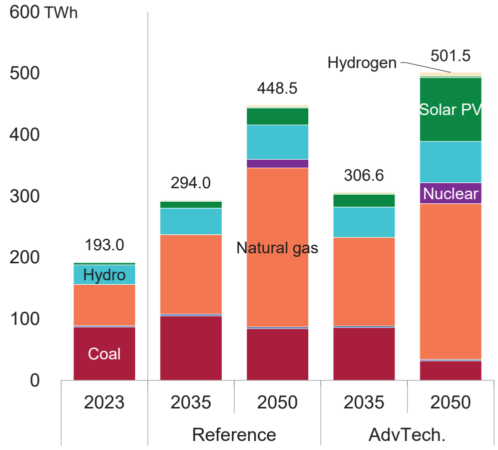


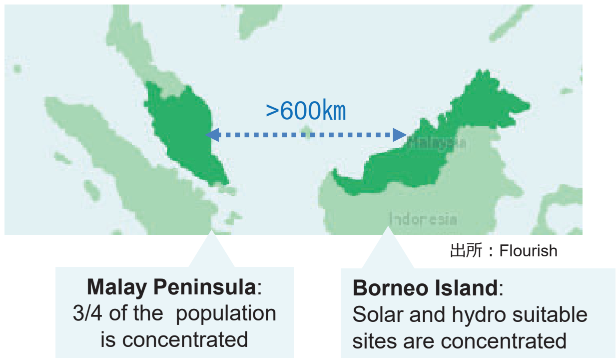
*Calculated as 1-(Final Electricity Consumption/Generation)

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)

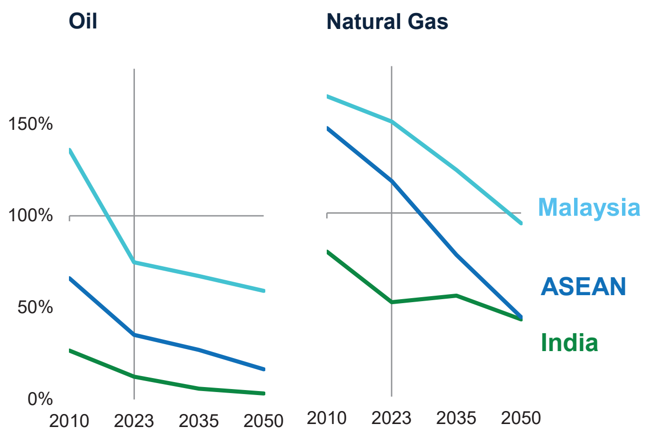




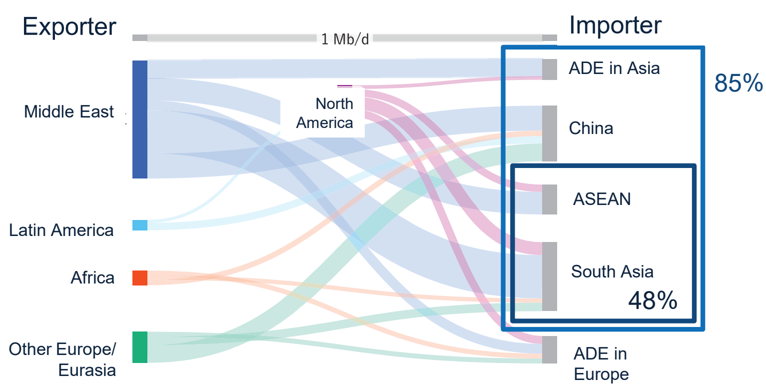
Challenges in Energy Supply and Demand (2): Rising Import Dependence on Fossil Fuel

- 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)



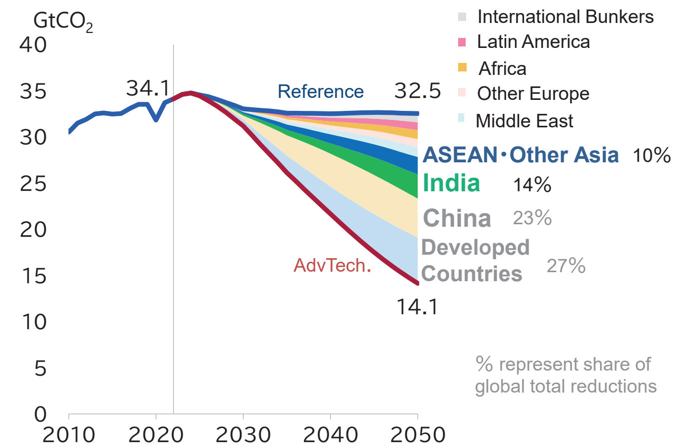
Note: Shows flows of 0.5 Mb/d or greater. Percentages represent share of total inter-regional trade volume.

Challenges in Energy Supply and Demand (3): Investment for CO_2 Reduction

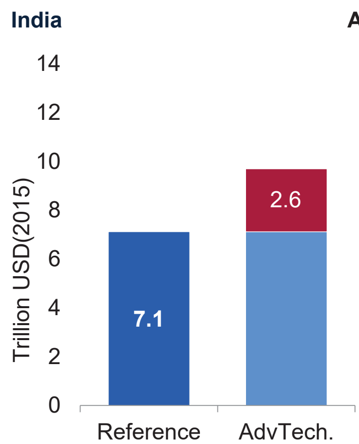
- Emission reduction potential (Reference – AdvTech.) in India, ASEAN, and Other Asia EDEs approaches scale of developed countries or China.
- On the other hand, substantial energy investment is required for AdvTech.
  - Additional investment needed for reductions in these three regions alone equals 80% of target amount agreed at COP29*.

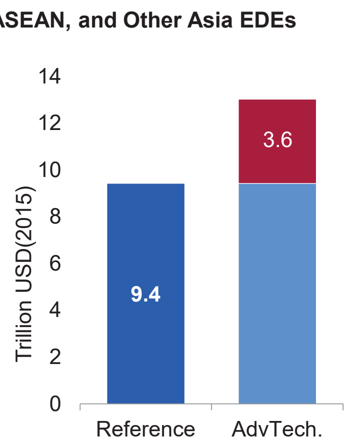
*300B USD/year.
(Target for all EDEs. Includes adaptation)

CO_2 Emissions(Energy-related)



Energy Investments (Cumulative, 2024-2050)





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.

The 451st Forum on Research Work 17 Oct. 2025

IEEJ Outlook 2026

Evaluating the Integration Costs and Deployment Potential of Variable Renewable Energy

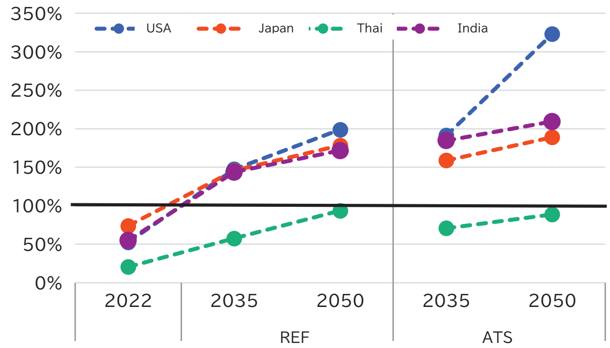
The Institute of Energy Economics, Japan

Yu NAGATOMI
Executive Analyst, Energy Data and Modelling Center
(Co-author: Hideaki OBANE, Seiya ENDO)

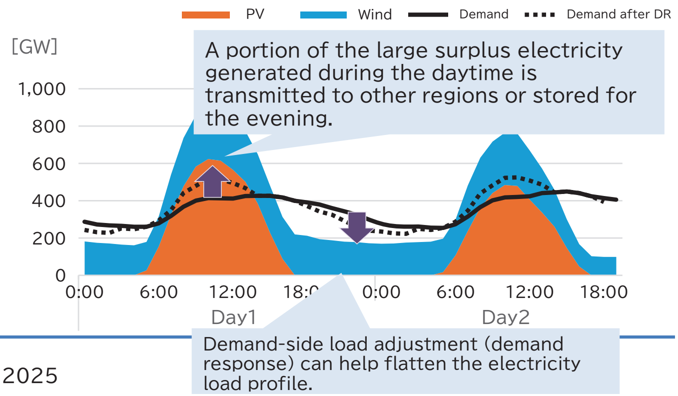
Rising VRE Penetration and the Changing Supply-Demand Balance in the Power System

- 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)

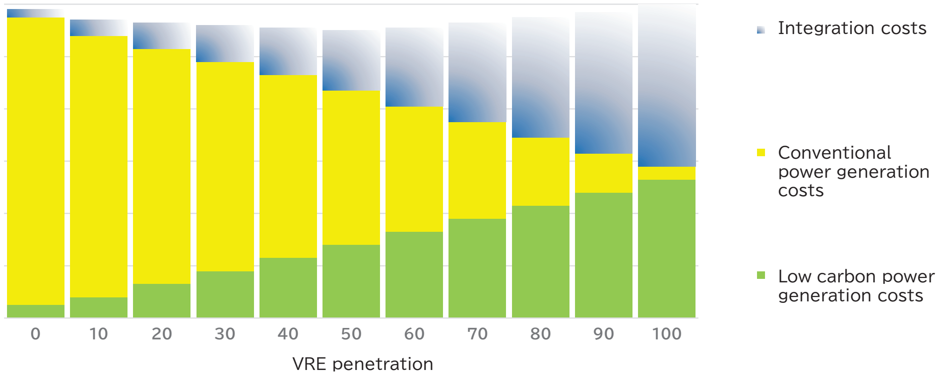


Source:IEEJ Outlook 2025

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

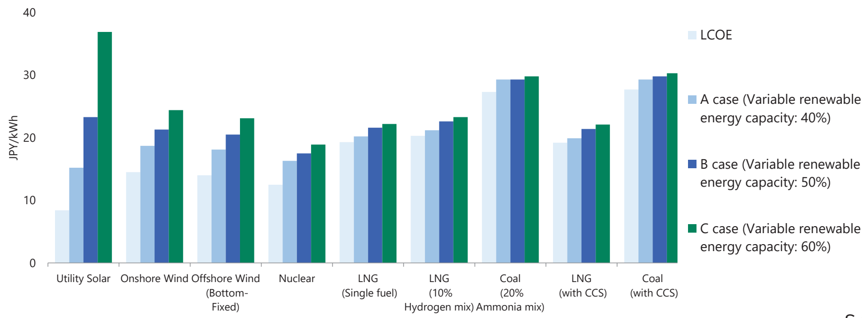


Source：Author, based on Matsuo (2021) and The Working Group on Power Generation Cost Verification (2025)

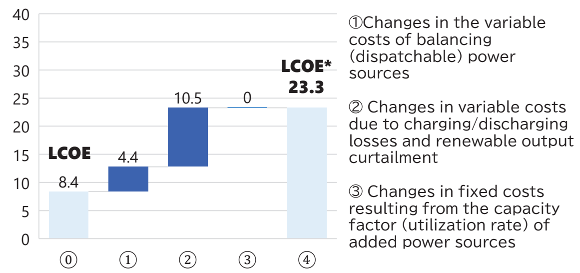
Example of the Study on Integration Cost: The Working Group on Power Generation Cost Verification (2025)

- 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

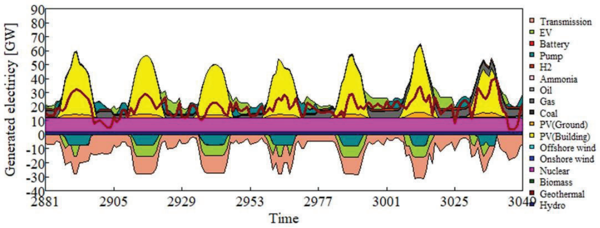


Source：Author, based on The Working Group on Power Generation Cost Verification (2025)

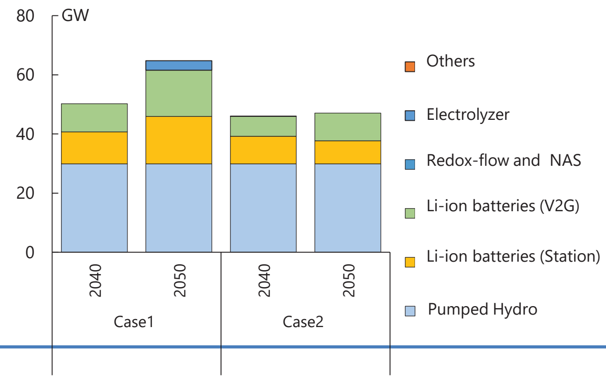
Overview of the IEEJ Technology Selection Model (IEEJ-NE Model)

- 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)



Required storage capacity estimated by area



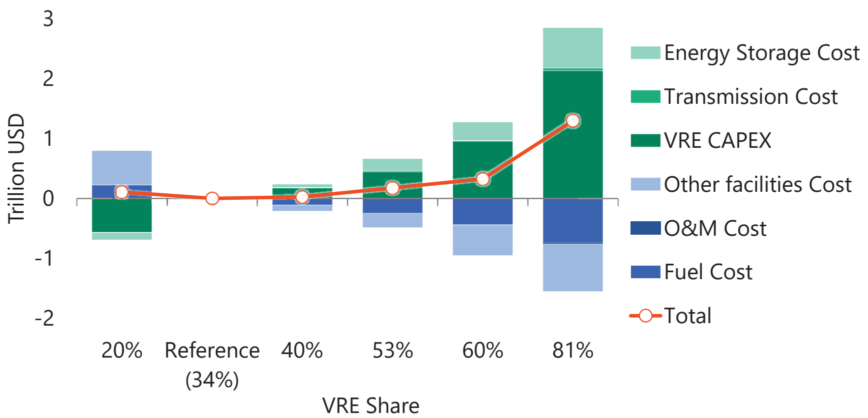
Technology list

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

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

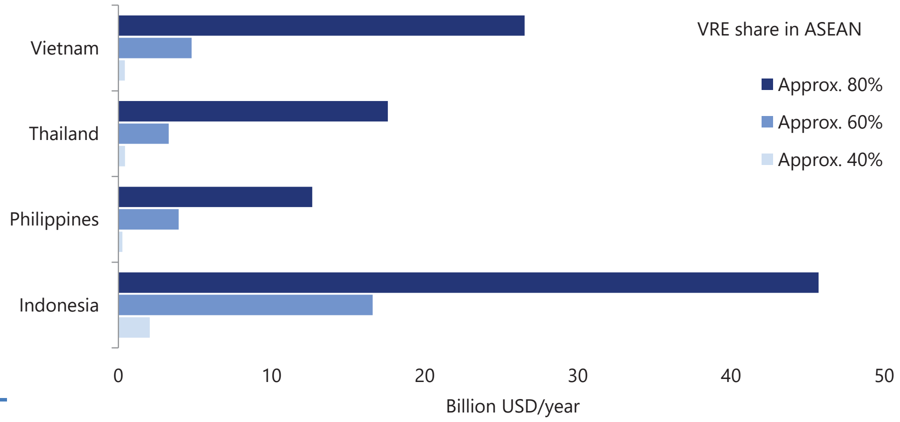
Cost Decrease: Other facilities (mainly conventional; power plants), O&M, Fuel

Note: Interconnection capacity is capped based on ASEAN Power Grid assumptions. Costs are shown in 2017 real USD.

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)



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.

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)

The 451st Forum on Research Work October 17, 2025

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.

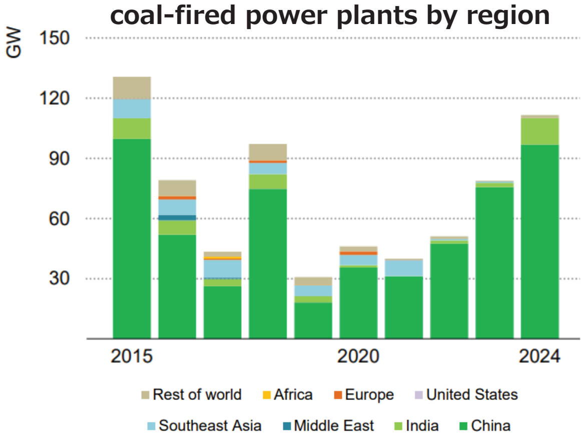
Recent developments concerning the 1.5°C target (Emerging countries)

- 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

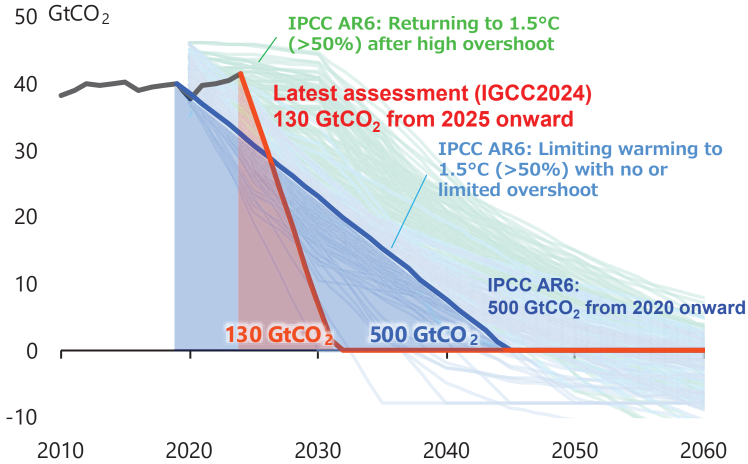


(Source) IEA, World Energy Investment 2025

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.

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.)

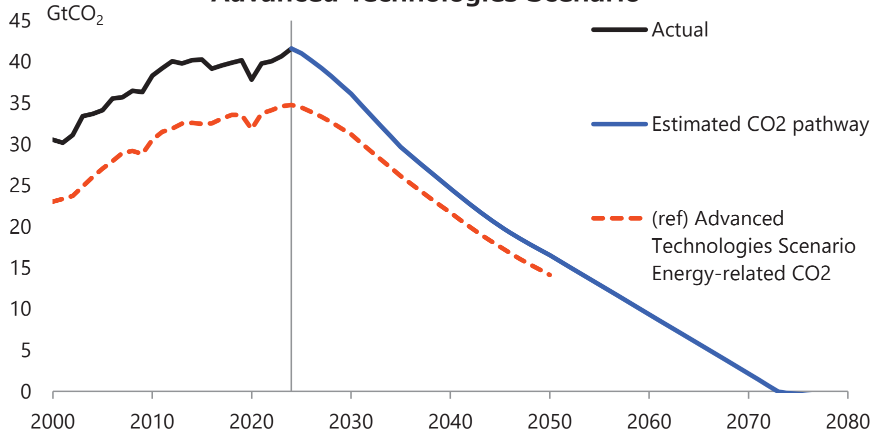
- Carbon budget comparison targets
  - IPCC 6th Assessment Report Synthesis Report (IPCC AR6 SYR)
  - Global Carbon Budget 2024（GCB 2024）：International research projects, updated annually
  - Indicators of Global Climate Change 2024（IGCC 2024）：Same above

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/

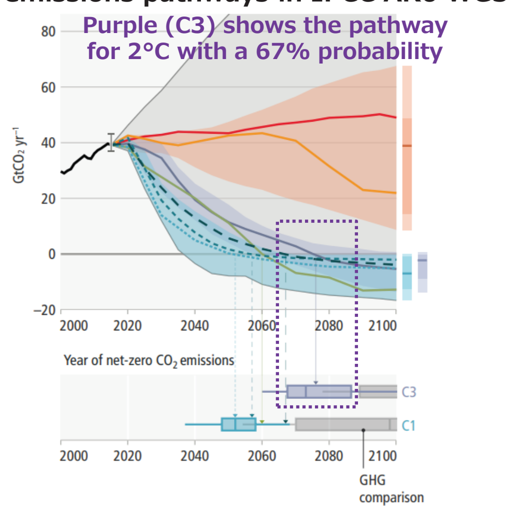
Comparison of the Advanced Technologies Scenario and the 2°C target (CO_2 emissions pathway)

- 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

Comparison of the Advanced Technologies Scenario and the 2°C target (Carbon budget)

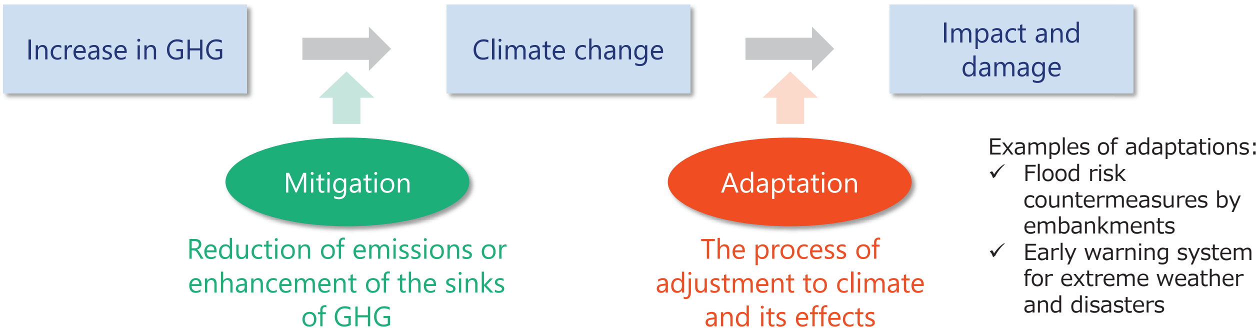
- The cumulative emissions from 2025 onwards until net-zero is achieved in the estimated CO_2 emission pathway would total 906 $GtCO_2$, a level comparable to the latest remaining carbon budget and sufficient to limit global temperature rise to 2°C with 50% probability.
- However, it slightly exceeds 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.

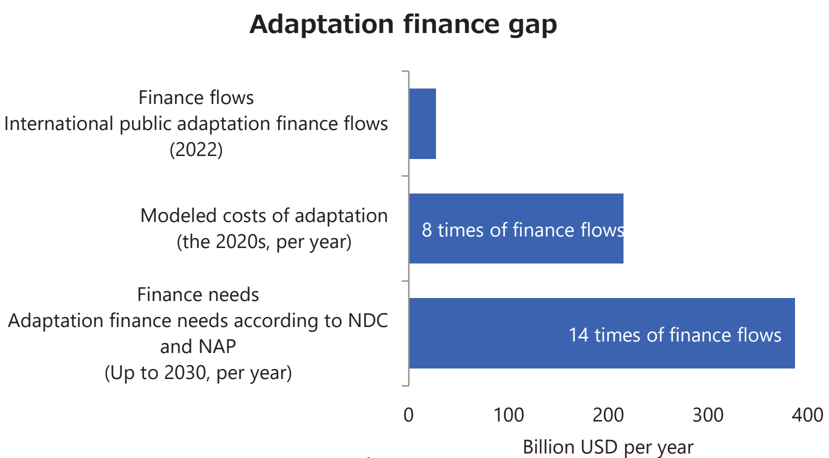
What is adaptation?

- 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?



- 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.

What is the gap in adaptation finance?

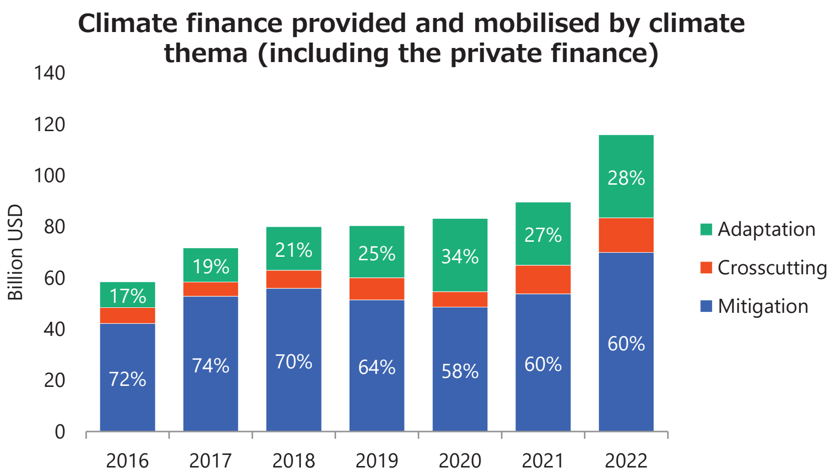


Note: NAP (National Adaptation Plan)

- 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.

Source: Created from UNEP (2024), Adaptation Gap Report 2024.

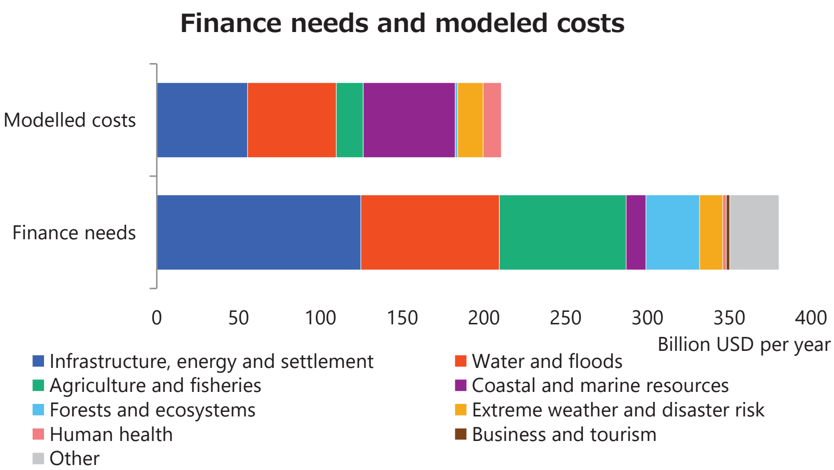
Balance between adaptation and mitigation finance



- 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.

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.

(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

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.

The 451st Regular Research Forum, October 17, 2025

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 CO_2 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).**

Electricity Consumption at Data Centres：Was 2020 a turning point？

Trends in Data Centres Electricity Consumption

2015-2019

Data center electricity consumption remained flat

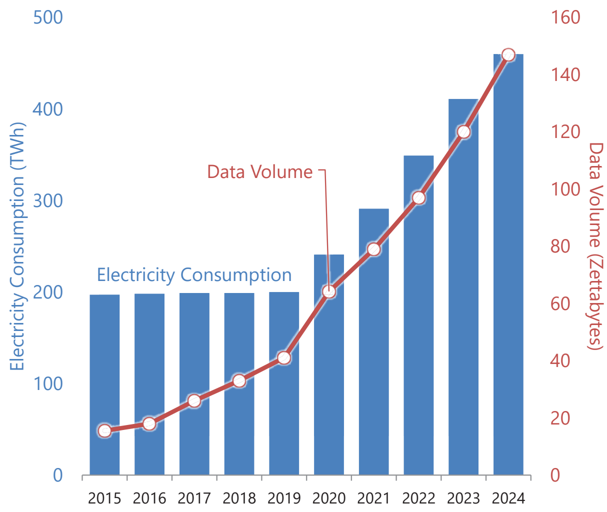
- Data volume triples
- Energy efficiency advances in servers, storage, networking, infrastructure, etc.
- Shift from small data centers to large cloud and hyperscale data centers
- Improved efficiency of Graphics Processing Units (GPUs) contributes

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



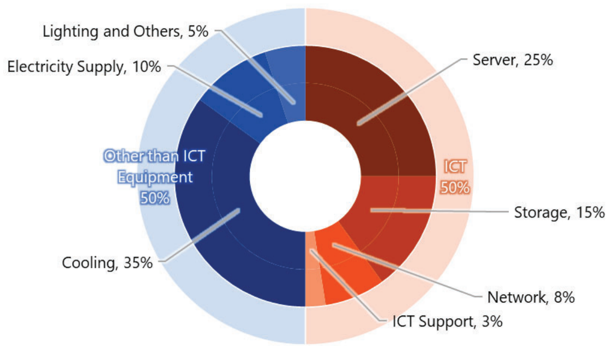
Source : Masanet et al. (2020), Cisco, IEA, Goldman Sachs Research,

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.

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 |

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).

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

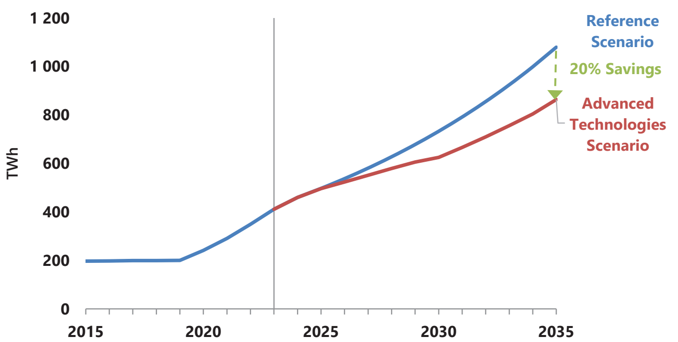
- iMasons Climate Accord (ICA)：A framework aimed at decarbonizing digital infrastructure, organized by iMasons, an industry group comprised of digital infrastructure companies, primarily big tech companies.
- Semiconductor Climate Consortium (SCC)：Framework for decarbonization in the semiconductor industry
- 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.

