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Current global actions to achieve carbon neutrality

Ex-post Review on National and Regional Fluctuations in Demand for Energy (Electricity, City Gas, and Fuel Oil) due to Covid-19

International marine initiatives for decarbonization and LNG bunkering

Second half of the Series “Ushering in a New Era of Carbon Neutrality”

The Institute of Energy Economics, Japan

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IEEJ Forum on Latest Energy Situation towards Carbon Neutrality◆

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On July 26, the Institute of Energy Economics, Japan, held its 438th forum on research works online. Under the general theme "the latest energy situation towards carbon neutrality," IEEJ experts made reports on five topics: (1) carbon neutral policy trends in major countries, (2) Japanese and foreign initiatives for carbon pricing, (3) European Union and other trends regarding carbon border adjustment, (4) challenges for further renewable energy diffusion and (5) fossil fuel decarbonization initiatives in the world. As decarbonization initiatives have accelerated in the world since 2020, interests in long-term energy transition are growing globally. In the following, I would like to summarize the major points of the five reports as an introduction of the 438th Forum on research.

The first report titled "Carbon Neutrality Trends in Major Countries – How Do Major Countries Plan to Reach Carbon Neutrality?" came from Takahiko Tagami, Manager, Climate Change Group, Climate Change and Energy Efficiency Unit. The report reviewed key points of energy scenarios (supply and demand outlooks) in the European Union, the United Kingdom, France, Germany, Japan and other major economies and analyzed the characteristics of their respective prescriptions for carbon neutrality. As for greenhouse gas emission cuts towards 2050, these economies basically plan to reduce such emissions by around 80% from the present levels and use forest sinks and CO_2 removal technologies (including direct air capture) to offset the remaining emissions. They commonly place great hopes on energy savings among GHG emission reduction measures, planning to cut final energy consumption by 30-40% by 2050. They also plan to promote electrification and achieve zero emissions in the power sector. Most of these economies plan to raise their respective electrification rates from present levels around 20% to about 50%. China has set a goal of boosting the electrification rate to more than 70%, indicating that electrification holds the key to carbon neutrality in the country. Great hopes are placed on renewable energy to achieve zero emissions in the power sector. However, renewables' shares of power generation mixes in 2050 range wide from more than 50% for Japan to more than 80% for the United Kingdom and the European Union. Nuclear shares range from 9% to 16% for these economies other than France with a high nuclear share. Hydrogen (and synthetic fuels and synthetic methane) is projected to account for some 20% of final energy consumption in 2050, indicating that hydrogen and other innovative technologies hold the key to reaching carbon neutrality.

The second report titled "Carbon Pricing Trends in Japan and Other Countries – Can the Related Mechanism Be Designed to Contribute to Economic Growth?" was made by Tohru Shimizu, Senior Researcher, Climate Change Group, Climate Change and Energy Efficiency Unit. Explicit carbon pricing systems including carbon tax and emissions trading have attracted interests as economic means for promoting GHG emission cuts. Cases of European and other countries that have introduced high carbon taxes indicated that backgrounds and effects of the carbon tax introduction differ from country to country, including tax reforms and national energy supply and demand characteristics (such as a unique power mix comprising hydro and nuclear alone). The report pointed out that it is difficult to predict the relationship between tax rates and CO_2 emissions and that it is not easy to make carbon taxes consistent with emission reduction targets. Attracting attention regarding emissions trading are the recent trend of the European Union Emissions Trading System known as EU-ETS (including the enhancement of emission reduction targets for some sectors from 2030) and China's introduction of emissions trading touted as featuring the world's largest scale. The report also indicated that any emissions trading system, though being made consistent with an emission reduction target easily in comparative term, would be extremely complex and that emissions prices would be very volatile. It pointed out that carbon pricing towards carbon neutrality would

◆ Created based on the published research in the 438th Forum on Research Works

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contribute to hikes in final energy prices, affecting industrial competitiveness and household consumption.

The third report titled "Up-to-date Carbon Border Adjustment Trends – Cooperation or Confrontation?" was made by Miki Yanagi, Senior Researcher, Climate Change Group, Climate Change and Energy Efficiency Unit. It focused on the Carbon Border Adjustment Mechanism proposal announced by the European Commission in July. Carbon border adjustment is designed for a country to impose a tax or surcharge on imports from countries with lax GHG emission reduction measures to adjust emission reduction cost gaps. It is aimed at spreading momentum for enhancing emission cuts in the world, securing fair competitive conditions, preventing carbon leakage, and protecting domestic industries forced to take tougher emission reduction measures or ensuring tax revenue. The European proposal calls for testing the CBAM from 2023 to 2025 before its full introduction in 2026. While details of the CBAM are being discussed now, relevant issues to note may include its consistency with World Trade Organization rules, its impact on the global economy, developing economies' possible opposition to the CBAM and the escalation of the North-South confrontation. The report noted that Japan should proactively engage with the European mechanism by promoting talks with Europe and cooperating with countries outside the European Union in dealing with the European measure.

The fourth report came from Yoshiaki Shibata, Manager, New and Renewable Energy Group, Electric Power Industry & New and Renewable Energy Unit, under the title "Challenges for Further Renewable Energy Diffusion – What Diverse Viewpoints Are Required?" As solar photovoltaics and wind power generation expands, hopes are growing on renewable energy's roles in realizing carbon neutrality. Japan's draft strategic energy plan indicates that renewable energy power generation would expand substantially to 330-350 billion kWh by 2030. Solar PV and other renewable energy power generation will have to be expanded dramatically to achieve a target of cutting GHG emissions by 46% in 2030. However, challenges for the expansion exist, including how to secure suitable sites for solar PV and wind power generation and how to utilize renewable energy power generation projects for which the feed-in-tariff scheme has expired. Although renewable energy power generation costs are expected to decline in the future, the report pointed to a potential rise in renewable energy costs including those for countering variable output and inertia, as well as the need for developing wider grid networks and battery systems. Hydrogen as well as batteries will be important for storing electricity. Anyway, additional costs will be required for storing electricity in line with the expansion of renewable energy power generation. The report also pointed out that how to secure lithium and other key materials would become a significant challenge in line with the promotion of renewable energy and that policy to enhance domestic relevant industries would be required in parallel to the renewable energy promotion.

The fifth report titled "Fossil Fuel Decarbonization Trends: Could Stable Supply Be Balanced with Emission Cuts?" was presented by Yoshikazu Kobayashi, Manager, CCUS Group, Fossil Energies & International Cooperation Unit. While interests are growing in the key role of renewable and other non-fossil energy sources in realizing carbon neutrality, the decarbonization of fossil fuels accounting for most of present energy consumption could play a key role. The report introduced decarbonization initiatives in the downstream oil sector (transition to biorefineries and supply of sustainable aviation fuels and synthetic fuels) and the gas sector (synthetic methane and carbon-neutral LNG initiatives) and pointed out relevant challenges. It also indicated hopes and technological and economic challenges for carbon capture and storage technology as one of the key technological options for decarbonizing fossil fuel. The report noted that international rulemaking for measuring, reporting and verifying methane emissions will be required as Europe and the United States move to toughen restrictions on such emissions and that there are challenges regarding CO_2-free hydrogen/ammonia utilization initiatives on which hopes are growing towards realizing carbon neutrality. Future relevant developments in the world would be worthy of attention.

Carbon Neutrality Trends in Major Economies
- How Do They Realize Carbon Neutrality? -
<Summary>◆

Takahiko Tagami*

Analysis of carbon neutrality scenarios

1. Carbon neutrality scenarios (energy supply and demand analyses) through 2050 (or 2045 or 2060) have been released by governments or major research organizations for the European Union, the United Kingdom, France, Germany, Japan and China. I analyzed these scenarios, focusing on (1) energy savings, (2) electrification, (3) zero-emission power generation (renewable and nuclear energy), (4) impacts on electricity costs and prices, (5) non-electrification measures (hydrogen and other measures) and (6) the removal by forests and CO_2 removal technologies including BECCS (bioenergy with carbon capture and storage) and DACCS (direct air capture with carbon storage) applied to remaining emissions.
2. Each economy assumes that GHG emissions in 2050 would decline by about 80% from present (2015-2020) levels (with remaining emissions planned to be removed). China plans to keep the current emission level until 2030 before reducing emissions rapidly.
3. Energy savings: Each economy assumes final energy consumption in 2050 to decline by 30-40% from present (2015-2020) levels.
4. Electrification rate (electricity's share of final energy consumption): The rate is assumed to rise to 45-58% in 2050 from current levels between 18-27% in those economies other than China. The rate for China is projected at 71%, indicating that electrification would be the key for China.
5. Zero-emission power generation: Renewable energy's share of the power mix is assumed at more than 80% in the UK and EU, at 75% in China and at 54% in Japan. Nuclear energy's power mix share is assumed to range from 9% to 16% for those other than France that would depend heavily on nuclear. China plans to boost nuclear power generation 6.4-fold, while the UK and EU expect to retain their current nuclear power generation levels. As for Japan, the Research Institute of Innovative Technology for the Earth in its scenario analysis (interim report) in the reference case assumes nuclear power generation at about '10% of the total power generation in consideration of social constraints.' The renewable and nuclear energy share in France is left undecided for 2050 (assumed at 50% for 2035).
6. Electricity costs/prices: Electricity costs including those for integrating renewable energy into grid networks are assumed to rise nearly two-fold in Japan from the present to 2050. In the EU, electricity prices are assumed to rise 1.5-1.6-fold from the present to 2050. In China, electricity costs are projected to rise 1.4-fold from the present to 2028 and fall to lower levels than at present in 2050. The high electrification rate may depend on the electricity cost decline.
7. Hydrogen: Hydrogen's share of final energy consumption in 2050 is assumed at about 20% for the UK and at about 10% for China, Japan and the EU. The share for hydrogen plus synthetic fuels and methane is projected at 18% for the EU and 15% for Japan. Hydrogen is expected to play a key role in realizing carbon neutrality.
8. Remaining emissions: Most of these economies assume that nearly 20% of the present emissions would be removed in 2050. Removals in China are projected at 12%, offsetting remaining CO_2 emissions. Removals by forests, etc. are expected to increase substantially in France and the EU. In Japan, removals by forests, etc. was limited to 4% of GHG emissions in 2019 and is expected to continue a downtrend. CO_2 removal technologies in 2050 are assumed to account for 14% of present (2015-2020) emissions in Japan and 12% in the UK.
9. Comparison of major economies' prescriptions for carbon neutrality indicate that energy savings, electrification and

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hydrogen are commonly assumed to make almost the same contributions among economies. Zero-emission power generation measures as well as removals by forests, etc. and CO_2 removal technologies applied to remaining emissions differ by economy, reflecting differences in regional conditions and relevant costs.

10. International comparison indicates that zero-emission energy sources' share of total power generation for Japan is lower than for other economies and that Japan should also consider an option expanding nuclear power generation to raise the zero-emission share. Japan is also required to steadily develop and deploy CO_2 removal technologies and consider measures to maintain and increase removals by forests, etc.

U.S., European and Chinese policy trends

11. In the United States, whether Congress could pass the clean electricity standards which set the share of renewable energy, etc. in power generation, is attracting attention. An executive order came on May 20 to require the Financial Stability Oversight Council to assess climate-related financial risks and to report within 180 days, including the necessity of enhancing climate-related disclosure. It is worthy of attention that the United States has begun to tackle climate-related financial risks.
12. The EU on July 14 announced a series of draft policies and measures to achieve the targets for 2030. For details such as the expansion of the EU ETS (EU Emissions Trading System) into the transportation and buildings sectors, the revision of energy tax directives and the draft carbon border adjustment mechanism, see a separate report for this forum.
13. China on May 26 established the leaders group for the works of carbon peaking and carbon neutrality. It launched an emissions trading system on July 16. Attracting attention is what policies and measures for carbon peaking and carbon neutrality would be formulated.

Carbon Pricing Trends in Japan and Other Countries - Can Carbon Pricing be Contribute to Economic Growth? - <Summary>◆

Tohru Shimizu*

What is carbon pricing?

1. Carbon pricing represents an economic instrument to use carbon tax or emissions trading to put a price on CO_2 emissions and encourage CO_2 emitters to reduce emissions.
2. Carbon pricing can be divided into two categories: (1) explicit measures including a carbon tax, emissions trading, and energy taxes, and (2) implicit measures including energy efficiency and conservation, renewable energy promotion subsidies, and voluntary initiatives.
3. Explicit carbon pricing began to be introduced in Northern Europe in the early 1990s and 64 economies by 2020.
4. Not only explicit carbon pricing but also national energy supply and demand conditions and policies influence actual CO_2 emission cuts.

Carbon tax systems in major countries

5. Carbon tax systems in major countries differ from country to country, featuring various tax rates and coverages. However, fuel for power generation and raw materials use are exempted from a carbon tax, indicating that these systems are commonly designed to impose less burden on the industry sector.
6. Sweden's carbon tax, which is frequently referred to by other countries, was introduced along with an income tax cut under a tax reform of the century. The carbon tax rate has been gradually raised, standing at 1,150 SEK/t-CO_2 in 2018. By contrast, the industry sector's tax rate was set at a low level (300 SEK/t-CO_2) until 2015.
7. As well Sweden, Switzerland, and Denmark have introduced high carbon tax rates and have been viewed as having decoupling CO_2 emission cuts with economic growth. However, we must note that their respective conditions (Sweden's and Switzerland's zero-emission power mix comprising hydro and nuclear energy and Denmark's large power mix shares for biomass and wind) are essential background factors.
8. Germany introduced an electricity tax when an ecological tax reform for a social security reform was implemented in 1999. However, electricity tax revenue has been used primarily to reduce companies' social security contributions rather than for subsidizing energy savings and promoting renewable energy to reduce emissions.
9. Generally, it is challenging to predict contributions of specific carbon tax rates (price effects) to CO_2 emission reduction, making it difficult to link tax rates to emission reduction targets.

Emissions trading in major countries

10. After the European Union Emissions Trading System (EU ETS) was introduced in 2005, China, South Korea, and some states in North America introduced their respective emissions trading systems. As is the case with carbon tax systems, emissions trading systems differ from country to country and are complex regulations for taking into considering the industry sector competitiveness.
11. Since its launching in 2005, the EU ETS has been plagued with problems such as excessive allocation and allowance price fluctuations, leading the system to be modified with minor revisions almost every year.
12. Emission allowances are allocated by free or auction to ETS sectors. However, the allocation is bound by complex

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rules considering East European countries and the industry sector.

13. On July 14, the European Commission proposed revising the ETS directive. It proposed emissions reduction from ETS sectors in 2030 by 61% (current is 43%) from 2005, for subjecting shipping, transport and building sectors to the ETS and for phasing out free allocation for sectors subject to the Carbon Border Adjustment Mechanism to accelerate the transition to auctions.
14. Separately from the EU ETS, Germany has introduced a domestic emissions trading system for the transport and building sectors, requiring fuel suppliers to purchase emission certificate.
15. China had planned to introduce emissions trading in 2017 but has taken time for domestic coordination, launching emissions trading only in the power generation sector in 2021. It started trading in July, making the first step to utilizing the market.
16. Generally, it is easy to link emissions trading systems to emission reduction targets. But these systems are extremely complex and vulnerable to price fluctuations.

Challenges for carbon pricing

17. In Japan, energy costs paid by the industry sector and consumers and impact their behaviors are higher than international levels.
18. Any additional carbon pricing measures may further boost energy costs and cause electricity bill hikes to raise burdens on final energy consumers such as the industry and household sectors and affect international industrial competitiveness.
19. While overall spending in a low-income household is limited, payments for basic needs such as electricity and gas account for a high share of their spending. Sufficient consideration should be given to the regressivity of carbon pricing.
20. In designing carbon pricing in Japan, the government should pay attention to international trends including carbon border adjustment mechanisms and the expansion of voluntary credit markets.

The Carbon Border Adjustment Mechanism: Collaboration or Confrontation? <Summary>◆

Miki Yanagi* Hiroko Nakamura** Soichi Morimoto*

Key developments

1. EC announces plans to establish a carbon border adjustment mechanism

On July 14, 2021, the European Commission (EC), the executive arm of the European Union (EU), published a proposal[1] for a regulation to establish the world's first carbon border adjustment mechanism (CBAM). CBAM is a mechanism under which countries that bear the carbon costs for taking strict climate measures to impose taxes, surcharges, and emission permits purchase duties on imported goods from countries that do not take such measures, thereby adjusting the differences in such costs. The purpose of this paper is to offer a summary of the EC's CBAM regulation proposal brief and its implications for Japan.

The EC's proposed CBAM designates products of iron and steel, cement, aluminum, fertilizers, and imported electricity as target products. The revenue generated by the CBAM is estimated to amount to 2.1 billion euros in 2030 and will source the NextGenerationEU, a more than 800 billion euro temporary recovery fund for repairing the economic damage caused by COVID-19. According to IEEJ estimates based on Combined Nomenclature ('CN') goods codes using Eurostat, imports from Russia, Ukraine, Turkey, and China are expected to be subject to CBAM.

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[1] European Commission(2021) "Proposal for a regulation of the European parliament and of the council establishing a carbon border adjustment mechanism" 2021/0214 (COD), Brussels, 14.7.2021.
https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021PC0564

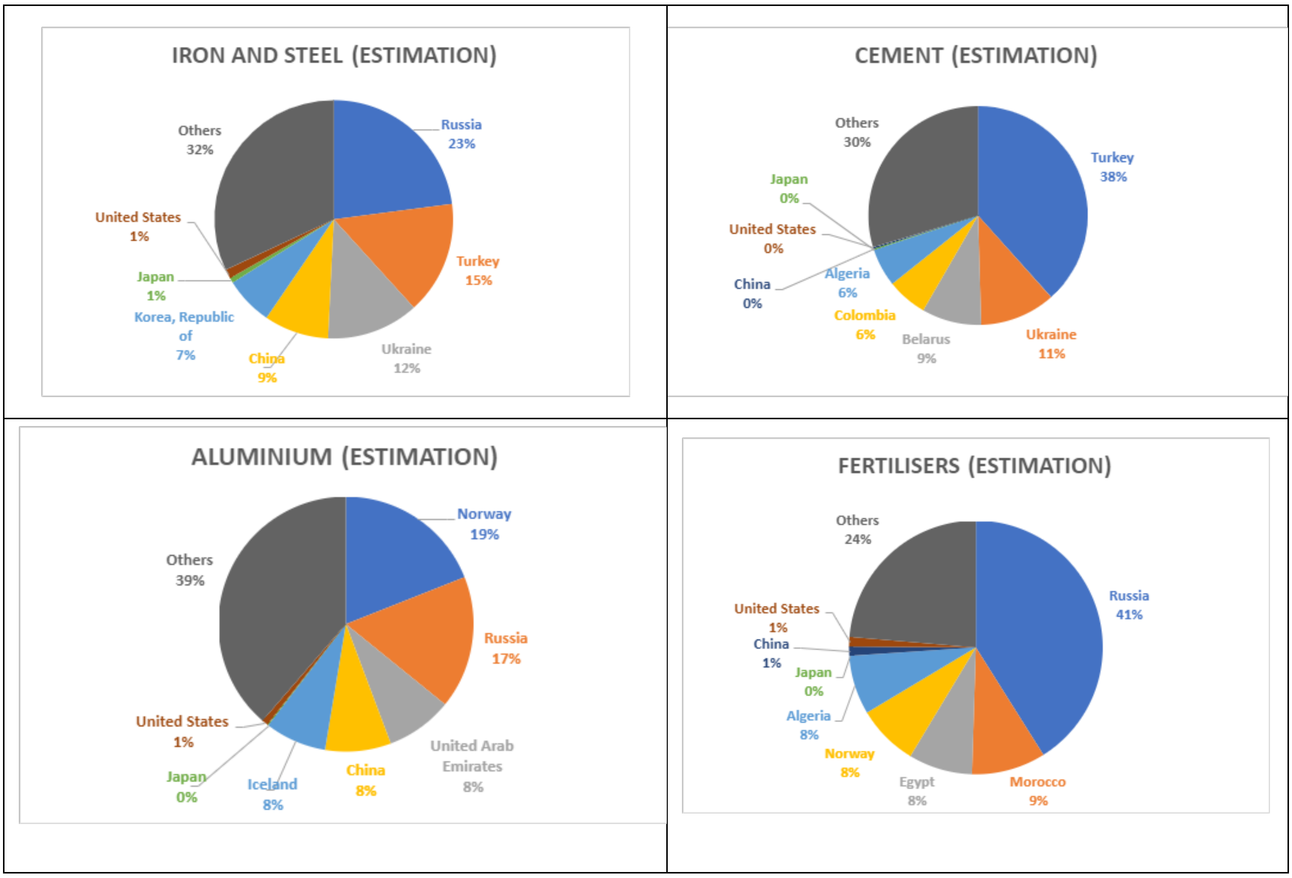

Fig. 1 EU imports goods share estimation based on EC regulation proposal, in 2019

Source: Based on Eurostat ("Extra-EU imports since 2010 by country of origin and country of consignment, by HS2-4-6 and CN8 (DS-059071)"), the author's estimations

Note: In the statistics, the U.K. is included in the EU. The graph covers the top five import partner countries, as well as Japan, the US and China.

2. A "transitional period" will start in 2023 through 2025

CBAM will impose obligations to report the embedded emissions of the imported product, which includes not only direct emissions from the manufacturing process but also indirect emissions from electricity and heat. The carbon price due in the country of origin should be reported as well. The reports must be submitted to authorities quarterly. The methodology for measuring emissions will be prescribed in an implementing act to be determined, and the EC will continue to engage in dialog with third countries on the detailed design of the system during the transitional period. The EC will submit an assessment report on the measurement of indirect emissions and other topics to the European Parliament and the European Council before the transitional period ends.

3. CBAM is scheduled for implementation in 2026

The obligation to pay the carbon price for imported products through CBAM certificates will begin in 2026, according to the EC proposal. A CBAM certificate is a certificate corresponding to one tonne of embedded emission in goods. Importers (termed "declarants" in the proposal) will thereafter be required to pay for the embedded carbon emissions of their products with CBAM certificates, whose prices will mirror the EU Emission Trading System (EU-ETS) price. Carbon emissions will initially be calculated for only direct emissions, such as those from fuels consumed in manufacturing plants. However, based on assessment results by the EC during the transitional period, the CBAM could eventually be expanded to include indirect emissions associated with purchased electricity, heat etc. Furthermore, the proposal states that the CBAM will allow carbon prices that have been paid in the country of origin to be deducted; however, this will basically apply only to explicit carbon taxes and explicit carbon prices used in emissions trading.

From 2026, CBAM will be rolled out in stages, in step with the phasing-out of free emission allowances, which have served as a carbon leakage countermeasure under the EU-ETS. In 2035, free allowances will be suspended completely, and CBAM will be fully implemented.

4. Next steps and implications for Japan[2]

The European Parliament and the European Council will conduct deliberations based on the EC's proposal. At present, prospects for final approval of the proposal and the actual design of the system, if approved, remain unclear. Japan's exports of the target products to the EU are miniscule; and therefore, the impact on Japan will be limited even if the proposal is passed. However, Japanese companies may be affected if products from Russia, China, and other economies that are shut out of the EU flow into Asian markets. Attention must also be paid to the risk that CBAM may hamper free trade and exacerbate the North-South divide.

On the other hand, it is desirable, from a trade perspective, to standardize the methodology for measuring emissions for each product, and Japan should play an active role in developing such standards. It is also essential to confirm whether the proposal is consistent with WTO rules. This includes monitoring for any arbitrary or unjustifiable discrimination, including using the proceeds from auctioning free allowances to provide technological support such as CCS technologies to targeted sectors, in effect, compensating for the free allowances they would have earned, and thus subsidizing domestic products while imposing charges only on imported goods.

5. Developments in the United States

Under these circumstances, at the margin of the G20 s Finance Ministers meeting in July 2021, Secretary of the Treasury Janet Yellen commented as follows, questioning the EC CBAM proposal, which focuses only on explicit carbon prices: "It is important that any carbon border adjustment system focus on the degree to which a country's climate policies reduce emissions (and hence carbon content), rather than focus only on explicit carbon pricing."[3]

However, the situation is not so simple. During the election campaign, President Biden made reference to applying a carbon adjustment fee at the border in conjunction with regulatory measures on domestic manufacturers ("Democratic Platform"[4]). Meyer & Tucker (2021) also point out the possibility of introducing carbon border adjustments on national security grounds based on Section 232 of the 1962 Trade Expansion Act[5].

Meanwhile, there are moves by Congress Democrats in connection with carbon border adjustments that deserve attention. These include a proposal by Senator Coons and Peters on a carbon border adjustment mechanism that includes implicit carbon prices that are linked with standards or regulations, to be applied to iron and steel, cement, aluminum (and products containing at least 50% of these materials), as well as oil, gas, coal, and other fossil fuels (July 2021). Later in August, a "carbon polluter import fee" was included in the 3.5 trillion-dollar budget resolution, which is under committee deliberation at the time of writing (October 25, 2021).

6. Conclusion and implications

A trial run of the carbon border adjustment mechanism is being pursued mainly in the EU as the world's first such effort. Future challenges include verification in terms of international trade law, including consistency with WTO rules.

