Technology Roadmap for "Transition Finance" in Gas Sector

February 2022

the Ministry of Economy, Trade and Industry

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1. Premise | Necessity for Roadmap for Gas Sector

- The sectors covered in The Roadmap for “Transition Finance” (hereinafter referred to as the Technology Roadmap) have been selected for the following reasons: they are industries with high CO2 emissions, alternatives to zero emissions are technically and economically not available to them, and transitions are highly important for them.
- **Heat demand accounts for about 60% of energy consumption in our country's industrial and consumer sectors.** Heat is essential for people's daily lives. Gas, which supplies thermal energy to meet this demand, **plays a role as the basis of various industrial and consumer sectors with heat demands.**
- In the industrial and consumer sectors such as high-temperature zones in the industrial sector, where electrification is difficult, **the decarbonization of heat through the decarbonization of gas** and in other fields (on the demand side), **the reduction of CO2 emissions during the transition period** will contribute to the realization of a carbon-neutral society by means of fuel conversion and higher efficiency of gas appliances. Therefore, **gas will continue to be indispensable in the industrial and consumer sectors**. On the other hand, about 89 million tons of CO2 are emitted from city gas and about 30 million tons from LP gas due to combustion on the demand side. **It is essential to shift to net zero in the gas sector.**
- For transition**, funding will be necessary for the effective use of existing facilities and related equipment, as well as the replacement and introduction of low-carbon fuels and energy-saving equipment, the development and implementation of next-generation thermal energy technologies, such as synthetic methane, synthetic LP gas, and hydrogen, for decarbonization**. Therefore, domestic and overseas technologies were summarized and a roadmap to 2050 was drown.
- Innovations in technology and business structure for decarbonization also are companies’ strengths. To attract global ESG funds, which grew to 3,500 trillion yen ($35 trillion according to the Global Sustainable Investment Alliance) in 2020, high-emission industries are also required to disclose their strategies as well as understand investors’ perspectives.
- Based on the energy situation in Japan and the characteristics of the gas industry, discussions were held by experts in technology and finance and representatives of gas companies, and this technology roadmap was formulated.

1. Premise | Objectives and Positioning of Technology Roadmap

- The Technology Roadmap is designed to serve as a reference for **the gas companies in Japan, when investigating measures against climate change using transition finance (Note)** based on "the Basic Guidelines on Climate Transition Finance" (Financial Services Agency, Ministry of Economy, Trade and Industry, Ministry of the Environment, May 2021).
- It is intended to help banks, securities companies and investors **to assess the eligibility of the fundraiser's decarbonization strategies and approaches**.
- The final goal of the Technology Roadmap is to achieve 2050 carbon neutrality and the Technology Roadmap provides envisions of low-carbonization/decarbonization technologies that are expected to be deployed by 2050 and when these technologies will be deployed based on information currently available.
- The Technology Roadmap is aligned with Nationally Determined Contribution (NDC) based on Paris Agreement[*1], Green Growth Strategy[*2], and R&D and Social Implementation Plan using Green Innovation Fund[*3].
- Technologies to realize carbon neutrality in the gas sector has not been established. Public and private sectors will collaborate to develop technologies that are not yet mature and indispensable toward 2050 carbon neutrality.
- **The gas industry in Japan needs to work on "transition" including energy conservation and energy transition aiming at decarbonization without waiting for the establishment of decarbonizing technologies, while referring to the Technology Roadmap.**
- Meanwhile, looking ahead towards 2030 and 2040, the transition period, **it is essential to further advance efforts on fuel conversion and energy saving/efficient technologies in addition to R&D**.

* 1 : https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Japan%20First/JAPAN_FIRST%20NDC%20(INTERIM-UPDATED%20SUBMISSION).pdf
* 2 : https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/pdf/ggs_full_en1013.pdf
* 3 : https://www.meti.go.jp/press/2021/09/20210915001/20210915001-2.pdf

(Note)" Transition finance refers to 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" - *Basic Guidelines*

1. Premise | Objectives and Positioning of Technology Roadmap

- Transition finance includes not only the investment on facilities and R&D toward low-carbonization/decarbonization within the company **but also for efforts/activities that contribute to the transition of other industries, cost of dismantlement/removal of existing facilities and response to other environment or social impact (such as land contamination associated with withdrawal from business, decommissioning of furnaces, etc. and impact on employment) arising from activities to reduce emissions.**

- These efforts/activities are important elements for the decarbonization of whole society and economy. At the same time, as these efforts/activities are extremely broad, **the Technology Roadmap will cover the "technologies" for low-carbonization/decarbonization mainly in the gas sector.**

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2. Overview of Gas Industry

	City gas	LP gas
Main raw materials	Natural Gas (LNG) P9	Propane, butane P35
Number of business operators	193 companies (Former General Gas Pipeline Service Provider)	Approximately 18,000 companies (Number of Retailers)
Service area	Mainly urban center, less than 6% of the country	Possible to supply nationwide
Main supply methods	Pipeline P45	Cylinder, Bulk Tank
Number of customers	Approximately 30 million	Approximately 23 million households P35
Annual supply	Approx. 40 billion m3 (Approx. 33 million tons) P12 (Residential 23%, Commercial 10%, Industrial 59%, Other 8%)	Approximately 14 million tons P37
CO2 emissions	Approximately 89 million tons/year P13	Approximately 30 million tons/year P35
Ratio of emissions from combustion over the life cycle	84% P15	90% P35
CO2 emissions ratio when coal is 100	57 P9	67 P35
Low carbon measures	Energy saving, fuel conversion, etc. P 31 ~ 33, 47~51	P 39 ~ 40, 47~51
Decarbonization measures	Synthetic methane P 24 ~ 30	Green LPG P 41 ~ 42
	Direct use of hydrogen, biogas, CCUS/Carbon recycling, offset by credits, etc. P 52 ~ 61	

2. Overview of Gas Industry

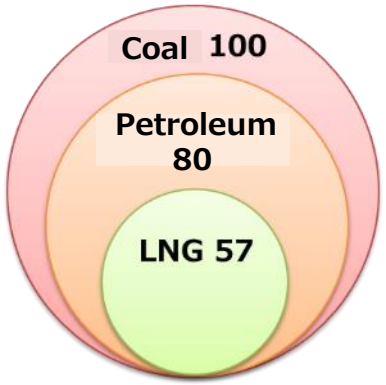
- City gas
- LP gas
- Common

2. Overview of Gas Industry (City Gas) | Importance of LNG in Japan

- LNG, which is used for electricity and city gas, **has the lowest CO2 emissions compared to other fossil fuels**.
- LNG suppliers are **diversified,** including the Middle East, Australia, Southeast Asia, Russia, and the U.S., and **the risk of supply disruption is lower** than for crude oil (89% dependence on the Middle East).
- Natural gas has been the world's most expanded energy source in the past 40 years. Pioneered by Tokyo Gas and Tokyo Electric Power Company, which began importing it in 1969, Japan is **the world's largest importer of LNG**, driving the expansion of the market. In recent years, **demand in China has been growing rapidly, and it will overtake Japan to become No.1 as early as 2021.**

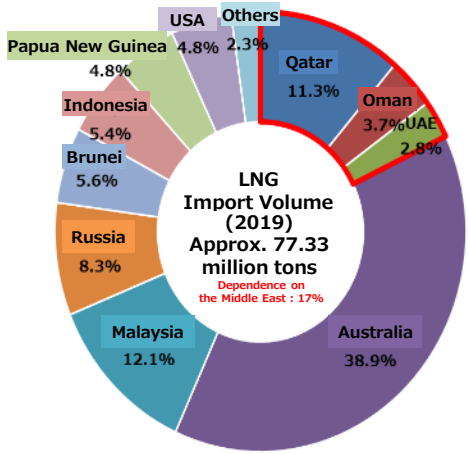
Combustion CO2 Emissions

*Coal as 100



Source: Energy White Paper 2010

Japanese LNG Suppliers



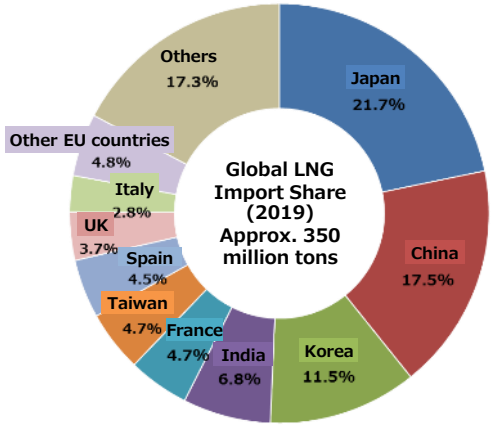
Source: Trade Statistics

< Breakdown of world energy supply >

	1970	1990	2010	2019
Crude Oil	46%	39 %	33%	33%
Natural Gas	18%	22%	24%	24%
Coal	30%	27%	30%	27%
Nuclear Power	0%	6%	5%	4%
Hydraulic Power	5%	6%	6%	6%
Renewable Energy	0%	0%	1%	5%

Source: BP Statistics, Cedigaz (~ 2015), GIIGNL

Global LNG Import Share



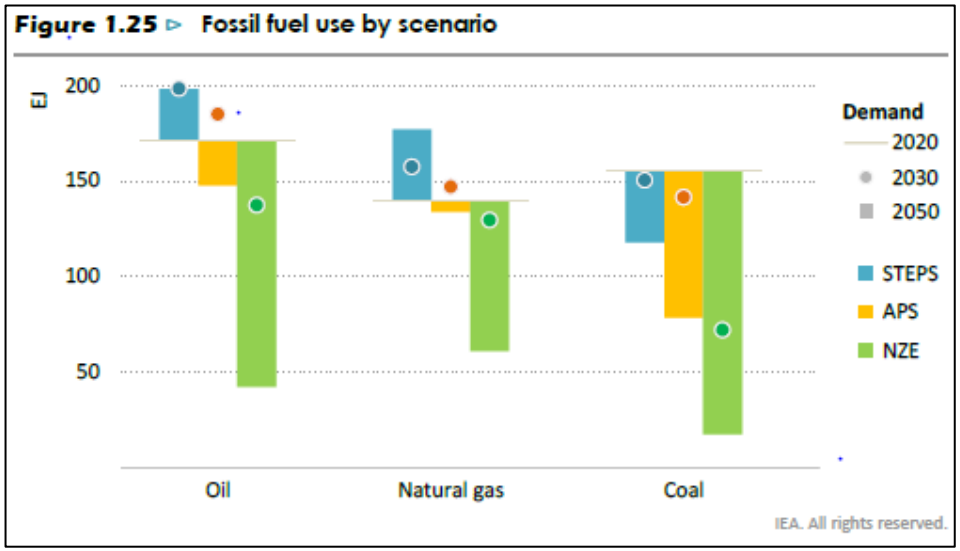
Source: Compiled by METI from BP Statistics 2020

Source: Explanatory materials for the 3rd Study Group on Gas Business toward 2050, the Petroleum and Natural Gas Division, Agency for Natural Resources and Energy, October 26, 2020
Explanatory materials for the 1st Study Group on Gas Business toward 2050, Agency for Natural Resources and Energy, September 4, 2020

2. Overview of Gas Industry (City Gas) | (Reference) International Demand Forecast

- According to the IEA World Energy Outlook 2021, **while demand for natural gas will increase over the next 5 years in all future scenarios, subsequent demand will vary by scenario.**
- In all scenarios, it is assumed that **demand for natural gas will still be present in 2050**.

Natural gas demand increases in all scenarios over the next five years, with sharp divergences afterwards. Many factors affect to what extent and for how long natural gas can retain a place in the energy mix when clean energy transitions accelerate, and the outlook is far from uniform across different countries and regions. In the STEPS, natural gas demand grows to around 4500 bcm in 2030 (15% higher than in 2020) and to 5100 bcm in 2050. Use in industry and in the power sector increases to 2050 and natural gas remains the default option for space heating. In the APS, demand reaches its maximum level soon after 2025 and then declines to 3 850 bcm in 2050; countries with net zero pledges move away from the use of gas in buildings and see a near 25% decrease in consumption in the power sector to 2030. In the NZE, demand drops sharply from 2025 onwards and falls to 1750 bcm in 2050. By 2050, more than 50% of natural gas consumed is used to produce low-carbon hydrogen, and 70% of gas use is in facilities equipped with CCUS.



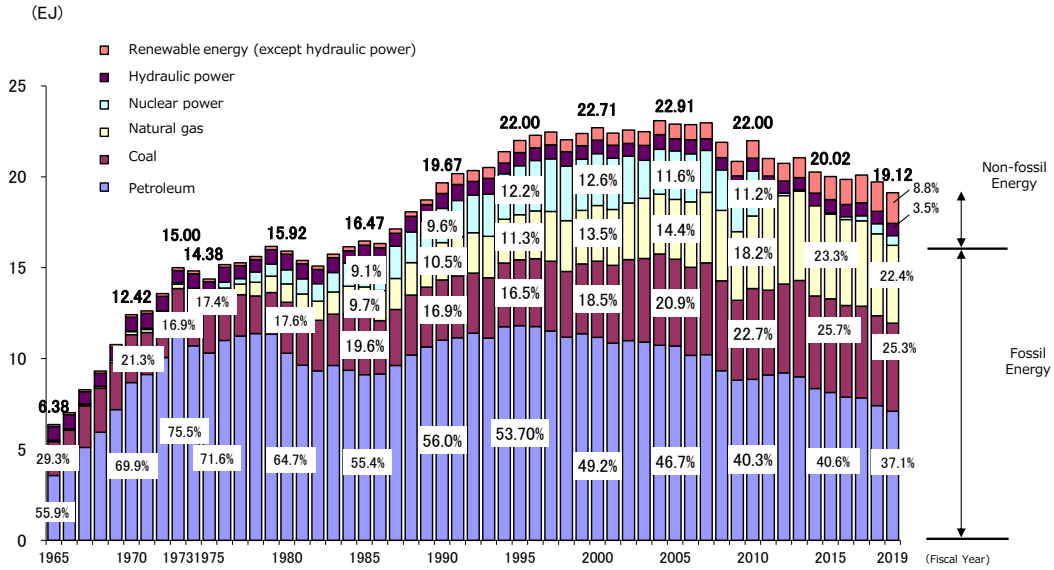
- **Net Zero Emissions by 2050 Scenario** (NZE), which sets out a narrow but achievable pathway for the global energy sector to achieve net zero CO2 emissions by 2050.
- **Announced Pledges Scenario** (APS), which assumes that all climate commitments made by governments around the world, including Nationally Determined Contributions (NDCs) and longer term net zero targets will be met in full and on time.
- **Stated Policies Scenario** (STEPS), which reflects current policy settings based on a sector-by-sector assessment of the specific policies that are in place, as well as those that have been announced by governments around the world.

Source: IEA World Energy Outlook 2021

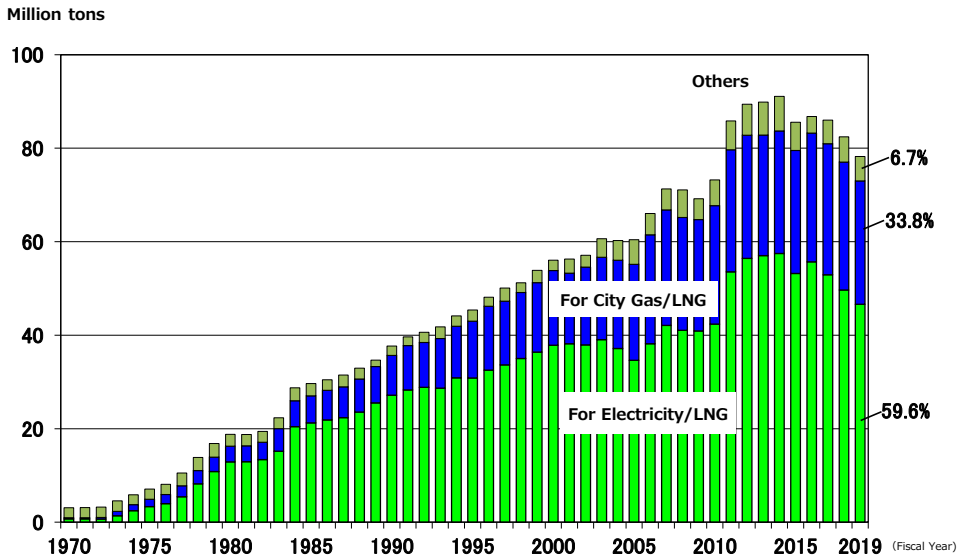
2. Overview of Gas Industry (city gas) | Percentage of primary energy supply

- Natural gas accounts for **about 22% of Japan's primary energy supply** and about 60% of its use is for electricity, **about 34% is for city gas**.

< Transition of domestic primary energy supply >



< Trends in Natural Gas Consumption by Application >

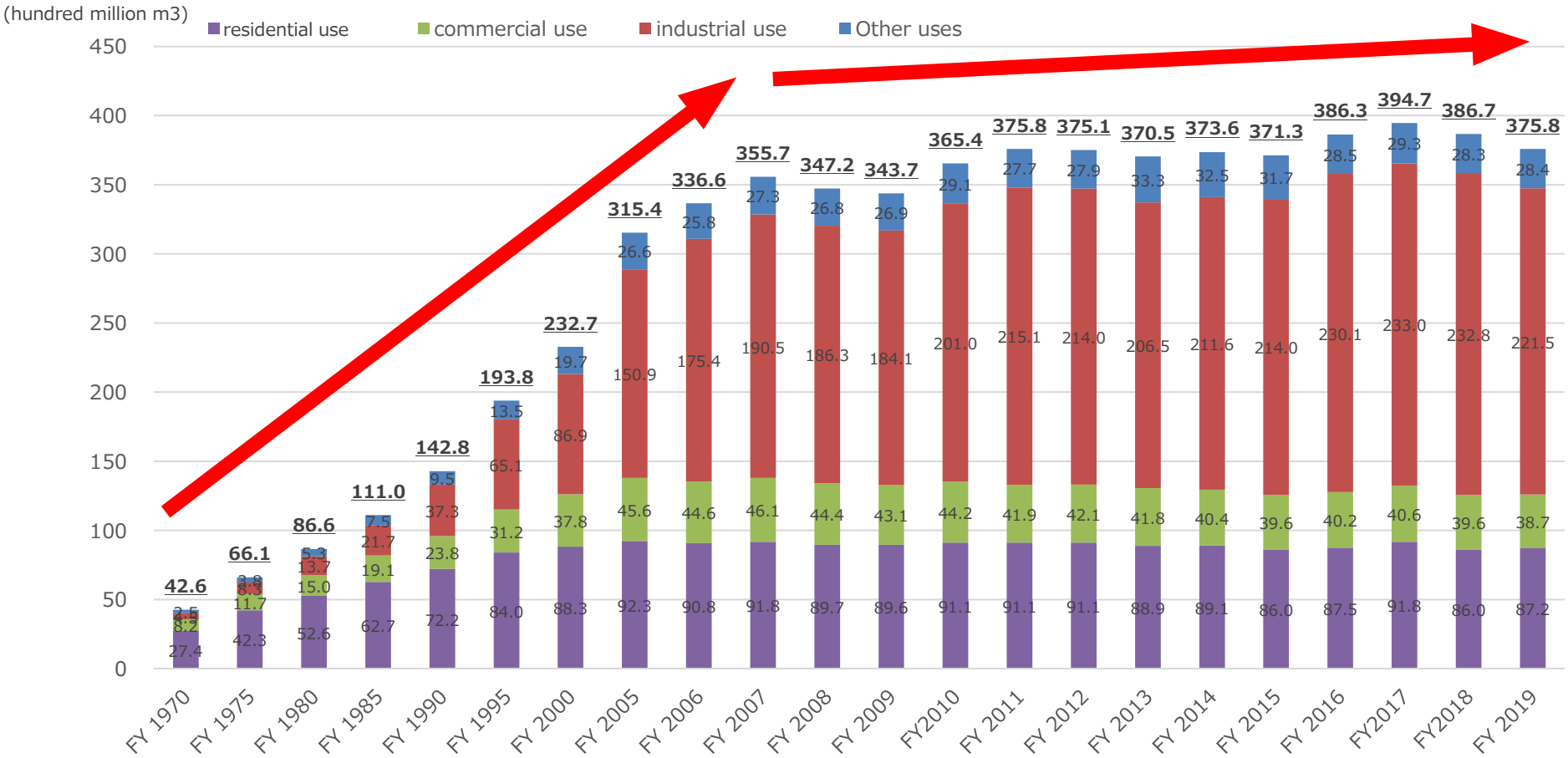


Source: the Ministry of Economy, Trade and Industry, Energy, Energy White Paper 2021

2. Overview of Gas Industry (City Gas) | Trend in City Gas Sales

- **City gas sales** rose steadily until FY 2007 and have been **on a gradual upward trend since then.**
- By application, residential and commercial use is on a gradual decline, but **industrial use is on an increasing trend, supporting the overall upward trend.**

Trends in city gas sales



Source: Statistics on the state of gas production

2. Overview of Gas Industry (City gas) | Current Status of CO2 Emissions in Gas Sector

- The amount of city gas supplied is equal to about 90 million tons in terms of CO2 emissions, which is about 10% of Japan's CO2 emissions.

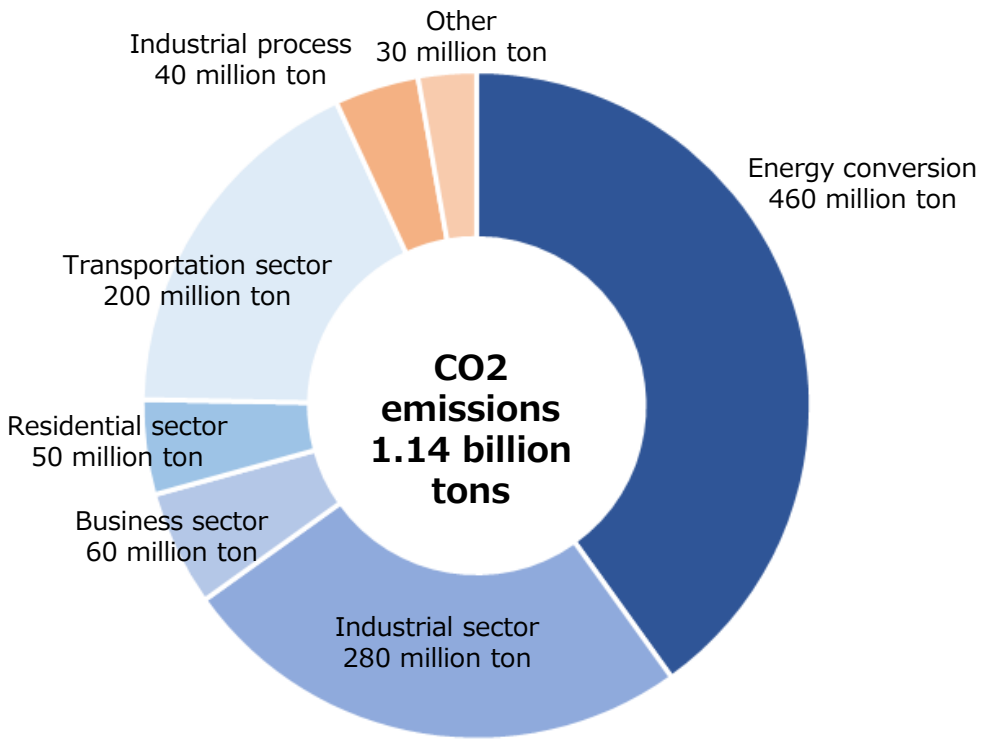
CO2 emissions from city gas (converted value)

Annual sales of city gas:
approx. 40 billion m^3 *1

CO2 emissions from city gas
2.23 kg-CO_2/m^3 *2

CO2 emissions:
Approximately 89 million t-CO2

CO2 emissions in Japan (2018)



Source: Compiled from GIO Japan Greenhouse Gas Emissions Data

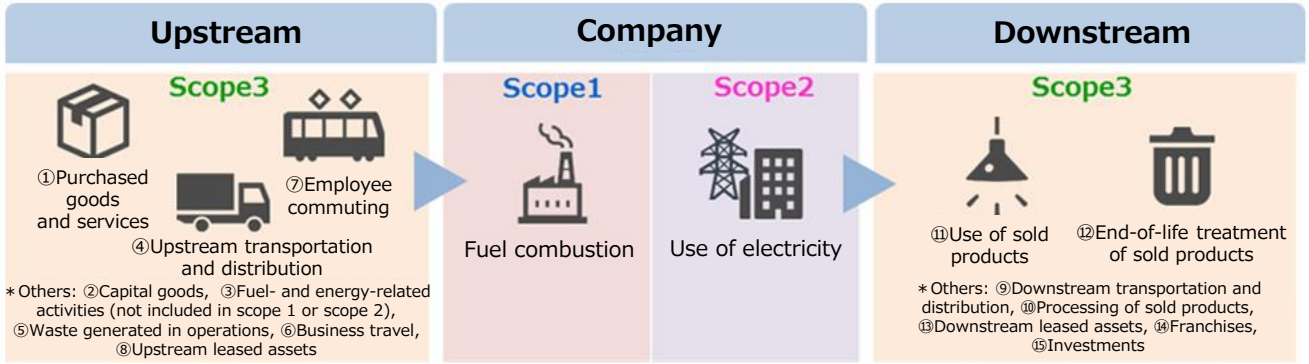
Source: The 36 session of the Basic Policy Subcommittee on January 27, 2021

*1 Based on FY 2019 results
*2 List of calculation methods and emission factors under the the Ministry of the Environment Calculation, Reporting and Publication System

2. Overview of Gas Industry (City Gas) | (Reference) What is supply chain emissions?

- Supply chain emissions refer to the total emissions of not only the company's own emissions but also all emissions from those related to its business activities.
- In other words, it refers to the amount of greenhouse gas emissions generated by the entire process, including raw material procurement, manufacturing, distribution, and disposal.

