Provisional translation

Green Growth Strategy Through Achieving Carbon Neutrality in 2050

June 18, 2021

Cabinet Secretariat

Ministry of Economy, Trade and Industry

Cabinet Office

Financial Services Agency

Ministry of Internal Affairs and Communications

Ministry of Foreign Affairs

Ministry of Education, Culture, Sports, Science and Technology

Ministry of Agriculture, Forestry and Fisheries

Ministry of Land, Infrastructure, Transport and Tourism

Ministry of the Environment

The ministries and agencies listed on the front cover of this strategy are responsible for describing their respective responsibilities.

The Cabinet Office has a wide range of responsibilities, but the Economic and Social Research Institute and the Secretariat for Science, Technology and Innovation Promotion are in charge of statistics and indicators, as well as parts related to the Environment Innovation Strategy.

Contents

1. Green Growth Strategy Through Achieving Carbon Neutrality in 2050[1]

(1) Relationship Between Carbon Neutrality and Green Growth Strategy

In October 2020, the Japanese government has declared to realize “Carbon Neutrality by2050”. In addition, in April 2021, a new policy was announced to set a new greenhouse gas reduction target for FY2030, aiming to reduce greenhouse gas emissions by 46% from FY2013 levels while continuing strenuous efforts in its challenge to meet the lofty goal of cutting its emission by 50%.

Gone are the days when countermeasures to global warming are considered as a cost or constraint to the economic growth, the world has entered a new era to grasp them as a great opportunity for further prosperity[2]. Changing from the conventional mindset, to take measures positively to tackle climate change heralds transformation in the industrial structure and social economy, and leads to the next strong growth. The Green Growth Strategy[3] is a set of industrial policies to create a “virtuous cycle of the economy and the environment”.

It is easy to tell rhetoric such as “changing from the mindset” and “transformation”, but in reality, achieving Carbon Neutrality will require enormous efforts. In the industry, many companies will have to fundamentally change the business models and strategies they have been using. While, it’s also a chance for them to lead the new era. The role of the government is to provide full support to private companies in conducting their forward-looking challenges, such as a bold investment to make innovation[4].

The government needs to put up an as-specific-as-possible prospect, set high goals, and develop an environment that facilitates ventures of private enterprises. What is particularly important towards achieving Carbon Neutrality in 2050 will be initiatives in the energy sector that accounts for more than 80% of greenhouse gas emissions. Therefore, from the perspective of industrial policy, it is necessary to first present a picture of energy policy and energy supply and demand (3E+S) to achieve Carbon Neutrality in 2050 in order to find fields and industries that are expected to grow. Through the Green Growth Strategy, the Japanese government will set high goals and muster all possible and necessary policies for the thus-determined industries (14 industrial fields) that are expected to grow.

Decarbonization of the power sector is the major premise for achieving Carbon Neutrality in 2050. Given the current level of technology, it is generally difficult to meet 100% of electricity demand with a single type of power source, so all options will be pursued.

Renewable energy will be introduced as much as possible. For this reason, we will reduce costs, secure suitable sites that can coexist with the local community, and expand the ability to adjust

---

[1] On October 26, 2020, the Prime Minister Suga declared that by 2050 Japan will aim to reduce greenhouse gas emissions to net-zero, that is, to realize a carbon-neutral, decarbonized society.

[2] Some private-sector companies, such as global IT companies and manufacturers, are aiming to decarbonize their entire supply chains and are asking their business partners to take on decarbonization initiatives as well.

[3] This Green Growth Strategy has been reported on and discussed at the "Growth Strategy Council" regarding its direction and other issues. The framework of the plan was included in the "Growth Strategy Action Plan" (approved by the Cabinet on June 18, 2021) (see p. 170).

[4] As of 2021, there have been a number of examples of "game changing" or "paradigm shifting" management decisions and R&D policy changes in the private sector. In order to accelerate this trend, the content was further materialized in June 2021. Review of the contents and fields, etc. as appropriate in response to social and economic conditions and technological progress, will be followed up.

fluctuating output by using storage batteries, etc. Through these efforts, it is necessary to develop an offshore wind power industry, storage battery industry, next-generation solar industry, and geothermal industry as growth industries.

Regarding thermal power, the government will pursue its use as an option, presupposing recovery of carbon dioxides CO_2. Technology will be established, suitable sites will be developed, and the cost will be reduced. Globally, thermal power will remain necessary, especially in Asia, although the extent of use should be as minimal as possible. Considering that, the government shall pursue the use of hydrogen power generation where possible, as an option. Both supply and demand quantities will be increased, infrastructure will be established, and the cost will be reduced. To achieve them, creation of hydrogen industry will be required. At the same time, carbon recycling industries and fuel ammonia industries will have to be developed.

With regard to nuclear power, the government will reduce the dependence on nuclear power as much as possible, while proceeding with the restart of nuclear power plants which are confirmed to comply with one of the world's most stringent regulatory standards by NRA. Also, the government will steadily establish effective nuclear regulations and nuclear emergency preparedness systems. Furthermore, the government will promote R&D and human resource development in the nuclear industry, such as the pursuit of reactors with further safety, etc.

For sectors other than the electricity sector (industrial, transport, commercial, and residential sectors), the primary course of action will be electrification. For heat demands, decarbonized fuel such as hydrogen as well as recycling of CO_2 and recovery of CO_2 from fossil fuel will also be utilized. As demand for electricity is expected to increase due to electrification, it is necessary to develop energy-saving related industries as a growth field, and in terms of heat demand, it is necessary to significantly grow the gas supply business so that it can respond to the next generation of heat energy supply.

It goes without saying that stable supply of energy must be secured even in 2050, when electrification will have advanced greatly. Increasing energy self-sufficiency by maximizing the introduction of domestically-produced renewable energy and the use of nuclear power will enhance the strategic autonomy of Japan's energy supply and demand and contribute greatly to ensuring stable supply. To fully realize the benefits of this stable supply in an electrified society, it will be necessary to promote businesses that aggregate the value of dispersed energy resources and utilize them through digital control and market transactions, and to foster a next-generation power management industry that will lead to the construction of a grid that makes this possible. In addition to this, strengthening the resilience and disaster prevention functions of electricity is a prerequisite for this. For example, even as the introduction of electric vehicles and the electrification of heating and cooling equipment progresses, it is necessary to work on the development of coordinating power and the strengthening of the grid to ensure stable supply of electricity in the event of emergencies such as heavy snowfalls, tsunamis, and earthquakes, as well as to promote the use of[5], a system that enables self-sufficiency even in the event of temporary supply disruptions, while taking into account the state of technology and costs.

---

[5] For example, by utilizing a seat heater, it is possible to maintain the temperature of the seat surface for a relatively long period of time even in a cold environment, thereby suppressing a drop in body temperature. As

In the industrial sector, changes in manufacturing processes such as hydrogen-reduced iron making and growth in the materials industry are necessary. The transport sector has to use biofuel and hydrogen fuel, while promoting motorization. The commercial and residential sectors anticipate net zero energy houses/buildings, electrification, hydrogen-powered systems, and use of storage batteries. In light of this, it is necessary to develop the hydrogen industry, the automobile and storage battery industry, transportation-related industries, and housing and building-related industries as growth sectors.

When pursuing Carbon Neutrality in 2050, in addition to realizing such energy supply and demand structure, digital control of power network will become necessary. What upholds the Green Growth Strategy is resilient digital infrastructures; green and digital are the 2 inseparable wheels of a car. Therefore, the digital infrastructure needs to be strengthened, and the semiconductor and information and communications industries need to be fostered as growth areas. For example, in the power sector, digital technology is essential in managing smart grids for advanced operation of systems, supply-demand adjustment for solar power and wind power generation whose output varies depending on the weather, and also essential for maintenance and inspection operations of infrastructures. In the transport sector, automatic driving of cars, drones, aircrafts, and trains will not only improve the convenience of the people but also contribute to improved energy use efficiency. In addition, at factories, manufacturing will be automated through factory automation (FA) and robots. Meanwhile, in the commercial and residential sectors, advent of smart houses (which combine renewable energy and storage batteries using an energy management system for optimal energy use) and service robots will not only realize comfortable life but also achieve efficient energy use.

In addition, the new announcement in April 2021 of an ambitious 2030 emissions reduction target, which is more than 70% higher than the previous target, will further increase the need to strengthen policies and create innovation at an accelerated pace. For example, institutional measures such as a non-fossil value trading market, conversion of coal-fired in-house power generation, mainly in energy-intensive industries, to gas and more efficient facilities, promotion of offshore wind power through regulatory reform, institutional measures to expand the introduction of non-fossil energy on the demand side, and promotion of electrification and energy-saving homes are necessary. As a result of these measures, expectations for the growth potential of such decarbonization technologies and opportunities for innovation are increasing, as the position and direction of further deepening the amount of energy efficiency measures, maximum introduction of renewable energy and use of nuclear power, and introduction of hydrogen and fuel ammonia power generation are showed in FY2030.

Buds of technology to realize such a society has already come to the surface through research and development (R&D) conducted to date. In January 2020, the government formulated the " Environment Innovation Strategy" (decided by the Integrated Innovation Strategy Promotion Council on January 21, 2020), which aims to establish innovative technologies that will enable a "Beyond

---

for heating in cold regions, if synthetic fuels and synthetic methane made from CO_2 and hydrogen become more widespread, it is assumed that the use of heating will not be much different from the current use of petroleum products and natural gas. With regard to energy-saving traffic signal lights that use LEDs, the surface temperature does not rise high enough to melt snow when the snow accumulates, and the signal lights may not be visible, but by devising the shape and materials of the signal lights, technology is being developed that will not interfere with traffic safety.

Zero" a reduction in the accumulated amount of CO_2 since the Industrial Revolution. In addition to the above, we have been deepening our examination of the issues. Challenges awaiting ahead of the establishment of such innovative technologies are societal implementation and cost reduction by investment for mass production.

The government has to muster all available and necessary policy measures such as budget, tax systems, finance, regulatory reform/standardization, and international cooperation under the Environment Innovation Strategy to steer private enterprises to in the direction of positively investing the cash equivalent of 240 trillion yen they amass.

This strategy is expected to generate economic benefits of about 140 trillion yen in 2030 and about 290 trillion yen in 2050.[6]

In addition, the employment effect is expected to be about 8.7 million people in 2030 and about 18 million people in 2050.[7]

Although the creation of new products and services is expected to have not only a positive impact, but also a certain degree of negative impact on the industries involved, the government will actively support efforts by, for example, small and medium-sized suppliers that have been manufacturing transmission gears for gasoline engines to take on the new challenge of manufacturing motor parts for electrified vehicles. In addition, while taking into account the needs of industries that are tackling these new challenges, it is necessary to take employment-related measures in the medium and long term as well, such as the use of subsidy systems that promote companies' recruitment of human resources and investment in human resources, the use of education and training benefit systems, and the improvement of the environment of regional vocational training institutions, etc., as support for businesses that are tackling human resource development and workers who are upgrading their skills. By implementing such policies, the aim is to steadily create jobs.

---

[6] The economic effects were estimated by accumulating the future market size forecasts and export expansion obtained through interviews with companies and other sources. It is an estimate of what kind of growth potential exists in the market in the future, and does not take into account spillover effects on related industries or negative impacts that could arise from the creation of new products and services.

[7] The employment effect was estimated by the input-output analysis, including the spillover effect to related industries. In doing so, any negative impact that may arise from the creation of new products and services are taken into account.

(2) Realization of Carbon Neutrality in 2050

Electricity demand in 2050 will need to increase to a certain extent due to the electrification of the industrial, transport, commercial, and residential sectors. For heat demand that cannot be met by electrification, decarbonized fuels such as hydrogen and the capture and reuse of CO_2 from fossil fuels will also be utilized.

Innovations such as innovative manufacturing processes and carbon-removal technologies will be essential outside of the power sector to achieve Carbon Neutrality in 2050. The power sector will be decarbonized through maximum introduction of renewable energy and use of nuclear power, as well as through use of hydrogen, ammonia, CCUS, etc. The decarbonized electricity will be used to decarbonize other sectors.

Since various visions of the future are possible for 2050, based on the exchange of opinions among various experts in the energy field, the following values were set as reference values for further discussion: approximately 50-60% of power generation in 2050 will be covered by renewable energy sources such as solar power, wind power, hydropower, geothermal power, and biomass; approximately 10% will be covered by hydrogen and fuel ammonia power generation; and approximately 30-40% will be covered by nuclear power and thermal power generation with CO_2 capture. In order to realize these reference values for power sources in 2050, each power source will need to overcome various challenges, including natural conditions, societal constraints, and technological issues, so achieving these levels will not easy.

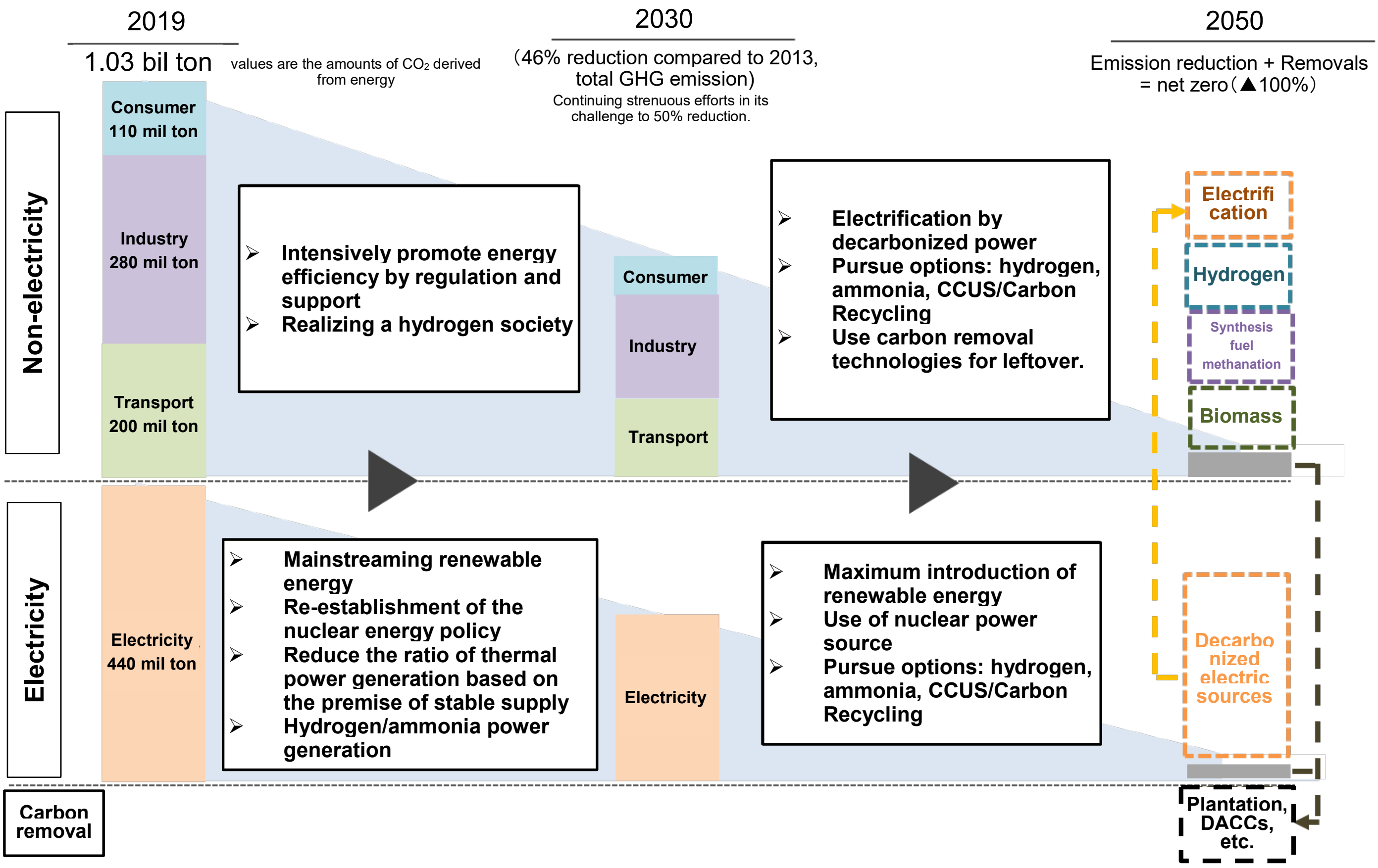
In addition, a scenario analysis conducted by a specialist organization[8], suggested that in order to achieve Carbon Neutrality in 2050, it is important to pursue all options for decarbonization, including nuclear power, hydrogen/ammonia, CCUS/carbon recycling, as well as renewable energy to be introduced to the maximum extent possible, without narrowing down policy options in order to meet the enormous demand for electricity, as electricity demand is expected to increase by about 30-40% due to progress in electrification.

The path to achieving Carbon Neutrality in 2050 is subject to a variety of uncertainties, including technological progress and changes in societal conditions. Therefore, it is important to view this as a direction to aim for on the basis of the assumption of various scenarios, and to review it flexibly depending on future technological progress and other factors.

Aiming at the final vision of Carbon Neutrality in 2050, we will continue to promote the introduction of electrified vehicles and energy-saving homes, develop technologies, overcome grid constraints, promote the introduction of renewable energy by securing suitable sites that can coexist with local communities, promote institutional measures such as the expansion of non-fossil markets, and promote the use of distributed energy in accordance with this strategy.

---

[8] Research Institute of Innovative Technology for the Earth (RITE)



- Intensively promote energy efficiency by regulation and support
- Realizing a hydrogen society

- Electrification by decarbonized power
- Pursue options: hydrogen, ammonia, CCUS/Carbon Recycling
- Use carbon removal technologies for leftover.

- Mainstreaming renewable energy
- Re-establishment of the nuclear energy policy
- Reduce the ratio of thermal power generation based on the premise of stable supply
- Hydrogen/ammonia power generation

- Maximum introduction of renewable energy
- Use of nuclear power source
- Pursue options: hydrogen, ammonia, CCUS/Carbon Recycling

In order to achieve Carbon Neutrality in 2050, a certain increase in burdens is expected under the current level of technology and cost, etc.

On the other hand, if the challenges of each decarbonized power source are overcome through technological innovation, cost reduction, promotion of public understanding, and easing of introduction restrictions, and if the introduction of decarbonized power sources is further expanded, the cost of electricity could avoid a large increase and the realization of Carbon Neutrality in 2050 could be achieved at a lower cost. For example, in 2030-35, offshore wind power (seafloor-mounted) is estimated to cost 8-9 yen/kWh, and in 2050, fuel-ammonia-fired power generation is estimated to cost 12 yen/kWh, and hydrogen-fired power generation is estimated to cost less than 12 yen/kWh. If costs comparable to current thermal power generation like these are assumed, the possibility of achieving Carbon Neutrality will be increased.

In addition, through the conversion of houses to ZEH and the introduction of HEMS, for example, it is expected that costs will be pushed down on the demand side. Furthermore, we will work tirelessly to create innovations to establish solid advantages by combining various initiatives, such as improving resilience and disaster prevention functions.

In light of this, in order to ensure Carbon Neutrality, it is necessary to introduce renewable energy to the maximum extent possible as major power sources and take policy measures to drive innovation and societal implementation of all options, such as hydrogen, fuel ammonia, and CCUS/carbon recycling, etc.

2. Framework of Green Growth Strategy

The Japanese government is committed to lead challenges towards the 2050 Carbon Neutrality to major growth via reforms of industrial structure and economic society. The Green Growth Strategy will encourage private investment to utilize the cash equivalent of 240 trillion yen in Japanese companies. Also, it will draw environment-related investment funds in the world that are said to be in the scope of 3,000 trillion yen into Japan, and thereby generate employment and growth. The government will mobilize all available political tools to realize that.

For each of the key areas essential to achieving Carbon Neutrality by 2050, an "action plan" will be formulated that includes (1) targets with clearly defined time limits, (2) research, development, and demonstration, (3) regulatory reform, standardization, and other institutional improvements, and (4) international collaboration, with all relevant ministries and agencies working together.

In the action plans for important fields, the current status, issues, and future action policies in the relevant fields should be clearly indicated, and a process chart with a time axis up to 2050 should be presented. Relevant policies shall prioritize creation of demand through regulatory reform/standardization and financial market, and price reduction through expansion of private investment.

In the process charts, specific measures will be presented to strengthen Japan's international competitiveness and to expand the market on its own, with an awareness of the following key technologies that will be crucial to achieving growth in this field.

1) "Research and Development Phase," which is to be carried out through a fund created by the government and private sector for investment in R&D
2) “Demonstration Phase,” which is to be realized by public-private cooperative investment on the premise of fostering private investment
3) “Introduction and Expansion Phase,” for expanding demand through public procurement and development of relevant systems such as regulations and standards, and for reducing costs through associated shifting to mass production
4) “Autonomous Commercialization Phase,” where commercialization develops autonomously without public support, presupposing systems such as regulations and standards

Attention needs to be paid, however, that the rate of progress in each phase varies depending on the field, and in some cases the phase may shift from a “research and development phase” to an “introduction and expansion phase” leaping over a “demonstration phase”.

In terms of the budget, first of all, in order for the government to take a big step forward in environmental investment, it has established an unprecedented 2 trillion yen fund (Green Innovation Fund) to provide continuous support for companies that take on the challenge of ambitious innovation for the next 10 years.

In the aspect of tax systems, in order to rouse private investment, the government will establish an Investment Promotion Tax System toward Carbon Neutrality, expand R&D tax systems, and take a special exception to raise the upper limit of tax deduction for loss carried forward targeting companies that work on business restructuring or reorganizing.

In the financial aspects, the Japanese government will call for financing on innovative technology toward low carbonization or decarbonization through creation of rules in the financial market about, for example, information disclosure and basis of appraisal.

Regarding regulatory reform and standardization, the government will deliberate various matters including reform of regulations on hydrogen stations, revision of system operation rules to prioritize renewable energy, utilization of fuel consumption regulations to promote the electrification of automobiles, and public procurement of concrete made by absorbing CO_2, to create demand and reduce prices.

As for private funding, the government will proceed with creation of rules of financial market, such as standards of information disclosure and appraisal, while cooperating with relevant agencies and institutions overseas.

3. Major Cross-cutting Policy Tools

(1) Budget (Green Innovation Fund)

Achieving the 2050 Carbon Neutrality is an extremely challenging task, and requires attempting more ambitious innovation than ever. For that reason, regarding particularly important fields, the government will, once the public and private sectors share bold and specific goals, provide continuous support to companies committed to take on challenges toward achieving the goals, from R&D through demonstration to social implementation. To this end, the government has established a 2 trillion yen “Green Innovation Fund” and decided to assign the New Energy and Industrial Technology Development Organization (NEDO) to its operation.

For priority fields that are essential to a carbon-neutral society and form the basis of industrial competitiveness, ambitious 2030 targets will be set (performance, amount of installation, price, CO_2 reduction rate, etc.) based on the implementation plan of this strategy, and ambitious projects from R&D through demonstration to social implementation by companies that demonstrate their commitment to these targets will be continuously supported for the next 10 years.

Regarding the management of the Fund's project, discussions were held at the Green Innovation Project Subcommittee of the Industrial Structure Council, and a "Basic Policy of the Green Innovation Fund’s project" (decided by Ministry of Economy, Trade and Industry on March 2021) was formulated in March 2021 to ensure the execution of R&D, demonstration and social implementation over a long period of time. In order to maximize the results of each project amidst intensifying competition for leadership in the business of leading toward carbon-neutral societies around the world, the following evaluation axes is established based on this policy.

(1) Potential to contribute to CO_2 reduction and economic ripple effects, etc.

(2) Necessity of policy support based on the degree of technical difficulty and the possibility of practical application

(3) Potential market growth and international competitiveness

Based on the above, priority investment will be given to projects of particular importance. With the participation of external experts with a wide range of expertise in management, technology, new business, finance, etc., the content and priority of each project will be discussed. After careful examination by both the government and NEDO, the project will be launched sequentially from the summer of 2021.[9]

It should be noted that there are some areas where it would be effective to encourage the participation of SMEs and start-ups that support the base of the supply chain and play a role in creating new industries. To this end, effective collaboration with SMEs and start-ups. will be promoted by 1) considering effective collaboration with SMEs and venture companies an advantage in the selection process, 2) flexibly organizing small-scale projects, 3) dividing a R&D theme into

---

[9] As for projects related to the hydrogen industry, R&D and social implementation plans have already been formulated, and projects are scheduled to start as early as the summer of 2021. Other projects will continue to be considered.

smaller segments on publicly inviting proposals, and collaborating with existing support measures for SMEs and venture companies.

At the same time, the government will seek a strong commitment from top management to challenge goals of projects as one of the most critical business management issues, and working groups established under the Subcommittee will continuously check the status of initiatives, etc. with a wide range of stakeholders. Specifically, at the time of adoption, the company implementing the project will submit a long-term business strategy vision in the relevant field (e.g., a 10-year innovation plan or the formation of a team directly connected to top management) under the commitment of top management. Furthermore, we ask the managers themselves to clarify their commitment to persistently tackle the project as a critical business issue and to participate regularly in working groups to explain their efforts and discuss progress of the project. The government will then introduce mechanisms such as the cancellation of projects and the partial return of commissioning fees in the case of inadequate efforts as a critical business issue, and incentive measures in which the government will increase its support depending on the degree of achievement of the target.

By creating mechanisms to require a commitment from top management, the government's 2-trillion-yen budget will be used as pump priming to induce private companies to invest approximately 15 trillion yen in R&D and equipment, and to move toward ambitious innovation. It will also draw an estimated $30.7 trillion (approx. 3,000 trillion yen) in global ESG (environmental, social and governance) funds and thereby generate income and employment for Japanese people in the future.

(2) Tax systems

Realizing Carbon Neutrality in 2050 is a high-set goal, and short-term capital investment by companies that is highly effective in achieving the goal needs to be encouraged, let alone R&D investment from long-term views. Therefore, from the aspect of tax systems, the Japanese government will strongly push decarbonization investment by companies.

Specifically, the government will establish tax treatments to induce private investment toward decarbonization in order to cultivate new demand through early marketing of products with large greenhouse gas reduction effect, or to promote decarbonization of production process currently in use. In addition, the government will take a special exception to raise the upper limit of tax deduction for loss carried forward targeting companies that are resolutely taking on challenges towards “new normal” and realization of Carbon Neutrality, even though their business is in the red, amid the severe business environment induced by the COVID-19 pandemic. Further, as for R&D tax systems, the government will strengthen incentives to positive R&D investment amid the coronavirus crisis to prop up enterprises’ desire to make medium- to long-term investment.

These measures are anticipated to generate approximately 1.7 trillion yen of private investment over the course of 10 years, as they will strongly encourage enterprises to make every sort of short-, medium-, and long-term decarbonization investment.

1) Establishment of the Investment Promotion Tax System (tax deduction or special depreciation) toward Carbon Neutrality

Based on the plan approval system newly established in the " Act on Strengthening Industrial Competitiveness ", a tax credit of up to 10% or a special depreciation of 50% will be provided for the introduction of the following (i) and (ii) equipment (for three years from the enforcement of the revised Act on Strengthening Industrial Competitiveness to the end of FY2023).

(i) Introduction of production facilities for products with large decarbonization effect

The Environment Innovation Strategy (decided by Integrated Innovation Strategy Promotion Council on January 21, 2020) specifies 39 themes that greatly reduce greenhouse gas emissions and Japan is considered to have technical capability for. Among these 39 themes, focusing on the energy conversion sector that accounts for more than 40% of CO_2 emissions in Japan, the government will support introduction of facilities primarily used for the production of the products below selected from the said sector that have an immediate need for investment yet private companies will likely face a difficulty in expanding introduction in the early stage by their autonomous initiatives alone.

<Target products>

- Compound power semiconductor devices or semiconductor substrates used for manufacturing them
- Lithium-ion storage batteries for electric vehicles or plug-in hybrid vehicles
- Stationary lithium-ion storage batteries (those that satisfy at least 7,300 discharge/charge

cycles)
- Fuel cells (those that satisfy one of the following: power generation efficiency is at least 50%, overall efficiency is at least 97%,
  or pure hydrogen is used as fuel)
- Main exclusive parts of offshore wind power generation facilities (those that satisfy the rated output of at least 9 MW per unit)
  (nacelle, generator, speed-up device, bearing, tower, foundation)

(ii) Introduction of facilities that realize both decarbonization and improved added value of production process, etc.

This program supports the introduction of equipment that is necessary for a plan to improve the carbon productivity (value added / energy-derived CO_2 emissions) of business establishments, etc. to a considerable extent (the introduction of which will improve the carbon productivity of business establishments by 1% or more).

<Improvement of carbon productivity to a considerable degree and rate of preferential measure>

As criteria to be fulfilled by companies for the government to provide assistance in investment into existing equipment and facilities toward the 2050 Carbon Neutrality, the government specifies the carbon productivity improvement rate and the according ratio of preferential measures:

• Improve by 7% or more within 3 years.[10]	5% tax deduction or 50% special depreciation
• Improve by 10% or more within 3 years.[11]	10% tax deduction or 50% special depreciation

2) Establishment of a special exception to raise the upper limit of tax deduction for loss carried forward targeting companies that work on business restructuring or reorganizing

If a business operator with a loss due to the effects of the COVID-19 pandemic makes an investment to respond to the "new normal" including the realization of Carbon Neutrality based on the plan approval system to be newly established in the "Act on Strengthening Industrial Competitiveness", a special exception will be established to increase the maximum deduction for loss carried forward[12] to a maximum of 100% within the scope of the approved investment amount as a limited time measure.

Investments covered by this measure shall be those made by enterprises for the purpose of business restructuring and reorganization based on an approved business adaption plan, and are required to likely achieve certain goals within the term of the plan (e.g., ROA increases by at least

---

[10] Calculated based on the energy-derived CO_2 emission targets for FY2030 assumed in existing government plans such as the "Basic Energy Plan" (approved by the Cabinet on July 3, 2018), the "Global Warming Prevention Plan" (approved by the Cabinet on May 13, 2016), and the "Long-Term Energy Supply and Demand Outlook" (formulated by the Ministry of Economy, Trade and Industry in July 2015), as well as the GDP growth rate in the "Estimates for Medium- and Long-Term Economic and Fiscal Policy" (submitted to the Council on Economic and Fiscal Policy on July 31, 2020).

[11] Calculated assuming a level higher than the FY2030 energy-derived CO_2 emissions target assumed in the above-mentioned government plans, etc., with a view to becoming carbon neutral in 2050.

[12] A system in which a loss carried forward from a previous business year can be deducted (offset) from taxable income of present or later business year. Currently, 50% is the upper limit for middle- and large-sized enterprises.