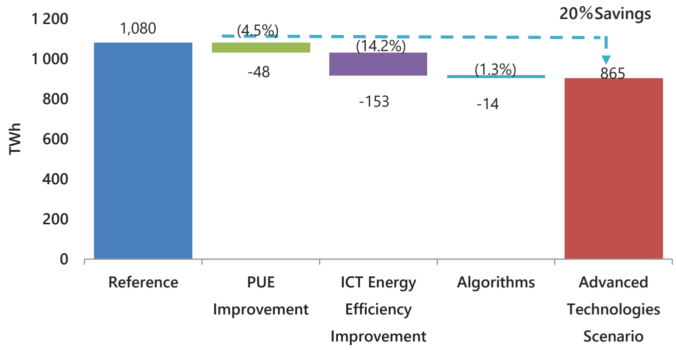
Data Centre Electricity Demand Outlook and Electricity Savings Potential（2035）

- 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）

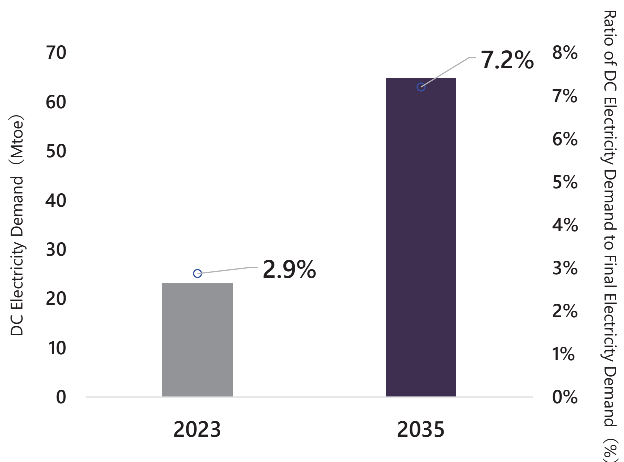


Source：IEEJ (2025).

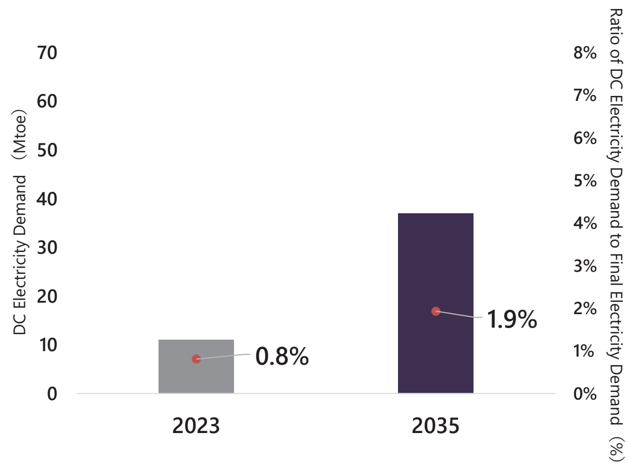
Data Centre Electricity Demand and Ratio to Final Electricity Demand (2023 and 2035)

- 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



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

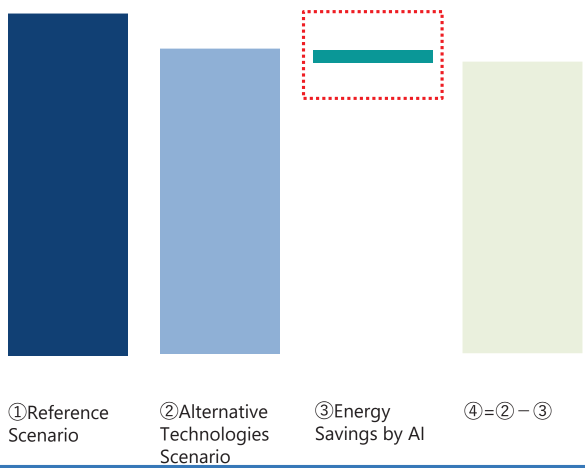
What contributions does AI can make to the energy sector?

- 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 ▪ Weather forecasting and renewable energy use
Prediction	▪ 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

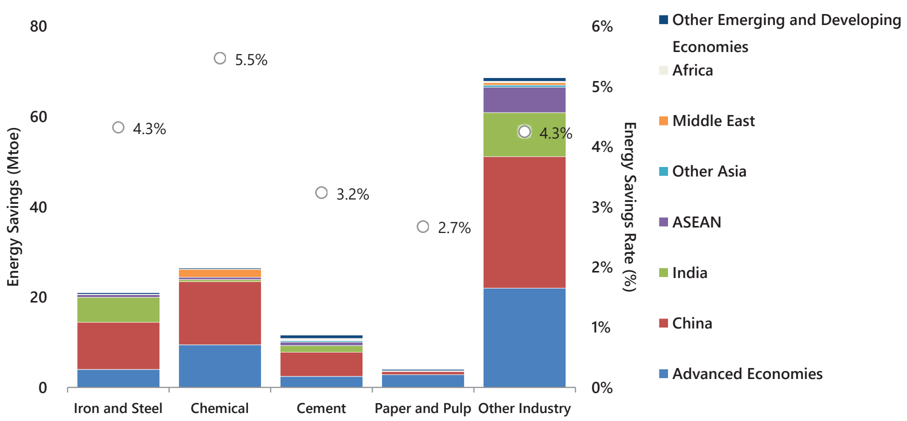


Source：ICEF（2024）他より作成。

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】



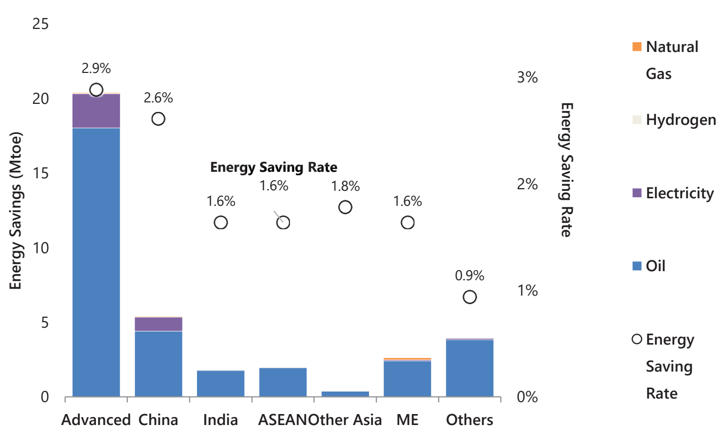
Source：IEEJ (2025).

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】



Examples for Energy Savings of AI in the Road Transport

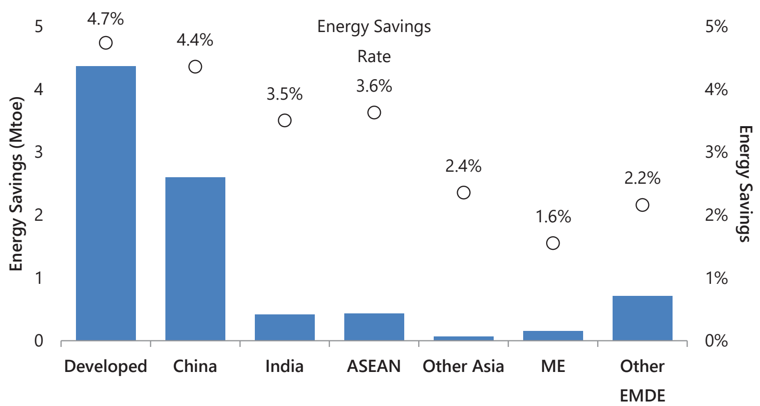
	Exampes
Demand Projection	The loading efficiency and passenger efficiency of cargo trucks, buses, taxis, etc. can be improved by taking into account weather and traffic information.
Route Optimization	Through machine learning, AI suggests route optimization that takes into account the driver's travel 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.

Source：IEEJ (2025).

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.

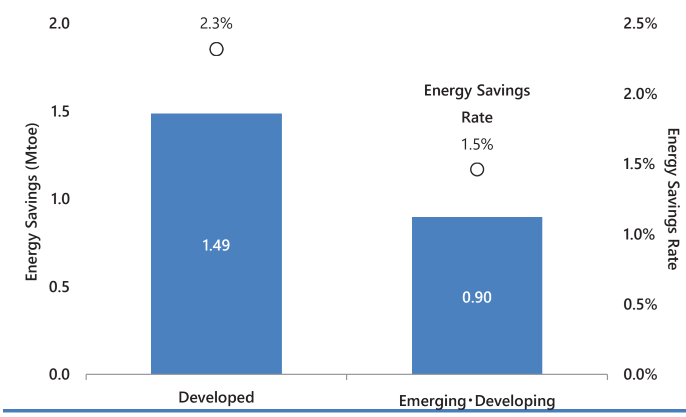
Source：IEEJ (2025).

Residential : Energy Savings Potential of AI (Ratio to Alternative Technologies Scenario)

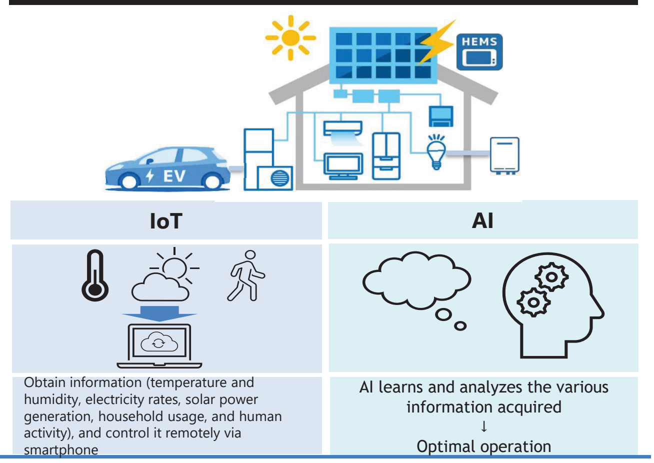
✓ Estimates of the energy savings potential for heating and cooling using AI suggest that in 2035, **it could reach 1.5 Mtoe in developed economies (a 2.3% savings compared to the Advanced Technologies Scenario)** and **0.9 Mtoe in emerging and developing economies (a 1.5% savings compared to the Advanced 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】



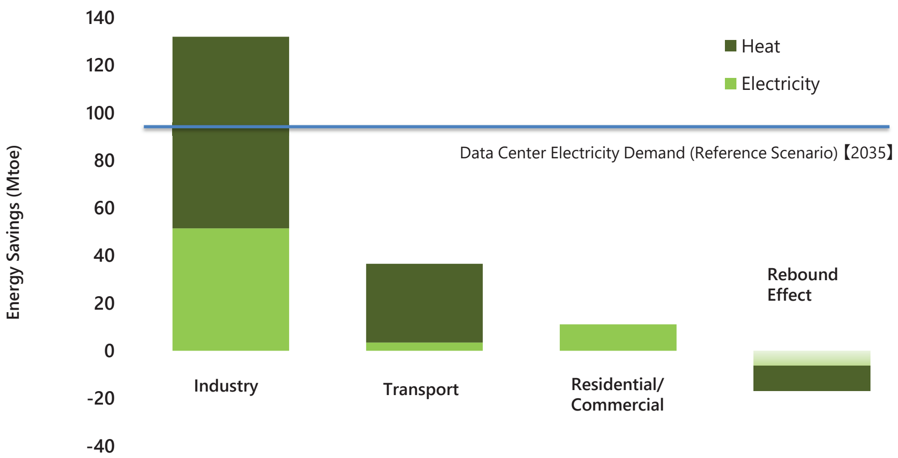
Images for Energy Savings of AI in the Residential Sector



Source：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).

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.	

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.

Reference materials

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

Modelling framework

Major assumptions

GDP, population, energy prices, exchange rates, international trade, etc.

Macroeconomic model

Calculate GDP-related indices, price indices, activity indices including material production, etc. consistently.

Technology assessment model

Use a bottom-up approach to calculate future efficiencies of appliances, vehicles, etc.

Optimal power generation planning model

Calculate the cost-optimal power generation mix to meet the projected future electricity demand.

Energy supply-demand model

Econometric model to project future energy supply and demand by regression analysis of historical trends based on the energy balance tables data of the International Energy Agency.

This model calculates energy demand, supply and transformation as well as related indices including CO_2 emissions, CO_2 intensities and energy self-sufficiency ratios.

Experts' opinions

World trade model

Use the linear programming (LP) method to calculate the future international trade flows of crude oil, petroleum products, etc.

Computable general equilibrium model

Estimate economic impacts induced by changes in energy supply and demand, based on input-output table data.

Climate change model

Calculate future GHG concentration in the atmosphere, temperature rise, damage caused by climate change, etc.

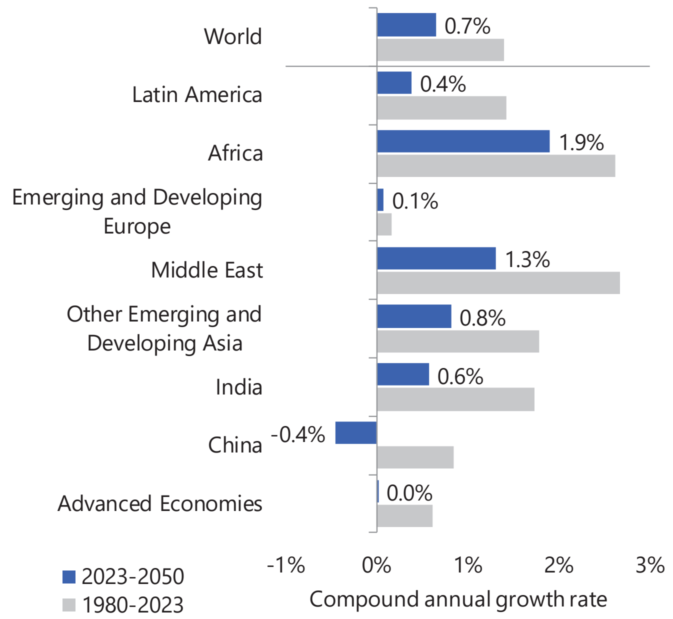
Basic scenarios in IEEJ Outlook

	Reference Scenario	Advanced Technologies Scenario
	Reflects past trends with technology progress and current energy policies, without any aggressive policies for low-carbon measures	Assumes introduction of powerful policies to address energy security and climate change issues with the utmost penetration of low-carbon technologies
Socio-economic structure	Stable growth led by developing economies despite slower population growth. Rapid penetration of energy consuming appliances and vehicles due to higher income.	
International energy prices	**Oil** supply cost increases along with demand growth. **Natural gas** prices converge among Europe, North America and Asia markets. **Coal** price decreases due to request for decarbonization.	All prices decrease along with decrease in demand due to progress in energy saving and request for decarbonization
Energy and environmental policies	Gradual reinforcement of low-carbon policies with past pace	Further reinforcement of domestic policies along with international collaboration
Energy and environmental technologies	Improving efficiency and declining cost of existing technology with past pace	Further declining cost of existing and promising technology

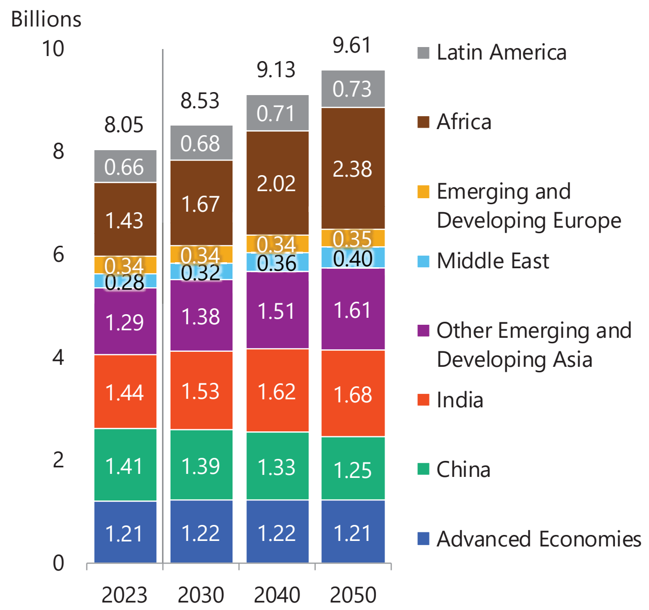
Assumptions

Population

CAGR



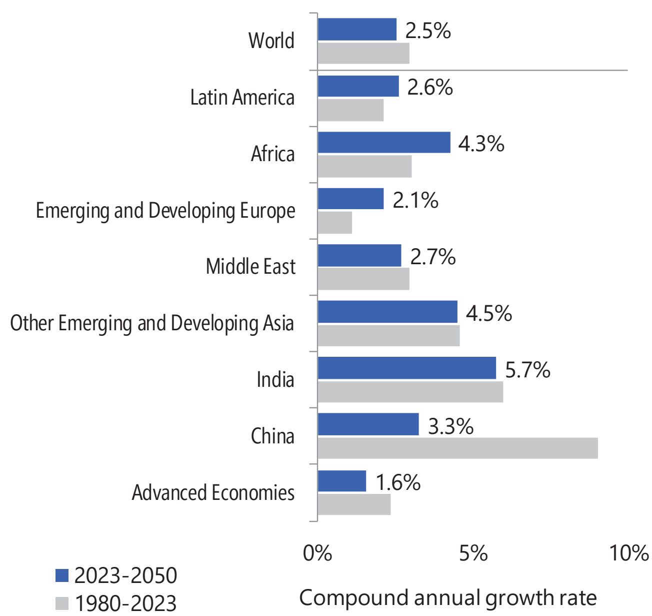
Composition



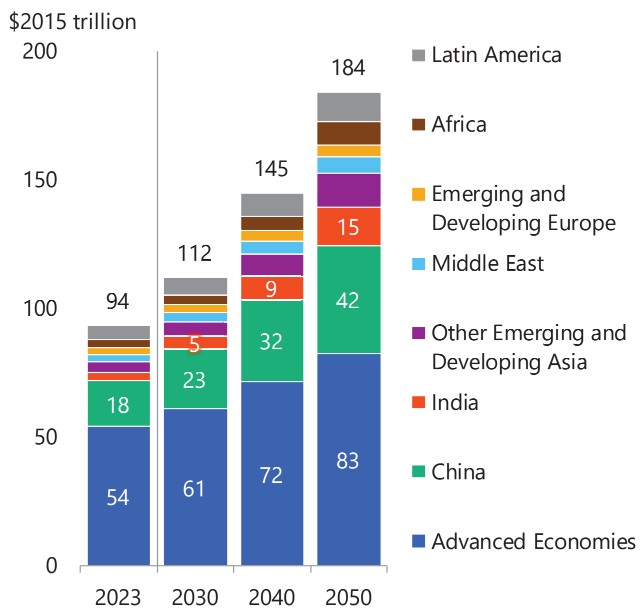
Assumptions

Real GDP

CAGR



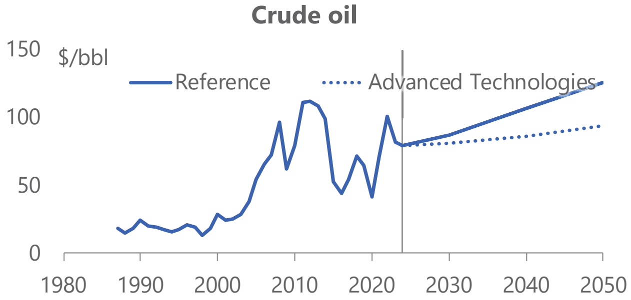
Composition

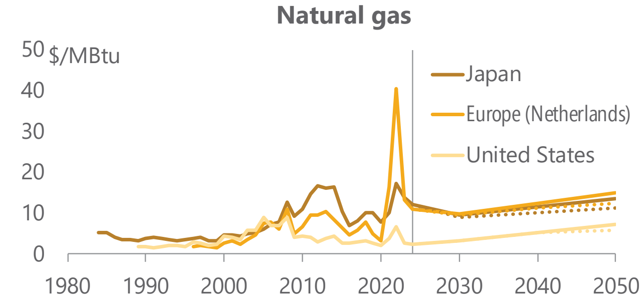


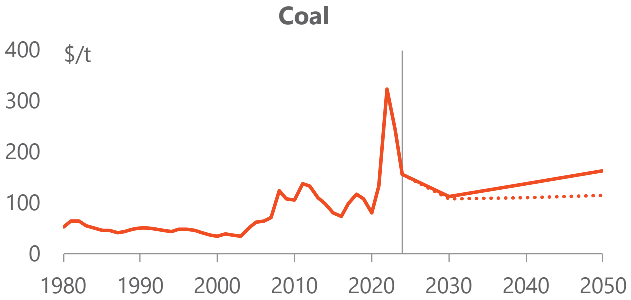
Assumptions

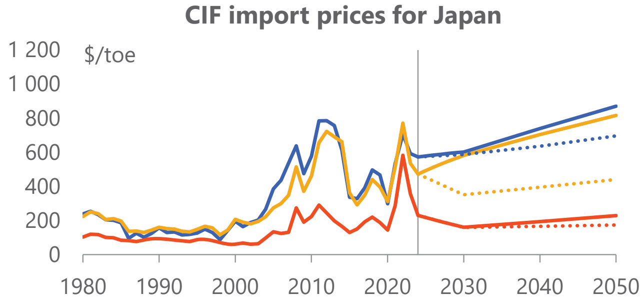
International energy prices

Reference : ——— Advanced Technologies : ··········









Note: Historical prices are nominal. Assumed future prices are real in $2025.

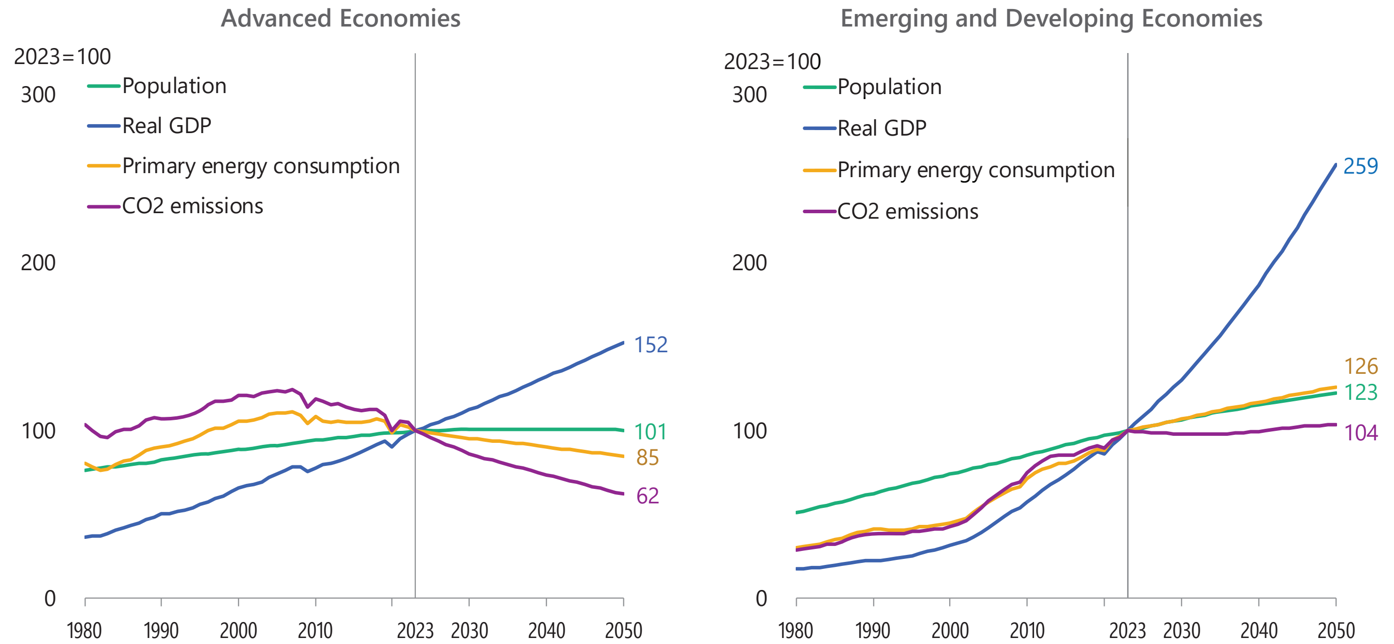
Assumptions

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.

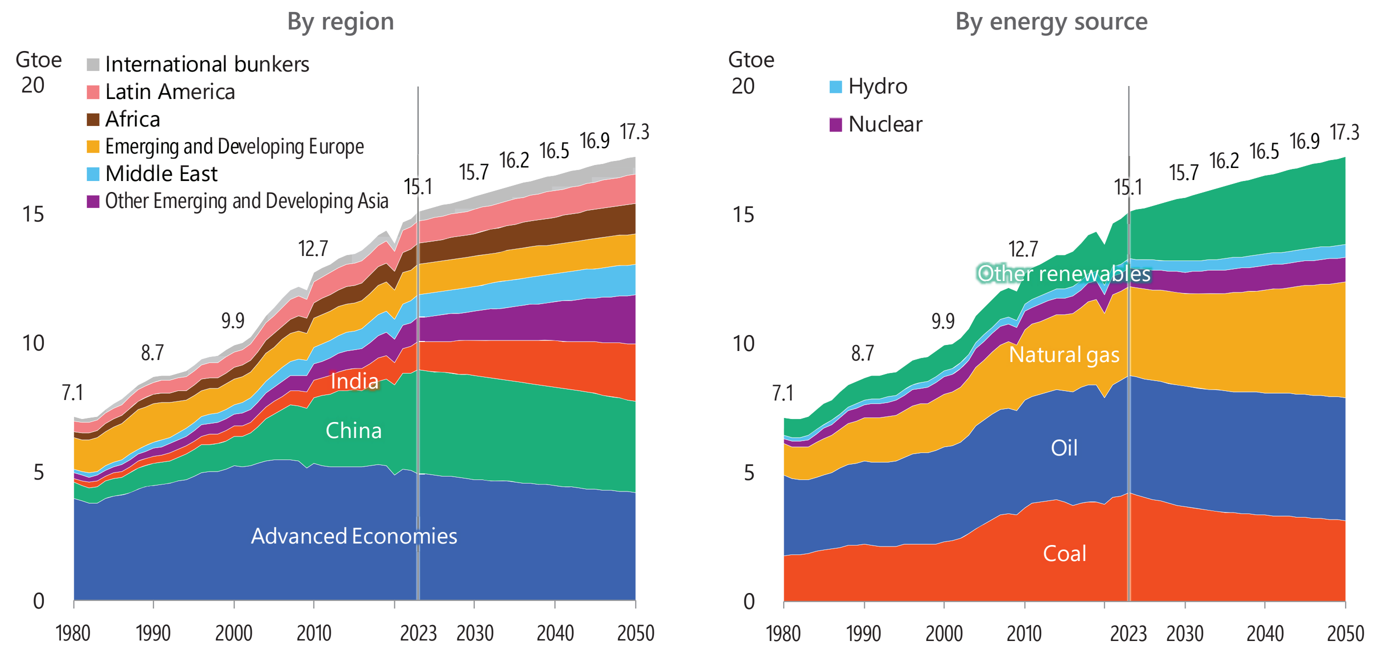
Reference Scenario

Population, GDP, energy and CO_2



Reference Scenario

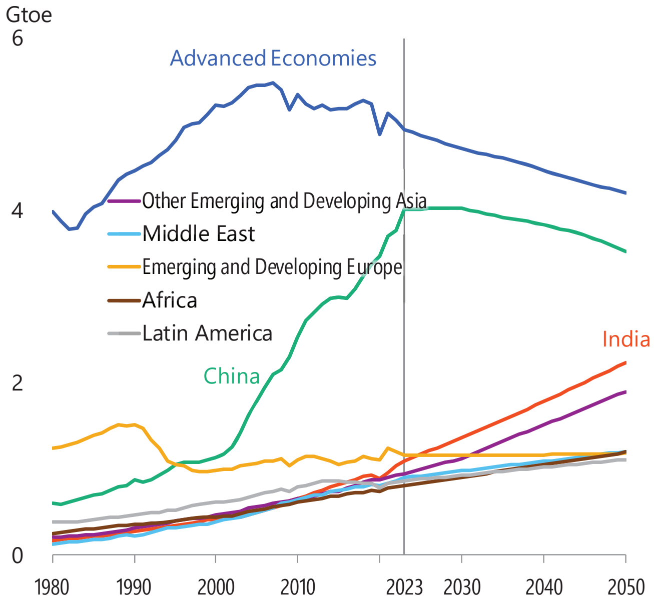
Primary energy consumption



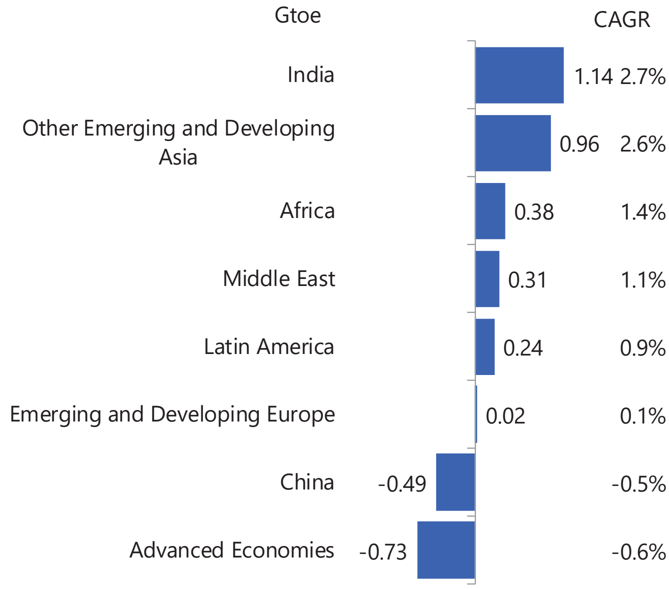
Reference Scenario

Primary energy consumption (by region)