Supply chain emissions = Scope 1 emissions + Scope 2 emissions + Scope 3 emissions



Scope 1: Direct Emissions of Greenhouse Gases by Business Operators (Combustion of fuels and industrial processes)

Scope 2: Indirect emissions from the use of electricity, heat and steam supplied by other companies

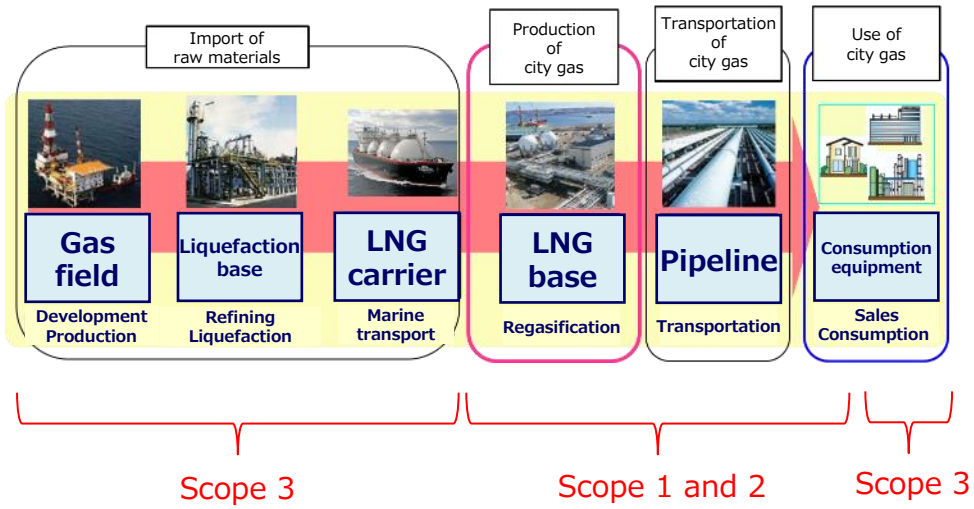
Scope 3: Scope 1 and indirect emissions other than Scope 2 (emissions from other companies related to business activities of the reporting company)

Source: the Ministry of the Environment Green Value Chain Platform

2. Overview of Gas Industry (City Gas) | Breakdown of Life Cycle Emissions of City Gas

- Looking at the entire life cycle of city gas, **most of the greenhouse gas emission is generated at the combustion stage.**
- In addition to reducing emissions at the city gas production stage, **it is important to advance emission reduction at the combustion stage by converting to decarbonized gas.**

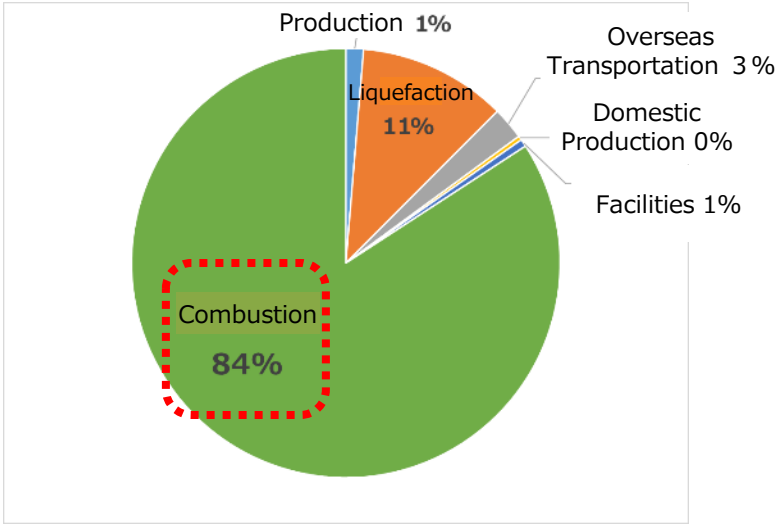
Value Chain of the City Gas Business



Source: Prepared by the Ministry of Economy, Trade and Industry based on the Japan Gas Association's FY2019 Performance Report for the Low-Carbon Society Action Plan

※ In September 2021, Japan announced its participation in the Global Methane Pledge, an initiative aimed at reducing global methane emissions by 30% compared to 2020 levels by 2030. Gas companies in Japan have been working to control methane emissions through proper management and operation, from the receipt of imported LNG and vaporization at manufacturing plants to supplying gas to customers via distribution lines. Therefore, Japan's methane emissions in this sector have been controlled at a low level.
Japan is expected to take initiatives as a frontrunner in reducing methane emissions, such as sharing information on successful domestic efforts as good practices with other countries in particular.
Under the Global Methane Pledge, emission reductions at development and production stages of natural gas are an issue to be addressed. Moreover, for synthetic methane production at plants in the future, it can be expected that methane emissions will be controlled through appropriate management.

Breakdown of greenhouse gas emissions



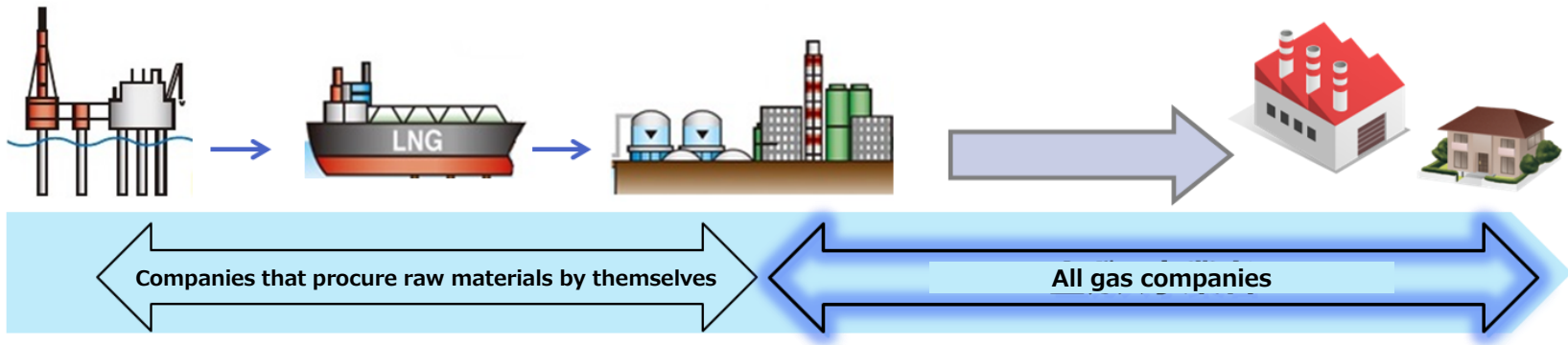
Life cycle stage	Production	Liquefaction	Overseas transportation	Domestic manufacturing	Facility	Combustion	Total
GHG emissions [g-CO2/MJ] Based on total calorific value	0.80	6.77	1.48	0.19	0.34	50.96	60.54

Reference: "Calculation of Life-Cycle Greenhouse Gas Emissions from LNG and Town Gas 13 A" (Proceedings of the Research Meeting of the Japan Society of Energy and Resources, 2016).
*Added in July 2020.

Source: Created by the Ministry of Economy, Trade and Industry based on the website of the Japan Gas Association.

2. Overview of Gas Industry (City Gas) | Outline of City Gas Business in Japan

- Gas companies take various efforts to ensure stable supply and safety, from the procurement of raw materials to the delivery of city gas to consumers.



Strengthening resilience

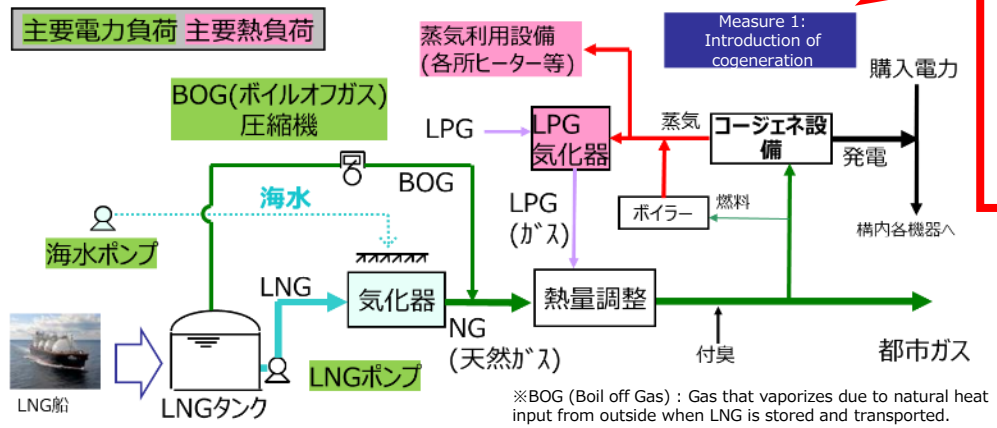
- Participation in upstream interests
- Diversification of LNG sources and contracts
- Ownership of LNG carriers
- Expanding the use of distributed energy systems
- Refurbishment of aged pipelines
- Periodic maintenance and repair of manufacturing and supply facilities
- Widespread use of microcomputer meters
- Earthquake and tsunami countermeasures (Improvement of seismic resistance of manufacturing facilities and pipelines, early restoration in the event of damage, etc.)
- Disaster and emergency preparedness training and development of response manuals

Source: October 26, 2020 3rd Study Group on Gas Business toward 2050 Explanatory Materials of Japan Gas Association

2. Overview of Gas Industry (City Gas) | Efforts to reduce emissions in domestic business activities

- In the city gas production process, emission reduction efforts are being taken such as introducing power generation using LNG cold heat (**cold power generation**), using waste heat from **gas cogeneration systems**, and introducing **vaporizer using seawater** powered by natural energy.

Efforts to reduce emissions (overview)



※BOG (Boil off Gas) : Gas that vaporizes due to natural heat input from outside when LNG is stored and transported.

Measure 2: LNG cold heat utilization	Measure 3: Improvement of efficiency of facilities	Measure 4: Improvement of operational efficiency
(ex) 1. Cold power generation 2. Utilization of cold heat in BOG re-liquefaction unit	(ex) 1. High efficiency LNG pumps 2. Seawater pump VVVF expansion 3. Use of waste heat from adjacent waste treatment and power generation facilities for LNG vaporization	(ex) 1. Reduction of operating hours by reviewing the discharge rate of LNG pumps 2. Steam emissions reduction through proper maintenance of steam traps on premises

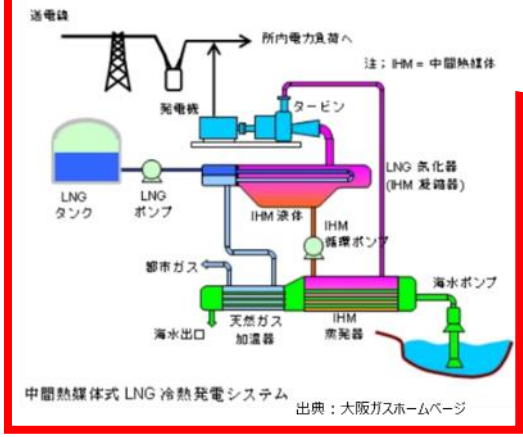
Cogeneration

A system that produces and supplies electricity and heat from fuel. Internal combustion engines (engines and turbines) and fuel cells are used to generate electricity, and the waste heat generated during the process is effectively utilized.

■コージェネレーションの概要

Cold power generation

A system to save energy by circulating intermediate heat medium in the stage of vaporizing LNG and recovering cold heat as electric energy



中間熱媒体式 LNG 冷熱発電システム

出典：大阪ガスホームページ

Source: Compiled from Material 6 of the Working Group on Resources and Energy of the Global Environment Subcommittee of the Industrial Technology and Environment Subcommittee of the First Industrial Structure Council, December 7, 2020

2. Overview of Gas Industry (City Gas) | Trend toward CN in the Gas Sector

- In the **Growth Strategy** approved by the Cabinet in June 2021 and the revised **Green Growth Strategy,** gas is positioned as a **"next-generation thermal energy industry"** in which major growth is expected.

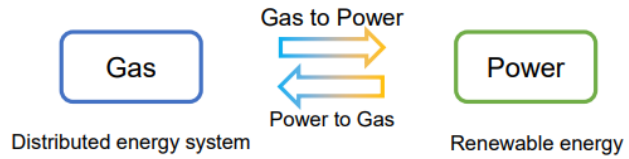
Implementation Plan for the Next-Generation Thermal Energy Industry in the Green Growth Strategy (June 2021) (Overview)

3 Next-generation heat energy industry

<Main future efforts>

- Making city gas carbon neutral by 2050.
  - Aiming to achieve carbon neutrality for city gas by injecting synthetic methane by 1% into existing infrastructure in 2030 and by 90% in 2050.
  - Promoting fuel conversion to gas on the demand side. By switching to synthetic methane, smooth decarbonization can be expected while reducing costs.
- Promoting the transformation into comprehensive energy service companies.
  - Building a distributed energy system that makes effective use of heat by promoting the introduction of gas cogeneration. Achieving optimal energy control in the region through the use of digital technology.
  - Promoting the transformation into comprehensive energy service companies that provide total services including energy supply, management, and facility maintenance, as well as a decarbonization menu. Developing new markets in Japan and overseas that have not been fully captured by gas supply alone.
- Achieving inexpensive supply of synthetic methane (equivalent to LNG).
  - Aiming to achieve a cost equivalent to LNG price (40-50 yen/m^3) by 2050 through the development of innovative technologies such as higher efficiency of methanation and the establishment of inexpensive overseas supply chains.

Smart energy network



Source: Prepared based on the Interim Summary of the Study Group on the Future of the Gas Business Toward 2050 (April 5, 2021).

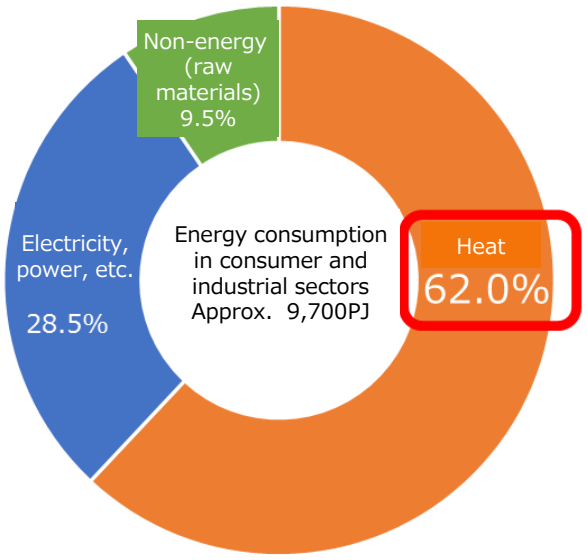
Benefits to people's lives in 2050

- Avoiding an additional burden of about 14,000 yen per year by utilizing the existing infrastructure.
  - Synthetic methane by methanation can utilize the existing infrastructure and facilities. If the entire system were to be renovated with new infrastructure investment, the cost would be approximately 20 trillion yen, which is expected to increase the burden of an average household by approximately 14,000 yen per year.
- Maintaining socioeconomic activities and living environment even during a disaster.
  - Promoting the simultaneous use of heat and electricity through gas cogeneration to create a community that will not experience a power outage during a disaster.

2. Overview of Gas Industry (City Gas) | (Reference) Importance of Decarbonization of Heat by Decarbonization of Gas

- **Heat demand accounts for about 60%** of energy consumption in the residential, commercial and industrial sectors in Japan. There are also **areas where electrification is difficult, such as high-temperature industrial processes.**
- **Decarbonization of heat demand is important** for achieving carbon neutrality by 2050. **Decarbonization of gas** which supplies thermal energy to the demand side **will play a major role**.

Energy consumption by application in commercial and industrial sectors

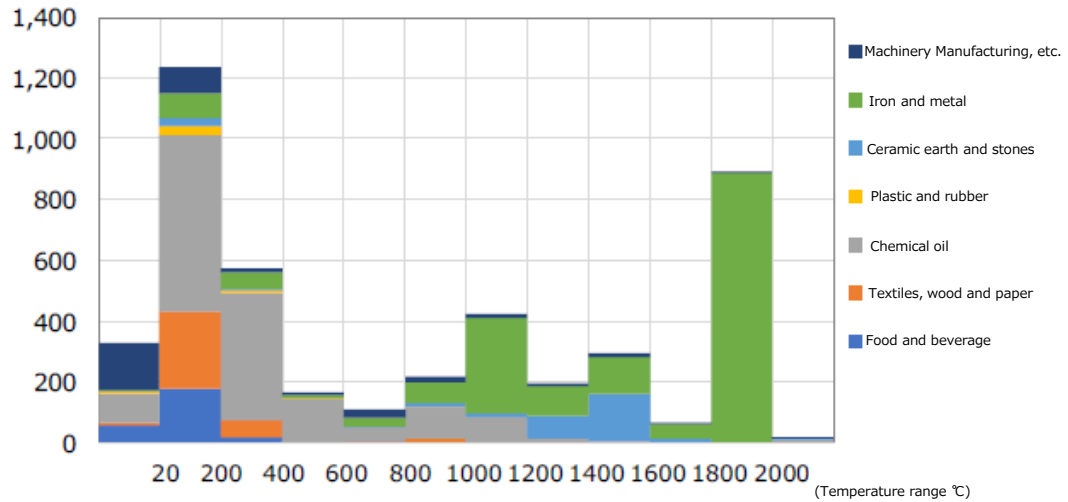


Source: Compiled by the Japan Gas Association based on the 2020 Energy White Paper

- **Heat demand** in the industrial sector **ranges from low temperature zone to high temperature zone**.
- For example, for **demand in industries where high temperature zone is necessary**, such as the steel industry, **it is difficult for electricity to be consistently supplied economically and calorically.** Though chemical sectors utilize a wide range of temperature, **there is no electrification facility that can be applied to existing large-scale facilities in areas using high-temperature zones** such as petrochemicals.

Images of heat demand in the industrial sector by industry type and temperature zone

(Heat demand PJ)



(Source) FY 2017 Basic Survey on Promotion of Introduction of New Energy, etc.

Source: Materials of the 36 session of the Strategic Policy Committee on January 27, 2021

2. Overview of Gas Industry (City Gas) | Green Growth Strategy Targets for 2050

- **The Green Growth Strategy establishes targets for gas to achieve carbon neutrality**.
- **Focusing on synthetic methane,** it aims to **make gas carbon neutral** by **promoting direct hydrogen utilization, Carbon/GHG offset LNG, CCU/carbon recycling, etc. together**. At the same time, it aims to **lower the supply cost of synthetic methane**.
- **The Japan Gas Association also establishes the same targets; the public and private sectors will work together to achieve these.**

Targets established in the Green Growth Strategy

Annual introduction

2030: **Injection of synthetic methane into existing infrastructure by 1%.**
Together with other measures*, **5% of gas achieves carbon neutrality.**

2050: **Injection of synthetic methane into existing infrastructure by 90%.** (25M-tons)
Making Gas Carbon Neutral in combination with other measures*

*Direct use of hydrogen, LNG offset by credits, CCU/carbon recycling, etc.

Supply cost

2050: Price of synthetic methane is at the current level of **LNG price (40 to 50 yen/Nm3).**

2. Overview of Gas Industry (City Gas) | (Reference) Direction of initiatives in Japan, Europe, and the U.S.

- In terms of the use of green hydrogen in gaseous energy, **Japan plans mainly to use synthetic methane,** while **Europe proposes to use hydrogen as its main resource along with biogas, biomethane, and synthetic methane**.
- **Japan, Europe, and the United States all intend to utilize existing gas infrastructure, such as gas pipelines. Europe assumes that the demand for natural gas will decrease due to electrification.** Meanwhile, **Japan assumes that a certain level of demand will be maintained from the use of synthetic methane in the city gas sector.**

	Japan	Europe	United States
Type of hydrogen utilization	・Synthetic methane ・Direct hydrogen utilization *Mixed use in individual regions is not excluded.	・Hydrogen mixture ・Direct use of hydrogen ・Synthetic methane	< Transport and Storage > • Transport and storage of hydrogen or hydrogen mixtures using existing natural gas and city gas pipelines. < Use > • Industry: e-fuel production that provides options for highly versatile net-zero carbon fuels such as methanol and renewable natural gas by reacting CO2 with clean hydrogen. • Stationary power generation facilities such as cogeneration: Direct use of hydrogen and mixing of hydrogen into natural gas (which requires compatibility evaluation to existing infrastructure and equipment, development of burners that meet high hydrogen mixing ratio (up to 100%), etc.)
Other gases	・Use of biogas ・Use of offset natural gas	・Use of biogas and biomethane ・Use of CCUS and natural gas	
Breakdown	2050 ●Synthetic methane: 90% ●Direct use of hydrogen: 5% ●Biogas: ●Offsetted natural gas: ●CCUS and natural gas ●Other: } 5%	The predicted percentage of gaseous energy in the energy mix in 2050 will be 20%. ●Renewable low-carbon gas: 2/3 ・Hydrogen ・Biogas and biomethane ・synthetic methane ●CCUS and natural gas: 1/3	
Source	Green Growth Strategy	• Hydrogen and Gas markets Decarbonization Package (Combined Evaluation Roadmap/Inception Impact Assessment) • Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on common rules for the internal markets in renewable and natural gases and in hydrogen • Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the internal markets for renewable and natural gases and for hydrogen (recast)	Department of Energy Hydrogen Program Plan

2. Overview of Gas Industry (City Gas) | Gas Sector's Direction for 2050 in Japan

- Regarding the transition of city gas toward 2050, **shifting from LNG and natural gas to synthetic methane is positioned at the center of measures in Japan** in the Green Growth Strategy (formulated in June 2021), and the 6th Strategic Energy Plan (approved by the Cabinet in October 2021). (Target amount: synthetic methane accounts for 90% in 2050)

- **Both Japan and the EU assume the direct use of hydrogen, synthetic methane, biogas/biomethane** as gaseous energy to achieve carbon neutrality by 2050. Since **synthetic methane is a form of hydrogen utilization**, **Japan aligns with the EU in terms of utilizing hydrogen** as gaseous energy toward 2050 carbon neutrality. Among others, **focusing on the use of synthetic methane**, produced by synthesizing CO2 collected as carbon recycling and hydrogen (methanation), **is one of the features of Japan's transition strategy**.