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[2] A METI study group has also made references to CBAM:
METI, Japan, "Interim report of a study group on ideal economic and other approaches for achieving worldwide carbon neutrality"
https://www.meti.go.jp/press/2021/08/20210825002/20210825002-1.pdf

[3] "Remarks from Secretary of the Treasury Janet L. Yellen at the G20 Finance Ministers and Central Bank Governors Meeting's High Level Symposium on International Tax",U.S. Department of the tresurery, July 9, 2021
https://home.treasury.gov/news/press-releases/jy0266

[4] The 2020 Democratic Party Platform said, "We will apply a carbon adjustment fee at the border to products from countries that fail to live up to their commitments under the Paris Climate Agreement, because we won't let polluters undermine American competitiveness."

[5] Meyer & Tucker (2021) "Trump's Trade Strategy Points the Way to a U.S. Carbon Tariff", August 24, 2021.
https://www.lawfareblog.com/trumps-trade-strategy-points-way-us-carbon-tariff

(1) The EC's CBAM proposal seeks dialog and international cooperation with non-EU countries during the 2023–2025 transitional period It is strategically important for Japan to become actively engaged in dialog with Europe and to collaborate with relevant non-EU countries.
(2) Furthermore, the development of methodology will be the world's first attempt to calculate all the emissions embodied in products. Establishing the methodology will be a technical challenge.
(3) From 2026, when the mechanism is gradually implemented, it will be important to verify that the system is compatible with WTO/GATT rules, and thus does not discriminate between countries in and outside the EU. The most important discussion point is whether the obligations imposed are equivalent for both the EU companies that are subject to the EU-ETS and the non-EU companies that will be required to purchase CBAM certificates and to comply with reporting obligations. In addition, to avoid trade frictions, the international community is urged to actively engage and discuss CBAM in the meetings offered in various forums such as the EU, G20, etc.

Challenges in Further Expanding Renewable Energy
What multilateral viewpoints are needed?
<Summary>◆

Yoshiaki Shibata*

Status of global use of renewable energy

1. Renewable energy including large-scale hydropower accounted for 28% of the global power output in 2020, growing 9 points in the last decade. Wind power and solar PV are spreading more rapidly but each account for just 6% and 3% of the total; hydropower is still the largest renewable power source at 16%.
2. Europe is the world's forerunner in adopting renewables, which account for 41% of its total power output (wind power 13% and solar PV 5%). Renewables account for 26% of the total power output in North America (wind power 8% and solar PV 3%) and 25% in Asia and Oceania (wind power 4% and solar PV 4%).
3. In Japan, renewable power generation, including large-scale hydropower, amounted to 205 TWh and accounted for 22% (wind power 1% and solar PV 9%) as of the end of 2020.

Renewable capacity required for achieving carbon neutrality by 2050

4. To meet the IEA's 2050 net-zero carbon scenario, the world must increase the share of renewables in the total power output to as high as 88% in 2050. This means that wind and solar PV must expand nine-fold from current levels.
5. As for Japan, the share of renewable energy required to achieve carbon neutrality by 2050 is 54% or 730 TWh out of a total power output of 1,350 TWh, according to a reference estimate from an analysis of the 2050 carbon neutrality scenario conducted by the Strategic Policy Committee.

Challenges in further expanding renewable energy

6. Further expansion of renewable energy is essential for Japan to achieve the 2030 GHG emissions reduction target (raised to 46%). At present, METI anticipates that renewable power generation will increase to 330–350 TWh in 2030 by implementing policies that are already concrete and by ramping up initiatives.
7. However, a multitude of issues must be resolved to expand renewable capacity. First, regarding the securing of appropriate land, a decision has been made to standardize rooftop solar PV to be installed on public buildings; however, other pending issues include offering incentives for new houses, construction methods that make it easier to mount solar panels on existing houses, and development of lighter solar PV. Abandoned farmland, land with unknown owners, and municipal land for ground-mounted solar PV and forest reserve areas for wind power could be used, but rules and regulations must be established to make this possible.
8. Together with the use of renewable capacities whose purchase period under the Feed-in-Tariff program will expire in the near future, it is also necessary to establish a system to replace facilities that have come to the end of their life so as to continue to produce power, and also to raise their power generation efficiency or increase their output by repowering.
9. Regarding the economics of renewables, the Power Generation Cost Verification Working Group has indicated that mega-solar PV would have the lowest generation cost in 2030 at JPY 8–11 /kWh, though far from the government goal of JPY7 /kWh. The cost of offshore wind power is JPY26 /kWh, far off the target set by the Public-Private Council of JPY8–9 /kWh. Further, grid integration costs, including the costs for addressing the loss of grid inertia,

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must also be included in.

10. To abate the regional imbalance in renewable energy abundancy and electricity demand, a study for establishing a nationwide transmission network is under way. Cost-benefit evaluations have been published for scenarios with varying amounts of renewables. Benefits exceeded costs for most of the scenarios, but for a scenario in which renewables account for as much as 50–60% in the power generation mix, the results showed that solely reinforcing transmission networks would not be sufficient for significantly reducing the curtailment rate of renewables. Demand-side measures as well as the introduction of batteries and hydrogen (Power to Gas: PtG) that would lead to the use of surplus renewable electricity, were suggested.
11. Batteries are expected to play a key role in energy storage, which is crucial for expanding renewables, but it is also important to make use of existing facilities that are ready for use, such as thermal storage facilities in the residential and commercial sector and the energy storage function of gas networks. Furthermore, repurposing coal-fired thermal power plants, which are expected to be closed, to energy storage facilities is another possibility. To address the loss of grid inertia, not only batteries but the possibility of synchronous energy storage using compressed air, liquefied air, and Carnot batteries (which can utilize the steam turbines of coal-fired thermal plants) needs to be discussed. However, it must be noted that all of these energy storage technologies require additional costs.
12. The expanded deployment of EVs and batteries is expected to cause a surge in global demand for lithium and other critical minerals. It will therefore be necessary to address the best mix of a wide variety of energy storage technologies, including non-lithium batteries and PtG, taking into account their technological characteristics and the supply risk of critical mineral resources.
13. Renewables curtailment should decrease as electricity demand grows with the progress in electrification. Even so, energy system integration (sector coupling), including accommodating renewable energy in the city gas sector through PtG, remains an important issue to be examined.
14. It is essential to develop and revive a highly competitive related industry in the process of expanding renewables, in light of contribution to the domestic economy. It is also necessary to create a venous industry such as recycling, preparing for supply constraints of critical mineral resources.

Update on the Decarbonization of Fossil Fuel Utilization Can we achieve the dual goals of stable supply and emission reduction? <Summary>◆

Yoshikazu Kobayashi*

1. International efforts for reducing greenhouse gases are quickly gathering steam. Unforeseen forms of pressure and calls for action are emerging, including governments setting net-zero emission targets and moving up their interim reduction targets, institutional investors demanding the adoption of bolder climate measures, and court rulings on the responsibility for reducing emission. The environment surrounding fossil fuels is becoming harsher than ever.
2. Under these circumstances, energy industries in and outside Japan are exploring a wide range of decarbonization measures. The US, the Middle East, and some countries in Europe are preparing for the full-scale introduction of carbon capture and storage (CCS) as an essential technology for achieving net-zero emissions. The CO_2 storage potential is known to be sufficient, but it will be necessary to study and prepare an institutional system to accelerate the actual adoption of CCS, alongside addressing any technological challenges (including the sustainability of storage) and economic issues (cost reduction).
3. In the downstream oil industry in Europe and the US, conventional refineries that process crude oil are starting to be converted into bio refineries that produce petroleum products from plant-based oil and animal fat. Decarbonization projects for the future are also under way, including producing sustainable aviation fuel, making synthetic fuel from captured CO_2, and replacing the hydrogen used in the refining process with green hydrogen.
4. In Europe, which is the forerunner in gas projects, initiatives to decarbonize the gas industry such as utilizing biogas, synthetic methane (methanation), and clean hydrogen are being studied. Decarbonization of LNG is also under way, as shown by the expansion of carbon-neutral LNG trade. Plans for introducing CCS at liquefaction plants are also in progress.
5. Methane emissions are receiving attention as a new GHG emission issue, and several international bodies are collecting data and formulating rules on the way to establishing guidelines. The EU and the US are also considering legislating and implementing new regulations regarding methane.
6. For ammonia, a new clean fuel attracting much attention, studies are under way in Japan toward practical application. Going forward, it will be important to secure supplies from a wide variety of locations and feedstocks. Alongside the use in Japan, ammonia is expected to see growing demand in other countries that rely heavily on thermal power, particularly Asian countries.
7. Due to the long lifecycle of infrastructure, it is difficult to switch energy sources quickly. This makes it necessary to maintain existing supply capabilities and supply chains and continue to invest in them, at least during the transition period. In the area of oil supply, upstream investment for oil is expected to remain at just 60% of the 2010–2019 average in 2021, even though oil demand is recovering globally. It is important to make appropriate investments to avoid supply-demand imbalances in the future.
8. Under the basic principles of the 3E+S policy, giving up fossil fuels, with their unique resilience, is not an option. The essence of climate action is to reduce GHG emissions. Fossil fuel is not inherently a "problem"; rather, it is the GHG emissions from using fossil fuels that cause problems. If fossil fuels can be decarbonized before use, it would be possible to reduce emissions while using fossil fuels. Development of new technologies, reduction of costs, and construction of infrastructure must continue to be pursued for fossil fuel decarbonization technologies, mainly CCUS,

◆ Created based on the published research in the 438th Forum on Research Works

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hydrogen, and ammonia, to enable the continued use of fossil fuels and to ensure supply stability and reduce emissions at the same time.

Ex-post Review on National and Regional Fluctuations in Demand for Energy (Electricity, City Gas, and Fuel Oil) due to Covid-19

Hideaki Okabayashi*

1. Introduction

How much energy demand has Japan lost due to the Covid-19-induced economic slump? Although it is difficult to measure the exact amount, this report analyzes the impact of the pandemic to the extent possible based on data. The release of electricity statistics for February 2021 by the Ministry of Economy, Trade and Industry (METI) on May 31, 2021 provided all the necessary data on the full-year actual energy demand since Covid-19 started spreading in Japan. This report looks back on the national (monthly year-on-year comparison) and regional (annual aggregate) changes in demand for electricity, city gas, and fuel oils.

Social patterns changed dramatically after March 2020 when former Prime Minister Abe requested the temporary closure of all elementary, middle, and high schools at a press conference on February 29. This report attempts to capture the changes in demand before and after Covid-19 struck through a year-on-year comparison of various energy statistics for the March 2020–February 2021 period with the previous year, taking into consideration potential factors other than Covid.

2. Review of national energy demand

2-1. Trends in sales of electricity

Fig. 1 compares the monthly electricity sales (in TWh) for the most recent March–February period with those for the previous year based on METI's electricity statistics. Electricity sales for the year from March through February were 819 TWh/year in total, down 1.9% year-on-year. The Fig. 2 shows the rate of change (%).

The categories for electricity statistics are aligned with those of electricity contracts: extra-high voltage (20,000 V or more and 2,000 kW or more) for large factories and railway facilities, high voltage (50 kW) for small and medium factories, corporations, and others, low voltage (three-phase electricity of up to 50 kW) used mainly by shops for large air-conditioners and motors, and low voltage lighting (single-phase 100 V and 200 V electricity of up to 50 kW) used by homes for power plugs and lighting. Unlike for city gas, they are not divided by purpose of use.

Fig. 1 and 2 clearly indicate that sales dropped more for larger contract voltages, whereas demand for low voltage lighting even increased for most months. This suggests that Covid-19 caused extreme strain on demand from corporate production activities and railway transport while generating additional demand from residential users associated with stay-at-home advisories and working from home.

Further, the greatest decline in sales of electricity (excluding lighting) from pre-Covid levels was marked in May 2020 during the first state of emergency, with extra-high and high voltages posting double-digit falls in percentage.

However, as mentioned earlier, not all increases or decreases in electricity sales are necessarily pandemic-related, and for energy demand in particular, the impact of higher or lower demand for air-conditioning cannot be ignored. From the increases or decreases in monthly average temperature shown in Fig. 3, we can assume that while the cooling demand in summer was generally fully offset, the severe cold weather during the second state of emergency in January 2021 pushed up electricity sales, while causing the supply-demand balance to tighten. However, annual sales nevertheless dropped, even when factoring in the air temperature, indicating that Covid-19 is still continuing to hit power companies.

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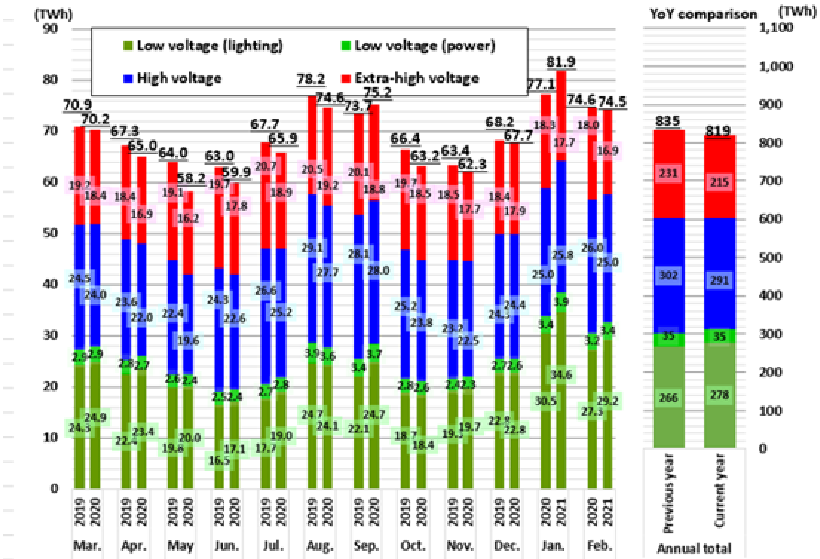


Fig. 1 National electricity sales for the past two years (year-on-year)

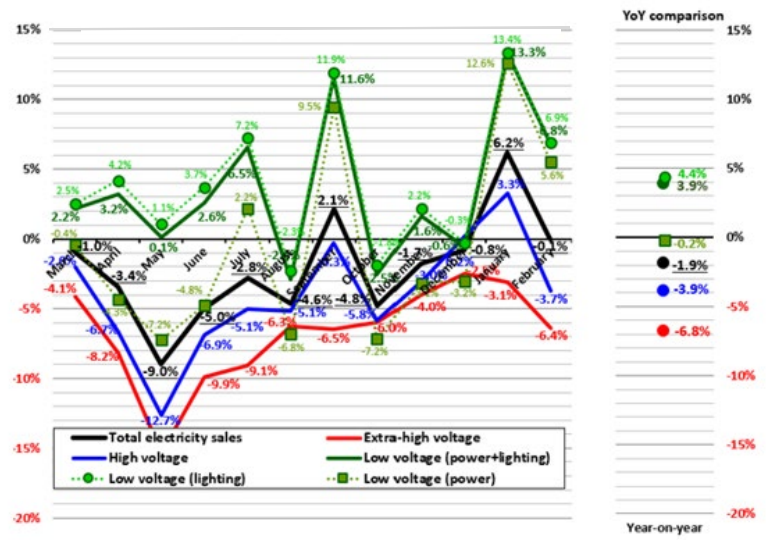


Fig. 2 National electricity sales: Rate of change for the past two years (year-on-year)

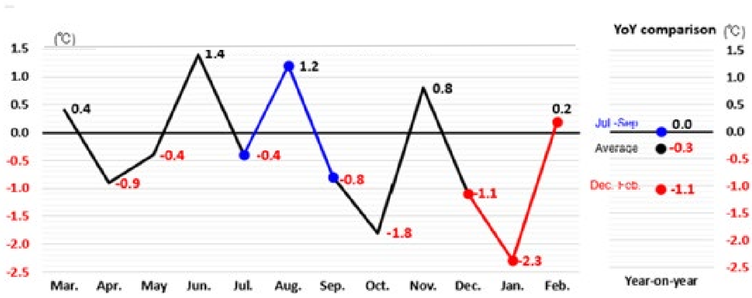


Fig. 3 Change in national (9 cities/regions, population weighted) monthly average temperature (year-on-year)

2-2. Trends in sales of city gas

Fig. 4 compares the monthly city gas sales (in 100 million m^3 [41.8605 MJ (10,000 kcal) per m^3]) for the most recent March–February period with those of the previous year based on METI's statistics on production by gas companies. City gas sales for the one-year period were 39.4 billion m^3, down 2.5% year-on-year. The rate of change (%) is shown in Fig. 5.

The statistical categories for city gas are divided into residential, commercial, industrial, and others (public and medical services). Industrial city gas can be divided further based on its use—power generation and general industry—by drawing on the electricity statistics under section (1). The categories are very clear-cut and directly linked with consumer characteristics, and seem to directly reflect the impact of Covid-19, such as the year-on-year decline of 44.4% for the commercial category in May this year and the increase in demand from homes.

Fig. 4 and 5 indicate that city gas sales for the March–February one-year period fell more than electricity sales (−1.9%) with −2.5%, due in part to the double-digit fall in the general industry and commercial categories, even though city gas for power generation, which accounts for around 20% of industrial city gas demand, grew sharply in absolute terms since August 2020, and despite the high demand for heating during the cold winter. Unlike the commercial category which made a V-shaped recovery in sales after May, the sales for general industry kept posting double-digit declines until September, possibly because adjustment of production goods (by manufacturers) took longer than adjustments in commercial services.

Though the sales of city gas remained above the previous year between November 2020 and February 2021, this result is largely due to gas for power generation which has little relation with Covid-19 and the additional demand due to the cold weather. Until the sales for general industry and commercial uses normalize, the impact of Covid-19 may not be completely over for city gas companies.

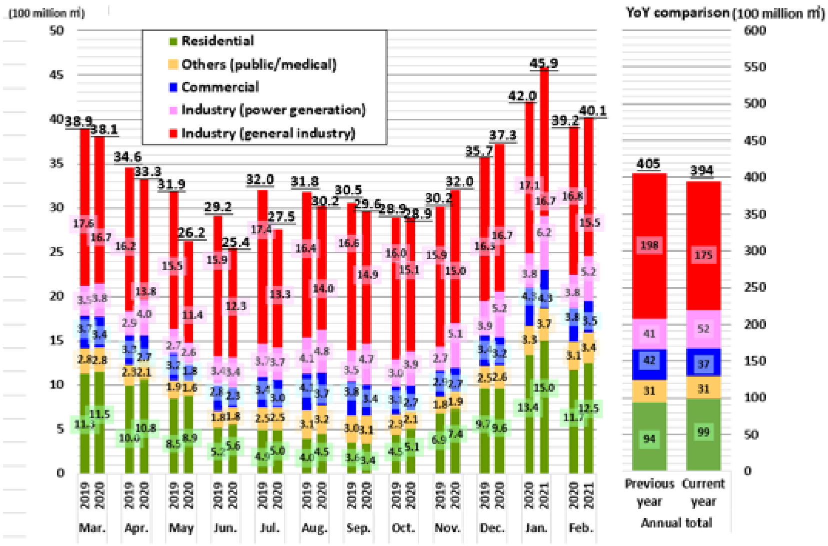


Fig. 4 National fuel oil sales for the past two years (year-on-year)

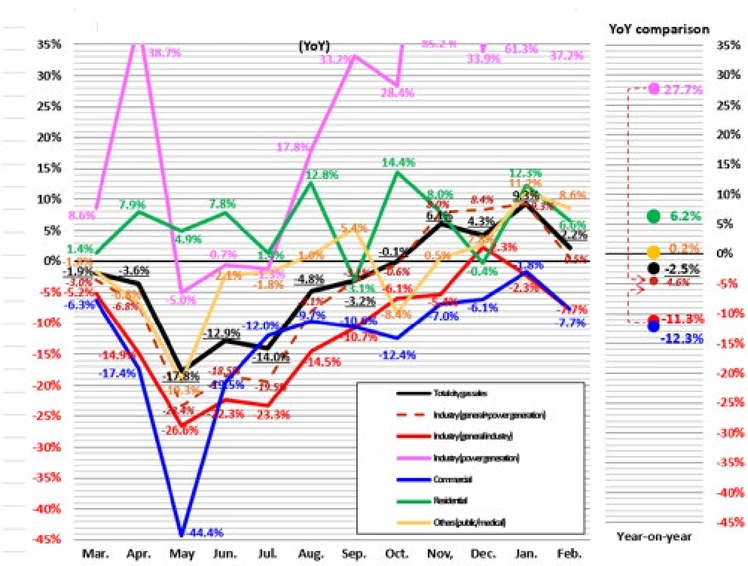


Fig. 5 National city gas sales: Rate of change for the past two years (YoY)

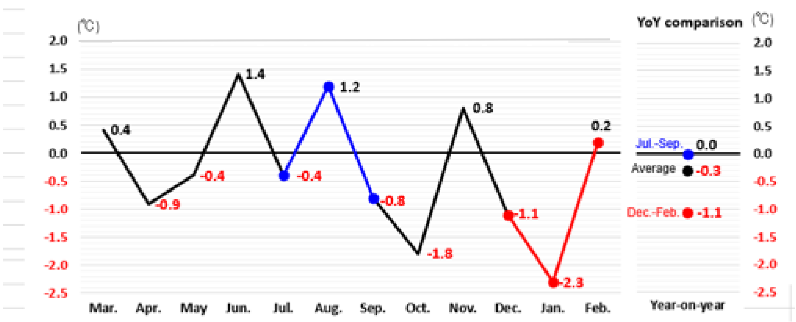


Fig. 3 Change in national (9 cities/regions, population weighted) monthly average temperature (year-on-year) (Reposted)

2-3. Trends in sales of fuel oil

Fig. 6 compares the monthly domestic fuel oil sales (in million kL) for the most recent March–February period with those of the previous year, based on METI's Monthly Report of Mineral Resources and Petroleum Products Statistics (petroleum). Sales of fuel oils for the one-year period were 151 million kL, down 7.6% year-on-year. The rate of change (%) is shown in Fig. 7.

The statistical categories for the domestic sales of fuel oils are gasoline, naphtha, jet fuel, kerosene, diesel oil, Bunker A, and Bunker B/C.

Fig. 6 and 7 indicate that gasoline, diesel oil, and jet fuel, which directly reflect the drop in transport demand due to the stay at home advisories, fell drastically year-on-year in April and May 2020 as did electricity and city gas. Gasoline, which reflects the demand for leisure, commuting, and business-use vehicles, and diesel oil, which reflects that for land transport, continued to post single-digit declines thereafter, though with increasingly smaller falls. Jet fuel, which directly reflects the reduction in flights in the aviation industry, did not recover thereafter and remained at around half the level of the previous year.

Bunker B/C, whose demand bottomed out in August 2020, also suffered a great decline of −14.1% year-on-year for the full year. As the demand for Bunker B/C for power generation, which accounts for 0.2 million kL out of the aggregate sales of around 0.5 million kL, was relatively stable at −1.6% (though not shown in Fig. 6 and 7), the demand for Bunker B/C other than for power generation, which includes much of that for shipping, fell even more at −21.3%. Covid is assumed to have pushed down the demand in the shipping industry as well, though to a lesser extent than aviation demand.

Sales of naphtha shrank significantly by 8.3% for the year, given the sluggish demand for synthetic resins as domestic production of cars declined.

Bunker A remained mostly flat for the full year (−1.0% year-on-year) as the fall in demand from production was offset by the additional demand for heating and hot water in buildings, hospitals, and schools.

Kerosene, which is considered to reflect the demand of users in their homes, was the only fuel oil to grow year-on-year at 7.0%, due in part to the high heating demand resulting from unusually cold weather during the peak winter season.

Overall, sales of fuel oils for the year between March through February showed a substantial drop of −7.6% year-on-year.