5.0% points). Specific examples include R&D investment into the development of new technology that contributes to realizing the 2050 Carbon Neutrality, introduction of equipment that greatly reduces CO_2 emissions through consolidation of production equipment, and investment to increase production of high-added value products.

Losses subject to the special provisions shall be those incurred in the fiscal year that includes a date within the period from April 1, 2020 to April 1, 2021 (in certain cases, the fiscal year that ends between February 1, 2020 and March 31, 2020 and the fiscal year that follows), and the maximum period for increasing the deduction shall be five fiscal years.

3) Expansion of R&D tax system

Amid the protracted impact of COVID-19 pandemic, business environment of enterprises remains severe, and income and sales are feared to keep dropping. At the time of the bankruptcy of Lehman Brothers where business conditions of enterprises just shattered, the amount of R&D investment in Japan plummeted and took long time to recover after that. Leaning from that experience, as for R&D investment that is the very source of medium- and long-term growth and indispensable for realizing Carbon Neutrality in Japan, it is important for the government to strengthen incentives for pandemic-hit enterprises to increase the amount of their R&D investment.

Under the current R&D tax system, enterprises can deduct experiment and research costs (multiplied by a certain ratio) up to 25% of the amount of corporate tax. However, if the amount of corporate tax decreases due to reduced sales and deteriorated earnings, the amount exceeding the upper limit is generated or increases, and that may disincentivize enterprises from investing. To that end, for enterprises that are increasing experiment and research costs even though the amount of their sales is reduced by 2% or more compared to prior to the COVID-19 pandemic (last business year that ends by the end of January 2020), the upper limit of tax deduction will be raised up to 30% of the amount of corporate tax. By this, the Japanese government will bolster enterprises' desire to make investment toward creation of innovation for realizing the 2050 Carbon Neutrality.

(3) Finance

In order to achieve Carbon Neutrality by 2050, the Japanese government will draw in private investment using governmental funds as priming water. The International Energy Agency (IEA) estimates that up to 8,000 trillion yen will be needed worldwide to achieve the Paris Agreement. In addition to renewable energy (green), financing is needed for the transition to decarbonization (transition) through steady low-carbon efforts such as energy conservation, and for innovative technology (innovation) for decarbonization.

According to the Climate Innovation Finance Strategy 2020 (September 2020), the government will take measures to attract private investment into green, transition and innovation initiatives.

With regard to green finance, the green bond market is expanding steadily both domestically and internationally, with annual domestic issuance exceeding 1 trillion yen by 2020. In order to further promote green finance, including green bonds, we will improve our issuance support system, and further study the use of funds to be raised, the procedures for issuance, and the environment, based on international trends and issuance results, and revise the Green Bond Guidelines in FY2021.

Transition finance is the concept of providing funds for greenhouse gas reduction efforts based on a long-term strategy to realize a decarbonized society. There is a risk that the steady efforts of companies to make the low-carbon transition will not be evaluated, if based solely on the dualism of "green" or "non-green" activities. Based on the "International Principles on Transition Finance" published in December 2020, Japan has formulated its own "Basic Guidelines on Transition Finance". Founded on the Basic Guidelines, sector-specific roadmaps (steel, chemicals, pulp and paper, cement, electricity, gas, oil, etc.) will be sequentially developed in FY2021 for high-emission industries that cannot decarbonize in a single step.

In order to promote energy transition in emerging countries in Asia and elsewhere with the aim of achieving global Carbon Neutrality, we will also promote the formulation and dissemination of the concept of an "Asian version of transition finance" based on the domestic Basic Guidelines. Along with the formulation of various "transition" paths (roadmaps) based on each country's needs for economic growth, economic and geographical diversity, energy policies, etc., we will formulate a framework for transition finance for Asia based on the Basic Guidelines, and seek to involve these countries through various initiatives to realize transitions.

In addition, for businesses that have been approved for a long-term business plan of 10 years or more, a long-term funding mechanism to realize the plan and a results-linked interest subsidy system (loan size of 1 trillion yen over three years) will be established in the Act on Strengthening Industrial Competitiveness to promote long-term transition initiatives by businesses.

Furthermore, the government will promote initiatives to encourage private enterprises to actively invest in advanced equipment that contributes to low-carbon development by utilizing a leasing method, which is expected to have a significant effect on inducing capital investment, and aims to induce investment of 150 billion yen or more.

Regarding the innovation finance, the Japanese government has been conducting visualization of enterprises that engage in decarbonization as information for investors (Zero-Emission Challenge: 325 companies as of March 2021). In the future, the government will expand the target industrial fields and create opportunities of dialogs for investors, enterprises and policymakers to call in finance to enterprises working on decarbonization innovation.

In addition, the government will provide risk money support to green ventures including renewable energy business (e.g., offshore wind power), utilization of low fuel consumption technology, and next-generation storage battery business. Specifically, the Development Bank of Japan (DBJ) has established the "Green Investment Promotion Fund" (project scale: 80 billion yen) as part of its Special Investment Operations. In addition, in January 2021, the Japan Bank for International Cooperation (JBIC) established the "Post-COVID-19 Growth Facility" (project size: 1.5 trillion yen) to support the overseas development of quality infrastructure and other overseas business activities by Japanese companies toward a decarbonized society.

While governments and institutions in Japan and abroad are working on various guidelines for sustainable finance, there is a growing demand from companies and investors for a comprehensive set of guidelines from a practical perspective. While taking these points into account, in addition to the revision of the Green Bond Guidelines mentioned above, guidelines for social bonds will be formulated, and the formulation of a document that provides a wide range of examples of specific indicators, etc. for solving social issues will be considered. In addition, from the perspective of providing information that is highly convenient from the perspective of companies and investors, stock exchanges, etc. will take the lead in establishing an information platform that includes the provision of ESG-related market information, etc.

With the aim of creating a "Green International Financial Center" where transactions of green bonds, transition bonds, etc. are actively conducted, the Financial Services Agency and others will encourage the private industry to establish a certification mechanism for evaluating the eligibility of green bonds, etc. (where an external organization provides objective certification of the eligibility of green bonds, etc. on the premise of an external evaluation), in addition to the establishment of the above-mentioned information platform. In addition, the FSA and others will examine the nature of ESG evaluation organizations (transparency, governance, etc.) in light of some comments that external evaluation methods for ESG, etc. are not always clear.

With regard to sustainability-related disclosures, based on the revision of the Japan’s Corporate Governance Code in June 2021, companies listed on the prime market will be encouraged to enhance the quality and quantity of their disclosure based on the Task Force on Climate-related Financial Disclosure (TCFD) recommendations or an equivalent international framework.

Japan will actively participate in the initiative to develop a comparable and consistent disclosure framework for sustainability, including climate change, by the International Financial Reporting Standards (IFRS) Foundation.

In addition, financial institutions will be encouraged to help their lending counterparts address climate change and create business opportunities. A guidance will be developed by supervisor to encourage financial institutions to manage their own risks related to climate change.

In addition, the role of regional finance is important from the perspective of promoting the decarbonization of each region in Japan, where the focus is on indirect finance. In order to link the decarbonization of the region to the creation of a virtuous cycle between the economy and the environment in the region, the government of Japan should set out a clear vision for the region and promote ESG finance by focusing on the impact of ESG finance on the environment, economy, and society by cooperating with leading regional financial institutions, providing them with information, sharing know-how, and promoting the creation of models for building businesses that make use of regional resources and solving regional problems.

(4) Regulatory reform and standardization

With regard to innovative technologies, etc., which will be the key to future growth, after the "demonstration phase," which will be promoted through public-private cooperative investment based on the premise of inducing private sector investment, domestic regulations and systems will be improved by (1) strengthening regulations so as to create demand for new technologies, and (2) rationalizing regulations that were not designed for new technologies. In addition, as the competition to formulate international rules on global warming countermeasures becomes increasingly fierce, Japan will (3) actively work on international standardization and other measures to facilitate the use of new technologies worldwide, thereby creating an environment in which Japan's interests and social circumstances are reflected in international rules and Japan's excellent new technologies are properly evaluated. This institutional environment in Japan and abroad will increase demand and green investment for these products, and lead to mass production and price reductions.

1) Regulatory Reform

<Specific initiatives (examples)>

(i) Hydrogen

- Obligate electricity retailers to procure carbon-free power source at no less than a certain percentage, and utilize carbon-free value trading markets. Along with renewable energy and nuclear power, we will evaluate hydrogen and ammonia as carbon-free power sources, and develop an electricity market where incentives can be received if hydrogen and ammonia are used.
- From the viewpoint of reducing the burden on business operators and users to expand the use of fuel cell vehicles, the government will study the state of regulations for fuel cell vehicles, with a view to unifying the related regulations in the "Road Vehicles Act" and the "High Pressure Gas Safety Act", and will compile certain directions in June 2021 and reach a conclusion by the end of this year.

(ii) Offshore wind power

- Promote the technological development necessary for the nationwide deployment to local grids, etc., of a system that allows more renewable energy to be connected to the grid on the condition that the output is partially reduced when renewable energy is generated beyond the available capacity of the grid. In addition, studies will be conducted to begin applying rules that allow renewable energy to use the power grid in preference to coal-fired power, etc.
- To reduce the burden on businesses and shorten the examination period, the examinations by the Ministry of Economy, Trade and Industry ("Electricity Business Law") and the Ministry of Land, Infrastructure, Transport and Tourism ("Port Law" and "Ship Safety Law") will be unified from April 2021. In addition, with regard to the safety review by the Ministry of Economy, Trade and Industry ("the Electricity Business Act"), from the same month, the percentage of equipment types that do not require detailed verification by experts under certain conditions was significantly increased to streamline the procedures.

- As for clarifying the criteria for permission to abandon the fixed-bottom offshore wind turbines based on the "Law Concerning the Prevention of Marine Pollution and Marine Disaster", a study group comprised of experts will be held from fiscal 2021, and an explanatory note will be presented by the first half of the same year.
- In March 2021, a committee consisting of academics, operators, wind turbine installers, and aviation authorities was established to study the relaxation of standards for the installation of aviation obstacle lights on offshore wind turbines under the "Civil Aeronautics Act". The mitigation measures will be finalized by the end of FY2021, and the standards will be promptly revised.

(iii) Automobile and battery

- Using technology-neutral fuel economy regulations, we will combine all technologies to effectively reduce CO_2 emissions.
- Consideration will be given by fiscal 2021 to the institutional framework for making CO_2 emissions visible throughout the life cycle of storage batteries, ensuring the ethical procurement of materials, and promoting reuse and recycling, etc., and the implementation methods for making CO_2 emissions visible, etc., will be put into practice as soon as possible.

(iv) Housing and buildings

- Strengthen regulatory measures, such as requiring compliance with energy conservation standards, including for housing.
- The system to promote the introduction of renewable energy such as photovoltaic power generation will be developed with an eye to the development of next-generation photovoltaic cells that can be installed in (1) existing houses and buildings with small roof load-bearing capacity and (2) walls and windows of houses and buildings, which are difficult to install with existing photovoltaic cells due to technical limitations.

(v) Shipping industry

- The government is striving to develop international regulations to improve energy efficiency of ships so as to promote the replacement of old inefficient ships with new greener ships. The government drafted and co-sponsored a joint-proposal to the International Maritime Organization (IMO) on the mandatory energy efficiency requirements on existing ships, consisting of the energy efficiency existing ship index (EEXI) and the annual operational carbon intensity indicator rating (CII rating), which was approved in November 2020, and aims for the early implementation from 2023. The early implementation of the EEXI and CII rating will require existing ships to achieve the same level of energy efficiency performance with new greener ships, and will incentivize replacement of old inefficient ships with new greener ships.

(vi) Logistics, human flow, and civil engineering infrastructure

- By FY2025, the standards for the installation of road lighting facilities, etc. will be reviewed to promote the introduction of new road lighting that can further reduce energy consumption.

(vii) Carbon recycling

- When reducing the cost of plastic production by artificial photosynthesis by about 20% by 2030, it is necessary to consider the related regulations to optimally promote the large-scale demonstration and social implementation of artificial photosynthesis, while also considering the safety assurance in a series of processes from the generation of low-pressure gas mixed with hydrogen and oxygen by photocatalyst to the separation and recovery of hydrogen and oxygen.
- In order to prevent Japan from losing its competitive edge due to delays in establishing technologies and implementing them in society, we will work on formulating new safety and security standards with foresight while anticipating future technological trends, and on complying with the "High Pressure Gas Safety Act" and other related regulations.

2) Standardization

When moving from the research and development stage to the social implementation stage, it is extremely important not only to develop a technology-driven market, but also to establish and deploy technology-related standards domestically and internationally in order to implement new technologies in society as quickly as possible and to promote and disseminate innovative technologies toward Carbon Neutrality on a global scale. In other words, in order not to make the same mistake as in the past of "winning in technology but losing in the market," it is extremely important to strategically promote standardization while being aware of the expected path to market acquisition for technologies, products, and services.

On the other hand, for companies that inevitably have to secure short-term performance, it is difficult to understand the necessity of forming rules that will be effective over the medium to long term. In addition, as the external environment surrounding companies is undergoing major changes, collaboration with a wider range of stakeholders is becoming more important, as represented by ESG (Environmental, Social and Governance), in which medium- to long-term business expansion and corporate sustainability are positioned as axes of value assessment, but the importance of this is not necessarily understood by companies, and effective initiatives have not yet been implemented. As a result, many companies have fallen into the difficult situation of being able to create technology but not a market.

In order to get out of this situation, it is necessary not only to create products and services that contribute to solving problems through research and development and external collaboration, but also to formulate rules that aim to build a social and economic system in which the products and services developed are appropriately supplied and accepted as value by specifically highlighting the social significance of the problems to be solved and involving various stakeholders including the social sector and the public sector.

From this perspective, in April 2021, we developed and released the "Market Formation Potential Index Ver. 1.0" as an objective indicator of market formation potential (potential ability to create and expand markets) of individual projects in order to objectively assess the status of efforts to create markets led by medium- to long-term, cross-market rule formation. The index consists of "capability to envision an agenda," "capability to solve social challenges," and "capability to develop rules," and measures, respectively, "the capability to set an agenda that stakeholders can relate to and design a story that forms a market where solutions to inherent social challenges are valued," "the capability to solve social issues using the company's own resources and external collaboration (including human resources and know-how)," and "the capability to develop the rules necessary for market formation by involving stakeholders.

By applying this to projects for Carbon Neutrality, we will encourage rule-making driven market creation and strategic standardization for the realization of Carbon Neutrality and market development of new technologies. Furthermore, in order to support these activities, we will continue our efforts to raise the level of Japan's rule-making capability itself, by fostering human resources that implement rule-making and standardization activities, and promoting the active participation of Japanese personnel in international rule-making and standardization discussions. In addition, the development of an index that enables the evaluation of market-making power on a company-by-company basis will be studied by the end of fiscal 2021.

Apart from this, standardization has the following objectives: (i) to expand the market by opening up technical information on elements that should be common, (ii) to aim at market formation and differentiation as a "yardstick" for legitimate evaluation of products, technologies, etc., and (iii) to serve as a basis for regulations and standards concerning safety, security, convenience, and environmental impact. With these objectives in mind, we will continue to promote standardization with an eye to market formation in each field.

(i) Standardization that expands the market by opening up technical information on elements that should be common.

- In order to capture the hydrogen-related market, which is estimated to be 270 trillion yen[13] in 2050, we will study the standardization of hydrogen filling methods for large-scale mobility, equipment necessary for transporting liquefied hydrogen such as loading arms, and methods for measuring CO_2 emissions during hydrogen production, which are necessary for establishing an internationally consistent definition of clean hydrogen.
- In the fuel ammonia market, which is expected to be worth about 500 billion yen if 10% of the coal-fired power plants in Southeast Asia are equipped with fuel ammonia co-firing technology, we aim to take the initiative in the global supply and utilization industry by establishing international standards for fuel specifications and nitrogen oxide emission standards during combustion.
- In order to establish the standard evaluation technology for CO_2 separation and recovery with a view to a wide range of applications and to accelerate the deployment of Japanese technology in Japan and overseas, international standardization will be considered.
- The development and standardization of wooden building materials and construction methods that contribute to using wood for construction of high-rise buildings will be promoted.

---

[13] Hydrogen Council “Hydrogen Scaling up" (Hydrogen market is estimated to be $2.5 trillion in 2050).

(ii) Standardization, which aims at market formation and differentiation as a "measure" to evaluate products and technologies legitimately.

- In order to promote the reuse of on-board storage batteries and their reuse as low-cost stationary batteries, international standardization of methods for evaluating the residual performance of storage battery packs and the performance and safety of stationary energy storage systems including reused storage batteries will be conducted, and international rules and standards for promoting reuse will be promoted.
- The development and JIS certification of performance indicators and performance labels for household storage batteries, including safety after degradation will be promoted.
- Through activities such as the ISO certification of ZEB, further demonstrations and horizontal development of ZEB will be promoted for overseas deployment with ASEAN and other countries in mind.
- Standardization of performance evaluation for next-generation solar cells will be promoted with an eye to capturing overseas markets.

(iii) Standardization as a basis for safety and security, etc.

- We are working on the international standardization of safety evaluation methods for floating offshore wind turbines, which are considered to be an emerging field in the world.
- The convenience of EV recharging will be improved by promoting the installation of information signs on main roads in areas where EV recharging facilities are scarce.

While open strategies such as standardization have the effect of expanding the market by publicizing and disseminating technical information, they also induce intensification of competition due to an increase in new entrants based on technical information, etc. Naturally, it is a prerequisite that companies have a closed strategy as a counterpart. In order to secure a sustainable advantage in the market that has been formed, core competencies will be identified and companies will be informed of the importance of a closed strategy through black boxing, utilization of intellectual property rights, and concentrated investment of R&D resources, etc. In the unlikely event that a company does not have a closed strategy, it will be encouraged it to establish one.

3) Economic methods that use market mechanisms (e.g., carbon pricing)

As for economic instruments that use market mechanisms, such as carbon pricing, we will introduce without hesitation those that contribute to growth, so as to strengthen industrial competitiveness and promote innovation and investment. Under the Prime Minister's direction, the Ministry of Economy, Trade and Industry (METI) and the Ministry of the Environment (MOE) will collaborate in the study. The study will be conducted from the perspective of whether the system can be designed in accordance with the objectives of the Growth Strategy and setting an appropriate time frame that takes into account the status of macroeconomic and climate change measures and the development of alternative technologies for decarbonization.

In addition, in light of the growing corporate demand for credits with carbon reduction value, such as J-credits and Non-fossil Fuel Energy Certificates, we will first review the existing systems for these credits and promote voluntary and market-based carbon pricing. In terms of carbon taxes and emissions trading systems, we will proceed with specialized and technical discussions on whether it is possible to design a system that will promote investment and contribute to growth in terms of both price signaling and revenue generation, while taking into account the added cost borne by companies. In doing so, it is necessary to have specialized and technical discussions based on international trends and the situation in Japan, including the fact that many companies are willing to decarbonize, the efforts of leading local governments, and the impact on the international competitiveness of industry including the impact on corporate R&D and capital investment.

(i) Carbon Credit Trading

While emissions trading systems, in which the government sets the upper limit, has advantages such as progress in reducing total CO_2 emissions, depending on the design of the system, there are issues such as how to allocate emissions based on economic growth, and we will continue to discuss these issues in an expert and technical manner.

With regard to voluntary carbon credit trading, Japan is also considering further strengthening the trading market for carbon-free value and the trading market for J-credits, after requiring retail electricity utilities to procure carbon-free power sources above a certain ratio, in line with the movement of private companies to procure carbon-free electricity to attract ESG investment. Specifically:

(1) Consideration will be given to adding hydrogen and ammonia to the list of items pertaining to carbon-free value, in addition to renewable energy and nuclear power.

(2) Consideration will be given to reviewing the nature of the trading market to make it easier for end users, including manufacturers of automobiles and semiconductors, to procure carbon-free value. In March 2021, the Ministry of Economy, Trade and Industry (METI) proposed the creation of a new market for trading the value of renewable energy in a way that allows consumers to participate in market transactions, and will continue to study the issue.

(3) J-Credit Scheme will be expanded while ensuring quality through the introduction of energy-saving and renewable energy facilities by forest management and plantation-derived and small- and medium-sized enterprises, promotion of environmental value credits associated with subsidized projects by the government, etc., and consideration of creating credits with new technologies such as hydrogen, ammonia, CCUS/carbon recycling, etc. In addition, demand will be expanded by allowing their use for offset by companies, governments, and municipalities.

(4) Promotion of digitization to ensure the permanence and convenience of J-Credit Scheme, collaboration with other similar systems such as non-fossil certificates, and consideration of the improvement of the system environment such as through collaboration with local governments.

(ii) Carbon tax

A carbon tax has the advantage of being highly predictable in terms of its impact on business activities, since the price is fixed uniformly. On the other hand, there are issues such as the relationship with the purpose of the Growth Strategy, which is to encourage companies to invest using their cash and deposits, and the uncertainty of the effect of emission reduction. We will continue to discuss the issue professionally and technically, taking into account the burden of the "tax for global warming countermeasures" that Japan has already introduced, other energy taxes, and the FIT levy.

(iii) Carbon border adjustment measures

Carbon border adjustment measures are being considered in Europe with a view to preventing international carbon leakage.

In order to ensure fairness in international competition in trade with countries that are reluctant to take measures to combat global warming, particularly in high emission industries, and to prevent carbon leakage, we will continue to consider necessary measures based on the following "Basic thinking on to carbon border adjustment measures", while closely monitoring trends in Europe, the United States and other countries.

<Basic thinking on carbon border adjustment measures>

- The objective of a carbon border adjustment measure is to offset the competitive disadvantages resulting from differences in the intensity of climate change countermeasures adopted domestically by different countries, and therefore to avoid carbon leakage. It could be a charge on imports at the border based on carbon emissions, rebate on exports for the charged cost, or both.
- Japan’s basic approach is to encourage international community, including major emitting countries and emerging countries, to reduce their emissions through dialogue. Therefore, the introduction of a carbon border adjustment measures should not be an objective in itself, but carbon border adjustment measures should be designed to achieve its objective of preventing carbon leakage with the least effect on trade, and to provide other countries, including emerging countries with an incentive to implement more effective climate change countermeasures.
- Japan will work on the following actions in relation to carbon border adjustment measures, paying close attention to the discussions and considerations among other countries, and in parallel to the domestic discussion on carbon pricing that contributes to growth.
    (1) Consider possible actions on carbon border adjustment measures with close attention to discussion taking place in other countries, with a prerequisite that the carbon border adjustment measures are designed to be consistent with WTO rules.
    (2) Lead the development and application of global rule on measurement/evaluation methods for carbon emissions per product unit that are internationally reliable (i.e., establishment of ISO standard) and that are balanced in terms of both accuracy and feasibility. In addition, transparency of relevant data that is in the possession of each country must be ensured.
    (3) Verify carbon costs that are associated with a product that is subject to a carbon border adjustment measures in Japan, and countries that implement it.
    (4) Address whether the introduction of carbon border adjustment measures is appropriate

and how carbon border adjustment measures should be designed in cooperation with like-minded countries in the perspective of preventing carbon leakage and ensuring fair competitive conditions.

(5) International cooperation

The viewpoint of integrated internal and external industrial policies is essential in promoting the development and social implementation of innovative technology toward the realization of the 2050 Carbon Neutrality. The Japanese government will strengthen the competitiveness of Japanese industry through cost reduction taking advantage of the scale merit, by acquiring not only the domestic markets but also overseas markets, in emerging countries in particular. At the same time, we will incorporate foreign capital, technology, sales channels, management through direct investment in Japan, domestic and foreign cooperation, and M&A. In order to achieve sustainable growth through such efforts, it is necessary for Japan to lead the discussion in international cooperation and multilateral as well as bilateral international negotiations by actively proposing rule-making and the formulation of standards and criteria.

Specifically, the Japan Innovation Bridge (J-Bridge), a platform for collaboration and M&A between Japanese and foreign companies, will be used to promote collaboration between European and U.S. companies that have strengths in Carbon Neutrality, such as in the field of offshore wind power, and Japanese companies in order to strengthen the competitiveness of Japanese companies. In doing so, we will collaborate with local governments to build on the strengths of the region. We will also seize opportunities for the rapid progress of the creation of new markets in ASEAN members and other regions to promote cooperation with local companies by promoting collaboration with Japanese companies with technological capabilities related to decarbonization.

In addition, while collaborating with other countries in innovation and technology development in prioritized areas, etc., the government will promote social implementation by carrying out overseas demonstration projects with a view to social implementation and market acquisition, supporting the structuring of overseas infrastructure projects that utilize the technologies of Japanese companies, considering the enhancement and improvement of the operation of "Environmental Innovation Insurance" as part of the functional enhancement of trade insurance ("LEAD Initiative"), and fostering local industry and government officials, etc., who are responsible for the overseas dissemination of the technologies and know-how of Japanese companies and Japanese systems (standards, criteria, etc.). In addition, we will actively participate in the development of international rules as well as in the development of standards and criteria, including in market mechanisms, standards for information disclosure and evaluation in financial markets, and credit transfers under the Paris Agreement.

1) Cooperation with major countries

With the United States, Europe, and other countries, we will work on collaborating on innovation policy, promoting individual projects in prioritized areas, including support for decarbonization efforts in third countries, including emerging countries, standardization of elemental technologies in priority fields, and rule-making for the removal of trade barriers.

In addition, with emerging Asian countries and other countries, that are particularly important from the perspective of promoting global decarbonization, it is necessary to encourage their commitment to decarbonization with a more realistic approach, taking into account that emerging Asian countries have greater social and economic constraints than developed countries, in cooperation with international organizations such as the International Energy Agency (IEA) and the Economic Research Institute for ASEAN and EAST ASIA (ERIA). From this perspective, based on the concept of "all energy sources, all fuels" advocated by the IEA, a wide range of solutions for decarbonization will be presented, including not only renewable energy, but also CO_2 capture, nuclear power, hydrogen, biofuels, ammonia-hydrogen co-firing/extractive firing using existing infrastructure, and decarbonization of fossil fuels, including finance, technology, and human resources cooperation. In addition, from the viewpoint of market acquisition, the government will promote bilateral and multilateral cooperation.

Specifically, the following initiatives will be promoted.

(i) Based on the U.S.-Japan Joint Statement "U.S.-Japan Global Partnership in a New Era" Cooperation

In the "U.S.-Japan Competitiveness and Resilience (Core) Partnership" and the "U.S.-Japan Climate Partnership on Ambition, Decarbonization, and Clean Energy" launched at the U.S.-Japan Summit in April 2021, Japan and the United States confirmed their commitment to address climate change and promote green and sustainable global growth and recovery by fully leveraging the technological capabilities of both countries in clean energy and other related fields.

- Collaboration and support for innovation, development, and dissemination of clean energy technologies, including renewable energy and energy-saving technologies, next-generation grids, energy storage (storage batteries, long-term storage technologies, etc.), smart grids, hydrogen, CCUS/carbon recycling, decarbonization in industry, and innovative nuclear power.
- Promotion of the development and use of infrastructure that takes into account and adapts to climate change and the environment in relation to power system optimization, demand response, smart grids, renewable energy and energy conservation.
- Cooperation on ICT technologies (e.g. smart cities, energy-saving ICT infrastructure, digital solutions for infrastructure management), carbon neutral ports and other areas that contribute to climate change mitigation, clean energy and green growth and recovery, including sustainable and climate-friendly agriculture
- Supporting developing countries, including countries in the Indo-Pacific region, through the newly established U.S.-Japan Clean Energy Partnership (JUCEP) and other activities undertaken at the national level in partnership between the two countries in the areas of climate change and clean energy, in order to rapidly deploy renewable energy, decarbonize economies, and accelerate a diverse, ambitious, and realistic transition pathway in the region toward achieving virtually zero global emissions by 2050

(ii) Accelerating the "energy transition" in Asia and other emerging countries

In order to achieve global carbon neutrality, we will support the voluntary efforts made by developing countries, especially emerging countries in Asia, to accelerate their efforts to make realistic transitions toward carbon neutrality, while securing stable supplies of energy resources and achieving sustainable economic growth.

Specifically, promote the "Asia Energy Transition Initiative (AETI)," which is a package of the following supports:

(1) Formulate a roadmap for energy transition based on the needs and actual conditions of each country
(2) Formulate and disseminate an Asian version of the concept of transition finance
(3) Provide 10 billion dollars to individual projects
(4) Utilize the results of R&D and demonstrations by the Green Innovation Fund
(5) Provide humans resource development on decarbonization technology for 1,000 people
(6) Share knowledge on CCS in Asia through the Asia CCUS Network, etc.

In addition, we will expand the scope of these assistance programs to include not only Asia, but also other emerging economies, and promote cooperation with the United States, Canada, Australia, Middle Eastern countries, and other countries to increase the depth of the assistance package.

(iii) Cooperation based on the "Japan - EU Green Alliance Summit Statement"

The "Japan - EU Green Alliance" was launched at the Japan - EU Summit in May 2021. To achieve green growth and net-zero greenhouse gas emissions by 2050, both sides aim to create climate neutral, biodiversity-friendly, resource efficient economies. The Japan and EU will also cooperate, with a view to successes of COP26 on climate change and COP15 on biodiversity in 2021 and beyond. Specifically, cooperation is envisioned in the following areas

(1) Energy Transition: Technical cooperation on renewable energy, storage batteries, hydrogen, CCUS/carbon recycling, nuclear power, etc.
(2) Environmental Protection: Improvement of resource recycling efficiency and conservation of biodiversity
(3) Private Sector: Promotion of policies that contribute to corporate climate change countermeasures and environmental considerations
(4) Research and Development: Research and development of low-carbon technologies and social implementation
(5) Sustainable Finance: Cooperation to promote sustainable finance
(6) Cooperation in Third Countries: Facilitating cooperation on the transition to climate-neutral and resilient societies in developing countries
(7) Fair Climate Change Action: Development of international rules that give due recognition to Japan - EU initiatives, and joint efforts to reach out to major emerging economies

(iv) Japanese Proposal on "Trade and Climate Change"

In order to achieve Carbon Neutrality throughout the world, including Japan, it is necessary to not only utilize existing products and technologies, but also to develop and globally disseminate excellent and innovative products and technologies that contribute to emission reductions. This will require measures such as the removal of trade barriers, if any, and international rule-making will become increasingly important. Based on this idea, in order for Japan to take the lead in international rule-making toward global Carbon Neutrality, Japan proposed the elimination of tariffs on products that contribute to climate change measures and the creation of rules on regulatory aspects, etc., at the ministerial-level meeting of a small number of voluntary countries of the World Trade Organization (Ottawa Group Ministerial Meeting) in March 2021.

