Transition Roadmap for Power Sector

February 2022

Electricity Infrastructure Division,

Agency for Natural Resources and Energy

Purpose and Positioning of Transition Roadmap

- Based on the Basic Guidelines on Climate Transition Finance (May 2021, Ministry of Economy, Trade and Industry, Financial Services Agency, and the Ministry of the Environment), this roadmap has formulated as **reference materials for the consideration of funding utilizing transition finance[*1] for enterprises in the electric power sector**.

- Simultaneously, this is intended to help banks, securities companies, investors, rating agencies, etc., **determine whether the use of funds of the transition strategy or finance that our country intends to implement in the electric power sector is eligible for transition finance**.

- In working toward decarbonization, it is important for each company to draw up a company-wide decarbonization strategy. A strong link between individual initiatives and company-wide decarbonization strategies is a major premise in determining funding's transition eligibility.

- This roadmap sets the goal of achieving carbon neutrality by 2050 and **provides an image of low-carbon and decarbonization technologies that are expected to be put to practical use by 2050, outlining the timing of the practical use based on currently available information.**

- This roadmap is consistent with national emission reduction targets (NDC)[*2] established under the Paris Agreement, the Green Growth Strategy[*3], and the R&D and social implementation plan[*4] of the Green Innovation Fund.

- **The roadmap will be revised as necessary considering future trends in the development and practical application of decarbonization and transition technologies.**

- While decarbonization efforts in the electric power sector should be promoted mainly by companies in the electric power sector, the Government also support the transition in the electric power sector by formulating an energy mix as of 2030 and developing and introducing decarbonization technologies through a fund.

*1: The term "transition finance" is defined in the Basic Guidelines as "a financing means to promote long-term, strategic GHG emissions reduction initiatives that are taken by a company considering to tackle climate change for the achievement of a decarbonized society."
*2: https://www.kantei.go.jp/jp/singi/ondanka/kaisai/dai41/siryou1.pdf
*3: https://www.meti.go.jp/press/2021/06/20210618005/20210618005-3.pdf
*4: https://www.meti.go.jp/shingikai/sankoshin/green_innovation/energy_structure/pdf/003_03_00.pdf

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Concept of transition finance

- Under the 2015 Paris Agreement, the long-term global goal has been set to keep the average global temperature rise below a minimum of 2 °C above pre-industrial levels and to continue efforts to limit it to 1.5 °C.
- The Intergovernmental Panel on Climate Change (IPCC) reported that it is necessary to reduce greenhouse gas emissions to net zero around 2050 to limit the temperature increase to 1.5 °C above the level of the industrial revolution at the end of 21st century.
- To achieve this goal, it is important to actively invest in climate change measures. In addition to promoting green investment in renewable energy, etc., **it is necessary to make a transition to decarbonization, such as making efforts to reduce carbon emissions in hard-to-abate sectors**.

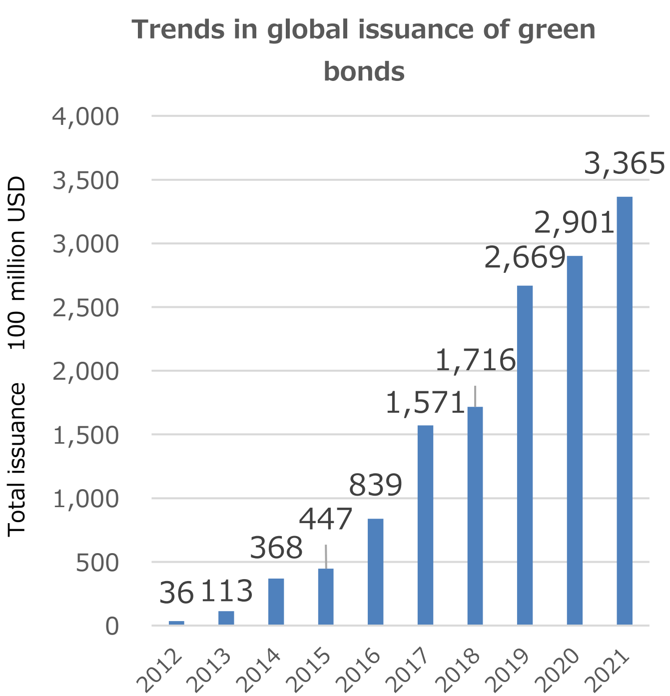
- **It is necessary to promote finance for companies in hard-to-abate sectors to set targets consistent with the Paris Agreement and to implement measures to reduce greenhouse gases in accordance with long-term strategies, as "transition finance".** (*)
- Early on, **it is essential to clarify what constitutes transition finance by accumulating examples** based on the ingenuity of both parties, such as the forward-looking attempts by funding-raisers and the understanding of funders. Once a sector-specific roadmap has been developed, it can be referred to and followed.

*May 2021 Basic Guidelines for Climate Transition Finance Financial Services Agency the Ministry of Economy, Trade and Industry the Ministry of the Environment

(Reference) Sustainable Finance

- The use of financing through green bonds and loans is limited to green projects. Issuances have been increasing since the Paris Agreement. However, as the issuance expands, Green Washing*1 comes to the surface, efforts are needed to secure reliability while promoting the widespread use of the product.

- The use of financing through sustainability-linked bonds and loans is not limitting the use of funds, but the conditions (including interest rates) of such bonds and loans may change depending on the degree of achievement of the sustainability/ESG targets set in advance by the fundraiser. It is necessary to indicate in disclosure materials of the bonds that the company will work to achieve the ambitious sustainability/ESG target set by the company.



	Green bond	Green loan (GL)	Sustainability-linked bond	Sustainability-linked loan (SLL)
Use of funds	Limited to green projects	Limited to green projects	Use of funds is not limited However, it is necessary to set goals to achieve ESG, etc.	Use of funds is not limited However, it is necessary to set goals to achieve ESG, etc.
Funder	Individual and institutional investors	Financial institutions including banks	Individual and institutional investors	Financial institutions including banks
Reporting	Public disclosure recommended	Recommend reporting to lenders Public disclosure is recommended for declaration of GL	Public disclosure recommended	Recommend reporting to lenders Public disclosure is recommended for declaration of SSL
External Review	External review recommended Results disclosure recommended	External review recommended Disclosure of results to lenders recommended Public disclosure recommended	External review recommended Results disclosure recommended	External review recommended Disclosure of results to lenders recommended Public disclosure recommended

*1: To use labels such as green bonds to make companies and their products and services appear to be environmentally conscious. A term coined based on whitewash to mean deception.
*2: Developed from Green Bond Guidelines 2020 (the Ministry of the Environment), Sustainability Linked Bond Principles Voluntary Guidelines 2020 (ICMA Japanese version)

(Reference) Differences between bonds and loans / Status of electric power companies

- In funding an electric power company, it is possible to issue ‘general obligation bonds’ granting an equitable lean secured by the entire assets held by the issuer. It provides access to a wide range of investors and contributes to lower interest rates.
- However, the issuance of ‘general obligation bonds’ will terminate the end of March 2025, and transition finance will be important for dealing with long-term funding since then.

Comparison of Characteristics of funding methods (Bonds and Loans)

	Bonds	Loans
Funder	Individual investors (unspecified) Institutional investors	Financial institutions, such as banks
Funding scale	Generally considered easier to raise a large amount than loans	Generally said to be harder to raise a large amount than bonds
Funding cost	Floating-rate financing (issuance) is available, but fixed interest rates are more common than loans.	Generally, "standard rate + spread (interest rate added according to progress of business)"
Borrowing period	In general, it is said that it is more likely to be extended than loans.	In general, it is said that most financial institutions will be able to handle this for about 5 to 10 years (up to about 20 years).
Repayment (redemption) flexibility	In general, installment payments are possible, but bullet repayment (redemption) is said to be more common than loans.	In general, the principle is equal interest and principal, but it is said to be possible to set a more flexible repayment schedule than bonds.
Flexibility such as rescheduling	It can be restructured, but it is less flexible than loans	Subject to the approval of creditors but is said to be easier than bonds.
Other	Basically, the idea is that creditors are unspecified. Certain measures are needed to unify the will of creditors.	The creditor is clear.

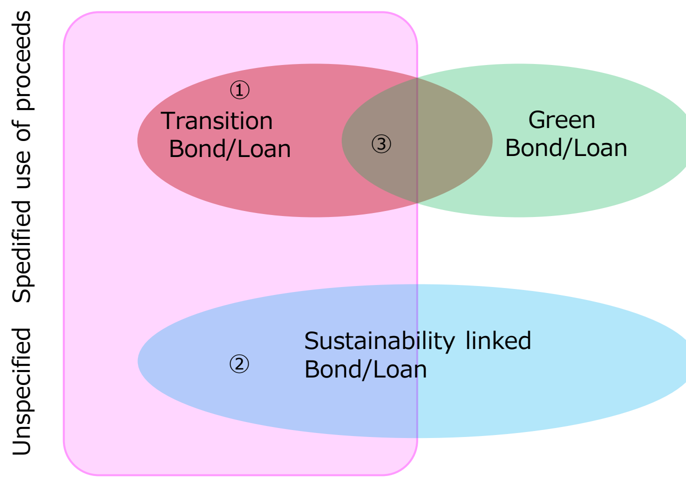
Positioning of transition finance

- From the perspective of promoting realistic transitions, it is important to promote transition finance to promote funding **<u>with a focus on the initiative of the transitional period that contributes to decarbonization.</u>**
- In the context of the clear requirement for fund-raisers to develop a strategy for realizing long-term goals consistent with Paris Agreement, **<u>it will provide financing to entities committed to more ambitious efforts in the future.</u>**
- It differs from green finance in that the use of funds are not limited to being green and from sustainability-linked bonds/loans in that the targets set by the fundraisers are required to be consistent with the Paris Agreement.
- In other words, not only financing specifying the use of funds such as green finance, but also financing not specifying the use of funds (transition link bond/loan), and the issuance of bonds using the framework that defines the use of funds or the project selection process*1 can be widely regarded as transition finance.
- As shown in the figure below, if the four elements of transition are met, green bonds and sustainability-linked bonds can be considered transition finance.

Transition Finance Disclosure Element

Element 1	Issuer's climate transition strategy and governance
Element 2	Business model environmental materiality
Element 3	Climate transition strategy to be science-based including targets and pathways
Element 4	Implementation Transparency

Transition Finance (Concept)



'Transition' Label Target

① Bonds/loans that meet the four elements of transition nad specify the use of funds (Funds will not be used for green projects)

② Bonds/loans of unspecified use of funds, meeting the four transition elements with targets set in line with the transition strategy and the borrowing condition varying according to the achievement status.

③ Meet the four transition elements and be in accordance with the principles of existing green bond principle and green bond guidelines

④ Meet the four transition elements, not limited to ① to ③.

*1: A policy that stipulates the use of procurement funds, the evaluation and selection process of projects, and procurement fund management methods prior to green finance.
*2. May 2021 "Basic Guidelines for Climate Transition Finance" Financial Services Agency, the Ministry of Economy, Trade and Industry and the Ministry of the Environment

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Trends in Decarbonization of Electricity Sector in Japan and Overseas

(International Trends)

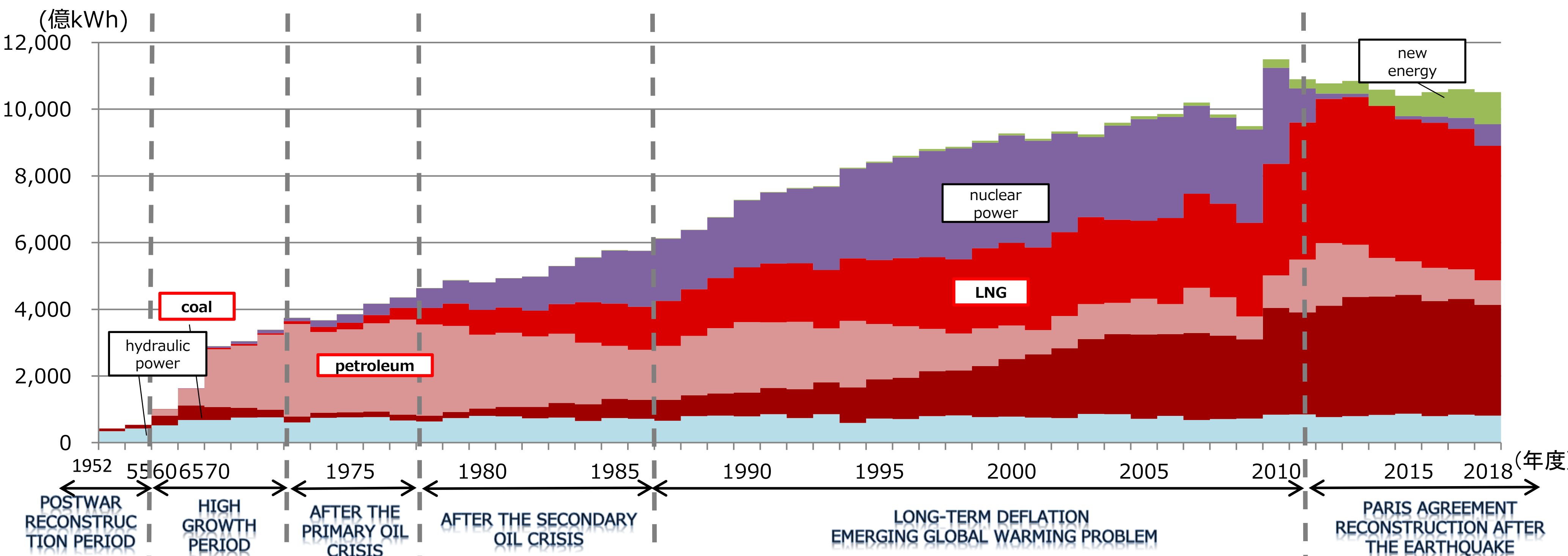
- In recent years, as natural disasters have become more severe worldwide, reducing greenhouse gas emissions has become an urgent issue. At COP 26 in November 2021, an agreement was reached to pursue efforts to limit the increase in temperature from before the Industrial Revolution to 1.5 degrees Celsius, and to accelerate efforts to reduce coal-fired power generation, for which measures to reduce emissions had not been taken.
- In particular, reducing CO2 emissions, which account for the majority of greenhouse gases, is the key issue, and there is an extremely high need for action in the electricity sector, where CO2 emissions are high. Against this background, at the G7 Summit held in June 2021, developed countries, including Japan agreed to "achieve maximum decarbonisation of the electricity system in the 2030s and commit to actions to further accelerate it".

(Domestic Trends)

- Considering these international trends, Strategic Energy Plan decided by the Cabinet in October 2021 states that all segments of the public, including industry, consumers, and the government, must make concerted efforts to realize carbon neutrality. Indirect emissions from electricity account for about 40% of Japan's CO2 emissions and reducing CO2 emissions in the electricity sector is an urgent issue in our country.
- At present, thermal power generation accounts for about 80% of our country's power generation mix. It is important to accelerate the decarbonization of power sources on the premise of ensuring a stable supply of electricity.
- Additionally, to achieve carbon neutrality in 2050, it is essential to reduce CO2 emissions in fields other than the electricity sector. In particular, to reduce CO2 emissions in the heat demand sector, it is important to promote electrification on the premise that the decarbonization of the electricity sector is promoted.
- While the major goal of achieving carbon neutrality by 2050 is shared by all countries worldwide, it is important to note that the specific path of the transition may differ depending on the individual circumstances of each country.

History of fossil fuels as an energy source

- After World War II, **hydroelectric power generation** was mainly used, but during the period of high economic growth, **thermal power generation,** such as **coal-fired thermal power generation and oil-fired thermal power generation,** increased rapidly as demand for electric power increased, and this led to **high economic growth.**
- Due to the oil crisis in the 1970s and global warming, **nuclear power and LNG thermal power increased.** After the Great East Japan Earthquake in 2011, **thermal power generation increased** replacing **suspended nuclear power plants.**
- In recent years, the amount of power generated by **thermal power generation** has **decreased** due to the **expansion of the introduction of renewable energy** and the **restart of nuclear power plants.**

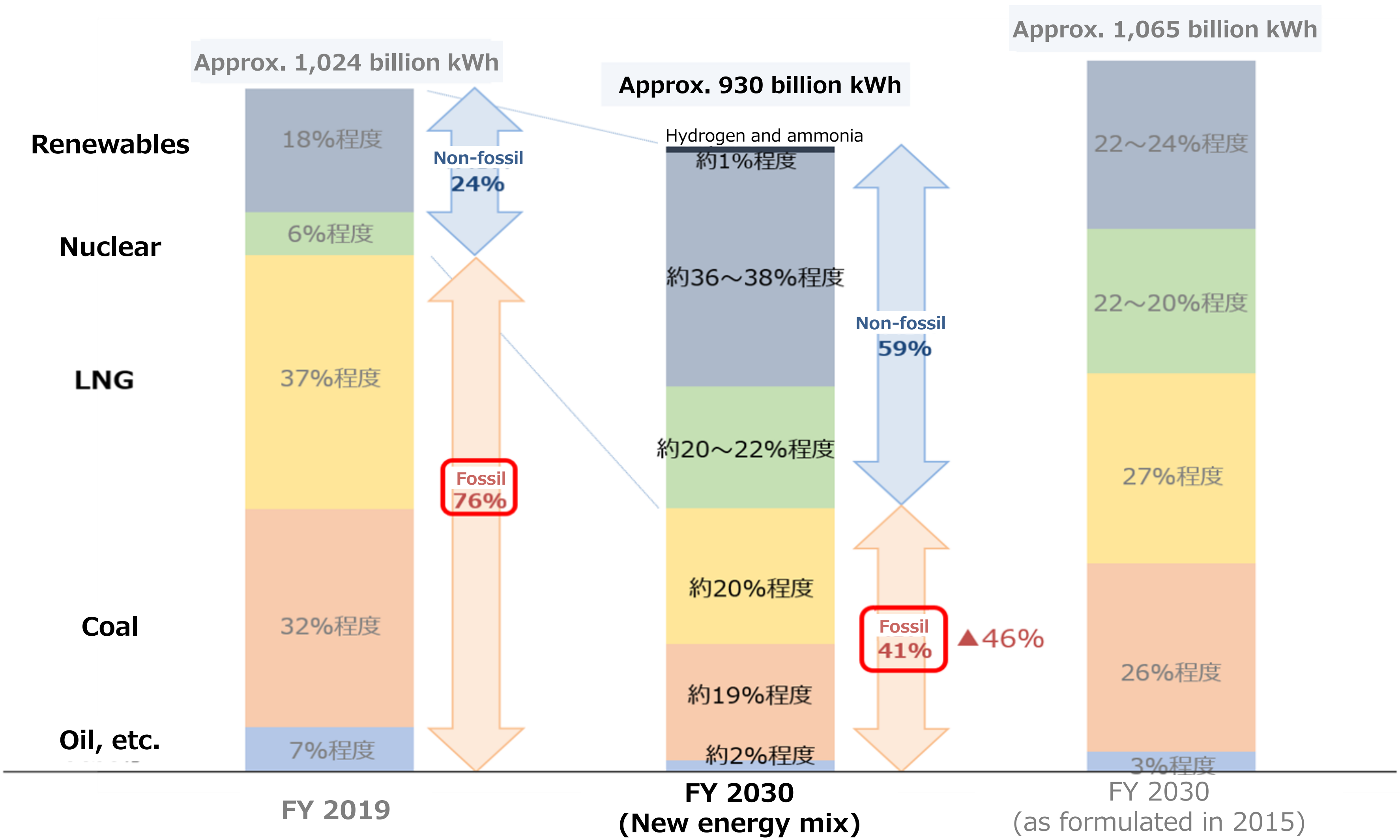


From hydraulic power to coal	From coal to oil	Lowering dependence on oil / Development of gas and nuclear power / Coal revaluation / Emphasis on nuclear power in response to global warming / Becoming the World's Best Energy Saving Nation	Renewable energy as mainstream power source

Source: Compiled based on "Outline of Power Development," "Outline of Power Supply Plan," and "Comprehensive Energy Statistics" from Agency for Natural Resources and Energy

The current situation and the new energy mix

- The 6th Basic Energy Plan (decided by the Cabinet on October 22, 2021) stipulates that thermal power generation will be reduced from the current level of about 76% to **about 41%** by FY 2030.
- This goes further than the 56% of the conventional power generation mix.



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Basic Concept of Transitions in the Power Sector (1)

(Basic Concepts of Electricity Policy)

- Electricity is essential for people's daily lives and economic activities. The impact of decarbonization efforts in the electric power sector must be fully considered in promoting such efforts.
- The goal of a decarbonized society is common to all countries. However, there are differences in the way in which they develop, and it is essential to promote realistic decarbonization efforts considering the circumstances in each country.
- In this regard, the decarbonization of the electricity sector should be promoted in conjunction with our country's energy policies, including the Basic Energy Plan.
- Specifically, it is necessary to aim for a stable supply of electricity and economic efficiency on the premise of safety.

(Circumstances Specific to Japan Surrounding Electricity)

- Our country is not rich in fossil resources and depends on imports for much of its energy supply. Further, it is characterized by a big hurdle in expanding the introduction of renewable energy as it has limited flat land areas and harsh natural conditions.
- Additionally, the country has different energy supply vulnerabilities than other countries, surrounded by the sea, and absence of international interconnection lines for importing and exporting electricity from overseas.
- Therefore, to secure a stable supply of electric power, it is necessary to secure fuel. In fact, at the beginning of 2021, the supply and demand of electricity was strained due to a decline in LNG inventories.
- Also, because of the high ratio of solar energy to renewable energy, there is a large difference in the amount of electricity supplied in a single day, and this is increasing the price difference in the wholesale electricity market.
- Taking these unique circumstances into account, promoting realistic decarbonization efforts will lead the country to implement effective climate change measures.