Energy consumption



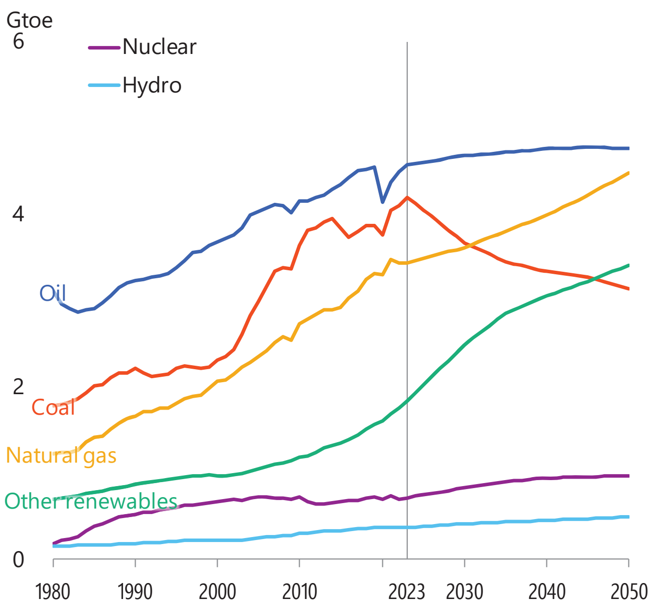
Changes (2023-2050)



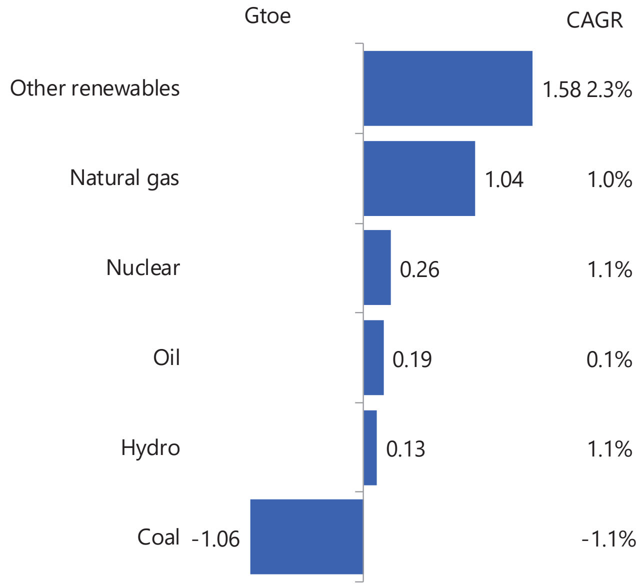
Reference Scenario

Primary energy consumption (by energy source)

Energy consumption



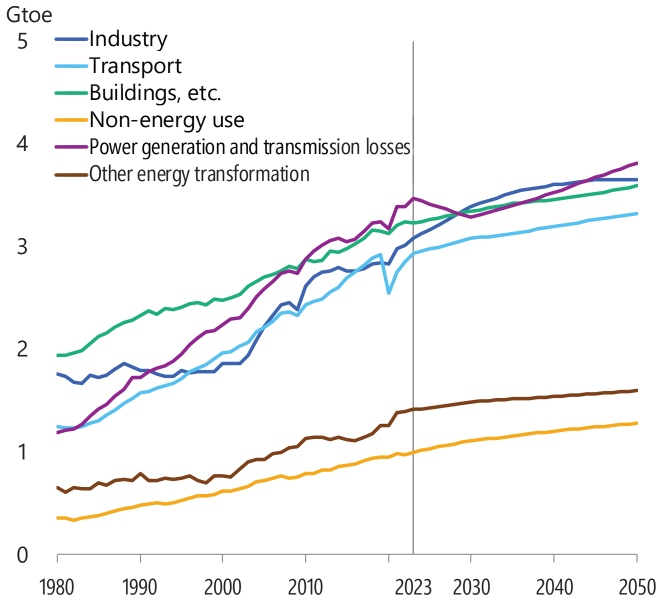
Changes (2023-2050)



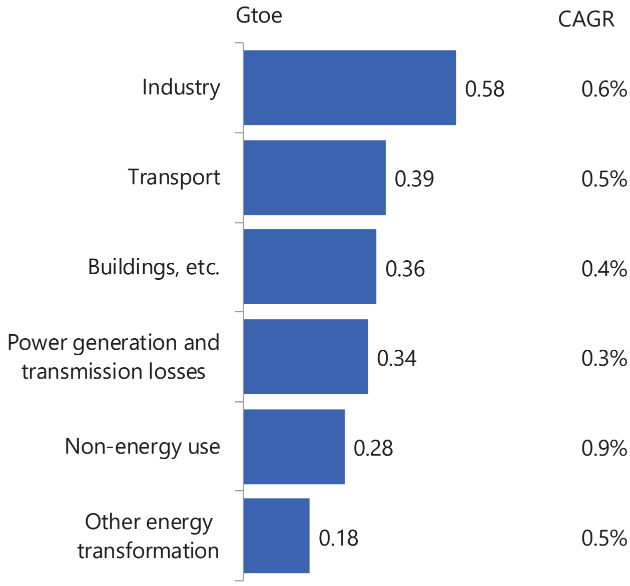
Reference Scenario

Primary energy consumption (by sector)

Energy consumption



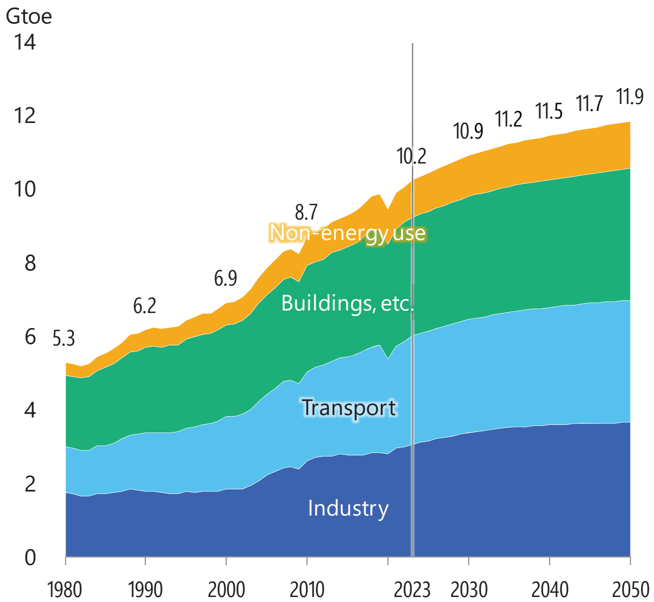
Changes (2023-2050)



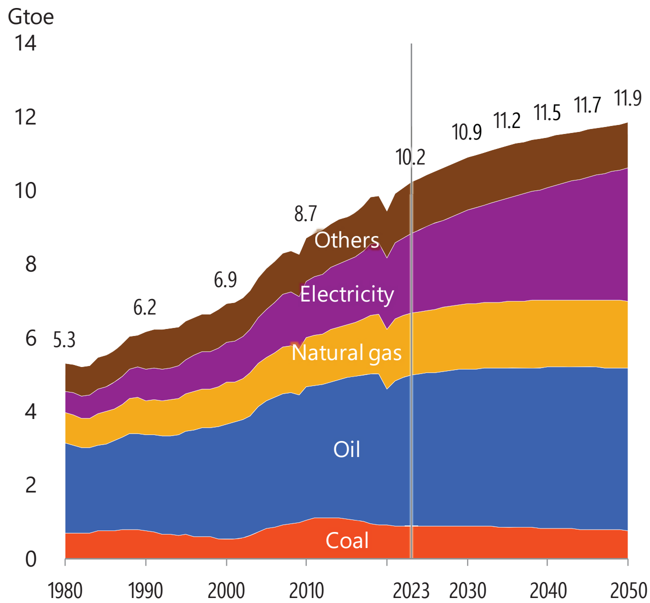
Reference Scenario

Final energy consumption

By sector



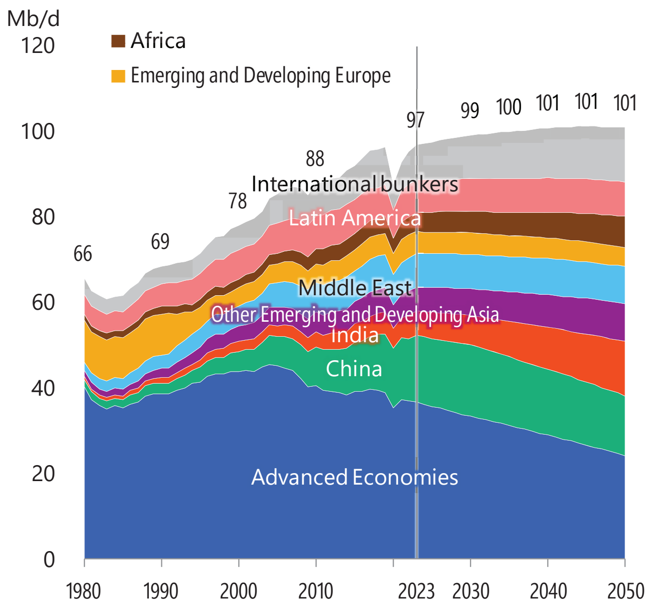
By energy source



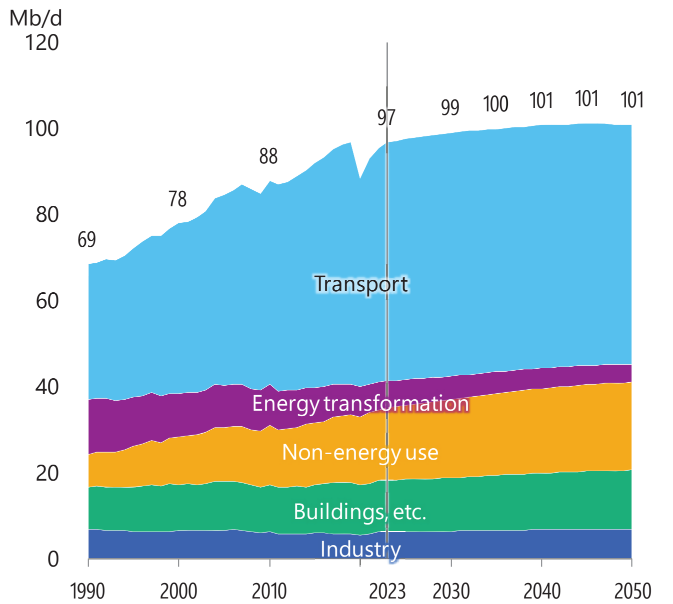
Reference Scenario

Oil consumption

By region



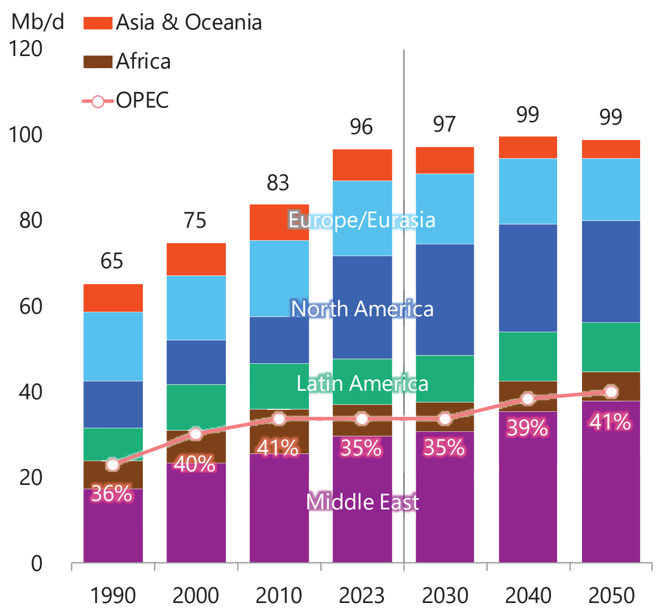
By sector



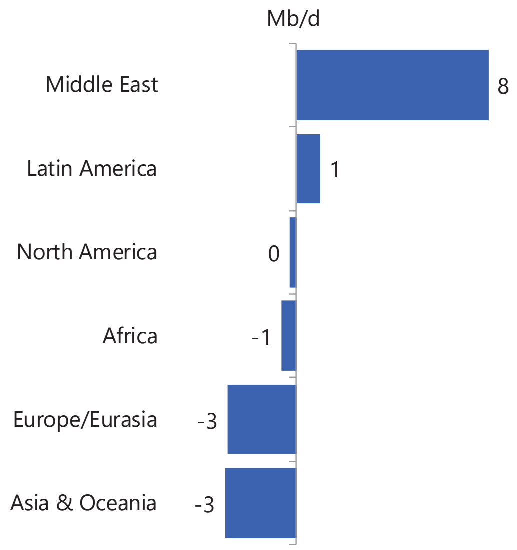
Reference Scenario

Crude oil production

By region

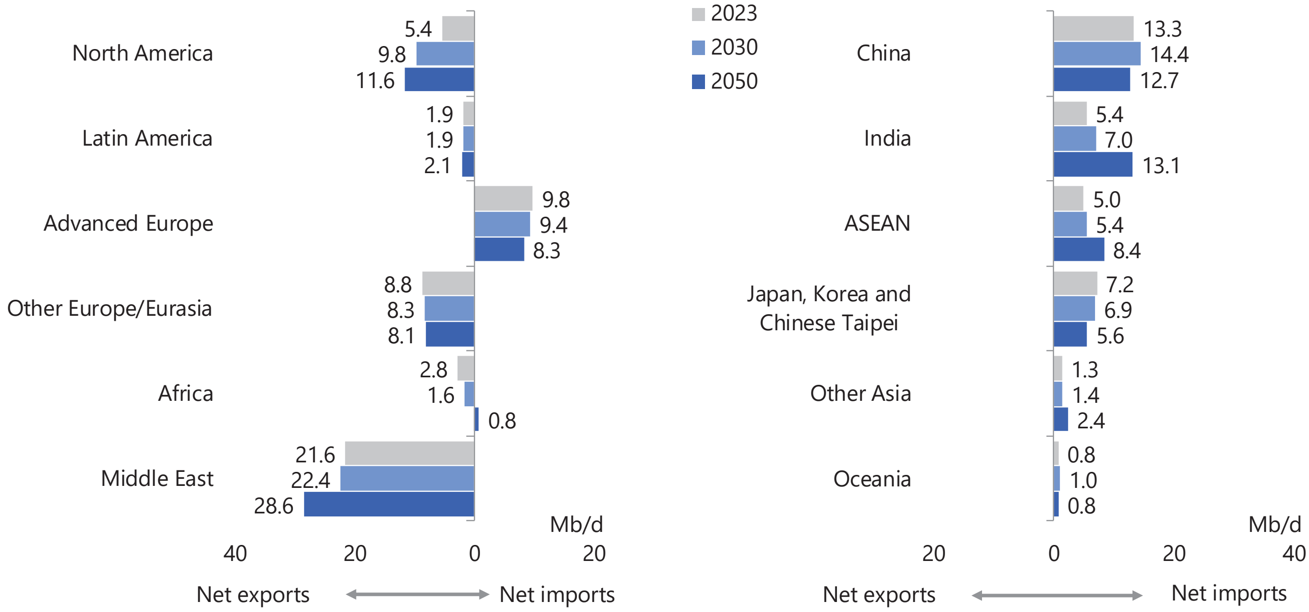


Changes (2023-2050)



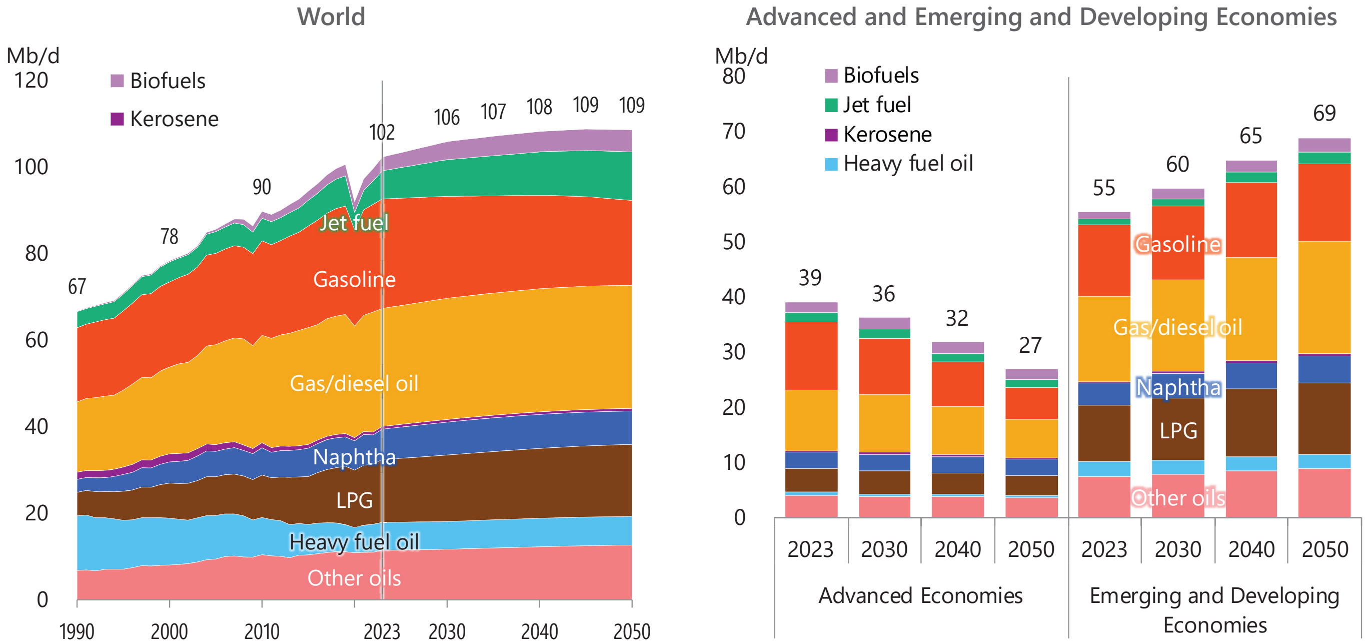
Reference Scenario

Net exports and imports of oil



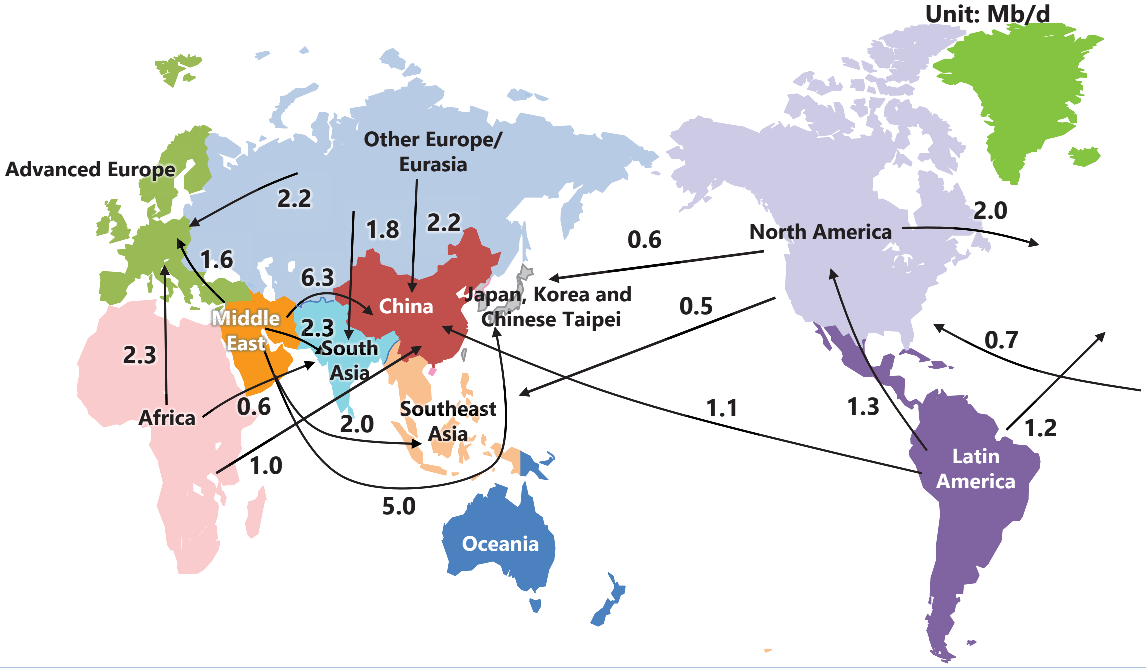
Reference Scenario

Petroleum product demand



Note: Other oils includes crude oil (direct consumption), asphalt, refinery gas, gas-liquefied oil [GTL], etc.

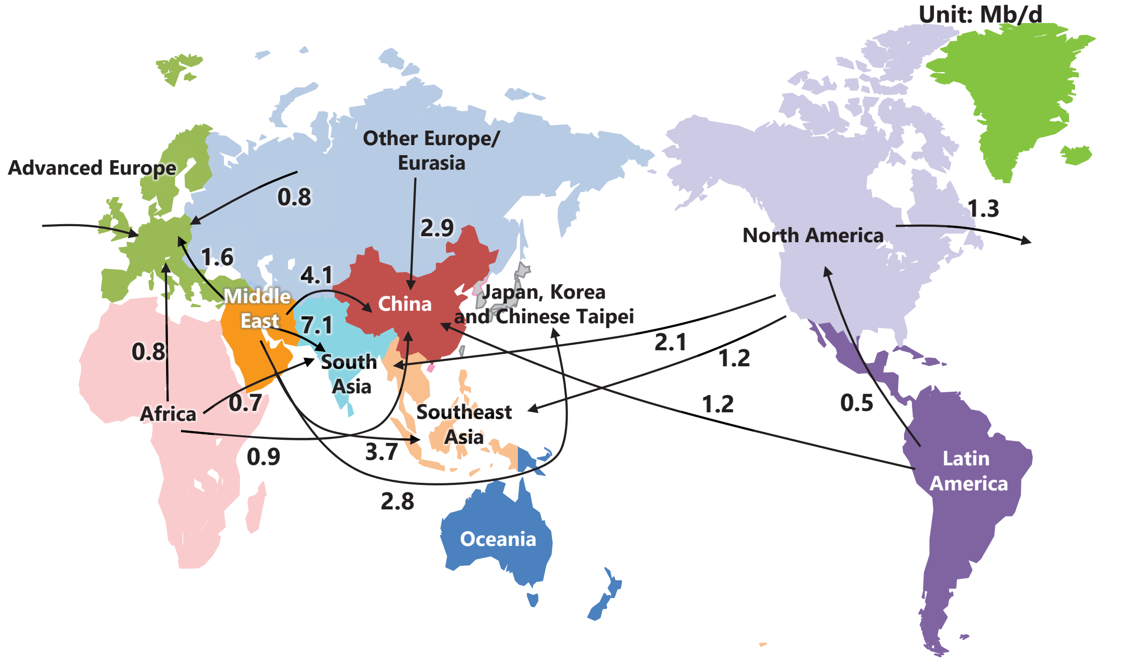
Major trade flows of crude oil (2025)



Note: 0.5 Mb/d or more are shown

Reference Scenario

Major trade flows of crude oil (2050)

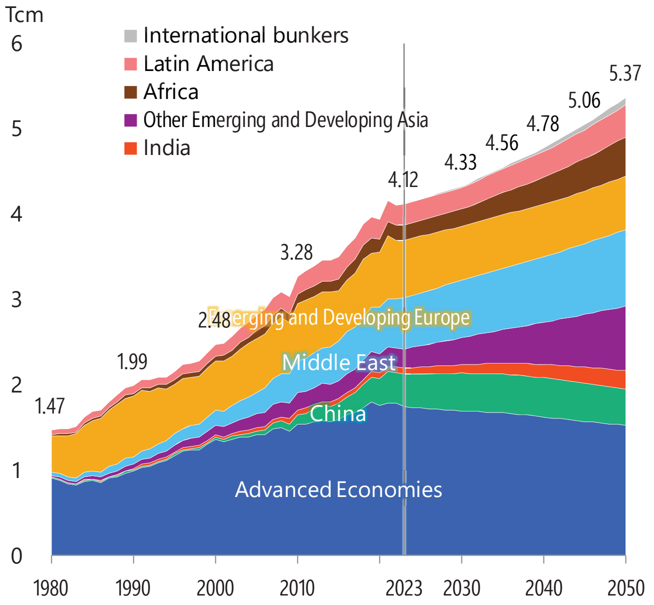


Note: 0.5 Mb/d or more are shown

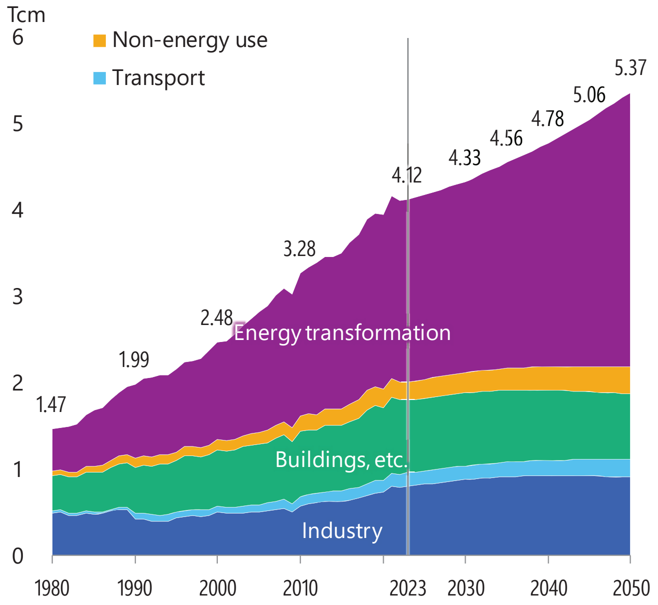
Reference Scenario

Natural gas consumption

By region



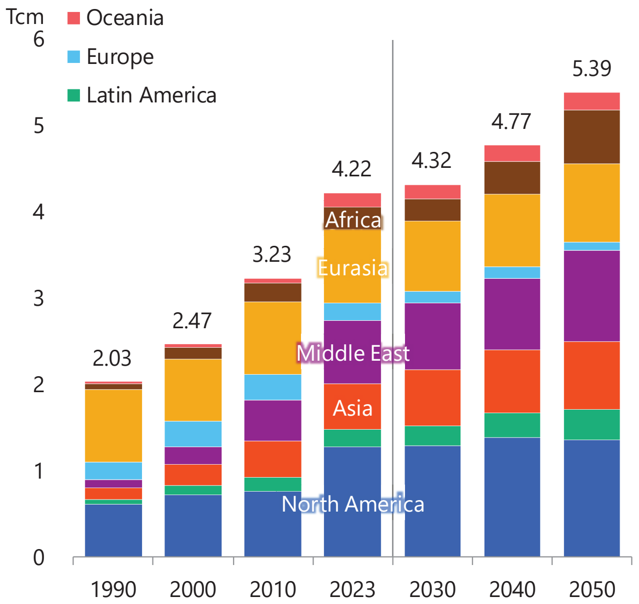
By sector



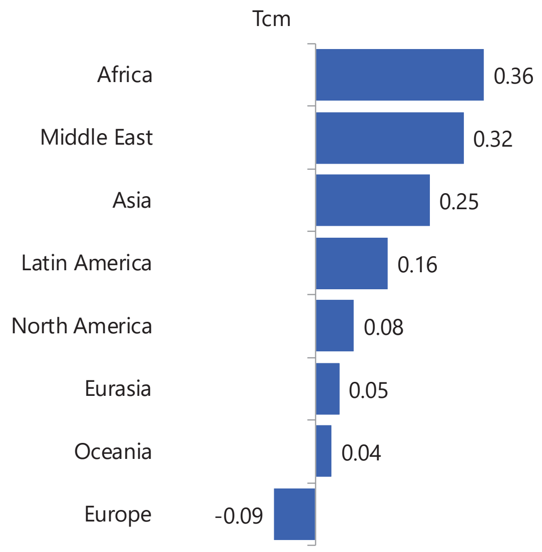
Reference Scenario

Natural gas production

By region

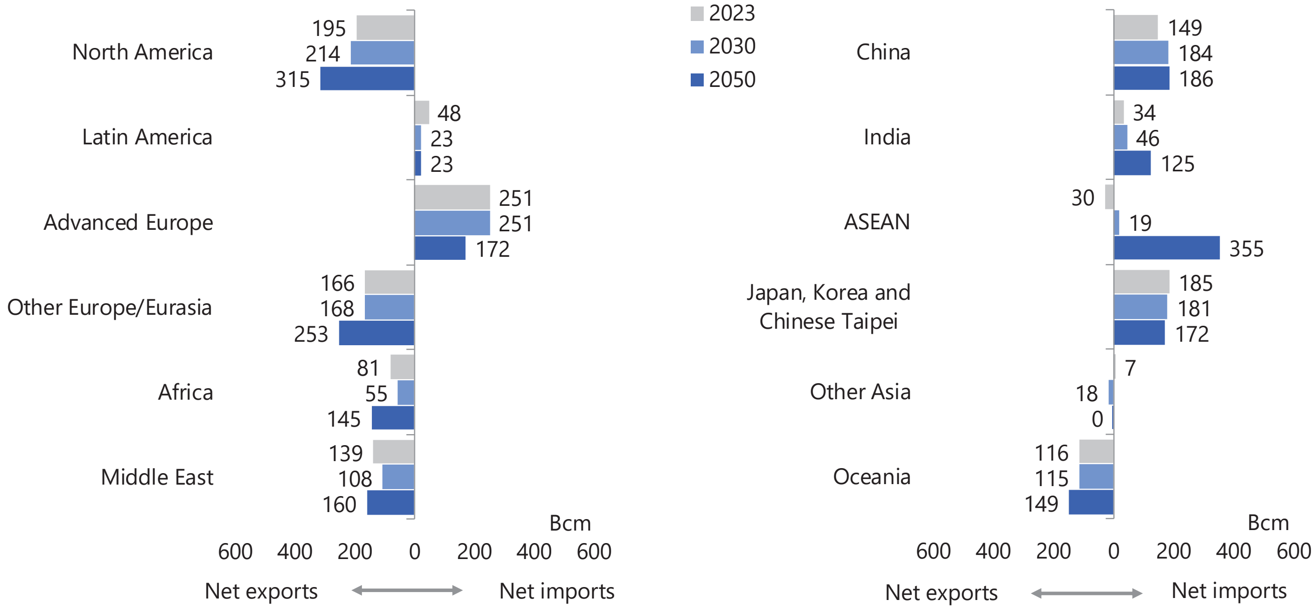


Changes (2023-2050)



