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"Global Energy Landscape under Trump 2.0 and Issues in Implementing the 7th Strategic Energy Plan"

The international energy situation under Trump 2.0

< Summary > ♦

Ichiro Kutani *

While the situation in the Middle East is de-escalating, future developments are unclear

1. The military conflict between Israel/the U.S., and Iran has de-escalated. Meanwhile, the global supply and demand balance for oil is weakening due not only to the economic slowdown caused by the reciprocal tariffs, but also the easing of additional oil production cuts by 8 participating countries of OPEC+.
2. However, the future developments of the Iran situation, such as the direction of the ceasefire (in the short term) and whether a solution will be found for the problem of Iran's nuclear program, are unclear.
3. If the situation were to begin to interfere with safe passage through the Strait of Hormuz, it would negatively affect the entire world, including Japan. Roughly 30% of the world's oil trade (20 mb/d, 2023), along with roughly 20% of the LNG trade (85 million tons, 2023), passes through the Strait, and there is only limited capacity available via alternative oil pipelines (4.2 mb/d). Though the chance of this occurring is low, the immense potential impact of this so-called "tail risk" still needs to be considered.
4. Even in global terms, Japan's dependence on the Middle East is significant. Therefore, it is necessary to continue with comprehensive measures to ensure a stable oil supply, including preparations for emergencies (stockpiling) and various risk measures (such as diversification of supplier countries and contributions to stabilizing the Middle East situation).

Interpreting the impact on China from the policies of Trump 2.0

5. The policies of Trump 2.0 may be benefiting China contrary to their intent, such as strengthening their position in terms of free trade and preventing climate change, and providing Chinese companies with opportunities to expand internationally. China may also be reaffirming its strengths through the negotiations related to tariffs.

♦ Created based on the published research in the 450th Forum on Research Works with the information available as of July 2025.

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6. On the other hand, if the China-U.S. confrontation were to escalate, it may put further pressure on the weakened Chinese economy and cause domestic political and economic problems. A slowdown in Chinese energy demand will also impact the international energy market, such as softening international demand and lowering prices.

Trump 2.0 and the consequences of the war in Ukraine

7. Despite its conciliatory approach to Russia, the U.S. has been unable to obtain a ceasefire and has failed to find a path toward ending the war. President Trump has already floated the possibility of imposing secondary tariffs on countries that import Russian oil, and these may become a reality depending on the response from Russia. If they do become a reality, the three largest importers (China, India, and Turkey) will feel the largest impact of the sanctions, and this will also affect the success of those sanctions. Focus will also be on the effects on the international energy market if the sanctions are strengthened.
8. Japan currently continues to import coal and LNG from Russia, and therefore needs to consider measures depending on the direction of the war and sanctions. Accordingly, focus will be on changes in energy prices and the impact on Japan under scenario 1.2.

Scenario 1.1: The war continues, and the U.S. economic sanctions on Russia remain roughly the same.

Scenario 1.2: The war continues, and the U.S. strengthens sanctions on Russia, including secondary tariffs on countries importing Russian oil.

Scenario 2: A ceasefire is reached, and the U.S. economic sanctions on Russia are lifted.

Developments to watch regarding domestic energy policy under Trump 2.0

9. The U.S. is considering relaxing regulations on CO₂ emissions from thermal power generation and the classification of greenhouse gases as hazardous for the purpose of ensuring a stable energy supply, improving the daily lives of the citizens, and reviving the manufacturing industry. It is therefore necessary to examine the future impact of this worsening of the investment environment for clean technologies.
10. The One Big Beautiful Bill Act was passed by Congress. Energy related provisions in the act include a reduction in the support period under the Inflation Reduction Act (IRA) established under the Biden administration and limits on foreign capital and parts, both of which affect clean technology investment in the U.S.

Some global movement toward a realistic energy transition under Trump 2.0

11. The establishment of the Trump administration has brought about changes to action on climate change, such as a move toward acceptance of a certain amount of funding for fossil fuels. Meanwhile, the World Bank lifted its ban on financing nuclear power (June 2025) while establishing a partnership with the IAEA (also June 2025).

Toward strengthening and deepening Japan-U.S. relations

12. One constant is that the U.S. is an important partner for Japan and that the strengthening and deepening of Japan-U.S. relations remains important. Meanwhile, a strategy is required that is predicated on the possibilities offered by the major changes in policy every four years.
13. Elements for energy cooperation must be found from the standpoint of U.S. national interests, irrespective of changes in administration. Current candidates thereof include SAF, biofuels, storage batteries, critical minerals, CCS, nuclear power (including fuel), and geothermal power.
14. On the other hand, LNG is important as a short-term solution for dealing with the trade deficit under the current administration. However, this requires procurement at competitive prices that are not inferior to those of other sources. While the overall vast supply of LNG in the U.S. should be considered subject to cooperation, it will be necessary to work with the countries of Southeast and South Asia because there is a limit to the amount that Japan can accept in terms of both quantity and time.

450th Forum on Research Works - July 18th, 2025

"Global Energy Landscape under Trump 2.0 and Issues in Implementing the 7th Strategic Energy Plan"

**Challenges in Japan's LNG procurement
toward achievement of its 7th Strategic Energy Plan
—The need for both private sector initiative and
stronger government engagement—
< Summary > ♦**

Takafumi Yanagisawa *

Points related to LNG procurement are indicated in the 7th Strategic Energy Plan

1. Under the “risk case” scenario in which decarbonization technologies are insufficiently advanced and costs are not adequately contained, Japan’s demand for LNG is expected to increase by 8 million tons over the FY2023 actual level to 74 million tons by FY2040. Demand is forecast to fall slightly from current levels under the other scenarios, but in any case, it is necessary to secure long-term LNG contracts from the perspective of ensuring a stable supply.
2. Securing long-term LNG contracts is becoming harder due to increasing uncertainty in fuel demand forecasts, a result of electricity market deregulation, growing adoption of volatile renewable energy, and lowering rates of LNG thermal utilization.
3. Japan must consider how to secure a steady fuel supply across normal times as well as emergencies, in preparation for LNG price spikes amid tight supply or strong demand and sudden shifts in the international situation.
4. Without compromising private sector initiative, coordination between the business and the public sector is necessary in areas of highly uncertain demand.
5. Strive to produce Japanese companies with global level competitiveness by relaxing destination clauses, a flexible approach to using tank facilities in Asia and elsewhere, joint procurement, and strengthening trading functions.
6. Promoting cooperation with IEA in the field of decarbonization of the whole LNG value chain, advancing the CLEAN partnership, and decarbonization policy based on the “various pathways”, taking into consideration the different situations of each country, which is seen in the statements by G7 and AZEC.

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Future outlook for Japan's LNG procurement

7. Japan is close to facing a series of expiration of existing LNG long-term contracts. In order to secure the long-term volume of LNG required in FY2040, it will need not only to “maintain and strengthen the relations with existing suppliers”, but also to “find new suppliers”.
8. Japan's continuing efforts to diversify and make flexible its LNG procurement would be required in order to cope with the “uncertainty” of energy supply/demand stemming from decarbonization and the development of AI and data centers, in addition to geopolitical and policy change risks. A “sustainability” perspective based on decarbonization targets would also continue to be vital.
9. In order to secure long-term LNG procurement, enhanced government support would be required to manage “uncertainty,” which firms have been struggling with, without compromising the principle of “private sector initiative” for procurement.
10. One of the vital issues for Japan to enhance its LNG procurement is boosting the function of Japanese companies as “portfolio players.” In fact, some of them have already been trying to diversify and make flexible its supply sources, like through the participation in the new projects not only in the United States but also in Canada, the UAE, Mozambique, and so on, as well as agreeing on the new long-term procurement. Meanwhile, companies are required to minimize the risk from market fluctuations, so it will be necessary for the government to provide not only support for traditional country risks, but also to prepare a kind of compensation mechanism for the uncertainty of the LNG market, including the possible loss by resale. In addition, stronger inter-company collaboration will also be needed.

Indirect support by the Japanese government for securing a stable LNG supply

11. Taking into consideration the difference with the other region, including Europe, where underground gas storage is possible, the Japanese government proposes three different types of reserves depending on geological conditions, such as policy measures and flexible contracts, in addition to underground gas storage.
12. Meanwhile, with increasing expectations toward the role of LNG, it would be required to examine the risk of reserve shortages in times of crisis and to raise the reserve level (for around 2 weeks, as the current level). While from the point of viability, the basic approach by the Japanese companies has been to secure stable LNG procurement while keeping reserve level to a minimum, on the procurement side, they have been promoting diversification, increasing flexibility, and boosting procurement for winter, a season more prone to supply and demand tension. In this context, it is important to explore stronger public-private partnerships in terms of raising reserve levels and storage tank capacity, for example.

13. “The highlight on the importance of LNG for the future” by the government is also expected to provide a “tailwind” to the signing of long-term LNG contracts by companies. In fact, positive statements have already been made at AZEC, G7, and the LNG Producer-Consumer Conference.
14. Furthermore, Coalition for LNG Emission Abatement toward Net-zero (CLEAN), as an initiative for methane emission reduction in the LNG value chain promoted by Japan, is not intended to introduce stronger regulation, but rather to promote “the spontaneous movement toward methane management and reduction by companies”. While the Japanese government is also providing stronger support, such as by actively collaborating with international organizations to establish a certification system, and the utilization of data from observation satellites.

Future challenges

15. In the 7th Strategic Energy Plan, the details of effective policies remain unclear and are left to future discussion between the public and private sectors. Amid a changing international situation for energy security, there is an urgent need for productive consideration on stronger LNG procurement both in ordinary times and in crisis through public-private partnership.

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"Global Energy Landscape under Trump 2.0 and Issues in Implementing the 7th Strategic Energy Plan"

**Challenges in electricity supply stability toward achievement
of the 7th Strategic Energy Plan
—Establishing a more predictable commercial environment—
< Summary > ♦**

Kenichi Onishi *

Power generation investment issues under the 7th Strategic Energy Plan and the future of electricity system reform

1. The 7th Strategic Energy Plan, published in February 2025, forecasts electricity generation in FY2040, taking into account the demand increase stemming from the expansion of data centers, and proposes the maximization of renewables and nuclear power in order to decarbonize electricity.
2. Electricity system reform was implemented in the wake of the 2011 Great East Japan Earthquake disaster. A review of the reforms was released in March 2025, together with the outlook for the sector. With regard to the returns on power generation investment and establishing a better commercial environment for the sector, liberalization has brought significant uncertainty. Due to concerns that generators may hesitate to make new investments, the review notes an intention to look at policies to facilitate financing.

Electricity demand forecasts in Japan

3. National electricity demand projections (end use) published by the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) in January 2025 for FY2024-FY2034 were for annual growth averaging 0.6%. Demand projections in January 2023 for the same period were for an annual average decline of 0.2%. It is noteworthy that the projected decrease has now reversed.

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Capacity pricing in Japan and future outlook

4. The capacity market, which aims to secure electricity supply four years before the delivery year, has already been launched. A capacity auction for the supply of power in FY2028 took place in January 2025, with overall capacity prices rising. The main reason for the increase was likely the rise in provisional bid price to secure the necessary future supply.
5. However, capacity assurance agreements last 12 months in the capacity market, and if generators are unable to win bids every year, they are unable to recover their long-term fixed costs. Therefore, such agreements may not necessarily contribute to the development of new power generation.

Long-Term Decarbonization Power Source Auction Trends in Japan

6. Long-Term Decarbonization Power Source Auctions were launched in January 2024 with the aim of promoting new investment in zero-carbon power generation and enhancing the predictability of returns on investment. The winning bidder acquires stable revenue from the facility for 20 years in principle and is required to retroactively refund about 90% of the revenue received from other markets.
7. As shown by the auction results for FY2024 released on April 28, 2025, around 3.15 million kW was bid on investment in safety measures for existing nuclear power plants. On the other hand, there was limited bidding for thermal plant refurbishment. Bidding conditions were stricter than last year for battery storage, yet offers increased. Bidding levels and the state of competition varied according to the type of generation.

Thoughts on the evolution of Long-Term Decarbonization Power Source Auctions

8. For generation such as nuclear power with its long lead-times and tremendous up-front costs, the challenges are (1) the risk of non-recovery of fixed costs, (2) allocation of funds during the construction period, and (3) consideration of risk premiums, etc.
9. As the third auction approaches, information pertaining to (1) setting of commercial rates of return by generation type, (2) raising of price ceilings, and (3) correction of bid prices has been published. However, this does not mean that the issues related to power generation investment are resolved.
10. Overseas, countries are looking into and adopting systems that promote the maintenance of nuclear plants and new investment in generation without losing sight of the impact on power users. Of those jurisdictions, RAB in the United Kingdom and CfD in Sweden may be the systems that enable some reduction of the risk burden on companies by cutting the risk of non-recovery of fixed costs and implementing cost recovery during the construction period.

Facilitating financing of electricity infrastructure investment

11. As with investment in the power grid, financial institutions are becoming less able to assume risks against the backdrop of uncertainty; therefore, methods like harnessing supplemental state funding and financing backed by the creditworthiness of the government should be considered.
12. Texas has a program applying 20-year, low-interest loans to new gas thermal generation.

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"Global Energy Landscape under Trump 2.0 and Issues in Implementing the 7th Strategic Energy Plan"

**Challenges in renewable energy toward achievement
of the 7th Strategic Energy Plan
—Outcome dependent on expanded adoption of self-consumption
solar and offshore wind—
< Summary > ♦**

Yasushi Ninomiya *

The status of renewable energy in the 7th Strategic Energy Plan

1. The 7th Strategic Energy Plan calls for a thorough focus on renewable energy as the primary energy source from the standpoint of balancing a stable energy supply with decarbonization, and for maximizing the introduction thereof while striving to harmonize with local communities and managing national burdens.
2. Specifically, the plan assumes that approximately 40% to 50% of the total power generated in FY2040 (1,100-1,200 TWh) will be comprised of renewable energy. Furthermore, solar power is slated to be the largest power source at 23% to 29%, comparable to the 30% to 40% comprised by thermal power. Meanwhile, wind power is expected to comprise a total of 4% to 8% combining on- and offshore wind, with hydropower at 8% to 10%, geothermal at 1% to 2%, and biomass at 5% to 6%.
3. When comparing the adoption potential versus the current rate of adoption, the successful outcome of the renewable energy goals will be largely dependent on the expanded adoption of solar and offshore wind power.