The proposal, on "Trade and Climate Change"

(1) Elimination of tariffs on goods in which technologies that directly contribute to decarbonization are used (environmental goods), such as hydrogen-related products
(2) Strengthening the discipline of export controls on "environmental goods" and their components and raw materials, and establishing rules on regulatory aspects such as harmonization of domestic regulations with international standards
(3) Implementing capacity building in developing countries

The proposal consists of the three pillars above. We will first discuss the issues with interested countries in preparation for the WTO's 12th Ministerial Conference scheduled in November-December 2021.

2) International dissemination and cooperation through “Tokyo Beyond-Zero Week”

Based on these domestic and international trends, the "Tokyo Beyond Zero Week" will concentrate on holding international conferences related to energy and the environment, bringing together experts and leaders from around the world who are leaders in their respective countries and fields, and promoting the dissemination to the world of Japan's growth strategy for realizing a "virtuous cycle between the economy and the environment" toward the realization of Carbon Neutrality (ICEF), promoting cooperation among leading-edge research institutions (RD20), and creating an environment for mobilizing funds to support the realization of innovation and transitions (TCFD Summit). In addition, the government will utilize it as a platform for leading international discussions and cooperation in prioritized industrial areas, such as hydrogen, Carbon Recycling, and decarbonization of fossil fuel.

(6) Promotion of university initiatives toward the year 2050, etc.

1) Toward the development of an education and research system that contributes to Carbon Neutrality

In order to realize a carbon-neutral society in 2050, it is important to develop an environment for human resource development and research and development at universities. Such human resource development needs to be carried out promptly, without waiting for 2050, and it is necessary to immediately start improving the environment for this purpose, including for those who are already enrolled in universities.

In particular, it is necessary that the required human resources are matched with university departments.[14] Specifically, given the drastic changes in society, such as Carbon Neutrality in 2050 or the major trend of digitalization that is currently underway, universities are required to develop human resources that can respond flexibly to the needs of students and society.

For example, it is necessary to develop university faculties, departments, curricula, and resources that contribute to the realization of a carbon-neutral society by promoting education and research across and in cooperation with undergraduate and graduate schools, such as by establishing degree programs that contribute to Carbon Neutrality, and by creating leading initiatives that utilize the limited and exceptional capacity increase of regional national universities. In addition, in order to respond to the major social change of realizing a carbon-neutral society, it is also important to relearn for career advancement and career change, and it is necessary to accelerate recurrent education related to Carbon Neutrality through the enhancement of the certificate of completion system in graduate schools, the expansion of credit recognition before enrollment, the shortening of the period of enrollment, and the use of online classes. At this time, in developing human resources for the realization of a sustainable society, including Carbon Neutrality, it is necessary to have cross-disciplinary knowledge pertaining to what elements are necessary, not only in science fields, and related ministries and agencies will collaborate to promote discussions among universities and other institutions.

In addition, from the perspective of contributing to the realization of a carbon-neutral society, it is necessary to enhance education on global environmental issues from the elementary and secondary education levels so that students, who are expected to be the builders of a sustainable society, can deepen their understanding of environmental issues and take action to protect the environment. In schools, it is important to promote inquiry-based learning such as STEAM education, in which students integratedly apply what they have learned in each subject to issues in real life and society such as global environmental problems, while utilizing the infrastructure of the GIGA School Program.

2) University and Local Communities

---

[14] For example, the increase in the number of college students during 1960-70 was about 120%. On the other hand, the rate of increase in the number of students in the field of engineering was about 210% amid the industrial development during the period of rapid economic growth (Ministry of Education, Culture, Sports, Science and Technology, "Monbukagakusho Statistical Handbook", 2020 edition).

In order to achieve Carbon Neutrality by 2050, it is necessary to promote cross-disciplinary research and development from the humanities and social sciences to the natural sciences from the perspective of creating and disseminating knowledge for the transformation of the nation and the region, as well as to promote cooperation between universities and local communities, and to strengthen the function of universities and other institutions as "centers of knowledge" in the region. To this end, the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Ministry of Economy, Trade and Industry (METI), and the Ministry of the Environment (MOE) have established the " University Coalition for Carbon Neutrality 2050" [15] to promote the social implementation of knowledge and technology toward Carbon Neutrality through the horizontal development and discussion of advanced initiatives and research results in cooperation with local communities and human resource development.

In addition, in order to return the results of university research, etc. that contribute to Carbon Neutrality to society, designated national university corporations will be encouraged to utilize investments in university-launched ventures.

At the same time, for small- and medium-sized companies in the region, it is essential to secure human resources with regard to addressing social issues such as Carbon Neutrality. In this regard, the role of universities as human resource hubs in each region is significant. Therefore, a network of several universities and companies will be formed to promote human resource development and research and development in the region to achieve Carbon Neutrality. In addition, we will widely collect information on internship initiatives at universities and other institutions that contribute to the development of carbon-neutral human resources through collaboration with the University Coalition, etc., and promote horizontal development.

3) Study of analysis methods of economic ripple effects, etc.

For example, it is important to be able to show the positive and negative economic effects and the economic ripple effects of the increase in the number of new products in order to plan and propose policies at the national and local levels, universities, and research institutes toward Carbon Neutrality in 2050, and to verify the effects of these policies.

Therefore, in order to realize sufficient verification of the effects of policy planning toward Carbon Neutrality, studies will be conducted in cooperation with the relevant government ministries and agencies to identify item groups that contribute to Carbon Neutrality and to establish analysis methods, including the possibility of reflecting the results in the Input-Output Table[16], which can

---

[15] This is an inter-university network for universities to further contribute to the achievement of Carbon Neutrality by strengthening cooperation with the national government, local governments, businesses, and universities in Japan and overseas, and by enhancing their functions and communication capabilities related to the promotion of research and development and social implementation that contribute to the decarbonization of the nation and regions, and the zero-carbonization of regions and campuses. It is scheduled to launch in the summer of 2021.

[16] Over the next few years, we expect to see a significant acceleration of corporate activity in each of these areas, which will lead to changes in the items that contribute to Carbon Neutrality. Furthermore, taking into account the fact that, for example, the Input-Output table covers about 200 items in the integrated sub-categories and requires surveys on a multi-year basis, and that the estimation method for economic statistics, including the Input-Output table, is scheduled to be changed in the future as part of the review of government-wide statistics, we will proceed with the study, assuming, for example, the introduction of carbon-neutral related product groups from the 2025 Input-Output table.

calculate economic ripple effects. In this way, for example, the setting of various parameters for multiple calculations will be carried out in a unified manner.

In addition, in order to achieve Carbon Neutrality, related ministries and agencies will collaborate in research and development of statistics (such as Green GDP (tentative name)) and indicators that take environmental factors into account, in line with the System of Environmental and Economic Accounts (SEEA), an international standard set by the United Nations, and research by international organizations.

(7) The 2025 World Exposition in Japan

In aiming to realize a carbon-neutral and decarbonized society in 2050, Japan's basic policy is to take advantage of the opportunities presented by the Expo 2025 Osaka, Kansai, Japan (hereinafter referred to as “the Expo”), and to use the opportunity presented by the Expo to drive co-creation by the international community in designing a sustainable society that makes individuals maximize their potential as an "advanced nation in problem solving".

In addition, as the Expo venue is positioned as "People's Living Lab (a testing field for future society)" where new technologies and systems are tested for demonstration, the expo site is designed to drive the innovation of diverse players to make the event work as a huge facilitation mechanism for social implementation

1) Demonstration of innovative technology

The waterfront area in Osaka City (Yumeshima), the site of the Expo, is well served by three major airports, several large ports, expressways, stations of bullet trains and other transportation infrastructure, making it an easily accessible location for domestic and international visitors. In addition, comprehensive disaster prevention measures have been taken.

At this time, collaboration with future projects adopted by the Green Innovation Fund will contribute to the promotion of efficient R&D not on an individual company basis, but for Japan as a whole. In particular, initiatives at international and citizen-participation events such as the Expo make it relatively easy to reflect the views of not only the supply side but also the users who will actually enjoy the fruits of innovation. It also meets the basic philosophy of the foundation, which is to take the entire process of social implementation into consideration. As of June 2021, the treatment of the following demonstrative initiatives under the Fund has not yet been determined, but the government will encourage the establishment of a mutually cooperative relationship, for example, by conducting a part of the demonstration at the Expo site.[17] Other demonstrative efforts shall also be implemented based on the same concept.

For example, we aim to demonstrate the following initiatives at the Expo site and other locations.

- As for the fuel ammonia industry, we will demonstrate ammonia power generation near the venue.
- In the area of the hydrogen industry and the shipping industry, we will demonstrate hydrogen power generation, supply CO_2-free electricity to the venue, and promote a hydrogen society by using hydrogen-derived energy in mobility vehicles that will be operated inside and outside the venue.
- In the area of the carbon recycling industry, technologies for capturing CO_2 and for generating synthetic methane from biomass-derived CO_2 generated from food waste will be demonstrated

---

[17] The "Basic Policy of the Green Innovation Fund Project" (March 12, 2021) states that "(3) To promote steady social implementation, we will promote development methods (agile development) that make use of user feedback to quickly change course by exchanging opinions with users who can use the results of R&D, providing prototypes to users, and exhibiting at international exhibitions (Expo 2025 Osaka, Kansai, Japan, etc.) without waiting for the completion of the project."

at the Expo site. In addition, the Expo site will be used to demonstrate the CO_2-absorbing concrete needed to improve its performance.

- In order to realize a carbon-neutral and decarbonized society in 2050, we will conduct demonstrations leading to negative emission technology (DACCS: Direct Air Carbon Capture and Storage).
- We will demonstrate prototypes of next-generation solar cells, such as perovskite at the Expo site.
- In the area of the resource recycling industry, we will demonstrate the recycling and recycling of biomass-derived biodegradable containers that can be used for serving and selling food and beverages.

2) Overall approach to the Expo

In addition to the demonstration of these innovative technologies, the pavilions and other facilities at the Expo site will actively promote exhibits and events with a strong awareness of the "vision of society in 2050," with a focus on Carbon Neutrality. As a whole, the Expo will present a theme of the Expo *"Designing Future Society for Our Lives"* for Japan and the world, with Carbon Neutrality as one of its axes.

As for the energy to be used at the site, we will promote the use of renewable energy sources such as next-generation solar cells, hydrogen and ammonia, as well as the use of CO_2-absorbing concrete and negative emission technology. In this way, the Expo will be used as a venue to demonstrate Japan's cutting-edge technologies that will lead to "Beyond Zero" urban development.

3) Dissemination of the initiatives and effects both domestically and internationally

The Expo is a project that is expected to welcome 28.2 million visitors from Japan and abroad during the six-month period. With regard to the Expo, Japan’s efforts regarding Carbon Neutrality, the opinions of visitors will certainly be sorted out, and including points for reflection, they will be disseminated both domestically and internationally in a form useful for social implementation.

In doing so, we will also focus on organizing the voices of the underage population, with a strong focus on the working-age population in 2050. At the same time, with an eye on the aging society of 2050, we are also conscious of the voice of convenience from the elderly. In providing these voices, we will try to make it simple and easy for people to provide their frank impressions.

This will also be the case for the demonstration of creative innovation technologies. The venue and areas around the venue, including the various pavilions, will be used to study mechanisms that will allow feedback from visitors while utilizing attractive designs and virtual technologies. In doing so, we aim to design the system in such a way that individual technologies do not exist in a scattered or independent manner, but as a whole, we can better feel and experience how they are connected to the larger goal of Carbon Neutrality.

(8) Youth WG on Green Growth

In order for our society to continue to develop toward the realization of Carbon Neutrality in 2050, it is also important to incorporate the opinions of the younger generation who will be working in 2050. Therefore, the Ministry of Economy, Trade and Industry (METI) established the "Youth WG on Green Growth[18]" to study the issues and policies to be addressed for Carbon Neutrality in 2050 from the perspective of young people, and compiled the report "To make it my business / Carbon Neutrality starting from empathy" in June 2021. The key points of the recommendations made in the report are as follows, and discussions by the younger generation will continue with the aim of realizing these policies.

1) Establishing new indicators of economic sustainability

Efforts toward Carbon Neutrality can be seen as a cost in the short term. In order to maintain long-term sustainability of efforts toward 2050, efforts toward Carbon Neutrality need to be evaluated relatively more highly than other efforts. It is also important to look at "what can be left for the future" to ensure future wellbeing.

The Youth WG discussed specific policies, such as Gross Domestic Sustainability (GDS), a new indicator that measures "total assets to be left in the future" as opposed to GDP, which measures "current gross productive capacity".

2) Visualization of actions toward Carbon Neutrality

In order to achieve Carbon Neutrality, it is important for each individual to think about Carbon Neutrality and take action, and it is important for each stakeholder to achieve behavioral change, regardless of whether they are interested in Carbon Neutrality or not.

The Youth WG discussed specific policies, such as visualization (presentation) of actions that contribute to Carbon Neutrality, systematic organization of initiatives that contribute to Carbon Neutrality from the consumer's perspective, and initiatives that encourage consumers to change their behavior, such as the granting of points for undertaking such initiatives.

3) Promotion of CO_2 visualization (life cycle assessment)

In order to properly evaluate each entity's efforts toward Carbon Neutrality, it is necessary to properly visualize the emission and reduction of CO_2 and the impact. It is important to look at the entire industry and supply chain, not just specific industries.

As specific policies, the Youth WG discussed the formulation of unified calculation rules and standards for evaluating CO_2 emissions, reductions, and impact, as well as incentivizing companies to disclose such information, including the establishment of a certification system for investors based on the visualized information.

---

[18] A private study group established by the Ministry of Economy, Trade and Industry in December 2020. The group consists of 76 young volunteers (average age: 30) from private companies, universities, research institutes, and government ministries.

4) Formulation of guidelines on cost sharing for transition to Carbon Neutrality

In order to encourage corporate efforts toward Carbon Neutrality, it is necessary to clarify the costs of such efforts and to share the costs appropriately within the supply chain, rather than having the costs borne by a single company alone.

Based on the awareness that it is necessary to present an overall image of costs and to list individual items (R&D, capital investment, nullification of R&D already conducted, etc.) when companies work on Carbon Neutrality, the Youth WG discussed the formulation of guidelines that summarize the image of specific costs, a model for investment plans, and the concept of cost sharing in the supply chain, etc., according to industry, region, business scale, etc., as specific policies.

5) Establishment of a carbon cycle process

It is important to establish a carbon cycle process based on CO_2 capture and recycling to ensure the survival and development of existing industries based on carbon resources, and to create new industries by recycling CO_2.

The Youth WG discussed specific policies, such as support for basic research on CO_2 capture and utilization technologies and adjustment of product prices using CO_2.

6) Human resource development

(i) Support for entrepreneurial talent

Startups are being called upon to play an active role in a variety of fields as leaders in the creation of innovation. In order to realize a carbon-neutral society in 2050, it is expected that a large number of start-ups will create innovations that contribute to the realization of carbon-neutrality through trial and error, because there is a high degree of uncertainty as to which technology will be the winner. On the other hand, in the environment-related startup ecosystem, there are issues such as:

- Difficulty to attract investment due to the relatively long period until commercialization
- Lack of information (precedent cases, environment-related technologies, investor trends, etc.)

Based on the awareness of the need to provide priority support for carbon-neutral start-up activities, the Youth WG discussed specific policies, such as support for the establishment of networks to link entrepreneurial human resources in the environmental field with a variety of related parties, including companies, universities, and government agencies, and the formulation of guidelines for the launch of new carbon-neutral businesses.

(ii) Support for the acquisition of knowledge on Carbon Neutrality

In order to steadily promote initiatives toward Carbon Neutrality, it is essential to have human resources to implement various initiatives. In the case of companies, in addition to the fact that R&D personnel and personnel involved in management are required to have knowledge of Carbon Neutrality, the entire workforce is also required to have at least some knowledge of Carbon Neutrality. Thus, it is necessary for various entities to acquire knowledge of Carbon Neutrality according to their roles, and to respond flexibly to the progress of efforts toward Carbon Neutrality.

The Youth WG discussed specific policies, such as recurrent education for working people, double majors in university education, and support for various human resources to acquire knowledge on Carbon Neutrality through reviewing the curricula in primary and secondary education.

4. “Action Plans” in key industrial fields

From the viewpoint of taking on the challenge of 2050 Carbon Neutrality as a growth strategy, the government shall establish “Action Plans” in the key industrial fields where future growth is expected, and efforts are essential to achieve 2050 Carbon Neutrality also from the viewpoint of reduction of greenhouse gas emissions.

From the fields of which market is expected to grow from their current status through 2030 to those to launch through 2050, 14 fields of different time axis are discussed.

These fields, namely, energy-related industries, transportation/manufacturing-related industries, household/office work-related industries and so on, are with different necessities from one to another, from those require actions in current “introduction and expansion phase” to others for future “research and development phase”. Considering characteristics of respective fields, the government intends to incorporate concrete measures, which will strengthen Japan’s international competitiveness and lead to autonomous market expansion.

Through the steady implementation of the action plans in these fields, the feasibility of a carbon-neutral society in 2050 will be enhanced year by year through the concerted efforts of the relevant ministries and agencies.

At this time, it is important to increase the certainty of the realization of the action plans in each field by mutually collaborating with the "Environment Innovation Strategy[19]", “Strategy for Sustainable Food Systems[20]", the "Semiconductor and Digital Industry Strategy[21]", the "Regional Decarbonization Roadmap[22]", and the "MLIT’s Green Challenge[23]", which focus on the creation of innovation and social implementation through innovative technologies while setting Carbon Neutrality as one of the goals.

---

[19] URL reference < https://www.kantei.go.jp/jp/singi/tougou-innovation/pdf/kankyousenryaku2020.pdf >

[20] In May 2021, the Ministry of Agriculture, Forestry and Fisheries (MAFF) compiled the "Strategy for Sustainable Food Systems" as a policy to strategically address the issues from a medium- to long-term perspective in order to achieve both improved productivity and sustainability of the food, agriculture, forestry and fisheries industries through innovation.
URL reference < https://www.maff.go.jp/j/kanbo/kankyo/seisaku/midori/index.html >

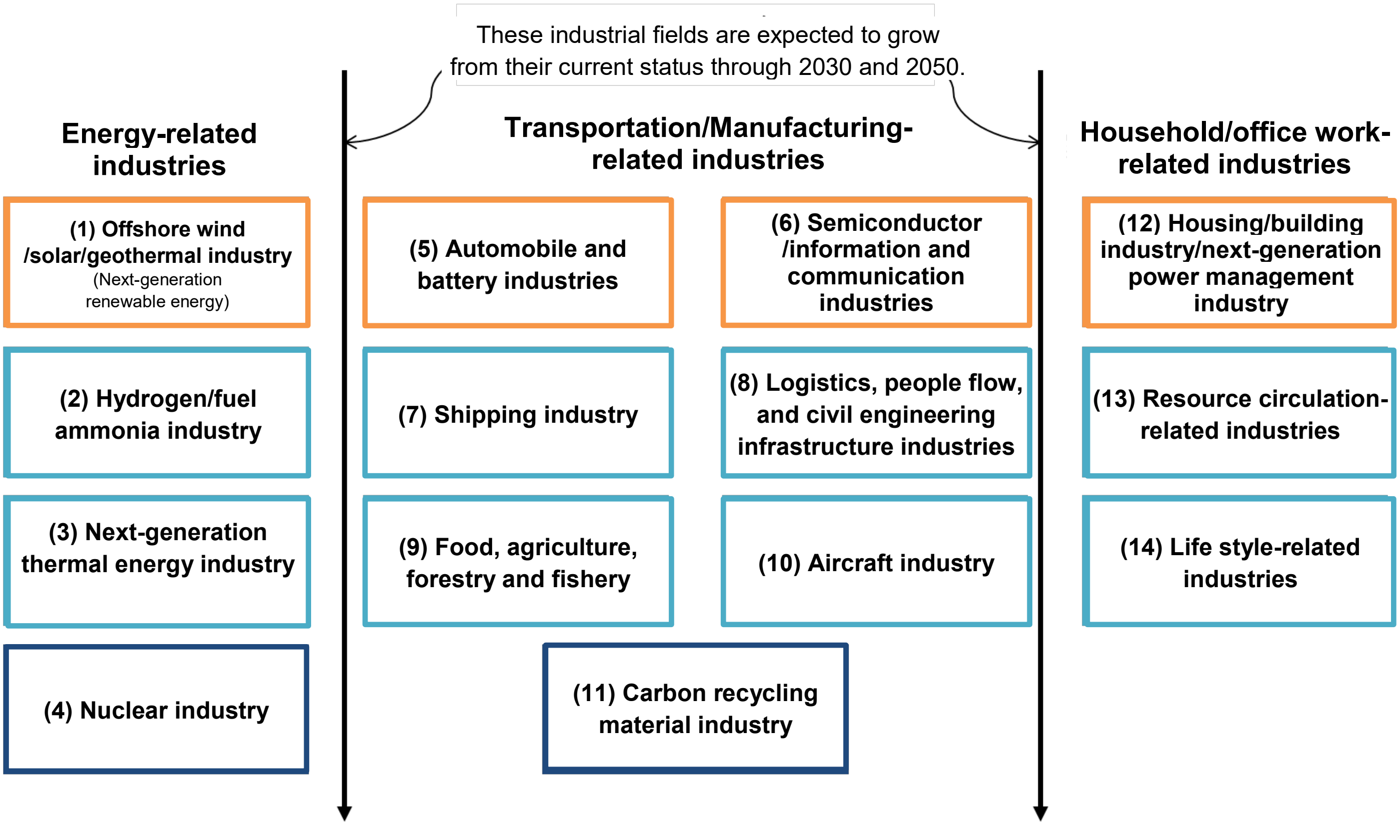
[21] The Ministry of Economy, Trade and Industry (METI) held the "Semiconductor and Digital Industry Strategy Review Conference" and compiled the "Strategy for Semiconductors and the Digital Industry" in June 2021, which consists of strengthening the competitiveness of semiconductors, strengthening and optimally allocating digital infrastructure such as data centers, and fostering digital industries that support the digital society. For details, please refer to "4(6) Semiconductor and Information Technology Industry".
URL reference < https://www.meti.go.jp/press/2021/06/20210604008/20210604008.html >

[22] The Council for National and Local Decarbonization discussed the roadmap for the realization of a decarbonized society in 2050 from the perspective of citizens and ordinary people, and the ways in which related ministries, agencies, and local governments should collaborate to realize the roadmap, with a particular focus on the fields of "livelihoods" and "society," which are closely related to local initiatives, with the aim of realizing a decarbonized society in 2050 through collaboration and co-creation between the national government and local governments.
URL reference < https://www.cas.go.jp/jp/seisaku/datsutanso/ >

[23] The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) will strategically promote cross-sectoral, public-private partnerships for decarbonization and adaptation measures in the field of livelihood, urban development, transportation, and infrastructure from FY2021, based on the "MLIT’s Green Challenge" to be compiled in the summer of 2021, with the aim of realizing a green society in national land, urban, and regional spheres.
URL reference < https://www.mlit.go.jp/policy/shingikai/s204_green.html >

In addition, the essence of Carbon Neutrality lies in the change of behavior of companies and people who change society. Behavioral change transforms "how to use" and "how to connect" technology, both on the provider and the user side of technology, resulting in a spiral of innovation. Therefore, we will promote the Green Growth Strategy and the action plans in each field with an awareness of the benefits to people's lives other than the decarbonization effect as a result of 2050 Carbon Neutrality.

(14 fields expected to grow)



These industrial fields are expected to grow from their current status through 2030 and 2050.

Energy-related industries

- (1) Offshore wind /solar/geothermal industry (Next-generation renewable energy)
- (2) Hydrogen/fuel ammonia industry
- (3) Next-generation thermal energy industry
- (4) Nuclear industry

Transportation/Manufacturing-related industries

- (5) Automobile and battery industries
- (6) Semiconductor /information and communication industries
- (7) Shipping industry
- (8) Logistics, people flow, and civil engineering infrastructure industries
- (9) Food, agriculture, forestry and fishery
- (10) Aircraft industry
- (11) Carbon recycling material industry

Household/office work-related industries

- (12) Housing/building industry/next-generation power management industry
- (13) Resource circulation-related industries
- (14) Life style-related industries

(1) Offshore wind, solar and geothermal industries (Next-generation renewable energy)

i) **Offshore wind power**

Given the feasibility of large-scale introduction and cost reductions as well as the anticipated economic ripple effects, offshore wind power generation holds the key to making renewable energy a main source of power. With a project scale of several tens of billions of yen and the number of pieces of equipment and parts totaling in the tens of thousands, the economic ripple effect on related industries will be significant.

It is important to make full-scale efforts to introduce offshore wind power in Japan from both an energy policy and industrial policy perspective while reducing costs by cultivating Japan's offshore wind power industry and strengthening competitiveness. It is also vital for the public and private sectors to work together to build strategies to capture growth markets in Asia in the future.

Therefore, firstly, the government commits to creating an attractive domestic offshore wind power market to attract domestic and foreign investment. On top of that, the government and the Industry will develop a competitive and resilient domestic supply chain by promoting investment through the establishment of business and other infrastructure. In addition, the government and the Industry will engage in next-generation technology development and international cooperation with an eye to expanding into Asia and create next-generation industries that can compete on the global stage.

Based on the first "Vision for the Offshore Wind Industry" (December 15, 2020), which outlines the direction of the industry as described above, the government and private sector will work together to promote initiatives through the "Public-Private Sector Council for Enhancing the Competitiveness of the Offshore Wind Industry".

1) Creation of attractive domestic market

<Current status and issues>

The global offshore wind market is growing steadily, and according to an analysis by an international organization, it is a growth industry with an expected investment of 562 GW worldwide (24 times the current level) and over 120 trillion yen by 2040.[24]

On the other hand, wind turbines are manufactured by foreign companies located mainly in USA, Europe and China. Especially in Europe, cost reductions have been made over the past decade through the enlargement of wind turbines and investment in mass wind turbine production while at the same time reducing transportation costs by building factories close to demand areas. Against this backdrop, there have been cases where companies have won bids to supply wind power at less than 10 yen/kWh or at market price (unsubsidized).

Meanwhile, the Asian offshore wind power market is expected to grow rapidly going forward, with Asia projected to account for 41% (96GW) of the global market in 2030.[25] This has spurred European and U.S. wind turbine manufacturers to enter the Asian market in earnest, while competition to attract industry players has begun across the region. In Japan, public tenders (four

---

[24] International Energy Agency (IEA) "Offshore Wind Outlook 2019" Sustainable Development Scenario (SDS)

[25] Global Wind Energy Council (GWEC) "Global Offshore Wind Report 2020"

sites, approximately 1.5 million kW) based on the "Law Concerning the Promotion of the Utilization of Marine Areas for the Development of Offshore Renewable Energy Power Generation Facilities (Renewable Energy Marine Area Utilization Law)" began in FY2020, and efforts are being made throughout the supply chain, mainly by power generation companies, to acquire projects.

In order to newly establish an offshore wind power supply chain in Japan, it is necessary to first attract investment from both Japan and overseas. The Industry has expressed the view that it is necessary to project the size of the market in order to make investment decisions. Therefore, the government will set clear introduction targets as well as promote efforts to realize them so that targets don’t just become a "pie in the sky.”

<Future efforts>

Firstly, to encourage domestic and foreign investment by committing to create an attractive domestic market, sets offshore wind power generation introduction targets (authorized capacity under the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities). Specifically, the government will continue to award capacity of 10GW by 2030 and 30-45GW, including floating offshore wind, by 2040.[26]

Secondly, based on Act on Promoting Utilization of Sea Areas for Renewable Energy Generation enforced in April 2019, project formation process will be steadily developed. In addition, considering the knowledge obtained by the enforcement, necessary improvements to expedite the project formation will be made. Moreover, the national government will systematically promote the establishment of power grids, ports and harbors, and other infrastructure necessary to realize the above offshore wind power capacity introduction targets. For example, regarding the securing of power grids, which has been a problem in terms of multiple grid operators securing the same grid, introduce a scheme whereby Government provisionally secures power grids necessary for project development. Specifically with regard to securing grids, which has been an issue due to the multiplicity of grid operators, the relevant rules will be improved during FY2021, including revisions of the guidelines and regulations of relevant organizations, in order to utilize the grid-securing scheme[27] for public solicitation. In addition, the Government will take the lead in promoting demonstration projects for wind surveys, seabed, and oceanographic surveys, etc., to promote the formation of projects.

Thirdly, the Government will systematically promote the establishment of power grids, ports and harbors, and other infrastructure necessary to realize the above offshore wind power capacity introduction targets. Based on the interim report compiled in May 2021, we aim to complete the master plan for grid development that will contribute to the realization of the introduction target by the end of FY2022. In addition, because the power transmission network that brings offshore wind

---

[26] In the "Action Plan" (Growth Strategy Council, December 1, 2020), it is stated that "Japan aims to create 30 million kW of construction-related demand by 2040, equivalent to 30 large thermal power plants," but the introduction target for 2040 has been raised in order to attract investment from industry to achieve Carbon Neutrality by 2050. However, in order to achieve 45 million kW, the cost of floating power plants needs to be significantly reduced through technological development and mass production.

[27] The GOJ will make a request to the Organization for the Promotion of Electric Power Industry-wide Operations regarding the provisional securing of grid capacity by general transmission and distribution companies for the purpose of designating promotion areas as stipulated in Article 8, paragraph 1 of the Act on Promoting Utilization of Sea Areas for Renewable Energy Generation.

power from suitable locations to areas of high demand is important, a study group on the development of long-distance submarine direct current transmission lines will be launched in March 2021 to form a detailed development plan for the introduction of such lines, including technical issues and costs. In addition, the government will promote the development of technology necessary for the nationwide deployment of local grids, etc., for a system that allows more renewable energy sources to be connected to grids on the condition that the output of renewable energy sources is partially reduced when they generate more electricity than the available capacity of the grid. At the same time, studies will be conducted to start applying rules that allow renewable energy sources to use the power grids with priority over coal-fired thermal power generation. As for the base port, the installation of wind turbines has been started by power generation companies using the Akita Port which has already been improved to strengthen the ground bearing capacity. As for the remaining three ports, we will continue to steadily proceed with construction work to strengthen the ground bearing capacity and other work necessary for the installation and maintenance of large wind turbines. In addition, a study group consisting of experts and related organizations will be established. The study group will examine the functions required of Japan's base ports in the future and measures to attract companies to coastal areas to revitalize local economies and create jobs, while taking into account the schedule for system development and designation of promotion areas and the trend toward larger wind turbines.

2) Promotion of investment and formation of supply chain

<Current status and issues>

From the perspective of stable power supply and economic ripple effects, it is important to establish a competitive and resilient supply chain, using the creation of a domestic market by Government as a catalyst for investment.

On the other hand, wind turbines are currently imported from overseas due to the absence of manufacturing sites in Japan, and the reality is that both the potential of domestic parts manufacturers with technical capabilities built up through their experience in onshore wind power and manufacturing sites in Japan, including generators, accelerators, bearings, carbon fiber for blades, are not being fully utilized.