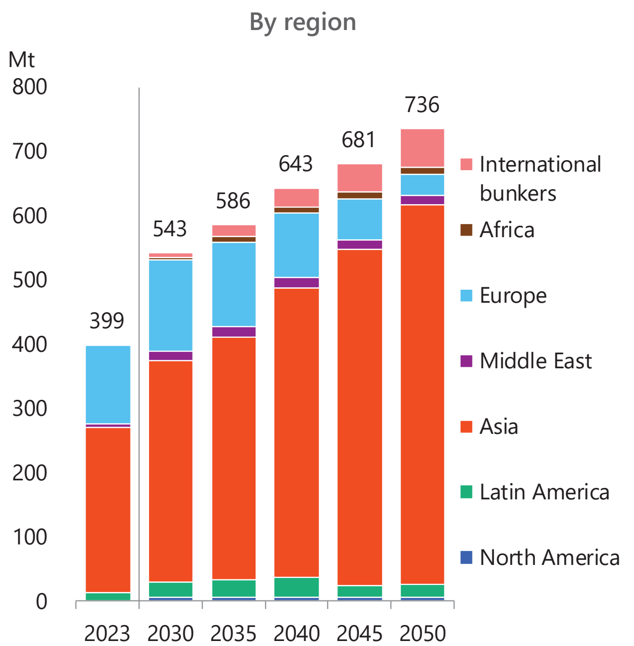
Reference Scenario

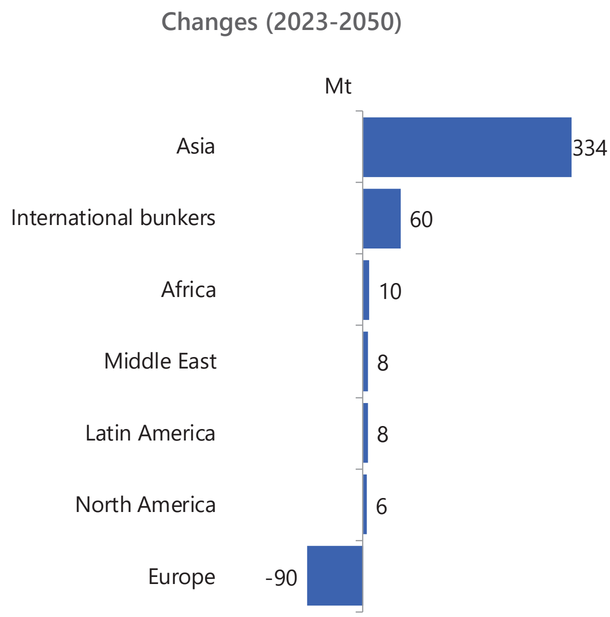
Net exports and imports of natural gas



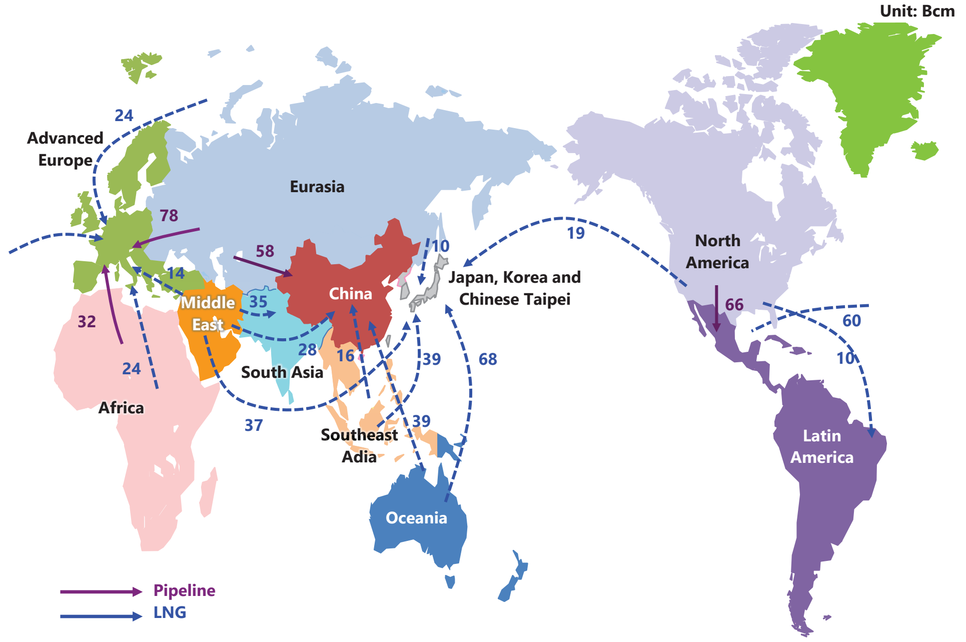
Reference Scenario

LNG demand





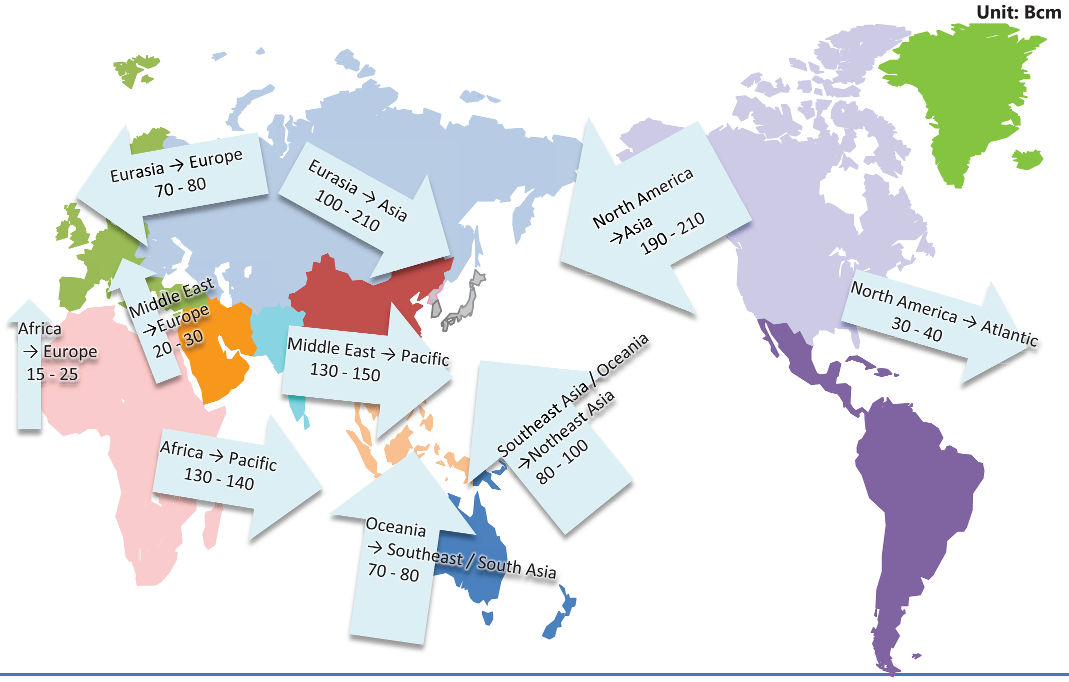
Major trade flows of natural gas (2025)



Note: This figure shows the main interregional trade and does not include the total trade volume.

Reference Scenario

Major trade flows of natural gas (2050)

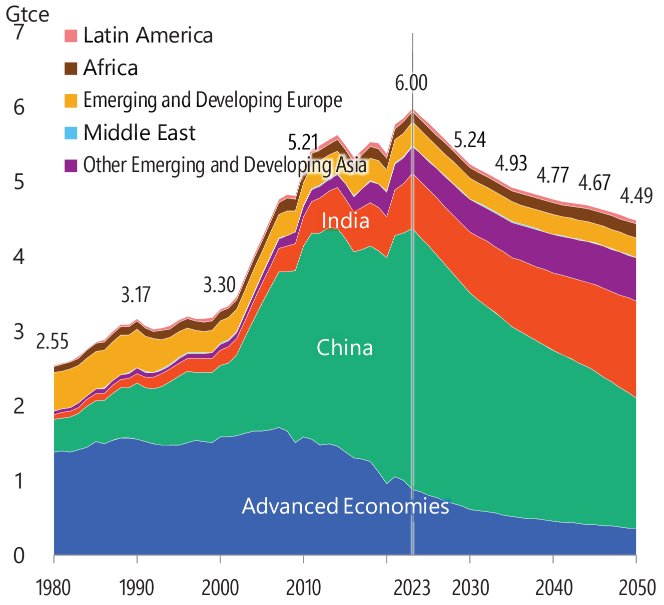


Note: This figure shows the main interregional trade and does not include the total trade volume.

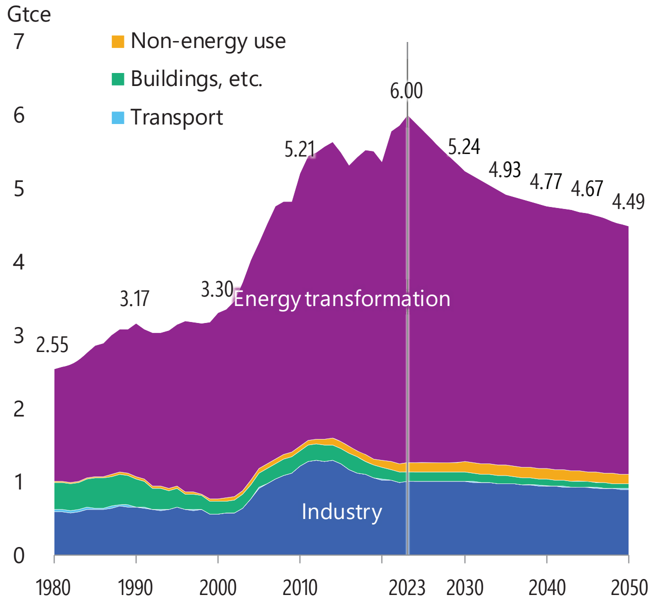
Reference Scenario

Coal consumption

By region



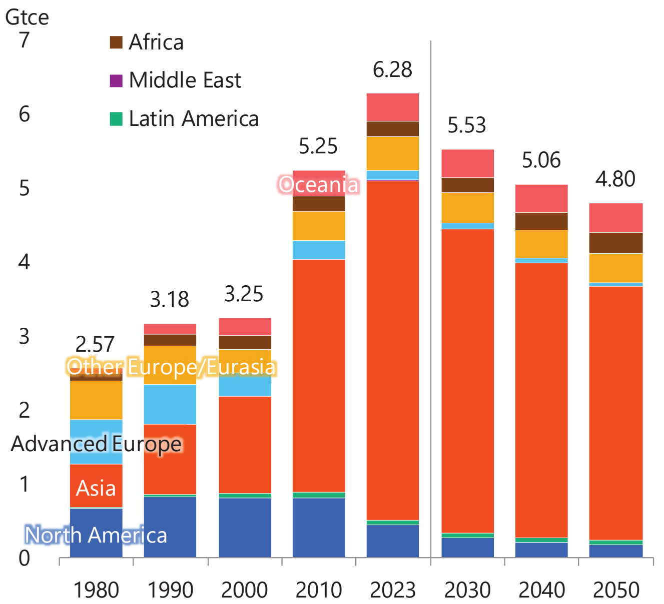
By sector



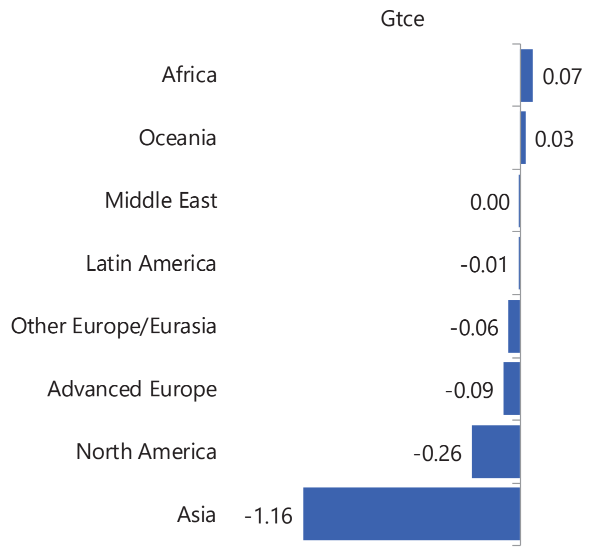
Reference Scenario

Coal production

By region

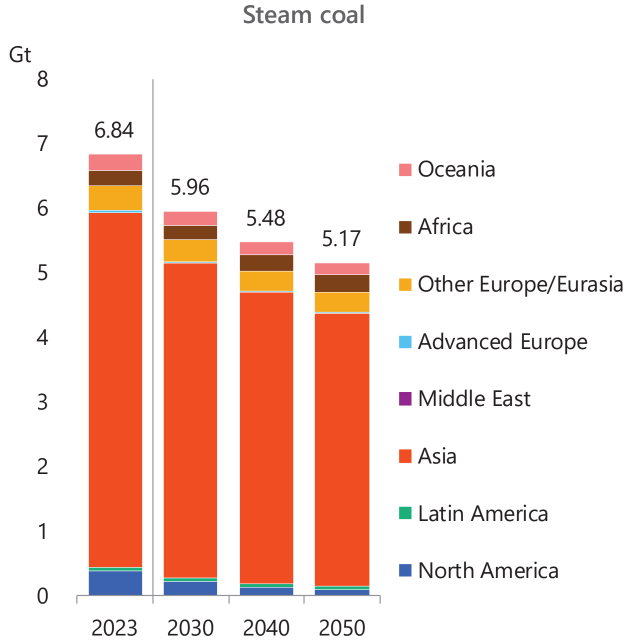


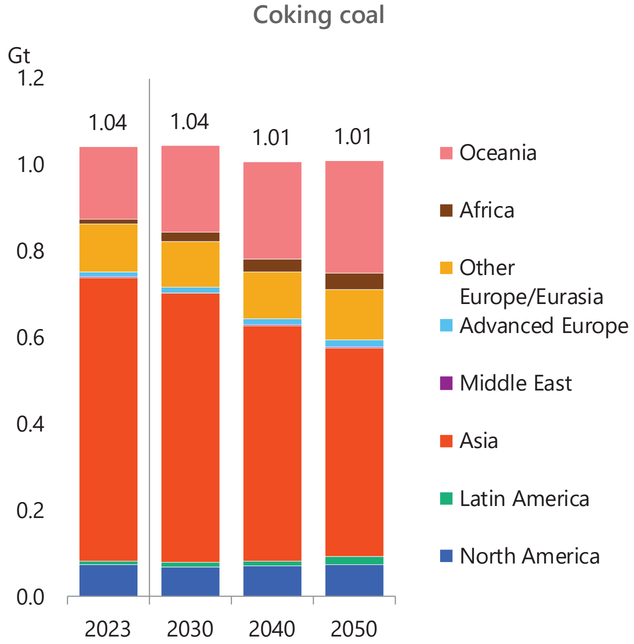
Changes (2023-2050)



Reference Scenario

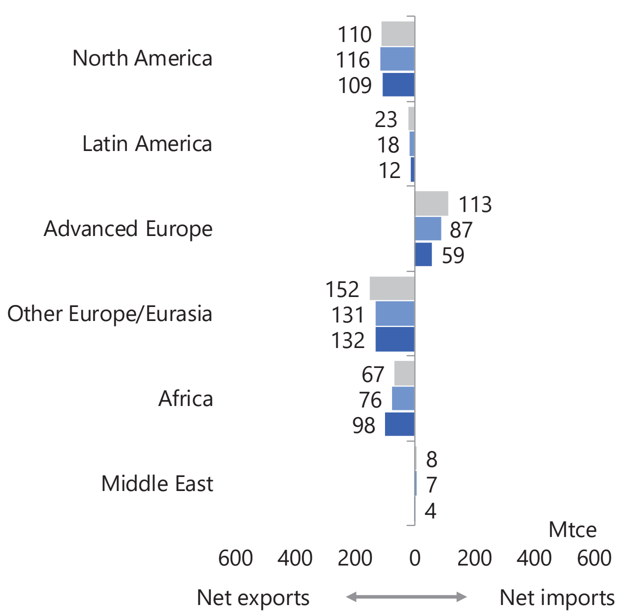
Coal production (steam and coking coal)

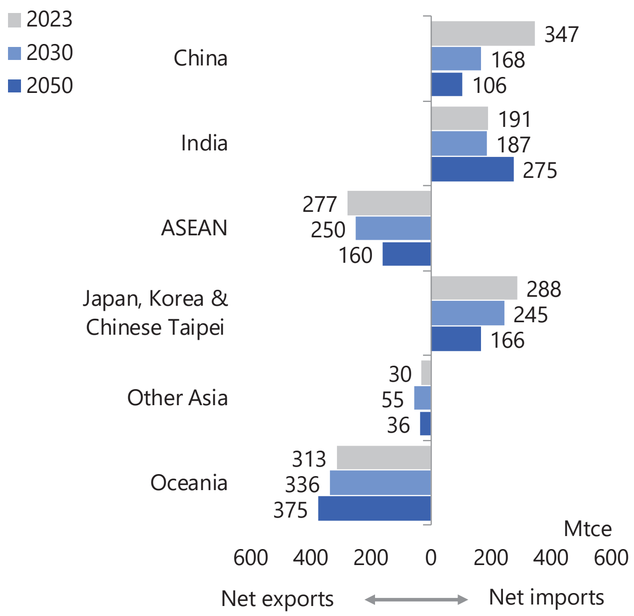




Reference Scenario

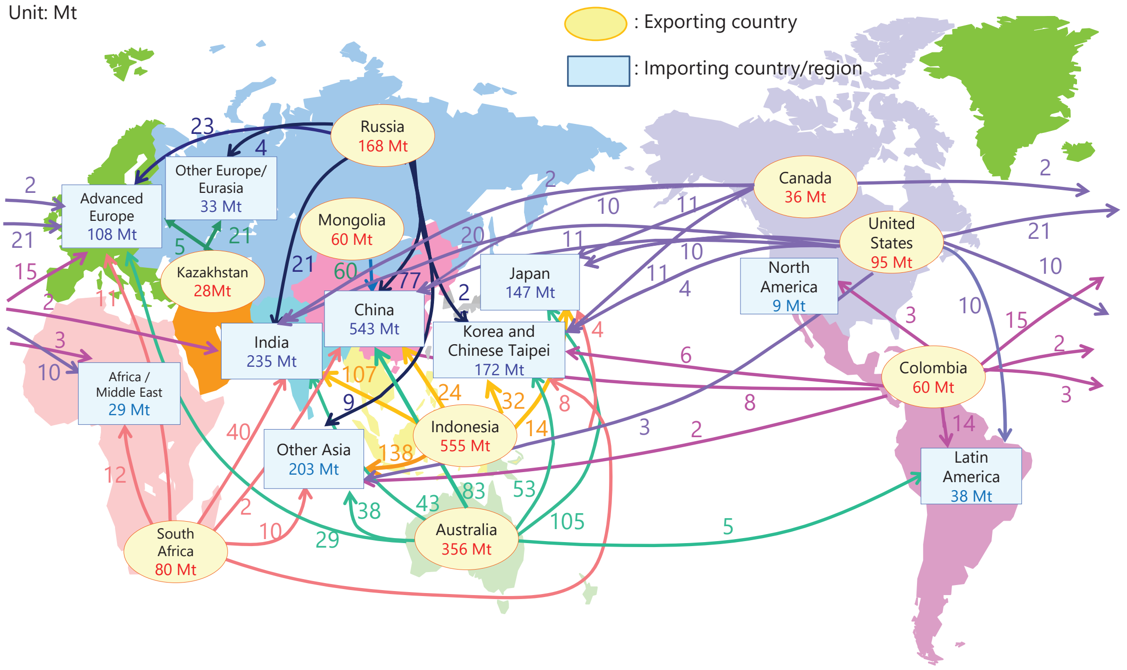
Net exports and imports of coal





Major trade flows of steam and coking coal (2025)

Unit: Mt

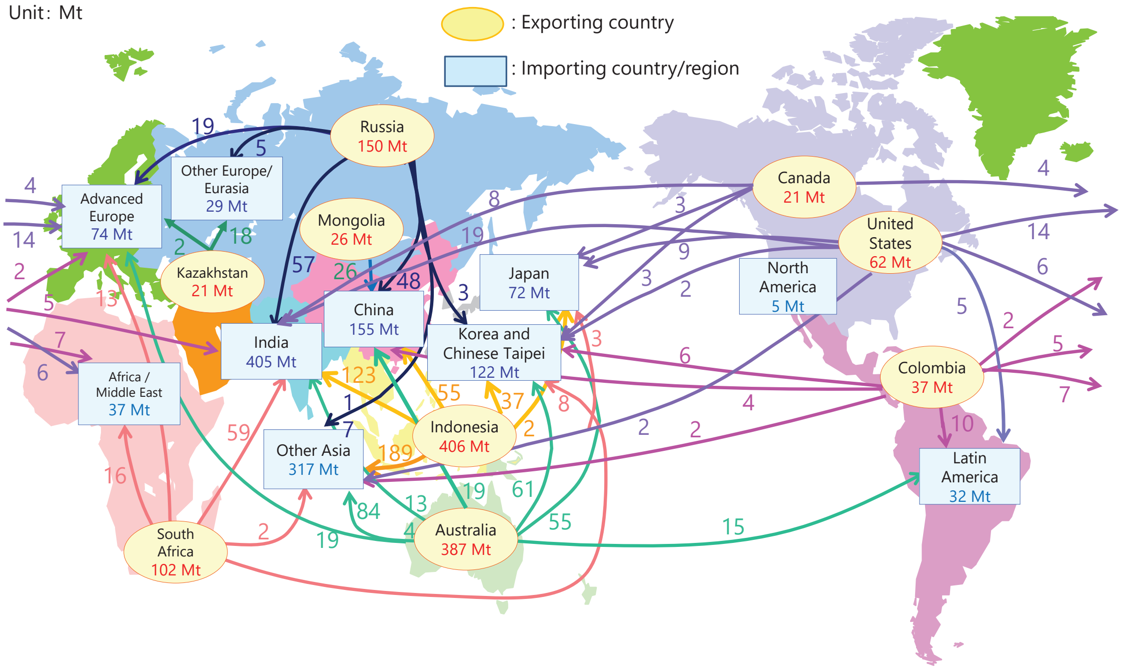


Notes: Total value of steam and coking coal. 2 Mt or more are shown. South Africa includes Mozambique. Source: Estimated from IEA “Coal Information 2025”, “TEX Report”, etc.

Reference Scenario

Major trade flows of steam and coking coal (2050)

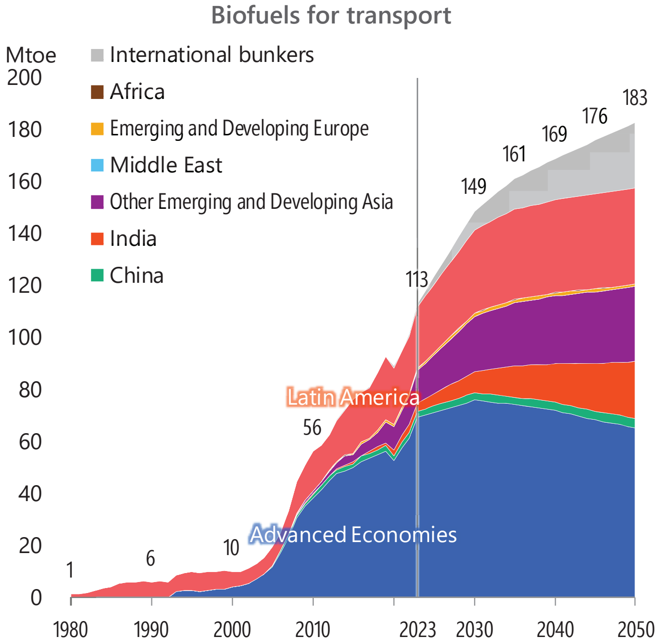
Unit: Mt

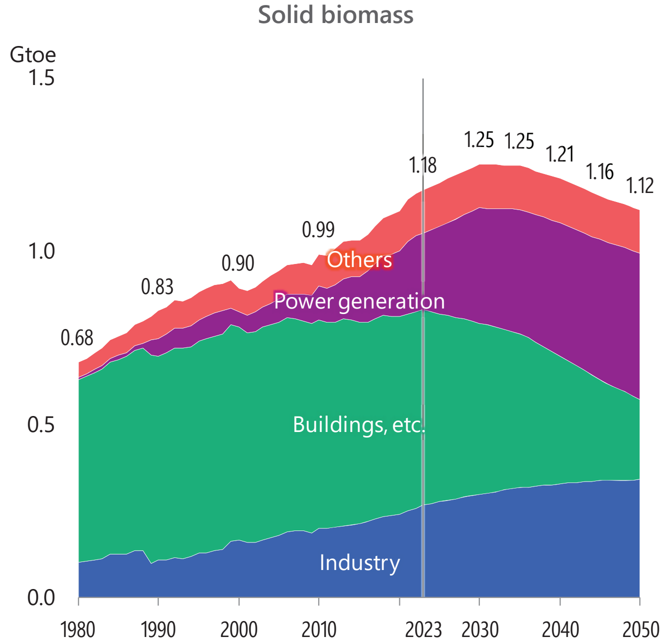


Notes: Total value of steam and coking coal. 2 Mt or more are shown. South Africa includes Mozambique.