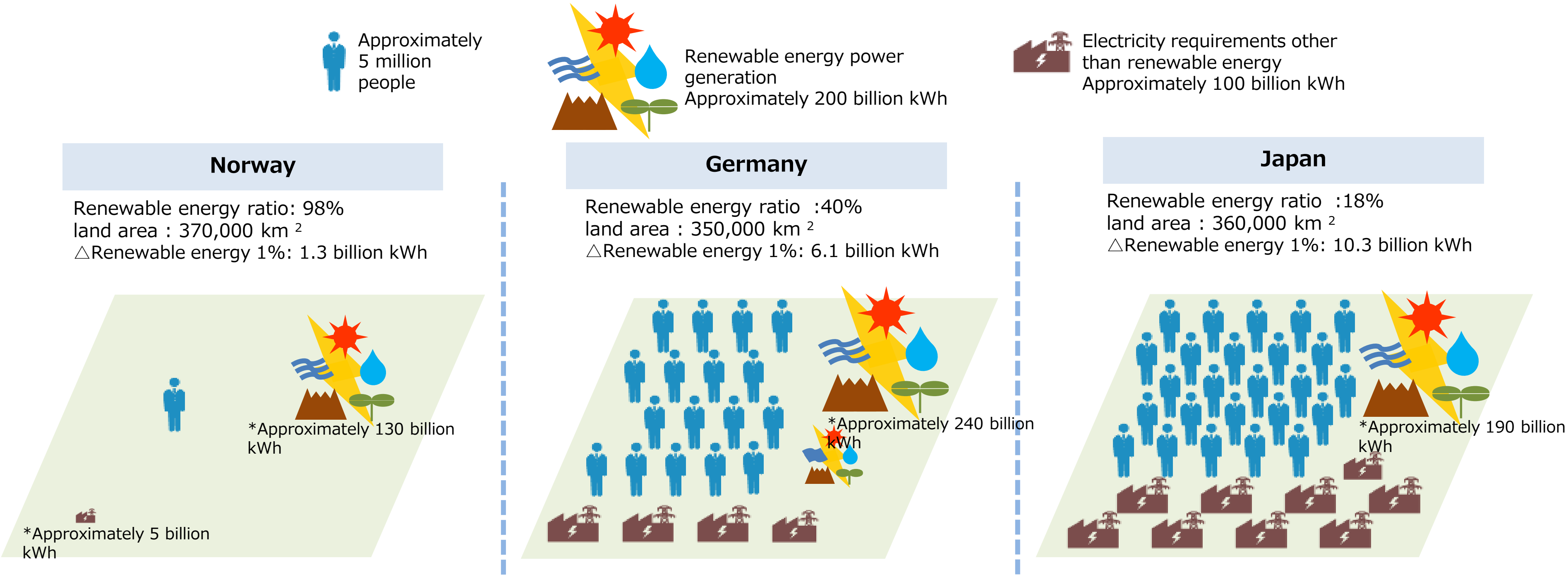
(Reference) Electricity Demand, National Land and Renewable Energy Ratio

- **Japan ranks third in the world for solar power and sixth in the world for total renewable energy** installed capacity.
- Because **renewable energy has a low energy density**, **the narrowness of suitable place for renewable energy is a constraint in increasing 'the amount of introduction'**.
- The renewable energy **'ratio'** depends on the size of electricity demand. **The proportion is lower in countries with high electricity demand.**

=>While Japan has a small land area, there is a large demand for renewable energy, so there is a limitation on increasing the ratio of renewable energy compared with other countries.

(Note: The size of the E.U. is 12 times larger than that of Japan, and electricity demand is 3 times larger.)

Even if the land area is the same, the availability of renewable energy and its ratio are different (2019).



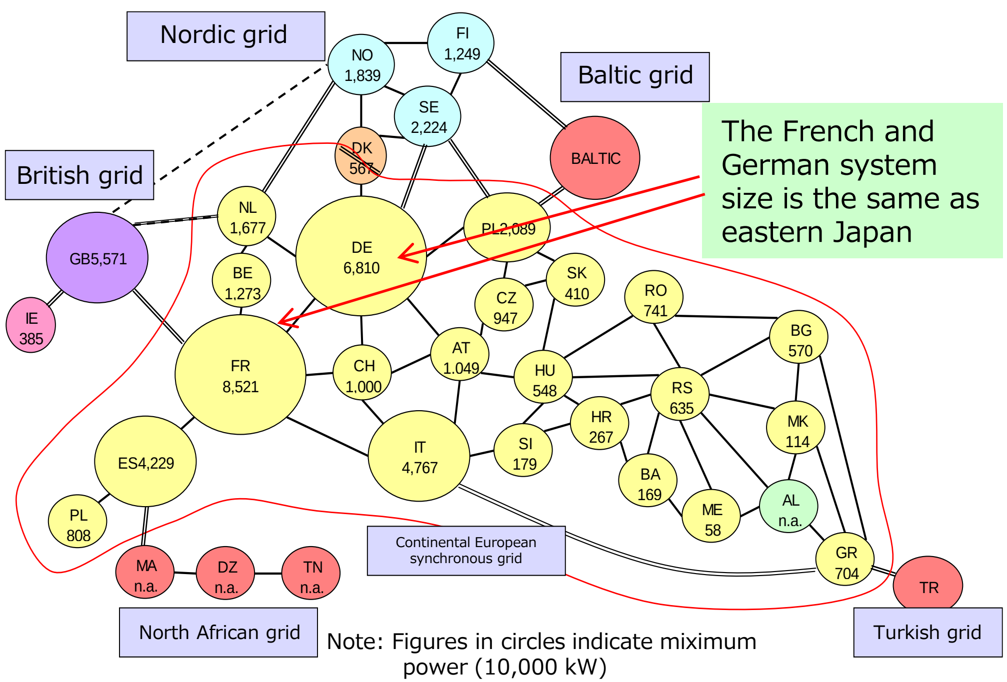
(Source) Electricity Generation: IEA General Energy Statistics, Population and Area: World bank

(Reference) Comparison of transmission grids in Europe and Japan

- **Europe** forms **a meshed transmission network throughout Europe.** When domestic supply is unstable, **it is possible to receive electricity through wheeling from other countries using various types of power sources such as nuclear power and coal.**
- On the other hand, **Japan does not have international interconnection lines, so it is necessary to secure supply capacity only with domestic power sources,*** and **there is a limit on the amount of wheeling capacity (transmission capacity) between areas.** To this end, **we must secure a stable supply of electricity while considering the power supply structure and flexibility constraints only within our own country.**

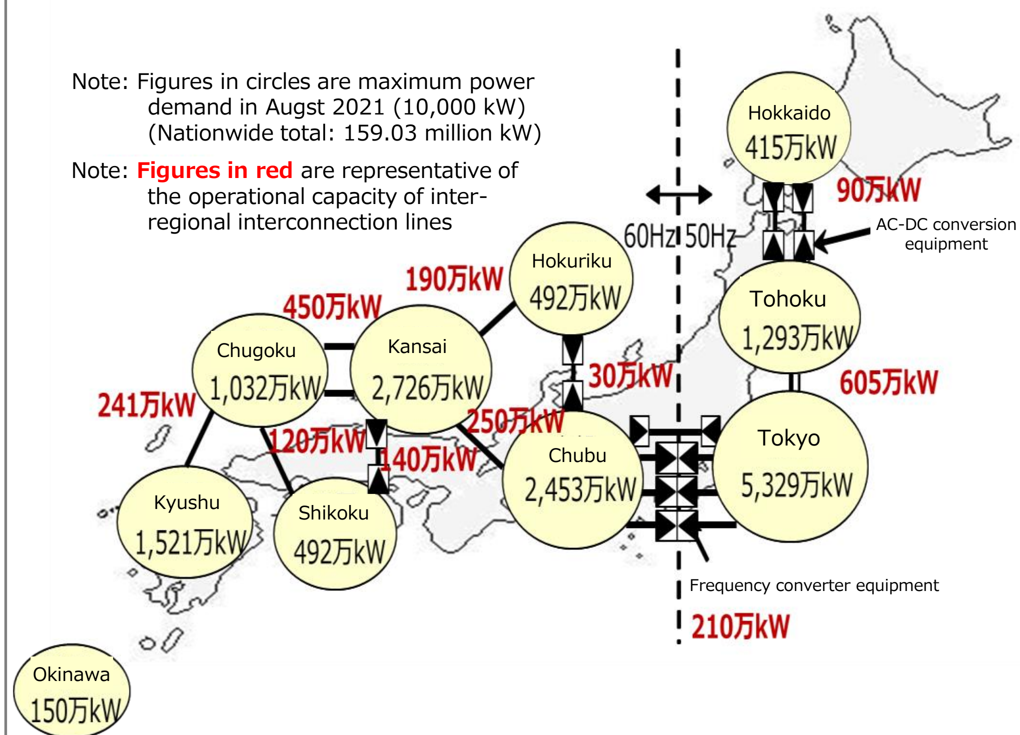
*In realizing international interconnection, there are various challenges, including security issues such as the stable supply of electricity, as well as an economic question of whether the construction of long-distance submarine cables is worth the high cost, and whether the development of domestic and international legal systems can overcome differences in rules between the two countries.

< Europe >



Size of the system in continental Europe: about 380 million kW

< Japan >

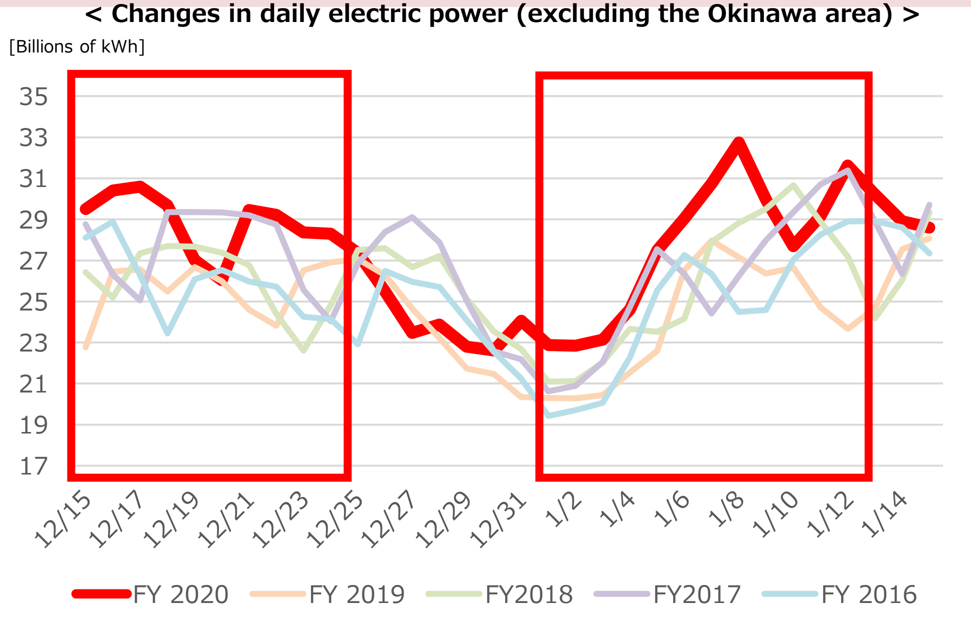


Size of the system in Japan: about 160 million kW

(Reference) Factors behind the tight electricity supply in January 2021

- 2021's winter's tight supply and demand is **mainly due** to **a large increase in electricity demand due to intermittent cold weather** and **a reduction in LNG thermal power generation due to a decrease in LNG inventory** caused by problems with LNG supply facilities. Additionally, the **stoppage of coal-fired thermal power generation troubles** and the **decline in the utilization rate of hydroelectric power due to drought and fluctuations in the amount of solar power generation** combined to create a **growing tight supply-demand.**
- Behind these pressures are structural events such as the **suspension and decommission of oil-fired thermal power plants** and the **decrease in the number of operating nuclear power plants.**

increase in demand



Comparison of Electricity Demand over Time in the Second Half of December (12/15–31) (FY 2020)

	Compared to fiscal 2016	Compared to fiscal 2017	Compared to fiscal 2018	Compared to fiscal 2019
rate of increase	+7%	0%	+4%	+9%

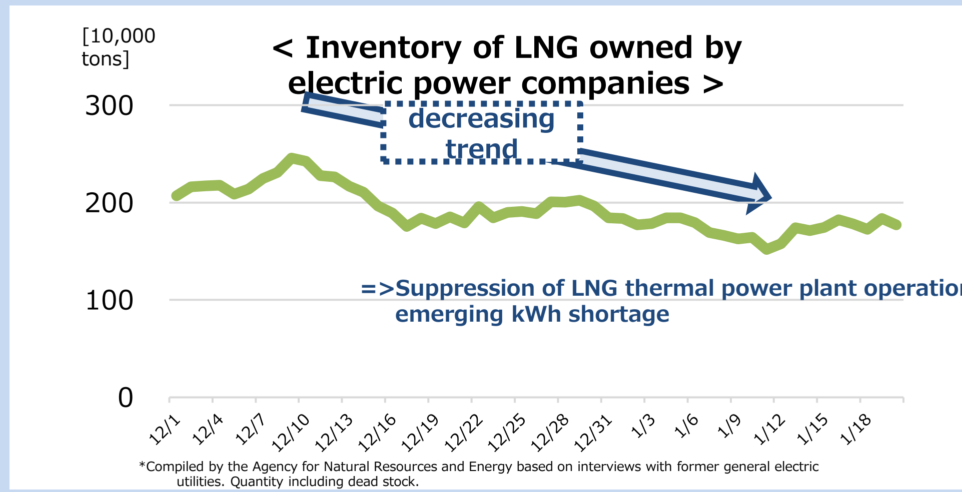
Annual comparison of electricity demand in the first half of January (1/1 – 15) (FY 2020)

	Compared to fiscal 2016	Compared to fiscal 2017	Compared to fiscal 2018	Compared to fiscal 2019
rate of increase	+11%	+6%	+8%	+14%

*System Information Disclosure System for Organization Promoting Wide-Area Operation of Electric Power (preliminary report)

decline in supply

[LNG thermal power]
Operation suppression due to fuel shortage



*Compiled by the Agency for Natural Resources and Energy based on interviews with former general electric utilities. Quantity including dead stock.

Increase tight supply and demand

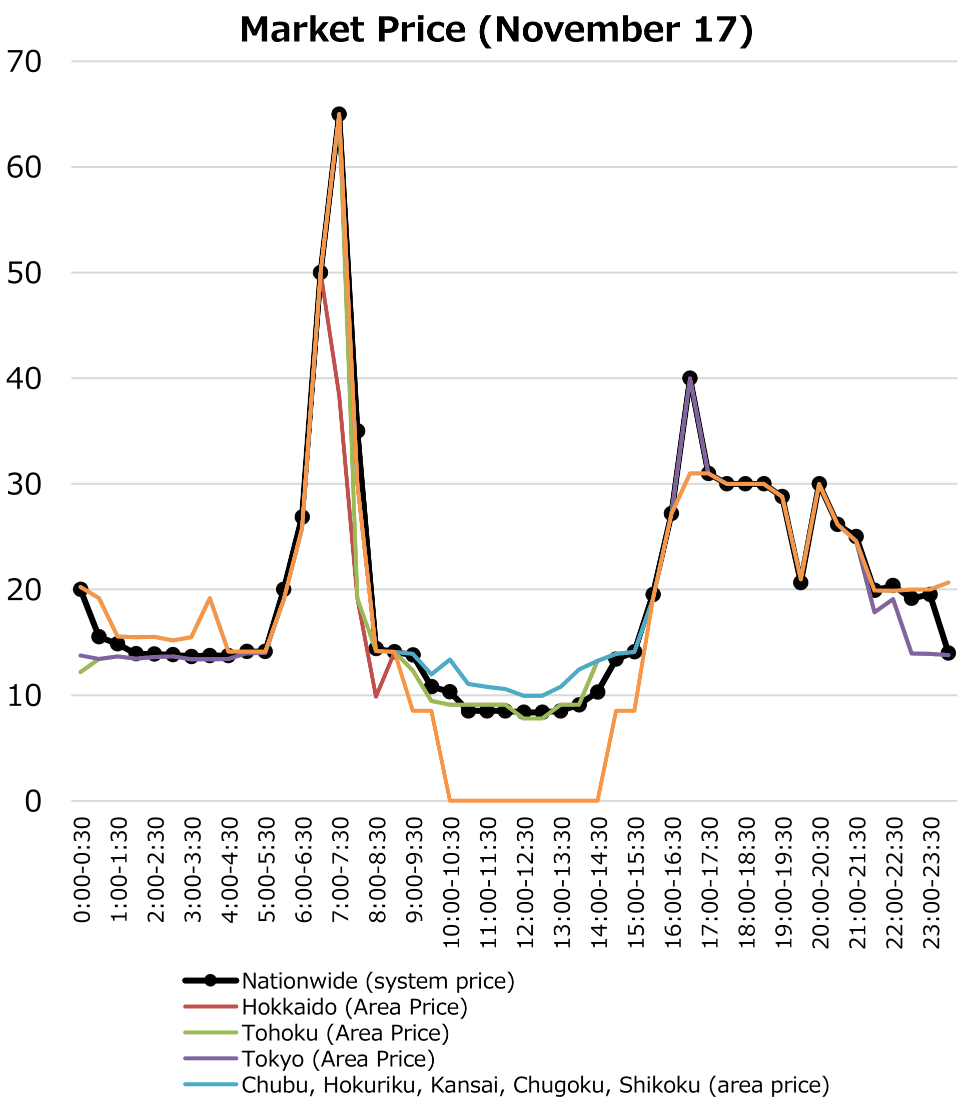
background

- **[Coal power]** trouble stop
- **[Hydropower]** drought-induced decline in utilization
- **[Solar]** fluctuation in power generation

structural event

- **[Oil fired power]** suspension and decommission
- **[Nuclear]** Reduction in the number of operating units at full capacity

(Reference) Example of recent changes in daily electricity market prices



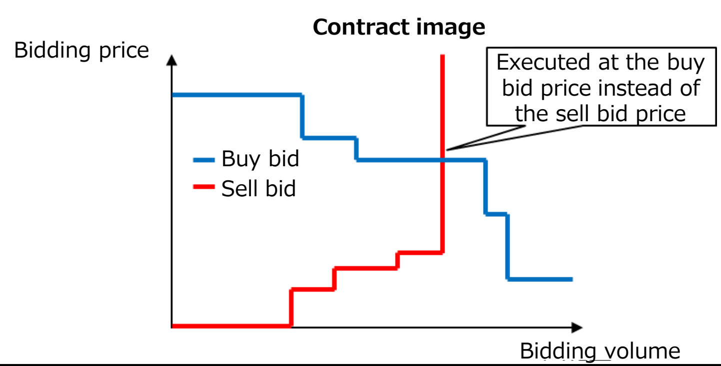
(1) Against a backdrop of **rising fuel prices** and other factors, overall electricity market prices tend to rise.

(2)At **around noon,** the electricity market price tends to be lower against the background of **increased output of photovoltaic power generation** (0.01 yen/kWh) and others

(Reference) Number of frames multiplied by 0.01 yen/kWh

	2020 October, November	2021 October, November
Nationwide (system price)	8	18
Kyushu (Area Price)	36	336

(3)In the **early morning or early evening** market prices tend to be higher against the background of **output decrease of photovoltaic power generation** (0.01 yen/kWh) and others



Basic Concept of Transitions in the Power Sector (2)

(How Transition in the Power Sector should be)

- To promote decarbonization under these preconditions, it is important to build a power system of integrated by various power sources.
- Specifically, as the ratio of fossil power sources is reduced, it is necessary to ensure a stable supply of electricity throughout the entire system, with highly variable renewable energy, thermal power as a balancing power source, and storage batteries and nuclear power complementing each other. Additionally, it is also necessary to integrate power generation, transmission and distribution, and the demand side into a unit of a highly flexible power system.
- To construct such an electric power system, it is essential to implement the most advanced technologies, and it is necessary to develop technologies for this purpose as well as to promote research and development that contributes to reducing the cost of introducing such technologies.
- The transition in the electric power sector is an initiative that should be promoted in consideration of these factors.

Scope of transition roadmap in the electric power sector (initiatives at the corporate level (1))

(Basic Views)

- In decarbonization efforts, it is important to draw up strategies for decarbonization at the company-wide level, rather than simply using individual project-based technologies. A strong link between individual initiatives and company-wide decarbonization strategies is a major premise in determining funding's transition eligibility.
- The path to carbon neutrality in 2050 should depend on the circumstances of each company. Concretely, it is necessary to take into consideration the conditions that differ depending on the area, such as the system size and renewable energy potential, and the difference in the current power supply configuration.

(Power Generation Sector)

- In the power generation sector, it is important to promote steady decarbonization using renewable energy and nuclear power, which are currently available decarbonized power sources.
- Because of expanding the introduction of renewable energy, which is a variable power source, and the absence of an international interconnection line, thermal power plays an important role in the stable supply such as for supply capacity, balancing power, and inertial function. On the other hand, due to the large CO2 emissions, it is necessary to develop and demonstrate technologies for decarbonization, such as the co-firing and mono-firing of hydrogen, ammonia, and biomass, and the use of CCUS, and to implement them as soon as possible.
- In addition to these decarbonization ways of thermal power sources, the following are also part of the transition.

  ○Reduction of the ratio of thermal power generation by suspension or decommission of existing thermal power plants and lowering the minimum output of thermal to reduction of the output control of renewable energy.

  ○Reduction of CO2 emissions through a combination of reduction in operating rates and introduce higher efficient thermal power.

Scope of transition roadmap in the power sector (initiatives at the corporate level (2))

(Electricity Transmission and Distribution and Demand)

- Although Efforts to upgrade the transmission and distribution network and introduce storage batteries and water pumping to expand the introduction of renewable energy do not directly contribute to decarbonization, they are necessary for the decarbonization of the power generation mix. Therefore, these efforts are also transitions because they are indirectly promoting decarbonization.
- Demand-side initiatives such as the promotion of the electrification of heat demand and demand response (DR) are transitions in terms of reducing heat use associated with CO2 emissions and contributing to the introduction of renewable energy. The same applies to the use of heat using hydrogen produced by water electrolysis (= indirect electrification). However, for the electrification of heat demand and indirect electrification, decarbonization in the power generation sector is a major premise.