Therefore, the Industry will promote the formation of a resilient supply chain by setting targets for Japan content. Government will strengthen industrial competitiveness by providing incentives for capital investment, promoting business partnerships in Japan and overseas, and improving the business environment through regulatory reforms. At the same time, the Industry, Government, and academia will work together to develop the human resources necessary for offshore wind power generation.

<Future efforts>

Firstly, for establishment of a competitive and resilient supply chain, The Industry sets two targets, namely, to increase Japan content to 60% by 2040, and to reduce cost of fixed-bottom offshore wind turbine-generated power to 8 to 9 yen/kWh by 2030-2035, and promote efforts to realize them.

Secondly, for creation of a supply chain, Government will evaluate the supply chain in public tenders, provide incentives for capital investment, and promote global business matching. Specifically, when assessing public occupancy plans related to the Act on Promoting Utilization of Sea Areas for Renewable Energy Generation, evaluate the formation of a resilient supply chain (domestic or equivalent) from the perspective of securing a stable power supply. We will also encourage capital investment in the construction of supply chains. Furthermore, we will promote business matching between Japanese and foreign companies through the Japan Innovation Bridge (J-Bridge), which is a platform for collaboration and M&A between Japanese and foreign companies, and take measures to secure raw materials such as rare earths, which are necessary for the manufacture of wind turbines, but on which Japan is highly dependent in certain countries.

Thirdly, to improve the business environment, Government will conduct a comprehensive assessment of the requested regulatory review items in cooperation with individual ministries. Among them, first of all, in order to reduce the burden on operators and shorten the examination period, the Ministry of Economy, Trade and Industry (METI) ("Electricity Business Act") and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) ("Ports and Harbors Act" and "Ship Safety Act") have integrated their examinations, which have been implemented since April 2021. In addition, the Ministry of Economy, Trade and Industry (the "Electricity Business Act") has streamlined its safety review procedures by significantly increasing the percentage of equipment types that do not require detailed verification by experts under certain conditions, starting in the same month. Furthermore, a study group comprised of experts will be held from fiscal 2021 to clarify the criteria for permission on the abandoning of fixed-bottom offshore wind turbines based on the "Law Concerning the Prevention of Marine Pollution and Marine Disaster", and an explanatory note will be presented by the first half of the same fiscal year. In March 2021, a committee consisting of academics, operators, wind turbine installers, and aviation authorities was established to study the relaxation of the standards for the installation of aviation obstacle lights on offshore wind turbines under the Civil Aeronautics Law. The committee will compile relaxation measures by the end of fiscal 2021 and promptly revise the standards. Moreover, the Industry will conduct a comprehensive review of the standards that need to be developed for the introduction of offshore wind power and will work with Government to develop highly necessary standards.

Fourthly, in order to ensure the long-term and stable penetration of offshore wind power, it is necessary to develop human resources in a wide range of fields, including engineers involved in the manufacture of wind turbines, survey and construction engineers, and maintenance workers. To achieve this end, the Industry will formulate a program for the development of offshore wind power human resources, which will include taking an inventory of the required skills and concrete measures for acquiring those skills. The program will promote the transfer and redeployment of engineers from different industries in the short term as well as the development of human resources over the mid to long term.

3) Next-generation technology development and cross-border collaboration with a view to expansion into Asia

<Current status and issues>

While enhancing competitiveness through development of the supply chain, it is important to aim for expansion into Asia in the future, where weather and sea conditions are similar, and the market is expected to grow.

Although introduction of offshore wind power currently in progress in the world is mainly of fixed-bottom offshore wind, there is a bigger chance for new players such as the shipbuilding industry with floating offshore wind, for which particularly intensified competition is expected in the future. It is necessary to accelerate the development of technologies and cultivate Japan’s competitiveness to play in the global market, while consistently looking ahead toward commercialization. At the same time, looking ahead to future expansion into Asia, Government and the Industry need to lay the groundwork with corporation through international standardization and bilateral dialogue

<Future efforts>

Firstly, the government will proceed with the next-generation technology development with a view to expansion into Asia. Based on the "Roadmap for Technology Development to Strengthen the Competitiveness of the Offshore Wind Industry," which was formulated in April 2021 to identify the elemental technologies needed to strengthen the competitiveness of the industry, we will accelerate the development of elemental technologies, especially for wind turbines, which are essential for building the supply chain, and for floating turbines, which are expected to expand in the medium to long term. In addition, with a view to conducting demonstrations in actual marine areas, the Green Innovation Fund will be used to support the development and demonstration of technologies over an extended period of time in an integrated manner, after obtaining commitments from companies.

Secondly, in anticipation of future expansion into the Asian market, Government will promote the building of cooperative inter-governmental relationships as well as cooperation among domestic and foreign companies through policy dialogue and international demonstration projects. Specifically, a workshop was launched in April 2021 through the Japan-EU Energy Policy Dialogue, a bilateral policy dialogue, to further deepen Japan-EU cooperation by fostering understanding on both sides of the issue on cooperation cases, certification and conformity assessments of technologies, and initiatives and issues related to offshore wind power, floating systems, etc. In addition, Government will provide supports to Japanese companies looking to participate in overseas offshore wind power projects in the areas of feasibility studies, demonstration, and finance. Furthermore, Government will work towards international standardization of methods to assess the safety of floating offshore wind. Through these initiatives and other efforts, Government will lay the groundwork for overseas deployment of floating offshore wind.

ii） Solar

The introduction of solar power has been expanding as a mainstay of renewable energy, with the world's largest amount of solar power installed per square meter of land area in Japan. In addition, as a distributed energy resource (DER) for self-consumption and local production for local consumption, it is expected to be used from the perspective of resilience, and further expansion of its introduction is essential to achieve Carbon Neutrality.

On the other hand, the amount of solar power installed was 7-8 GW per year when the FIT system was first introduced, and has remained around 5-6 GW per year since 2016, but the amount certified has dropped to 1.5 GW at present. This is thought to be the result of the efforts to optimize the industry by reducing the purchase price and strengthening business discipline, etc., in response to the rapid expansion that occurred when the industry as a whole was not yet mature after the introduction of the FIT system, but in the future, it will be essential to draw a picture of the industry's expansion based on this history.

At present, however, the global share of Japanese companies in solar module shipments has also declined significantly, falling to a share of 1.8% in 2019.

In light of these circumstances, in order to further expand the introduction of solar power, it is urgent to create a new market in the medium and long term through the development of technology for next-generation solar cells that can be installed in places where it is difficult to install existing silicon solar cells, which are the mainstream of the market, while aiming to expand the amount of solar cells introduced at present, based on the premise that the project is implemented by appropriate business operators in harmony with local communities.

Specifically, we will work to develop next-generation technologies, such as next-generation solar cells that can be installed in locations where existing solar cells are difficult to install due to technical limitations, and we will promote the expansion of the potential for using solar power. In addition, by promoting the improvement of the environment through the revitalization of related markets, etc., we will foster and restructure the industry, while securing suitable sites that can coexist with the region through the re-examination of various regulations and systems.

1) Development of next-generation technologies

<Current status and issues>

Although the price of existing solar cells has been reduced, there is a technical problem that installation is not easy in existing houses and buildings where the load-bearing capacity of the roof is low, or on the walls of houses and buildings. R&D of the next generation solar cells to overcome these technical problems is being pursued by various research institutes around the world. Specifically, Japan has achieved a conversion efficiency of 24.9% at the laboratory level, while Korea has achieved a conversion efficiency of 25.4% (the world's highest). As for modules, Japanese companies have achieved the world's highest conversion efficiency of 17.9%.

In the future, it will be important to develop new markets such as building wall surfaces (e.g., building material-integrated solar cells) by realizing performance that exceeds that of existing solar cells at the product level (e.g., conversion efficiency, durability, cost) and by developing technologies that meet the needs of end users (e.g., design).

In addition, the increase in the introduction of variable renewable energy sources such as photovoltaic power generation, combined with a decrease in thermal power generation, will lead to an increase in asynchronous power sources, so securing inertia and other measures will be necessary to stabilize the grid.

<Future efforts>

The government will thoroughly support the development of promising technologies such as Perovskites, and accelerate research and development for performance improvement. In particular, in order to put next-generation solar cells, which can be installed on walls with technical restrictions for existing solar cells, into practical use and create a new market, it will demonstrate the social implementation etc. of next-generation solar cells and related products.

Specifically, the Green Innovation Fund will be considered, and industry, academia, and government will cooperate to accelerate the development of common basic technologies related to perovskites, as well as to promote R&D by individual companies to achieve product-level performance. Furthermore, based on the results of the aforementioned R&D, we will develop products that take into account the needs of end-user companies and conduct demonstrations using prototypes of the developed products to accelerate the introduction of next-generation solar cells to the market.

Through these efforts, we will encourage the focus of R&D so that we can achieve a power generation cost of 14 yen/kWh under certain conditions by 2030 and move to the dissemination stage. In addition, we will promote the standardization of the performance evaluation of next-generation solar cells with a view to capturing overseas markets in conjunction with such R&D. It is predicted that a cumulative 4.4 TW of solar power will be installed globally by 2050, which would result in an annual global market size of approximately 10 trillion yen.[28] According to the New Energy and Industrial Technology Development Organization (NEDO), the market for next-generation solar cells is expected to account for 50% of the total photovoltaic market in 2050, and based on this assumption, the market for next-generation solar cells is expected to be approximately 5 trillion yen in 2050. The aim is to capture such global market share by promoting the development of the above-mentioned technologies at an early stage (assuming that the market share is equal to 25%, the peak share of Japanese companies after 2010 when the market expanded rapidly, the economic effect would be 1.25 trillion yen).

In addition, if photovoltaic power generation equipment can be installed in homes and buildings where installation is difficult due to technical limitations of existing solar cells, and assuming that approximately 30% of the electricity generated is consumed in-house, it would be possible to provide approximately 30% of the electricity consumed by the average household (mechanically speaking, this would save the equivalent of 10,000 yen per year on electricity bills).

In addition, we will promote technological development of next-generation inverters and grid control methods that provide inertia, and secure inertia, etc. through grid coding and market opening

---

[28] From the implementation outlook of the current policy scenario in the International Renewable Energy Agency (IRENA) (IRENA Remap 2019 dataset, IRENA Future of Solar PV 2019)

from the 2030s.

2) Fostering and rebuilding of related industries

<Current status and issues>

In promoting the expansion of the introduction of solar power generation, it is necessary to promote independence from the support of the FIT system, etc., while further reducing costs, etc. For this reason, it is necessary to establish a business model that utilizes solar power generation whose FIT purchase period has ended, and to develop an environment in which the introduction and expansion of solar power generation is possible even without the FIT system. Against this backdrop, the FIP system will be introduced in April 2022 to promote efforts to make renewable energy generators more aware of electricity supply and demand, and to encourage the integration of renewable energy sources, including solar power, into the electricity market.

In addition, we will encourage the participation of a diverse range of players and expand the photovoltaic power generation-related industry by stimulating and fostering an aggregation business that uses FIP systems or utilize photovoltaic power generation whose FIT purchase period has expired, reducing the price of household storage batteries, which remains high compared to overseas markets, and creating and expanding new business forms such as off-site PPAs, in which consumers install power generation equipment in remote locations and receive power themselves.

<Future efforts>

First, with regard to the FIP system, we will steadily make preparations for the launch of the system, and after the launch of the system, we will set and review the premium level and the scope of coverage in a timely and appropriate manner, taking into account the status of the system operation and the market environment. Additionally, to ensure that the value of DERs can be appropriately traded in various markets, the government will promote the activation of the aggregation business by encouraging studies with reference to overseas precedents. With regard to storage batteries, in order to reduce the price and expand the use of stationary storage batteries, the introduction of storage batteries for household use will be promoted by setting a price target of 70,000 yen/kWh in FY2030 (the price of an electricity storage system including installation costs) as a requirement, promoting investment in manufacturing facilities, and verifying technologies for providing power regulation, etc.

In light of the fact that the initial cost of installing residential solar power has become a burden for installers and that the number of consumers who wish to purchase renewable energy directly is increasing as RE100 and other initiatives progress, the creation and expansion of new business models that capture demand will also contribute to the expansion of solar power installations. From this perspective, we will work to expand these models by creating advanced examples of PPA models and off-site PPA models that make it possible to introduce equipment with zero initial cost, and by developing advanced examples horizontally.

3) Securing suitable land, etc.

<Current status and issues>

In order to expand the introduction of solar power generation, many people have voiced concern about the lack of suitable sites where projects can be implemented at low cost while coexisting with the local community. For example, in recent years, local governments have increasingly enacted ordinances that discourage the installation of renewable energy generation facilities for the purpose of preserving the natural environment and landscape (renewable energy ordinances), and as of FY2020, less than 10% of all local governments in Japan have enacted renewable energy ordinances. There are also expectations for the expansion of farm management in farmland suitable for the introduction of renewable energy, while securing prime farmland, and for the expansion of the amount of introduction by making it easier to secure grid capacity.

In order to expand the base of the industrial scale of photovoltaic power generation in Japan, it is necessary to reexamine regulations and systems in various fields in light of this situation.

<Future efforts>

First of all, in order to expand the introduction of the system while coexisting with the local community, the issue is how to encourage positive consensus building in the community. In this regard, the revised Law Concerning the Promotion of the Measures to Cope with Global Warming adds provisions that allow local governments to set targets for the implementation of measures to promote the use of renewable energy, establish "promotion areas" to encourage the introduction of renewable energy, etc., and determine matters to be considered for environmental conservation and regional contribution in each respective region. The relevant ministries and agencies will promote the materialization of these initiatives in cooperation with existing measures, thereby encouraging the acceleration of individual development projects.

The government will also provide advice on easing the requirements for the reuse of abandoned farmland, speeding up the decisions on non-agricultural land for abandoned farmland that is difficult to reuse, and facilitating the exclusion of abandoned farmland from agricultural land areas.

In addition, in order to secure grid capacity, we will first implement non-firm connections in local grids on a trial basis, and based on the results of the trials, we will promote nationwide expansion, while also studying grid reinforcement.

Furthermore, through the practical application of next-generation solar cells and other measures, we will work to expand the spread of ZEH and ZEB, which contribute to the introduction of solar power generation in homes and buildings.

iii） Geothermal

Unlike photovoltaic power generation and wind power generation, geothermal power is a renewable energy source that can be used as a base-load power source because it generates almost no CO_2 during power generation. The promotion of geothermal power generation is very important as a power source that contributes to the stable introduction of renewable energy, as the maximum introduction of renewable energy is required to achieve Carbon Neutrality in 2050.

Therefore, the government will reduce development costs and development risks by conducting its own surveys of the extent of resources in suitable areas for development, providing risk money to business operators, and making efforts to foster local understanding.

Based on the fact that 80% of Japan's geothermal resources are located in national and quasi-national parks, the Ministry of the Environment (MOE) will set a target to double the number of geothermal power generation facilities nationwide by 2030 and shorten the lead time by up to two years, based on the "Plan for Accelerating Geothermal Development", by reviewing the operation of the "Natural Park Law" and the "Hot Spring Law", encouraging the establishment of promotion zones based on the revised Law for the Promotion of Measures to Cope with Global Warming, collecting and investigating scientific data such as hot spring monitoring, and working to achieve smooth regional coordination. As an aspect of the implementation of the Plan, it is necessary to accelerate development and expand development sites that are compatible with the conservation of the surrounding natural environment.

Furthermore, toward 2050, on top of these efforts, we will utilize geothermal resources that we have not been possible to utilize so far by developing new technologies.

Through these efforts, it is important to aim for a significant introduction of geothermal power generation, and to promote the further growth of various industries related to geothermal development, such as drilling, turbines, and other power generation systems, as well as materials and components for drag wells.

In particular, taking advantage of the fact that Japanese companies currently account for 70% of the turbines used for geothermal power generation in Japan and abroad, we will expand the market and strengthen the competitiveness of Japan's geothermal industry by providing support, including financial support, to developing countries for the vast amount of undeveloped geothermal development in the world, especially in developing countries, from the preparation of master plans to exploration, exploratory drilling, excavation, and plant construction, together with the world's top-class power generation systems. We will also lead the world in developing next-generation geothermal power generation technologies, such as supercritical geothermal power generation, and sell the entire power generation system, including supercritical geothermal resource exploration technology, deep drilling technology, surface and underground piping, and turbines, as a package to overseas markets. In this way, we will work to further expand the overseas development of Japan's geothermal industry.

1) Supply of risk money, promotion of understanding

<Current status and issues>

Some of the disincentives for geothermal power development are the significant risks and costs involved in the development of geothermal power generation, such as the high cost of drilling and surveying required before a decision is made to proceed with commercialization, the risk of not being able to secure the expected thermal resources in the drilled production wells, and the time and cost required to connect to the grid.

In addition, the understanding of local stakeholders is essential for geothermal development, but in most cases, the developers have to obtain this understanding on their own, and the coordination costs are a significant burden for them.

<Future efforts>

In order to reduce risks and costs for operators, the Japan Oil, Gas and Metals National Corporation (JOGMEC) will continue to provide subsidies, equity participation, debt guarantees and other risk money. At the same time, we will work to improve exploration and drilling technologies in order to accelerate development and reduce the impact on the conservation of the natural environment. To reduce development risk, we will promote regional understanding, reduce investment risk, and develop technologies that contribute to improving drilling success rates and efficiency. Furthermore, efforts will be made to resolve other technical issues for expanding geothermal development, such as grid connectivity.

In addition, multi-stage utilization of energy, such as the use of hot water after power generation, is also expected. For example, the hot water produced by steam from geothermal power plants can be used for agricultural greenhouses and other facilities, and can play a role in supporting the stabilization of the local energy supply. Based on these points, we will promote sustainable development that coexists with the local community and disseminate such good practices nationwide.

JOGMEC will also conduct its own geothermal resource surveys, provide drilling survey data and other information to a wide range of developers, and take over drilled wells at the request of developers.

Furthermore, through the "Plan for Accelerated Geothermal Development," while also collaborating with related ministries and agencies, we will encourage the designation of areas for geothermal development based on the revised Law for the Promotion of Measures to Cope with Global Warming, collect and survey scientific data to resolve local concerns and obstacles to the natural environment for hot spring operators, etc., and accelerate the development of projects through smooth regional coordination.

2) Regulations under relevant laws

<Current status and issues>

Japan's geothermal resource potential is the third largest in the world, but it has not been fully utilized compared to other countries due to the fact that high-temperature zones such as those directly under volcanoes are not suitable for development, and there are issues such as grid connections (Japan ranks third in the world in terms of potential, but tenth in terms of actual utilization). About 80% of Japan's geothermal resources are located in national parks. National parks are scenic areas with natural beauty and play an important role in protecting Japan's natural environment, so it is necessary to take them into consideration when developing geothermal resources. Two deregulations on the "Natural Park Law" have been promoted by the Ministry of the Environment, such as allowing excavation into Class 2 and Class 3 Special Areas in National Parks and slope excavation into underground areas in Class 1 Special Areas, and the number of development projects in National Parks has increased to more than 60, but further review of operation in National Parks is necessary to promote development.

Since geothermal power generation uses underground thermal water, it requires a permit from the prefectural governor in accordance with the Hot Springs Law, which aims to protect hot springs and ensure their proper use. For this reason, the "Guidelines for the Protection of Hot Spring Resources (Geothermal Power Generation)" have been formulated with the aim of promoting smoother and fairer drilling permits for geothermal development so that the introduction of renewable energy can be promoted while protecting hot spring resources. However, the approach to permitting drilling at great depths differs from prefecture to prefecture. For example, while multiple wells are required for geothermal power generation, regulations require that wells must be separated from each other by more than a certain distance even if they are drilled by the same operator, and while the shape and amount of geothermal reservoirs vary from point to point, the same separation distance regulations are applied to other points based on the distance set when problems occurred in the past at specific points. This has been pointed out by some geothermal power generation companies as not allowing them to effectively utilize geothermal resources.

The Forest Act and other regulations and their operation are also factors that prevent the smooth promotion of geothermal power generation.

<Future efforts>

In addition to promoting the "Plan for Accelerating Geothermal Development", which includes necessary reviews of the operation of the "Natural Park Law" and the "Hot Spring Law", and the promotion of hot spring monitoring that will help dispel local concerns and build consensus, the relevant ministries and agencies will review the operation of regulations based on the "Regulatory Reform Implementation Plan" approved by the Cabinet in June 2021, with the aim of further accelerating geothermal development. The main implementation items are as follows.

(Nature Park Act)

- Clarification of licensing criteria and examination requirements for geothermal power generation in natural parks are discussed based on the opinions of experts and business organizations, and the results are reflected in notifications.
- It is important to note that it is not necessary to submit a detailed layout of the final geothermal power generation project plan at the time of surface investigation or drilling of research wells, as it is difficult to formulate the entire project plan.

(Hot Springs Act)

- With regard to the regulations on the separation distance and the number of units for sloping excavation at great depths under the "Hot Springs Act," we will first request that the prefectural governments check their regulations, including the abolition of such regulations in cases where they have no scientific basis. Furthermore, we will inform the public of the content of the prefectural regulations and the scientific basis for them in a notice.

- After hearing the opinions of prefectures, etc., understanding the actual situation, and examination by experts, a conclusion will be reached on the concept and direction based on scientific knowledge regarding the distance separation regulation and the number of restrictions, etc., which will be reflected in the "Guidelines for the Protection of Hot Spring Resources (Geothermal Power Generation)".

3) Development of next-generation geothermal power generation technology

<Current status and issues>

In order to achieve Carbon Neutrality in 2050, it is necessary to promote the swift introduction of geothermal energy by developing new technologies in addition to the above-mentioned efforts.

Conventional geothermal power generation uses hydrothermal resources located 1,000 to 2,000 meters underground at a temperature of about 150°C. However, by using hydrothermal resources located 5,000 meters underground at a temperature of about 400 to 500°C (water that has become "supercritical" due to temperature and pressure), geothermal power generation can be made possible on a larger scale than ever before.

Overseas, an experimental drilling project was carried out in Iceland in the deep high-temperature region, and water with a temperature of 427°C and a pressure of 34 MPa was confirmed at a depth of 4,650 m, which satisfied the conditions for a supercritical state, but it has not yet been put to practical use for power generation. In Italy, a drilling survey was conducted to utilize supercritical water, but the project has been suspended due to insufficient verification of the drilling technology and materials to be handled.

The maximum power generation capacity of conventional geothermal power generation in Japan is several thousand to several tens of thousands of kW per site, but supercritical geothermal power generation is expected to increase the scale of power generation facilities to about 100,000 kW and reduce power generation costs. The further development of geothermal power generation technologies is crucial for achieving Carbon Neutrality by 2050.

Japanese companies have strengths in advanced technologies and knowledge related to supercritical geothermal power generation, such as technology for drilling deep underground (5 km or more) into high-temperature strata, the development of components and materials that can handle high-temperature and highly acidic fluids, and know-how for designing and constructing entire power generation systems based on precise simulations of drilling and fluid behavior.

By mobilizing all of these resources and working on geothermal development using supercritical fluids at high temperatures, high pressure, and high acidity, which are even more difficult to develop, Japanese companies are expected to establish supercritical geothermal power generation technology ahead of the rest of the world and realize commercialization.

<Future efforts>

Supercritical geothermal resources have higher concentrations of silica and acidic hydrothermal fluids than conventional geothermal resources, in addition to ultra-high temperatures, so it is necessary to develop elemental technologies to prevent corrosion of surfaces of equipment and facilities such as wells and turbines. It is also necessary to develop systems and components such as drag wells to efficiently use supercritical water for power generation. It is essential to also establish drilling technology for use under ultra-high temperature and pressure conditions deep underground.

The promotion of long-term technological development and demonstration, etc. in collaboration with universities, research institutes, and companies, etc. in an integrated manner is also needed. Specifically, by 2030, in parallel with the above-mentioned technology development, actual drilling and testing of research wells will be conducted to demonstrate the existence of supercritical geothermal resources and to verify the developed drilling technology, casing, piping and other components and materials. By 2040, while developing technologies based on the results of these verifications, the entire power generation system, including ground facilities such as turbines, will be verified through the installation of pilot plants. In view of the development lead time of about 10 years, the aim is for the commercialization and spread of the technology around 2050. This will be the first time in the world that such technology will be developed on a commercial basis. The companies will be the first in the world to achieve such commercialization.

If supercritical geothermal power generation can be realized, the market size in Japan is expected to be more than 1 trillion yen. Furthermore, by deploying the technology worldwide, we can expect to capture a market that is at least as large as the domestic market.

Next-generation technologies other than supercritical geothermal power generation are also expected to realize even more efficient and economical geothermal development. Therefore, we will grasp the overseas trends of these next-generation technologies and examine the applicability of these technologies to geothermal development in Japan.

(2) Hydrogen and fuel ammonia industry

i) Hydrogen

Hydrogen, which can be widely used in various sectors (power generation, industry, and transportation etc.) is a key technology to achieve Carbon Neutrality. Although Japan was the first in the world to formulate the “Basic Hydrogen Strategy” and possesses advanced technology in multiple fields, Europe and Korea among others have also established strategies and are following Japan. Hereafter, the government positions hydrogen as a new resource, and will involve wide range of players not only automobile applications. Moreover, for example, in the fields of usage, transportation and manufacturing, by estimating global market size based on a certain hypothesis and taking various measures described below, decarbonization will be promoted and, at the same time, industrial competitiveness will be strengthened.

To this end, through the expansion of the amount of hydrogen to be introduced, we aim to achieve a level that is sufficiently competitive with fossil fuels, such as a supply cost of 30 yen/Nm^3 (less than 1/3 of the current sales price) in 2030 and a hydrogen power generation cost less than gas-fired power generation (less than about 20 yen/Nm^3) in 2050. As for the target amount, while being conscious that the situation is different between countries and regions with regard to renewable energy potential, market size and so on, from the viewpoint of early launch of the domestic hydrogen market, hydrogen introduction amount of up to 3 million tons in 2030 is aimed for.[29] Of these, the amount of clean hydrogen (hydrogen which is produced from fossil fuels plus CCUS/carbon recycling, renewable energy, etc.) to be supplied in 2030 is aimed at being more than the amount of hydrogen supplied from renewable energy sources (approximately 420,000 tons) as stated in Germany's National Hydrogen Strategy announced in June 2020. In addition, supply amount of ca. 20 million tons in 2050 is aimed for.

1) Hydrogen utilization

By utilization and application of hydrogen, realization of decarbonization in various fields such as electric power generation (fuel cell, turbine), transportation (automobile, shipping, aircraft, railway and so on) and industries (steelmaking, chemical, petroleum refining and so on) is expected. The government will strengthen international competitiveness focusing on the fields where Japanese companies possess excellent technologies therefore growth is expected, such as hydrogen power generation turbine, commercial vehicles including fuel cell (FC) truck and hydrogen reduction steelmaking.

<Current status and issues>

Large-scale hydrogen power generation using turbines is one of the options of power source in the era of Carbon Neutrality, which may also contribute to stabilization of system as a balancing capacity. Japanese companies, which are leading technology development in controlling combustion of flammable hydrogen in turbines and so on, have competitive advantage against

---

[29] The figures introduced include those introduced by the direct use of hydrogen carriers including ammonia.

foreign companies. However, verification of stable combustion by real machine has not been completed yet. The potential domestic hydrogen demand (introduction amount based on a certain hypothesis) is estimated to be ca. 5 to 10 million tons per year.

As for the use of hydrogen in mobility, we are promoting the use of fuel cell vehicles and supporting the development of hydrogen stations. Moreover, commercial vehicles such as trucks, for which long haul is regularly required therefore it is difficult for EV to be adopted, is one of the areas in transportation field where hydrogen utilization is expected. The potential domestic hydrogen demand of ca. 6 million ton per year of is anticipated. Since Europe, China and other countries are also working actively on the conversion of commercial vehicles to fuel cell (FC) vehicle, Japanese companies must accelerate the development by forming alliances and using the knowledge obtained through their experience with passenger vehicles.

In addition, Japan is leading the world in the commercialization of FCVs and household fuel cells (EneFarm), which are key components that can contribute to the decarbonization of a variety of sectors, including mobility, trucks, and the consumer and business sectors. In anticipation of market expansion, there are moves to strengthen industrial competitiveness in other countries. Therefore, it is necessary to further reduce the cost and improve the power generation efficiency of fuel cells from the viewpoint of overcoming the competition with foreign countries and protecting Japan's domestic industrial base.

In addition, the great demander in the industrial field is the steel industry. If coal and so on currently used as reduction agent of iron ore can be replaced by hydrogen by the hydrogen reduction steelmaking, significant amount of CO_2 emission reduction can be achieved. However, the reduction reaction by hydrogen absorbs heat (endothermic reaction) and cools down the blast furnace, so there are very high technical hurdles to overcome, such as how to compensate for the heat required for continuous reduction (in the case of coke, it heats up by itself) and how to create a gap in the furnace for ventilation of the reaction gas as the coke is reduced. In addition, even if the technology can be established, a large amount of money will be required to install the equipment, and a large and inexpensive supply of hydrogen will be essential to maintain the same level of competitiveness and production volume as at present. The potential domestic demand for hydrogen is thought to be about 7 million tons/year.

<Future efforts>

As for hydrogen power generation turbines, the global cumulative installed capacity is expected to be up to about 300 million kW (about 23 trillion yen) by 2050.[30] In order to acquire this global market, the government, first of all, will support early real machine verifications to accelerate commercialization in Japan. In addition, as with renewable energy and nuclear power, hydrogen will be valued as a carbon-free power source, and a power market where incentive is granted for utilization of hydrogen will be developed. In this manner, a full launch of the domestic hydrogen market by creating a large demand in the electric power generation field will be supported. After that, making use of knowledge and experience obtained in the launched domestic market, export not only

---

[30] Estimated based on IEA "Energy Technology Perspectives 2020" Sustainable Development Scenario (SDS) and other data (turbine price: 80,000 yen/kW).

to the developed countries where projects are going ahead, but also to Asia with vigorous growth of electric power demand and so on is aimed for.

We will accelerate the spread of fuel cell vehicles and the systematic development of hydrogen stations. Among them, FC trucks in particular are expected to have a cumulative installation of up to 15 million units by 2050, amounting to about 300 trillion yen.[31] Currently, from the perspective of reducing the burden on businesses and users to expand the use of fuel cell vehicles, the government is studying the state of regulations for fuel cell vehicles, etc., with a view to unifying related regulations under the "Road Vehicles Law" and the "High Pressure Gas Safety Law", and will compile certain directions in June and reach a conclusion by the end of this year. The government will also study measures to support the introduction of FC trucks as part of demonstrations to accelerate their commercialization and the promotion of electrification. In addition, necessary infrastructure development such as hydrogen refueling stations will be implemented in a flexible and timely manner according to the situation. Specifically, in addition to development and demonstration of large hydrogen refueling stations, efforts for cost reduction such as consideration of the boost of hydrogen tank accepted in Europe will be continued by means of further regulatory reform and so on.