Reference Scenario

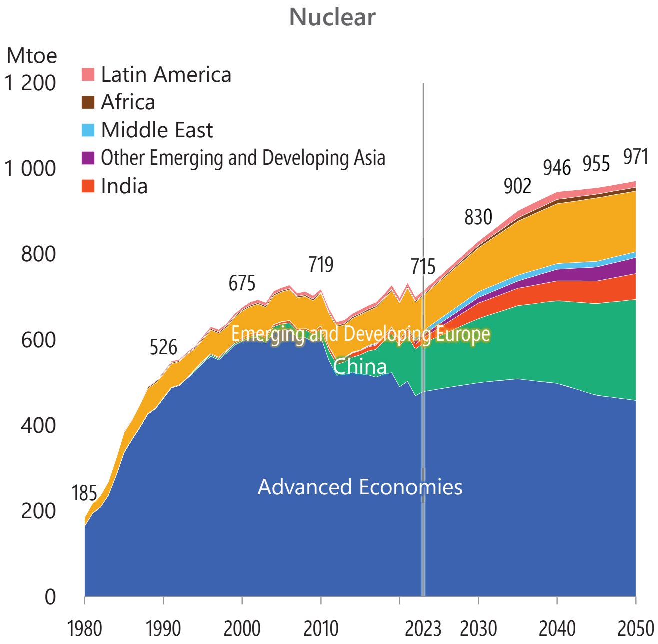
Biomass consumption

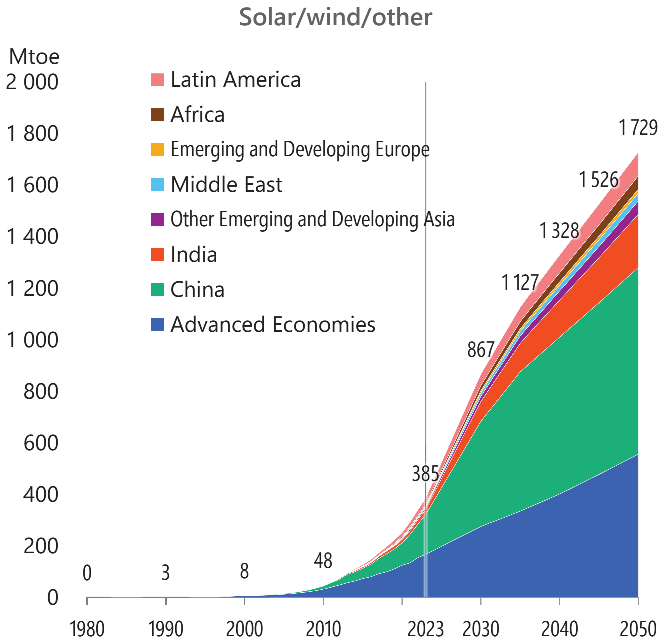




Reference Scenario

Consumption of nuclear and solar/wind/other

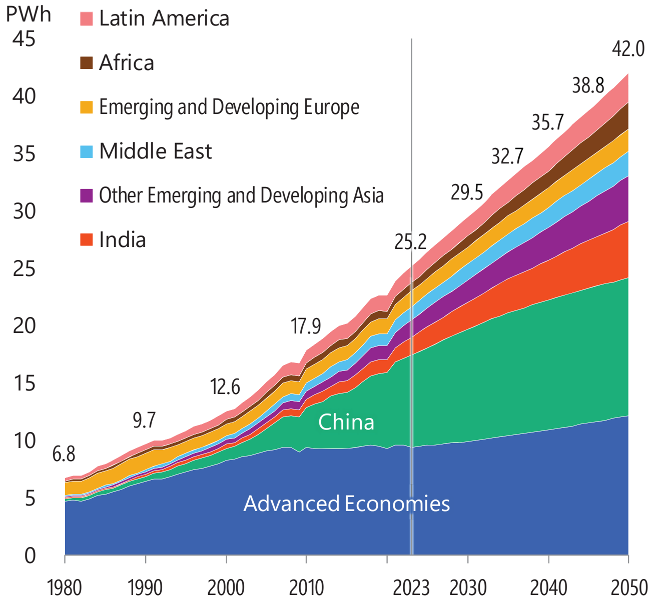




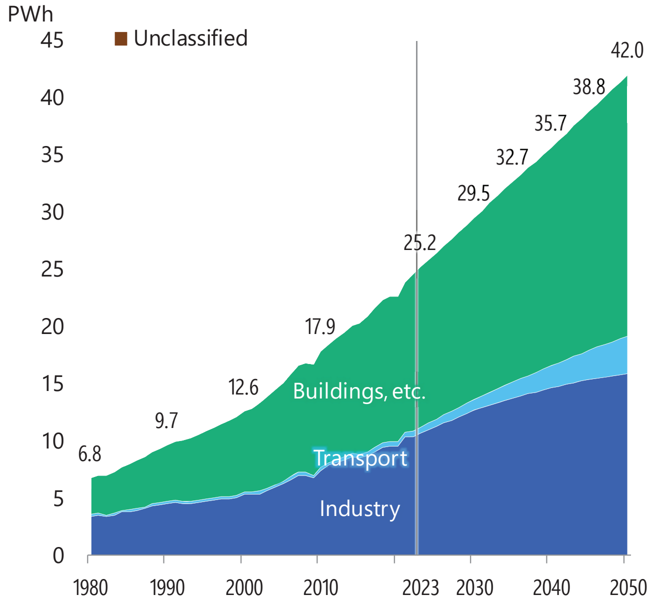
Reference Scenario

Final consumption of electricity

By region



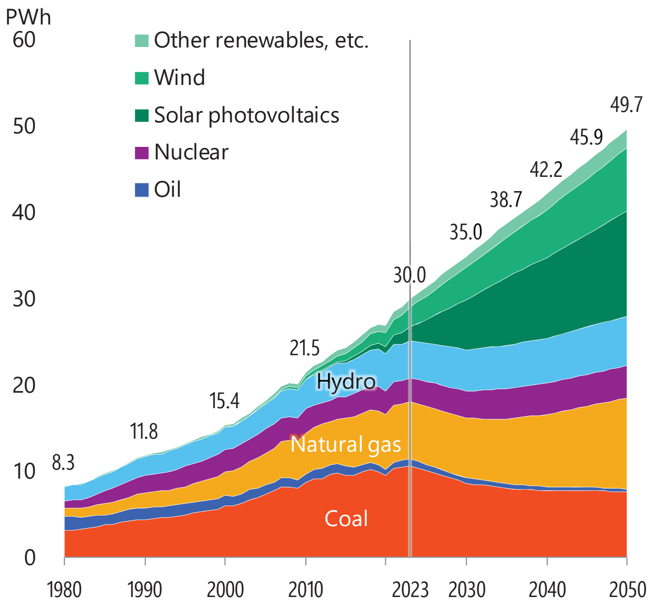
By sector



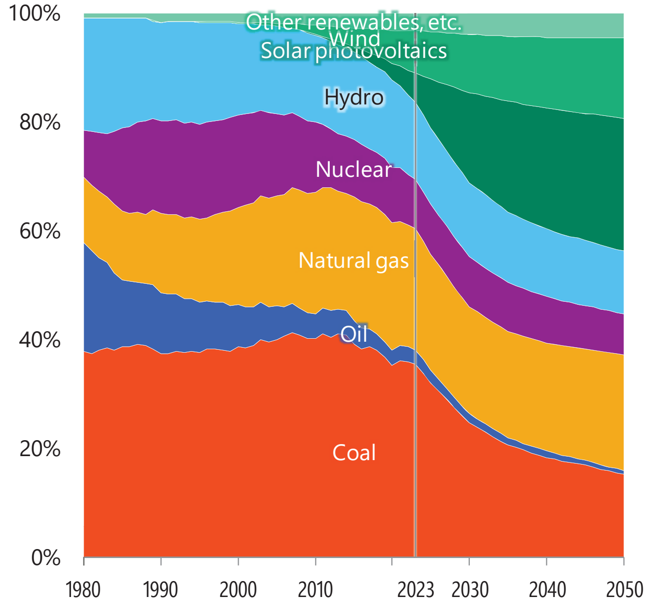
Reference Scenario

Power generation mix

Electricity generated



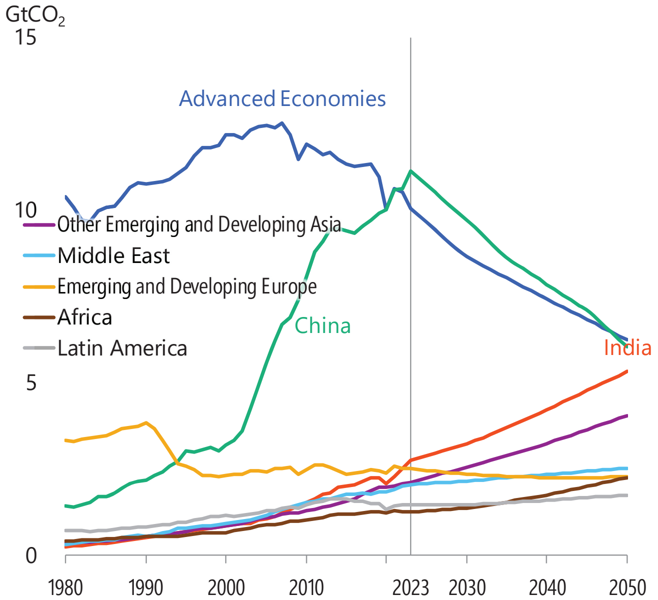
Shares



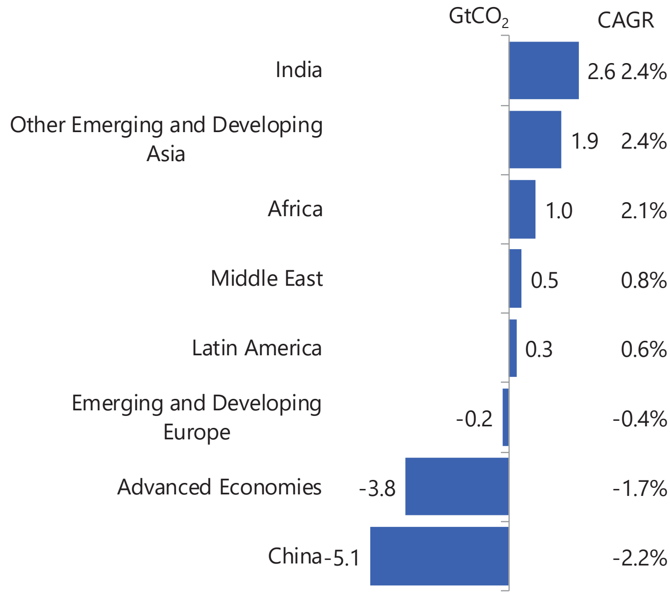
Reference Scenario

Energy-related CO_2 emissions

Emissions



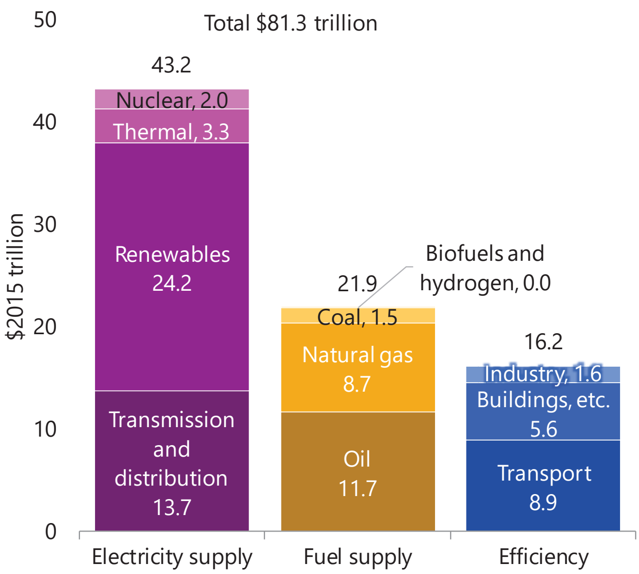
Changes (2023-2050)



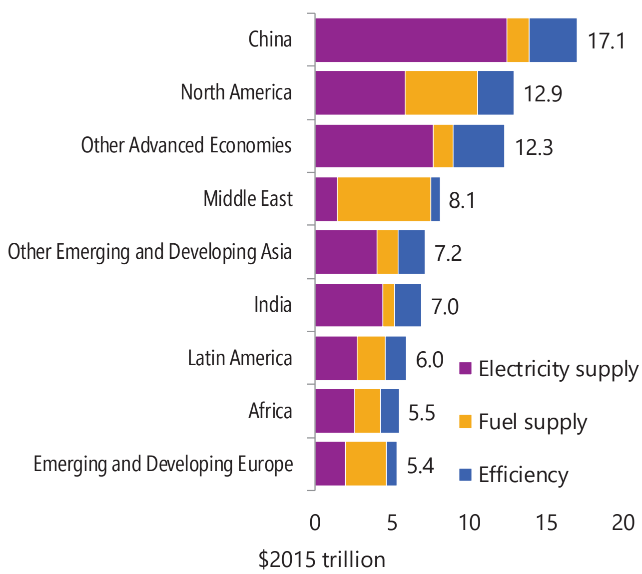
Reference Scenario

Energy-related investments (2025–2050)

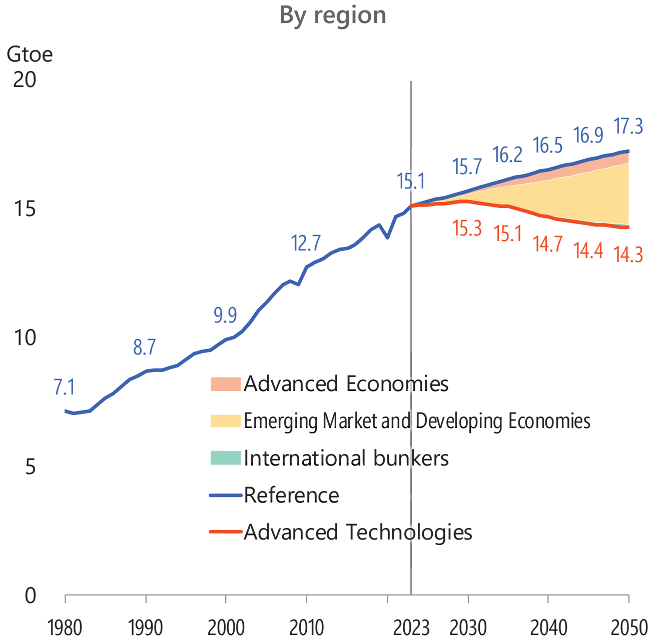
By region

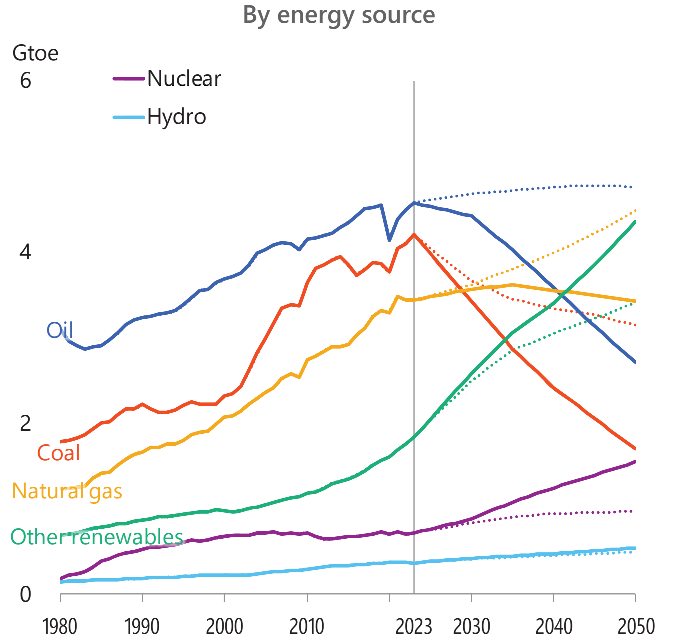


By sector



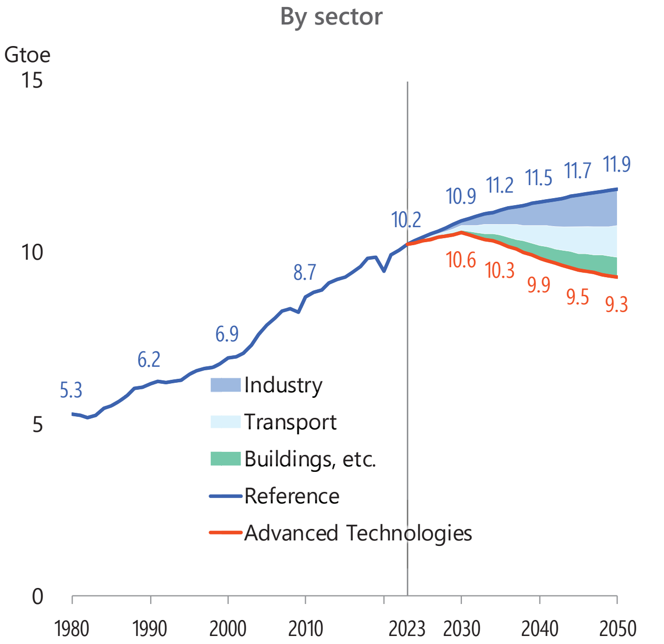
Primary energy consumption

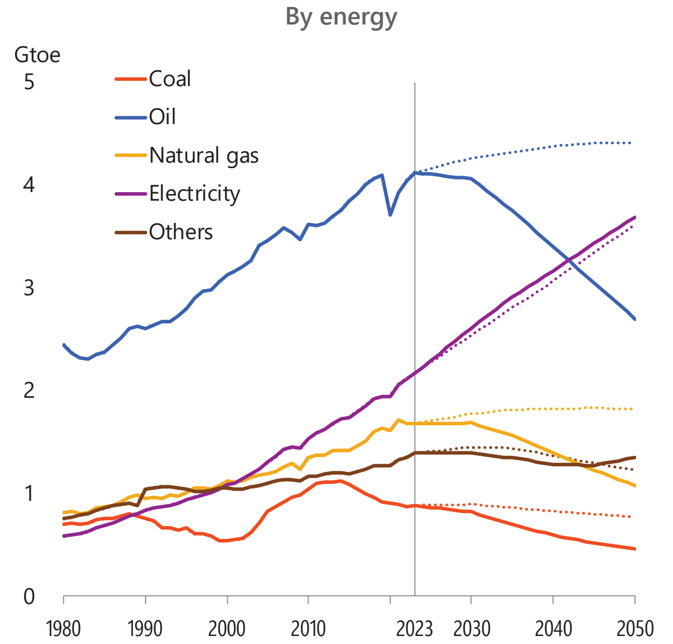




Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

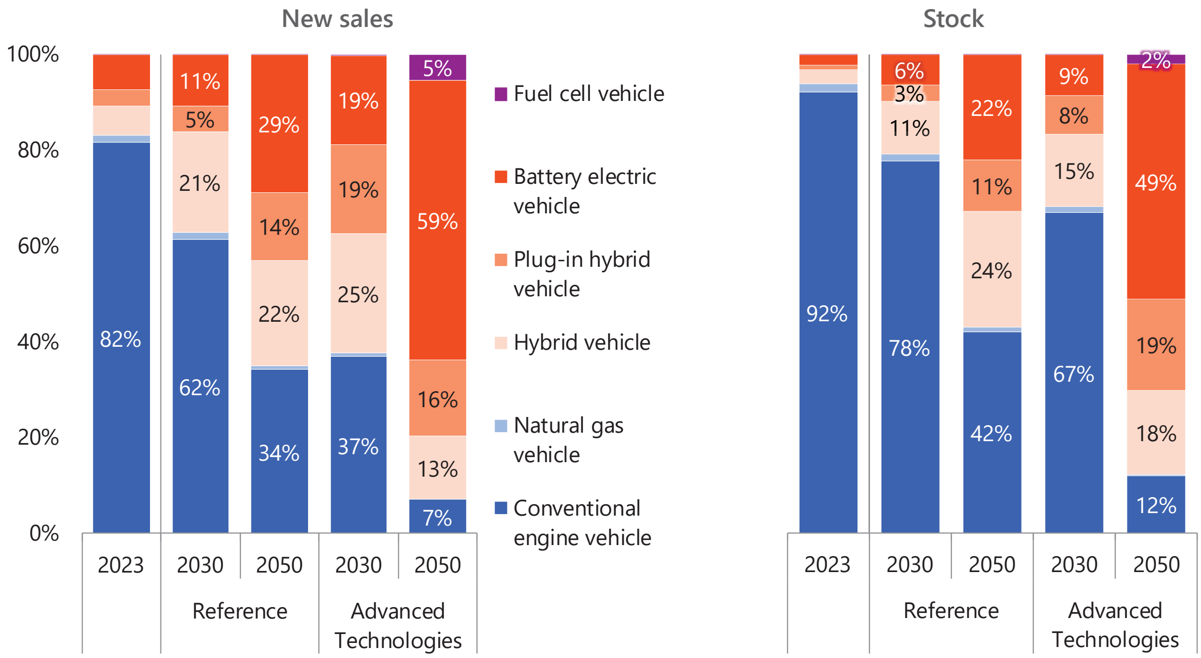
Final energy consumption





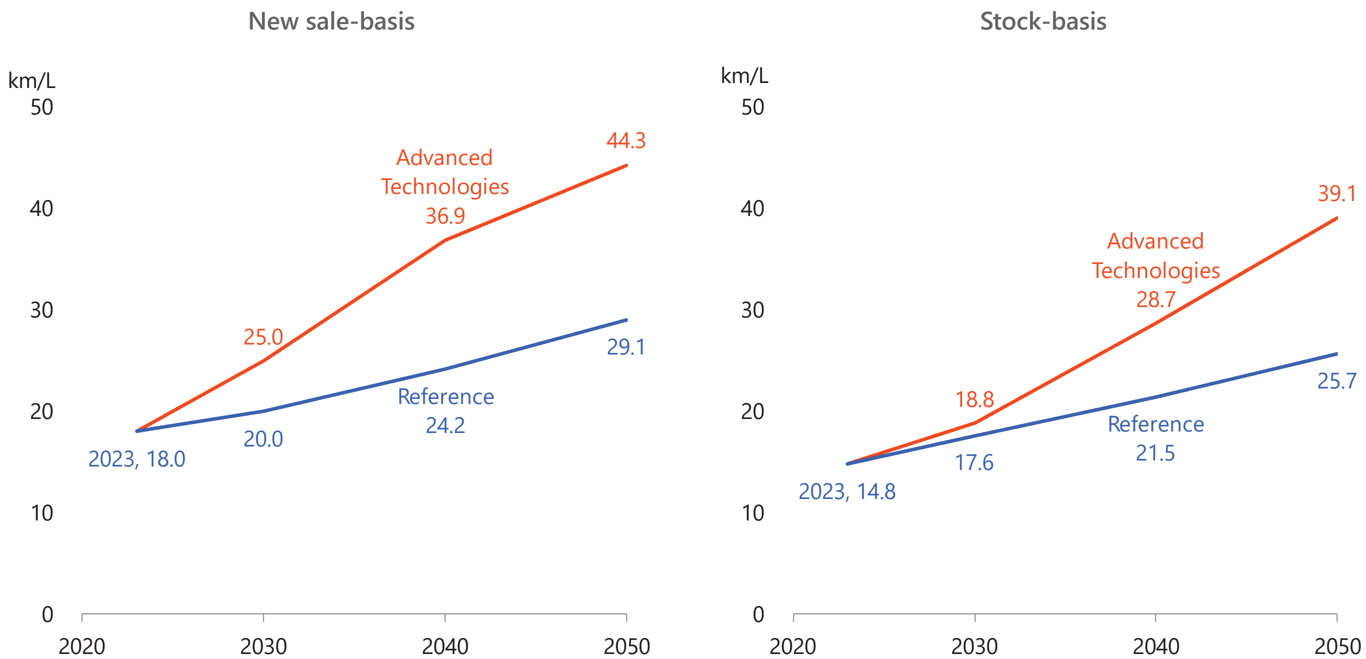
Advanced Technologies Scenario

Share of passenger vehicle



Advanced Technologies Scenario

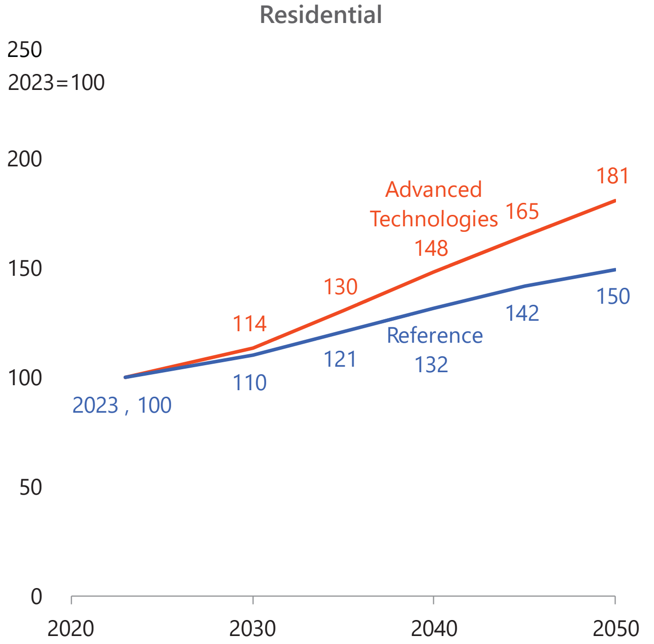
Fuel efficiency of passenger vehicle

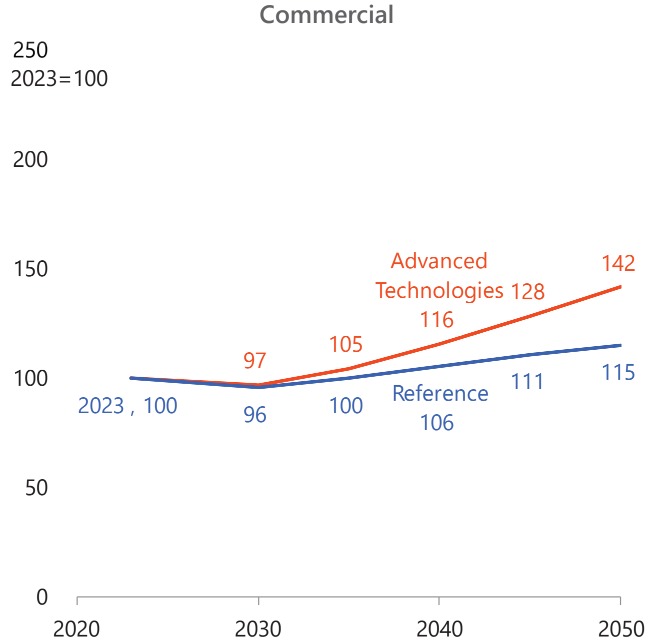


Note: Litres of gasoline equivalent

Advanced Technologies Scenario

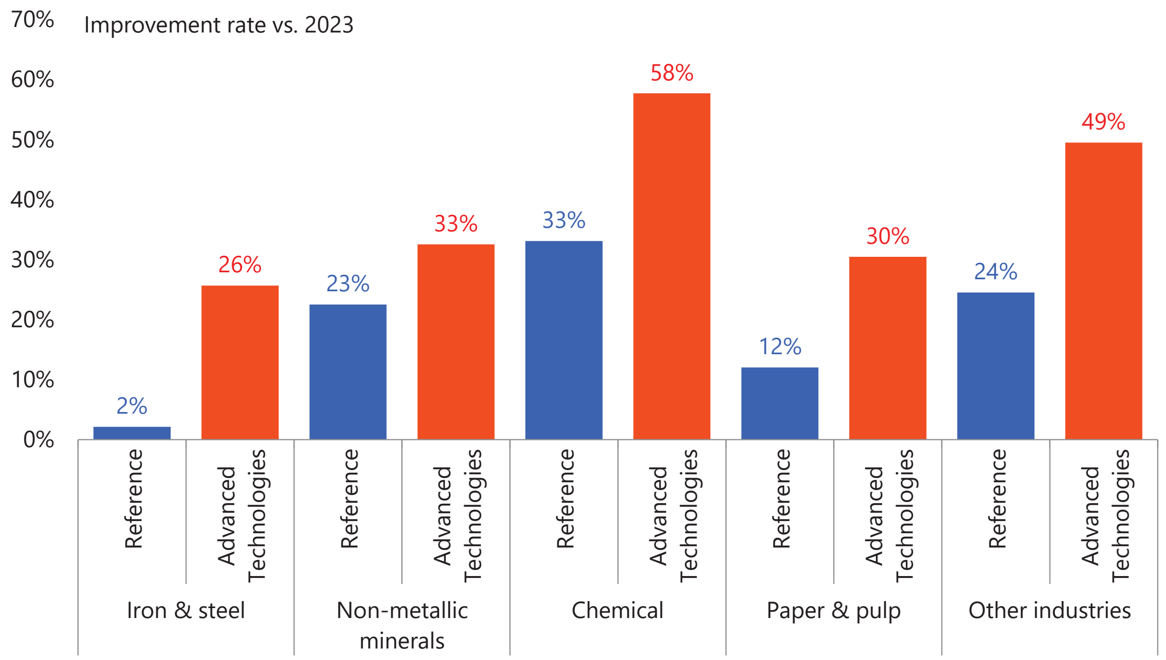
Energy efficiency in buildings sector





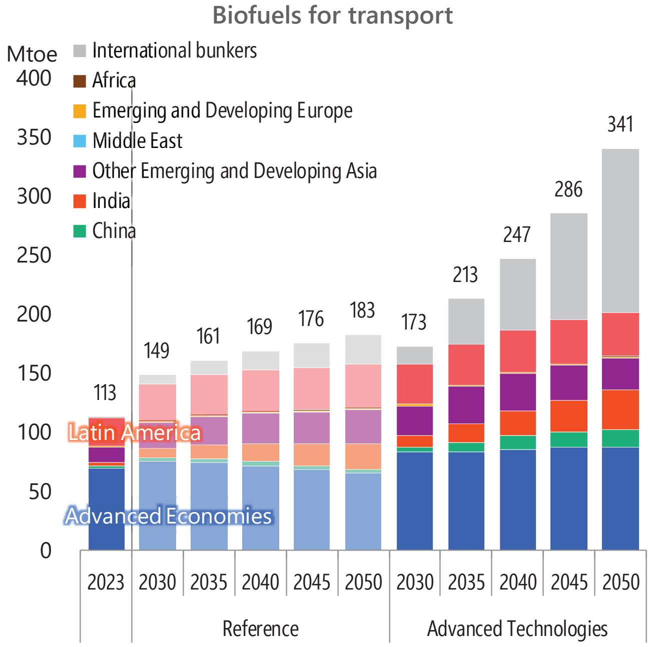
Advanced Technologies Scenario

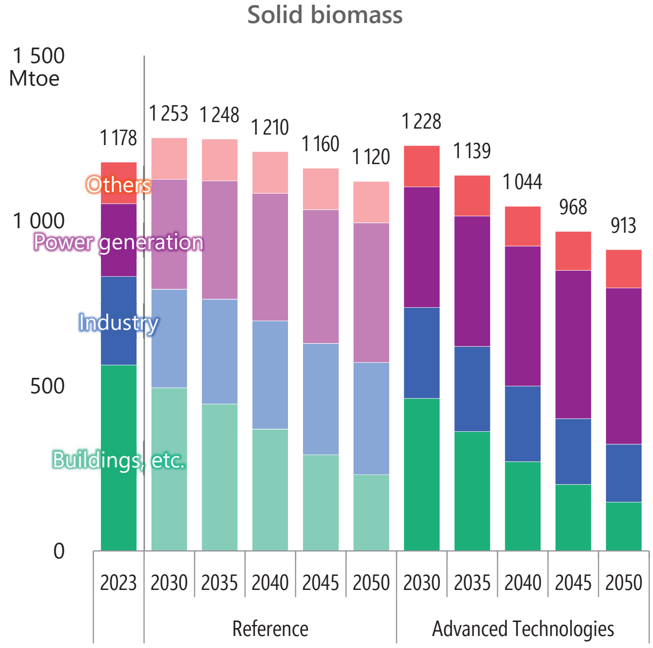
Energy intensity improvement in industry sector



