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Contents

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What Happened in the Middle East 50 Years Ago? <Summary > ◆

Shuji Hosaka*

What happened in the Middle East?

1. One of the root causes of the various conflicts in the Middle East today is the Israel-Palestinian Conflict. Based on the United Nations Partition Plan for Palestine adopted in 1947, the Jewish state of Israel was declared established in 1948. Arab countries raised opposition to the establishment and launched attacks on Israel, triggering the Arab-Israeli War (Palestine War).
2. Israel later expanded its territory by occupying the West Bank of the Jordan River, the Gaza Strip, the Sinai Peninsula, and the Golan Heights through the Suez Crisis in 1956 and the Third Arab-Israeli War (Six-Day War) in 1967. During the Fourth Arab-Israeli War (the October War, Yom Kippur War, or Ramadan War) in 1973, the Arab oil-producing countries invoked the so-called oil weapon strategy to raise oil prices, reduce production, and ban exports. The strategy led to the first Oil Crisis (Oil Shock in Japan).

What happened in Japan?

3. Japan then had an extremely strong sense of crisis in the face of the possibility that oil exports could be restricted under the oil weapon strategy of the Arab oil-producing countries. As Japan depended on the Middle East for about 60% of all energy supply then, wild price hikes and hoaxes immediately forced the entire country into a panic, putting an end to the so-called Japanese Economic Miracle.
4. Japan successfully overcame the crisis by improving energy efficiency, diversifying energy and oil import sources, and stockpiling oil, and preventing any panic during the second Oil Crisis in 1979. Nevertheless, the first Oil Crisis exerted significant impacts on Japan. The crisis and its great impacts became a significant trauma for many energy stakeholders.

Japan's Middle East diplomacy

5. At the time, Japan lacked interest in Middle Eastern oil producers and energy security and had no readiness to gather and analyze information on the Middle East. In particular, Japan had no embassies in the United Arab Emirates, Qatar, Oman, or Bahrain, failing to gather sufficiently quantitative or qualitative information in these countries. In addition, Japanese media reports on the Middle East were often inaccurate and sensational, contributing to the panic.
6. Rivalries between politicians and government agencies were intertwined with a confrontation between those in favor of relations with the United States and energy security to delay analysis and policy-making.

Present and future prospects for Japan-Middle East relations

7. Even after the second Oil Crisis, Japan has been at the mercy of the 1990-91 Gulf Crisis and War, the 9/11 terrorist attacks on the United States in 2001, the Iraq War in 2003, and other incidents related to the Middle East.
8. As Japan's oil demand peaked and turned down in the 1990s, South Korea and other Asian countries aggressively expanded into the Middle East, threatening Japan's presence. In the 21st century, China, supported by its remarkable economic development, has dominated the Middle East market with its Belt and Road Initiative. Asian countries, including China, initially supplied cheap and low-quality goods to the market but now provide a wide range of products,

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from high-technology products to giant plants. In recent years, China and South Asian countries have become major oil and LNG export destinations for the Middle East, leading Japan's economic presence in the region to decline.

9. Furthermore, China, under the banner of "Major Power Diplomacy" with Chinese characteristics, has been aggressively intervening in political affairs in the Middle East by taking advantage of arms exports and other leverages that Japan lacks. China's mediation in the normalization of relations between Saudi Arabia and Iran is perhaps the greatest achievement of such Chinese diplomacy.
10. However, the Middle East remains an important resource supply source and a large market for Japan today. Especially after the outbreak of the Ukraine crisis, Japan has expanded its crude oil imports from the Middle East to reduce its dependence on Russia. In May 2023, Japan depended on the Middle East for 97% of its crude oil imports. As Japan's economic influence on the Middle East declines, how to strengthen the relationship between Japan and the region has become important.
11. On the other hand, the mutual trust that Japan has cultivated over its long history with the Middle East and Japan's high-level research on the region are great leverages that other Asian countries lack. In addition, Japan's anime and video games have a great influence on the younger generation in the Middle East.
12. It is important for Japan to take advantage of these leverages for building multilayered and comprehensive industry-government-academia partnerships with the Middle East to maintain Japan's presence in the Middle East. Therefore, Japan should promote cooperation with Middle Eastern countries in realizing decarbonization, a circular carbon economy, and a hydrogen society.
13. Under these circumstances, the achievements of Japanese Prime Minister Fumio Kishida's visit to the Gulf states on July 16-18 are attracting attention. Japan is required to enhance its relations with the Middle East, including the Gulf states, to secure its stable energy supply and stabilize the Middle East in the current international situation where the world has been increasingly divided.

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Gas Market Developments
- Efforts Toward Market Stabilisation -
<Summary > ◆

Hiroshi Hashimoto*

Toward LNG Market Stabilisation: Supply, Demand, and Price Issues

1. During the past 50 years since the oil crisis, natural gas, including LNG, has grown to become the cleanest of fossil fuels and one of the most important sources of energy. Its impact on energy security increased, and the importance of securing a stable supply of LNG has increased significantly.
2. Regarding supply, it is important to increase stable supply from non-Russian supply sources. In the short term, it is necessary to continue dealing with the reduction of the Russian pipeline gas supply, ensuring stable production in the existing LNG-producing countries, and smoothly launching new LNG production projects in the next couple of years.
3. Fluctuations in demand outlooks depending on the impact of the long-term decarbonization agenda, a shift of demand centres to developing economies, and requirements of flexible supply arrangements, are increasingly important factors. In the short term, uncertainty in demand due to the effects of nuclear power and renewable energy, fluctuations of gas demand reductions and decreases in Europe, and recovery in gas demand in growth markets such as China, will determine the balance of the market.
4. It is always necessary to diversify and optimize contract pricing and set prices in a balanced manner that supports both stable market growth and investment activities. The increasing volatility continues to pose challenges.

Volatility in LNG Market Prices

5. Spot LNG gas prices were on a downward trend in the first half of 2023. In the Asian LNG market, the advantage of oil-linked long-term contract LNG prices has shrunk. The situation may change quickly.
6. Spot LNG and spot gas prices in Europe soared from the second half of 2021 after a slump in 2020, amplifying fluctuations. From August 2021 to April 2023, those spot prices were more expensive than crude oil.
7. In the first half of 2023, an easing market balance (declining prices) is observed. However, a further reduction of Russian pipeline gas, a recovery in LNG intake by China, and unexpected LNG production problems could lead to a reversal of the supply-demand balance.

Factors Amplifying Market Instability

8. Russian pipeline gas supply to the European Union declined from just over 8 million tonnes of LNG equivalent in December 2021 to less than 2 million tonnes by December 2022. On the other hand, Russian LNG supply to the EU increased slightly in 2022. However, there are also uncertain factors in the trend of Russian LNG supply from 2023.
9. In 2022, the shutdown of an LNG facility in the United States and the prospect of its restart is another major factor in the market uncertainty. An outage of a large-scale LNG production facility could change the market balance significantly. The stable and timely start of new projects is also a major factor.
10. In 2022 - 2023, three regulatory changes affecting the LNG business were announced in Australia: ADGSM (Australian Domestic Gas Security Mechanism); Safeguard Mechanism regulating GHG emissions; and PRRT

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(Petroleum Resources Rent Tax). How long-term LNG export contracts are protected, how stricter reduction limits are enforced, and how LNG business economics are affected should be closely monitored, respectively.

Policy and Securing Investment Challenges Toward Stable LNG Market

11. While G7 recognized the importance of natural gas and LNG, it is important to establish standards for transition-compliant LNG. The importance of strengthening methane and GHG emission measurement and international standardization, and the importance of international cooperation in emission reduction efforts were emphasized at the G7 Ministerial Meeting and the LNG Producer Consumer Conference. The concrete measures to enhance the IEA's role in gas and LNG security are also critical.
12. LNG investment activities are expected to increase in the international LNG market, mainly in the United States, supported by an increase in long-term contract commitments. On the other hand, among the past investment decisions, the realization of projects in Russia has become uncertain, and there have been delays in projects in other regions, making it difficult to predict the prospects for securing supply capacity.
13. It is necessary to develop various financial instruments to meet the financing needs of LNG projects, emphasizing the economic and environmental advantages of LNG as investment and financing destinations.
14. In light of buyers' demands for flexibility and shorter contract periods, including in developing markets with relatively low credit ratings, it will be effective to build cooperation between buyers from different economies.

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Utilization of Nuclear Power -- Its Roles and Challenges <Summary > ◆

Kenji Kimura*

History and recent situation regarding nuclear energy

1. In Japan and Western countries, the use of nuclear energy expanded rapidly immediately after the oil crisis, contributing to oil substitution and energy security enhancement. Since the 1990s, however, the expansion has been stagnating.
2. As countries around the world have set ambitious targets for reducing greenhouse gas emissions in recent years, however, nuclear energy has attracted attention as a zero-emission baseload electricity source.
3. In addition, global fossil fuel prices have soared since 2021, prompting each country to give priority to the stable supply of energy, including electricity. Russia's invasion of Ukraine further strengthened that trend.
4. In this way, the importance of not only climate change countermeasures but also energy self-sufficiency and stable baseload electricity sources is being reaffirmed, leading to many developments indicating growing hopes for the role of nuclear energy.

Suggestions about the roles of nuclear energy

5. In 2019, the International Energy Agency (IEA) released a report on the roles of nuclear energy. In addition to its earlier outlook, the IEA analyzed an assumption that investment in nuclear energy would shrink in developed countries, pointing out that significant additional costs would be required to realize a sustainable energy system using renewable energy alone.
6. In France, RTE, a power transmission company, conducted a scenario analysis to achieve carbon neutrality by 2050. The report analyzed six power mix scenarios for 2050, including full dependence on renewable energy and a 50% energy mix share each for renewables and nuclear energy, indicating that the inclusion of nuclear energy into the power mix could reduce total costs.
7. The Institute of Energy Economics, Japan, conducted an analysis using a model to minimize the cost of the entire electric power system under the assumption that Japan will achieve zero-emission power generation in 2050, suggesting that the presence of nuclear energy in the power mix would contribute to optimizing the economic efficiency of the entire electric power system.

Actual trends

8. The United States has launched a support program for existing reactors that are on the brink of being closed for economic reasons and supported the development of small modular and fourth-generation nuclear reactors. The Inflation Reduction Act, enacted in August 2022, introduced a production tax credit program covering nuclear energy.
9. In its energy security strategy announced in April 2022, the United Kingdom set a target of introducing up to 24 GW in installed nuclear power generation capacity by 2050 to cover 25% of the electricity supply. The planned construction of the Sizewell C nuclear power station will be supported by the nuclear Regulated Asset Base model, as well as direct investment from the government.
10. Based on the abovementioned scenario analysis, France announced the construction of at least six large light water reactors (and up to eight more) in February 2022. In July 2022, the French government also announced a plan to fully

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nationalize EDF, a big utility, to secure energy supply and promote decarbonization. Recently, a law was partially enacted to simplify procedures for constructing new nuclear reactors near existing nuclear facilities.

11. In Japan, the Green Transformation (GX) Decarbonization Power Supply Act was enacted in May 2023. The act allows nuclear power reactor operators to subtract operation suspension periods for safety and other examinations from the service life of nuclear reactors to extend the deadlines for terminating their operations. After operating for 30 years, however, any reactor will be subjected to the assessment of anti-aging measures to determine whether or not to continue its operation every 10 years. In June 2023, seven out of the 10 regional electric power utilities raised their regulatory electricity prices, excluding Kansai Electric Power Co. and Kyushu Electric Power Co., which avoided the hike by achieving greater progress in restarting nuclear reactors than others.
12. There are many other moves toward the utilization of nuclear energy in many countries. In particular, central, eastern, and northern European countries have strong incentives to reduce their dependence on Russian fossil fuels and electricity, as well as Russian nuclear technology, and enhance climate change and environmental measures. On the other hand, Russia's strength remains conspicuous in the global nuclear market.

Challenges for Japan

13. As mentioned above, the GX Decarbonization Power Supply Act has created a path for the effective utilization of existing nuclear reactors in Japan. In order for nuclear energy to fulfill its expected roles, however, Japan must implement initiatives to improve nuclear project feasibility and resolve nuclear back-end and other issues. In addition, Japan should promote steady and stable nuclear energy initiatives from the long-term perspective in order to contribute to a long-term energy transition for energy security enhancement and decarbonization.

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Stable Supply of Critical Minerals
- The Threat of Maldistribution -
<Summary > ◆

Ichiro Kutani*

Energy Transitions and Critical Minerals

1. Energy transitions will develop unprecedented structures surrounding energy supply and demand, international trade, and technologies that will also shift the centers of geopolitical risks.
2. Under the conventional fossil energy-centered system, geopolitical risks arise from fossil energy imports. Since the oil crisis 50 years ago, the world has reacted to this issue. However, in the world, while pursuing carbon neutrality, the world will become less dependent on fossil fuel imports while ensuring a stable supply of clean technologies, such as renewable energies and batteries, and the critical minerals necessary for its production will become imperative.
3. Supply disruptions and price spikes for critical minerals can pose genuine crises. Japan actually experienced a rare earth supply crisis in 2010.

Risks of Critical Minerals and Global Debate

4. As we progress toward the future, electric vehicles, wind power generators, and solar power generators are becoming increasingly prevalent around the world. When compared with internal combustion engine vehicles and thermal power generation, these technologies are relatively more critical mineral intensive in terms of their requirements.
5. We know that critical mineral reserves are unevenly distributed among certain countries, and it is often the case that downstream processes of mineral products are unevenly distributed among other countries. It is not enough to simply focus only on resource reserves; we must also focus on the maldistribution of downstream processes.
6. The maldistribution of critical minerals is not the only concern. There is also the risk of supply shortages. Taking nickel as an example, under the accelerated decarbonization scenario (Advanced Technology Scenario, IEEJ Outlook 2023), there could be nickel shortages in the mid-2030s. What's more, there is the risk that cumulative demand by 2050 could exceed the world's current resources, even taking into account the amounts recycled. The same is true for lithium, which could be in short supply around the year 2030, even earlier than nickel. This supply-demand crunch will be further accelerated depending on the speed and actions of decarbonization efforts.
7. Given this scenario, the world is hastening its efforts to secure critical minerals. The United States and Europe respectively developed strategies to tackle this situation in 2022 and 2020. They are rolling out programs and financial assistance aimed at conserving resources, strengthening recycling, expanding domestic and international supplies, and building emergency stockpiles.
8. However, the uneven distribution of resources makes it impossible for any one country to establish a system of self-sufficiency on its own, and there is momentum building for international cooperation. Leaders at the G7 Hiroshima Summit 2023 agreed on the need to manage the risks of critical minerals in a joint declaration, and the "Five-Point Plan for Critical Minerals Security" was established by the G7 Ministers' Meeting on Climate, Energy and Environment.

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Japan's Supply of Critical Minerals and Future Directions

9. Japan's critical mineral procurement as a whole has an oligopoly supply structure. With that said, some minerals are imported from G7 and other friendly import-partner countries, so there is potential for cooperating with these countries.
10. Recent policies include the "New International Resource Strategy (2020)", whereby one of the pillars of industrial competitiveness was strengthening the security of rare metals. The Economic Security Promotion Act of 2022 also described ensuring a stable supply of essential minerals as one of its pillars, and designated 11 specific essential minerals through government ordinance. Then in 2023, the Economic Security Promotion Act formulated the "Systems for Ensuring Stable Supply of Critical Products" and presented support measures for securing resources overseas. Japan and the United States also entered into the "Japan-U.S. Critical Minerals Agreement," in which the two countries agreed to cooperate in addressing issues relating to the critical mineral supply chain.
11. The issues surrounding critical minerals in Japan garnered significant attention in 2010 when China effectively suspended rare earth exports to Japan following an incident concerning the Senkaku Islands. Japan was relying on China for more than 90% of its rare earth imports at the time. It has since reduced its dependence on China to less than 60% by diversifying its import partners to include countries such as Vietnam, Malaysia, Thailand, India, and France. Japan also filed a complaint with the World Trade Organization (WTO) and won the right to abolish China's export controls.
12. These are the steps Japan should take to secure a stable supply of critical minerals in the future: 1) Reduce the need for critical minerals by developing resource-saving and alternative resource technologies; 2) Reduce imports by strengthening recycling; 3) Enhance resource security abroad; and 4) Strengthen emergency reserves. In addition, formulating an energy mix also involves a crucial consideration of the technology mix. The Government has already announced a number of policies, and it is expected to implement these policies in collaboration with the private sector, which is responsible for supply.
13. Once again, cooperation with the international community will be essential. Maldistribution risks can be mitigated by strengthening relationships with reliable partners, joint development in the fields of resource extraction, downstream processes, and utilization technologies, and by maintaining fair trade systems.

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Negative Emission Hydrogen / Ammonia - Promoting the Acceleration of Decarbonization - <Summary > ◆

Yoshikazu Kobayashi*

Hydrogen and Ammonia

1. Today, 50 years after the oil crisis, there is a growing demand to promote energy transitions that will achieve both decarbonization and energy security. Efforts must be strengthened in various fields if this is to be realized, but the all-important key to whether we succeed or whether we fail will be in realizing innovation. There are a variety of efforts already underway within the field of innovation itself, but what the world is currently looking toward is innovative fuels, such as hydrogen and ammonia, and negative emission technologies.
2. During the G7 Hiroshima Summit held in May of this year, G7 leaders affirmed that hydrogen derived from renewable energy is not the only effective means of decarbonization; so long as they meet the 1.5°C target, both fossil fuel hydrogen with CO_2 captured at the production stage and hydrogen-derivatives such as fuel ammonia are also effective means. That the leaders of the G7 countries have agreed upon a pragmatic approach in flexibly adopting hydrogen that greatly contributes to decarbonization rather than excessively insisting on one specific type of hydrogen is significant. With this official recognition of being an effective decarbonized fuel, it is likely that we will see an accelerated use and expansion of ammonia as fuel both domestically in Japan and overseas going forward.
3. The importance of promoting the production and distribution of low-carbon hydrogen based on carbon intensity was also mentioned at the G7 Summit. During the transition period, the oil-producing Middle East and other resource-rich countries will have a cost-competitive advantage when providing low-carbon hydrogen due to their low-cost gas production and plentiful sites suitable for CCS. Though there have been changes in the position of Middle-Eastern-produced crude oil in terms of Japan's overall energy demand over the past 50 years since the oil crisis, maintaining good relations with resource-rich countries in the Middle East will remain crucial for Japan in the future. With that said, resource-rich countries in the Middle East will also need to secure stable hydrogen and fuel ammonia export destinations as the world moves toward carbon neutrality.
4. When it comes to creating international hydrogen trade supply chains, the export side is generally in the lead while the import side is lagging behind. Japan's Basic Hydrogen Strategy, revised in June of this year, describes a policy for developing international supply chains through strengthening resource diplomacy, acquiring upstream interests, and providing financial support for plant construction, but an important step going forward will be to hasten the adoption of hydrogen within importing countries through price differential support and infrastructure development.
5. There is also growing interest in using ammonia as a fuel for applications beyond power generation. The port sector has plans underway to establish bases for importing ammonia in locations such as Shunan City in Yamaguchi Prefecture, Singapore, and Rotterdam. The shipping sector has plans to utilize ammonia as a marine fuel from 2025 and, finally, Japanese companies in the industrial sector are developing industrial furnaces to meet the heat demand in the ceramics and chemical sectors.