The global market for stationary fuel cells is expected to be about 1.5 million units per year, or about 1.1 trillion yen.[32] Therefore, in addition to improving power generation efficiency and durability, we will promote R&D for the development of multiple applications, including mobility. In addition, by standardizing methods for evaluating the performance of basic cells and other components in the development phase of fuel cells, we aim to improve the efficiency of R&D in non-competitive areas, while providing tax support and other measures for capital investment to encourage mass production in the commercial phase and cost reductions through the promotion of competition. We will also conduct demonstrations of the use of fuel cells as a supply and regulating force in power systems, with the aim of making the most of their potential. We will continue to expand the use of stationary fuel cells, including pure hydrogen fuel cells, from the perspective of resilience, such as the ability to generate power even during power outages caused by disasters, and the ability to reduce utility costs through high overall energy efficiency.

In the case of steel, the global market for green steel (the sum of hydrogen-reduced steelmaking, blast furnace + CCUS, carbon recycling, etc.) is expected to be up to about 500 million tons/year (about 40 trillion yen/year) by 2050.[33] Therefore, in order to capture this market, we will support the establishment of world-leading hydrogen-reduced steelmaking technology. Specifically, we will develop a technology that can reduce 50% of CO_2 emissions from the steelmaking process by effectively utilizing current blast furnaces, reducing iron ore using hydrogen, and separating and recovering CO_2 contained in blast furnace exhaust gas, converting it into a reductant, and utilizing

---

[31] Estimated based on Hydrogen Council's "Hydrogen Scaling up" and other sources (average price: 20 million yen/unit).

[32] Estimated based on IEA "World Energy Outlook 2019" Sustainable Development Scenario (SDS) and other data (annual average number of household fuel cell installations from 2018 to 2040: approximately 1.5 million units; average capacity: 1.5 kW/unit; system price: 500,000 yen/kW). Fuel cells for business and industrial use and mobility are not included.

[33] Estimated based on IEA "Energy Technology Perspectives 2020" SDS and other data (average steel price: 80,000 yen/ton).

it. Furthermore, with a view to achieving "zero-carbon steel" by 2050, we will establish basic technologies for the realization of the "hydrogen direct reduction method" that can reduce iron ore using only hydrogen (e.g., (1) heat compensation technology in furnaces necessary for the reduction of iron ore, (2) technology to remove impurities contained in raw materials, and (3) technology to upgrade electric furnaces essential for dissolving reduced iron). The established top runner technology will be successively designated as the decarbonization standards required for the industry to promote its introduction. Through these efforts, realization of “zero-carbon steel” contributing to decarbonization of Japanese manufacturing industry including automobile is aimed for.

With regard to border adjustment measures, as an integrated domestic and international industrial policy to ensure international competitiveness, we will continue to study measures in cooperation with other countries to ensure international fairness in trade with countries that are reluctant to take measures against global warming.

2) Transportation and storage of hydrogen (liquefied hydrogen carriers, etc.)

<Current status and issues>

Future launch of international transactions of hydrogen is expected as Germany and other countries are showing interest in import of hydrogen. Since our country has been assuming to utilize imported hydrogen from the beginning, the government has been supporting technology development and verification of marine transportation technology and infrastructure using liquefied hydrogen and MCH (methylcyclohexane). As a result, Japan has the world-leading technology to build the world’s first liquefied hydrogen carrier ship and so on.

The problem is how to achieve early commercialization hereafter. Moreover, since marine transport of hydrogen has not been foreseen, there is a concern for inconsistency of regulations between countries.

<Future efforts>

Assuming that 10% of hydrogen is being traded in the international market in 2050, size of the trading market is anticipated to be up to ca. 55 million tons per year (ca. 5.5 trillion yen per year).[34] In order to create such a market, it is important to support the enlargement of transportation-related facilities that will contribute to the further reduction of hydrogen transportation and storage costs through various means, such as R&D, demonstrations, and the creation of domestic demand, utilizing the Green Innovation Fund, with the aim of achieving commercialization by 2030. We will also promote the R&D of innovative hydrogen liquefaction and refrigeration technologies. Through these efforts, realization of supply cost of 30 yen/Nm^3 in 2030 is aimed for.

Moreover, in order to establish a foundation for export of equipment, technology and so on to the world in the future by securing international safety and compatibility of the equipment, international standardization of related equipment such as loading arm for transfer of hydrogen from liquefied hydrogen carrier ships to the receiving terminal is promoted. As for the environmental improvement

---

[34] Estimated based on Hydrogen Council's "Hydrogen Scaling up" and other data (average hydrogen trading price: 100 yen/kg).

of quays and supply facilities for hydrogen export at overseas loading and unloading ports, we will consider the provision of risk money through joint investment with private companies by the Japan Overseas Infrastructure Investment Corporation for Transport and Urban Development (JOIN) and the use of hands-on support, depending on the project, and in Japan, we will consider the review of technical standards and port plans to enable the necessary import and storage of hydrogen at ports.

3) Hydrogen production (water electrolyzer and so on)

<Current status and issues>

For hydrogen production, the water electrolyzer to create hydrogen by electrolysis of water will become important in the future. With the decline in the cost of renewable energy and water electrolysis equipment, it is expected that some regions will be able to produce hydrogen at a lower cost than that produced by fossil fuel + CCUS/carbon recycling in 2050. In response to such anticipation, Europe and other countries, which are actively introducing renewable energy, aims at introduction of the electrolyzer at the same time.

Japan has built one of the world’s largest electrolyzer, and also possesses underlying technologies of the world’s highest level. However, with regard to the technology development aiming for further enlargement and so on, companies in other countries including European countries precedes partially.

<Future efforts>

Water electrolyzer is expected to be installed at a maximum average of about 88 GW per year (about 4.4 trillion yen per year) globally by 2050.[35] In the future, in order to first focus on capturing markets in Europe and other regions where markets are emerging ahead of the rest of the world, the Green Innovation Fund will also be utilized to intensively support Japanese companies to increase the size of their equipment and implement superior elemental technologies in their equipment, with the aim of maintaining and strengthening international competitiveness by further reducing equipment costs[36] and improving durability. In addition, by preparing an environment for performance evaluation of the water electrolyzer in Japan as in Europe and other countries, the government aims at lowering entry barriers to the overseas market for companies intending to do development in Japan and to export products. Furthermore, in anticipation of increase of surplus renewable energy in medium- to long-term also in Japan, active utilization promotion measures of low-cost electric power will also be considered with proper evaluation of a raised DR (demand response). Spreading the use of water electrolyzer through such efforts will lead to increased opportunities for hydrogen production from renewable energy sources, etc., and thus there is a possibility of making full use of renewable energy sources, which are expected to become more widespread in Japan in the future.

We will also promote research, development, and demonstration of innovative hydrogen

---

[35] Estimated based on IEA "Energy Technology Perspectives 2020" Faster Innovation Case, etc. (Average equipment price: 50,000 yen/kW).

[36] We are aiming for 52,000 yen/kW for the alkaline type and 65,000 yen/kW for the PEM type. (The alkali type is characterized by its low cost and ease of enlargement, while the PEM type is easy to miniaturize and has high load-following capability, so it is expected to be used as a regulating force.)

production technologies using photocatalysts and high-temperature heat sources such as high-temperature gas furnaces.

In addition to the above-mentioned efforts in relation to individual themes, as a cross-thematic effort, we will continue to work on research, development, and demonstration of innovative technologies for hydrogen use, transportation, and production, and conduct intensive demonstrations of hydrogen utilization in various fields, focusing on locations where hydrogen production facilities have already been established, such as Fukushima, as well as ports, waterfront areas, and airports, including power plants where large-scale hydrogen demand is expected. Specifically, while utilizing the Green Innovation Fund, the project aims to establish a model for social implementation that will serve as a forerunner for the realization of a hydrogen society, by working on the integrated demonstration of hydrogen transportation technology for mass and low-cost hydrogen through the establishment of an international hydrogen supply chain and hydrogen power generation technology for which a large demand for hydrogen is expected in the future, as well as the development and demonstration of technology for reducing supply costs by increasing the size of water electrolyzer and utilizing the produced hydrogen as a raw material for basic chemicals. We also aim to solve regional issues such as the creation of disaster-resistant communities through the demonstration, transition support, and dissemination of independent and decentralized energy systems that utilize local resources such as renewable energy will also be implemented. At the same time, Carbon Neutrality in ports and waterfront areas will be realized by having multiple businesses use the large amount of imported hydrogen for a variety of purposes, including the introduction of stand-alone hydrogen and other power sources that also serve as emergency power sources, and port cargo handling machinery that use fuel cells.

After such advanced cases will have been established as a model, its nationwide expansion is envisioned. In promoting the spread of hydrogen across regions, the council will work in close cooperation with private-sector initiatives such as the Hydrogen Value Chain Promotion Council, which was launched last year with the participation of companies from a wide range of industries, the Central Japan Region Hydrogen Utilization Council, and the Kobe/Kansai Region Hydrogen Utilization Council. Additionally, it will also consider collaboration with the 2025 World Exposition in Japan and other initiatives that contribute to dissemination and outreach to the international community.

Japan is already promoting the standardization of hydrogen station-related products by actively submitting proposals to the International Organization for Standardization (ISO). By considering international standardization in parallel with future technological development as well as corporate and market trends, we will promote the smooth market introduction of technologies that will be Japan's strength in order to capture the hydrogen-related market, which is estimated to be 270 trillion yen[37] in 2050. For example, studies will be conducted to standardize hydrogen filling methods for large-scale mobility, equipment necessary for transporting liquefied hydrogen, and methods for measuring CO_2 emissions during hydrogen production in order to establish an internationally consistent definition of clean hydrogen. Moreover, considering also the viewpoint of stable supply of

---

[37] Estimated based on Hydrogen Council "Hydrogen Scaling up" and other sources (hydrogen-related market: 2.5 trillion dollars in 2050).

hydrogen and export of infrastructure, by strengthening of relations with resource-rich countries, not only in terms of fossil fuels, but also those with high potential in renewable energy, and by active development of countries of demand, the government will lead establishment of stable, flexible and transparent international hydrogen market. In promoting such international collaboration, we will make maximum use of the Japan-led hydrogen ministerial conference, while also cooperating with the International Energy Agency (IEA). In addition, there will be sufficient collaboration with fields that utilize hydrogen in their value chains, such as ammonia and carbon recycling.

In addition, the construction of a stable hydrogen supply chain will be realized by reducing the dependency on specific overseas regions and increasing the domestic procurement ratio, at the same time, if the cost of hydrogen-fired power generation is reduced to less than the price of gas (12 yen/kWh) in 2050, and hydrogen becomes sufficiently competitive with fossil fuels, it is expected that the price of hydrogen-fired power generation will be more stable than that of power generation from fossil fuels with high dependence on foreign countries, etc.

For example, in the past, the cost of LNG-fired power generation soared to the level of 13.8 yen/kWh[38] (2012) due to the impact of rising crude oil prices and other factors. If in the future hydrogen-fired thermal power generation can be stably supplied at the level of 12 yen/kWh after cost reduction is realized, it may have the effect of deterring the impact of such sudden price hikes on end users. (For example, to express a sudden price hike equivalent to about 1.8 yen/kWh in an easy-to-understand manner, if it is expressed as a restraining effect on electricity price expenditures in one household, it would be equivalent to about 8,600 yen/year[39] for an average household of two or more people (electricity consumption 400 kWh/month[40]).)

---

[38] Estimated unit cost of power generation at the time of the sharpest rise in the price of LNG (2012: 16.55$/MMBtu) based on the summary of the results of the 2014 model plant trial calculation and the summary of the sensitivity analysis by the Working Group on Power Generation Cost Verification of the General Energy Research Council (April 2015).

[39] The difference in expenditure between consumers who choose the 100% hydrogen-derived electricity retail option and the 100% natural gas-derived electricity retail option, assuming that the two options are the same, and assuming that there is a surge of approximately 1.8 yen/kWh only for the latter retail option. It should be noted that actual electricity price expenditures in 2050 will depend on the sales prices, offerings, power supply composition, etc. of each power company. It should also be noted that the effect is not a decrease in rates, but a reduction in price increases.

[40] Quoted from Ministry of Internal Affairs and Communications, "Family Income and Expenditure Survey" (2020).

ii） Fuel ammonia

Ammonia, which does not emit carbon dioxide (CO_2) when it is burned, will be the main decarbonized fuel used in the transition to the hydrogen economy, being used for co-firing of thermal power (coal-fired etc.) and so on. A 20% co-firing of ammonia (on a calorie basis) in one coal-fired thermal power unit would result in a 20% reduction in CO_2 emissions, and if 20% co-firing were implemented in all coal-fired thermal power units of Japan's major electric power companies, this would result in a reduction of approximately 10% of CO_2 emissions from Japan's electric power sector.

On the utilization side, the technology to stabilize combustion and suppress NOx generation has already been completed for 20% co-firing, and from FY2021 to FY2024, verification of 20% co-firing in actual equipment will be conducted. Practical application of the technology will begin in the second half of the 2020s, and domestic demand for fuel ammonia is expected to be on the scale of 3 million tons per year (approximately 500,000 tons of hydrogen equivalent) in 2030. In the 2030s, we will expand the introduction of these burners, and in the future, we will improve the co-firing rate and shift to single fuel firing, as well as expand the use of burners for power generation (co-firing and single fuel firing) to Southeast Asia and other regions.

On the other hand, in terms of supply, Japan will be the first to construct an international supply chain through by establishing new plants and so on, and take the initiative among supplier and utilization industries of fuel ammonia. At the same time, we will develop technologies for large-scale production, transportation and storage of fuel ammonia, as well as for higher efficiency, in order to ensure a stable and low-cost supply. Utilization of other decarbonized fuels will also be considered.

Specifically, through the following measures for utilization and supply, a market of 1.7 trillion yen per year is expected in 2050, and domestic demand for fuel ammonia of about 30 million tons per year (about 5 million tons in hydrogen equivalent) is assumed as a procurement supply chain that can be controlled by Japan, aiming for a demand volume of 100 million tons per year worldwide.

1) Use (Power generating burner for co-firing and so on)

<Current status and issues>

With regard to co-firing technology for coal-fired power plants, we developed a 20% co-firing burner with reduced NOx generation under the Strategic Innovation Program (SIP) from FY2014 to FY2018, and conducted co-firing tests in a large-capacity combustion test facility at NEDO from FY2018 to FY2020.

In the future, it will be necessary to verify whether NOx generation can be suppressed by the above-mentioned mixed burner technology in actual equipment. Moreover, since flame temperature during combustion and radiant heat are lower with ammonia than with coal, development of a heat collection technology is required to secure the amount of heat needed for power generation in order to improve co-firing ratio of ammonia and to aim for a shift to ammonia-fired power generation.

<Future efforts>

In the short term (until 2030), introduction and diffusion of co-firing with 20% ammonia to thermal power is set as a goal. Therefore, in terms of technology, we will establish 20% co-firing technology by conducting a demonstration of 20% co-firing using actual equipment for four years from FY2021, and then aim to implement NOx-controlled co-firing burners in existing power plants and introduce fuel ammonia through electric power companies.

In addition, the legal status of fuel ammonia is still unclear in relation to energy policy, as ammonia has never been envisioned for fuel use. While introducing and expanding the use of fuel ammonia, we will take measures to ensure that it is evaluated under the law through the realization of non-fossil values under the "Act on Advancement of Energy Supply Structure (Advancement Act)" and deducted from energy input when calculating power generation efficiency under the "Act on the Rational Use of Energy (Energy Conservation Act)".

In order to contribute continuously to decarbonization of the world, especially Southeast Asia where significant portion of power source is thermal power, expansion of the co-firing technology including burners will be considered. If the co-firing technology can be introduced to 10% of thermal power in Southeast Asia, investment of ca. 500 billion yen is anticipated. In addition to expanding the global use of fuel ammonia, we will promote comprehensive resource diplomacy that goes beyond the conventional framework of fossil fuels in order to build a global supply chain for fuel ammonia, and to promote a realistic energy mix transition toward a global decarbonized society. Specifically, the following international collaborations will be strengthened.

(1) Raise overseas awareness of fuel ammonia and promote understanding of the importance of fuel ammonia, including with international organizations (IEA, ERIA, etc.)

(2) Strengthen cooperation and formulate joint projects through bilateral meetings and policy dialogues with oil and gas producing countries/areas suitable for renewable energy production (North America, Australia, Middle East, Asia, etc.) and potential demand countries (Asia, etc.)

From the perspective of facilitating such international distribution and utilization of ammonia, standardization of ammonia management methods and performance of equipment during combustion will be effective. A WG specializing in standards and criteria has been established within the Clean Fuel Ammonia Association (CFAA) (formerly known as the Green Ammonia Consortium), with the aim of establishing international standards for ammonia specifications as a fuel and nitrogen oxide emission standards during combustion. In this way, the company aims to expand exports to, for example, the Southeast Asian power market.

In addition, new applications such as transportation including shipping and industrial use will be considered. Specifically, the International Maritime Organization (IMO) is promoting the decarbonization of international shipping by setting out greenhouse gas reduction strategies and targets in 2018, and ammonia is expected to be used as a marine fuel.

In the long term (up to 2050), we will actively promote the development of technologies to increase the co-firing ratio (50% or more), including the development of heat recovery technologies, and to develop technologies for exclusive firing, with the aim of putting these technologies to practical use by replacing existing thermal power generation. As a zero-emission thermal power generation system, the technology will be deployed not only in Southeast Asia but also throughout the world, accelerating the decarbonization of the entire world and promoting the growth of Japan's green industry.

2) Supply (Ammonia production plant)

<Current status and issues>

Annual global production of ammonia is about 200 million ton worldwide, most of which is used as fertilizer and locally consumed. In the future, if 20% co-firing with ammonia is implemented for thermal power, ca. 0.5 million ton of ammonia will be required annually for one plant (1 GW). For example, if all of the country's major power companies implemented 20% co-firing of coal-fired power plants, they would need about 20 million tons of ammonia per year, which is equivalent to the current global trade volume. Therefore, the challenge is to create a fuel ammonia market and supply chain that is different from that of the conventional ammonia for raw materials, and to supply inexpensive fuel ammonia through this market.

<Future efforts>

In the short term (~2030), to expand fuel ammonia production, we will build new production plants and establish a system to stably supply the necessary fuel ammonia.

To supply inexpensive fuel ammonia, we will strengthen our efforts to improve manufacturing efficiency through modularization and other measures, as well as strengthen financial support from Nippon Export and Investment Insurance (NEXI), Japan Bank for International Cooperation (JBIC), and Japan Oil, Gas and Metals National Corporation (JOGMEC). JBIC will move forward with studies on specific project support, including support through the Post-COVID-19 Growth Facility, which was established in January 2021. NEXI will consider adding fuel ammonia projects to the scope of support under the "Environment and Innovation Insurance" program. In addition, we will consider adding ammonia to the resources covered by the "Comprehensive Insurance for Natural Resources and Energy" so that the premium rate for projects for fuel ammonia business can be reduced and the credit coverage rate can be increased. In addition to the supply of risk money, JOGMEC will also consider strengthening support measures by utilizing its expertise in underground technology and facility technology cultivated through oil and gas development.

The Japan Overseas Infrastructure Investment Corporation for Transport & Urban Development (JOIN) is to provide risk money through joint investment and hands-on support, depending on the project, to improve the ports and supply facilities for ammonia exports at overseas loading ports. In Japan, we will consider reviewing technical standards and port plans to enable ports to import and store the necessary fuel ammonia. At the same time, we will achieve Carbon Neutrality in ports and waterfront areas by having multiple businesses use the large amount of ammonia imported for a variety of purposes.

From the perspective of stabilizing supply, we will aim to build a procurement supply chain that Japan can control through organic collaboration between the producing countries (North America, Australia, and the Middle East) and the consuming countries (Asia including Japan), paying attention to the political stability and geographical characteristics of the source countries. In addition, since securing sufficient supply is essential for steadily expanding the introduction of fuel ammonia, we will promote international recognition of the importance of both fossil fuel-derived and renewable energy-derived ammonia through bilateral talks and international meetings.

In the case of fossil fuel-derived ammonia, CO_2 is generated during production. For the time being, we will introduce and promote the use of fuel ammonia even without treatment of CO_2 in the manufacturing process, while paying attention to the relationship with the manufacturing country (legal system of the manufacturing country, etc.). Then, after a certain level of introduction and diffusion, CO_2 emitted during production will be treated in a rational manner through appropriate means from CCUS/carbon recycling, afforestation, offsetting by voluntary credits, etc. In this way, we will steadily expand the use of fuel ammonia without waiting for the price of ammonia derived from renewable energy sources to fall sufficiently.

The current price of ammonia is in the low 20 yen per Nm^3 range (equivalent to hydrogen by calorific value), and through such efforts to expand supply, we aim to supply ammonia in the low 10 yen per Nm^3 range (equivalent to hydrogen by calorific value) by 2030 (assuming current natural gas prices, etc.).

In the long term (up to 2050), the co-firing rate is expected to increase in the power generation field, and the use of nuclear fuel in other applications, such as ships and industrial furnaces (in various manufacturing industries), is also expected to expand. In order to appropriately respond to this expansion of ammonia use, we will develop new catalysts, increase the scale and efficiency of production, transportation, and storage processes, and develop inexpensive green ammonia production technology derived from renewable energy sources.

Through these efforts to expand supply and the above-mentioned efforts to expand utilization, domestic demand for ammonia is expected to reach 3 million tons per year (about 500,000 tons of hydrogen equivalent) in 2030 and 30 million tons per year (about 5 million tons of hydrogen equivalent) in 2050.

In addition, the establishment of a stable ammonia supply chain will be achieved by reducing dependence on specific overseas regions and increasing the ratio of domestic procurement. At the same time, if the ammonia supply price is reduced to less than the gas price (12 yen/kWh) in 2030 (and remains at that level until 2050) and ammonia becomes sufficiently competitive with fossil fuels, the price of ammonia-fired power generation will be more stable than that of hydrocarbon power generation, which is highly dependent on foreign countries.

For example, in the past, the cost of LNG-fired power generation rose to the level of 13.8 yen/kWh[41] (2012) due to the impact of soaring crude oil prices and other factors. If ammonia-fired power generation in the future can be stably supplied at the level of 12 yen/kWh after cost reduction is realized, it may have the effect of deterring the impact of such sudden price hikes on end users. (For example, to express a sudden price hike equivalent to about 1.8 yen/kWh in an easy-to-understand manner, if it is expressed as a restraining effect on electricity price expenditures in one household, it would be equivalent to about 8,600 yen/year[42] for an average household of two or

---

[41] Based on the summary of the results of the 2014 model plant trial calculation and the summary of the sensitivity analysis conducted by the Working Group on Power Generation Cost Verification of the General Energy Research Council (April 2015), we estimated the unit cost of power generation at the time of the LNG price resurgence (2012: 16.55$/MMBtu).

[42] The difference in expenditure between consumers who choose the 100% ammonia-derived electricity retail option and the 100% natural gas-derived electricity retail option, assuming that the two options are the same, and assuming that there is a surge of approximately 1.8 yen/kWh only in the latter retail option. It should be noted that actual electricity price expenditures in 2050 will depend on the sales prices, offerings, power supply

more people (electricity consumption 400 kWh/month[43]).)

---

composition, etc. of each power company. It should also be noted that the effect is not a decrease in rates, but a suppression of soaring rates.

[43] Quoted from Ministry of Internal Affairs and Communications, "Family Income and Expenditure Survey" (2020).

(3) Next-generation heat energy industry

Heat demand accounts for about 60% of the energy consumption in the industrial and consumer sectors in Japan. Heat is essential for people's daily lives, and we can contribute to the decarbonization of heat demand by promoting the decarbonization of the gas that supplies heat energy to the demand side in order to achieve Carbon Neutrality by 2050.

For the decarbonization of gas, the use of synthetic methane synthesized (methanation) from hydrogen derived from renewable energy sources etc. and CO2, or the direct use of hydrogen etc., is to be considered, and by promoting these efforts for the decarbonization of heat demand, an industry that supplies next-generation heat energy that achieves Carbon Neutrality (next-generation heat energy industry) will be born.

The realization of this next-generation heat energy industry cannot be achieved only by the efforts of the heat energy supply side (currently the gas supply business side). The decarbonization of gas will make a significant contribution to the decarbonization of all industrial and consumer sectors with heat demand, and it will be necessary to involve the demand side in the efforts to use the next generation of heat energy.

Toward the realization of Carbon Neutrality in 2050, we aim to create a next-generation heat energy industry through the following initiatives.

1) Supply-side carbon neutralization (decarbonization of gas)

<Current status and issues>

Various means of decarbonizing gas exist, including the use of synthetic methane or the direct use of hydrogen, the introduction of LNG offset by credits, and the use of technologies such as CO_2 separation/recovery and utilization. In order to achieve Carbon Neutrality in 2050, it is necessary to pursue each of these various means, given the existence of various uncertainties.

Among these, synthetic methane is expected to be a hydrogen carrier because of its methanation. The main component of city gas (natural gas) is methane, and synthetic methane can replace natural gas by utilizing existing infrastructure and facilities such as city gas pipelines, etc. Therefore, it is expected to contribute to a smoother transition toward Carbon Neutrality in 2050 while keeping costs low. In addition, synthetic methane, which captures emitted CO_2 and combines it with green hydrogen, can be considered carbon neutral because it does not emit any new CO_2. When combined with CO_2 separation/recovery and utilization, etc., it can contribute to the further reduction of CO_2 emissions.

Gas pipelines are highly resilient, as they are buried and therefore less susceptible to the effects of wind and rain, and most of them are also earthquake-resistant, with continuous efforts being made to improve their earthquake resistance. In addition, by securing a diversity of carbon-neutral energy sources and energy networks other than electricity, they will contribute to a stable supply of energy in a decarbonized society.

As for methanation technology, the New Energy and Industrial Technology Development Organization (NEDO) carried out the development of basic technology for methanation in a small-scale test facility from FY2017 to FY2021. In addition, from FY2019 to FY2020, NEDO is also conducting leading fundamental technology development to confirm the elemental technologies necessary for innovative SOEC methanation technology that can produce synthetic methane more efficiently than conventional methanation technology without the need for hydrogen procurement.

In the future, it will be necessary to develop technologies such as larger equipment and higher efficiency for practical use and lower cost of methanation. Methanation requires the procurement of inexpensive hydrogen and CO_2, and so the construction of a supply chain is an issue. Regarding the counting of CO_2 reductions, it is necessary to consider in a direction that contributes to Carbon Neutrality.

In addition to synthetic methane, direct use of hydrogen is also a promising option for decarbonizing heat demand. This is particularly expected in local areas such as waterfront areas where additional costs for infrastructure development are considered to be relatively minor. The supply of hydrogen through new medium- and low-pressure gas pipelines has been confirmed to comply with the current technical standards for gas, and in some areas, efforts are underway to supply heat and electricity using hydrogen through hydrogen cogeneration systems. It is also possible to contribute to the decarbonization of the demand side through the supply of heat energy using hydrogen in areas where hydrogen pipes have been installed.

In addition, major gas companies have begun to sell LNG offset by credits to the demand side. Also, gas utilities and others are developing technology for CCU/carbon recycling, which separates and recovers CO_2 emitted on the demand side for use. In order to achieve Carbon Neutrality in 2050, it is necessary to pursue various options and to develop networks according to the transition of gas energy and the quantity and distribution of demand, and to supply the next generation of heat energy.

Some gas utilities are promoting smart energy network initiatives that contribute to energy conservation and CO_2 reduction, including the effective use of heat, by using a combination of renewable energy and gas cogeneration (distributed energy system) in the region, controlling heat and electricity with digital technology, all in an integrated manner. Distributed energy systems can be expected to serve as a regulating force for renewable energy with fluctuating output, and also contribute to improving resilience in the region by ensuring the diversity of energy sources and energy networks.

In the future, if renewable energy sources become the main power source and hydrogen and synthetic methane are produced from surplus electricity from renewable energy, it will be possible to store and utilize electric power (Power to Gas, PtoG), and by using this synthetic methane to generate power while effectively utilizing heat through gas cogeneration (Gas to Power, GtoP), it can be expected to play a role as a backup for power supply shortages in emergencies and as a regulating power source necessary when introducing variable power sources such as renewable energy. Therefore, toward Carbon Neutrality in 2050, the integration of electricity and gas is likely to progress in a distributed energy system, utilizing digital technology while optimizing supply and demand by appropriately performing PtoG and GtoP through data linkage between electricity and gas.

In this way, gas utilities, which have been supplying gas to meet heat energy demand, are changing into energy supply businesses that stably supply optimal energy to meet the various heat and electricity needs of the demand side by utilizing not only gas but also a variety of energy sources such as renewable energy.

Decarbonization by multiple means, including electrification, hydrogen, ammonia, and synthetic methane, is being considered for 2050 Carbon Neutrality. The optimal energy demanded by the demand side will not be uniform, but will require the supply of a greater variety of energy sources. Gas utilities, as energy suppliers, are required to transform themselves into integrated energy service companies, actively incorporating the needs for heat, electricity, and other services, involving the demand side, and using digital technology to comprehensively manage local energy and provide related services.

As a comprehensive energy service industry, the management base will be strengthened by capturing the needs of the demand side and diversifying operations. On top of that, we will actively promote new investments to win out in active competition, and through competition and collaboration with businesses in the same and different industries, we will develop new markets in Asia and elsewhere, aiming for Japan's economic growth.

<Future efforts>

In 2030, the goal is to inject 1% synthetic methane into existing infrastructure, and to make 5% of gas carbon neutral, along with other measures such as direct hydrogen use. By 2050, 90% of synthetic methane will be injected into the existing infrastructure, and together with other means such as direct use of hydrogen, we aim is to achieve Carbon Neutrality of gas. In addition, we aim to start supplying synthetic methane, etc. as gas fuel for ships around 2030.

If all of the city gas in Japan were to be replaced with synthetic methane from methanation, it would reduce about 10% of the country's CO_2 emissions. In addition, if all of the infrastructure were to be updated, an investment of approximately 20 trillion yen would be required, which is expected to increase the burden on the average household by approximately 14,000 yen per year, but with synthetic methane, this burden can be avoided because existing infrastructure and facilities can be utilized.

To this end, we will first work on the development of technologies necessary for reducing the cost of water electrolysis equipment required for hydrogen production and increasing the size of methanation facilities, and on the development of innovative technologies necessary for highly efficient methane synthesis and CO_2 separation and recovery.