- **Synthetic methane has the same properties as LNG and natural gas and is completely substitutable;** therefore, **transition can be achieved with minimal cost**, as follows:

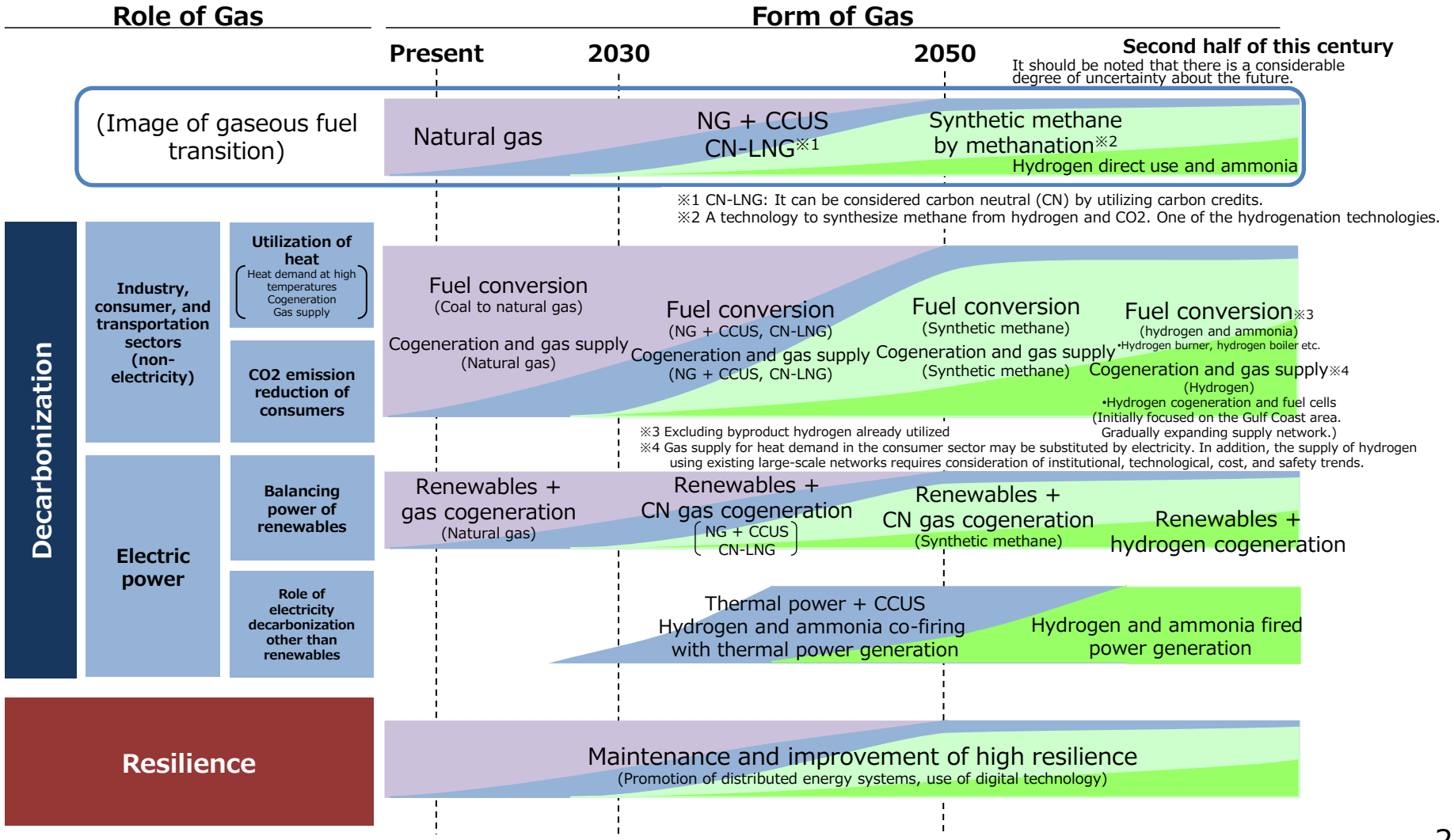
  ① Existing **LNG supply chain, domestic city gas infrastructure, and equipment and facilities for city gas on the demand side can be utilized**.

  ② Since **it is easy to mix and use synthetic methane with LNG and natural gas**, it is possible to **change city gas from LNG and natural gas to synthetic methane continuously and in a phased manner**.

  ③ **Beyond the fuel conversion from coal, oil, etc. to natural gas** as a transitional measure, **the fuel conversion from natural gas to synthetic methane can be planned.**

2. Overview of Gas Industry (City Gas) | (Reference) Image of the transition of the gaseous energy

- Regarding the transition of gaseous energy in non-electric power sectors, it is assumed that while promoting the **utilization of natural gas by fuel conversion** in other fields, controlling consumption through **efficiency improvement by advanced utilization**, **further conversion to synthetic methane, and expansion of direct hydrogen use** will also be promoted **toward 2050**.

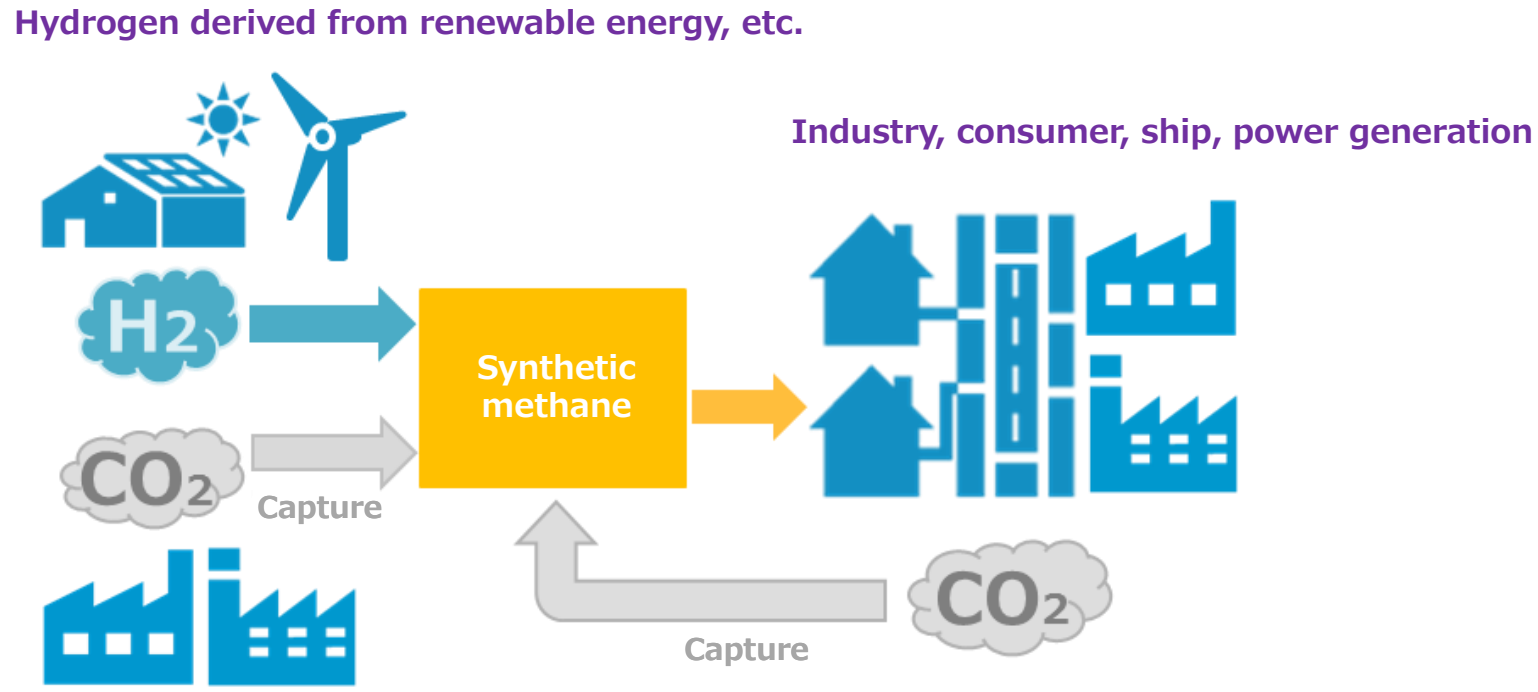


Source: April 5, 2021 Interim report of the Study Group on Gas Business toward 2050

2. Overview of Gas Industry (City Gas) | Synthetic methane/methanation

- Synthetic methane, which is synthesized (**methanation**) from **hydrogen derived from renewable energy** and **collected CO2**, is considered to **contribute to low carbon and carbon neutrality.**
- Synthetic methane **can replace natural gas.** It is **easy to inject and mix it into existing supply chains, infrastructure, and facilities.**
- It is possible to **convert** from current natural gas use to synthetic methane **seamlessly and flexibly**, thus **achieving both cost minimization and decarbonization**.

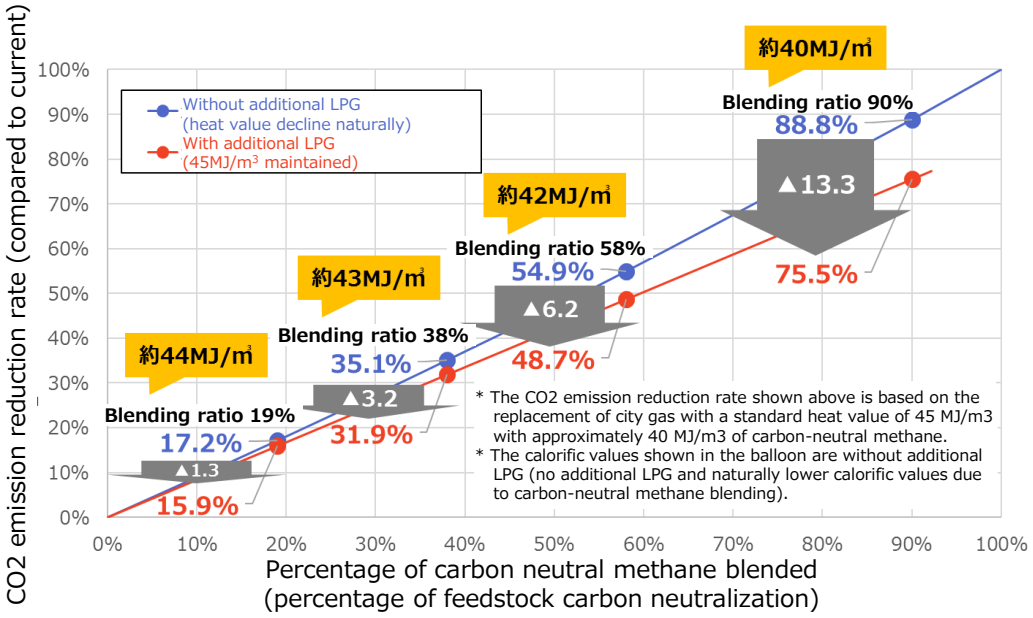
Methanation/Carbon Recycling (illustrative)



2. Overview of Gas Industry (City Gas) | (Reference) Calorific Value Systems for Transition Period and for Achieving Carbon Neutrality

- If LPG is not added for increasing calorific value, **the current 45 MJ/m³ of city gas calorific value will decrease along with the increase in the ratio of synthetic methane.**
- For this reason, the **optimum calorific value system for achieving carbon neutrality in 2050** was examined by the Working Group on Gas Business Systems, which so far considers it reasonable to **reduce the standard calorific value to 40 MJ/m³ in 2045–2050, assuming a transition period of 15 to 20 years.**

Ratio of Synthetic Methane Mixture and CO2 Emission Reduction Ratio



Source: February 24, 2021 6th Study Group on Gas Business for 2050 Explanatory Materials of Japan Gas Association

Gas Business System Review WG Point (March 16, 2021)

- **Shifting to the standard calorific value system (40 MJ/m³)** which enables CN gas such as synthetic methane by methanation to be injected into existing gas conduits without carburetion. Simultaneously, to introduce and expand technologies which realize the stable and affordable supply of CN gas in the future, it is necessary to **continuously examine the portfolio of gaseous energy to achieve CN in 2050.**
- To reduce transition cost, the **transition period will be for 15–20 years**, and the **reduction of standard calorific value is planned for 2045–2050.** Then, **after preliminary verification, the optimum calorific value system to be shifted to in 2030 will be determined.**
- To steadily promote the transition to an optimal calorific value system to realize CN, the GOJ will **set milestones such as the effect of reducing the carbon content of gas (CN rate)** and confirm the progress toward the transition.
- An optimal calorific value system to be shifted to will be **verified around 2025** as needed, based on the positioning of the city gas business in the overall energy policy, future trends of technological development, and readiness of household combustion equipments.

Source: Material 1 of the 41st session of the Basic Policy Subcommittee on April 22, 2021

2. Overview of Gas Industry (City Gas) | Technology Development Trend of Methanation by Sabatier Reaction

- As a methanation technology, **a Sabatier reaction to synthesize methane from hydrogen and CO2 by catalytic reaction** ($CO_2+4H_2 \rightarrow CH_4+2H_2O$) is understood; Japan was first to succeed in synthetic methane production in the world (in 1995).
- At present, methanation by Sabatier reaction is **at the stage of basic technology development for practical application**, which will be followed by **technology development and demonstration for facility enlargement** for this methanation method.

Examples of technology development

8 Nm3/h class methanation test equipment

[Overview]

- INPEX conducted tests under the NEDO project in FY2017-FY2021 using Hitachi Zosen's catalysts and reactors.
- Achieved technological development targets (Reaction control, catalyst activation, equipment testing).

Soma IHI Green Energy Center

Methanation test equipment of 12.5 Nm3/h class

[Overview]

- IHI developed its own catalyst and reactor and conducted a 12.5 Nm3/h test in FY2020.
- Achieved technological development targets (Verification of catalyst and reactor performance and system operation).

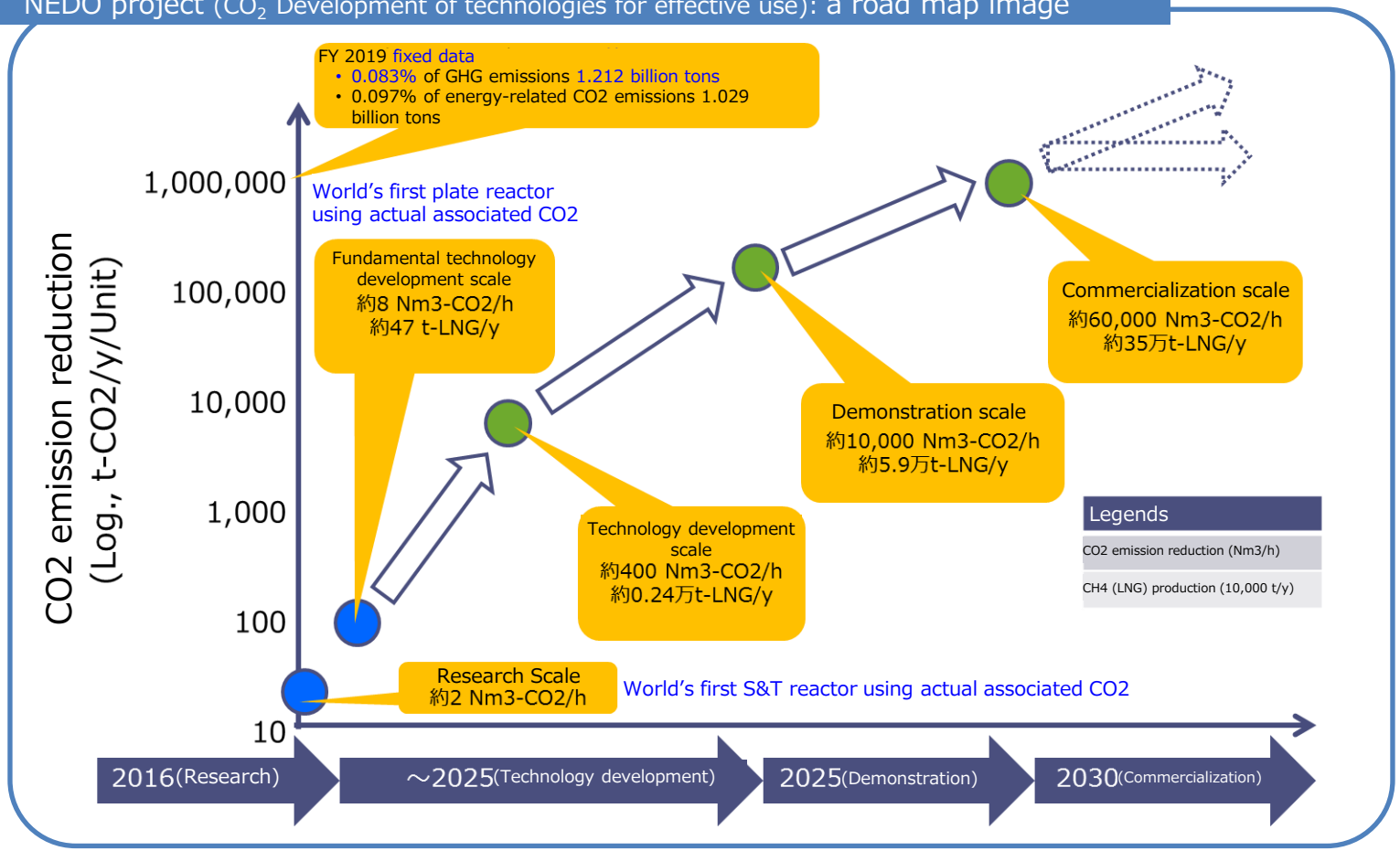
Source: Compiled by the Energy Agency based on data from Public-private Council for Promotion of Methanation (Part 1 and Part 2)

Source: Report 5 of Working Group on Energy Structure Conversion, Green Innovation Project Subcommittee, Industrial Structure Council, December 23, 2021

2. Overview of Gas Industry (City Gas) | Image of Methanation Scale-up by Sabatier Reaction

- Under the NEDO project, **the test on the 8 Nm³/h scale,** a milestone in the **Technology Development Roadmap for Methanation by Sabatier Reaction, has been completed**. By FY2025, technology development at a **400 Nm³/h scale** will be conducted.
- **To shift to the demonstration scale and the commercial scale (10,000 - 60,000 Nm³/h), it is necessary to develop technologies to increase the size of methanation facilities.**

NEDO project (CO_2 Development of technologies for effective use): a road map image



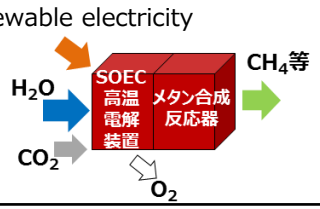
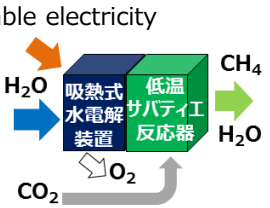
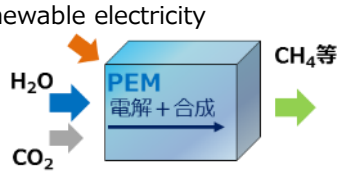
Source: Material 7 of the first meeting of the Public-private Council for Promotion of Methanation, June 28, 2021 (explanatory material by INPEX)
Source: Compiled by the Agency for Natural Resources and Energy from Material 5 of the Working Group in the Field of Energy Structure Conversion, Green Innovation Project Subcommittee, Industrial Structure Council, December 23, 2021

2. Overview of Gas Industry (City Gas) | Trends in Technology Development of Innovative Methanation

- As part of the **Green Innovation Fund Project,** a national council* deliberated twice on the project "Fuel manufacturing technology development using CO2, etc." (Synthetic fuels, sustainable aviation fuels (SAF), **Synthetic methane,** and green LPG) and **formulated a plan for R&D and practical application.**
- Regarding **innovative technologies with potential of highly efficient methane synthesis**, the council has set **targets, R&D contents, and schedules toward FY2030**, etc. (Total budget: up to 115.28 billion yen, of which **Synthetic methane, up to 24.22 billion yen**). **NEDO is currently accepting applications** (until March 7, 2022).

Innovative Methanation Technology (examples)

*Industrial Structural Reform Working Group, Green Innovation Project Subcommittee, Industrial Structural Council

		Methanation using the linkage reaction of SOEC and methane synthesis	Methanation using the linkage reaction of water electrolysis and low temperature Sabatier reaction	Methanation using PEM
Image				
Features	Raw material	●Water and CO2	●Water and CO2	●Water and CO2
	Reaction method	●Electrochemical reaction	●Electrochemical reaction	●Electrochemical reaction
	Temperature	●High temperature (about 700°C)	●Low temperature (about 200°C)	●Low temperature (about 80°C)
Benefits		●No need to procure hydrogen ●High efficiency (Effective use of waste heat)	●No need to procure hydrogen ●High efficiency (Effective use of waste heat)	●No need to procure hydrogen ●Equipment cost can be reduced (Methane synthesis by one-step reaction) ●Easy to increase size due to low temperature
Overall efficiency*		85%	80%	60%
Equipment cost		●High	●Medium	●Low
Challenges		●Development of cells necessary for high-temperature electrolysis ●Improvement of durability and reaction control of methane synthesis catalyst ●Construction of a system that continues a series of reactions at high temperatures	●Development of cells necessary for water electrolysis ●Improvement of durability and reaction control of methane synthesis catalyst	●Improvement of durability and reaction control of methane synthesis catalyst

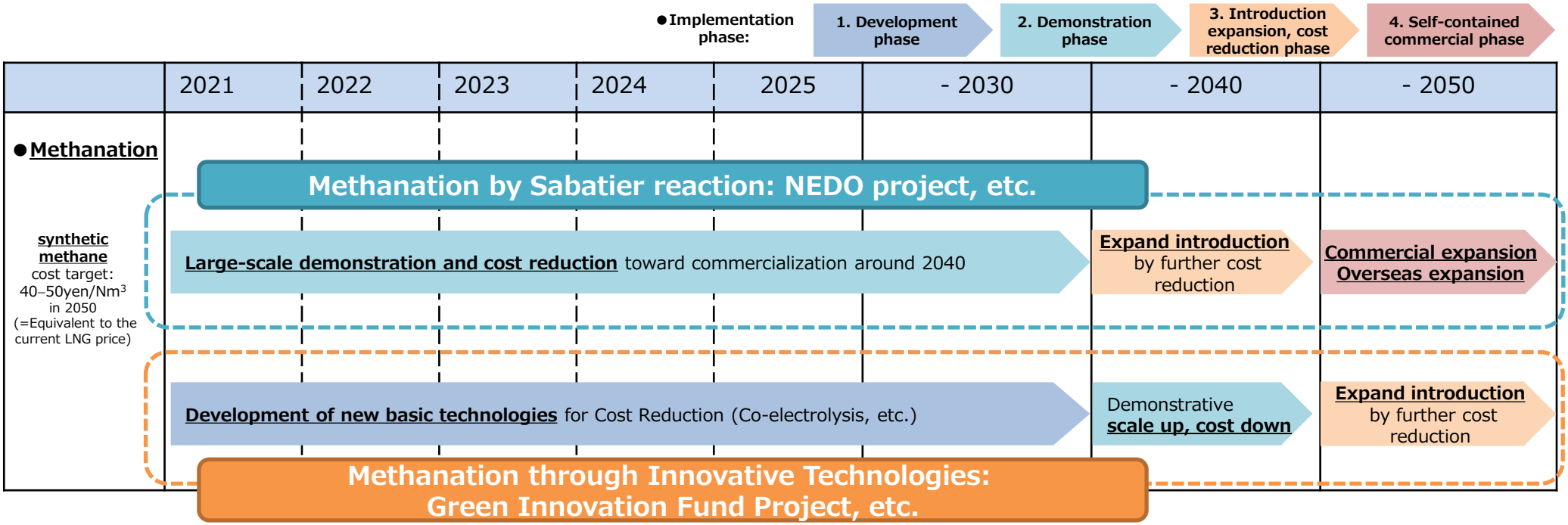
*Estimated by the Agency for Natural Resources and Energy based on published information.

Source: Compiled by the Agency for Natural Resources and Energy from Material 5 of the Working Group in the Field of Energy Structure Conversion, Green Innovation Project Subcommittee, Industrial Structure Council, December 23, 2021

2. Overview of Gas Industry (City Gas) | Methanation Technology Development Schedule

- The goal of the Green Growth Strategy is to **expand the introduction of methanation by Sabatier reaction in the 2030s and commercialize it around 2040,** for which technological development is currently in progress.
- **Targets for methanation through innovative technologies are to establish basic technologies by 2030, to demonstrate in the 2030s, and to expand the introduction of the system in the 2040s.**

Excerpt prepared from the Green Growth Strategy (Next Generation Thermal Energy Industry) Roadmap:



Source: Compiled by Agency for Natural Resources and Energy from Green Growth Strategy, June 18, 2021

2. Overview of Gas Industry (City Gas) | (Reference) Public-private Council for Promotion of Methanation

- To implement synthetic methane in society, in addition to **technological development,** it is necessary to **build a supply chain** such as transporting synthetic methane produced overseas, where the cost of hydrogen is relatively low, and to **consider counting CO2** in a direction contributing to carbon neutrality.
- To address these issues, in June 2021, the **Public-private Council for Promotion of Methanation was established in cooperation with various stakeholders,** including companies on supply/demand sides and the government, under which **public and private sectors will work together to promote initiatives.**

Members

Provider side: **Gas** (Japan Gas Assn., Tokyo Gas, Osaka Gas, Toho Gas, INPEX), **Electric Power** (TEPCO, JERA, Kansai Electric Power)

Engineering (IHI, Hitachi Zosen, JGC, Chiyoda Kako, Mitsubishi Heavy Industries)

Demand side: **Iron**, (Nippon Steel and JFE Steel), **Automobile** (Denso, Aisin), **Cement** (Mitsubishi Materials)

Supply chain: **Ships** (Mitsui O.S.K. Lines, Nippon Yusen), **Trading companies** (Sumitomo Co., Mitsubishi Co., Shell Japan)

Research institutions: Japan Energy Economics Research Institute, CCR Study Group/National Institute of Advanced Industrial Science and Technology, NEDO

Financial sector: Development Bank of Japan, JOGMEC

Experts: Hirotaka Yamauchi (Professor Emeritus, Hitotsubashi Univ.), Keigo Akimoto (Principle researcher, RITE), Takeo Kikkawa (Vice President, International Univ.),

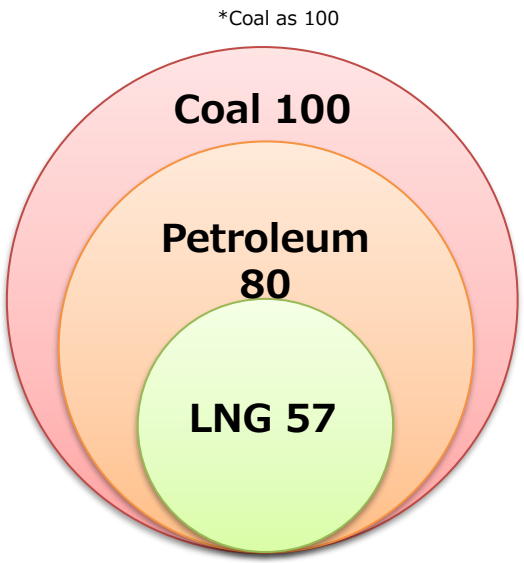
Note: All Expers are members of the Basic Policy Subcommittee on the Comprehensive Energy Policy

Government: Ministry of Economy, Trade and Industry, Agency for Natural Resources and Energy, Ministry of Land, Infrastructure, Transport and Tourism, Ministry of the Environment.