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Negative Emissions

6. Negative Emission Technologies (NETs) remove greenhouse gases from the atmosphere in the long term. There has been an increasing interest in these technologies over the past few years, both in Japan and abroad. Energy transitions have been progressing alongside ensuring energy security over the past 50 years since the oil crisis, but this will not suffice over the next 50 years; we must also promote energy transitions with a view to achieving carbon neutrality. NETs that offset residual CO_2 emissions will be an essential means to achieving such carbon neutrality.
7. Although there are a wide variety of NETs available, each with its own merits and demerits, technology-based NETs using CCS (DACS, BECCS) have several advantages. They have a relatively high level of technological maturity, they have significant removal potential, they can easily and accurately quantify the actual amount of CO_2 removed, and they have long CO_2 fixation periods.
8. While efforts to introduce CCS are currently being promoted as a means to reduce CO_2 emissions from conventional fossil fuels, this technology will also play a critical role in the future toward negative emissions. As such, swift action regarding the commercialization of CCS is warranted.
9. As NETs are being rolled out, other countries are setting numerical removal targets and linking these with their emissions trading systems. Meanwhile, Japan has finally gotten around to discussing their implementation and is currently financially supporting the technological development of Direct Air Capture and other such technologies, as well as considering how to create and expand upon markets. However, further discussions will be necessary to delve deeper into these matters in the future.

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GX Initiatives: Transformation of Japan’s Economic and Social Systems <Summary > ◆

Takahiko Tagami*

Green Transformation (GX) of Japan’s Economic and Social Systems

1. The oil crises in the 1970s served as an important catalyst for Japan's energy transformation, which focused on its reduced dependence on oil, to strengthen its energy security. At the same time, however, Japan had to transform its economy and industry to survive under this energy transition. Similarly, how to leverage the current energy crisis and the upcoming energy transformation as an opportunity for transforming the industry for the future is an important challenge. Recently, the gross domestic products of chemical and allied products, electronic parts and devices, and general-purpose, production, and business-oriented machinery have been increasing. It is necessary to analyze whether they will be seeds for future economic growth.
2. The vision or goals, and the roadmap or pathways for the green transformation (GX) of Japan's economic and social systems are illustrated in the appendix of Japan's Basic Policy for Realization of GX formulated in February this year, with 22 future business areas as examples. But in which of these areas should Japan aim to "win" (achieve economic growth), and how? It is also important to compare Japan's industrial policies with those being worked on in the US and the EU, on the methodologies of how support is being provided.

Overview of Japan’s Basic Policy for Realization of GX (“GX Basic Policy”)

3. Areas involving large amounts of GX investment, namely automobile and storage batteries, renewable energies and next-generation networks, houses and buildings, and investment in digitalization for decarbonization, were all classified in the Green Growth Strategy as the areas in a deployment and expansion phase, and thus these investments aim to achieve short-term results.
4. The initiatives for the 22 areas illustrated in the GX Basic Policy can be divided roughly into the following: short- to medium-term initiatives involving (1) industrial policies (semiconductors, storage batteries) and (2) transformation of social systems (automobile, houses and buildings, renewable energy), and medium- to long-term initiatives involving (3) research and development (R&D) and deployment.
5. While the industrial policies under the GX Basic Policy focus chiefly on semiconductors and storage batteries, whether these industrial policies can ensure sustainable economic growth and how to identify the industrial areas that will lead to medium- to long-term economic growth (through selection and concentration) are a challenge.
6. As for R&D and deployment, long-term goals for cost and volume have been set for only a few areas, including hydrogen and ammonia; the pathways for achieving these goals and the means of support are still uncertain. For the longer term, how to build a support framework for promoting R&D in broader areas, and, out of these areas, how to identify and select areas of R&D that will lead to economic growth and to concentrate resources in them, will be the issues going forward.

Growth-Oriented Carbon Pricing Initiative

7. Japan’s Growth-oriented Carbon Pricing Initiative has a two-phase structure that transitions from investment support to carbon pricing. Investments will be mobilized through large-scale government support worth 20 trillion yen, utilizing

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GX economic transition bonds, and private finance worth 130 trillion yen over 10 years from FY2023. A carbon emissions trading system will enter full operation in FY2026, a carbon surcharge (fossil fuel surcharge) will be introduced in FY2028, and an emission allowance auction will be introduced gradually for the power sector in FY2033. The 20 trillion yen in capital will be funded by revenues from the carbon surcharge and the emission allowance auction.

Industrial Policies of the US and the EU

8. In the Inflation Reduction Act (August 2022), the largest tax credits over ten years are estimated through the following: (1) Extension and Modification of Credit for Electricity Produced from Certain Renewable Resources, (2) Clean Electricity Investment Credit, and (3) Residential Clean Energy Credit. Production tax credits (tax credits allowed in proportion to products) also play a significant role.
9. Under the EU's Green Deal Industrial Plan (February 2023), the proposed Net-Zero Industry Act merely simplifies the regulatory framework for the manufacturing of net-zero technologies. On the topic of EU-level funding, the setup of the Sovereignty Fund as a mid-term structural answer to the investment needs is uncertain, and additional funding is not identified.
10. Regarding the methodologies of support, the main tools employed by the US Inflation Reduction Act are amendments of and additions to production tax credits stipulated in the Internal Revenue Code. The requirements are specified, and the tax credits are thought to be of high interest and attractive to private businesses. As they allow funds to be monetized quickly, they are incentivizing companies to make investments, and could lead to the creation of new industry seeds and their growth. Meanwhile, the EU aims to create markets through carbon pricing such as the EU ETS, and regulations, but the markets are still in the process of being created. As no additional EU-level funds have been specified, some companies are redirecting their investments to the US from the EU. Japan needs to ensure that its investment support achieves results before the full launch of its carbon pricing system.

Challenges for the GX Initiatives

11. (1) With regard to the targeted GX areas in industrial policies, as well as R&D and deployment measures, it is important to build a mechanism to objectively evaluate and identify the areas that would lead to economic growth, and to concentrate resources in those areas. (2) As for the methodologies on supporting GX, Japan should, while learning from the industrial policies of the US and the EU, operationalize investment support as soon as possible, in an accelerated and enhanced dialogue with the private sector and businesses, in order to create seeds for new industries aiming for future development and growth, before carbon pricing and regulations could create markets.

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Energy Transition in Asia
- Simultaneously Achieving Economic Growth and Net-Zero Emissions -
<Summary > ◆

Toshiyuki Sakamoto*

Pathways for net-zero emissions compatible with robust economic growth

1. As was reaffirmed at this year's G7 meetings, economic and energy situations vary significantly among the countries of the world, and while carbon neutrality is our common goal, there are various pathways for getting there. The desirable pathway varies greatly depending on a country's economic growth scenario and its estimated future demand for energy.
2. This is clearly indicated in Decarbonization Pathways for Southeast Asia, a report published by the International Energy Agency (IEA) with the full support of the IEEJ as a contribution to the G7 Ministers' Meeting on Climate, Energy and Environment in Sapporo in April this year.

Why ASEAN is so important

3. As the global divide widens due to the Ukraine crisis, the importance of the Global South is increasing. If we look at the future growth of global energy demand, the leading growth centers are expected to be India and ASEAN, not China. In particular, ASEAN has much in common with Japan in terms of the energy environment, such as relatively small renewable energy potential. Fifty years after the oil crisis, as Japan embarks on its next energy transition, it has a major role to play in using its technologies and know-how to support ASEAN countries on their paths to carbon neutrality in line with their respective situations. Such support is of great value not only for Japan and ASEAN but also for the entire world.

Comparison of the decarbonization scenarios for the ASEAN countries between the IEA and ERIA/IEEJ

4. The IEA report is a comparative analysis of the decarbonization pathway scenarios for ASEAN and Indonesia between the IEA and the ERIA (Economic Research Institute for ASEAN and East Asia)/IEEJ. The scenarios used for comparison were the Announced Pledges Scenario (APS) in the IEA's World Energy Outlook 2022, and Decarbonization of ASEAN Energy Systems: Optimum Technology Selection Model Analysis to 2060 (CN2050/2060), a scenario created by the IEEJ in cooperation with the ERIA.
5. The first noteworthy point in this comparative analysis is the different predictions for future economic growth that have a profound impact on final energy consumption. While both scenarios predict a similar population increase, the IEA expects the real GDP of the ASEAN economies to grow by 3.0 times (annual growth rate of 3.8% per annum) and that of Indonesia to grow by 3.3 times (4.1% p.a.) between 2020 and 2050, while the ERIA/IEEJ forecasts the ASEAN economies' real GDP to grow by 3.9 times (4.6% p.a.) and that of Indonesia by 4.4 times (5.0% p.a.). The cause of the difference is that while the IEA incorporated the trends observed in past macroeconomic analyses, in which the growth rate declines as income levels rise, the ERIA/IEEJ based their scenario on the economic growth forecasts of the ASEAN countries themselves. Indeed, the Indonesian government's economic growth forecast in their long-term

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strategy submitted to the UNFCCC coincides with the ERIA/IEEJ's forecast.

6. In addition, the IEA forecasts greater progress in energy efficiency improvement (reduction in final energy consumption per GDP) than the ERIA/IEEJ, resulting in a gap of 1.7 times for ASEAN and 1.9 times for Indonesia in the final energy demand forecast in 2050 between the IEA and the ERIA/IEEJ. It should be noted that the Indonesian government's final energy demand forecast in its long-term strategy is somewhat even larger than the ERIA/IEEJ's forecast. The absolute value of energy demand after reflecting on the progress in energy efficiency improvement will have a decisive impact on decarbonization.
7. Meanwhile, the scenarios of the IEA and the ERIA/IEEJ have some points in common: both anticipate that ASEAN and Indonesia will introduce renewable energies to the maximum extent, and their forecasts for renewable contribution in primary energy supply are similar. However, the ERIA/IEEJ scenario assumes that fossil fuels (especially gas) use will need to continue to grow for some time to meet the strong final energy demand, while also estimating increased use of carbon dioxide removal (CDR) through DACCS, BECCS, and forest sinks, as well as hydrogen/ammonia and CCS, to achieve decarbonization of fossil fuels and net zero, compared to the IEA scenario.

Necessity of a pathway that accounts for future uncertainties

8. While attention tends to focus on the percentage of renewable energy when discussing net-zero roadmaps, a key matter is how to estimate the energy needed by an economy and society, which is decisive in deciding the target energy mix. There are uncertainties about future economic growth in developing countries, but as the development of energy infrastructure takes a very long time, pathways to carbon neutrality should take these uncertainties into full account.

Comparison of Ammonia Co-firing and Early Retirement of Coal-fired Power Plant

Yoshikazu Kobayashi* Yuji Mizuno **

1. Introduction

Actions to reduce CO_2 emissions to address climate change issues have gained further momentum globally in recent years. Among the efforts to reduce the emissions, adopting renewable energy sources such as wind and solar, are often given the highest priority to mitigate the adverse effects caused by the climate change. It is no doubt that these renewable energy sources must be adopted to the highest degree in any country in order to combat climate change. It is, however, also true that such renewable energy resources are not evenly distributed across the world and, depending on the resource endowment, are not always sufficient to fully substitute the existing fossil fuel consumption and eliminate the CO_2 emissions from the use of fossil fuels. This resource limitation is particularly acute in the developing world whose electricity demand is highly likely to grow fast in the coming decades.

What makes the emissions reduction actions in Southeast Asia more complicated is the existence of a relatively young fleet of coal-fired power generation. The number of coal power units has rapidly grown in the last decade and is expected to increase in the next few years because of the additional units currently under construction. These plants are still new and it takes years to fully recover the initial investment. In Southeast Asia, in addition to the installation of additional renewable power generation, decarbonization of the existing coal power units is a critical challenge for this region's energy and environmental policies.

As a solution to decarbonize the coal-fired power generation units in Southeast Asia, there are two approaches: earlier retirement including replacement with renewable power units, and co-firing of clean ammonia. Both approaches will require technical and financial support from the firms in the developed world and multilateral development financial institutions. This paper compares these two solutions with multiple scenarios, in terms of generation costs and CO_2 emissions. The paper first offers an overview of the current status of coal-fired power plants in five major Southeast Asian countries. It then explains the assumptions and analyzes the generation costs and CO_2 emissions of various scenarios. The paper concludes by summarizing the findings and raising future study agendas.

2. Coal-fired power plants in Southeast Asia

Coal-fired power generation is regarded as one of the primary energy generation sources in Southeast Asia, and a number of new units have been constructed in the last decade. As shown in Figure 1, the majority of the generation capacity is less than 10 years old with the average age of the total capacity at 8.16 years[1]. This is a stark difference from the status of the coal-fired power plants in the EU, most of which are more than 20 and even 30 years old.

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[1] The age of the units under construction is counted as negative.

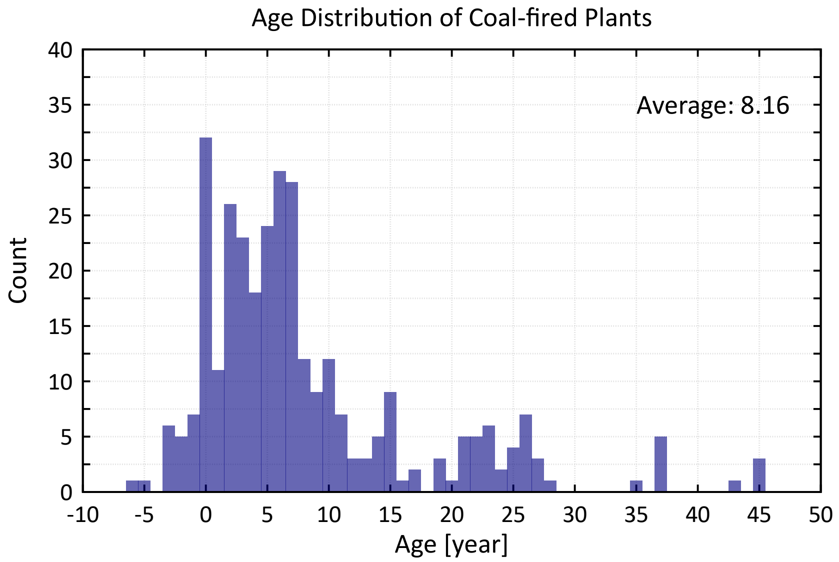

Figure 1 Age distribution of coal-fired plants in five countries*

*: Indonesia, the Philippines, Malaysia, Thailand, and Vietnam

Source: Enerdata Database

Because of this young age, the total capacity of coal-fired power plants is expected to remain high in Southeast Asia. Figure-2 shows the capacity of coal-fired plants of the five countries from 1976 to 2066 (the figures from 2021 are assumptions). The figure suggests that the peak of the total generation capacity has yet to come until around 2030 because of the on-streams of the under-construction units in the next several years. This is not only a surprise but also an inconvenient fact in terms of the urgency to reduce CO_2 emissions to tackle the climate change issues, necessitating a policy action to somehow mitigate the emissions from these units.

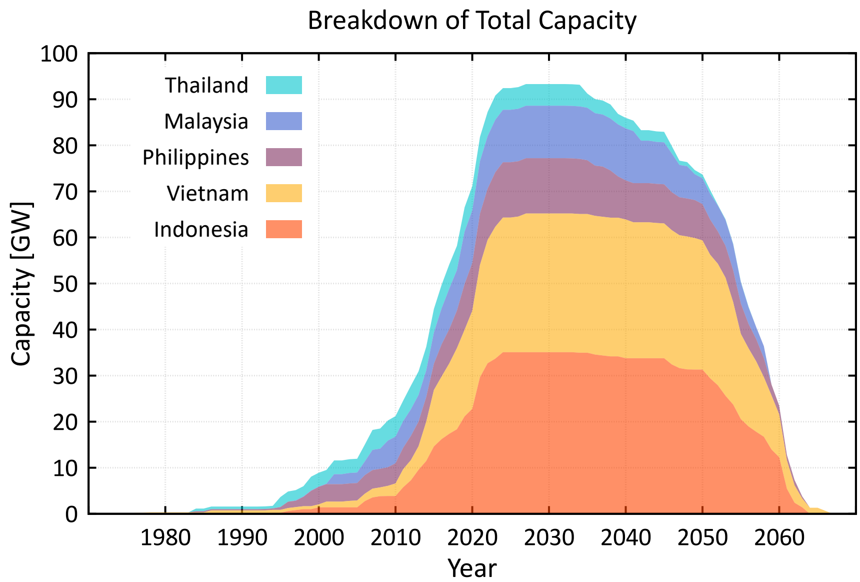

Figure 2 Total generation capacity of coal-fired power generation in five ASEAN countries

Source: Enerdata Database

3. Assumptions

(1) General assumptions

This paper assumes two emission reduction options for existing coal-fired power generation units in Southeast Asia, namely, 1) early retirement of coal unit and replacement with solar power and storage batteries, and 2) installation of clean ammonia co-firing facilities to the existing coal units. In order to analyze various possibilities of each emissions reduction option, this paper assumes six different scenarios depending on the timing of early retirement of coal power generation and the level of co-firing ratio for clean ammonia (Table 1). Three scenarios are based on the option 1) and the other three scenarios are based on the option 2). Except for the NH3-Newbuild scenario, all scenarios assume that the coal-fired power plant is 10 years old, and the construction cost of the coal-fired power plant is not considered when calculating the generation cost.

Table 1 Scenarios of the Study

Scenario	Generation patterns
ETM-Base	Coal 100% for 25 years [5 years early retirement] + Solar & Battery for 25 years
ETM-10	Coal 100% for 20 years [10 years early retirement] + Solar & Battery for 25 years
ETM-15	Coal 100% for 15 years [15 years early retirement] + Solar & Battery for 25 years
NH3-Base	Coal 100% for 5 years + NH3 20% for 5 years + NH3 50% for 20 years
NH3-50	Coal 100% for 5 years + NH3 50% for 25 years
NH3-Newbuild	Coal 100% for 5 years + NH3 20% for 5 years + NH3 50% for 30 years
BAU	Coal 100% for 30 years

Remarks: ETM stands for early transition mechanism, NH3 stands for ammonia based on its chemical composition. BAU stands for business as usual.

Source: IEEJ

The graphical representations of ETM-Base, ETM-10, NH3-Base, and NH3-50 scenarios are shown in the Figure 3. The figures show that NH3 co-firing scenarios (NH3-Base and NH3-50) can reduce CO_2 emissions at an earlier timing than ETM scenarios (ETM-Base and ETM-10).