For the 2025 World Exposition in Japan, a demonstration is proposed that methanation be used to generate synthetic methane from biomass-derived CO_2 generated from food waste at the venue and hydrogen derived from renewable energy sources, and that this be used in facilities at the venue. In addition, a study on counting CO_2 reductions in a direction that contributes to Carbon Neutrality will be conducted promptly.

Furthermore, in order to achieve Carbon Neutrality in 2050, it is necessary to secure a considerable amount of hydrogen for the generation of synthetic methane. In order to keep the cost of synthetic methane low, it is considered effective to transport synthetic methane generated overseas where the hydrogen cost is relatively low to Japan. Based on the above, we will promote the construction of overseas supply chains for the decarbonization of gas, including the introduction of synthetic methane. We will start transporting synthetic methane from overseas to Japan in the latter half of the 2020s, and expand its introduction nationwide in the 2030s, aiming to achieve commercialization in the 2040s while reducing costs.

In order to promote these efforts, it is important that various stakeholders involved, including private companies on the supply side and demand side, as well as the government, work together. Therefore, the "Public-Private Sector Council for the Promotion of Methanation" was established in June 2021 to promote the study of the decarbonization of gas through the unified efforts of the public and private sectors.

By replacing a certain percentage of the rapidly growing LNG demand in Asia with synthetic methane, it will contribute to the development of the synthetic methane market in Asia and to the smooth decarbonization of the region. If 10% of Southeast Asia's natural gas demand were to be replaced by methanation, the investment is expected to be approximately 500 billion yen.

Through these efforts, we aim to supply 25 million tons of synthetic methane by 2050, and bring the price of synthetic methane to the same level as the current LNG price (40-50 yen/Nm^3).

We will also work to promote the direct use of hydrogen, the introduction of LNG offset by credits, and the separation, recovery and use of CO_2 emitted on the demand side.

While taking these factors into consideration, the supply network of next-generation heat energy will be developed according to the transition of gas body energy and the quantity and distribution of demand.

The introduction of gas cogeneration will be promoted to create a distributed energy system that makes effective use of renewable energy and heat from gas cogeneration. Since gas cogeneration serves as a regulating force for renewable energy, it will also contribute to the promotion of renewable energy as a main power source. In addition, the use of digital technology will enable optimal energy control in the region for distributed energy systems centered on gas cogeneration.

By using digital technology, heat and electricity can be optimized and integrated by collecting and analyzing information on the flow of people and the use of heat and electricity on the demand side, and this can contribute to low-carbon and resilient urban development in the region in conjunction with compact city policies, etc. We can also expect new businesses that utilize the data.

In addition, we will work on the development of technologies such as synthetic methane and hydrogen production to realize PtoG, and the promotion of the construction of a distributed energy system through the expansion of the introduction of gas cogeneration to realize GtoP.

These efforts will encourage current gas utilities to transform themselves into integrated energy service companies by providing comprehensive services such as optimal energy supply, management, and facility maintenance in the region, taking into account the needs of the demand side and utilizing digital technology, as well as implementing various energy supply services such as providing decarbonization options, and developing new markets in Japan and overseas that have not been fully captured by the conventional gas supply alone.

2) Demand-side carbon neutralization (low carbon and resilience)

<Current status and issues>

In order to achieve Carbon Neutrality in 2050, it is important to thoroughly promote the low-carbonization and decarbonization of energy used on the demand side during the transition period, and it is important to promote the fuel conversion from coal and oil to natural gas and the improvement of the efficiency of equipment using natural gas. Since natural gas has the lowest CO_2 emissions of all fossil fuels, it can contribute to a low-carbonization through fuel conversion to natural gas during the transition to Carbon Neutrality. Once the methanation technology is established, synthetic methane can replace natural gas by utilizing the existing infrastructure and facilities such as city gas pipelines, etc. Therefore, the demand side that has conducted fuel conversion, etc. can expect a smoother transition to decarbonization while reducing costs toward 2050 by receiving a supply of synthetic methane, etc. in the future.

In the industrial sector, since existing gas utilization facilities can be utilized when the fuel is converted from natural gas to synthetic methane, active capital investment is expected from the transition period by ensuring business predictability on the demand side, which will lead to the enhancement of Japan's industrial competitiveness through the maintenance and improvement of production efficiency.

If the CO_2 separation/recovery technology is put to practical use, it will be possible to separate and recover CO_2 emitted from factories, etc., use the CO_2 to generate synthetic methane by methanation, and reuse it as fuel in the factories, etc. Therefore, realizing Carbon Neutrality in factories, etc. is expected through the recycling of CO_2.

In the consumer sector, there is the advantage of being able to continue to use conventional gas appliances. If gas appliances were to be renovated, it is expected that the burden would increase by approximately 600,000 yen[44] for an average household, but with synthetic methane, existing equipment can be utilized, and the transition to decarbonization can be achieved while avoiding this burden.

To promote demand-side decarbonization, it is necessary to pursue various means, such as the direct use of hydrogen and LNG offset by credits, even before methanation technology is established.

In particular, the direct use of hydrogen is expected in local areas such as waterfront areas where additional costs for infrastructure development are considered to be relatively minor. The supply of hydrogen through the new medium- and low-pressure gas pipelines has been confirmed to comply with the current technical standards for gas, and in some areas, efforts are underway to supply heat and electricity using hydrogen through hydrogen cogeneration systems. It is also possible to contribute to the demand-side need for decarbonization by hydrogen through the supply of heat energy by the direct use of hydrogen in areas where hydrogen pipelines have been installed.

Major gas companies have started to sell LNG offset by credits to the demand side. A private sector organization has also been established with the aim of expanding the use of LNG and realizing greater value from its use, and many demand-side companies and other organizations have joined this organization. In addition, gas utilities and others are developing technology for CCU/carbon recycling, which separates and recovers CO_2 emitted on the demand side for use. Toward Carbon Neutrality in 2050, such demand-side needs are expected to increase in the future, and efforts to pursue various means are necessary.

In order to supply the next-generation heat energy to the demand side, it is necessary to develop

---

[44] Estimated costs for construction, IH cooking equipment, and pure hydrogen fuel cell (700W) based on information released by businesses and estimates for stationary fuel cells in the hydrogen industry.

the network according to the transition of gas body energy and the amount and distribution of demand in order to achieve Carbon Neutrality. In addition to the progress of low-carbon initiatives such as fuel conversion to natural gas during the transition period and the expansion of the use of LNG offset by credits, the development of methanation technology will increase the certainty of decarbonizing heat and gas, which will be expected to ensure business predictability and expand the gas network through increased gas demand. In addition, the formation of a direct hydrogen supply network is also expected. As a result, further growth of the next-generation heat energy industry is expected.

Gas pipelines have a high degree of resilience. The number of accidents is on a downward trend, and a high level of security is being maintained. In addition, the risk of supply disruptions in the event of natural disasters such as typhoons and major earthquakes in recent years is low, and early recovery can be expected, given the strengthened measures taken in the past due to disasters. In addition, some gas utilities have recently been considering the use of smart meters to remotely read meters and open and close faucets, and have been working to improve safety and resilience through the use of new safety technologies utilized digital technology. Continued improvement in resilience will lead to more stable energy use on the demand side.

By utilizing gas cogeneration, it is possible to use both heat and electricity. Gas cogeneration is highly energy efficient because it converts gas into heat and electricity at the point of demand. In addition, even in the event of a power outage due to a disaster, etc., heat and electricity can be used continuously, thus maintaining socioeconomic activities and the living environment even in such cases.[45]

Ensuring diversity of energy sources and energy networks such as the combination of renewable energy and gas cogeneration (distributed energy system) can contribute to the improvement of resilience in the region. Efforts are also underway to create a smart energy network that combines renewable energy and gas cogeneration and controls heat and electricity with digital technology.

In the future, further resilience enhancement can be considered through the integration of electricity and gas through the optimization of PtoG and GtoP, since electricity can be stored by producing synthetic methane from surplus electricity associated with the shift to the main power source of renewable energy in the local distributed energy system, and electricity generation and heat supply can be performed by gas cogeneration.

Many gas utilities are rooted in their local communities, and in the midst of a declining population, falling birthrates, and an aging society, they will contribute to regional development and the SDGs by providing energy and services required by the demand side of local communities, as well as by addressing various local issues and needs in cooperation with local governments and local companies by leveraging the relationships of trust they have cultivated with local residents and other factors. They will also play a role in the decarbonization of local communities by utilizing local

---

[45] In the wake of the 2018 earthquake in the eastern part of Hokkaido, gas cogeneration at Sapporo Sosei Square continued to supply heat and electricity to occupied offices and the adjacent city hall, despite power outages throughout Hokkaido. During power outages in the Kinki region and elsewhere due to Typhoon No. 21 in 2018, electricity, baths, and hot water could be used by residences utilizing ENE-FARM. During the power outage caused by Typhoon No. 15 in 2019, renewable energy and gas cogeneration was used at Mutsuzawa Wellness Town (Chiba Prefecture) to supply electricity to the roadside station and residences and to use hot water at the roadside station's hot spring facilities.

resources such as renewable energy, hydrogen, and biogas. These will enable the demand side to secure a variety of inexpensive and stable energy options in a carbon-neutral manner, and contribute to the growth of local companies and the decarbonization of the region.

<Future efforts>

In the industrial sector, fuel conversion from coal and oil to natural gas will be promoted along with increasing the efficiency of equipment using natural gas. Progress in the development of methanation technology and the substitution of synthetic methane for natural gas will lead to a smooth transition to decarbonization on the demand side.

In order to achieve Carbon Neutrality by 2050, a sectoral roadmap, including gas, will be formulated by the end of FY2021 to promote transition finance, which supports businesses that make steady efforts to reduce CO_2 emissions during the transition period.

While promoting the direct use of hydrogen in local areas, gas utilities will work on the formation of a network for the direct supply of hydrogen in cooperation with local governments and businesses, etc., and will also study how to solve the issues involved. In the Athletes' Village area after the Tokyo 2020 Olympic and Paralympic Games, a hydrogen pipeline will be constructed to generate electricity from hydrogen supplied to residential and commercial facilities in each district.

Gas utilities and others will work to promote the introduction of LNG offset by credits, and to put into practical application of technologies for the separation, recovery, and use of CO_2 emitted by the demand side, so that the demand side with decarbonization needs can receive these supplies.

While taking these factors into consideration, we will develop a network to supply next generation heat energy to the demand side according to the transition of gas body energy and the quantity and distribution of demand.

Work will be undertaken to enhance the continued resilience of gas infrastructure. We will work to enhance resilience through further improvements in earthquake resistance and other measures by promoting to improve security and resilience by considering smart meters and using digital technology. In addition, by utilizing the data collected through the use of digital technology, the demand side is expected to diversify its services, such as adopting new services such as remote monitoring services, energy-saving services, and lifestyle-related services that utilize data on gas, electricity, water, etc.

The introduction of gas cogeneration will be promoted in order to build a distributed energy system. In addition, through the use of digital technology, such as the collection and analysis of information on the flow of people and the use of heat and electricity on the demand side, gas cogeneration, etc., can be operated flexibly throughout the region to achieve optimal energy control.

With the aim of supplying next-generation heat energy to the demand side in the region, community-based gas utilities will promote proactive efforts by referring to examples to improve operational efficiency and create new businesses by collaborating with local governments and other industries, while at the same time promoting contributions to the region by gas utilities and strengthening their management base through support from major gas utilities, industry organizations, and government. In this way, the community-based gas utilities will contribute to solving regional issues such as decarbonization, regional revitalization, and urban development in the region, and will also contribute to ensuring a stable supply of energy in the future.

(4) Nuclear industry

In order to realize carbon neutrality in 2050, it is important to pursue every option, including nuclear power. Therefore, in addition to the further safety improvement of light-water reactors, it is necessary to proceed with R&D for nuclear power innovation by advanced technologies, which also contribute to improving reactor safety. Nuclear power can supply mass-produced and stable carbon-free electricity, and is also highly technological self-sufficiency. We will achieve further improvements in nuclear safety, reliability, and efficiency, the reduction in volume and harmfulness of high-level radioactive waste as well as the effective utilization of resources for improving natural resource recycling, with further innovation. Nuclear power can also respond to various social needs, such as coexisting with renewable energy, carbon-free hydrogen production, and heat utilization. In the current light-water reactor market, China and Russia are dominant with the backing of government finance, while the U.S., Britain, Canada, and other advanced countries are finding a way to make use of small and innovative reactors, and are accelerating R&D by investing large government budgets with the aim of commercialization around 2030. Considering these circumstances, the goals are (1) To consistently promote fast reactor development by utilizing international cooperation, (2) To demonstrate small modular reactor technology through international cooperation by 2030, (3) To establish component technologies related to hydrogen production at high-temperature gas-cooled reactor by 2030,, and (4) To consistently promote nuclear fusion R&D through international collaboration such as in relation to the ITER project.

1) Fast reactors

<Current status and issues>

For the sustainable use of nuclear energy, including innovative reactors such as small reactors and high-temperature gas-cooled reactors, it is necessary to treat and dispose of radioactive waste appropriately. And it is also important to reduce the volume and toxicity of radioactive waste, and to develop technologies for the effective use of resources in the mid- to long-term. Fast reactors remain important, because they utilize fast neutrons and contribute to enhancing the effects of the nuclear fuel cycle, including reduction in volume and harmfulness of high-level radioactive waste and the effective use of resources.

In the world, Russia already achieved the first criticality of its demonstration reactor in 2015, and China is also developing a demonstration reactor aiming to complete construction in 2023. In 2020, the U.S. has decided to provide up to 160 billion yen to fast reactor venture companies that plan to construct demonstration reactors within seven years. In addition, North America is also accelerating to develop fast reactors by venture companies with government support.

<Future efforts>

We will steadily promote development based on the "Strategic Roadmap" for fast reactor development, which was decided at the Ministerial Conference on Nuclear Energy in December 2018. The "Strategic Roadmap" states that, with a view to the full-scale utilization of fast reactors in the latter half of the 21st century, it is expected that the operation of fast reactors on a realistic scale in terms of technological maturity, finance, and operational experience will be started at an appropriate time, for example, around the middle of the 21st century. First, for the time being, for about five years, the government, the Japan Atomic Energy Agency (JAEA), and electric utilities will promote competition among various technologies by utilizing innovations by the private sector (Step 1), and then the government, JAEA, and electric utilities will narrow down the technologies with the cooperation of manufacturers (Step 2), and if certain technologies are selected, the process will be materialized (Step 3). In order to narrow down and focus on the technologies for FY2024 and beyond, it is essential to verify the technologies through irradiation tests in the experimental reactor "Joyo", which is owned by JAEA, and preparations for the resumption of operation will be made as soon as possible.

In addition, the "Strategic Roadmap" states that the development of fast reactors will be promoted by utilizing international cooperation with France, the U.S., and other countries. With France, we are developing technologies to improve safety and economy based on the new General Arrangement from 2020. For example, we will jointly develop innovative technologies such as a cooling system with natural circulation and a mechanism to automatically insert control rods as the temperature rises.

We concluded a memorandum of understanding (MOU) with the U.S. on cooperation in the development of a versatile test reactor (VTR), which is a test reactor for fast reactors, in 2019, and will proceed with efforts based on these agreements.

In promoting the development of fast reactors, JAEA will make maximum use of the data accumulated through the operation and maintenance experience of "Joyo" and the prototype reactor "Monju", as well as the world's valuable data and facilities such as the sodium experimental loop "AtheNa". Based on the expectation of cooperation from related organizations, we will make use of such cooperation within France-Japan and Japan-US cooperation as well, and promote cooperation with related organizations in other countries for the dissemination of Japanese standards and norms, taking into account the situation where Japan is also ahead of other countries in terms of the formulation of standards and norms.

In addition, "Joyo" can produce large quantities of medical radioisotopes, which are rare in the world. The restart of "Joyo" is expected to contribute to the development of advanced cancer treatment.

2) Small module reactor (SMR)

<Current status and issues>

Because the core of a small modular reactor (SMR) is compact, it is relatively easy to avoid shutdowns due to human errors or equipment failures by incorporating natural principles, such as a reactor cooling mechanism using natural circulation, into the safety equipment. The aim is to increase the reliability of the safety system through system simplification. By such design methods, probability of occurrence of loss of coolant accident due to piping rupture is significantly reduced and, as a result, reduction of evacuation area is aimed for. In addition, by reducing the initial investment cost by shortening construction period by means of modular production, mitigation of constraints to site selection and financing for construction is aimed for.

The innovative design adopted by SMRs to improve safety and economic efficiency requires some technological development and demonstration, and the USA is still in the process of developing safety standards and industrial standards ahead of other countries. In addition to USA, projects for construction of an SMR demonstration unit and for further expansion to the third countries are proceeding in UK, Canada and other countries, while some Japanese companies are making efforts to participate in these projects with their high design and production capacities. In addition, development of the SMR by Japanese companies with their original designs considering diverse needs, for which continuous R&D support is essential.

<Future efforts>

The government will actively support the efforts of Japanese companies in cooperation with foreign demonstration projects by USA, UK, Canada and other countries, which aims at commercial operation at the end of 2020s, giving thoughts to safety, economy, supply chain construction, regulatory compliance and so on. Based on the development of regulations foregoing by foreign stakeholders, participation in development and demonstration will be realized. While cooperating in solving R&D issues of the innovative technologies adopted for the SMR, contributions will be made to realize the SMR, which is a decarbonization technology, by utilizing excellent design and production technologies. Through these efforts, while further enhancing design and production technologies for the SMR, the position of major supplier will be acquired and the mass production system in line with global expansion of the SMR will be established.

In addition to light-water reactors, fast breeder reactors, and high-temperature gas-cooled reactors, there are various types of SMRs such as molten salt reactors and microreactors, depending on the coolant and power. Based on this, we will promote technological development and basic technology development through the ingenuity of the private sector, depending on the level of technological maturity and other factors.

3) High-temperature gas-cooled reactor (HTGR)

<Current status and issues>

High-temperature gas-cooled reactor (HTGR) utilizes carbon-free high temperature heat over 700°C by using chemically stable helium coolant, Tri-isotropic coated fuel particles (TRISO-CFPs) which does not melt even at high temperature and structure material absorbing high temperature heat and, in addition to electric power generation, attracts attention with its possibility for effective heat utilization and massive and low-cost carbon-free hydrogen production.

As for hydrogen production which attracts attention with regard to decarbonization in industrial fields including steelmaking and chemical, there is a possibility that one HTGR decarbonizes one shaft furnace capable of complete hydrogen reduction steelmaking. Since required footprint is 1/1600 compared to the case of electrolysis of water by solar power, if a high level of safety is verified of the HTGR, local production for local consumption of hydrogen combined with heat supply needed for industrial process will become possible without incurring additional transportation cost of hydrogen. In combination with power generation and heat supply, a cost of about 12 yen/Nm^3 could be achieved in 2050, which would be less than that of gas-fired power (about 20 yen/Nm^3 or less in hydrogen equivalent).

USA has just decided on development support of up to 160 billion yen to an HTGR venture company aiming for construction of a demonstration reactor within seven years. UK, too, has announced establishment of a fund of ca. 23 billion yen for innovative module reactors, among which HTGR applicable to hydrogen production and so on is named as a strong target for support.

In Japan, JAEA possesses the High Temperature Engineering Test Reactor (HTTR). The HTTR has achieved continuous high-temperature operation at the world's highest temperature of 950°C for 50 days, and has the world's leading technology, including a test that simulated a loss-of-coolant accident similar to the accident at TEPCO's Fukushima Daiichi Nuclear Power Plant and confirmed that the reactor cooled naturally. Moreover, while manufacturers are developing various concepts including hydrogen production using high temperature heat and storage of thermal energy, it is necessary to establish underlying technologies also for hydrogen production.

<Future efforts>

Utilizing the HTTR which recorded world’s highest temperature, the government will support, in addition to international safety demonstration, necessary technology development for massive and low-cost carbon-free hydrogen production by 2030. Simultaneously, development of carbon-free hydrogen production method using ultra high temperature heat including IS process and methane pyrolysis method will be supported. In supporting the development, the government will participate in technology development and verification giving thoughts to safety, economy, supply chain construction, regulatory compliance and so on, and will compose overseas joint projects considering the status of preceding overseas projects.

Moreover, considering the situation where Japan is leading the world also in terms of establishment of standards, cooperation with related organizations of other countries for diffusion of Japanese standards will be promoted through construction, operation and restart of the HTTR.

4) Fusion energy

<Current status and issues>

Fusion reactor, which generates plasma of over 100 million °C, is a technology which can be used for heat utilization and hydrogen production in addition to electric power generation by heating coolant up to ca. 1,000 °C. Its fuel is basically hydrogen and no high-level radioactive waste requiring long-term management is generated. Since plasma generation is a technology of which reaction is difficult to maintain, it is of high level of safety without risk of reactor excursion.

With regard to the ITER project, towards the commencement of operation in 2025, construction and production of various equipment is being implemented with the cooperation of seven members in the world to start ITER machine assembly and its installation in July 2020. Japanese companies are manufacturing major equipment such as superconducting toroidal filed (TF) coils, which are being delivered to the ITER site in France. Specifically, the third TF coil made in Japan was delivered in March 2021, and the final test of the first central solenoid (CS) coil, which was jointly manufactured by Japan and the United States, was completed in the United States in February of the same year. The fabrication of major equipment is progressing steadily at each pole.

Simultaneously, towards complementation and support of the ITER project and a future fusion DEMO (Demonstration) reactor, with the cooperation of Europe and Japan, Broader Approach (BA) activities are implemented. We have been conducting tests to improve plasma control technology using the large tokamak device (JT-60SA) under construction in Japan, developing structural materials with durability against fusion neutrons and low activation characteristics for a fusion DEMO reactor, and developing fuel generation technologies such as lithium recovery technology from seawater, technology to produce tritium from lithium, and technology to refine metals such as beryllium with low temperature and low CO_2 emission.

Moreover, a large number of venture companies aiming for early realization of fusion power generation are being established in USA, UK and Canada, and venture companies in the fusion energy field have been founded since late 2010s also in Japan, though private investment to fusion energy is relatively small compared to other countries.

<Future efforts>

As for the ITER project, commencement of operation in 2025 and commencement of fusion reaction with real fuel operation in 2035 are aimed for. Regarding BA activities, the operation of JT-60SA and other R&D will be steadily carried out toward a fusion DEMO reactor. Through these efforts, technological verification of the major equipment and a technology to maintain energy output state for a long time will be established to realize fusion energy. Simultaneously, various design and technology development for the fusion DEMO reactor construction project in Japan will be implemented to promote R&D to have a prospect of practical application of fusion energy by the mid-21st century. As for the development of fuel refining technology, work will be conducted on the demonstration of lithium refining technology and low-temperature, low-CO_2 emission metal refining technology, with the aim of commercialization.

Moreover, by expanding the range of fusion research through outreach activities aimed at arousing interest for fusion energy and at mutual understanding, the government will encourage more companies to join from a long-term viewpoint aiming for participation of domestic venture companies and so on in overseas projects.

Furthermore, not limited to power generation, R&D of underlying technologies which may contribute to Carbon Neutrality such as a carbon-free hydrogen production process utilizing high temperature of fusion reactors will be promoted.

(5) Automobile and battery industries

The government will promote the electrification of automobiles. These efforts are not limited to the automotive industry, but involve energy supply, various industries, daily life and work, mobility and logistics, and regional and town planning, and must be actively mobilized as a package of support, regulations, and a wide range of other policies. In addition, it is necessary to show a variety of paths by optimally combining powertrain, energy, fuel, and other technologies, without being limited to specific technologies, so that Japan's industry can be internationally competitive. Furthermore, Japan's automotive industry is a key industry with world-class comprehensive technological capabilities that supplies vehicles to countries around the world, and it is necessary to take comprehensive measures by paying attention to the goals, regulations, support, and other measures related to electrification in other countries and the status of the electric vehicle market as a result of these measures. Since many of the related industries are dominated by small, medium, and micro-sized companies, we should aim to create an industrial structure that can positively work toward the realization of Carbon Neutrality by responding to electrification, challenging new fields, changing business categories, diversifying, and fostering cooperation and mergers among companies.

Based on this basic approach, Japan must aim to become a leader in this field by promoting the following initiatives.

Comprehensive measures will be taken to achieve 100% of new passenger vehicle sales being for vehicles that are electrically driven[46] by 2035.

With regard to commercial vehicles, for light-duty vehicles of 8 tons or less, the government will take comprehensive measures, including the introduction of vehicles and promotion of infrastructure development, aiming for 20-30% of new vehicle sales to be electrified vehicles by 2030, and 100% of new vehicle sales to be electrified vehicles and vehicles suitable for the use of decarbonized fuels such as synthetic fuels combined by 2040. As for large vehicles over 8 tons, we will aim to introduce 5,000 units of electrified vehicles in advance in the 2020s while promoting technological verification to develop and promote the use of electrified vehicles suitable for commercial use such as cargo and passenger businesses, and we will also set a target for the diffusion of electrified vehicles in 2040 by 2030, taking into account the progress in technological development and diffusion efforts to reduce the price of hydrogen and synthetic fuels.

In order to continue to lead the global market for motorcycles, the shift to electrified vehicles will be promoted through initiatives in Japan and overseas, including the international standardization of storage battery standards and infrastructure development.

In many countries, measures to promote the use of electric vehicles, etc., have been launched one after another. For example, some European countries and the State of California have set targets to switch to zero-emission vehicles such as electric vehicles and fuel cell vehicles by 2040 or earlier, while Europe and the United States are considering providing approximately 250 billion euros (inclusive) and 174 billion dollars, respectively, in support.

The G7 Summit in June 2021 also noted that it (i) commits to sustainable, decarbonized mobility and to scaling up zero-emission vehicle technologies, including in the bus, train, shipping, and

---

[46] Electric Vehicles, Fuel Cell Vehicles, Plug-in Hybrid Vehicles, Hybrid Vehicles.

aviation industries; (ii) recognizes the need to dramatically accelerate the pace of global decarbonization of the road transport sector to this end throughout the 2020s and beyond (including accelerating the roll-out of necessary infrastructure, including charging and fueling infrastructure, and supporting the enhanced provision of more sustainable transport options, including public transport, shared mobility, cycling and walking); and (iii) commits to accelerating the transition away from new sales of diesel and petrol cars to promote the uptake of zero-emission vehicles.

In Japan, the introduction of electric vehicles will be strongly promoted during this decade to build a world-leading industrial supply chain and mobility society, starting with batteries. The government will take special measures in this process, especially for converting light vehicles (kei-cars) and commercial vehicles to electric vehicles and fuel cell vehicles. It will also support "aggressive business transformation and business restructuring" to encourage parts suppliers, auto dealers, maintenance companies, and service stations (SS), which support the local economy, to respond to the accelerated shift to electrification.

To reduce CO_2 emissions and activate mobility at the same time, the government will also work on resolving local mobility issues through the transformation of how to use automobiles. For example, the ideal future mobility society is one in which traffic accidents and traffic congestion are reduced to zero. In the automotive field, we will promote the implementation of automated driving and digital technologies in electrified vehicles. In this way, we will accelerate the social implementation of new services and infrastructure that respond to user behavior change and electrification, with the aim of resolving mobility issues over the medium to long term.

In addition, storage batteries are a "new energy infrastructure" that will play a key role in the advancement of digitalization and greening, such as carbon-free regulating power, which is necessary for the electrification of automobiles and the spread of renewable energy. The government will strengthen batteries' industrial competitiveness through policies such as supporting research and development, demonstrations, and capital investment, studying institutional frameworks, and developing international cooperation toward standardization.

Through these initiatives and efforts to decarbonize energy, we will pursue various options for Carbon Neutrality and aim to achieve zero CO_2 emissions through the production, use, and disposal of CO_2-emitting automobiles in 2050.

1) Promoting vehicle electrification and transforming how to use automobiles

<Current status and issues>

Europe and China are strategically promoting the spread of electric vehicles and plug-in hybrid vehicles, and the penetration of these vehicles is increasing rapidly. On the other hand, Japan falls behind Europe and China in the widespread use of these types of vehicles.[47] On the other hand, Japan falls behind Europe and China in the widespread use of these types of vehicles.

The challenges to be addressed toward the widespread use of electrified vehicles include

---

[47] Sales of electric vehicles and plug-in hybrid vehicles in the first quarter of 2021 will be approximately 350,000 units in the EU as a whole (more than 1.5 times as many as in the same period of 2020, on the preliminary basis of the European Automobile Manufacturers Association) and approximately 11,000 units in Japan (approximately 20% more than in the same period of 2020, based on data published by the Japan Automobile Dealers Association and compiled by the Ministry of Economy, Trade and Industry).

expanding social acceptance through vehicle price reductions and infrastructure development such as electrified vehicle charging infrastructure and hydrogen stations. Another challenge will be to strengthen electrified vehicle-related technologies, supply chains, and value chains, including storage batteries, fuel cells, and motors. Especially critical issues are (i) strong cost awareness of light vehicle and commercial vehicle users, (ii) the electrification of automobiles with body design restrictions, and (iii) the need to strengthen the competitiveness of suppliers such as SMEs. Facilitating procurement of low-carbon energy sources would also be essential to reducing life-cycle CO_2 emissions from automobiles.

In addition to the above, each country is currently demonstrating/implementing sustainable urban transportation utilizing Mobility as a Service (MaaS) and autonomous driving technology. For example, Europe is set to formulate a strategy called "Sustainable and Smart Mobility Strategy" to optimize environmental load reductions and urban transportation systems, with a large-scale demonstration project[48] underway in collaboration among member states in the region. In Japan, while MaaS demonstration efforts are underway across the country, there are only a few cases where such initiatives have led to large-scale commercialization. For this reason, there is a need for the entire region to pursue both reducing environmental loads and solving mobility issues. Regarding autonomous driving technology, driving data collection through public road demonstrations is not easy in Japan, compared with the U.S. and China. For this reason, there is an urgent need for creating a development and evaluation environment utilizing digital technology.

<Future efforts>

The government will take the following actions to promote vehicle electrification.

(a) Expanding the introduction of electrified vehicles and infrastructure

The government will utilize fuel economy regulations, promote public procurement, expand charging infrastructures, support the introduction of electrified vehicles, encourage car replacement, and the like.

As we move toward Carbon Neutrality in the future, it will be necessary to address both regulatory and incentive measures.

(Passenger vehicles and commercial vehicles)

Using technology-neutral fuel economy regulations, we will combine all technologies to effectively reduce CO_2 emissions. To this end, the government will encourage automobile manufacturers, etc. to improve the fuel efficiency of new vehicles by achieving the new fuel efficiency standards[49] for the target fiscal year of 2030. At that time, the operation of recommendations and announcements will be reviewed to consider strengthening enforcement to ensure compliance with fuel efficiency

---

[48] Sixty-nine organizations from 13 EU countries are jointly implementing the SHOW project. The project plans to actually place at least 70 autonomous driving vehicles in 12 cities within the region by 2024, with a dedicated driving lane and 5G network installed.

