

Slides

The 451st Forum on Research Work

IEEJ Outlook 2026

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

Tokyo, 17 October 2025

The Institute of Energy Economics, Japan

451st Regular Research Forum, October 17, 2025

IEEJ Outlook 2026

Global Energy Supply and Demand Outlook to 2050

The Institute of Energy Economics, Japan (IEEJ)

Seiya Endo

Senior Economist

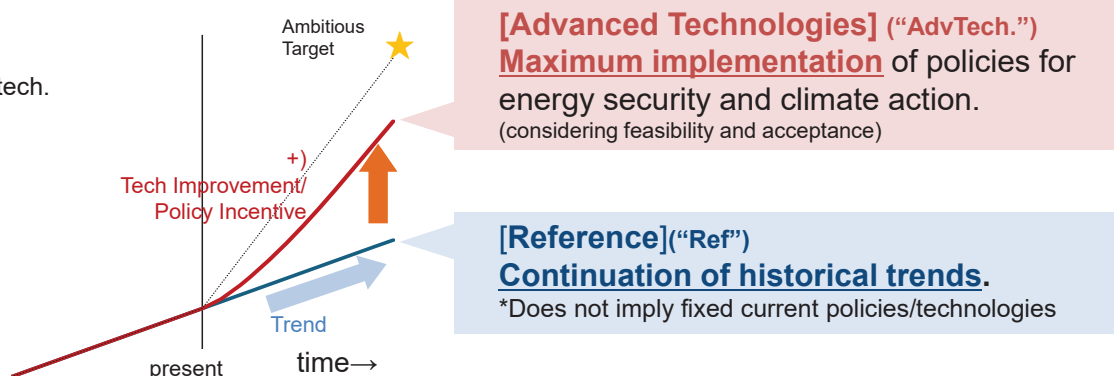
- Global energy supply and demand outlook to 2050
- Economic growth in India and ASEAN and its global impact

What is IEEJ Outlook?

- Global energy supply and demand projections through 2050.
 - Compiled latest energy and socioeconomic data to estimate future energy demand and CO₂ 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



Substantial Increase in Power Demand, in addition to Data Centres

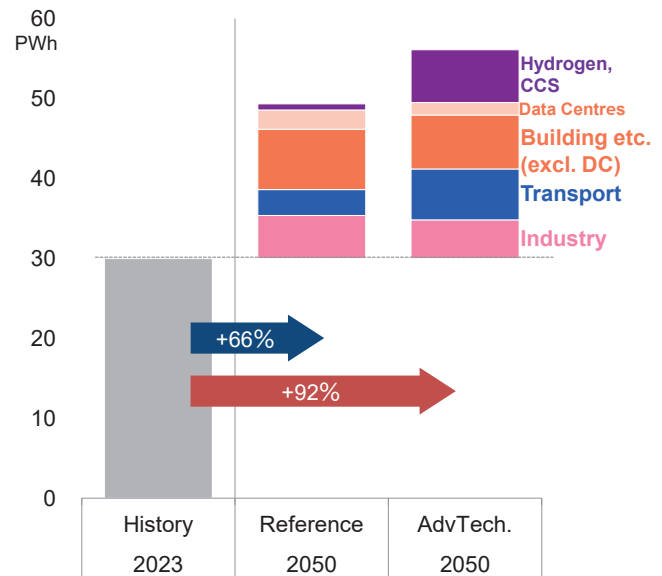
Historical Data Trend [Global]

- 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

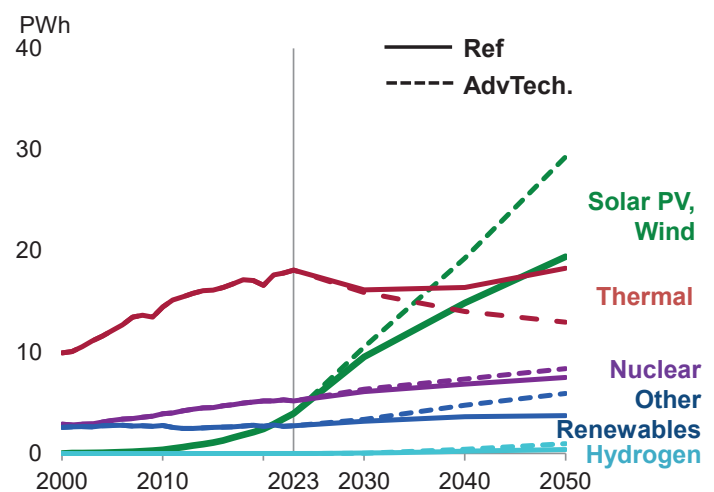
Historical Data Trend [Global]

- 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)

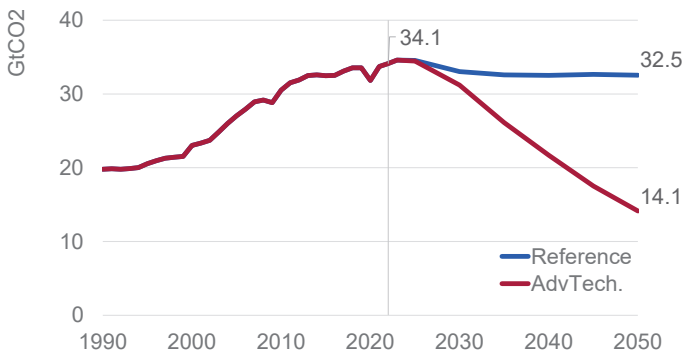


*Energy Institute, Statistical Review of World Energy (2025)

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

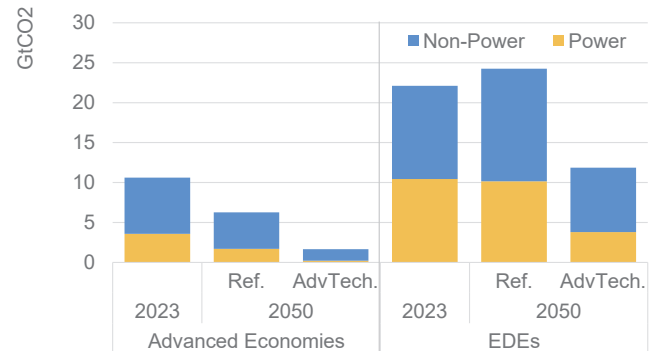
- **Reference**: Global emissions remain around current levels.
- **AdvTech.**: Emissions reduction accelerates after 2030, reaching -59.3% vs 2023.
 - Non-power sectors in EDEs is the most significant challenge for net zero, accounting for most remaining emissions.
 - Prioritizing power decarbonization and efficiency measures is essential.

CO₂ Emission* (World)



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

CO₂ Emission** (Regional, Sectoral)



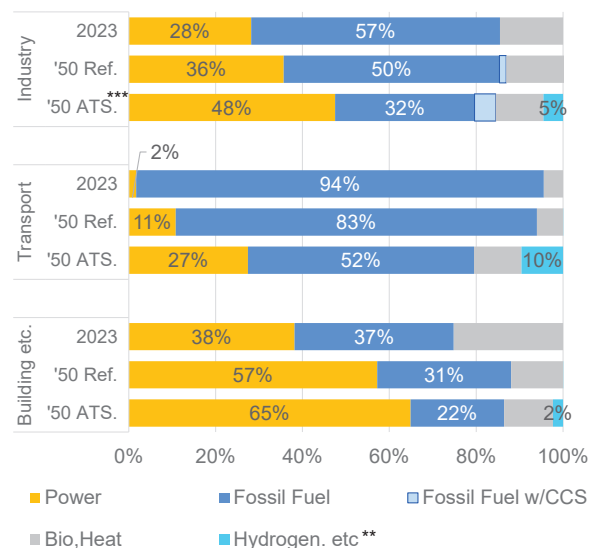
**EDEs: Emerging and Developing Economies

6

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".

7

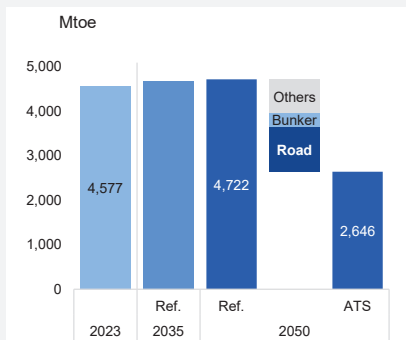
Fossil Fuel Consumption Shows a Wide Range Between the Scenarios

- 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)

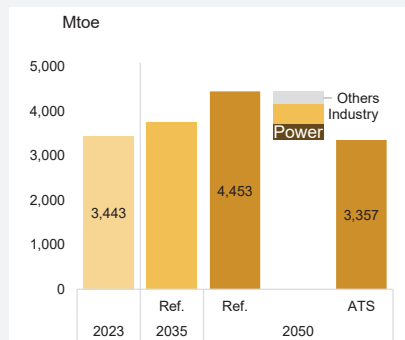
Oil

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



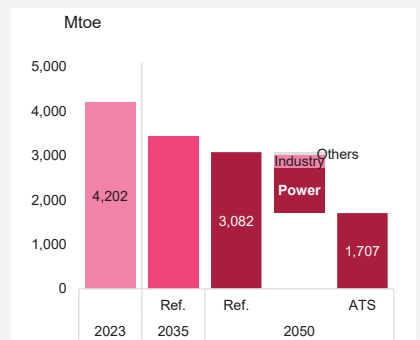
Natural Gas

- 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.

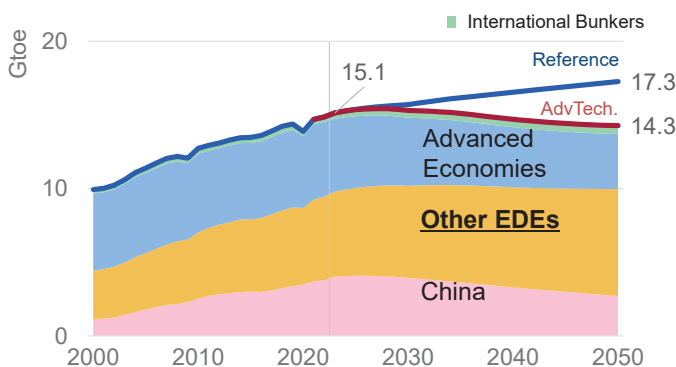


8

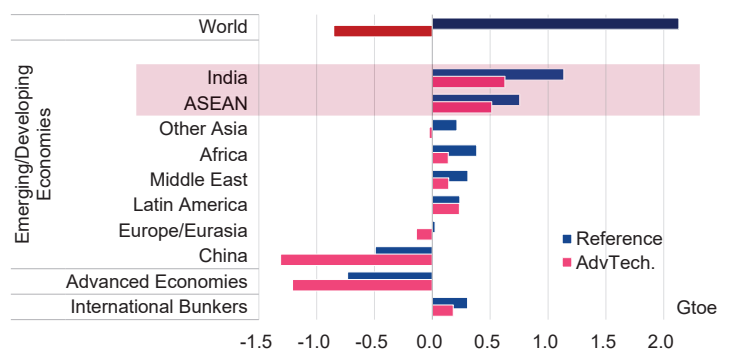
India and ASEAN Drive Energy Consumption Growth

- **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)

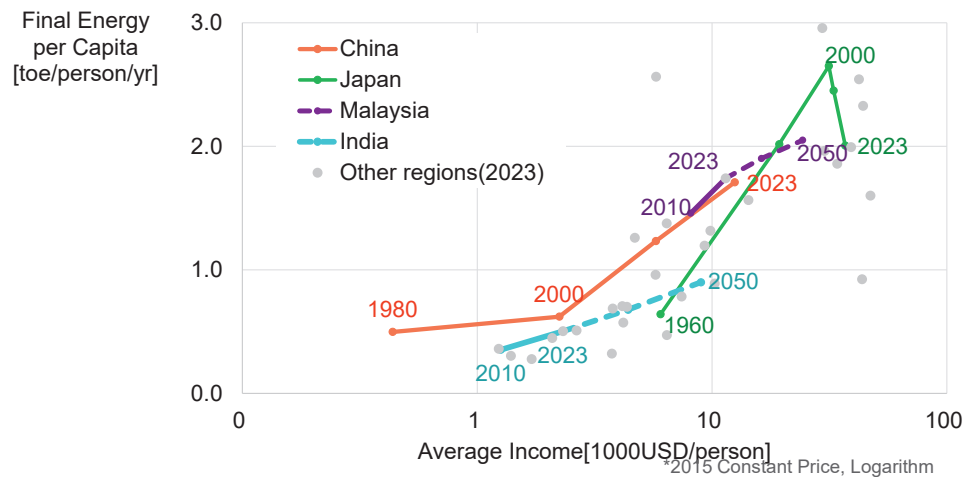


9

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)

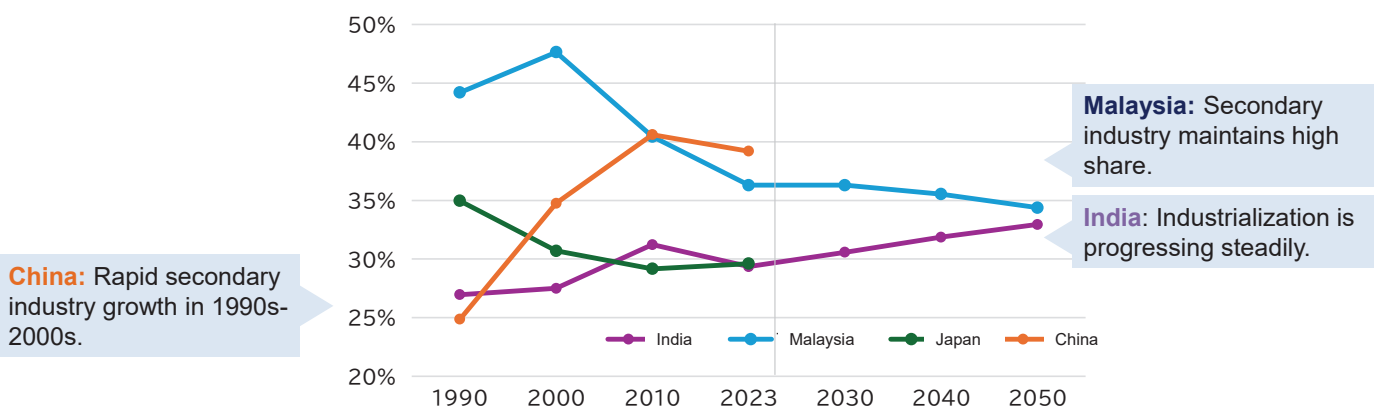


Source) History: IEA(2025), World Bank(2025), IEEJ(2025) . Future projections are from this outlook.

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

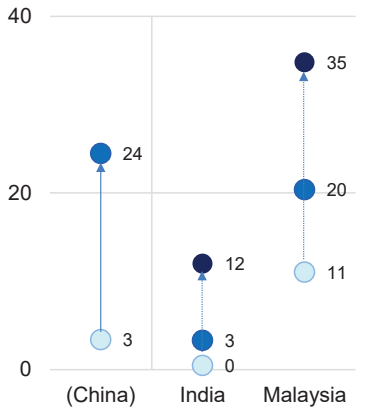
- Rising income levels stimulate increase **especially in ownership of cooler, cars**, additionally crude steel production.
(e.g.) Penetration of "3C" in 1960s Japan/economic growth in 2000s China

Buildings:

Cooler



Units per 100 people (residential)

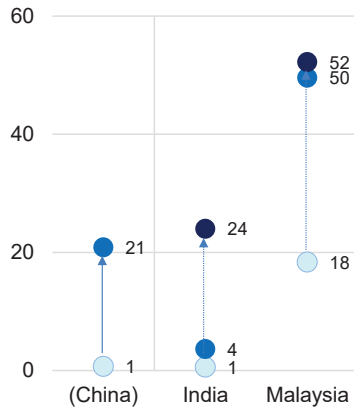


Transport:

Car



Passenger Vehicles per 100 people

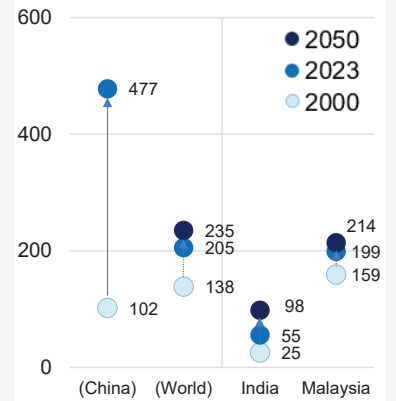


Industry:

Crude Steel



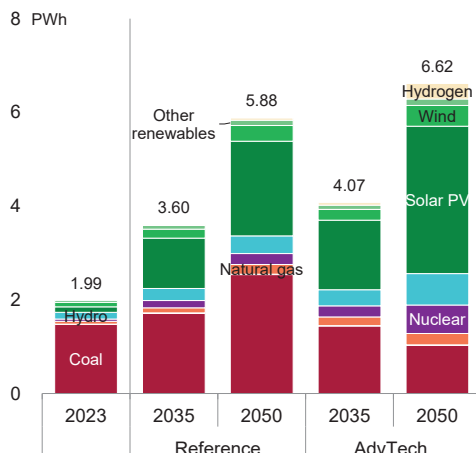
Per capita production (kg/person/year)



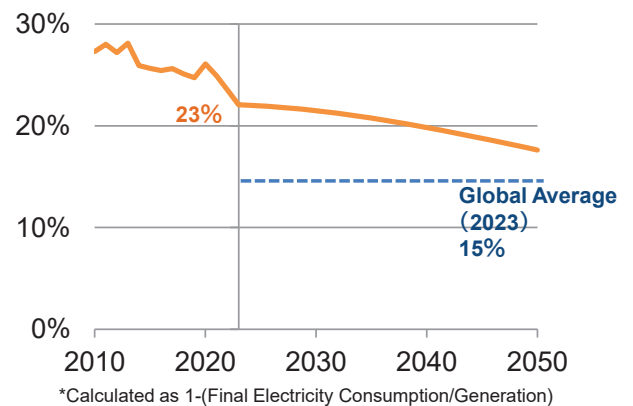
Challenges in Energy Supply and Demand (1): Rapid Increase in Power Generation (India)

- 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)



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

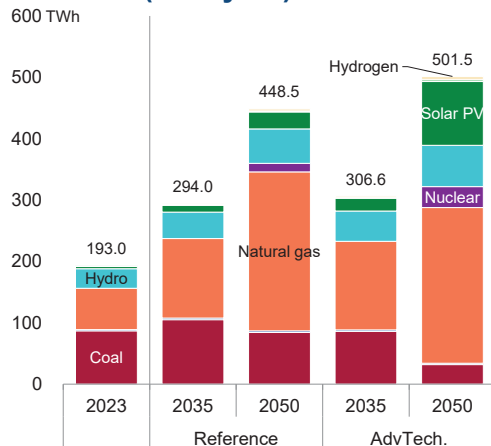
■ Ref: Generation increases $\times 1.6$ by 2035 and $\times 2.3$ by 2050 (vs. 2023)

- 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)



Malay Peninsula:
3/4 of the population
is concentrated

Borneo Island:
Solar and hydro suitable
sites are concentrated

出所: Flourish

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

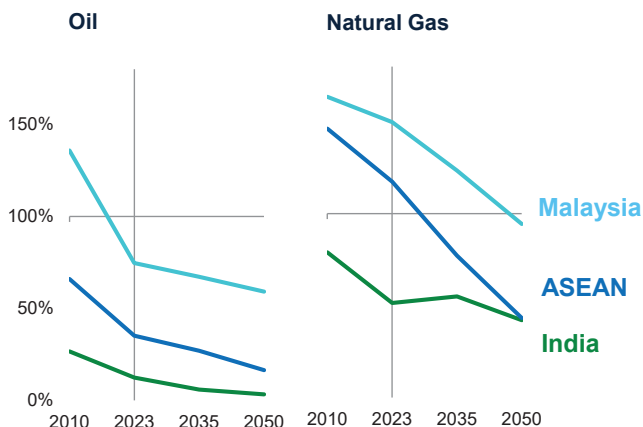
■ Oil and gas self-sufficiency declines in India and ASEAN;

- Oil: Already import-dependent in both regions, and the dependency get deepen.
- Gas: ASEAN becomes a net gas importer by 2035.

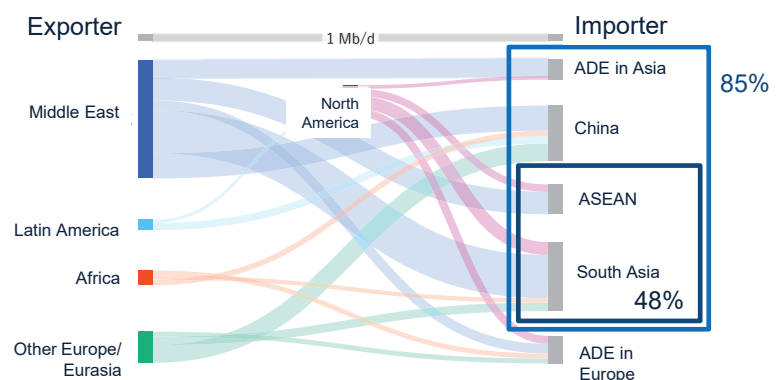
■ Asia's share of global crude oil trade rises sharply.

- 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)



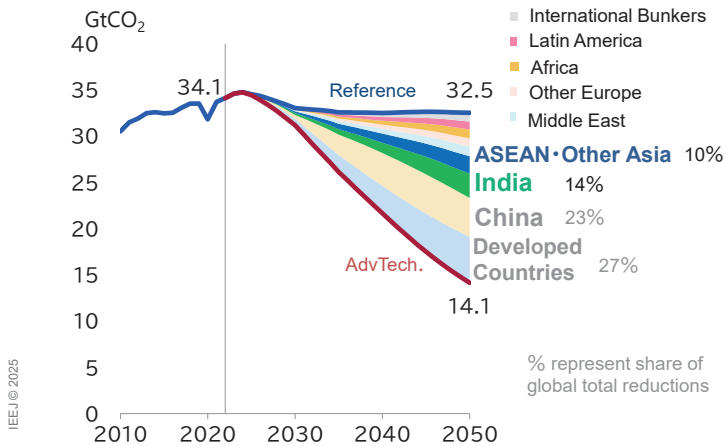
Note: Shows flows of 0.5 Mb/d or greater. Percentages represent share of total inter-regional trade volume.

Challenges in Energy Supply and Demand (3): Investment for CO₂ Reduction

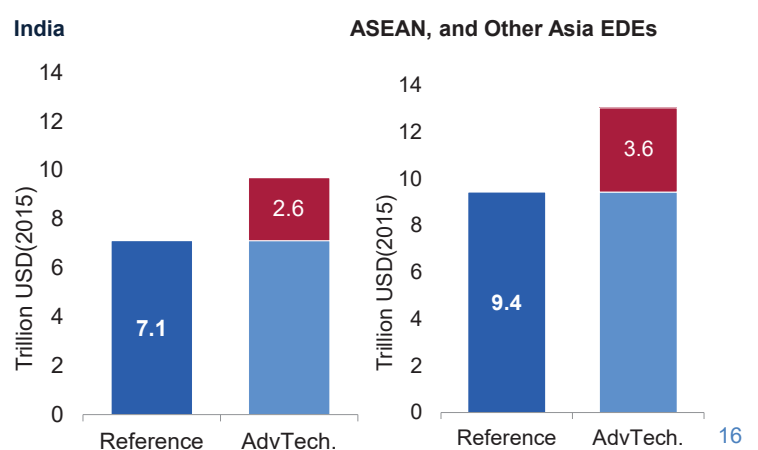
- Emission reduction potential (Reference – AdvTech.) in India, ASEAN, and Other Asia EDEs approaches scale of developed countries or China.
- On the other hand, substantial energy investment is required for AdvTech.
 - Additional investment needed for reductions in these three regions alone equals 80%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

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

CO₂ 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 CO₂ reduction.

IEEJ Outlook 2026

Evaluating the Integration Costs and Deployment Potential of Variable Renewable Energy

The Institute of Energy Economics, Japan

Yu NAGATOMI

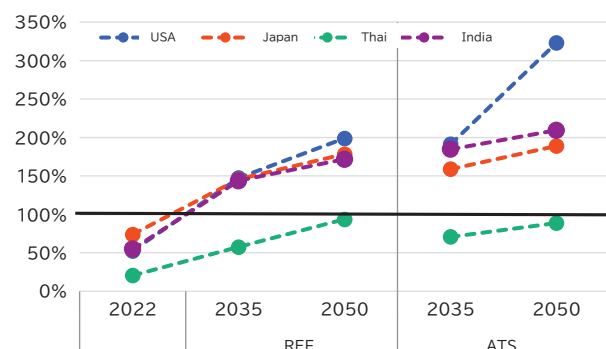
Executive Analyst, Energy Data and Modelling Center

(Co-author: Hideaki OBANE, Seiya ENDO)

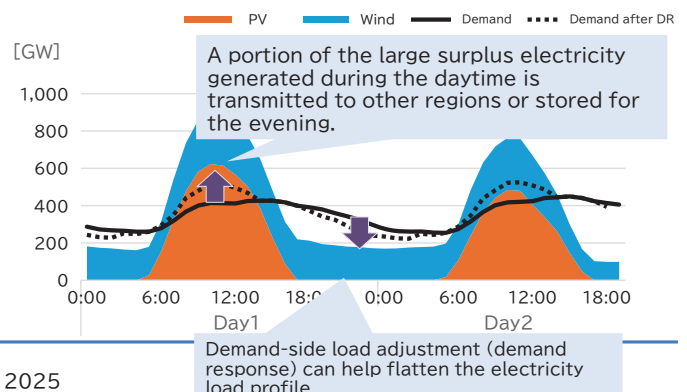
Rising VRE Penetration and the Changing Supply-Demand Balance in the Power System

- 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)

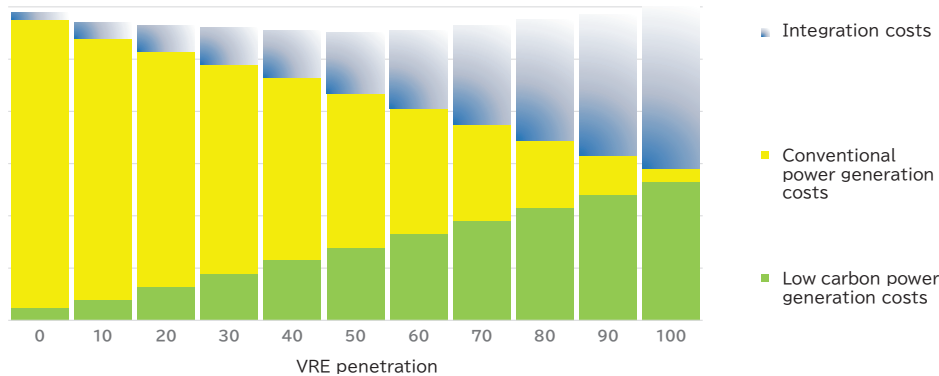


Source:IEEJ Outlook 2025

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



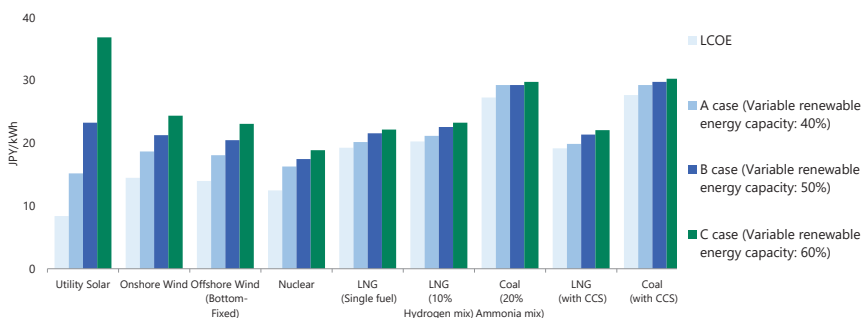
Source: Author, based on Matsuo (2021) and The Working Group on Power Generation Cost Verification (2025)

20

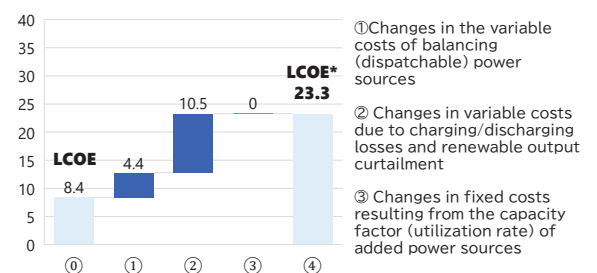
Example of the Study on Integration Cost: The Working Group on Power Generation Cost Verification (2025)

- 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



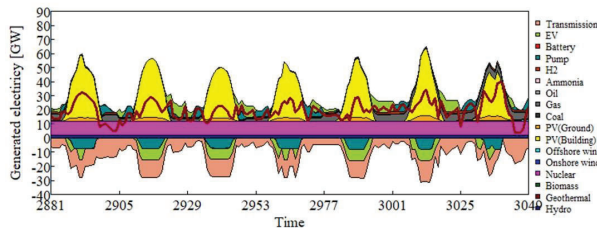
Source: Author, based on The Working Group on Power Generation Cost Verification (2025)

21

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

- Using the IEEJ-NE model, we analyze the least-cost technology mix for ASEAN under varying levels of VRE deployment.
- The analysis assumes each country follows its NDC targets and evaluates VRE deployment and integration costs through 2060.
- IEEJ-NE Model Framework
 - ✓ Simulates annual power and hydrogen supply-demand on a time-step basis
 - ✓ Calculates required capacity for power generation and storage
 - ✓ Considers grid reinforcement and energy storage for power system balancing

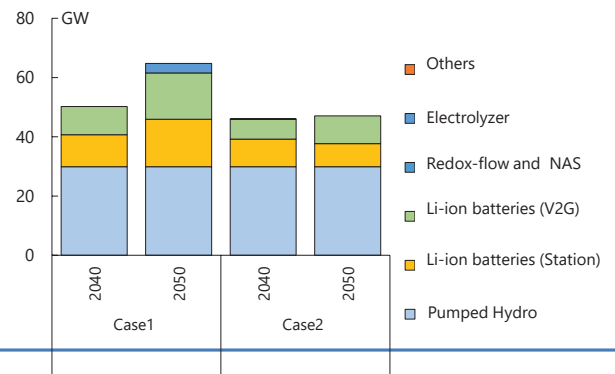
Example of Power Supply-Demand (hourly)



Technology list

Energy Storage	Pumped hydro, Li-ion batteries (grid-side and demand-side), NaS batteries, redox-flow batteries, hydrogen storage
(Demand Response)	Demand-side flexibility: EV charging, passenger EV V2G, and heat pump water heater load shifting

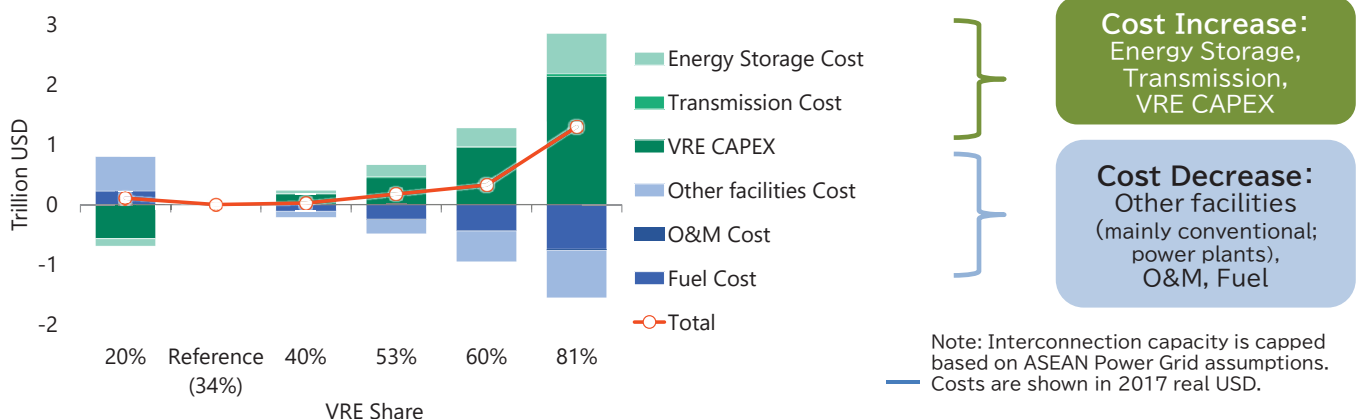
Required storage capacity estimated by area



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.