Advanced Technologies Scenario

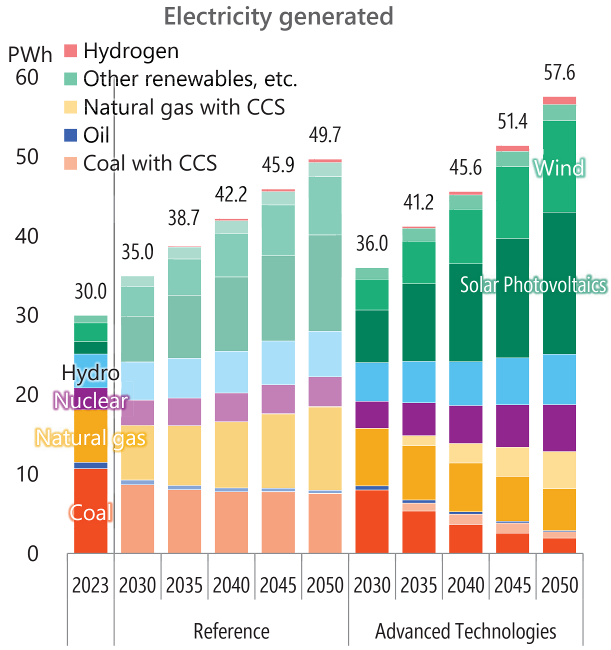
Biomass consumption

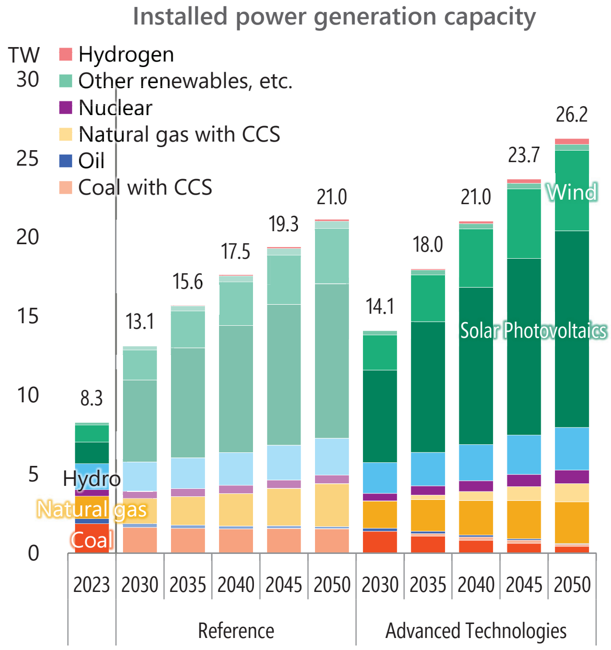




Advanced Technologies Scenario

Power generation mix

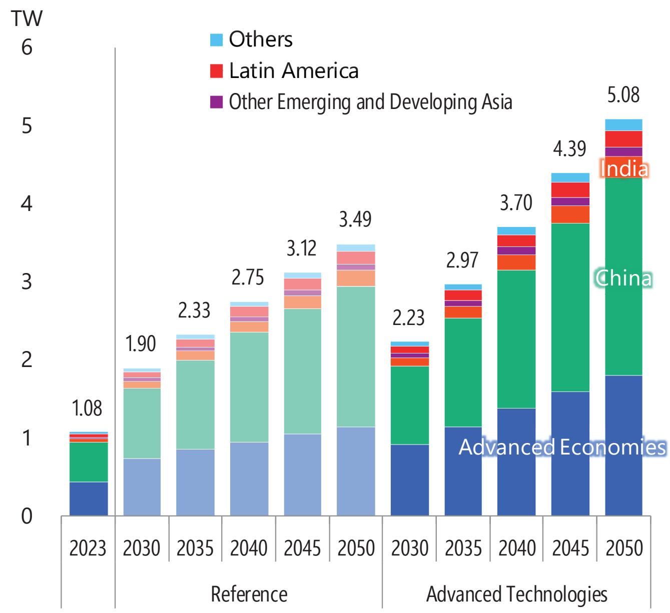




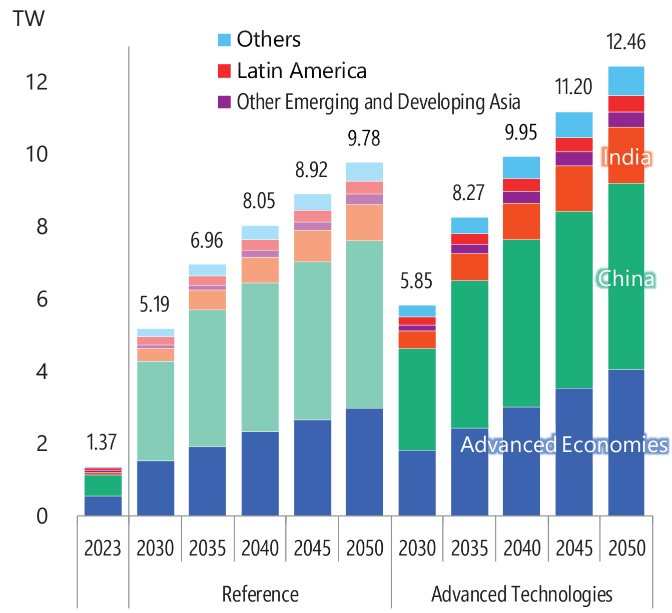
Advanced Technologies Scenario

Installed wind and solar PV power generation capacity

Wind



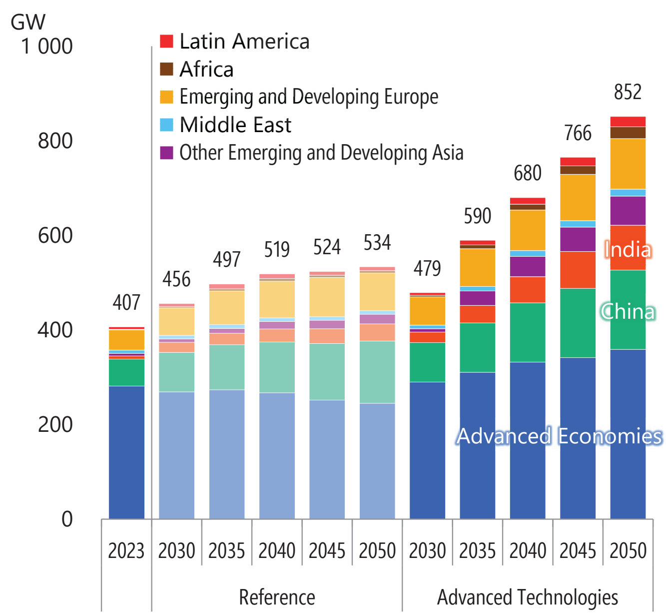
Solar photovoltaics



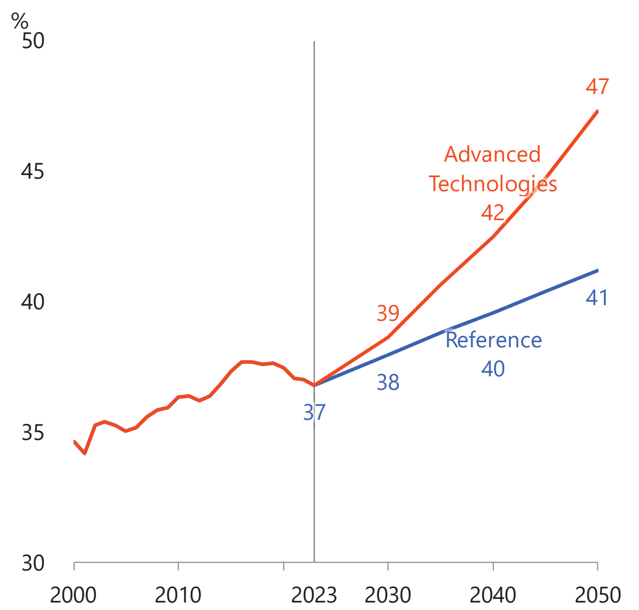
Advanced Technologies Scenario

Installed nuclear power generation capacity and thermal power generation efficiency

Nuclear



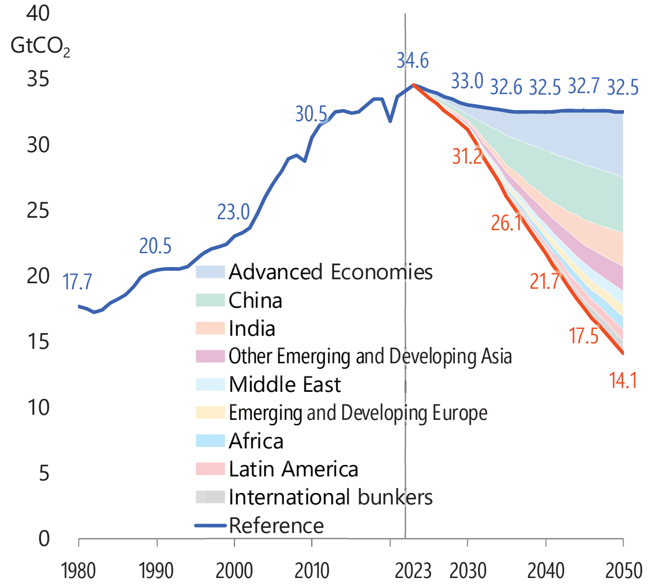
Thermal power generation efficiency (generation end)



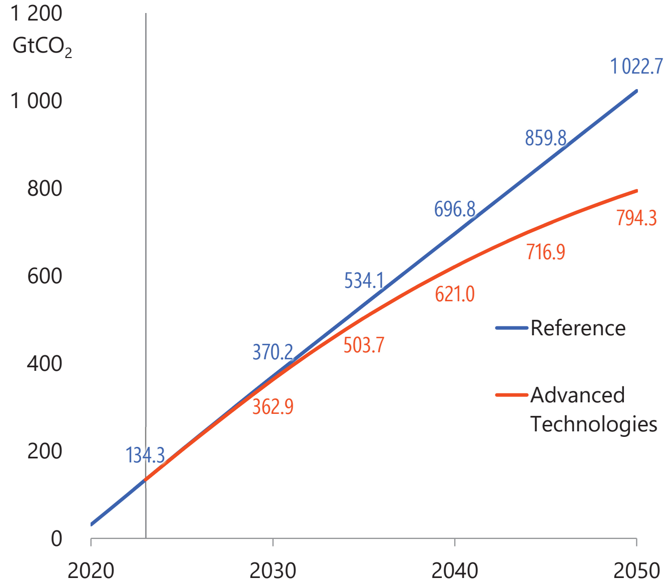
Advanced Technologies Scenario

Energy-related CO_2 emissions

By region



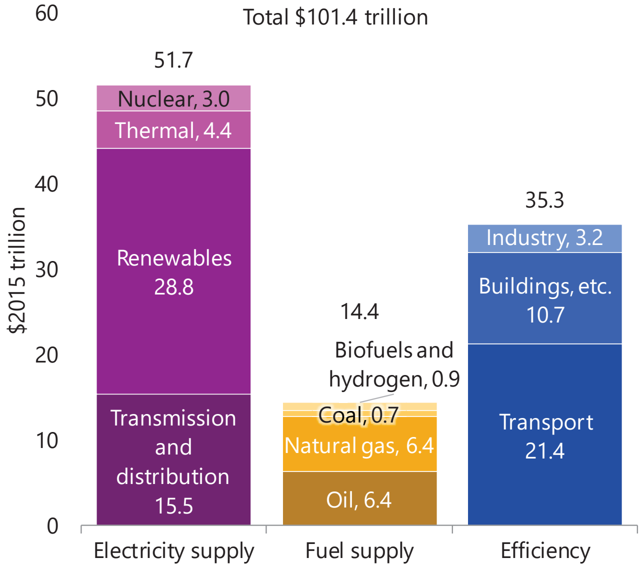
Cumulative net CO_2 emissions (2020-)



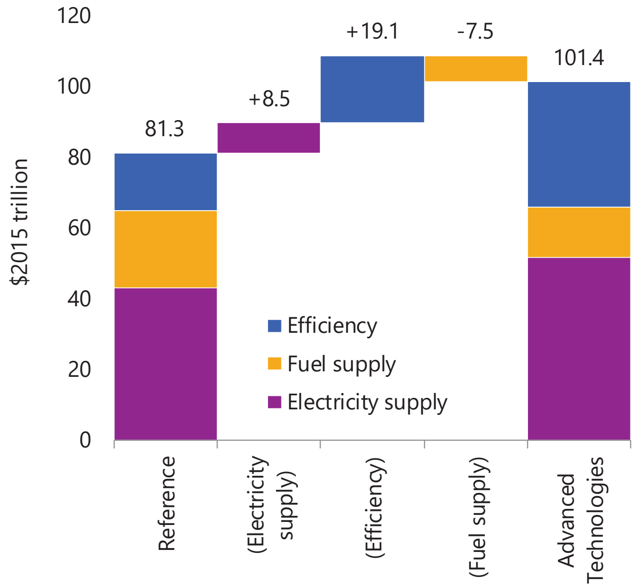
Advanced Technologies Scenario

Energy-related investments (2025–2050)