2. Overview of Gas Industry (City Gas) | Fuel conversion to natural gas, etc.

- Toward 2050 carbon neutrality, it is important to consider how we can fill the technological gap until methanation and other low-carbon technologies are put in place. **In the transition period, it is important to reduce the carbon content of heat demand.**
- CO2 emissions from natural gas are the lowest among fossil fuels, which helps to lower carbon content of heat demand by means of **switching from coal and oil to natural gas and installing high-efficiency equipment**. There are **companies that have implemented fuel conversion**, **contributing to emission reduction in other sectors (demand side)**.
- Once methanation is put to practical use, **synthetic methane can replace natural gas,** and **it will lead to decarbonization in the future.**

CO2 emissions during combustion



Source: Energy White Paper 2010

Examples of fuel conversion

Asahi Kasei Corporation

Nobeoka District
(Nobeoka City, Miyazaki Pref.)

coal-fired power generation

fuel conversion

Natural gas thermal power generation (Gas cogeneration)
CO2 reduction: 160,000t/yr
Scheduled to start operation in 2022

Showa Sangyo Co., Ltd.

Kashima Plant
(Kamisu City, Ibaraki Pref.)

coal boiler

fuel conversion

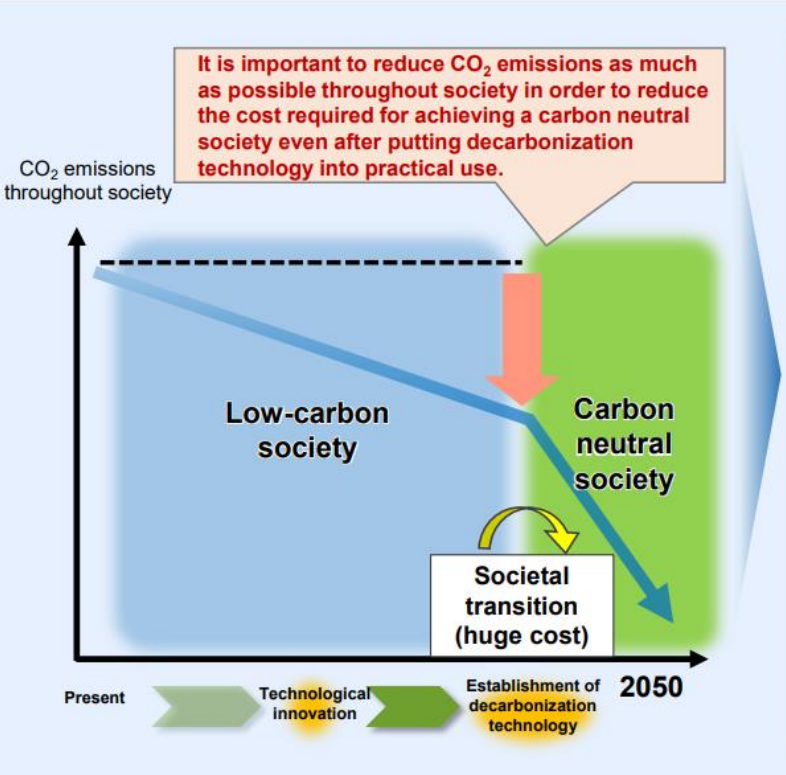
gas cogeneration
CO2 Reduction: 60,000 t/yr
Started operation in September 2021

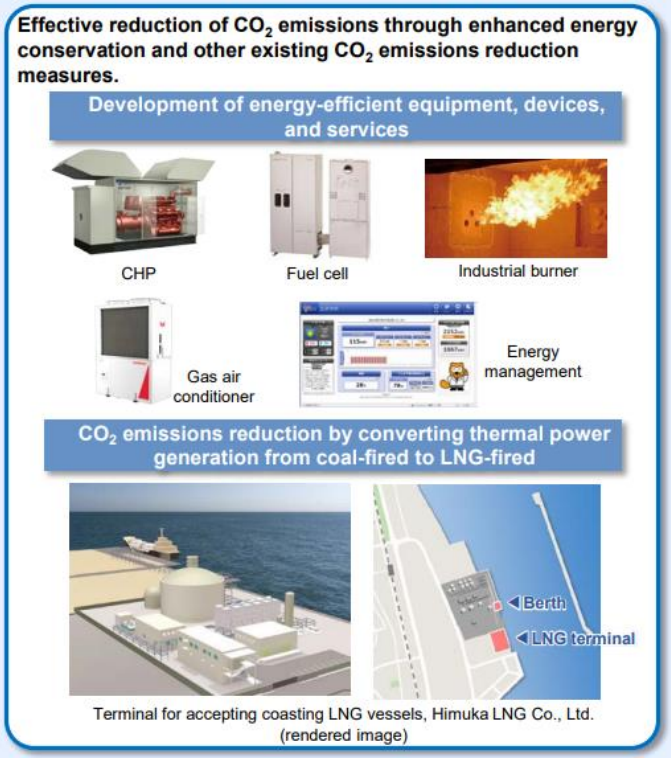
Source: Compiled by the Agency for Natural Resources and Energy based on published information

2. Overview of Gas Industry (City Gas) | (Reference) Importance of Carbon Emissions Reduction during Energy Transition

- **Decarbonization using innovative technologies** is subject to the develompmento of relevant technologies and, if established, will **require significant costs in its implementation**
- During the transition period, it is important to **cut down the decarbonization costs by reducing the carbon footprint of society as a whole through fuel conversion, energy-saving, and CO2 emissions reduction.**

Steady CO2 Emissions Reduction Efforts in the Transition to Carbon Neutrallity





Source: Daigas Group Carbon Neutral Vision (January 25, 2021)

Source: April 5, 2021 Interim report of the Study Group on Gas Business toward 2050

2. Overview of Gas Industry (City Gas) | (Reference) Avoided CO2 emissions on Demand Side

- **Lowering carbon content of heat (such as switching to natural gas) increases gas demand**. As a result, **CO2 from city gas on the supply side will be increased, while a larger volume of CO2 will be reduced, contributing to advance emission reductions on the demand side**.

(Excerpt) Basic Guidelines on Climate Transition Finance

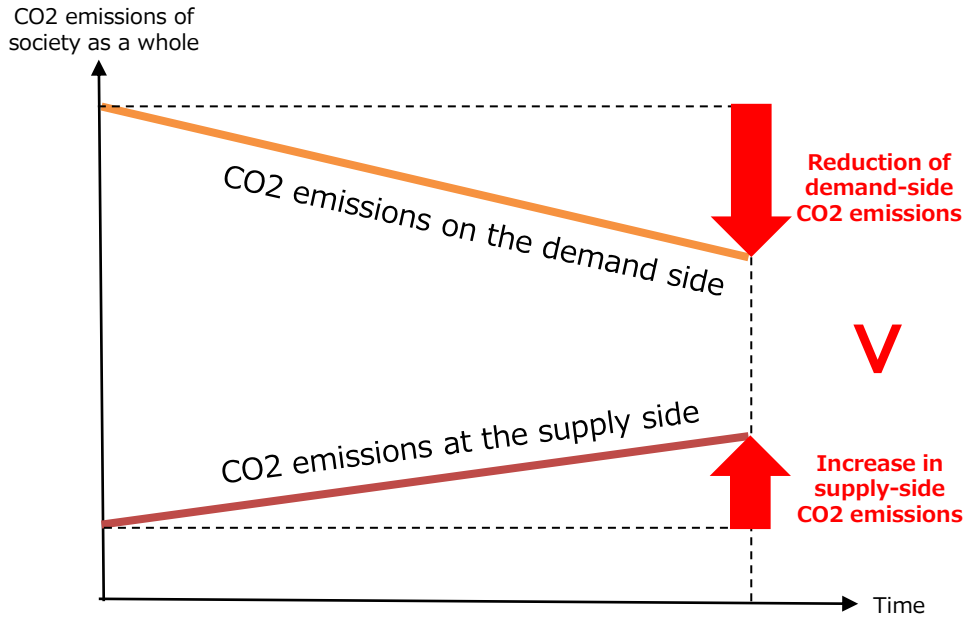
2. Specific Approaches to respective disclosure elements

(3)Element 3: Climate Transition Strategy to be Science-based Including Targets and Pathways

○ Main issue

c) In addition, it is recommended that GHG reduction targets, which could be formulated either in intensity and absolute terms, should consider environmental materiality and **cover Scopes 1 through 3 of GHG Protocol**, the international standard on supply-chain emissions. It is recommended that targets covering Scope 3 be set using a practical calculation method when it could be subject to significant reduction in the fundraiser's business model. **It is also possible to disclose the avoided emissions** as necessary.

Image of avoided emissions through fuel conversion to natural gas



Reference: Standard carbon emission factor for each fuel (equivalent to total heat generation)
Imported coking coal: 24.60 g C/MJ (Gross)
Crude oil: 18.98 g C/MJ (Gross)
City gas: 13.95 gC/MJ (Gross)
Source: Comprehensive Energy Statistics

2. Overview of Gas Industry

- City gas
- LP gas
- Common

2. Overview of Gas Industry (LP Gas) | Overview of LP Gas

- **LP gas is a combustible gas consisting of propane (C_3H_8) and butane (C_4H_{10}) and is a type of fossil fuel. CO2 emissions during combustion are the second lowest after methane gas (city gas).**
- LP gas has **advantages in portability and ease of storage** and is widely used as boiler fuel and for heat processing in houses, restaurants, and factories, for automobile fuel, and for city gas carburetion. In particular, it is widespread in rural areas and remote islands where city gas is not connected, which accounts for **40% of houses (23 million households)**.
- **CO2 emissions from LP gas combustion is approx. 30 million tons of CO2 per year.***

*10.06Mt/year (LPG demand in FY2020 excluding chemical raw materials) x 3 (CO2 emission index during LPG combustion) = 30.34Mt-CO2

BREAKDOWN OF LPG DEMAND

Total demand: approx. 12.53 million tons (FY 2020)

Fractions of crude oil by product

LP gas	3%
Naphtha	10%
Gasoline	27%
Intermediate distillate (Jet fuel, kerosene, and light oil)	40%
Heavy oil	20%

Comparison of carbon emissions by fuel

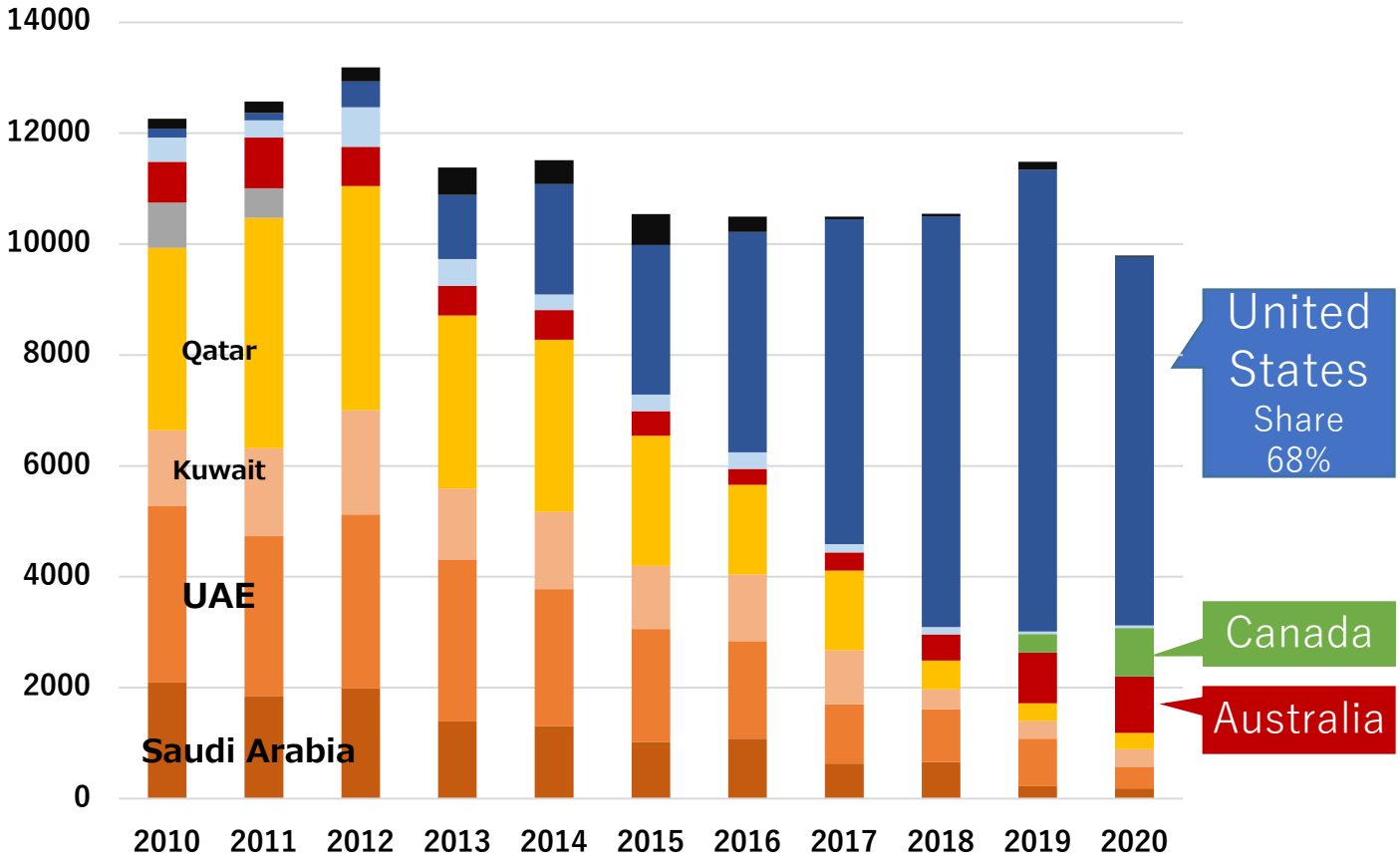
	index with crude oil at 1
Coal	1.28
Bunker A	1.02
Crude oil	1.00
Gasoline	0.99
Kerosene	0.98
LP gas	0.86
City gas	0.73

2. Overview of Gas Industry (LP Gas) | Import Status of LP Gas

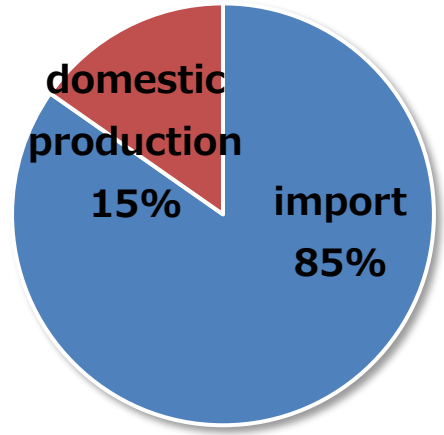
- 85% of domestic supply is imported.
- Japan used to depend on the Middle East for LPG imports, but in recent years, the share imported from the United States has increased because of the import of shale gas-associated LP gas.
- In addition, in Japan import companies also take efforts to diversify origin countries such as Canada and Australia.

Unit: 1000 tons

Trends in LP Gas Imports



Import ratio of LP gas in Japan in FY2020

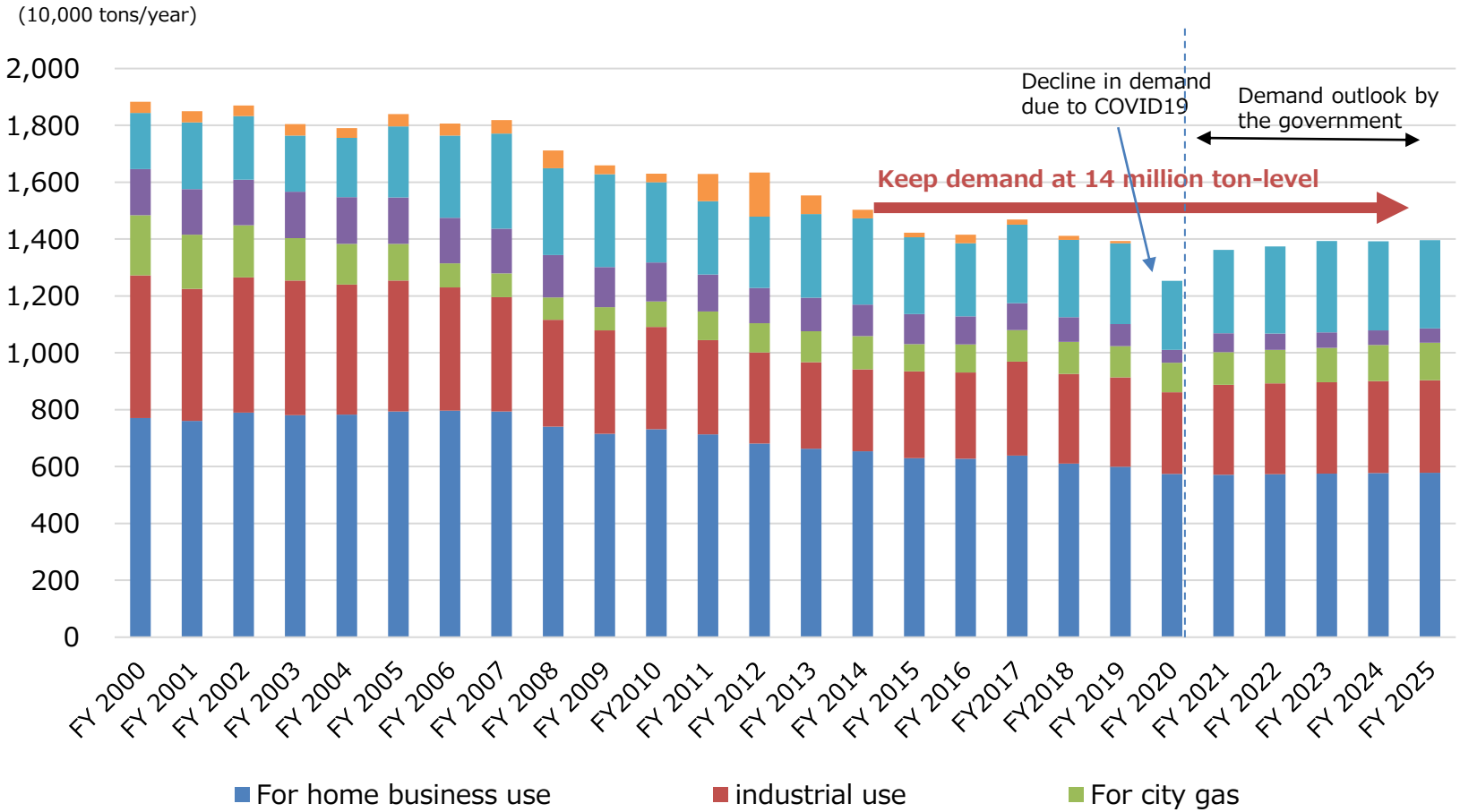


*Domestic production is produced by petroleum refining; the quantity distributed except for private consumption
*Estimated from FY2020 import, export, and production volumes

2. Overview of Gas Industry (LP Gas) | Trends in Domestic LP Gas Demand

- LP gas demand was on the decline due to depopulation in rural areas, more efficient gas appliances, and the spread of all-electric houses; but, in recent years, it has remained at around 14 million tons.
- The installation of LP gas emergency power generators with bulk tanks has been increased in schools, hospitals, and welfare facilities preparing for an increasing number of disasters in line with recent years, indicating that advantages of LP gas have been noted (good storability which does not deteriorate during long-term storage).

Trends and Forecasts of Domestic LPG Demand



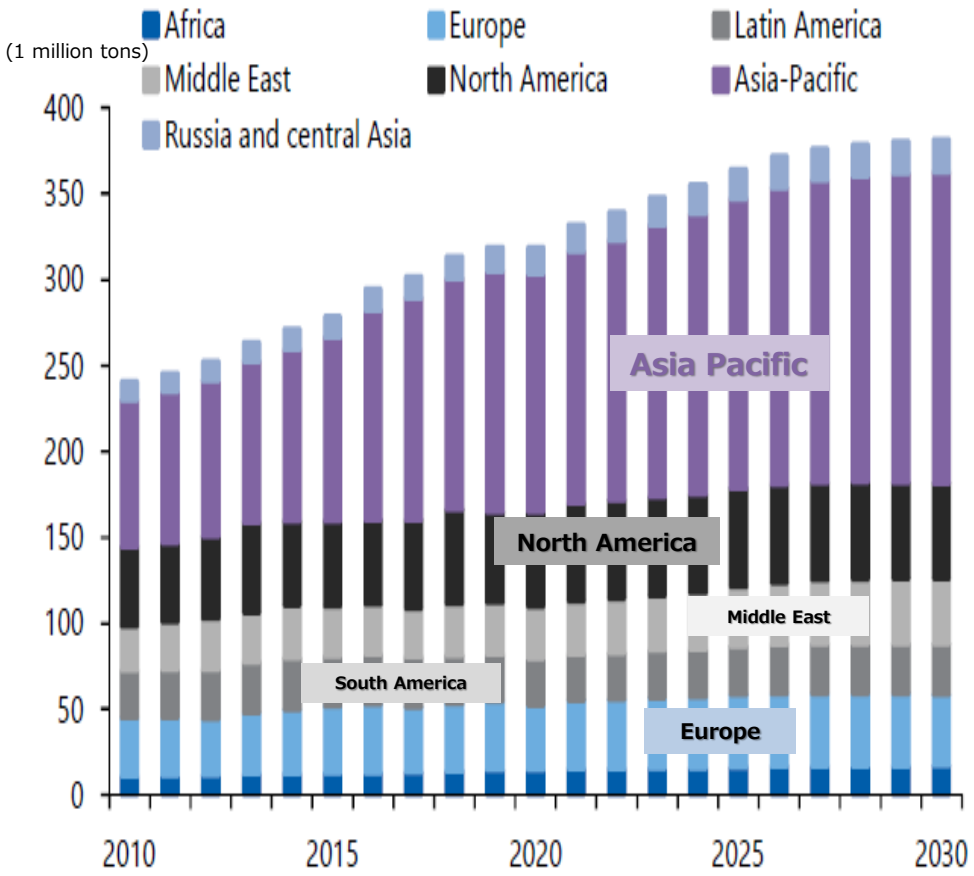
LP gas bulk for disaster

LP gas emergency generator

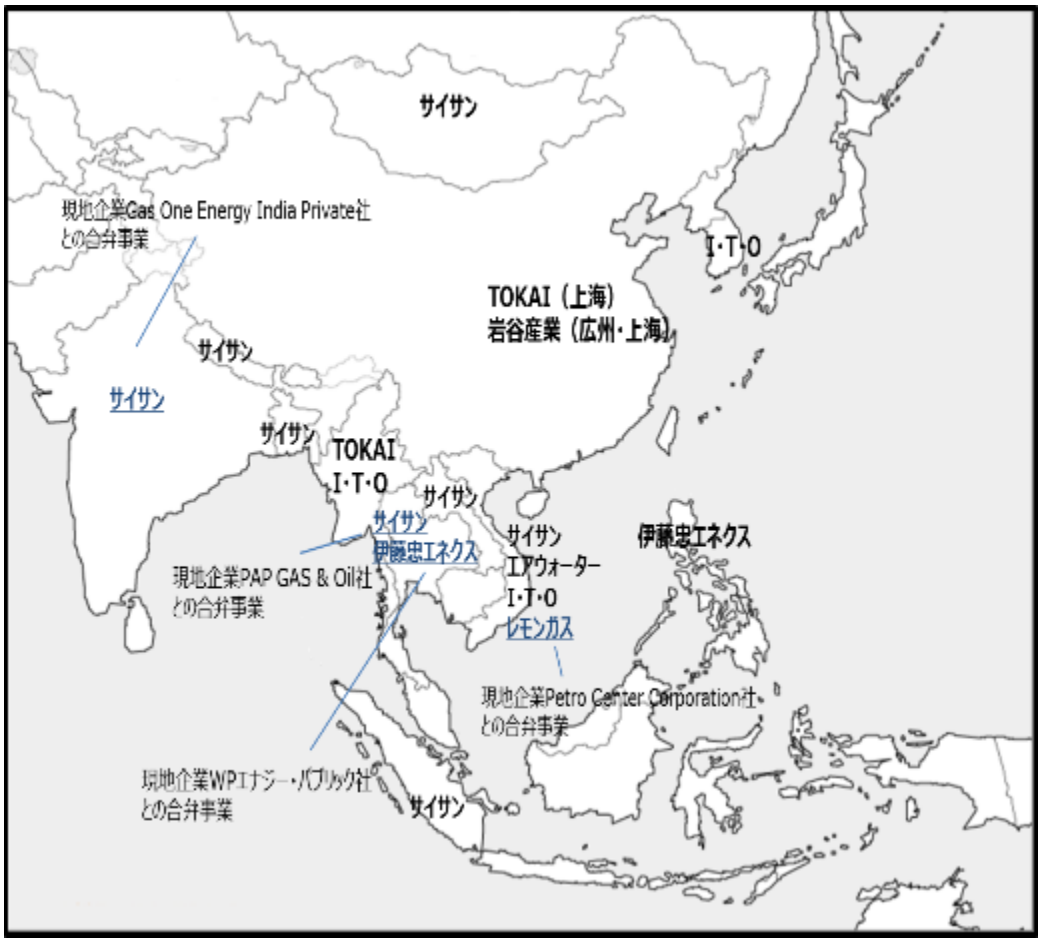
2. Overview of Gas Industry (LP Gas) | Global LP Gas Demand

- LPG consumption continues to increase in Asia and Oceania. In particular, the **rapid increase in consumption in China and India** caused by fuel conversion from firewood and coal has driven LPG consumption worldwide in the long run.
- LPG companies in Japan have also taken steps into the rapidly-growing Asian markets.