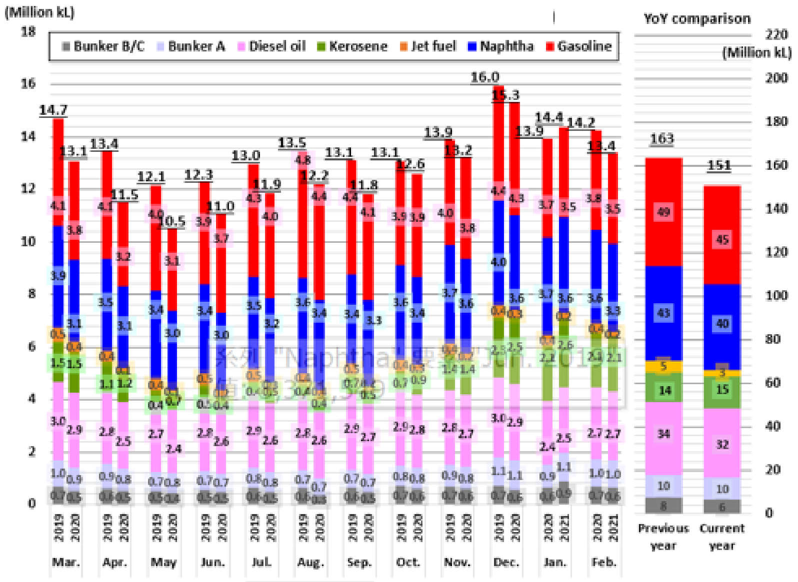


Fig. 6 National fuel oil sales for the past two years (YoY)

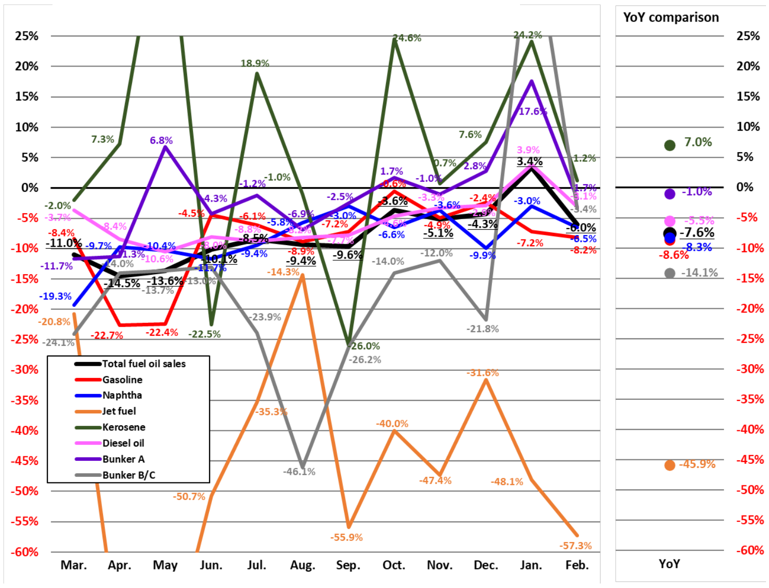


Fig. 7 National fuel oil sales: Rate of change for the past two years (YoY)

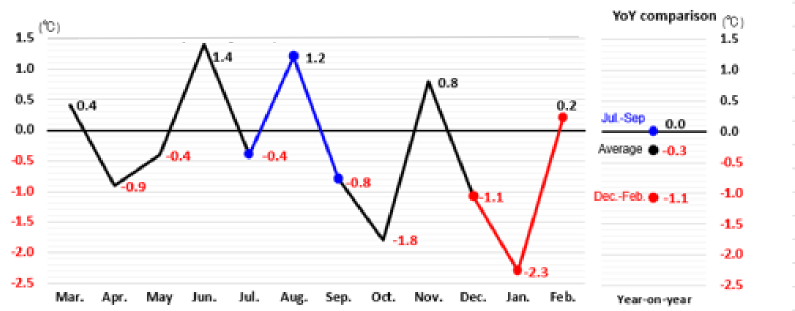


Fig. 3 Change in national (9 cities/regions, population weighted) monthly average temperature (year-on-year) (Reposted)

2-4. Wrap-up of national energy sales

Fig. 8 shows that while electricity sales were hit by Covid-19 but are now recovering, city gas declined most at one time but also recovered most, although, except for gas for power generation, only to the same extent as electricity sales, and fuel oil sales were hit harder than electricity and have yet to fully recover.

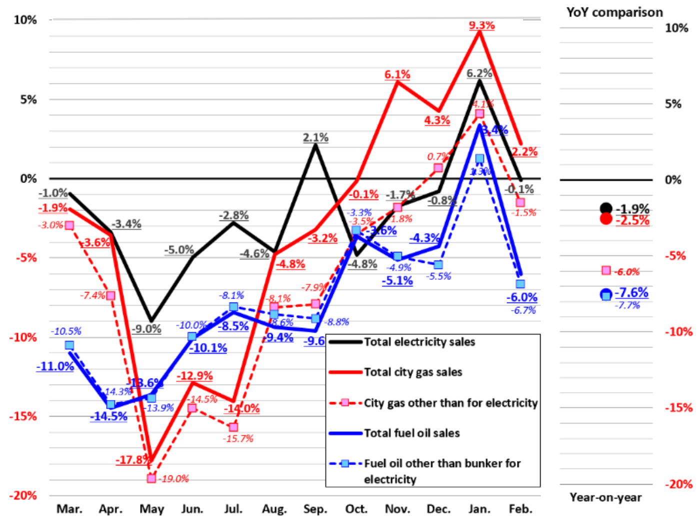


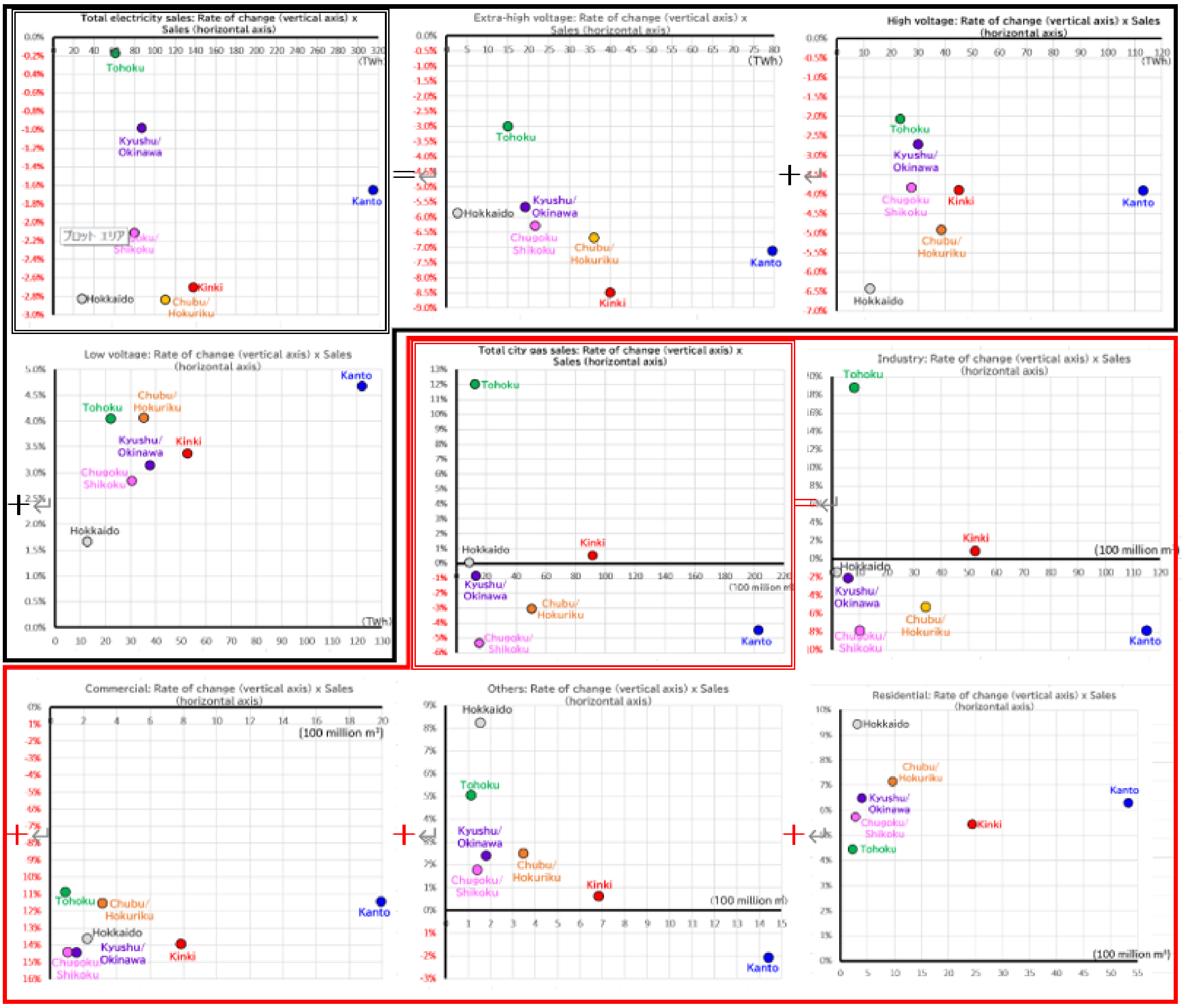
Fig. 8 National sales of electricity, city gas, and fuel oil: Rate of change (year-on-year)

3. Review of regional energy demand

Japan's national energy demand is the total of the sales in each of its regions spanning from Hokkaido to Okinawa, as well as the total of the sales in each category. This section analyzes the regional energy demand, examining the rate of year-on-year change (impact of Covid-19 and other factors on the increase/decrease in demand) against annual sales (contribution of the industrial, population, and energy consumption structure).

Electricity was analyzed using the prefectural electricity demand data for March 2020 through February 2021 from METI's electricity statistics, which was used in the previous sections. The data for city gas are based on the regional appendix (the data for the nine regions under each regional Bureau of Economy, Trade and Industry, organized into seven by merging the Chugoku and Shikoku regions and the Kyushu and Okinawa regions) for March 2020 through February 2021 from METI's statistics on production by gas companies, the same source documents as used in the previous sections. As the data for fuel oil, unlike for the previous sections, the prefectural sales statistics for FY2020 (April 2020 through March 2021) issued by the Petroleum Association of Japan were used due to the absence of regional data in METI's Monthly Report of Mineral Resources and Petroleum Products Statistics (petroleum). This results in a one-month lag in fuel oil data compared with electricity and city gas data, but it is assumed that the results obtained from comparing the regional changes in demand using these documents would be significant nevertheless.

As shown in Fig. 9, after summing up the sales in each of the seven regions (Hokkaido, Tohoku, Kanto, Chubu/Hokuriku, Kinki, Chugoku/Shikoku, and Kyushu/Okinawa), the result of each region was plotted on a chart with year-on-year rate of change on the vertical axis and annual sales on the horizontal axis. Any regional deviations for each category were studied.


Total electricity sales: Rate of change (vertical axis) x Sales (horizontal axis)
(TWh)
Tohoku
Kyushu/ Okinawa
Kanto
Chugoku/ Shikoku
Kinki
Hokkaido
Chubu/ Hokuriku
Extra-high voltage: Rate of change (vertical axis) x Sales (horizontal axis)
(TWh)
Tohoku
Hokkaido
Kyushu/ Okinawa
Chugoku/ Shikoku
Chubu/ Hokuriku
Kanto
Kinki
High voltage: Rate of change (vertical axis) x Sales (horizontal axis)
(TWh)
Tohoku
Kyushu/ Okinawa
Chugoku/ Shikoku
Kinki
Kanto
Chubu/ Hokuriku
Hokkaido
Low voltage: Rate of change (vertical axis) x Sales (horizontal axis)
Kanto
Chubu/ Hokuriku
Tohoku
Kyushu/ Okinawa
Kinki
Chugoku/ Shikoku
Hokkaido
(TWh)
Total city gas sales: Rate of change (vertical axis) x Sales (horizontal axis)
Tohoku
Hokkaido
Kinki
Kyushu/ Okinawa
(100 million m³)
Chubu/ Hokuriku
Chugoku/ Shikoku
Kanto
Industry: Rate of change (vertical axis) x Sales (horizontal axis)
Tohoku
Kinki
(100 million m³)
Hokkaido
Kyushu/ Okinawa
Chubu/ Hokuriku
Chugoku/ Shikoku
Kanto
Commercial: Rate of change (vertical axis) x Sales (horizontal axis)
(100 million m³)
Tohoku
Chubu/ Hokuriku
Kanto
Hokkaido
Kyushu/ Okinawa
Chugoku/ Shikoku
Kinki
Others: Rate of change (vertical axis) x Sales (horizontal axis)
Hokkaido
Tohoku
Kyushu/ Okinawa
Chubu/ Hokuriku
Chugoku/ Shikoku
Kinki
(100 million m³)
Kanto
Residential: Rate of change (vertical axis) x Sales (horizontal axis)
Hokkaido
Chubu/ Hokuriku
Kyushu/ Okinawa
Chugoku/ Shikoku
Kinki
Kanto
Tohoku
(100 million m³)

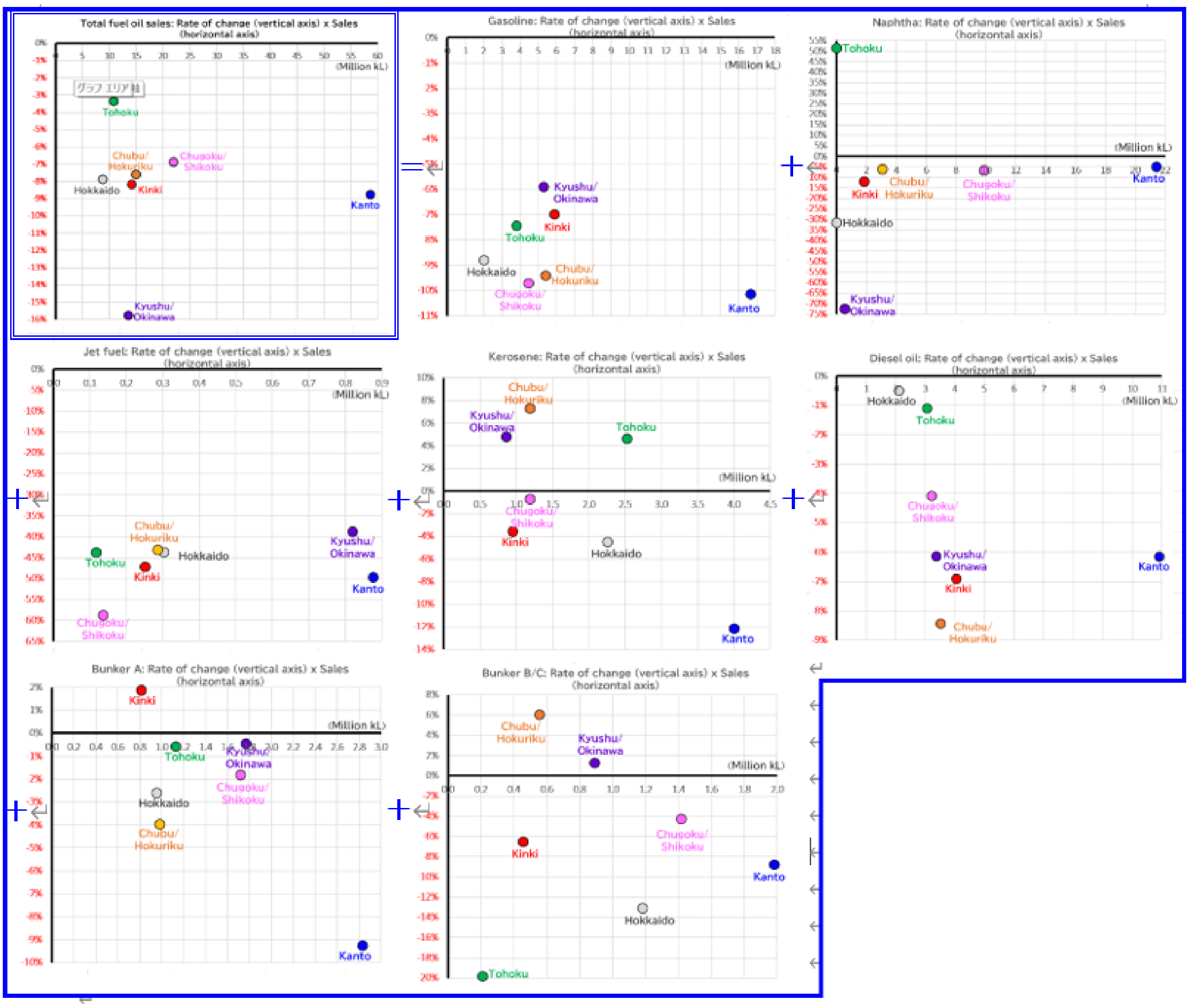


Fig. 9 Regional distribution of energy demand:
year-on-year increase/decrease rate (vertical axis), annual sales (horizontal axis)

① Kanto and Tohoku: Kanto was strongly affected by lower demand, unlike Tohoku

On all the charts for the sales of electricity, city gas, and fuel oil, Kanto was located at the bottom right-hand corner and Tohoku at the top-left. This was also true at the category level, except for the categories of low voltage for electricity, residential for city gas, and Bunker B/C for fuel oil. In fact, sales increased in Tohoku except in the commercial category for city gas, and in the naphtha and kerosene categories for fuel oil. While the deviations in the horizontal direction (amount of sales) can be explained by the different sizes of the economies, the vertical deviations (rate of change) could be attributed to the strong impact of the Covid-induced decrease in demand on Kanto, including Tokyo, which had a long state of emergency, as opposed to Tohoku which had fewer cases throughout and hence less damage.

② Kanto and Tohoku: Kanto was also strongly affected by increased demand, unlike Tohoku

Kanto is at the upper right-hand corner and Tohoku is at the bottom left-hand corner for the charts for the categories of low voltage for electricity and residential for city gas. This suggests that Kanto was also strongly affected by the increase in demand for homes due to Covid-19, in contrast to Tohoku.

③ Kinki and Chubu/Hokuriku: Decrease in demand was greater than Kanto for electricity but less for city gas and fuel oil

While Kinki and Chubu/Hokuriku were both more heavily affected by the decrease in demand than Kanto (located lower and further to the left), Kanto had a greater decrease in demand for city gas and fuel oil sales (located lower and further to the right) than the two regions. Kinki had a less rate of change than Kanto for extra-high voltage as did Chubu/Hokuriku for high voltage (the regions were located lower and further to the left than Kanto). The horizontal gap (amount of sales) for electricity and city gas between Kanto and the two regions suggests that activities in the industrial and corporate sectors have a greater impact (composition ratio) than the residential sector.

④ Kinki and Chubu/Hokuriku: Ahead of other regions in switching from fuel oil to city gas, except Kanto

Kinki and Chubu/Hokuriku are located to the right of other regions except Kanto for city gas and to the left of them for fuel oil, suggesting that they are ahead of other regions in switching to city gas, except Kanto.

⑤ Kyushu/Okinawa: Greatest decrease in demand of all regions in fuel oil

In Kyushu/Okinawa, naphtha sales decreased by 72.6% (1,519 thousand kL) year-on-year, posting a larger decrease than Kanto. With jet fuel sales also decreasing by 520 thousand kL, the region had the largest decrease in demand in fuel oil sales than any other region (the region's decrease in demand was not as significant for electricity and city gas).

⑥ All regions: Experienced a decrease in demand in the commercial category for city gas and jet fuel for fuel oil

The commercial category for city gas and jet fuel for fuel oils had little regional deviation between any regions in the country, suggesting that the tourism (travel), retail, and aviation sectors are experiencing a significant decrease in demand nationwide.

METI's 9regions ↓ 7regions	Electricity sales					Extra-high voltage					High voltage					Low voltage and low voltage lighting				
	2020.3–2021.2 electricity sales (GWh)	Compared to the same period of the previous year (GWh)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.3–2021.2 electricity sales (GWh)	Compared to the same period of the previous year (GWh)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.3–2021.2 electricity sales (GWh)	Compared to the same period of the previous year (GWh)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.3–2021.2 electricity sales (GWh)	Compared to the same period of the previous year (GWh)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order
Hokkaido	28,458	-828	6	-2.8%	2	2,846	-177	7	-5.9%	5	12,539	-863	5	-6.4%	1	13,072	213	1	1.7%	1
Tohoku	61,210	-105	7	-0.2%	7	15,100	-469	6	-3.0%	7	23,723	-505	7	-2.1%	7	22,387	869	3	4.0%	5
Kanto	315,119	-5,299	1	-1.7%	5	79,754	-6,122	1	-7.1%	2	113,227	-4,620	1	-3.9%	3	122,137	5,443	7	4.7%	7
Chubu/Hokuriku	110,320	-3,222	3	-2.8%	1	36,120	-2,590	3	-6.7%	3	38,783	-2,012	2	-4.9%	2	35,417	1,380	5	4.1%	6
Kinki	137,876	-3,823	2	-2.7%	3	39,986	-3,712	2	-8.5%	1	45,108	-1,832	3	-3.9%	4	52,782	1,721	6	3.4%	4
Chugoku/Shikoku	80,326	-1,733	4	-2.1%	4	21,780	-1,465	4	-6.3%	4	27,862	-1,114	4	-3.8%	5	30,684	845	2	2.8%	2
Kyushu/Okinawa	87,537	-866	5	-1.0%	6	19,418	-1,169	5	-5.7%	6	30,219	-847	6	-2.7%	6	37,900	1,150	4	3.1%	3
Total	820,846	-15,876	—	-1.9%	—	215,004	-15,705	—	-6.8%	—	291,460	-11,793	—	-3.9%	—	314,382	11,622	—	3.8%	—

METI's 9regions ↓ 7regions	City gas sales [41.8605 MJ (10,000 kcal) per m³]					Industrial					Commercial					Others (public and medical services)					Residential				
	2020.3–2021.2 city gas sales (Million m³)	Compared to the same period of the previous year (Million m³)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.3–2021.2 city gas sales (Million m³)	Compared to the same period of the previous year (Million m³)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.3–2021.2 city gas sales (Million m³)	Compared to the same period of the previous year (Million m³)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.3–2021.2 city gas sales (Million m³)	Compared to the same period of the previous year (Million m³)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.3–2021.2 city gas sales (Million m³)	Compared to the same period of the previous year (Million m³)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order
Hokkaido	872	1	5	0.1%	5	180	-3	5	-1.5%	5	224	-35	4	-13.6%	4	155	12	7	8.2%	7	312	27	4	9.4%	7
Tohoku	1,249	134	7	12.0%	7	819	130	7	18.8%	7	90	-11	7	-10.9%	7	114	5	5	5.0%	6	227	10	1	4.5%	1
Kanto	20,270	-956	1	-4.5%	2	11,506	-984	1	-7.9%	1	1,992	-258	1	-11.5%	6	1,442	-30	1	-2.1%	1	5,329	316	7	6.3%	4
Chubu/Hokuriku	5,057	-160	2	-3.1%	3	3,431	-192	2	-5.3%	3	313	-41	3	-11.5%	5	348	8	6	2.5%	5	964	64	5	7.2%	6
Kinki	9,140	48	6	0.5%	6	5,234	45	6	0.9%	6	784	-127	2	-13.9%	3	683	4	4	0.6%	2	2,439	126	6	5.4%	2
Chugoku/Shikoku	1,539	-87	3	-5.4%	1	1,016	-87	3	-7.9%	2	105	-18	6	-14.4%	2	141	2	2	1.8%	3	277	15	2	5.7%	3
Kyushu/Okinawa	1,320	-11	4	-0.8%	4	588	-13	4	-2.1%	4	158	-27	5	-14.4%	1	180	4	3	2.4%	4	394	24	3	6.5%	5
Total	39,447	-1,032	—	-2.5%	—	22,775	-1,103	—	-4.6%	—	3,667	-516	—	-12.3%	—	3,063	6	—	0.2%	—	9,942	582	—	6.2%	—

METI's 9regions ↓ 7regions	Fuel oil sales					Gasoline					Naphtha					Jet fuel				
	2020.4–2021.3 oil sales (thousand kL)	Compared to the same period of the previous year (thousand kL)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.4–2021.3 oil sales (thousand kL)	Compared to the same period of the previous year (thousand kL)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.4–2021.3 oil sales (thousand kL)	Compared to the same period of the previous year (thousand kL)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.4–2021.3 oil sales (thousand kL)	Compared to the same period of the previous year (thousand kL)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order
Hokkaido	8,865	-760	6	-7.9%	4	2,030	-196	7	-8.8%	4	23	-11	6	-31.7%	2	303	-235	3	-43.7%	5
Tohoku	10,853	-378	7	-3.4%	7	3,809	-307	6	-7.5%	5	3	1	7	51.4%	7	118	-92	7	-43.8%	4
Kanto	58,694	-5,637	1	-8.8%	2	16,668	-1,884	1	-10.2%	1	21,416	-1,129	2	-5.0%	6	876	-865	1	-49.7%	2
Chubu/Hokuriku	15,039	-1,241	5	-7.6%	5	5,413	-563	2	-9.4%	3	3,088	-204	5	-6.2%	5	286	-217	5	-43.1%	6
Kinki	14,234	-1,268	4	-8.2%	3	5,884	-442	4	-7.0%	6	1,834	-248	4	-11.9%	3	251	-224	4	-47.1%	3
Chugoku/Shikoku	22,032	-1,632	3	-6.9%	6	4,473	-482	3	-9.7%	2	9,885	-716	3	-6.8%	4	137	-194	6	-58.7%	1
Kyushu/Okinawa	13,610	-2,551	2	-15.8%	1	5,317	-334	5	-5.9%	7	573	-1,519	1	-72.6%	1	820	-520	2	-38.8%	7
Total	143,326	-13,467	—	-8.6%	—	43,594	-4,206	—	-8.8%	—	36,822	-3,825	—	-9.4%	—	2,789	-2,346	—	-45.7%	—

METI's 9regions ↓ 7regions	Kerosene					Diesel oil					Bunker A					Bunker B / C				
	2020.4–2021.3 oil sales (thousand kL)	Compared to the same period of the previous year (thousand kL)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.4–2021.3 oil sales (thousand kL)	Compared to the same period of the previous year (thousand kL)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.4–2021.3 oil sales (thousand kL)	Compared to the same period of the previous year (thousand kL)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order	2020.4–2021.3 oil sales (thousand kL)	Compared to the same period of the previous year (thousand kL)	Decrease amount ranking ascending order	Compared to the same period of the previous year (%)	Decrease rate ranking ascending order
Hokkaido	2,260	-106	2	-4.5%	2	2,113	-11	7	-0.5%	7	955	-25	4	-2.6%	3	1,182	-178	2	-13.1%	2
Tohoku	2,527	111	7	4.6%	5	3,057	-34	6	-1.1%	6	1,128	-7	6	-0.6%	5	211	-52	4	-19.8%	1
Kanto	4,001	-554	1	-12.2%	1	10,919	-716	1	-6.2%	3	2,834	-289	1	-9.3%	1	1,981	-191	1	-8.8%	3
Chubu/Hokuriku	1,189	81	6	7.3%	7	3,526	-325	2	-8.4%	1	982	-41	2	-4.0%	2	556	32	7	6.0%	7
Kinki	950	-35	3	-3.6%	3	4,045	-300	3	-6.9%	2	814	15	7	1.9%	7	455	-32	5	-6.5%	4
Chugoku/Shikoku	1,189	-9	4	-0.8%	4	3,211	-137	5	-4.1%	5	1,719	-32	3	-1.8%	4	1,417	-64	3	-4.3%	5
Kyushu/Okinawa	861	39	5	4.8%	6	3,378	-221	4	-6.1%	4	1,770	-8	5	-0.5%	6	891	11	6	1.2%	6
Total	12,976	-473	—	-3.5%	—	30,249	-1,743	—	-5.4%	—	10,202	-387	—	-3.7%	—	6,694	-474	—	-6.6%	—

[Definition of prefecture correspondence in each region]
Nine regions under each regional Bureau of Economy, Trade and Industry, organized into seven.
[Hokkaido] Hokkaido
[Tohoku] Aomori, Iwate, Akita, Miyagi, Yamagata, Fukushima
[Kanto] Tokyo, Ibaraki, Tochigi, Gunma, Saitama, Chiba, Kanagawa, Niigata, Yamanashi, Nagano, Shizuoka
[Chubu / Hokuriku] Toyama, Ishikawa, Gifu, Aichi, Mie
[Kinki] Osaka, Kyoto, Shiga, Nara, Wakayama, Hyogo, Fukui
[Chugoku / Shikoku] Okayama, Hiroshima, Yamaguchi, Shimane, Tottori, Tokushima, Kagawa, Ehime, Kochi
[Kyushu / Okinawa] Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima,

Table 1 Regional distribution of energy demand: numerical data (Reference)

4. Conclusion and remarks

In regard to energy demand, our results show that electricity and city gas sales are recovering after an enormous drop, while fuel oil sales have yet to start a full recovery. There are signs that the battle against Covid-19 is being won thanks to the vaccine rollout. Though the state of emergency remains in place, the catastrophic fall in energy demand is likely to be overcome through government policies that focus on controlling the pandemic while sustaining and expanding the economy.