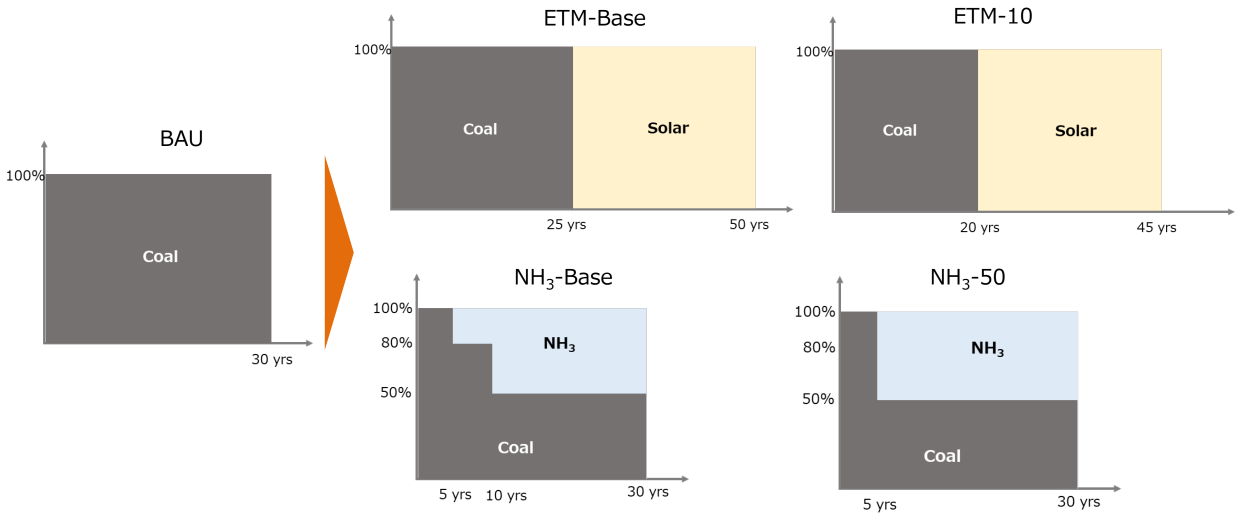

Figure 3 Graphical representation of generation patterns of selected scenarios

Source: IEEJ

(2) Assumptions for coal-fired power plant and ammonia co-firing

This paper aims to analyze the economics and the emissions of the above scenarios. The assumptions for coal-fired power generation are provided in Table 2. The generation capacity of a coal-fired power plant is assumed at 700 MW, and its capacity factor (utilization rate) is estimated at 70%, considering that most coal-fired power plants are used as base-load generation. The price of coal is set at $44/ton based on the IEA (2021), assuming the coal used is domestic.

Table 2 Assumptions for coal-fired power plant

Item	Assumptions
Generation capacity	700MW
Capacity factor	70%
Operational lifetime	40 years
Heat efficiency	45.7% (LHV)
Heat value of coal	24.8 MJ/kg (LHV)
Price of coal	44 $/ton
Internal use rate	5%
CO_2 intensity of coal	93.7 g-CO_2/MJ

Source: IEA (2021); Advisory Committee for Natural Resources and Energy (2022); Agency of Natural Resources and Energy (2020)

Assumptions for clean ammonia co-firing operation are shown in Table 3. Since ammonia co-firing has not been commercialized yet, the assumptions refer to relevant literature. The number of additional investments required for 20% and 50% co-firing are estimated with reference to the study by J-Power (2018). Both coal and fuel ammonia prices are assumed based on IEA (2021).

Table 3 Assumptions for coal-fired power plant

Item	Assumptions
Capital expenditures for co-firing facilities	US$ 224 million for 20% co-firing; US$ 337 million for additional 30% co-firing
Price of fuel ammonia	317.5 $/t-NH3
Heat value of ammonia	14.1 MJ-Nm3 (LHV)
CO_2 intensity of ammonia	0 g-CO_2/MJ

Source: J-Power (2018); International Energy Agency (2021)

(3) Assumptions for solar and battery

This paper assumes that solar power will be the alternative power source for the early retirement program of coal-fired power generation. This is because the generation cost of solar is more competitive, and most of the existing coal power plants are being operated on land where the replacement of solar power generation is more easily done. The capacity for the solar power is calculated based on the electricity generated by the replaced coal fired power generation plus the required power generation for battery transactions. Since coal-fired power generation is used as a baseload power source in Southeast Asia, it is assumed that coal-fired power generation will not be simply replaced by solar power generation units alone but will accompany storage batteries. While coal-fired power generation is capable to supply very stable power generation if sufficient fuel is available, solar power generation is inevitably intermittent by its nature, and it is necessary to install enough storage batteries to stabilize the intermittent power generation. Based on this approach, we assumed that the storage batteries would be used for 12 hours, half of the day, and that the combined efficiency of charge and discharge would be 81%. We assumed the construction cost of large storage batteries to be the one mentioned in the New Energy and Industrial Technology Development Organization (2013), as there is no commercialized case for large storage batteries combined with intermittent renewable power generation sources.

Table 4 Assumptions for solar and battery installation

Item	Assumptions
Capacity factor of solar	17.2%
Required capacity solar	3.0GW
CAPEX of solar	1,600 $/kW
Operational lifetime for solar	25 years
Compensation for battery	12 hours per day
Required battery capacity	36GWh
Battery cost	US$ 177/kWh (including PCS)
Efficiency of battery transactions	81%
Annual operating expenses of battery	2% of investment
Operational lifetime of battery	25 years
Land requirement for solar	0.86MW/ha (0.35MW/acre)

Source: New Energy and Industrial Technology Development Organization (2013); International Energy Agency (2021); Bolinger and Bolinger (2022)

4. Results

(1) CO_2 emissions reduction

The volume of CO_2 emissions reduction of the NH3-Base case is more than twice as large as the one of the ETM-Base scenario. This is because, in the ETM-Base scenario, coal-fired power generation will continue to be used for the next 25 years until the switch to solar power generation. The emissions of ETM-Base case will inevitably be larger than those of NH3-Base scenario, where the switch to clean ammonia co-firing will be made gradually from the sixth year of the assumed period. In the NH3-50 scenario, the blending rate is increased to 50% from the sixth year, resulting in the larger emissions reduction than in NH3-Base case. Given the cumulative nature of CO_2 (Rhys 2011), if emissions reduction is the most prioritized goal, it is clearly preferable to start ammonia co-firing as early as possible rather than to support early retirement of coal-fired power plants at a later point in time.

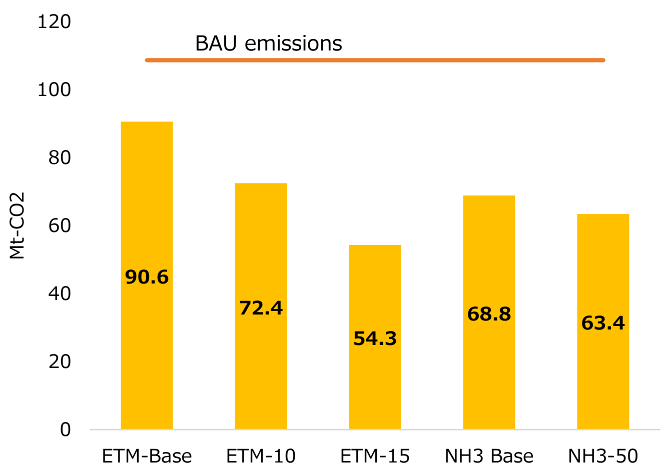

Figure 4 CO_2 emissions of each scenario

Source: IEEJ

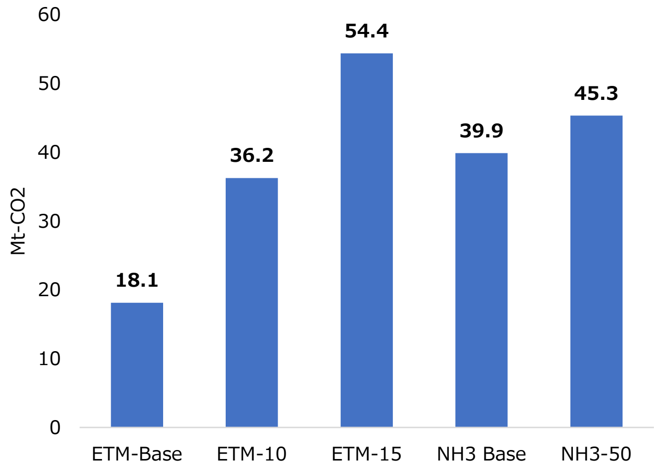

Figure 5 CO_2 emissions reduction of each scenario

Source: IEEJ

(2) Generation costs

In terms of generation costs, NH3-Base case provides slightly lower cost than ETM-Base case. This is because the overall capital cost of NH3 case is lower than the cost of ETM-Base although its fuel cost is much higher. In the comparison with ETM-10 and ETM-15 cases, which speed up the early retirement process, their generation costs tend to be higher than that of ETM-Base case because of the earlier timing of investments in solar and storage batteries.

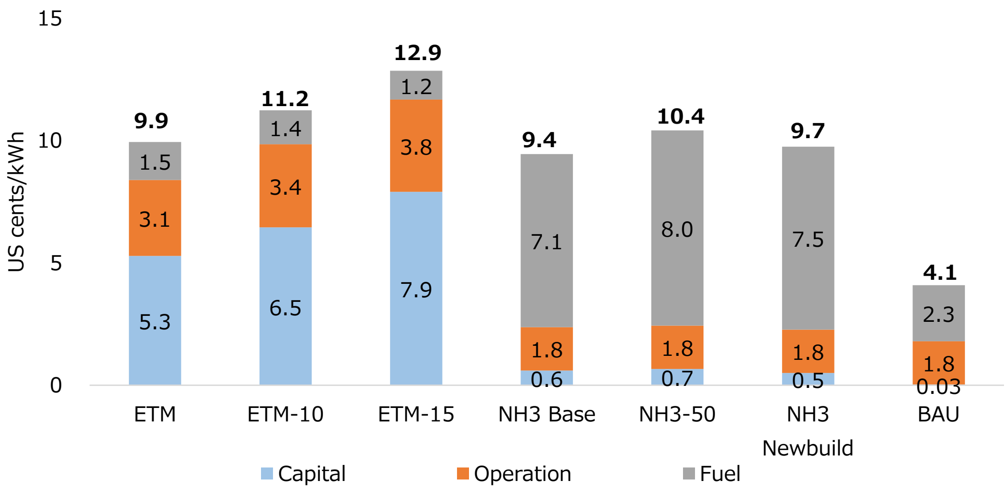

Figure 6 Generation cost of each scenario

Remarks: The initial investment for coal power plant is not included.

Source: IEEJ

(3) Land requirements

Replacing the 700 MW of coal-fired power plants that operate at 70% capacity factor with solar power panels requires a substantial area of land. Based on the analysis of Bolinger and Bolinger (2022) that reflects the latest efficiency improvements of solar PV power generation, the required land for the replacement of 700 MW coal-fired power plant is calculated as 3,478 hectares. It should be noted that not all of the coal-fired power plants have this size of substantial land nearby. If additional land needs to be procured for the replacement, additional acquisition costs (if required) must also be considered when converting from coal-fired to solar power.

5. Conclusions

It is clear that CO_2 emissions need to be reduced as much as possible at the earliest possible time to avoid the catastrophic effects of climate change. On the other hand, many coal-fired power plants in Southeast Asia are still new, and many more are still under construction. Because the electricity demand in Southeast Asia is certain to grow significantly in the future, early retirement of these relatively new coal-fired power plants in the near future is not a realistic option neither in terms of the requirement of power generation capacity to meet the growing demand, nor in regards to the recovery of the investment. To solve this dilemma, the study found that in addition to accelerating the adoption of renewable energy sources, co-firing of clean ammonia at existing coal-fired power generation units will be an effective option.

Because this paper is still a preliminary attempt to examine the validity of ammonia co-firing option, the study left several important issues for future research. First, it is necessary to update the investment amount for facilities that have not yet been fully commercialized, such as ammonia co-firing and large-scale storage batteries juxtaposed to solar power generation. Second, it is also needed to examine the impact of the global high prices of resources after 2022. While coal and natural gas prices have continued to soar as of August 2022, the price of mineral resources used for photovoltaic power generation have also risen in recent years. Such increase of resource prices may contribute with different implications to the comparison of ETM and NH3 cases depending on the relative impacts on each resource market. Third, the feasibility of the substitution of coal power plants with solar energy and batteries needs to be examined in regard to each specific coal power plant. This paper was conducted under the assumption that solar power can fully substitute coal-fired power generation if storage batteries are installed. Yet, in some locations that do not have sufficient land for such solar power plants, investment for additional power grid or land acquisition would be required, and such additional investment would have a negative impact on the feasibility and economics of the solar and batteries option. Hence, a detailed analysis should consider the specific conditions of each coal-fired power plant in each country.

This paper shows that ammonia co-firing for existing and under-construction coal-fired power plants can be an effective decarbonization option for the future, but its conclusions need to be further elaborated and refined in future studies, including the above-mentioned research agenda.

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3) Bolinger, M., and G. Bolinger. 2022. "Land Requirements for Utility-Scale PV: An Empirical Update on Power and Energy Density." IEEE Journal of Photovoltaics, vol. 12, no. 2, pp. 589-594. March 2022.

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7) Rhys, John. 2011. "Cumulative Carbon Emissions and Climate Change." The Oxford Institute of Energy Studies. July 2011. (https://a9w7k6q9.stackpathcdn.com/wpcms/wp-content/uploads/2011/07/EV-571.pdf) Accessed on August 15, 2022.

Car sharing and EVs

Mitsuaki Ota [*]

1. Introduction

The number of car sharing services has been increasing in recent years. While the majority of cars offered by such services are currently gasoline or hybrid vehicles, electric vehicles (EVs) are also slowly being introduced. The weaknesses of EVs, such as shorter range and long recharging times are less of a problem for car sharing because the vehicles can be recharged while not in use. Car sharing also makes the EVs more accessible to users by removing the high cost of purchase. Furthermore, expected uses for EVs when they are not being driven include use as storage batteries for energy management and as part of business continuity plans (BCP[1]) during disasters.

2. What is car sharing?

Car sharing refers to a service in which multiple cars are shared among the members registered with the service. They are similar to car rental services in that the cars are lent out, but the fees and procedures required differ. (Table 1)

Table 1 Comparison between car sharing and car rental

		Car sharing	Car rental
Fees	Basic monthly fee	Yes (sometimes none)	None
	Fee unit	By minute	By hour
	Distance fee	Yes (after 6 hours)	None
	Gasoline fee	None	Yes *Return w/ full tank
	Insurance	Included	Optional
Procedures	Member registration	Yes	None
	Counter application	None	Yes
	Lending hours	24h	Business hours only
	Cancel fee	Free until reservation start	Incurred days in advance
	Drop-off service	No	Yes

Source: Data compiled from various websites

With regard to fees, car sharing services allow cars to be borrowed in units of 15 minutes, and the fees include the cost of gasoline, insurance, and other costs. In comparison, car rental services lend the cards for longer periods, such as six hours, and the cost of gasoline, insurance, and other expenses is charged separately. Accordingly, car sharing services are less expensive for shorter periods of time, or for short distances over longer periods of time, while care rentals tend to be cheaper for longer periods of time or longer distances. But considering that the costs of gasoline and insurance are not incurred, car sharing may also be cheaper for longer distances as well. With regard to the paperwork required, the lending procedure for car sharing services may be completed online once you have registered as a member. Cars can be borrowed for up to 24 hours, and there are no cancellation fees until the start of the reservation period. Car rental services do not require membership registration, but instead require paperwork to be filled out at the shop. The cars must be returned during business hours, and cancellation fees are incurred for cancellations days before the reservation period. However, whereas car share services require the cars to be returned where they were borrowed, car rental services offer drop off services where the car can be returned to a different branch of the service.

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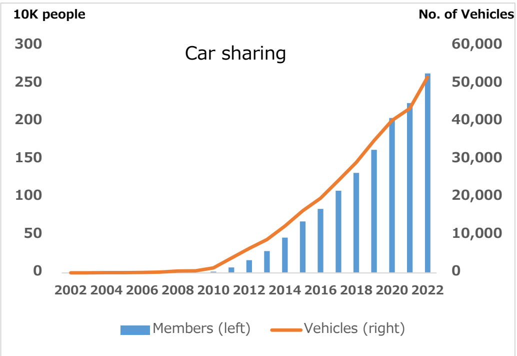
[1] Companies and organizations typically prepare business continuity plans (BCP) for emergency situations such as disasters.

To review the above points, car sharing services have the advantage in terms of short rental periods, short distances, and ease of rental procedures, while car rental services have the advantage in terms of long rental periods and use over different routes coming and going.

3. Domestic Car Sharing Market Trends

According to the Foundation for Promoting Personal Mobility and Ecological Transportation (the Eco-Mo Foundation), car sharing services in Japan had reached a level of approximately 2.636 million members and 52,000 vehicles as of March 2022. In comparison, car rental services, with their longer history, included approximately 490,000 vehicles (passenger cars[2]) as of March 2022, representing a larger market. Meanwhile, in terms of market growth, car sharing services grew significantly by approximately 36 times in terms of members and 13.2 times in terms of vehicles between 2011 and 2022, whereas the number of vehicles for car rental services grew slowly by approximately 2.3 times between 2009 and 2022. One of the possible reasons behind the rapid growth in car sharing services is the global emergence of the sharing economy from the 2010s, under which individuals and companies began lending their unused assets via the Internet for exchange or use by other individuals, which also garnered attention in the automobile industry.



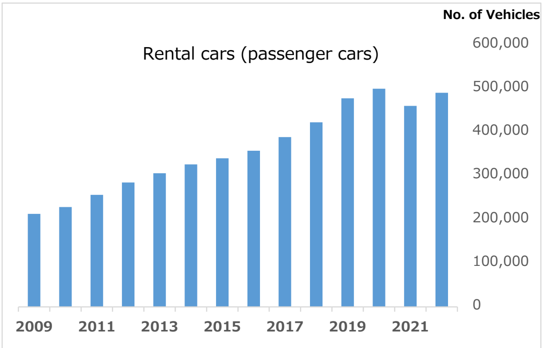


Figure 1: (Left) Changes in car sharing members and vehicles in Japan. (Right) Changes in car rental vehicles in Japan.

Sources: (Left) Prepared based on Changes in Car Sharing Vehicles and Members in Japan, the Foundation for Promoting Personal Mobility and Ecological Transportation. (Right) Prepared based on Changes in Rental Vehicles per Type, the All Japan Rent-A-Car Association.

The car sharing market is predicted to continue to expand, with a 2020 survey by Fuji Keizai forecasting an increase in vehicles to 320,000 by 2030. Furthermore, while roughly 70% of users in the current market are private individuals, car sharing operators are aggressively pushing corporate sales, and corporate customers are expected to exceed 40% by 2030. There is also high demand for car sharing as a mobility solution for daily living, such as shopping or commuting to work or school, and many car sharing stations are installed near major train stations and parking areas near populated residential areas. Convenience stores are also attracting attention as possible car sharing stations due to the number of people that gather there.

To find out which specific consumers are utilizing car sharing services, we will examine a member survey[3] conducted by Careco Car Sharing, one of the leading car sharing services, in 2017. The survey asked the 5,959 members at the time for information on their (1) gender and age, (2) living situation, (3) family structure, and (4) household income. The results showed that in terms of (1) gender and age, men in their 30s comprised 27.0%, men in their 40s comprised 21.8%, men in their 20s comprised 15.9% and men in their 60s comprised 9.6%, while women in their 30s comprised 8.0%, women in their 40s comprised 7.2%, and women in their 20s comprised 3.8%, showing that many men in their 20s through 40s used

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[2] While car rental services also cover categories other than passenger cars, such as trucks and microbuses, car sharing services primarily lend passenger cars, so that is what we will focus on here.

[3] Notification of Member Survey Results 2016, Careco
https://www.careco.jp/wp/wp-content/themes/careco/images/page/news170612.pdf

the service. The breakdown of (2) living situation was 46.7% living in rented apartments, 35.6 living in owned apartments, 13.0% living in owned detached houses, and 3.0% living in rented detached houses, showing that many apartment dwellers used the service. The breakdown for (3) family structure was 41.9% with cohabitant children, 24.9% single, 21.4% couples only, and 8.1% living with parents, showing high usage among families with children in addition to singles and couples. The breakdown of (4) household income was 24.9% between 5 and 7.5 million yen, 21.8% between 7.5 and 10 million yen, 20.4% under 5 million yen, 16.9% between 10 and 15 million Yen, and 8.4% over 15 million yen, also showing usage by high income households over 10 million yen. Next, we will look at the number of vehicles[4] per prefecture for the top five car sharing services (Times Car, Careco, Orix CarShare, Cariteco, and Honda EveryGo) to see where the cars are being used. The breakdown by prefecture of car share vehicles as of December 2022 was 40.7% in Tokyo, 12.4% in Osaka, 11.5% in Kanagawa, 4.7% in Hyogo, 4.6% in Saitama, 4.4% in Chiba, and 4.2% in Aichi, showing that the majority are being used in major metropolitan areas.