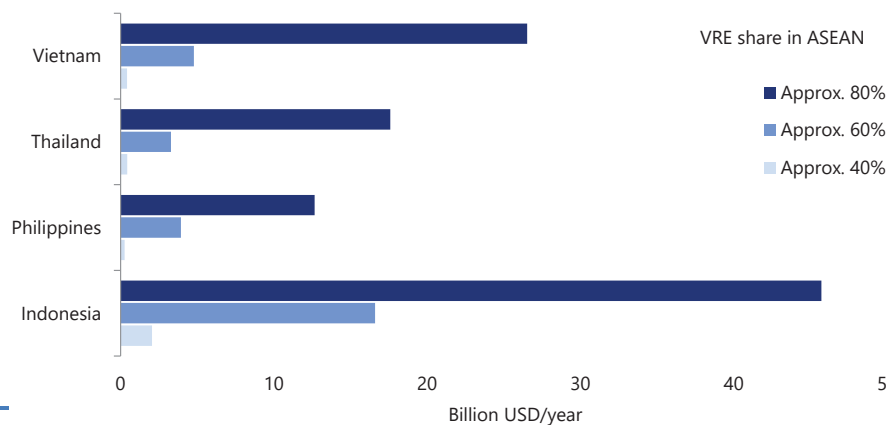
Cumulative System Cost Change in ASEAN (2030–2060, vs. baseline)



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.	<u>This study</u>
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).	<u>This study</u> The Working Group on Power Generation Cost Verification
		Curtailment costs	Higher unit cost of electricity when VRE output exceeds demand and curtailment is needed.	<u>This study.</u> 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)

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,

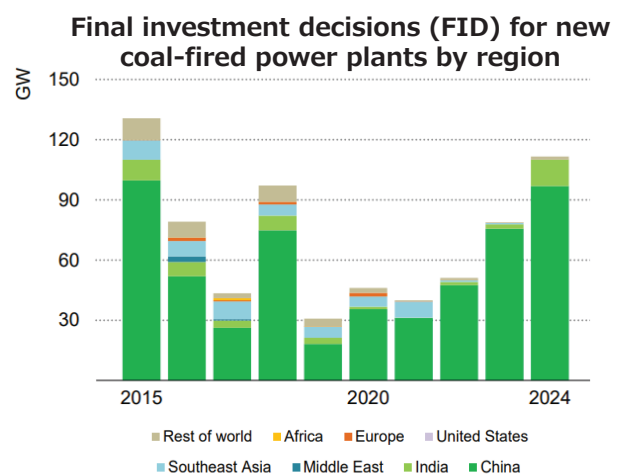
- The United States has announced its withdrawal from the Paris Agreement and is also advancing domestic measures, including the early termination of tax credits under the Inflation Reduction Act (IRA), the revocation of the GHG endangerment finding, and the removal of emission regulations for automobiles 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 CO₂ 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.

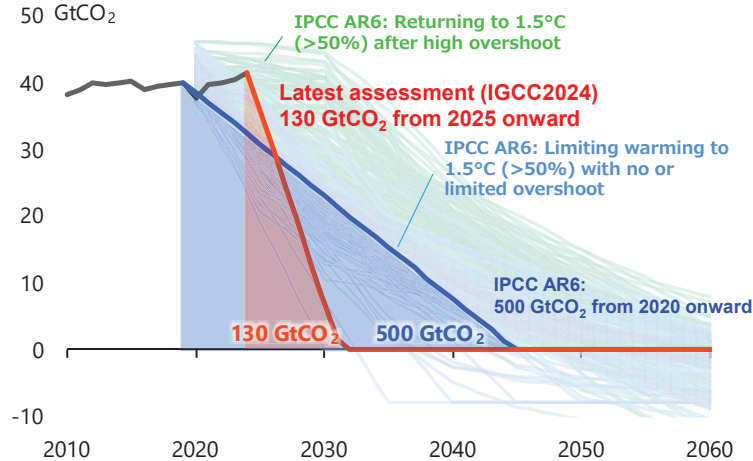


(Source) IEA, World Energy Investment 2025

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 CO₂ emissions permitted globally going forward to achieve a target.
- The latest assessment is 130 GtCO₂^{*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..

CO₂ emissions pathway consistent with the 1.5°C target



*2: According to the Indicators of Global Climate Change (IGCC) 2024. The difference from 500 GtCO₂ at the time of AR6 is due to a decrease of 200 GtCO₂ in emissions from 2020 to 2024, a decrease of just over 100 GtCO₂ due to an upward revision of global warming due to the reduction of aerosols with cooling effects, and a decrease of about 40 GtCO₂ 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)

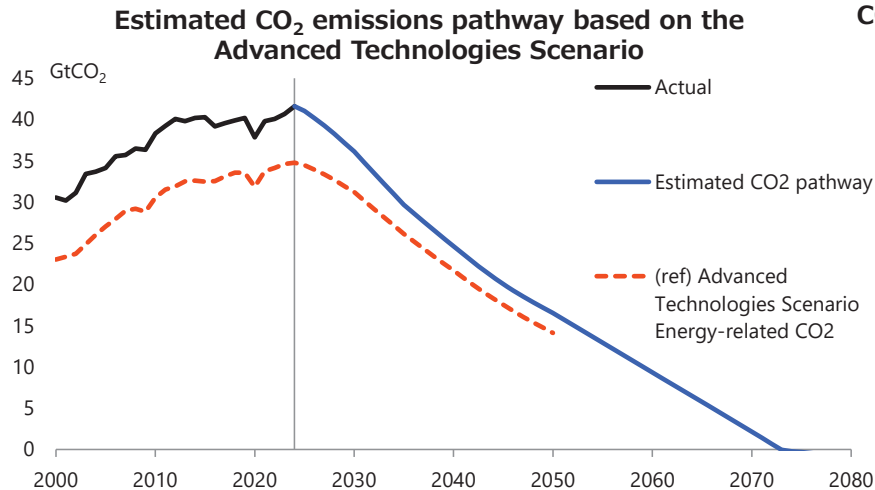
- Based on the energy-related CO₂ emission pathway to 2050 in the IEEJ Outlook 2026 Advanced Technologies Scenario, the total anthropogenic CO₂ emission pathway including non-energy by the year of achieving net-zero was estimated.

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.)

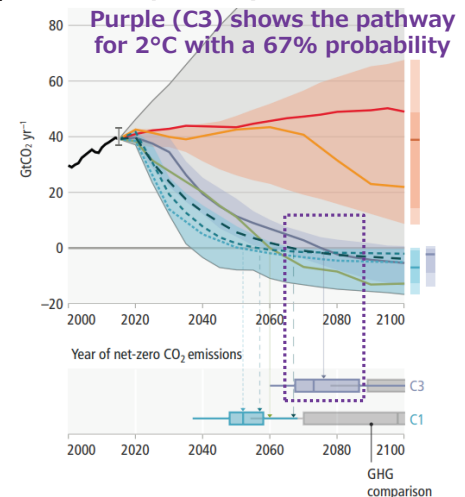
- Carbon budget comparison targets
 - IPCC 6th Assessment Report Synthesis Report (IPCC AR6 SYR)
 - Global Carbon Budget 2024 (GCB 2024) : International research projects, updated annually
 - Indicators of Global Climate Change 2024 (IGCC 2024) : Same above

Comparison of the Advanced Technologies Scenario and the 2°C target (CO₂ emissions pathway)

- The estimated CO₂ emissions pathway achieves net-zero in 2073. The IPCC AR6 Working Group III (WG3) report states that the CO₂ 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.



CO₂ emissions pathways in IPCC AR6 WG3



Note: (Left) The estimated CO₂ pathway shows total CO₂. The Advanced Technologies Scenario shows energy-related CO₂.
(Right) IPCC AR6 WG3 SPM p.26

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

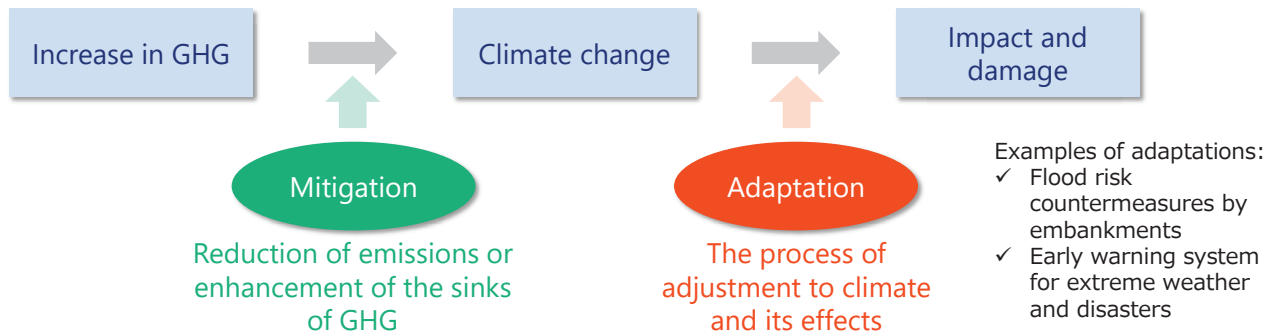
- The cumulative emissions from 2025 onwards until net-zero is achieved in the estimated CO₂ emission pathway would total 906 GtCO₂, a level comparable to the latest remaining carbon budget and sufficient to limit global temperature rise to 2°C with 50% probability.
- However, it slightly exceeds the 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 GtCO₂ emissions for 5 years from 2020 to 2024.

What is adaptation?

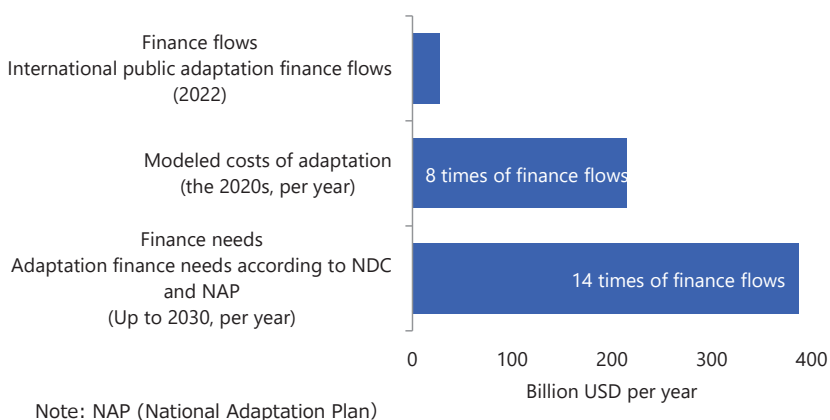
- Current mitigation efforts are not sufficient in scale or level to keep the rise in global mean temperature within the Paris Agreement's long-term climate targets. As a result, global temperatures are rapidly approaching over 1.5 °C increase above pre-industrial levels. The growing frequency and intensity 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?

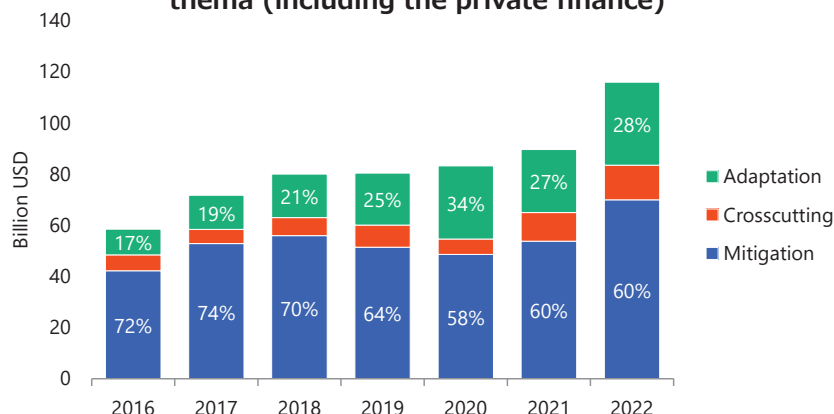
Adaptation finance gap



- 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.

Balance between adaptation and mitigation finance

Climate finance provided and mobilised by climate theme (including the private finance)

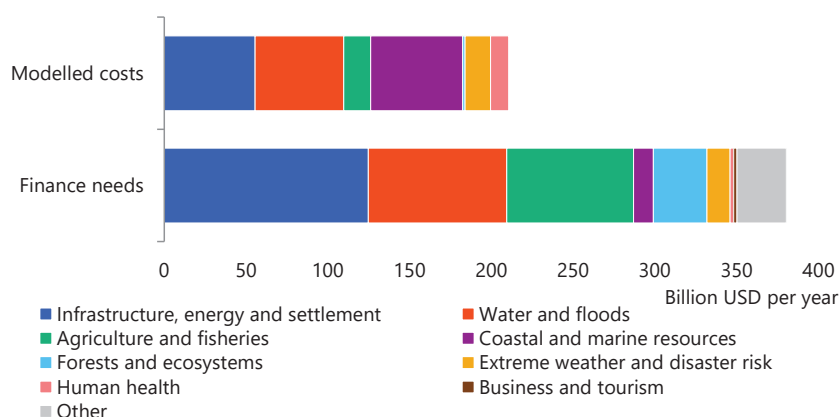


- Article 9, paragraph 4 of the Paris Agreement states, "The provision of scaled-up financial resources should aim to achieve a balance between adaptation and mitigation". This is likely to bring the ratio of adaptation and mitigation finances closer to 1:1.
- Breaking down the climate finance provided 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

Finance needs and modeled costs



- 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.

IEEJ Outlook 2026

AI and the Future of Energy Demand

The Institute of Energy Economics, Japan

Naoko Doi, Asamu Ogawa, Songhee Kim, Taichi Kusayagi, Soji Koikari, Kagami Kotegawa, Kei Kobashi, Arina Sato, Toru Shimizu, Yi-chum Chen, Yu Nagatomi, Junya Nishi, Rino Hirose, Soichi Morimoto, and Atsutaka Yamada

Background and Study Objectives

● Background

- The close interrelationship between artificial intelligence (AI) and energy is attracting global attention.
 - The growing use of generative AI and the advancement of digitalization will lead to a significant expansion of data centers.
 - Locally, there are concerns that the construction of power supply facilities will not keep up with the pace of data center construction.
- AI is expected to bring significant benefits in key sectors related to energy use.
 - Various energy-saving and CO2 emission reduction effects are expected
- However, there are challenges to using AI on the demand side, such as a lack of awareness, human resources, and investment.

● Study Objectives

- To analyze the future electricity demand in data centres and its energy-saving potential.
- To analyze the energy-saving effects of AI in demand sectors (industry, transportation, business, and households).

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

Trends in Data Centres Electricity Consumption

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

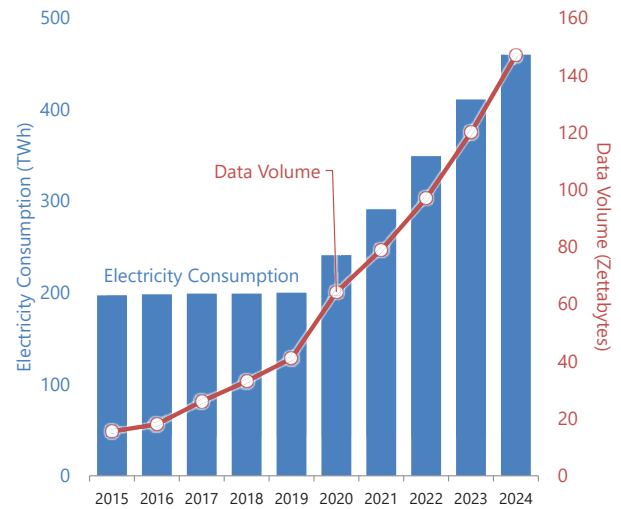
Data center electricity consumption increased by 70%

- 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

2015-
2019

After
2020

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.>

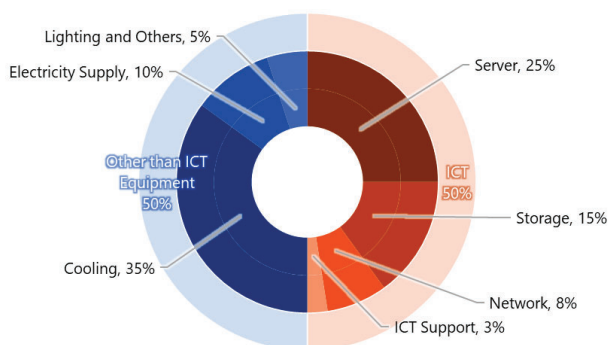
42

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)

Toward Electricity Savings



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.

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.

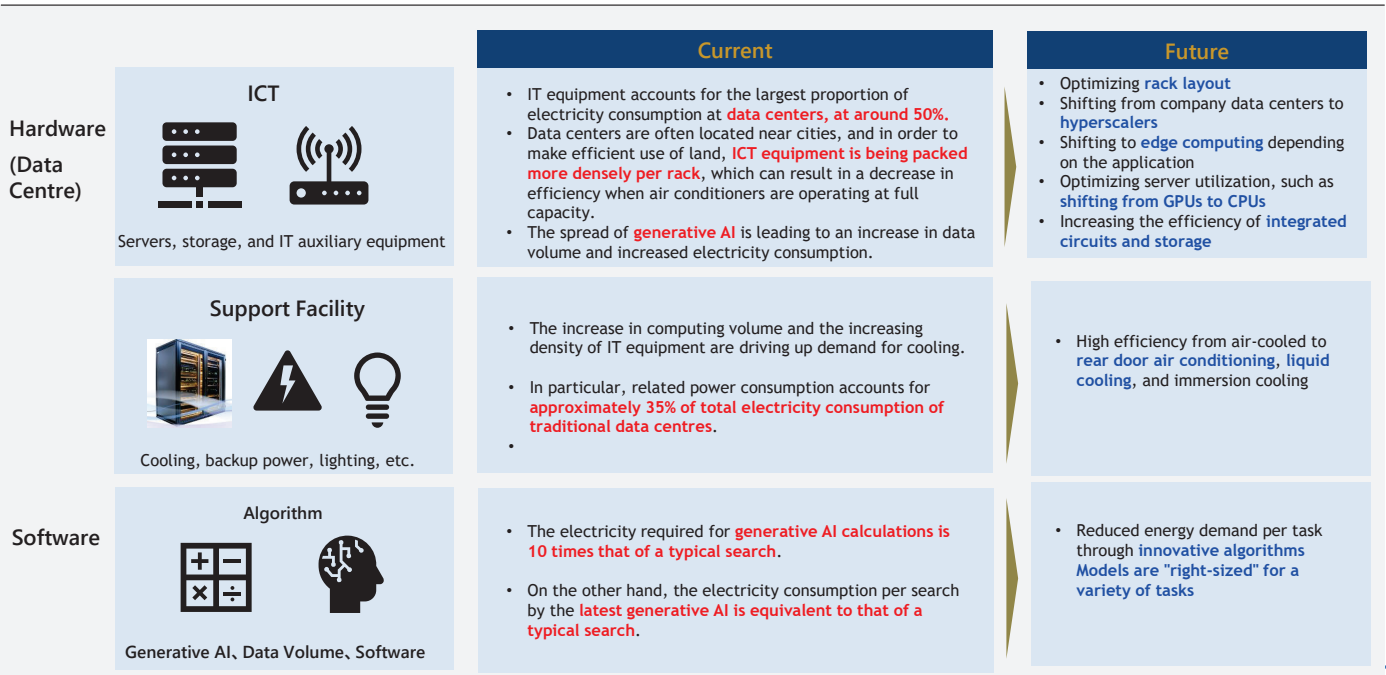
Future

- ✓ Increase in electricity consumption, waste heat and need for cooling
- 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 |

43

Data Centre, AI and Energy : Current and Future



Source : IEEJ (2025).

44

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.

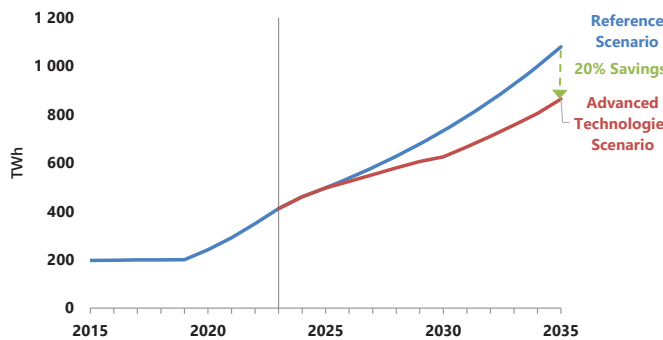
Source : From sustainability report of respective company.

45

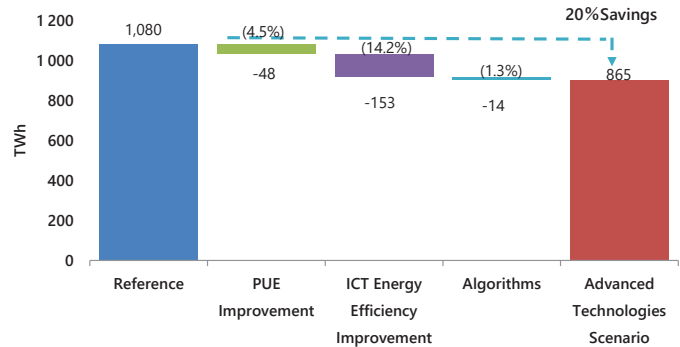
Data Centre Electricity Demand Outlook and Electricity Savings Potential (2035)

- 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)

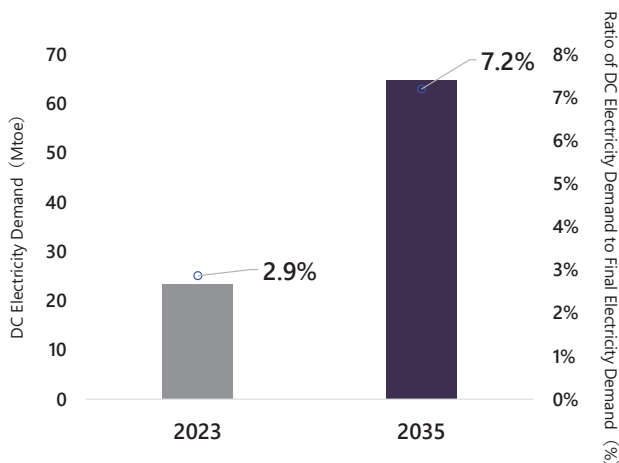


Source : IEEJ (2025).

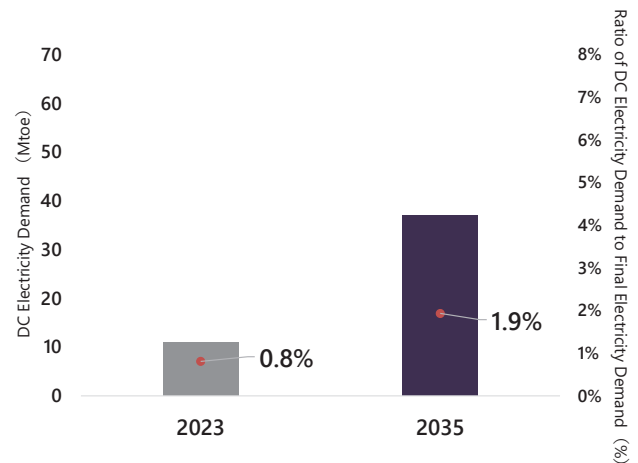
Data Centre Electricity Demand and Ratio to Final Electricity Demand (2023 and 2035)

- 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

Sector•Sub-sector•Technology

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.

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

↑
Estimation of Technical Potential Energy Savings

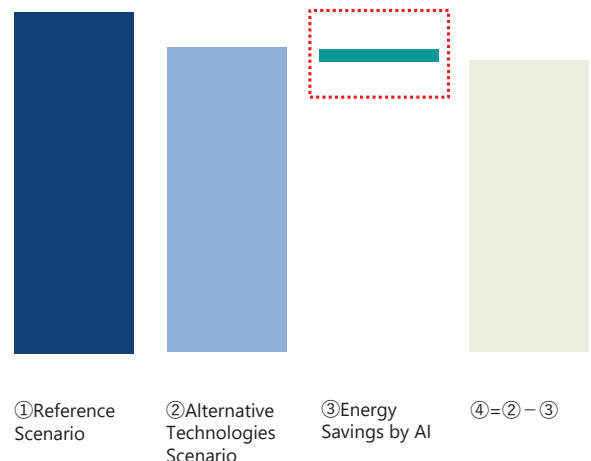
What contributions does AI can make to the energy sector?

- AI is expected various benefits to the energy sector.
- This study conducted a quantitative analysis of the energy savings potential of AI for optimization of the demand sector.

Examples

Detection	▪ Automatic detection of malfunctions and other issues, detection of methane leaks ▪ Remote sensing
Prediction	▪ Weather forecasting and renewable energy use ▪ Industrial production forecasting and building operation forecasting ▪ Transportation demand forecasting and vehicle route optimization
Optimization	▪ Optimizing industrial production processes ▪ Optimizing energy usage in buildings and equipment ▪ Improving fuel efficiency through autonomous driving ▪ Demand response through energy supply and demand optimization
Simulation	▪ Simulations related to identifying new materials and manufacturing new products ▪ Simulations of the effects of energy conservation and clean energy adoption

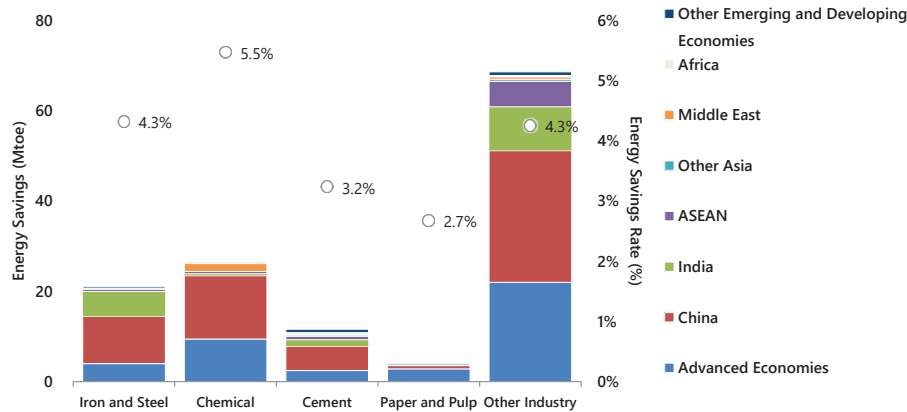
Image of Energy Savings Potential by AI



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]

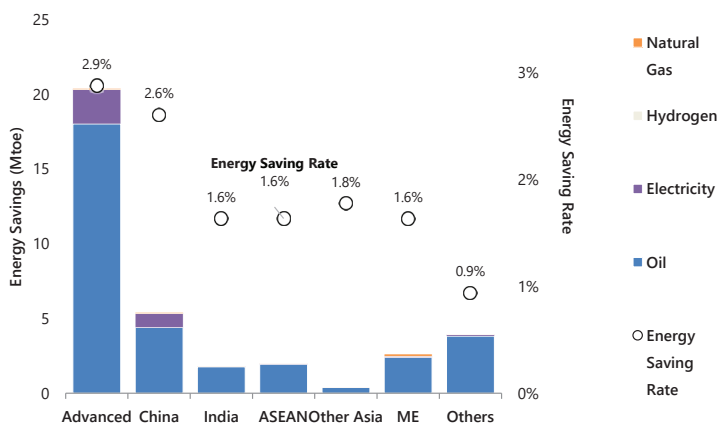


Source : IEEJ (2025).

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]



Source : IEEJ (2025).

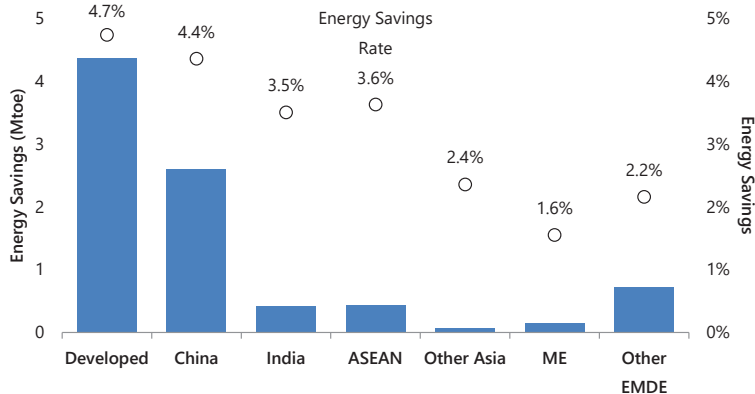
Examples for Energy Savings of AI in the Road Transport

	Exampes
Demand Projection	The loading efficiency and passenger efficiency of cargo trucks, buses, taxis, etc. can be improved by taking into account weather and traffic information.
Route Optimization	Through machine learning, AI suggests route optimization that takes into account the driver's travel preferences and, in the case of cargo trucks, delivery efficiency.
Maintain distance between vehicles	By maintaining a constant distance between vehicles through autonomous driving, vehicles can move without congestion, contributing to improved fuel efficiency. Platooning also reduces air resistance, contributing to improved fuel efficiency.

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.

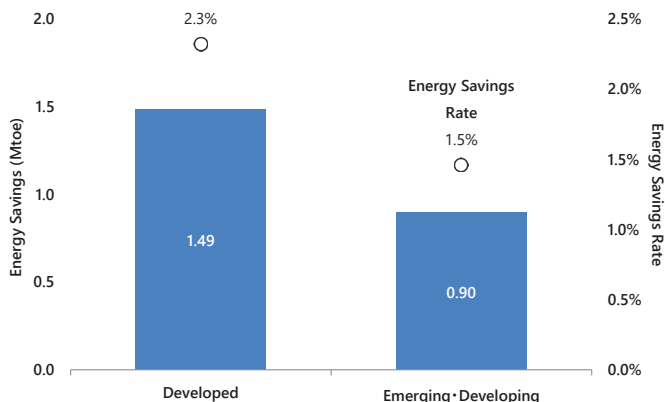
Source : IEEJ (2025).

52

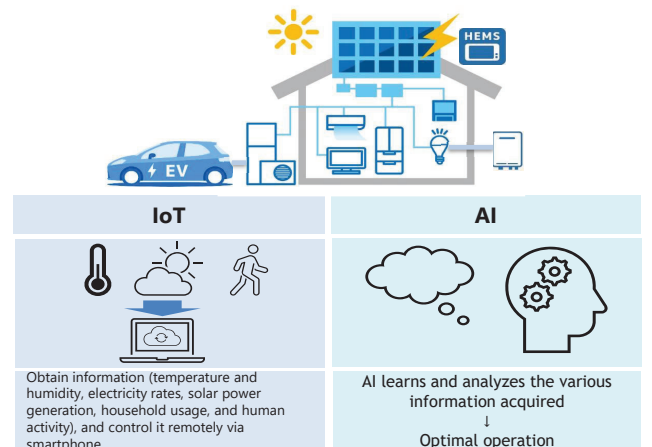
Residential : Energy Savings Potential of AI (Ratio to Alternative Technologies Scenario)

- ✓ 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

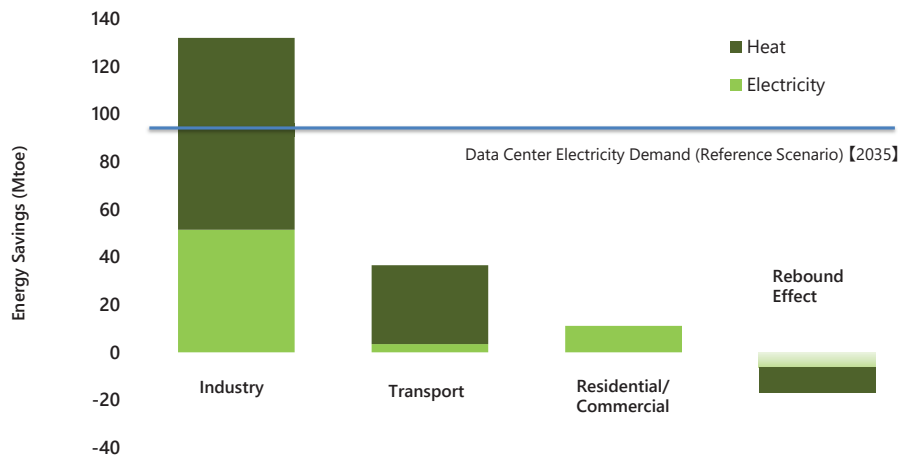


Source : IEEJ (2025).

