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IEEJ Outlook 2025
Risk scenarios of energy security

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1. Risks of Fossil Fuel Underinvestment
2. More Serious and Diverse Geopolitical Risks
3. Risks of Electricity Supply Instability
4. Risks of Critical Mineral Supply
5. Increasing Risks of Cyberattacks

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Summary

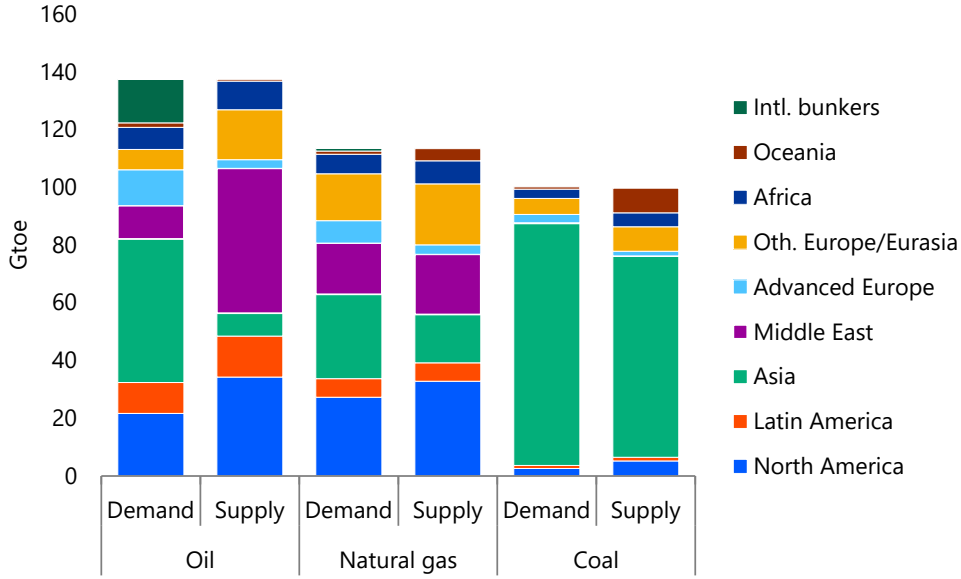
- Risks of Fossil Fuel Underinvestment
  - ✓ According to the IEEJ Outlook Reference Scenario, fossil fuels will still provide 73% of global energy demand in 2050. Without additional investment, oil and natural gas production in 2050 would plummet to about one-tenth of current levels. Underinvestment will result in a large gap from fossil fuel demand in the real world.
- More Serious and Diverse Geopolitical Risks
  - ✓ Geopolitical risks in the Middle East region are becoming more serious as Japan's dependence on the region for crude oil imports increases. In addition, policy changes in developed countries have also become a risk factor in recent years.
- Risks of Electricity Supply Instability
  - ✓ Electricity supply is subject to various risks on both supply and demand sides. In order to achieve stable supply, it is necessary to take measures in the fields such as ensuring fossil fuel, securing baseload power like nuclear power, securing supply capacity, and optimizing the power system. It is also essential to pursue the best power mix for stable supply.
- Risks of Critical Mineral Supply
  - ✓ Some critical minerals that are essential raw materials for clean technologies have high market concentration and emerging as a risk to the energy transition. Risks can be mitigated by combining various technologies with different nature of risk.
- Increasing Risks of Cyberattacks
  - ✓ The number of critical cyber attack incidents has increased significantly around the world. Cyber-attacks against energy, a fundamental infrastructure, becoming a key issue in energy security.

Risks of Fossil Fuel Underinvestment

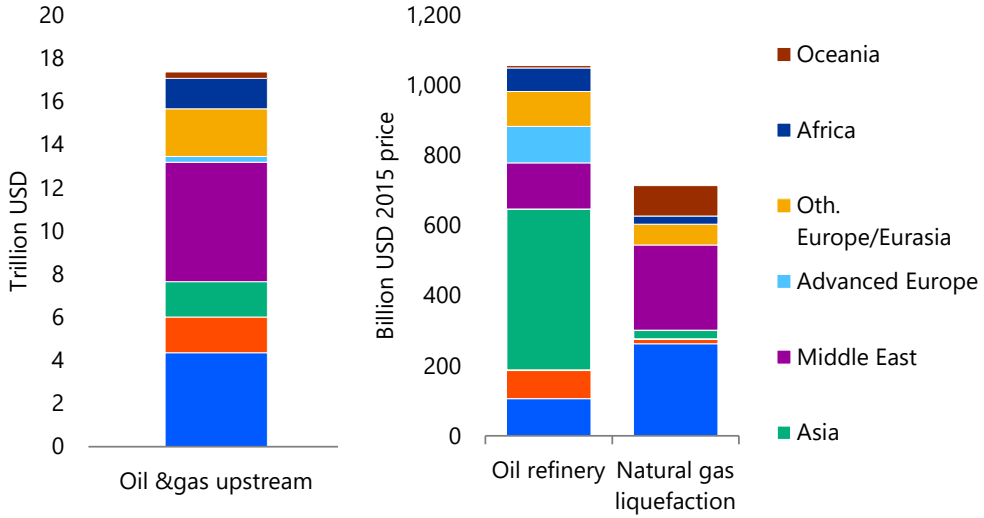
Supply-demand and investment of fossil fuel

- In the Reference Scenario, fossil fuels will still provide 73% of global energy demand in 2050.
- Asia is the center of demand growth, while the Middle East and North America (oil and natural gas) and Asia (coal) have the highest shares in the supply region.
- Stable investment, particularly in these regions, is vital for the stable supply of fossil fuels.