4. Domestic Car Sharing Operator Trends

Next we will compare the trends of car sharing operators. The top domestic positions in terms of vehicles and members are occupied by operators that launched their services in the 2000s (Table 2). The top three companies that began in the 2000s, namely Times Mobility, ORIX Auto Corporation, and Mitsubishi Fudosan Realty, comprise 94% of all members and 87% of all vehicles. While some of these operators offer EVs, the vast majority are existing gasoline and hybrid cars. For example, Times Mobility, occupying the top place in terms of vehicles, had only adopted 99 EVs as of October 2021[5], suggesting it is cautious about investing in EVs before they are fully adopted.

Beginning in the late 2010s, the number of car sharing services operated by automobile manufacturers began to rise, such as E-Share Mobi by Nissan Car Rental Solutions (launched 2018) and Toyota Share by the Toyota Motor Corporation (launched 2019). These operators differ significantly from existing car share operators in that they offer their own vehicle models (including EVs.)

The Toyota Motor Corporation had already been operating a sharing service called Ha:mo RIDE using their own ultra-mini-EV COMS vehicles. This service was tested beginning in 2012, and launched in 2016. Car sharing stations were installed at locations throughout Toyota City, including train stations, event facilities, and convenience stores, to cover the last mile of commuter travel in support of public transportation services. The service was ended at the end of 2021 and is currently offered as part of Toyota Share. Launched in 2019, Toyota Share offers gasoline and hybrid vehicles for use throughout Japan, but recently, EVs have also been added to the lineup, such as the mass produced bZ4X and the ultra-mini C+pod EV for two. Furthermore, an ongoing one year proving test using the C+pod was launched in Toyota City in February 2023, and expectations are for a service that will cover the last mile of transportation needs like the Ha:mo RIDE.

E-Share Mobi, launched by Nissan Car Rental Solutions in 2018, offers only the EVs from the Nissan lineup, such as the Nissan Leaf and the Note e-power. Initially launched only within Kanagawa and Tokyo prefectures, the service uses a pricing scheme similar to their competitors, and garnered attention as an easy way to experience driving EVs. It has currently expanded coverage throughout Japan. It was announced in November 2021 that the service would be added to d Car Share®, a service provided by NTT Docomo that combines access to multiple car sharing and car rental services. This addition makes it possible to search for e-Share Mobi stations using d Car Share, which is expected to lead to a further increase in members.

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[4] 360° Car Sharing Comparison, Car Sharing Market Trends Q4 2022: Top 5 Services, https://www.carsharing360.com/market/quarter/

[5] "Times Parking and Car Sharing Business, Slow EV Adoption - Popularity a Bottleneck", Bloomberg https://www.bloomberg.co.jp/news/articles/2022-03-15/R8I410DWX2PS01

Table 1 Overview of leading car sharing operators (as of March 2022)

No.	Operator	Service name	Launched	Region	Vehicles	Members (10K people)
1	Times Mobility Co., Ltd.	Times Car	2005/2	National	**36,855**	**181.3**
2	ORIX Auto Corporation	ORIX CarShare	2002/4	29 prefectures	**2,591**	**34.6**
3	Mitsui Fudosan Realty Co., Ltd.	Careco Car Sharing	2009/1	15 prefectures	**5,735**	**32.2**
4	Toyota Motor Corporation	**Toyota Share**	2019/11	42 prefectures	713	4.7
5	Meitetsu Kyosho Co., Ltd.	Meitetsu Kyosho Car Share Cariteco	2009/11	7 prefectures	492	3.9
6	Nissan Car Rental Solutions Co., Ltd.	**E-Share Mobi**	2018/4	National	270	2.5
7	Earthcar Co., Ltd.	Earthcar	2011/3	National	192	2.2
8	Nishio Rent All Co., Ltd.	Mobi-system	2008/10	National	4,200	0.9
9	Nippon Car Service Development Co., Ltd.	Ecoloca	2008/7	Tokyo, Osaka, etc.	400	0.6
10	Adachi Industry Corporation	Car Share TOP24	2012/9	Nagasaki	13	0.2

Source: Compiled from the National List of Car Sharing Case Studies, Foundation for Promoting Personal Mobility and Ecological Transportation.

5. Entrance into the Car Sharing Market by Energy Companies

Following after automakers, energy related companies, such as oil and electric companies, have been entering the car sharing market in recent years, and these entrants are notable for offering EVs. And while many of these only operate in specific areas, a difference in services compared to existing car sharing operators is emerging.

There are two notable characteristics of the services offered by oil companies (Table 3). The first is a focus on small sized EVs. Idemitsu Kosan is manufacturing ultra-mini low-spec EVs and carrying out proving tests in areas where public transportation infrastructure is weak, such as the mountainous areas that auto makers have not yet developed. The proving tests, carried out in Takayama City, Gifu Prefecture, and Tateyama City, Chiba Prefecture, have demonstrated a demand for the mini-EV among the elderly and individuals with limited driving experience, and among companies requiring easy-to-operate highly maneuverable vehicles for sales activities. Based on the tests, the company announced in April 2021 the establishment of a new company called Idemitsu Tajima EV to develop next generation mobility services, such as ultra-mini EVs, in collaboration with Tajima Motor. The announcement mentioned the establishment of service stations by the company in 2022 to sell mini EVs and for use by their sharing service. ENEOS has also launched a mini-EV sharing service in urban centers such as Omiya Station, Saitama-Shintoshin Station, and Shin Yokohama Station. Rather than developing their own EVs, they have become the first in the country to adopt the FOMM ONE, the world's smallest class of EV developed by R&D-oriented mini-EV manufacturer FOMM, for the purpose of car sharing. Their operations in Saitama City include not only mini EVs, but also the sharing of electric bicycles and scooters.

The second notable characteristic of these market entries is the use of existing service stations. Beginning in April 2021, the Cosmo Oil has been operating an EV car sharing and quick charger service at their service stations in Shinjuku City. The company has also entered into a joint agreement with e-Mobility Power, a joint venture established in June 2020 by TEPCO and Chubu Electric Power, to use the quick chargers provided by e-Mobility Power. Meanwhile, the electricity for the service is provided from the CO_2 free source of wind power by their subsidiary Cosmo Eco Power. In May 2021, ENEOS announced the creation of new services, including car sharing, and expansion of their EV charging network in collaboration with NEC, using their approximately 13,000 service stations throughout Japan, and in June 2022, they concluded a contract with NEC to acquire the EV charging network they operate. One possible reason for this entry into the car sharing market by oil companies is the decline in the number of service stations nationwide. According to the Agency for Natural Resources and Energy, the number of service stations declined from a peak of 60,421 in 1994 to 28,475 in 2021. Therefore, they are likely to enter the EV sharing business and related businesses as new business strategy or growth strategy for their service station networks.

Table 1 Entry into the car sharing market by oil companies

No.	Company	Launched	Region	Services	Customers
1	Idemitsu Kosan	2019/8 -2022/3	Takayama, Gifu Prefecture	• Mini EV sharing	• General public • Companies
		2020/4	Tateyama, Chiba Prefecture		
		2021/4	Ichihara, Chiba		
2	ENEOS	2021/3	Omiya Station, Saitama Saitama-Shintoshin, Saitama	• Mini EV sharing • Electric bicycle and scooter sharing	• General public
		2021/5	National	Services focused on service stations: • Expansion of EV charging network • Creation of new services through EV charging networks	• Companies • General public
		2021/12	Kohoku Ward, Yokohama, Kanagawa Prefecture	• Mini EV Sharing	• General public
3	Cosmo Oil	2021/4	Shinjuku, Tokyo	• EV sharing at service stations • Charging service with quick chargers at service stations	• General public

Source: Prepared based on press releases from each company

Meanwhile, the notable characteristics of services launched by electric companies differ depending on whether their target users of either corporations and organizations (including local governments) or the general public. One characteristic of corporate oriented services is that rather than providing a single EV car sharing service, they combine it with a variety of other services according to the customer's needs. Specifically, there are three such services commonly provided (Table 4)

The first of those is energy management. Four separate companies (Rexev, Kansai Electric Power, Shikoku Electric Power, and Chugoku Electric Power) are providing services to promote efficient energy use. In addition to EV car sharing, they also provide services for charge controlling to avoid peak electrical demand periods at EV adopting facilities, to make effective use of excess solar power to charge EVs, to control electricity demand using excess EV battery charge, and BCP measures to provide electricity during power outages.

The second service is the leasing of EVs and charger/discharger. Kansai Electric Power provides a leasing service for EVs and charger/discharger, as well as an EV charge/discharge control system, for use as a BCP measure during power outages and for energy management at business locations. Shikoku Electric Power also provides a service that offers CO_2 free electricity equivalent to the charged EV amount at customer request, in addition to their EV lease service.

The third service is the provision of regular and quick chargers as a sharing service. From November 2021 through January 2022, TEPCO carried out a rapid charger sharing service proving test for corporate customers in Numazu City. This proving test provided 100% carbon free electricity from renewable sources and utilized dynamic pricing, where the electricity prices are relatively low during time periods of low wholesale electricity price and periods when there were fewer users, such as nighttime and weekends. Meanwhile, Kansai Electric Power conducted a proving test of a regular and quick charger sharing service for their partner companies located in Osaka from February through late March 2023.

There are also companies providing local production and consumption services of renewable energy and support services for EV adoption. Rexev, a company established in 2019 to focus on e-mobility, launched an EV sharing service in Odawara City and Hakone Town that maximizes the use of locally generated renewable power in cooperation with the Odawara City government and local power producer and supplier Shonan Power. Chugoku Electric Power is offering a service that provides such services as company car reservation, visualization of creation and management of daily driving reports, optimized vehicle management, and data analysis of vehicle utilization to propose the ideal number of vehicles to operate.

Table 2 Entry into the car sharing market by power companies (for companies)

No.	Company	Launched	Region	Services	Customers
1	REXEV	2020/6	Odawara, Kanagawa Prefecture Hakone, Kanagawa Prefecture	• EV Sharing • (1) Energy management • Local production and consumption of renewable energy	• Companies • Local governments • General public
2	Kansai Electric Power	2020/7	Kansai	• EV Sharing • (1) Energy management • (2) Leasing of EVs, and charger/discharger, etc.	• Companies
		2022/2	Osaka	• (3) Sharing of quick and regular chargers	• Companies
3	Shikoku Electric Power	2020/10	Shikoku	• EV Sharing • (1) Energy management • (2) Leasing of EVs and chargers	• Companies • Local governments
		2022/9	Shikoku	• (3) Sharing of regular chargers	• Companies • Local governments • General public (apartments)
5	REXEV Sumitomo Corporation Nippon Gas	2021/3-2022/2	Kagoshima, Kagoshima Prefecture	• EV Sharing • (1) Energy management	• Companies
7	Chugoku Electric Power	2021/8	National	• EV Sharing • (1) Energy management • EV adoption support	• Companies • Local governments • General public (apartments)
8	TEPCO	2020/10	Numazu, Shizuoka Prefecture	• EV Sharing	• Companies
		2021/1	Numazu, Shizuoka Prefecture	• (3) Sharing of quick chargers	• Companies

Source: Prepared based on press releases from each company

Notable services for the general public are services geared towards apartment dwellers, in addition to the aforementioned local production and consumption of renewable energy and EV adoption support. Compared to detached homeowners, the cost of vehicle ownership is higher for apartment dwellers due to the additional parking costs, suggesting a stronger need to use EV car sharing. The weev service offered by Kyushu Electric Power, originally launched only in Kyushu and Tokyo, has begun extending their service throughout Japan through a joint business contract in May 2022 with Seibii, a company offering on-site auto maintenance and repair services. This service is particularly notable for offering foreign vehicles such as the Tesla Model 3 and the Hyundai Ioniq 5. Meanwhile, Shikoku Electric Power was the first to introduce regular charger sharing in the Shikoku area given the delay in introducing charging infrastructure to housing complexes.

Table 3 Entry into the car sharing market by power companies (for the general public)

No.	Company	Launched	Region	Services	Customers
1	REXEV	2020/6	Odawara, Kanagawa Prefecture Hakone, Kanagawa Prefecture	• EV Sharing • Local production and consumption of renewable energy	• General public • Companies • Municipalities
2	Kyushu Electric Power	2020/12	National	• EV Sharing	• General public (apartments)
3	Chugoku Electric Power	2021/8	National	• EV Sharing • EV adoption support	• General public (apartments) • Companies • Municipalities
4	Shikoku Electric Power	2022/9	Shikoku	• Sharing of regular chargers	• General public (apartments) • Companies • Municipalities

Source: Prepared based on press releases from each company

6. Challenges to EV popularity and EV sharing

Numerous challenges have been raised in the past regarding the popularity of EVs. Here we will list four of those. The first is that EVs are typically higher priced than traditional gasoline or hybrid vehicles. While gasoline driven compact cars start at around 1.5 million yen, and hybrids start at 2 million yen, EVs start at 2.4 million yen for mini car models, and around 3.7 million yen for full sized passenger cars. The second is their short driving range (the distance they can travel on a single full charge). The current average driving range for EVs is between 300 and 500 km, far short of the average range of 600 to 1,500 km for gasoline vehicles. The third is the amount of time it takes to charge them. It takes more than 10 hours to fully charge an EV using a regular charger, and about 30 minutes using a quick charger, compared to the several minutes it takes to fill the tank of a gasoline vehicle. The fourth challenge is the shortage of charging stations. Compared to the approximately 28,475 gas stations operating in Japan as of the end of March 2022 (according to the Ministry of Economy, Trade and Industry), the number of regular charging stations was only 21,198 (according to Zenrin) for the same time period, while the number of quick charging stations was even lower at 8,265 (also Zenrin).

To address these issues, one likely effective method is to deepen the understanding of users for EVs through sharing services. With regard to the first challenge, sharing services obviously eliminate the cost of purchasing the vehicle. The only costs incurred are the monthly membership as well as time and distance fees. Time based fees are typically set at around 200 yen for every 15 minutes. Distance fees are typically charged per kilometer. There are also numerous plans currently available that do not require a monthly membership or distance fees. Furthermore, many services allow vehicle reservations online, meaning that the cars can be accessed easily when needed. The second challenge, driving range, is less of an issue when using the car sharing for daily needs, rather than for long distances. According to a user survey conducted by Times before the Covid-19 pandemic in 2018[6], car sharing is more commonly utilized for such purposes as shopping, leisure driving, picking up and dropping off family or friends, and carrying items, rather than for long distances such as vacation or travel. Car sharing also eliminates the third challenge, long charging times, because the cars are already fully charged by the time the user makes use of them. Meanwhile, when recharging mid journey is required, such as for long distance travel, quick charge stations are available around the country, such as those provided by Nissan e-Share Mobi. And the cost to use those chargers is low because fees are often included in the car sharing plan. The fourth challenge regarding the number of charging stations is less of a problem when the car sharing service is used for short distances. However, in the event that charging is required when using the vehicle for short distances, then car sharing services need quick chargers rather than normal chargers. As mentioned above, the installation of quick chargers has not progressed as much as normal chargers. However, expectations for further infrastructure are increasing, with the government announcing a goal in June 2021 to reach an installed base of 30,000 units by 2030, similar to the number of gas stations available.

7. Conclusions

The momentum towards a transition to EVs is expected to continue to accelerate to achieve carbon neutrality by 2050. Domestic automakers have announced aggressive strategies, with Toyota adopting 3.5 million EVs by 2030, Nissan shifting new vehicles sold in primary global markets to EVs and HVs in the early 2030s, and Honda shifting all new vehicles sold globally to EVs and FCVs by 2040. However, according to statistics from the Japan Automobile Dealers Association, EVs account for only about 1.4% of new vehicle sales in Japan, though the surpassed 1% for the first time in 2022.

Issues behind that low number include the high price of EVs, their limited range, long charging times and the shortage of charging stations. On the other hand, the number of car sharing service memberships is growing significantly, as stated in this text, and services focusing on EVs have been launched by automakers and energy companies alike. Therefore, using car sharing services to deepen the understanding of EVs among users is likely an effective way to accelerate the adoption of EVs.

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Recent Developments in Methane Emissions Management in the World and Japan

Seiya Matsukura*, Hiroshi Hashimoto**

1. Introduction

Companies involved in the natural gas and oil value-chains around the world are making efforts to reduce greenhouse gas (GHG) emissions in order to realize a decarbonized society. Until now, carbon dioxide (CO_2) has been the main GHG under international frameworks, but in recent years, methane (CH_4) has entered a new phase with the spread of similar initiatives. In the case of liquefied natural gas (LNG), of which Japan is the world's largest importer, methodologies for MRV (Measurement, Reporting and Verification) of methane emissions in the value chain of upstream development, transportation, and consumption have already been discussed worldwide. One of the reasons for the growing interest in methane emission management is the relatively high greenhouse effect of CH_4 compared to CO_2, which is 28 times greater over 100 years and 84 times greater over 20 years. In addition, compared to CH_4 emissions from agricultural and other sources, those from energy sources are considered to have greater room for effective control. Against this background, the United States is already pursuing policies to curb CH_4 emissions, and Europe is also moving forward with the standardization of MRV based on the EU Methane Strategy, which was announced in October 2020. In November 2021, more than 100 countries joined the Global Methane Pledge (GMP) initiative to reduce CH_4 emissions collectively by 30% from 2020 levels by 2030 at COP26 hosted by the United Kingdom, and the initiative's signatory base was expanded to more than 150 countries by the time of COP27 hosted by Egypt in November 2022. This paper introduces the current status and initiatives for CH_4 emissions management, which is rapidly expanding around the world, and summarizes measures and issues for Japan.

2. Global Methane Emissions

This chapter analyzes the reported methane emissions calculated by national governments and estimated data compiled by different research institutions to summarize the global methane emissions situation.

2.1. IPCC (Intergovernmental Panel on Climate Change)

The IPCC is an intergovernmental organization established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), and is currently participated by 195 countries and regions. The IPCC evaluates the latest scientific findings on climate change and produces two types of reports: periodic reports and thematic special reports. Regular IPCC reports have been produced every five to eight years, beginning with the First Assessment Report (FAR) in 1990, and the Sixth Assessment Report (AR6) synthesis report was released in March 2023. These IPCC reports are cited by policymakers around the world and serve as the basis for international negotiations, including the United Nations Framework Convention on Climate Change (UNFCCC), and for domestic policies.