[49] Taking into account the number of vehicles shipped in FY2016, the fuel efficiency standard in FY2030 is equivalent to 25.4 km/L. To achieve this standard, the industry-leading actual level of 20.5 km/L in FY2019 must be increased by approximately 24% (however, the standard may increase or decrease depending on the number of vehicles sold by weight).

standards.

We will also promote the electrification of official and company vehicles owned by local governments and private companies. As for the government's official vehicles, in reviewing the government's action plan, the government will consider making them electrified by FY2030, unless there are no alternative electrified vehicles available, etc.

When promoting the use of electrified vehicles to individuals and private companies, we will consider the promotion of introduction and replacement of electrified vehicles from a medium- to long-term perspective, taking into account the economic difference between electrified vehicles and gasoline vehicles, the degree of penetration of electrified vehicles, and the state of support in other countries. Based on the "FY2021 Ruling Party Tax Reform Proposal[50]", a fundamental review of the tax system will be carried out when the next eco-car tax reduction, etc. expires, and consideration will be given to make it contribute positively to the realization of the 2050 carbon-neutral target.

In addition, by providing incentives for electrified vehicles when using expressways, we will reduce emissions by shifting traffic from roads to expressways and promote the spread of electrified vehicles. Furthermore, we will consider reducing or exempting parking fees at national parks. Additionally, the government will consider measures to deal with the fact that light vehicles and commercial vehicles are more difficult to convert to electrified vehicles.

Lack of charging and recharging infrastructure will hinder the spread of electrified vehicles. Therefore, in addition to upgrading aging facilities, we aim to install 150,000 units of charging infrastructure, including 10,000 quick chargers at service stations (SS) where existing infrastructure can be effectively used, and 30,000 quick chargers for public use, to achieve the same level of convenience as gasoline vehicles by 2030 at the latest. At this time, we will promote the spread of charging infrastructure, deregulation, and other measures to promote optimal placement and business feasibility, as well as the introduction of charging facilities in housing complexes, where their widespread use has been slow. In addition, with regard to refueling infrastructure, in anticipation of the widespread use of fuel cell vehicles, fuel cell buses, and fuel cell trucks, about 1,000 hydrogen stations will be constructed by 2030, taking into account human flow and logistics to achieve optimal locations, and regulatory reform will be undertaken. Development of recharging facilities and hydrogen stations for commercial vehicles such as buses and trucks will be promoted, including recharging and refueling facilities exclusively for business premises. At the same time, will be done on technological development and the standardization of charging and recharging infrastructure equipment.

In addition to the above, institutional measures are also important for the widespread adoption of electrified vehicles. For example, depending on the weight and volume of the batteries installed in electric vehicles and fuel cell vehicles, measures will be considered as necessary to ensure that

---

[50] The "FY2021 Ruling Party Tax Reform Proposal (December 10, 2020)" states that "With regard to automobile-related taxes, the government will actively contribute to the realization of the 2050 carbon-neutral goal, and will study the way of taxation, including the relationship between benefits and burdens, from a medium- to long-term perspective, based on the premise of securing stable financial resources through the national and local governments, while taking into account trends in environmental changes surrounding automobiles, such as the need for technological innovation including automated driving, the shift from ownership to use, and the expansion of users in response to the diversification of mobility, as well as the growing needs for regional public transportation and the need to maintain and strengthen the functions of infrastructure to respond to the aforementioned environmental changes."

trucks and other large vehicles are not impeded in their operation. Additionally, from the viewpoint of reducing the burden on business operators and users to expand the use of fuel cell vehicles, the government will study how to regulate fuel cell vehicles, etc., with a view to unifying the related regulations in the "Road Vehicles Act" and the "High Pressure Gas Safety Act", and will compile certain directions in June and reach a conclusion by the end of this year. With regard to charging infrastructure, to promote the installation of such infrastructure in commercial facilities, flexible measures will be encouraged with regard to the operation of the "Large-Scale Retail Store Location Law "by local governments.

(Motorcycles)

Two-wheeled electrified vehicles have issues such as a short cruising range due to the small capacity of the storage batteries that can be installed and the high vehicle cost due to the storage batteries, and at present, not all types of vehicles necessarily have the performance to withstand use by many consumers. On the other hand, there is a movement to actively promote the electrification of motorcycles, particularly in Asia, and this movement has prompted many companies to enter the electrified vehicle market. Japan's motorcycle manufacturers hold more than half of the global market share, with Asia as the axis, and it is essential that they respond to the electrification of motorcycles in order to continue to maintain their international competitiveness.

Therefore, taking into account that motorcycles emit less CO_2 than other forms of mobility, we will first promote the electrification of motorcycles starting with short-distance travel applications that have potential for use even with current performance. For this reason, we will continue to promote the introduction and replacement of electrified vehicles in order to expand the spread of electrified vehicles, and at the same time, we will improve the mass-producibility of storage batteries, which are the main cause of the cost hurdle, by working on the international standardization of standards led by Japanese manufacturers. In addition, we will promote the development of battery stations (interchangeable, etc.) for short-distance travel, and work to build an environment in which vehicles with short cruising ranges can be used for travel without inconvenience.

(b) Promotion of policies that work in tandem with energy policies

In order to reduce emissions from the automotive sector, it is essential to promote both the electrification of vehicles and the decarbonization of energy, given the accelerating pace of change in the global automotive market. For example, electrified vehicles require a large amount of electricity not only for recharging during the use phase, but also for battery production during the production phase, so low-cost decarbonized electricity is needed to reduce CO_2 emissions throughout the vehicle lifecycle. Specifically, renewable energy will continue to be the main source of power, with the aim of maximizing its introduction while reducing costs and encouraging independence. We will also pursue new options such as nuclear power, hydrogen, ammonia, and CCUS/carbon recycling. Additionally, in order to maintain and improve the competitiveness of the Japanese industry, we will promote maximum control of energy costs. Furthermore, in the non-fossil value trading market, which trades the environmental value of electricity derived from non-fossil power sources, we will increase the number of non-fossil certificates with tracking, make them available for purchase by consumers, and review the reduction of the price of non-fossil certificates.

In this way, we will take comprehensive measures to make automobiles carbon neutral in conjunction with energy policy. At the same time, in order for Japan's automobile industry to continue to supply vehicles with excellent environmental performance to countries around the world, we will strive to develop a fair and transparent international competitive environment, taking into account the status of international discussions on Carbon Neutrality.

(c) Strengthen electrified vehicle-related technologies, supply chain, and value chain, including storage batteries, fuel cells, and motors

Large-scale investment support, technology development and demonstration, support for the electrification of light vehicles and commercial vehicles, etc. will be provided along with work on the electrification response, business transformation and business restructuring of automobile-related industries, including suppliers such as small- and medium-sized companies, automobile dealers and maintenance companies, and service stations (SS), as well as the establishment of a digital development infrastructure to support this.

Batteries and motors, which are key components of electrified vehicles, and their materials will determine the competitiveness of the automotive industry in the future. From the standpoint of supply chain resilience, the domestic location of production bases that are above a certain scale will be promoted.

In addition to advancing the technological development of next-generation batteries, as described below, we will also work on improving the performance (weight, volume, output, etc.) and developing materials for mobility motor systems, because it is considered effective for strengthening industrial competitiveness, including that of suppliers, to promote efforts for electric powertrains for mobility in the near field, such as agricultural and construction machinery, drones, and flying cars.

Also, in order to strengthen the entire supply and value chains, we will also promote the development of technologies and the construction of facilities to reduce CO_2 emissions throughout the entire lifecycle of vehicles (including vehicle bodies and frames) and changes associated with electrification, such as weight reduction technologies to cope with the increased weight of vehicle bodies caused by electrification, and CO_2 emission reductions in manufacturing processes characteristic of vehicles such as painting and recycling processes. In this way, the entire automobile-related industry will be carbon neutral.

Moreover, "aggressive business transformation and business restructuring," will be encouraged, such as engine parts suppliers taking on the challenge of manufacturing parts for electrified vehicles and other new fields, and service stations (SS) and maintenance bases becoming new logistics nodes, service bases, and EV stations.

Specifically, the government will encourage technological development, capital investment, and the securing, utilization, and training of human resources in order to accelerate suppliers' responses to electrification. In addition, we will build a system and improve the environment (including inter-company collaboration and restructuring) to provide support to suppliers in making their manufacturing processes carbon neutral and adapting their businesses.

For auto dealers and maintenance companies, the government will encourage capital investment and human resource development to respond to structural changes in vehicles associated with electrification, as well as DX investment to further improve the efficiency and productivity of maintenance operations. At the same time, efforts will be made to improve the attractiveness of the used car market through the development of new services using MaaS, the promotion of initiatives to evaluate the deterioration of storage batteries to promote the replacement of electrified vehicles, and the improvement of the related environment. In addition, service stations (SS), which have been responsible for supplying fuel to automobiles, will be encouraged to restructure their business by becoming integrated energy centers and diversifying their management, so that they can supply energy to electric vehicles and fuel cell vehicles, in addition to synthetic fuels for hybrid vehicles, as electrified vehicles become increasingly popular.

(d) Change in the way we use our cars

In addition to promoting the selection and use of electrified vehicles by users, and expanding the response and options for this purpose, we will work on the use of automated driving and digital technology, as well as collaboration with road and urban infrastructure, in order to achieve sustainable mobility services, and more efficient and productive logistics.

First, in addition to continuing to improve the safety of electrified vehicles on their own through the widespread use of safe driving support functions, the widespread use of electrified vehicles equipped with high-precision digital maps for accurate self-positioning, continuous software update functions via over-the-air (OTA) capability, and narrow-range communication functions between vehicles, road vehicles, and pedestrians will reduce accidents and traffic congestion not only for individual vehicles but also for the entire transportation system, thereby creating a safe and secure environment for the surrounding vehicles and pedestrians. At the same time, by ensuring that all vehicles run smoothly without accidents or congestion through connected functions, the environmental impact of the entire traffic flow can be reduced. In order to implement the high-precision digital maps, OTA functions, and narrow-area communication functions that will form the basis of these next-generation transportation systems in society, the necessary verification and studies for their widespread use will begin in fiscal 2021.

Furthermore, in order to minimize the power consumption of networks and cloud data centers, which will increase along with the amount of information being processed, it is necessary to implement advanced information processing, including automated driving, as much as possible on the side of automobiles, which are the edge devices to networks, toward the digital society of Beyond 5G around 2030. At the same time, since electrified vehicles are driven by electric systems, they are compatible with automatic driving in terms of control, and the widespread use of electrified vehicles by 2050 is expected to progress along with the implementation of automatic driving and safe driving support technologies. On the other hand, it has been pointed out that the increase in power consumption at the point of the vehicles, due to the sophistication of information processing within the vehicles, will affect the cruising range of electrified vehicles in relation to the limit of storage battery capacity. In order to achieve both automated driving and electrification, we will engage in R&D of advanced sensors and computers using advanced semiconductors, etc., mainly for automated driving systems, as well as new in-vehicle network systems and digital development platforms that support these next-generation devices, in order to simultaneously improve their performance and achieve thorough energy conservation.

In addition, in order to develop electrified vehicles suitable for commercial use, which is an issue for the spread of electrified vehicles in the commercial vehicle field, from the last mile to long-distance transportation, and to maximize economic efficiency by optimizing the arrangement of recharging and refueling infrastructure, operation management and energy management, large-scale connected demonstrations in the field of commercial vehicles such as trucks and buses and operational demonstrations of automated vehicles, linked to regional energy systems will be studied in cooperation with road and urban infrastructure.

(e) Cooperation with Asia and other countries to promote the use of electrified vehicles

We will work on the promotion of electrification in cooperation with Asia and other regions that are closely related to Japan's automotive industry. In Asia and other regions where the spread of electrified vehicles is expected to become more widespread in the future, we will discuss a path toward Carbon Neutrality through bilateral dialogue on electrification, etc., and coordinate policies. In addition, we will engage in activities such as international harmonization of charging standards, support for international standardization, technical guidance for local suppliers, and local demonstration tests, in order to improve charging infrastructure, support the electrification of the supply chain, and expand the market for electric vehicles and fuel cell vehicles.

While promoting cooperation in the development of an environment for the widespread use of electric vehicles and fuel cell vehicles, from the perspective of social acceptability and the use of existing infrastructure and supply chains, it is realistic and effective for decarbonization to promote the widespread use of electrified vehicles in stages. In order to contribute to the decarbonization of emerging countries where motorization is progressing, both in terms of technology and policy, we will take into account the domestic circumstances of each country and promote initiatives related to electrification in an integrated manner with Asia and other regions.

(f) Disaster response for electrified vehicles

Electrified vehicles are expected to contribute to disaster prevention, such as by providing power supply in times of disaster. For example, during the power outage that occurred mainly in Chiba Prefecture due to Typhoon No. 15 in 2019, electrified vehicles were used to charge mobile phones and secure lights at evacuation centers, as well as to supply power to private homes with infants and the elderly, nursing homes, and so forth, contributing to securing necessary power sources. On the other hand, some issues have been pointed out regarding how to deal with out-of-charge situations in times of disaster, so a survey will be conducted and measures will be studied, including the state of road services, in anticipation of the large-scale spread of electrified vehicles.

(g) Mobility society in 2050 (social transformation and ideal vision of life brought about by electrified and automated vehicles)

Innovation in the automotive sector toward Carbon Neutrality in 2050 should not only contribute to reducing CO_2 emissions, but should also aim to continue to revitalize the movement of people and goods, and to promote social change that will lead to the satisfaction of everyone's mobility needs and the resolution of certain issues. This is because any new technology or service that provides greater new added value to Japanese society and people's lives will be more readily accepted by society. In this sense, it is appropriate for electrified vehicles to not only have a low environmental impact and be highly sustainable, but also to provide new added value, such as being safer, providing more comfort, offering more freedom, and being more attractive, for example, through their combined automation. Therefore, in order to achieve Carbon Neutrality in 2050, we will not only focus on electrification, but also on electrified and automated vehicles, with a view to changing the nature of the mobility of society in 2050.

At this time, it is natural that the infrastructure for electrified vehicles should be built by 2035 as one of the targets for the construction of a new mobility society. In parallel with this, the necessary infrastructure and other environmental improvements and dissemination measures should be studied so that automated vehicles can be implemented in society as early as possible.

In parallel with the electrification of automobiles, in order to promote the implementation of automated driving and digital technologies in electrified vehicles, innovation will be carried out in stages from 2030 to 2040, and strong attention will be paid in the future to measures to promote innovation and the development of an environment suitable for social implementation, so that new mobility characteristics, such as those listed below, can be created by 2050.

(A) Improving the safety and convenience of travel

(a) Toward "zero accidents"

In addition to the widespread use and sophistication of safe driving support and automated driving technologies, the collaboration between vehicles, road vehicles, and pedestrian traffic through advanced digital and communication technologies will not only prevent human error affecting individual vehicles, but will also create a safe and secure environment for the surrounding vehicles and pedestrians. This will improve the safety of not only drivers, but also pedestrians, and is a major step toward zero traffic accidents. To this end, we should promote the reliable social implementation of automated driving and digital technologies, so that the necessary level of safety and reliability can be ensured throughout the system.

(b) Towards "zero mobility vulnerability"

Securing a means of transportation for the elderly and children who cannot or have difficulty or anxiety with regard to driving on their own, especially in rural areas where public transportation is inadequate, is a lifeline itself. Also in urban areas, as the birthrate declines and the population ages, it will become increasingly important to secure means of transportation for people with limited mobility in bedroom communities, for example, and to ensure smooth transportation for foreign visitors to Japan, who are likely to increase again after the COVID-19 pandemic ends. The uneven distribution of the population expected in 2050 and the shortage of public transport drivers as part of the labor shortage will add to this situation. It is important for electrified vehicles to run automatically in order to achieve the goal of zero mobility vulnerability. As a result, this will contribute to solving the shortage of manpower in public transportation and ensure the necessary means of transportation for all people.

(c) Towards "zero traffic congestion"

In order to achieve zero traffic congestion, traffic information will be analyzed in real time using digital technology to automatically propose optimal travel routes and means of transportation, and traffic demand management and rectification using ITS and automated driving technology will greatly reduce time loss in human flow and logistics, thereby improving productivity.

(B) Innovations in the use of travel time (effective use of travel time)

Automatic driving frees the driver from the burden of driving operations, for example, troublesome low-speed driving in traffic jams or long hours of driving for business. In addition, advanced safety driving support technologies enable a safer and more secure driving experience than ever before. The result is a new experience of mobility for people everywhere, and more freedom to use their travel time.

Additionally, if advanced automated driving technology is implemented in conjunction with electrification, there is a high possibility that the interior space and interior[51] will not be based on what seen in the design of current vehicles, but will become a "moving, living, and service space" so to speak. This will facilitate the effective use of interior vehicle space, allowing for making the most of the time spent traveling by car, and is expected to create a variety of new value through a combination of transportation and services. For example, by combining automated driving technology with telework technology, it will be possible to work comfortably from any location while on the move. The concept of "commuting" will disappear, as it will no longer be necessary to go to the office, and it will become commonplace to travel to places of leisure while working. In this way, the need to travel in the "shortest time" is dramatically reduced, and the importance of "optimization" to reach a certain point in time or place is increased, which leads to an increase in the degree of freedom of route options and transit points, which inevitably leads to the optimization of traffic flow as described below. In addition, the quietness of electrified vehicles can be utilized to provide daily living functions such as lodging and entertainment functions including movies and so on. In addition to "home" as a home identity, the concept of living space will be expanded and the range of lifestyles will be broadened, which is expected to lead to the development of new businesses.

Additionally, the ability to receive a greater variety of services in the post-pandemic period without having to travel is anticipated as an example of new value. Alternatively, the number of areas, particularly in rural areas, where access to essential infrastructure such as medical care and shopping is difficult, is expected to increase. For example, if mobility as a "moving service space" can provide services anywhere in a cheaper and more convenient way, it will free people from the time it used to take to travel to the necessary infrastructure, and it will also reduce the social cost of maintaining fixed infrastructure with low operating rates. As a result, even in the midst of declining birthrates and depopulation, the comfort of life for all people will continue to be ensured while

---

[51] Even in current railcars, manufacturers are working to make them barrier-free by lowering the floors and increasing the interior space. Electrified vehicles, which are expected to expand in earnest in the future, are generally compatible with lower floors and are expected to have potential. For example, lowering the driver's seat in commercial trucks will lead to an increase in the number of female and elderly truck drivers.

consolidating and improving the efficiency of certain infrastructure and other facilities. We will continue to promote the development of the necessary environment, including the institutional aspects, so that Japanese society can make maximum use of mobility as moving infrastructure, overturning the common notion that infrastructure is fixed, and bearing in mind the possibility that mobile infrastructure will replace fixed infrastructure in the medium to long term.

C) Social implementation of "moving storage batteries"

(a) Smart city upgrading

The realization of smart cities, which utilize digital technology and various types of data to optimize all kinds of services, could lead to the maximization of resident satisfaction. On the other hand, electricity demand is expected to increase in line with the increase in telecommunication capacity and the development of data centers, and there will be a greater need for optimal energy management in order to optimize and upgrade resident services. By connecting all types of electrified vehicles within a certain area in real time through high-speed communications, etc., it will be possible to maximize the adjustment capacity of electrified vehicles by using idle vehicles to become "moving storage batteries" even in normal times, and to use them as VPP[52] and V2X.[53] This will make it possible to overcome the increasing demand for electricity in a society that is more electrified than at present, and to contribute to the realization and advancement of so-called smart cities.

In addition, through highly accurate prediction of passenger demand and congestion, it is possible to move to the place you want to go when you want to, without wasting time waiting.

(b) Improving resilience to disasters

As the innovations in storage batteries described below progress and their capacity and capability improve, electrified vehicles are expected to come into their own, not only as a means of transportation, but also as "moving storage batteries". The increasing of depopulation due to the uneven distribution of the population in 2050 will require the strengthening of disaster prevention functions in depopulated areas, especially in preparation for earthquakes and typhoons.

(D) Providing new added value through mobility

Changes in society, such as the realization of a carbon-neutral society in 2050, technological innovations such as automated driving technology, and the social implementation of new mobility services that utilize these technologies, will provide new added value that satisfies the mobility needs of all people and solves mobility-related problems, as described above. As a result, it is expected that the relative cost burden of owning and using mobility will be reduced for all people.

2) Carbon-neutral fuel (such as synthetic fuel (e-fuel))

---

[52] A technology that uses digital technology to bundle and remotely control a large number of distributed energy resources, such as the on-board storage batteries of electrified vehicles, to adjust the supply and demand of electricity, avoid renewable energy output control, and alleviate power system congestion.

[53] The supply of electricity from an electric vehicle to various targets such as consumers (households, buildings, etc.) and power grids.

<Current status and issues>

In order to become carbon neutral, it is also necessary to decarbonize the energy used to power the system. Especially for commercial vehicles whose electrification is considered challenging, efforts to make carbon-neutral fuel are essential, in addition to the efficient use of fuel.

Synthetic fuels are produced by synthesizing CO_2 and hydrogen, and can be regarded as carbon-free decarbonized fuels because they reuse emitted CO_2. In particular, liquid synthetic fuels, which are mixtures of gasoline, kerosene, diesel oil, etc., are aggregates of multiple hydrocarbon compounds, or "artificial crude oil," so to speak. In particular, when hydrogen derived from renewable energy is used, it is called e-fuel. Since existing fuel infrastructure and internal combustion engines can be utilized, the introduction cost can be reduced compared to other new fuels such as hydrogen.

Synthetic fuels, like fossil fuels, are liquid fuels and therefore have a high energy density and portability. For example, when heavy-duty vehicles and jet aircraft are electrified and converted to hydrogen, they will require storage batteries and hydrogen energy with a larger capacity than liquid fuels to travel the same distances as liquid fuels. These liquid synthetic fuels will continue to exist as long as there are mobility products that are difficult to replace with electric and hydrogen energy.

The challenges for the commercialization of synthetic fuels are the cost and the establishment of production technology, making it necessary to improve the efficiency and cost of existing technologies and to develop innovative new technologies and processes.

<Future efforts>

For synthetic fuels, in order to establish an integrated production process for commercialization, we will develop innovative new technologies and processes (co-electrolysis[54], Direct-FT[55], etc.) in addition to improving the efficiency of existing technologies (reverse shift reaction + FT synthesis process[56]) and designing and developing production facilities so that the cost of synthetic fuels will be lower than the price of gasoline in 2050.

By intensively developing and demonstrating technologies related to these synthetic fuels over the next 10 years, we aim to establish high-efficiency, large-scale production technologies by 2030, expand their introductions and reduce their costs in the 2030s, achieving independent commercialization (based on environmental value) by 2040.

3) Battery

<Current status and issues>

The storage battery is a "new energy infrastructure" that will be a key element in the advancement of digitalization and greening, such as carbon-free power regulation, which is necessary for the electrification of automobiles and the spread of renewable energy. For the time being, the market for on-board storage batteries is expected to grow in line with the progress of the electrification of automobiles, and the need for stationary storage batteries is also expected to expand as the share

---

[54] Water electrolysis and CO_2 electrolysis at the same time.

[55] A new technology that simultaneously realizes the reverse shift reaction and the FT synthesis process to produce hydrocarbons directly from CO_2 and hydrogen.

[56] CO_2 from to CO (reverse shift reaction) and used a catalyst to convert the synthesis gas (CO and hydrogen) to synthetic fuel (FT synthesis process).

of renewable energy sources increases, so a comprehensive strategy to strengthen the competitiveness of the storage battery industry as a "new energy infrastructure" is necessary with an awareness of this market expansion trend.

The securing of storage batteries and the stabilization of supply chains are important issues when promoting the electrification of automobiles and other forms of mobility, as electric vehicles are equipped with storage batteries with a capacity 50 to 100 times greater than that of hybrid vehicles, and 10 to 20 times greater than that of plug-in hybrid vehicles. In Europe, the "European Battery Alliance" has been established to build a supply chain for storage batteries in the region, and support for manufacturers of materials, storage batteries, and automobiles is provided as well.[57] In addition, France and other countries have announced their support for investment in storage battery factories.[58] Furthermore, the EU announced in December 2020 the final draft of the Battery Regulation, indicating the introduction of labeling regulations on life-cycle CO_2 emissions from batteries and discipline on reuse and recycling of them. The ability to procure energy with less CO_2 emissions may determine batteries' competitiveness in the future.

Chinese and South Korean companies are aggressively investing in batteries, with their global market shares increasing. On the other hand, Japanese companies' market share is declining.[59] China and South Korea are also strengthening their technological development of next-generation batteries.[60] In order to expand the use of electrified vehicles and further spread the use of stationary storage batteries, it is necessary to make storage batteries lighter, smaller, as well as less expensive, and large-scale investment and the strengthening of technological capabilities are key issues.

Meanwhile, given the widespread use of home-use solar panels and growing interest in disaster resilience, the market size of home-use batteries in Japan has grown to the world's largest[61] on a capacity basis. On the other hand, South Korean companies accounted for about 70% of the market, and Japanese companies' market share is only around 30%. As part of its industrial technology enhancement, Japan is working on aqueous lithium-ion batteries and other product developments to significantly reduce production costs and improve safety by using clay and resin for main battery components. The government must resolve issues with further cost reductions and the need to increase the predictability of investment recovery toward self-reliant penetration for batteries, including those for business, industrial, and power grid use.

<Future efforts>

In order to secure a stable base for domestic automobile manufacturing even amidst the changing trend toward electrification, the domestic manufacturing capacity for automotive storage batteries

---

[57] The participating countries committed supporting research funds up to a total of 3.2 billion euros towards 2031 (2019), etc.

[58] The "Plan de soutien à l'automobile" (Automobile Assistance Plan), announced by France in May 2020, includes up to 850 million euros in public funds to support storage battery manufacturing plants.

[59] According to a private survey, from 2016 to 2019, the Japanese share declined from 37% to 29% of the global market for automotive storage batteries for EVs and PHEVs, while the Chinese global market share increased from 35% to 46% and that of Korea increased from 14% to 19%.

[60] For example, from 2001 to 2018, Japan accounted for about 37% of the total number of patent applications for all-solid-state lithium-ion batteries, while China accounted for about 28%. China also ranked first in the world in terms of the number of patent applications filed in 2018.

[61] About 28% of the global market in 2019 on a storage capacity basis.

will be increased to 100 GWh as early as possible by 2030, and large-scale investment, including in storage battery materials, will be encouraged to strengthen the storage battery supply chain. The goal is to achieve an in-vehicle storage battery pack price of 10,000 yen/kWh or less, which will bring the economic efficiency of electric vehicles and gasoline vehicles to parity, a system price of 70,000 yen/kWh or less (including installation costs) for household storage batteries with solar panels, and a system price of 60,000 yen/kWh (including installation costs) for storage batteries installed in factories and other business and industrial sectors. In addition, the aim is to achieve a cumulative introduction of approximately 24 GWh by 2030 (approximately 10 times the cumulative amount introduced by 2019) for household and commercial/industrial storage batteries in total. Additionally, we aim to commercialize next-generation batteries that are expected to further improve the performance of storage batteries after 2030. Specifically, the objective is to initially commercialize all-solid-state lithium-ion batteries and then commercialize more innovative batteries (fluoride batteries, zinc anode batteries, polyvalent ion batteries, etc.) around 2035. To this end, the government will take the following actions and capture the growth markets.[62]

(a) Lower prices through the scaling of storage batteries

The government will support large-scale investment in batteries, resources, materials, etc., and the introduction of stationary batteries.

(b) Secure mineral resources

The production of storage batteries requires mineral resources such as nickel, cobalt, and lithium, and demand for related mineral resources is expected to increase as electric power generation progresses toward the realization of Carbon Neutrality. In light of this situation, the stable supply of mineral resources for Japanese companies will be strengthened through resource exploration through the Japan Oil, Gas and Metals National Corporation (JOGMEC), a supply of risk money to secure overseas interests, and the development of a rare metal stockpiling system.

(c) Research and development and technology demonstration

The government will support the research and development and technology demonstration such as matters: (i) improving the performance of all-solid-state lithium-ion batteries and innovative batteries, (ii) improving the performance of battery materials, (iii) high-speed, high-quality, and low-carbon production processes for batteries and their materials, (iv) reuse and recycling, and (v) power supply and demand balancing capabilities utilizing stationary batteries, etc.

For example, private and academic research institution will work on the development of technologies necessary for the full-scale mass production of all-solid-state lithium-ion batteries in 2030, which will achieve a volumetric energy density more than twice that of current lithium-ion batteries. In doing so, efficient R&D will be promoted through the use of materials informatics and analysis technology using synchrotron radiation and neutron beams, etc. In addition, taking into account the similarities in materials between aqueous lithium-ion batteries and all-solid-state lithium-

---

[62] According to private sector estimates, the global market of all solid-state batteries will double between 2018 and 2030 (from approximately 8 trillion yen to 19 trillion yen). The global market of in-vehicle batteries alone will grow five-fold during the same period (from approximately 2 trillion yen to 10 trillion yen).

ion batteries, R&D and technological verification will be conducted with an awareness of improving performance and productivity that will contribute to lowering the price of aqueous lithium-ion batteries when developing materials.

(d) Promoting the reuse and recycling of storage batteries

Because storage batteries use rare metals such as nickel and cobalt, as well as large amounts of energy, it is important to promote reuse and recycling. For this reason, R&D and technological demonstrations will be undertaken in order to reuse them as vehicle-mounted parts or stationary storage batteries if they can be reused after initial use, and to efficiently recover mineral resources if they can no longer be used. In addition, standardization and other initiatives described below will be promoted, and the institutional framework for promoting the reuse and recycling of storage batteries will be studied.

(e) Rule development and standardization

Consideration will be given by fiscal 2021 to the institutional framework for making CO_2 emissions visible throughout the life cycle of storage batteries, ensuring the ethical procurement of materials, and promoting reuse and recycling, and the implementation methods for making CO_2 emissions visible will be put into practice as soon as possible.

In addition, in order to promote the reuse of on-board storage batteries and their reuse as low-cost stationary storage batteries, international standardization of methods for evaluating the residual performance of storage battery packs and the performance and safety of stationary energy storage systems, including reused storage batteries, will be conducted, and international rules and standards for promoting reuse will be promoted. In order to visualize the durability, safety, and other performance features that are Japan's strengths, the development of performance indicators and performance labels for the safety of household storage batteries after degradation will be promoted and JIS will be used.