This report analyzed the increase and decrease in energy sales by region, as well as the national total, and confirmed some remarkable statistical deviations. It may be possible to acquire deeper insights by analyzing at finer regional levels, such as prefectures or cities, towns, and villages. To reduce GHG emissions and to make the nation's energy supply more carbon neutral toward 2050, it is essential to build a system for numerically (in quantity and percentage) grasping and evaluating the region-conscious efforts of municipalities and energy companies. To this end, I will continue to communicate the need for such a system on various occasions.

International marine initiatives for decarbonization and LNG bunkering

Seiya Matsukura*

1. Introduction

In recent years, marine environmental regulations have been tightened with the aim of reducing sulphur oxides (SOx), particulate matter (PM), nitrogen oxides (NOx) and greenhouse gas (GHG) emissions such as CO_2 from ships. Vessels that do not meet these emission standards are forced to withdraw from the market, which has a great impact on economic activities. Moreover, in Japan, which relies on imports for most of its natural gas and oil, the impact on energy security will be enormous.

In response to these environmental regulations, the introduction of exhaust gas cleaning equipment to ships and conversion to low-sulphur fuels are progressing, and particularly use of liquefied natural gas (LNG) fuels that do not contain any sulphur is expanding. Ship transportation represented 99.6% of Japan's total export and import in 2019 (on a tonnage basis), and the Japanese merchant ships (ocean-going vessels operated by Japanese shipping companies) transported 63.1% of the global maritime transportation of goods[1]. That is why Japan should take the initiative in international shipping. This paper gives an overview of the status of tightening environmental regulations in the ocean, explains next-generation ship fuels as countermeasures, and then summarizes the progress of LNG bunkering (fuel supply to ships) circumstances and issues for the future.

2. Environmental regulations in the ocean

In March 1958, the International Maritime Organization (IMO), a specialized agency of the United Nations, was established to promote intergovernmental cooperation on issues in the maritime sector, such as the prevention of marine pollution. As of September 2021, 174 countries including Japan are members. The targets of marine air pollution regulations set by the IMO are roughly divided into three categories: 1) sulphur content in fuel oil (SOx, PM), 2) NOx and 3) GHG (energy efficiency) (Fig. 1).

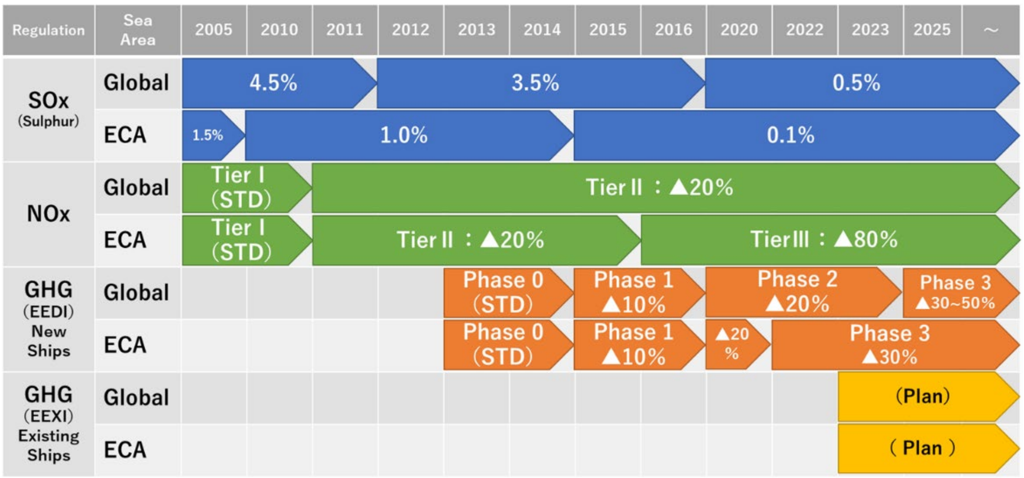


Fig. 1 Marine environment regulations

Source: Summarized from IMO

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2-1. MARPOL Convention: Marine Pollution Control Convention

In November 1973, the MARPOL Convention was adopted with the aim of preventing marine pollution caused by the ships. In February 1978, the "73/78 MARPOL Convention" was adopted and came into effect in October 1983. Currently, there are six annexes: (I) Oil, (II) Noxious Liquid Substances, (III) Harmful Substances, (IV) Ship Sewage, (V) Ship Garbage, (VI) Air Pollution. Of these, Annex VI was adopted in September 1997 and came into effect in May 2005, and SOx, PM and NOx are regulated.

2-1-1. Emission control area and Global area

Environmental regulations are applied separately to the ECAs (Emission Control Areas) and other general "Global" sea areas (Fig. 2). Initially, ECAs were designated as the North American Sea, Baltic Sea, and North Sea ECAs. China set its own ECA in January 2019 and Korea set its in April 2020. The Mediterranean ECA application may come into effect as early as March 2024.

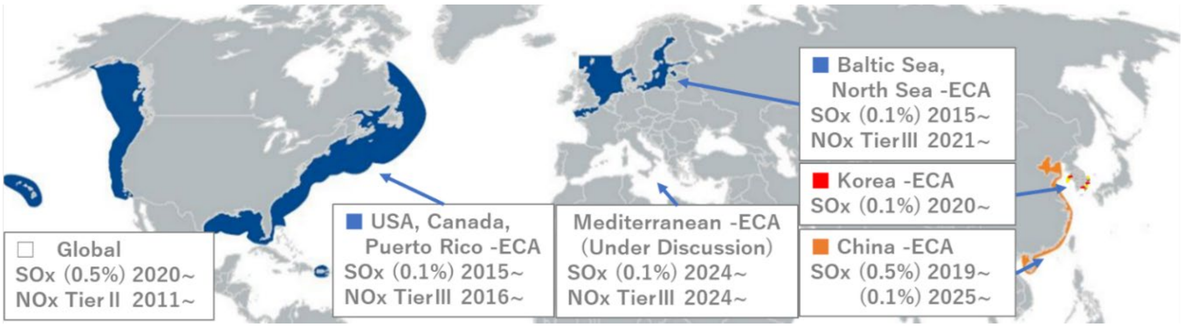

Fig. 2 ECA and Global area

Source: Summarized from DNV[2]

2-1-2. SOx and NOx emission regulations

The SOx regulations have been tightened with sulphur content of fuels in ECA to 0.1% or less from 2015, and in Global areas to 0.5% or less from 2020 (Fig. 3). The NOx regulation is based on the emissions at the engine rated speed of during 2000-2010 laying vessels in Tier I, 20% reduction in laying vessels since 2011, and 80% reduction was requested in ECA since 2016 for Tier III. (Fig. 4). Tier III regulations have been imposed in the North American ECA since 2016 and in the Baltic Sea and North Sea ECAs since 2021.

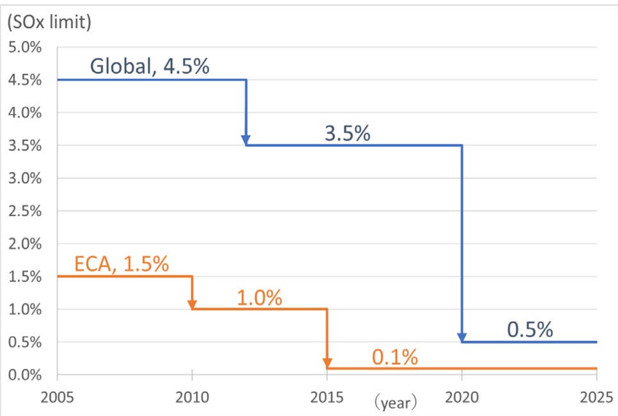

Fig. 3 SOx regulations

Source: Summarized from IMO

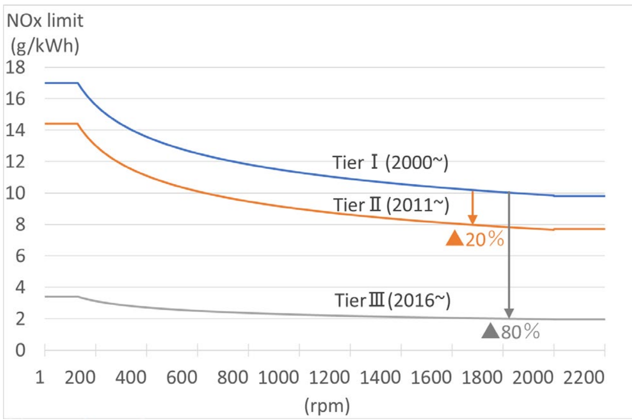

Fig. 4 NOx regulations

Source: Summarized from IMO

[2] DNV: An international accredited registrar and classification society headquartered in Oslo, Norway. Established in 1864.

2-2. Measures for GHG emissions

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted and entered into force in 1994. At the third Conference of the Parties (COP 3) in 1997, the "Kyoto Protocol" was adopted and GHG reduction targets were set. Next, at COP 21 in 2015, the "Paris Agreement" was adopted to keep the global average temperature rise below 2°C and further to promote efforts to 1.5°C. Among them, regarding the NDC set by each country, a reduction target is set every five years.

On the other hand, in the international shipping sector, according to the "Kyoto Protocol[3]", IMO's own climate change measures are set separately from UNFCCC (Fig. 5). This is because it is difficult to set the boundaries of responsibility for GHG emissions by shipping company, cargo owner, port and region. In the international aviation sector, emission control measures have been set by the United Nations specialized agency, ICAO (International Civil Aviation Organization).

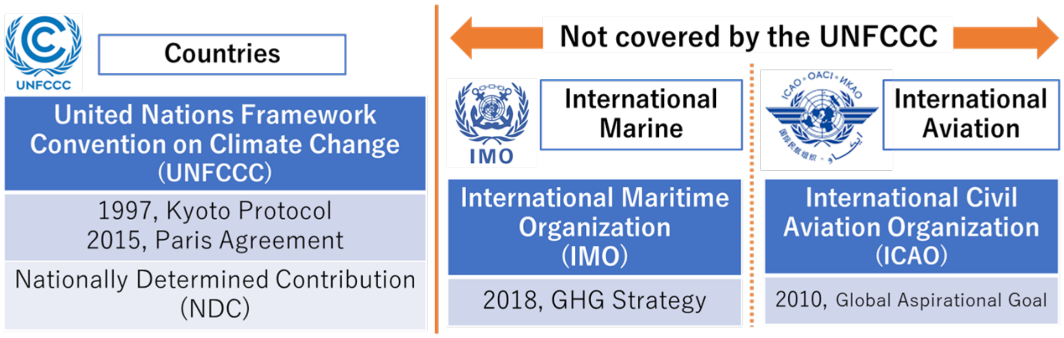

Fig. 5 GHG reduction measures outside the UNFCCC framework

Source: Based on UNFCCC, IMO and ICAO

2-2-1. CO_2 emissions from international shipping

According to the International Energy Agency (IEA), global energy-derived CO_2 emissions in 2018 were 33.5 billion tonnes, of which international shipping accounted for 708 million tonnes, or 2.1% of the total (Fig. 6, 7). The value is ranked between the fifth and sixth largest emitting countries, namely, Japan's 1.08 billion tonnes and Germany's 696 million tonnes.

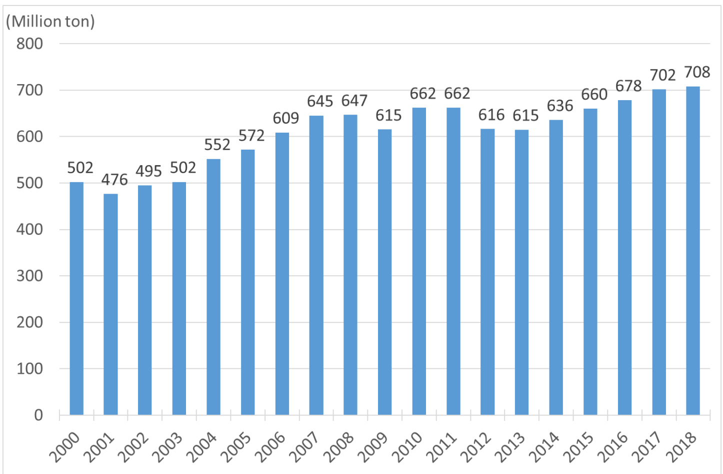

Fig. 6 CO_2 emission from international shipping

Source: IEA

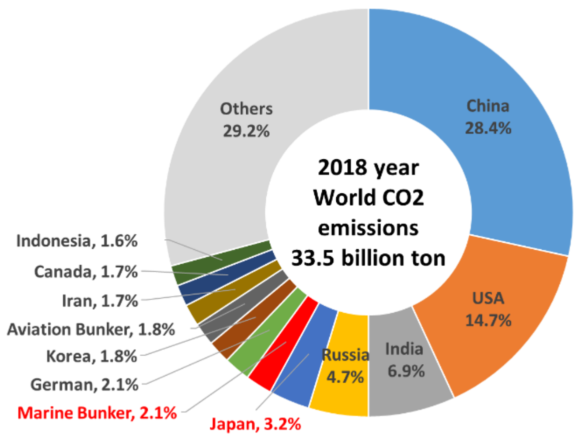

Fig. 7 Global CO_2 emission ratio

Source: IEA

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[3] Kyoto Protocol Article 2, Paragraph 2 " The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the ICAO and the IMO, respectively".

2-2-2. IMO GHG emission reduction strategy

MEPC (Marine Environment Protection Committee), one of the IMO committees, has been considering pollution prevention and regulations from ships. At the 72nd meeting (MEPC 72) in April 2018, the "IMO GHG Reduction Strategy" was adopted. The strategy aims to peak out GHG emissions from shipping as soon as possible, to reduce emissions by 50% by 2050 compared to 2008, and to achieve zero emissions by 2100 (Fig. 8). In addition, it aims to improve efficiency in terms of emission intensity of transportation per unit of transported volumes by 40% in 2030 and 70% in 2050 compared to 2008.

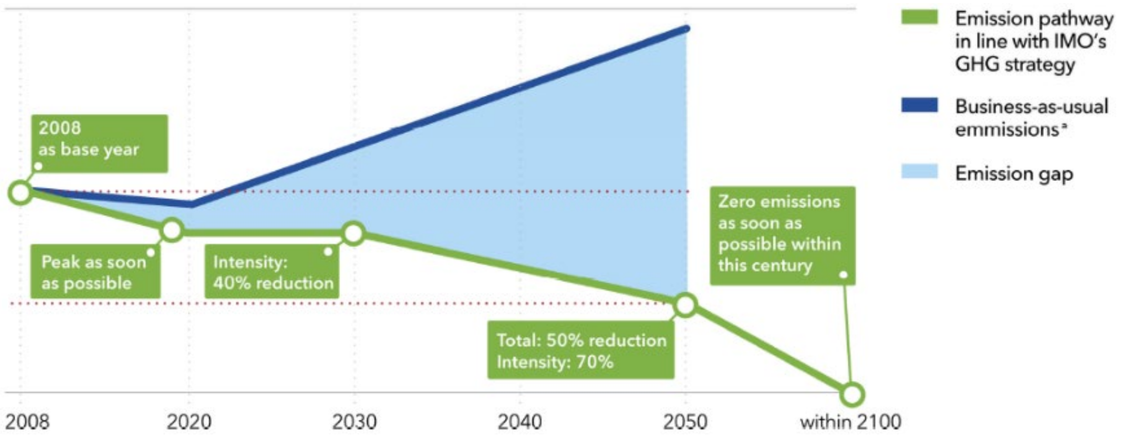

Fig. 8 IMO GHG emission reduction strategy

Source: DNV

2-2-3. Initiatives in Europe

In September 2020, the European Parliament passed a bill to incorporate shipping-derived CO_2 emissions into the EU-ETS[4]. And then, in July 2021, the European Commission proposed to include shipping emissions in the EU-ETS gradually from 2023 and phase them in over a three-year period.

If the shipping version of EU-ETS is adopted, it will be necessary to purchase emission allowances according to the CO_2 emissions based on EU-MRV[5], which will increase operating costs. In addition, there is concern that the GHG measures for international shipping will be taken by the IMO, resulting in double standards. In June 2021, Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT) also issued an "opposition to the expansion of EU-ETS international shipping". The shipping version of EU-ETS is expected to be discussed intensively in the future.

2-2-4. Initiatives in Japan

As policies for reducing GHG, energy efficiencies of ships should be improved and conversions to low-carbon fuels will be made in the short term, and to decarbonized fuels in the long term. In March 2020, the MLIT announced that it would formulate a roadmap for decarbonization of international shipping and aim for commercial operation of "zero emission vessels" by 2028 (Fig. 9).

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[4] EU-ETS (EU-Emission Trading Scheme): Effective in 2005. Multilateral CO_2 emissions trading system in the EU.

[5] EU-MRV (EU-Monitoring, Reporting and Verification): Effective in 2018. A regulatory system that imposes the obligation to report shipping data on vessels departing from and arriving in the EU.

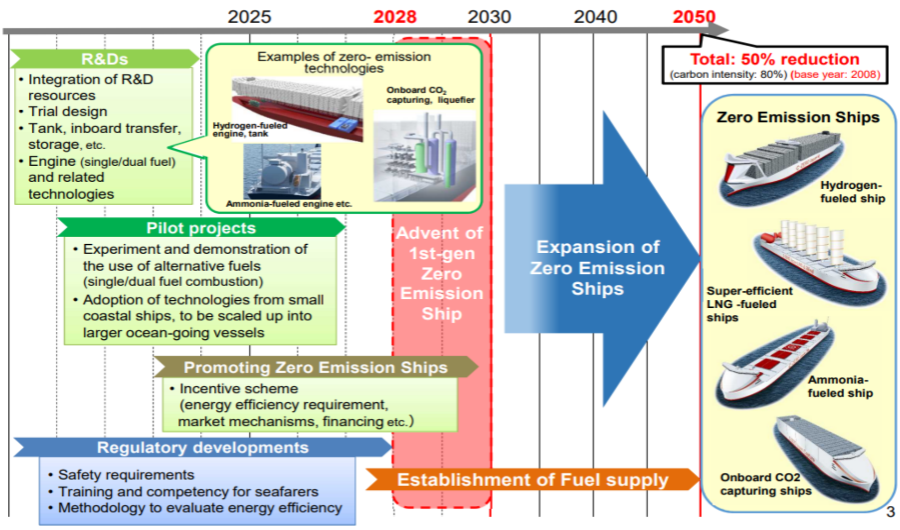

Fig. 9 Roadmap to Zero Emission from International Shipping

Source: MLIT

In December 2020, the Ministry of Economy, Trade and Industry (METI) announced the establishment of a JPY 2 trillion (USD 18 billion) "Green Innovation Fund" to support companies over the next 10 years and the implementation plan "Green Growth Strategy" in 14 important fields. In June 2021, METI announced an implementation plan of the strategy. In the shipping industry, the plan calls on work on strengthening the shipbuilding and shipping industries and carbon neutrality (Fig. 10).

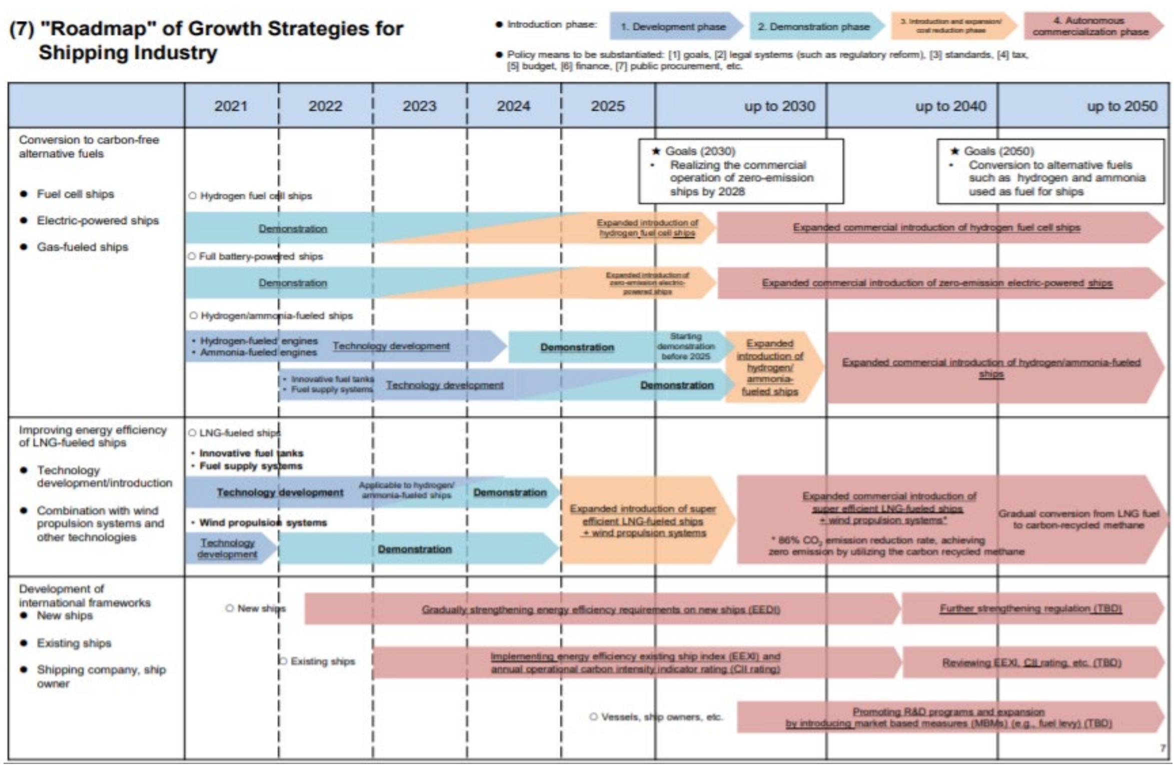

Fig. 10 Road map of Growth Strategies for Shipping Industry

Source: METI

2-3. Existing GHG emission regulations

MEPC 62 was held in July 2011 when (1) SEEMP and (2) EEDI were adopted for the purpose of reducing CO_2 emissions. SEEMP and EEDI came into effect in January 2013. They have been applicable to international vessels with a gross tonnage of 400 tonnes or more.

2-3-1. SEEMP (Ship Energy Efficiency Management Plan)

In order to improve energy efficiencies of all ships, it has been obligatory to prepare a management plan (SEEMP) showing operational efforts before each voyage, operate according to the plan during the voyage and make a review after the voyage. MEPC70 was held in October 2016, when a SEEMP revision proposal was adopted. Since 2019, international vessels with a gross tonnage of 5,000 tonnes or more have been required to collect and report operational data such as fuel consumption.