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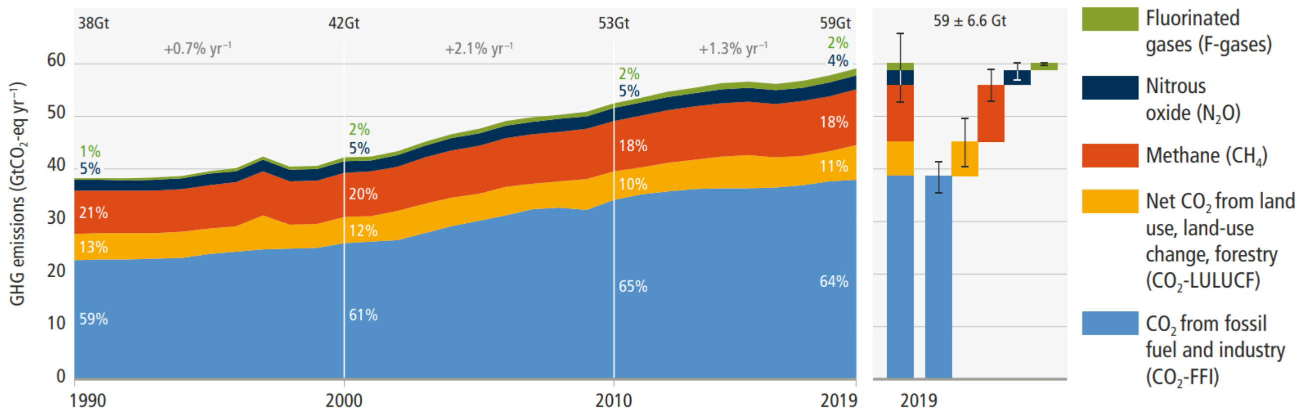

Figure 1：Global Net Anthropogenic GHG Emissions (1990-2019)

Source: IPCC Sixth Assessment Report (WG III) (2022)

The IPCC Sixth Assessment Report (WG I), published in August 2021, assessed that "there is no doubt that the increases in atmospheric CO_2, CH_4, and N_2O since the pre-industrial era have been caused by human activities." The report also states that the composition of global GHG emissions in 2019 will consist of 75% CO_2 (64% of which is from fossil fuels), 18% CH_4, 4% N_2O , and the remainder 2% CFCs (fluorinated gases) and others. Among them, CH_4 concentrations increased at an average rate of 7.6 ± 2.7 ppb (1 ppb = 1 mg / 103 kg)/year during the last decade (2010-2019), but accelerated to 9.3 ± 2.4 ppb/year during the last 6 years (2014-2019), with the dominant source being from human activities. In particular, since 2007, fossil fuels and agriculture (mostly from livestock) were considered the main contributors.

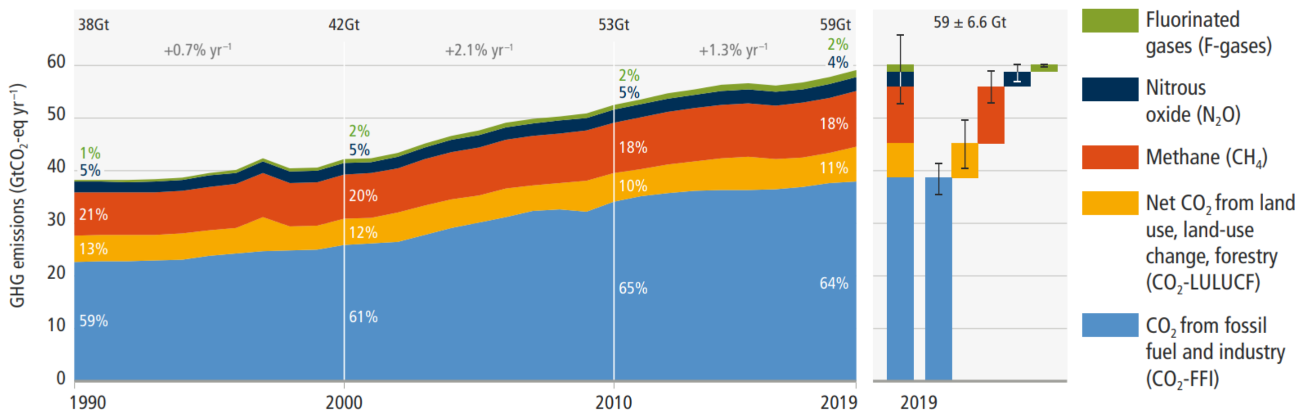

Figure 2: Global Net Anthropogenic GHG Emissions (1990-2019)

Source: IPCC Sixth Assessment Report (WG III) (2022)

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2.2. IEA (International Energy Agency)

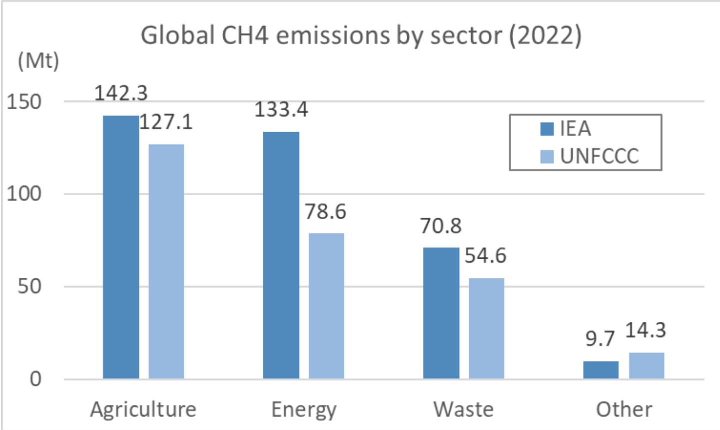

Figure 3: Differences in Global Methane Emissions data (IEA vs. UNFCCC) (2022)

Source: Compiled from IEA Methane Tracker 2023

According to the International Energy Agency's (IEA) Global Methane Tracker 2023, released in February 2023, the overall CH_4 emissions are larger than officially reported by governments such as the UNFCCC, suggesting that there is significant room for improvement in the respective aggregation methods. In particular, the tracker claims, methane emissions from the energy sector are 70% larger than officially reported values, and industry efforts such as reflecting actual measurement results in emission factors are expected in the future.

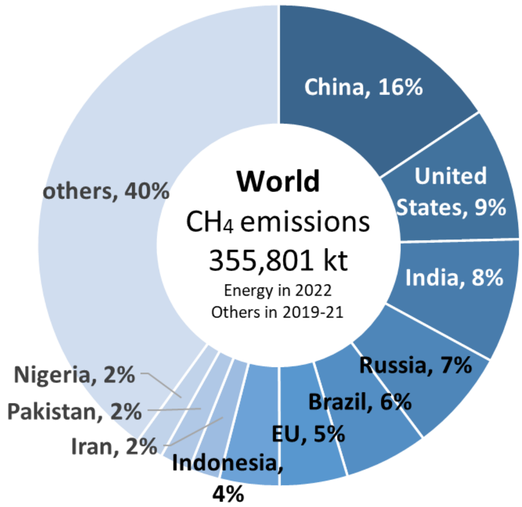

Figure 4: Global Methane Emissions (Share by Country) (2022)

Source: Compiled from IEA Methane Tracker 2023

According to the tracker, global methane emissions were estimated at 355.8 million tonnes in 2022, down 0.3% from 356.89 million tonnes the previous year. The largest emitter by country was China with 55.68 million tonnes (16% share), followed by the United States with 31.84 million tonnes (9%), and India with 29.67 million tonnes (8%). The tracker estimates Japan's emissions in the year as 1.54 million tonnes (0.4% share).

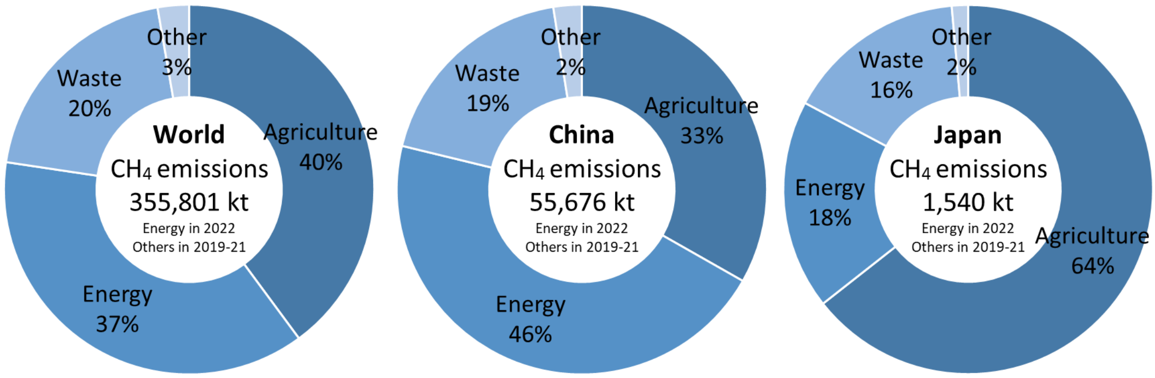

Figure 5: CH_4 emissions by Country (World, China, Japan) (2022)

Source: Compiled from IEA Methane Tracker 2023

According to the IEA, the largest source of CH_4 emissions in the world is agriculture at 40%, followed by 37% from energy, 20% from waste, and 3% from other sources. However, the areas of focus vary depending on the situation in each country, with 46% coming from energy in China and 64% from agriculture in Japan.

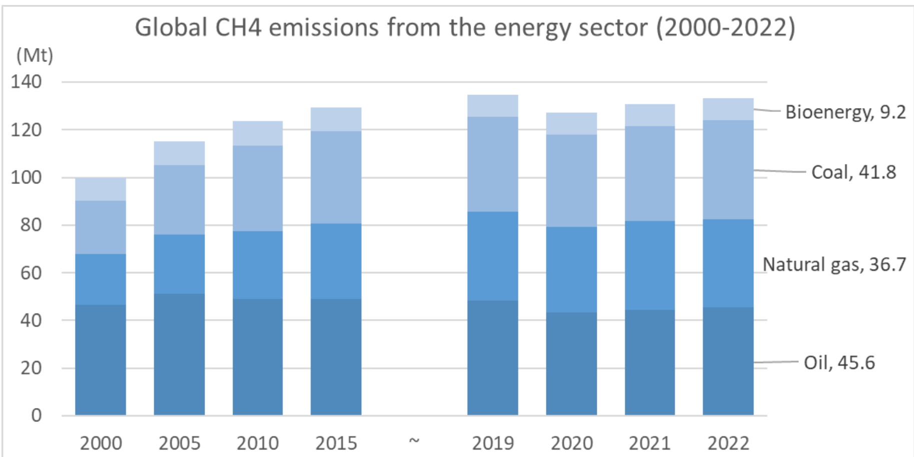

Figure 6: Global CH_4 emissions from the energy sector (2000-2022)

Source: Compiled from IEA Methane Tracker 2023

According to the IEA, methane emissions from the energy sector totaled 133.3 million tonnes in 2022, up 2% from 130.9 million tonnes the previous year, but down from a record high of 134.7 million tonnes in 2019. Over the last 10 years, its emissions have remained largely unchanged, suggesting that countries' efforts to reduce emissions may have been partially successful.

3. Global Trends in Methane Emissions Management

This chapter describes policy trends in each country, with a focus on the United States and Europe, which are leading the way in methane emissions management. It also summarizes trends in the OGMP 2.0, a natural gas and oil industry-led leading methane emissions MRV framework, and its supervising body, IMEO, and the GMP, which aims to reduce overall global methane emissions.

3.1. Trends in the United States

During the period of the Obama Administration, the U.S. Environmental Protection Agency (EPA) announced the New Source Performance Standards (NSPS 2012) for oil and natural gas source categories in August 2012. Subsequently, the Obama Administration released its "Climate Action Plan to Cut the Pollution" to curb domestic GHG emissions in June 2013 and its "Climate Action Plan - Strategy to Reduce Methane Emissions" in March 2014. In May 2016, the EPA adopted new regulations governing methane emissions from oil and natural gas production (NSPS 2016). However, after the Trump administration took office in January 2017, the EPA withdrew NSPS 2016 regulation in August 2019 and removed methane from the transportation and storage portion of the gas in September 2020.

After Democratic President Biden took office in January 2021, the U.S. Senate adopted a proposal in April 2021 to reinstate methane emission regulations including the 2012 and 2016 "NSPS" for methane emissions from oil and gas operations set by the Obama administration. In January 2022, the United States also enacted "the U.S. Methane Emissions Reduction Action Plan", and in August 2022, "the Inflation Reduction Act (IRA)". The Act provides incentives for early implementation of methane reduction technologies and imposes emission charges on oil and gas facilities that emit in excess of certain standards. In addition, in November 2022, the EPA expanded methane regulations, requiring drillers to find and plug leaks at all domestic drilling sites, and other policies to curb methane emissions in rapid succession.

3.2. Trends in Europe

In October 2020, the European Commission (EC) published the EU Methane Strategy to reduce methane emissions. The Strategy outlines European and international measures to reduce methane emissions and proposes legal and non-legal measures in the energy, agriculture, and waste sectors.

In December 2021, the EC published the EU Methane Emissions Management Bill (a package of gas bills). The bill proposed three policy amendments: (1) shifting gas consumption from natural gas to renewable and low-carbon gases, (2) reducing methane emissions in the energy sector, and (3) energy performance of buildings. In particular, (2) methane emission reduction regulations include: the ban on Routine Venting and Flaring (BRVF) of fossil fuels, methane emission monitoring for EU member states, the introduction of leak detection and repair obligations (LDAR) for various companies, and supplier side regulations on imported fossil fuels. The BRVF also establishes the obligation of suppliers to submit information on their MRV and emission reduction methods with respect to imported fossil fuels.

Furthermore, in December 2022, the European Council (at the Heads of State or Government level) reached an agreement in principle on a proposal to track and reduce methane emissions in the energy sector, which would introduce new MRV obligations in the oil, gas, and coal sectors. Under the proposal, oil and gas operating companies would be required to measure and report their methane emissions and third-party verification would be required, and methane emissions from EU energy imports would also be tracked. The new rules also promote global monitoring tools to improve the transparency of methane emissions from oil, gas, and coal imports into the EU. The consideration of the bill now advances to the European Parliament.

3.3. OGMP（Oil and Gas Methane Partnership）

In November 2020, the OGMP announced OGMP 2.0, a new framework for MRV of methane emissions. Its predecessor, OGMP 1.0, was established at the 2014 UN Climate Summit as a voluntary framework for methane measures in the oil and gas industry. The latest OGMP2.0 framework was established by UNEP, the European Commission (EC), the Environmental Defense Fund (EDF), and the Climate And Clean Air Coalition (CCAC). The number of partner companies has increased from six at the beginning of the original OGMP in 2014 to 98 as of March 2023. Although no Japanese companies have not joined OGMP2.0 yet, their future participation in OGMP 2.0 could have significant impacts due to their presence in the LNG market.

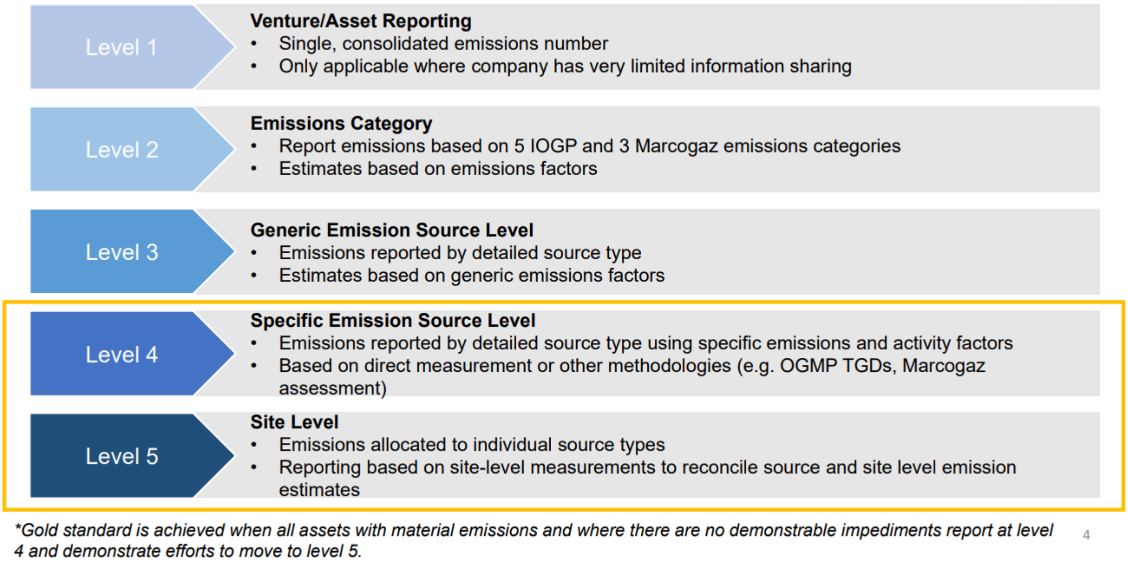

Figure 7: Five levels of CH_4 emissions measurement and reporting in OGMP 2.0

Source: UNEP

The OGMP 2.0 emissions measurement and reporting are classified into five levels. Of these, Levels 1-3 require quantification using emission factors, while Levels 4-5 require quantification using direct measurements. In particular, the latter (Levels 4-5) is called the "Gold Standard," and Level 4 requires Bottom-Up type measurements such as on-site measurements, while Level 5 requires Top-Down type direct measurements such as drones and satellites. In addition, participating companies are required to commit to the initiatives as a condition of membership, not as an absolute requirement to achieve them by the deadline. Furthermore, reporting data will be published only by sector and source, and not on an individual asset basis. Only methane is covered, and other GHGs such as CO_2 are not. In addition, only Scope 1 emission sources are covered, Scope 2 and 3 are not covered, and a Global Warming Potential (GWP) of 72-85x is recommended for CO_2-based emissions calculations. The OGMP 2.0 Technical Guidance Documents (TGDs) have been published, which provide specific methodologies for Levels 3 and 4 for major emission sources. However, member companies may choose to adopt a different methodology, in which case proof of equivalence to the TGDs is required.

3.4. IMEO (International Methane Emissions Observatory)

In March 2021, the UNEP, in cooperation with the EC, announced the creation of the International Methane Emissions Observatory (IMEO) as a supervising body for OGMP 2.0 reporting. IMEO's role is to collect data from companies through reporting to the OGMP, improve the accuracy of emissions estimates, and publish an annual report on the status of methane emissions. In October 2021, the launch of the observatory was reported at the G20 Summit, and the first OGMP 2.0/IMEO annual report, the IMEO 2021 Report, was published. In this report, 64 of the 74 member companies (12 upstream, 33 midstream, and 19 downstream) submitted reports. In October 2022, the IMEO 2022 Report was released with 13 new member companies (10 upstream, 3 midstream/downstream), and 36% upstream, 56% midstream, and 10% downstream achieved Level 4 (Gold Standard) reporting, an improvement from the previous year.

3.5. OGCI (Oil and Gas Climate Initiative)

The concept of the OGCI, a voluntary initiative by the upstream sector of the oil and gas industry to accelerate cooperative coordination on climate change into meaningful action, was announced at the World Economic Forum (Davos) in January 2014 and launched at the UN Climate Change Summit in September 2014. The OGCI is comprised of 12 member companies, including oil majors and state-owned companies such as bp, Chevron, and Shell, which together account for about 30% of global oil and gas production.

Figure 8: OGCI Targets for Methane Intensity Reduction

Source: OGCI

OGCI's target is to reduce average methane intensity in the oil and gas industry (upstream sector) from a baseline of 0.30 % in 2017 to a level below 0.20 % by 2025. In November 2016, OGCI also established OGCI Climate Investments, a fund that will invest USD 1 billion over the next 10 years. It aims to accelerate the global implementation of low-carbon solutions in the energy, industrial, building, and commercial transportation sectors, investing in 31 technologies and projects (10 methane emission reductions, 12 CO_2 reductions, and 9 CO_2 recycling projects) as of March 2023.