Fossil fuel demand



Selected oil and gas investment amount



Cumulative total of 2022-2050 in the Reference scenario
Source: IEEJ

Increasing hurdles to investment

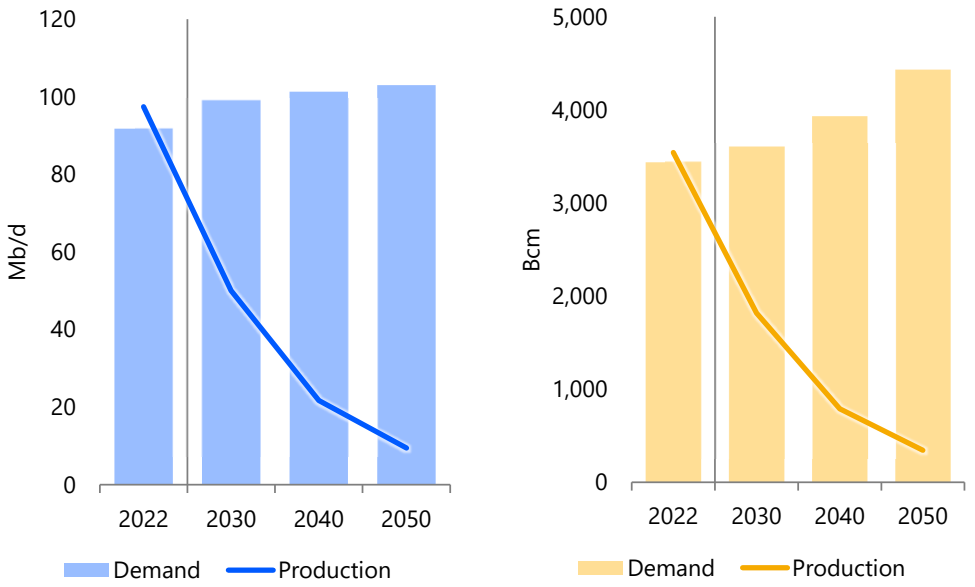
- Underinvestment is currently not serious, but the risk of underinvestment due to climate change concerns and decarbonization policies has become apparent.
- Without additional investment, oil and natural gas production in 2050 will be about 1/10th of current levels.

Head wind against fossil fuel projects

Oil	Natural gas	Coal
Financial institutions and pension funds restrict investment in fossil fuel development and coal-fired projects		
Upstream asset sales by IOCs ($290 billion over 2015-2023)		Thermal coal asset sale by coal majors
Europe: Refining capacity may decrease by 1-1.5 million b/d by 2030	Suspend LNG projects with high environmental impact. (e.g. Natuna field in Indonesia)	Ban of new coal-fired power in OECD countries

IOC = international oil companies
Source: IEEJ, IEA, Bloomberg

Prospect of oil and gas production without investment and demand in the Reference scenario

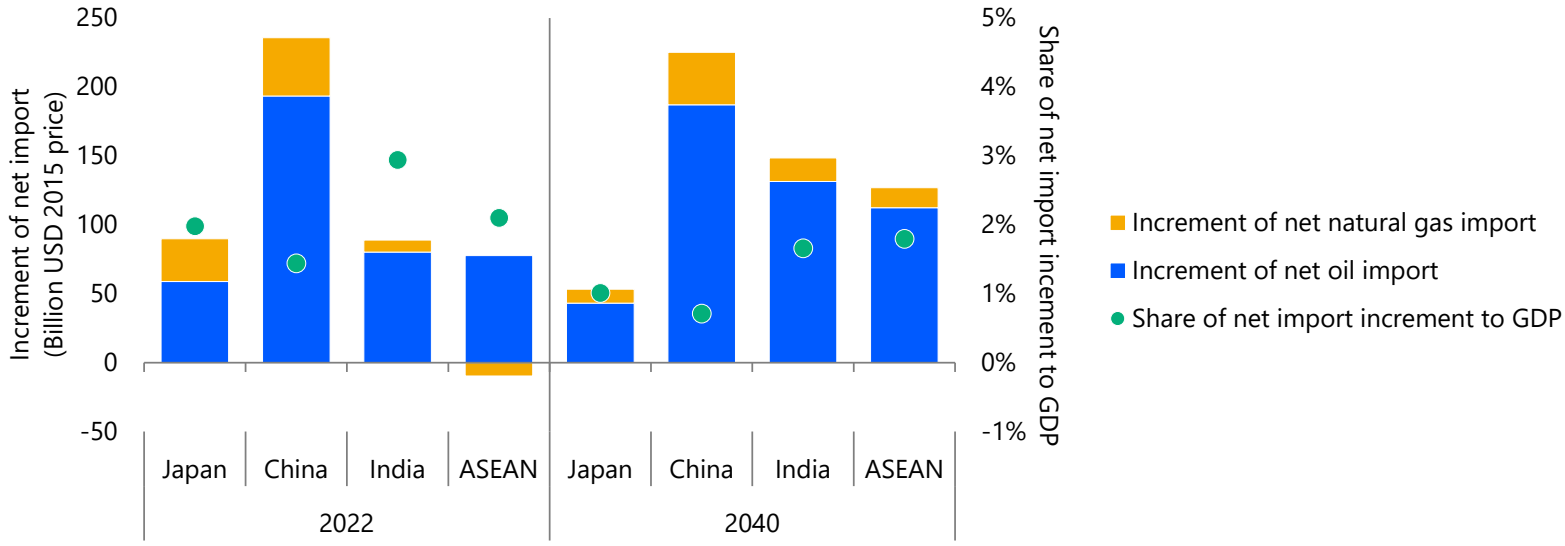


Source: IEEJ

Economic impact of price increases

- Tight supply and demand leads to higher prices: the average Brent price in 2021 was 70% higher than the previous year, partly due to lack of upstream investment during the pandemic period as well as a recovery in demand after the pandemic.
- For a 50% price increase, the share of oil and natural gas imports in the GDP of Asian importing countries rises by 1-3 percentage points. The rise in India and ASEAN is relatively large and the impact on the economy is more worrying.