Prospects for Global LP Gas Consumption



Japanese LPG companies operating in Asia



Source: World LP Gas Association Statistical Review of Global LPG 2020

2. Overview of Gas Industry (LP Gas) | Demand for fuel conversion from oil

- To reduce CO2 emissions, fuel conversion from oil to gas, for fuel use for boilers and ships, is being promoted.

Example of fuel conversion for gas boilers

Maruhon Homma Suisan (Sapporo, Hokkaido)
Reduced CO2 emissions by 21.2% and fuel consumption by 46.1% by switching from kerosene boilers to two high-efficiency steam boilers. Maintenance costs were successfully reduced by approximately 80%. The energy saving rate of the plant is 12.4%, soot emissions are low, and the plant meets the high environmental standards set by the parent company.

サムソン製ボイラーBOα-750N

1tハイパーバルク

Demand for fuel conversion for gas boilers

- Shipments of heavy oil boilers: Approx. 1,200 units per year
- Gas Boilers Approx. 6 mil. yen/unit x 1,200 units = **7.2 bil. yen/yr**

*Shipments is the value for FY2020. Gas boiler price is for those with about 300,000 kcal/h.

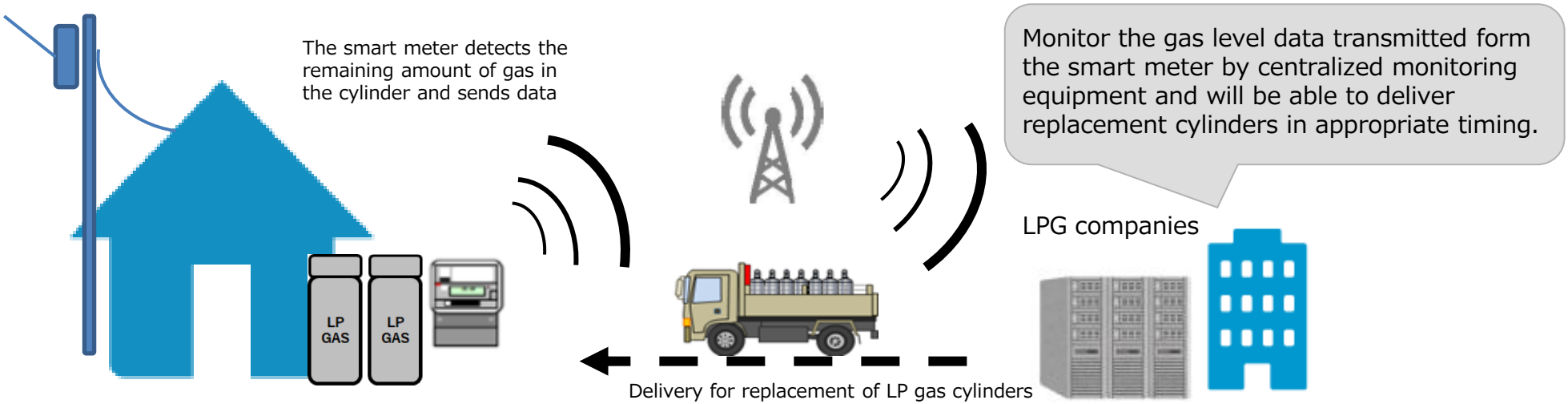
- Conventionally, ships use heavy oil as fuel for power.
- Kawasaki Heavy Industries, Mitsubishi Shipbuilding, and others undertake construction of a ship* using LP gas with lower CO2 emissions during combustion as the fuel to comply with CO2 regulations in the maritime sector.

*Bi-fuel ship that uses heavy oil with high horsepower at its start and then switches to LPG during stable navigation, which reduces CO2 emissions by 20% by using LPG as fuel.

2. Overview of Gas Industry (LP gas) | Rationalization of distribution

- Because the amount of residual gas in the LP gas cylinder is not known from the outside, LP gas companies have used their experience to determine when to replace the cylinder. Since it is necessary to change the cylinder before the remaining amount of gas runs out, the cylinder is changed.
- With the introduction of smart meters and centralized monitoring devices, customers will be able to remotely and accurately determine the remaining amount of gas in cylinders installed at their customers' locations, reducing the frequency of gas cylinder replacement deliveries, which had used employees' experience in the past. As a result, energy consumption for delivery has been reduced, contributing to CO2 reduction.

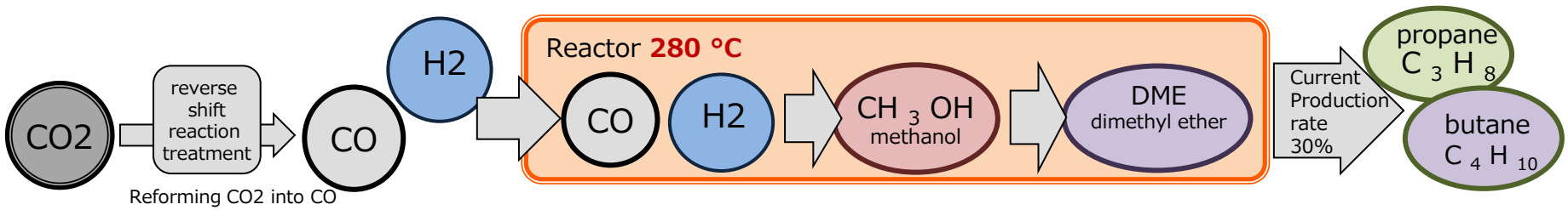
Installation of smart meters reduces CO2 emissions by 2.1 kg per house per year



2. Overview of Gas Industry (LP Gas) | Trend toward CN in the Gas Sector (Domestic Policy)

- **Japan aims to commercialize green LPG in 2030**
  - To make LP gas green, establish LP gas synthesis technology by chemical synthesis, and conduct demonstration toward the implementation in society in 2030.
  - By intensively developing and demonstrating technologies related to the synthesis of green LP gas over the next 10 years, establish synthesis technologies and commercialize them by 2030. Aim to replace all demand with green LP gas by 2050.

Chemical synthesis of green LP gas



Reforming CO2 into CO

Green Growth Strategy for Carbon Neutrality 2050 (Overview)

	2021	2022	2023	2024	2025	~ 2030 years	~ 2040 years	~ 2050 years
Green LPG	Development of basic technologies necessary for demonstration tests of catalysts, etc.					★Target (as of 2030) Commercialization of green LPG	★Target (as of 2050) Achieving carbon neutrality in LP gas	
	Demonstration for commercialization						cost reduction	Widespread use of green LP gas synthesis technology

< Current Issues >

Technology establishment for commercialization is a challenge

・The demand for LP gas is expected to remain constant in 2050.
・From a global perspective, no technology has been developed for the main purpose of green LP gas synthesis, and Japan aims to establish this technology and implement it in society as soon as possible.

< Future Initiatives >

Implementation of demonstration projects for large-scale production

・Development of basic technologies such as catalysts capable of production that can withstand commercialization
・Development of technology to integrate basic technologies such as catalysts and peripheral basic technologies and implement them in demonstration plants
・Aim for commercialization in 2030 through support for these efforts

Source: Prepared based on the Green Growth Strategy

2. Overview of Gas Industry (LP Gas) | Overseas Trends in Green LP Gas

- In Europe, LP gas derived from vegetable oil is synthesized. However, LP gas is produced as a by-product of biodiesel fuel, and the amount of LP gas produced is very small.
- As a **mass production method** for green LP gas derived from non-fossil fuels, it is necessary to establish **chemical synthesis technology** (synthesis from CO and H2). Basic research on chemical synthesis is conducted worldwide.

Overseas Production of Bio-LP Gas (2018)

Source: World LP Gas Association Report

Business operator	Country	Production volume (1000 tons/year)	Bio LP gas brand name
World Energy (formerly AltAir Fuels)	United States	7	
Renewable Energy Group	United States	1.3	Bio Propane
Valero: Diamond Green Diesel	United States	10	Renewable naphtha
Global Bioenergies	Denmark	0.1	Isonutylene (Seller: Butagaz)
Repsol	Spain	Production begins in 2018	
Total	France	30	
Eni	Italy	20	Green LPG
Irving Oil	Ireland	3	
Neste Oil	Netherlands	90	Bio LPG (Seller: SHV, Energy,
PREEM	Sweden	15	Ecoblem (Seller: AGA) Biomix (Seller: Kosangas)

2. Overview of Gas Industry (LP Gas) | Direction of Social Implementation of Green LP Gas

- The following two measures will be taken to promote the use of this technology.
  ① **Supply by mixing with conventional LP gas** (the same applies to synthetic methane produced by methanation of city gas).
  Benefits: Green LP gas production costs can be passed on to the entire LP gas bill
  ② **Sale of green LP gas differentiated from conventional LP gas** (same as sale of bio LP gas in Europe)
  Benefits: Meet the needs of consumers for sustainable energy.

[Discussion] Changes in industrial structure due to the establishment of green LP gas production technology

- At present, LP gas is delivered to consumers from importers through wholesalers and retailers, and the supply chain structure of LP gas from upstream to downstream has become longer. The retail price of LPG is about twice as high as that of city gas, which is imported and retailed, because the companies involved in the distribution of LPG deal with LPG in a manner that secures profits for the business.
- If the production technology of green LP gas is established and business risk declines, LP gas related companies and industrial gas manufacturing companies may enter into the production of green LP gas and engage in the production and sales. Even if the manufacturing cost of green LP gas is high, there is a possibility of price competition with ordinary LP gas because there is no intermediate distribution cost.

Current LP gas supply chain

Possibility of integrated business development of production and sales of green LP gas

Manufacturing cost: 200,000 ~ 300,000 yen/ton

If green LP gas manufacturers sell their products directly, the existing intermediate distribution costs will be eliminated.

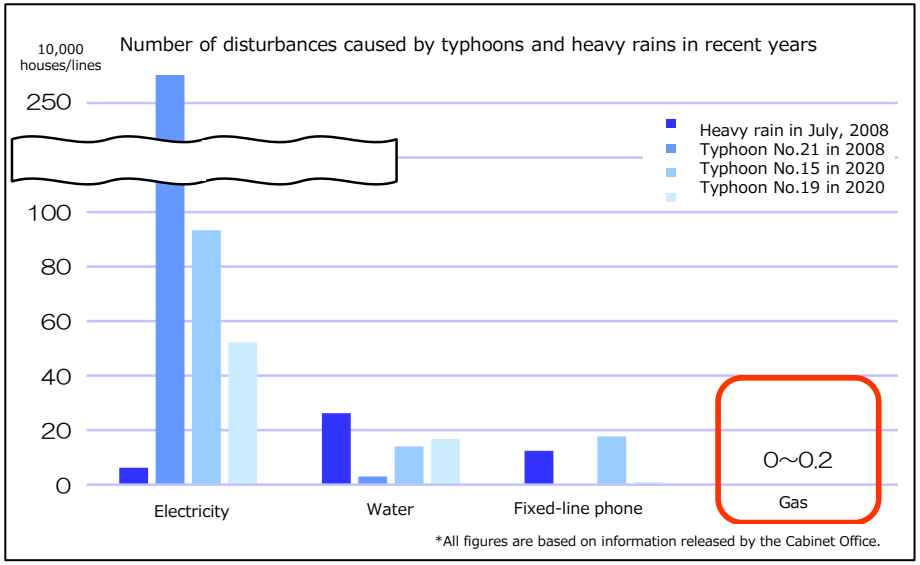
Source: Direction of R & D and social implementation of "Development of fuel manufacturing technology using CO2" project (draft)

2. Overview of Gas Industry

- City gas
- LP gas
- Common

2. Overview of Gas Industry (Common) | (Reference) Resilience of city gas (Resilience of city gas)

- Since most of the gas conduits are buried, they are **not easily affected by wind and rain.**
- Most of them are also earthquake-resistant, and efforts are being made to continuously improve their earthquake resistance.



Source: Subcommittee on Gas Safety 21 (deliberation in writing from March 11 – 18, 2020)

Number of problems caused by recent earthquakes

	Great East Japan Earthquake	Kumamoto earthquake	Northern Osaka Earthquake	Hokkaido Eastern Iburi Earthquake
date of occurrence	2011.3.11	2016.4.16	2018.6.18	2018.9.6
seismic scale	Intensity 7, M 9.0	Intensity 7, M 7.3	Intensity 6 lower, M 6.1	Intensity 6 upper, M 6.7
stoppage of supply number of houses	Approx. 460,000 units	Approx. 100,000 units	Approx. 110,000 units	No Supply Stop
recovery period	54 days	15 days	7 days	-

toughness of the gas pipeline

○ High seismic resistance of high and medium pressure gas conduits has been confirmed.

- At the time of the Great Hanshin-Awaji Earthquake, a medium-pressure gas pipeline attached to a bridge was deformed when the bridge fell. No gas leakage occurred.
- During the Great East Japan Earthquake, there was no damage to high-pressure gas conduits.

(Source: Tokyo Gas website)

○ Efforts to improve the earthquake resistance of low-pressure gas pipelines are ongoing (Earthquake resistance rate: approximately 90%).

Further strengthening of earthquake countermeasures

○ **facility measures**
- Continued improvement of earthquake resistance of low-pressure gas pipelines (earthquake resistance rate: approximately 90%)

○ **emergency measures**
- Application of new emergency stop criteria (uniform setting → block setting)
- Refinement of the supply stop block

○ **recovery measures**
- Strengthening cooperation among business operators concerning acceptance of support (Preparation of manuals and implementation of exercises)
- Strengthening information dissemination (Visualization of restoration progress and utilization of SNS), etc.

Source: Material 1 of the 41 session of the Strategic Policy Committee on April 22, 2021

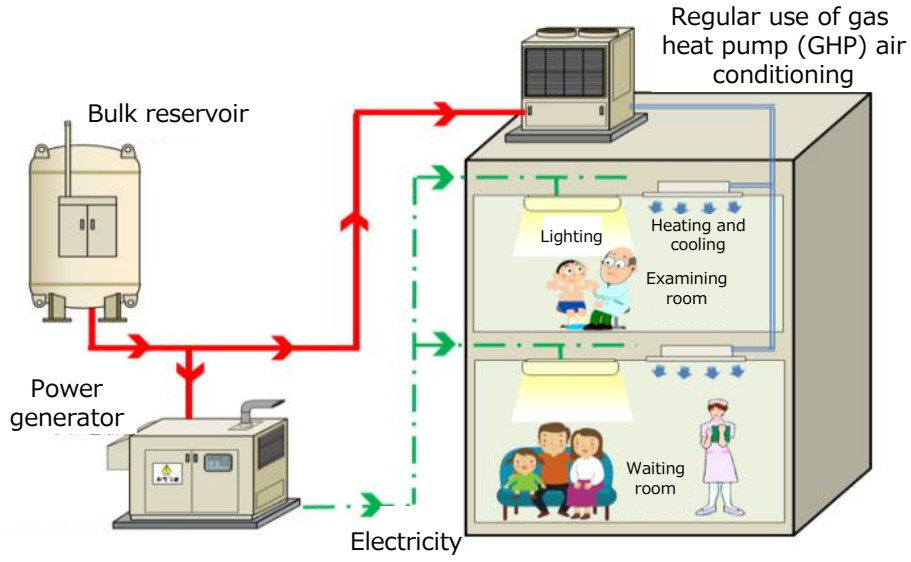
2. Overview of Gas Industry (Common) | (Reference) Resilience of LP Gas

- Because LP gas is excellent in portability and does not deteriorate, it is being used in evacuation centers and medical and social welfare facilities as a backup fuel in times of disaster.
- Considering these circumstances, it is important to utilize not only electricity but also LP gas at socially important facilities to prepare for power outages.

Use of LP Gas in the Eastern Iburi Earthquake in Hokkaido

- ✓ Although the kitchen was all-electric, meals could be provided to the residents by cooking with LP gas. (Nursing home: Obihiro City)
- ✓ A generator, a rice cooker, a microwave oven, and an induction heating cooker were used to provide meals to residents. (Nursing home: Sapporo City)
- ✓ GHP works without any problems and air conditioning can be operated, ensuring the safety of residents. (Facility for Persons with Disabilities: Sapporo City)

Examples of use in hospitals, etc.

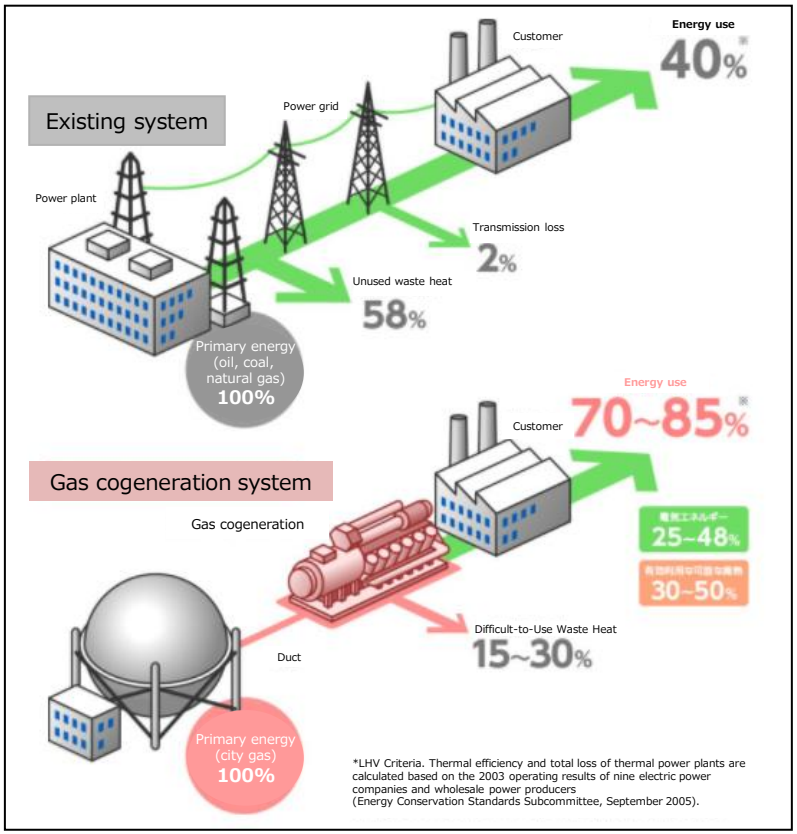


Source: Material 2 of the 36 session of the Strategic Policy Committee on January 27, 2021

2. Overview of Gas Industry (Common) | Effective Heat Utilization/Gas Cogeneration System

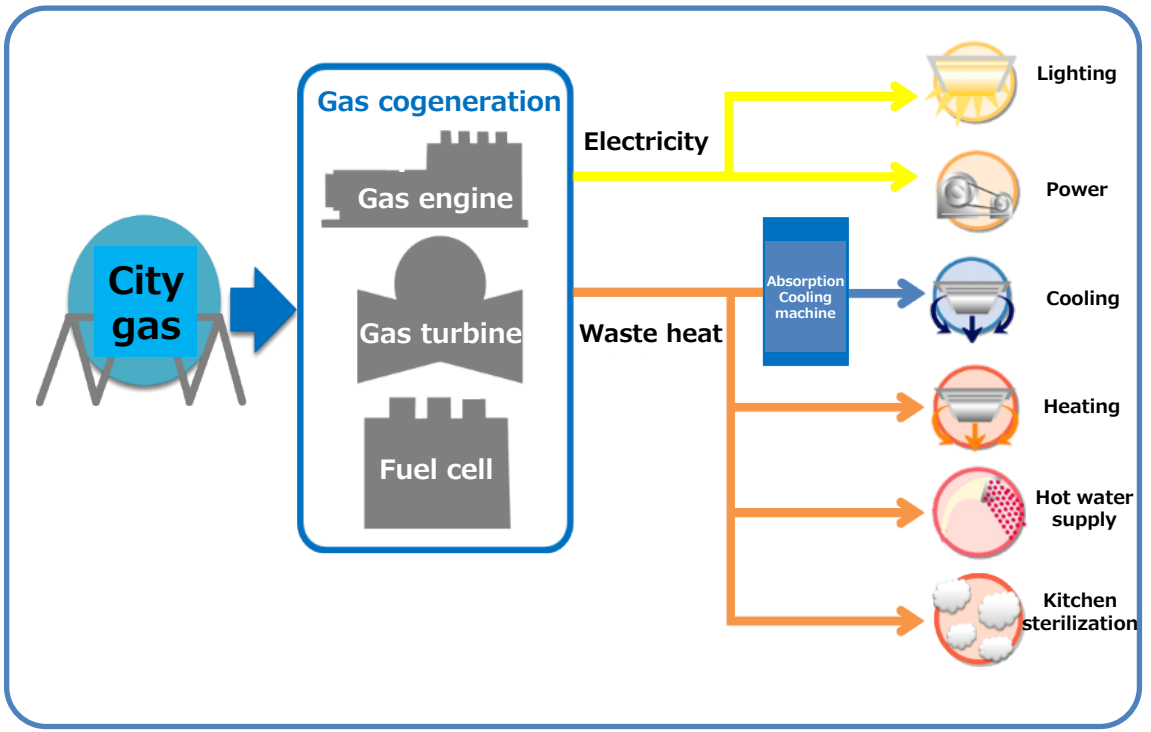
- **Because gas is converted to heat in the area of demand, energy efficiency is higher than when heat is produced by electricity.**
- The use of **gas cogeneration systems** * is expected to spread as a **regional distributed energy system that contributes to strengthening resilience and energy conservation** because it **uses gas** and **can continuously and stably supply electricity and heat**. *A highly efficient energy system that generates electricity using gas and uses the waste heat generated in this process for air conditioning, hot water supply, and steam.

Comparison of energy efficiency



Source: Japan Gas Association website

Gas cogeneration system



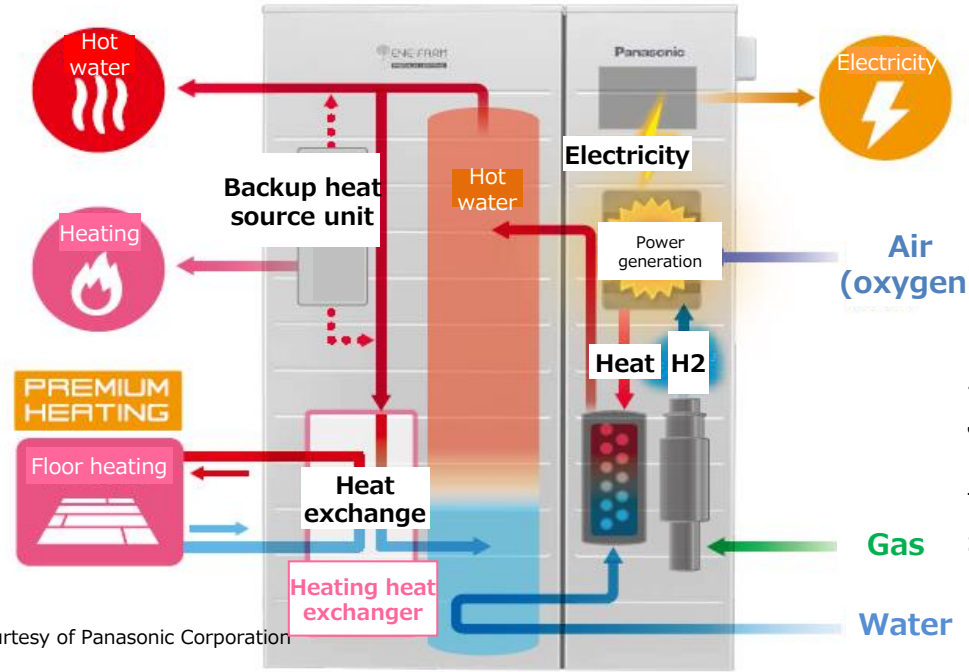
Source: April 5, 2021 Interim report of the Study Group on Gas Business toward 2050

2. Overview of Gas Industry (Common) | Dissemination of gas appliances that contribute to energy conservation

- From the viewpoint of promoting energy saving in gas appliances, the spread of high-efficiency water heaters "EcoJaws" and home fuel cells "EneFarm", which are highly energy efficient appliances, is being promoted.
- With the introduction of EneFarm, **38% reduction in CO2 emissions is possible** and the amount of CO2 that can be reduced in 1 year is 1,330 kg. This is equivalent to the CO2 absorbed by 2,460 m2 of forest.