In addition, OGCI announced in July 2020 its commitment to join the Global Gas Flaring Reduction Partnership (GGFR) and the Payne Institute for Public Policy (PIPP) at the Colorado School of Mines in providing approximately USD 1 million in financial and technical assistance. The project develops an online platform, "Global Gas Flaring Explorer" featuring mapping and visualization of gas flaring data at oil production sites around the world. It is expected to improve monitoring and demonstration in the Zero Routine Flaring by 2030 (ZRF) Initiative, which was proposed by the World Bank in 2015 and aims to end routine flaring by 2030. Subsequently, in June 2022, each country announced a contribution of USD 4 million (USD 1.5 million for the United States, USD 1.5 million for Germany, and about USD 1 million for Norway) to support the GGFR.

In March 2022, OGCI announced the launch of the Aiming for Zero Methane Emissions Initiative, an industry-led effort to achieve near zero methane emissions from its own operated oil and gas assets by 2030. In June 2022, QatarEnergy announced its participation in the Initiative, becoming the first company outside of the initial 12 signatories to join, followed by Wintershall DEA, Neptune Energy and Australia's Woodside Energy later in the year. In February 2023, JGC Holdings became the first Japanese company to announce its participation, and as of March 2023, more than 40 companies have joined the Initiative.

3.6. GMP (Global Methane Pledge)

In September 2021, the United States Whitehouse announced the Global Methane Pledge (GMP) at the Major Economies Forum on Energy and Climate (MEF) to reduce global methane emissions collectively by at least 30% below 2020 levels by 2030. In September of the same year, the second QUAD (Japan-US-Australia-India) summit meeting was held in the United States, at which Japan announced its participation in the GMP. Also in November 2021, at COP26 hosted by the United Kingdom, 103 countries in addition to the United States and the European Union (EU) launched the GMP to reduce global methane emissions. Furthermore, by the time of COP27 hosted by Egypt in November 2022, the number of countries participating in the GMP had expanded to more than 150. And in June 2022, the

United States, the EU, and 11 countries (including Japan) announced the launch of the Global Methane Pledge Energy Pathway (GMPEP) to advance both climate change action and energy security. The initiative's reductions in flaring and methane emissions in the oil and gas sector are cost-effective and will help address climate change, improve air quality, and contribute to global gas supplies. In November 2022, the United Nations (UN) and IMEO also announced a new satellite system for methane emissions detection, MARS (Methane Alert and Response System). The purpose of the system will be to scientifically corroborate the methane emissions reported by companies and to measure and monitor changes over time. The initiative is being built within the framework of GMPEP with initial funding from the European Commission, the U.S. government, the Global Methane Hub, and the Bezos Earth Fund.

4. Methane emission reduction measures and associated MRV framework

This chapter summarizes the main MRV methodologies and measurement techniques related to methane emissions, as well as emissions accounting schemes and framework development efforts undertaken by operators in the LNG supply chain. One example of the background to these efforts is carbon neutral (CN) LNG, which was introduced around 2019-2021, but the detailed rules for offsets and other details have not yet been determined, leading to criticism of "greenwashing".

4.1. Major Guidelines for GHG Emission Calculation/Reporting Standards

(1) EPA (U.S. Environmental Protection Agency):

The EPA was established in 1970 and the EPA Mandatory Greenhouse Gas Reporting Rule (GHGRP) was published in 2010. The purpose of the GHGRP is to provide accurate and timely GHG data to stakeholders. It covers facilities that directly emit 25,000 tons of CO_2 equivalent or more per year. Suppliers of specified products that lead to GHG emissions through emissions, combustion, etc. are required to submit an annual report to the EPA.

(2) API (American Petroleum Institute):

The API, the standard-setting organization for the U.S. oil and natural gas sector, was established in 1919. The API has developed five complementary API-related standard guidelines for accounting, reporting, and characterization of GHG emissions in the oil and gas industry: i) API Compendium, ii) Guidelines, iii) API Template, iv) Sustainability Guidance, and v) Uncertainty Document.

(3) AGA (American Gas Association):

The AGA was established in 1918 as the U.S. gas supply industry association. The AGA publishes standards and guidelines related to the Natural Gas Sustainability Initiative (NGSI) to support ESG initiatives of companies in the gas value chain.

(4) Marcogaz:

The Marcogaz was established in 1968 as a representative body of the European gas industry. The Assessment of methane emissions for gas Transmission and Distribution system operators was published in October 2019 as a Marcogaz related standards guideline. In addition, the MARCOGAZ methane emissions reporting template was published and submitted to the European Committee for Standardization (CEN) in August 2020 to develop a standard for methane emissions quantification. In addition, the Guidance for the MARCOGAZ methane emissions reporting template was published in October 2020 and the template has been adopted for reporting in the OGMP 2.0.

(5) MiQ:

The MiQ was established in December 2020 by the U.S. RMI and the U.K. SYSTEMIQ as a third-party auditing organization for methane. It has developed its own framework, the MiQ Standard, as a rulebook for conducting assessments related to methane emissions management. The MiQ Standard provides an A-F grading system for reportable facilities based on the degree of achievement of three criteria: Methane Intensity, Company Practices, and Monitoring Technology Deployment. Recent trends include the use of a new rating system for facilities that are scheduled to be completed by 2023. As a recent development, in January 2023, MiQ announced that it had monitored and rated 17% of U.S. gas production in one year, and that 10 companies, including bp, Exxon, and Chesapeake, had obtained certification.

(6) GIIGNL (International Group of LNG importers):

The GIIGNL was established in 1971 as an industry association for LNG importers. In November 2021, the GIIGNL MRV and GHG Neutral LNG Framework, incorporates all GHG emissions associated with cargo. The guidelines define four categories of CNL common terms, i) GHG footprint, ii) GHG Offset, iii) GHG Offset with Reduction Plan, and iv) GHG Neutral, and recommend measurement of GHG amounts for each cargo. As a recent development, Shell announced in January 2023 that it had delivered LNG from Gorgon LNG (Australia) to CPC (Taiwan) for the first time in accordance with the framework.

4.2. Main measurement technologies: Satellites, Drones, OGI (Optical Gas Imaging) cameras

This section summarizes the characteristics and main approaches for satellites, drones, and OGI cameras, which are commonly used in measurement technology surveys.

4.2.1. Satellites (Top Down)

Although wide-area observations of methane emissions by satellite have proven to be useful as technology has advanced, it is difficult to quantitatively estimate emissions at this time. One of the strengths of satellites is their ability to make measurements over a wide area, at high frequency, and over a long period of time. On the other hand, the weaknesses of satellites are that the detection limit is limited to large-scale leakage, detailed leakage cannot be measured, and offshore measurement is not possible due to the influence of weather conditions such as cloud cover and reflections from the sea surface.

Leading measurement companies include GHGSat, a company specializing in monitoring satellite technology, Scepter, a general measurement company, and Kayrros, an environmental information company. In a recent development, Kayrros announced in January 2023 that it will collaborate with UNEP and provide its data to IMEO in order to make global data on methane emission sources available.

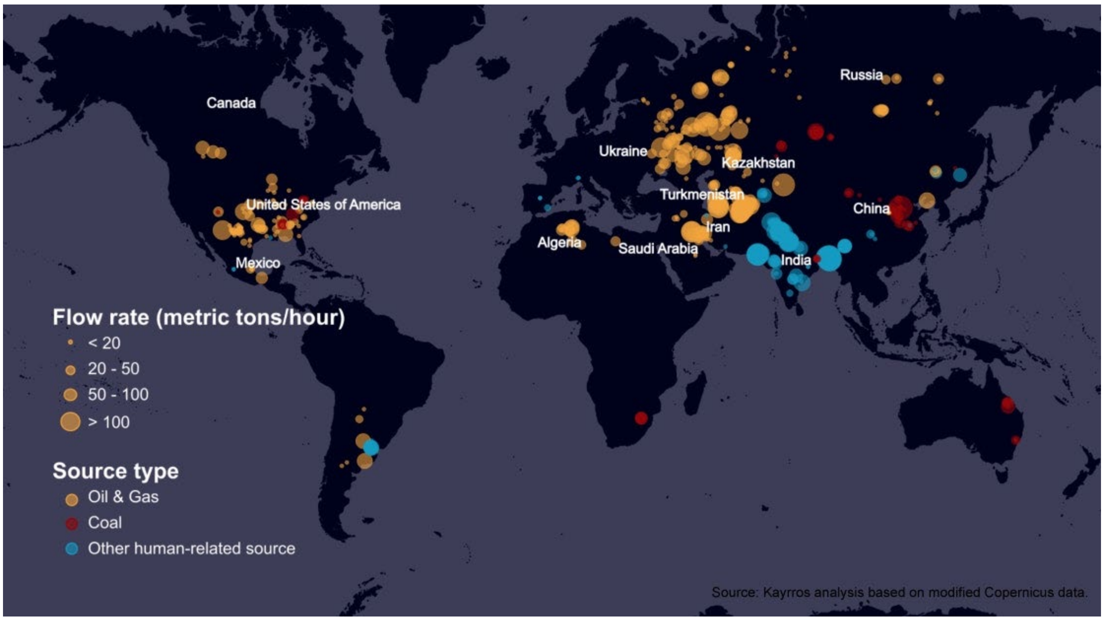

Figure 9: Methane emissions from human activities detected by satellite (2022)

Source: Kayrros

As a result of the satellite measurements, a paper on methane emissions, "Chasing after methane's ultra-emitters" was published in the scientific journal Science in February 2022. The paper stated that more than 1,200 methane emission events of 25 tonnes per hour or more detected by satellite in 2019 - 2020 were observed as ultra-emitters, but these were not included in national GHG inventories. It also noted that the majority of these were in the six largest oil and gas producing countries (Turkmenistan, Russia, the United States, Iran, Kazakhstan, and Algeria).

4.2.2. Drone (Top Down / Bottom up)

Drones are considered promising as a method that is less expensive than satellites and can be implemented at offshore plants, and are considered the most advanced in terms of cost-effectiveness. The strengths of drone measurement include area-level quantification, element-by-element leakage identification, measurement of inaccessible areas, and ease of setup. On the other hand, weaknesses include difficulty in quantifying each element, limited payload, non-explosion-proof, and the absence of regulations under domestic laws and regulations. SeekOps is one of the leading measurement companies.

4.2.3. OGI (Optical Gas Imaging) camera: (Bottom up)

OGI cameras are considered a more quantitative method of observation than satellites or drones. Strengths of the measurement include continuous measurement and the ability to measure even trace amounts of leakage. Weaknesses include the limited area that can be measured with fixed sensors and the need for a power supply and cable installation. FLIR is one of the leading measurement companies.

4.3. Major Upstream Operator Initiatives (Production Sector)

4.3.1. QatarEnergy, PavillionEnergy, Chevron; SGE Methodology

In April 2020, Singapore's Pavilion Energy solicited LNG deliveries of up to 2 million tonnes per year for five years beginning in 2023, and requested cooperation from suppliers in establishing and implementing GHG measurement and reporting methods for emissions from the wellhead to the unloading terminal. Subsequently, in November 2020, Qatar Petroleum (now QatarEnergy) signed a deal with Pavilion Energy, the first long-term LNG deal to include environmental conditions aimed at reducing the carbon footprint of the LNG supply. Then, in November 2021, Pavilion Energy, QatarEnergy, and Chevron announced that they had issued a quantification and reporting methodology for preparing a Statement of GHG Emissions (SGE) for LNG cargoes. The SGE Methodology is complementary to GIIGNL's MRV and GHG Neutral Framework efforts.

4.3.2. Cheniere Energy, CE Tags

Cheniere Energy of the United States announced the release of an LNG Life Cycle Assessment (LCA) analysis that will improve the way it assesses GHG emissions in August 2021. The analysis utilizes GHG emissions data specific to Cheniere's LNG supply chain and will serve as the basic analysis tool for GHG emissions estimates included in Cheniere's Cargo Emissions Tags (CE Tags). In April 2022, Cheniere also announced that it will collaborate with natural gas midstream companies, methane detection technology providers, and university research departments, including Colorado State University, to Quantify, Monitor, Report and Verify (QMRV) GHG Emissions in its LNG supply chain. The QMRV implementation will use a combination of surface, mid-air, and drone emissions monitoring technologies. Additionally, in October 2022, Cheniere announced its participation in OGMP 2.0. The company also announced the start of issuing CE Tags to buyers with estimated GHG emissions for each cargo it produces.

4.3.3. Five International Major Companies

(1) ExxonMobil:

In September 2021, the company announced that its Poker Lake facility in the Permian Basin, New Mexico, had received the highest grade A from MiQ for methane emissions control in natural gas production. In April 2022, the Permian Basin facility's 200 million cubic feet per day of natural gas production received the highest grade A from MiQ, making it the first company to receive certification for petroleum-associated natural gas production.

(2) Chevron:

In May 2022, the company announced that it is working to improve its own methane emissions detection and reduction through multiple approaches, including surface and overhead. Also in February 2023, Chevron New Ventures and Egypt's Ministry of Petroleum and Mineral Resources (MOPMR) announced that they had signed a Memorandum of Understanding (MOU) to share best practices and expertise in methane emissions reduction.

(3) TotalEnergies:

In May 2022, the company announced that it will begin drone-mounted emissions detection and surveying at its upstream oil and gas operations. This will be done using AUSEA (Aerial Emission Survey Equipment for Environmental Action) technology developed with CNRS (France) and the University of Reims Champagne Ardenne, which is a small, combined sensor mounted on a drone that can detect CH_4 and CO_2 and identify the source of emissions at the same time. The company expects to reduce methane emissions by 50% by 2025 and 80% by 2030, compared to 2020 levels.

(4) bp:

In March 2022, bp ventures announced a EUR 3 million investment in Flyogix, a pioneer in the unmanned aerial vehicle (UAV) business that uses drones to help monitor and measure methane gas. In addition, in March 2023, bp's U.S. and onshore natural gas producer bpx Energy announced that it had obtained MiQ certification for all onshore facilities it operates in Texas and Louisiana in that country.

(5) Shell:

In 2020, the company announced that it would use drones to enhance methane leak detection and repair (LDAR) at its more than 400 sites in the Permian Basin in the United States. The company is targeting a methane emission intensity of 0.2% or less by 2025 for all oil and gas assets it operates.

4.4. Midstream Operator Initiatives (Transportation Sector)

Methane emissions occur in the LNG value chain, for example, and some events involve leaks during LNG transfer to liquefaction facilities or LNG carriers. Boiloff gas (BOG), which is partially evaporated from the heat input to the tanks, may also be discharged during loading and may occur as unburned gas (methane slip) in marine engines.

According to the IEA, based on detailed data on global LNG trade and data measured by the GHGSat satellite, total methane emissions from LNG liquefaction plants and shipping in 2022 are estimated to be about 0.4 million tonnes, or about 0.1% of the annual globally transported LNG volume of 400 million tonnes.

The International Maritime Organization (IMO), one of the specialized agencies of the United Nations (UN), is studying LCA guidelines for GHG emissions from marine fuels. Currently, the draft guideline for the assessment of GHG emissions throughout the life cycle of marine fuels (LCA guideline) jointly prepared by Japan, Australia, Norway, and the EC is being considered as a base document, and is scheduled to be finalized at the 80th MEPC (Marine Environment Protection Committee) in July 2023.

In addition, in September 2022, the Safetytech Accelerator, established by Lloyd's Register, announced the launch of the Methane Abatement in Maritime Innovation Initiative (MAMII), an initiative to reduce methane emissions from shipping. MAMII is an initiative to reduce methane emissions from shipping. Initially, seven companies, including Maran Gas Maritime, Shell, and others, will support the initiative. The MAMII also states that in its first six months, it has mapped the status of LNG fuel from well to ship and identified key measurements and potential new technologies for onboard measurement. In addition, in March 2023, seven international LNG shipowners and operators, including CoolCo, Mitsui O.S.K. Lines (MOL), and TMS Cardiff Gas, announced that they had joined MAMII.

5. Trends in Japan

This chapter describes policy trends in each country, with a focus on the United States and Europe, which are leading the way in methane emissions management. It also summarizes trends in the OGMP 2.0, a natural gas and oil industry-led leading methane emissions MRV framework, and its supervising body, IMEO, and the GMP, which aims to reduce overall global methane emissions.

5.1. Greenhouse Gases and Methane Emissions in Japan

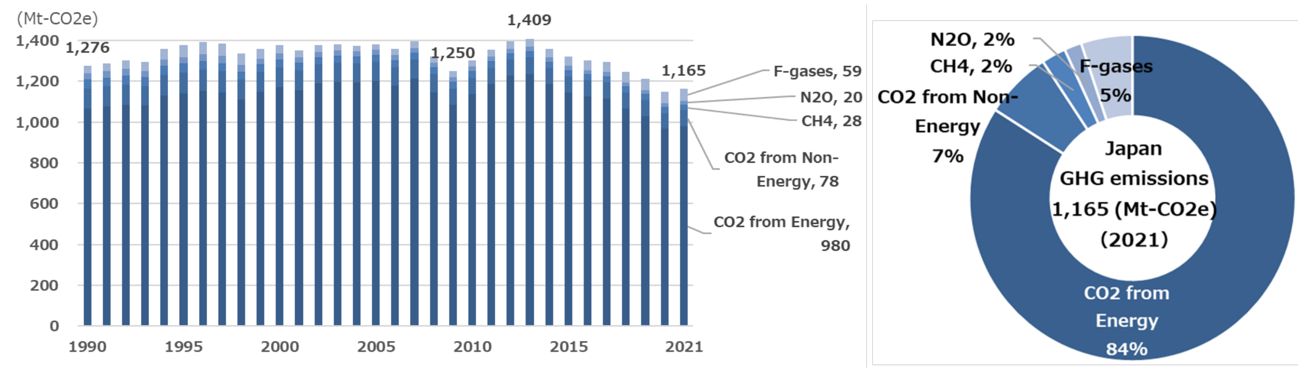

Figure 10: Japan's GHG emissions (FY1990-2021) *FY2021 figures are provisional.

Source: Compiled from NIES' information, based on data from the Greenhouse Gas Inventory Office

According to provisional data from the NIES as of February 2023, Japan's total GHG emissions in FY2021 were 1.165 billion tonnes (CO_2 equivalent), a 17% decrease from the record 1.409 billion tonnes in FY2013. Methane emissions account for 2.4% of the total GHG emissions, at 28.33 million tonnes (CO_2e) in FY2021 (provisional data, based on methane's GWP 25).

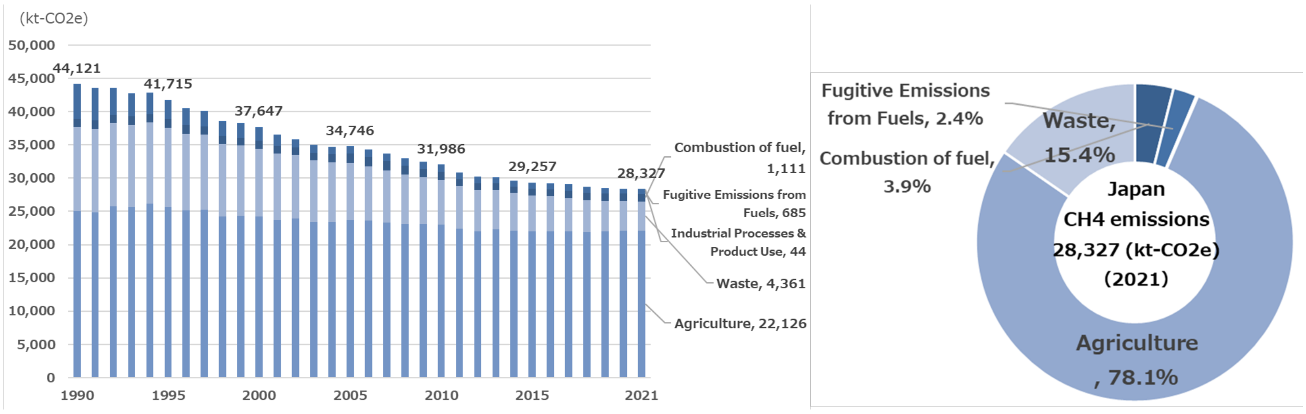

Figure 11: Methane Emissions in Japan (FY1990-FY2021) *FY2021 figures are provisional.