Impact of crude oil and natural gas price increase on import bill

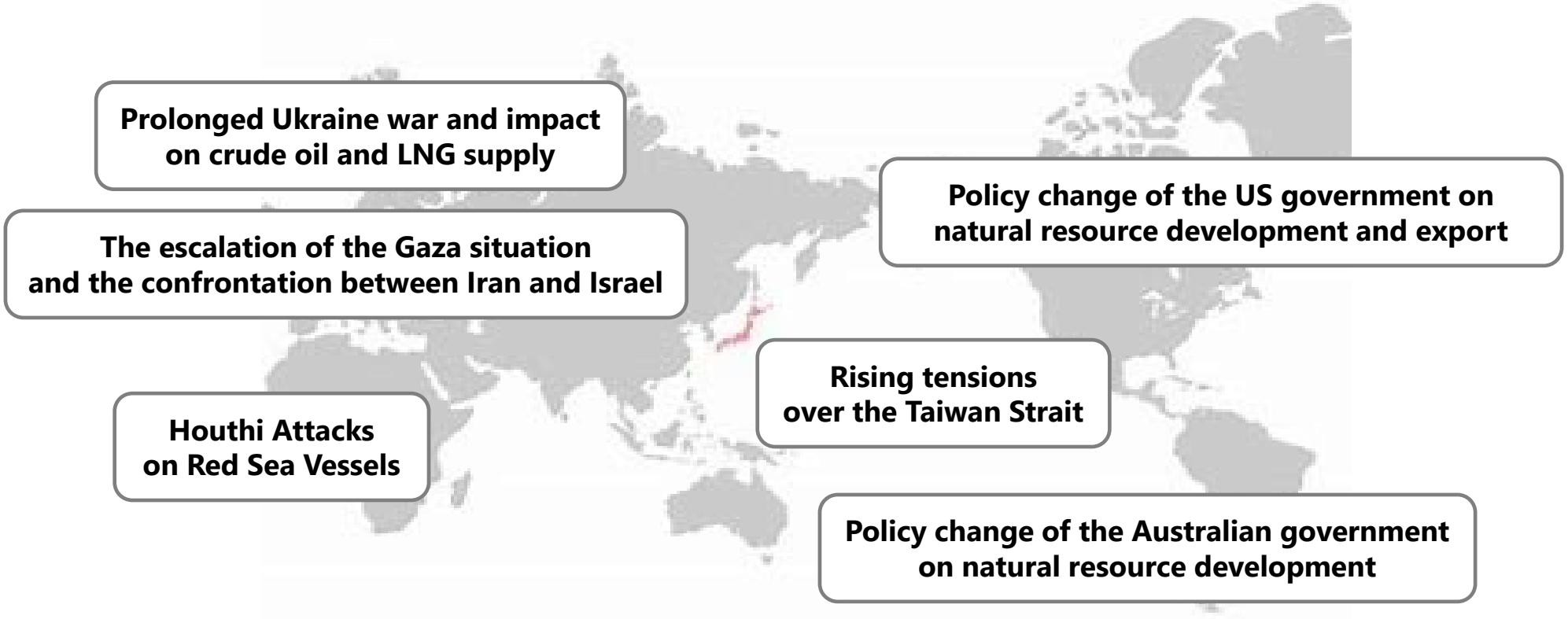


Assume that oil and natural gas import prices will be 50% higher than actual (2022) or preconditioned (2040) due to tight supply and demand caused by underinvestment. Source: IEEJ

More Serious and Diverse Geopolitical Risks

More diverse geopolitical risks

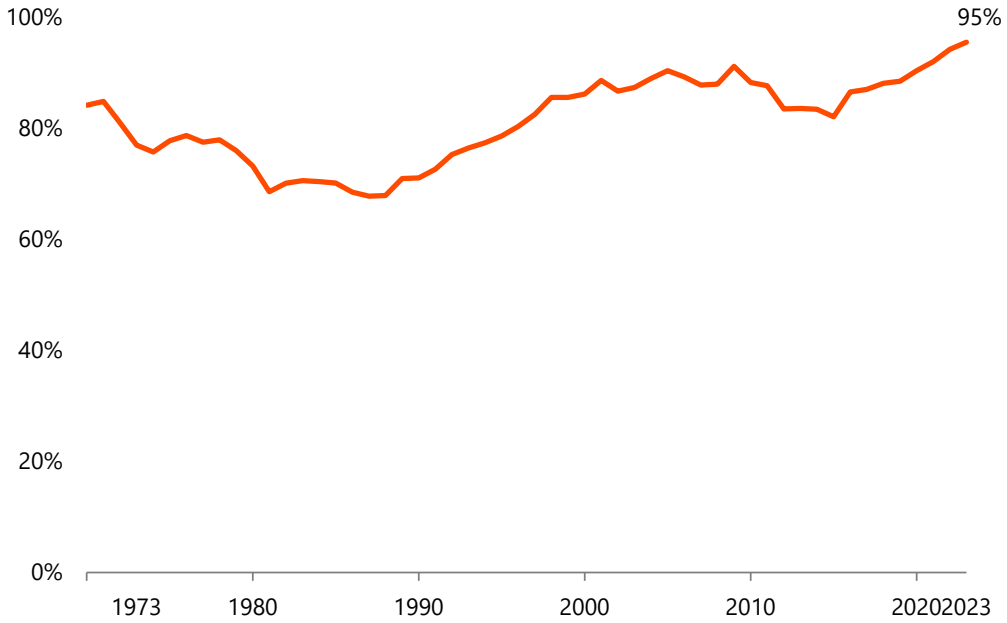
- Geopolitical risks remain a major concern in energy security.
- In addition to the risk of political instability in resource-exporting countries/regions, policy changes in developed countries have also been a risk factor in recent years.