Renewable energy targets and challenges for FY2040: solar power generation

4. A calculation of the amount of renewable energy generation needed to achieve the FY2040 adoption targets, under certain assumptions, suggests a range between 202 GW and 241 GW for solar power generation in FY2040. In order to reach that level, an annual adoption rate of between 10 GW and 12 GW per year must be maintained for the ten-year period between FY2030 and FY2040.

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5. This is not necessarily an unfeasible adoption level from the standpoint of past performance, as an adoption rate of approximately 10 GW per year was achieved for two consecutive years in FY2014 and FY2015. However, it should be noted that that rate was achieved during a rapid boom period after the adoption of the FIT program. Because the rate of adoption for FY2024, including PPA, etc., slowed to between 4.5 and 5.0 GW per year, the key to achieving the FY2040 targets will be whether it is possible to accelerate adoption to the level of 10 GW per year once again.
6. Given the large potential for adoption of 283 GW (Obane et al., 2024), it is therefore important to promote the adoption of rooftop solar for self-consumption that places less burden on the grid and promotes coexistence with the community. Solar power for self-consumption is an energy source from which the end user can receive direct economic benefits thanks to the decline in generating costs, and it is believed there is room to consider strengthening associated policy, including making installation on buildings over a certain size mandatory. Meanwhile, the potential for ground-mounted solar depends largely on how farmland is treated, given that a decline in suitable land has been pointed out. Therefore, it is necessary to consider the potential for expanded adoption of agrisolar (agrivoltaics) in terms of both technology and policy.

Renewable energy targets and challenges for FY2040: wind power generation

7. A calculation of the amount of renewable energy generation needed to achieve the FY2040 adoption targets for wind power, under certain assumptions, suggests an estimated maximum of 19 GW for onshore wind and 15 GW for offshore wind. Given the potential for 23 GW (Obane et al., 2024) for onshore wind in Japan overall, the estimated limit for adoption is about 19 GW, not much more than the FY2030 target of 17.9 GW. Therefore, the challenge for achieving the FY2040 wind targets can be condensed into how to achieve the 15 GW in offshore wind. Incidentally, there is an estimated potential of 134 GW of offshore wind when counting bottom-fixed installations alone (Obane et al., 2021), so expanded adoption of offshore wind is important from that standpoint as well.
8. In order to achieve this target, it is necessary to maintain an offshore wind adoption rate of 0.9 GW per year until 2040. This is generally consistent with the government's designation of promotional zones with a pace of 1 GW per year of adoption, and the goal of establishing 10 GW of projects by 2030, so it will be necessary to realize those plans accordingly to achieve the target.
9. Unlike solar power, offshore wind has been significantly impacted by the global rise in costs, and it will be difficult to balance managing the national burdens with maximized adoption. Therefore, the greatest challenge at the moment is how to secure investment in offshore wind given the rising costs.
10. In the long term, it will be essential to move toward mass production of related equipment and parts while reducing costs by forming a domestic supply chain. To that end, the government must

express and adhere to a commitment to its capacity adoption goals in order to increase the future predictability of the market, thereby promoting private investment under the government's leadership.

Shared challenges for achieving FY2040 renewable energy targets

11. The share of variable renewable energy (VRE) is expected to expand to up to 37% by FY2040. Furthermore, Japan will be in a globally unique position with an energy composition biased toward solar power. Accordingly, measures to ensure and strengthen grid flexibility will be essential for maintaining a stable electricity grid. This will require the promotion of measures such as improving and expanding the grid, securing low-carbon dispatchable electricity sources, expanding storage capacity, and DSM over the long term.
12. Meanwhile, the need to push renewable energy development more than previously to meet the FY2040 goals will make coexistence with the community an even more important issue. It will also be important to shift to orderly development directed by local municipalities under designated renewable energy promotion zones in order to prevent the sort of problems that emerge from unregulated renewable energy development that is left up to the private sector.

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"Global Energy Landscape under Trump 2.0 and Issues in Implementing the 7th Strategic Energy Plan"

Challenges in hydrogen and CCS toward achievement of the 7th Strategic Energy Plan

—Policy issues for hydrogen and CCS and the long-term perspective required—

< Summary > ♦

Yoshiaki Shibata *

Recent trends in hydrogen

1. Recent years have seen a string of suspensions and cancellations of hydrogen-related projects around the world (including hydrogen-based fuels such as ammonia, e-methane, and e-fuels). The key reasons have been the difficulty of cost-cutting, procuring finance, and securing off-takers.
2. Underlying this is the growing realization that using renewables, battery storage, and CCS are likely to be more realistic and rational options than hydrogen. Another factor is that the only means of international long-haul seaborne transport of hydrogen is ammonia, which is limited in its applications.
3. However, decarbonization will require a supply of hydrogen for hard-to-abate applications. It is likely that projects to enable commercial viability and secure off-takers with subsidies will survive.

Looming challenges for hydrogen policy

4. In Japan, Long-Term Decarbonization Power Source Auctions, a contract-for-difference subsidy scheme (to subsidize the price gap between low-carbon hydrogen and fossil fuels), and a hub development subsidy scheme are the three pillars. Based on the results of bidding over the first two Long-Term Decarbonization Power Source Auctions, expanded support is expected to be sought for hydrogen and ammonia-fueled electricity generation from the third round onward. With regard to the contract-for-difference subsidy scheme and the hub development subsidy scheme (a FEED subsidy in FY2025), proposal selection is due to take place before the end of FY2025.
5. While financial support is needed for the adoption of hydrogen, the burden on Japanese taxpayers needs to be considered. Therefore, efforts to cut costs through continuous technological development are essential. In addition to reducing the cost of hydrogen production, it is

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fundamentally a “hard-to-transport” energy, so reducing the cost of converting the hydrogen to hydrogen carriers is a major challenge. Any scheme design needs to promote cost reduction.

6. However, cost-cutting is uncertain. When it comes to the import supply chain in particular, raising the investment ratio of Japanese firms at each stage of the process—hydrogen production, shipping, and use—is an important point.
7. On the other hand, there is a need to scale up cost reductions. Concerning imported hydrogen, Japan needs to look at the possibility of joint procurement with other nations.

Discussion points on the future of hydrogen

8. Imported hydrogen is heavily affected by the strategy and institutions of the exporting nations. As such, it brings with it a variety of challenges, such as policy dialogue and diversity of suppliers. Regarding domestic hydrogen, challenges include the need to minimize the transport of hydrogen and to expand renewables. Therefore, we must have a debate based on potential foreseen risks and feasible possibilities.

CCS support scheme

9. In June 2025, to address a pipeline proposal, the “Working group on considering support frameworks for CCS projects” devised a proposal for a scheme to subsidize the price gap between CCS cost (strike price) and the carbon price (reference price). The CAPEX and OPEX of both the transportation and storage, and the capture of carbon, would be covered by the subsidy.
10. Under this support scheme, selection of proposals to receive the subsidy would take place with the timing of final investment decisions around 2026 in mind. It would aim for the launch of commercial production from FY2030 at the earliest.

Looming challenges for CCS policy

11. Firstly, an initial budget must be secured to establish this support scheme.
12. Other future challenges include creating a system that can make use of specialized knowledge (technology and finance) to implement this support scheme; responding to various technical and operational issues related to the use of ships for CCS projects and the development of the support scheme; investigating how CO₂ accounting rules will operate in conjunction with the greenhouse gas emissions accounting, reporting, and disclosure system (SHK system), and cooperating with local communities around reservoirs.
13. Globally, CCS projects are advancing at a pace. Preparations are underway in Europe for the start

of commercial operation of its new CCS project, while CCS tax incentives under the Inflation Reduction Act are being continued by the Trump administration. In Japan, thought is being given to both domestic and overseas storage. Therefore, the continuation of intergovernmental consultation and regulatory settings development for the realization of CCS across borders is vital.

Model analysis for Japan’s energy mix in 2040 and 2050

Hideaki Obane*

1. Background

In pursuing the goal of achieving carbon neutrality by 2050, it is essential to transform the energy supply–demand structure by adopting renewable energy and other advanced, cost-effective energy technologies. Extensive analyses of long-term energy supply and demand have already been conducted using energy system models, and the results of scenario studies by various organizations have been presented at policy deliberation committees. For example, at the 44th meeting of the Strategic Policy Committee in June 2021, six organizations reported their findings on energy scenarios for 2050.

These scenario analyses indicate that large-scale adoption of solar and wind power will be indispensable for achieving carbon neutrality. However, in recent years, solar power facilities have increasingly been installed in forested areas, prompting local governments to introduce regulations that limit development in ecologically sensitive locations. Similarly, while offshore wind projects have primarily been planned in shallow waters, future expansion is expected to require development in deeper areas where economic feasibility is lower. Accordingly, long-term energy supply and demand scenarios must take into account the impact of site location constraints associated with large-scale solar and wind deployment.

This study employs a technology selection model to evaluate the installed capacity of energy technologies across the energy system, explicitly accounting for constraints and location changes related to the large-scale adoption of solar and wind power in Japan. Based on this analysis, this study presents long-term energy supply and demand scenarios for 2040 and 2050.

2. Technology selection model

The technology selection model used in this study is based on a linear programming model (the NE Japan model) constructed by Otsuki et al.¹⁾⁻³⁾ This model assumes input values for the capital costs, fuel costs and other components of each energy technology in order to output installed amounts etc. for the energy technologies with the smallest costs in the energy system as a whole, based on linear programming. The technologies covered by the selection are approximately 300 technologies in the power generation, energy conversion, industry, transport, residential, and commercial sectors, and they are given a flowchart format that flows from primary energy supply through to energy conversion, secondary energy, interregional transmission and final consumption (**Fig. 1**).

In this model, the sum total of the costs relating to a technology *k* is considered to be the energy system costs, and the minimization of the cumulative costs is undertaken following discounting according to the objective function shown in Equation (1). The energy system costs include the capital costs and operating and maintenance costs for the demand side and supply side facilities, respectively, as shown in Equation (2), and the energy procurement costs (imports and domestic production of primary energy, and imports of secondary energy). The capital costs are converted into an annual cost across the number of years a facility is used, in line with Equations (3) and (4). The analysis period is 2022-2075, and supply and demand are estimated at six points in time, 2022, 2030, 2040, 2050, 2065 and 2075, as representative years *YR_y*.

$$\min \sum_{y=0}^5 \sum_{\tau=YR_y}^{YR_{2y}} \left\{ \frac{ac_y \cdot (YR_{y+1-\tau}) + ac_{y+1} \cdot (\tau - YR_y)}{YR_{y+1} - YR_y} \cdot \frac{1}{(1+DR)^{\tau - YR_0}} \right\} \dots (1)$$

$$ac_y = ivc_y + foc_y + voc_y + flc_y \dots (2)$$

$$ivc_y = \sum_{y' \in Y, y' \leq y} \sum_r \sum_k AC_{k,y'} \cdot LM_{k,y',y} \cdot nnk_{k,r,y'} \dots (3)$$

$$AC_{k,y} = C_{k,y} / \sum_{j=1}^{LIFE_k} (1 + HR)^{-j} \dots (4)$$

Here, *DR* is the time discount rate (5%), *YR_{2y}* is = *YR_{y+1}* - 1, *Y* is the aggregate of the points in time, *ivc_y* is the capital

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This paper is based on “Model calculation for Japan’s energy mix in 2040 and 2050”, which Seiya Endo, Takashi Otsuki, Hideaki Obane, Yuhji Matsuo, Soichi Morimoto and Akira Yanagisawa presented at the 66th meeting of the Strategic Policy Committee of the Advisory Committee for Natural Resources and Energy on December 3, 2024.

cost of point in time y (unit: yen/year), fo_c_y is the fixed operating and maintenance cost (yen/year) at point in time y , vo_c_y is the variable operating and maintenance cost (yen/year) at point in time y , fl_c_y is the energy procurement cost (yen/year) at point in time y , $AC_{k,y}$ is the capital cost of technology k at point in time y converted into an annual cost (yen/kW/year), $C_{k,y}$ is the capital cost (yen/kW) of technology k at point in time y , $LM_{k,y}$ is a constant value showing the remaining equipment life of the technology k , (if equipment introduced at point in time y' is approaching the end of its service life at point in time y the figure is 0, and if the equipment has service life remaining the figure is 1), $LIFE_k$ is the service life (years) of technology k , and HR is the subjective discount rate of investment.

There was assumed to be a total of 39 energy service demands (hereinafter “service demand”) covering industry (iron and steel, chemical, cement, paper and pulp, data centers, semiconductor factories, other industries); transport (passenger, freight); residential (lighting, cooling, heating, cooking) and commercial (lighting, cooling, heating, cooking). Within the model, service demand within each segment is further segmented, with transport (passenger) subdivided into the five categories of passenger vehicle, bus, marine vessel, rail and airplane, for example.

Electricity demand and thermal demand are determined endogenously according to the installed amount of the respective technology selected in order to meet each service demand. For example, in ordinary vehicle transport, in a case where electric vehicles are selected, electricity demand is assumed to increase within the model in response to that.

Notable features of the technology selection model used in this calculation are that it assumes a temporal resolution of 8,760 hours and divides regions in Japan into five areas (Hokkaido, Tohoku, Tokyo, West Japan, Kyushu/Okinawa), and both the temporal resolution and spatial resolution are subdivided. This makes it possible to take the time variability of solar power generation and wind power generation and the constraints of interregional connection lines into account in more detail, and it thus becomes possible to undertake a more refined assessment of the installed amount of storage batteries and variable renewable energy.