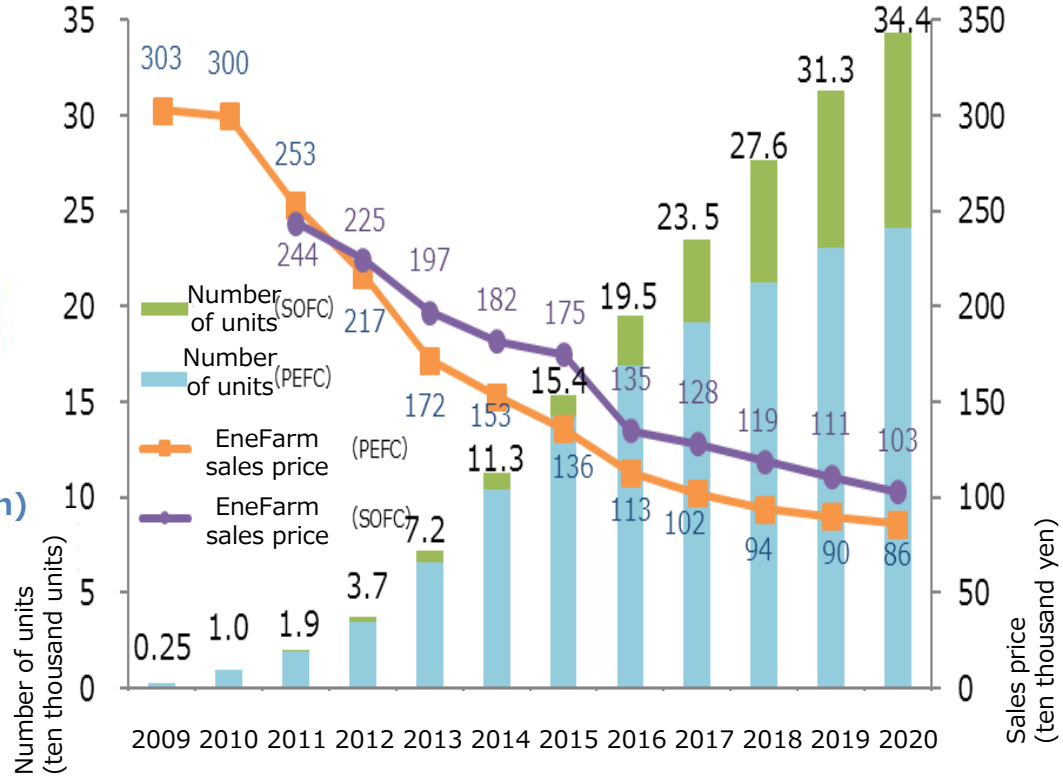
Features of EneFarm Home Fuel Cell

The residential fuel cell Ene-Farm is **a cogeneration system that** takes **hydrogen from LP gas and city gas** and conducts a **chemical reaction with oxygen** in the air to **generate electricity** and simultaneously **uses waste heat to supply hot water.**
Ene-Farm power generation **covers approximately 70% of the electricity used by households,** contributing to a reduction in the amount of grid electricity purchased and a reduction in peak demand.



Courtesy of Panasonic Corporation

Number of units and sales price

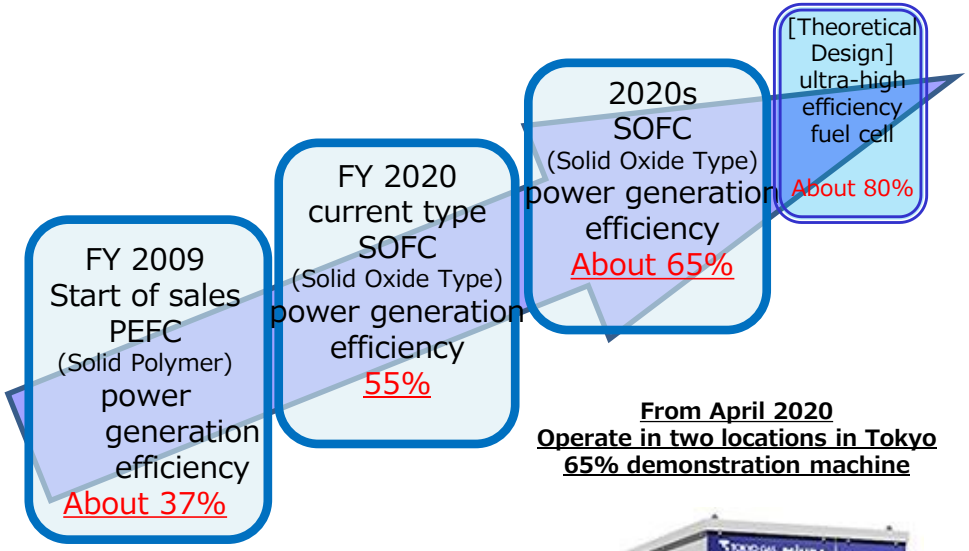


*SOFC (solid oxide type): Designed to be installed in customers with high power generation efficiency and low heat demand.
PEFC (solid polymer type): Designed for high exhaust heat collection efficiency and relatively easy startup and shutdown.

2. Overview of Gas Industry (Common) | (Reference) Development and expansion of high-efficiency gas cogeneration

- The introduction of a **highly efficient gas cogeneration system** will not only contribute to **reducing carbon emissions during the transition period,** but will also contribute to **resilience and renewable energy coordination.**

Transition of fuel cell power generation efficiency



From April 2020
Operate in two locations in Tokyo
65% demonstration machine

Source: Tokyo Gas and Osaka Gas website
*Power generation efficiency is based on LHV s

Development of high-efficiency gas engines

The SGP M 450, jointly developed by Mitsubishi Heavy Industries Engine & Turbocharger Co., Ltd. and Toho Gas Co., Ltd., is characterized not only by its high power generation efficiency but also by its short start-up and shutdown times. Startup time is 40 seconds, stopping time is as short as 3 minutes including cooling time, and performance as BOS adjustment force is high.

■Performance
Power generation output: 450 kW
Power generation efficiency: 42%
Overall efficiency: 81.5%

■Awards received
2016 Agency of Natural Resources and Energy Director-General's Award for Outstanding Energy-Saving Equipment;
2015 Cogeneration Award Special Award;
2018 Japan Gas Association Technology Award

SGP M 450 Source: Toho Gas Co., Ltd. Website

Source: April 5, 2021 Interim report of the Study Group on Gas Business toward 2050

2. Overview of Gas Industry (Common) | Distributed Energy System

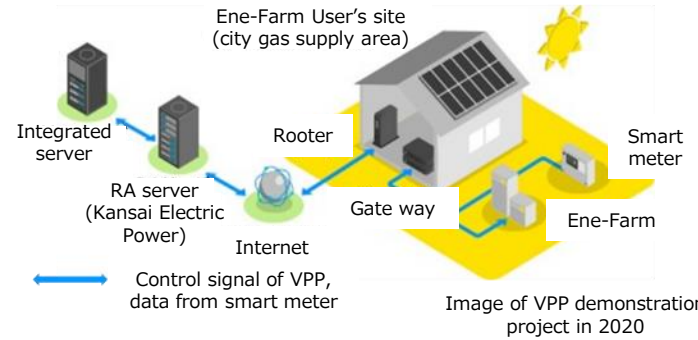
- **Distributed energy systems utilizing renewables, gas cogeneration systems, and digital technologies such as VPP*** can contribute to **stabilizing energy supply, enhancing energy resilience,** and **backing up intermittent renewables.**
- In the future, surplus renewable electricity could be utilized to produce hydrogen and synthetic methane, which could result in **"storage" and utilization of electricity**.

* Virtual Power Plant can work as a real power plant by controlling (including reverse power flow from) demand-side energy resources, power generation facilities directly connected to the grid, and power storage facilities, which are implemented by the owners or third parties.

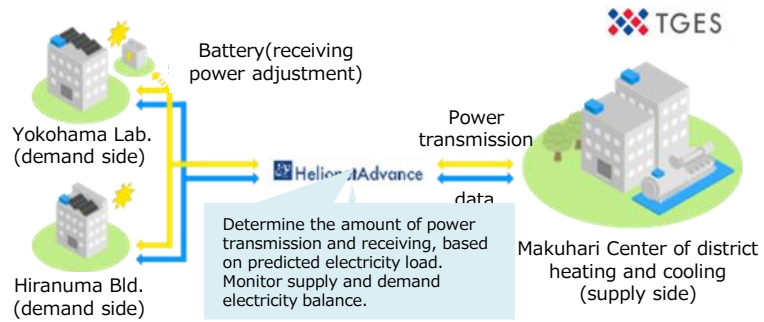
< Initiatives by Tokyo Gas >

VPP demonstration in the residential and commercial sectors

(Residential) EneFarm adjusts output fluctuations of PV



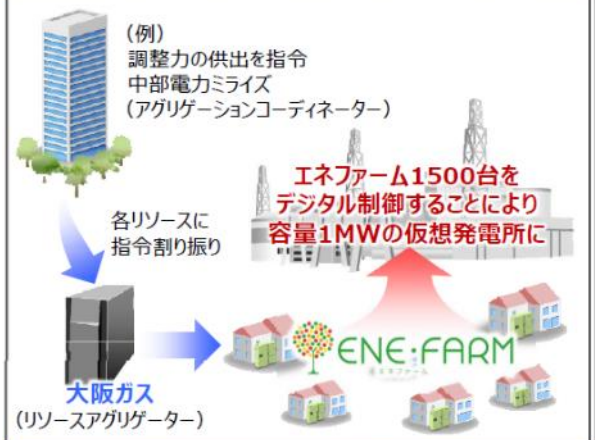
(Commercial) Integrated control of PV, batteries and cogeneration at multiple sites



Source: Report 8 of the Study Group on Gas Business toward 2050, Part 2, October 6, 2020

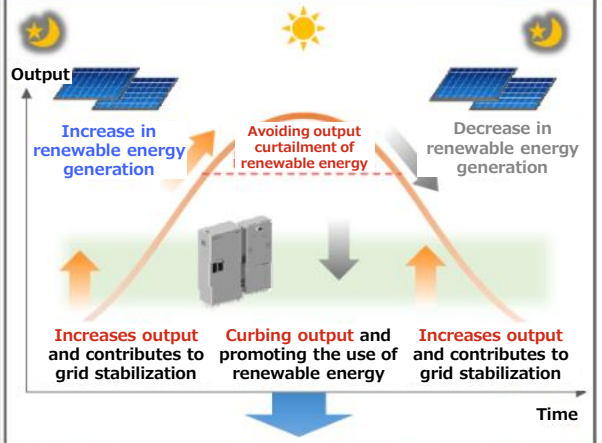
< Initiatives by Osaka Gas >

Demonstration 1
Regulating power delivery technology for grid stabilization



- Accumulates real-time data for each resource and predicts in advance the amount of adjustable capacity to be provided on the following day.
- Assumes future participation in **the balancing market**

Demonstration 2
Control technology based on the supply-demand situation of the grid



- **Aiming to stabilize the grid and improve economic efficiency** by controlling the ENE-FARM in accordance with the grid's supply and demand situation for renewable energy (≒market price situation).

Source: October 6, 2020 2nd Study Group on Gas Business toward 2050 Materials 9

Source: April 5, 2021 Interim report of the Study Group on Gas Business toward 2050

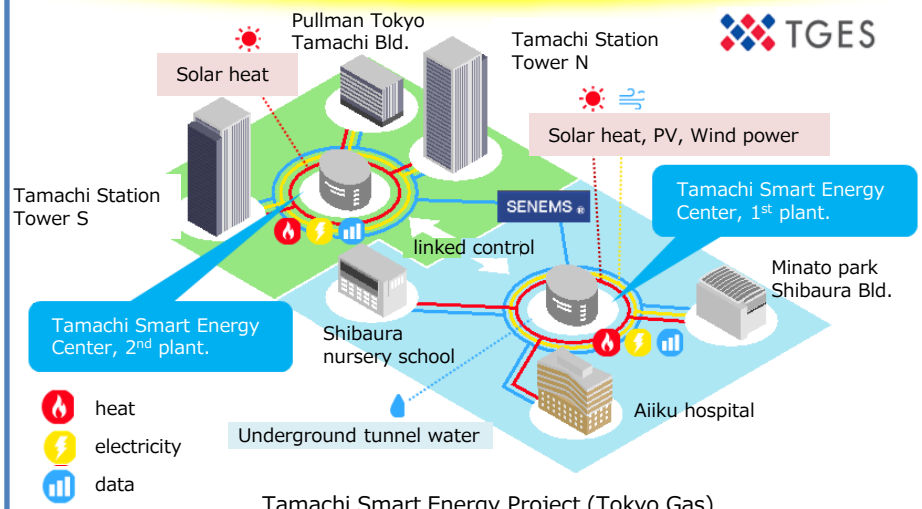
2. Overview of Gas Industry (City Gas) | (Reference) Smart Energy Network

- **Smart Energy Network** is a system that combines **renewable energy and gas cogeneration** and **optimally controls it by digital technology** to realize energy saving and reduction of CO2 by utilizing electricity and heat.

Smart Energy Network Initiatives in Urban Areas

- By using digital technology, the optimization of energy system is considered through data collection and analyses not only electricity demand but also heat loads on the demand side (digitization of heat).
- By linking information such as electricity, heat, and human flow data from two energy centers, the community as a whole can flexibly operate cogeneration, chillers, and heaters; take in renewable energy; and contribute to urban development by realizing energy efficiency improvements and CO2 emission reduction.

Two cogeneration-based energy centers work together to optimize power and heat



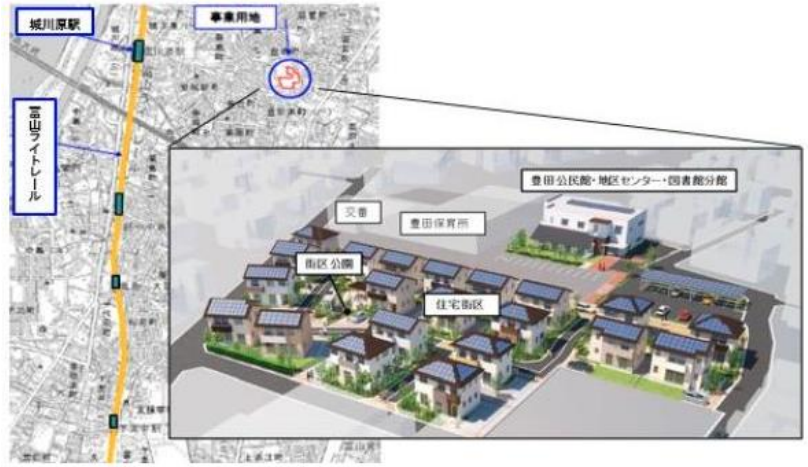
Tamachi Smart Energy Project (Tokyo Gas)

Source: October 6, 2020 2nd Study Group on Gas Business toward 2050 Tokyo Gas Explanatory Materials Processed

Smart Energy Network Initiatives by Local Gas Utilities

- Local gas companies also work with local governments and related companies to develop model blocks that are environmentally friendly, safe, secure, and comfortable.
- In the future, by taking advantage of the strengths of community-based businesses and looking ahead to solving problems such as population decline, the companies try to expand the use of the system in conjunction with the Compact City Policy.

Contribute to the development of low-carbon communities by optimizing energy use



Development of Safe and Environmental Smart Model Block (Nihonkai Gas Co., Ltd.)

Source: Toyama City website

Source: April 5, 2021 Interim report of the Study Group on Gas Business toward 2050

2. Overview of Gas Industry (Common) | Direct Use of Hydrogen (Examples of Hydrogen Supply)

- **Efforts to supply electricity and heat using hydrogen in some regions** are being promoted.
- In the future, it is possible to contribute to decarbonization of the civilian sector by **supplying hydrogen in areas where hydrogen pipelines have been constructed.**

Demonstration project in Port Island, Kobe

- The hydrogen cogeneration system is the first in the world to supply electricity and heat to nearby public facilities using hydrogen-only power generation in urban areas (from April 2018).

Source: Report 6 of the Study Group on Gas Business toward 2050 (explanatory material of Kawasaki Heavy Industries, Ltd.), Part 2, October 6, 2020

Supply to Tokyo Olympic Village District

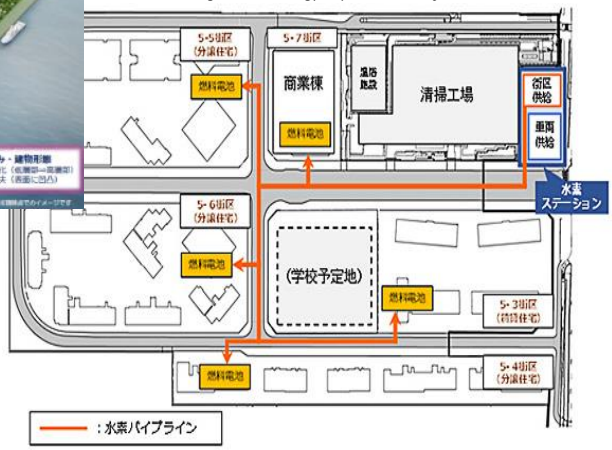
- A hydrogen pipeline will be constructed at the planned site of the Olympic Village after the Tokyo 2020 Games.
- Pure hydrogen fuel cells will be installed in residential buildings and commercial buildings in each block to generate electricity from hydrogen.

< Olympic Village after the Tokyo 2020 Games >

*Excerpt from Tokyo Metropolitan Government's "Development Plan for Community Development in Olympic Village after the Tokyo 2020 Games"

< Construction of hydrogen pipeline (planned) >

*Excerpt from Tokyo Metropolitan Government's "Athlete Village District Energy Improvement Project"



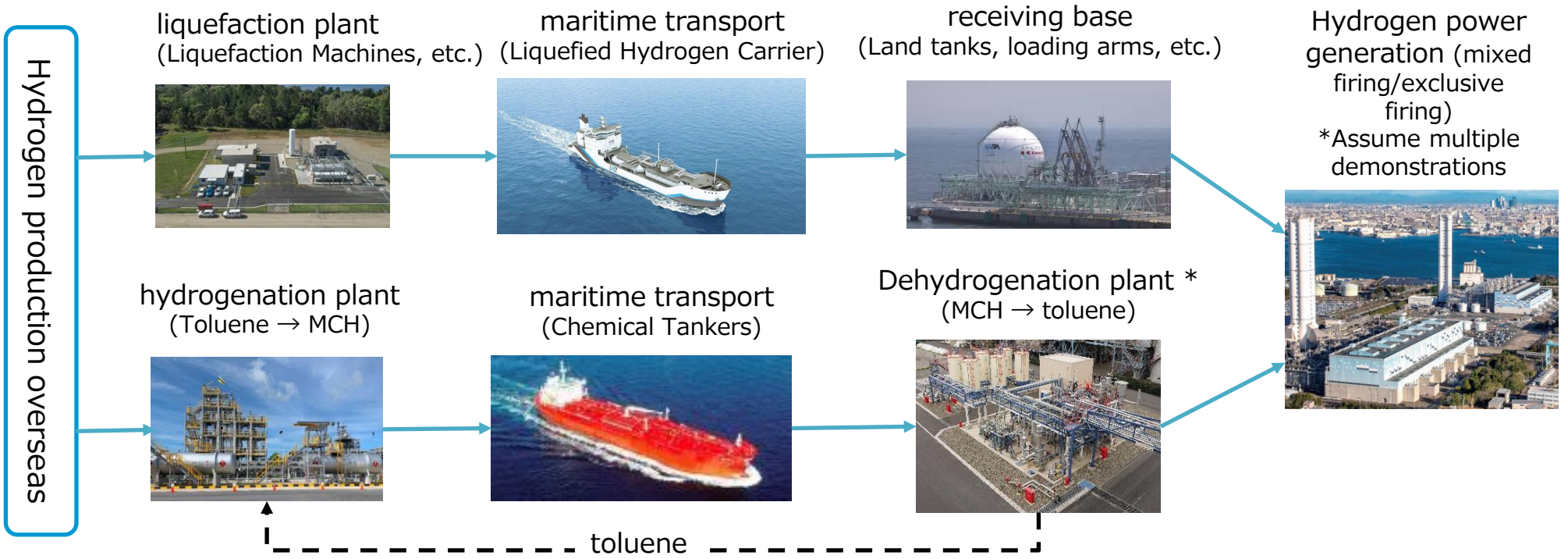
Source: October 6, 2020 2nd Study Group on Gas Business toward 2050 Materials 8 (explanatory materials of Tokyo Gas Co., Ltd.)

Source: Material 1 of the 41 session of the Strategic Policy Committee on April 22, 2021

2. Overview of Gas Industry (Common) | (Reference) GI Fund Business: Construction of a large-scale hydrogen supply chain (Amount of national expenditure: 300 billion yen maximum)

- 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 ramp up** in the future, Japan **leads the world in technology** by building a liquefied hydrogen carrier ahead of other countries. **Thus, Japan is ahead in hydrogen power generation technology,** which is expected to attract large-scale demand.
- Therefore, in addition to **(1) supporting technology development and large-scale hydrogen transportation demonstration such as the enlargement of transportation facilities** with multiple hydrogen carriers (Liquefied hydrogen, MCH), **(2) the demonstration of hydrogen combustion stability in actual hydrogen power generation** will be promoted in an integrated manner, and the **formation of a virtuous cycle to create large-scale demand for hydrogen and reduce supply costs** will be promoted, aiming at **supply costs of 30 yen/Nm3 in 2030 and 20 yen/Nm3 or less in 2050 (equivalent to fossil fuels)**.

Large hydrogen supply chain (image) of liquefied hydrogen, methylcyclohexane (MCH)



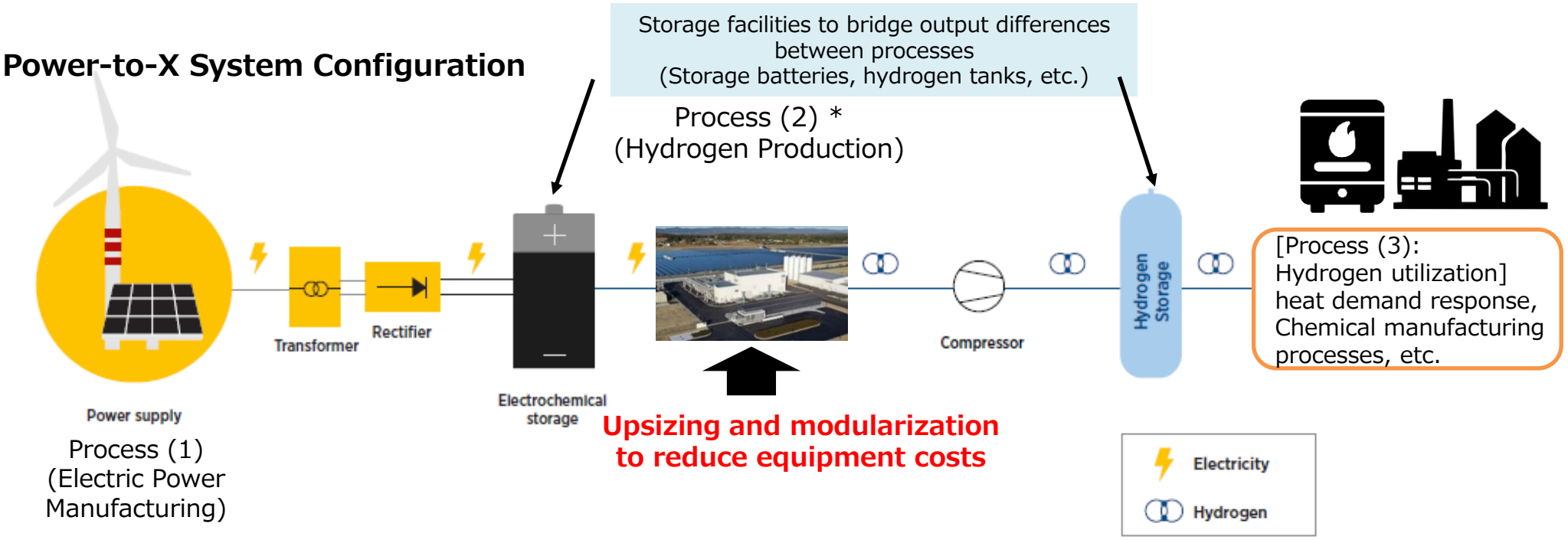
*Expected to make maximum use of existing facilities such as refineries

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

2. Overview of Gas Industry (Common) | (Reference) GI Fund Business: Hydrogen production by water electrolysis using electric power derived from renewable energy, etc. (Amount of national expenditure: 70 billion yen maximum)

- Although Japan has one of the world's largest water electrolysis facilities in Fukushima, **European companies are leading the development**. **Europe and other countries, where renewable energy is cheap, take the lead.**
- Aiming to **establish a domestic hydrogen production base** utilizing surplus renewable energy, etc., and to **acquire an overseas water electrolysis market**, the government strongly supports **enlargement and modularization, mounting of excellent elemental technologies such as membranes, demonstration of Power-to-X system integrated with hydrogen utilization**, etc. of multiple types of water electrolysis equipment (Alkaline type, PEM type), and **aims to further reduce equipment costs (up to 1/6 of the present cost)**.