More serious geopolitical risks in the Middle East

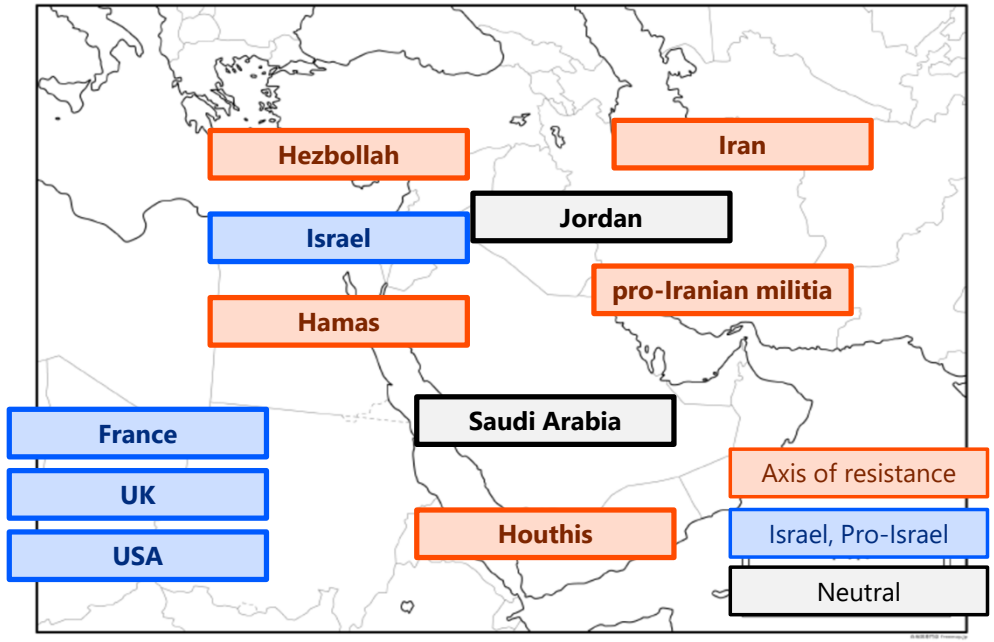
- As Japan's dependence on the Middle East crude oil rises, the geopolitical risks in the region, escalation of conflicts surrounding Israel, are becoming even more serious for Japan.
  - In particular, the worsening of Iran-Israel relations could be a factor linking the situation in Palestine to energy supplies in the Persian Gulf, and the impact of these developments would be very significant.

Middle East dependency of Japan's crude oil import



Source : Ministry of Finance, "Trade statistics"

Israel and the Axis of Resistance

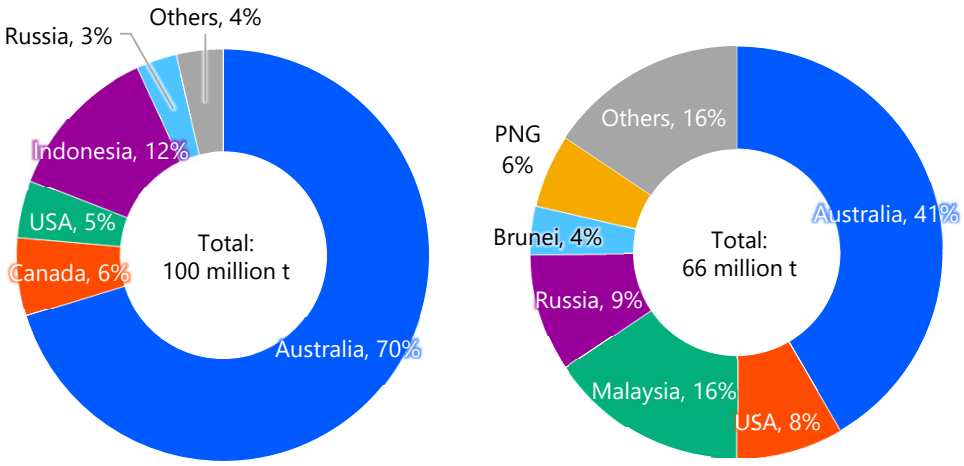


Source : JIME, IEEJ

Policy change risks in developed countries

- Coal and LNG imports are highly dependent on developed countries (81% for coal and 50% for LNG: 2023).
- There are concerns that policies have been introduced in the US and Australia that place restrictions on the development and export of domestic fossil resources, reflecting domestic interest in climate change issues, which may pose a challenge to market stabilization.