In addition, when it comes to solar power generation and wind power generation, for which changes in site location

are predicted to accompany progress with introducing them, it is assumed they will be installed in locations where they are unlikely to suffer the effects of restrictions resulting from regional regulations, based on reviews of such regulations. Additionally, accompanying the expansion in the installed amount, they will be sited in locations where generation costs are high, and so installation locations were divided into grades according to site conditions such as quantity of solar radiation, wind conditions, and water depth.

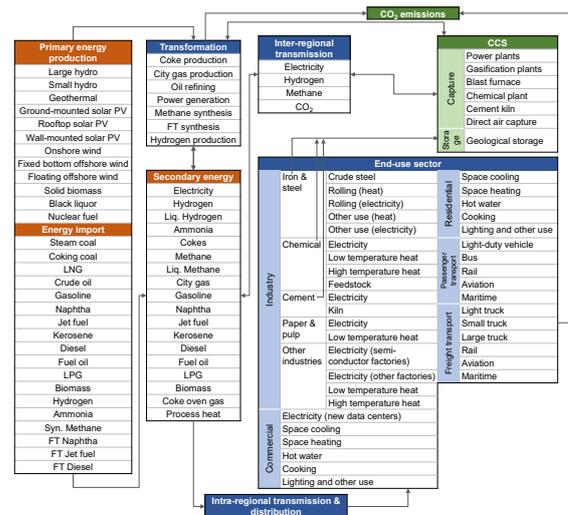


Fig. 1 The energy system in the technology selection model

3. Key assumptions

3.1 Scenario setting

Under the constraint that energy source CO₂ emissions will decline by 73% (333Mt–CO₂) by 2040 compared to 2013, and to a net 0 Mt–CO₂ by 2050, four types of scenarios were set in line with factors such as site conditions and degree of technological progress (**Table 1**).

(1) The renewable energy expansion case envisages a case in which maximum use is made of renewable energy, including making it possible to install agrivoltaic (dual use of land for solar energy and agriculture) power generation wherever possible on all agricultural land; (2) the hydrogen expansion case envisages a case in which import prices for hydrogen energy carriers decline as a result of declining costs for procuring green hydrogen from overseas and declining costs for carrier manufacturing facilities; (3) the CCS expansion case envisages a case in which it becomes possible to store CO₂ up to 240 million/t–CO₂, the upper limit of the target value for annual CO₂ storage volume presented in the CCS Long-Term Roadmap Study Group's final summary; while (4) the expanded innovative technologies case envisages that a renewable energy expansion, hydrogen expansion and CCS expansion are all realized.

3.2 Upper limits of installed amounts for solar and wind power generation

The upper limits of the installed amounts for solar and wind power generation are shown in **Table 2**. The upper limits of the installed amounts for ground-mounted solar power generation and onshore wind power generation are premised on the respective power sources being installed in locations that exclude zones restricted by regulations, based on Obane et al.⁴⁾ Incidentally, in the renewable energy expansion case, it was assumed that installation will be partly permitted in those zones where there is a low occurrence of cities, towns and villages where restrictions are in place as a result of them being landscape preservation areas, for example.

Where roof-mounted solar power generation is concerned, the upper limit of the installed amount was set

by taking into account the installation coefficient that is the ratio of area where solar power generation is installed as a component of the entire roof area, based on Obane et al.⁴⁾ In the standard case an installation coefficient that is based on actual installation figures was used (7.9–38.8% depending on the type of building), while in the renewable energy expansion case the installation coefficient used (49.9%) is based on the concept of buildings' potential greenification areas. When it came to detached houses, they were divided into grades of solar radiation pattern according to roof angle.

With reference to Asano et al.,⁵⁾ the upper limit of the installed amount of agrivoltaic power generation was assumed to be the installation capacity in a case where all agricultural management entities as of 2023 install 49.9 kW of solar power generation facilities, which falls within the range that does not require the appointment of a licensed electrician. Incidentally, in the renewable energy expansion case, installation was assumed to be possible on all agricultural land.

Where offshore wind power generation was concerned, based on Obane et al.,⁶⁾ the assumed premise was that installation would take place in those marine areas that satisfy the specified prerequisites of "Promotion Zones" under the Act on Promoting the Utilization of Sea Areas for the Development of Marine Renewable Energy Power Generation Facilities. In the standard case, installation was assumed to be possible in marine areas 10–100 km away from the shore, taking into account the impact on the landscape and system connectivity constraints, while for the renewable energy expansion case, installation was assumed to be possible in marine areas 0–370.4 km away from the shore. In addition, because power generation costs differ considerably depending on the location of installation, a total of 60 grades were established, comprising four water depth patterns x three windspeed patterns x five power generation area patterns, with capital costs, capacity factors, and upper limits for installed amount set for each grade (**Fig. 2**).

Table 1 Set scenarios

Case	Upper limits of installed amounts for solar power and wind power generation	Hydrogen price	CO ₂ storage volume
Renewable energy expansion (Case 1)	Renewable energy expansion	Standard	Low level (120 million t/year)
Hydrogen expansion (Case 2)	Standard	Advances in hydrogen technologies	Low level (120 million t/year)
CCS expansion (Case 3)	Standard	Standard	High level (240 million t/year)
Expanded innovative technologies (Case 4)	Renewable energy expansion	Advances in hydrogen technologies	High level (240 million t/year)

Table 2 Upper limits of installed amounts for solar power and wind power generation

		Approach taken	Upper limit of installed amount [GW]
Roof-mounted solar (detached houses)	Standard	Installed on roofs facing south, east and west	146.3
	Renewable energy expansion	Installed on roofs facing south, east and west, and north	194.4
Roof-mounted solar (other than detached houses)	Standard	Installed on 7.9%-38.8% of the entire roof area, depending on the type of building	137.2
	Renewable energy expansion	Solar power generation installed on 49.9% of the entire roof area	280.4
Ground-mounted solar	Standard	All types of zones restricted by regulations are excluded	52.3
	Renewable energy expansion	Some zones restricted by regulations are excluded	116.1
Onshore wind power	Standard	All types of zones restricted by regulations are excluded	25.2
	Renewable energy expansion	Some zones restricted by regulations are excluded	35.3
Agrivoltaic	Standard	Assumes that all agricultural management entities (84,000 management entities) install 50 kW of solar power generation facilities, which falls within the range that does not require the appointment of a licensed electrician	46.5
	Renewable energy expansion	Installation possible on all agricultural land	2,365

* Where ground-mounted solar power and onshore wind power are concerned, because they include facilities, etc. that are already installed in forests, they do not match the figures in Obane et al.⁴⁾

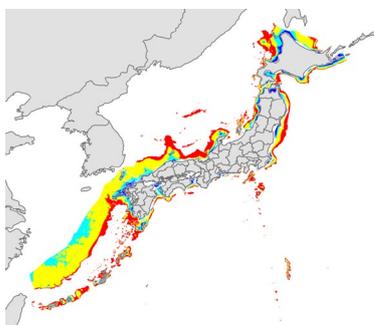


Fig. 2 Example of grading of offshore wind power generation
(Four water depth patterns)

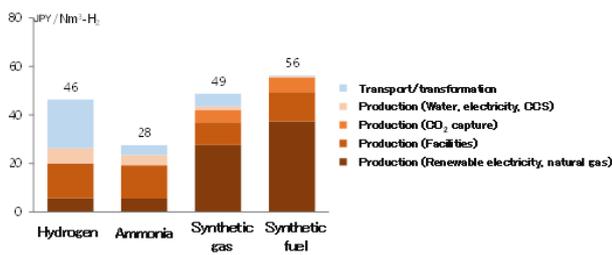
3.3 Imported fuel costs

In this study, in terms of fossil fuels imports of crude oil,

petroleum products (seven types), LNG, fuel coal and raw coal were taken into account. The assumed import prices were estimated by taking actual figures for FY2022 based on CIF prices in trade data as a base, and applying the growth rates for price forecasts contained in the IEA World Energy Outlook 2024's Net Zero Emissions by 2050 scenarios.

Where hydrogen energy carriers were concerned, liquid hydrogen, methylcyclohexane (MCH), ammonia, e-methane and synthetic liquid fuel were taken into consideration. The assumed prices were estimated by adding up the costs at each stage of the international supply

chain, based on the approaches taken in reports such as the IEA’s The Future of Hydrogen, and Otsuki and Shibata⁷⁾ (Fig. 3). Where hydrogen (liquid hydrogen and MCH) was concerned, the costs up to reconversion after unloading were assigned as a precondition, with the energy unit cost after unloading to be determined endogenously within the model. In addition, where liquid hydrogen, MCH and ammonia were concerned, manufacture from CCS-equipped natural gas upgrades was assumed, and for e-methane and synthetic liquid fuel manufacture from electrolytic hydrogen and atmospherically derived CO₂ was assumed.



* Of the import costs, the export port and reconversion are determined endogenously based on the energy unit prices within the model

Fig. 3 Import costs for hydrogen energy carriers (2050, standard case)

3.4 Capital costs of solar and wind power systems

The capital costs of solar power generation and wind power generation were set according to the FY2024 Power Generation Cost Verification Working Group. The capital cost of agrivoltaic power generation was assumed to be 20,000 yen/kW higher than the capital cost of ground-mounted solar power generation, based on questions put to operators. Furthermore, for offshore wind power generation the capital costs were premised on fixed bottom-type wind turbines being installed at water depths of 0-60 m and floating-type wind turbines being installed at water depths of 60 m or deeper, and with reference to NREL, the capital costs were assumed to be 416,000 yen/kW at a water depth of 0-30 m, 537,000 yen/kW at a water depth of 30-60 m, 806,000 yen/kW at a water depth of 60-100 m, 891,000 yen/kW at a water depth of 100-200 m and 1.02 million yen/kW at a water depth of 200m or deeper.

3.5 Energy service demand

Service demand up to 2050 was estimated recursively

based on per capita GDP predictions and other information. Taking iron and steel production as one example, for instance, steel and iron production output into the future was predicted with industrial GDP as an explanatory variable. Table 3 shows estimated results for representative service demand. Incidentally, the figures for GDP, population and number of households that appear within the table are explanatory variables for recursively predicting key service demand, and are shown for reference. It is assumed that the electricity demand of data centers and semiconductor factories will increase by a total of 100 TWh in 2040 and a total of 214 TWh in 2050, based on Mase et al.⁸⁾

Table 3 Key service demand and assumed macro prerequisites

	Unit	2022	2040	2050
Steel and iron production volume	million ton	87.84	78.34	73.49
Ethylene production volume	million ton	5.48	5.45	5.34
Cement production volume	million ton	51.48	48.83	48.15
Paper production volume	million ton	30.83	28.21	27.75
Passenger vehicle traffic volume	billion people-km	767	695	667
Truck traffic volume	billion ton-km	228	217	205
Real GDP (2015 benchmark)	Trillion yen	554	737	857
Population	million people	124.35	116.27	110.70
Number of households	million households	60.27	60.55	58.20

4. Results

4.1 Generated electricity

The generated electricity under each scenario in 2040 and 2050 is shown in **Fig. 4**. The red figures displayed in the diagram show the ratio of electricity generated by renewable energy as a component of the total volume of electricity generated, and significantly differing results were shown for each scenario: 41% - 55% in 2040 and 48% - 63% in 2025.

In Case 1, the renewable energy expansion case, because this case is premised on it being possible to install agrivoltaics power generation on all agricultural land, the ratio of electricity generated by solar power generation is larger compared to the other cases. In Case 2, the hydrogen expansion case, because import prices for hydrogen carriers are set low, the volume of electricity generated by ammonia thermal power generation is increasing in place of offshore wind power generation. Additionally, in Case 3, the CCS expansion case, because CO₂ storage volume is being increased, the volume of electricity generated as a result of CCS-equipped LNG-fired power generation is increasing.

In all the scenarios, the volume of electricity generated is rising significantly from 2040 to 2050. In addition to growth in electricity demand from data centers and semiconductor factories, this is due to electrification in energy demand sectors and increases in the electricity consumed by direct air capture (DAC) of CO₂.

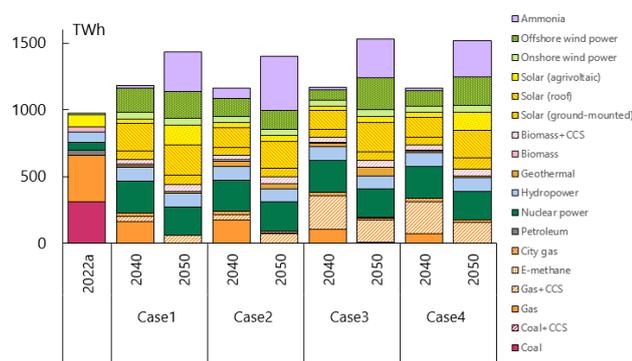


Fig. 4 Volume of electricity generated [TWh]

4.2 Primary energy supply

Primary energy supply in 2040 and 2050 is displayed for each scenario in **Fig. 5**. Those results suggested primary energy supply of 320 ~ 340 Mtoe in 2040, down by

approximately 20% compared to 2022's primary energy supply of 392 Mtoe.

The ratio of fossil fuels as a component of the overall primary energy supply was 87% in 2022, but the calculation results indicated that the ratio falling to 57-64% in 2040 as a result of a decrease in the volume of electricity generated using coal-fired power generation. Incidentally, the results suggested that primary energy supply for natural gas for LNG-fired power generation, along with petroleum products for automobile and marine vessel use, will remain.

The results suggested that in 2050, the ratio of fossil fuels as a component of the overall primary energy supply will fall substantially, to around 20%, as a result of increases in the ratios of hydrogen energy carriers and renewable energy.