Power-to-X System Configuration



In conjunction with the development of water electrolysis equipment, the project plans to demonstrate the optimization of the entire system for decarbonization in the non-electric power sector using renewable energy power sources by combining heat related equipment such as boilers and basic chemical manufacturing processes.

*Photo shows Fukushima Hydrogen Energy Research Field (image)

2. Overview of Gas Industry (Common) | Biogas

- **Biogas is fuel gas derived from biomass and is generated by methane fermentation of sludge, sewage, waste, livestock, and energy crops.**
- **Biogas has high affinity with city gas,** and **to contribute to the decarbonization of gas energy by utilizing local resources**, efforts for biogas supply are being advanced in the region.

Types of biomass

Waste biomass

- Sewage sludge
- Food waste (kitchen garbage, food processing waste, etc.)
- Wood waste (wood waste from lumber mills, house demolition sites, etc.)
- Used paper
- Black liquor (pulp waste)
- Livestock waste

Unused biomass

- Forest residues (e.g., trees left on forest land after thinning)
- Agricultural crops (rice straw, rice husks, wheat straw, etc.)
- Pruned branches (roadside trees, fruit trees, etc.)

Resource crops

- Carbohydrate resources (sugarcane, sugar beet, etc.)
- Starch resources (rice, potatoes, corn, etc.)
- Oil resources (rapeseed, soybeans, peanuts, etc.)

Source: Japan Gas Association website

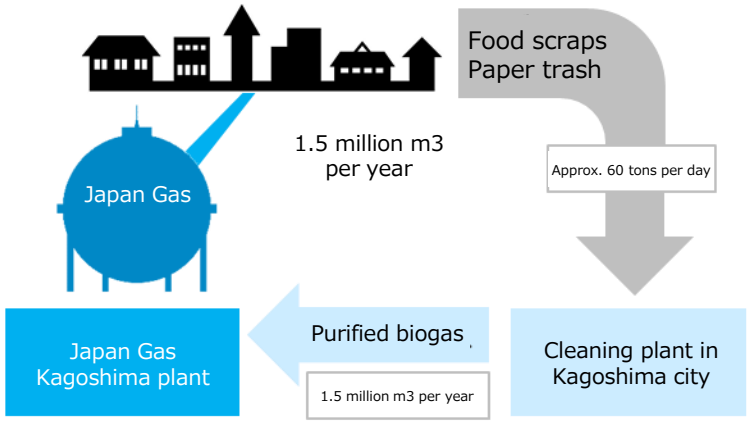
Use of biogas (example)

power generation

Gas

automobile

Examples of Biogas Utilization (Japan Gas Co., Ltd., Kagoshima City)



Project period: 2022/1-2042/3 (20 years)
Volume of gas received: 1.5 million m3 per year (equivalent to approx. 6.5% of residential demand)
Business characteristics: Biogas generated from household waste at Kagoshima city's waste incineration plant will be used as a raw material for city gas in the area, thereby realizing **decarbonization of gaseous energy and local consumption of decarbonized energy**.

Source: Report 10 of the Study Group on Gas Business toward 2050, Part 5, January 28, 2021

2. Overview of Gas Industry (Common) | CCUS/Carbon Recycling

- **Carbon recycling reduces CO2 emissions into the atmosphere** by using CO2 as a resource for fuel and other purposes and **it is important technology for realizing a carbon-neutral society**.
- Developments for the establishment of **CO2 separation and capture technology** and for **utilization of CO2 in exhaust gas from city gas equipment at the customer's site as a resource** (Concrete products, carbonates, carbonated beverages, etc.) are in progress.

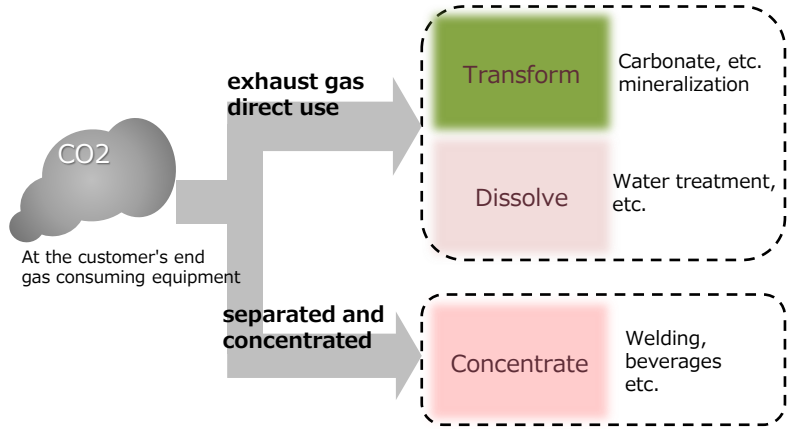
Demonstration of CO2 separation and capture technology (NEDO demonstration)

・Toward decarbonization in the future, Toho Gas participates in several NEDO projects by utilizing seeds possessed by universities and others and technological knowledge possessed by Toho Gas, such as the utilization of cold heat, as CO2 separation and capture technology can be key technologies.

Project Name	joint implementer
Utilization of LNG Unutilized Cold Heat in Absorptive CO2 Separation and Capture	Nagoya University
Development of Capture Technology for CO2 in Combustion Gas from Unutilized Cold Heat	Nagoya University
Research and Development of Direct Capture for Atmospheric Carbon Dioxide Using Cold Heat	Nagoya University Tokyo University of Science

CCUS at the customer site

・Tokyo Gas accelerate technology development and commercialization of the service to capture and utilize CO2 emitted at the customer site.
・Through joint demonstration with customers, Tokyo gas aims to commercialize the service in fiscal 2023.



Source: February 24, 2021 6th Study Group on Gas Business for 2050 Explanatory Materials of Japan Gas Association

Source: Material 1 of the 41 session of the Basic Policy Subcommittee on April 22, 2021

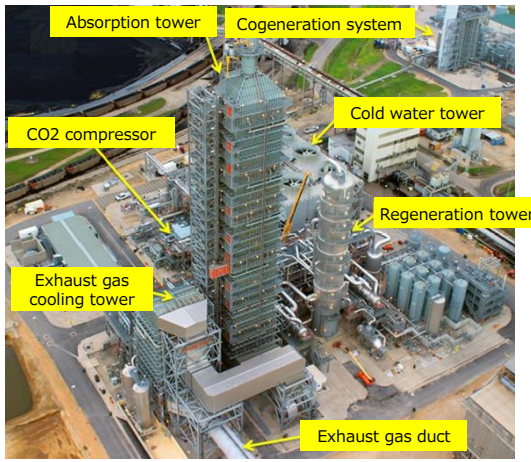
2. Overview of Gas Industry (Common) | (Reference) CO2 Separation collection Technology Scenario

2020 → 2030 → 2040 → 2050

coal-fired power plant

12 ~ 14% CO_2

commercial application of the amine absorption method

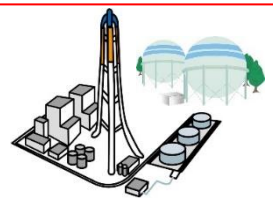


Mitsubishi Heavy Industries Engineering Petra Nova

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

Source: Mitsubishi Heavy Industries Technical Review Vol. 55

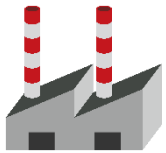
Natural gas thermal power plant



4 ~ 5% CO2

*Case of Natural Gas Combined Cycle Thermal Power Generation (NGCC)

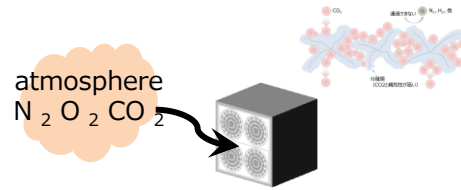
small and medium-sized factories



7 ~ 9% CO2

*Case of industrial furnace using Combustible gas derived from Naphtha as fuel

DAC



Atmospheric 0.04% CO2

Green Innovation Fund Project

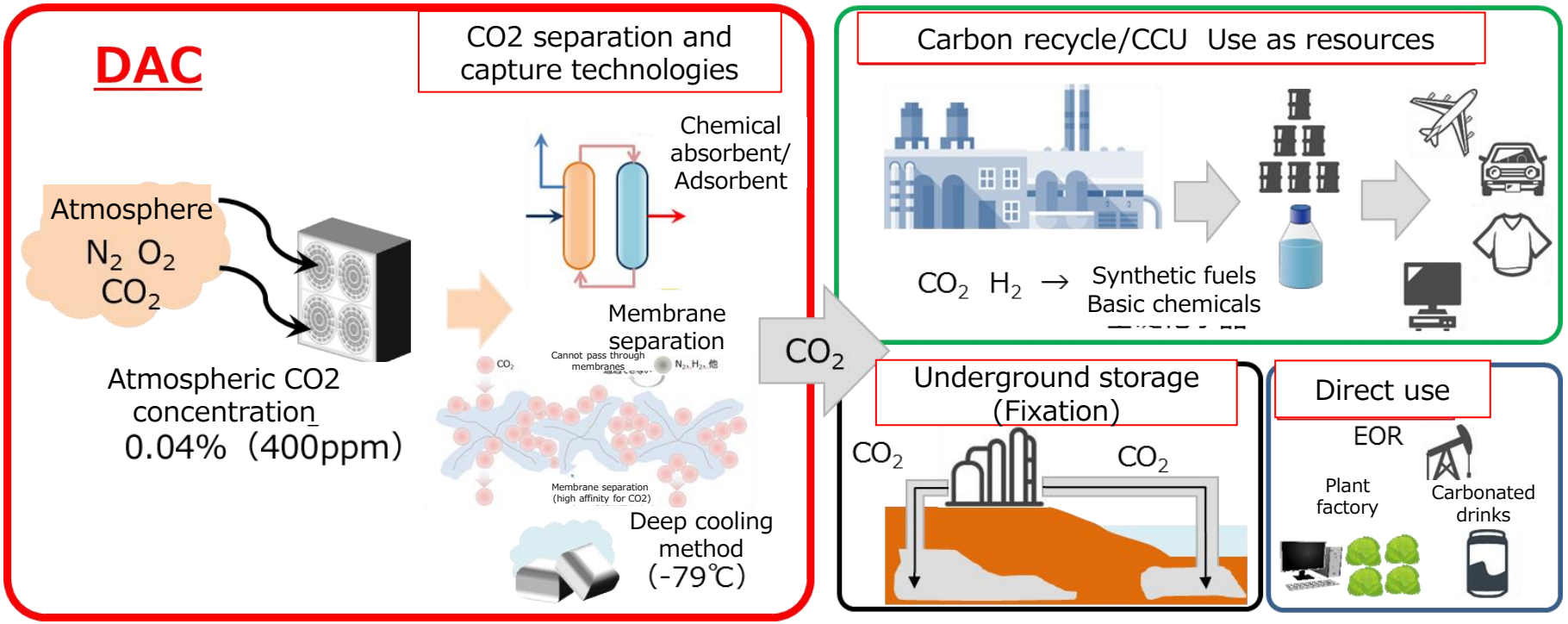
NEDO project (Moonshot R & D)

Scale classification	Source (e.g.)		Requirements required for exhaust gas treatment	Technology selection (example)
① large scale	Natural gas thermal power plant		massive exhaust gas treatment	amine absorption method
② small to medium scale	factory	boiler	Miniaturization and use of waste heat	Physical adsorption method, membrane separation method, combination method, etc.
	chemical plant	naphtha cracking furnace	Dealing with water content	
	Gas plant; materials industry	Gas engine, cogeneration	Response to load fluctuations and use of cold heat	
	materials industry	Heating treatment furnace	Measures against NOx and other contaminants	

Source: 2021 December 23, Compiled by Agency for Natural Resources and Energy from Document 3 of the Working Group on Energy Structure Conversion, Green Innovation Project Subcommittee, 8th Industrial Structure Council.

2. Overview of Gas Industry (Common) | (Reference) DAC (Direct Air Capture)

- **DAC** (Direct Air Capture) are technologies that **directly separate and collect atmospheric CO2.**
- Since the concentration of CO2 in the atmosphere is approximately 1/100 of that in the exhaust gas from natural gas, this CO2 separation and collection technology is difficult to be applied. Therefore, it is necessary to develop the technology to reduce the energy cost required for separation and collection, and this is being carried out by the NEDO project (Moonshot Research and Development Project).



Source: 2021 September 13, Source: Material 7 of Working Group on Energy Structure Conversion, Green Innovation Project Subcommittee, 6th Industrial Structure Council

2. Overview of Gas Industry (City Gas) | Carbon/GHG offset LNG

- Various gas companies have introduced **Carbon/GHG offset LNG*** as an effort to offset GHG which are generated in the process, from extraction to the burning of natural gas.
- To meet the needs of consumers, some gas companies have begun selling city gas as a Carbon/GHG-offset.

*While trading carbon reduction value through credits can contribute to the efficient reduction of greenhouse gases toward carbon neutrality throughout the world, it is necessary to pay attention to the various methodologies and characteristics of credits, and discussions are being held in Japan and overseas on how to utilize them and promote their value.

Gas companies working to introduce

Atsugi Gas	Shikoku Gas	Tomakomai Gas
Izumo Gas	Shizuoka Gas	Toyooka Energy
Iruma gas	Shibata Gas	Nabari Kintetsu Gas
Echigo Natural Gas	Joetsu City Gas and Water Bureau	Nihonkai Gas
Ome Gas	Shirane gas	Noda Gas
Osaka Gas	Shingu Gas	Hiroshima Gas
Okayama Gas	Seibu Gas	Biwako Blue Energy
Ojiya City Gas and Water Bureau	Daito Gas	Buyo Gas
Obihiro gas	Daiwa Gas	Bushu Gas
Kamahara Gas	Takaoka Gas	Hokkaido Gas
Kiryu gas	Tokai Gas	Horikawa Sangyou
Keiyo Gas	Tokyo Gas	Honjo Gas
Saitama Gas	Toho Gas	Matsue City Gas Bureau
Saibu Gas	Tottori Gas	

Source: Compiled by the Agency for Natural Resources and Energy based on information published as of January 21, 2021

Example of customer adoption

Marunouchi Building **Otemachi Park Building**

Carbon neutral city gas is used for all city gas used in the SOFC of Marunouchi Building and gas cogeneration of Otemachi Park Building, contributing to a significant reduction in CO2 emissions during electricity use. (Supply started in March 2020)

Tamagawa Gakuen

The entire amount of city gas used in the university was switched to carbon neutral city gas, **contributing to a total reduction of about 7,000 tons of CO2.** (Supply started on February 2, 2021)

Central Research Institute, Yakult Honsha Co., Ltd.

The total amount of city gas supplied to Yakult Honsha Central Research Laboratory was switched to carbon neutral city gas, **contributing to a CO2 reduction of about 11,500 tons.** This is the first time that Tokyo Gas will supply carbon-neutral city gas to the beverage industry. (Supply started on April 1, 2021)

Source: Material 1 of the 41 session of the Strategic Policy Committee on April 22, 2021

- According to the July 2021 IEA Report, at least 15 Carbon/GHG-offset LNG cargoes were delivered in about 1 year since July 2019, of which 12 were destined for Asia. In Europe, two cases were in Britain.
- The IEA assessed that high transparency and a standardized MRV framework would be beneficial for LNG use mechanisms that offset GHG emissions with credits.

Keep counting: Carbon/GHG-offset LNG continues to gain traction

Date	Seller	Buyer	Source	Destination	Volume	Offset scope	Mechanism
July 2019	Shell	Tokyo Gas	QCLNG Australia	Japan	1 cargo	CO_2 well-to-wheel	Shell project portfolio
July 2019	Shell	GS Energy	QCLNG Australia	Korea	1 cargo	CO_2 well-to-wheel	Shell project portfolio
July 2019	JERA	-	Das Island UAE	India	1 cargo	CO_2 end-use combustion	CER
March 2020	Shell	CPC	Sakhalin Russia	Yung-An Taiwan	1 cargo	CO_2 well-to-wheel	Shell project portfolio
June 2020 (announced)	Shell	CNOOC	-	China	2 cargoes	CO_{2eq} well-to-wheel	Shell project portfolio
October 2020	Total	CNOOC	Ichthys Australia	Dapeng China	1 cargo	CO_2 well-to-wheel	VCS
November 2020	Shell	CPC	Bonny Island Nigeria	Yung-An Taiwan	1 cargo	CO_{2eq} well-to-wheel	Shell project portfolio
March 2021	Mitsui	Hokkaido Gas	Sakhalin-II Russia	Ishikari Japan	1 cargo	CO_2 well-to-wheel	Mitsui portfolio
March 2021	Gazprom	Shell	YAMAL LNG Russia	Dragon United Kingdom	1 cargo	GHG well-to-wheel	VCS
March 2021	RWE	Posco	Pluto LNG Australia	Gwangyang Korea	1 cargo	CO_2 well-to-tank	VER
April 2021	Diamond Gas	Toho Gas	Cameron LNG United States	Chita Japan	1 cargo	-	Carbon credits
April 2021		Pavilion Energy	Corpus Christi United Stated	Jurong Singapore	1 cargo	CO_2 well-to-tank	VCS+CCB
April 2021	Cheniere	Shell	Sabine Pass United States	United Kingdom	1 cargo	GHG well-to-wheel	Shell project portfolio
June 2021	Oman LNG	Shell	Qalhat Oman	-	1 cargo	CO_2 well-to-wheel	Verified Nature-Based Carbon Credits

Notes: CER = Certified Emission Reduction; VCS = Verified Carbon Standard; VER = Verified Emission Reduction; CCB = Community and Biodiversity Standard.
Sources: IEA analysis based on companies' press releases and various news reports

Source: IEA Gas Market Report Q3 -2021

2. Overview of Gas Industry (Common) | (Reference) Fuel ammonia

- **Ammonia** does not emit CO2 when it is burned, so **it is one of the effective fuels for decarbonization.**
- Ammonia is considered as **one of the scenarios for ship fuel conversion,** and some gas companies are working on the **technology development of engines using ammonia as fuel.**

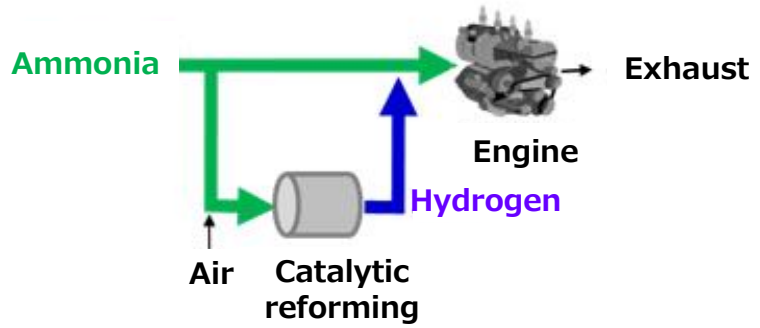
International Shipping Fuel Conversion Scenario Achieving IMO Greenhouse Gas Reduction Targets

	1. LNG to Carbon-Recycled Methane	2. Expansion of Hydrogen / Ammonia
Technical and operational improvements	• efficiency improvement over the fleet at least 40% by 2030 • efficiency improvement over the fleet at least 45% by 2030	
Use of petroleum fuel	• Supply for shipping sector gradually decreases by 2050 due to decreasing product volume in energy sector • Demands for new ships gradually decrease (zero by 2035), as LNG fuels increase	
LNG fuel	• Accounts for approx. 35% of energy consumed in international shipping in 2050	• Accounts for approx. 35% of energy consumed in international shipping in 2050
Carbon-recycled methane / Biomethane	• Accounts for approx. 40% of energy consumed in international shipping in 2050	• Accounts for approx. 7% of energy consumed in international shipping in 2050
Hydrogen / Ammonia	• Accounts for approx. 10% of energy consumed in international shipping in 2050	• Accounts for approx. 45% of energy consumed in international shipping in 2050
Onboard CO_2 capturing	• Installed in approx. 20% of LNG-fueled ships in 2050.	• Installed in approx. 5% of LNG-fueled ships in 2050.
Wind propulsion / Battery	• Introduced in approx. 2% of ships engaged in international shipping	

Source: Roadmap for Zero Emissions for International Shipping
(March 2020: International Shipping GHG 0 Emissions Project (jointly organized by the Ministry of Land, Infrastructure, Transport and Tourism Maritime Bureau and Japan Ship Research Association)

Technology Development and Demonstration of Ammonia-fueled Small Engine System

- Aiming to realize the world's first small engine system that can be used with ammonia-fueled non-consolidated by establishing elemental technologies for ammonia engines, demonstrating the performance of the engine system, and demonstrating the operation of the system using actual equipment. (FY 2021 to FY 2022)



Engine System Overview

Source: Osaka Gas website

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3. Technology pathways to Decarbonization | Concept of Roadmap Formulation (Gas Sector)

- To develop a technology roadmap that will contribute to the promotion of transition finance in the gas sector, the scope of the target technology is specified based on the following concepts.

- Most GHG are emitted from gas combustion. Therefore, **conversion from fossil fuel gas to decarbonized gas is necessary** in the long term.
  - The technical options for decarbonized gas are **synthetic methane, hydrogen, biogas, etc.** for city gas and **synthetic LP Gas** for LP Gas
  - In particular, it is important to develop technologies for the expansion of **synthetic methane, hydrogen, and synthetic LP gas.**
  - Research and development of **CCUS technology** is also important to produce synthetic methane and synthetic LP gas.
- However, technological development takes time, so it is important to reduce CO2 emissions by **switching to gas,** which emits less CO2 than other fossil fuels (As demand for gas increases, CO2 from city gas increases at the supply side, but contributes to the reduction of CO2 at the demand side ＊.).

  ※ In the Basic Guidelines on Climate Transition Finance, it is shown to be effective to use the concept of "contribution to reduction" as a method of evaluating these efforts.
  - In particular, it is difficult to electrify high-temperature heat demand in the industrial sector and marine transport. Therefore, the use of gas is important.
  - The gas cogeneration system contributes to the effective utilization of heat and decarbonization as flexible resources for renewable energy.
  - **In the future, gas will be decarbonized by changing gas raw material from fossil fuel to synthetic methane and synthetic LP gas**

Based on the above concept, the technical list and the draft roadmap were prepared with reference to the international outlook on technology introduction (IEA, etc.) and the outlook in our country (Green Growth Strategy, Strategic Energy Plan, Vision of Industry Organizations, etc.). (Starting on next page)

3. Technology pathways to Decarbonization |
①-1 Low-Carbon and Decarbonization Technologies for Carbon Neutrality: City Gas

	Technology	Overview	Emission Intensity *1	Implementation year #2	Main Reference *3
city gas / natural gas	Energy conservation in the city gas production process	✓ Energy-saving through use of cooling equipment	-	Already installed	• Low Carbon Society Action Plan
	Development of natural gas supply network	✓ Strengthening Supply Infrastructure for Expanding Use of Natural Gas	-	Already installed	• green growth strategy
	Fuel conversion	✓ Installation of facilities necessary for demand-side fuel conversion	-	Already installed	• green growth strategy
	Advanced use of natural gas	✓ Energy conservation through energy measurement and high-efficiency boilers	-	Already installed	• Basic Energy Plan • green growth strategy
	Distributed energy system	✓ Energy-saving through the spread of smart energy networks, cogeneration systems, fuel cells, etc.	-	Already installed	• Basic Energy Plan • green growth strategy
	Conversion of city gas raw material from natural gas to synthetic methane	✓ Conversion of city gas raw materials to synthetic methane to reduce CO2 emissions from city gas use to zero	Up to 100% reduction	2030s	• green growth strategy
synthetic methane	Methanation (Sabatier reaction)	✓ Synthesis of methane from hydrogen and CO2	Up to 100% reduction	2030s	• green growth strategy • IEA-ETP 2020
	Methanation (innovative technology)	✓ Innovative technology (co-electrolysis, etc.) for synthesizing methane more efficiently than methanation by Sabatier reaction	Up to 100% reduction	2040s	• green growth strategy • GI Fund - Social Implementation Plan *5 • IEA-ETP 2020
	Establishment of domestic and overseas supply chains	✓ Combined use of synthetic methane in existing infrastructure such as liquefaction stations, LNG carriers, receiving stations, and pipelines	-	2030s	• green growth strategy • IEA-ETP 2020

*1: Calculated from the CO2 reduction of the target technology based on the existing emission intensity. The CO2 reduction is only accounted for from the relevant process.
*2: Refers to the starting year of introduction and expansion/cost reduction phase in the Social Implementation Plan
*3: Underlined when referenced for Implementation Year.
*4: R&D and Social Implementation Plan in the Green Innovation Fund.