Import partners of Coal (left) and LNG (right) supply in Japan (2023)



PNG = Papua New Guinea
Source : Ministry of Finance, "Trade statistics"

Recent policy developments in the US and Australia that would affect their LNG export

US	• In January 2024, the Biden administration announced a pause on the review and approval of export licence applications for new LNG projects for non-FTA countries as part of its response to the global climate crisis.
Australia	• In October 2022, the ADGSM was amended to restrict gas exports in the event of a domestic gas supply crisis. • July 2023, requiring GHG emissions from designated large emission sources, including LNG liquefaction and coal mines, to be reduced by 4.9% annually. Requires new LNG facilities to have net-zero emissions from the start of operations.

ADGSM = Australian domestic gas security mechanism
Source : Ministry of Finance, "Trade statistics"

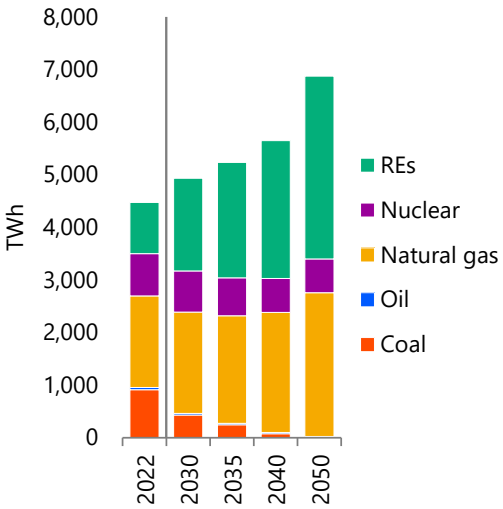
Risks of Electricity Supply Instability

Increasing electricity demand and VREs

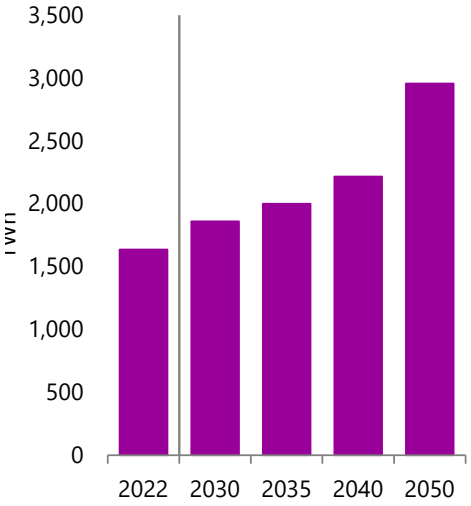
- Society is becoming increasingly reliant on electricity as the digitalization of the economy and the electrification of demand continue. Electric vehicles and the expansion of data centres are the key drivers of demand growth.
- The energy transition is pushing solar photovoltaic and wind power, whose output fluctuates with the weather and the seasons, to become the mainstay of electricity supply.

Electricity demand and supply in the US

Generation



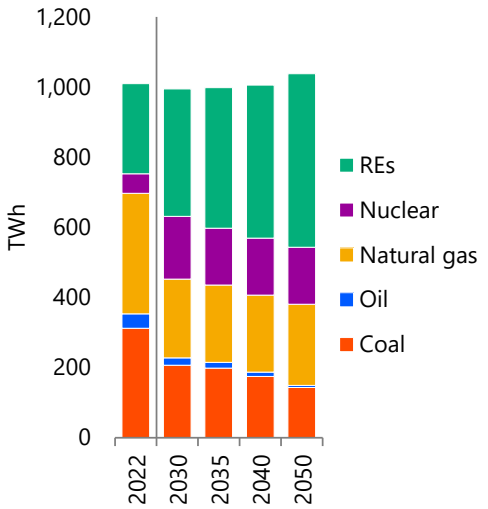
Consumption in commercial sector



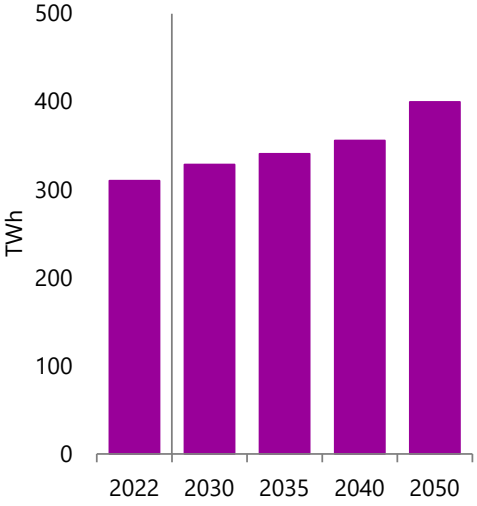
Reference Scenario
Source : IEEJ

Electricity demand and supply in Japan

Generation



Consumption in commercial sector



Reference Scenario
Source : IEEJ

Risks, challenges, and measures of supply security

- On the supply side, risks of supply stability include supply shortage and price fluctuation of fossil fuels, geopolitical risks, and fluctuations in the output of renewable energy sources. While on the demand side, there is the risk of an increase in electricity demand and uneven distribution of electricity demand.
- To address these risks, it will be necessary to secure fossil fuel procurement and baseload power sources such as nuclear power, secure supply capacity, and optimize the power system.