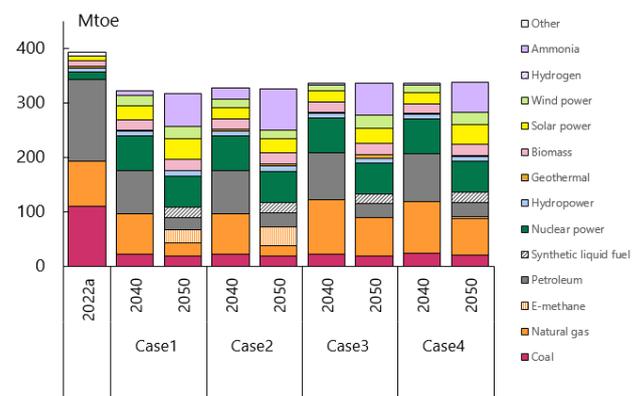


Fig. 5 Primary energy supply [Mtoe]

4.3 CO₂ emissions by sector

CO₂ emissions by sector in 2040 and 2050 for each scenario are shown in **Fig. 6**. The calculation results suggested that CO₂ will be emitted by sectors such as the industrial sector and transport sector in any of the scenarios in 2040. Additionally, in 2050, emissions such as CO₂ emissions from fossil fuel consumption in industrial sectors where electrification is difficult due to those sectors' reliance on intense heat sources will remain, with that remainder portion to be offset through BECCS (Bioenergy with carbon capture and storage), a technology combining biomass power generation with carbon capture and storage, and DAC (direct air capture), a technology for capturing and storing CO₂ directly from the atmosphere.

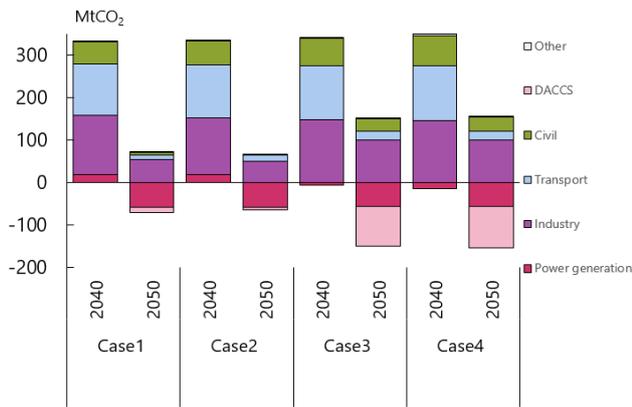


Fig. 6 CO₂ emissions by sector [Mt-CO₂]

5. Policy implications

This study employed a technology selection model to demonstrate long-term energy supply and demand scenarios, after taking into account siting restrictions for solar power generation and wind power generation, and the changes in site location that will accompany solar and wind power generation being adopted in large amounts. The results of that calculation suggest that with electricity demand anticipated to increase in the medium to long term, and given that the costs to the energy system as a whole will increase accompanying solar power generation and wind power generation being adopted in large amounts, it will be important to utilize not just renewable energy but a variety of energy sources, including nuclear power generation, CCS-equipped LNG-fired power generation and ammonia power generation. Incidentally, it needs to be kept in mind that the power supply mix in which the cost of the overall energy system is smallest will change significantly depending on factors such as CO₂ storage volume and the fuel import cost of hydrogen energy carriers. For example, the lower limit of CO₂ storage volume is assumed to be 120 million t-CO₂/year, but should a case arise in which actual CO₂ storage volume falls below 120 million t-CO₂/year, it will give rise to the need for alternative power sources, such as renewable energy, in place of CCS-equipped LNG-fired power generation.

Consequently, given the large degree of uncertainty surrounding factors such as how much progress is made with the different types of technologies and the cost of hydrogen energy carriers in the future, at the present point in time, it will be desirable to pursue the development of a variety of technologies and aim for a balanced energy mix.

Acknowledgement

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Preliminary Analysis and Consideration on Replacement of Vehicle Fleets

Yuto Nakano *

1. Background and Awareness of Problems

Countries around the world are promoting the adoption of electrified vehicles and zero-emission vehicles (ZEVs) to decarbonize the transportation sector. At the Group of Seven's (G7) Climate, Energy, and Environment Ministers' Meeting in Sapporo in April 2023, the G7 countries shared not only the traditional goal of electrifying new vehicles but also the recognition of efforts to reduce greenhouse gas emissions from their vehicle fleets.⁽¹⁾ Conceivable measures to reduce emissions from vehicle fleets include promoting synthetic and other carbon-neutral fuels and switching to electrified vehicles.

Table 1 shows some country-specific goals for adopting electrified vehicles and ZEVs as published in the International Energy Agency's Global EV Policy.⁽²⁾ The table indicates that vehicles subject to adoption goals are varied. Some countries fall short of setting adoption goals. The composition of vehicle fleets must be considered for analyzing CO₂ emissions in the transportation sector. The promotion of electrified vehicles and ZEVs in new vehicle sales must be assured, along with the time it takes to replace fleets. Therefore, I would like to estimate country-specific vehicle retention rates in a preliminary analysis of the replacement of vehicle fleets and consider the estimates.

Table 1 Country-specific electrification goals for new car sales and fleets

	New vehicle sales		Fleets	
	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)
Canada	The ZEV share will be raised to 20% by 2026, to 60% by 2030, and to 100% by 2035.	The ZEV share will be raised to 35% (100% for some types) by 2030.		
China	The NEV share will be raised to about 20% by 2025.	The NEV share of buses, postal vehicles, and logistics vehicles will be raised to 80% by 2025.		
	The NEV share of all types of new vehicle sales (including buses) will be raised to 45% by 2027.			

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	New vehicle sales		Fleets	
	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)
Germany			15 million EVs will be introduced by 2030.	
Spain			The number of EVs will be increased to 5 million (including buses) by 2030.	
France			The respective numbers of BEV (including FCEV) and PHEV will be increased to 660,000 and 500,000 by 2030 and to 3 million and 1.8 million by 2028. (The number of FCEV will be increased to 5,000 by 2023 and to 20,000-50,000 by 2028).	The number of low-emission large vehicles will be increased to 21,000 by 2023 and to 65,000 by 2028. The number of heavy commercial FCEV will be increased to 200 by 2023 and to 800-2,000 by 2028.
U.K.	The ZEV share will be increased to 80% for passenger cars and 70% for vans by 2030, and to 100% for both by 2030.			
Italy	The EVs and HEV share will be raised to 30% by 2022, to 50% (including methane and hydrogen in some cases) by 2025, and to 85% by 2030.	The EVs and HEV share of large vehicles will be increased to 30% by 2022, to 50% (including methane and hydrogen in some cases) by 2025, and to 85% by 2030.	The number of EVs will be increased to 6 million (including 4 million BEVs) by 2030.	
Japan	Electrified vehicles will account for 20-30% of new vehicle sales by 2030 and for 100% by 2035. Electrified and decarbonized fuel vehicles will account for 100% of new vehicle sales by 2040.	Aiming for an advanced introduction of 5,000 electrified vehicles in the 2020s.		

	New vehicle sales		Fleets	
	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)
Korea	Electrified vehicles will account for 50% of new vehicle sales by 2025 and for 83% by 2030.		By 2025, the number of BEV will be increased to 1.13 million and the number of FCEV to 200,000. By 2030, the number of BEV will be increased to 3.62 million, the number of FCEV to 880,000, and the combined number of PHEV and HEV to 4 million.	
U.S.	ZEV will account for 50% of new vehicle sales by 2030.			

Note: Electrified vehicles cover hybrid electric vehicles (HEV), battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and fuel cell electric vehicles (FCEV). While EVs, zero-emission vehicles (ZEVs), and new energy vehicles (NEVs) include BEV, PHEV, and FCEV, notations in the table fail to be unified and are according to each country's notations or source notations.

2. Analysis

The vehicle retention rate is estimated as an indicator for analyzing the replacement of vehicle fleets. The retention rate is defined as the percentage of vehicles that are retained from the previous year to the current year among those on the road in the previous year, excluding scrapped ones. It is estimated based on Equation (1).

$$\text{Vehicles owned}_t - \text{New vehicle sales}_t = \beta \text{ Vehicles owned}_{t-1} \quad \text{Equation (1)}$$

$$t: \text{Year} \quad \beta: \text{Retention rate} \quad \beta > 0$$

The retention rate is thought to move between 0 and 1. The closer it is to 1 means that the smaller the decrease through scrapping, etc., and the less vehicle replacement per year.¹

This analysis covers 12 countries: Brazil, Canada, China, Germany, Spain, France, the United Kingdom, India, Italy, Japan, Korea, and the United States, compiling country-specific data from the Japan Automobile Manufacturers Association, the International Organization of Motor Vehicle Manufacturers, and the EDMC Handbook of Japan's & World Energy & Economic Statistics.⁽⁴⁾⁽⁵⁾⁽⁶⁾ First, an estimation result for Japan is shown by Equation (2).

¹ If the influence of variables (such as the number of used vehicle sales) that are not considered for Equation (1) is large, β may exceed 1.

$$\text{Vehicles owned}_t - \text{New vehicle sales}_t = 0.9348 \text{ Vehicles owned}_{t-1} \quad \text{Equation (2)}$$

(t: 665.19)

Estimation period: 2000-2022 Determination coefficient = 0.9579

Standard error = 510,262.314 Durbin-Watson ratio = 0.822

According to the estimation, Japan's retention rate is 0.9348, meaning that 93.48% of vehicles owned in a year were retained in the next year. In fact, there are cases where vehicles are suddenly scrapped due to accidents, etc. If 6.52% of vehicles owned are considered to be replaced in order of old vehicles every year, all vehicles owned in a year may be considered to be replaced in about 15 years. This estimate may be a roughly reasonable result because the average age of use published by the Automobile Inspection and Registration Information Association is 13.32 years for passenger cars and 16.08 years for cargo vehicles.⁽³⁾

Next, the estimation results for all 12 countries, including Japan, are shown in Table 2. It suggests that the vehicle retention rate varies from country to country, meaning that the time for the replacement of vehicle fleets differs by country. Japan recorded the lowest rate, at 93.48%, while India posted the highest rate, at 98.63%.

Table 2 Country-specific estimation results

	Estimation period	Determination coefficient	Durbin-Watson ratio	Coefficient β	(Retention rate)	t value for Coefficient β
Brazil	2001-2022	0.9981	1.976	0.9654	(96.54%)	348.45
Canada	2004-2022	0.9914	1.531	0.9373	(93.73%)	446.54
China	2010-2022	0.9997	1.078	0.9725	(97.25%)	391.73
Germany	2000-2022	0.9259	0.597	0.9352	(93.52%)	506.78
Spain	2000-2022	0.9946	1.250	0.9660	(96.60%)	450.76
France	2000-2022	0.9865	0.763	0.9423	(94.23%)	720.50
U.K.	2000-2022	0.9797	1.017	0.9441	(94.41%)	259.36
India	2008-2022	0.9897	2.202	0.9863	(98.63%)	113.98
Italy	2000-2022	0.9913	0.839	0.9596	(95.96%)	436.18
Japan	2000-2022	0.9579	0.822	0.9348	(93.48%)	665.19
Korea	2000-2022	0.9990	0.930	0.9540	(95.40%)	723.73
U.S.	2004-2022	0.9632	2.002	0.9464	(94.64%)	549.34

3. Consideration

The reason for the difference in country-specific retention rates may be that the spread of vehicles differs from country to country. Relations between the number of vehicles owned per 1,000 people (in 2022), a vehicle penetration indicator, and the retention rate indicate that retention rates are higher for India, China, and other countries with lower vehicle penetration indicators and lower for those with higher vehicle penetration indicators (Figure 1 Relations between the vehicle retention rate and the number of vehicles owned per 1,000 people

). This may be because countries where the vehicle penetration indicator is rising have relatively fewer old vehicles being scrapped, resulting in higher retention rates.

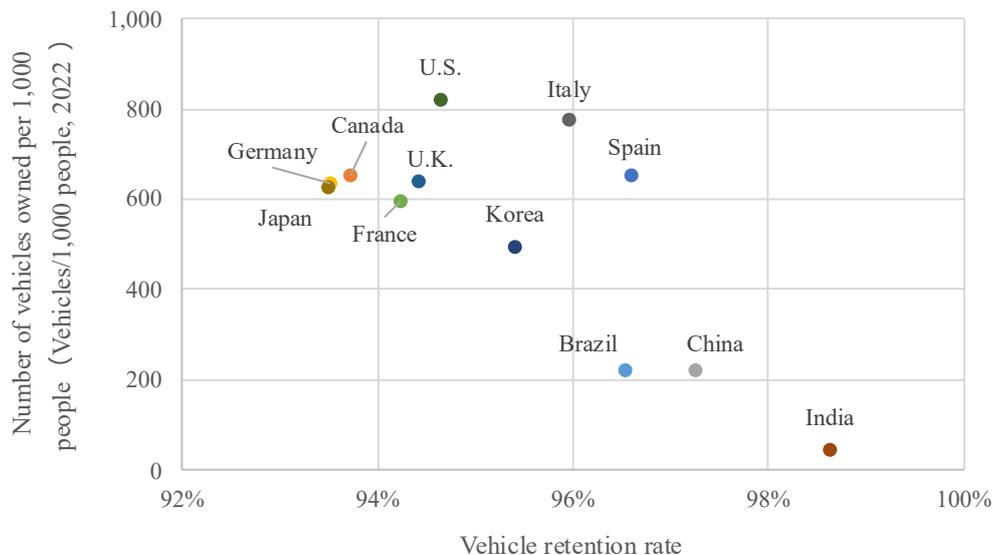


Figure 1 Relations between the vehicle retention rate and the number of vehicles owned per 1,000 people

Some countries with similar vehicle penetration indicator levels post lower retention rates than others. For example, Spain, while having a number of vehicles owned per 1,000 people that is similar to that of Japan, Germany, and Canada, posts a higher retention rate than the other three countries. This gap may be due to differences in the national environment surrounding vehicles. In countries that have tougher vehicle safety and inspection standards than others, for example, vehicles may become unable to meet such standards and be scrapped faster than others. In addition, the vehicle retention rate may be affected by the introduction of scrap incentives and other systems to promote the replacement of vehicles by increasing taxes on old vehicles and providing subsidies. For example, Japan's special green taxation system increases the automobile tax on vehicles beyond a certain age. In Germany and France, the vehicle tax is determined in proportion to emissions, subjecting older and poorer performing vehicles to higher tax amounts. Scrap incentives include Japan's eco-car tax reduction and Germany's environmental tax premium.