Source: Compiled from NIES' information, based on data from the Greenhouse Gas Inventory Office

Methane emissions (CO_2 equivalent) in Japan have decreased by 15.79 million tonnes (36%) over the approximately 30 years from 1990 to 2021. Looking at the breakdown of 28.33 million tonnes of methane emissions (CO_2e) in FY2021 (provisional figures), agriculture-derived emissions accounted for the largest share of 78.1% at 22.13 million tonnes, followed by waste at 4.36 million tonnes or 15.4%, Energy-related activities accounted for 1.8 million tonnes, or 6.3% of the total. Here, if the GWP of methane is converted to 25, CH_4 emissions in 2021 would be 1.13 million tonnes, 36% smaller than the 1.54 million tonnes of CH_4 emissions in Japan estimated by the IEA.

5.2. JOGMEC: GHG and CI Guidelines

In May 2022, JOGMEC (Japan Organization for Metals and Energy Security) developed and published the Recommended Working Guidelines for Calculating GHG Emissions and Carbon Intensity (CI) of LNG, Hydrogen, and Ammonia (GHG and CI Guidelines). The guideline is an approach to the calculation of GHG emissions associated with the production of different energy products and the calculation of CI, which indicates GHG emissions per unit. The guideline has been developed by JGC Global engaged through the JOGMEC project.

In September 2022, JGC HD announced that JGC Global had signed a memorandum of understanding (MOU) with PT

Panca Amara Utama (PAU), an Indonesian ammonia production and sales company that includes Mitsubishi Corporation (MC) as a shareholder, to conduct GHG emission measurement, including methane. Prior to this, in March 2021, JOGMEC and MC agreed with PAU to conduct a joint study on CCS and carbon dioxide utilization for ammonia production, and an MOU was signed between the four parties including Bandung Institute of Technology in Indonesia. Based on the concluded MOU, the CI value of the product was calculated by calculating GHG emissions per ton of ammonia at PAU's production site from November to December 2022. This was the first measurement case in which the guidelines were applied as part of a JOGMEC project. It is expected that Japan will continue to expand its technical contribution by applying the same method to other facilities in Asian countries.

5.3. Trends in the Ministry of Environment (MOE), Japan

(1) Satellite Project GOSAT Series

A The NIES, MOE, and the Japan Aerospace Exploration Agency (JAXA) are promoting the GOSAT series of satellite projects to observe GHGs from space. SATellite (Ibuki), the world's first technical satellite dedicated to GHG observation, was launched in January 2009, and started continuous observation of CO_2 and CH_4 concentrations. In 2018, the GOSAT-2 (Ibuki 2), was also launched and began observations of carbon monoxide (CO) in addition to CO_2 and CH_4. The third satellite, GOSAT-GW (Global Observing SATellite for GHG and Water Cycle), is currently under development for launch in FY2024. As a major achievement in recent years, in March 2022, GOSAT observation data revealed that the average annual increase in the total atmospheric concentration of methane from 2011 to 2020 was 8 ppb, while the annual increase in 2021 was 17 ppb, the largest since the start of observations. In November 2022, they also analyzed methane emissions in China (2010-2018) and found that methane emissions varied significantly by region. In particular, they found significant increases in China as a whole and in northeastern China.

(2) Greenhouse Gas Emissions Calculation, Reporting and Publication System (SHK System)

The SHK (Japanese acronym of Calculation, Reporting and Publication) system is based on the Act on Promotion of Global Warming Countermeasures, which requires businesses that emit more than a certain amount of GHGs to calculate their own emissions and report them to the government, and the government publishes the reported information. Since the introduction of the SHK system in 2006, the activities subject to calculation in the national inventory have been reviewed every year based on the actual emissions and the latest scientific findings. On the other hand, the activities covered by the SHK system were rarely reviewed, and there was a situation in which there was a discrepancy between the activities covered by the national inventory and those covered by the SHK system. In January 2022, the MOE and the Ministry of Economy, Trade and Industry (METI) established the "Study Group on Calculation Methods in the SHK System," held a total of five discussion sessions on the review of calculation methods, and released an interim summary in December 2022. In the summary, based on the scheduled review of the GWP used in the national inventory, it was indicated that the GWP used in the SHK system will be 28 after the review, instead of the current 25, starting from the 2024 report (= emissions in 2023) for methane.

5.4. LNG operators: Reporting of emissions

Under the Law Concerning the Promotion of the Measures to Cope with Global Warming, methane is required to be reported by businesses that emit 3,000 tonnes of CO_2 equivalent or more per year, and only Scope 1 is covered. However, many companies in Japan voluntarily disclose emissions below the standard in their own sustainable reports.

Table 1: Methane Emissions Disclosure by Japanese Companies (2017-2021)

(Tonnes)			CH4-t					CO2e-t				
Industy	No.	Company	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
City Gas	1	Tokyo Gas	425	354	323	290	290	11,000	9,000	8,000	7,000	7,000
	2	Osaka Gas	77	88	106	58	62	1,925	2,200	2,650	1,450	1,553
	3	Toho Gas	22	19	191	16	36	546	468	4,766	408	891
	4	Shizuoka Gas	7	7	7	7		170	170	176	176	
	5	Hiroshima Gas	11	26	9	10	10	275	650	225	250	250
	6	Saibu Gas	10	10	9	9	7	250	250	225	225	175
Electric Power	1	JERA	-	-	400	400	400	-	-	10,000	10,000	10,000
	2	Hokuriku	20	23	21	20	23	500	575	525	500	582
	3	Chugoku	-	-	-	240	320	-	-	-	6,000	8,000
	4	Kyushu	8	0	0	4	8	200	0	0	100	200
Development	1	INPEX (Domestic)	556	1,040	1,400	640	560	13,892	26,000	35,000	16,000	14,000
		〃 (Total)	577	5,120	13,160	9,160	4,880	14,417	128,000	329,000	229,000	122,000
	2	JAPEX (Domestic)	5,725	3,823	2,519	1,514	1,114	143,113	95,586	62,975	38,000	28,000
		〃 (Total)	5,725	3,828	2,519	1,533	1,119	143,113	95,699	62,975	38,480	28,120
Oil	1	ENEOS	1,659	1,690	1,868	1,713	1,897	41,480	42,259	46,691	42,814	47,431
	2	Idemitsu	-	-	1,986	14,531		-	-	49,650	363,275	
Trading	1	Mitsubishi (MC)	37,680	36,800	34,800	33,600	68,880	942,000	920,000	870,000	840,000	1,722,000
	2	Mitsui & Co.	71,840	36,320	39,880	55,120	53,440	1,796,000	908,000	997,000	1,378,000	1,336,000
	3	ITOCHU	-	0	58	4,729	5,435	-	0	1,459	118,224	135,884

※ Blue Text: Converted value = 25 (CO2e-t/CH4-t), GWP 100

Source: Compiled from company data * Blanks indicate undated data

In recent years, an increasing number of companies have begun to disclose their emissions due to the growing importance of methane emissions management worldwide. In addition, some companies have subdivided their emissions reporting items and are now publishing emissions by factor and gas type, as well as by domestic and overseas emissions. Furthermore, some companies, mainly trading companies, have expanded the scope of emissions and are gradually compiling and disclosing greenhouse gases other than energy-derived CO_2 to include "CH_4 from swine rearing and waste management", "CH_4 from wastewater treatment" and "CH_4 from waste composting and landfill disposal".

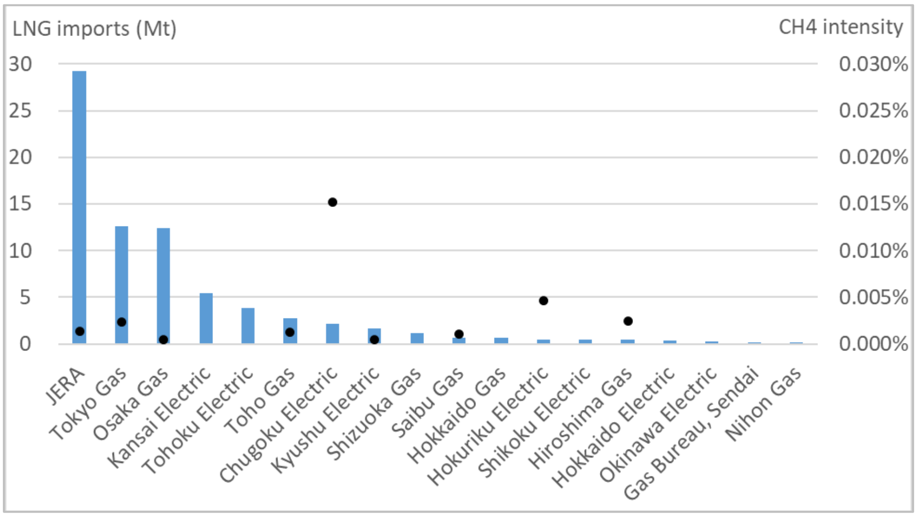

Figure 12: LNG imports and methane emission intensity by Japanese companies (FY2021)

Source: Compiled from data included in each company's sustainability report

In recent years, there has been active public disclosure regarding methane emissions. Calculating the methane emission intensity (methane emissions / LNG imports) of Japanese companies, the values are mostly controlled at low levels, less than 0.005%. This indicates that leakage control, which Japanese companies have cultivated in the past on the back of safety measures, has been thoroughly implemented. For example, Spanish downstream operator Nedgia, which has been awarded Level 4 for two consecutive years among OGMP2.0 participants, has relatively large methane emissions of 2,140 tonnes in 2021 and an emission intensity target of 0.022% by 2025.

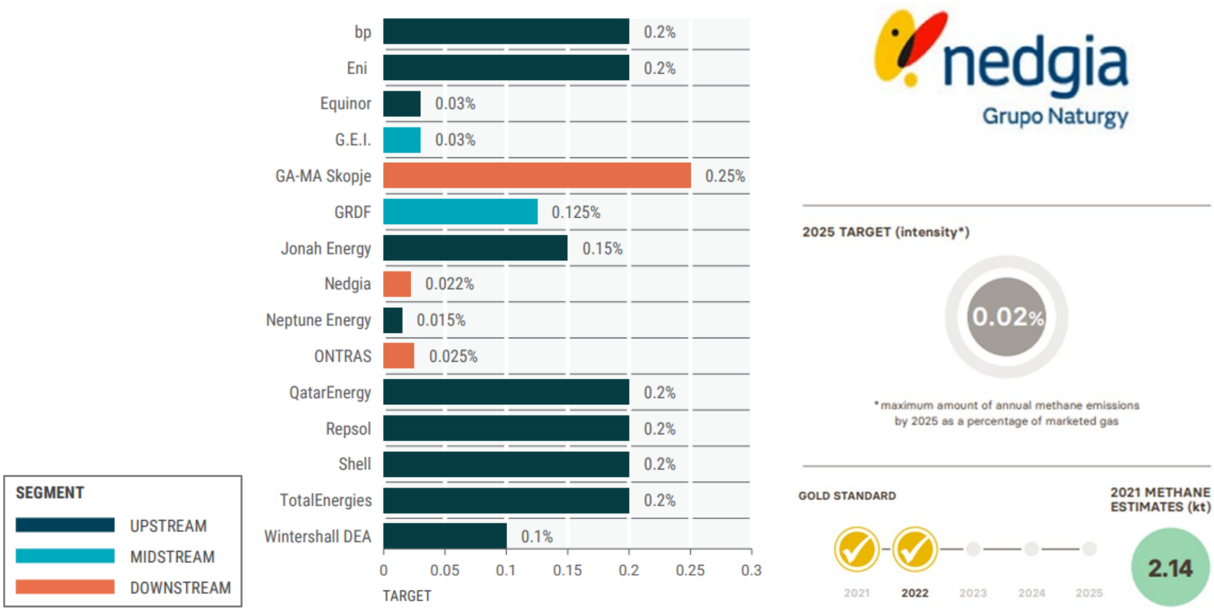

Figure 13: Methane Emission Intensity Targets for OGMP 2.0 Member Companies (2021)

Source: IMEO 2021/2022 Report

5.5. Potential Contribution of Japanese Companies

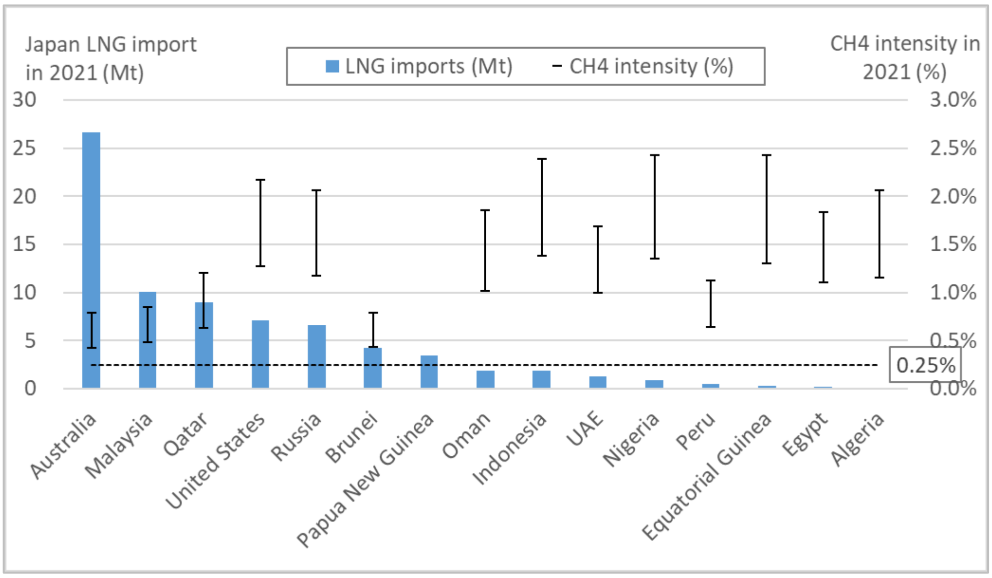

Figure 14: Japan LNG Imports and Methane Emission Intensity by Country (2021)

＊CH_4 intensity: (Min) (Emissions from On/Offshore gas production) divided by total gas production,

(Max) (Emissions from [Gas production＋PL/LNG facilities]) divided by total gas production

Sources: Trade Statistics of Japan, IEA Methane Tracker 2022, IEA Natural Gas Information 2022

The methane emission intensity for each country from which Japan procures LNG (except Papua New Guinea, which has no emission data) exceeds 0.25%, although it includes not only the intensity for the LNG production value chain but also the intensity of the overall gas production and other activities. Japan has a large number of companies with advanced engineering technologies, and there is potential for Japan to contribute to the world by utilizing its methane leakage prevention technologies.

In recent years, Japanese companies have also been working to reduce methane emissions in other countries. For example, in April 2022, PERTAMINA, Osaka Gas, INPEX, and JGC HD signed an agreement for joint research on the utilization of biomethane derived from palm oil mill effluent (POME) in Indonesia. POME produces a large amount of methane, which is released into the atmosphere, and the two parties aim to utilize this methane as biomethane. In March 2023, JGC HD and NUS signed a memorandum of understanding with Gas Malaysia Bhd to conduct a "Joint Study for Sustainable Development of Palm Oil Industry" in Malaysia.

6. Conclusion

This paper provides a cross-section of global methane emissions management trends, from policies mainly in Europe and the United States, and from international frameworks to corporate initiatives. Among them, attention to methane emissions management is rapidly increasing, as represented by the Global Methane Pledge (GMP), a common global goal launched in 2021. Japan, as the world's largest LNG importer and having been involved in the LNG value chain for more than 50 years, has a responsibility to pursue cleaner natural gas. As an LNG buyer, Japan will increasingly need to cooperate with LNG sellers in order to continue using natural gas in the future. In this context, Japan, as a leader in Asia, is expected to contribute to the management of methane emissions through the advanced technological capabilities it has cultivated to date and its ability to collaborate with other countries.

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Comparison of Hydrogen Imports vs. Product Imports

- Old and new viewpoints on hydrogen application through an example of hydrogen-based direct reduction ironmaking -

Yoshiaki Shibata [*]

Summary

Hydrogen is extremely difficult to transport. Even if it were possible to produce cheap hydrogen outside of Japan, an increase in the cost for conversion to hydrogen carriers and transportation is inevitable when importing hydrogen to Japan. Changing the viewpoint, a question may arise; which is more economical, to import hydrogen for the purpose of manufacturing a product, or to manufacture that product in the country where the hydrogen is produced, and then import the product.

This paper analyzed that question using the example of hydrogen-based direct reduction ironmaking. The results of this analysis showed that the cost of supplying direct reduced iron to Japan by manufacturing it in the country that produces the hydrogen, and then importing it to Japan, is much cheaper than the cost of using imported hydrogen to produce direct reduced iron in Japan. The point that the result raises is how we should consider the economics of manufacturing products domestically using imported hydrogen, rather than only focusing on the comparison of the import cost of hydrogen carriers.

With Japan's high dependence on imports for energy, resources, and products, there is a need to curb the outflow of national wealth by making an effort to minimize import costs. There are many products produced using hydrogen other than direct reduced iron, so the results of this analysis cannot be generalized. However, if the dependence on imports is inevitable then we should elaborate the option to import products manufactured using hydrogen abroad, rather than persisting on importing the hydrogen which is quite difficult to transport physically. It is important to make an assessment according to the situation of the industry and the supply chain of the individual product.

It is also necessary to remember that the direct reduced iron used for this analysis is an intermediate product. Accordingly, consideration should include optimization of the overall supply chain by minimizing any hollowing out of the industry, such as by retaining the blast furnaces, electrical furnaces, and other processes required for the manufacture of final products in Japan[1], including the downstream supply chain, which uses the imported direct reduced iron.

From another point of view, if domestic product manufacturing should be retained to avoid hollowing out of the industry, then it would be meaningful to look into the potential of domestic hydrogen for minimizing the outflow of national wealth at the very least, assuming the same cost level for imported and domestic hydrogen. But even in that case, it is necessary to minimize the conversion to hydrogen carrier and transport with a view to curbing costs. In order to do so, it is worth considering shifting the industry to regions where renewable energy is abundant and relatively cheap, as an example that the shift of data centers to Hokkaido in recent years shows. This would contribute to the expansion of renewable energy through the increase in demand.

It is unable to escape the principle that it is more efficient to directly use hydrogen as a gas near the location where hydrogen is produced, rather than converting hydrogen to a hydrogen carrier. Depending on the hydrogen application, discussions are required based on multifaceted viewpoints that address the impact on the economy and industry, without taking hydrogen

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[1] The use of the imported direct reduced iron as feedstock in blast furnaces and electrical furnaces (supplementing iron ore and scrap iron which is not suitable for direct reduction) can significantly reduce CO_2 emissions when compared to conventional ironmaking (using blast furnaces and electric furnaces), but the energy required must still be decarbonized (such as by using CCS). Doing so would enable the ironmaking industry to optimize use of the furnaces and downstream processes while achieving progress in decarbonization.

imports as a given.