53

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).

54

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

55

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

58

Geographical coverage

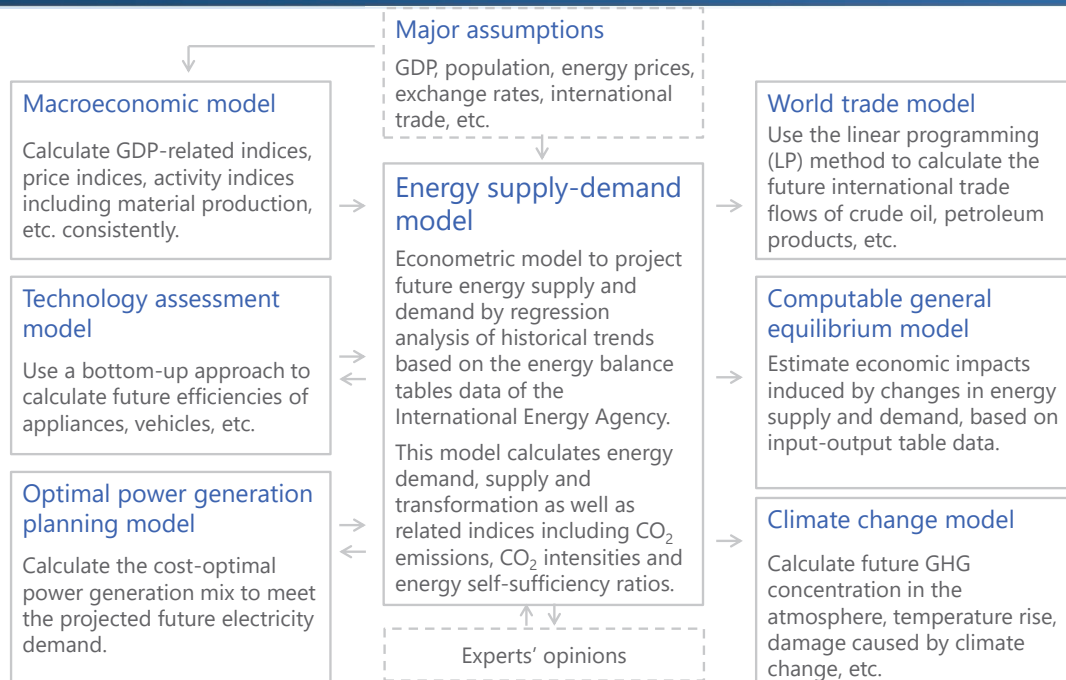
- Countries/regions in the world are geographically aggregated into 44 regions.
- Especially the Asian energy supply/demand structure is considered in detail, aggregating the area into 17 regions. That of the Middle East is also aggregated into eight regions.



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

59

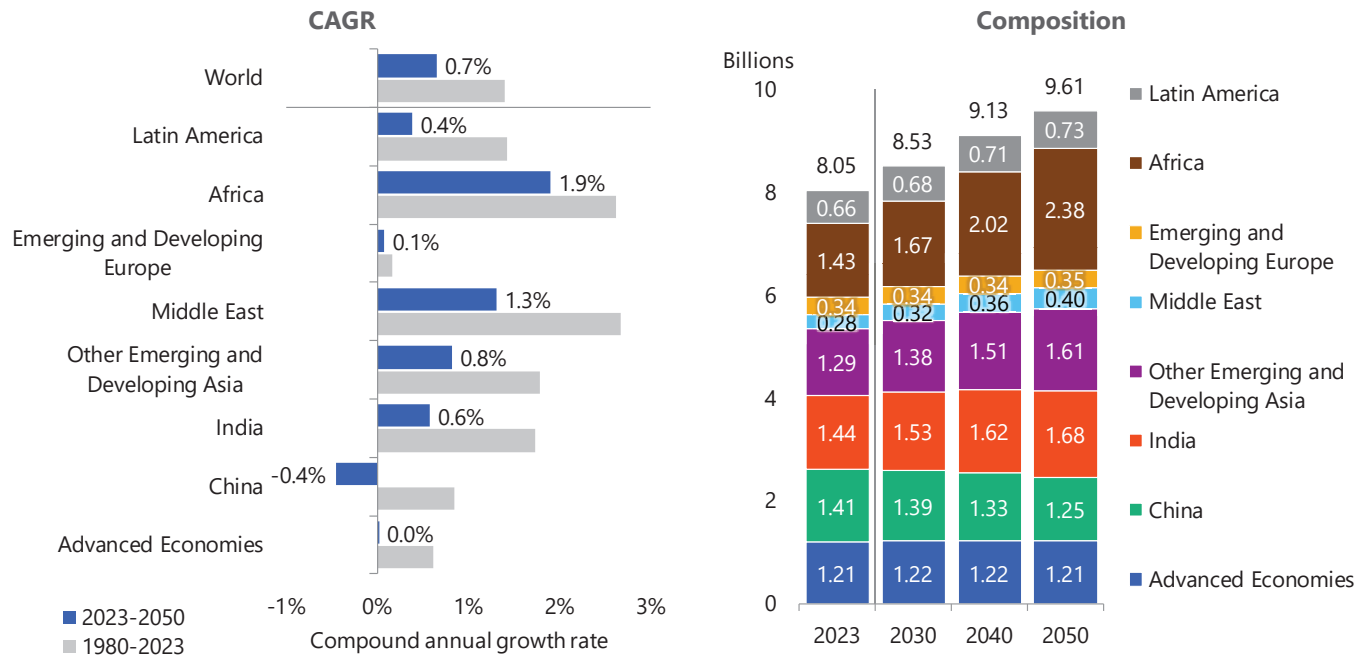
Modelling framework



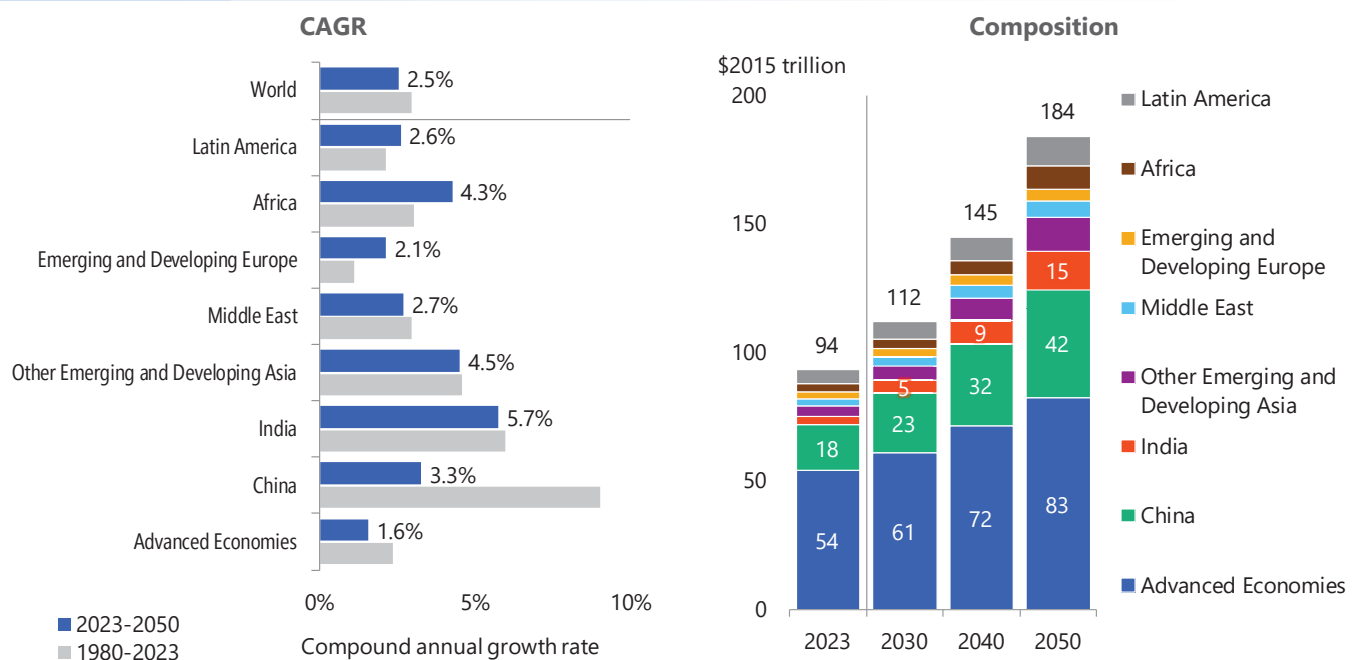
Basic scenarios in IEEJ Outlook

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

Population

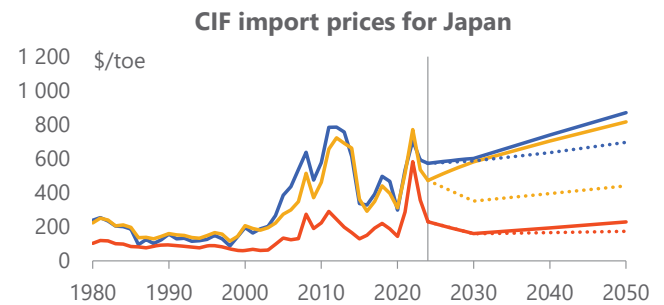
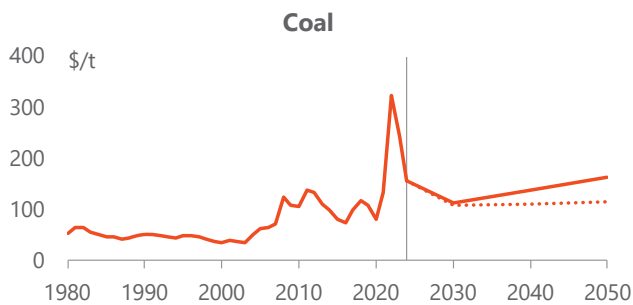
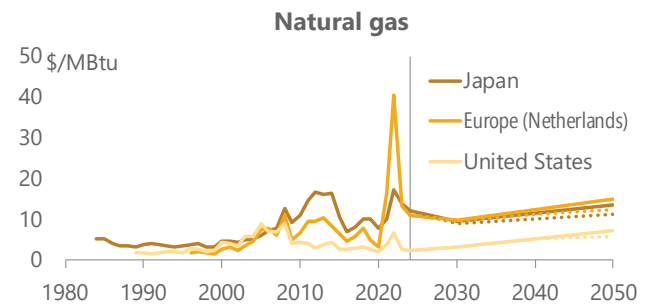
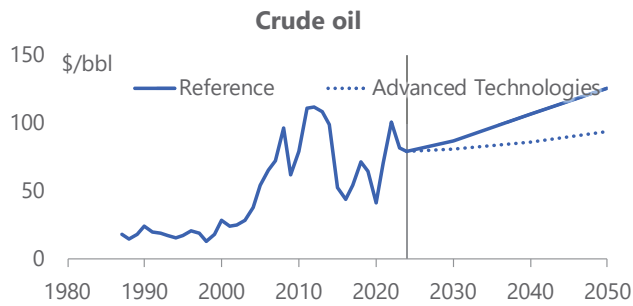


Real GDP



International energy prices

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



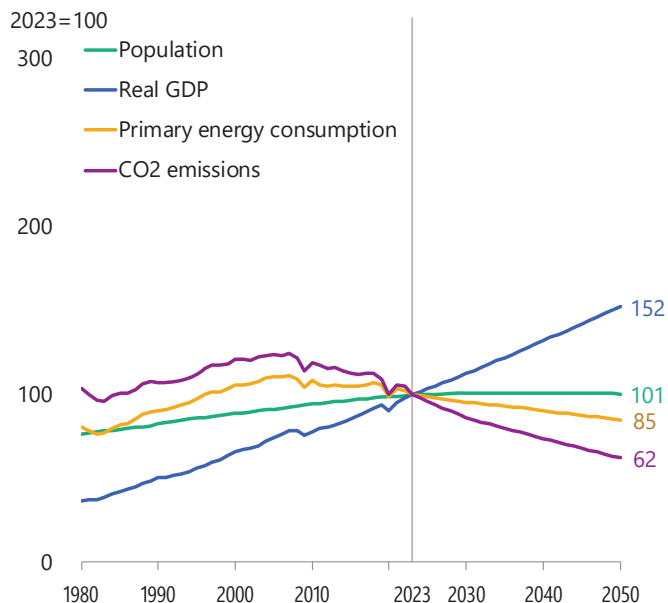
Note: Historical prices are nominal. Assumed future prices are real in \$2025.

Energy and environmental technology

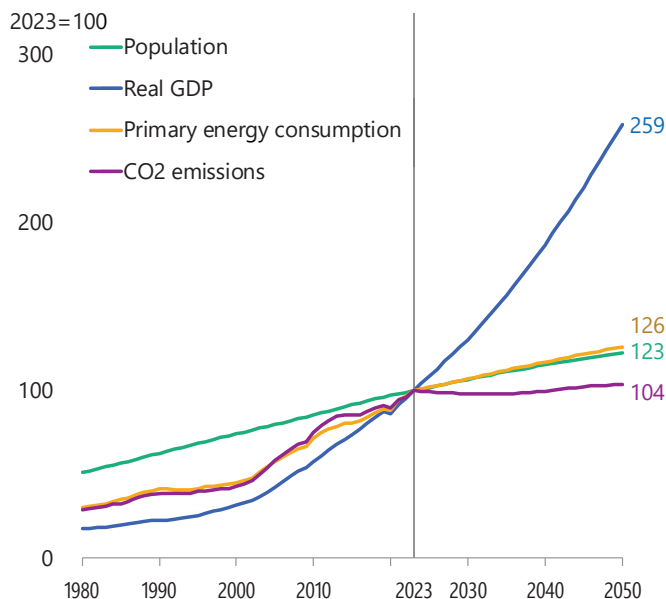
				2050		Assumptions for Advanced Technologies Scenario
				Reference	Advanced Technologies	
Improving energy efficiency	Industry	Intensity in steel industry (ktoe/kt)	0.273	0.268	0.203	100% penetration of Best Available Technology by 2050.
		Intensity in non-metallic minerals industry	0.095	0.073	0.064	
	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.
	Solar PV power generation capacity		1,374	9,785	12,456	Efficient operation of power system.
	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.

Population, GDP, energy and CO₂

Advanced Economies

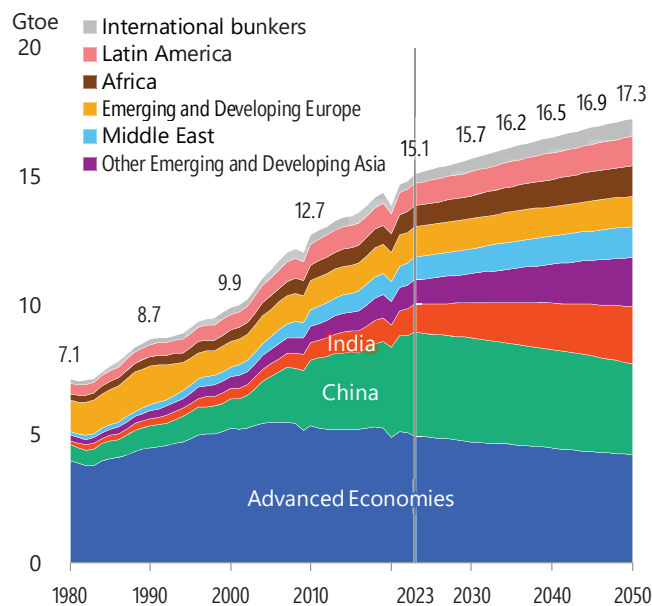


Emerging and Developing Economies

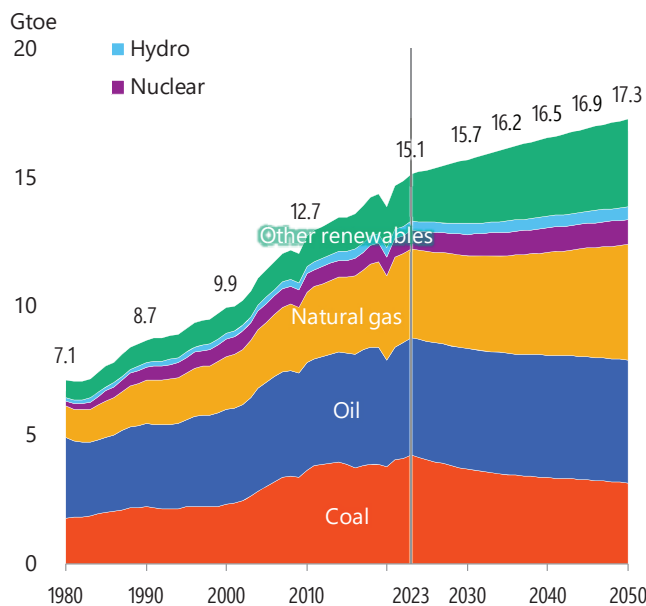


Primary energy consumption

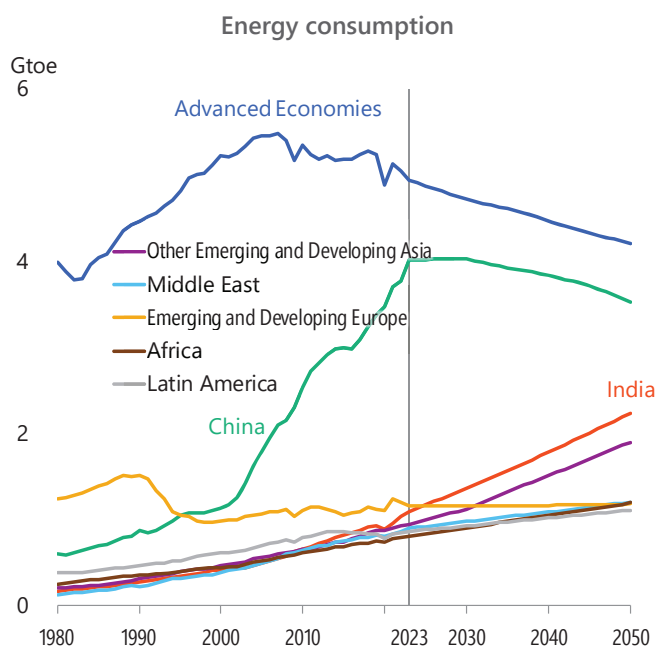
By region



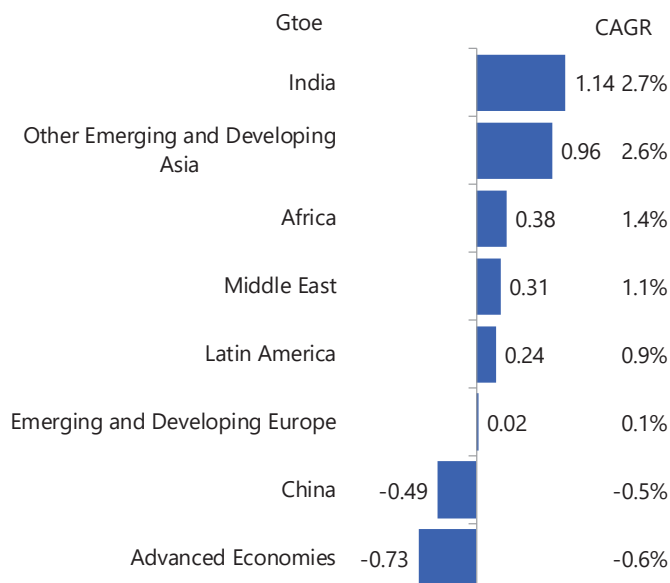
By energy source



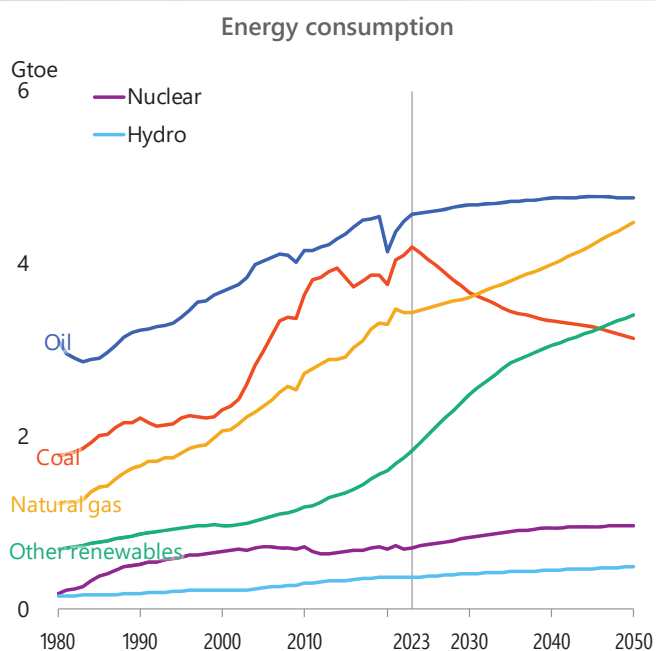
Primary energy consumption (by region)



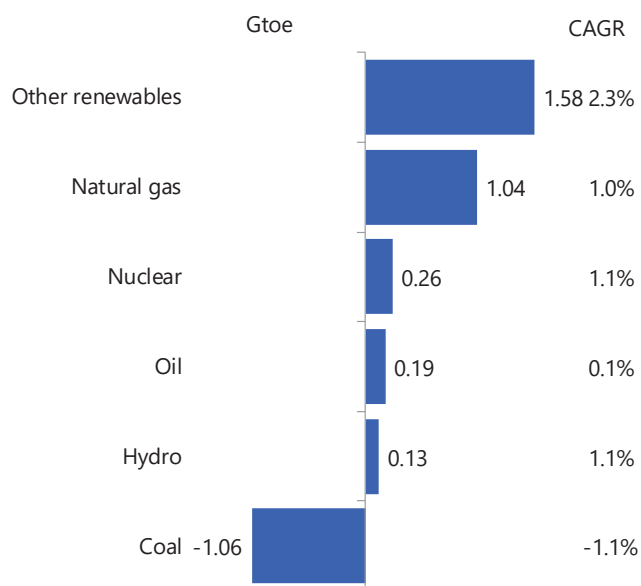
Changes (2023-2050)



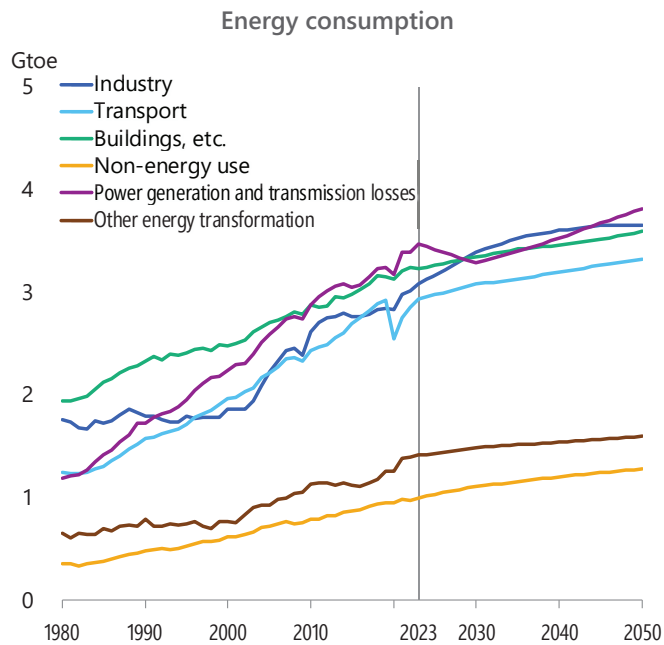
Primary energy consumption (by energy source)



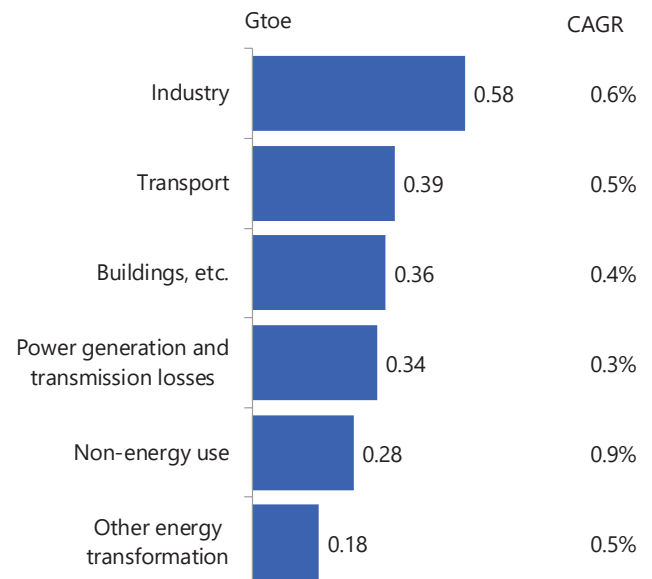
Changes (2023-2050)



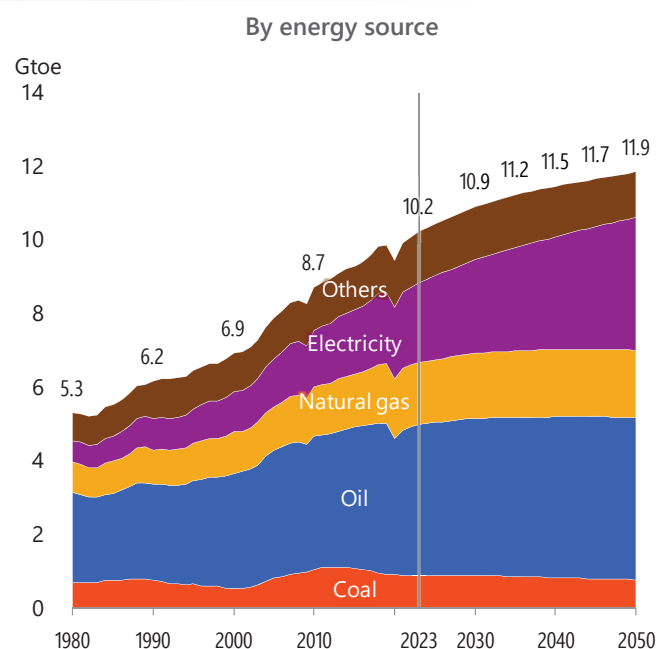
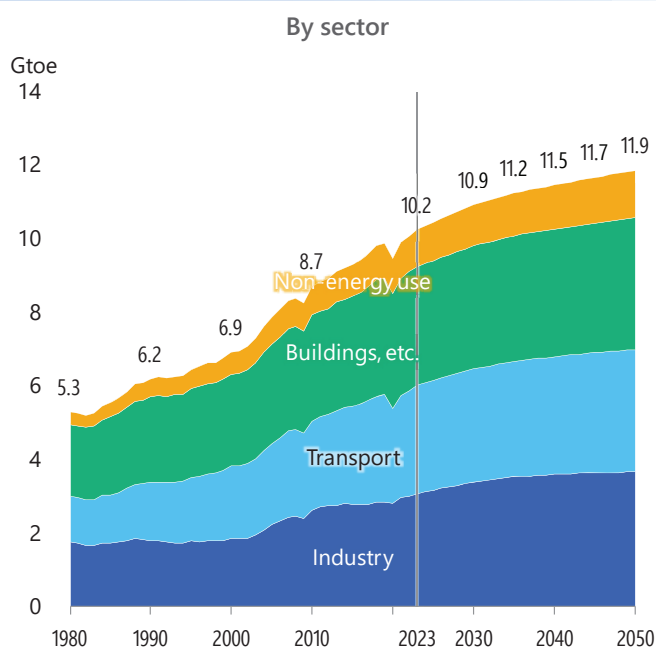
Primary energy consumption (by sector)



Changes (2023-2050)