By sector

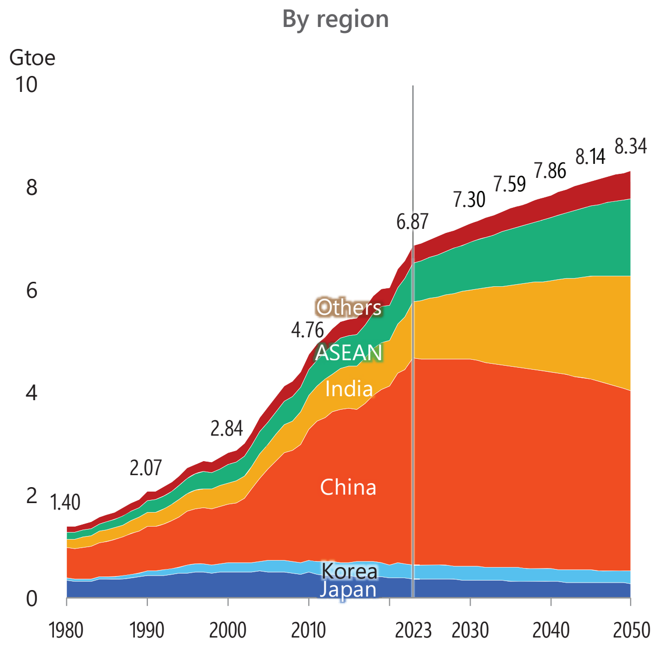


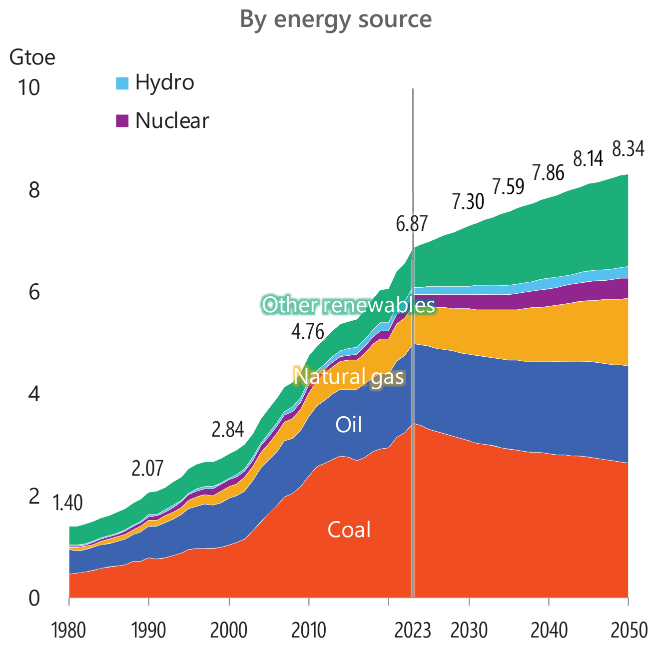
Changes from Reference Scenario



Asia | Reference Scenario

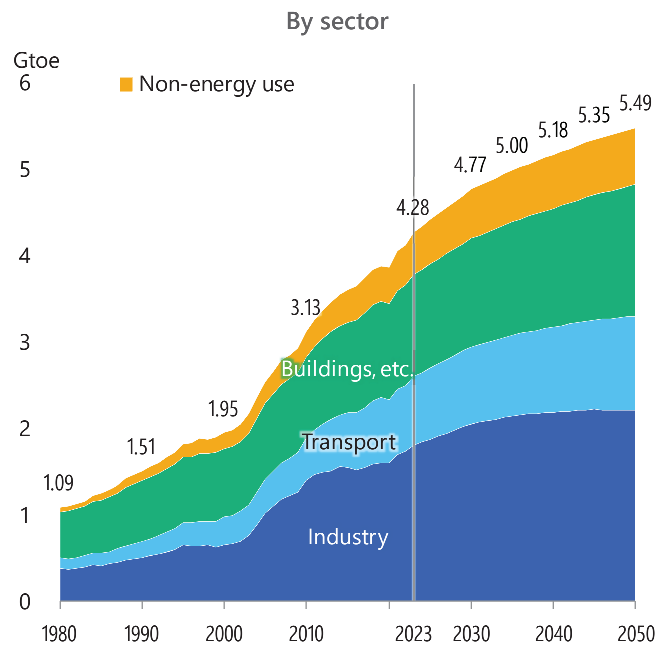
Primary energy consumption

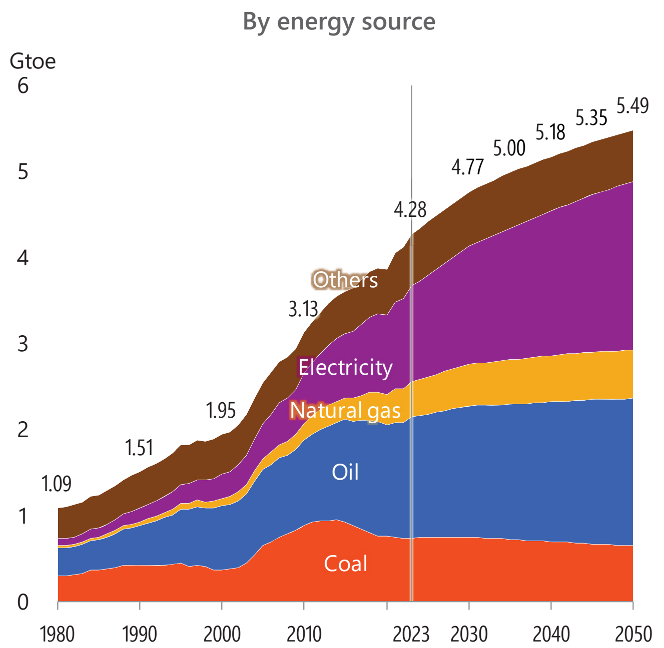




Asia | Reference Scenario

Final energy consumption

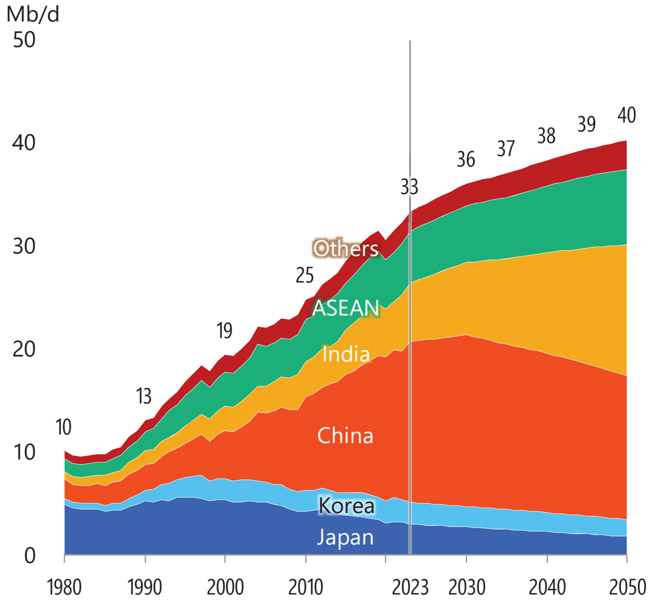




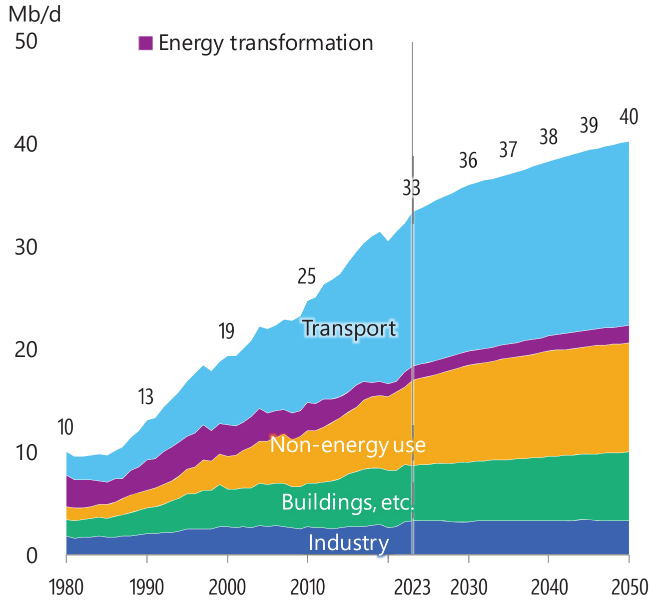
Asia | Reference Scenario

Oil consumption

By region



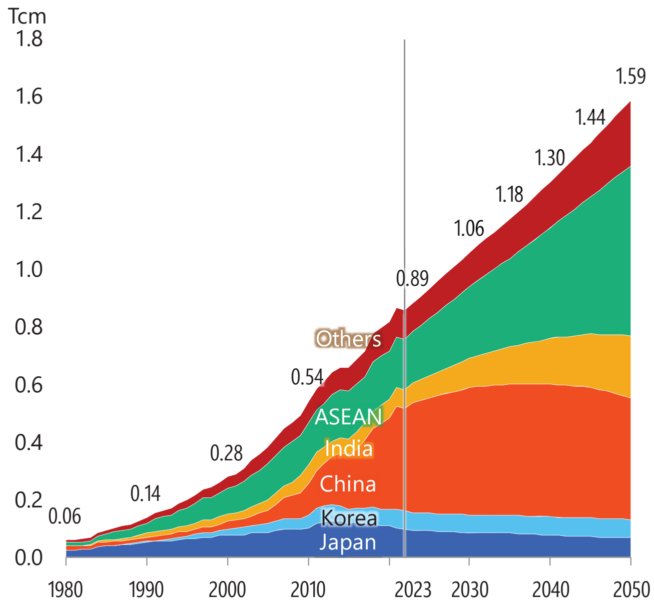
By sector



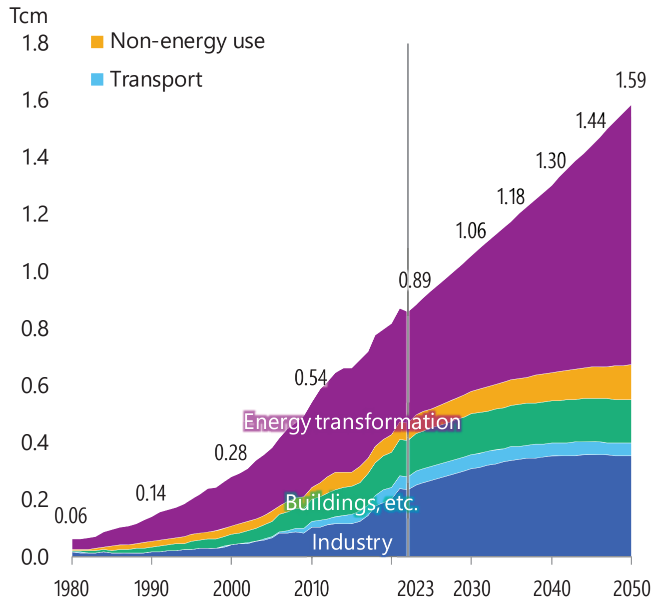
Asia | Reference Scenario

Natural gas consumption

By region

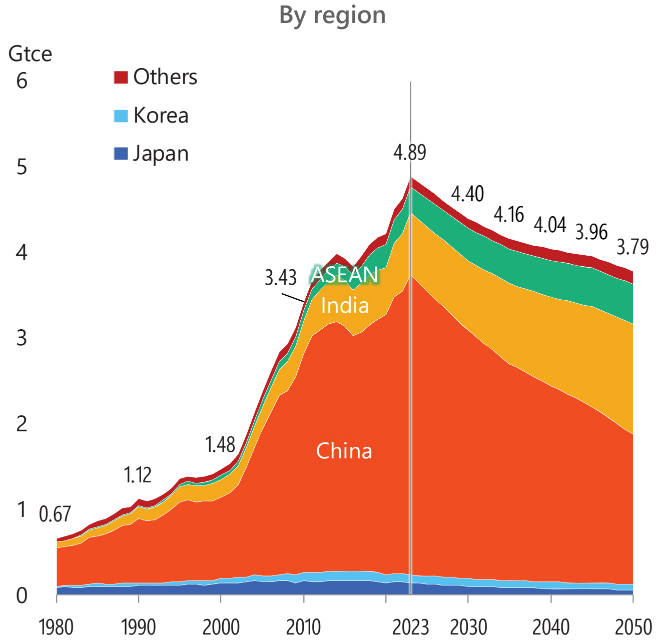


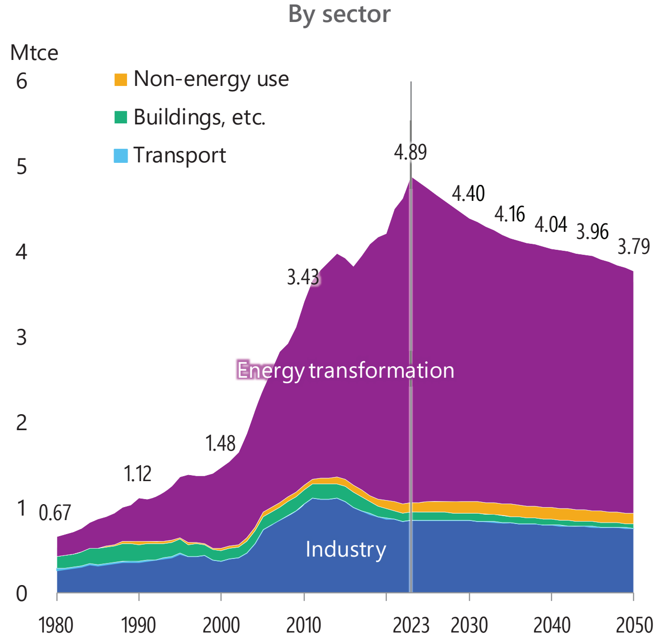
By sector



Asia Reference Scenario

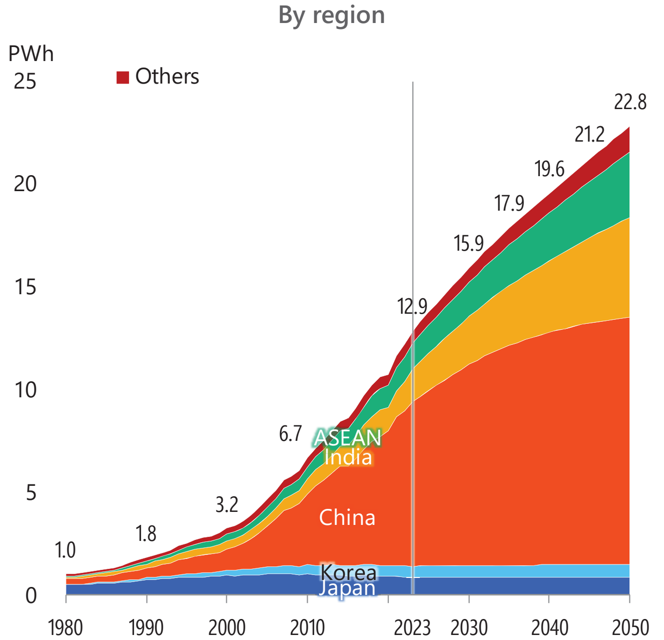
Coal consumption

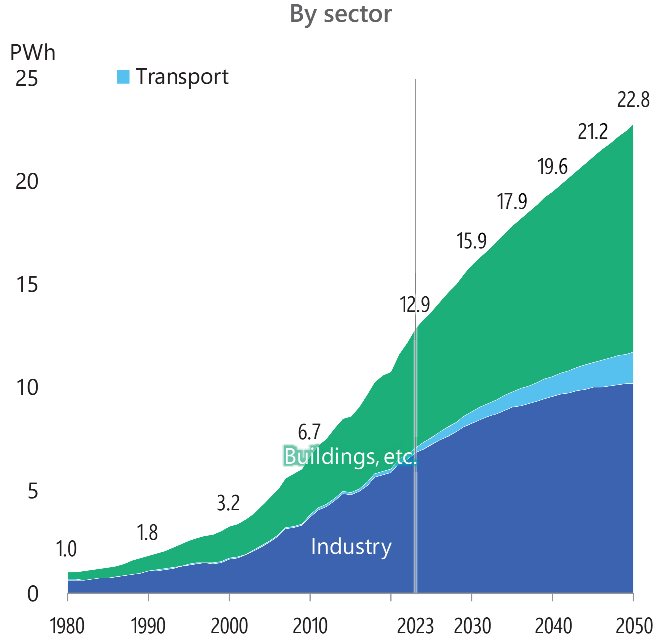




Asia Reference Scenario

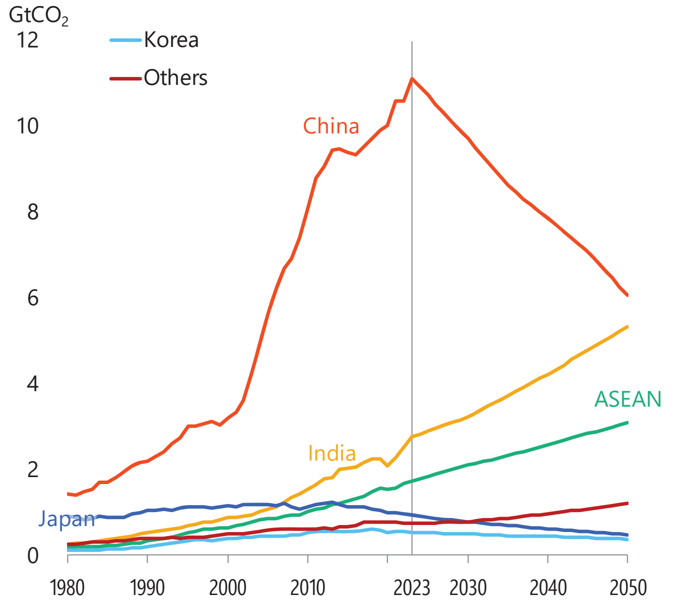
Final consumption of electricity



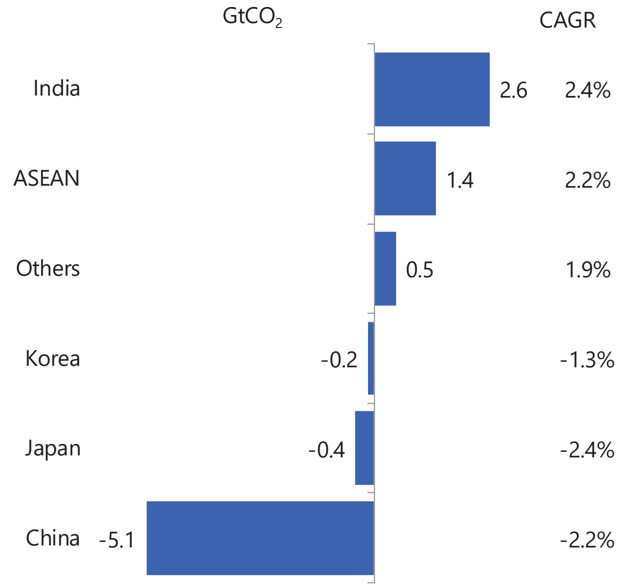


Energy-related CO_2 emissions

Emissions

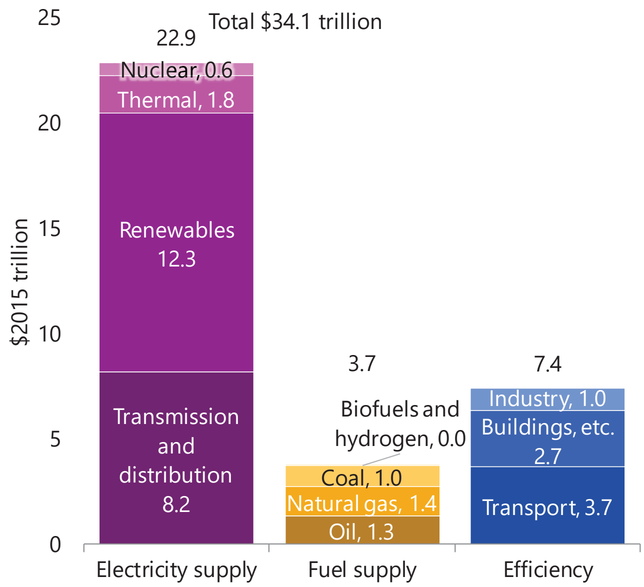


Changes (2023-2050)

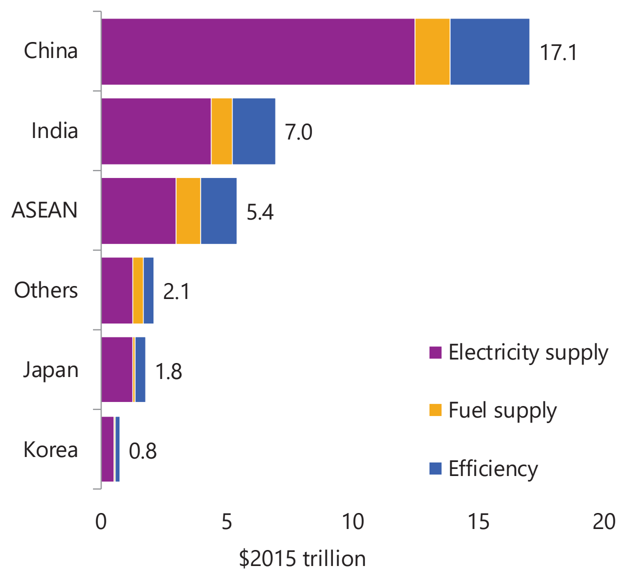


Energy-related investments (2025–2050)

By sector

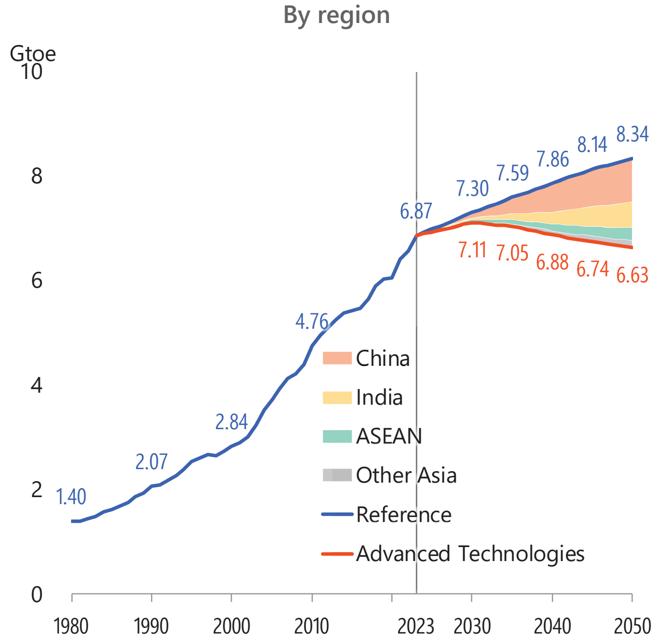


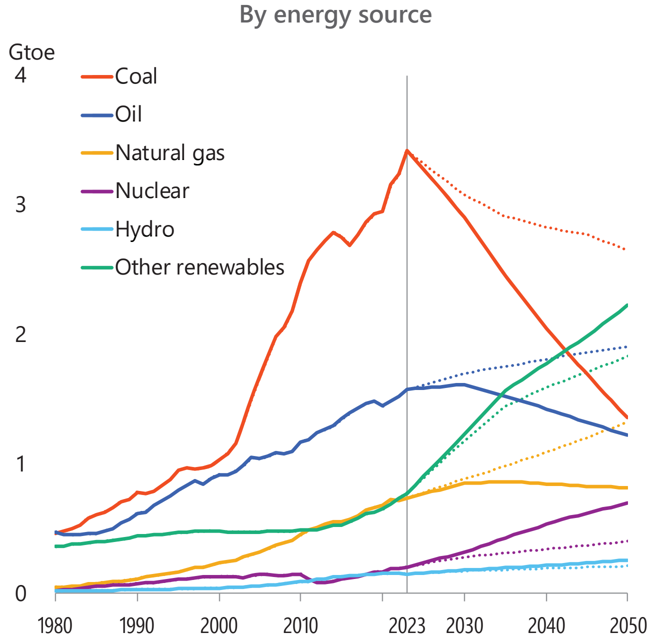
By region



Asia | Advanced Technologies Scenario

Primary energy consumption

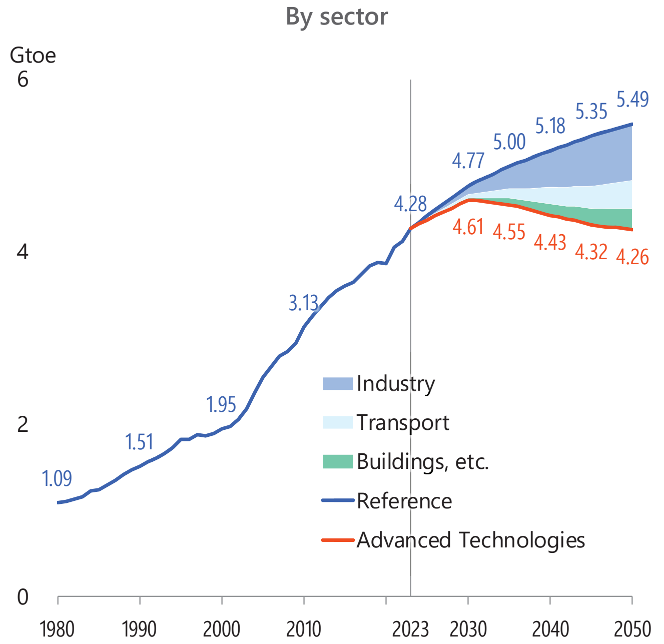


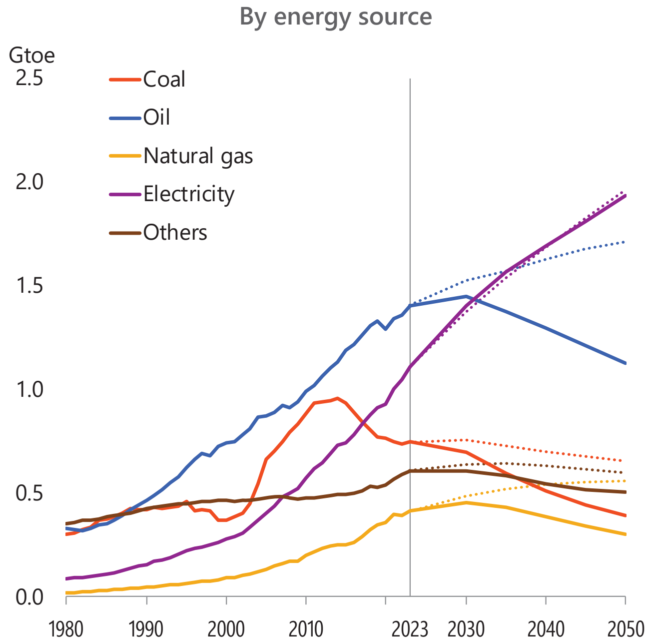


Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

Asia | Advanced Technologies Scenario

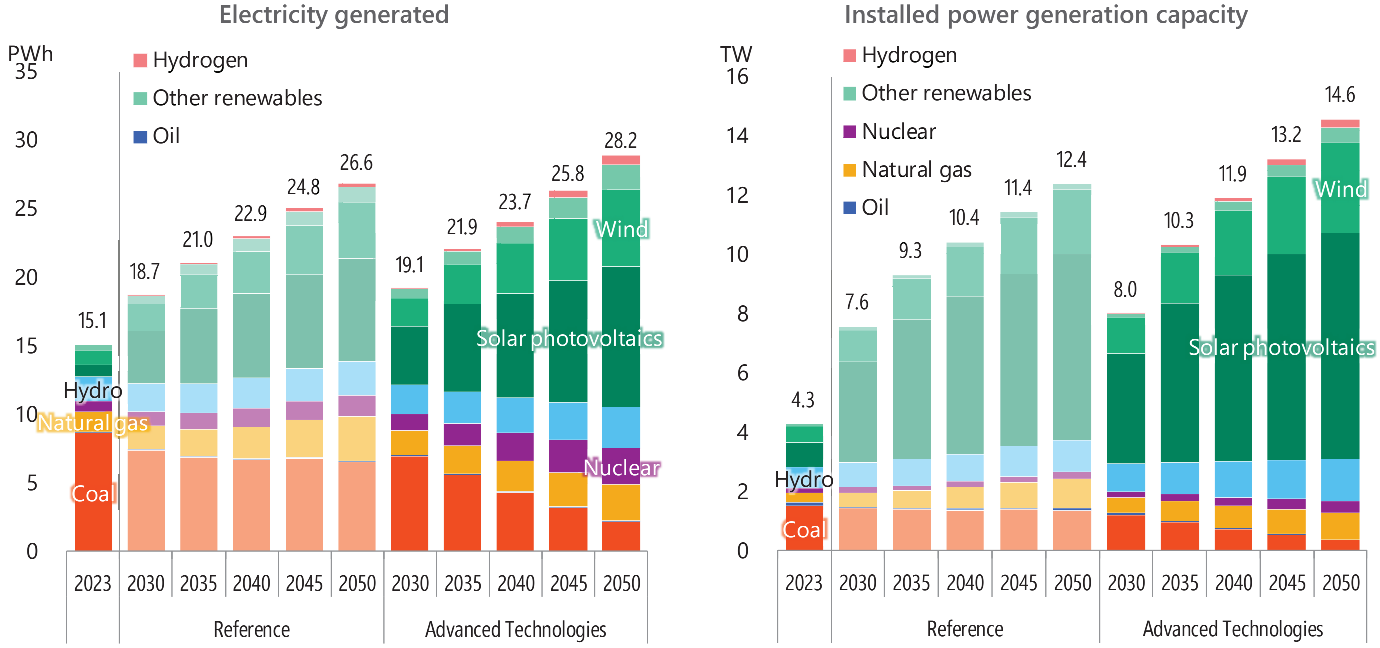
Final energy consumption





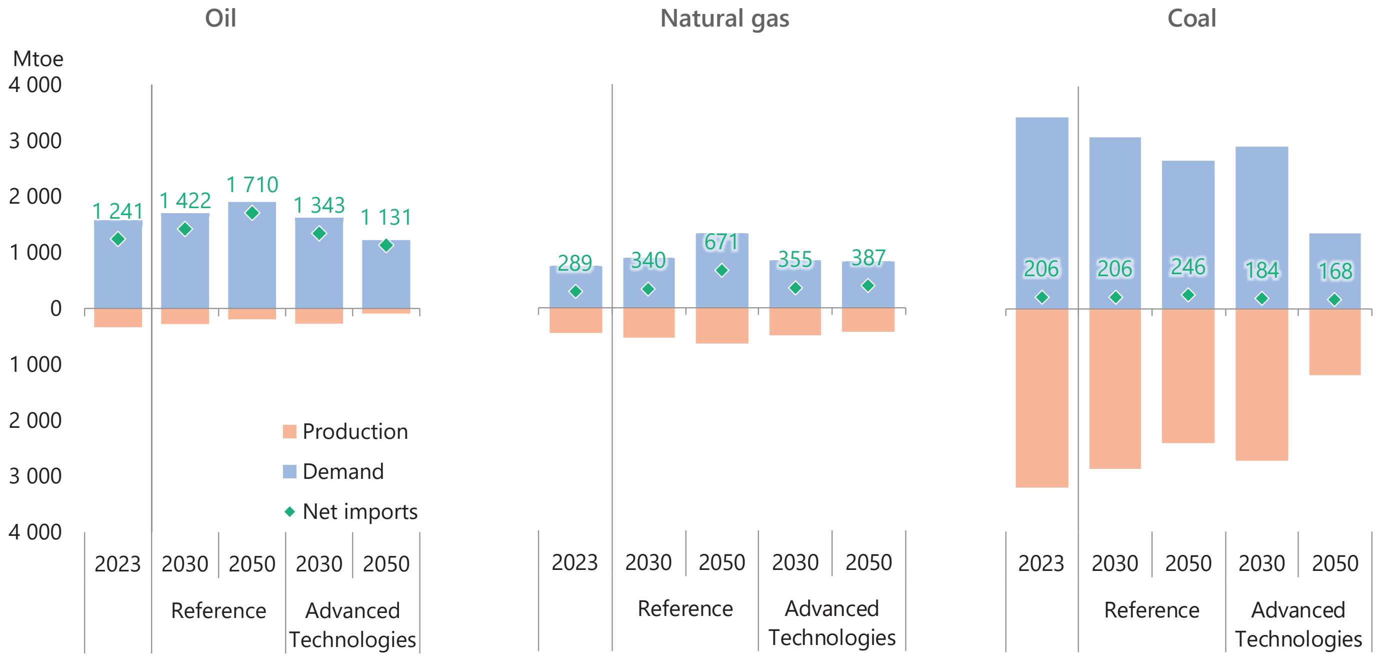
Asia

Power generation mix



Asia

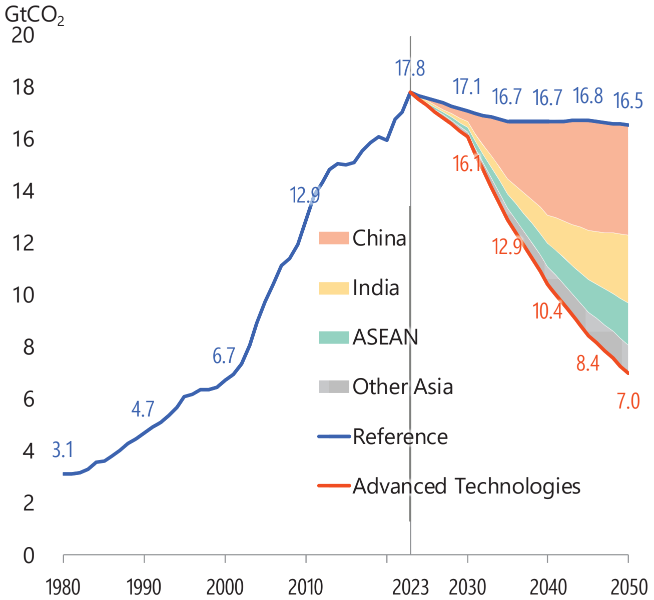
Supply and demand balance of fossil fuels



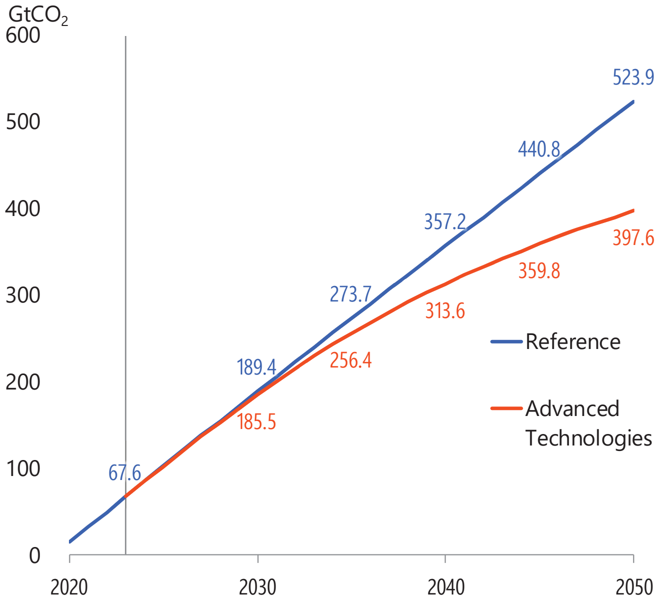
Asia | Advanced Technologies Scenario

Energy-related CO_2 emissions

By region



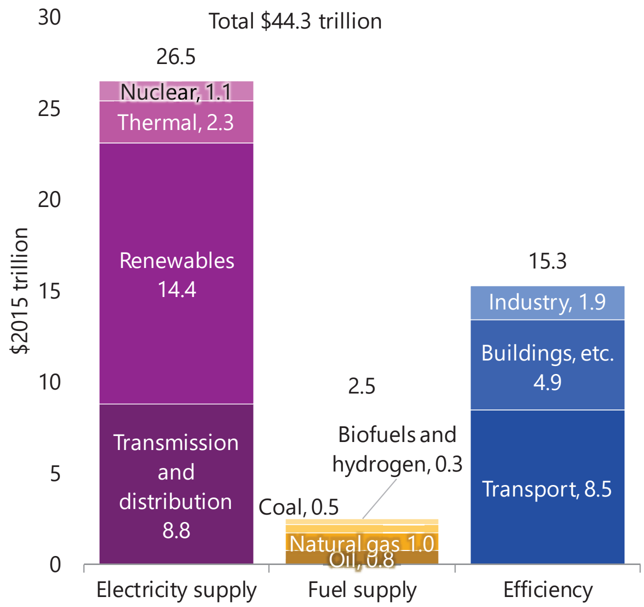
Cumulative net CO_2 emissions (2020-)



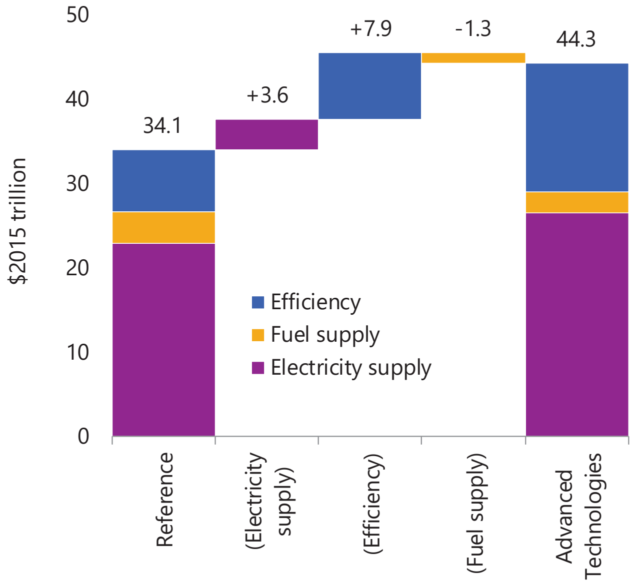
Asia | Advanced Technologies Scenario

Energy-related investments (2025–2050)

By sector

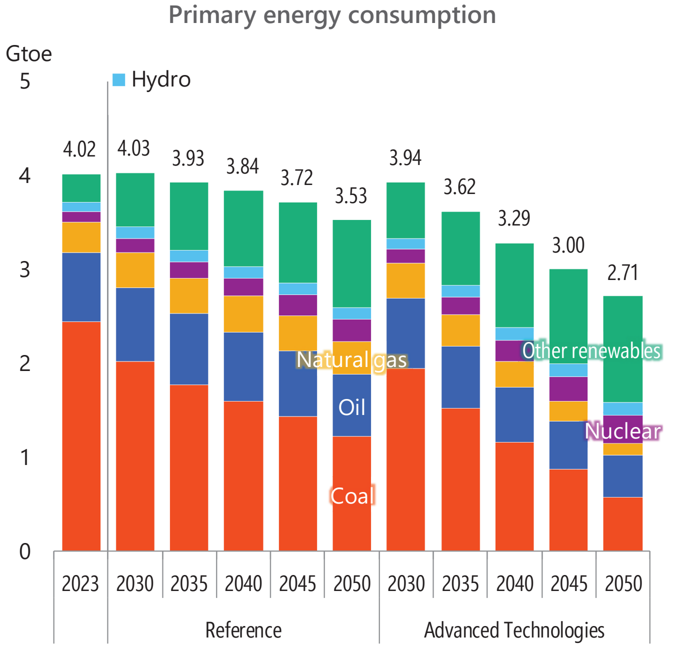


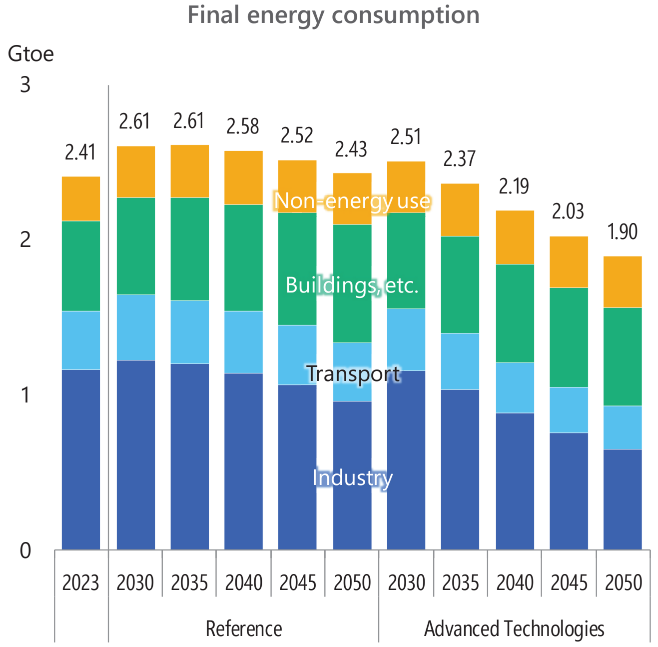
Changes from Reference Scenario



China

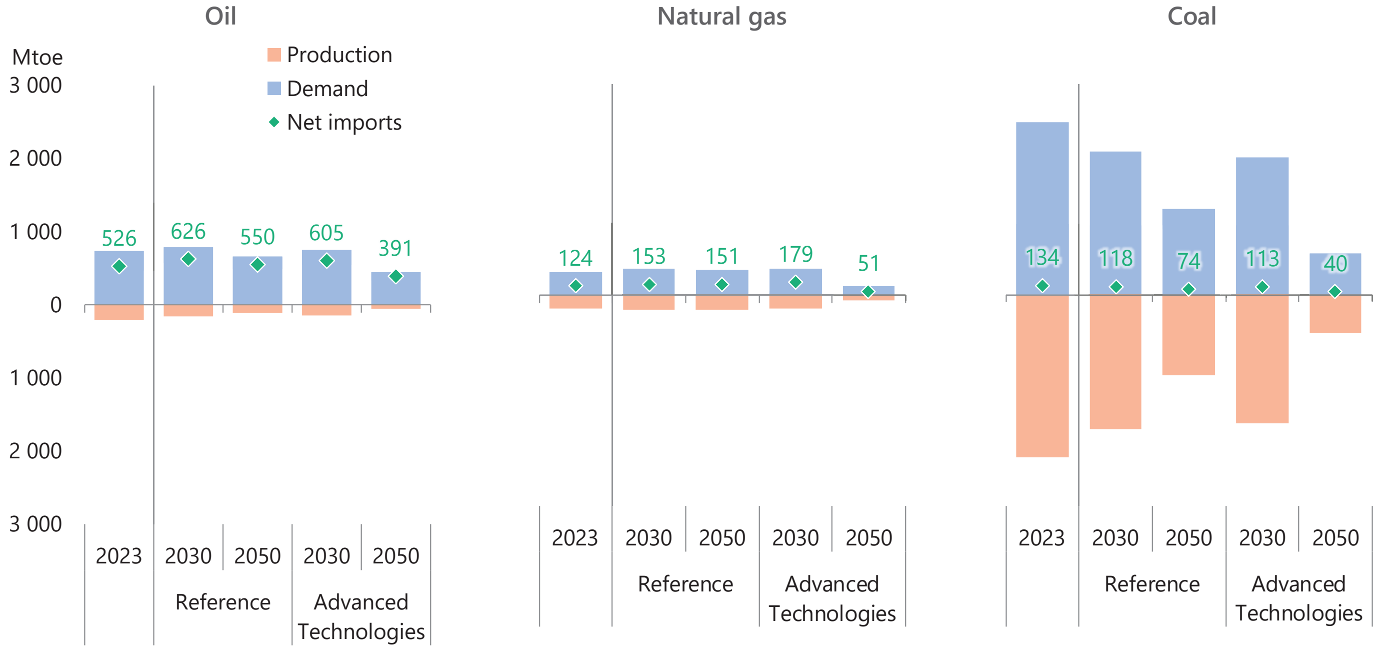
Energy consumption





China

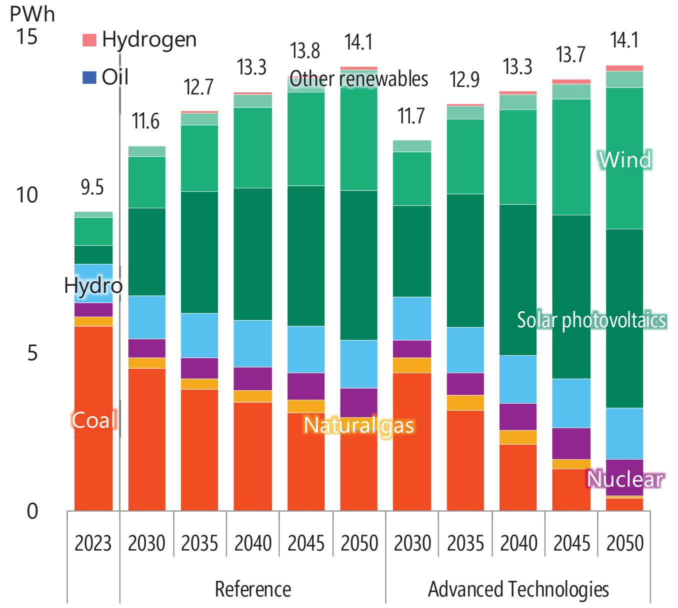
Supply and demand balance of fossil fuels