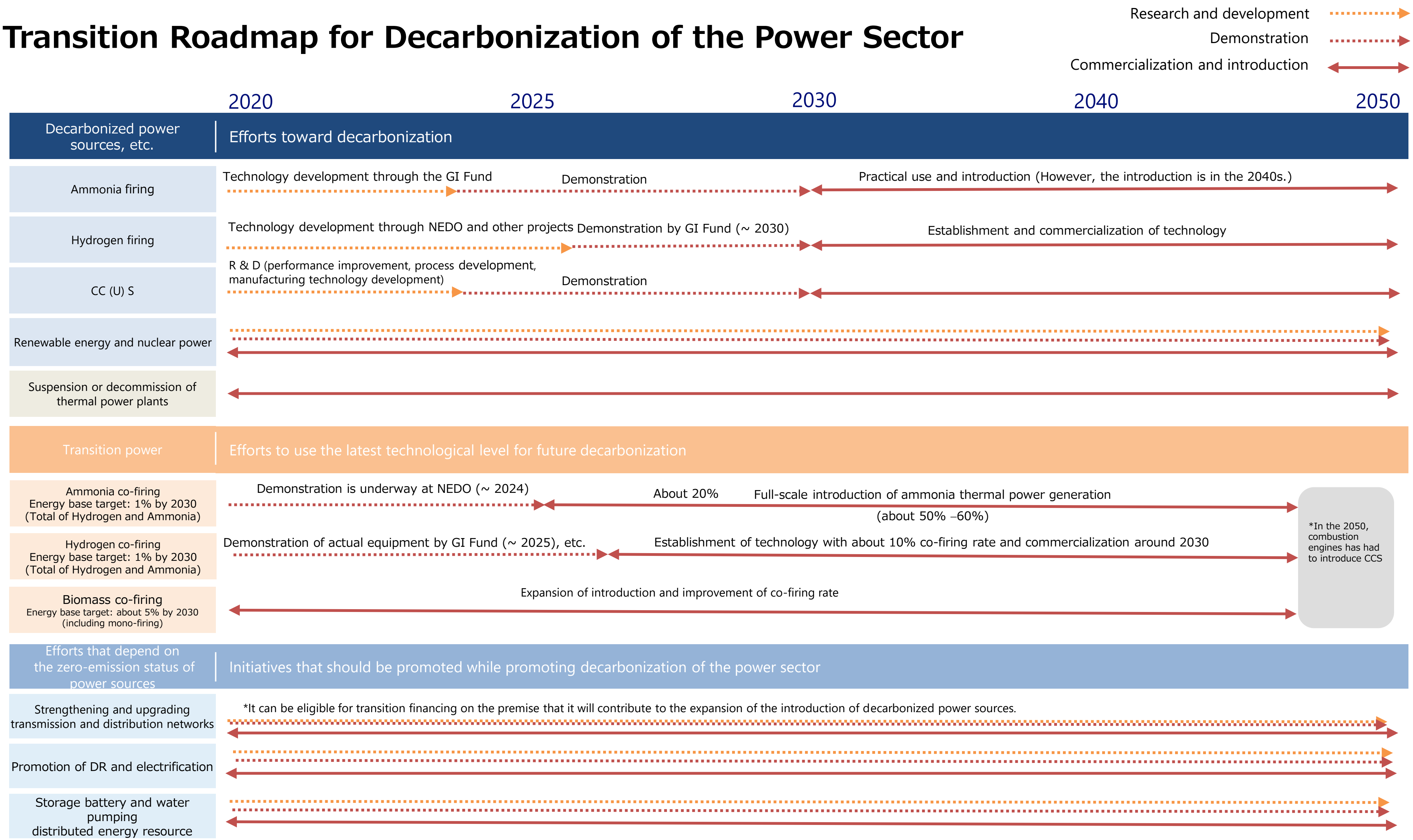
(Other)

- As indicated in the Basic Guidelines on Climate Transition Finance, the transition can be seen not only as a direct effort by businesses to reduce emissions, but also as a "just transition," including support for those who are economically disadvantaged by transitions, and support for decarbonization efforts by other companies.
- For example, in decarbonization efforts, including the suspension and decommission of large-scale power plants, it is necessary to proceed with the transition according to local conditions, considering the impact on the local economy and employment.
- On the premise that each business entity will make thorough efforts to reduce emissions, there may be business entities with special circumstances that make decarbonization difficult by such efforts alone. In such cases, the option of reducing emissions through the use of carbon credits or the purchase of carbon offset products is not denied.

Scope of transition roadmap for power sector (Technology)

- In the electric power sector, decarbonization technologies are diverse and often take a long time to develop. Therefore, to promote decarbonization efforts, it is important to pursue the possibility of developing a variety of technologies, rather than deciding on specific technologies in advance.
- Based on this concept, this roadmap shows the current prospects of promising technologies as quantitatively as possible.
- Specifically, the decarbonization of thermal power sources, such as the co-firing and mono-firing of hydrogen, ammonia, and biomass; the use of CCUS; as well as state-of-the-art renewable energy, nuclear power, and technologies for grid enhancement and demand-side electrification, can be eligible.
- To realize these new technologies, it is also necessary to establish a fuel supply chain for hydrogen, ammonia fuels, etc., and to develop elemental technologies such as CO2 separation and capture and carbon recycling.

Transition Roadmap for Decarbonization of the Power Sector



*Efficiency improvement and conversion from coal to natural gas of thermal power sources can be subject to transition financing on the premise of decarbonizing power sources by 2050, with an eye toward the introduction of mixed combustion and exclusive combustion of ammonia and hydrogen and CC (U) S in the future.

*"Electrification" includes indirect electrification (utilization of hydrogen produced by water electrolysis using electric power derived from renewable energy, etc.).

*The mixing ratio is based on heat quantity.

(Reference) Technology Pathways to Decarbonization

Decarbonization Power Supplies

Decarbonized power sources, etc.

Technology	Overview	Emission Intensity *1	Implementation year *2	Main Reference *3
Ammonia firing	✓ Mono-firing of ammonia in boilers and gas turbines	Up to 100% reduction	2030s	• Green Growth Strategy • Strategic Energy Plan • GI Fund - Social Implementation Plan *4
Hydrogen firing	✓ Mono-firing by hydrogen turbine	Up to 100% reduction	2030s	• Green Growth Strategy • Strategic Energy Plan • GI Fund - Social Implementation Plan *4
CC (U) S	✓ Promotion of technological development, demonstration, introduction, and commercialization of CCUS	Up to 100% reduction	2030s	• Strategic Energy Plan • GI Fund - Social Implementation Plan *4
Renewable energy and nuclear power	✓ Introduction of renewable energy and nuclear power	Up to 100% reduction	Already installed	• Green Growth Strategy • Strategic Energy Plan
Suspension or decommission of thermal power sources	✓ Suspension or decommission of existing thermal power sources	-	Already installed	• Strategic Energy Plan

*1: Calculated based on the emission factors of the existing technologies and the reduction by the technologies.
*2: For the Social Implementation Plan, ~~see~~ referenced the year of the implementation expansion and cost reduction phase started.
*3: The document which mentions implement year are underlined.
*4: R&D and Social Implementation Plan of the Green Innovation Fund.

(Reference) Technology Pathways to Decarbonization

Transition Power Sources and Initiatives that depend on the state of zero emission of power sources

	Technology	Overview	Emission intensity *1	Implementation year *2	Main Reference *3
Transition power	Ammonia co-firing	✓ Ammonia mixed firing in coal fired power plants	(Dependent on Co-firing Rate)	Late 2020s (20% co-firing with coal fired power)	• Strategic Energy Plan • green growth strategy • GI Fund - Social Implementation Plan *4
Transition power	Hydrogen co-firing	✓ Hydrogen mixed firing in gas thermal power generation	(Dependent on Co-firing Rate)	Late 2020s (10% Mixed grilling in gas fired)	• Strategic Energy Plan • Green Growth Strategy • GI Fund - Social Implementation Plan *4
Transition power	Biomass co-firing	✓ Biomass mixed combustion in coal-fired thermal power plants	(Dependent on Co-firing Rate)	Already installed	• Strategic Energy Plan
Efforts that depend on the zero-emission status of power sources	Strengthening and upgrading transmission and distribution networks	✓ Enhancement of transmission and distribution networks to expand the introduction of renewable energy	-	Already installed	• Strategic Energy Plan
Efforts that depend on the zero-emission status of power sources	Promotion of DR and electrification	✓ Demand-side decarbonization initiatives, electrification, etc.	-	Already installed	• Green Growth Strategy • Strategic Energy Plan
Efforts that depend on the zero-emission status of power sources	Storage battery and water pumping distributed energy resource	✓ Introduction of storage batteries and distributed energy resources that contribute to stability of the system	-	Already installed	• Green Growth Strategy • Strategic Energy Plan

*1: Calculated based on the emission factors of the existing technologies and the reduction by the technologies.
*2: For the Social Implementation Plan, referenced the year of the implementation expansion and cost reduction phase started.
*3: The document which mentions implement year are underlined.
*4: R&D and Social Implementation Plan of the Green Innovation Fund.

(Reference) Outline of hydrogen and ammonia power generation

The 35th Strategic Policy Committee of the Advisory Committee on Natural Resources and Energy (December 21, 2020) Document 1

	Hydrogen	Ammonia
Overview	➢ Hydrogen is mixed into gas-fired power generation whose combustion speed is relatively close. Since the combustion speed of hydrogen is high, technology to control its combustion is necessary. ➢ By using the above control technology, it is also possible to exclusively burn hydrogen in the gas turbine.	➢ Ammonia is injected at a constant rate into the recirculation area (high temperature and low oxygen) at the center of the power generation burner to burn ammonia while accelerating the decomposition and reduction reactions of ammonia. ➢ Ammonia has a combustion rate close to that of coal, making it suitable for use in coal-fired power plants.
Current efforts	➢ The demonstration of the mono-firing of the small unit (1 MW) has started in the actual plant and the technology development of the combustor has been completed to achieve the co-firing rate of 30% for the large unit (several 100,000 kW class). ➢ JERA also announced that it would aim to start co-firing from around 2030, as it could become a promising power source in 2050 if costs fall. Other power companies are also interested in using this technology.	➢ Although the reduction of NOx generation was a problem, we succeeded in developing a mixed combustion burner. Currently, a co-firing test with a large capacity is being conducted, and from FY 2021 to FY 2024, a demonstration of 20% co-firing using actual equipment is planned. ➢ Based on these efforts, JERA announced plans to use ammonia fuel in thermal power generation from the late 2020s. Other power companies are also interested in using this technology.
Strength	➢ **Many facilities such as turbine parts of existing gas turbine power generation facilities can be used as they are, and assets can be effectively utilized.** ➢ Equipped with adjustment force and inertial force function, contributing to grid operation stabilization.	
	➢ One location can create large-scale hydrogen demand and **contribute significantly to the construction of an international supply chain to further enhance hydrogen utilization**. ➢ It is expected that technology for 100% hydrogen firing will be developed.	➢ The ammonia market already exists mainly for fertilizer applications. **Infrastructure development using existing manufacturing, transportation, and storage technologies is possible.** ➢ Liquefaction is possible at -33 °C (atmospheric pressure), **which reduces transportation and storage costs.**
Weakness	➢ In the case of liquefied hydrogen, in addition to embrittlement, it is necessary to use materials that can withstand extremely low temperatures. ➢ When MCH or ammonia is used as a hydrogen carrier, the dehydrogenation process also uses energy.	➢ **NOx control technology and heat recovery technology to secure the amount of heat required for power generation are necessary** to improve the co-firing rate and to specialize in firing. ➢ Due to its toxicity, it must be handled with care.

(Reference) Overview of CCUS/Carbon Recycling

The 41th Strategic Policy Committee of the Advisory Committee on Natural Resources and Energy Document 1

- Consistent basic technology has already been established, and demonstration is currently being carried out for large-scale operation and commercialization.
- There are many areas in which Japanese companies are internationally competitive.

	Separation and Capture	Transport	Storage	Carbon recycling
Overview	**<u>Separating CO2 from emission sources</u>** < Separation/capture Technology > Physical Absorbent/Chemical Absorption/Membrane Separation/DAC < Source of emission > Natural gas treatment, power generation, iron production, cement production, fertilizer production, bioethanol production, refinery, biomass power generation, waste treatment plant, blue hydrogen production	**<u>Captured CO2 is transported to storage/recycling sites</u>** < Transportation > [Land area] Pipelines, tanker trucks, railways [Sea area] Undersea pipeline, shipping	**<u>Injection and storage of CO2 into underground reservoirs and monitoring</u>** < Drilling, injection and monitoring > [Reservation area] Land and land area, under the seabed, and on the sea [Injection] Aquifer Storage/Oil Tank Storage (EOR) [Monitoring] CO2 monitoring after injection	**<u>Manufacturing chemicals and fuels using CO2 as a resource</u>** < Carbon recycled products > [Chemicals] General purpose products (paraxylene, etc.) [Fuel] Methane, the main raw material for gasoline and city gas [Minerals] Concrete products, etc.
Current efforts	**<u>Already commercialized technology exists</u>** **<u>Innovative absorption methods are under R&D</u>** ・There is a proven track record in amine absorbents in Japan and overseas. ・Conducted R&D on separate and capture for each emission source in Japan and overseas.	**<u>No experience in long-distance transportation of CO2 in Japan</u>** ・In Japan, onsite pipeline transport only. Overseas, we have experience with long-distance pipelines (over 100 km). *In the case of carbon recycling, it is possible to reuse CO2 in the vicinity of the emission source. *In long-distance transportation (over 200 km), shipping is more cost-effective than pipelines, and efforts to commercialize shipping in Japan and overseas have progressed.	**<u>Technical demonstration of injection and monitoring technology</u>** ・Cumulative injection volume reached 300,000 tons in November 2019 in a large-scale CCS demonstration test conducted in Tomakomai City (Establishment of operation technology) ・Continued monitoring of CO2 after injection	**<u>Some products are commercialized.</u>** **<u>Many are in the R & D and demonstration stages.</u>** **<u>Research and development is active worldwide</u>** ・Development and expansion of R&D bases ・R&D, demonstration, and commercialization of chemicals, fuels, and minerals are all in full swing in some areas. ・Globally, R&D, demonstration and commercialization are becoming more active

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Scientific basis

- This Roadmap is aligned with the Paris Agreement, referring to various Japanese policies and international scenarios aimed to achieve carbon neutrality in 2050.
- In addition to the steady use of renewable energy and nuclear power, which are already in practical use as decarbonized power sources, the suspension and decommission of thermal power plant, introduction and expansion of ammonia, hydrogen co-firing and exclusive firing technologies, and CCUS will contribute to achieving carbon neutrality in 2050 .

Reference/ Evidence

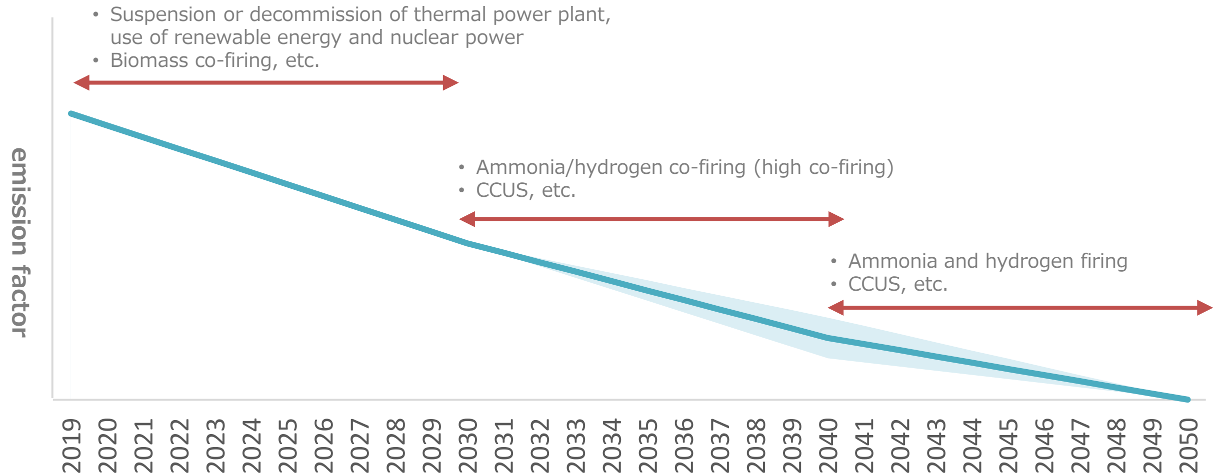
Government Policies

✓ The Basic Energy Plan and Strategic Policy Committee Materials
✓ Green Growth Strategy Through Achieving Carbon Neutrality in 2050
✓ R&D and Social Implementation Plan for the construction of a large-scale hydrogen supply chain project
✓ R&D and Social Implementation Plan for the construction of fuel ammonia supply chain project
✓ R&D and Social Implementation Plan for the development of technology for CO2 separation, capture, etc project

International Scenarios/ Roadmaps, etc. aligned with Paris Agreement

✓ Clean Energy Technology Guide (IEA)
✓ World Energy Outlook 2021 (IEA)
✓ Science Based Target initiative

Assumed CO2 Reduction Pathway *



1 **2020~2030**
In addition to expanding the use of renewable energy and nuclear power, which are decarbonized power sources that have already been put into practical use, efforts will be made to reduce carbon emissions by co-firing biomass into thermal power generation and suspending or decommission thermal power. In parallel, ammonia/hydrogen co-firing technology and CCUS technology will be developed and demonstrated.

2 **2030~2040**
Expanding the introduction of the co-firing of ammonia/hydrogen and increasing the ratio of them to achieve higher co-firing.

3 **2040~2050**
Achieved carbon neutrality by significantly reducing emissions through the commercialization and expansion of ammonia/hydrogen exclusive firing.

* It should be noted that this only illustrates the assumption of the overall Japanese power sector’s decarbonization pathway. In reality, decarbonization will be achieved based on each company’s long-term strategy and hence, will not necessary be the reflection of this assumption.

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Overview of the Strategic Energy Plan

*Excerpt from the outline material of the 6th Basic Energy Plan

- In the new Strategic Energy Plan, the key theme is to show **the path of the energy policy** to realize **carbon neutrality by 2050 (announced in October 2020),** and reduce greenhouse gas emissions by 46% in FY 2030 from its FY 2013 levels, while continuing strenuous efforts in its challenge to meet the lofty goal of cutting its emission by 50% **(announced in April 2021).**

  - In the midst of the global move for decarbonization, it is important for Japan to **lead international rule making** and improve international competitiveness through **decarbonization technology that has been fostered so far and innovation further contributing to decarbonization.**

- At the same time, another important theme is to overcome the challenges Japan's energy supply-demand structure faces. **On the major premise of safety,** efforts **will be made for energy security and economic efficiency of energy while promoting climate change countermeasures (S+3E).**

- Strategic Energy Plan mainly consists of parts of **(1) Progress in the past decade after the accident at TEPCO's Fukushima Daiichi Nuclear Power Station, (2) Challenges and responses for achieving carbon neutrality by 2050**, and **(3) Policy responses towards 2030 looking ahead to 2050**.

Points of challenges and responses to realize carbon neutrality by 2050

*Excerpt from the outline material of the 6th Basic Energy Plan

- Towards 2050, **efforts for energy sector accounting for over 80% of greenhouse gas emissions** are important.
  - ➢ Even taking into account the industrial structure where manufacturing industry accounts for 20% of the nation's GDP and the natural conditions, **realizing carbon neutrality is not easy**. In order to overcome challenges, **all-out efforts at all sectors of society such as industry, consumers and the government** are required.
- Power sector will steadily be decarbonized **through decarbonized power sources under practical use** as well as **pursue innovation in the thermal power generation, etc. by means of hydrogen/ammonia-fired power generation and the carbon storage/utilization based on CCUS/Carbon Recycling .**
- Non-power sector will **electrified by decarbonized power sources**. Sectors where electrification is not feasible (e.g. high-temperature heat demand) will promote decarbonization through the use of hydrogen, synthetic methane and synthetic fuels. Particularly **in industry sector**, **innovations are essential** such as hydrogen-reduced iron making and artificial photosynthesis.
  - ➢ **The Government strives to make all-out efforts toward decarbonization innovations using "Green Innovation Fund" and so on so that it will lead to enhancement of competitiveness in Japan's industries.**
  - ➢ Fields where carbon dioxide emissions are unavoidable at the end will be addressed by **DACCS, BECCS and forest sink measures.**
- Through our efforts towards carbon neutrality by 2050, **it is essential to support the economic activities by ensuring stable and cost-efficient energy supply on the major premise of safety.** On this premise, **we will address maximum introduction of renewable energy as major power sources on the top priority ; societal implementation of hydrogen and CCUS will be promoted**; and **necessary amount of nuclear power will be continuously utilized on the major premise of ensuring safety and public trust.**
- Including these efforts, **all options will be pursued** to realize carbon neutrality by 2050 with striving to maintain global competitiveness and restrain national burden by securing stable and cost-efficient energy supply.

Points of the policy responses towards 2030 [Basic Plan]

*Excerpt from the outline material of the 6th Basic Energy Plan

- The major principal of the energy policy is to **first and foremost ensure stable supply**, and **realize low cost energy supply by enhancing its efficiency on the premise of safety**. It is also important to make maximum efforts to **pursue environment suitability (S+3E)**.

Points of the policies towards 2030 [Demand side's efforts]

- Further pursuit of **thorough energy efficiency improvement**
  - **In the industrial sector,** the index and the target values of **the Benchmark Program will be reviewed** to urge business operators to improve their energy efficiency, **the development and the introduction of energy efficient technologies** will be promoted under the new "Energy Efficient Technological Strategies".
  - **In the commercial and residential sectors**, **mandating to meet and enhancing the energy efficiency standards based on the Act on the Improvement of Energy Consumption Performance of Buildings** , and **strengthening the Top Runner equipment/building material standards** will be addressed, in order to enable new housings and buildings built from 2030 to meet ZEH/ZEB efficiency standards.
  - **In the transport sector**, the introduction and dissemination of **electrified vehicles and its infrastructure** will be promoted and **the electrified vehicle-related technologies (e.g. batteries) and supply chains** will be enhanced, **the applications of AI and IoT** will be promoted to encourage the collaboration of shippers and carriers **for overall optimization of freight transportation**.
- Consideration of **new systems to encourage energy transition on demand side**
  - **The amendment of the Act on the Rationalization etc. of Energy Use**, which is aimed at rational use of fossil energies, will be considered. In the new system, **the rationalization of overall energy consumption** including non-fossil energies and **the enhancement of non-fossil energies** will be promoted in parallel.
  - New framework will be established to assess business operators who **enhance the usage rate of non-fossil energies** or **optimize their energy demand in response to the fluctuation of energy supply.**
- **Sophistication of the secondary energy structure** including effective use of distributed energy resources such as batteries
  - **Aggregation businesses utilizing distributed energy resources** such as storage batteries will be promoted; and **efficient energy use, enhanced resilience and activation of the local community** by local production for l consumption will be promoted **by microgrid implementation**.

Points of policy responses towards 2030 [Renewable energy]

*Excerpt from the outline material of the 6th Basic Energy Plan

- On the major premise of S+3E, utilization of renewable energy **as the major power source** will be ensured; the **top priority** will be put on renewable energy; and **maximum introduction of renewable energy** will be promoted while **managed excessive national burden and co-living with local communities** are being sought.

[Specific efforts]

- **Ensuring optimal siting while living in harmony with local communities**
  → **Introduction and expansion of solar photovoltaic/onshore wind** will be addressed by setting of renewable energy promotion zones **("positive zoning")** based on the amended Act on Promotion of Global Warming Countermeasures; and **acceleration of offshore wind projects** based on the Act on Promoting the Utilization of Sea Areas for the Development of Marine Renewable Energy Power Generation Facilities will be addressed.

- **Enhancement of business discipline**
  → **Enhancement of safety measures** by steady implementation of technical standard dedicated to solar photovoltaics and strengthening of accident reporting in small power sources; and backup for local communities in **developing the ordinances** aiming at smooth co-living will be addressed.

- **Cost reduction and market integration**
  → **Integration of renewable energy into the market** will be addressed by **policy collaboration of bidding system, mid- to long-term target prices** and **FIP system** that enhances renewable power suppliers to sell electricity according to the market price.

- **Overcoming power grid constrains**
  → **The bulk systems** such as cross-regional interconnection lines, etc. will be **upgraded by the master plan in "push-type approach"** and **non-firm access will be extended to local grid networks, The rules for use of power grids** will be reviewed so that renewable energy can use the bulk system preferentially to coal-fired power, etc.

- **Rationalization of regulations**
  → **Assessment will be optimized** towards **smooth introduction of wind power generation** and **review of regulations operations of Natural Parks Act, Hot Springs Act, and Forest Act** towards **introduction and expansion of geothermal power** will be addressed.

- **Promotion of technological development**
  → **R & D and societal implementation of advanced solar photovoltaic** mountable on the building walls and less resilient roofs will be accelerated; development of **element technology of floating wind power generation** will be accelerated; and **development of deep drilling technology** to leverage **supercritical geothermal resources** will be addressed.