Since the times for the replacement of vehicle fleets differ from country to country, as shown above, it is essential to take this point into account when assuming the composition of future fleets in conjunction with a goal for promoting the spread of electrified vehicles and ZEVs among new vehicle

sales. Japan and Canada have low vehicle retention rates and are expected to take about 15 years to replace their vehicle fleets, according to a simple computation. If they achieve their target shares for electrified vehicles or ZEVs in new car sales by 2035, as shown in Table 1, they may realize their assumed vehicle fleet compositions in time to accomplish the goal of carbon neutrality by 2050. In contrast, the United Kingdom posts a higher vehicle retention rate than Japan and Canada while having set a similar target share for ZEVs among new vehicle sales for 2035. For this reason, it may have to try to achieve the target share a few years earlier, considering that it would take a longer time to replace its vehicle fleet than Japan and Canada.

4. Future Challenges and Prospects

In this paper, I estimated the vehicle retention rate for a preliminary analysis of the replacement of vehicle fleets. I used a uniform equation for the estimation, limiting variables to the number of vehicles owned and the number of new vehicle sales. As the abovementioned impact of used vehicle markets, vehicle inspection and tax systems, and other factors are expected to affect the retention rate, this analysis is considered to fall short of taking these factors into account. A future challenge is to further increase the accuracy of estimates by looking into each country's vehicle uses, relevant systems, and vehicle markets, including these factors, by considering factors to be taken into account, and by improving the resolution of the interpretation of analysis results.

In the future, I would like to conduct a simulation analysis on future vehicle fleet compositions and assess country-specific greenhouse gas emission goals for the road sector from a long-term perspective, considering that the times to replace vehicle fleets differ from country to country.

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The IEEJ Outlook and the Technology Selection Model

The Differences and Implications of the Analyses Using Two Modelling Frameworks

Seiya Endo *

1. Introduction

In February 2025, the Japanese government received Cabinet approval for the 7th Strategic Energy Plan. In the formulation process for that Plan, six organizations, including the Institute of Energy Economics, Japan (IEEJ), submitted scenario analysis for 2040 and 2050 to the Strategic Policy Committee (December 2024). Additionally, separate from that analysis, the IEEJ also publishes global long-term energy supply and demand projections in its annual IEEJ Outlook. These two analyses, which serve different purposes, do not necessarily present the same solution and therefore rely on different analytical frameworks. In this paper, these two analytical frameworks and their results are compared to show the challenges toward achieving net zero in 2050 and the points to keep in mind when interpreting the results.

2. Comparing the two models' analyses:

2.1. Analytical methods

Table 1 compares the two analytical frameworks' differences. The IEEJ-NE (technology selection model) that was used for the Strategic Energy Plan is a backcast-type model for calculating "What should be done?" with cost minimization through linear programming. In contrast, the IEEJ Outlook is a forecast-type model that uses an econometric approach to predict "What if ~?" When the two are compared, their scenario categories are contrastive, and significant differences in how they handle CO₂ emissions and the determining factors of the energy mix can be viewed in the background to that.

Table 1 Characteristics of the Analytical Frameworks

	Technology Selection Model IEEJ-NE	IEEJ Outlook Model
Coverage of analysis	<u>Overall energy supply and demand up to 2050</u> (primary supply, transition, end use)	
Category of scenario	<u>Backcast-type scenario</u>	<u>Forecast-type scenario</u>
Character of scenario	<u>What should be done</u> in order for ~?	<u>What</u> if ~?

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	Technology Selection Model IEEJ-NE	IEEJ Outlook Model
Model used	Technology selection model (cost minimization through linear programming)	Cohort of models centered on an econometric-type model
Handling of CO₂ emissions	Is a <u>constraint</u> of the model analysis, and its attainment is taken as a given. (70-71% reduction in 2040 and net zero in 2050)	The <u>result of estimates</u> that are calculated for a case that envisages the maximum countermeasures in each sector. (In the case of the Advanced Technologies Scenario ¹)
Energy demand	Service demand (crude steel production, volume of goods transported) is <u>given</u> . Calculates the energy supply volume that satisfies this.	Demand is <u>the estimation result</u> from economic assumptions for GDP, population, etc., and assumed energy prices and energy intensity.
Determining factors of the energy mix	Cost minimization based on conditions such as technology costs and upper limits for the introduction of technologies.	Time trends, energy price elasticity values + assumptions, collectively

To begin with, for CO₂ emissions, the analysis submitted for the debate on the Strategic Energy Plan utilized a technology selection model known as the IEEJ-NE Japan model. This analysis can be described as a backcast-type analysis that asks: “What sort of energy mix should be selected in order to realize reduction targets for the smallest cost?” On the other hand, the Advanced Technologies Scenario in the IEEJ Outlook, which is the main IEEJ Outlook scenario taken up in this paper, is a forecast-type analysis that asks: “In a case in which each country implements conceivably realistic emission reduction measures to the maximum extent, what sort of energy mix will it give rise to, and to what extent will CO₂ emissions reduction progress?” An important difference between this and the technology selection model is the fact that the attainment of reduction targets is not taken as a given.

In addition, there is also an important difference in the method that the two models use to calculate the energy mix. Here, I will explain the example of the competitive relationship between gasoline hybrid vehicles and electric vehicles (Fig. 1). The technology selection model is a model that calculates the technology mix with the lowest cost, and in a case where a difference in cost between competing technologies arises, it is possible that the optimal solution in terms of technology share

¹ Please bear in mind that although a scenario with the same name is presented in the supporting material for the 7th Strategic Energy Plan, its positioning differs considerably. In contrast to the IEEJ Outlook, where the Advanced Technologies Scenario is a scenario that assumes the maximum advances in climate change measures, in the 7th Strategic Energy Plan it is a scenario that assumes delays in progress with decarbonization technologies.

will change suddenly at a certain threshold. On the other hand, in the IEEJ Outlook, by taking into consideration assumptions for empirical price elasticity values, the pace of technology switches that account for time trends, etc., and other factors, it utilizes an analytical model² structured so that in a case where the costs when using a certain technology decline, that technology's share **gradually rises.** A technology structure is estimated that simulates the intensity and pace at which users undertake the energy transition, after taking into consideration also information such as technology cost changes, and furthermore, in the case of the Advanced Technologies Scenario, experts' views on various policy measures and the volume of the technologies introduced.

This difference is also one of the factors that makes the two analyses “backcast” and “forecast”. The technology selection model is a model that poses “What should be done?” and calculates the cost-optimal energy mix in regard to conditions. On the other hand, the IEEJ Outlook can be described as an analysis for estimating a technology structure that simulates users' responses to changes in conditions such as technology costs; it is an analysis that asks “What if?”, in other words.

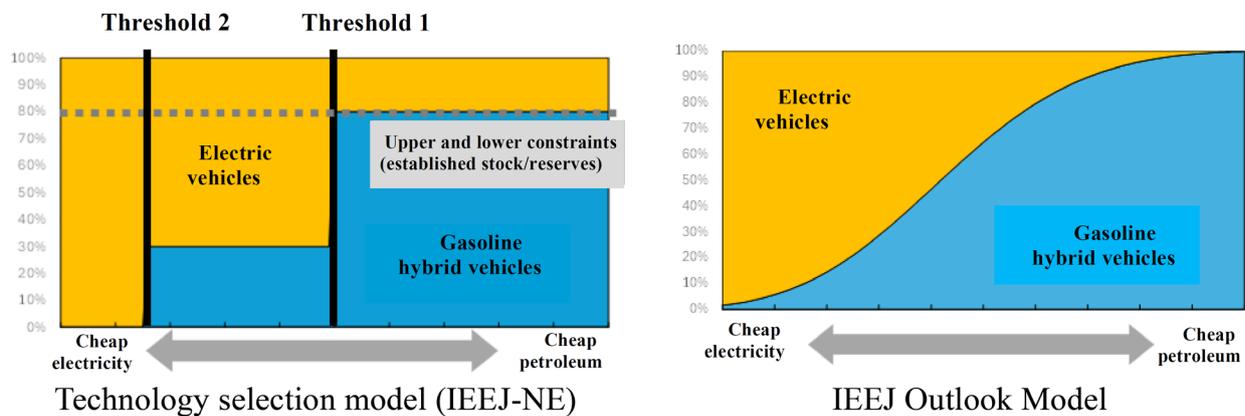


Fig. 1 Schematic diagram of energy mix determining factors

2.2. Analysis results (1) CO₂ emissions (by sector)

Fig. 2 shows Japan's energy-related CO₂ emissions and their breakdown by sector, according to the two models' calculation results. Incidentally, the technology selection model analysis introduced here comprises four cases in which differences have been set for the degree of advancement of the respective technologies, and of those four cases, Fig. 2 displays the results for “Case 1: Advanced renewables” and “Case 3: Advanced CCS”.

(a) Comparison of total CO₂ emissions (energy-related)

The technology selection model's analysis takes the attainment of the 2040 NDC³ and net zero by 2050 as given constraints, and it comes up with an energy mix toward that. On the other hand, in the

² Founded on a logit model. This is a method for estimating selection probability on the basis of relative costs and benefits between technologies, and is commonly used for estimating share in a diverse range of fields, such as the selection of fuels and transport modes.

³ This is a target to reduce greenhouse gas emissions by 73% (compared to 2013 levels) by 2040, which the government set as Japan's “nationally determined contribution” in February 2025. A 70-71% reduction in energy-related CO₂ emissions, which is consistent with that target, is set as a premise.

IEEJ Outlook, as a result of stacking up factors such as phenomena trends, maximum technological advances, and policy measures in each sector, and behavior changes among users accompanying that, the model's 2040 prediction aligns with the NDC, but a gap of around 6% (compared to 2013) remains at 2050. This unattained portion could be described as hinting at the limits of the maximum accumulation of technologies and policies that is currently conceivable, as well as the difficulty in attaining the net-zero target.

Incidentally, it is necessary to bear in mind that in the Outlook analysis and the analysis that utilized the technology selection model that are compared here, the assumed economic growth rates differ. Supposing a case in which the economic growth rate of 1.6%/year, which is assumed in the technology selection model's analysis, is utilized in place of the economic growth rate of 0.8%/year (2022-2040) on which the Outlook analysis is premised, the Outlook analysis's energy demand and CO₂ emissions would climb higher.

(b) Comparing the breakdown of CO₂ emissions by sector

In the energy mix for which the overall minimum cost is calculated through the technology selection model, a clear order of preference emerges in terms of CO₂ emissions by sector. To begin with, the power generation sector approaches zero emissions rapidly, and in 2050, a picture emerges of significant declines in emissions in the buildings and transport sectors, also. On the other hand, because the industrial sector requires high-temperature heat that is difficult to attain with electrification, the need will emerge to rely on future technologies such as hydrogen reduction, synthetic fuels, and CCS. As a result of this, the pace of the sector's emissions reduction will be slow compared to other sectors, and the sector will account for around half the emissions in 2050.

On the other hand, in the Outlook model, the pace of reductions between sectors is nearly in line. Like the technology selection model, in the Outlook model, the industrial sector will account for the largest amount of emissions in 2050. However, in contrast to the technology selection model, in the Outlook model, a certain amount of emissions will persist even in the buildings and transport sectors. The Outlook model does not take it as a premise that decarbonization will necessarily occur in each sector; it simulates actual behavioral changes by stacking up price elasticity values and systems. In the determining factors of the energy mix that were shown earlier in Fig. 1 (right graph), the end portions represent groups of users that remain largely unresponsive to prices and policy incentives. And because strata such as this exist in every user sector, in the Outlook model, this means that a certain amount of emissions will persist in any sector.

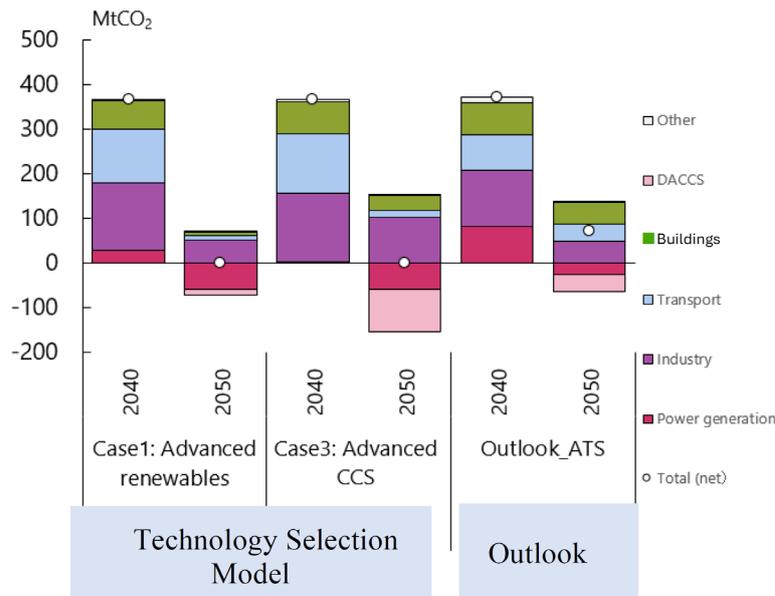


Fig 2. The models' calculation results (energy-related CO₂ emissions)

Note: Both models cover energy-related CO₂ emissions overall, but the definitions of the sectors into which the emissions are broken down do not match completely.