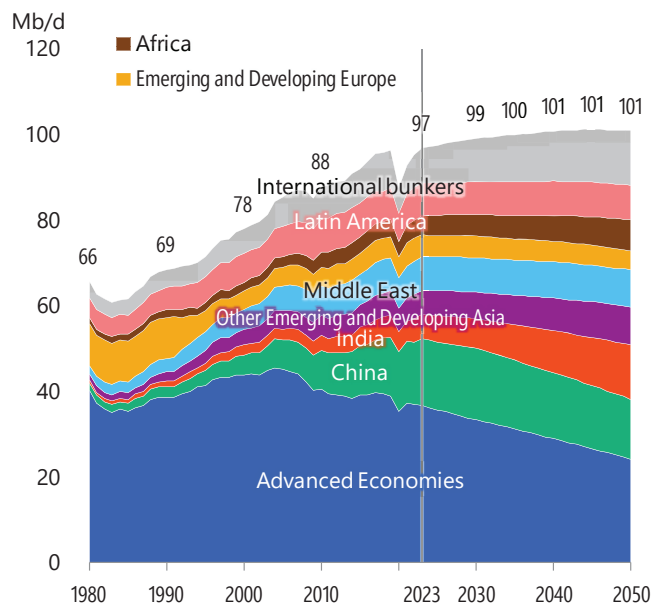


Final energy consumption

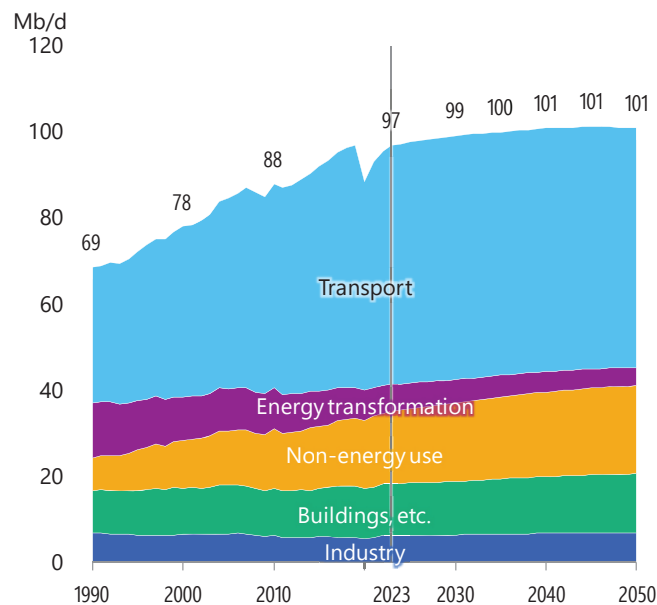


Oil consumption

By region

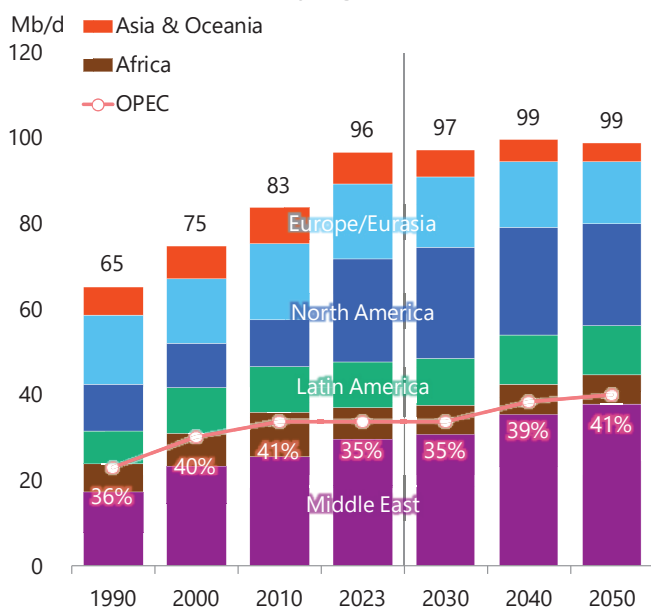


By sector

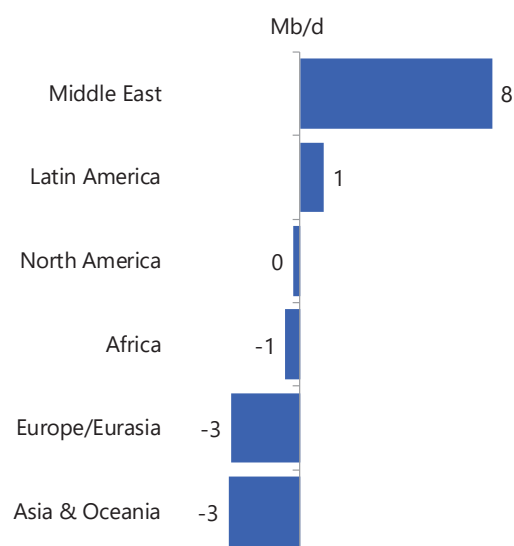


Crude oil production

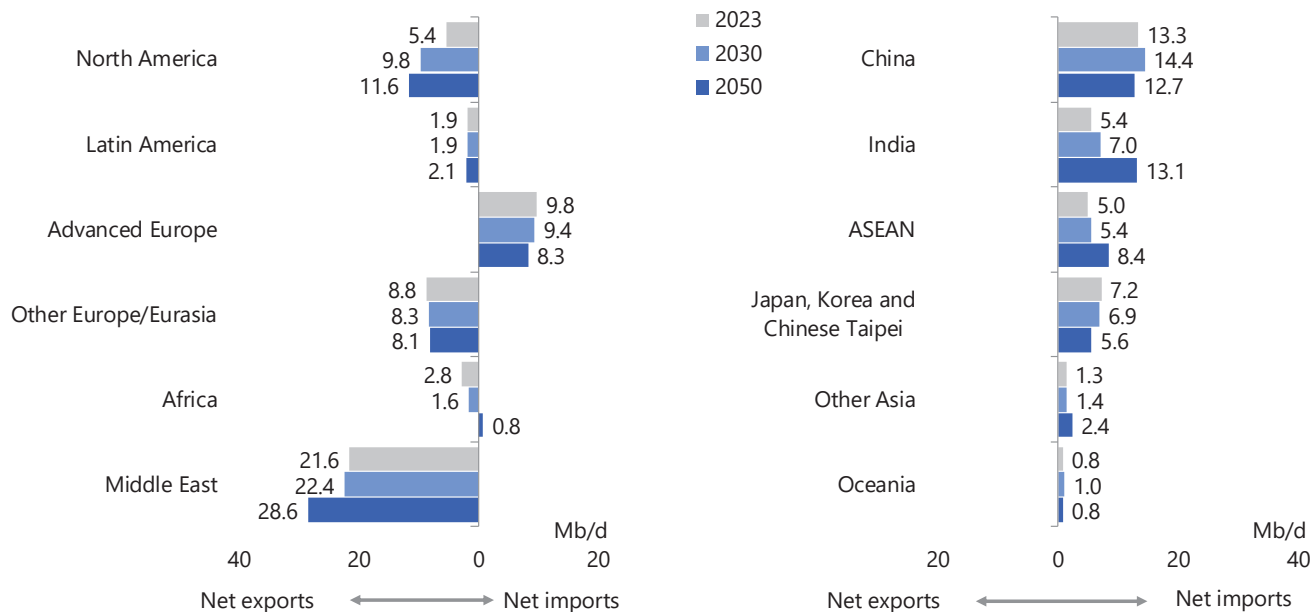
By region



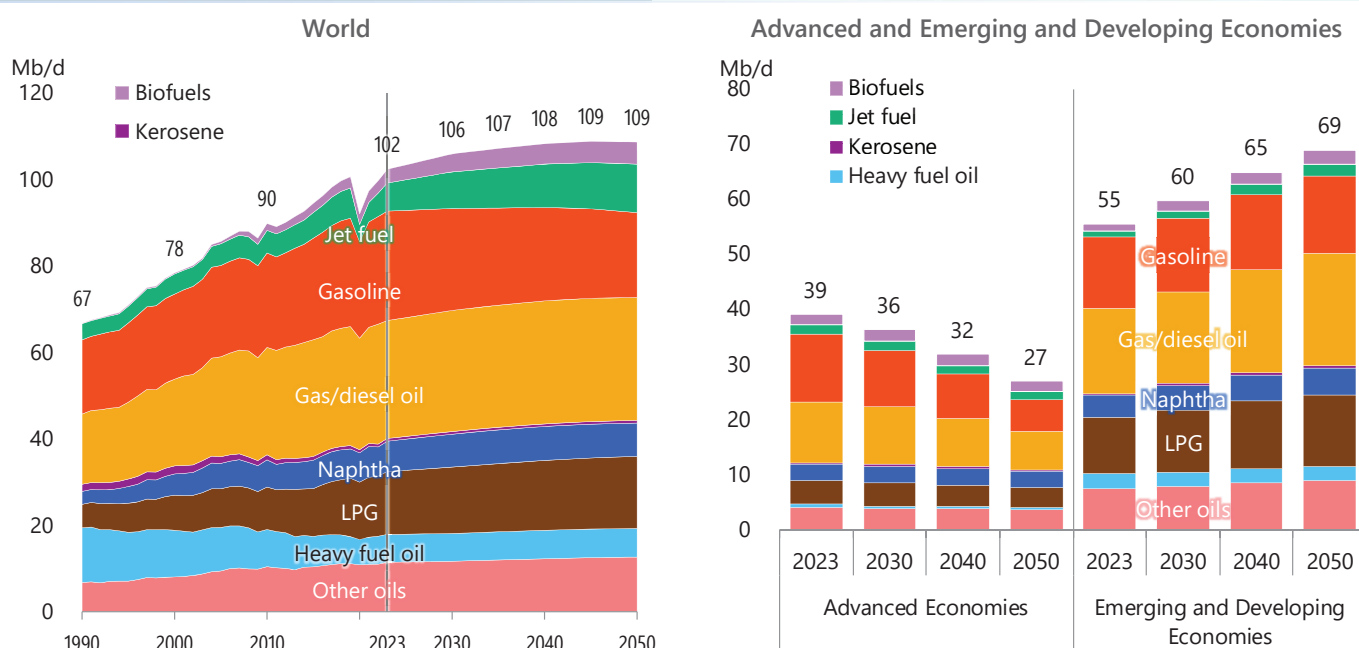
Changes (2023-2050)



Net exports and imports of oil

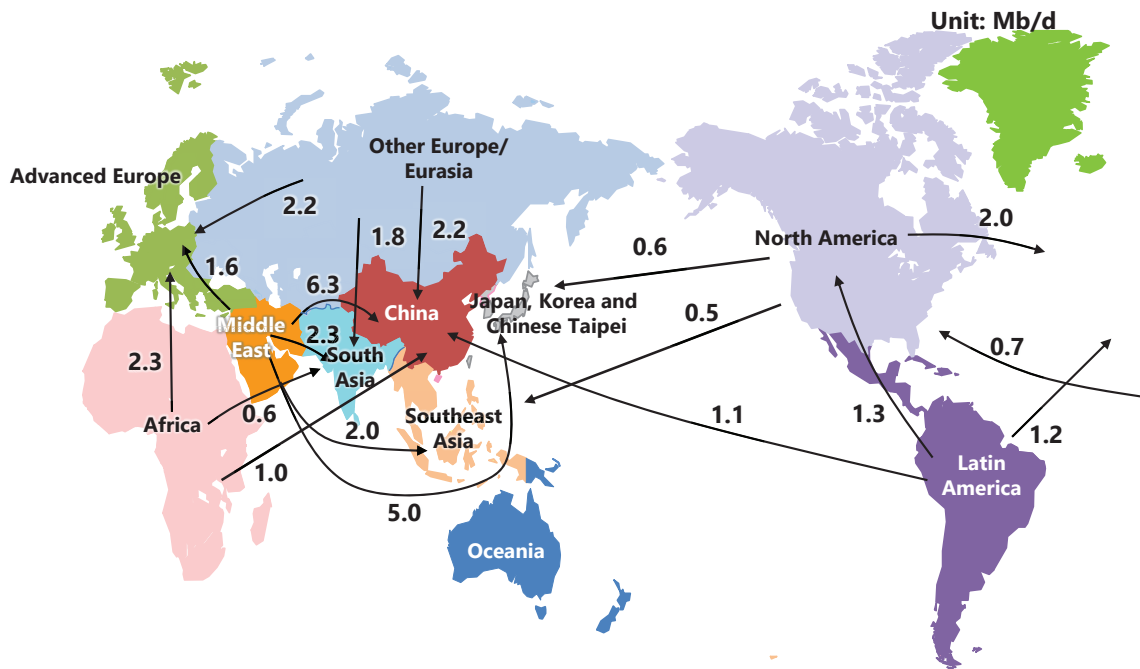


Petroleum product demand



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

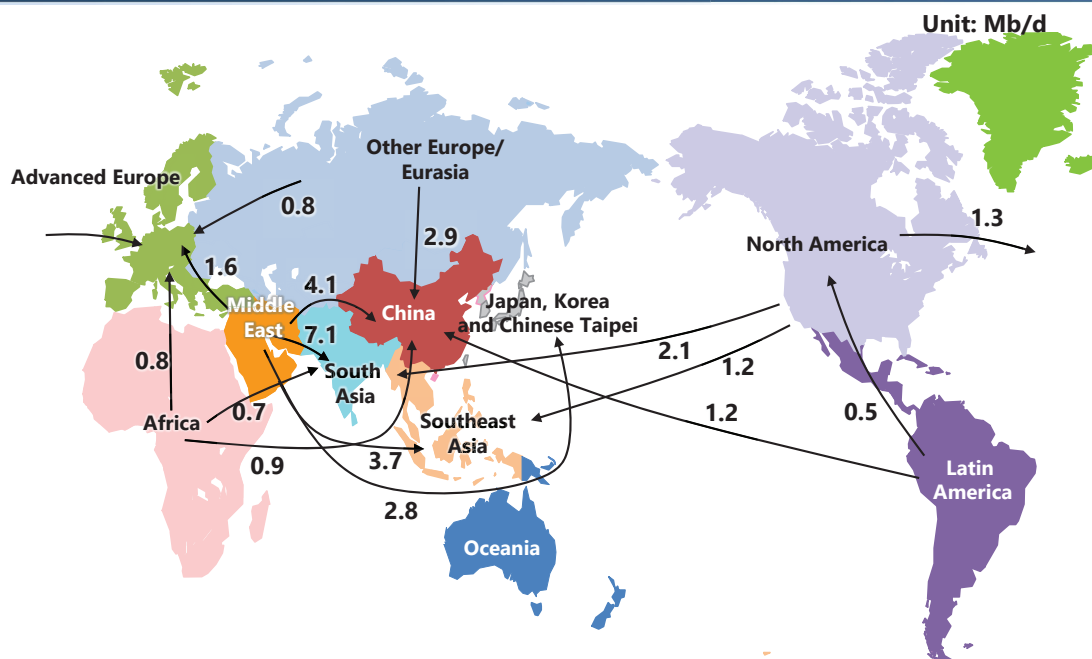
Major trade flows of crude oil (2025)



Note: 0.5 Mb/d or more are shown

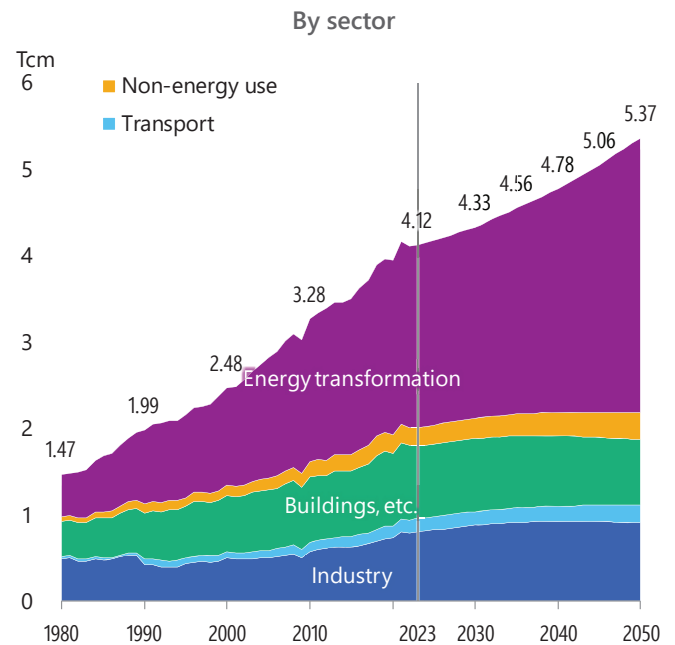
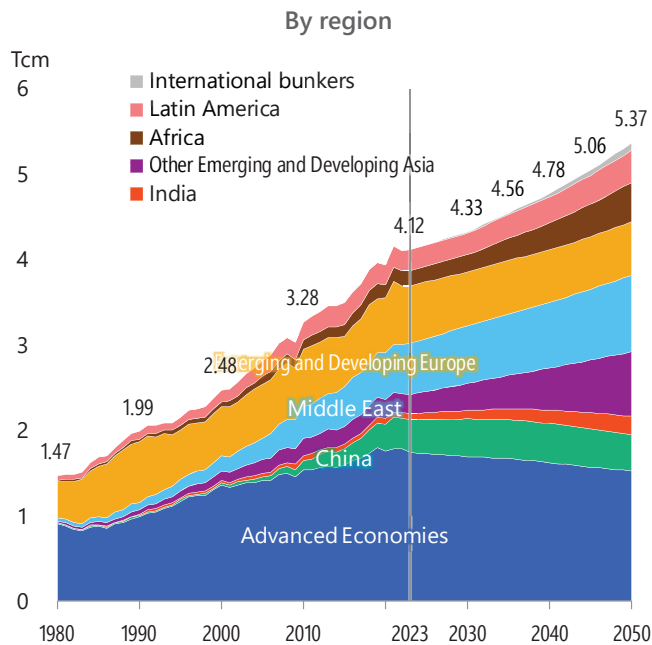
Reference Scenario

Major trade flows of crude oil (2050)

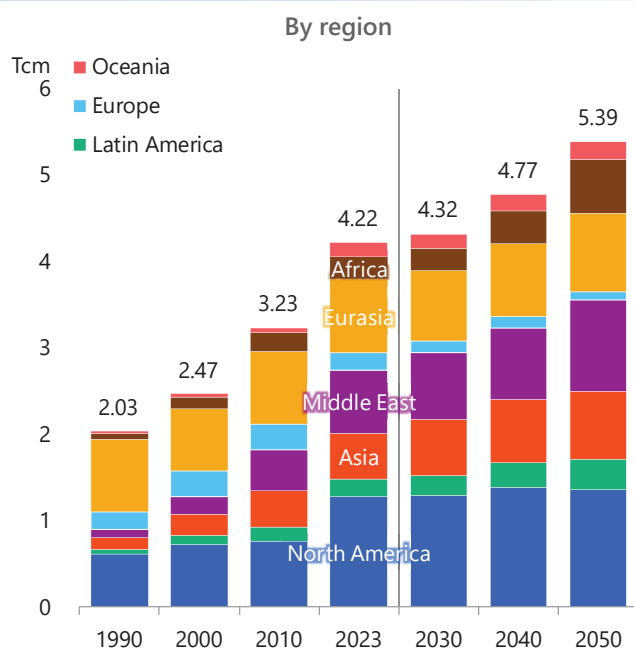


Note: 0.5 Mb/d or more are shown

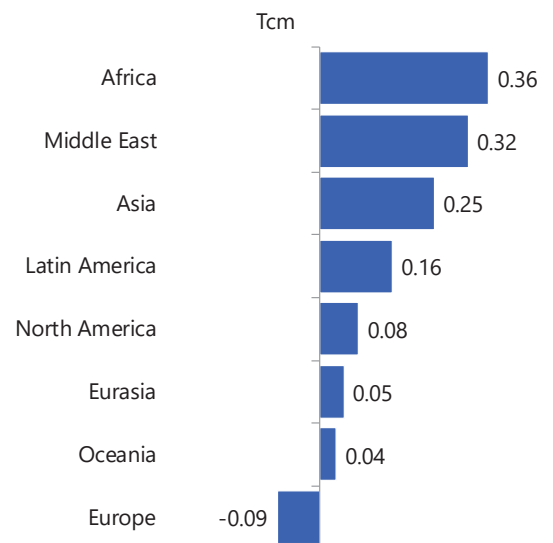
Natural gas consumption



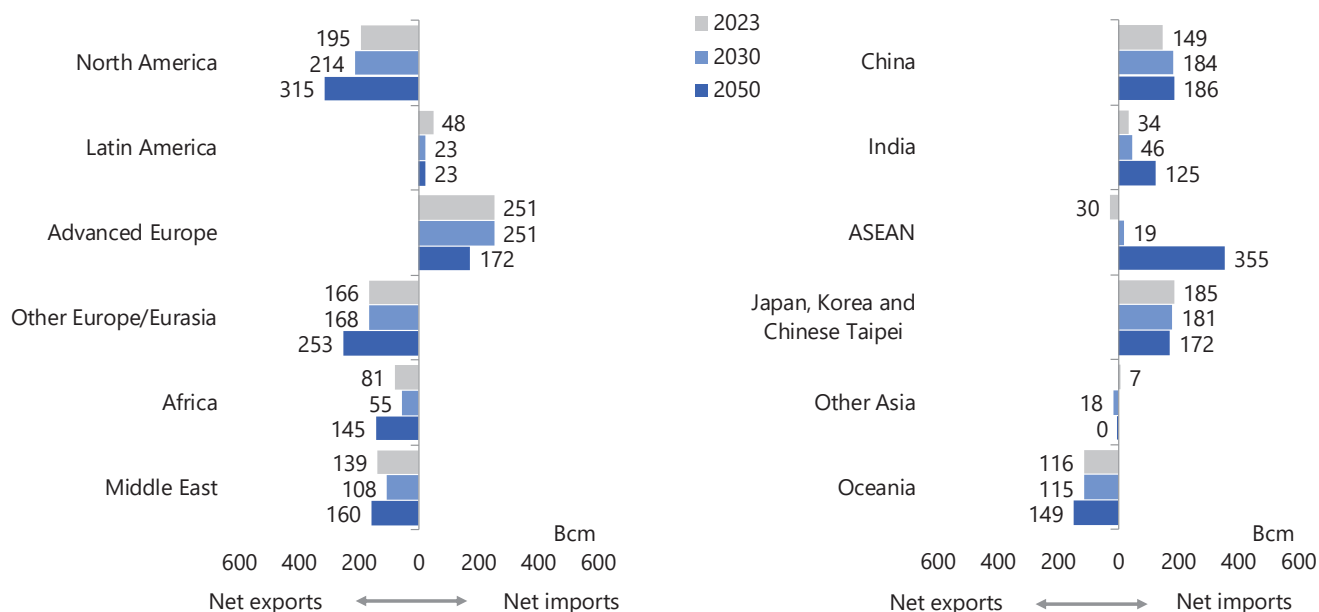
Natural gas production



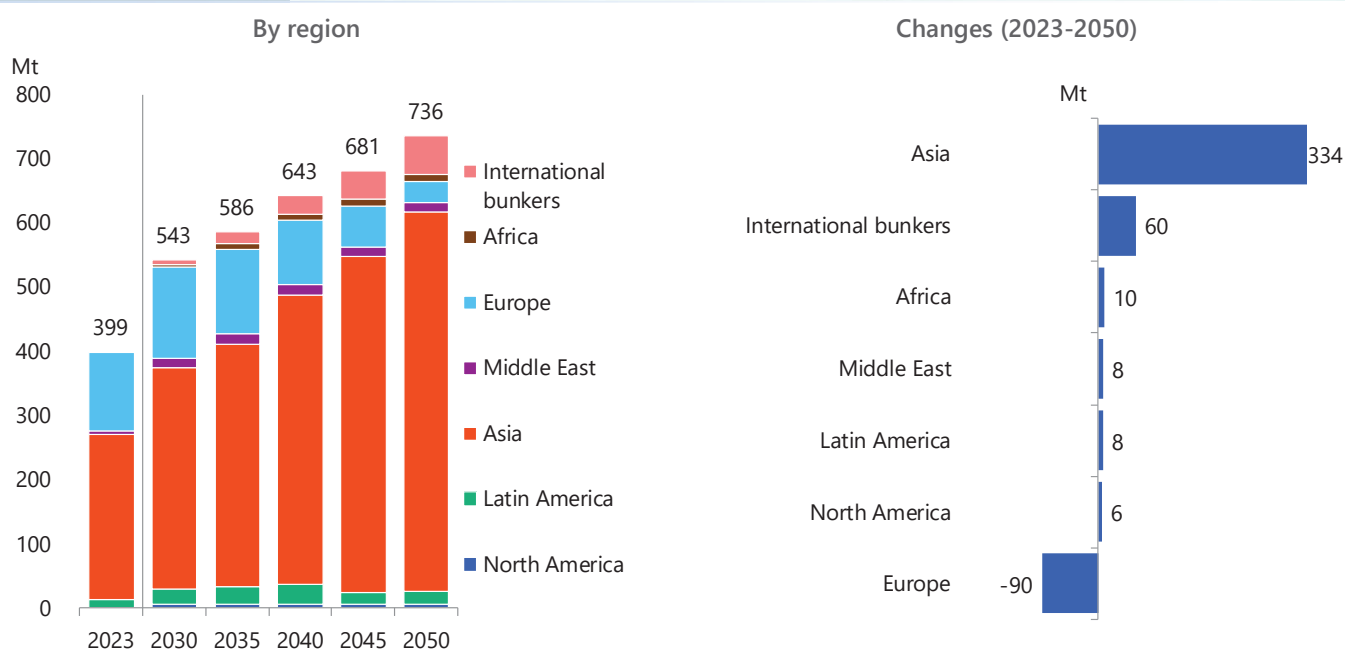
Changes (2023-2050)



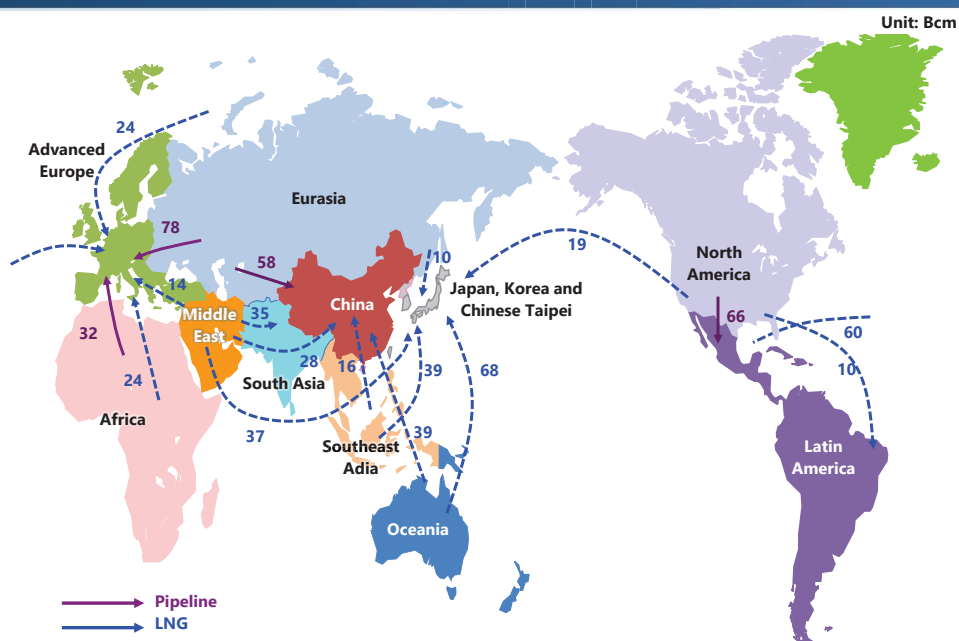
Net exports and imports of natural gas



LNG demand

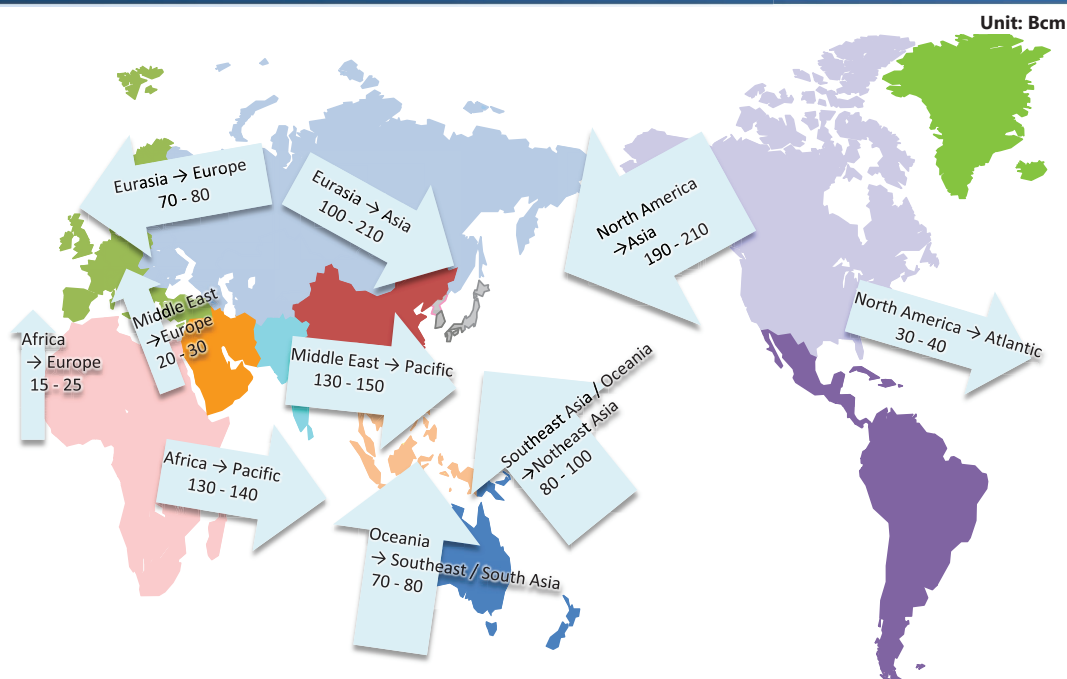


Major trade flows of natural gas (2025)



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

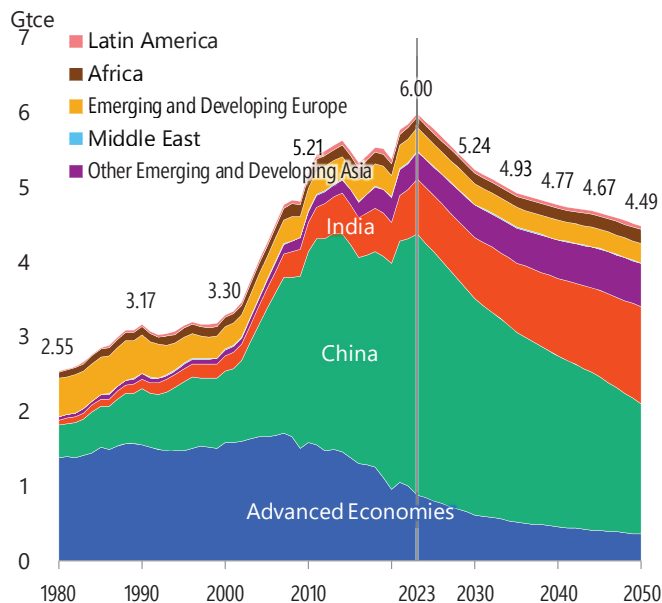
Major trade flows of natural gas (2050)



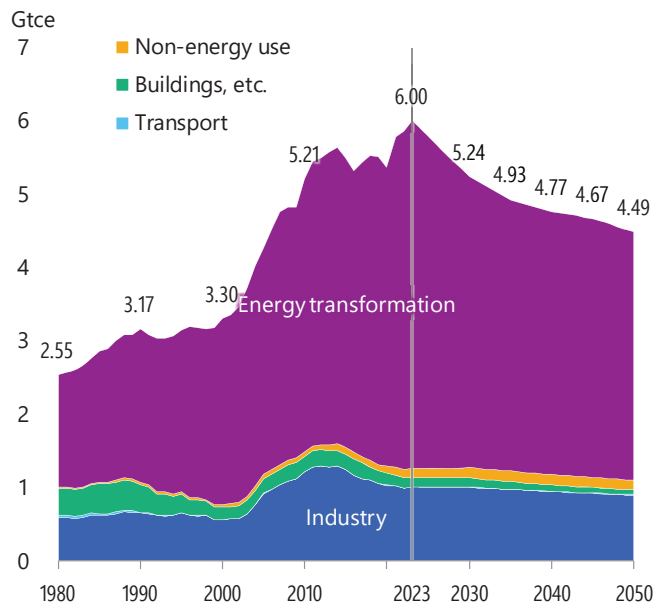
Note: This figure shows the main interregional trade and does not include the total trade volume.