Points of policy responses towards 2030 [Nuclear]

*Excerpt from the outline material of the 6th Basic Energy Plan

- **Sincere regrets for the accident of TEPCO's Fukushima Daiichi Nuclear Power Station** is the start point of nuclear policy
  - On the premise that **safety comes before everything else** and **every possible effort is made to resolve people's concerns**, judgment as to whether nuclear power plants meet the new regulatory requirements will be left to the Nuclear Regulation Authority (NRA) and **in case that the NRA confirms the conformity of nuclear power plants with the new regulatory requirements, which are of the most stringent level in the world, the Government will follow NRA's judgment and will proceed with the restart of the nuclear power plants. In that case, the Government will make best efforts to obtain the understanding and cooperation of the host municipalities and other relevant parties.**
- Stable use of nuclear power will be promoted on the major premise that public trust in nuclear power should be gained and that safety should be secured.
  - **Restart of operation with safety as top priority:** launch of **restart acceleration task force; bringing human resources and knowledges together;** and **maintaining and improving technological capability**
  - **Measures for spent nuclear fuel: promotion of construction/utilization of interim storage facilities and dry storage facilities, etc. to increase storage capacity;** and **technology development for reducing the volume and harmfulness of radioactive waste**
  - **Nuclear fuel cycle: makes efforts towards the completion and operation of Rokkasho Reprocessing Plant by public and private partnership** obtaining understanding of relevant municipalities involved and international society; and **further promotion of plutonium-thermal (MOX(Mixed Oxide) fueled) power generation**
  - **Final disposal: steady implementation of literature surveys** in two municipalities of Hokkaido, and **commencement of surveys in as many areas as possible across Japan**
  - **Efforts for various challenges, etc. in proceeding with long-term operation with secured safety :** Fulfilling conservation activities and considering of various issues depending on each role of public and private sectors
  - **Public understanding:** interactive dialogue including regions where electricity is consumed; and easy-to-understand polite public relations/public hearing
- Building up trustful relationship with local community of the site
  - Perception will be shared and trustful relationship will be deepened through **polite dialogue with local community of the site**; and **support matching its reality** will be provided by **picturing of the region's future profile including multistreaming of local industry and creation of new industries and employment**.
- Promotion of R & D
  - By 2030, while making the most of the private sector's ideas and wisdom**, development of fast reactor will be steadily promoted by utilizing international cooperation; small modular reactor technology will be demonstrated through international cooperation**; and **component technologies related to hydrogen production at high temperature gas-cooled reactor will be established**; as well as **R&D of nuclear fusion** will be promoted through international collaboration such as ITER Project, etc.

Points of policy responses towards 2030 [Thermal]

*Excerpt from the outline material of the 6th Basic Energy Plan

- As to thermal power generation, **on the major premise of its stable power supply**, **thermal power ratio in power generation mix will be lowered as much as possible while assuring installed capacity** in a manner that keeps supply capability to cope with instantaneous/continuous power generation reduction in renewable energy and taking into account the following:
  - From the perspective of procurement risk, CO_2 emission per electricity generated, and contribution to improvement in resilience such as stockpiling/ease of storage, **appropriate thermal portfolio will be maintained** in LNG, coal and oil.
  - While promoting next generation/high efficient thermal, **fadeout of inefficient thermal** will be steadily addressed; **CO_2 emission reduction measures such as co-firing with decarbonized fuels e.g. ammonia/hydrogen, etc. and CCUS/Carbon Recycling, etc.** will be promoted towards its replacement with decarbonized type thermal power generation.
- **An end to new direct government support for unabated international thermal coal power generation by the end of 2021, including through Official Development Assistance, export finance, investment, and financial and trade promotion support.**

Points of policy responses towards 2030 [Hydrogen/Ammonia]

*Excerpt from the outline material of the 6th Basic Energy Plan

- Looking ahead to the carbon neutral, **hydrogen will be positioned as a new resource and its societal implementation will be accelerated.**

- In order to supply cost-effective hydrogen/fuel ammonia, **steadily and by large amount in the long term, inexpensive hydrogen from overseas will be utilized** and **hydrogen production base will be established by utilizing domestic resources.**

  - **Commercialization of hydrogen production utilizing international hydrogen supply chain and water electrolysis equipment using excess renewable energy, etc.; and development of innovative hydrogen production technology** utilizing high temperature heat sources **such as photocatalyst/high-temperature gas-cooled reactor** will be addressed.

  - **Supply amount of hydrogen will be increased** by **reducing its supply cost to the similar level to those of fossil fuels.**

    Cost: reduction from current 100 yen/Nm^3 to 30 yen/Nm^3 in 2030, and not more than 20 yen/Nm^3 in 2050.

    Supply amount: increase from current approx. 2 million tons/year to max. 3 million tons/year in 2030, and 20 million tons/year in 2050.

- Use of hydrogen on demand side (power, transport, industry and consumer sectors) will be expanded.

  - **In power generation sector** expected to large amount of hydrogen demand, aiming at **introduction/expansion of 30%-hydrogen co-firing in gas-fired power generation or hydrogen-fired power generation** and **20%-ammonia co-firing in coal-fired power generation, demonstration of co-firing/single fuel firing will be promoted** and the environment for appropriate assessment of non-fossil value will be prepared. In addition, **1% hydrogen/ammonia will be positioned in power generation mix in FY2030.**

  - **In transport sector, hydrogen station will be strategically streamlined for further expansion of FCVs and future FC trucks.**

  - **In industry sector, large scale diversion of manufacturing process such as** hydrogen-reduced iron making and **technology development of burners and large and highly functional hydrogen-fired boilers** based on its combustion characteristics will be addressed.

  - **In buildings sector, technology development towards cost reduction** will be addressed **for further introduction and expansion of stationary fuel cells** including pure hydrogen fuel cell.

Points of outlook for energy supply and demand in FY2030 (1)

*Excerpt from the outline material of the 6th Basic Energy Plan

- In the light of new GHG emission reduction target in FY2030, this outlook shows **energy supply and demand on the ambitious assumption that various challenges in both aspects of supply and demand** in promoting thorough energy conservation and expansion of non-fossil energy **will be overcome**.

- In implementing the measures towards this ambitious outlook, **degree and timing of implementation of the measures need to be carefully considered for stable supply of energy not to be impaired.** (e.g. If fossil fuel power sources are immediately curtailed at a stage prior to full introduction of non-fossil fuel power sources, stable supply of electricity can be impaired.)

		(FY2019 ⇒ previous energy mix)		Energy mix in FY2030 (**ambitious outlook**)	
Energy efficiency improvement		(16.55 million kl ⇒ 50.30 million kl)		**62 million kl**	
Final energy consumption (without energy conservation)		(350 million kl ⇒ 377 million kl)		350 million kl	
Power generation mix Electricity generated : 1,065 TWh ⇒ Approx. 934 TWh	**Renewable energy**	(18% ⇒ 22-24%)	solar 6.7% ⇒ 7.0% wind 0.7% ⇒ 1.7% geothermal 0.3% ⇒ 1.0~1.1% hydropower 7.8% ⇒ 8.8~9.2% biomass 2.6% ⇒ 3.7~4.6%	**36-38%** **※If progress is made in utilization and implementation of R&D of renewable energy currently underway, 38% or higher will be aimed at.**	(details of renewable) solar 14~16% wind 5% geothermal 1% hydropower 11% biomass 5%
	Hydrogen/Ammonia	(0% ⇒ 0%)		**1%**	
	Nuclear	(6% ⇒ 20-22%)		**20-22%**	
	LNG	(37% ⇒ 27%)		**20%**	
	Coal	(32% ⇒ 26%)		**19%**	
	Oil, etc.	(7% ⇒ 3%)		**2%**	
(+ non-energy related gases/sinks)					
GHG reduction rate		(14% ⇒ 26%)		**46%** **Continuing strenuous efforts in its challenge to m the lofty goal of cutting its emission by 50%**	

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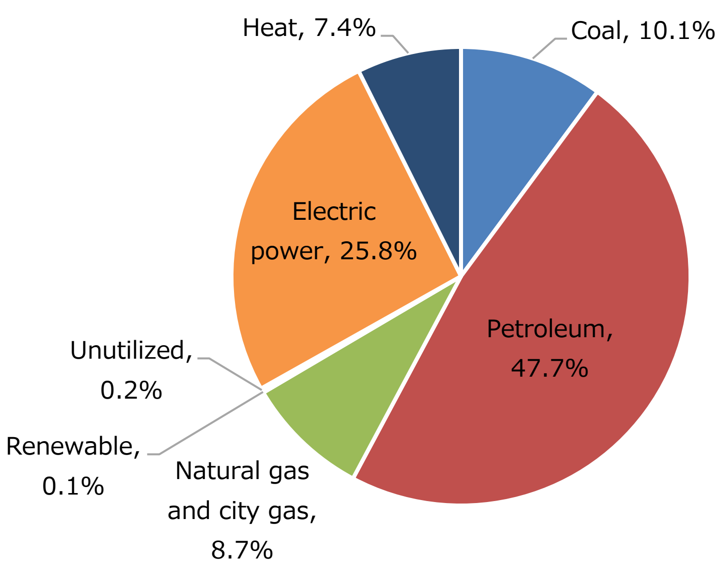
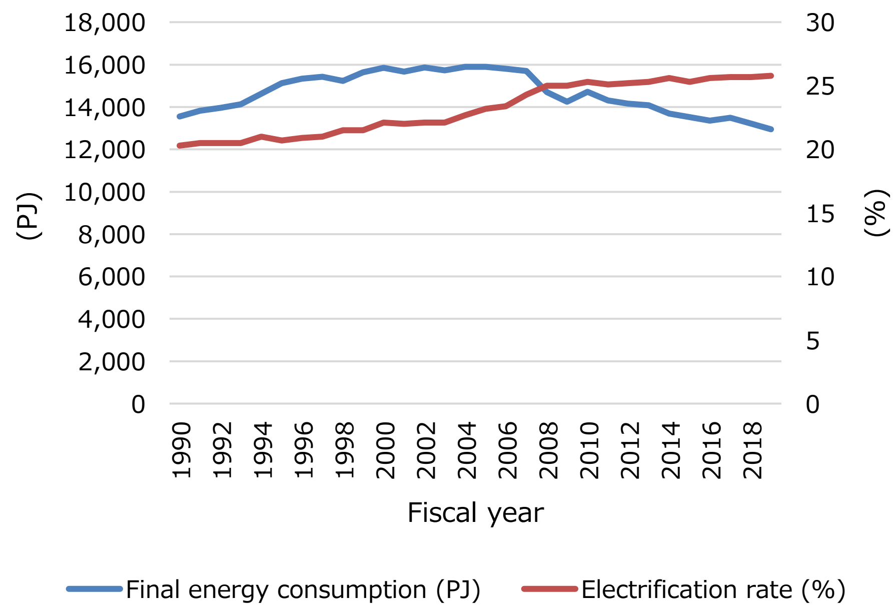
Ratio of electric power to final energy consumption in Japan

- Electricity accounts for about 25% of final energy consumption.
- Final energy consumption has been declining since its peak in the mid-2000s, but the electrification rate is on an uptrend.

Final energy consumption by energy source (FY 2019)



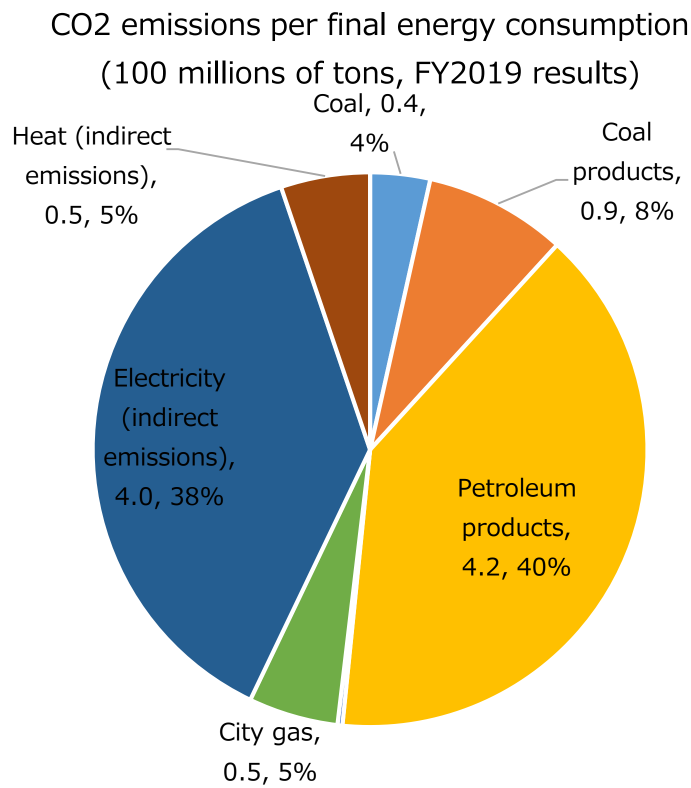
Trends in Final Energy Consumption and Electrification Rate (FY 1990 to FY 2019)



Source: the Ministry of Economy, Trade and Industry, "Comprehensive Energy Statistics" (FY 2019 figures)

Current status of CO_2 emissions in the electric power sector

- Indirect emissions from electricity accounted for 38% of our country's CO2 emissions per unit of final energy consumption in FY 2019. In the electric power sector, **reducing CO2 emissions is an urgent issue.**

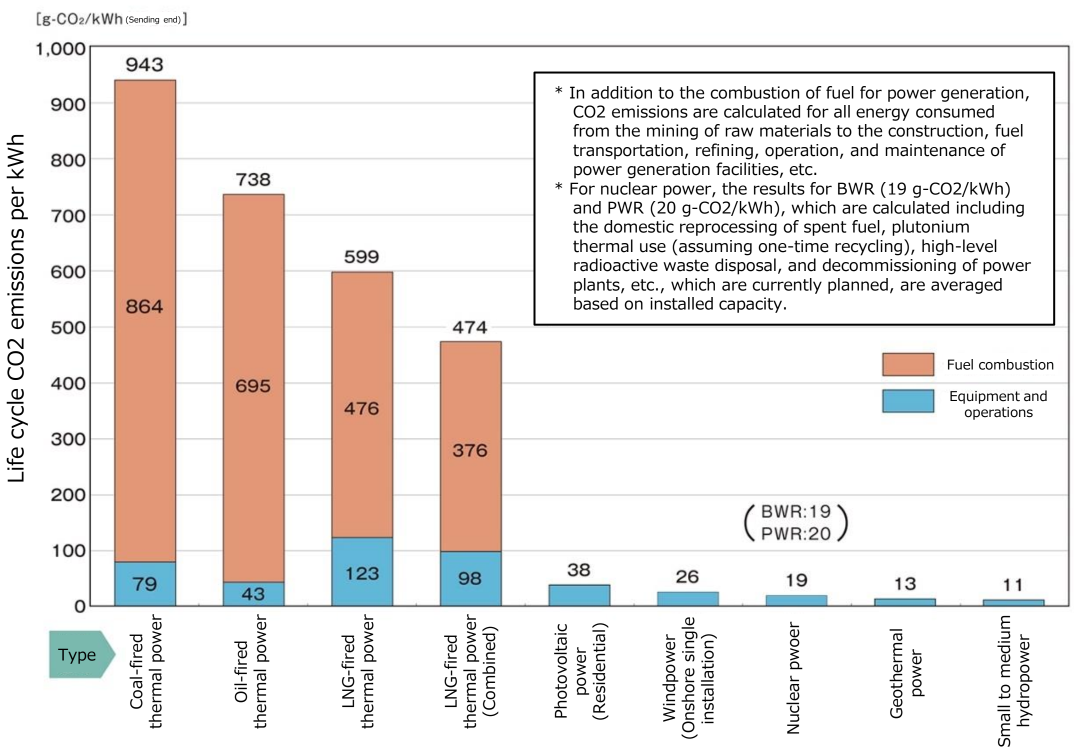


Source: the Ministry of Economy, Trade and Industry, "Comprehensive Energy Statistics" (FY 2019 figures)

Breakdown of CO2 emissions from power generation

- **<u>About 10 to 20%</u>** of CO2 emissions during the life cycle of fossil power generation are from raw material mining to fuel refining and transportation, as well as from the construction and maintenance of power generation facilities.
- To achieve carbon neutrality in the electric power sector, **<u>it is important to expand the use of non-fossil power sources and to apply decarbonization technologies (such as CCUS).</u>**

Life cycle CO2 emissions by power source

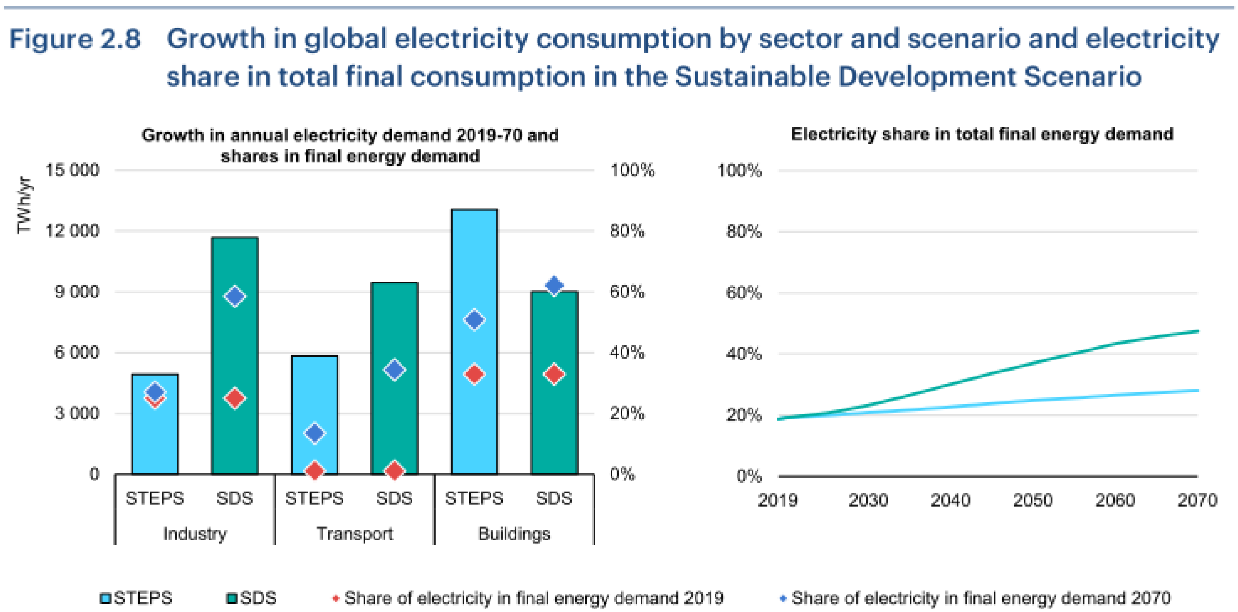


Source: Data released by the Federation of Electric Power Companies of Japan (prepared from the report of the Central Research Institute of Electric Power Industry)

Global Electricity Demand Forecast and Overseas Business Trends

- The share of electricity in global final energy consumption is expected to increase from the current level of about 20% to nearly 50% in 2070.
- Although overseas electric power companies are actively investing in renewable energy expansion and energy storage facilities, they are likely to maintain thermal power generation to a certain extent from the perspective of stable energy supply.

Forecast of Electricity Demand and Transition of Electrification Rate in the Industrial, Transport, and Business Sectors



Trends among overseas electric power companies

- Enel aims to reduce Scope 1 by 80%, Scope 3 by 16% by 2030, and achieve net zero in all Scopes by 2050. **To significantly reduce Scope 1, the company will phase out coal-fired thermal power generation and accelerate the development of renewable energy.** (Enel: Italy)
- Target to make GHG emissions from power generation (Scope 1 + 2) carbon neutral by 2035: **Announced plans to invest €2.7 billion in PtG, energy storage, green/blue hydrogen, CCU, etc. over 3 years from 2021.** (Uniper: Germany)
- With the target of 2050 net zero (Scope 1), the company is working on the development of renewable energy, the introduction of large-scale energy storage facilities, and the construction of a hydrogen supply chain (in cooperation with Japanese companies). **Thermal power generation will be gradually reduced and abolished by 2050, although it will be maintained to a certain extent from the viewpoint of energy supply stability and profitability.** (AGL: Australia)

Source: Prepared on the basis of IEA Energy Technology Perspectives 2020 and materials published by each company

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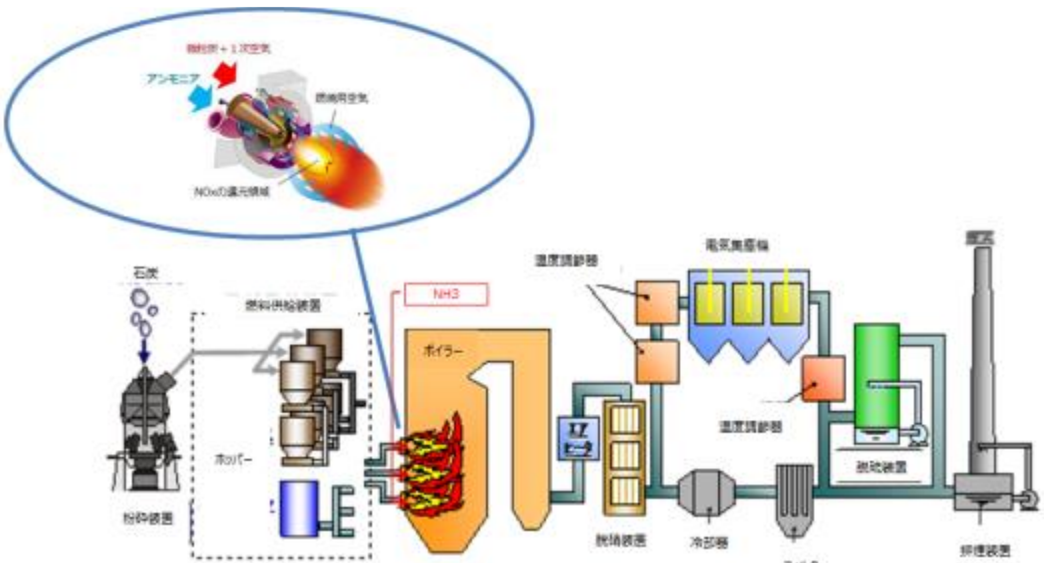
Growing demand for fuel ammonia

- Studies are under way to use ammonia as a fuel and the basic technology for co-firing coal-fired power plants with reduced NOx emissions has already been established.
- In the future, it is expected that the use of high-mixed combustion and mono-fuel combustion will expand, and applications such as ships and industrial furnaces will expand, so it is necessary to establish a new supply chain of fuel ammonia to meet the growing demand for electricity power.

Power Generation

- Already succeeded in reducing NOx emissions and achieving stable combustion when 20% ammonia is mixed in the burner of coal-fired power generation.
- Demonstration of 20% co-firing (4 years) in actual plant (1 million kW) from this fiscal year. After that, it aims at high mixed combustion and exclusive consumption.
- If all coal fired power plants of major Japanese power companies were to co-burn 20% of ammonia, annual demand for ammonia would reach about 20 million tons.