The differences in the calculation results of both models illustrate the gap between theoretical optimal solutions and moves toward fuel transition by actual users. Based on the results of both, it can be seen that: (1) **for decarbonizing the industrial sector, an acceleration in technological innovation, along with negative emissions technologies⁴ that can offset the portion that cannot be fully reduced, will be particularly vital,** and (2) **even in other sectors, not all users are necessarily capable of fuel transition.** This suggests that in pursuing actual policy-making toward carbon neutrality, in order to move from the “upper limits of the collective assumptions that are conceivable now,” as is presented in the Outlook model, and draw closer to the “theoretical optimal solutions” presented in the technology selection model, it will be particularly important to have measures in place to support strata in all user sectors that will struggle with fuel transition.

2.3. Analysis results (2) Power generation mix

Next, the power generation mix is shown in Fig. 3. Incidentally, the amount of power generated differs significantly as a result of differences in the economic growth assumptions of both models. Note that a comparison was carried out using generation mix ratios in Fig. 3.

In both analyses, common points in the energy mix from 2040 are that there is substantial transition progress, renewable energy is adopted in large quantities (around 55-63% in 2050), nuclear power supports the baseload, and thermal power remains (20-30% of the mix).

The models differ, however, in how that thermal power is made up. In the technology selection

⁴ Indicates technologies that collect and remove CO₂ from the atmosphere. In the two models explained in this paper, both take Direct Air Carbon Capture & Storage (DACCS) and Bioenergy with Carbon Capture and Storage (BECCS) into consideration.

model, ammonia is the mainstay in Case 1, and gas CCS and ammonia are the mainstays in Case 3, with limited use of coal-fired thermal power in both Cases, but in contrast, in the Outlook model, coal, gas, and ammonia are in balance, being employed in comparatively close amounts. This is because the technology selection model optimizes the energy mix by evaluating the merit order across a year’s 8,760 hours (365 days x 24 hours), making it likely that the energy mix will converge on the most competitive fuels.

Results such as this provide a large number of hints as theoretical cost-optimal solutions, but there is no guarantee that facilities that are inferior in terms of the merit order will, in fact, necessarily cease operating. That is because in the real world, each region’s supply and demand gap, operators’ investment strategies, system responses, and other factors work in combination, and so things will not necessarily move toward optimal solutions in a straight line. The IEEJ Outlook can be said to be presenting a balance after incorporating elements such as this (strictly as macroscopic elasticity values), while also taking differences in generation cost into consideration. However, when it comes to a desirable power generation mix that actually covers these points at issue, a more detailed bottom-up analysis will be needed.

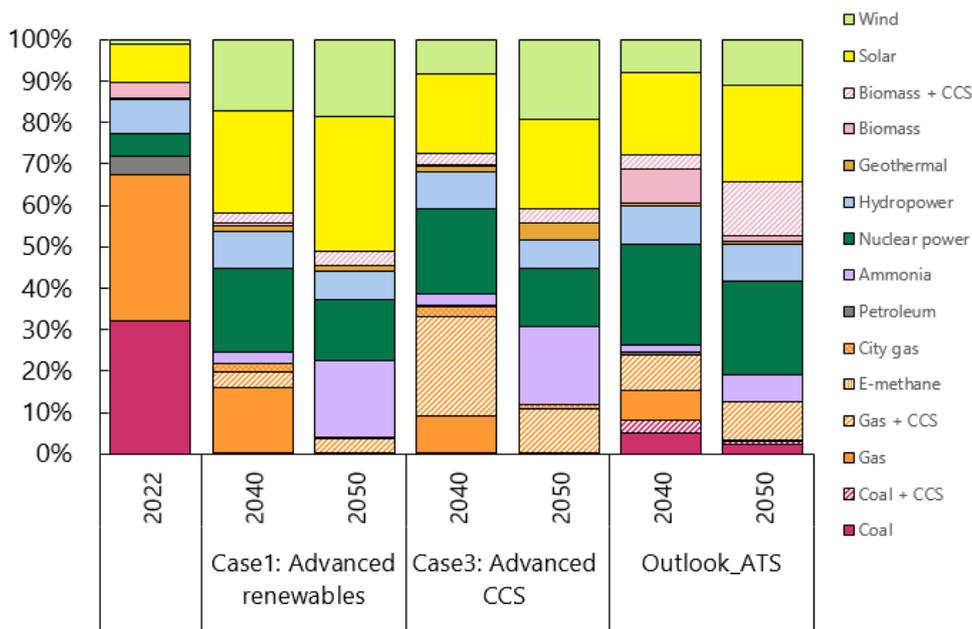


Fig. 3 The models’ calculation results (power generation mix)

Note: The definitions of technology categories in the two models do not match completely.

3. Conclusion

Currently, a large number of organizations are announcing quantitative scenarios. Attention needs to be given to the fact that the implications of those figures will change greatly depending on which of the questions they are based on: “What should occur?” or “What will occur?”

The supporting material for the 7th Strategic Energy Plan only mentions that thermal power will account for “30-40%” of the energy mix in 2040, and the fact that the omission of a breakdown by

fuel suggests a deliberate decision, reflecting both the characteristic features of the analytical frameworks and the uncertainty of future developments. In the analysis by the six organizations at the Strategic Policy Committee, what was presented were “theoretical optimal solutions” based on their respective assumptions, and since their assumed conditions are accompanied by many uncertainties, the analysis is some distance away from predictions as “forecasts.”

In addition, the recent Strategic Energy Plan presents an overall image of energy supply and demand, but in the process, from here on, there are expected to be discussions on specific ways forward in each sector. The authors also intend to continue providing analysis that contributes to the energy transition, while appropriately combining the two analytical frameworks discussed in this paper.

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Two FIDs Herald a New Era of LNG Production Development

Hiroshi Hashimoto *

Introduction

Two FIDs (final investment decisions) on new LNG production projects in Americas were announced around late April and early May 2025 - one in Louisiana, United States, and the other in Argentina, with combined annual production capacity of 19 million tonnes. Both projects have additional plans beyond the sanctioned capacities. Other projects are expected to follow in both countries.

The Louisiana LNG project, promoted by Australia's Woodside, in late April 2025 reached an FID covering the first three trains of a combined 16.5 million tonne per year capacity, targeting first LNG in 2029. The FID represented the first one for a large-scale LNG production project in the United States since July 2023. The Southern Energy FLNG project in Argentina in early May 2025 reached its FID covering the first FLNG vessel of an LNG processing capacity of 2.5 million tonnes per year.

1. Australia's Woodside Energy develops the LNG project in the United States

The Louisiana LNG project was renamed from *Driftwood LNG* after it was acquired along with its parent company Tellurian Inc. by Woodside in July 2024. The project had been developed by Tellurian since 2016, securing the construction approval from regulators and export authorizations from the Department of Energy, yet missing an FID by the time of the acquisition.

Woodside announced on 29 April 2025 an FID to develop three trains, targeting first LNG in 2029. The development has an additional capacity from another two LNG trains and is fully permitted for a total capacity of 27.6 million tonnes per year.

The notable factors of the FID are risk mitigation and GHG emission management measures. Amid the rising trend in LNG project costs, the company says that it has agreed with the contractor on 95% of the total value of the construction contract¹. In addition, civil engineering work has progressed ahead of the FID, and more than 90% of high-value orders have been placed, according to the company. In addition, the project boasts the high procurement ratio in the United States and the use of a designated foreign trade zone.

In early April, prior to the FID, Woodside agreed with Stonepeak to hand over a 40% equity interest in Louisiana LNG Infrastructure LLC. Woodside continues discussions with multiple counterparties for further equity sell-down in the project. On the LNG marketing front, Woodside had signed LNG SPAs (sale and purchase agreements) with Germany's Uniper prior to the FID. Louisiana LNG LLC will supply one million tonnes per year of LNG on an FOB (free-on-board) basis for up to thirteen years from the commercial operations date (COD) of Louisiana LNG. Woodside Energy Trading

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¹ "WOODSIDE APPROVES LOUISIANA LNG DEVELOPMENT" 29 April 2025, <https://www.woodside.com/docs/default-source/asx-announcements/2025/028-woodside-approves-louisiana-lng-development.pdf>

Singapore Pty. Ltd. will supply up to one million tonnes per year of LNG on a DES (delivered ex-ship) basis from Woodside's global portfolio into Europe commencing on the same COD until 2039. The SPAs were subject to an FID - the one of 29 April.

Woodside announced a contract with bp to purchase gas to be supplied to the LNG project on 30 April, the next day of the FID, securing access to low-methane-emission-intensity gas certified by MiQ, the prominent independent verifier. Woodside has indicated that it plans to supply cleaner LNG as a member of the OGMP 2.0, a global initiative of energy companies to reduce and better manage methane emissions.

Woodside signed an agreement in 2014 to purchase 0.85 million tonnes of LNG annually from Corpus Christi LNG in Texas. The supply from the project has been incorporated into Woodside's global portfolio since 2023. Woodside participated in the development of the Kitimat LNG project in British Columbia, western Canada, from 2014 until May 2021. The latest FID represents the full-scale launch of Woodside's LNG business in North America.

Besides Woodside's activities, in the United States, Energy Transfer signed an HOA (heads of agreement) with MidOcean Energy for the latter's 30% participation in the Lake Charles LNG project. Mubadala Energy of Abu Dhabi agreed to acquire a 24.1% stake in Kimmeridge's asset holding company of the Commonwealth LNG project. The Rio Grande LNG project, with its first phase under construction, secured LNG sale deals for its next phase project. Securing investment partners and term sales continue being the key to promoting LNG production projects, along with busy regulatory developments².

2. Argentina emerges as a potential LNG power house

Argentina, a giant gas producer in South America, began importing LNG in 2008 using FSRUs (floating storage and regasification units, LNG transport vessels converted by installing regasification equipment on board and use them as LNG import facilities) to respond to seasonal demand fluctuations. From 2011 to 2013, there were some cases of re-export and resale of some imported LNG. Subsequently, while continuing import of LNG to meet seasonal demand fluctuations, the concept of LNG exports emerged in response to the increase in domestic gas production. From 2019 to 2020, Argentina exported LNG based on domestic gas production using a small-scale FLNG vessel.

Harbour Energy, Pan American Energy, state-owned YPF, Pampa Energía and Golar LNG announced an FID on the Southern Energy FLNG project in Argentina on 2 May 2025. The project envisages deploying two FLNG vessels for a combined LNG processing capacity of six million tonnes per year. The latest FID covers the first FLNG vessel for 2.5 million tonnes per year, targeting the first LNG by the end of 2027. Additional LNG export projects are also expected in the country.

² See the appendix of this paper.

**[Appendix: Regulatory developments surrounding LNG export projects
in the United States - notable ones in 2025]**

mm / dd Agency, relevant project, policy/order

01 / 21	DOE: The end of "pause" of non-FTA LNG export authorization
02 / 07	FERC: Venture Global CP2, draft supplemental environmental impact statement
02 / 14	DOE: Commonwealth LNG, conditional non-FTA export authorization FERC: Commonwealth LNG, draft supplemental EIS
02 / 28	DOE: JAX LNG, Removal of barriers to the use of LNG as a marine fuel
03 / 05	DOE: Golden Pass LNG, extension of export commencement deadline
03 / 10	DOE: Delfin LNG, extension of export commencement deadline
03 / 10	FERC: Corpus Christi Mid-Scale 8-9, construction and operation approval
03 / 18	DC Circuit Court, Rio Grande and Texas LNG, validity of FERC's approvals
03 / 19	DOE: Venture Global CP2, conditional non-FTA export authorization
03 / 20	DOE: 2024 LNG Export Study public comment period completes
03 / 21	MarAd: Delfin LNG, construction and operation approval
03 / 28	FERC: Rio Grande, Texas LNG, draft supplemental EISs
04 / 01	DOE: Removal of barriers for requests to export commencement date extensions
04 / 17	USTR: limited restrictions on transporting LNG via foreign vessels.
04 / 17	DOE: Lake Charles LNG, application to extend the commencement date
05 / 09	FERC: Commonwealth LNG, final supplemental EIS

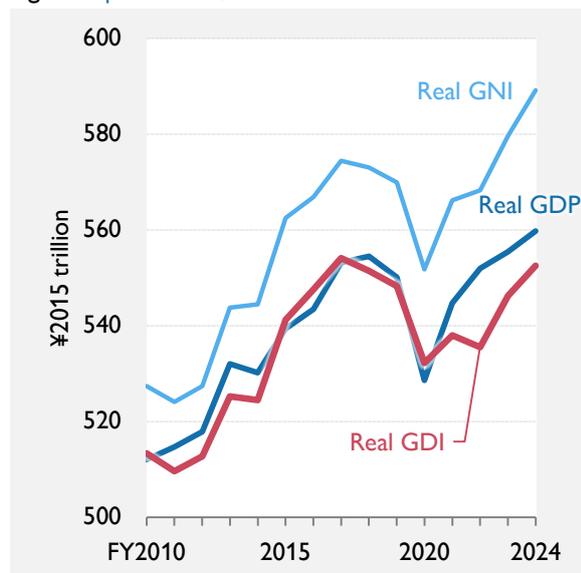
The cause is not high oil price. And yet subsidies continue—Where are we heading?

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There is much that is uncertain about the current economy, such as the rising prices of foods, including rice, salary increases biased toward the minority of younger workers and the uncertainty emanating from the United States. Despite these factors, the Japanese economy is continuing to recover in terms of the real gross domestic product (GDP), though that may not seem to align with how it feels at all times. In fact, the GDP for FY2024 announced on 16 May reached 559.8 trillion yen (in 2015 prices), setting a new record for the second year in a row (Figure 1). Meanwhile, the real gross national income (GNI) also set a new record for the second year in a row at JPY589.2 trillion, boosted by the net income receipts from abroad that continue to grow, though not all of them are being returned within Japan. On top of that, even the real gross domestic income (GDI) which, unlike the real GDP and real GNI, had been unable to return to its peak, has improved considerably.