1. Introduction

Hydrogen is expected to play an important role in decarbonization. However, when considering the use of hydrogen, it is necessary to remember that the transport of hydrogen is extremely difficult. How to economically transport large amounts of hydrogen from foreign countries over long distances has long been a challenge for Japan, and numerous hydrogen carrier technologies are being developed. But from a different viewpoint, there is an alternative option to use the hydrogen where it is produced, rather than transport it. This paper compares the economics of the manufacturing of domestic products using imported hydrogen, as feedstock for industry, versus the use of hydrogen to manufacture products overseas and then import those products. The advantages and disadvantages of the two options will be discussed.

2. Hydrogen-based direct reduction ironmaking for an example

Technological development is being carried out mainly in the areas of blast furnace hydrogen reduction, large electrical furnaces, and hydrogen-based direct reduction ironmaking, in order to decarbonize the steel industry.[2,3,4] With regard to blast furnace hydrogen reduction, research and development are progressing on both the COURSE 50 Project, which aims to reduce CO_2 emissions by 30%, and the Super COURSE 50 Project, which aims to reduce CO_2 emissions by 50%, through the use of hydrogen reduction and CCUS. With regard to large scale electrical furnaces, research and development are being carried out for producing high-grade steel using iron scrap.

In comparison, whereas numerous technological challenges remain for hydrogen-based direct reduction ironmaking[5], similar natural gas (methane)-based direct reduction ironmaking has a long history which was commercialized in 1969 and has since vastly expanded production volume[6]. The research, development and demonstrations for hydrogen-based direct reduced ironmaking are also promoted in recent years[7] and drawing more attention than ever[8], which leads to commercialization represented by a contract that Midrex Technologies, Inc., a subsidiary of Kobe Steel will provide the world's first commercial steel plant using 100% hydrogen-based direct reduction for the Swedish steelmaker H2GS AB in 2022[9].

Based on this background, the following sections compare the costs in a case where hydrogen-based direct reduction iron is manufactured in Japan using imported hydrogen and in a case where Japan imports hydrogen-based direct reduction iron manufactured overseas.

3. Cases

The two cases are shown in Fig.1. For the case in which imported hydrogen is used in hydrogen-based direct reduction ironmaking in Japan (H_2-Import Case: top of Fig.1), liquid hydrogen (LH), methylcyclohexane (MCH), ammonia (NH3), and synthetic methane (e-CH_4) are chosen as the hydrogen carriers used to import the hydrogen. LH, MCH, and NH3 are gasified, dehydrogenated, and cracked, respectively after being imported to Japan to be converted to hydrogen gas that is fed into the reduction furnace (shaft furnace) to produce direct reduced iron (DRI). Meanwhile, e-CH_4 is directly fed into the reduction

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[2] Document 3 "Hydrogen Use in the Ironmaking Process" - Project Research and Development, Social Implementation Directions, Energy Structural Transformation Domain Working Group, Green Innovation Project Subcommittee, 5th Industrial Structure Council, Ministry of Economy, Trade and Industry.

[3] Nippon Steel (https://www.nipponsteel.com/csr/env/warming/future.html)

[4] Course 50 （https://www.course50.com/technology/technology01/）

[5] Hydrogen-based direct reduction has several technical challenges, such as the need to heat the hydrogen because it is an endothermic reaction like blast furnace hydrogen reduction, and the tendency for the iron ore to become powdered or solidified during the reaction. High-grade iron ore representing only about 10% of the total volume traded is used to avoid the latter challenge, but there is a need to develop technology that allows the use of low-grade iron ore. Also, the solid direct reduced iron produced through hydrogen-based direct reduction includes the veins and other impurities in the iron ore. Therefore, it is necessary to separate those components by melting the direct reduced iron in a blast furnace or electrical furnace.

[6] Kobe Steel (https://www.kobelco.co.jp/products/ironunit/dri/)

[7] Kobe Steel (https://www.kobelco.co.jp/releases/1201993_15541.html)

[8] Kobe Steel, Midrex Technologies (https://www.kobelco.co.jp/releases/1210984_15541.html)

[9] Kobe Steel (https://www.kobelco.co.jp/notices/files/20230317_2_01.pdf)

furnace (shaft furnace) without being converted to hydrogen gas, since natural gas (methane)-based direct reduction ironmaking is already commercialized. Ammonia-based direct reduction ironmaking, though expected[10], is not included in the analysis, since the technical specifications such as the reaction mechanism and the capital costs are unknown. Note that the case where domestically produced hydrogen is used will be analyzed as a reference. The iron ore is imported by Japan.

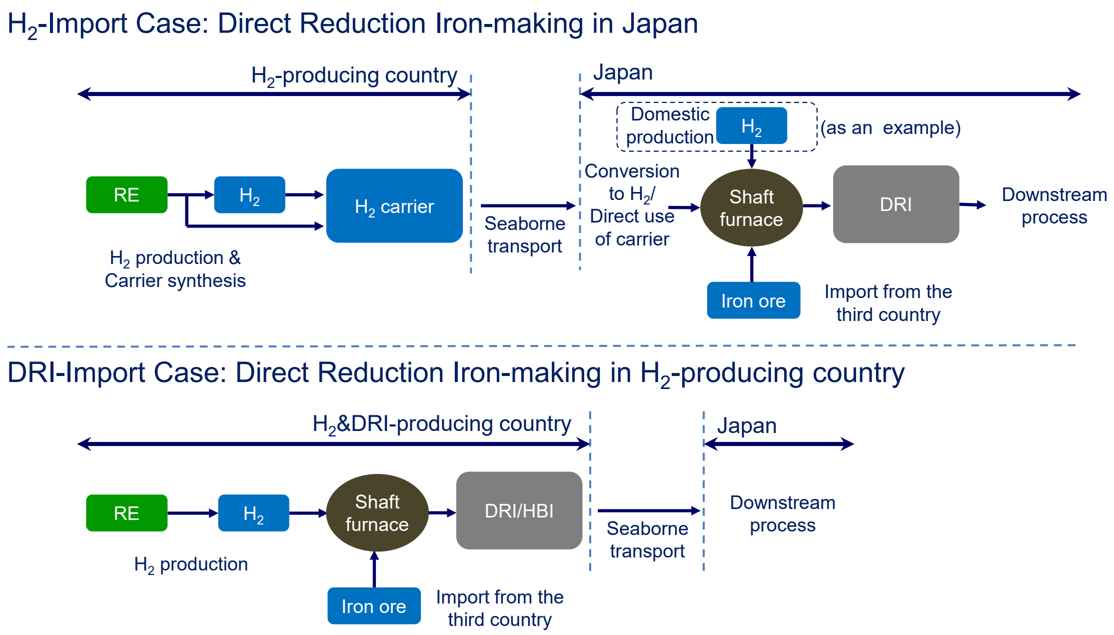

Figure 1: Supply chains for the Hydrogen-Import Case and DRI-Import Case

Note: Water (for water electrolysis hydrogen production) and CO_2 (for methanation) are also required, although not indicated in the figure.

Note: Under the Hydrogen-Import Case, methane-based direct reduction ironmaking is carried out when synthetic methane is used as the hydrogen carrier.

Note: Under the DRI-Import Case, the DRI is converted to HBI via compression molding for convenience of maritime transport.

Note: Domestic hydrogen Case is presented as a reference.

The case where direct reduction ironmaking is performed overseas (DRI-Import Case: bottom of Fig.1) assumes that the DRI is manufactured in the country where the hydrogen is produced. Hydrogen gas is fed into the reduction furnace (shaft furnace) to produce the DRI, which is then converted to hot briquetted iron (HBI) for shipment to Japan. The iron ore is imported by the country where the DRI is manufactured (where the hydrogen is produced). The DRI production process results in numerous pores in the material, which can be heated and ignited easily when combined with oxygen, so the long-duration storage and maritime transport are constrained due to safety concerns[11]. However, HBI, in which the pores have been reduced through compression molding, is capable of being transported seaborne and is traded globally[12,13,14].

It should be noted that this study regards DRI as the final target product and does not accurately describes the overall flow of the ironmaking process for the sake of simplicity in discussions, in spite of the fact that the downstream process such as electrical

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[10] Document 3 (p. 23) and reference document 2, Energy Structural Transformation Domain Working Group, Green Innovation Project Subcommittee, 5th Industrial Structure Council, Ministry of Economy, Trade and Industry.

[11] Some DRIs need to be sealed (inerted) with inert gas, such as nitrogen, to ensure safety when transported by sea (https://www.piclub.or.jp/ja/news/10789).

[12] "MIDREX® Process: Bridge to Ultra-low CO_2 Ironmaking," Vincent CHEVRIER, Lauren LORRAINE, Haruyasu MICHISHITA, Kobe Steel Engineering Reports /Vol. 70 No. 1 (Jul. 2020)

[13] "MIDREX® Process," Masaaki Atsushi, Hiroshi Uemura, Takashi Sakaguchi, Kobe Steel Engineering Reports /Vol. 60 No. 1 (Apr. 2010)

[14] Journal of the Japan Society of Mechanical Engineers (https://www.jsme.or.jp/kaisi/1239-36/)

furnace to which the DRI is fed is required.

With regards to synthetic methane (e-CH_4), one of the hydrogen carriers, there is an innovative technology[15] for the production of e-CH_4 in addition to the existing technology. This innovative technology uses renewable electricity to synthesize methane directly from water and CO_2, so hydrogen is not involved. Therefore, renewable energy is used as the input for all hydrogen carriers so that the different hydrogen carriers and different cases can be compared on a level playing field. Table 1 summarizes the reducing agents for direct reduction ironmaking.

Table 1: Reducing agents for direct reduction ironmaking

Case	H_2 carrier	➡	Reducing agent
H_2-Import Case	Imported LH	Gasification	Hydrogen
	Imported MCH	Dehydrogenation	Hydrogen
	Imported NH_3	Cracking	Hydrogen
	Imported e-CH_4	—	Methane
	(Domestic hydrogen gas)	—	(Hydrogen)
DRI-Import Case	Hydrogen gas	—	Hydrogen

Note: Ammonia can be used for ammonia-based direct reduction ironmaking without being split into hydrogen. However, it is not included in the analysis as the technical specifications are unknown.

4. Assumptions

Existing research [1] is referred to for the cost of each imported hydrogen carrier (the price for arrival in Japan including the conversion process to hydrogen gas) and existing research [2] is referred to for the technical specifications and capital costs for direct reduced ironmaking. [1] assumes approximately 2.9 billion Nm^3-H_2/year of hydrogen imports, which is slightly different from the 2.0 billion Nm^3-H_2/year in direct reduction ironmaking volume assumed in [2], but the difference is not adjusted by a scale factor. No location factor will be considered for the capital costs of direct reduction ironmaking. The domestic hydrogen unloading port and the overseas hydrogen production location are both assumed to be located adjacent to their respective reduction furnaces (shaft furnaces), ignoring hydrogen transportation facilities.

Table 2 shows the cost of hydrogen in each case. The cost of the hydrogen which is produced overseas at JPY 20/Nm^3-H_2 increases 1.5 to 2.5 fold when arriving in Japan after hydrogen carrier synthesis and international shipment. All other assumptions are described in the Appendix.

Table 2: Procurement cost of hydrogen in each case

Case	H_2 carrier	Procurement Cost
H_2-Import Case	Imported LH (Gasification)	JPY 53/Nm^3-H_2
	Imported MCH (Dehydrogenation)	JPY40/Nm^3-H_2
	Imported NH_3 (Cracking)	JPY 45/Nm^3-H_2
	Imported e-CH_4	JPY 32~38/Nm^3-H_2
	(Domestic hydrogen gas)	(JPY 42 /Nm^3-H_2)
DRI-Import Case	Hydrogen gas	JPY 20 /Nm^3-H_2

Sources: Estimated based on [1] and references in [1]. Synthetic methane is converted to hydrogen calorific value of 107-126 Yen/Nm^3-CH_4

The range of values refers to the difference between existing and innovative technologies.

15 Tokyo Gas (https://www.tokyo-gas.co.jp/news/press/20221220-02.html)

5. Estimation results

Figure 2 shows the estimation results. As a whole, fixed costs (CAPEX) for DRI are very minimal, and variable costs (OPEXs) account for the majority. No huge difference among cases is observed in the "OPEX: others" that is dominated by iron ore procurement cost.

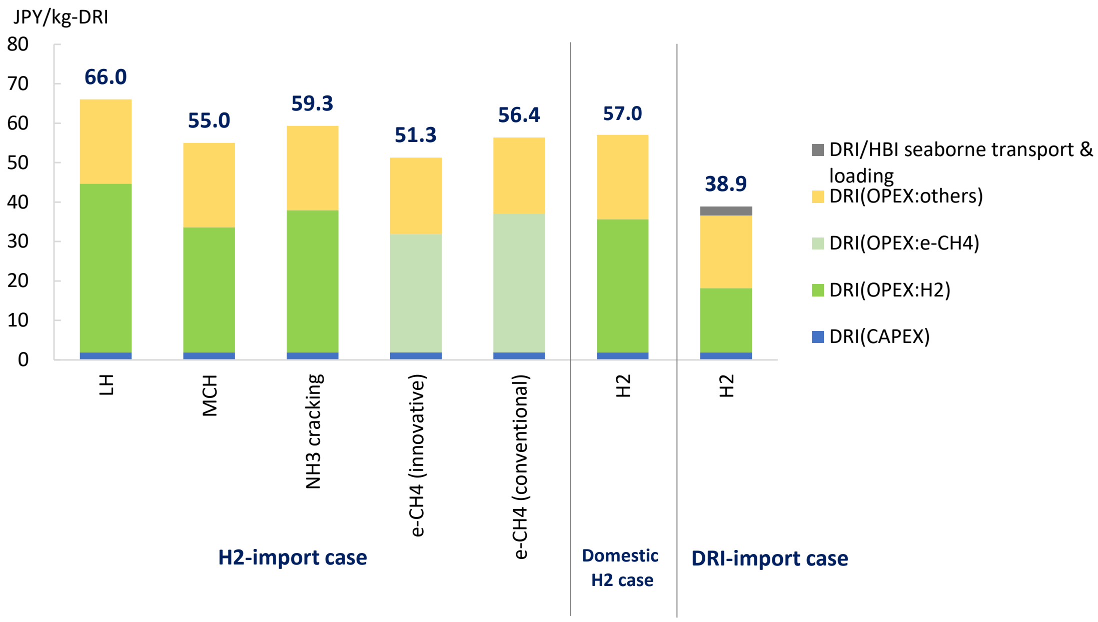

Figure 2: Procurement costs for direct reduced iron

Note: It should be noted that the compositions of hydrogen-based direct reduced iron and methane-based direct reduced iron are slightly different.

Note: "OPEX: others" includes the cost to import the iron ore and the energy used by the reduction furnace, but the iron ore import cost accounts for the majority.

The most significant difference is observed in OPEX of hydrogen or e-CH_4. The difference in the procurement cost of DRI among hydrogen carriers is almost identical to the difference in the cost of hydrogen in the H_2-Import Case as shown in Table 2. However, compared with H_2-Import Case, the DRI-Import Case is substantially inexpensive. This is because the cost of converting and transporting the hydrogen carrier is much higher than the cost of transporting the DRI/HBI. It also should be noted that there is no major difference between the case of direct reduced ironmaking using domestic hydrogen and the H_2-Import Case.

6. Implications

It could be interpreted that the estimated result that the cost of the DRI-Import Case (the supply cost to Japan) is lower than the H_2-Import Case merely highlighted the obvious fact that the cost of conversion to a hydrogen carrier and subsequent shipment increases greatly even if the production cost of hydrogen overseas is cheaper. However, this estimated result still suggests how we should address the economics of manufacturing products domestically using imported hydrogen, rather than focusing on the comparison of the import cost of hydrogen carriers.

With Japan's high dependence on imports for energy, resources, and products, there is a need to curb the outflow of national wealth by making an effort to minimize import costs. There are many other products produced using hydrogen other than direct reduced iron, so the results of this analysis cannot be applied generally. However, if the dependence on imports is inevitable then we should consider the option to import products manufactured using hydrogen abroad, rather than persisting on importing the hydrogen which is quite difficult to transport physically. It is important to make an assessment according to the situation of the industry and the supply chain of the individual product.

It is also necessary to remember that the direct reduced iron used for this analysis is an intermediate product. Accordingly, consideration should include optimization of the overall supply chain by minimizing any hollowing out of the industry, such as by retaining the blast furnaces, electrical furnaces, and other processes required for the manufacture of final products in Japan, including the downstream supply chain, which uses the imported direct reduced iron.

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It is unable to escape the principle that it is more efficient to directly use hydrogen as a gas near the location where hydrogen is produced, rather than converting hydrogen to a hydrogen carrier. Depending on the application, discussions are required based on multifaceted viewpoints that address the impact on the economy and industry, without taking hydrogen imports as a given.

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[1] Otsuki, Shibata, "Estimation of Production and Supply Costs of Synthetic Methane, etc.," 9th Public-Private Conference on Methanation Promotion, November 22, 2022

[2] "Evaluation and Technical Issues of Direct Hydrogen Reduction Ironmaking Processes," Center for Low Carbon Society Strategy, May 2022.

Appendix (Estimate assumptions)

Direct Reduction Ironmaking

			DRI in Japan		DRI in oversea
			H_2	e-CH_4	H_2
Capacity			2.5 million t-DRI/year		
Fixed expenses	CAPEX		JPY 28.5 billion		
	Annual expense rate		15%		
	Labors		100 persons		
	Unit labor cost		JPY 5 million/person		
Variable expenses	Unit	Iron ore	1,417kg/t-DRI		
		H_2	800 Nm^3/t-DRI	—	800 Nm^3/t-DRI
		Natural gas	50 Nm^3/t-DRI	279 Nm^3/t-DRI	50 Nm^3/t-DRI
		Electricity	135 kWh/t-DRI		
	Unit cost	Iron ore	JPY 12,000/t		
		H_2	JPY 40~53/Nm^3*1	—	JPY 20/Nm^3*1
		Natural gas	JPY1.1/MJ	JPY 3.0~3.5/MJ*1,2	JPY 0.4/MJ
		Electricity	JPY 17.9/kWh		JPY 6.2/kWh

Sources: Assumed and estimated based on references [1], [2] and the sources listed in these documents.
Note: Natural gas is used to increase the carbon content in the DRI.
*1: See Table 2 in the text.
*2: Price of imported e-CH_4.

Seabourne Transport of DRI

Deadweight (Cape size bulker)	150,000 ton	Estimated from "Trend of the World and Japanese Ship Building", Maritime Bureau, Ministry of Land, Infrastructure, Transport and Tourism, July 2022
Ship price	USD 50 million /ship	
Loading/unloading facility	JPY 1 billion	Miscellaneous information

Note: Voyage distance is assumed to be 12,000 km based on [1]. The number of vessels required is estimated based on the annual volume of DRI/HBI transported with estimates for ship speed and days required to load/unload. Fuel consumption (MJ/km) of the cape size bulk carrier is estimated based on the relationship between loaded weight and fuel consumption of LH_2, MCH, and NH_3. Fuel used is assumed to be green ammonia, with the cost estimated based on [1].

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