Coal consumption

By region

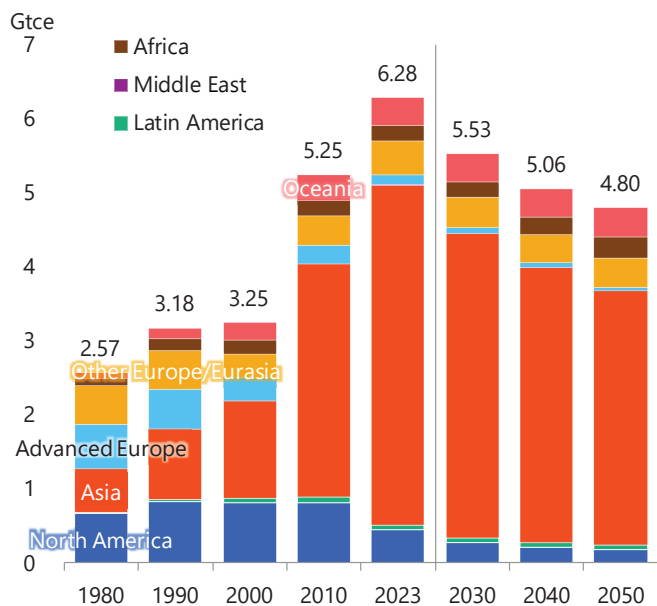


By sector

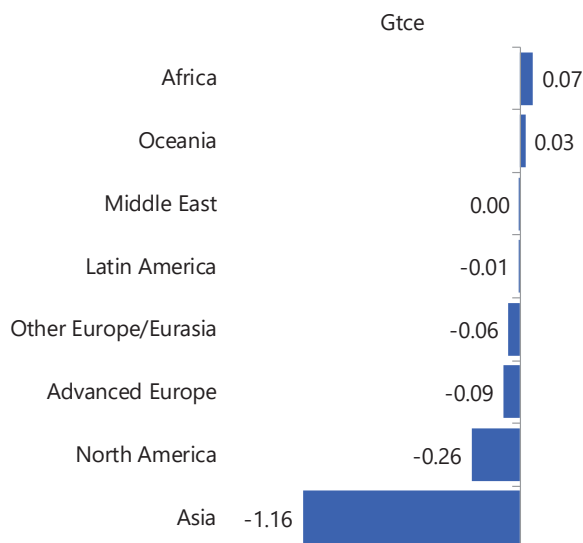


Coal production

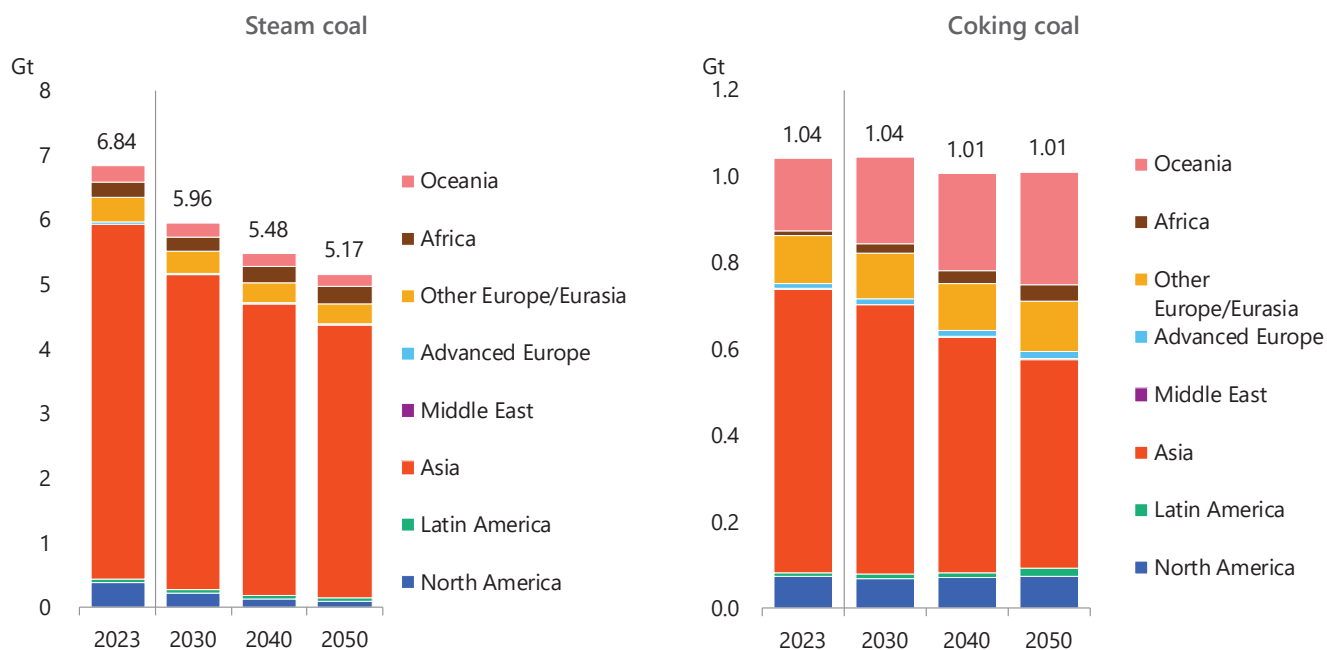
By region



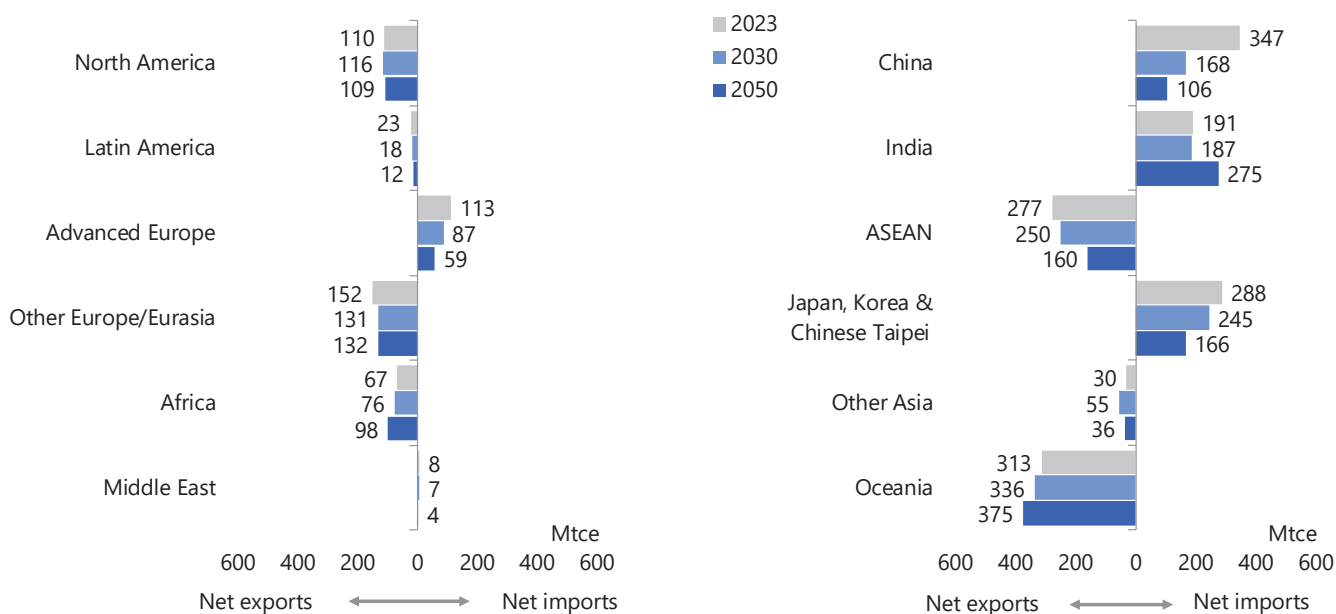
Changes (2023-2050)



Coal production (steam and coking coal)

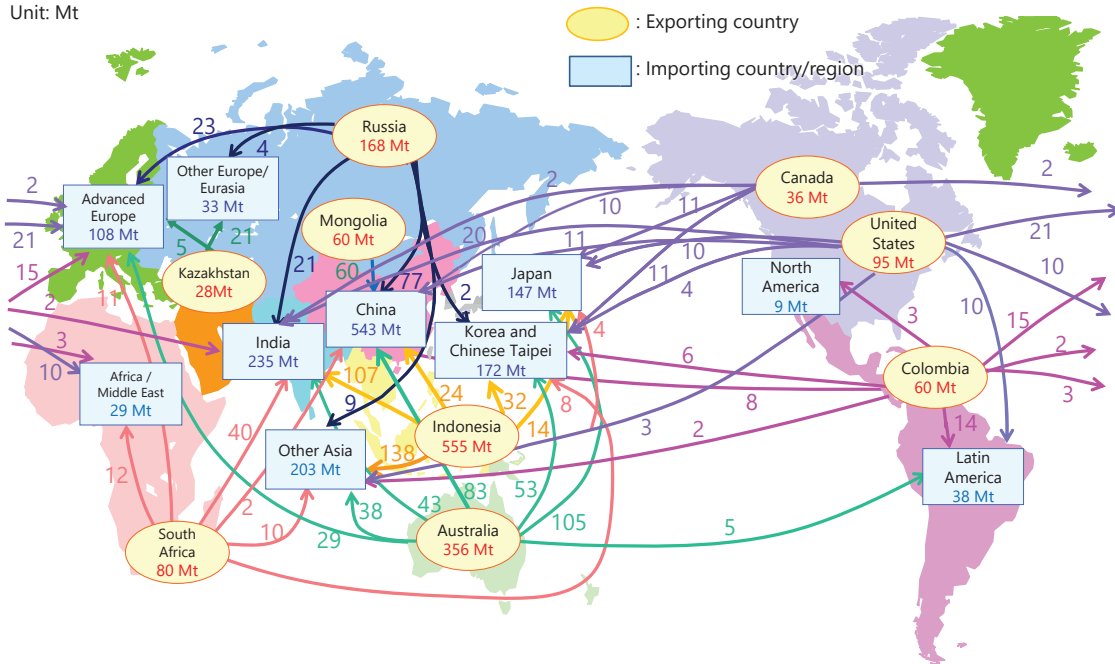


Net exports and imports of coal



Major trade flows of steam and coking coal (2025)

Unit: Mt

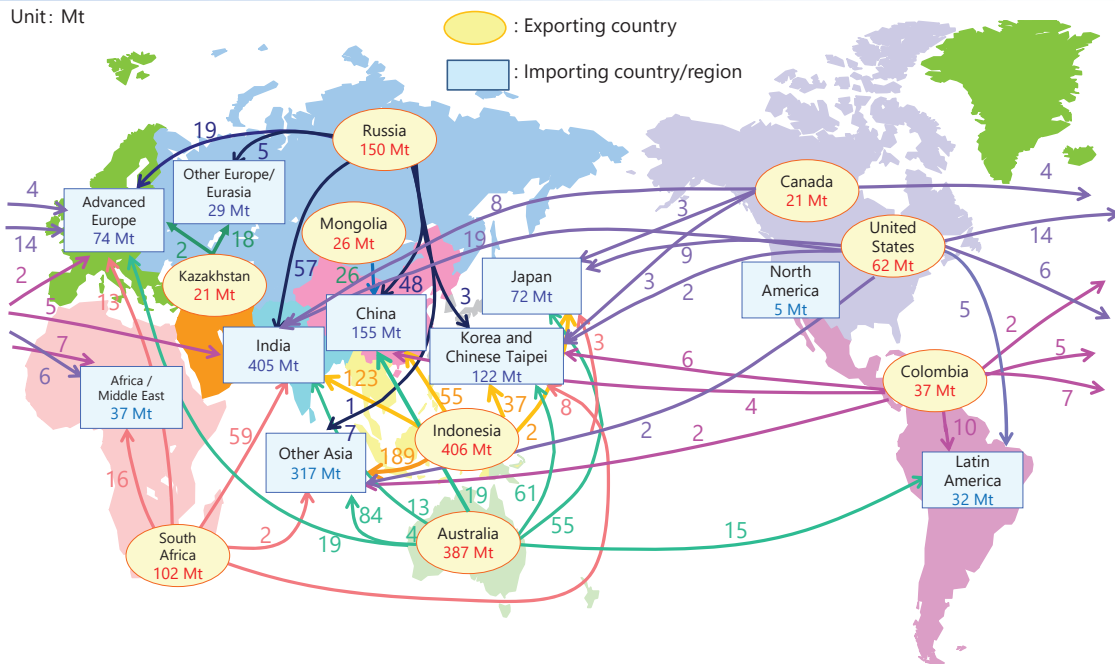


Notes: Total value of steam and coking coal. 2 Mt or more are shown. South Africa includes Mozambique. Source: Estimated from IEA "Coal Information 2025", "TEX Report", etc.

Reference Scenario

Major trade flows of steam and coking coal (2050)

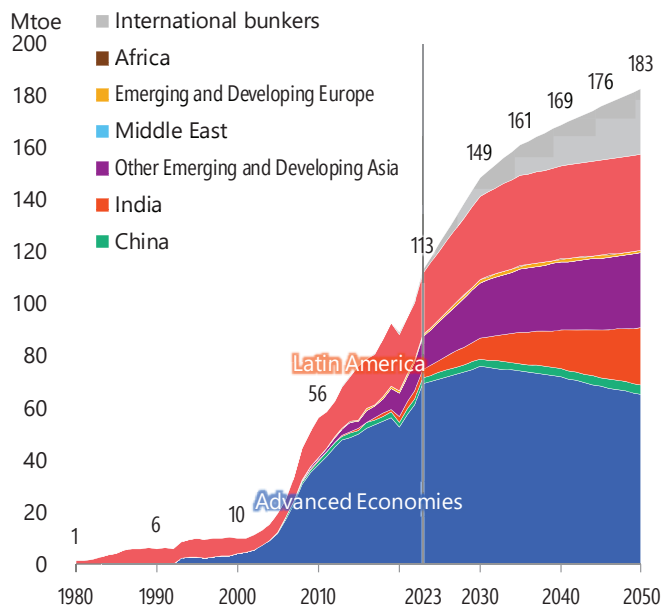
Unit: Mt



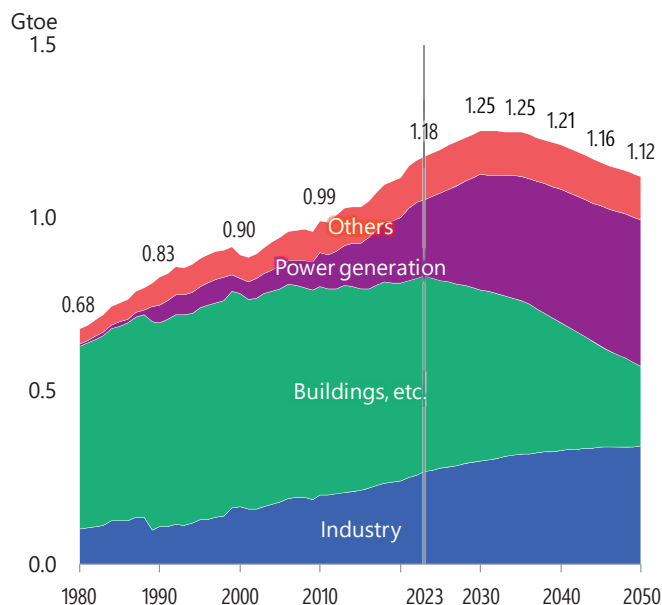
Notes: Total value of steam and coking coal. 2 Mt or more are shown. South Africa includes Mozambique.

Biomass consumption

Biofuels for transport

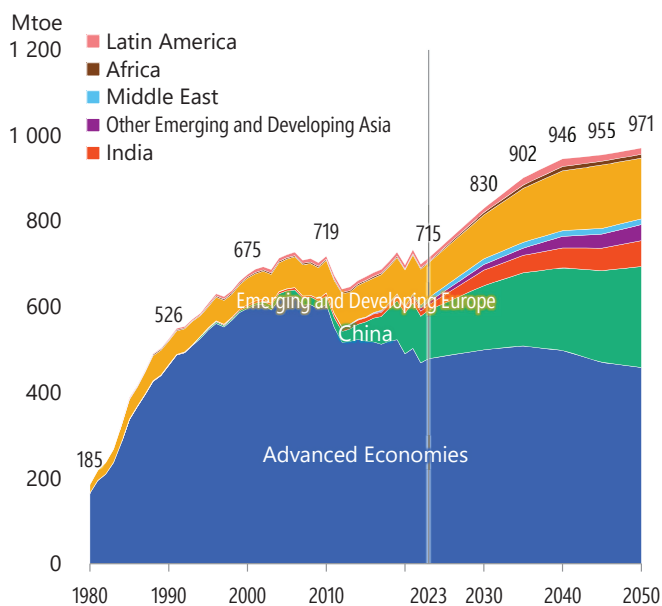


Solid biomass

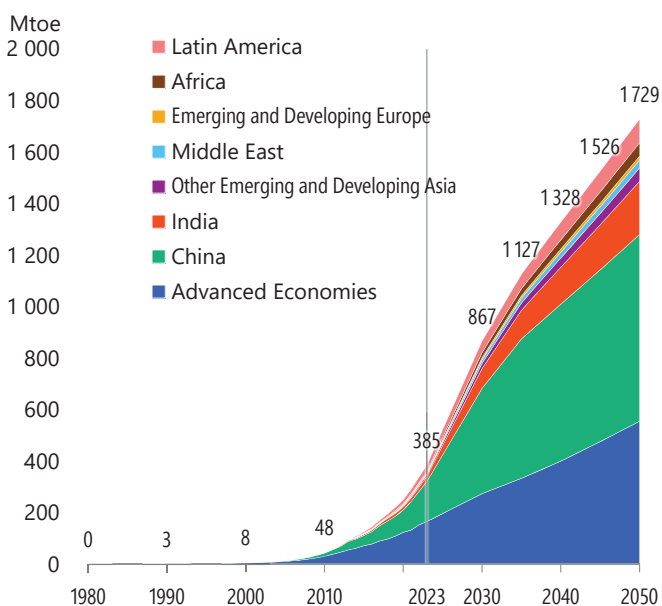


Consumption of nuclear and solar/wind/other

Nuclear

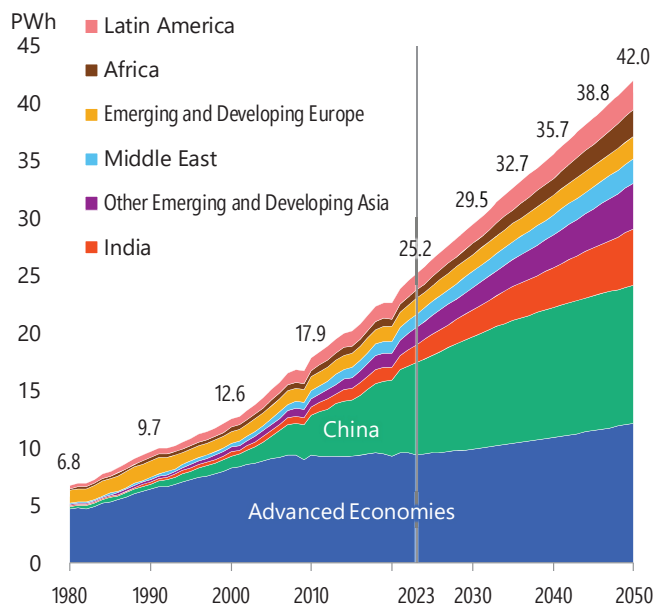


Solar/wind/other

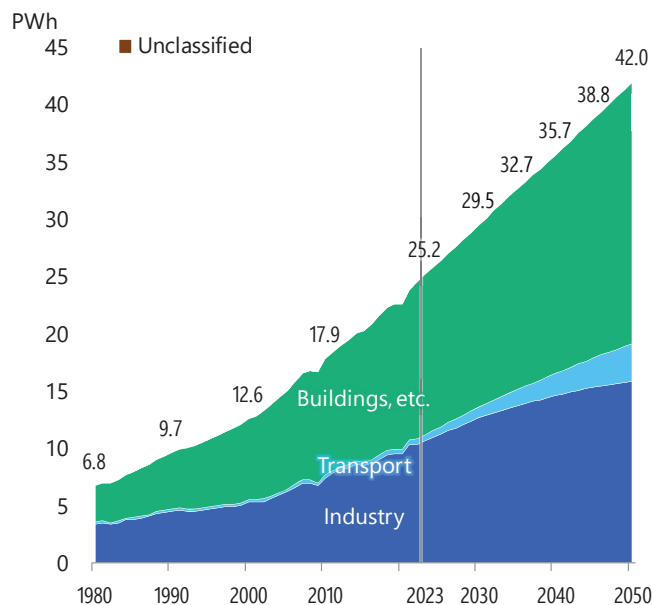


Final consumption of electricity

By region

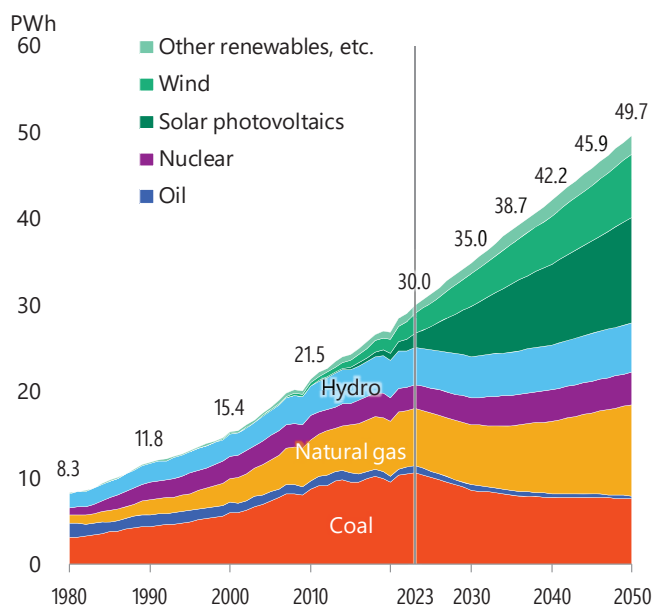


By sector

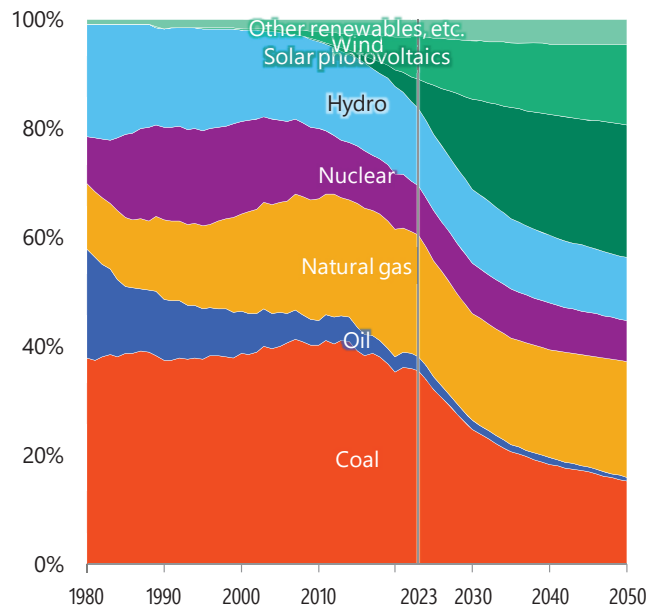


Power generation mix

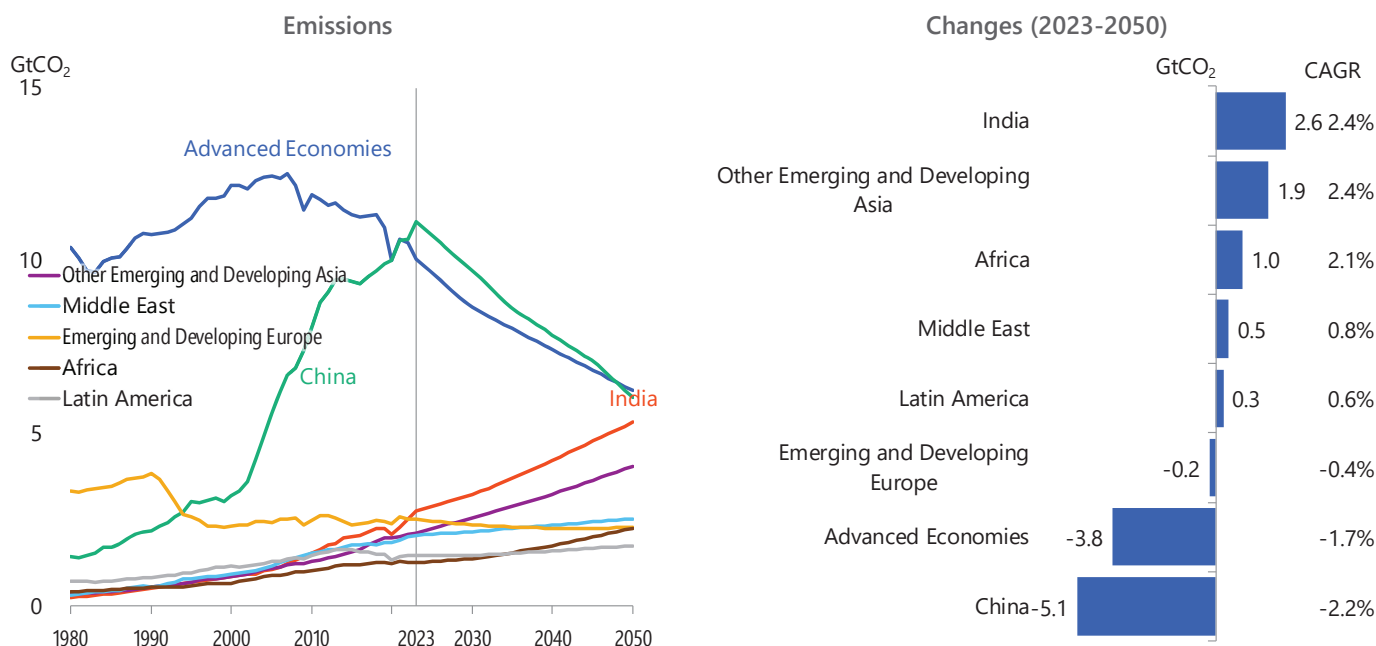
Electricity generated



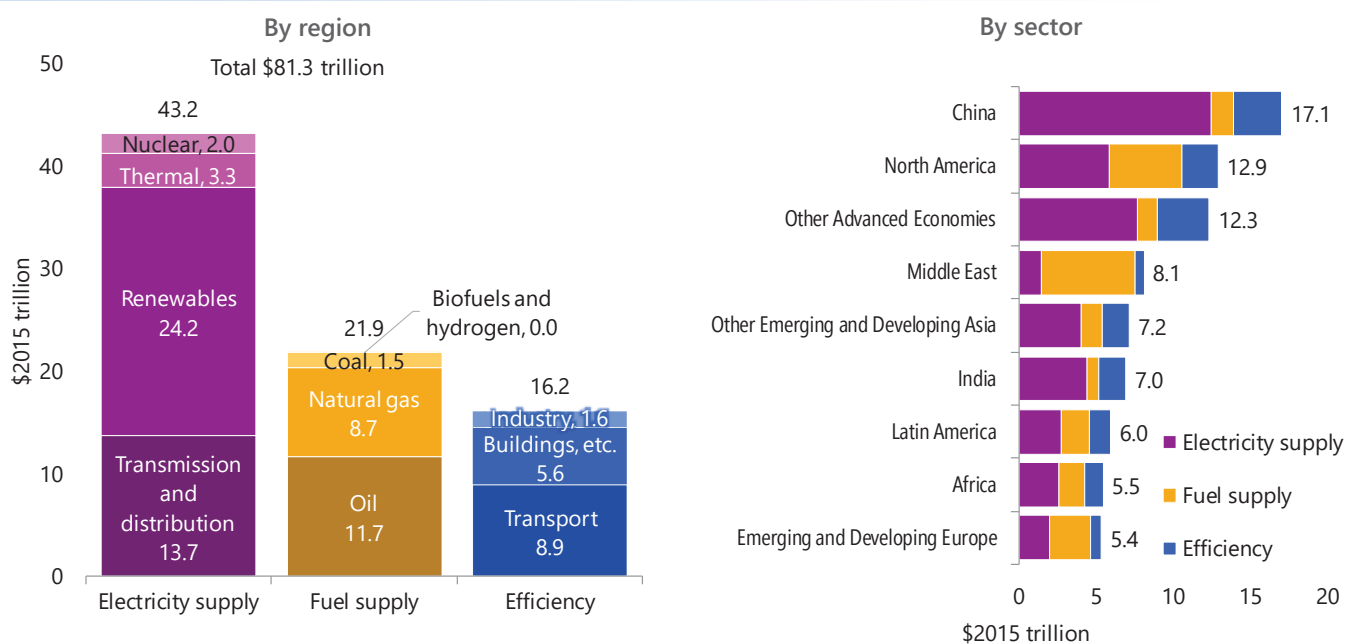
Shares



Energy-related CO₂ emissions

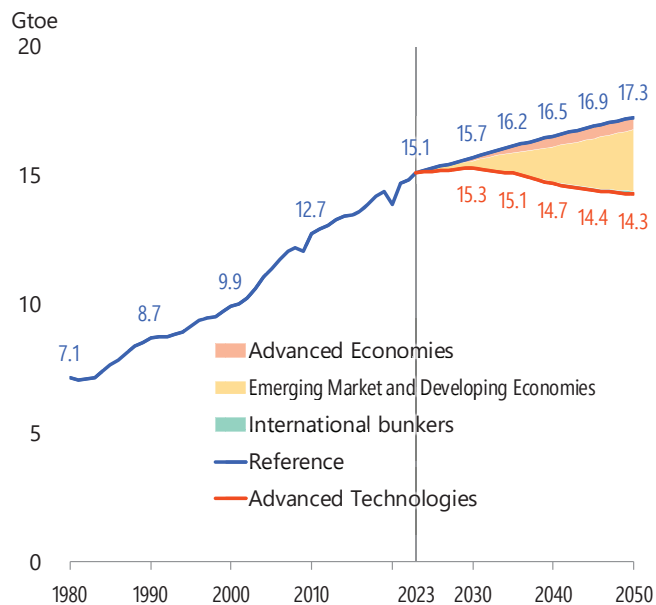


Energy-related investments (2025–2050)

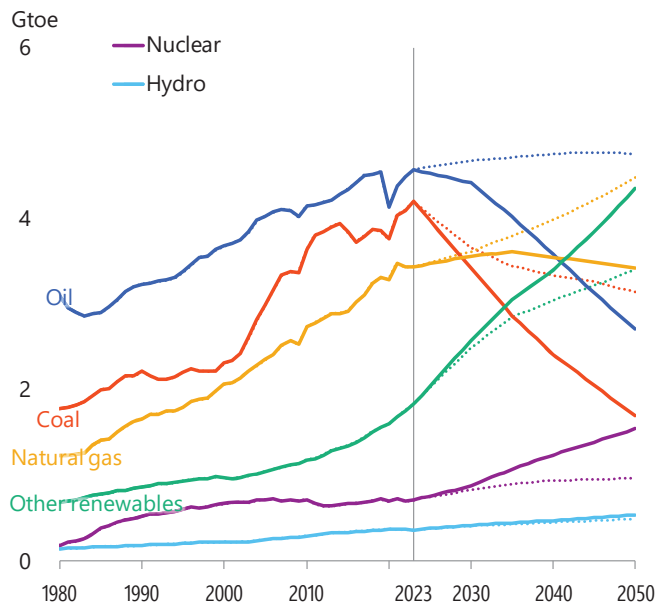


Primary energy consumption

By region



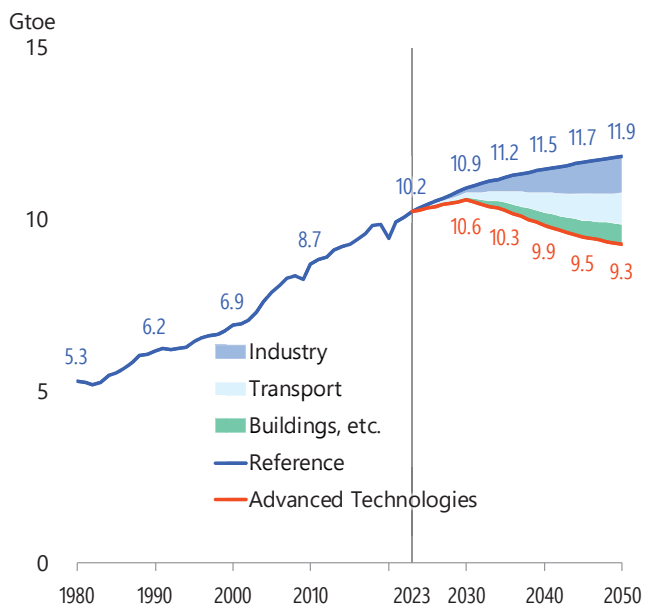
By energy source



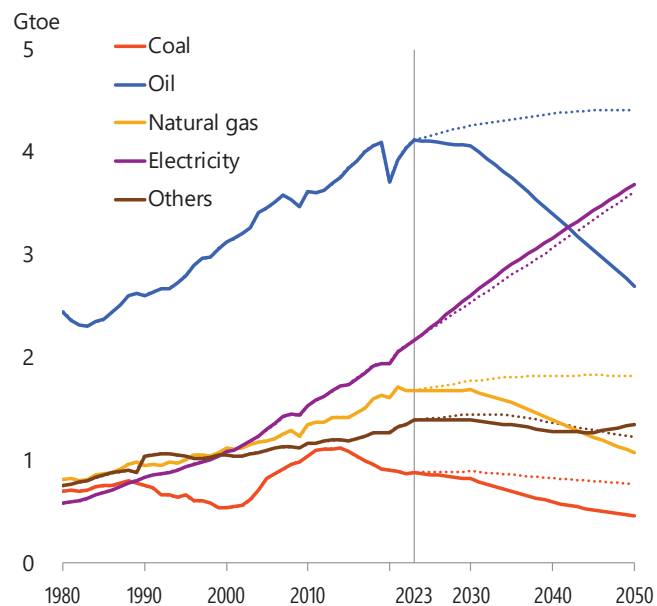
Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