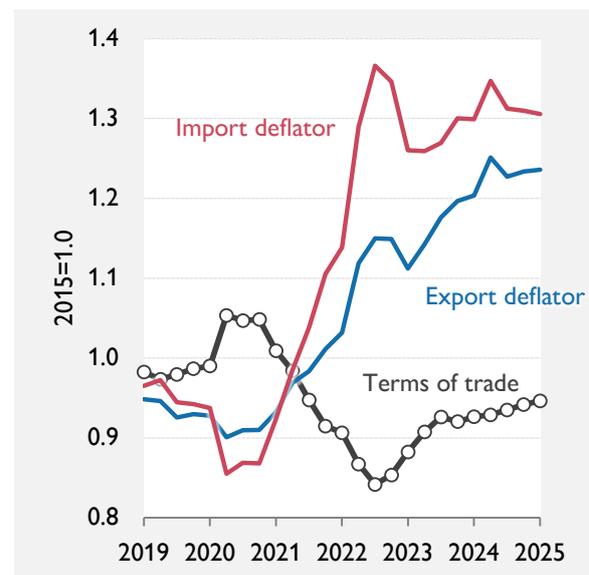
Figure 1 | Real GDP, real GDI and real GNI



Source: Cabinet Office, Government of Japan "National Accounts"

One reason that kept the recovery of the real GDI behind the real GDP is the decline in real purchasing power (trading loss) brought about by the 'cheap Japan' situation compared to other countries¹. While the export deflator is rising due to the pass-through of domestic prices and the depreciation of the yen, the import deflator is rising even more (Figure 2). The ratio between the two—the terms of trade, or the exchange ratio between exports and imports—has fallen below pre-COVID-19 pandemic levels. Nevertheless, the import deflator has fallen from its recent peak in the third quarter of 2022 (3Q2022), and the terms of trade are improving after bottoming out.

Figure 2 | Import/export deflators and terms of trade



Source: Cabinet Office, Government of Japan "National Accounts"

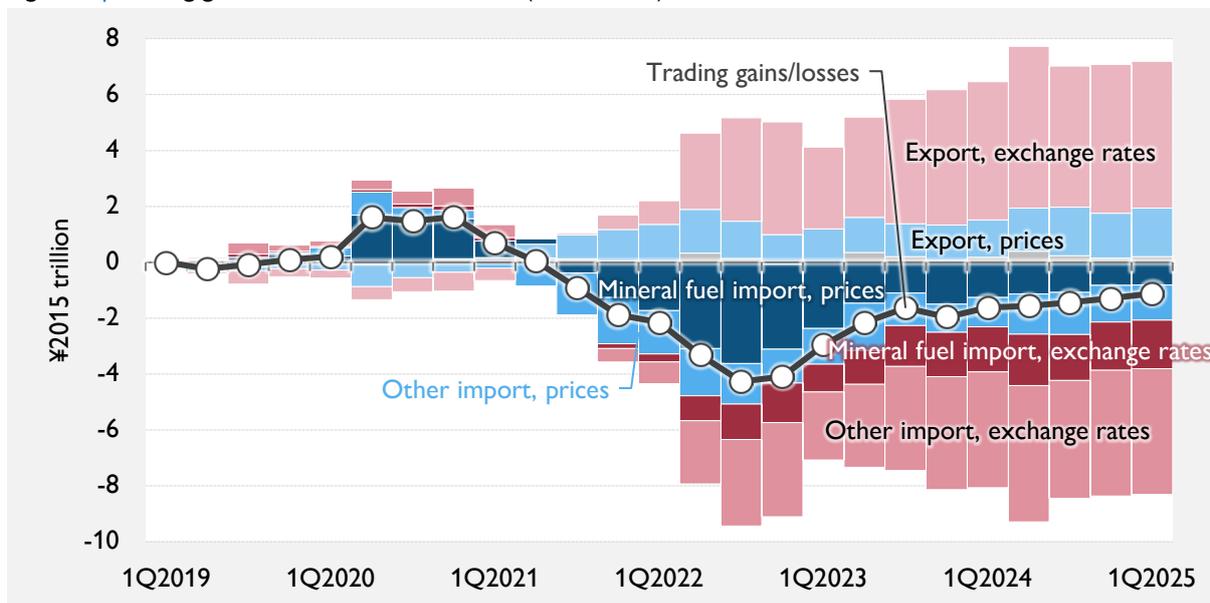
The decline in the import deflator is aided by the settling down of the import prices of mineral fuels (energy), which soared after the Russian invasion of Ukraine that broke out in February 2022. The increase in energy prices in contract currency (mainly dollars) basis caused a decline

¹ Real GDP + trading gains/losses = real GDI. Real GDI + net income receipts from abroad = real GNI.

in real purchasing power by JPY3.6 trillion (in 2015 prices, compared to 1Q2019) in 3Q2022

(Figure 3). This has now shrunk to JPY800 billion, less than a quarter of the recent peak.

Figure 3 | Trading gains/losses and contribution (vs. 1Q2019)



Note: Numbers rounded

Source: Calculated based on Cabinet Office, Government of Japan “National Accounts” and Ministry of Finance “Trade Statistics”

You may wonder, ‘Have the energy prices really fallen that much?’ In fact, while domestic energy prices have fallen, they are still higher than they were before the COVID-19 pandemic. But the real cause thereof is now the cheap yen more so than international prices. For example, the yen-dollar exchange rate has fallen from 110 yen a dollar in 1Q2019 to JPY153/USD in 1Q2025. Therefore, the depreciation of the yen is costing a loss in purchasing power of JPY1.7 trillion just for energy imports, more than double the contribution of higher prices in contract currency basis.



However, the excessive depreciation of the yen is currently being corrected. In addition, the oil price has been cut back to close to USD60/bbl. Despite these favourable conditions, the government will once again expand the previously eliminated petroleum product subsidies in a new form, starting on 22 May, while also resuming electricity and city gas subsidies between July and September.

Currently, the main reason for high energy prices is the weak yen, which is also eroding purchasing power through the import of other goods. If that is the case, then—excluding the argument of ‘volume’—it is difficult to find a suitable answer to the simple question, ‘Why is petroleum subsidised, while vegetable oil—another type of oil whose raw materials are also largely imported—is not?’

The inability to stop offering a subsidy for energy consumption is a trap that developing countries often find themselves caught in². Japan once admonished on this in the 2000s as a member of the advanced countries, but now the country’s position has changed completely.

Economist and Nobel laureate Simon Kuznets (1901–1985) once said, ‘There are four kinds of countries in the world: developed, undeveloped (backward)³, Japan and Argentina’. If he were to look at the current situation today, he might label Japan as a ‘backward country’ in the sense that it is moving backward, or perhaps as a country like Argentina that had fallen from the rank of a developed country to a developing country.

² Yanagisawa “Analysis on subsidised retail gasoline prices and subsidy programme”, <https://eneken.ieej.or.jp/data/10845.pdf>.

³ What would be called a developing country today.

How is GHG intensity calculated for LNG and biofuels as marine fuel?

Takahiko Tagami *

On April 11, the International Maritime Organization (IMO)'s Marine Environment Protection Committee approved the 'IMO Net-Zero Framework.' Going forward, how the GHG intensity of LNG and biofuels is calculated will attract attention. Below, I explore this issue based on the new regulation and existing guidelines.

The regulation relating to the IMO Net-Zero Framework will be implemented using GHG fuel intensity (GFI).

The 'Target annual GFI' comprises two targets: a 'Base target' and a stricter 'Direct compliance target.' The Base target will decline from 89.6 gCO₂eq/MJ by 2028 (a 4% reduction from the GFI in 2008) to 65.3 gCO₂eq/MJ by 2035 (a 30% reduction compared to 2008), while the Direct compliance target will decline from 77.4 gCO₂eq/MJ by 2028 (a 17% reduction compared to 2008) to 53.2 gCO₂eq/MJ by 2035 (a 43% reduction compared to 2008). In cases where the 'Attained annual GFI' (discussed later) is larger than the Direct compliance target, ships must make up the shortfall by acquiring 'Remedial Units' from the IMO Net-Zero Fund for \$100/tCO₂eq (2028-2030; the prices from 2031 to be determined). For the part that the Attained annual GFI is larger than the Base target, ships must (1) transfer (purchase) Surplus Units from other ships; (2) use Surplus Units banked from previous reporting periods; or (3) acquire Remedial Units from the IMO Net-Zero Fund for \$380/tCO₂eq (2028-2030; the prices from 2031 to be determined). A ship can receive Surplus Units in cases where ships achieve the Direct compliance target, for the overachieved amount.

On the other hand, Attained annual GFI will be calculated, taking into account the GFI Calculation Guidelines that are to be developed by the IMO. The GHG intensity of each fuel type in that equation will be calculated on a well-to-wake basis, taking into account the 2024 LCA Guidelines, as may be amended.

The 2024 LCA Guidelines present a calculation methodology divided into well-to-tank (WtT) and tank-to-wake (TtW). WtT is calculated by adding (1) the emissions associated with the feedstock extraction/cultivation, processing, transport and delivery, and (2) the emissions from carbon stock change caused by land use change, and then subtracting (3) soil carbon accumulation via improved agricultural management and (4) credit from CCS. For the time being, (2) the land use change component and (3) soil carbon accumulation are set to zero, pending methodological guidance to be developed by the IMO. TtW is calculated based on the emissions from fuel combustion and slippage. Where TtW values are concerned, a value calculated regardless of the carbon source (includes CO₂

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emissions from biomass combustion), and a value calculated taking into account the carbon source for fuels of biogenic origins or made from captured carbon (emissions from fuel combustion and slippage, minus the biomass growth and the used captured CO₂ as carbon stock to produce synthetic fuels) are calculated.

In the case of biofuels, the (2) land use change component in WtT will attract attention. In the 2024 LCA Guidelines, this is determined as the yearly average of the difference between the carbon stock associated with the land-use in January 2008 or 20 years before the raw material was obtained, whichever was later, and that after 20 years. As an example, using the default values of the IPCC inventory guidelines to calculate a case in which the tropical rainforests of South America are converted to cropland, the figure would be 230.5gCO₂eq/MJ (with energy yield calculated at 180GJ/ha, a slightly old figure), which is well above the IMO's target. However, in a large number of cases in the future, the land use 20 years prior will be energy crops, and in those cases, the emissions of this component can be expected to be almost zero. As the GFI, emissions associated with cultivation, processing and transport will be added to this, while the CCS credits and so forth will be subtracted. Aside from the direct land use change outlined above, there is also indirect land use change, which is a change in the use or management of land that occurs outside the product system being assessed, induced by increased biofuel demand or commodity price. Because quantitative assessments of the GHG effects of indirect land use changes are uncertain, the 2024 LCA Guidelines state that quantitative values are not calculated but that a qualitative risk-based approach should be used.

For LNG's TtW, using the 2024 LCA Guidelines' default factors and assuming the percentage of fuel which escapes from the energy converter without being oxidized is 0.01-3.5%, the figure is 58.0-76.3 gCO₂eq/MJ, which ends up exceeding the IMO's targets between 2028 and 2035 (in a case where the percentage of leakage is 0.1%, the 2035 Base target is met). Additionally, if WtT is calculated with an upstream methane leakage of 2%, the figure is 31.4 gCO₂eq/MJ, and this will be added to TtW. In using LNG, it will thus be essential to reduce upstream methane leakage, utilize CCS credits, and so on.

The GHG intensity of LNG and biofuels will be discussed in the course of the amendment of the 2024 LCA Guidelines and the development of the GFI Calculation Guidelines by experts. How the land use change (in particular the indirect land use change), soil carbon accumulation, and captured CO₂ used in synthetic fuel are to be handled will attract attention.

Israeli and U.S. Attacks on Iran, and the Oil Market in the Second Half of 2025

Tetsuo Morikawa *

Israel attacked Iran on June 13, and the U.S. carried out air strikes on Iran's nuclear facilities on June 21. On June 23, Iran attacked a U.S. military base in Qatar, and oil prices exceeded \$80 per barrel temporarily. However, on the same day, President Trump announced on his social media account that Israel and Iran had agreed to a ceasefire, and Iran refrained from closing the Strait of Hormuz. As a result, the Brent price plunged 8.3% from the previous trading day to \$70.65/barrel. Although neither Israel nor Iran had issued a statement on the ceasefire agreement as of June 23, the following discussion is based on the assumption that a ceasefire agreement has been reached.

The most important point for the oil market was whether or not Iran's export volume would fall significantly over the long-term if Israel or the U.S. attacked Iran's oil fields or export facilities, or if Iran were to go through a regime change. If there were no attacks on oil fields or export facilities and no regime change were to occur, the impact on the oil market may be limited. However, if there were an attack and regime change (or large-scale political and social upheaval), and oil production and export capacity were lost for an extended period of time, there would be an increased possibility of a global oil supply shortage, even if only temporary, and further oil price hikes would be inevitable. For the immediate future, whether the ceasefire agreement is implemented or not is a matter of key importance. The Trump administration is treating the attack as limited in scope and is aiming for an early end. If Iran did, in fact, notify the U.S. before the attack on the U.S. military base in Qatar, it would be reasonable to assume that Iran, too, is exploring options to bring the war to an end. However, some believe that despite the U.S. air strikes, damage to Iran's nuclear facilities is only partial. It is necessary to pay close attention to whether Israel, which is committed to preventing Iran's nuclear program, will halt its attacks. Accordingly, concerns about oil supply disruptions and price hikes have not yet been completely dispelled.

According to the Monthly Oil Statistics published by the International Energy Agency on June 17, global oil demand in 2025 is estimated to increase by 720,000 barrels per day (0.7%) year-on-year to 103.8 million barrels per day, and global oil supply is expected to increase by 1.59 million barrels per day (1.5%) year-on-year to 104.6 million barrels per day, resulting in an oversupply of 900,000 barrels per day for the full year of 2025. However, this forecast does not take into account Iran's declining export volume or production cuts.

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Iran is the most significant element of uncertainty in the crude oil market outlook for the second half of 2025. Hypothetically, however, if Iran's oil export volume were maintained, it would be more likely for conventional issues—such as an increase in production by OPEC+ countries and weakening demand due to economic slowdown—to be considered material in the market.