2-3-2. EEDI (Energy Efficiency Design Index)

Fuel efficiency standards have been applied to new ships depending on construction contract and delivery date of them. Based on the average emission per ton/mile of ships built from 1999 to 2008, Phase 0 is set. The standard has been stricter for those ships built in and after 2020 at Phase 2 (20% reduction) and even stricter for those to be built in and after 2025 at Phase 3 (30% reduction) (Fig. 11). However, Phase 3 will be applied ahead of schedule to large new ocean-going vessels such as VLGC (Very Large Gas Carrier), container vessels, cruise vessels, general cargo vessels and LNG carrier vessels, for which construction contracts are made in and after April 2022.

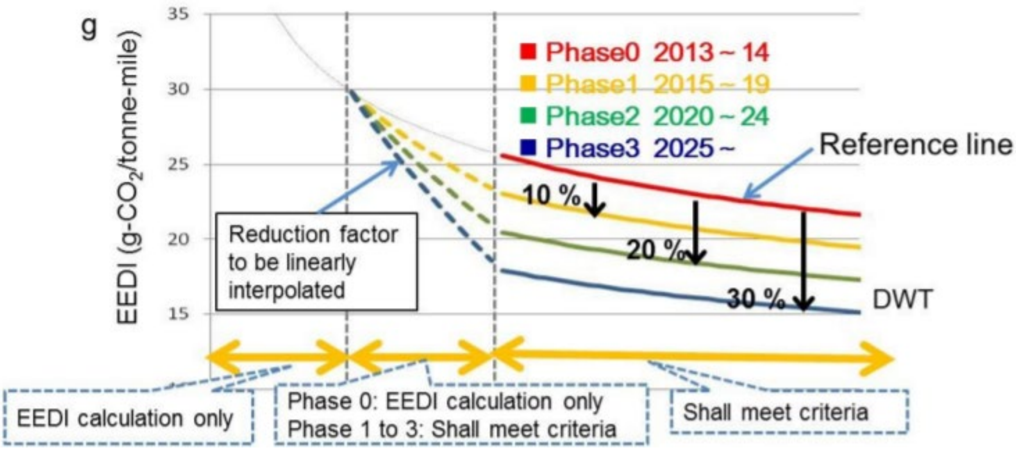

Fig. 11 EEDI regulations

Source: MLIT

2-4. Future GHG emission regulations

MEPC 75 was held in November 2020, when (1) EEXI and (2) CII were agreed as short-term GHG measures. Adopted by MEPC 76 in June 2021, the regulation will enter into force in January 2023.

2-4-1. EEXI (Energy Efficiency Existing Ship Index)

Fuel efficiencies of existing ships will be evaluated in advance, to apply the same fuel efficiency standards as new ships (EEDI). If an existing ship does not meet the standards, Engine Power Limitation (EPL)[6] and/or modifications will be required, prompting the conversion to new ships (Fig. 12).

[6] Engine power limitation (EPL) is one possible solution to improve energy efficiency of an existing ship by limiting its engine power fulfilling the requirements of the Energy Efficiency Existing Ship Index (EEXI). EPL represents one of the effective measures although it is considered as a tentative solution.

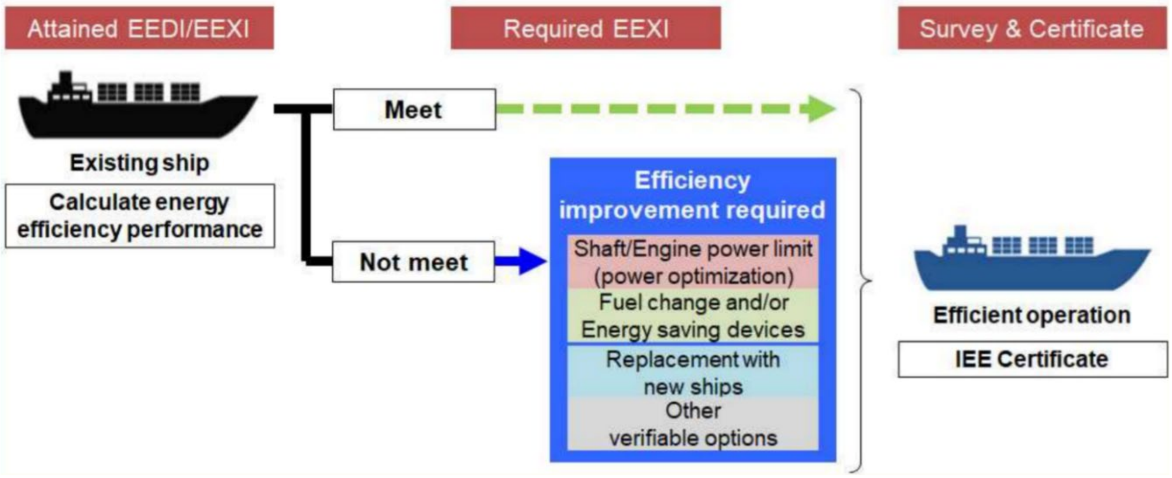

Fig. 12 EEXI regulations

Source: MLIT

2-4-2. CII (Carbon Intensity Indicator)

This is a system that verifies the fuel efficiency performance annually and evaluates it on a five-point scale (A to E). In case of E or D evaluations for three consecutive years, submission and execution of an improvement plan are required (Fig. 13).

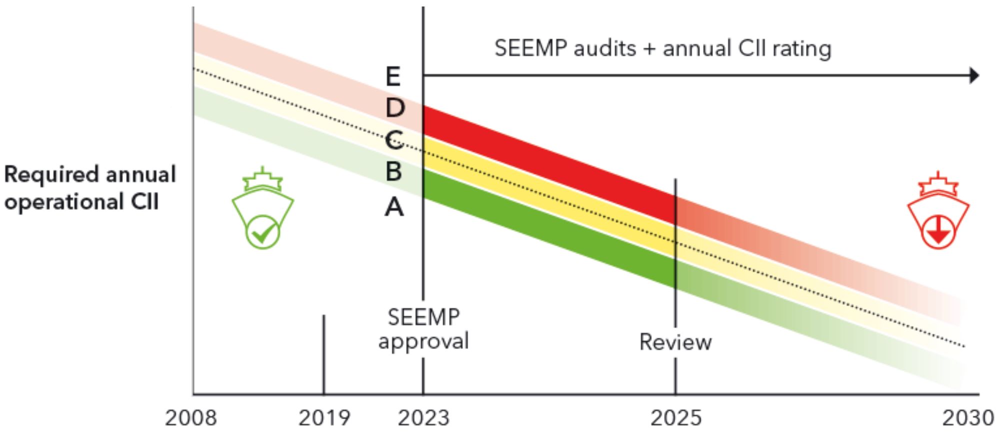

Fig. 13 CII regulations

Source: DNV

2-4-3. Impact of GHG regulations on LNG carrier ships

The IMO's GHG regulations on existing vessels are expected to have limited impacts on Japanese vessels in general as they are relatively. However, some of the LNG carrier vessels that transport LNG to Japan are estimated to have lower energy efficiencies than the standards as they are old due to its fuel characteristics and durability.

Table 1 Features of each propulsion system of ships

type	propulsion system	feature
Steam	ST: Steam Turbine	BOG / heavy oil is boiler burned and turbine driven by steam
	Reheat Steam Turbine	Reheat the steam output and drive the lower pressure turbine
Diesel	SSDR: Diesel Re-Liquefaction	Heavy oil exclusive firing diesel (with BOG reliquefaction)
	DFDE: Dual Fuel Diesel Engine	BOG / heavy oil combustion, medium-speed diesel engine
	TFDE: Tri-Fuel Diesel Engine	BOG / heavy oil / light oil combustion, medium-speed diesel
	MEGI/XDF: Low-Speed Diesel Engine	BOG / heavy oil combustion, low-speed diesel engine
Mix	STaGE: Steam Turbine & Gas Engines	Combination of high efficiency steam turbine and diesel

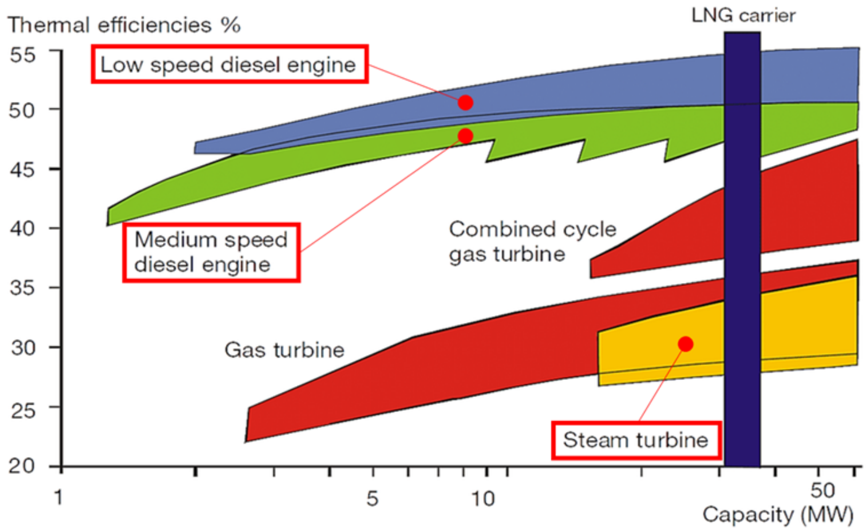

Fig. 14 Thermal efficiencies of steam turbines and diesel engines

Source: MAN Energy Solutions

Marine propulsion systems are divided into two categories, steam turbines[7] and diesel engines[8] (Table 1). As their thermal efficiencies[9] differ significantly (steam turbine: 30%, diesel: 50%. Fig. 14), after the 1970s oil crisis almost all ships (except for LNG carriers) adopted diesel engines. On the other hand, steam turbines were used in almost all over 300 LNG shipping up to the 2000s (Fig. 15). The reason is that it was difficult to reliquefy or stably burn BOG (boil-off gas from LNG cargo tanks) in a diesel engine with the conventional technology[10]. Although steam turbines with a low failure rate are expected to account for 34% of LNG shipping as of 2023 (Fig. 16), future GHG regulations may add pressure to decommission them.

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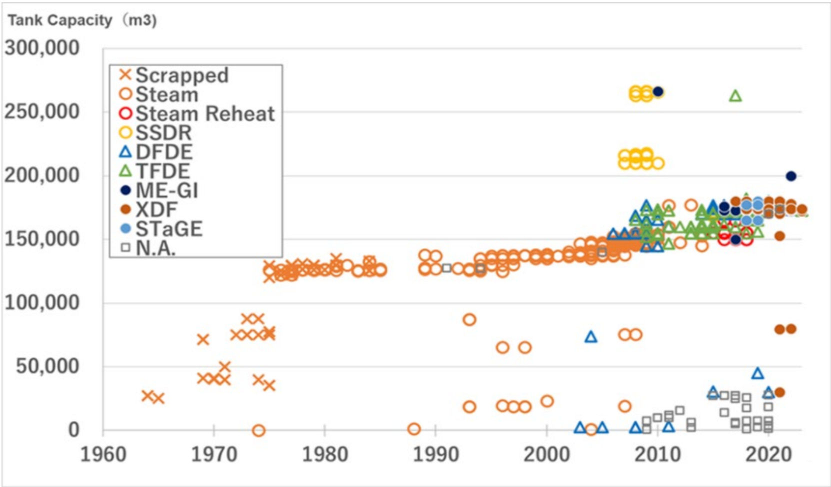
[7] Steam turbine: Boil the fuel and drive the turbine with high temperature and high-pressure steam.
[8] Diesel engine: Piston is driven by injecting fuel into high-temp and high-pressure air inside the cylinder and burning it.
[9] Thermal efficiency: The ratio that can be utilized as energy from the amount of heat generated when fuel burned.
[10] BOG (Boil Off Gas): LNG is vaporized by external heat into the tank, and naturally generated gas



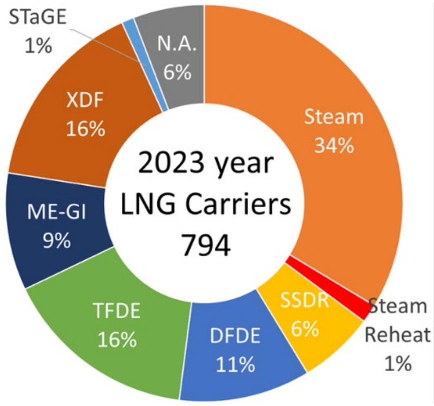


Fig. 15 Number of LNG carrier ships by propulsion type

Source: Summarized from IGU and GIIGNL reports, and company data

Fig. 16 Ppropulsion type ratio

Source: Summarized from IGU and GIIGNL reports, and company data

3. Measures against environmental regulations

Environmental regulations include (1) Oil conversion, (2) Scrubber and (3) Fuel conversion.

3-1. Conversion to low-sulphur oil

Due to the tightening of SOx regulations after January 2020, the conversion of marine fuel has progressed from HSFO (High Sulphur Fuel Oil) with a sulphur content of 3.5% to VLSFO (Very Low Sulphur Fuel Oil) with 0.5% or less and MGO (Marine Gas Oil) with 0.1% or less. Japan's MOL Group (Mitsui O.S.K. Lines) reports that it has handled 90% of more than its 800 vessels with low sulphur oil and 10% with scrubbers. Challenges include conversion to cleaner fuels to reduce GHGs, and 20%-30% higher costs of the cleaner fuels (Fig. 17).

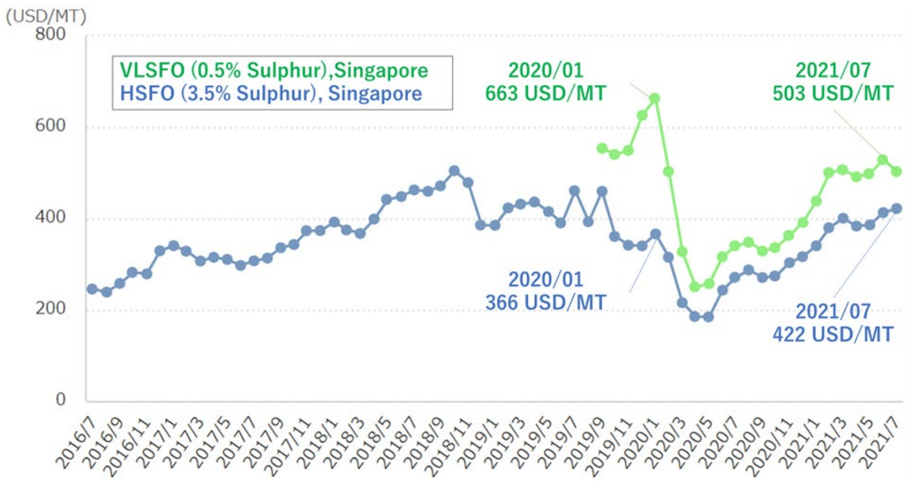


Fig. 17 HSFO and VLSFO price trends

Source: Summarized from K-Line

3-2. Installation of scrubber equipment

Scrubber devices (Fig. 18) can remove 90% of SOx and PM and 60% of black carbon. With scrubber equipment, there is an advantage that HSFO can be used continuously.

Fig. 18 Scrubber equipment

Source: MARINELOG, MOL

Although the total number of scrubbers installed by 2017 was only 400, as of 2021, it has exceeded 4,000 (Fig. 19). About 2,400 vessels installed scrubbers in 2019, reflecting the last-minute demand to respond to the tightening of SOx regulations in January 2020.

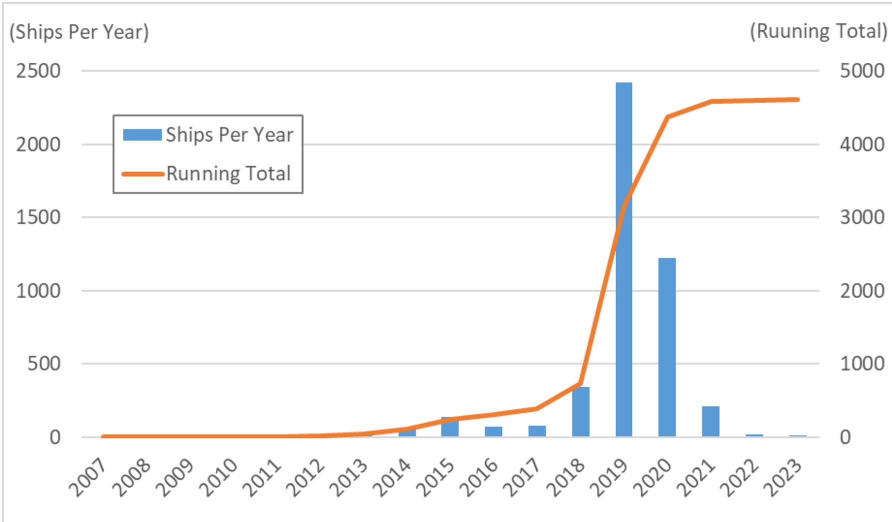


Fig. 19 No. of ships equipped with scrubbers

Source: Summarized from DNV

However, further penetration of scrubbers is limited as they are not effective for GHG reduction and drainage flows out into the ocean. In addition, scrubber auxiliary devices deteriorate fuel efficiency by about 3%.

3-3. Fuel Conversion: i) LNG, ii) Synthetic fuel (e-fuel), iii) LPG, iv) Methanol, v) Hydrogen, vi) Ammonia, vii) Battery

3-3-1. LNG

Compared to the conventional petroleum fuels, SOx and PM can be reduced by about 100%, NOx and CO_2 reduced by 80% and 30%, respectively. Issues include limited CO_2 reduction effects and methane slip emitted from engines. However, LNG is considered as the most promising alternative fuel in the short/medium term, due to its environmental performance and potential extensive supply facilities.

As of February 2021, 133 LNG receiving terminals are operating in 39 countries, and 42 liquefaction plants are operating in 21 countries (Fig. 20)[11]. LNG trade is expected to increase significantly from 356.1 million tonnes in 2020 for foreseeable future[12]. It is expected that the fuel will continue to be stably supplied in the future. These LNG marine fuel initiatives are described in the next chapter.

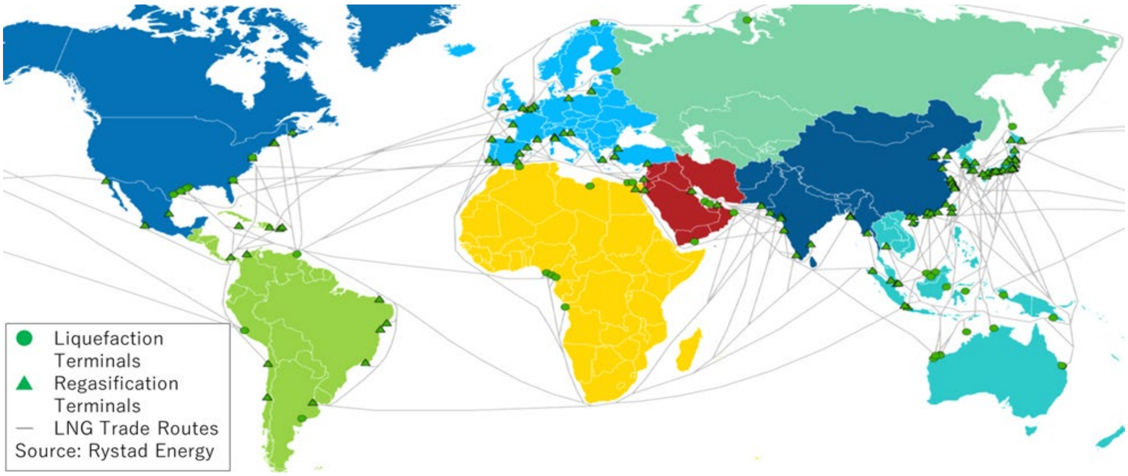


Fig. 20 Map of LNG trade routes and LNG liquefaction /regasification terminals

Source: IGU

3-3-2. SYNTHETIC FUEL (e-fuel)

Synthetic hydrocarbons (e-methane, etc.) can be produced by methanation using hydrogen derived from renewable energy and CO_2 (Fig. 21). Its biggest advantage is that the existing equipment can be used as it is. However, renewable energy hydrogen production equipment and CO_2 extraction technology are required, which is currently very expensive.

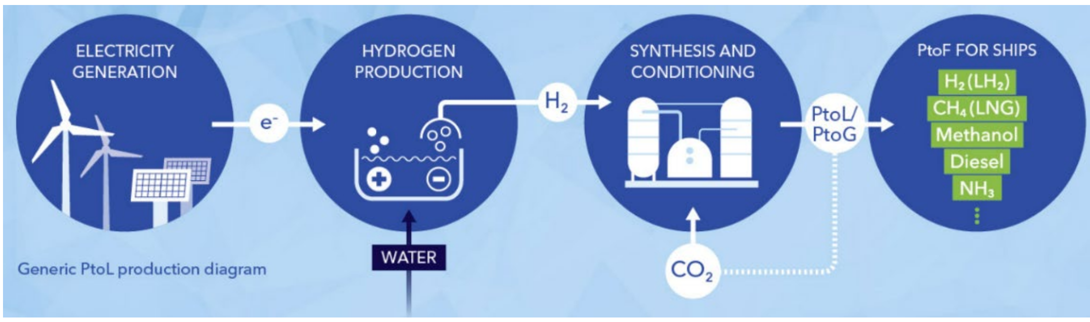


Fig. 21 The production flow of synthetic fuels

Source: DNV

In August 2019, MOL held the "Cross-Industry WG on Ship Zero Emission Alternative Fuel" at the CCR (Carbon Capture & Reuse) Study Group and indicated use of synthetic methane. In July 2020, nine companies including JFE Steel, Japan Marine United (JMU) and MOL announced a study group "Ship Carbon Recycling WG" to formulate a roadmap for the methanation fuel of marine.

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[11] IGU World LNG Report 2021

[12] GIIGNL Annual Report 2021, IEEJ Outlook 2022 (to be published in October 2021)

3-3-3. LPG

CO_2 emissions can be reduced by 20%. As an advantage, cryogenic materials used for LNG are not required. Challenges include underdeveloped legislation and inadequate global infrastructure. In October 2020, Singapore BW LPG completed the world's first LPG dual fuel VLGC modified ship BW Gemini. In June 2021, Belgium Exmar completed the world's first LPG fueled dual-fuel VLGC new ship, Flanders Innovation. In Japan, in April 2020, Iino Kaiun decided to build Japan's first LPG fueled dual-fuel VLGC new ship at Kawasaki Heavy Industries (KHI). According to DNV, as of May 2021, 15 LPG dual-fuel modified vessels have been ordered and 53 new vessels have been ordered.

3-3-4. METHANOL

SOx and PM can be reduced by 100% and NOx reduced by 20%. The GHG reduction effect depends on the manufacturing process, with a reduction against conventional fuels of 10% for natural gas sources and 80% for biofuels and synthetic fuels. Methanol has the advantage of being relatively easy to produce and has already been put to practical use in methanol tankers. The challenge is high fuel costs.

MOL completed the world's first methanol and heavy oil dual fuel ship MANCHAC SUN in September 2016, and started long-term charter in Canada. In May 2021, NYK Bulkship's dedicated methanol tanker Takaroa Sun provided the world's first Barge-to-Ship methanol fuel supply at the Port of Rotterdam. According to DNV, there are 25 methanol fuel vessels including the ordering stage.

3-3-5. HYDROGEN

The GHG reduction effect depends on the manufacturing process. The challenge is very expensive capital investment, and it is necessary to maintain liquefied hydrogen fuel at -253°C or 70MPa in fuel tanks.

As an initiative for hydrogen fuel cells, in September 2020, NYK, Toshiba Energy Systems, KHI, Japan Maritime Association (JMA), and ENEOS launched a "demonstration project for the practical application of ships equipped with high-power fuel cells" in Japan. The companies plan to conduct a demonstration operation with hydrogen fuel supply by 2024.

As an initiative for hydrogen engines, in April 2021, KHI, Yanmar Power Technology, and Japan Engine signed a basic agreement to establish "HyEng," a joint development company for hydrogen fuel engines for large vessels.

3-3-6. AMMONIA

The GHG reduction effect depends on the manufacturing process as hydrogen. The advantage is that liquid ammonia (-78°C) reduces investment costs such as storage and transportation compared to liquid hydrogen (-253°C). Problems include strong toxicity and corrosiveness, and there is also the problem of emitting NOx during combustion.

In August 2020, Nippon Yusen (NYK), IHI Motor, and the JMA signed a joint research agreement for the world's first commercialization of an ammonia fuel tugboat. In March 2021, six companies, including Sumitomo Corporation and Yara, signed a memorandum of understanding (MOU) for the commercialization of fuel supply for green ammonia vessels at the Port of Singapore. In May 2021, MOL, ITOCHU, Pavilion and other six companies signed an MOU for joint development of marine ammonia fuel in Singapore. Also in May 2021, NYK, Nippon Shipyard, and the JMA issued a joint study MOU between Yara and a dedicated liquefied ammonia gas carrier (AFAGC: Ammonia Fueled Ammonia Gas Carrier) that uses ammonia as its main fuel. In June 2021, a total of 23 domestic and overseas companies, including ITOCHU, Kawasaki Kisen (K-Line), and JERA, signed a MOU on the use of ammonia fuel and launched a council.