Source: 5th meeting of the Working Group on Energy Structure Conversion, Green Innovation Project Subcommittee, Industrial Structure Council

Shipping

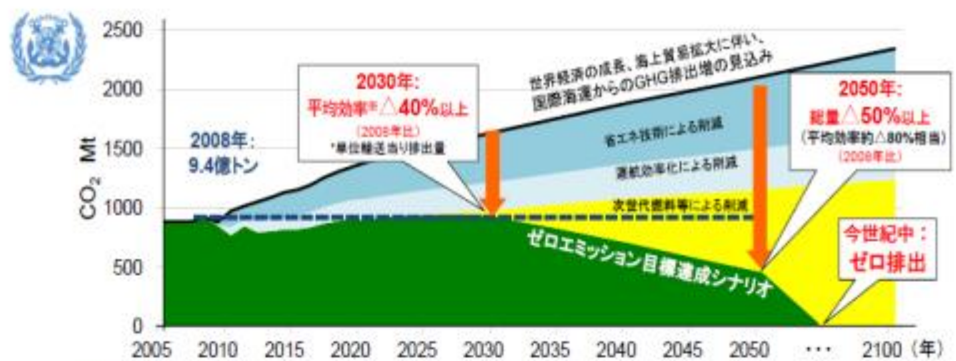
- The International Maritime Organization (IMO) developed a GHG reduction strategy in 2018 and agreed on GHG reduction targets for international shipping.

① Improve average fuel economy by 40% or more by 2030 (compared to 2008)

② Reduce total GHG emissions by at least 50% by 2050 (compared to 2008 levels)

③ Zero GHG emissions as early as possible in this century

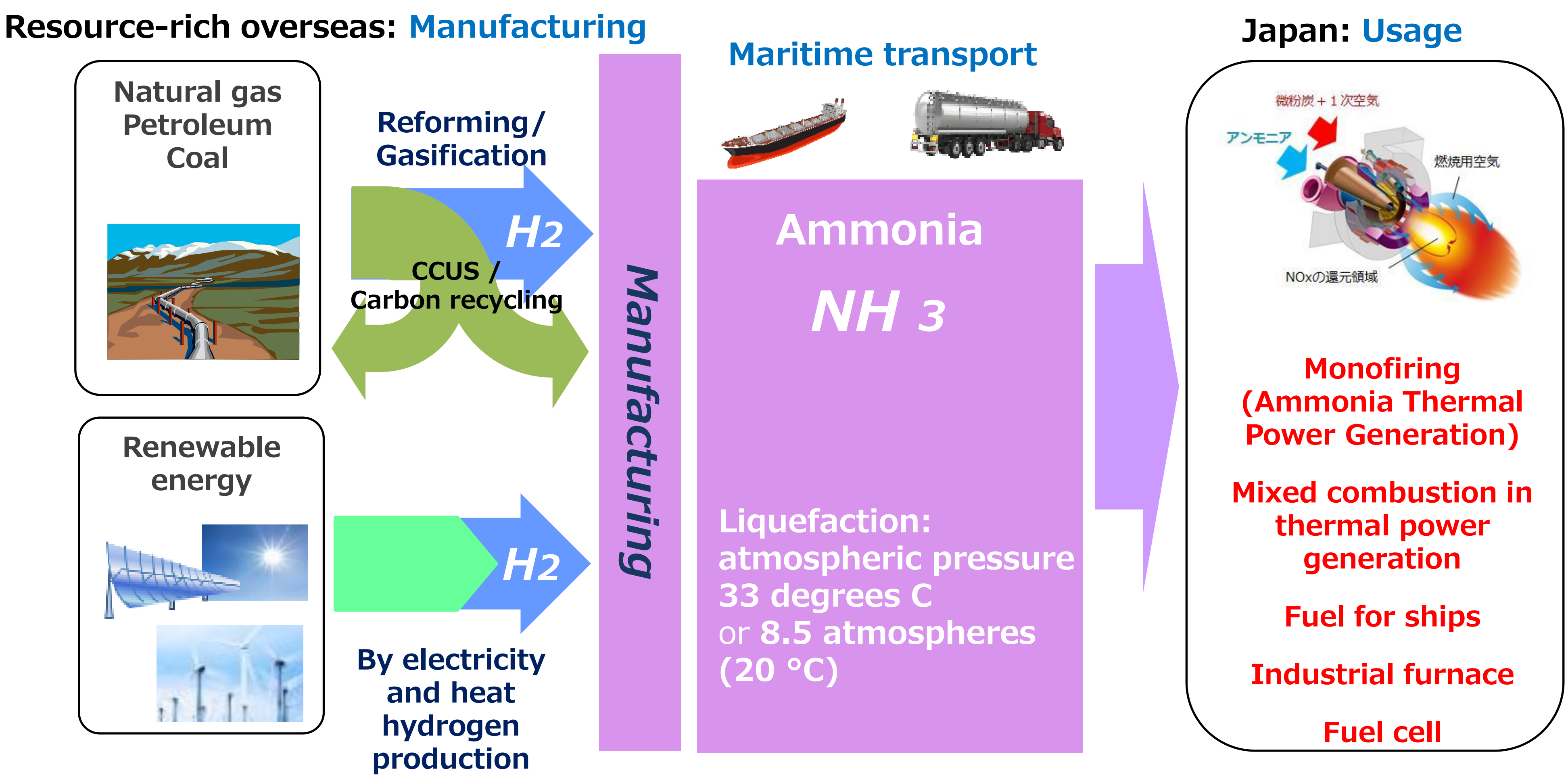
- Development of next generation ship using decarbonized fuel containing ammonia is under consideration.



Source: Summary of th Roadmap to Zero Emission from International Shipping

Positioning of fuel ammonia

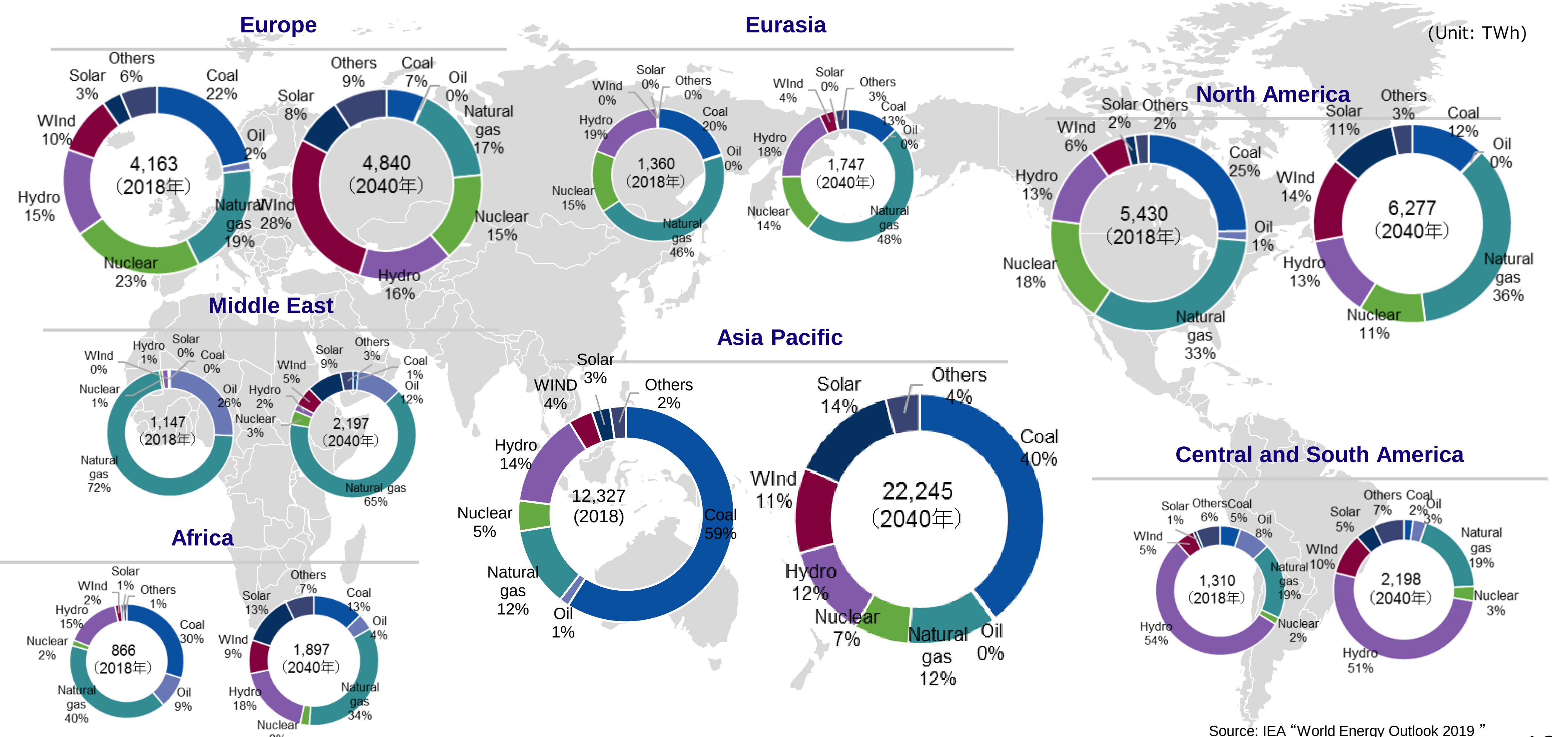
- Ammonia can be **produced from natural gas, renewable energy, etc.**, and **does not emit CO2 when it is burned**. Therefore, ammonia is an effective fuel for climate change countermeasures. Ammonia can also be used as a hydrogen carrier. Compared to hydrogen, ammonia is characterized by being **manufactured and used at a lower cost by utilizing existing infrastructure**.
- Ammonia is **positioned as one of the key areas in the Green Growth Strategy** and is **specified for the first time in the Sixth Basic Energy Plan***. *Hydrogen and ammonia accounted for 1% of electricity generated in 2030.



The Future of Ammonia Co-firing and Mono-firing in Coal-Fired Thermal Power Plants in the World

- The **Asia pacific region accounts for 70% of global energy demand growth**. In the region, **coal power will still account for 40% of the electricity mix in 2040.** Its coal-fired thermal power plant capacity is **1820 GW (about 100 times the capacity of USC in Japan).** (* 968 GW in WEO 2020 SDS)

→ If high-ammonia co-firing is introduced to 10% of the total, **250 million tons/year of demand will be created.**



Source: IEA "World Energy Outlook 2019" Stated Policies Scenario

Pathway to expanding ammonia use

- To steadily introduce and expand fuel ammonia, **it is necessary to make efforts both to expand its use in power generation and ships, etc., and to build and strengthen an inexpensive and stable supply chain. In turn, multifaceted policy support will be provided.**

	Ammonia production	Ammonia transport and storage	Fuel ammonia utilization
Current status	➢ Worldwide consumption is 200 million tonnes per year and trade is 20 million tonnes per year ➢ Both are gray ammonia ➢ Started demonstration of blue ammonia production in Saudi Arabia	➢ Small-scale transportation and storage facilities ・Ocean-going vessels: 25000 tons ・Tank: 15000 tons	➢ No use in fuel applications. ➢ Started demonstration of 20% co-firing.
2030	➢ **Creation of fuel ammonia market** ➢ **Large-Scale and highly efficient ammonia production** ✓ **Establishment of ammonia synthesis technology to replace the Harbor-Bosch process** ✓ **Development of electrosynthesis technology for green ammonia production**	➢ Technology Development for large-scale and high-efficiency ・Ocean-going vessels: over 100,000 tons ・Tank: more than 100,000 tons Fund project	➢ **Domestic demand of 3 million tons/year** ➢ **Start of 20% co-firing and overseas expansion of co-firing technology** ✓ **Development of technology improving the co-firing rate and mono-fuel combustion (NOx control, heat recovery technology, etc.)**
2030 – 40's	➢ **Expansion of supply of blue ammonia (in cooperation with oil and gas producing countries (blue ammonia manufacturing countries)** =>**Expanding supply of green ammonia through cost reduction and cooperation with renewable energy producing countries**		➢ **Expansion of high co-firing and start of mono-fuel combustion**
2050	➢ Further expansion of ammonia supply and reduction of supply price		➢ Expansion of exclusive firing after replacement of coal-fired thermal power plants ➢ **Domestic demand is 30 million tons/year, and CO2 emissions are reduced by 60 million tons/year.** *In the case of a single firing, about 10 ~ 20 units Estimation of about 20 ~ 40 units in the case of high mixed firing ➢ Global demand is 560 million tons/year and CO2 emissions are reduced by 1.12 billion tons/year.

Efforts to build a fuel ammonia supply chain

- To expand the supply and demand of fuel ammonia, comprehensive international cooperation from the following four perspectives is promoted.

  1. Collaborating with the **International Energy Agency (IEA) issues analysis report** to increase international awareness
  2. **Cooperation with gas producing countries and countries eligible for renewable energy to build supply chains** to Secure Supply
  3. **Collaborating with coal-fired power users (Malaysia and Morocco) on an ammonia power generation feasibility study** to expand demand.
  4. Hosting the **international conference on fuel ammonia** to **establish a platform for international cooperation led by Japan**

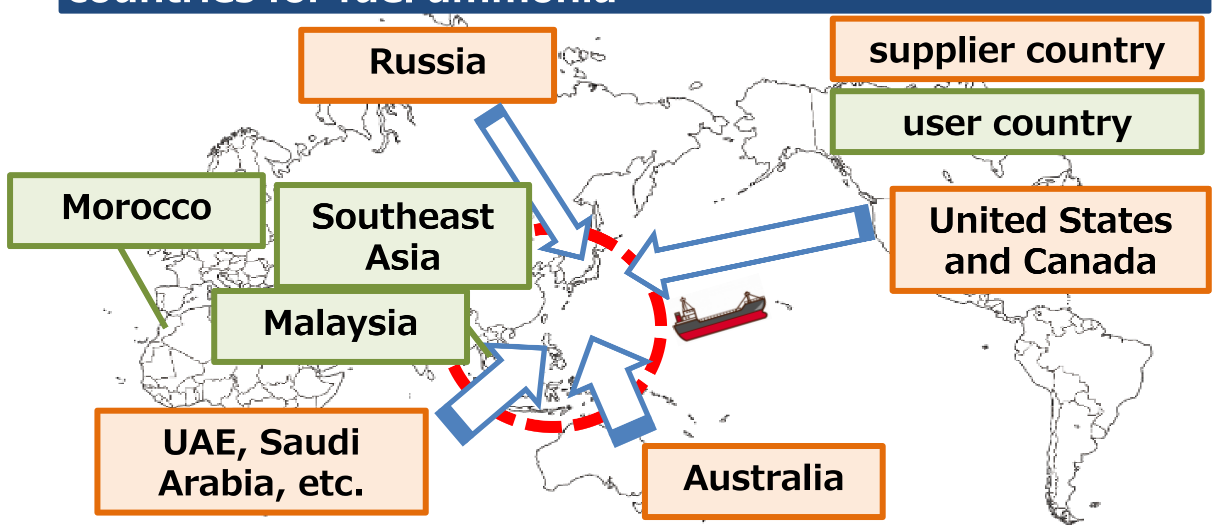
- On **Minister Hagiuda's business trip to Southeast Asia** in January 2022, **Intergovernmental MOC on energy transition including ammonia utilization with Indonesia, Singapore, and Thailand** was concluded. In particular, **Indonesia** agreed to **start FS on ammonia co-firing in local coal-fired thermal power plants** and **urged the removal of the moratorium on coal exports.**

① IEA analysis report

- "The Role of Low-Carbon Fuels in Clean Energy Transitions of the Power Sector" (October 2021)

- Key messages:
  - As renewable energy expands, it is important to ensure electric power security. **Ammonia is an effective means.**
  - **Developing countries in Asia and elsewhere will be able to use ammonia at low prices,** as developed countries develop technologies and build supply chains.

② ③Cooperation with potential supply and demand countries for fuel ammonia



④ Sponsoring the 1st International Conference on Fuel Ammonia (October 2021)

2- (1) Development and demonstration of high ammonia mixed combustion technology (including exclusive combustion technology) in coal boilers

Purpose and outline of the project

(1) It is planned to develop a high ammonia co-firing pulverized coal burner and an ammonia-only burner and conduct a technical demonstration for the social implementation of ammonia use at a business coal-fired power plant.
(2) Through various studies in the feasibility study prior to the demonstration test and the demonstration test on actual equipment, METI will establish a co-firing technology with ammonia co-firing ratio of 50% or higher and determine whether or not commercial operation is feasible.

Implementation system

*boldface: Managing company

IHI Corporation, Mitsubishi Heavy Industries, Ltd., JERA Co., Inc.

Business period

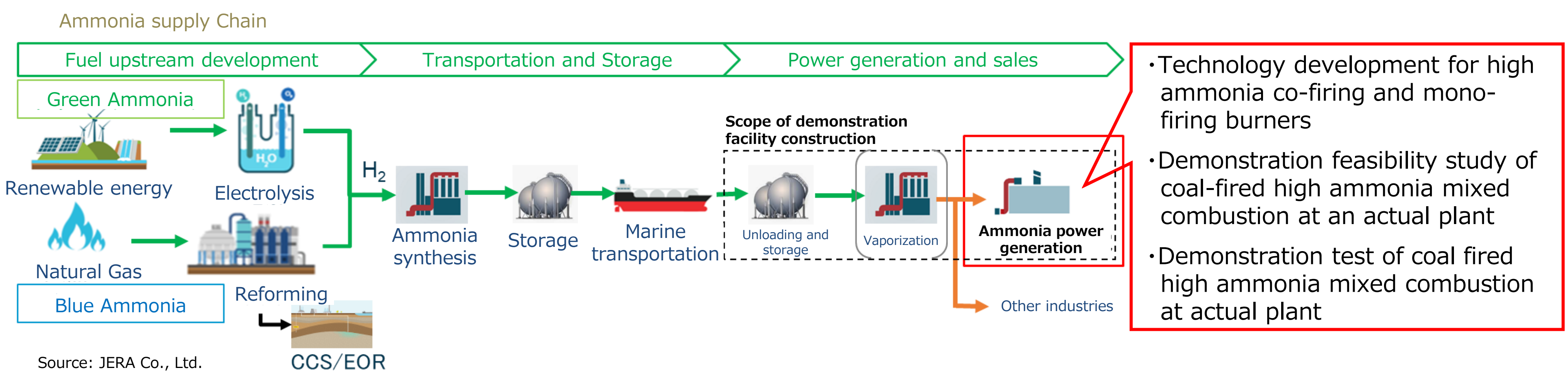
FY 2021 to FY 2028 (8 years)

Business scale, etc.

- Business scale : Approx. 45.2 billion yen
- Support scale *: Approx. 27.9 billion yen

*Includes incentive amount. Subject to change depending on the progress of the project at Stage Gate.
Subsidy rate, etc.: Subsidy 1/2, Outsourcing → Subsidy 1/2 (Incentive rate is 10%)

Business image



Source: JERA Co., Ltd.

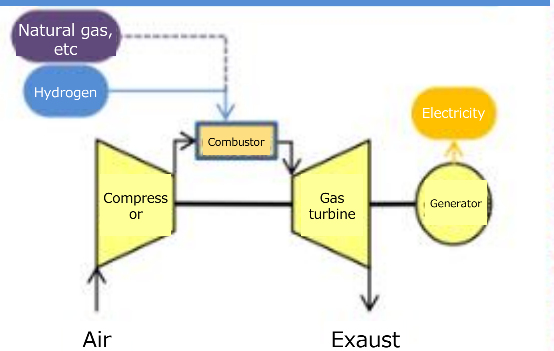
(Reference) Contents

Outline of hydrogen power generation

- There are three types of power generation methods using hydrogen as fuel
  - Fuel using hydrogen for gas turbine
  - Fuel using hydrogen as boiler fuel for steam turbine
  - Fuel cells

Types of power generation using hydrogen as a fuel

①Gas turbine power generation

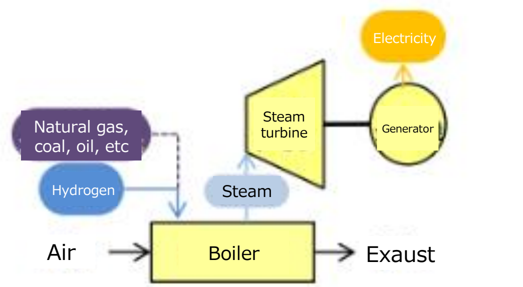


"Hydrogen" or "hydrogen + other fuel" is burned in a gas turbine to obtain rotational force and the generator is driven to generate electricity.

Higher efficiency than steam power generation if it can be used as combined power generation

If certain technical problems are solved, the scale of the existing gas turbine can be expanded.

②Steam power generation

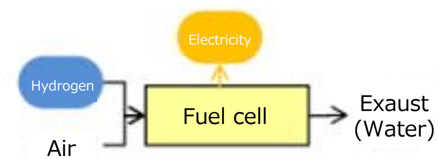


"Hydrogen" or "hydrogen + other fuel" is burned in the boiler and the generated steam obtains rotational force in the turbine to drive the generator to generate power.

Power generation efficiency comparable to conventional steam power generation

Scale can be expanded as with conventional steam power generation

③Fuel cell power generation



To directly extract electric power from a chemical reaction between hydrogen and oxygen.

Higher efficiency by using high-efficiency heat for power generation by chemical reaction

Scaling requires proportional stack growth and is currently expensive

Source: Handout of the Working Group on Strategy for Hydrogen and Fuel Cells of consult (Fourth Meeting)

Status of formulation of strategies in the hydrogen field

- Japan formulated the **World's First Basic Hydrogen Strategy** in December 2017. In recent years, hydrogen has been positioned as an indispensable energy source for decarbonization, and **many countries and regions have stepped up efforts related to hydrogen**. For Japan to continue to lead in this field, we need to **further strengthen our efforts.**

- In response to Prime Minister Suga's CN Declaration in October 2020, hydrogen has been **positioned as one of the priority fields in the Green Growth Strategy** formulated at the end of last year. The aim is to **increase the amount of hydrogen introduction** and **reduce the cost of hydrogen supply** through integrated efforts of supply and demand.