Risks, challenges, and measures against risks of electricity supply instability

Risks	Challenges	Measures
• Shortage of fossil fuel supply • Fluctuation of fossil fuel price • Geopolitical risks • Fluctuation of RE power output	• Procurement of fossil furl • Securing baseload power	• Attach conditions for long-term fuel procurement to PPA contracts • Procurement of stable power sources such as nuclear and geothermal
• Increase of demand	• Secure supply capacity	• Introduction of support schemes for new power supply installations • Consumers own back-up power generation
• Uneven distribution of demand	• Optimize power system	• Locate demand proximity to power generator • Announce areas with surplus supply capacity • Introduce dynamic line rating to transmission line

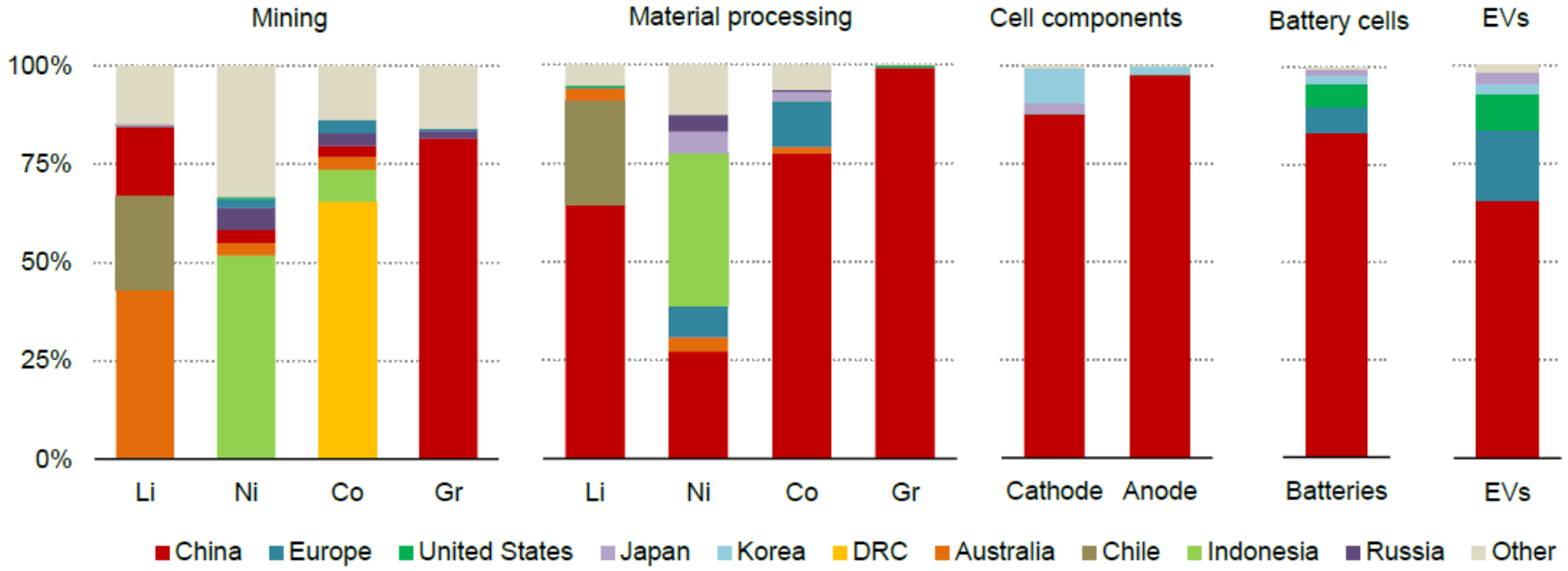
RE = renewable energy
Source : IEEJ

Risks of Critical Mineral Supply

Risks of clean technologies

- High market concentration observed in some clean technology production and in the supply of critical minerals that are essential for clean technologies. This is increasingly recognized as an emerging risk to the energy transition.
- Demand for critical minerals is expected to increase in the future. Therefore, the impact of supply disruptions (risk of supply shortages and price spikes) will also increase

Structure of on-board battery supply chain

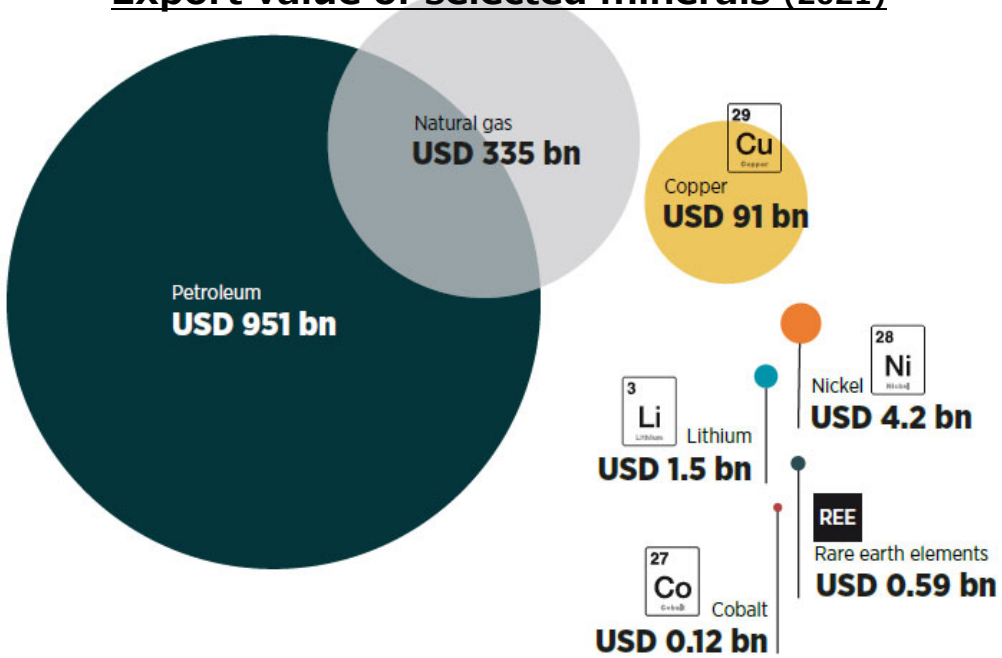


Li = lithium, Ni = nickel, Co = cobalt, Gr = graphite
Source: IEA (2024) "Global Critical Minerals Outlook 2024"

Challenges of stable supply of critical minerals

- The critical minerals market is small and immature, making it prone to the exercise of market power, cause supply-demand gaps and the resulting price volatility.
- As refining is energy-intensive and high environmental load, it is not easy for developed countries to make it competitive.
- Increasing international competition to secure key minerals and heightened resource nationalism should also be reminded.
- Uncertainty in future demand for critical minerals due to the potential for technological innovation.
- Long lead times for the development of new resources make it difficult to invest in supply source diversification.
- Overcoming these requires 1) consistent policy and 2) coherent development of supply and demand.