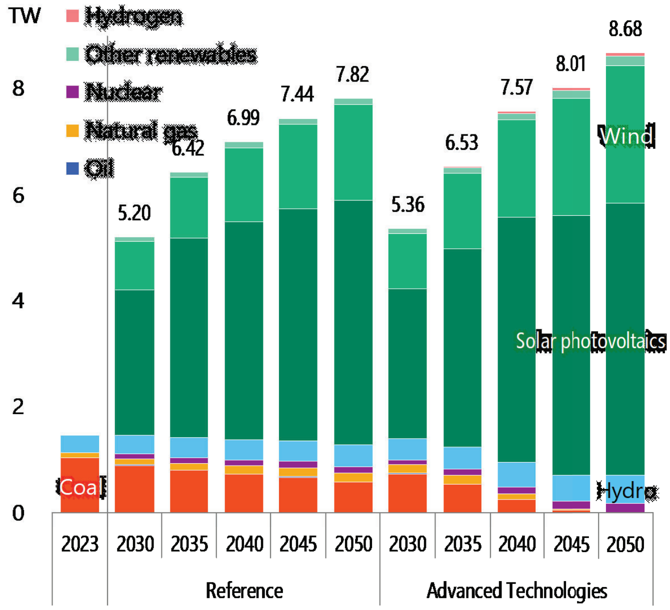
China

Power generation mix

Electricity generated



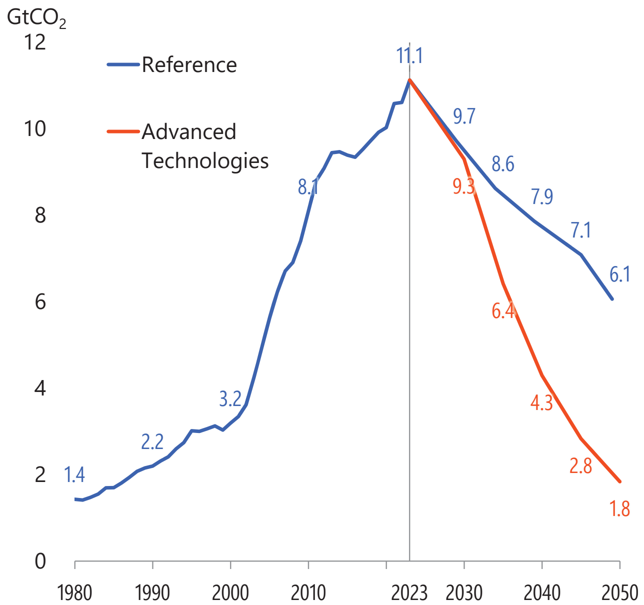
Installed power generation capacity



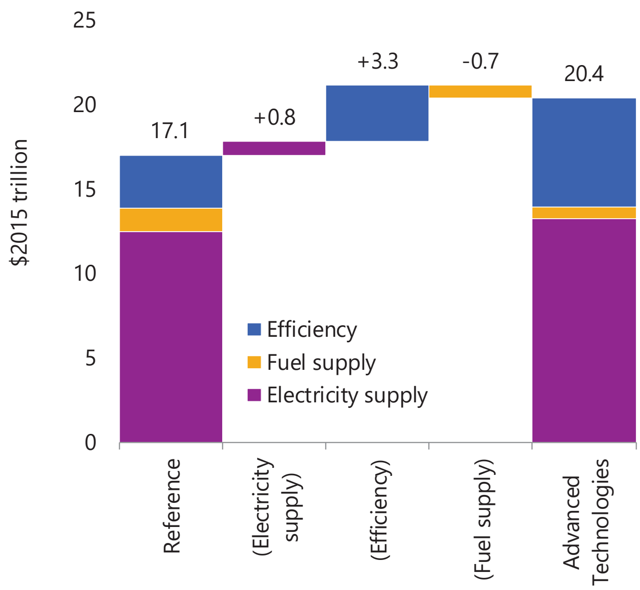
China

Energy-related CO_2 emissions and investments

CO_2 emissions

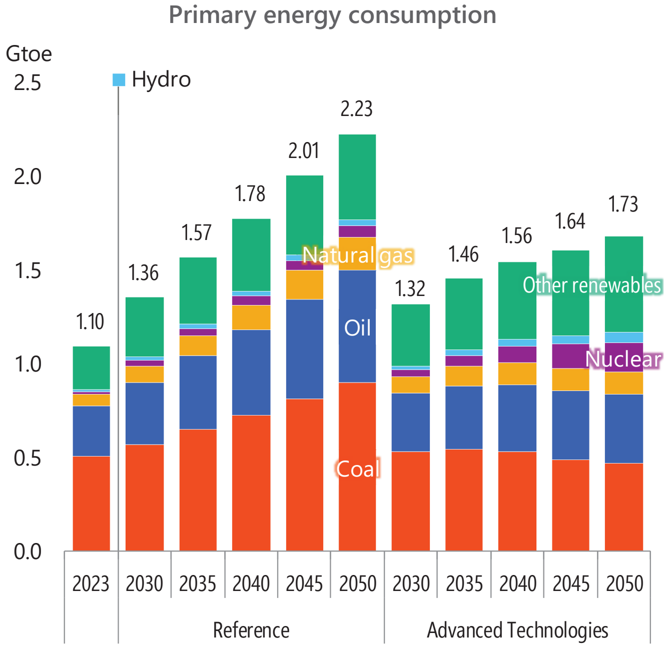


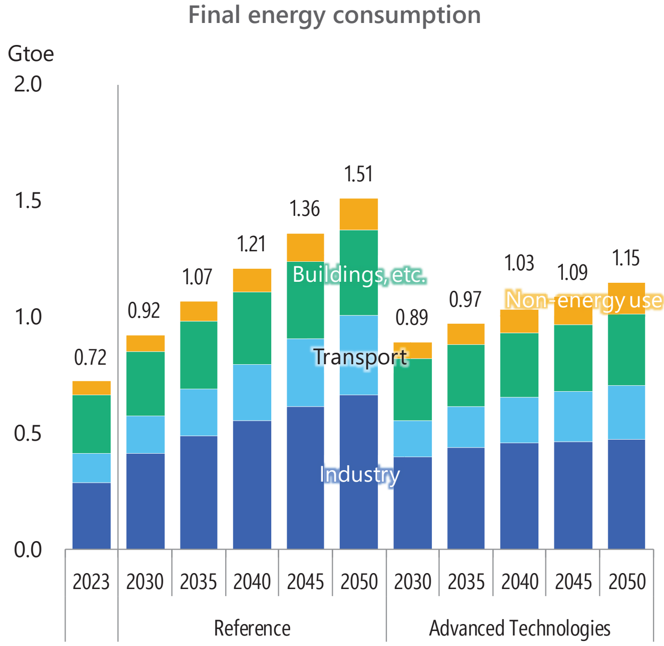
Investments (2025–2050)



India

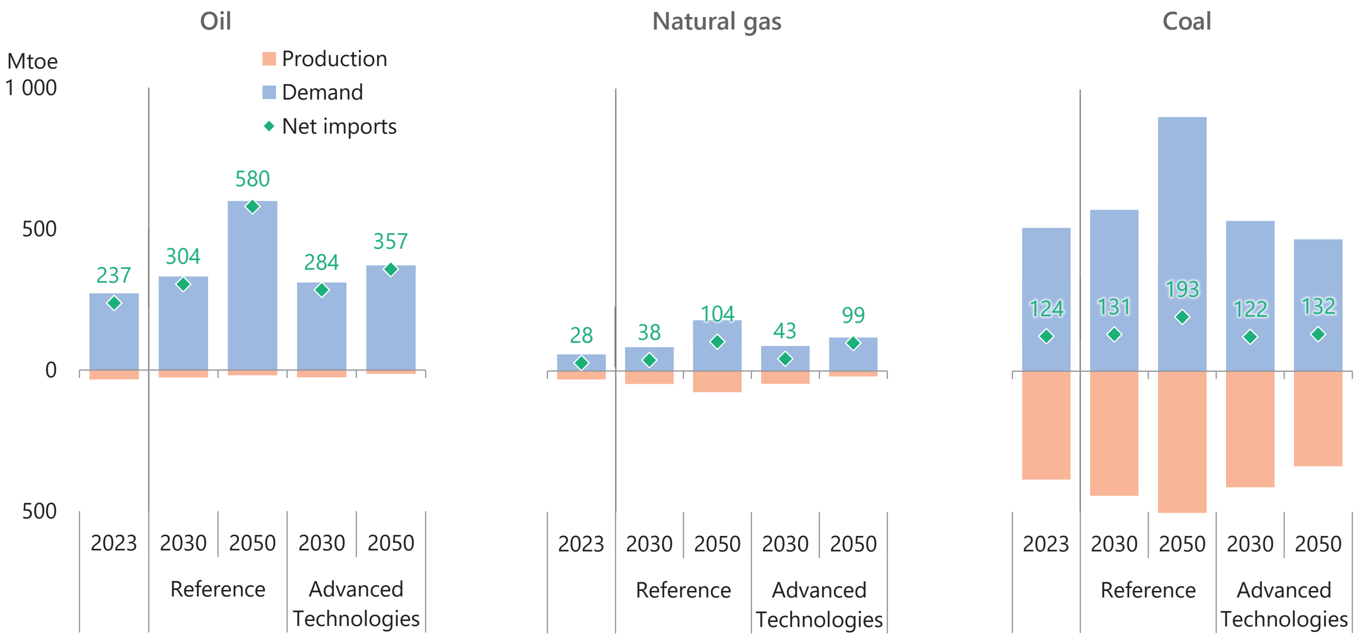
Energy consumption





India

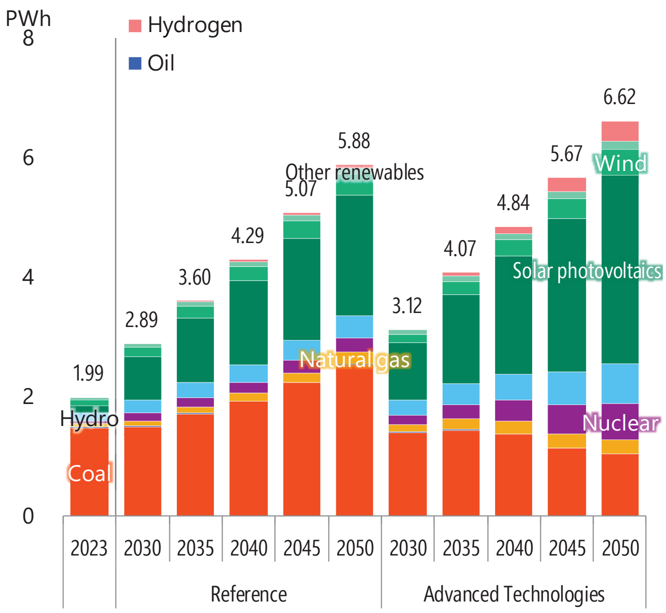
Supply and demand balance of fossil fuels



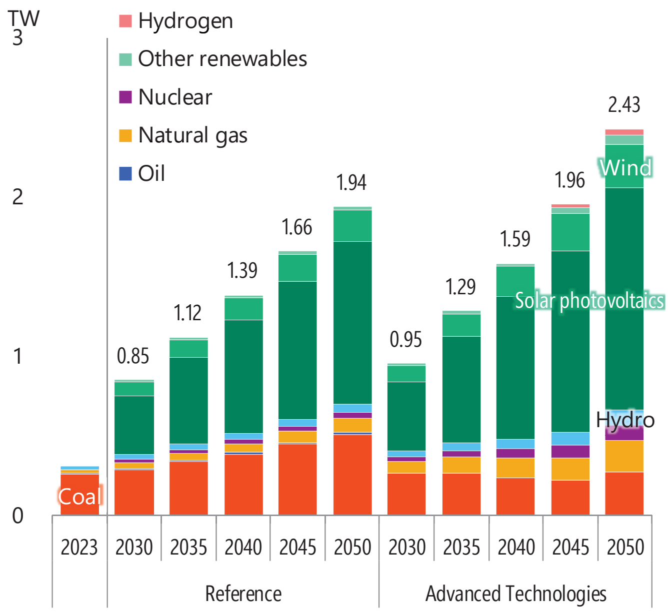
India

Power generation mix

Electricity generated



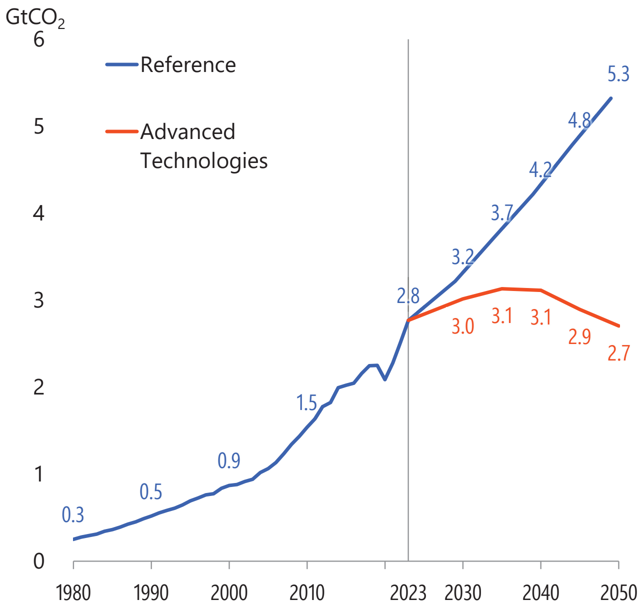
Installed power generation capacity



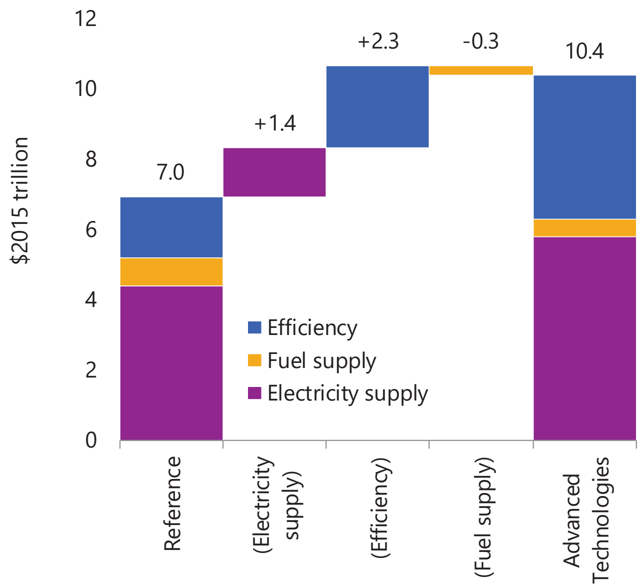
India

Energy-related CO_2 emissions and investments

CO_2 emissions

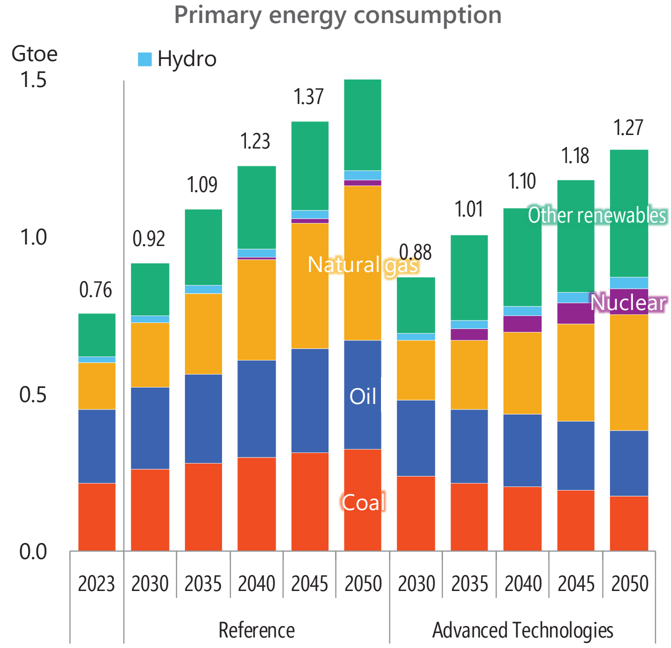


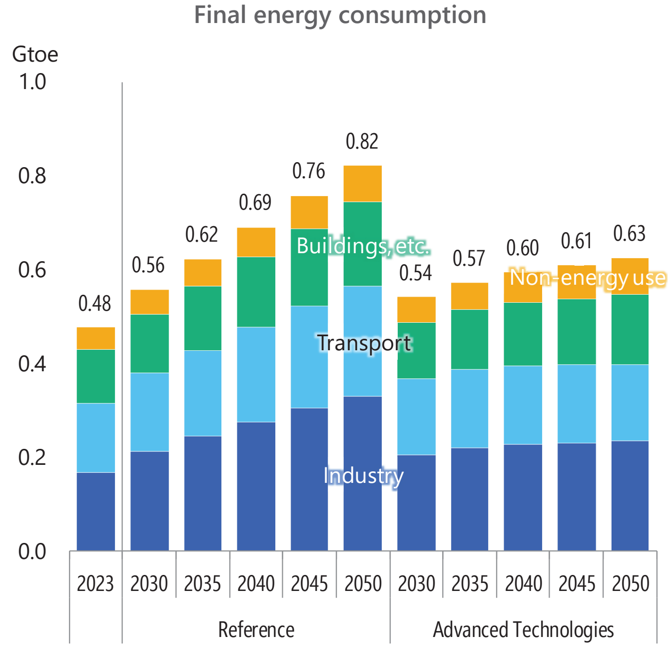
Investments (2025–2050)



ASEAN

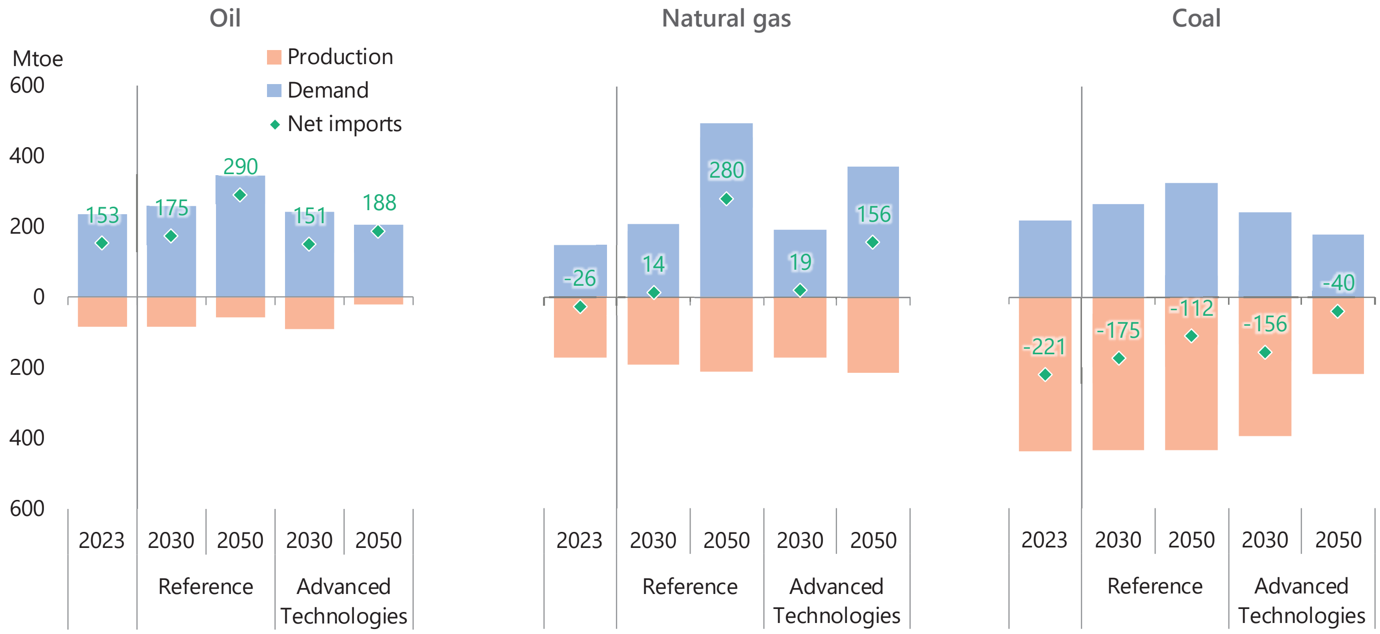
Energy consumption





ASEAN

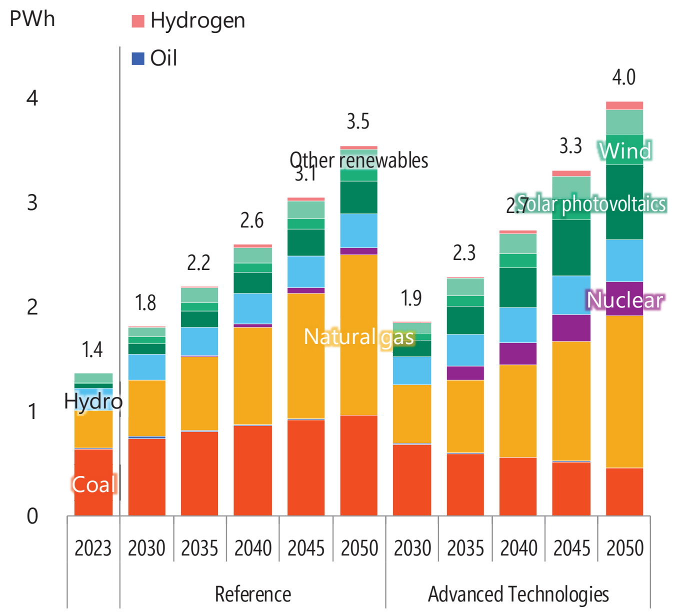
Supply and demand balance of fossil fuels



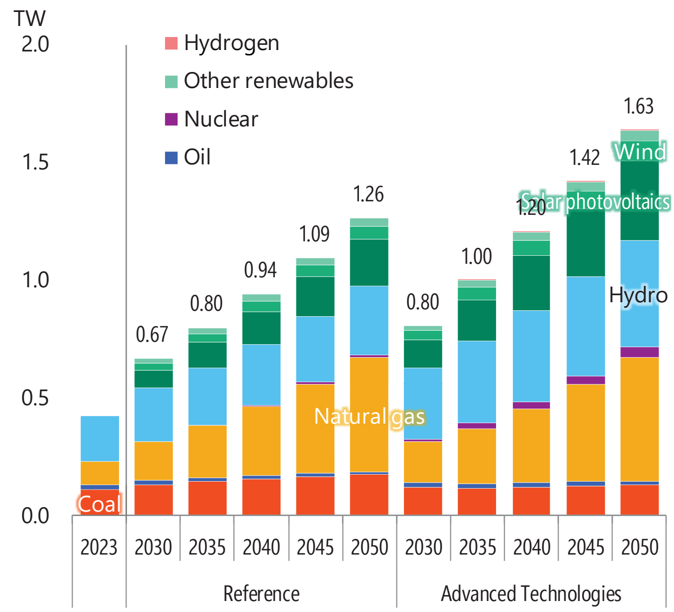
ASEAN

Power generation mix

Electricity generated



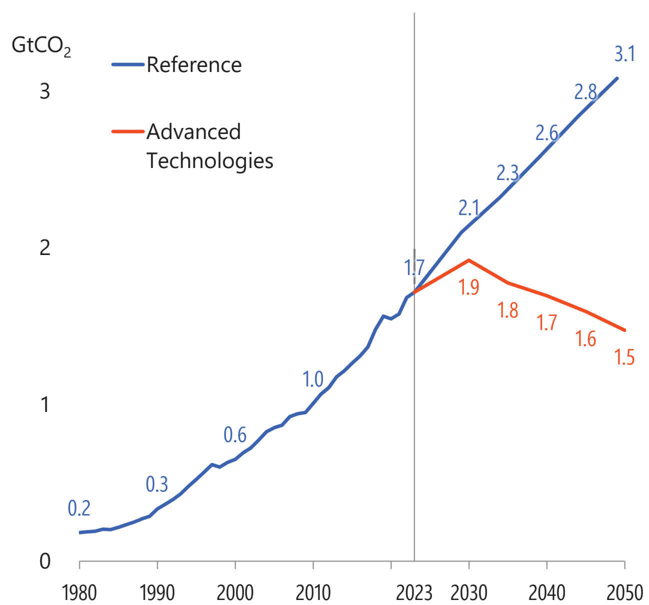
Installed power generation capacity



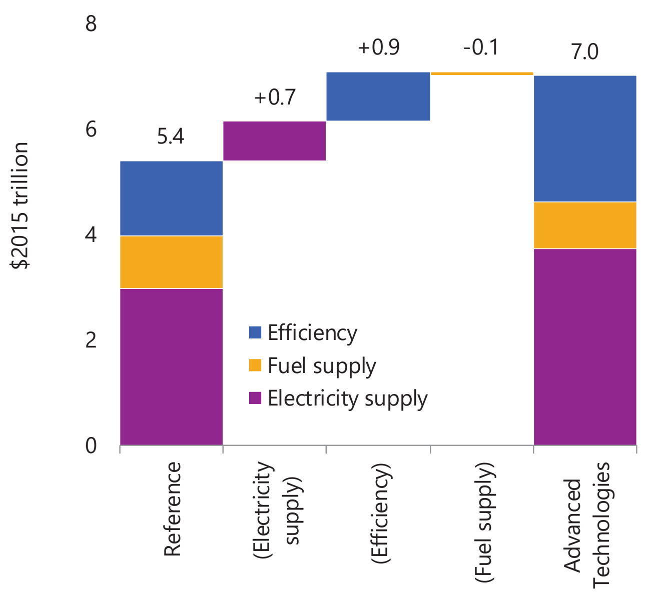
ASEAN

Energy-related CO_2 emissions and investments

CO_2 emissions



Investments (2025–2050)



The tables for IEEJ Outlook 2026 are currently available at https://eneken.ieej.or.jp/en/whatsnew/451.html.

The full text will be available early 2026 at the same URL.

IEEJ Outlook 2026

October 2025

The Institute of Energy Economics, Japan