Changes in the situation in Japan and overseas

December 2017
Formulation of basic hydrogen strategy

2019 – 2020 years
Each country developed a hydrogen strategy and focus on hydrogen in economic measures

October 2020
2050 CN Declaration by then Prime Minister Suga

December 2020
Formulating a Green Growth Strategy (positioning of hydrogen)

2021 –
Formulation of the 6th Basic Energy Plan and examination of the Basic Hydrogen Strategy review, etc.
(Ongoing)

Quantity and cost targets in green growth strategies

□ **Annual installations: Widely used in power generation, industry, transportation, etc.**
Current (approx. 2 million t) ->2030 (up to 3 million t) ->2050 (about 20 million tons)

□ **Cost: Achieves the same level as fossil fuels in the long run**
Present (100 yen/Nm3) - > 2030 (30 yen/Nm3) - > 2050 (20 yen/Nm3 or less)

Overseas trends in hydrogen

- Many countries, including the EU, Germany, the Netherlands, and Australia, have **formulated national strategies for hydrogen**, and efforts are in full swing worldwide.
- Progress is being made in **the use of hydrogen in commercial vehicles and industrial sectors** where decarbonization is difficult, in **the introduction of hydrogen power generation**, and in **the consideration of supply chains for hydrogen imports.**

Germany

- **The National Hydrogen Strategy was formulated in June 2020.**
- **Set target for domestic renewable hydrogen production capacity** (5 GW in 2030, 10 GW in 2040). Renewable energy duty is exempted for hydrogen production facilities using water electrolysis.
- A supply chain demonstration project is planned for large-scale hydrogen imports in the medium and long term.
- Under the economic measures adopted by the ruling coalition on June 3, 2020, it was planned to provide 7 billion euros to create a domestic market for hydrogen technology and 2 billion euros to build an international partnership.
- Supporting the construction of hydrogen filling infrastructure for large FC trucks.

United States

- Under the regulation that a certain percentage of new car sales is ZEV, the **introduction of FCV has progressed mainly in California (over 8000 units). The ZEV regulation will start to apply to commercial vehicles** in 2024.
- An IPP in Utah is planning a **large-scale hydrogen power generation project.** It aims at the hydrogen mixed combustion ratio of 30% in 2025 and the exclusive combustion operation of 100% in 2045. (MHPS received an order for gas turbine equipment.)
- As part of the Port of Los Angeles' **zero emissions** initiative, the consideration will be given to the use of hydrogen in the large-scale transportation sector.
- DOE supports the development of **large FC trucks.**

EU

- **The hydrogen strategy was announced in July 2020.**
- It aims to be at **40 GW of electrolytic hydrogen production capacity** by 2030.
- In the interim, low-carbon hydrogen (fossil + CCUS) is also used. The E.U. will work towards the production, transport, storage, and use of hydrogen.
- Launched Clean Hydrogen Alliance through public-private partnership.
- In the transport sector, it is to be focused on the use of **hydrogen utilization in commercial vehicles.**

France

- **The hydrogen strategy was revised in September 2020.**
- The goal is to install **6.5 GW of electrolysers** and produce 600,000 tons of green hydrogen per year by 2030.
- Electricity from **renewable energy sources and nuclear power** is assumed to be used for the production of green hydrogen.
- In addition to decarbonizing the industry, the development of **large FC trucks** is a priority.

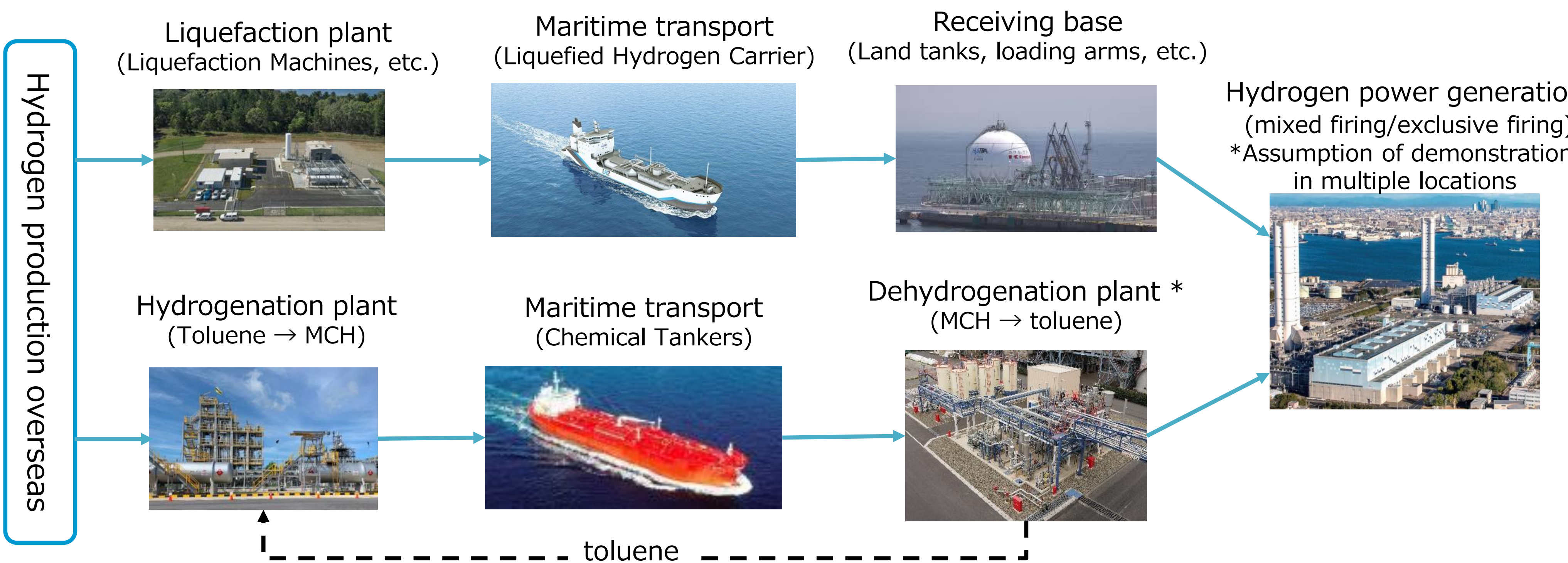
China

- FCV diffusion targets were established in the 2016 Technology Roadmap for Energy-Saving and New Energy Vehicles. At present, the **popularization mainly of commercial vehicles** advances.
- In April 2020, China announced a subsidy program for the FCV industry to build a supply chain. To establish the competitiveness of hydrogen-related technologies, model cities will be selected and incentives will be provided for the development and popularization of FCVs and hydrogen stations.

Construction of a large-scale hydrogen supply chain (up to ¥300 billion in national expenses)

- To realize a hydrogen society, it is necessary to promote the **construction of large-scale hydrogen supply chains and demand creation** in an integrated manner.
- While **the international hydrogen market is expected to start up** in the future, Japan **leads the world in technology** by building a liquefied hydrogen carrier ahead of other countries. **Japan is a pioneer in hydrogen power generation technology,** which is expected to attract large-scale demand.
- Therefore, METI will (**1) support the technological development and large-scale hydrogen transportation demonstrations such as the enlargement of transportation facilities**, in multiple hydrogen carriers (liquid hydrogen and MCH), and **(2) promote demonstrations for the combustion stability of hydrogen in actual hydrogen power generators** in an integrated manner. In this way, METI will promote **the establishment of a virtuous cycle between the creation of large-scale demand for hydrogen and the reduction of supply costs**, aiming to **reduce supply costs to 30 yen/Nm3 in 2030 and less than 20 yen/Nm3 in 2050 (equivalent to fossil fuels).**

Large-scale hydrogen supply chain for liquefied hydrogen and methylcyclohexane (MCH) (image)



*Expected to make maximum use of existing facilities such as refineries

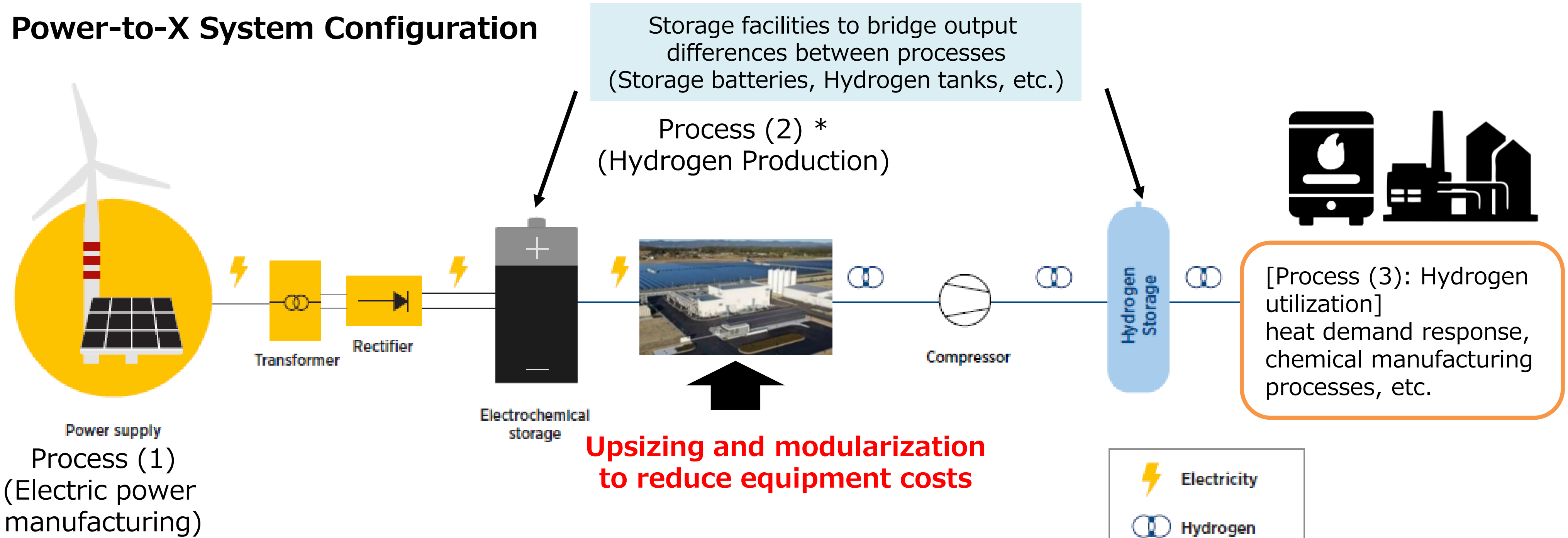
Source: Compiled by the Agency for Natural Resources and Energy from the websites of HySTRA, AHEAD, and other companies

Hydrogen production by water electrolysis using electric power derived from renewable energy (Up to 70 billion yen)

- Although Japan has one of the world's largest water electrolysis facilities in Fukushima, **European companies are leading the development**. **The market will also start up first in Europe and other regions where renewable energy is cheap**.

- Thus, aiming at the **establishment of a domestic hydrogen production base** utilizing surplus renewable energy, etc., and **leading the overseas water electrolysis market**, METI will strongly encourage the **enlargement and modularization** of several types of water electrolysis equipment (alkaline type and PEM type), **the implementation of superior elemental technologies such as membranes, and the demonstration of a Power-to-X system integrated with hydrogen utilization**, **aiming to further reduce the cost of the equipment (up to about 1/6 of the current cost).**

Power-to-X System Configuration



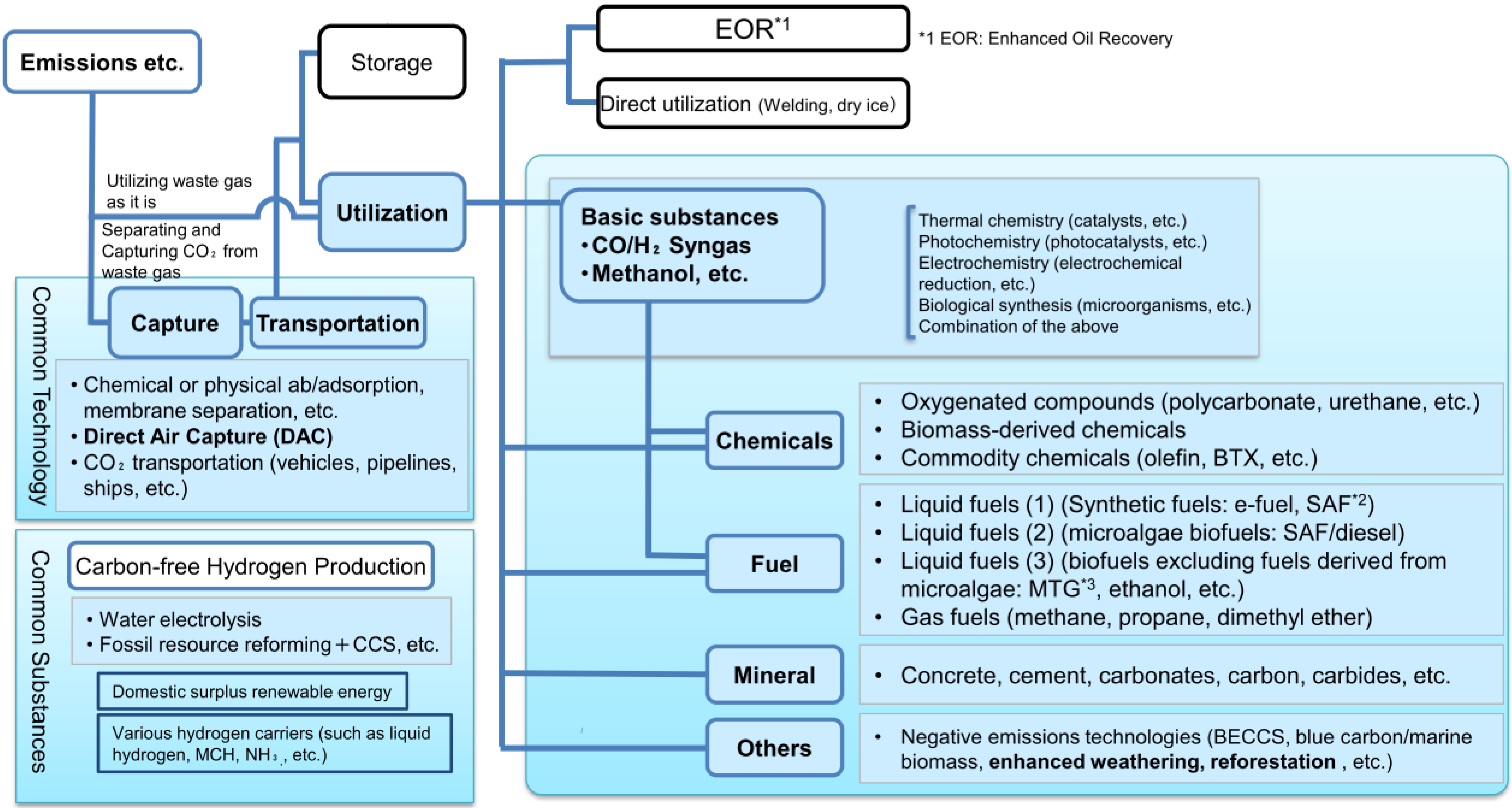
In conjunction with the development of water electrolysis equipment, it is planned to conduct a demonstration to optimize the entire system for decarbonization of the non-electric power sector using renewable energy sources, etc., in combination with heat-related equipment such as boilers and basic chemical manufacturing processes.

*Photo shows Fukushima Hydrogen Energy Research Field (image)

(Reference) Contents

What is CCUS/Carbon Recycling?

- **CCU/Carbon Recycling**: CO2 is regarded as a resource and is captured and separated for reuse in concrete, etc. by mineralization, chemicals by artificial photosynthesis, etc., and fuels by methanation, etc., thereby reducing CO2 emissions into the atmosphere.
- **CCS**: Technology to store carbon dioxide emitted from factories and power plants underground by capturing CO2 before it is released into the atmosphere.



*2 SAF: Sustainable aviation fuel
*3 MTG: Methanol to Gasoline

Blueprint for expanding carbon recycling (technology roadmap)

Volume of utilized CO_2

Phase 1

- **Pursue all potential technologies** for carbon recycling initiatives.
- **Priority should be given to technologies requiring no hydrogen and/or producing high-value added products**, which can be expected to be implemented from around 2030 onwards.

Chemicals (polycarbonate, etc.)

Further CO_2 emission cuts

Liquid fuels (Bio jet fuels, etc.)

Cost must be reduced to around 1/8 -1/16 of current levels.

Concrete Products (Road curb blocks, etc.)

Cost must be reduced to 1/3 – 1/5 of current levels.

Phase 2

- Attempt to **reduce costs** of technologies that are expected to spread from 2030 onwards.
- Priority should be given to technologies for producing **general-purpose commodity in robust demand**, among technologies expected to diffuse on the premise of cheap hydrogen supply from 2040 onwards.

Expected to spread from 2030

- **Chemicals**
  Polycarbonate, etc.
- **Liquid Fuels**
  Bio jet fuels, etc.
- **Concrete Products**
  Road curb blocks, cement, etc

***Technology requiring no hydrogen and/or high-value added products will be commercialized first.**

Phase 3

- **Pursue further cost reduction**

High consumption expected from 2030

- Chemicals: Polycarbonate, etc.
- Liquid fuels: Bio jet fuels, etc.
- Concrete Products: Road curb blocks, etc.

Expected to start spreading from around 2040

- **Chemicals**
  Commodity (olefin, BTX, etc.)
- **Liquid Fuels**
  Gas, Liquid (methane, synthetic fuels, etc.)
- **Concrete Products**
  Commodity

***Expansion into commodity markets with robust demand**

*Target for 2050

Hydrogen — JPY 20/Nm^3 (cost at delivery site)*

CO_2 capture technology — Reducing cost — **Less than ¼ of current cost**

Current — 2030 — From 2040 onwards

Promotion of carbon recycling technology development

- **<u>Development and demonstration of carbon recycling technologies (CO2 separation and recovery, minerals, fuels, chemicals, etc.) and the establishment of bases</u>** through **<u>NEDO</u>**.
- **<u>Using the Green Innovation Fund, METI will work on innovative technology development and social implementation toward carbon neutrality in 2050.</u>**

Carbon recycling budget (NEDO project)

Budget for FY 2022: 53.9 billion yen

Development and demonstration of highly efficient CO2 capture and separation technology and carbon recycling technology for the effective use of CO2.

< Project example >

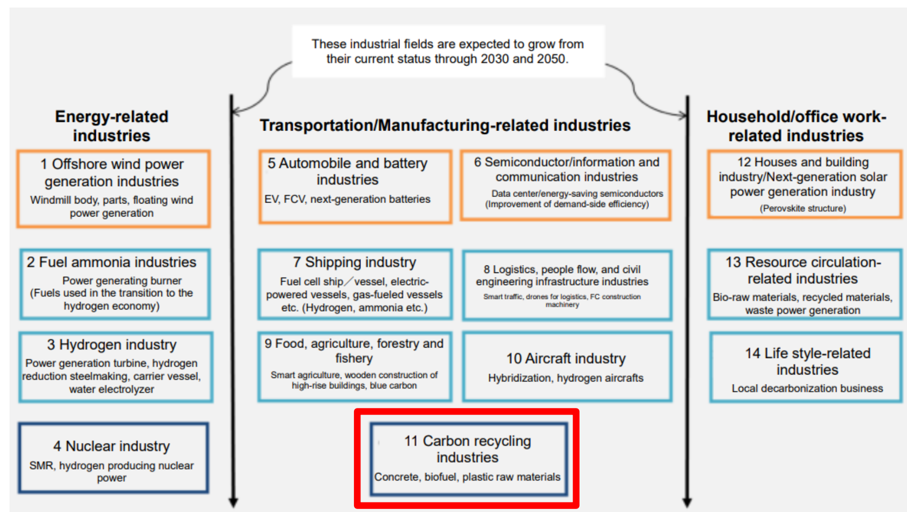
- ・Technological development of concrete that absorbs CO2
- ・Development of bio-jet fuel made from microalgae produced in large quantities by intensively blowing CO2
- ・Development of technology to produce synthetic fuel using CO2
- ・Development of artificial photosynthesis technology to produce chemicals from CO2
- ・Development of high-efficiency CO2 separation collection technology

*<u>**DAC (Direct Air Capture)**</u> was conducted by Moonshot-type R&D (NEDO).

Green Innovation Fund (NEDO project)

Supplementary budget for FY 2020 : ¥2 trillion

Continuous support from R&D and demonstration to social implementation in 14 fields, including carbon recycling, for 10 years.

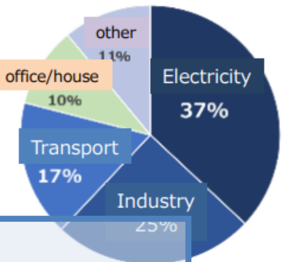


Role of CO2 separation collection

- The Green Growth Strategy envisions the creation of a carbon recycling industry, while pursuing thermal power as an option to the maximum extent possible (especially in Asia) on the premise of CO2 capture in the power sector.

- **Decarbonization of electricity**
  - Renewables
    Maximum introduction. Grid development, cost reduction, **batteries.**
    ➔ **Offshore wind and battery industry**
  - Hydrogen power
    Pursue as an option. **Increase of supply/demand**, infrastructure, **cost reduction**
    ➔ **Hydrogen industry**
  - Thermal power generation with CCUS/Carbon Recycling
    Pursue as an option. Technology development, site development, cost reduction
    ➔ **Carbon Recycling, ammonia as fuel industry**
  - Nuclear Power
    Proven de-carbonization technology. **Further safety enhancement,** restart of plants.
    ➔ **Maximizing utilization of existing nuclear infrastructure, while aiming to decrease dependency on nuclear power.**
    ➔ **R&D for safer next-generation reactors**

CO2 emission by sector



- Promote "**electrification**" in all sectors. For non-electricity demand, "**hydrogen use**" and "**CCUS**".

  Industry ・・・ Manufacturing process
  Transport ・・・ **Electrification,** bio fuel, hydrogen fuel
  Business/household ・・・ **Electrification, hydrogen, batteries**

  ➔ **Hydrogen, auto/battery, transport and housing industries**

Source: METI "Overview of Japan's Green Growth Strategy Through Achieving Carbon Neutrality in 2050"

Features and technical issues of CO2 separation collection technology (amine absorption method)

- **This method is suitable for collection with a large amount of CO2 separation**, on the other hand, **a problem emerges where a large amount of thermal energy is required** to capture CO2, thus it is necessary to develop a new solid absorbent.

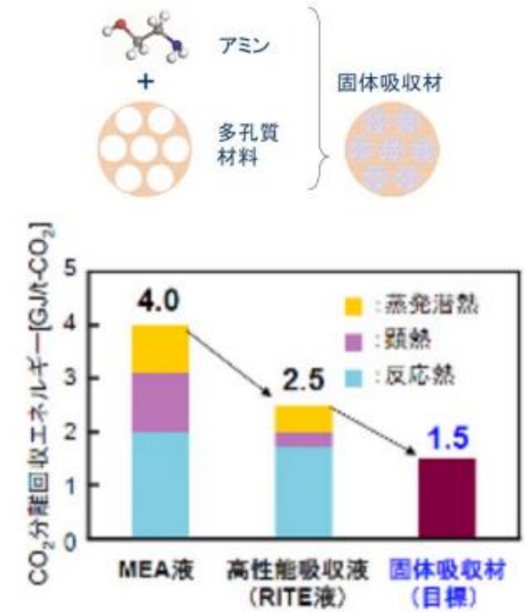
Example of commercial application of the amine absorption method

三菱重工エンジニアリング Petra Nova

出典：三菱重工技報 Vol.55

- World's largest coal-fired exhaust gas treatment plant (4776 t/d)
- Unique amine absorbent KS -1 TM
- Energy saving design by steam/electricity integration

Example of development of a new amine absorber



RITE 固体吸収剤

出典：RITE CO2回収技術高度化事業ホームページ

- New fixed absorbent for cutting latent/sensible heat of evaporation of water
- New composite material of molecularly designed amine and porous material

Source: Handout of the 6th meeting of the Working Group on Energy Structure Conversion, Green Innovation Project Subcommittee, Industrial Structure Council

Characteristics and technical issues of CO2 separation collection technology (physical adsorption method)

- **Separation and collection energy is relatively smaller and it is possible to make compact design.** However, depending on the adsorbent, **inhibition of water absorption and short life are problems.** It is necessary to develop a new adsorbent with high chemical stability and high absorption even at low pressure and low concentration.