Final energy consumption

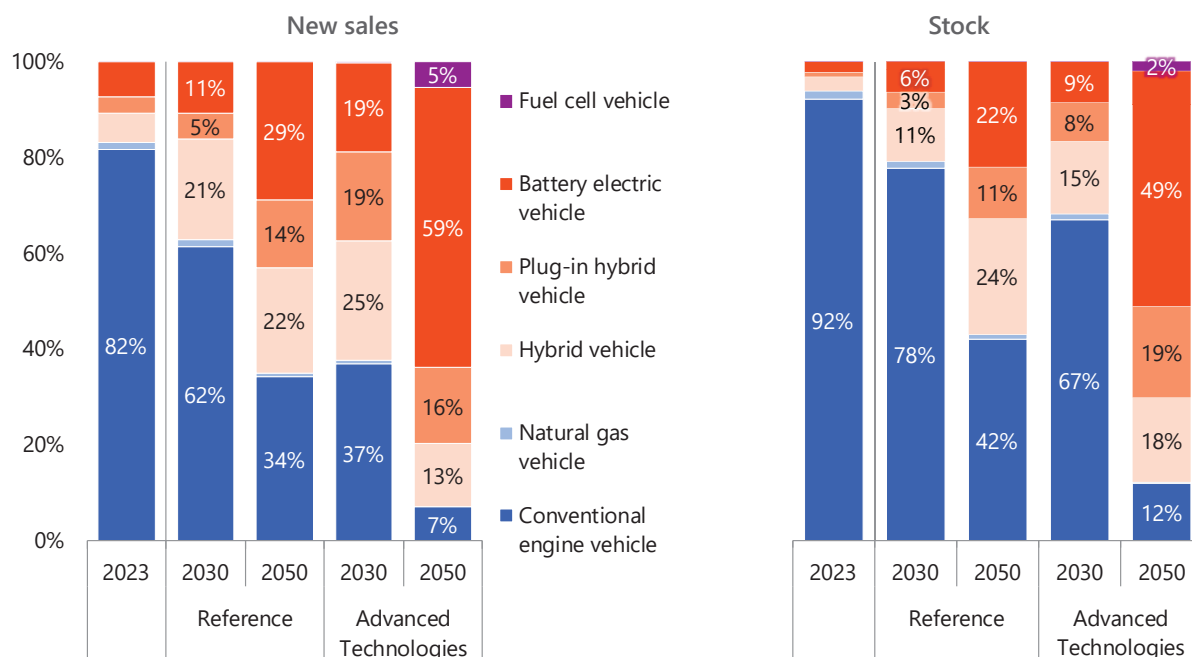
By sector



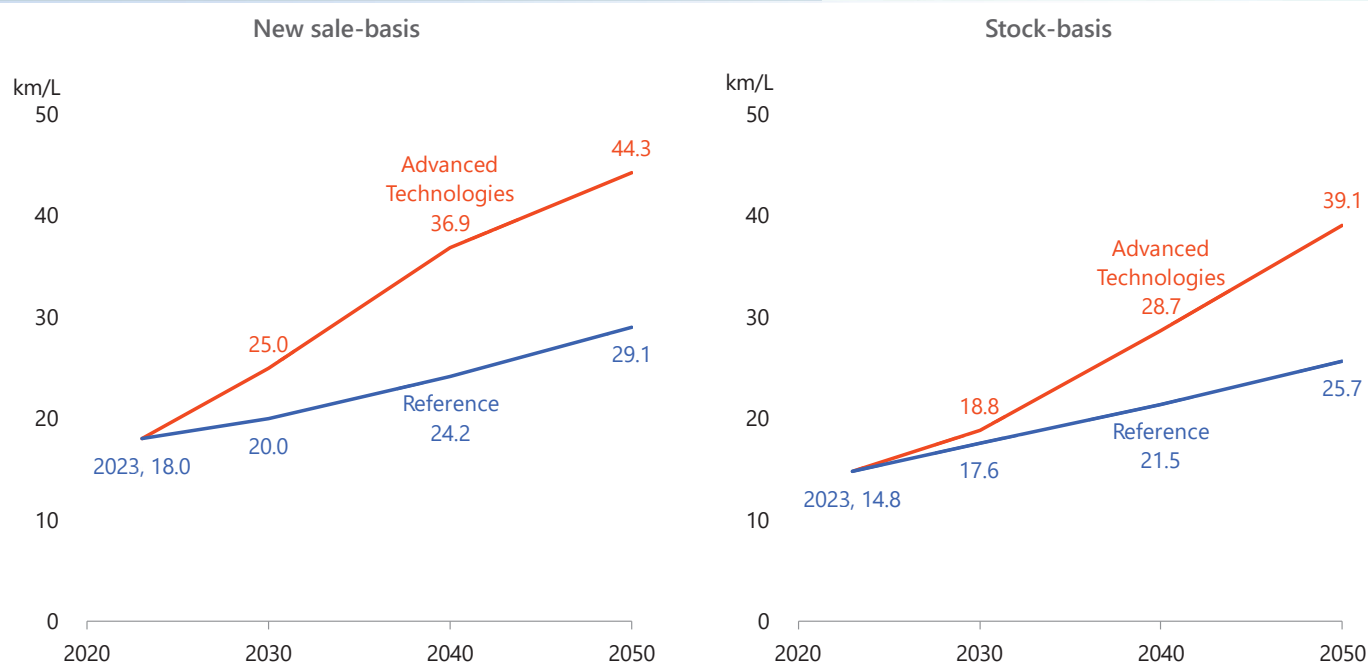
By energy



Share of passenger vehicle



Fuel efficiency of passenger vehicle

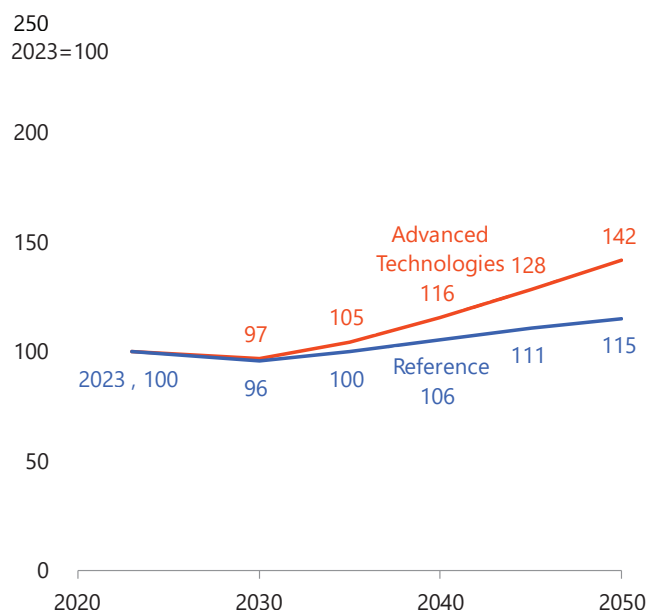
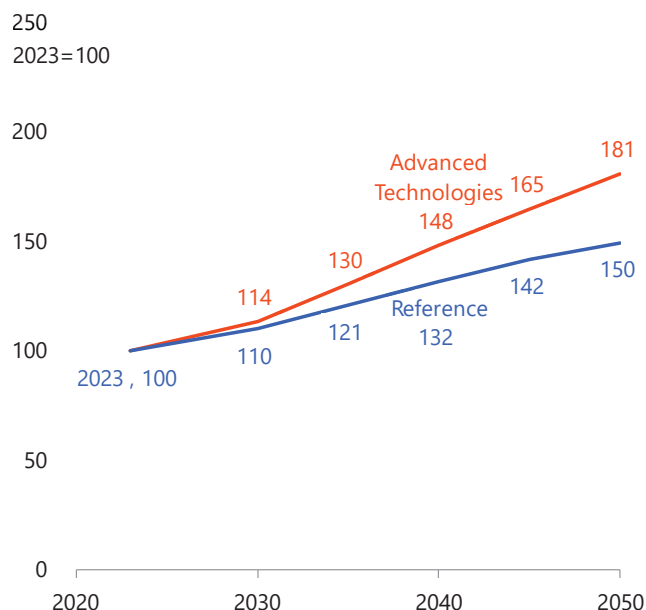


Note: Litres of gasoline equivalent

Energy efficiency in buildings sector

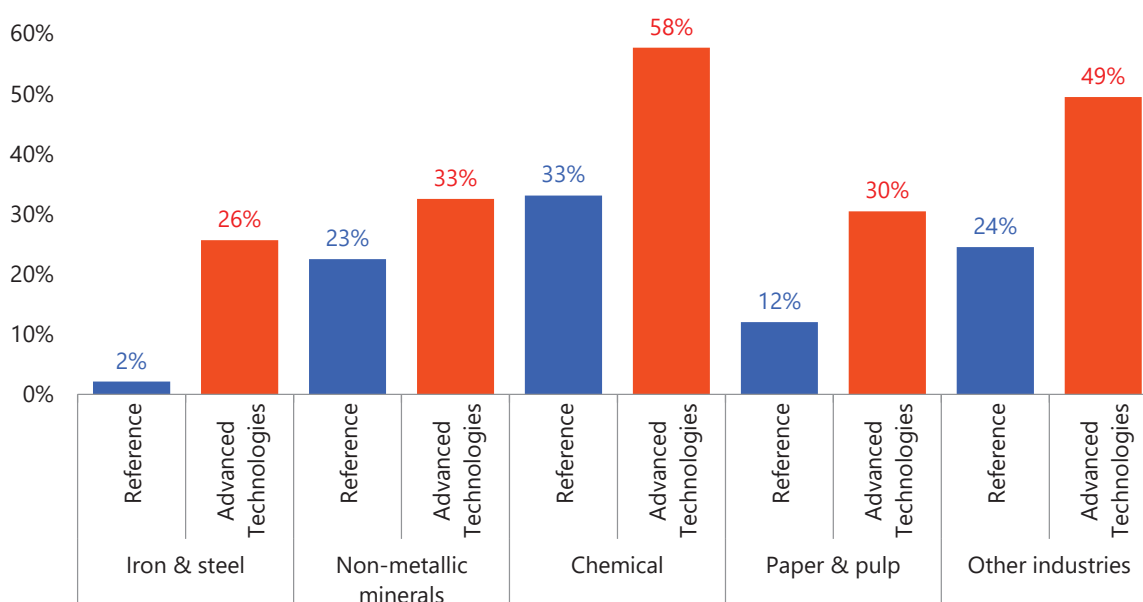
Residential

Commercial



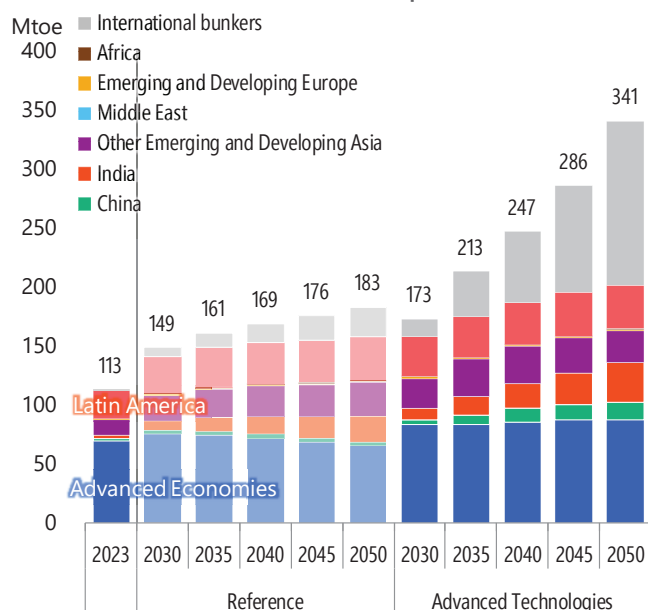
Energy intensity improvement in industry sector

Improvement rate vs. 2023

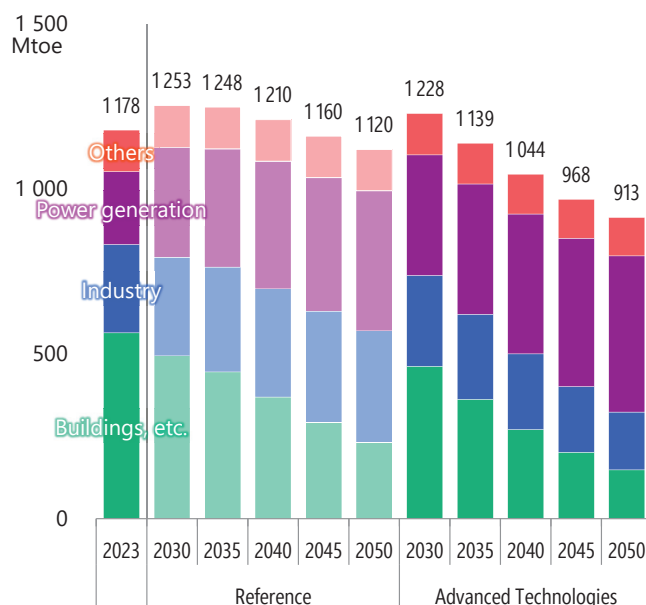


Biomass consumption

Biofuels for transport

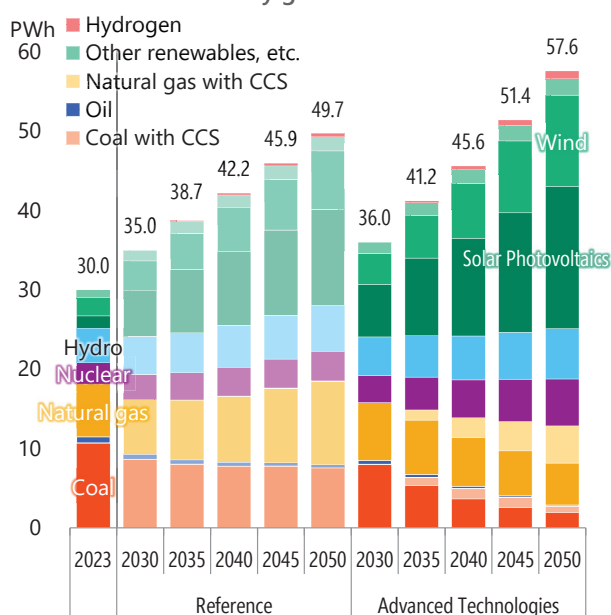


Solid biomass

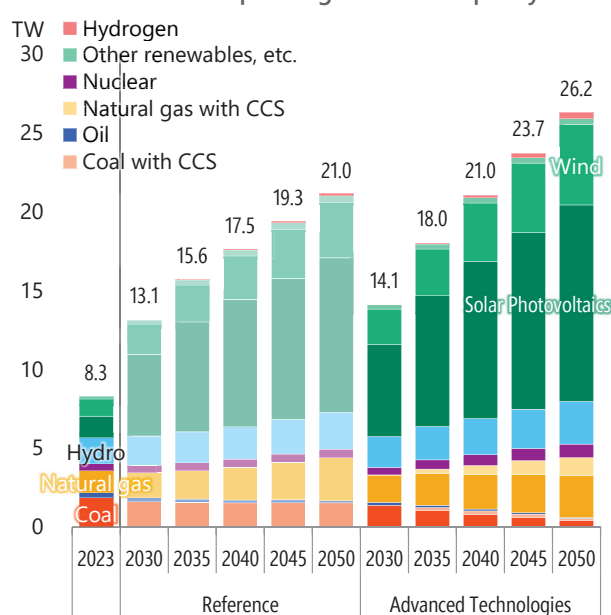


Power generation mix

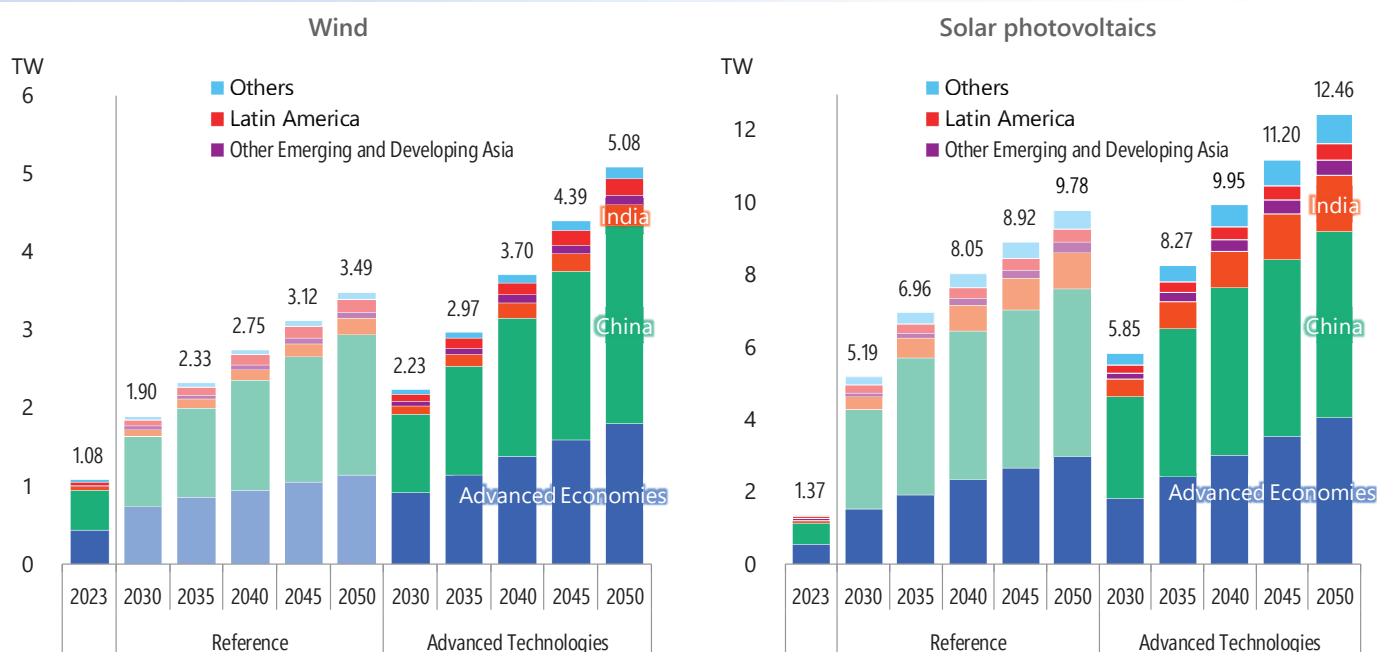
Electricity generated



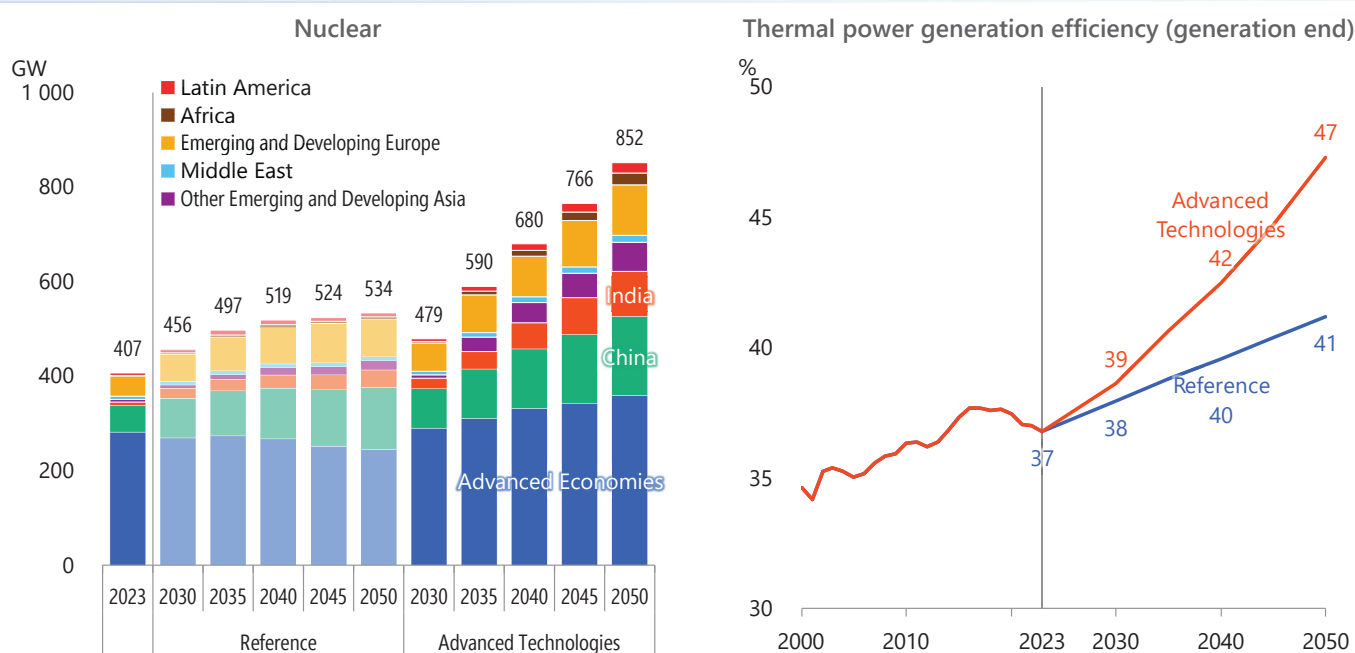
Installed power generation capacity



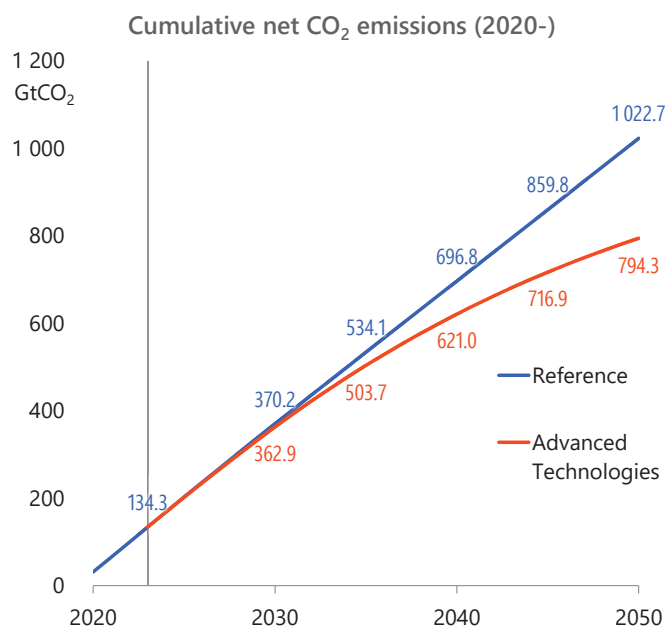
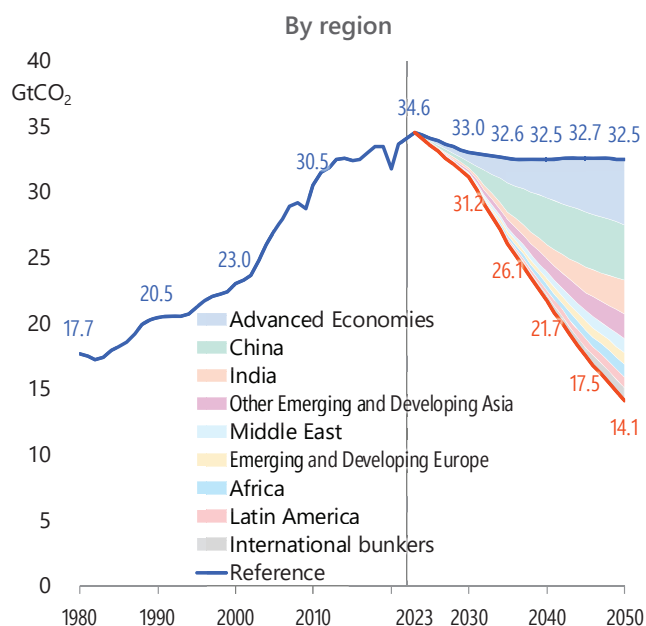
Installed wind and solar PV power generation capacity



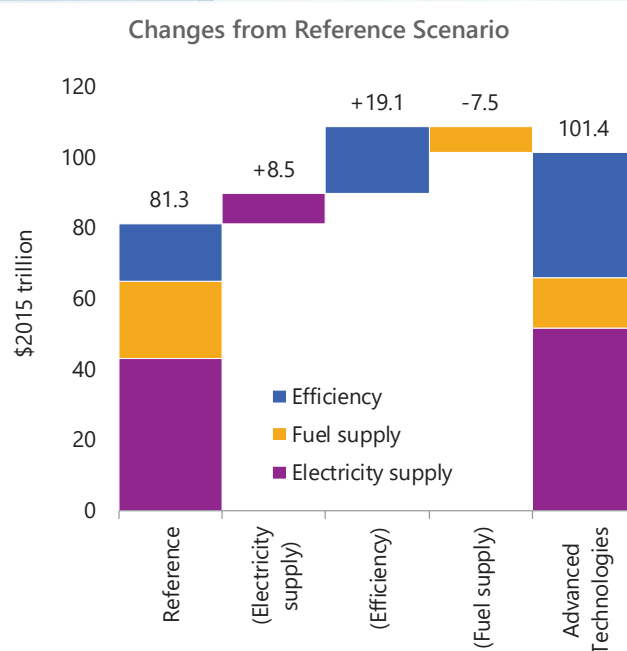
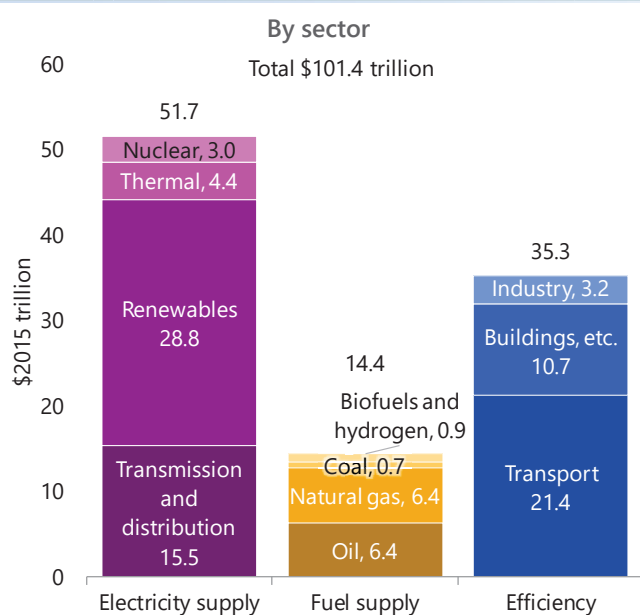
Installed nuclear power generation capacity and thermal power generation efficiency

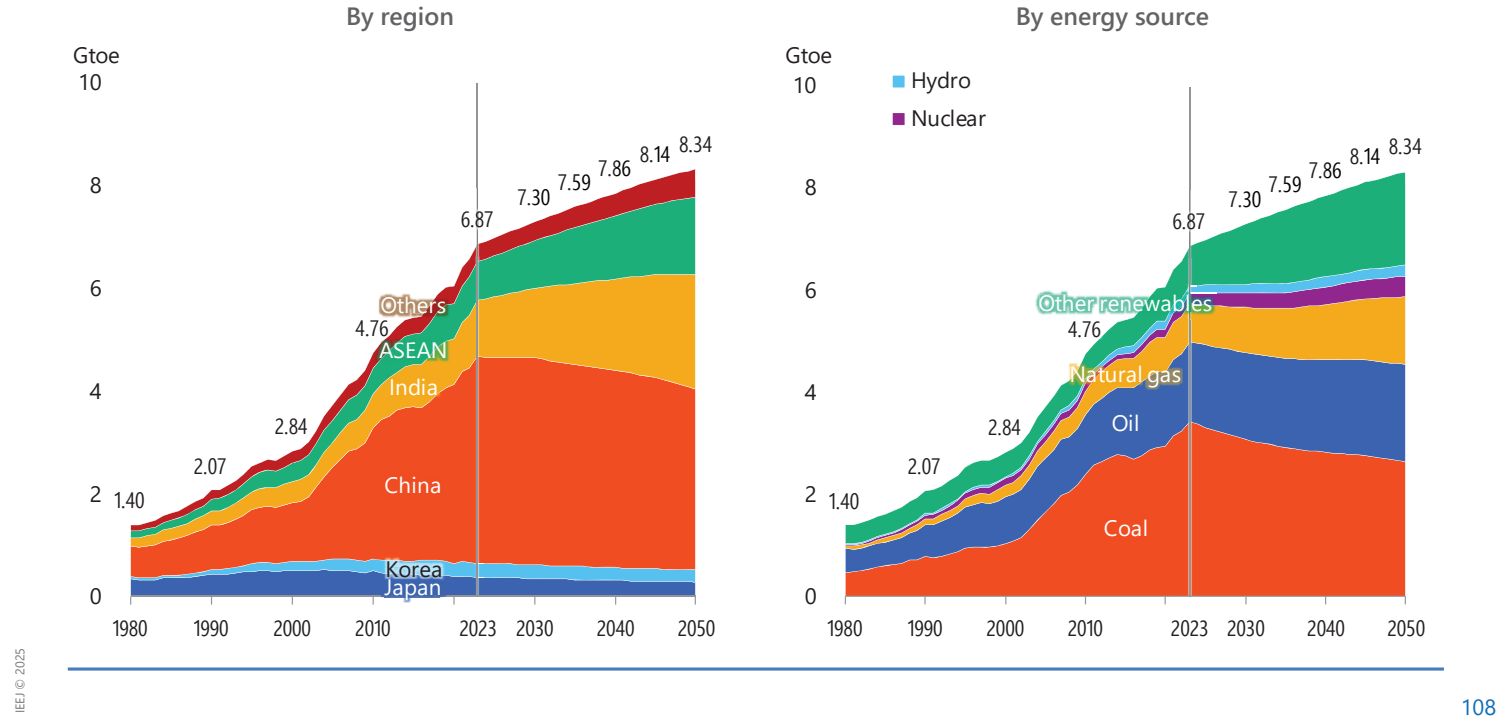


Energy-related CO₂ emissions



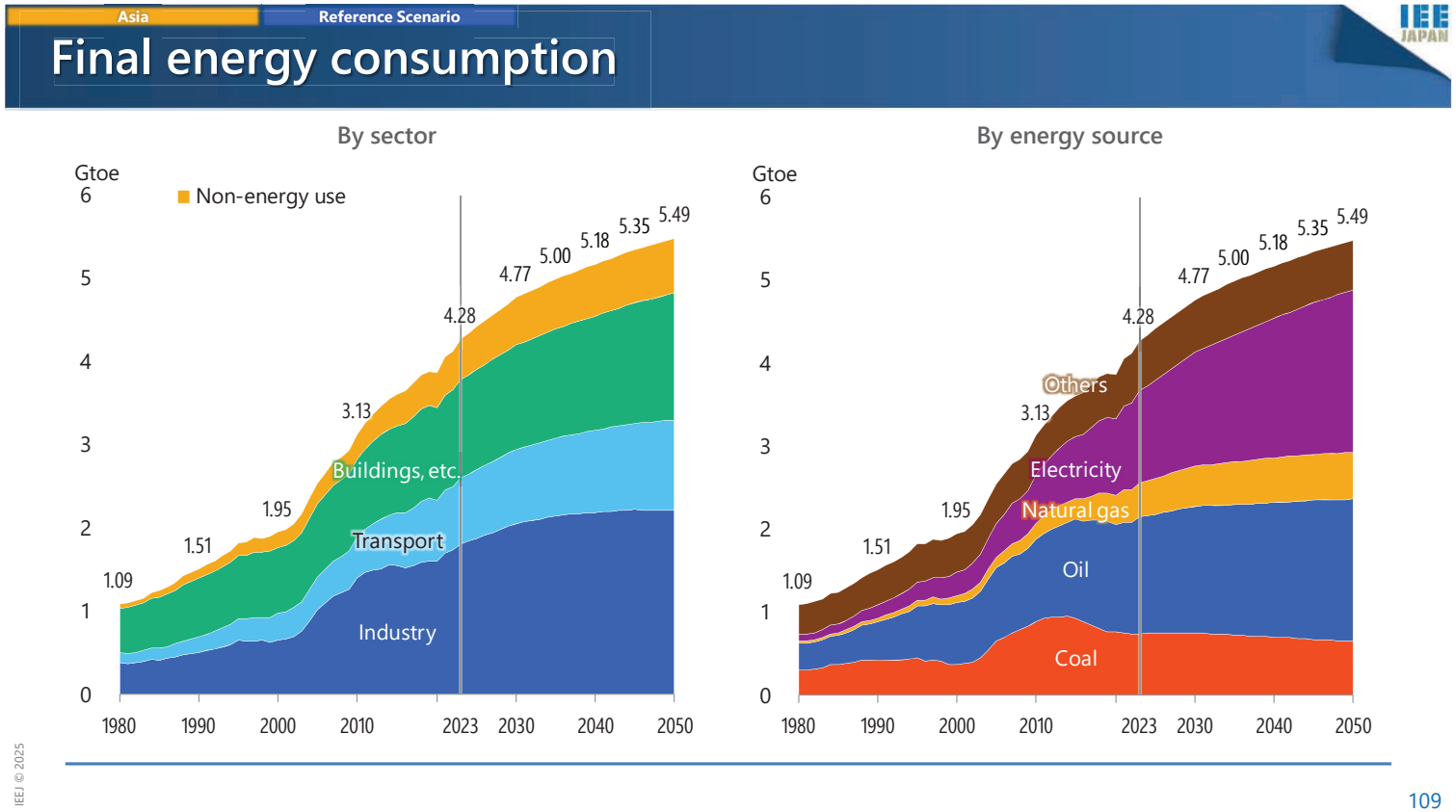
Energy-related investments (2025–2050)