3-3-7. BATTERY

At the moment a small capacity battery can be applied to small vessels for short distances. However, commercially available large-capacity battery technology is still under development, and charging equipment is underdeveloped. According to DNV, about 500 electric propulsion vessels are in operation, and 60% of the total is introduced in Europe, centered on Norway (Fig. 22, 23).

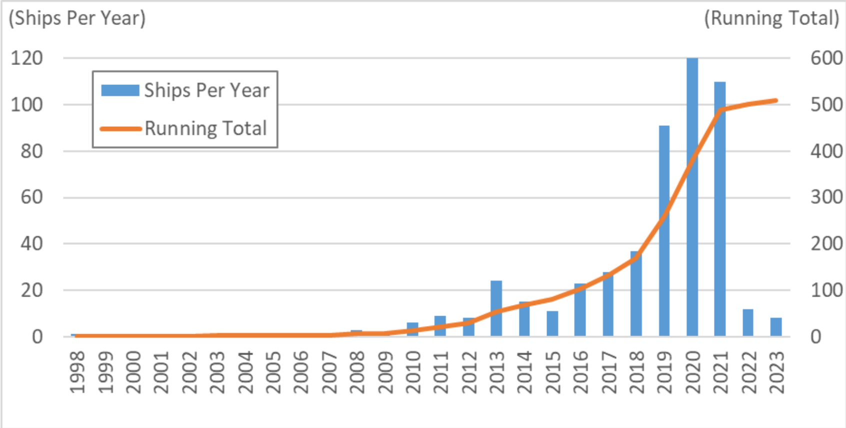

Fig. 22 No. of battery vessels

Source: Summarized from DNV

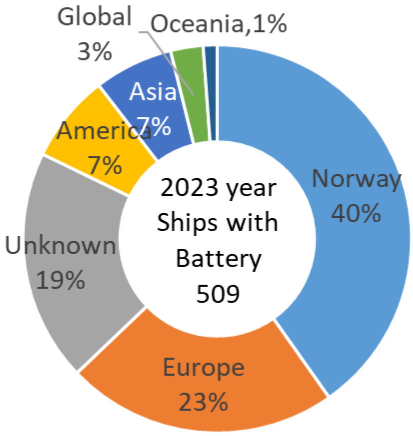

Fig. 23 Battery country ratio

Source: Summarized from DNV

In May 2020, seven companies, including Asahi Tanker and MOL, established the e5 Consortium (Secretariat: e5 Lab) aiming for a zero-emission electric propulsion vessel (EV vessel). As the first step, in October 2020, Asahi Tanker and e5 Lab ordered two of the world's first EV tanker vessels, which are scheduled to enter service in Tokyo Bay in 2022/23. In December 2020, e5 Lab completed the concept model of the world's first large EV bulk carrier (KAMSARMAX).

4. LNG bunkering

4-1. LNG bunkering methods

There are the following three methods for supplying fuel to ships with LNG (Table 2, Fig. 24). Currently, in Japan, 1) the Truck-to-Ship (TTS) method is the main method, and 3) the Ship-to-Ship (STS) method[13] was first implemented in October 2020.

Table 2 LNG bunkering methods

No.	Methods	Feature
1)	Truck to Ship (TTS)	✓ Supply from a tank truck. Low initial investment. ✓ Suitable for small LNG fuel ships (30m^3 etc.).
2)	Shore to Ship (Shore TS)	✓ Supply by shore tank and pipeline near LNG terminal ✓ Possible for large LNG fuel ships
3)	Ship to Ship (STS)	✓ Supply from a bunker vessel. Flexible operation on the ocean ✓ Possible for large LNG fuel ships (20,000m^3 etc.)

[13] A ship that supplies LNG to an LNG fueled vessel is referred to as an LNG bunkering ship.

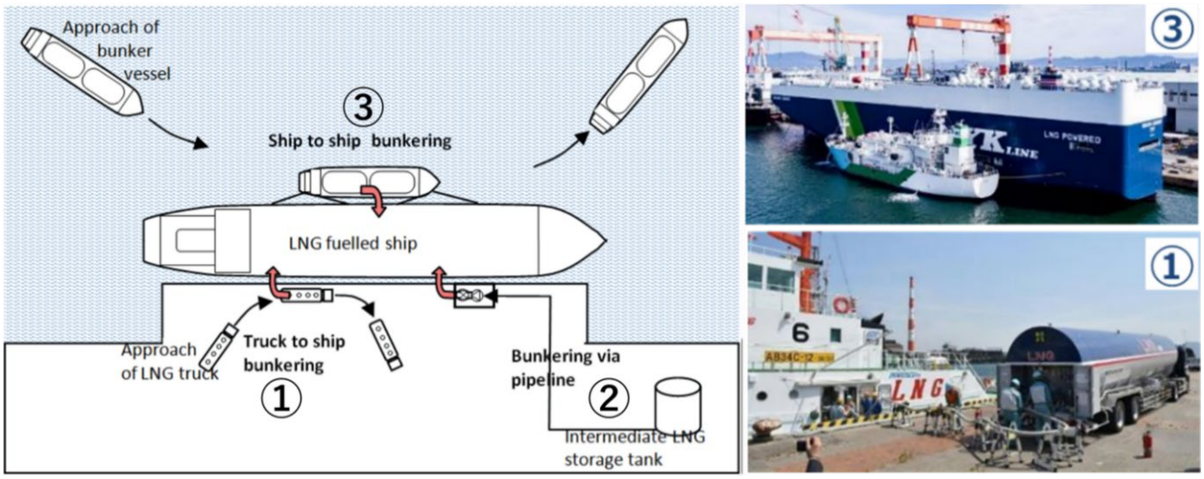

Fig. 24 LNG bunkering methods

Source: IMO, JERA, and Saibu Gas

4-2. LNG Bunkering Demand: World and Asia

In 2020, the world's LNG consumption volume as ship fuels reached 1.5 million tonnes, which is equivalent to 0.4% of the global LNG traded volume of 356.1 million tonnes[14]. Demand has doubled since 2019, and this trend is expected to continue. In addition, the forecast of LNG demand for ships of different institutions[15] is expected to be 4-10 million tonnes in 2025, 7-30 million tonnes in 2030, and 10-70 million tonnes in 2040, and is expected to expand consistently (Fig. 25).

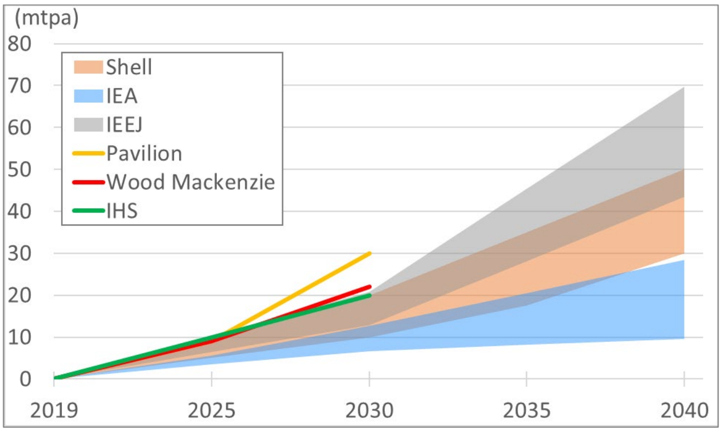

Fig. 25 Global LNG bunkering demand Outlook

Source: Shell, IEA, IEEJ, Pavilion, Wood Mackenzie and HIS

In Asia, Japan's LNG bunkering demand outlook is still under consideration, but figures are shown in China and Korea. The CNOOC[16] of China forecasts a demand of 3-5 million tonnes by 2030 (Fig. 26) and KEEI[17] of Korea expects 1.36 million tonnes by 2030 and 3.4 million tonnes in 2040 (Fig. 27).

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[14] IGU World LNG Report 2021, GIIGNL Annual Report 2021

[15] Shell LNG Outlook 2020, IEA WEO 2020, IEEJ Outlook 2021

[16] CNOOC (China National Offshore Oil Corporation): one of the largest national oil companies in China.

[17] KEEI (Korea Energy Economics Institute): Public research institute established by the Korean government

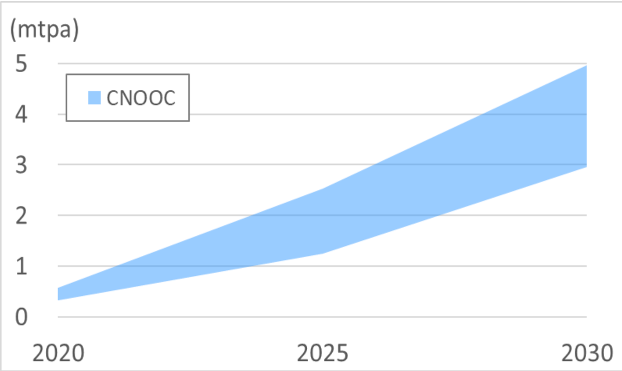

Fig. 26 China LNG bunkering demand

Source: Summarized from data of CNOOC

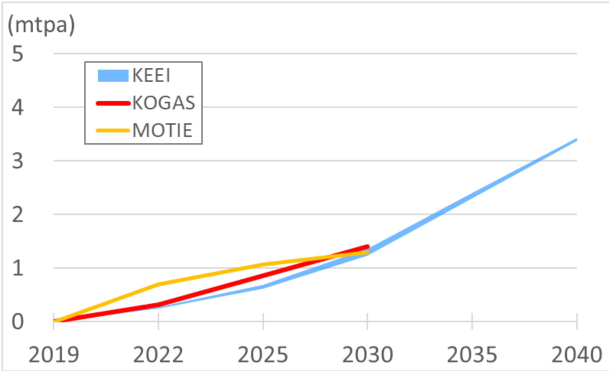

Fig. 27 Korea LNG bunkering demand

Source: KEEI, KOGAS, MOTIE

4-3. Number of LNG-fueled ships ※ excluding LNG carrier ships

As of June 2021, 200 LNG-fueled vessels are in operation, 270 have been ordered, and 150 are planned. In particular, the number of operations in 2021 has increased sharply, quadrupling from the previous year. In addition, crude oil tankers, container ships, and product/chemical tankers were rarely introduced until the latter half of the 2010s, but over the next three years, the number will increase rapidly to 138 (57 crude oil, 51 containers, 30 chemicals) and are scheduled to be completed. It accounts for half of the 279 vessels (Fig. 28, 29).

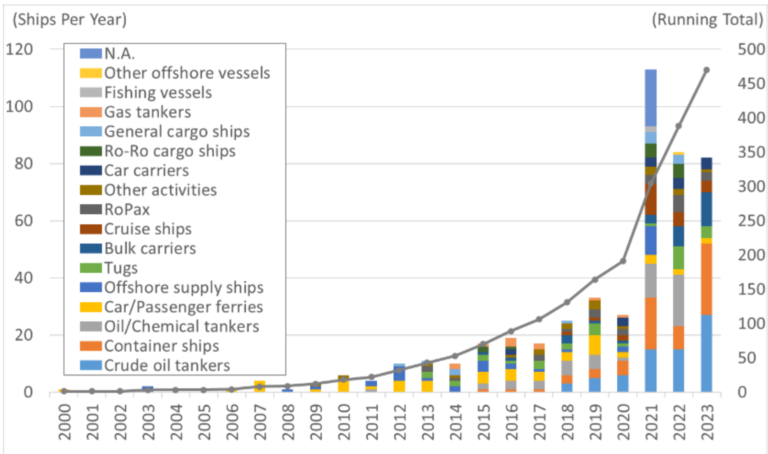

Fig. 28 No. of operating LNG-fueled ships by type

Source: IGU, GIIGNL, DNV

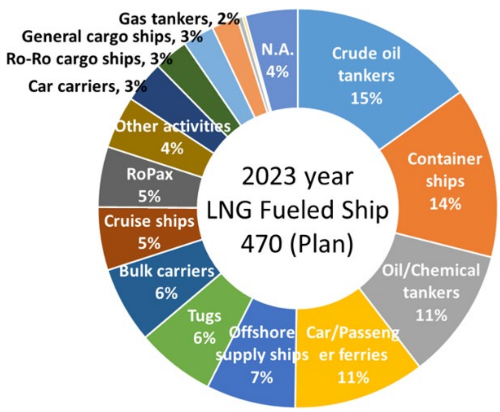

Fig. 29 Ship type ratio

Source: GU, GIIGNL, DNV

Europe accounted for 70 to 90% of LNG-fueled ships for about 20 years after the world's first LNG-fueled ship ferry Glutra in 2000, but the proportion of "Global" (international ocean going) ships has increased since 2020. (Fig. 30). In particular, the number of Global vessels introduced over the next three years (2021 - 2023) will be 164, accounting for about 60% of the 279 vessels scheduled to be completed.

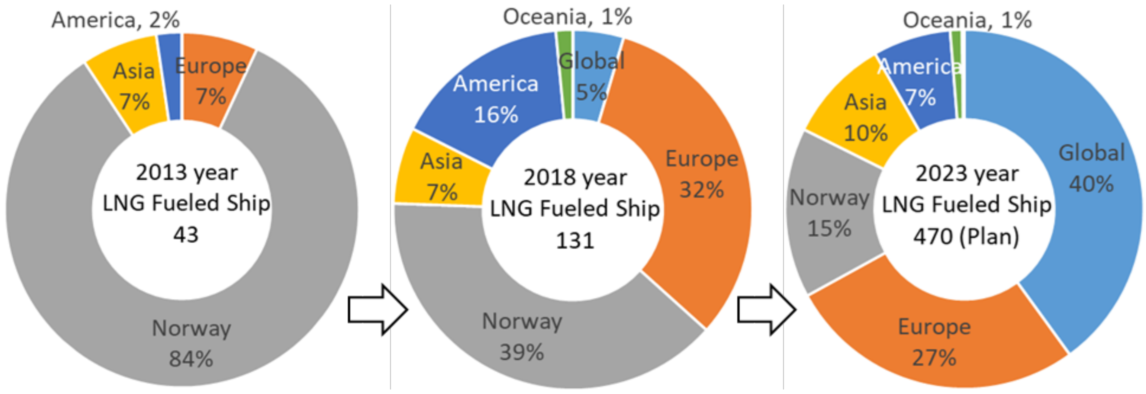

Fig. 30 LNG fuel ships by country

Source: Summarized from data of IGU, GIIGNL, DNV

4-4. Number of LNG bunkering vessels

As of May 2021, 30 LNG bunkering vessels are in operation, 20 have been ordered, and 17 are planned. In particular, the number of bunkering vessels in 2021 increased four-fold from the previous year, showing the same tendency as LNG fueled vessels. In addition, the introduction is progressing in Asia, and in the next three years (2021 - 2023), 13 vessels will account for about 40% of the total (37 vessels) (Fig. 31, 32).

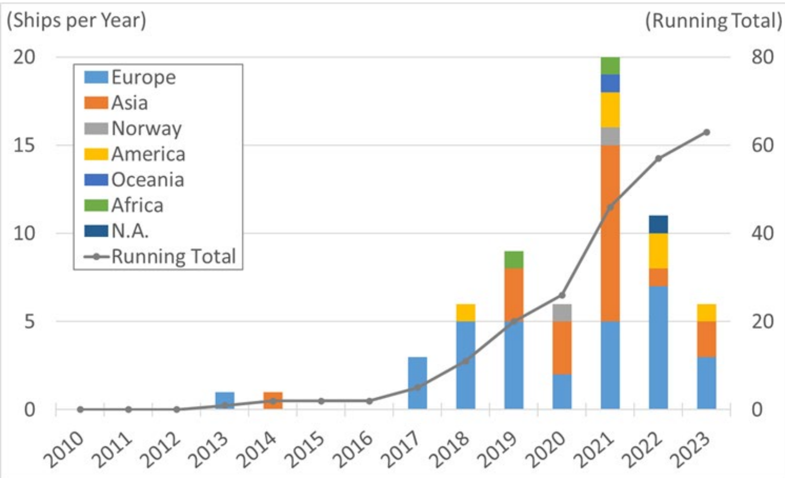

Fig. 31 World's LNG bunker ships by area

Source: IGU, GIIGNL, DNV

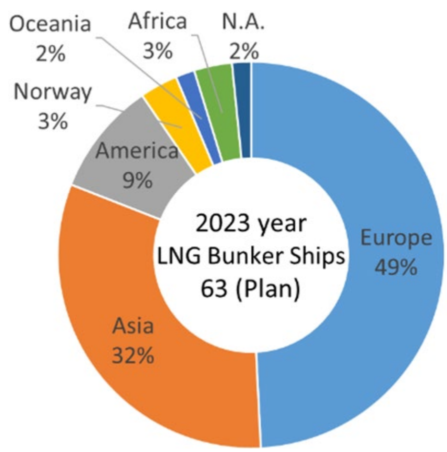

Fig. 32 Bunker ship ratio by area

Source: IGU, GIIGNL, DNV

In the world, the world's first modified LNG bunkering vessel Seagas (capacity 167m^3) was put into operation in Europe in 2013, and Asia's first LNG bunkering barge (500m^3) was put into operation in the Yangtze River, China in 2014. In June 2017, the world's first newbuilt LNG bunkering vessel, Green Zeebrugge[18] (5,100m^3), went into operation in Belgium. In September 2020, the world's largest LNG bunkering ship, Gas Agility (18,600m^3), was completed, and in November, 17,300m^3 was supplied to a container ship at the Port of Rotterdam, the Netherlands.

Japan's first LNG bunkering ship Kaguya (3,500m^3) went into operation in Ise Bay in October 2020, performing Japan's first STS-type LNG fuel transfer to the car carrier ship "SAKURA LEADER." In 2021, Japan's second LNG bunkering vessel, Eco Bunker Tokyo Bay (2,500m^3), is scheduled to start operation.

[18] Green Zeebrugge: The initial name in June 2017 was Engie Zeebrugge, which was renamed in November 2020.

4-5. Number of LNG-fueled ships and LNG bunkering ships

The progress of LNG-fueled and LNG bunkering vessels is often described as a "chicken and egg" issue. Challenges include the fact that the construction cost of LNG-fueled ships is higher by 20% to 30% compared to the conventional method, the LNG education and training of seafarers will be essential, and the size of LNG tanks should be twice as large as the conventional fuel tanks so that cargo loading capacity is squeezed. However, in recent years, the number of introductions has increased rapidly due to its effectiveness to comply with environmental regulations. The trend is summarized below (Table 3).

Table 3 Total No. of LNG fuel ships / bunkering ships

Area	Ships	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Global	Fueled	–	–	–	–	2	5	6	11	24	65	118	188
	Bunker	–	–	–	–	–	–	–	–	–	–	–	–
Europe	Fueled	32	39	49	60	70	79	93	114	124	177	197	199
	Bunker	–	1	1	1	1	4	9	14	17	23	30	33
Asia	Fueled	–	3	3	5	6	6	9	13	17	28	37	44
	Bunker	–	–	1	1	1	1	1	4	7	17	18	20
America	Fueled	–	1	1	5	9	14	21	24	24	31	32	33
	Bunker	–	–	–	–	–	–	1	1	1	3	5	6
Oceania	Fueled	–	–	–	–	2	2	2	2	2	2	3	5
	Bunker	–	–	–	–	–	–	–	–	–	1	1	1
Middle East	Fueled	–	–	–	–	–	–	–	–	–	1	1	1
	Bunker	–	–	–	–	–	–	–	–	–	–	–	–
Africa	Fueled	–	–	–	–	–	–	–	–	–	–	–	–
	Bunker	–	–	–	–	–	–	–	–	–	1	1	1
N.A.	Fueled	–	–	–	–	–	–	–	–	–	–	–	–
	Bunker	–	–	–	–	–	–	–	1	1	1	2	2
Total	Fueled	32	43	53	70	89	106	131	164	191	304	388	470
	Bunker	–	1	2	2	2	5	11	20	26	46	57	63

The world's first LNG-fueled vessel appeared in Europe in 2000, and the operation was limited to 30 vessels for the next 10 years, but since then the number of LNG-fueled vessels in Europe reached 70 in 2016. It is expanding at the pace of one bunkering vessel against five LNG-fueled vessels. As of 2023, 199 LNG-fueled vessels and 33 LNG bunkering vessels are expected in Europe.

In Asia, starting with the operation of three LNG-fueled vessels in 2013, against two LNG-fueled vessels approximately one LNG bunkering vessel has been launched, which is faster than in Europe (Fig. 33), and in 2023. At that time, 44 LNG-fueled vessels and 20 LNG bunkering vessels are expected.

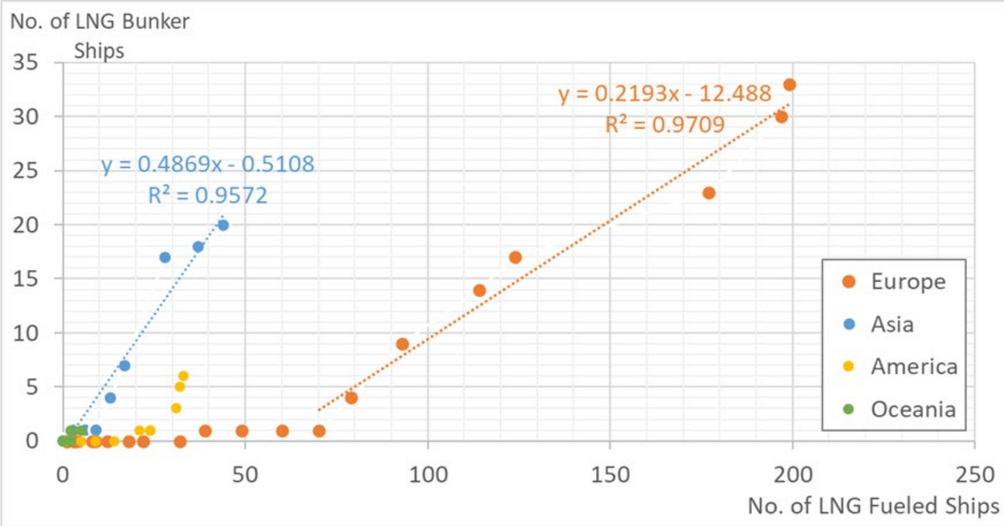

Fig. 33 Comparison of the No. of LNG bunkering and LNG-fueled vessels (2000-2023)

Source: IGU, GIIGNL, DNV

4-6. Regional Trends: i) North America, ii) Oceania, iii) Middle East, iv) Africa, v) Asia

LNG bunkering is expected to grow globally, and the major regional trends are summarized below.

4-6-1. North America

In August 2018, North America's first LNG bunkering barge, Clean Jacksonville (2,200m^3), was completed at the Port of Jacksonville, Florida. In August 2020, Eagle LNG plans to plan a larger facility at the Talleyrand LNG bunker base in Jacksonville, Florida, which will be equipped with North America's first Shore-to-Ship facility. In May 2021, Puget LNG and GAC Bunker signed an MOU from the Tacoma LNG terminal to carry out the first LNG bunkering on the west coast of North America. They are scheduled to start operations within 2021.

In September 2020, Sumitomo Corporation signed an MOU with Cryopeak LNG of Canada to jointly develop an LNG bunkering supply chain in the Pacific region of North America. Cryopeak plans to launch 4,000m^3 LNG bunkering barge in 2023. In February 2020, FortisBC Canada submitted a proposal to start a federal impact assessment of the Tilbury LNG liquefaction terminal expansion PJ, including their STS bunkering facility, and plans to start construction in 2022.

4-6-2. Oceania

In May 2020, the Pilbara Port Authority issued Australia's first LNG bunkering license to Woodside at Dampier and Port Hedland in Western Australia. In December 2020, BHP, one of the world's largest mining companies, signed an LNG supply contract for five Australian iron ore carriers Newcastlemax for China from 2022.

4-6-3. Middle East

LNG bunkering is being considered at UAE Fujairah Port, the second largest fuel oil bunkering hub in the world, and a 1 million tonne annual LNG bunkering hub base is under consideration at Total Energies at Sohar Port in Oman. In December 2018, they signed an agreement with INPEX and ADNOC L&S, and in September 2019 with Shell and Qatar Petroleum, respectively, to establish an LNG bunkering venture.

4-6-4. Africa

South Africa's Algoa Bay Coega port is strategically located on the route of the Brazilian iron ore carrier Valemax. In October 2020, South Africa's DNG Energy obtained Africa's first LNG bunkering business license from port authorities and expects to start operations by 2021 at the earliest.

4-6-5. Asia

The main trends in LNG bunkering are summarized below (Table 4).