3. Technology pathways to Decarbonization |
①-2 Low-Carbon and Decarbonization Technologies for Carbon Neutrality:LP Gas

LP gas

	Technology	Overview	Emission Intensity *1	Implementation year #2	Main Reference *3
LP gas	Promotion of energy conservation and fuel conversion	✓ Widespread use of high-efficiency gas water heaters and household fuel cells, energy conservation at LPG import bases, etc., and widespread use of LPG boilers and LPG fueled vessels	-	Already installed	• Low Carbon Society Action Plan
LP gas	Streamline delivery	✓ Popularization of smart meters and centralized monitoring equipment	-	Already installed	• Resources and Fuel Subcommittee Materials
Green LP gas	Synthetic LP gas	✓ Production of LP Gas from CO and H2 by Indirect Synthesis via Methanol and DME	Up to 100% reduction	2030s	• green growth strategy

*1: Calculated from the CO2 reduction of the target technology based on the existing emission intensity. The CO2 reduction is only accounted for from the relevant process.
*2: Refers to the starting year of introduction and expansion/cost reduction phase in the Social Implementation Plan
*3: Underlined when referenced for Implementation Year.

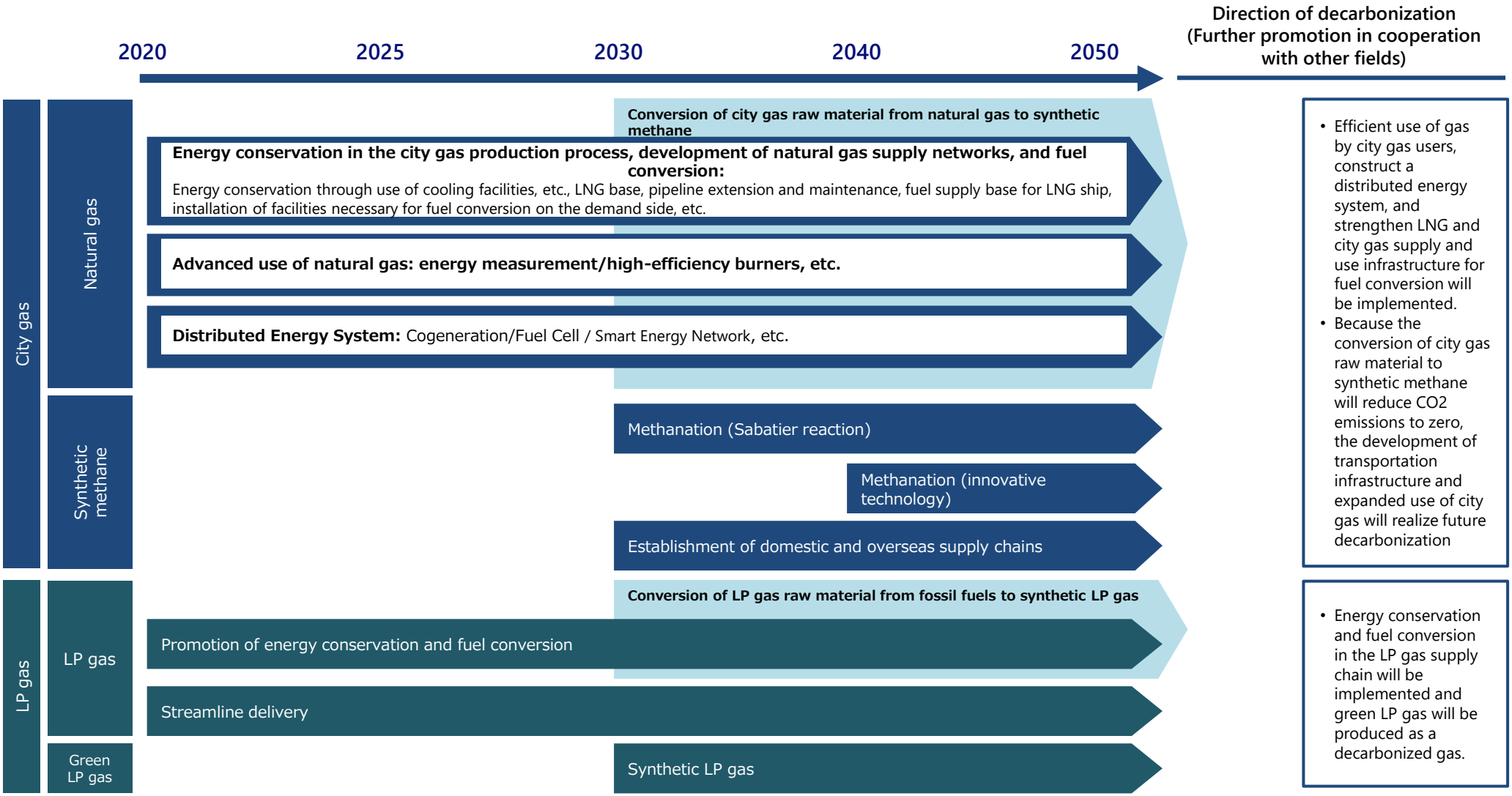
3. Technology pathways to Decarbonization |
①-3 Low-Carbon and Decarbonization Technologies for Carbon Neutrality: Common Technologies

common technology

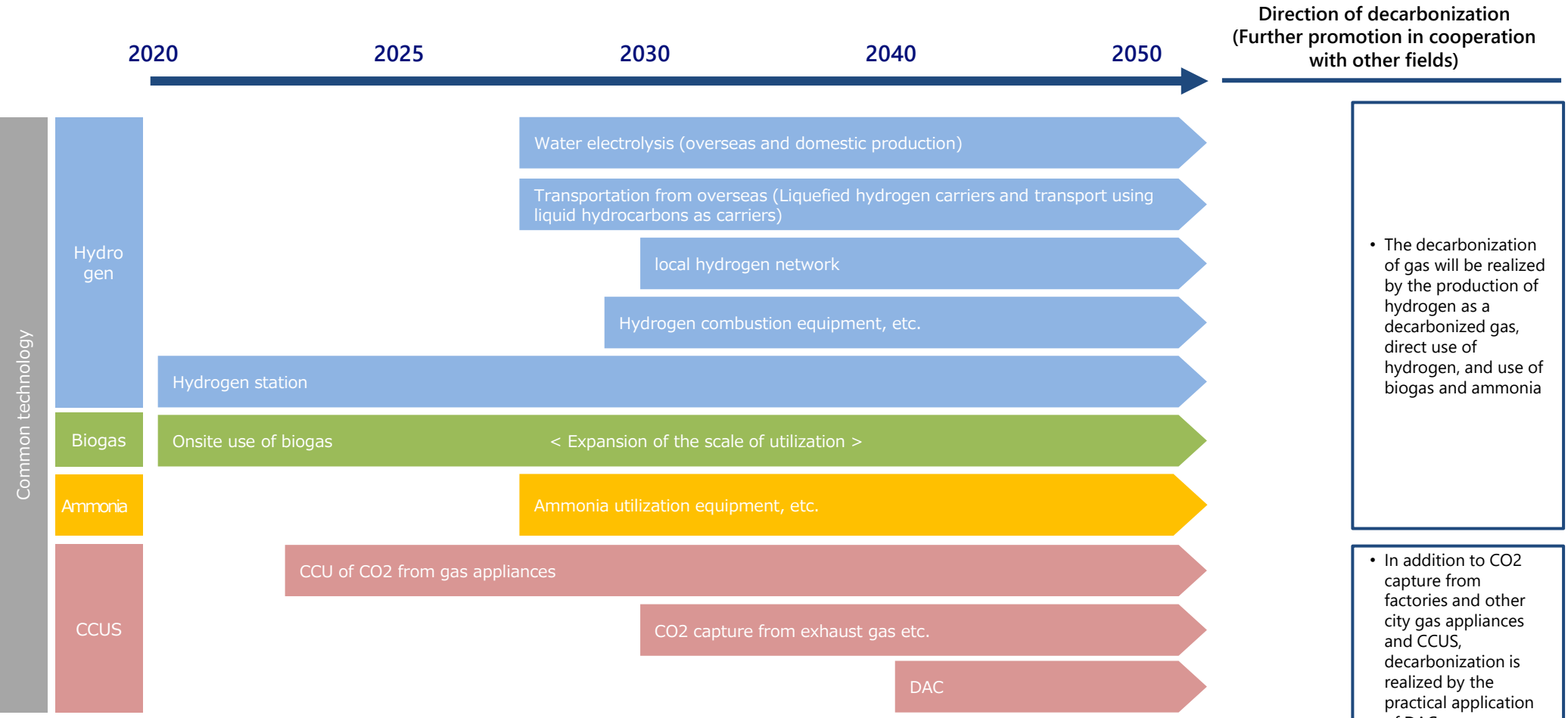
	Technology	Overview	Emission Intensity *1	Implementation year #2	Main Reference *3
Hydrogen	Water electrolysis (Overseas and domestic manufacturing)	✓ Production of hydrogen by electrolyzing water	Up to 100% reduction	Late 2020s	• green growth strategy • GI Fund - Social Implementation Plan *4 • IEA-ETP 2020
Hydrogen	Transportation from overseas (Liquefied hydrogen carriers and transport using liquid hydrocarbons as carriers)	✓ Liquefied hydrogen carrier and methylcyclohexane (MCH) carrier	-	Late 2020s	• green growth strategy • GI Fund - Social Implementation Plan • IEA-ETP 2020
Hydrogen	Local hydrogen network	✓ Development of domestic hydrogen supply network	-	2030s	• green growth strategy
Hydrogen	Hydrogen combustion equipment, etc.	✓ Use of hydrogen for industrial furnaces, cogeneration, fuel cells, etc.	Up to 100% reduction	Before 2030	• green growth strategy • IEA-ETP 2020
Hydrogen	Hydrogen station	✓ Social implementation of low-cost hydrogen production equipment from city gas	-	Already installed	• green growth strategy
Biogas	Biogas	✓ Utilization of gas derived from biomass fermentation	Up to 100% reduction	Already installed	• green growth strategy • IEA-ETP 2020
Ammonia	Ammonia	✓ On-site use of ammonia	Up to 100% reduction	Late 2020s	• green growth strategy • IEA-ETP 2020
CCUS	CO2 capture from exhaust gas etc.	✓ Capture and utilize CO2 emitted from city gas appliances	Up to 100% reduction	first half of the 2020s	• green growth strategy
CCUS	CO2 capture from exhaust gas etc.	✓ Capture, utilize, and store CO2 emitted from steel plants, power plants, chemical plants, etc.	Up to 100% reduction	2030s	• GI Fund - Social Implementation Plan • green growth strategy • IEA-ETP 2020
CCUS	DAC	✓ Direct CO2 capture from the atmosphere	Up to 100% reduction	2040s	• green growth strategy • IEA-ETP 2020

*1: Calculated from the CO2 reduction of the target technology based on the existing emission intensity. The CO2 reduction is only accounted for from the relevant process.
*2: Refers to the starting year of introduction and expansion/cost reduction phase in the Social Implementation Plan
*3: Underlined when referenced for Implementation Year.
*4: R&D and Social Implementation Plan in the Green Innovation Fund.

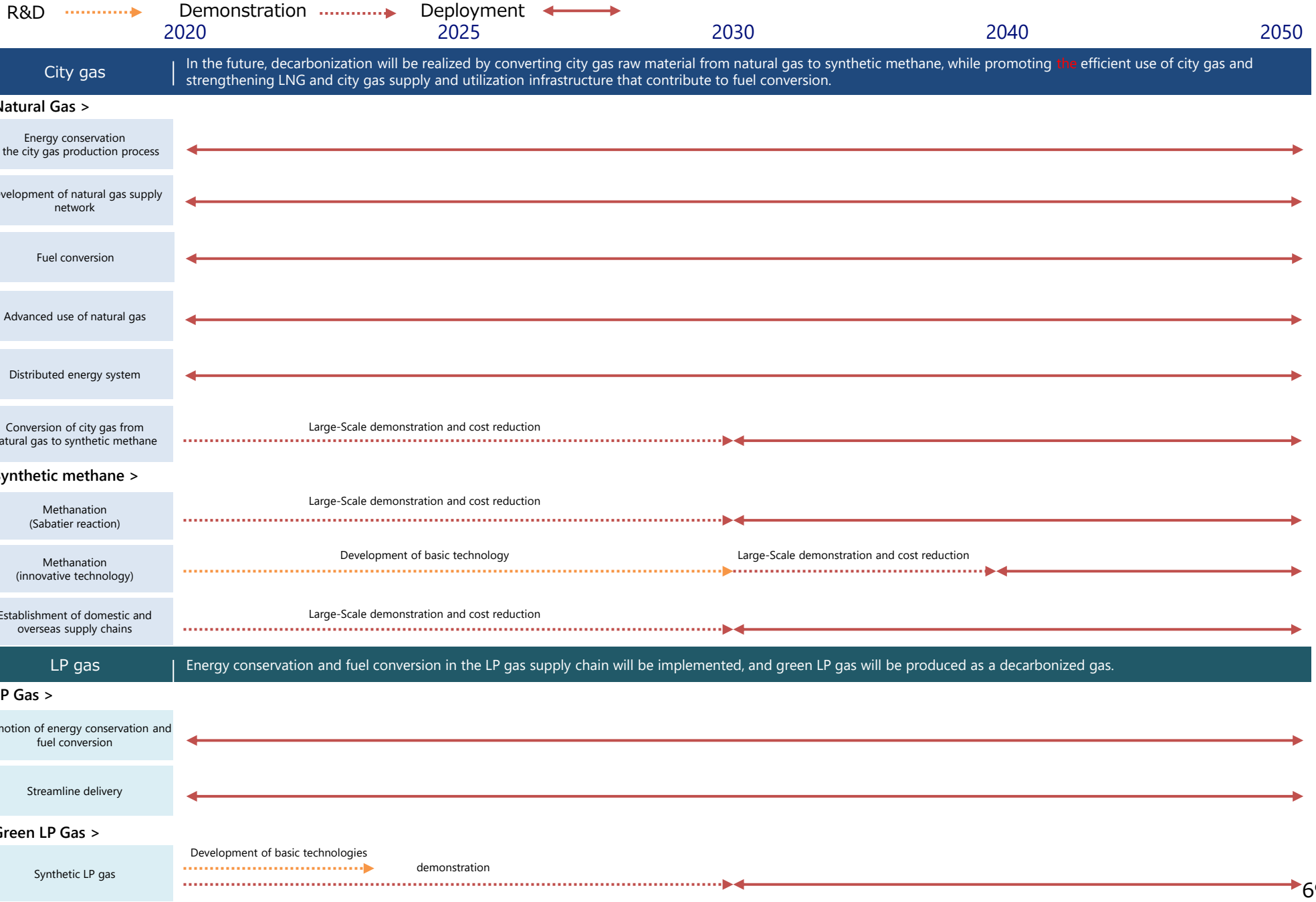
3. Technology Pathways to Decarbonization | ②Technology Roadmap (City gas and LP gas)



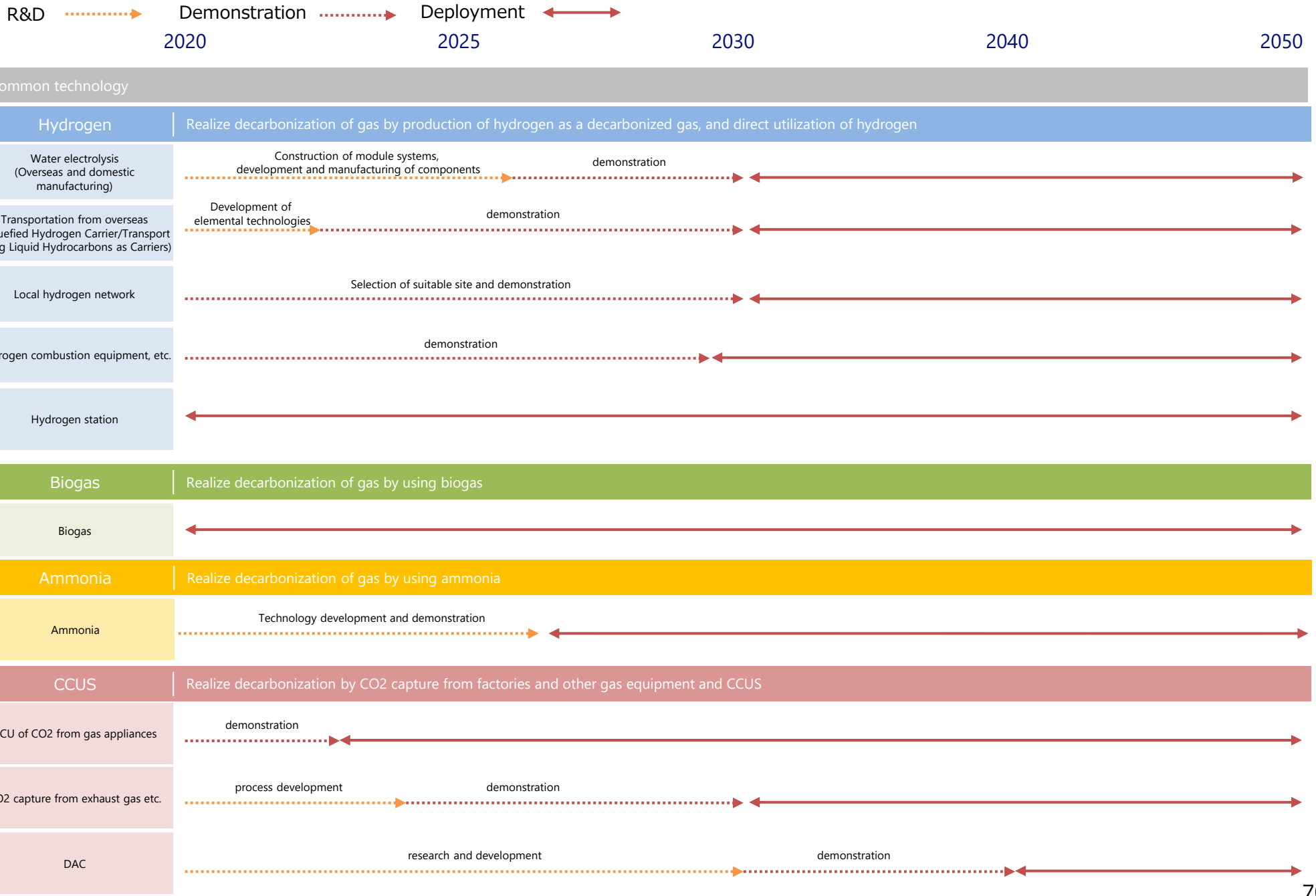
3．Technology Pathways to Decarbonization | ②Technology Roadmap (Common Technologies)



3．Technology Pathways to Decarbonization | ②Technology Roadmap【Appendix】



3．Technology Pathways to Decarbonization | ②Technology Roadmap【Appendix】



3. Technology Pathways to Decarbonization | ③Scientific Basis/Alignment with the Paris Agreement

- The Technology Roadmap refers to Japanese policies and international scenarios that aim to achieve carbon neutrality in 2050, and it aligned with the Paris Agreement.
- It is focused on achieving 2050 carbon neutrality by energy conservation, advanced use of gas, improvement of supply network, conversion to synthetic methane/LP gas and hydrogen, and introduction of innovative technologies such as CCUS and DAC.

Main Reference/ Evidence

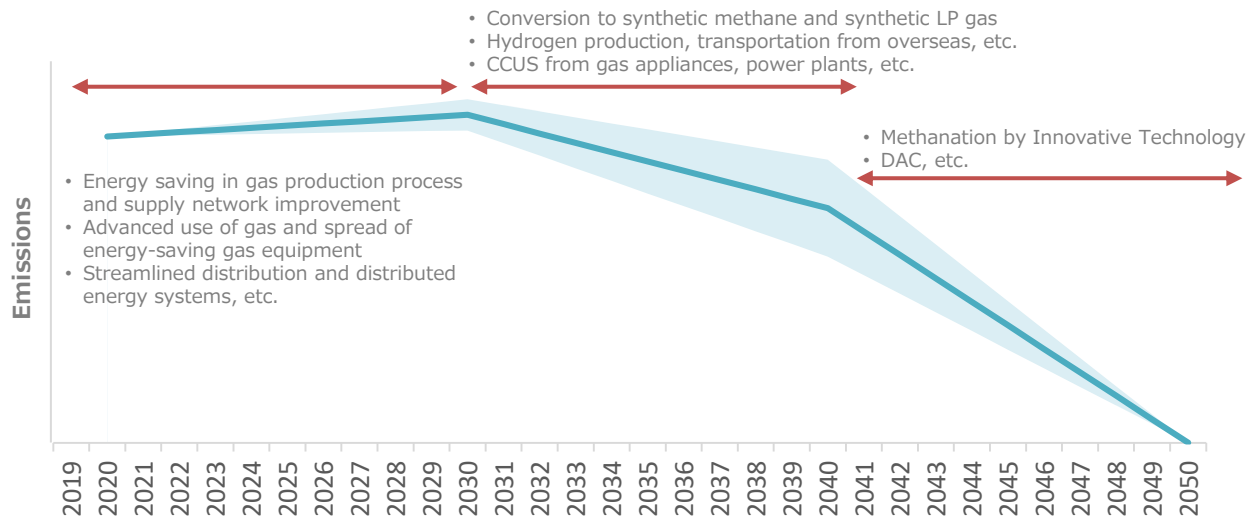
Government Policies

- ✓ Strategic Energy Plan and Strategic Policy Committee Materials
- ✓ Green Growth Strategy Through Achieving Carbon Neutrality in 2050
- ✓ R&D and Social Implementation Plan for the CO2 separation and recovery technology development project
- ✓ R&D and Social Implementation Plan for the fuel ammonia supply chain establishment project
- ✓ R&D and Social Implementation Plan for the hydrogen production through water electrolysis using electric power derived from renewable energy project
- ✓ R&D and Social Implementation Plan for the the large-scale hydrogen supply chain establishment 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
It should be noted that, although there is a possibility of an increase in emissions in the gas sector by promoting fuel conversion to gas through the development of gas supply networks and advanced use of gas, the contribution (reduction contribution) to low-carbon emissions in other sectors is more significant than this increase (p. 33). In addition, while promoting energy conservation in the gas manufacturing process and reduction of emissions through the popularization of energy-saving gas equipment, technologies for synthetic methane and other products for the future will be developed.

2 2030~2040
Production technologies for synthetic methane and synthetic LP gas will be established, and decarbonization by converting fossil fuel-derived gas to carbon-neutral gas will be promoted. Hydrogen supply chains and CCUS will be practically applied and expanded.

3 2040~2050
Conversion to synthetic methane and synthetic LP gas will be further promoted and carbon neutrality will be realized through the practical application of innovative technologies such as DAC.

※This only illustrates the assumption of overall Japanese gas industry's decarbonization pathway as an area covered by this roadmap. 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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4. Toward Decarbonization and Achievement of the Paris Agreement

- The Roadmap is intended to exemplify low-carbon and decarbonization technologies envisioned today and indicate an estimation of when these technologies are to be established for commercialization.
- Technology development is assumed to require long-term development, and it is possible that other low-carbon and decarbonization technologies which are not described in the Technology Roadmap will be developed and adopted. In addition, there exists some uncertainties, including as economic feasibilities.
- Commercialization of low-carbon and decarbonization technologies in the gas sector will also depend on the development of societal systems, such as decarbonized power sources and CCUS. Carbon neutrality in the oil sector will be achieved in coordination with other sectors.
- Therefore, the Roadmap will be revised and updated regularly and continuously to maintain the credibility and usability of the Roadmap by considering the progress of other technologies, the trends of businesses and policies, and dialogues with the investors.
- The companies in the gas sector will aim to achieve carbon neutrality by making the best combination of technologies listed in the Roadmap according to their business decision based on long-term strategy.
- In addition, efforts for reducing CO2 emissions may include the utilization of carbon credits and the purchase of carbon offset products, not limited to “the technology” of the Roadmap.

Taskforce Formulating Roadmaps for Climate Transition Finance
Gas 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]	
Kikkawa Takeo:	Vice President, Professor, International Management, International University of Japan
Shibata Yoshiaki:	Senior Economist, Manager, New and Renewable Energy Group, The Institute of Energy Economics, Japan
Hayakawa Koki:	Senior Managing Director, The Japan Gas Association
Yoshida Sakae:	Managing Director, Japan LP Gas Association