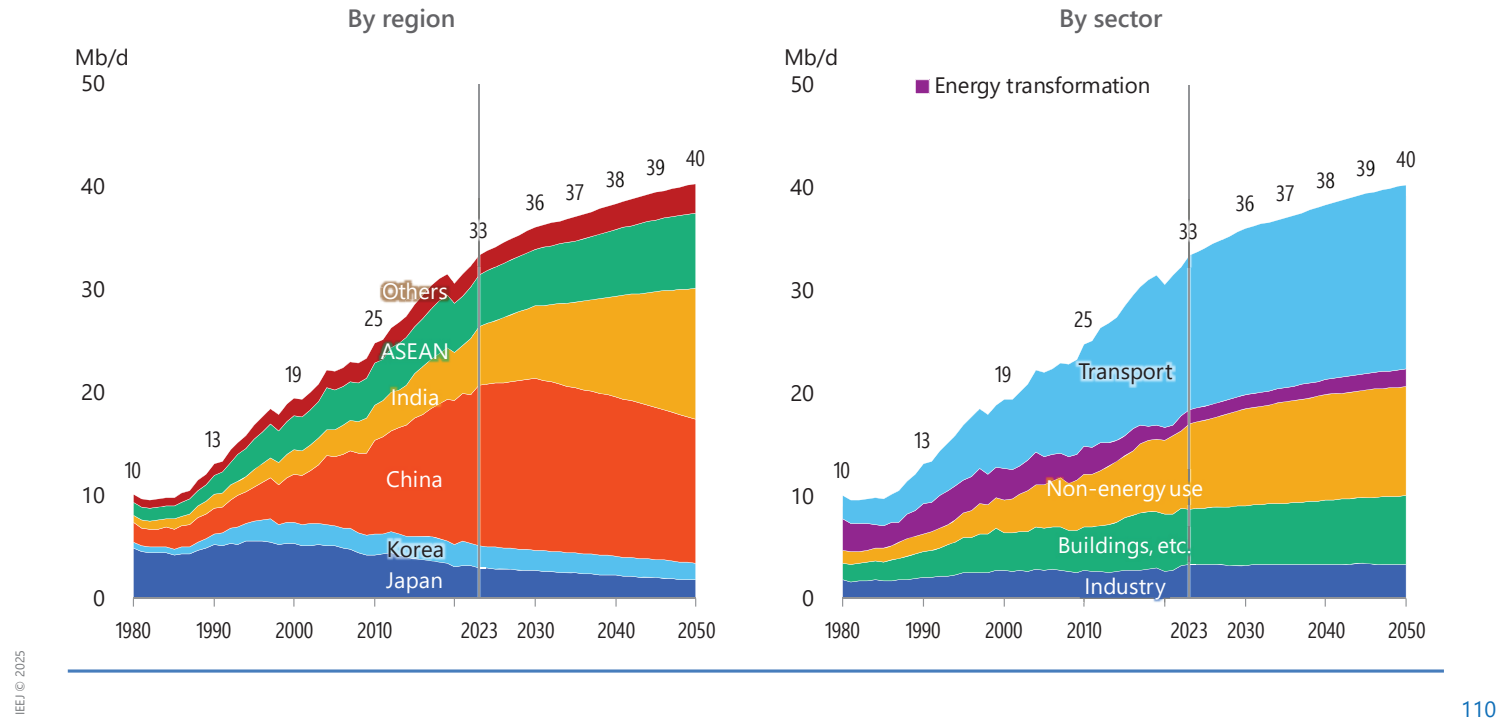
IEE / © 2025

108



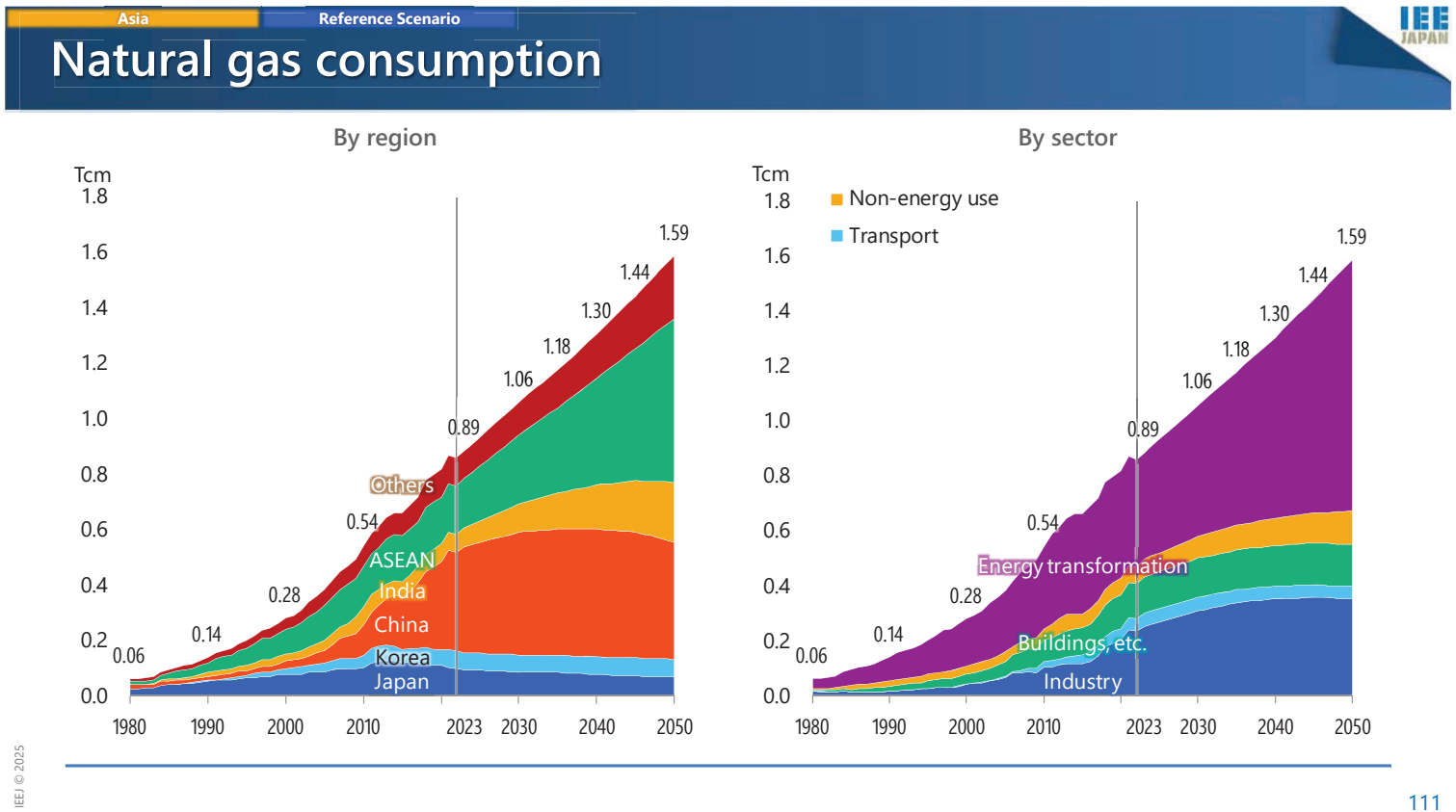
IEE / © 2025

109



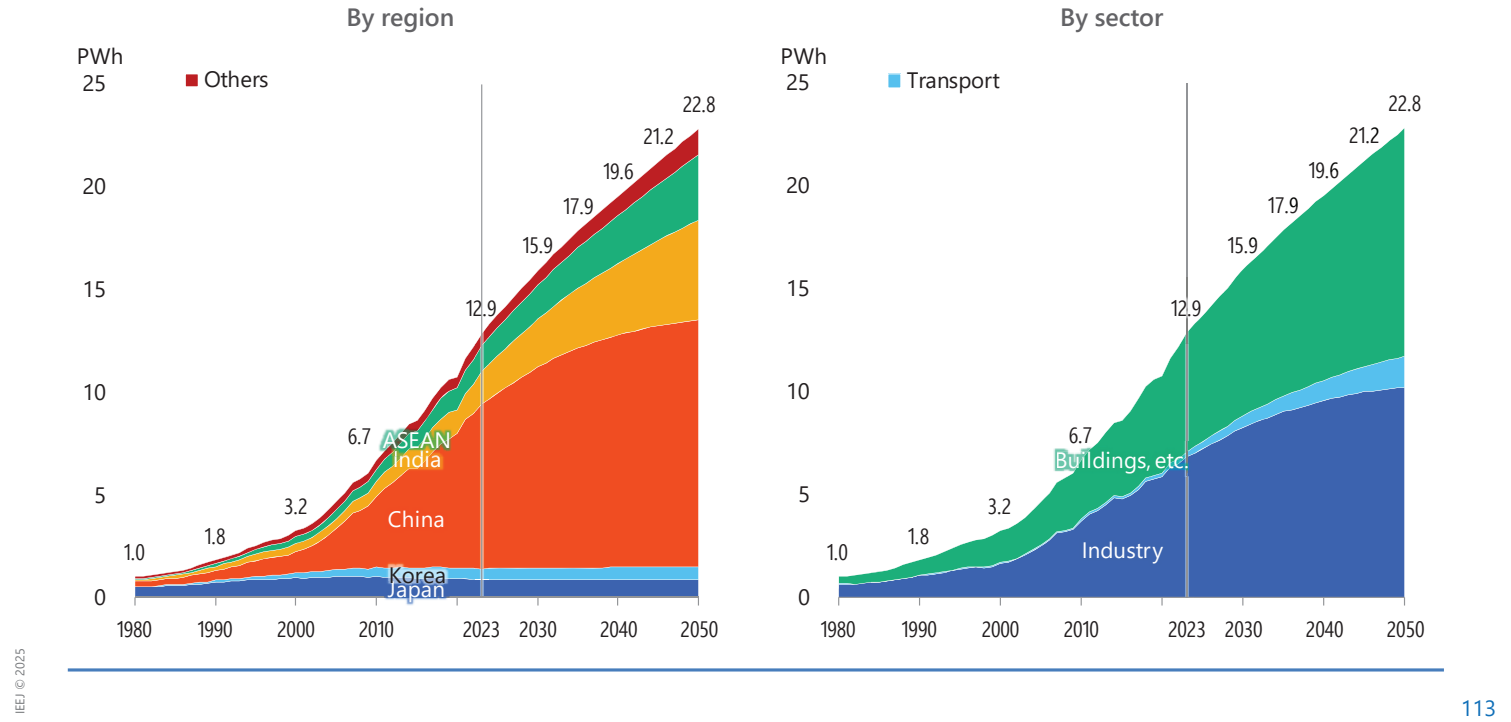
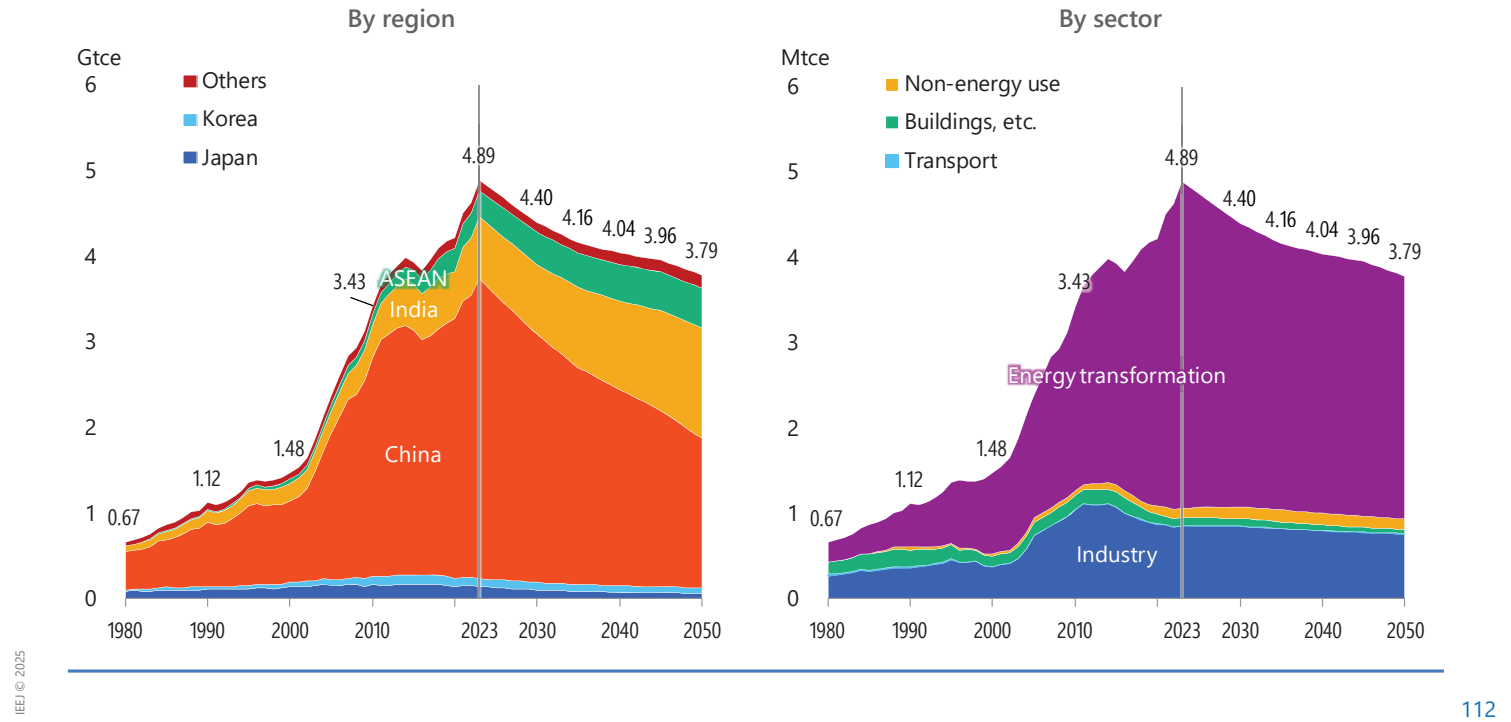
IEE / © 2025

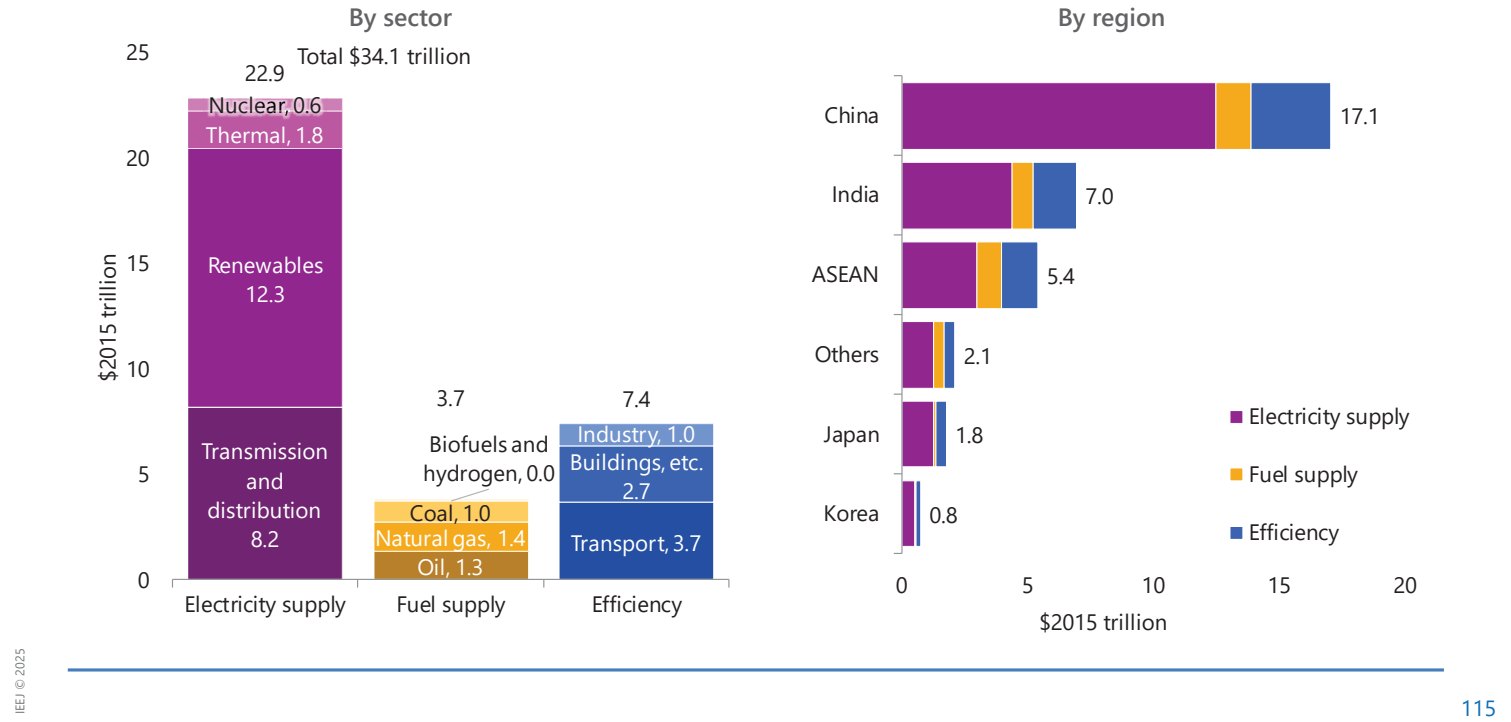
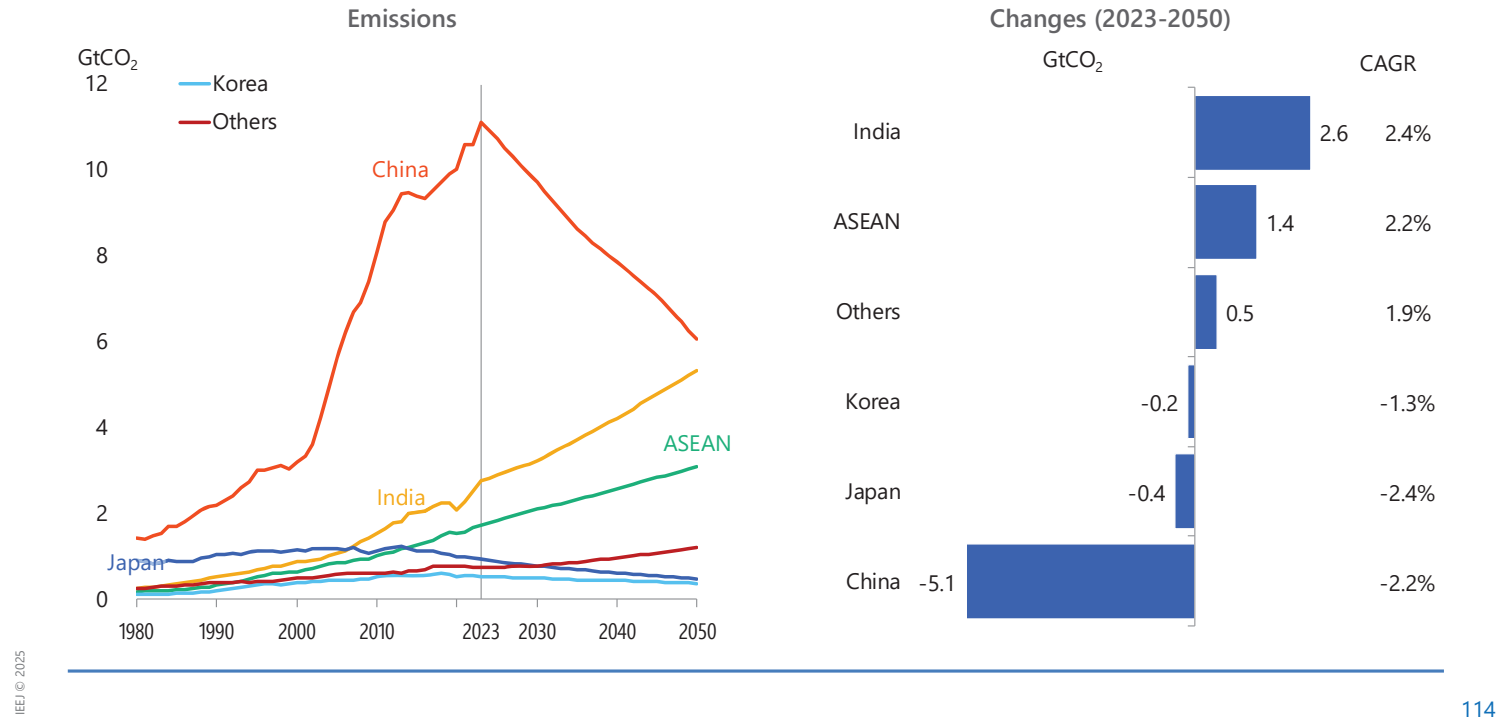
110



IEE / © 2025

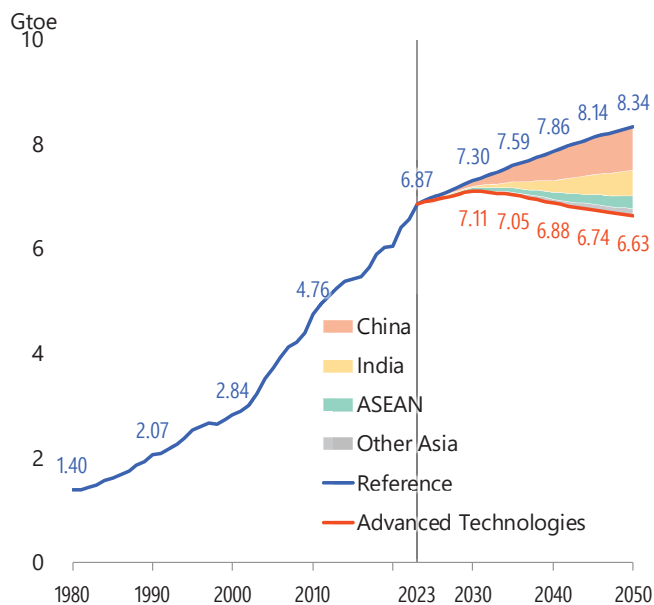
111



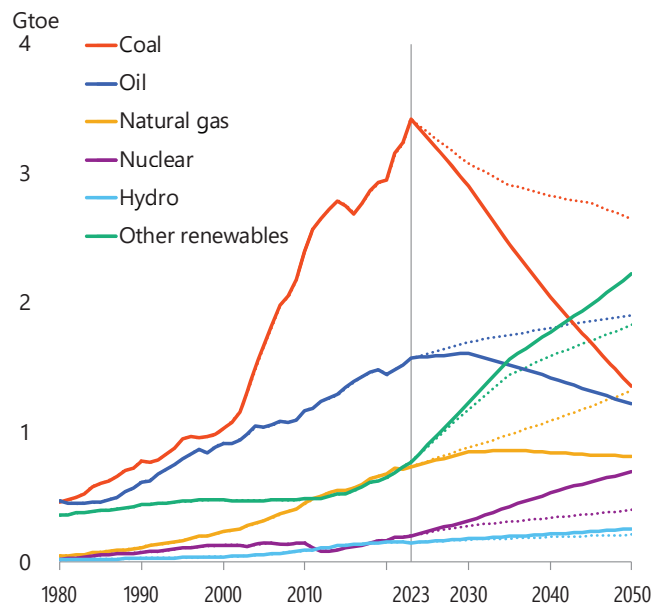


Primary energy consumption

By region



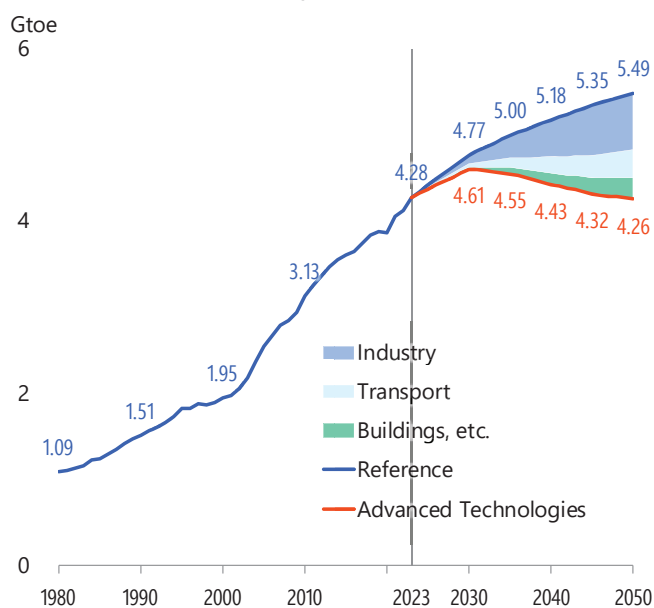
By energy source



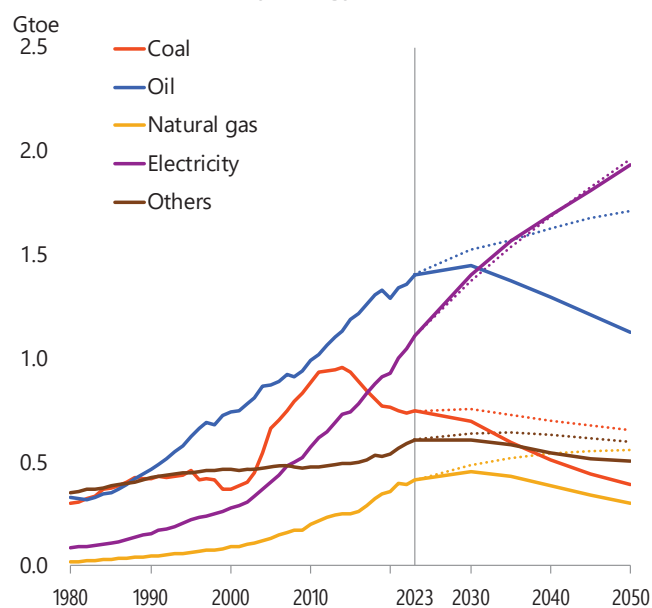
Note: Solid lines stand for Advanced Technologies Scenario and dotted lines stand for Reference Scenario.

Final energy consumption

By sector

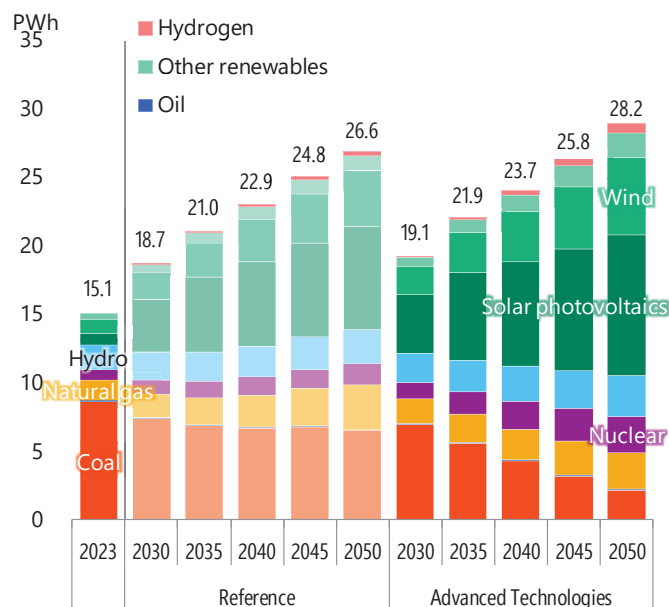


By energy source

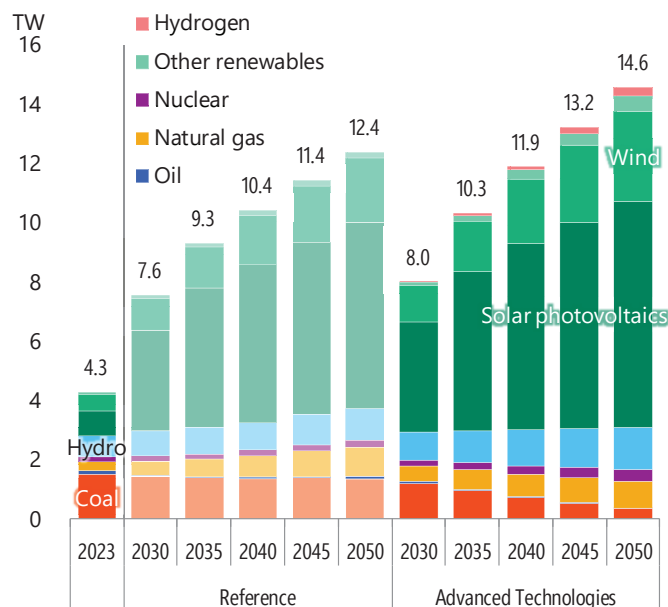


Power generation mix

Electricity generated

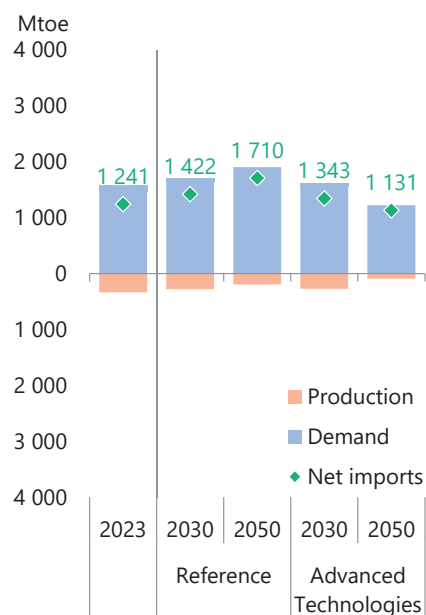


Installed power generation capacity

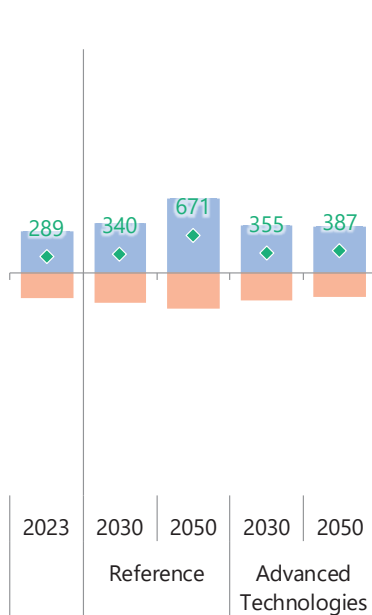


Supply and demand balance of fossil fuels

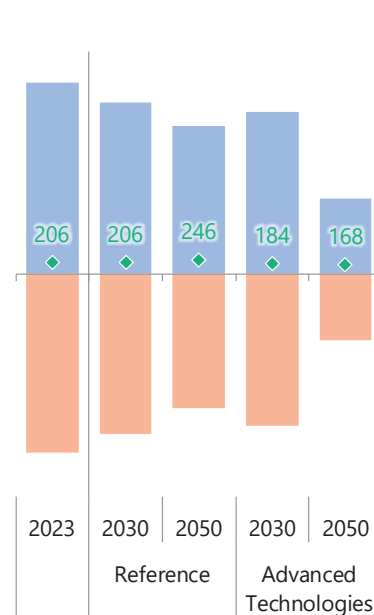
Oil



Natural gas

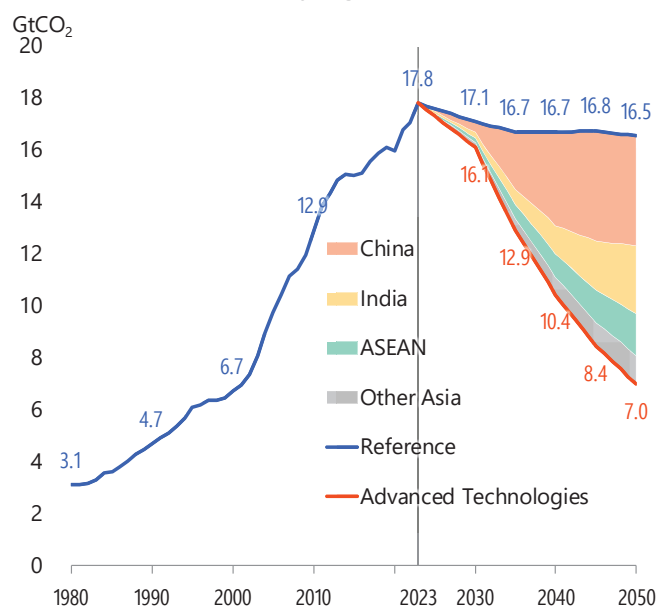
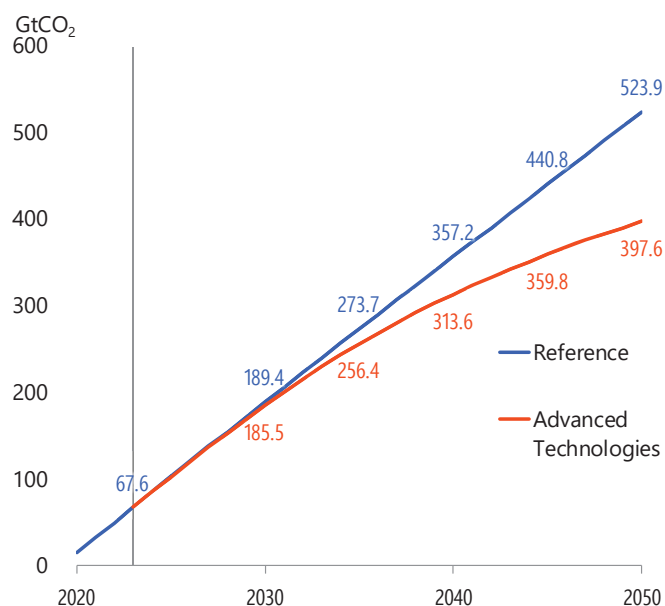