Table 4 Total No. of LNG fuel / bunker ships in Asia

Area	Ships	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
China	Fueled	—	2	2	3	4	4	4	5	7	17	17	17
	Bunker	—	—	1	1	1	1	1	1	1	7	7	8
Singapore	Fueled	—	—	—	—	—	—	2	4	5	6	10	14
	Bunker	—	—	—	—	—	—	—	2	2	4	4	4
Japan	Fueled	—	—	—	1	1	1	1	2	3	3	4	7
	Bunker	—	—	—	—	—	—	—	—	1	2	3	3
Korea	Fueled	—	1	1	1	1	1	2	2	2	2	2	2
	Bunker	—	—	—	—	—	—	—	1	2	3	3	4
Others	Fueled	—	—	—	—	—	—	—	—	—	—	4	4
	Bunker	—	—	—	—	—	—	—	—	1	1	1	1
Total	Fueled	–	3	3	5	6	6	9	13	17	28	37	44
	Bunker	—	—	1	1	1	1	1	4	7	17	18	20

i) China: Pursuing the most ambitious implementation plan in Asia. In May 2020, CSSC (China State Shipbuilding Corporation) signed the Guangdong LNG Carrier Agreement, which expects 1,500 modified fuel vessels, 19 supply facilities and 400,000 tonnes of demand by 2025. In March 2021, CNOOC said it would supply LNG to 50 new bulk carriers. In September 2021, Dalian Shipbuilding (DSCI), a subsidiary of China State Shipbuilding Corporation, said the world's first LNG-fueled very large crude carrier (VLCC) has completed its sea trials in Chinese waters.

ii) Korea: The spread of LNG bunkering is expected to have a synergistic effect on the shipbuilding industry. In June 2020, the Korean Ministry of Trade, Industry and Energy (MOTIE) announced support for the construction of bunkering vessels with a capacity of 7,500m^3 or more, and said that it would support a total of 30%, up to KRW 15 billion (USD 13 million). In November 2020, an STS test was conducted on Korea's first LNG carrier vessel, SM JEJU LNG 2. Korea LNG Bunkering was established in December 2020, and Korea's first TTS-type LNG supply was implemented in January 2021. In 2023, Korea's first LNG bunkering vessel (7,500m^3) is planned.

iii) Singapore: The world's largest supplier of heavy fuel oil for marine use, and LNG fuel is also promoted by national policy. In January 2021, Singapore's first LNG bunkering vessel, FueLNG Bellina, was completed. In March 2021, the Maritime and Port Authority (MPA) granted the LNG bunkering license to Total Energies Marine Fuels in addition to the two existing vendors (FueLNG[19], Pavilion).

iv) Malaysia: In October 2020, Avenir LNG carried out the first LNG bunkering vessel in Southeast Asia, Avenir Advantage (7,500m^3), to Petronas for three years, and the first LNG bunkering in November 2020.

v) Indonesia: In June 2021, Pertamina International Shipping signed a HoA for its five new vessels to receive LNG and bunkering equipment from PGN.

[19] FueLNG: A joint venture between Keppel Offshore & Marine/Shell, in January 2016 the Keppel O&M/BG Group and Pavilion Energy were granted the first two LNG bunkering licenses in Singapore.

4-7. International cooperation of LNG bunkering port

In October 2016, "Memorandum of Cooperation on the Development of LNG as Ship Fuel" was announced by eight port authorities in seven countries (Japan, Singapore, Ulsan Port in Korea, Antwerp/Zeebrugge Port in Belgium, Rotterdam Port in the Netherlands, Norway, and Jacksonville Port in the United States. In July 2017, three parties (Vancouver in Canada, Marseille France, and Zhejiang Province in China) joined, and in October 2018, the Suez Canal Economic Zone Authority of Egypt joined, reaching a total of 12 port authorities from 11 countries (Fig. 34). In October 2020, the MLIT of Japan signed an "MOU on Inter-Port Cooperation for Future Ship Fuels" with the Singapore MPA and the Rotterdam Port Authority of the Netherlands.

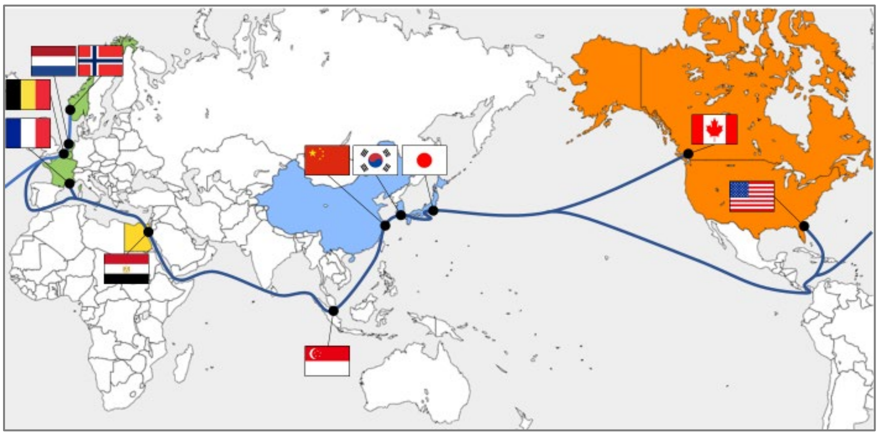

Fig. 34 Port map of the MOU regarding LNG carrier fuel

Source: Summarized from MLIT

4-8. LNG bunkering in Japan

The following is a summary of domestic LNG bunkering and port incentives[20] (Table 5, Fig. 35).

Table 5 Japan's LNG bunkering and progress

	Category	Kyushu/Seto Inland Sea	Osaka Bay	Ise / Mikawa Bay	Tokyo Bay
LNG bunkering (Supply)	Trucks (TTS)	May 2019 Kitakyushu Port to tugboat "Sakigake"	Jan. 2019, SakaiSenboku Sep. 2019, Kobe Port to tugboat "Ishin"	Nov. 2019 Nagoya Port to tugboat "Ishin"	July 2015, **Japan's First** Tokyo Bay to tugboat "Sakigake"
	Terminal	Hibiki LNG	Osaka Gas Senboku / Himeji	Toho Gas Chita Midorihama	Tokyo Gas Negishi
	Company	NYK, Kyushu Electric Power, Saibu Gas, Chugoku Electric Power	MOL Osaka Gas	MOL Toho Gas	NYK Tokyo Gas
	Ships (STS)	2022 (Plan)	—	Oct. 2020, **Japan's First** "Kaguya"	2021 (Plan) "Eco Bunker Tokyo Bay"
	Capacity	—	—	3500m^3	2500m^3
	Terminal	—	—	JERA Kawagoe	Tokyo Gas Sodegaura
	Company	—	—	Central LNG Shipping (NYK, K-Line, JERA, Toyota Tsusho)	Eco Banker Shipping (Sumitomo Corp, Ueno Transtech, Yokohama International Port, DBJ)
LNG fueled (Receive)	ship 1)	2022-2023 (Plan), **Japan's First** Ferries (between Beppu and Osaka) 2 ships "Sunflower Kurenai / Murasaki"		Oct. 2020, **Japan's First** Car carrier "SAKURA LEADER" (international ship)	Sep. 2015, **Japan's First** Tugboat "Sakigake"
	Company	MOL Group / Ferry Sunflower		NYK	NYK
	ship 2)	2023 (Plan), **World's First** Large-sized coal carrier, 2 ships (for Kyushu coal-fired power)	Feb. 2019 Tugboat "Ishin"	Dec. 2020, **Japan's First** Coastal cargo ship "Ise Mirai" (for JERA Thermal Power)	2025 (Plan), **World's First** Medium-sized cruise ship (Asuka Cruise)
	Company	NYK, MOL, Kyushu Electric Power	MOL	MOL group, Techno Chubu, Kyodo Kaiun	NYK (NYK Cruises)
	ship 3)	—	—	Mar. 2021 Car carrier "CENTURY HIGHWAY GREEN" (international ship)	—
	Company	—	—	K-Line	—
Incentive (Port entry fee exemption)	Green Award Certification	Nov. 2014, **Japan's First** Kitakyushu Port LNG carrier: ▲10%	June 2020, Osaka Port LNG Carrier: ▲10%	Nov. 2016, Nagoya Port LNG Carrier: ▲10%	Mar. 2017, Yokohama Port LNG Carrier: ▲10% + IP ESI System: ▲5%
	Others	—	Apr. 2021, Osaka Bay fueled ship: ▲10%	Apr. 2019, **Japan's First** Ise / Mikawa Bay bunkering ship: ▲100% fueled ship: ▲100%	Apr. 2021, Tokyo Bay bunkering ship: ▲100% fueled ship: ▲100%

[20] Green Award Certified by a Dutch NPO corporation aimed at marine environment protection.
International Port ESI (Environmental Ship Index) System: Operated by the World Port Climate Initiative (WPCI) aimed at reducing air pollutant emissions from ships.

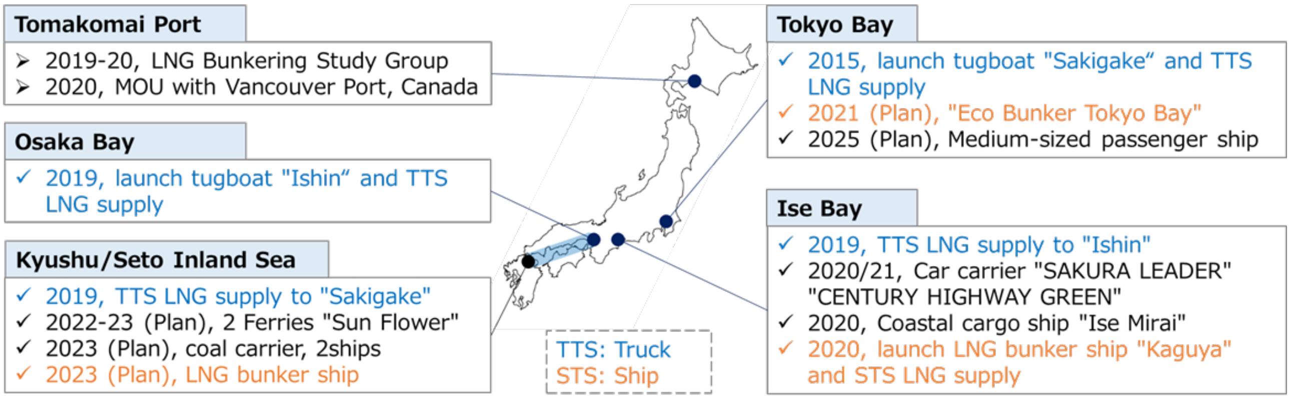

Fig. 35 LNG bunkering in Japan

Source: Summarized from each company information

【Initiatives in Japan】

i) Tomakomai Port, Hokkaido: In February 2019, Tomakomai Port and Japan Petroleum Exploration (JAPEX) established the LNG Bunkering Study Group, which had held a total of six meetings by April 2020, and then completed the study. In March 2020, Tomakomai Port and Vancouver Port, Canada signed an "MOU to Promote LNG Bunkering."

ii) Tokyo Bay: In February 2021, Sumitomo Corporation and Petronas Trading signed a memorandum of cooperation to jointly sell marine fuel LNG-related businesses in Malaysia and Tokyo. In May 2021, NYK Cruise, NYK, Eco-Bunker Shipping and Yokohama City signed an MOU on the acceptance of LNG-fueled cruise ships.

iii) Domestic companies: NYK has set up a "Sail GREEN PJ", and has set a goal of about 40 new car carriers for the next 10 years as LNG fueled vessels, aiming for zero-emission vessels such as hydrogen from around 2030. Eight LNG-fueled ships will be introduced by 2024 and 12 LNG-fueled ships will be set from 2025 to 2028, and the total investment in 20 ships will be close to JPY 200 billion.

MOL announced "Environmental Vision 2.1" in June 2021 and it would launch about 90 LNG fueled vessels by 2030 and about 110 zero-emission vessels by 2035. Approximately JPY 200 billion will be invested in the low-carbon and decarbonization fields over the next three years.

K-Line has established a long-term policy "Environmental Vision 2050”. In September 2021, eight LNG-fueled car carriers were ordered, bringing the total to 10 including the two ordered so far, which will be procured from 2023 to 2025.

iv) Collaboration with foreign companies: In February 2021, JERA and Petronas signed a memorandum of cooperation on the field of decarbonization. Consider ammonia and hydrogen fuel supply in Asian countries and LNG bunkering supply chain internationally. In September 2021, NYK Line and bp signed an MOU to collaborate on future fuels. The two companies will collaborate and identify opportunities to help transition from current marine fuels to alternatives such as LNG, biofuels, and methanol, and to develop future fuels such as ammonia and hydrogen.

5. Challenges and recommendations

Undeveloped incentives for LNG-fueled ships, slow progress of cooperation between international ports, and a decline in Japan's presence in the LNG market may pose challenges for penetration of LNG bunkering in Japan.

First, about Incentives. LNG-fueled ships have challenges such as higher construction costs than those fueled with conventional fuels, fluctuating LNG-fuel costs, securing crew members who have received LNG education/training, and limitation of cargo capacity that is squeezed by LNG fuel tanks. Incentives such as port entry fee exemption should be effective. Currently, full exemption is set for only two ports in Japan, Ise/Mikawa Bay and Tokyo Bay, and it is essential to strengthening preferential treatment on a nationwide scale.

Next, about cooperation between international ports. As of now, the MLIT has signed a "Memorandum of Cooperation for Developing LNG as Ship Fuel" among 12 port authorities in 11 countries, and has issued a "Memorandum of Cooperation for Future Ship Fuels to Support Decarbonization" which has been signed between the port authorities of the three countries. However, Southeast Asian countries such as Malaysia and Indonesia, Australia which have close ties with Japan in terms of LNG trade, have not yet participated in this initiative. In order to establish a supply chain system not only for low-carbon fuels such as LNG but also for future decarbonized fuels, it is necessary to strengthen cooperation between international ports.

Finally, about the LNG market presence. Japan has maintained the world's largest LNG handling volume for about half a century, but China is expected to replace Japan as the world's largest by 2021. In the future, in order for Japan to maintain and strengthen its influence in the LNG market, it is necessary to play the role of an LNG hub and lead LNG trading, infrastructure exports, active personnel exchanges in the Asian region.

6. Summary

With the tightening of marine environment regulations in international shipping, it is necessary to switch to low-carbon fuels such as LNG in the short and medium term, and to decarbonized fuels such as hydrogen, ammonia and synthetic fuels in the long term. LNG has already begun to play a role of transition fuel, and demand for marine LNG reached 1.5 million tonnes in 2020 and is expected to grow about 10-fold over the next 10 years. In particular, Asia is expected to become the world's largest LNG demand region in combination with economic growth and the conversion of coal-fired power generation, and in order to develop a more efficient LNG bunkering system, cooperation between ports and rapid facility construction are necessary. Japan, which has utilized the largest volumes of LNG in the world for half a century and has utilized it cleanly, has a major role to play in international shipping.

References

1) GIIGNL Annual Report 2021 (2021/04), https: //giignl.org/sites/default/files/PUBLIC_AREA/giignl_2021_annual_report_apr27.pdf
2) IEA, CO2 Emissions from Fuel Combustion (2020/07), https: //www.iea.org/reports/co2-emissions-from-fuel-combustion-overview
3) IEA, World Energy Outlook 2020 (2020/10), https://www.iea.org/reports/world-energy-outlook-2020
4) IGU World LNG Report 2021 (2021/06), https: //www.igu.org/resources/world-lng-report-2021/
5) JSA, SHIPPING NOW 2020-2021, https://www.jsanet.or.jp/data/pdf/shippingnow2020-2021.pdf
6) Shell LNG Outlook 2020 (2020/02), https://www.shell.com/energy-and-innovation/natural-gas/liquefied-natural-gas-lng/lng-outlook-2020.html#iframe=L3dlYmFwcHMvTE5HX291dGxvb2sv
7) Shell LNG Outlook 2021 (2021/02), https://www.shell.com/energy-and-innovation/natural-gas/liquefied-natural-gas-lng/lng-outlook-2021.html#iframe=L3dlYmFwcHMvTE5HX091dGxvb2svMjAyMS8

Series "Ushering in a New Era of Carbon Neutrality" (6)
Storage Battery Technologies that Support the Decarbonization of Power Sources◆

Hiroko Nakamura*

The role of storage batteries in decarbonization

In February this year, developers unveiled a plan to construct a storage battery facility with up to 1,200 MW rated output in the Hunter Valley, New South Wales (Australia). This is four times the output from the Moss Landing Energy Storage Facility (300 MW (rated power)/1,200 MWh (storage capacity)) that commenced operation in Monterey, California (United States) in December last year as the largest battery storage system in the world. Storage batteries are becoming ever-larger, and a new record is constantly being set for the "world's largest" storage battery.

What is the role of battery storage technologies? Batteries smooth the output fluctuation of "variable renewable energy," as solar power and wind power are called, because their power generation output varies depending on weather conditions. Storage batteries are charged with this variable renewable power and discharge electricity as needed; and this cycle of charging and discharging is repeated. Promoting electrification as widely as possible is key to decarbonization. At the same time, it is important to increase power sources that are capable of generating electricity in a stable manner without emitting carbon dioxide during power generation.

There are various types of storage batteries. Some are designed for "consumer applications" and can be found in consumer electronic devices such as smartphones and laptop computers. Others designed for "automotive applications" are used in electric mobility. Batteries for "stationary applications" are installed on the grid side, at substations and power plants, to stabilize the power grid, or installed behind-the-meter to complement on-site solar power systems for self-consumption. This paper focuses on grid-scale stationary storage batteries that are used to stabilize the power grid.

Grid-scale storage batteries are expected to fulfill the following three roles: (1) power storage; (2) variation regulation; and, (3) frequency regulation.

Firstly, with increasing amounts of renewable energy, storage batteries perform the role of storing surplus electricity generated during hours or seasons of low electricity demand, when supply exceeds demand depending on weather conditions.

Secondly, "apparent power demand," which is obtained by deducting from total demand the amount of electricity generated by consumers for self-consumption and power storage, falls during daytime when there is sunlight and starts to increase rapidly at sunset. These rapid fluctuations are difficult to compensate by increasing or decreasing output from sources such as thermal power and hydropower. Battery storage systems can offer a solution.

Thirdly, electrical frequency drops when demand exceeds supply capacity, and rises when demand falls. Frequency fluctuations may degrade the performance of various devices. Thermal power and hydropower have conventionally taken on the role of maintaining frequency at a constant level. However, the rule for "priority dispatch" of electricity, which suppresses thermal power generation output when the amount of renewable power increases, makes it difficult to secure regulating capacity. Instead, large-scale storage batteries, which are highly flexible and responsive, can be used to regulate frequency. Even if the adjustment to be made is only for a few seconds, it will require utility-scale capacity equivalent to an entire power plant.

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Different storage batteries and their adoption in Japan

In Japan, battery storage systems of several tens of megawatts have been introduced in the Hokkaido, Tohoku, and Kyushu regions in various ways (Table 1).

Tohoku Electric Power's Nishi-Sendai Substation and Minami-Soma Substation are equipped with 40 MW lithium-ion batteries. A transmission system operator in Hokkaido is also currently building one of the world's largest lithium-ion battery storage system in Toyotomi Town, Teshio County. With a rated output of 240MW and storage capacity of 720 MWh, this facility will smooth the output of a 600 MW-wind power generation plant. Lithium-ion batteries are characterized by high energy density and high charge/discharge efficiency, as well as low self-discharge. Furthermore, their ability to rapidly charge and discharge allows quick response to small frequency fluctuations.

Kyushu Electric Power's Buzen Power Plant is equipped with a sodium-sulfur battery (NAS battery) system with total output of 50 MW. The energy density of NAS batteries is about three times higher than that of lead storage batteries. They are large-capacity, long-duration batteries suitable for storing electricity for long periods. In 2002, a Japanese company, NGK Insulators, became the first in the world to launch commercial production of NAS batteries, which have been deployed at more than 200 projects around the world to date.

At Hokkaido Electric Power's Minami Hayakita Substation, a redox flow battery system with a rated output of 15 MW has been installed to stabilize the grid and absorb surplus electricity. Redox flow batteries make use of oxidation-reduction reactions of vanadium ions to charge and discharge the cell. Their low energy density makes redox flow battery systems bulkier than other systems; however, they bear advantages in safety as they do not use any ignitable materials and can be operated at normal temperatures. They also feature a long service life with almost no degradation of electrodes and the electrolytic solution.

Microgrids have been constructed on Japan's remote islands, combining renewable energy and battery storage systems. These are small-scale independent energy networks serving a specific local area that can offer stable electricity and heat supply by combining and regulating multiple variable renewable energy sources and controllable power sources within a certain area of demand.

Table 1 Comparison of the characteristics of storage batteries

	Lead storage battery	Lithium-ion battery	NAS battery	Redox flow battery
Active material (cathode/anode)	Lead dioxide/Lead	Lithium metal oxide/Carbon-based material	Sulfur/Sodium	Vanadium ion/Vanadium ion
Energy density	Low	Medium	High	Low
Safety	Medium	Medium	△Medium	High
Resource availability	○	△	◎	△
Lifespan No. of cycles	17 years 3,150 cycles	10～20 years 3,500 cycles	15 years 4,500 cycles	20 years No limit
Pros	Overcharge resistance Established domestic recycling system	High charge/discharge efficiency Low self-discharge	Large storage capacity/space-saving Free of rare-earth elements, low cost	High performance in arbitrary charge/discharge operations Capability to instantaneously discharge large amounts of power
Cons	Requires regular reset of SOC (state of charge)	Possibility of ignition Performs poorly against overcharging/over-discharging	Requires heating at 300°C Uses combustible materials	Bulkiness Shunt current loss

Note: The number of cycles refers to the number of times a battery can charge and discharge. Table may differ from updated data published by the respective manufacturers.
Source: Compiled by the author based on METI "Storage Battery Strategy," and websites of NEDO and Sumitomo Electric

Ever-increasing storage battery capacities

The significant growth in large-scale battery storage capacity not only supports global trends of mass deployment of renewable energy, but is also aligned with the movement to phase out thermal power generation, which is a source of carbon emissions.

In addition to the incentive for market participation to sell (discharge) electricity during hours when prices are high, encouraging policies have also supported recent trends. For example, a leader in the mass deployment of renewable energy, California State made it mandatory for electric power companies to install stationary battery storage systems in 2013. This has been followed by other states in the United States, including New York. Amidst a rise in the number of companies using renewable power to cover all the electricity needs of their business, more companies are installing battery storage systems at large-scale power facilities for self-consumption. Apple Inc. (U.S.) has announced plans to construct an energy storage project capable of storing 240 MWh of energy to support the nearby solar power plant that supplies energy to all of the company's facilities in California.

Pilot projects harnessing Japan's state-of-the-art technology are also being conducted overseas. A demonstration project in California involved installing a redox flow battery storage system at a substation for grid stabilization. In Lower Saxony, Germany, where a large amount of electricity is generated from wind power, a pilot hybrid system combining lithium-ion and NAS batteries was installed. These trends are expected to create new business opportunities for Japanese companies in overseas storage battery markets.

Series "Ushering in a New Era of Carbon Neutrality" (7)
Will Hydrogen be the Trump Card for the Realization of Decarbonization?◆

Akiko Sasakawa*

Expectations for hydrogen

Hydrogen is a colorless, odorless gas, and is the lightest among all the elements. While there are vast quantities of hydrogen on Earth, most of it is present not in the form of hydrogen itself but combined with oxygen (O) in the form of water (H_2O). Hydrogen was discovered by a British chemist about 250 years ago. Since then, it has been used across a wide range of applications, for example as the gas for making balloons and airships float, in the synthesis of ammonia for use as a raw material for fertilizers, and the refining of petroleum products and production of fats and oils.

Today, amid the trend of decarbonization, hydrogen has come into the limelight as a form of energy that is vital for the realization of a carbon-neutral society. It is highly rated for its properties of not emitting carbon dioxide (CO_2) during use, and its relatively higher calorific value per unit mass when compared to fossil fuels.

In addition, hydrogen can be produced from various resources using a wide range of methods, and some of these methods do not emit CO_2 in the production process. A specific example involves harnessing renewable energy as electricity in the process when water is electrolyzed to extract hydrogen. The hydrogen that is produced through this method is known as "green hydrogen." On the other hand, hydrogen that is produced from fossil fuels, such as natural gas and coal, is known as "grey hydrogen" when the CO_2 generated from this production process is released into the atmosphere, and as "blue hydrogen" when this CO_2 is captured and stored. Most of the hydrogen currently produced in the world is grey hydrogen, but there are growing moves, particularly in Europe, to popularize green hydrogen to achieve carbon neutrality.

There are also growing expectations for hydrogen to play an important role for storage and transportation. Variable renewable energy, such as wind power and solar power, presents a challenge as it is unable to provide a stable power supply corresponding to demand. To address this problem, there are ongoing efforts to develop energy storage technologies such as storage batteries. It is possible to ensure stable supply by storing renewable energy. This can be achieved by converting surplus electric power from renewable energy into hydrogen through water electrolysis. Moreover, converting renewable energy to hydrogen also makes it possible to transport renewable energy in areas that are far from the areas of demand, without being constrained by the limitations of the power grid.

Hydrogen strategies of various countries

Amid the rising expectations for hydrogen, many countries are formulating hydrogen strategies that set out the policy and measures toward the active utilization of hydrogen. Among these, Japan has moved ahead of other countries to establish a national strategy on hydrogen.