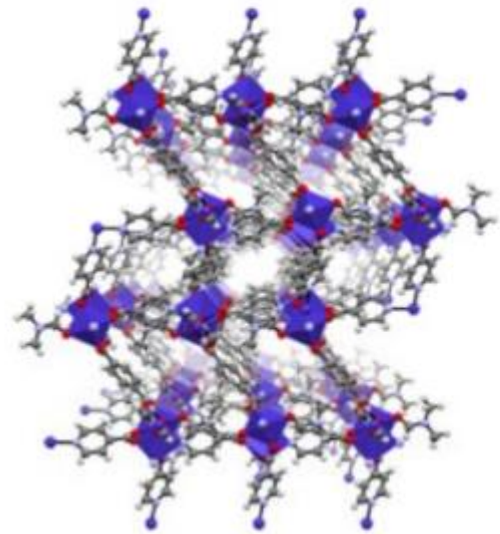
Example of demonstration of blast furnace exhaust gas

出典：NEDO COURSE50成果報告書

住友精化/JFE COURSE50 (2012)

- CO2 emissions per unit of production in collection: 129.7 kWh/t-CO2 achieved
- By combining with the chemical absorption method, it is aimed to achieve 2,000 yen/t-CO2 for high-concentration CO2 exhaust gas.

Example of development of a new adsorbent



Co-MOF 出典：立教大学プレスリリース (2020)

日本曹達/立教大学 (2020)

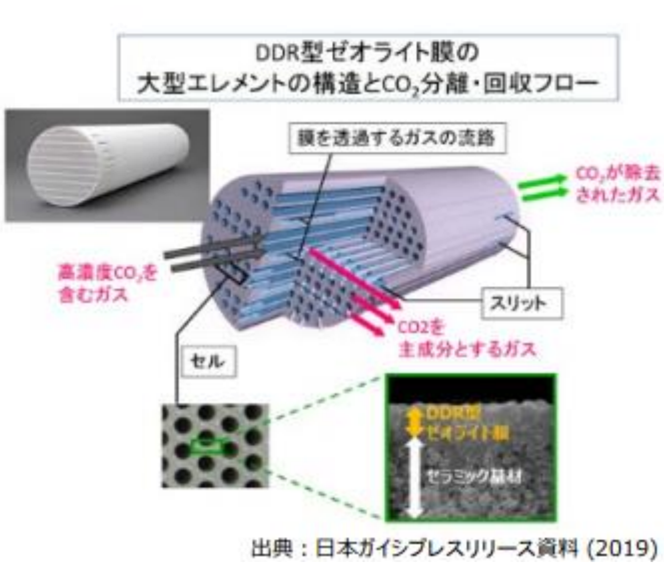
- A new CO2 storage material was developed by a new molecular design using isonicotinic acid as an auxiliary ligand.

Source: Handout of the 6th meeting of the Working Group on Energy Structure Conversion, Green Innovation Project Subcommittee, Industrial Structure Council

Features and technological issues of CO2 separation collection technology (membrane separation method)

- CO2 can be **selectively separated** and the equipment is simple, but the **improvement of separation performance and stability is a problem**. It is necessary to develop a new separation membrane with excellent stability against trace impurities and separation performance.

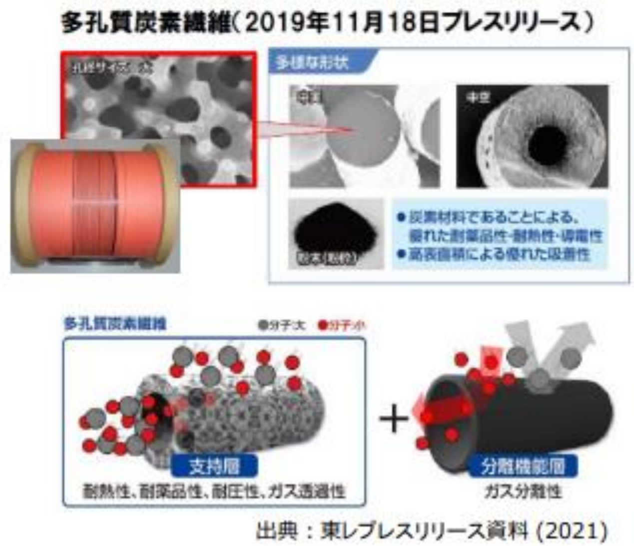
Zeolite separation membrane



NGK/JGC

- World's Largest Ceramic Separation Membrane
- Started demonstration of associated gas in North America (2019)

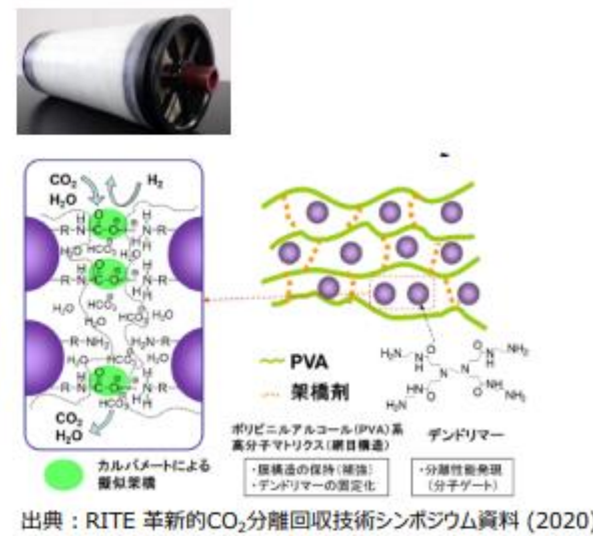
Carbon-based separation membrane



Toray

- World's first use of porous carbon fiber
- Composite with CO2 separation layer

Polymer separation membrane



Sumitomo Chemical/RITE

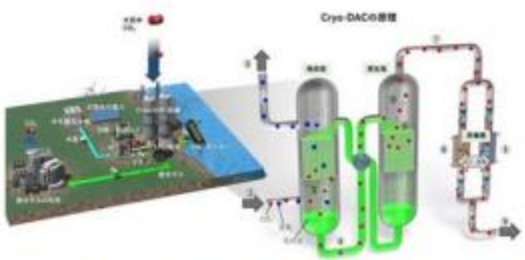
- Realization of "molecular gate function" that selectively transmits CO2

Source: Handout of the 6th meeting of the Working Group on Energy Structure Conversion, Green Innovation Project Subcommittee, Industrial Structure Council

Features and technical issues of CO2 separation collection technology (other methods)

- In addition to the aforementioned technology methods, there are other promising technology methods. It is important not to exclude the possibility of utilizing such technologies, but to select the most suitable technology according to the application after selecting a wide range of technologies as candidates for development, and to reduce CO2 separation costs.

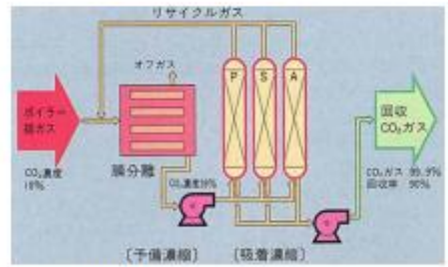
Use of cold heat



東邦ガス／名古屋大学(2021)　出典：東邦ガスプレスリリース資料 (2021)

- CO2 is solidified by LNG cold to obtain reduced pressure. CO2 collection energy is reduced by eliminating the need for vacuum pump power.

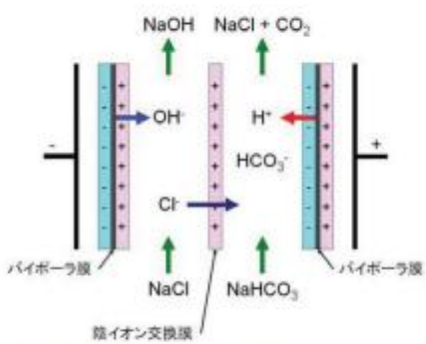
Hybrid method



中国電力　出典：中部電力技術開発ライブラリー58号

- Combination of membrane separation (rough CO2 removal) and physical adsorption (high concentration) reduces CO2 collection energy.

Electrodialysis method



成蹊大学／東京大学　出典：SCEJ 42nd Autumn Meeting 資料

- CO2 is separated by electrodialysis using an ion exchange membrane. CO2 collection energy is expected to be reduced by the reduction in ion resistance of the ion exchange membrane.

Electric swing method

MIT (2019)　出典：Energy Environ. Sci誌. (2019年). 12. 3530―3547

- CO2 is adsorbed/separated by ON/OFF of the electrode coated with the conductive polymer.

Source: Handout of the 6th meeting of the Working Group on Energy Structure Conversion, Green Innovation Project Subcommittee, Industrial Structure Council

International competitiveness of Japanese companies in CO2-separated collection technology

- To date, Japanese companies have held the top share in the commercialized collection plant for separating high-concentration CO2 emissions from coal-fired thermal power plants.
- By promoting the development of CO2 separation and capture technology with a CO2 concentration of 10% or less, which is expected to expand in the future, it is expected to gain further industrial competitiveness in the CO2 separation and capture business.

Technology	Major achievements	Domestic enterprise	Overseas competitor
Amine absorption method	• Absorbents from overseas manufacturers led the market in the application to high pressure gas such as natural gas, accompanying gas, and reformers. **For low pressure gas, Japanese manufacturers developed high performance absorbent and led in its commercial application and demonstration.**	Mitsubishi Heavy Industries Engineering, Toshiba, Nippon Steel Engineering	BASF Shell Dow Linde
Physical adsorption method	• Overseas, many achievements were made for reformers. Japan was the first country in the world to complete the demonstration of actual gas at COURSE 50 for steel manufacturing. **There is no particular superiority or inferiority in the physical adsorption system equipment, but Japanese manufacturers have a strong presence in the CO2 adsorbent, and it has been used in Europe and America.**	Sumitomo Seika, JFE Engineering Corporation, Taiyo Nippon Sanso, Kuraray	Linde UOP Air Liquid
Membrane separation method	• Regarding the application to natural gas associated gas, foreign manufacturers (UOP) took the lead in polymer membrane application, but **Japanese manufacturers developed a high-performance separation membrane (Molecular gate membrane and Zeolite membrane) and led the world in demonstration.**	NGK, RITE, Sumitomo Chemical, Toray, Mitsubishi Chemical	UOP
Physical absorption method	• The presence of overseas manufacturers in the application to high pressure gas such as natural gas accompanying gas and reformers.		Linde, UOP Air Liquid

Source: Handout of the 6th meeting of the Working Group on Energy Structure Conversion, Green Innovation Project Subcommittee, Industrial Structure Council

Hiroshima and Osaki Kamijima Carbon Recycling Demonstration Research Center

- To develop next-generation high-efficiency coal-fired thermal power generation technology towards decarbonization, demonstrations test of **technology to generate electricity by gasifying coal and burning it (IGCC)** and **a more efficient power generation technology (IGFC) by combining IGCC and fuel cells** are being conducted in **Osaki Kamijima, Hiroshima Prefecture.**
- Based on this, **utilizing CO2** captured by IGCC and IGFC, a **research base is being established to demonstrate carbon recycling technology** to produce bio-jet fuel and CO2-absorbing concrete.

Carbon Recycling Demonstration Research Center


Demonstration Research Area


Basic Research Area


CO2-derived paraxylene production technology development facility

Technology Development Theme (1) (CO2 Absorption Concrete Manufacturing Technology)

- An **Admixture** of concrete materials **absorbs CO2** and **CO2 emissions are reduced** in concrete manufacturing by **cement substitution**.
- CO2 absorbing concrete cannot be used for reinforcing steel structures because it causes the steel to rust and **its application is limited to road and pavement blocks**. Another problem is that **the cost is 3 ~ 5 times higher than that of conventional products.**
- **To expand applications and reduce costs, the development of the technology that can be used in reinforced concrete structures is underway.**

◆Technology development to expand applications (FY 2020 to FY 22)

・**Organization:** Chugoku Electric Power Company, Kajima Corporation, Mitsubishi Corporation

・**Issues:** Quality assurance when applied to reinforced concrete
Establishment of technology for application to on-site placing

◆Construction results

	Fiscal year	Orderer	Projects	Application
1	2013	the Ministry of Land, Infrastructure, Transport and Tourism	National Route 9: Dota Sidewalk (Hamada City, Shimane Prefecture)	Sidewalk and roadway boundary block
2	2014	Shimane Prefecture	Prefectural Road Route 52	Sidewalk and roadway boundary block
3	2015	Shimane Prefecture	Second Hamada Dam	Sidewalk and roadway boundary block
4	2019	Kanto Regional Development Bureau	Tokyo Outer Ring Road Central JCT Lamp	Embedded form
5	2011	Chugoku Electric Power	Fukuyama Solar Power Plant	Interlocking blocks, Fence foundation block, Sidewalk and roadway boundary block
6	2012	Chugoku Electric Power	Ube Solar Power Plant	Solar panel foundation block
7	2012	Development in front of Nakano Station	Nakano Central Park Credence	Ceiling panel
8	2015	Chugoku Electric Power	Geihoku Power Station	Revetment block
9	2016	Chugoku Electric Power	Nishinoshima Substation	Sidewalk and roadway boundary block
10	2016	Energia Communications	Enecom Hiroshima Building	Interlocking block

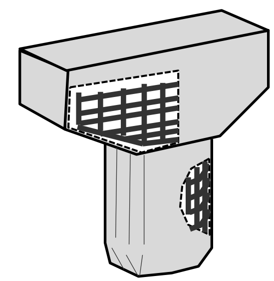
◆Application example

Road block

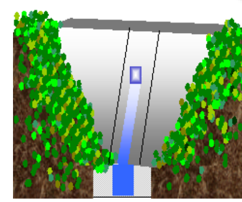
Formwork

Paving block

to expand the use of technological development

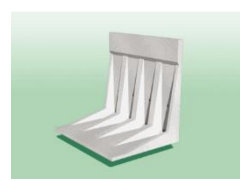


Dam

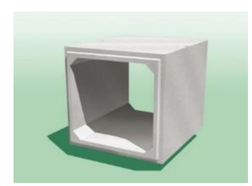


River structure

Beam of the structure

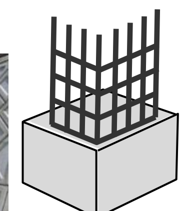


L-Shaped retaining wall for residential land development



Box culvert for common ditch, underground passage, etc.

Revetment block



Column of the structure

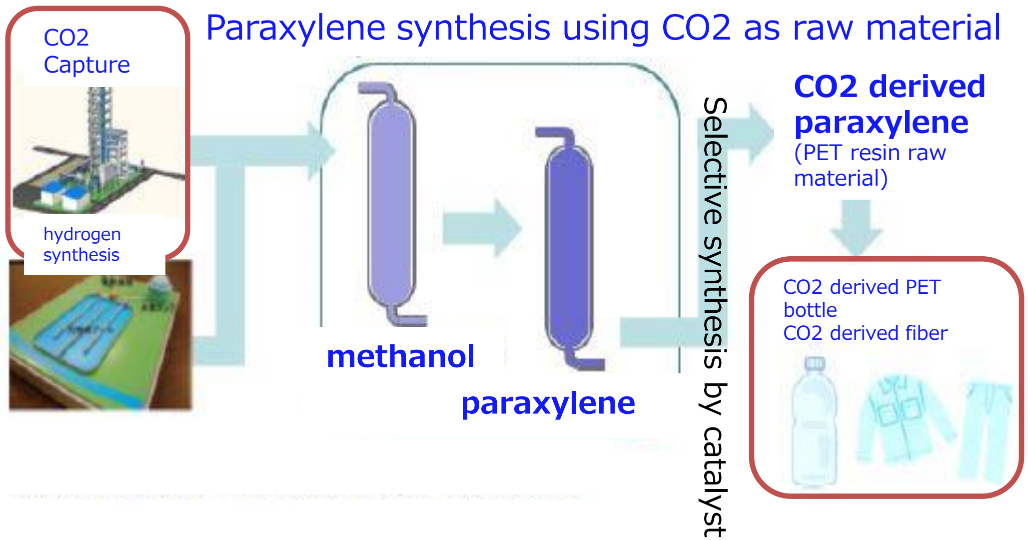
Technology Development Theme (2) Chemicals; (3) Fuel (microalgae)

- The development of **paraxylene production** technology using CO2 as raw material (not from crude oil)

 (Paraxylene is a raw material for PET and polyester fibers)

- Develop a **catalyst for the selective synthesis (yield enhancement) of paraxylene** and a synthesis process from methanol (synthesized from CO2).

->Cost reduction and value creation



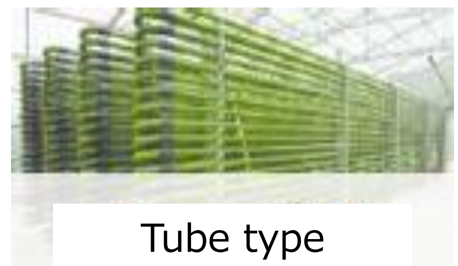
- The establishment and standardization of basic technology for injecting CO2 intensively into **microalgae** and making them **photosynthesize efficiently** (manufacturing **bio-jet fuel** from algae)

① **Develop and demonstrate a test bed** for comparative verification, standardization, and systematization of culture and analysis conditions.

② **Establish standard conditions** according to ①

->Cost reduction

① Development of the test bed



② Establishment of standard conditions

Establish standard conditions for environment/climate, culture test, analysis, etc.

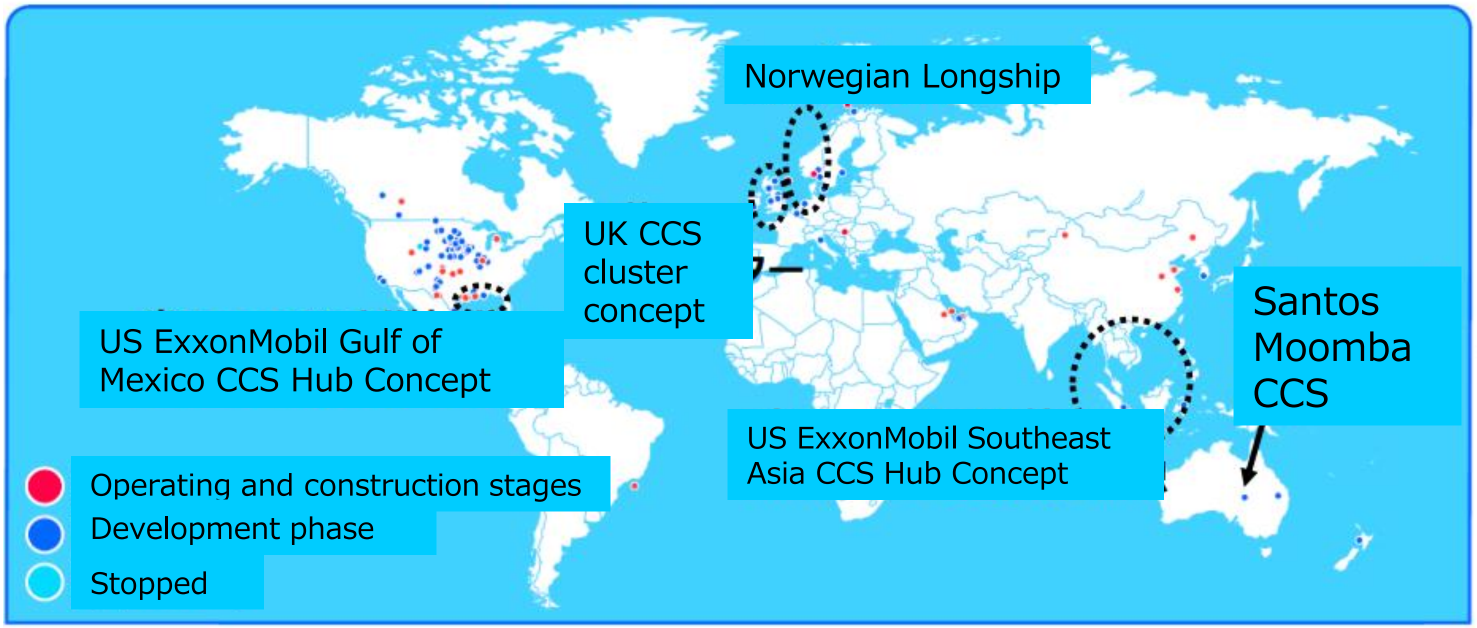
Implementation Structure
Kawasaki Heavy Industries, Osaka University

Implementation period FY 2020 to FY 2024

Implementation structure
Japan Microalgae Technology Association (Euglena, IHI, etc.)
Implementation period FY 2020 to FY 2024

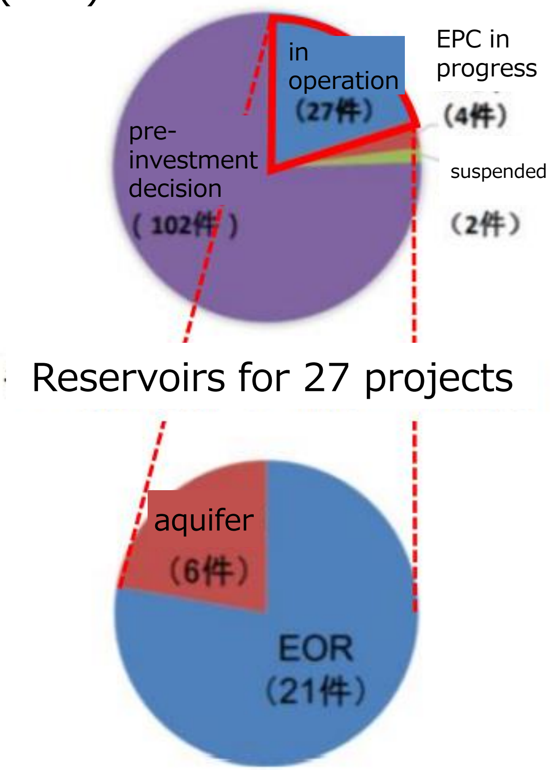
Overview of Commercial CCS Facilities Worldwide

- As of September 2021, there were **135 commercial CCS facilities worldwide** (of these, 27 were in operation, 4 were in the construction phase, 102 were in the development phase, and 2 were out of operation.)
- **Distribution mainly in North America (78 cases) and Europe (38 cases)**
- **71 more CCS facility plans added worldwide only in 2021**
  (41 in North America and 25 in Europe)



（GCCSI (2021)に加筆）

Number of large CCS projects (135)