OPEC+ countries, particularly Saudi Arabia, have made the decision to increase production (in other words, increase market share) by unwinding their voluntary output cuts. As a result, the production increase from May to July 2025 exceeded the original plan by 411,000 barrels per day, and production increase since April reached 1.37 million barrels per day (62% of the 2.2 million barrels per day of voluntary cuts). Meanwhile, on April 16, it was also decided that the seven countries participating in the voluntary output cut, excluding Algeria (in particular Iraq and Kazakhstan, which have significant production surpluses), will additionally cut production by 4.572 million barrels per day (monthly average of 305,000 barrels per day) through June 2026. However, Kazakhstan's continued overproduction is causing friction with other countries participating in the voluntary cut. As long as Saudi Arabia and Russia remain committed, production cuts by the OPEC+ countries will not collapse entirely, but overproduction by countries participating in the voluntary cut and withdrawal from the OPEC+ are perceived as potential factors that could lower prices.

On the demand side, there are concerns about the aftermath of Trump's tariffs and a resurgence of inflation. Among the tariffs imposed by President Trump, the 90-day suspension of the enforcement of reciprocal tariffs on many countries, starting from April 9, will expire on June 30. The 90-day suspension regarding tariffs on China, which was agreed to on May 12, will expire on August 9. While it seems unlikely that the Chinese tariff rate of 145% imposed in April will be reinstated, President Trump appears displeased with the negotiations with China, so it would not be surprising if there were considerable twists and turns before a final resolution is reached. Moreover, Trump's tariffs could cause the inflation rate in the U.S. to rise again. If the current surge in oil prices were to become prolonged, it may rekindle inflation not only in the U.S. but also globally. Again, if trade negotiations were to run into any difficulties, causing inflation to resurface and heightening fears of an economic slowdown, the outlook for oil demand would be lowered and prices would become more susceptible to downward pressure.

The “12-Day War” and the transformation of Middle Eastern geopolitics

Akiko Yoshioka *

On June 13, 2025, Israel launched a military strike against Iran. At the time, nuclear negotiations between Iran and the United States were ongoing, with talks scheduled to be held in Oman on June 15. For Iran, an attack at this juncture was an unexpected development, and Israel’s preemptive strike amid active diplomatic efforts came as a major shock.

It is believed that Israel was motivated to seize the moment and attack Iran’s nuclear facilities—long considered a strategic threat—before Iran could restore its air defense systems, which had been destroyed during military clashes between the two countries in April and October 2024.

The two countries have long had an adversarial relationship, and while skirmishes had previously occurred in neighboring states, the two military clashes in 2024 marked the first time they directly exchanged fire. Although these engagements represented an important turning point, the attacks were deliberately limited in scope. Both sides appeared intent on containing the escalation by keeping the intensity of the strikes within certain bounds. Nevertheless, the clashes undeniably lowered the threshold for launching full-scale direct attacks in the future.

Having initiated a preemptive strike, Israel proceeded with extensive and sustained attacks using missiles, drones, and fighter jets, while also leveraging an espionage network it is believed to have built within Iran over many years. Israel reportedly assassinated more than ten senior officials, including leaders of the Islamic Revolutionary Guard Corps and nuclear scientists. Iran launched a counteroffensive by firing several hundred missiles at Tel Aviv, Haifa, and other Israeli cities. Amid the ongoing exchanges, the airspace not only over Iran and Israel but also over Iraq and Syria—countries located between them—was closed, bringing regional air traffic to a near standstill. The evacuation of Japanese nationals residing in Iran and Israel began via land routes around June 19.

Initially, U.S. President Trump adopted a stance of tacitly approving of Israel’s attack on Iran, but perhaps inspired by Israel’s spectacular battle results, on June 19 Trump captured the world’s attention by announcing the U.S. would make a decision on whether to attack Iran within two weeks, and indeed, on June 21 the U.S. military proceeded with airstrikes targeting Iran’s nuclear facilities. In response, on June 23, Iran fired ballistic missiles at al-Udeid Air Base in Qatar, the largest U.S. military base in the Middle East, but it notified the U.S. government in advance and 13 of the 14

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missiles were intercepted, with no casualties confirmed.

Although there were concerns about a possible closure of the Strait of Hormuz, both Iran and Israel halted attacks on June 24 following appeals from President Trump, effectively bringing the “12-Day War” to an end. The conflict inflicted significant damage on both sides, with over 900 confirmed fatalities in Iran and 28 in Israel.

The extent to which the attacks curtailed Iran’s nuclear development—their original objective—remains unclear. However, from Israel’s perspective, the destruction of numerous strategic sites and the elimination of multiple key personnel with full U.S. support were major accomplishments; therefore, the strategy is viewed as a success.

What Israel had been viewing as a menace up to now was not only Iran’s nuclear and missile capabilities, but also the existence of Iran-aligned non-state organizations known as “proxy forces” or the “axis of resistance.” However, Gaza’s Hamas and Lebanon’s Hezbollah were severely weakened in fierce battles with Israel during the Gaza war that began in October 2023. Hezbollah’s diminished capabilities ultimately contributed to the collapse of Syria’s Assad regime in December 2024. As a result of this, Iran lost the “land corridor” linking Iraq, Syria and Lebanon. Yemen’s Houthis continue to launch missiles at Israel, but their effects are limited, and the Shiite militias within Iraq, fearing retaliation from the U.S. military, have also confined themselves to carrying out extremely small-scale attacks. It is thus clear that in the Middle East region, Iran and its allied forces are on the back foot.

For Arab nations that had long viewed Iran as a threat, the current situation is not necessarily unwelcome. Over the past two decades, Gulf Arab states in particular have regarded Iran’s growing influence in the Arab world—exercised through its Shiite networks—as a challenge to the regional order. This perception also underpinned the break in diplomatic relations between Saudi Arabia and Iran, which lasted from 2016 to 2023. Although diplomatic ties have improved in recent years, many Arab nations are still likely to welcome the outcome of the Israeli attack—namely, the diminished prospect of Iran acquiring nuclear weapons.

While such pragmatic calculations may be understandable at the political level, there is a risk that anti-U.S. and anti-Israel sentiment will intensify among ordinary citizens as a result of the recent conflict. Since the outbreak of the Gaza war in October 2023, more than 50,000 Palestinians have been killed. Israel’s intense military campaign, combined with the U.S. refusal to intervene or restrain it, has fueled deep and growing resentment.

In this latest conflict, Israel justified its unilateral attack on Iran by citing its own threat perception. Moreover, not only did the U.S. refrain from trying to prevent the attack, it actively joined the use of

military force — disregarding international law and bypassing the United Nations Security Council. This approach has undoubtedly shaken global trust in the superpower.

There is also a risk that this erosion of trust could undermine Arab nations' confidence in the U.S. and provide propaganda material for anti-American extremist groups. The outcomes of both the Gaza war and the 12-Day War currently give the appearance of Israel being the sole victor, but whether this will bring lasting stability to the Middle East remains highly doubtful.

The Trump Administration is striving to reinforce the U.S. presence in the international nuclear market.

Shoichi Itoh ^{*}, ^{**}

The International Energy Agency (IEA) assessed that the international community's interest in nuclear energy is reaching the highest level since the oil crises of the 1970s in its [The Path to a New Era for Nuclear Energy](#), published in January 2025, against the background that the growth rate of the world's electricity demand has doubled over the past decade and the world has entered a new age of electricity. In June of the same year, the [World Bank](#) signed a partnership agreement with the International Atomic Energy Agency (IAEA) on cooperation concerning nuclear energy development and lifted a ban on funding nuclear energy projects.

The Trump Administration, holding the banner of “Energy Dominance”, is beginning to pick up the pace of government support for the nuclear industry. On May 23, President Trump signed four Executive Orders (hereinafter “EO”) whose goal is to significantly increase domestic nuclear energy generation and to bolster the U.S. presence in the international nuclear energy market. One factor forming a backdrop to that is a significant increase in electricity demand accompanying the spread of artificial intelligence (AI) and rapid growth in the establishment of data centers. Another factor is mounting concern about maintaining the principle of peaceful use of nuclear energy (or nuclear non-proliferation) amid the rapidly expanding presence of Russia and China in the international nuclear energy market. The series of EOs does not confine its perspective to energy security. National security perspectives closely linked with the military sector are also factored in¹

The U.S. Energy Information Administration's [Annual Energy Outlook 2025](#) estimates that U.S. electricity demand will increase by 27% in 2040 and 46% in 2050 compared to 2025 (Reference Case). In the [commercial sector](#), the electricity demand is forecast to increase rapidly, especially in the computer field, with its share of total commercial electricity consumption projected to rise from 8% in 2024 to 20% in 2050. EO [14300](#) “Ordering the Reform of the Nuclear Regulatory Commission” posited that it is critically important to secure abundant energy in order to enhance international competitiveness in energy-intensive, cutting-edge industries (including AI and quantum computing) as well as to protect national- and economic-security interests, and it set a target of expanding nuclear energy capacity in the United States to 400 GW by 2050 (a fourfold increase compared to 2024). Also, the EO orders that the Nuclear Regulatory Commission's licensing process be simplified and expedited in order to promote the deployment of nuclear reactors, including advanced reactors, and to rebuild the U.S. leadership in the global nuclear energy market.

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** This text expresses the author's personal opinions, and does not in any regard represent the views held by any organizations with which the author is affiliated.

¹ [Energy Policy under the Trump Administration: Enhanced linkage with national security](#), by the author.

EO [14301](#) “Reforming Nuclear Reactor Testing at the Department of Energy” directs the Department of Energy (DOE) to revise the necessary regulations, guidance, and procedures in order to expedite the review, approval, and deployment of advanced reactors under the Department's jurisdiction. The EO also clarified that the DOE's jurisdiction will be maximized with regard to next-generation reactors under development. Additionally, with a view to establishing AI-related data centers and boosting U.S. economic competitiveness, EO [14302](#) “Reinvigorating the Nuclear Industrial Base” attaches importance to facilitating 5GW of power uprates to existing nuclear reactors and having 10 new large reactors under construction by 2030, and emphasizes the need to strengthen the nuclear fuel supply chain (including through the expansion of domestically produced nuclear fuel) toward promoting the deployment of advanced reactors.

The stability of the domestic electricity system and maintaining international competitiveness are not the only dimensions that form a backdrop to the Trump Administration's efforts to substantially bolster the nuclear energy industry. The Administration is also aiming to restrain Russia and China from expanding geopolitical influence through the nuclear energy sector, and to maintain and strengthen the U.S. voice on non-proliferation issues in the international community.

Currently, [China](#) has 58 nuclear reactors in operation and 32 under construction, approaching the U.S., with 94 nuclear reactors—the world's largest number as of today. As the world is increasingly divided, China and Russia have national strategies to export their nuclear energy-related equipment and technology to the Global South. The two countries are beginning to dominate the [global nuclear energy market](#). Of the 52 nuclear reactors whose construction began in 2017, 25 were built by China and 23 by Russia (as of the end of 2024).

EO [14299](#) “Deploying Advanced Nuclear Reactor Technologies for National Security” positioned the accelerated development, verification, and deployment of advanced nuclear energy technologies not simply as an issue of expanding energy supply capacity but as an urgent challenge from the standpoint of national security. The EO raises the alarm that unless the U.S. actively deploys advanced reactors (including Generation III+ reactors, small modular reactors (SMRs), and microreactors) domestically and exports them, the international energy market will be overwhelmed by the United States' adversaries rushing to export these technologies.² This, in turn, could pose a threat to U.S. national security. The EO also indicates a policy of undertaking new negotiations for Agreements for Peaceful Nuclear Cooperation (known as 123 Agreements) with at least 20 countries, and that of actively renegotiating with countries whose 123 Agreements are set to expire within the next decade.³ The EO also places an emphasis on the need to strengthen the domestic nuclear fuel (uranium and plutonium) supply chains by way of reducing reliance on foreign sources of fuel and boosting fuel fabrication and reprocessing capabilities.

² These “adversaries” are not named in the document, but it is clear that this refers to Russia and China.

³ A 123 Agreement refers to section 123 of the Atomic Energy Act of 1954, which makes it mandatory to conclude a bilateral agreement on non-proliferation as a general principle when building frameworks for nuclear energy cooperation with other countries.

Article IV of the Treaty on the Non-Proliferation of Nuclear Weapons states explicitly that the use of nuclear energy for peaceful purposes is an inalienable right of all the Parties to the Treaty, but the controversy over the scope of peaceful use between developed nations and developing nations is continuing. A large amount of nuclear energy-related equipment and technology is dual use (meaning it has both military and civilian uses). When participating countries in the [Nuclear Suppliers Group \(NSG\)](#) (currently 48 countries belong to the NSG, including the U.S., China, and Russia) export nuclear energy-related equipment and technology, they are required to follow the NSG Guidelines (which stipulate the applicable items and conditions on their peaceful transfer).

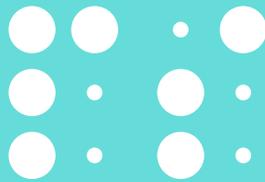
However, in recent years, [disagreements](#) between the West, including the U.S., and China and Russia, which are seeking to secure the support of developing countries in return for those guidelines to be eased, have grown. In response to developing countries' assertions that export restrictions on dual-use technology by developed countries impede developing countries' right to economic development, China and Russia are seeking to gain influence in the Global South via the nuclear energy sector by keeping such restrictions to a minimum. The NSG Guidelines are essentially nothing more than a "gentlemen's agreement," and in effect, they are already being reduced to a shell.

The issue of whether or not the U.S. can once again strengthen and continue to maintain its presence in the global nuclear energy market will undoubtedly have a major influence on the future of nuclear non-proliferation and nuclear security. Given that [the U.S.-Japan alliance](#) has an inseparable relationship in the nuclear industry, it is worth recalling once again the role and duty that Japan can perform in defending the principle of the peaceful use of nuclear energy in the international community.

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