Japan unveiled the Strategic Roadmap for Hydrogen and Fuel Cells in June 2014 and formulated the Basic Hydrogen Strategy in December 2017, setting out the country's comprehensive policy for hydrogen. It aims to achieve the goals of building an international hydrogen supply chain and establishing hydrogen production technologies for obtaining hydrogen from domestic renewable energy sources by 2030. The plans also set out measures to realize costs that are on par with gasoline and liquefied natural gas (LNG). The Strategy for Developing Hydrogen and Fuel-Cell Technologies, formulated in September 2019, identifies the priority areas for promoting technological development.

In Europe, hydrogen strategies were announced successively by various countries in 2020 (Table 1). Germany established the goal of reaching a hydrogen production capability of 5GW by 2030 and 10GW by 2040 for hydrogen derived from renewable energy, through the introduction of water electrolysis equipment. It is also putting in place measures such as

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providing subsidies to water electrolysis-based hydrogen production facilities as an incentive to produce green hydrogen, and exemption from renewable energy taxes and levies on the renewable energy that is required in the process of generating green hydrogen. France has set out the goals of installing 6.5 GW of water electrolysis equipment by 2030, as well as promoting an annual green hydrogen production volume of 600,000 tons.

In July 2020, the European Commission unveiled its Hydrogen Strategy and Energy System Integration Strategy. This Hydrogen Strategy divides the timeline from 2020 to 2050 into three phases and sets out targets for each of the phases, such as the capacity and number of water electrolysis equipment installed and green hydrogen production volume. Furthermore, it also sets out measures to support the expansion of investment and hydrogen demand, as well as measures to strengthen cooperative relations with neighboring countries in hydrogen-related areas. The Energy System Integration Strategy establishes initiatives toward achieving carbon neutrality in sectors such as electricity, gas, and heating. It also presents the stance of shifting toward decarbonization for the whole of the energy system by supplying green hydrogen to sectors such as the steel and chemical industries, which face technological challenges in realizing decarbonization through electrification. These strategies reflect its aim of advancing decarbonization by popularizing renewable energy in a cross-sectoral manner, while using hydrogen as the medium.

Challenges in aspects such as production cost and transportation

While ambitious hydrogen strategies are being established by various countries, there are also wide-ranging challenges that need to be overcome to achieve the practical application of hydrogen in society. The first is production cost. Hydrogen retail price at hydrogen stations in Japan is set at 100 yen/Nm^3 based on the policy, but there is a need to reduce costs significantly to popularize hydrogen. The Government of Japan has set out the target hydrogen retail price for imported hydrogen at 30 yen/Nm^3, which it aims to achieve by 2030, but there is a long way to go before hydrogen can secure cost competitiveness against natural gas and LNG prices. Particularly in the case of producing green hydrogen, the key lies in reducing the cost of electricity generated from renewable energy sources, and in scaling up and enhancing the efficiency of water electrolysis equipment.

The second challenge is transportation. In the case of transportation by pipelines, the small atomic radius of hydrogen means that it could leak easily, and this, in turn, gives rise to high costs in laying and maintaining pipelines. On the other hand, there are also other methods including compressing or liquefying hydrogen or converting it to organic hydride, ammonia, or methane for transportation. For each of the methods, technological development and demonstration projects are ongoing in various parts of the world. However, as each method has its advantages and disadvantages, there is a need to review the respective methods based on factors such as the conditions at the site of production, means of utilization in the areas of demand, and existing infrastructure.

Other challenges include the need to review regulations related to the use of hydrogen as well as the need to develop infrastructure. It is to be hoped that the public and private sectors will work together on initiatives to overcome these challenges.

Table 1 Hydrogen strategies of key European countries

Announced in	Country	Overview
April 2020	Netherlands	To introduce 500 MW of renewable energy-based water electrolysis equipment by 2025, and 3 – 4 GW of equipment by 2030. While the focus is on green hydrogen in the long-term, it aims to utilize a certain amount of blue hydrogen in the short- to medium-term while reducing the cost of green hydrogen.
May 2020	Portugal	To introduce 2 – 2.5 GW of renewable energy-based water electrolysis equipment by 2030. It will invest 7 billion Euros into expanding the use of hydrogen and exporting hydrogen to other European countries.
June 2020	Germany	To introduce 5 GW of renewable energy-based water electrolysis equipment by 2030, and 10 GW of equipment by 2040. While it is prioritizing the popularization of green hydrogen, blue hydrogen will also be utilized where necessary.
June 2020	Norway	Emphasis will be placed on the utilization of blue hydrogen as well as green hydrogen. It will promote the use of CO2 capture and storage technology (CCS) for blue hydrogen.
September 2020	France	It aims to introduce 6.5 GW of water electrolysis equipment by 2030, and to achieve annual green hydrogen production of 600,000 tons. The assumption is to produce green hydrogen using renewable energy and electricity generated through nuclear power.

Source: Prepared by the author based on the "Interim Report on the Future Issues of the Hydrogen Policy and Direction of Response (Draft)" by the Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry, and other publicly available materials.

Series "Ushering in a New Era of Carbon Neutrality" (8)

New Technologies that Contribute to Carbon Dioxide Reduction◆

Takashi Otsuki*

Technologies that reduce the carbon footprint of fossil fuels

The progression of global warming is the result of carbon dioxide (CO_2) from fossil fuels being released into the atmosphere. In short, even if fossil fuels are used, it is possible to suppress global warming by preventing the emission of CO_2 into the atmosphere. Carbon capture and storage (CCS) is a technology developed based on this concept. This is a form of technology that captures CO_2 from power plants and industrial plants that use fossil fuels (such as steelmaking blast furnaces and cement plants), then stores it underground.

By harnessing CCS technology, it is possible to continue using conventional power generation and industrial facilities while reducing their carbon footprint. For example, if CCS is used in thermal power generation fired by coal or natural gas, it would be possible to reduce net CO_2 emissions from the power plants by as much as 80% to 90%. While hydrogen is drawing attention as an energy source for the realization of a carbon-neutral society, CCS is still vital for the production of hydrogen from fossil fuels. CCS has the potential to contribute to a wide range of sectors, including electricity, hydrogen, and industries.

There is a wide variety of technologies that can be used to capture CO_2 (Table 1). Some representative methods are chemical absorption and physical absorption that make use of CO_2 absorbents, and membrane separation that uses a membrane for the selective permeation of CO_2. The characteristics of the gases that contain CO_2 (such as composition, CO_2 concentration, gas pressure) vary depending on the plant, so a suitable method is selected based on these characteristics.

Storage methods can be broadly categorized into the following: underground storage, in which CO_2 is pushed under the ground including in sea areas; dissolution at intermediate depths, in which CO_2 is dissolved in the ocean; and, seabed storage, in which liquid CO_2 is poured into deep-sea depressions. Of these, dissolution at intermediate depths and seabed storage are not accepted for practical purposes based on the London Convention, which is international law on marine pollution. For this reason, CO_2 storage methods are limited to underground storage.

Concerning underground storage in Japan, storage in the aquifer deep underground (a method that seals CO_2 in the ground by using, as a cover or "lid," strata that does not allow water or gas to pass through) has potential from a quantitative point of view. While there is a need to conduct a detailed study of the individual storage reservoirs, the storage potential in sea areas at a depth of 1,000 m or below is estimated to be 236 billion tons of CO_2 equivalent (about 200 years' worth of Japan's recent CO_2 emissions). The Government of Japan plans to select a suitable site around 2021.

In addition, proposals have also been made to store CO_2 by using CO_2 hydrate (a sherbet-like state consisting of CO_2 and water). This is a method that artificially generates CO_2 hydrate in the ground and stores it in solid state, while at the same time using that as a cover to seal in liquid CO_2 in the substratum. Operators in the private sector are engaged in research and development on this method, including power source development. As this method is not dependent on the geological structure of the ground and can also be applied to shallow strata, it is expected to deliver benefits in aspects such as increasing storage potential and reducing cost.

Possibility of lowering the average temperature of the world

Carbon neutrality is achieved when the emissions volume of greenhouse gases (GHG) corresponds to the volume of such gases that are absorbed or removed from the atmosphere, and fossil fuel-based CCS contributes to reductions in the

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emissions volume. In addition to the reduction of emission, CCS can also be applied to the removal of CO_2 from the atmosphere. From this perspective, it is increasingly coming under the spotlight.

CO_2 removal technology is also known as "negative emission technology." Specific examples include bioenergy with carbon capture and storage (BECCS), which combines biomass fuels with CCS, and direct air carbon capture and storage (DACCS), which combines direct air capture (DAC) with CCS. BECCS works in the following way: while biomass (such as plants) absorbs CO_2 in the atmosphere as it grows, if CCS is applied after the combustion of biomass, it will be possible to isolate this CO_2 that was absorbed from the atmosphere during the growth process, and store it in the ground. DACCS works in a similar way. DAC is a form of technology for capturing CO_2 from the atmosphere, so if this CO_2 were stored, it would effectively be removed from the atmosphere.

If methods such as BECCS and DACCS can be applied, it would be possible to offset the emissions from processes that cannot avoid releasing GHG. They could provide the solution in situations where alternatives are not viable, for example, in the case of fossil fuels that are used as raw material for chemical products (CO_2 is generated when the fossil fuels are incinerated as waste). Furthermore, if countries around the world were able to go beyond carbon neutrality to achieve "negative emissions," it would be possible to lower the average temperature of the world.

Challenges to CCS in Japan

The implementation of fossil fuel-based CCS, BECCS, and DACCS in Japan faces two common issues.

The first is the uncertainty of domestic storage capacity. There is a need to conduct a careful study into storage potential in the future, and there are factors that place constraints on expanding storage capacity, such as the number of rigs for excavating injection wells.

The second challenge lies in the legal system. For example, Japan currently only permits storage in underground strata for CO_2 recovered through the chemical absorption method (in accordance with the Law Relating to the Prevention of Marine Pollution and Maritime Disaster). Hence, there is a need to enable the use of a wide range of carbon capture technologies through the amendment of laws and other measures.

In addition, there are also challenges that are specific to each type of technology. Firstly, fossil fuel-based CCS is not a zero-emission method. Currently, it is possible to capture about 90% of the CO_2 generated from fossil fuels, so a part of the CO_2 generated is still released into the atmosphere even if CCS is utilized. As such, there is a need to offset the CO_2 that is emitted in order to progress toward a carbon neutral society. Next, the implementation of BECCS is constrained by the amount of biomass resources available in the country. If there are insufficient biomass resources in the country, importing biomass could be an option. However, it will be necessary to make use of biomass that was produced appropriately from the viewpoints of land use and the protection of ecosystems. As for DACCS, the development of DAC technology is still a work-in-progress. In Japan, DACCS was selected as one of the projects under the Moonshot Research and Development Program last year, and there is much uncertainty about cost levels in the future. Moreover, capturing CO_2 from atmosphere that has low CO_2 concentration consumes a large amount of energy, which in turn makes it necessary to procure low-carbon energy for that purpose.

In order to expand and popularize CCS in Japan, it will be important to overcome these challenges, and at the same time, consider a wider range of options going forward. For example, in the case of fossil fuel-based CCS, in addition to storage in Japan, there is also the possibility of transporting and storing CO_2 at suitable sites overseas, such as in oil/gas-producing countries. Furthermore, since CO_2 reduction is equally effective at any place on Earth, it would be economically rational to carry out BECCS or DACCS intensively at suitable sites overseas (such as countries that have rich biomass resources and are suited to CO_2 storage, or countries with low energy prices and are suited to CO_2 storage). Hence, there is a need to formulate strategies with a broad outlook without focusing overly on domestic implementation, and to design systems and put in place measures toward the realization of these strategies.

Table 1 Main carbon capture and storage technologies

Category	Main technologies
CO_2 capture	・CO_2 capture at plants, etc. that use fossil fuels or biomass fuels: Chemical absorption, physical absorption, membrane separation, solid absorption, physical adsorption, cryogenic separation ・CO_2 capture from the atmosphere: Direct air capture (Note)
CO_2 storage	・Underground storage: Storage in the aquifer, CO_2 hydrate storage, storage in depleted oil and gas fields, storage in coal seams ・Dissolution in intermediate strata ・Seabed storage

Note: A number of methods have been proposed in relation to direct air capture technology, and technological development is underway.
Source: Prepared by the author based on materials from the Ministry of Economy, Trade and Industry and other sources.

Series "Ushering in a New Era of Carbon Neutrality" (9)

Advancing Electrification in the Transportation Sector◆

Yuji Mizuno*

Electric-powered vehicles are an effective means of decarbonization

It would not be possible to transport goods and people to all corners of society without any automobiles. On the other hand, it is difficult to capture the carbon dioxide (CO_2) that is emitted by automobiles, and this poses a challenge for the decarbonization of the transportation sector. This is one of the reasons behind the advancing electrification of automobiles around the world.

As of 2018, the CO_2 emissions volume of Japan's transportation sector made up about 18.5% of Japan's total emissions, while CO_2 emissions from automobiles made up 15.9% of Japan's total emissions. Japan, following suit with global trends, is also pursuing the policy of promoting electrification in the transportation sector. In 2020, the Government of Japan announced that the sale of new gasoline-powered vehicles will be prohibited by the mid-2030s, and only the sale of electric-powered vehicles will be permitted.

Characteristics of internal-combustion vehicles and electric-powered vehicles

Automobiles can be classified as internal-combustion vehicles and electric-powered vehicles (Table 1), based on their drive systems. Internal-combustion vehicles can be broadly categorized as gasoline vehicles and diesel vehicles; the former is fueled by gasoline, while the latter is fueled by light oil (diesel fuel). Electric-powered vehicles are automobiles that are fully or partially driven by an electric motor; specifically, they include battery-powered electric vehicles, fuel-cell vehicles, and hybrid vehicles. The CO_2 emissions of automobiles can be grasped and understood through the concepts of "well-to-wheel" (WtoW) (the processes starting from the primary energy source that can be obtained from nature without any conversion or processing, to the actual driving of the vehicle), and "tank-to-wheel" (TtoW) (the processes starting from the storage battery or fuel tank, to the actual driving of the vehicle). Internal-combustion vehicles that use fossil fuels emit CO_2 in both the WtoW and the TtoW processes. On the other hand, liquid fuel such as gasoline and light oil generates high energy output per both unit mass and volume, and is characterized by the fact that it can be replenished in just a few minutes.

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Table 1 Characteristics of internal-combustion vehicles and electric-powered vehicles

	Internal-combustion vehicles		Electric-powered vehicles		
	Gasoline vehicles	Diesel vehicles	Battery-powered electric vehicles	Fuel-cell vehicles	Hybrid vehicles
TtoW CO_2 emissions	-	Somewhat superior	Superior (No emissions)	Superior (No emissions)	Somewhat superior
WtoW CO_2 emissions	-	Similar	Somewhat inferior – Superior	Somewhat inferior – Superior	Somewhat superior
Cruising distance	-	Somewhat superior	Similar	Similar	Somewhat superior
Speed of energy replenishment	About 5 minutes	About 5 minutes	30 minutes – 10+ hours	About 5 minutes	About 5 minutes
Characteristics	-	Strong torque, essential for buses, trucks, etc.	Vehicle weight increases if cruising distance is extended	Difficult to take advantage of the cruising distance merits for small vehicles	There are various formats in aspects such as storage battery capacity, motor output, etc.

Source: Prepared by the author based on the specifications of vehicles that are commercially available as of 2021

On the other hand, there are multiple types of electric-powered vehicles. Other than hybrid vehicles, vehicles that are powered only by electricity generate zero TtoW CO_2 emissions, and do not produce any emission gases. However, WtoW CO_2 emissions volume is dependent on factors such as the power generation method for the electricity used for charging, and the production method of hydrogen.

The simplest system for electric-powered vehicles belongs to the battery-powered electric vehicle. Its driving energy is supplied by an in-vehicle storage battery. However, the energy density of current storage batteries in 2021 is lower than that of liquid fossil fuels, and many electric vehicles have a shorter cruising distance (the distance it can continue driving for without recharging) than internal-combustion vehicles of a similar size. Furthermore, as charging speed is generally determined by "Size of charging current × Size of charging voltage × Charging time," it would take several hours to charge a car at 100V or 200V, which is the usual voltage available at domestic homes. Therefore, large electric currents and high voltages are necessary for rapid charging.

Fuel-cell vehicles compensate for these issues through the use of hydrogen and fuel cells. The amount of energy generated per kilogram of hydrogen is about 2.7 times that of gasoline, and the cruising distance per kilogram of fuel is about four times that of the actual fuel consumption of gasoline vehicles (converted as 20 km/liter). However, the amount of energy generated per unit volume of compressed hydrogen is about one-tenth that of gasoline. Moreover, hydrogen tanks come in large cylindrical shapes such as propane gas cylinders, and therefore cannot be efficiently mounted in vehicles. For such reasons, it is difficult to secure cruising distance in small vehicles. As hydrogen, which is the fuel, can be made from renewable electricity sources and water, it is relatively easy to achieve near-zero WtoW CO_2 emissions. However, it faces challenges such as the loss of approximately 40% of the energy from the point when hydrogen is produced from electricity, and the widespread development of hydrogen supply infrastructure.

Hybrid vehicles are electric vehicles mounted with internal-combustion engines, and fuel economy is improved by using motor drive to cover the driving ranges that the internal-combustion engine is inefficient at. In addition, electricity is generated through the regenerative brake, which uses the motor as a power generator when decelerating; this makes it possible to reuse a part of the vehicle's kinetic energy, which is conventionally discarded as heat, to drive the vehicle. There are various types of hybrid vehicles, including "series hybrid vehicles" that use the engine exclusively for power generation, "parallel hybrid vehicles" that use the motor as an auxiliary driving device for the engine, as well as "power-split hybrid vehicles" that enable the changing of the roles of the motor and engine at will. There are also "plug-in hybrid vehicles," which have in-vehicle batteries that can be charged directly.

The need for public-private partnership

In order to realize a zero-emission society through the electrification of automobiles, it is necessary to reduce WtoW CO_2 emissions, as well as decarbonize the primary energy source that is at the upstream of the supply-chain. For battery-powered electric vehicles, the power source can be changed from thermal power energy, which burns fossil fuels, to renewable energy or nuclear energy. As for fuel-cell vehicles, the primary energy source of hydrogen can be changed from fossil fuels to renewable energy, and capture and storage facilities for CO_2 can be installed in hydrogen production plants that use fossil fuels. Even for internal-combustion vehicles, the adoption of carbon-neutral fuels, such as biofuels, makes it possible to substantially reduce WtoW CO_2 emissions volume.

These measures cannot be fully achieved by the automobile industry alone. There is a need to put in place cross-industry initiatives in areas including the decarbonization of the power supply configuration, and the development of supply-chains to supply hydrogen and carbon-neutral fuels.

To realize decarbonization, it is necessary to develop and popularize vehicles with excellent economic rationality and convenience, while taking into consideration how the vehicles are used. For example, it is difficult to replace vehicles with long cruising distance per trip (such as express buses and large trucks that are responsible for long distance transportation) with battery-powered electric vehicles that take a long time to charge. If the society is to achieve decarbonization as a whole, it is also important to enhance the convenience of electric-powered vehicles through means such as enhancing power generation capacity, developing the power transmission and distribution networks, and expanding charging and hydrogen supply infrastructure.

If Japan aims to continue acquiring foreign currencies through the export of automobiles in the future, it is important to secure the raw material resources such as storage batteries and motors, and to establish supply networks for electric devices (storage batteries, semiconductors, motors, etc.) that return profits to Japan and create employment. In order for Japan to continue creating the world's best automobiles, there is a need for public-private partnership in areas such as the formulation of a national resource strategy and industry policies, and regulatory reform for the automobile sector.

Series "Ushering in a New Era of Carbon Neutrality" (10)
Utilization of Digital Technology in the Energy Sector◆

Akiko Sasakawa*

The growing trend of digitalization in the energy sector

Greening and digitalization are being promoted as the driving forces to stimulate growth in the post-COVID era. Taking response to climate change as an opportunity for growth, widespread efforts are ongoing to promote greening for achieving carbon neutrality, as well as to promote digitalization initiatives that harness information and communications technology (ICT), artificial intelligence (AI), and other technologies.

Digitalization, which advanced rapidly from the 2010s, brought about major transformations to economies and societies. According to the "World Development Report 2016: Digital Dividends" published by the World Bank in 2016, the direct changes caused by digitalization include improvement in access to information, spread and popularization of automation technology, and the rise of platform enterprises.

The wave of change is also exerting its influence on existing systems and business models that are under pressure to make the transition toward a decarbonized society. This article, which comes at the end of this series on carbon neutrality, focuses on initiatives that harness digital technology in the energy sector, which accounts for more than 80% of all greenhouse gas emissions, and requires urgent effort to reduce its carbon footprint.

One of the specific initiatives is the Virtual Power Plant (VPP). A VPP is a system that adjusts the demand and supply balance of electricity by functioning as a single power generation plant, using Internet of Things (IoT) technology to remotely integrate and control decentralized energy resources such as renewable energy power generation facilities, storage batteries, and electric vehicles (EV). To expand the adoption of renewable energy, which varies its power output depending on the weather conditions and time of the day, it is vital to secure adjustment capability to maintain the demand and supply balance of electricity stably. To provide this adjustment capability, it is necessary to have a grasp on the power generation and charging status of the decentralized energy resources, predict the potential for utilization, and based on that, aggregate and control the target energy resources. Hence, digital technology, such as AI technology for making advanced predictions and IoT technology for carrying out remote control of the decentralized resources, play an important role in the implementation of this series of processes quickly and accurately.

VPP is increasingly becoming one of the new business models for the electric power sector in Europe and the United States. For example, Next Kraftwerke GmbH and Energy2market GmbH (e2m) are representative VPP companies in Germany. In addition, there are about 100 other such businesses in Germany that are engaged in the trading and operation of energy resources on platforms based on digital technology.

In Japan, demonstration projects, which are primarily subsidized by the Ministry of Economy, Trade, and Industry, are being implemented, while diverse stakeholders, including electric companies, manufacturers, and local governments, are putting effort into developing a VPP market.

Blockchain and power trading

Power trading initiatives that make use of blockchain technology are also coming into the spotlight. A blockchain is a form of technology that allows participants on a network spread across dispersed terminals to save data and carry out transactions directly without going through a centrally managed server. The greatest characteristic of blockchain is its ability to reduce the risk of the data being tampered with to zero as far as possible. This is achieved through the multi-layered sharing of chained data among participants of the network. Furthermore, when compared to large-scale centrally managed

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systems, blockchain technology offers cost benefits by minimizing the cost of investing in system development, commissions to intermediaries, and management costs.

Prosumers (electric power producers and consumers) who own renewable power generation facilities are increasingly harnessing such technology to engage in power trading with electricity consumers. In the state of New York in the United States, for example, households (prosumers) that own solar power generation facilities are advancing efforts to sell their surplus electricity to electricity consumers on platforms that are based on blockchain technology. When prosumers generate surplus electricity, smart meters that are installed at the consumers' end detect that and automatically engage in trading if trading conditions, which are based on smart contracts, are met. Such a system is gradually being developed.

In addition to enabling direct power trading, blockchain technology also makes it possible for consumers to easily obtain information on purchasing power, which had previously been hard to get hold of. Individuals who wish to use electricity generated from renewable energy sources that are rooted in the local region, as well as companies that seek to procure energy only from renewable sources, have high expectations for the application of blockchain technology that is characterized by high data precision and traceability.

Making greening and digitalization work closely together

As described above, digital technology is actively being utilized to promote the adoption of renewable energy, which holds the key to decarbonization. As a result of digitalization, a wide range of information can now be handled by a diverse range of stakeholders, and platforms for managing information and trading are also emerging.

This series introduced the trends in and outside of Japan, with a focus on technology that contributes to decarbonization. This includes areas where innovation is advancing, such as next-generation solar power generation and storage battery technology, and areas where further development is expected in the future, such as offshore wind power generation, ocean energy power generation, biofuels, as well as hydrogen, carbon capture and storage (CCS) technology, and the electrification of vehicles. Despite the earnest and ongoing efforts to advance many initiatives, including research and demonstration projects, to develop such technology, there is still a long way to go toward achieving carbon neutrality in 2050.

To achieve the goal of carbon neutrality, on top of such technological innovation, there is also a need to promote digitalization for societies and economies as a whole. The "Green Growth Strategy through Achieving Carbon Neutrality in 2050" announced by the Government of Japan in June this year places emphasis on the importance of strengthening digital infrastructure. For example, it sets out the policy of introducing digital technology for the management of smart grids for the advanced operation of systems as well as the maintenance and inspection operations of infrastructure in the power sector, and of improving energy use efficiency by promoting the automatic driving of cars, drones, aircraft, and trains in the transportation sector. Further examples include the realization of a smart city in which all services are optimized through the use of digital technology.

Digitalization can optimize the cross-sectoral movement of people and things, as well as contribute to the efficient use of energy. As digitalization and decarbonization concurrently progress, and social transformation is urgently needed, it is important to take an extensive view of technologies and policies that are related to decarbonization and to effectively utilize digital technology for a better future. However, while the advancement of digitalization creates opportunities to enhance efficiency, improve information access, and develop new business models, it also throws up challenges at the same time, such as the monopolization of information and markets, and cybersecurity. While paying attention to such aspects and putting in place cautious measures, we can look forward to growth propelled by a tight link between greening and digitalization.

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