Coal



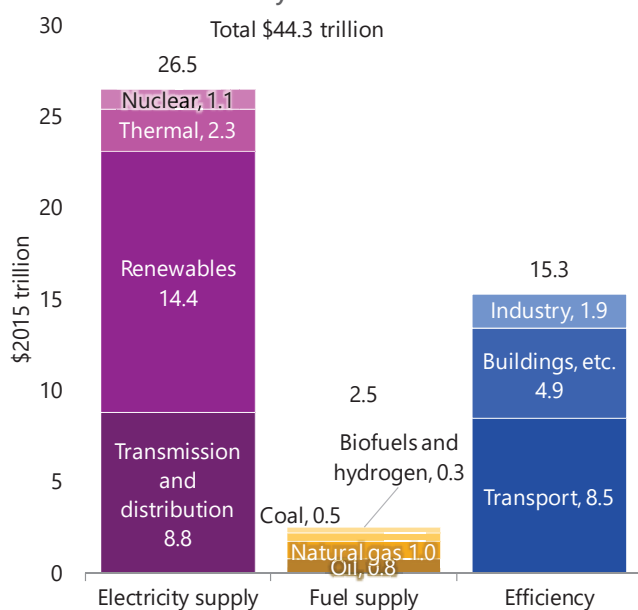
Energy-related CO₂ emissions

By region

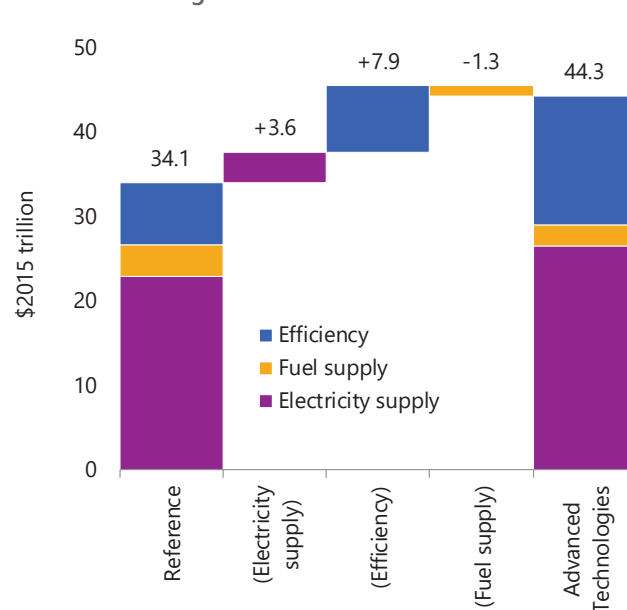
Cumulative net CO₂ emissions (2020-)

Energy-related investments (2025–2050)

By sector

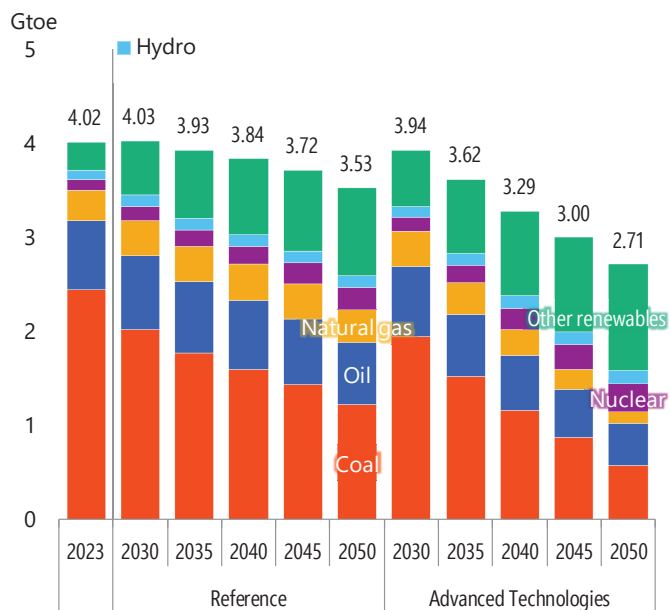


Changes from Reference Scenario

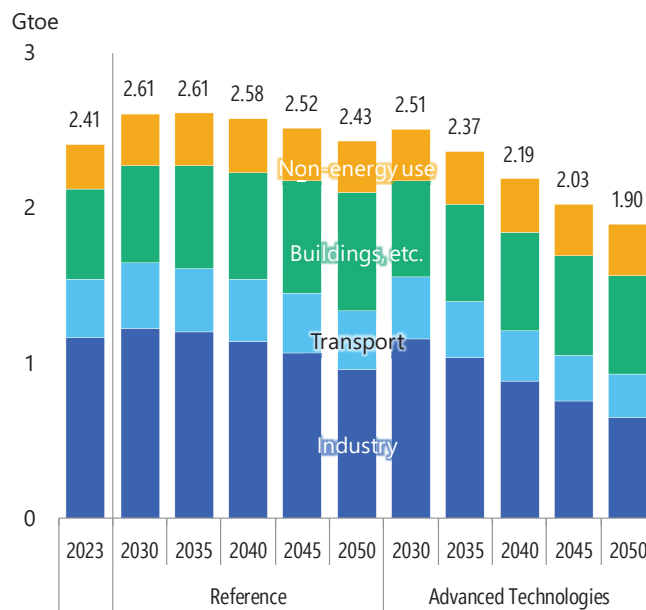


Energy consumption

Primary energy consumption

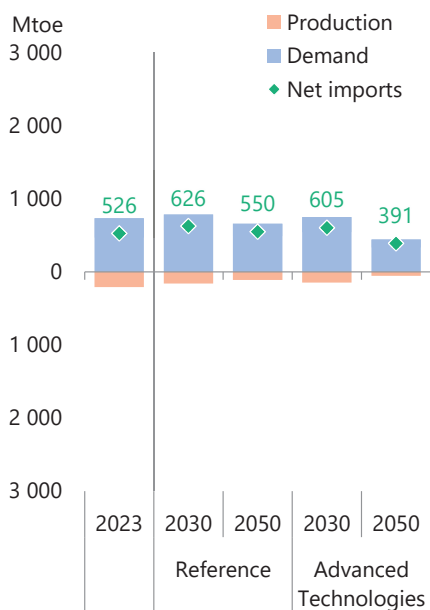


Final energy consumption

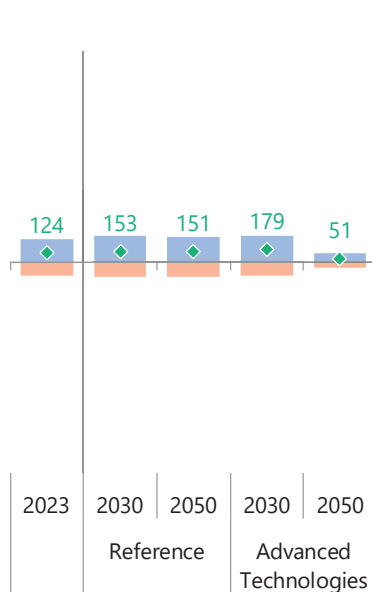


Supply and demand balance of fossil fuels

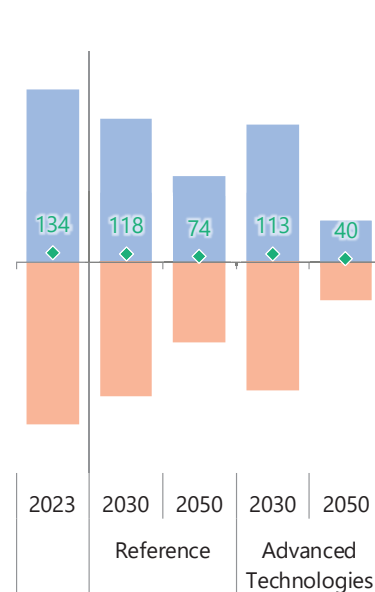
Oil



Natural gas

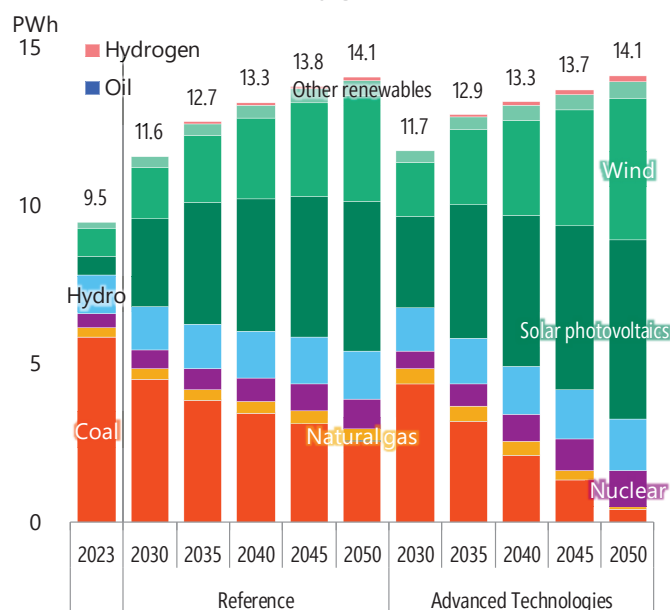


Coal

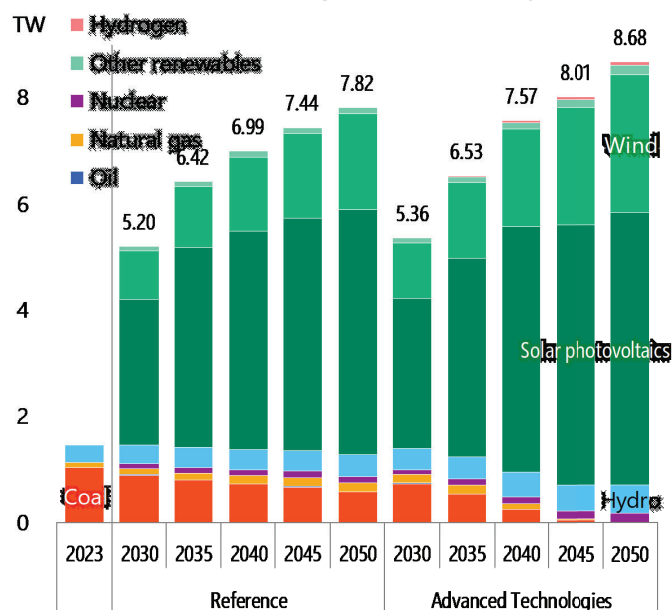


Power generation mix

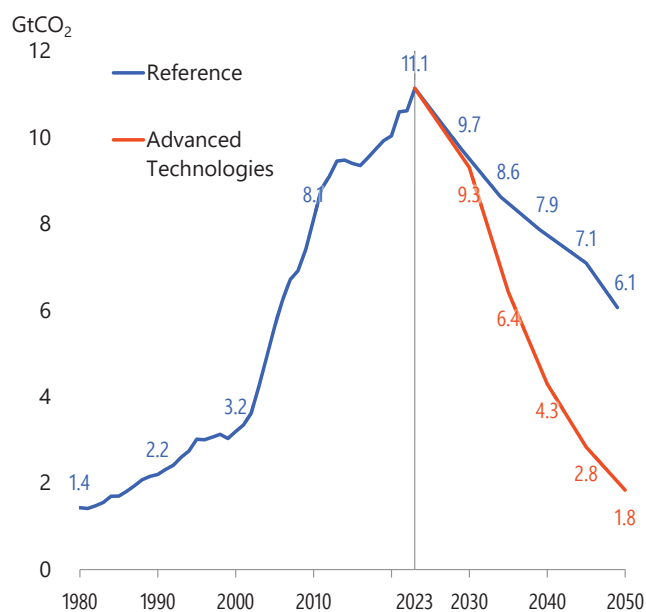
Electricity generated



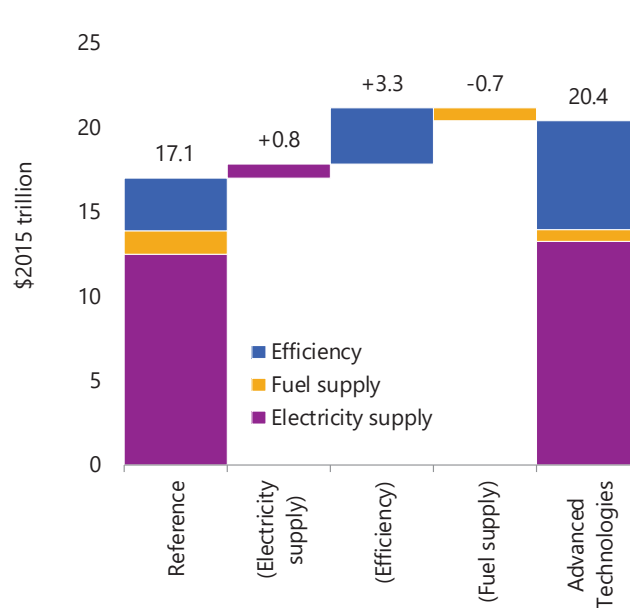
Installed power generation capacity



Energy-related CO₂ emissions and investments

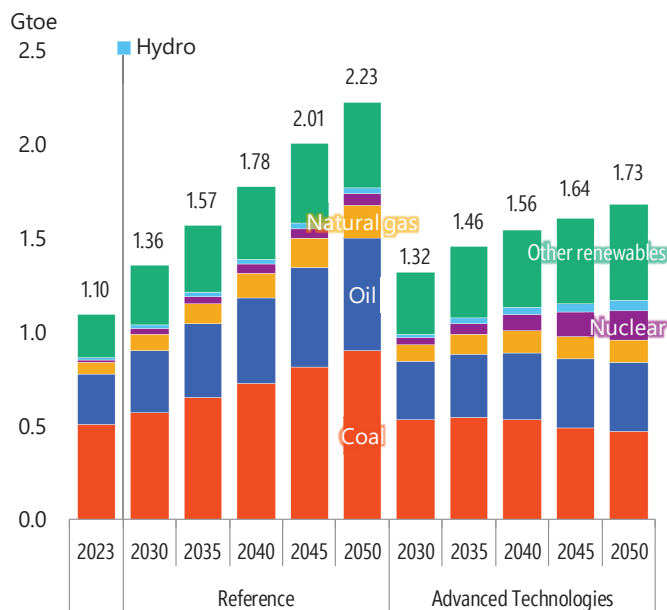
CO₂ emissions

Investments (2025–2050)

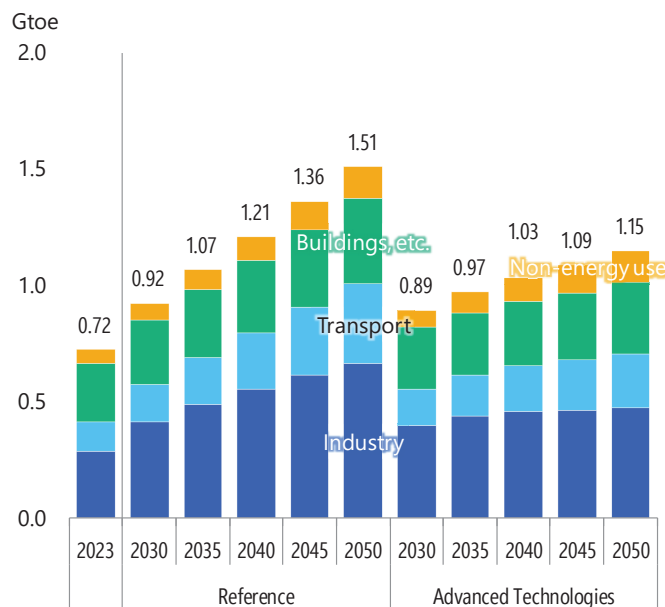


Energy consumption

Primary energy consumption

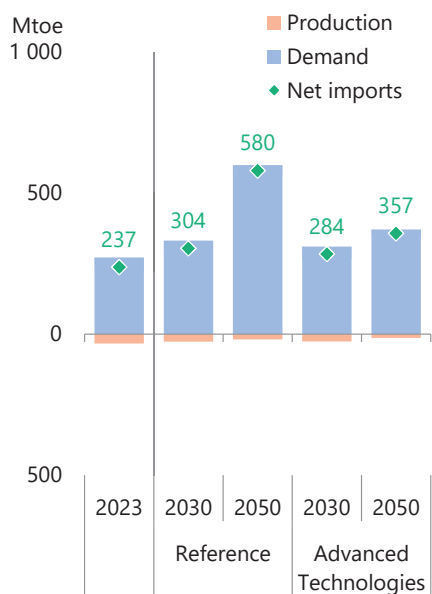


Final energy consumption

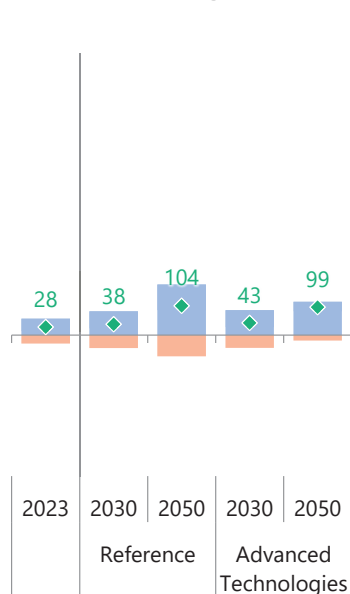


Supply and demand balance of fossil fuels

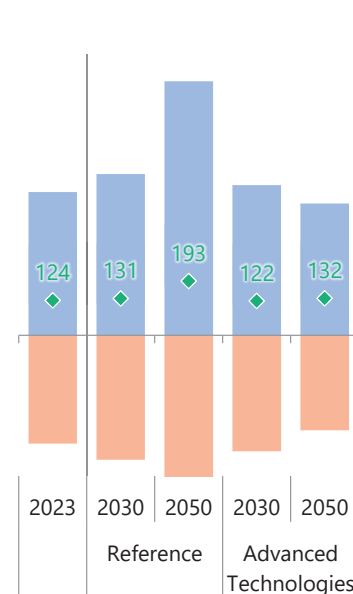
Oil



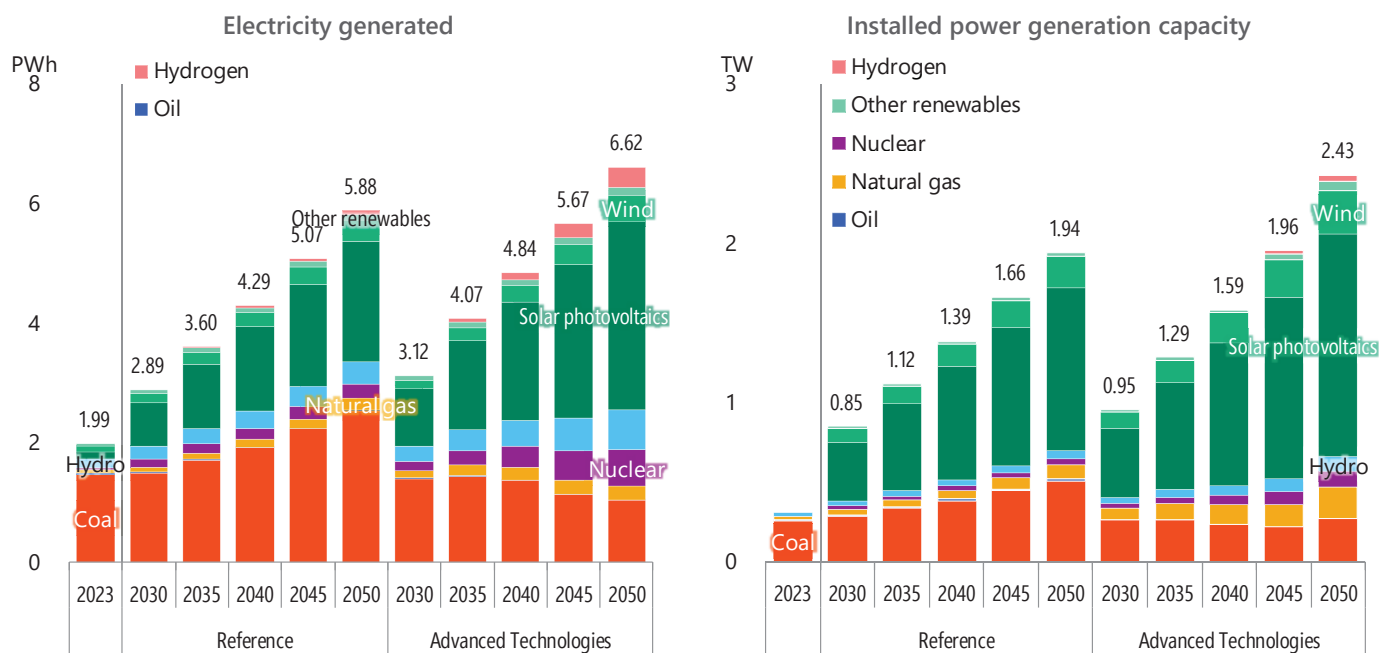
Natural gas



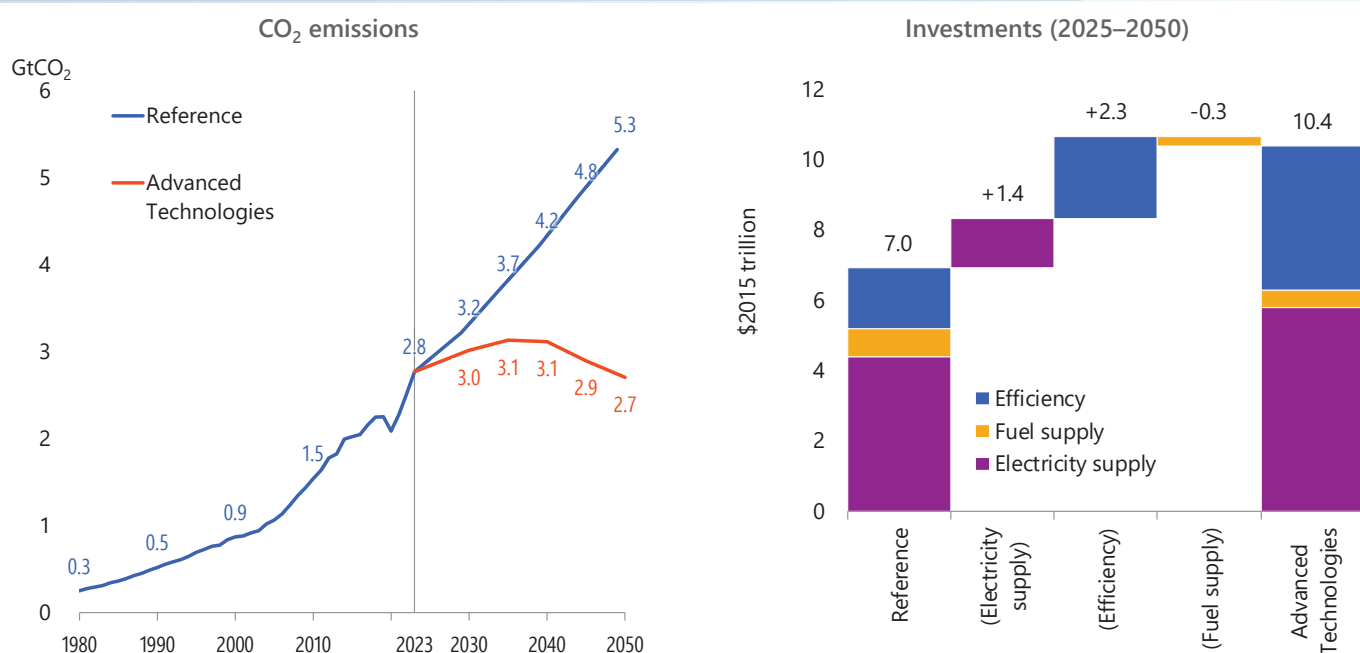
Coal



Power generation mix

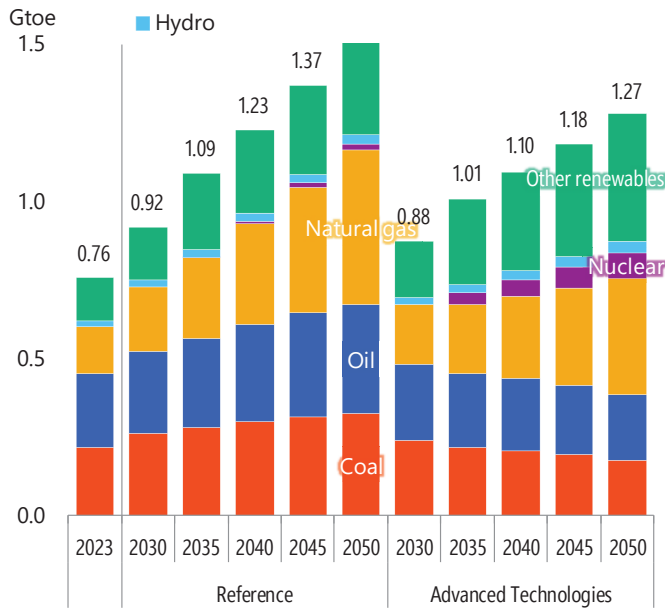


Energy-related CO₂ emissions and investments

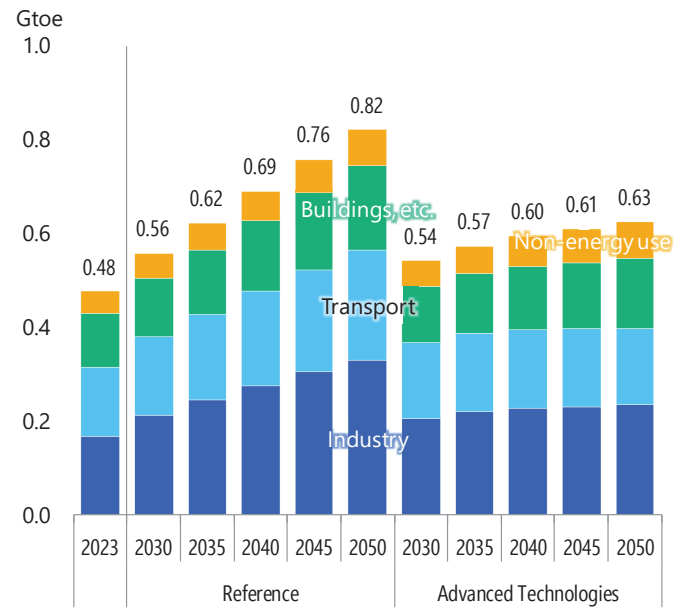


Energy consumption

Primary energy consumption

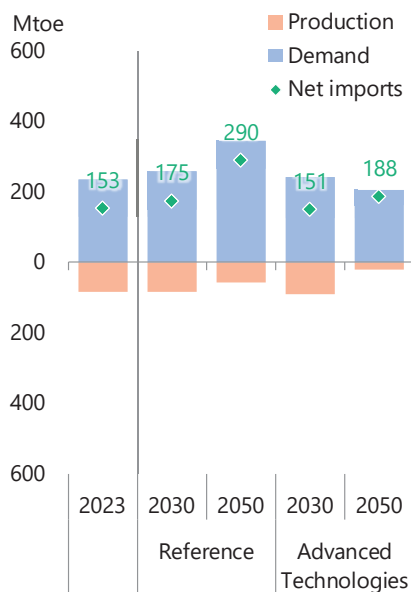


Final energy consumption

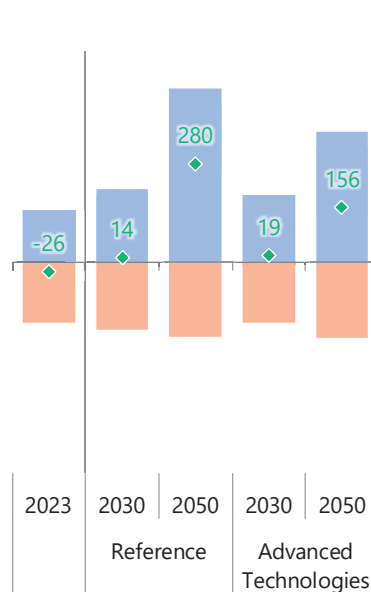


Supply and demand balance of fossil fuels

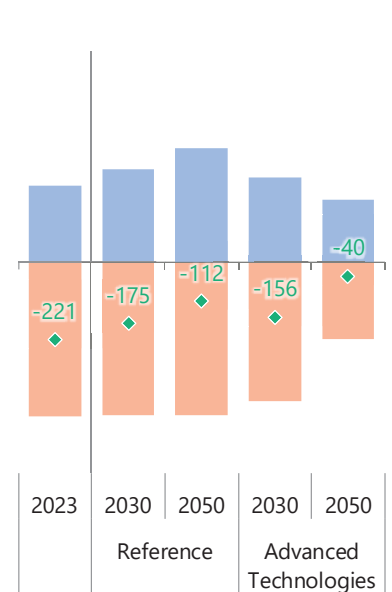
Oil



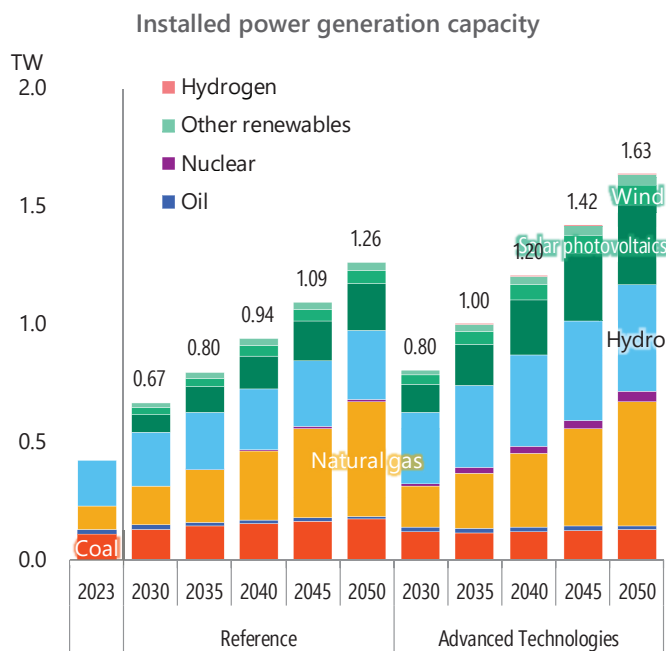
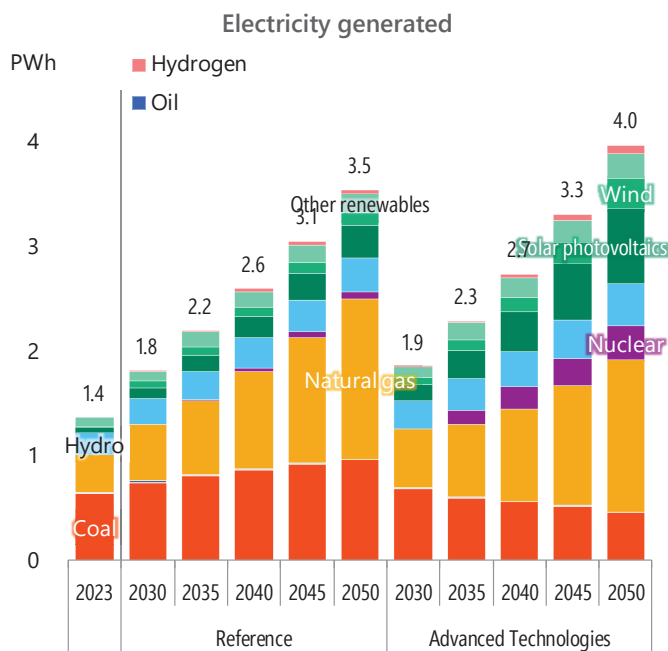
Natural gas



Coal



Power generation mix



Energy-related CO₂ emissions and investments