Export value of selected minerals (2021)



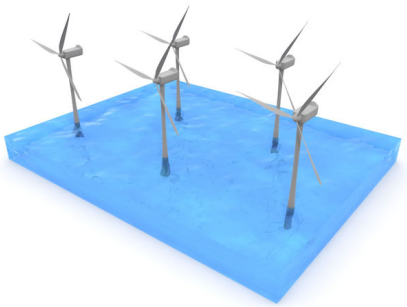
Source: (UN COMTRADE database).
Note: Numbers represent trade in raw, unprocessed fuels and ores only.

Source: IRENA (2023) "Geopolitics of energy transition, Critical Minerals"

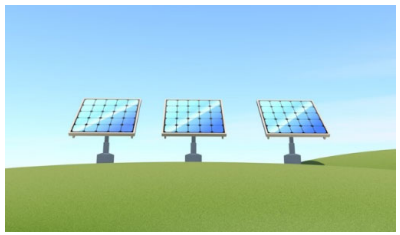
Technology mix for risk control

- Risks can be mitigated by combining different technologies with different risk characteristics.
- Development of those technologies and market creation is needed.

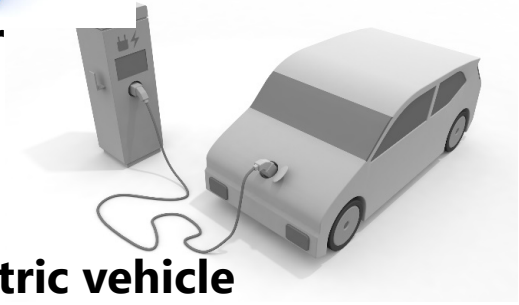
Technologies with higher market concentration



Wind power



Solar PV



Battery
Battery electric vehicle

Technologies with lower market concentration

- **Fossil power with CCS**
- **Hydrogen and ammonia power**
- **Nuclear power**
- **CN synthetic methane as city gas**
- **ICEV, HEV, and PHEV run by CN fuels**
  (biofuel, synthetic fuel)

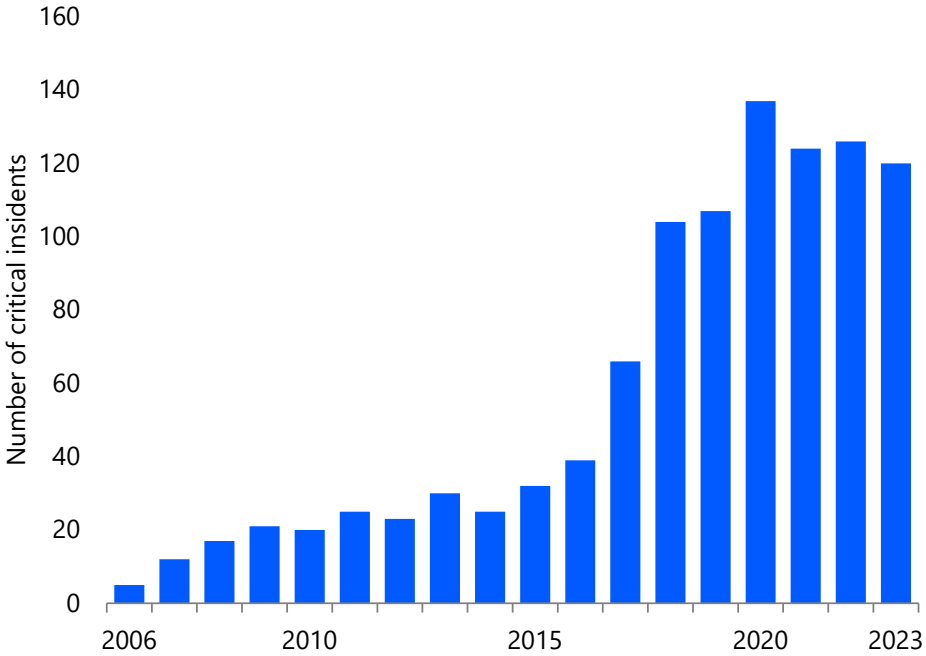
CN = carbon neutral, ICEV = internal combustion engine vehicle, HEV = hybrid vehicle, PHEV = plug-in hybrid vehicle
Source : IEEJ