(Reference) Contents

Main characteristics of each energy source

	Stable supply	Economic efficiency	Environmental compliance	Other Considerations
	Dependence on the Middle East 2020	Power generation cost (JPY/kWh) 2030	CO2 emissions (kg-CO2/kWh)	
Renewable energy	0%	[Solar (commercial)] ① 8.2 ~ 11.8 ② 19.9	0	・Securing appropriate sites and implementing projects in harmony with the local community
Nuclear power	0%	① 11.7 ~ ② 14.5	0	・Ensuring safety ・Restoration of public trust
LNG	16.4%	① 10.7 ~ 14.3 ② 10.3	0.38	・Price volatility
Coal	0%	① 13.6 ~ 22.4 ② 13.7	0.86	・International decarbonization trend
Petroleum	89.9%	① 24.9 ~ 27.6 ② -	0.70	・Necessary in Islands and emergencies

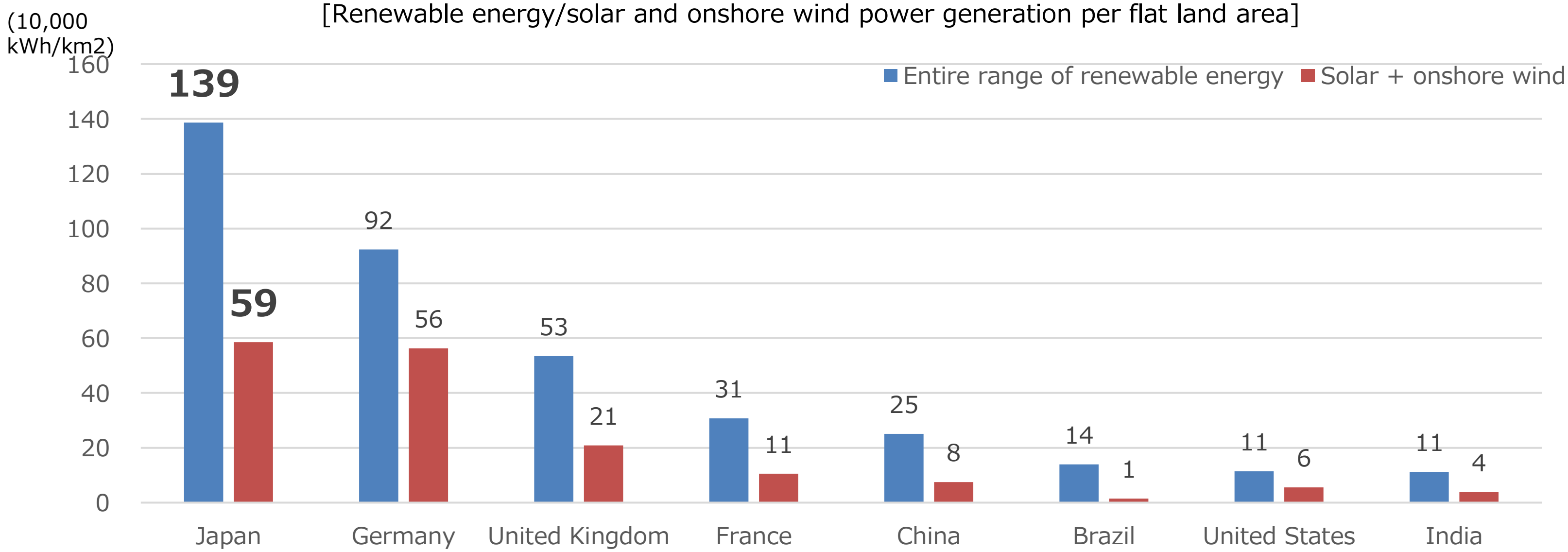
*① Power generation cost and ② Power generation cost considering part of the integration cost
*To secure a stable supply of energy, it is also important to improve the "technology self-sufficiency ratio" (the degree of energy supply that can be covered by the country's own technology in relation to domestic energy consumption) by securing core technologies in the supply chain in the country.
*The massive introduction of solar and wind power (natural variable power sources) will increase the cost of the entire power system (integration cost), such as lowering the efficiency of thermal power and using pumped water.

[Source] Ministry of Finance "Trade Statistics " (2020), BP Statistics (2021), Agency of Natural Resources and Energy "Power Generation Cost Verification Working Group" (2021)
Central Research Institute of Electric Power Industry, "Comprehensive Assessment of Life Cycle CO2 Emissions of Power Generation Technologies in Japan" (2016)

Renewable energy generation per flat area in each country

- The topography required differs depending on the power source, but it is important to secure suitable land such as flat land when introducing solar and onshore wind power.
- **<u>Japan is the largest in the world</u>** in terms of the amount of renewable energy generated per flat land. **<u>The introduction of renewable energy is progressing in a limited land area.</u>**

[Renewable energy/solar and onshore wind power generation per flat land area]



[Flat land area and renewable energy generation in each country]

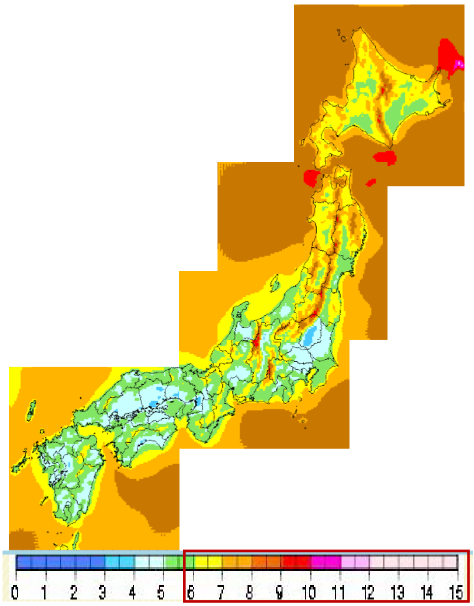
	Japan	Germany	UK	France	China	Brazil	US	India
land area	380,000 km2	360,000 km2	240,000 km2	540,000 km2	9.6 million km2	8.51 million km2	9.63 million km2	3.29 million km2
Flat land area * (Proportion of National Land Area)	**130,000 km2 (34%)**	250,000 km2 (69%)	210,000 km2 (88%)	370,000 km2 (69%)	7.4 million km2 (77%)	3.55 million km2 (42%)	6.53 million km2 (68%)	2.57 million km2 (78%)
Renewable energy generation (100 million kWh)	**1,853**	2,272	1,112	1,128	18,563	4,947	7,502	2,882
Solar + onshore wind power generation (100 million kWh)	**767**	1,384	433	387	5,556	519	3,650	974

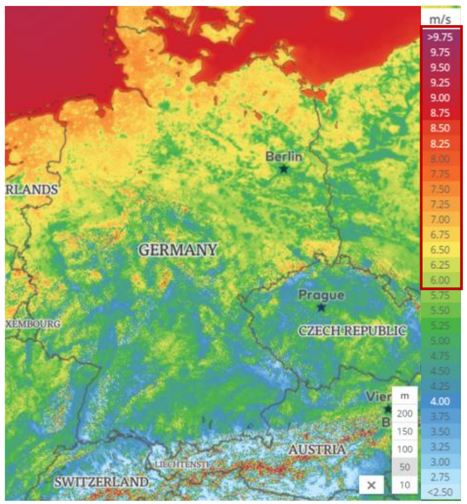
(Source) the Ministry of Foreign Affairs HP (https://www.mofa.go.jp/mofaj/area/index.html) Global Forest Resources Assessment 2020 (http://www.fao.org/3/ca9825en/CA9825EN.pdf)
Compiled from IEA Market Report Series - Renewables 2019 (electricity generation as of FY 2018 in each country) and comprehensive energy statistics (preliminary figures for FY 2019)
*The flatland area is calculated by subtracting the forest area in the Global Forest Resources Assessment 2020 from the national land area.

Suitable land for onshore wind power

- Areas with wind speeds of 6 m/s or higher, which are suitable for wind power, are concentrated in **coastal areas and mountains of Japan**, while **in Germany, the land spreads widely over the flatlands in the north.**
- Due to the limited availability of flat land, **large-scale introduction of low-cost onshore wind power generation** is **difficult to promote.**

Differences in wind conditions between Japan and Europe

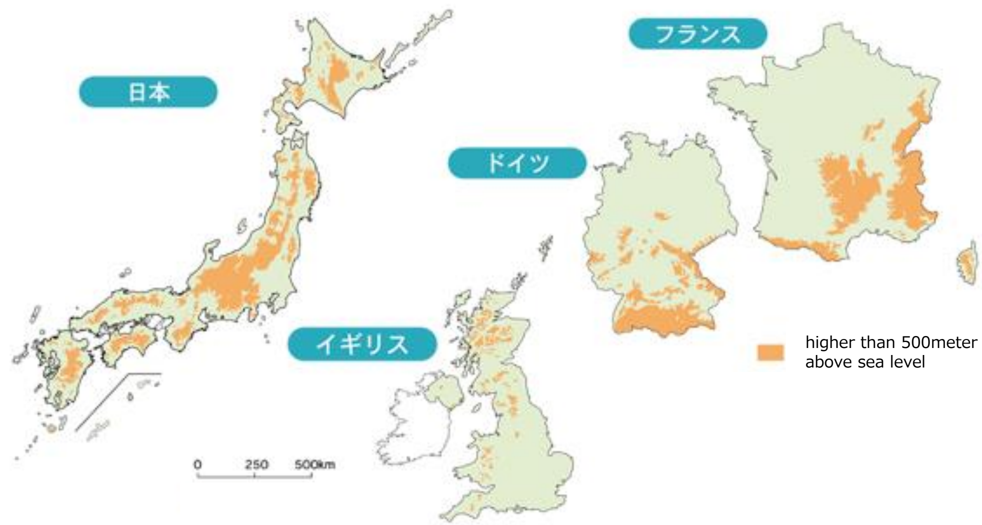




Wind velocity distribution at 50 m height (Germany)

Source: NEDO Local Wind Condition Map, Wind Velocity Distribution at 50 m Height (Japan)

Comparison of national land between Japan and European countries (same scale)



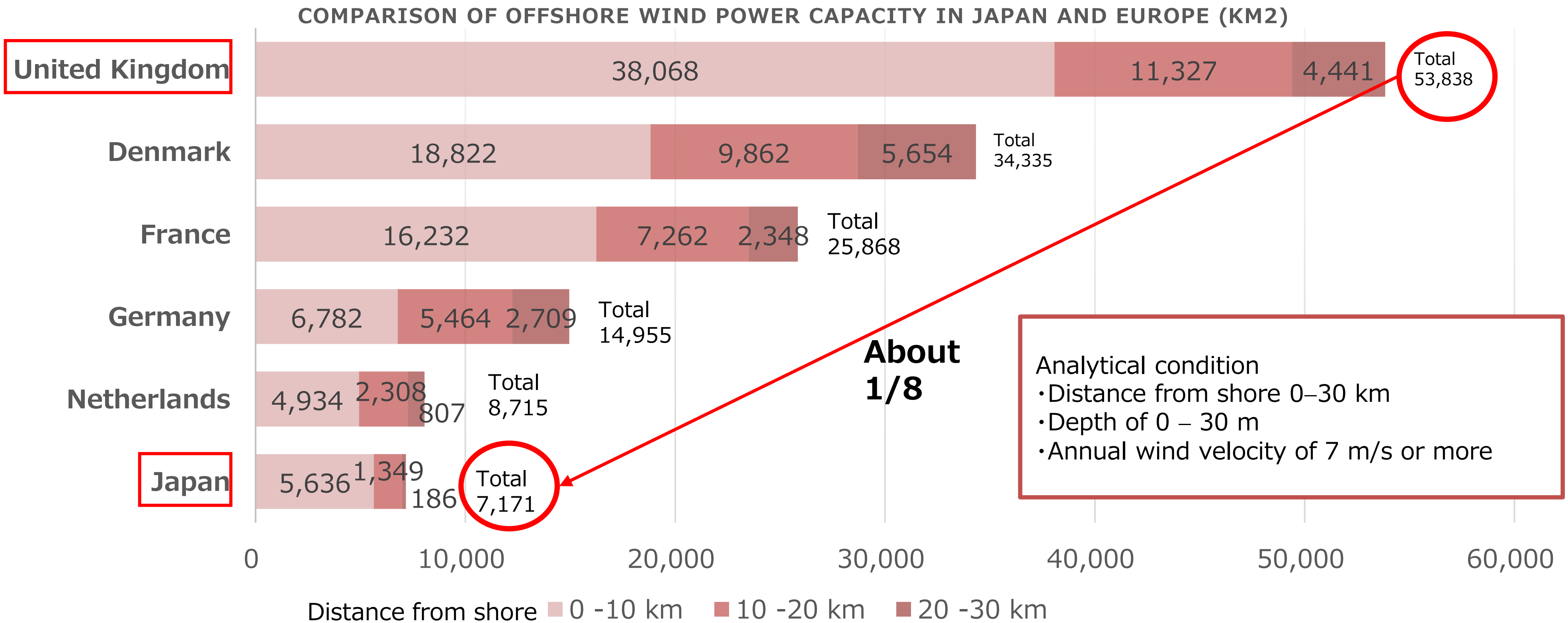
Source: National Land Technology Research Center

Suitable location for offshore wind power

- In Japan, suitable location for offshore wind power is **about 1/8 of UK** where offshore wind power is being introduced. **(54,000 km2 in the UK and 7,200 km2 in Japan)**

  *Estimated mechanically based on distance from shore, water depth, annual wind speed, etc.

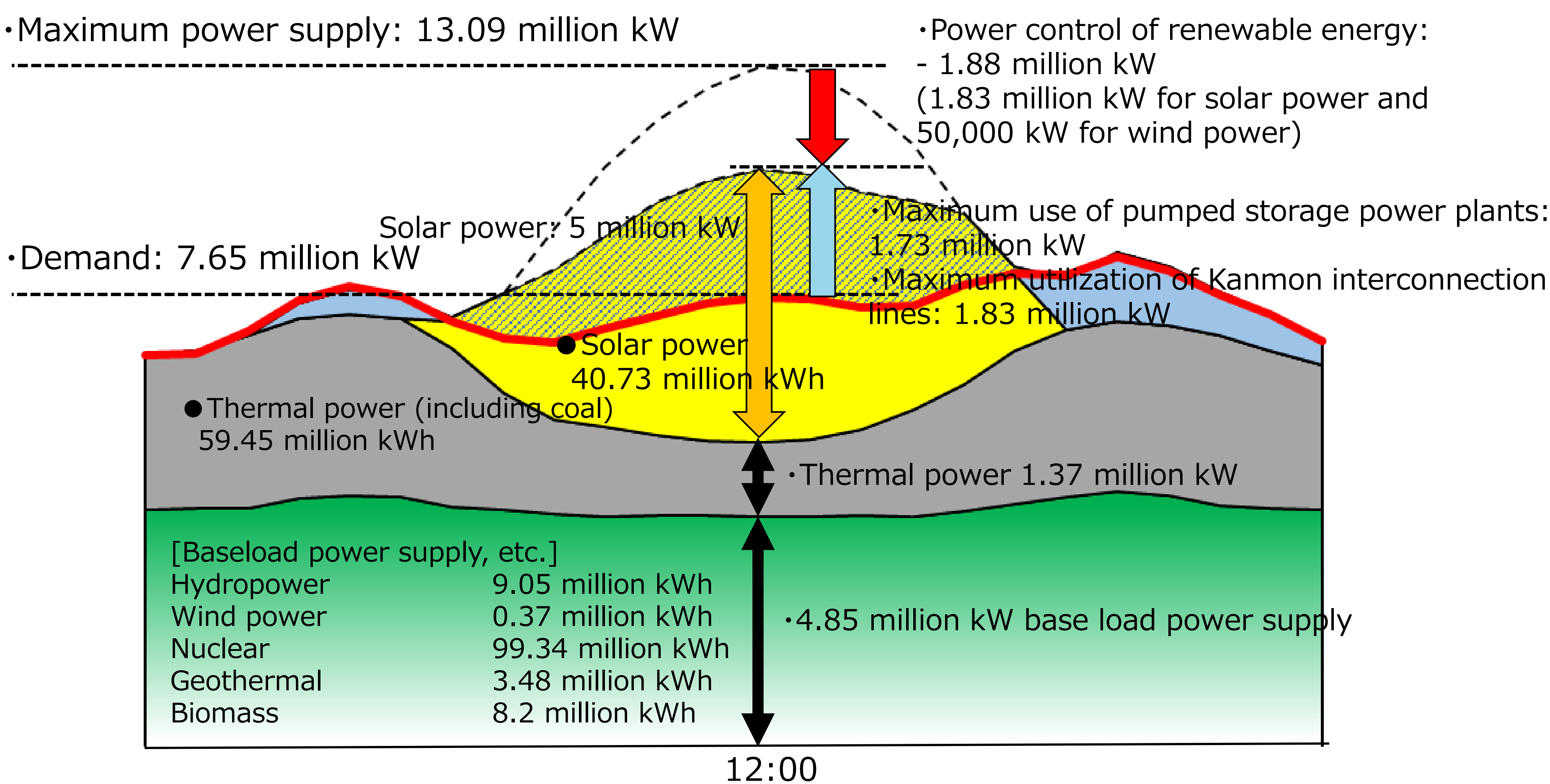
- **In Japan, where the seafloor topography is very steep, the location is limited, and it is necessary to coordinate with fishermen and local communities to develop projects.**



Source: "Deployment Guidebook for Installed Offshore Wind Power Generation" (2018.3. New Energy and Industrial Technology Development Organization)

Structure of renewable energy introduction in power supply and demand

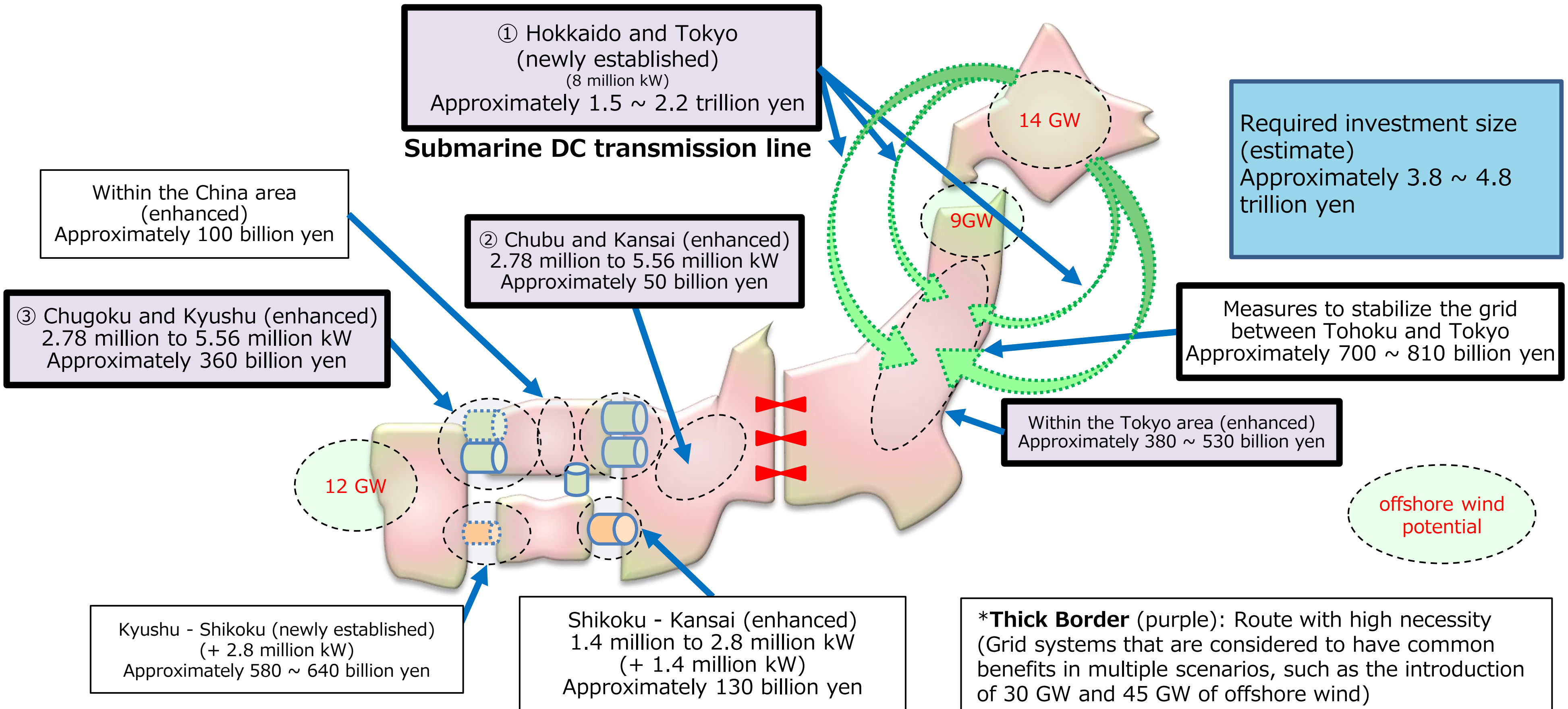
<Image of power supply and demand in Kyushu area (Example May 3, 2019) >



Improvement of the transmission network

- It is important to overcome power grid constraints to make renewable energy the main power source.
- **Interim Summary of the Master Plan was released in May 2021** to systematically promote the formation of a wide-area interconnection system on a national scale to respond to renewable energy potential and to improve resilience by facilitating electric power sharing. **It is aimed to be completed by the end of the FY2022.**
- **From the plan of the grid route which has high necessity (such as submarine DC transmission connecting Hokkaido and Honshu) would be taken shape in order.**

Overview of Interim Consolidation (Example of 45 GW Power Distribution Scenario)



*__Thick Border__ (purple): Route with high necessity (Grid systems that are considered to have common benefits in multiple scenarios, such as the introduction of 30 GW and 45 GW of offshore wind)

Taskforce Formulating Roadmaps for Climate Transition Finance
Power Sector: List of Committee Members

[Committee chair]

Akimoto Keigo: Research Institute of Innovative Technology for the Earth (RITE) Group Leader of Systems Research Group and Chief Researcher

[Committee member]

Oshida Shunsuke: Managing Director, Head of Credit Research, Japan, Manulife Investment Management (Japan) Limited

Kajiwara Atsuko: Executive Officer, Head of Sustainable Finance Evaluation Department, Japan Credit Rating Agency, Ltd.

Sekine Yasushi: Professor, Faculty of Science and Technology, School of Advanced Science and Engineering, Waseda University

Takamura Yukari: Professor, Institute for Future Initiatives, The University of Tokyo

Takegahara Keisuke: Executive Fellow/General Manager, Research Institute of Capital Formation and Head of Research Center on Financial Economics, Development Bank of Japan Inc.

Matsuhashi Ryuji: Professor, Electrical Engineering and Information Systems, Graduate School of Engineering, The University of Tokyo

[Expert committee member]

Shimizu Shigenobu: Vice Chairman, The Federation of Electric Power Companies

Maruo Masanori: Commissioner, The Electricity and Gas Market Surveillance Commission and Managing Director, SMBC Nikko Securities Inc.

Yamauchi Hirotaka: Adjunct Professor, Faculty of Business Administration, Musashino University, and Chairman, Electricity and Gas Basic Policy Subcommittee