Increasing Risks of Cyberattacks

Growing cyber risks to energy supply

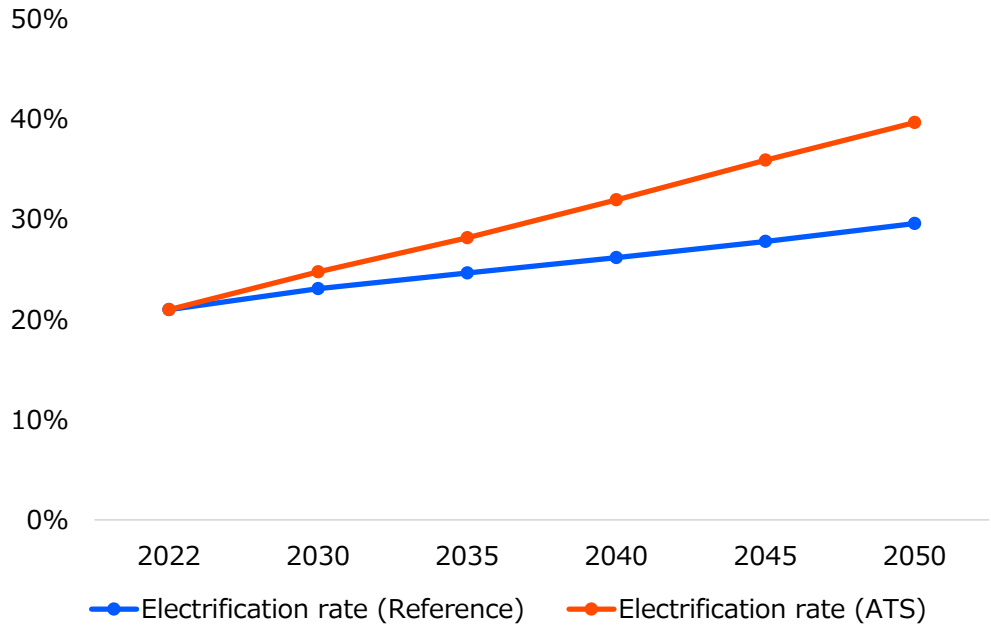
- Since mid-2010, the number of critical cyber-attack events has increased significantly worldwide.
- The energy transition, with its accompanying electrification, digitization, and network connectivity, will result in an increase in the severity of cyber-attacks as a potential risk factor.

Number of critical cyber incidents



Attacks targeting the government, defence or hi-tech sectors or with a damage value exceeding $1 million. Source : IEA (2020)、CSIS (2024)

Share of electricity in final consumption in the world



ATS = advanced technology scenario
Source : IEEJ

Increased cyber vulnerability

- As the energy transition progresses, vulnerability to cyber-attacks increases in the energy supply, storage and demand sectors.

Increase of vulnerability against cyberattack due to energy transition

Energy supply	Energy storage	Energy demand
• Upgrading of operational management systems - Operations management systems are integrated with information systems and connected to the internet - Increased use of cloud services and automation increases the impact in the event of an attack. • Increase in the number and diversification of distribute power operators - Increased number of attack points along the entire power supply chain, making it more difficult to build defences.	• Increased reliance on storage batteries - Potential impact of cyber-attacks on the operation of storage batteries (storage and discharge) due to an internet-connected storage battery management system (BMS)	• Increase in the number of Evs - EVs connected to each other and to the internet for diverse services - Potential intrusion into systems controlling energy-using equipment in dwellings via charging points • Smart dwellings and IoT in buildings - Possible attack points for cyber-attacks due to the introduction of systems that collect data on electricity use and temperature control in dwellings and control energy equipment

BMS = battery management system, EV = electric vehicle, IoT = internet of things
Source : Dawda, Herath, and Maccall (2022)

Scenarios of cyber-attack

- There are diverse patterns of cyber-attacks, with different actors, objectives and targets of attack.
- Considering Ukraine war, geopolitical risks should not be underestimated, and the possibility of weaponization in the form of threats to energy supply should also be taken into account.

Types of cyber-attacks on energy assets

Types	Methods	Incidents
Remote control and systemmalfunctioning by malware	Malware (malicious software) is fed into the attack target's internal network to remotely control the attack target's energy supply facilities from the outside, affecting the actual energy supply or causing the attack target's PCs or network to malfunction. State actors may also adopt this method.	2022, Germany: Wind power company 2022, Italy: Energy agency 2015, Ukraine: Power sysem
Securing ransom through ransomware	The same as above until the malware is sent to the internal network of the attack target. It then encrypts the internal data of the attack target and affects the operation of the system by the attack target. The attacks are often carried out by private actors.	2021, US: Oil pipeline company (the company stopped the operation for a week as a precaution)
System down through mass access	Concentrating large amounts of access against an attack target aim to bring down the target's systems.	2022, Lithuania: Energy company

Source : IEEJ

countermeasures against cyber-attacks

- It is difficult to provide 100% protection against cyber-attacks with their diverse patterns.
- However, the following measures can be taken to limit the damage caused by attacks and ensure early recovery.

Major countermeasures against cyber-attacks

Measures	At the government	At both ends	At the private sector
Institutional arrangement	• Develop policies to clarify the responsibilities of actors and encourage them to respond • Develop a framework for cooperation between actors	• Raise awareness of cyber security	-
Identify the risks	• Encouraging operators to identify cyber vulnerabilities and analyze risks	• Information sharing	• Identify and assess the risks • Identify and classify the risks of assets
Manage and minimize the risk	• Develop risk management processes • Prioritize response measures	• Develop and share methods for ensuring resilience • Human capacity building	• Develop risk management method • Prioritize response measures
Monitor the risks	• Develop risk monitoring processes • Cooperation with the National Intelligence Unit	-	• Regular monitoring of identified risks and vulnerabilities
Recovery from an attack	• Develop recovery plans / procedures and regular drills.	• Learning and preparation through sharing of past attack cases and lessons learnt	• Develop recovery plans / procedures and regular drills.

Source : Ecofys (2018); IEA (2021), World Energy Council (2022); METI･IPA (2022)

Any questions?