Effort will be put forth to promote the development of an environment for markets for evaluating the value of stationary storage batteries, including the design of a system for entering the supply and demand adjustment market (to be fully operational in 2024). In order to promote new businesses that utilize large-scale grid storage batteries and provide the regulation of power, the positioning of grid storage businesses under the Electricity Business Act will be clarified, and the process of jointly procuring grid storage batteries will be implemented in order to address the lack of power regulation for short-term fluctuations in the output of electricity from fluctuating renewable energy sources. Furthermore, in anticipation of the use of storage batteries to adjust supply and demand in the future, efforts will be made to develop a grid code (rules to be followed by power sources connected to the grid, etc.) for storage batteries, and the introduction of storage batteries for stationary use will be promoted.

(6) Semiconductor/information and communication industries

Amid rapidly advancing information utilization and digitization, an increasingly electrified and digitalized society can realize Carbon Neutrality in all fields including manufacturing, services, transportation, and infrastructure. Therefore, the semiconductor/information and communication industries, as a foundation for digitization and electrification, are the key to advancing green and digital initiatives at the same time.

With regard to the semiconductor and information and telecommunications industries, we will promote two approaches as two wheels of a cart: (1) promotion of energy demand efficiency and CO_2 reduction through digitization (Green by Digital), and (2) energy conservation and greening of the digital equipment and information and telecommunications industries themselves (Green of Digital).

In particular, in order for Japan to lead the world in building a sustainable society where green and digital technologies are compatible, it is necessary to accurately grasp the changes of the times and enhance the competitiveness of the semiconductor and digital industries, which are the "rice of industry", deeply related to all social and economic activities, and play a fundamental role in data communication and processing. Based on this background, the Ministry of Economy, Trade and Industry held the "Semiconductor and Digital Industry Strategy Study Council" with experts as members, and by receiving various opinions, compiled the "Semiconductor and Digital Industry Strategy" in June 2021, which consists of strengthening the competitiveness of semiconductors, strengthening and optimally allocating digital infrastructure such as data centers, and fostering digital industries that support the digital society. From this point forward, we will steadily implement the said strategy together with the Green Growth Strategy.

1) Pushing for efficient energy demand management and CO_2 emission reductions through digitalization (Green by Digital)

<Current status and issues>

The advancement of digitalization will result in the efficient use of energy and CO_2 emission reductions through the optimization of flows of people, things, and money. For example, converting enterprise systems to cloud-based could slash energy consumption by 80%, and the adoption of telework and online conferences could save energy required for commutation and trips. As these examples show, energy-saving effects through digitization will significantly contribute to all industries.

Toward the realization of Carbon Neutrality in 2050, the government aims to achieve the efficient use of energy in the entire society and economy by developing domestic digitalization-supporting data centers and information and telecommunication infrastructures and driving digital utilization and CO_2 emission reductions in urban and all other areas. Simultaneously, the government should support the development of digitization and digital transformation (DX) in all industrial fields.

a) Promotion of DX regardless of urban or rural areas

The importance of DX is becoming recognized widely in recent years. However, a closer look at what Japanese companies are doing in this area would reveal that most of them are not working on

DX at all, or they have just started such efforts from scratch. As a result, a sense of crisis is not shared among the entire industries and companies, and management reform has not yet occurred. Moreover, even in the same industry, each company develops and uses its software and systems, hindering system integration and abolition, utilization rate improvements, and business process optimization through information sharing across companies and industries. Thereby energy-saving and CO_2 emission reductions hasn't progressed.

As power-intensive infrastructures and industries are becoming commonplace from this time forward, promoting DX will contribute to energy-saving and CO_2 emission reductions and strengthening Japanese companies' competitiveness. Therefore, the government should expedite the development of DX.

(b) Data center locations at the core of the digital infrastructure

The development of digitization in the future, mostly due to the widespread use of AI and big data, would require data centers to have more advanced computing power, anticipating large-scale data center markets to grow worldwide. As far as domestic markets are concerned, the data centers built in the 2000s account for more than 40% of the total number of data centers today, generating demand for replacement soon.

In recent years, in addition to (1) power costs, (2) availability of backbone networks, (3) distance from demand centers, and (4) environmental conditions such as natural disasters, the use of decarbonized power sources such as renewable energy has become an important requirement for data center locations.

Japan has geopolitical advantages such as a large economy and stable political situations, but has the following downsides at the same time: 1) high electricity costs, 2) the difficulty efficiently purchasing decarbonized power, and 3) connection to a power infrastructure takes a few years when the data center consumes a considerable amount of energy.

Data centers are the heart of a digital society, and in a society where data centers are located domestically, connected by communication infrastructure, and where edge processing is advanced, low latency data communication will be realized, which will lead to the development of new services using data, such as IoT, automated driving, remote surgery, and smart factories. Furthermore, the aggregation and accumulation of data in the country are favorable from an economic security viewpoint. Given this background, the government will support to build data centers within the country. To ensure the stable utilization of data centers, the government must support to build those centers dispersedly across the country and respond to power disruptions in an emergency.

(c) Advanced information and telecommunications infrastructure (5G, post-5G, advanced 5G, Beyond 5G)

Promoting efficient energy demand management and CO_2 emission reductions through digitization would require building data centers and expediting the development of information and telecommunication infrastructures such as 5G. Japan just started the 5G service in 2020, but the government should move ahead with the early development of safe and secure 5G infrastructure, and also strive to realize various new services. In addition to enhanced Mobile Broadband services, Doing this would require the promotion of research and development on an improved version of 5G leveraging its unique features like Ultra-Reliable and Low Latency and massive Machine Type Communications (Post 5G) and an information communication system compliant with enhanced 5G functions (Advanced 5G).

Meanwhile, Beyond 5G's commercialization is expected around 2030, but international competition in its research and development has already started. Not to fall behind other countries, Japan should take strategic initiatives for research and development and standardization by bringing together the power of the industry, government, and academia.

<Future efforts>

The government will strive for Japan to become the world's green digital power by promoting DX, developing green data centers on the land in Japan, and developing the next-generation information and telecommunication infrastructure.

To promote DX, we will support the R&D of next-generation software that can bring our social lives online remotely, non-face-to-face, and non-contact, as well as demonstrations to promote regional CO_2 reduction through the use of digital technology, in order to establish technology and strengthen competitiveness. At the same time, we will study ways to further accelerate DX in each industry, company, and region. The government aims to acquire a DX-related market size of 24 trillion yen in 2030 by driving DX for social/economic systems and enterprises from now on.

In order to further advance digitization and provide new digital services, it is important to develop data center bases and promote the location of data centers in Japan. In addition, as data centers become critical infrastructure for society and the economy, the perspective of resilience is becoming more important than ever. Currently, most data centers in Japan are concentrated in Tokyo and Osaka, which poses a problem from a resilience perspective. In light of these changes in the environment and the increasing demand for data centers in the future, a policy package, including the formulation of a location plan, will be studied and implemented as soon as possible in order to encourage the development of a data center cluster base so that data centers can be located and attracted to Japan and optimally allocated. At the same time, in order to promote the location of data centers in Japan, we will create a model of zero-emission and resilience enhancement for data centers, and implement demonstrations, subsidy projects, and institutional support to promote the introduction of decarbonized power sources such as renewable energy.

Moreover, in order to promote the location of data centers, it is necessary to facilitate the purchase of decarbonized electricity. To improve consumers' convenience, the government will consider how the system of a non-fossil value trading market should be.

As a result of these efforts, the government aims to create a domestic data center service market of 3 trillion yen in 2030, investing approximately one trillion yen in data centers.

For information and telecommunication infrastructure, the government will support research and development and standardization on Post 5G, Advanced 5G, and advanced optical electronics. Additionally, for the realization of Beyond 5G in 2030, we will steadily promote efforts based on the "Beyond 5G Promotion Strategy" and with the cooperation of industry, academia, and government.

2) Energy saving and greening of the digital equipment industry (Green of Digital)

<Current status and issues>

CO_2 emissions will decrease thanks to "Green by Digital." On the other hand, as the electrification and digitization of houses, factories, and automobiles advance, digital-related power consumption will increase, suggesting that CO_2 emissions will increase accordingly. For example, some large-scale data centers consume as much power as a large thermal power plant can generate. In addition, digital-related power consumption is expected to increase dramatically in the future. For this reason, promoting further energy saving and CO_2 emission reductions such as utilizing renewable energy in electrical equipment, data centers, and communication networks is crucial from the viewpoint of net CO_2 emission reductions.

As some companies internationally developing a digital platform are poised to strive for Carbon Neutrality through investment in renewable energy power generation and green power purchase, greening has already become a significant movement in the information and communication industry.

Furthermore, in fields such as power semiconductors, memory chips essential for information processing, semiconductors, optical electronics (optical interconnection), and software, which are integrated into every electrical device, competition in investment and research and development toward energy-saving and high performance is intensifying. Therefore in the entire information and communication industry, the early achievement of energy-saving and greening will determine the winner in such competition.

From now on, the government will expand the fields where Japanese companies have competitive advantages, such as power semiconductors (Japanese companies have a world market share of 29%).The government should also promote energy-saving, CO_2 emission reductions, high performance, and early introduction in semiconductor-related areas such as memory chips, optical electronics, and high-performance computing. These efforts include information and communication infrastructure areas such as data centers, 5G and Post 5G, Advanced 5G, and Beyond 5G.

Thus, in order to achieve both green and digital growth, it is essential to save energy in relation to digital equipment and industries, and to decarbonize the electricity used by the digital sector in data centers and other facilities.

<Future efforts>

The government will strive to create a green digital society by promoting energy-saving, CO_2 emission reductions and high-performance of power semiconductors used in various fields, semiconductors indispensable for information processing such as memory chips, data centers, , and information and communication infrastructures, etc. The following sections describe each of the specific fields.

(a) Research and development, practical application, and expansion of the use of power semiconductors

With regard to the utilization of power semiconductors, in addition to improving the performance of conventional Si power semiconductors, we will support the research and development of ultra-high efficiency, next-generation power semiconductors (GaN, SiC, Ga_2O_3, etc.) by utilizing semiconductor-related technologies and facilities owned by academia, such as physical property evaluations using synchrotron radiation and neutron beam facilities as well as material searches using high-speed computers. In addition, in order to promote the introduction of next-generation power semiconductors, the government will provide support for capital investment in necessary parts of the semiconductor supply chain, thereby promoting the practical application and widespread use of next-generation power semiconductors with energy savings of 50% or more by 2030. As a result of these efforts, the government will strive for Japanese companies to achieve a world market share of 40% (1.7 trillion yen).

In addition, we will promote R&D of next-generation energy-saving devices (e.g., semiconductors for motor control), next-generation power electronics technology (e.g., high-efficiency control using AI, etc.), next-generation module technology (e.g., high heat-dissipating materials), and next-generation passive elements and mounting materials (e.g., coils), as well as support the demonstration, implementation, and advancement of technology for applications that can be applied from the present (e.g., electrified vehicles, data center power supplies, power converters, LEDs) using the results of Si power semiconductors and next-generation power semiconductors.

(b) Promotion of green data centers

To improve the energy efficiency of data centers, we will develop and demonstrate systems that integrate optoelectronic technology (optoelectronic fusion), such as optical wiring technology, with technology to improve the performance and energy efficiency of the elemental devices that make up servers (CPUs, accelerators, memory, etc.), develop technology to optimize performance and power consumption using software to control data centers, and provide capital investment support to expand the manufacture of energy-saving semiconductors. The use of decarbonized electricity in data centers and the fostering of demand-side needs for data centers that use renewable energy will also be promoted. Through these efforts, the aim is to achieve energy savings of at least 30% for all new data centers and decarbonization of a portion of the electricity used by data centers in Japan by 2030.

(c) Expansion of edge computing technology

The spread of new services such as IoT, automated driving, and smart cities will require data processing that includes a large amount of sensitive information. If all data acquired on the edge side is processed in the cloud, as has been the case in the past, the power consumption of networks and data centers will increase. Therefore, we will establish a collaborative infrastructure that efficiently interconnects multiple clouds while ensuring the security of data processing, and we will minimize the amount of data sent to the cloud and the amount of data processed in the cloud by edge computing, thereby reducing the load on networks and data centers and aiming to save more than 30% of energy in information and communications infrastructure.

In addition to steadily advancing these initiatives, we aim to achieve Carbon Neutrality in the semiconductor and information and telecommunications industries by 2040 by promoting the study of systems necessary for Carbon Neutrality, including systems for promoting energy conservation and CO_2 reduction in the electric and information and telecommunications industries, which consume increasing amounts of electricity.

3) Transformation of economic and social life through digitalization

Digitalization, which has been in full swing since the 2000s, is bringing changes to all industries and socioeconomic systems, including not only IT companies but also manufacturing, service, agriculture, and medical industries, as we approach 2020. In addition, Japan's challenges, such as green growth, regional development, productivity improvement, and the declining birthrate and aging population, cannot be solved without digitalization. Digitalization is no longer a "future goal" but a "prerequisite" that must be achieved, and it has become a major theme that cannot be avoided if Japan is to achieve sustainable growth. In particular, by accurately grasping the changes of the times with regard to digital infrastructure such as data centers, which are the foundation of digitalization, and semiconductors that support digital technology, and by enhancing competitiveness from the perspective of "Green by Digital" and "Green of Digital," Japan can lead the world in realizing a sustainable digital society (Society 5.0) in the future.

The social transformation caused by digitalization will bring about not only changes in the industrial structure, but also major changes in the lives of the people. For example, the location of data centers in Japan and the progress of social implementation of edge computing technology will make it possible to minimize the transmission delay (latency)[63] caused by data communication and processing while reducing power consumption. This will lead to the commercialization of new digital services and products that cannot afford delays, such as automated driving, remote surgery, augmented reality (AR), and virtual reality (VR). In the same way that the spread of mobile phones and the expansion of smartphones have made people's lives more convenient and affluent, these new services and products will be the driving force behind a major transformation of people's lives for the better in 2030 and 2050.

In addition, as we move toward Carbon Neutrality and the electrification of social life through electrified vehicles and other means, improving the performance of semiconductors used in all types of electrical products will help to reduce the burden on the public. For example, next-generation power semiconductors, such as GaN and SiC, are expected to become widespread not only in equipment and infrastructure applications that use large currents, such as electrified vehicles, robots, and trains, but also in home appliances, such as air conditioners, and thus in general households. As an example, the installation of next-generation power semiconductors in air conditioners can lead to energy savings of around 6% compared to conventional products.[64] The widespread use of next-generation power semiconductors will enable households to reduce their electricity bills by achieving higher levels of energy savings without compromising their standard of living.

---

[63] The location of a data center has a significant impact on the transmission latency (latency) of the data center. For example, for a user located in Tokyo, the transmission delay is 0.165 seconds when the data center is located in Sydney (Australia) and 0.069 seconds when the data center is located in Singapore, compared to 0.001 seconds when the data center is located in Tokyo.

[64] Assuming that all home appliances are equipped with next-generation power semiconductors, which would result in an overall energy saving of around 6% for home appliances, the energy-saving effect would be equivalent to a reduction in expenditure of around 7,700 yen for an average household (calculated based on the Ministry of Internal Affairs and Communications' Household Income and Expenditure Survey (2020) and the unit price of the new electricity rates proposed by the National Fair Trade Council for Home Appliances).

In this way, promoting "Green by Digital" and "Green of Digital" will not only affect industry, but it will lead to the transformation of people's lives in general, without imposing a heavy burden. It is therefore necessary to promote green and digital as two wheels of a cart.

(7) Shipping industry

Towards carbon neutrality by 2050, shipping is expected to play a major role in import and export including the import of decarbonized fuels such as hydrogen, and carbon neutrality in the entire supply chain is also required. For this reason, ships are forced to become even greener to strive for carbon-neutral maritime transportation, and the approximately 10 million tons of CO_2 emissions from coastal ships in Japan must also be reduced by 2050. In addition, greener ships and shipping services are Japanese maritime industries' strength, mainly in the shipbuilding and shipping industries. The more global interest in measures for tackling global warming people have, the more market value of such ships and services has been increasing. This means that the time has come for a game change. By providing ships and services with superior environmental performance, which is the strength of Japan's shipbuilding and shipping industries, we will contribute to the realization of carbon neutrality by 2050, including coastal shipping, which accounts for more than 40% of the total domestic cargo transportation.

Measures for tackling the climate change have been attracting increasing attention in a global manner, and efforts to achieve carbon neutrality by 2050 have been accelerated. Amid the situation, in order for Japan to secure stable maritime transport, Japan will acquire technical competence relating to developing gas-fueled ships, such as those powered by LNG[65], hydrogen, ammonia, and others, which are essential for achieving zero emissions, and establish production infrastructures. At the same time, Japan will strengthen the international competitiveness of its shipbuilding and shipping industries and strive for carbon-neutral maritime transportation by leading the establishment of international regulations. By technology development while considering the support of the Green Innovation Fund and other policy tools, Japan aims to start a demonstration project for zero-emission ships by 2025, realize the commercial operation of zero-emission ships before the conventional target year of 2028, and further spread zero-emission ships towards 2030. In 2050, the fuel used for ships is expected to be converted into alternative fuels such as hydrogen and fuel ammonia. Current CO_2 emissions from international shipping as a whole are approximately 700 million tons (of which Japanese merchant fleet's CO_2 emissions are estimated to be around 70 million tons), and it is necessary to reduce CO_2 emissions in the international shipping sector as well, mainly by switching to alternative fuels.[66] Therefore, if Japan's shipbuilding and shipping industries succeed in developing the technologies ahead of other countries, they will be able to

---

[65] Realizing carbon neutrality in 2050 would essentially require conversion to gas fuels such as hydrogen, ammonia, and clean methan from recycled carbon dioxide. LNG has a larger fuel volume per unit heating value than the heavy oil. It is in the gaseous state at ordinary temperatures because its boiling point is below zero, and its features are common to these carbon-neutral gases. It is vital to introduce hydrogen/ammonia-fueled ships ahead of the world by accumulating technical competence through introduction of LNG-fueled ships (fuel tanks, fuel supply systems, and gas-fueled engines). When the supply of clean methane from recycled carbon dioxide are realized in the future, LNG-fueled ships and the onshore fuel supply infrastructure can be diverted without modifications to those for carbon-recycled methane, which can contribute to achieving net-zero emissions.

[66] Although Japan's CO_2 emission reduction targets do not cover the international shipping sector, the International Maritime Organization (IMO) has set the goals of reducing the total greenhouse gas emissions from international shipping at least 50% by 2050 compared to 2008, and phasing out greenhouse gas emissions from international shipping as soon as possible in this century and Japan has been contributing to achieving these goals.

capture this demand.

1) Conversion to carbon-free alternative fuels

<Current status and issues>

Some companies are developing and demonstrating small-sized hydrogen fuel cell ships diverted from automotive hydrogen fuel cell systems and battery-powered ships using lithium-ion batteries. However, the application of hydrogen fuel cell systems and battery propulsion systems is limited to short-distance and small ships due to output, weight, and size. While long-distance and large ships require engines with higher output, there are no marine engines today that can burn hydrogen and ammonia directly.

<Future efforts>

For short distance and small ships, Japan will spread hydrogen fuel cell systems and battery propulsion systems, which are expected to not only contribute to decarbonization, but also making crews and passengers feel more comfortable by reducing noise and vibration. For long-distance and large ships, Japan will also promote the development and practical use of ships that directly burn hydrogen and ammonia, and start developing core technologies such as hydrogen/ammonia-fueled engines, fuel tanks, and fuel supply systems during fiscal 2021.

2) Improving energy efficiency of LNG-fueled ships

<Current status and issues>

LNG is capable to emit less CO2 emissions per transport work than the conventional petroleum-based fuel such as heavy oil. The International Maritime Organization (IMO) already developed international rules on LNG fuel for ships (the International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels (IGF Code) came into effect in January 2017). In Japan, the government promotes the spread of energy-efficient, CO_2 emission-reducing LNG-fueled ships by the certification system for introduction plan of smart ship and the rating system for energy efficiency of coastal ship. In March 2021, a Japanese shipping company became the first in Japan, including in other fields, to obtain transition finance certification for the introduction of LNG-fueled vessels. LNG is expected to become an alternative fuel for Carbon Neutrality. On the other hand, gas fuel, which has a low energy density and is bulky, has many issues, including the fuel tank taking up a lot of space from the cargo area.

<Future efforts>

The CO_2 emission reduction rate of 86% will be achieved by using a combination of LNG fuel and low-speed operation and wind propulsion systems. Additionally, in order to push for net-zero emissions by utilizing clean methane from recycled carbon dioxide, the government will start the development of technologies such as engines which emit less greenhouse gas during FY2021, and promote to develop space-efficient and innovative fuel tanks and fuel supply systems and to establish production infrastructures.

3) Development of frameworks to promote low-carbon ships<Current status and issues>

The government has been contributing to the IMO's work to introduce the energy efficiency design index (EEDI), which has been gradually strengthened. However, EEDI does not apply to existing ships. Consequently, the absence of international frameworks on CO_2 emissions from existing ships hinders the replacement of old inefficient ships to new greener ships.

With regard to international shipping, efforts are being made following the "Roadmap to Zero Emission from International Shipping," which was compiled by Japan in 2020 in collaboration with the industrial, academic, and public sectors, but there is no such roadmap for coastal shipping.

<Future efforts>

The government is striving to develop international regulations to improve energy efficiency of ships so as to promote the replacement of old inefficient ships with new greener ships. The government drafted and co-sponsored a joint-proposal to the IMO on the mandatory energy efficiency requirements on existing ships, consisting of the energy efficiency existing ship index (EEXI) and the annual operational carbon intensity indicator rating (CII rating), which was approved in November 2020, and aims for the early implementation from 2023. The early implementation of the EEXI and CII rating will require existing ships to achieve the same level of energy efficiency performance with the new greener ships, and will incentivize replacement of old inefficient ships with new greener ships.

Based on the discussions on the low carbonization and decarbonization of coastal shipping with all parties concerned in coastal shipping in Japan, by the end of 2021, the government will formulate a roadmap for promoting greener coastal shipping to achieve carbon neutrality, and lead necessary efforts including the establishment of systems following the roadmap.

(8) Logistics, people flow, and civil engineering infrastructure industries

Logistics/people flow systems and civil engineering infrastructure, which provide a foundation for all socioeconomic activities, are indispensable to the public's lives. The government will strive for Carbon Neutrality through technology development and social implementation in each phase of the formulation, introduction, construction, maintenance, and utilization of an eco-friendly transportation network and the like.

Specifically, the government will move ahead with the following activities: (i) introducing smart traffic, (ii) streamlining green logistics and transportation networks, (iii) improving the efficiency of construction at sites, and promoting the spread of EV/FCV construction machinery, (iv) pushing for more energy-efficient and sophisticated road facilities and conducting research and development on EV charging systems, and (v) reducing environmental loads in logistics and people flow at zero-emission ports.

In addition, based on the "MLIT’s Green Challenge " to be compiled in the summer of 2021, the government will strategically promote cross-sectoral decarbonization and other initiatives in the field of livelihood, urban development, transportation, and infrastructure through the acceleration of technological innovation and its implementation in cooperation with the private sector.

1) Formation of Carbon Neutral Port

Hydrogen, an essential key sector in the quest for Carbon Neutrality, is an energy source that can contribute to decarbonization in a wide range of sectors, including power generation, transport and industry, and the International Energy Agency (IEA) report (2019) has set out to make industrial ports the nerve center for expanding the use of clean hydrogen.[67]

In Japan, the ports and harbors are logistics centers that handle 99.6% of the country's imports and exports. They are also industrial centers where many of the industries that account for about 60% of Japan's CO_2 emissions are located. At these ports, we will strive to import, store, and deliver hydrogen, fuel ammonia, and other substances in large quantities, stably, and at low cost, and at the same time, we will form a "carbon neutral port (CNP)" that will reduce greenhouse gas emissions to zero, as a whole, through the upgrading of port functions and the concentration of coastal industries in consideration of decarbonization. The goal is to achieve Carbon Neutrality in ports by 2050.

<Current status and issues>

Amid growing international interest in the SDGs and ESG investment, it is becoming increasingly important for international ports to become more competitive in terms of cost, speed, and service, as well as in terms of environmental awareness.

Many of the power generation, iron and steel, and chemical industries, which account for about 60% of Japan's CO_2 emissions, are located mainly in ports and waterfront areas. In addition, containerized cargo transport by trailers and side-haul transport by trucks is carried out in large

---

[67] In "The Future of Hydrogen" (2019), the IEA identifies "making industrial ports the nerve center for expanding the use of clean hydrogen" as a near-term opportunity to expand hydrogen use (a stepping stone to getting hydrogen to the scale needed to reduce costs and risk in the real world).

quantities in and around ports and waterfront areas, meaning that there is a great deal of room for reducing CO_2 emissions in these areas. Ports are also important import bases for hydrogen, fuel ammonia, etc. in efforts to reduce CO_2 emissions, and thus have high potential for utilization (production, transportation/storage, and utilization) of hydrogen, fuel ammonia, etc. due to the proximity of supply and demand.

On the other hand, in order to utilize hydrogen and fuel ammonia, it is essential to procure them in large quantities, stably, and inexpensive. At present, however, transportation means and acceptance systems to realize such procurement have not yet been established.

As for the transportation and use of hydrogen, fuel ammonia, etc., each business operator is studying and developing technologies individually, but it is necessary for all parties concerned to work together to create a coherent supply and demand and to reduce costs.

In addition, in order to import large quantities of hydrogen, fuel ammonia, etc. in a stable and inexpensive manner, it is necessary not only to improve the domestic environment, but also to secure resources overseas and improve the transportation environment at shipping ports.

<Future efforts>

Toward the formation of CNPs, decarbonization efforts will be implemented in an integrated manner through support for matching demand and supply businesses of hydrogen, fuel ammonia, etc. and upgrading functions at ports where various companies such as port transport, warehouses, trucks, and shipping companies are operating. From January to March 2021, study groups were first held at seven ports in six regions where diverse industries are concentrated (Onahama, Yokohama/Kawasaki, Niigata, Nagoya, Kobe, and Tokuyama/Kudamatsu) to examine CO_2 emissions, demand for hydrogen and fuel ammonia, measures for their utilization, and the scale of port facilities needed in each port region. Based on the results of this study and others, a manual for CNP formation will be prepared within FY2021. Based on this plan, each port will prepare a "CNP Formation Plan" (tentative name) that includes CO_2 emission reduction targets and a roadmap, and promote the demonstration and implementation of initiatives based on the plan, in order to expand the formation of CNPs nationwide, create ports with high environmental value, and lead the decarbonization of ports worldwide. Specifically, the plan aims to have more than 20 ports in Japan that have formulated a plan by 2025.

Toward the formation of the CNP, the following points are specifically addressed.

Easing traffic congestion in front of container terminal gates by establishing a digital logistics system

Ceasing of ship idling by promoting the introduction of shore power supply to ships at anchor

Converting to FC-powered port cargo-handling equipment and vehicles

Promoting the introduction of independent power sources, such as hydrogen, that can be used in emergencies.

Improving fuel supply system for fuel vessels such as hydrogen, ammonia, LNG, etc.

Utilizing of electricity generated by offshore wind power

Constructing a domestic transport network for hydrogen derived from offshore wind power surpluses

Utilizating the Blue Carbon Ecosystem
Promoting the decarbonization of businesses located in ports and waterfront areas

In addition, we will consider the provision of risk money through joint investment with private companies by the Japan Overseas Transportation & Urban Development Corporation (JOIN) and the use of hands-on support, depending on the project, for the environmental improvement of wharves and supply facilities for the export of hydrogen and fuel ammonia at overseas loading ports. In addition, as an initiative for overseas cooperation related to the formation of CNPs, Japan and the United States will work together to promote "carbon-neutral ports" as described in the "U.S.-Japan Competitiveness and Resilience (Core) Partnership" stated in the U.S.-Japan Summit Joint Statement in April 2021.

2) Introducing smart traffic and promoting the use of bicycles for transportation

<Current status and issues>

Since CO_2 emissions from automobiles account for 15.9% of Japan's total emissions, the project aims to reduce the burden on the environment by encouraging people to change their behavior, including how they use their cars in their daily lives, and by reducing automobile traffic by promoting the use of public transportation. Specifically, it is important to secure and maintain public transportation in each region and improve convenience by utilizing MaaS in a way that contributes to solving regional issues, promoting the electrification of automobiles, and socially implementing sustainable mobility services that are compatible with automation in cooperation with roads and urban infrastructure.

Meanwhile, the government is developing road space for bicycles to improve bicycle user environment and promote bicycle usage further under the Bicycle Use Promotion Plan and bicycle network plans. The total length of bicycle tracks is approximately 2,930km as of the end of 2019 fiscal year, requiring further progress.

<Future efforts>

The public and private sectors will work together to promote the provision of MaaS in ways that contribute to the resolution of regional issues and the creation of infrastructure necessary for the widespread use of MaaS. At the same time, while resolving the various issues identified through the verification experiments carried out to date, the further evolution of mobility services themselves and the use of data will be examined, and the widespread use of MaaS that can respond to the various needs for mobility using public transport will be promoted. This will improve the convenience of travel by optimizing the combination of multiple public transportation services and various non-public transportation services to enable seamless search, reservation, payment, and transportation, thereby creating an environment in which people can move easily without relying solely on their own vehicles. The government will also create an environment where one can find some benefit in choosing electric-powered vehicles.

Utilizing the Act on the Revitalization of Regional Public Transport, the government will promote the use of public transport in the region by securing and improving the convenience of public transport through the reorganization of the regional transport network and the promotion of barrier-free transport, etc., in cooperation with urban development, and will also promote the introduction of transport systems with low CO_2 emissions using new technologies to achieve Carbon Neutrality, such as the conversion to Light Rail Transit (LRT) and Bus Rapid Transit (BRT) and the use of electrified and automated public transport. This will provide a public transportation service that is easy to use for local residents, including elderly people who cannot drive cars, and will help to realize a public transportation system that has a low environmental impact and is sustainable for the future. Furthermore, the integrated promotion of these efforts will contribute to the enhancement of each town's liveliness and attractiveness, and will further contribute to regional revitalization.

The government will help local governments formulate their Bicycle Use Promotion Plans. Simultaneously, the government will also formulate a new Bicycle Use Promotion Plan to create a safe and pleasant bicycle user environment. In this way, the goal is to achieve an 18.2% bicycle share for commuting purposes by FY2025.

3) Promoting green logistics and promoting transportation networks, hubs, transportation efficiency, and low carbonization

<Current status and issues>

In the logistics sector, trucks (commercial and private) account for about 7% of Japan's total CO_2 emissions, so reducing CO_2 emissions in the logistics sector is extremely important. In addition, the shortage of drivers due to the decrease in the working-age population and the severe working environment has become a social problem, making it an issue to promote the conversion to transportation means with low CO_2 emission intensity and the improvement of transportation efficiency, not only from the viewpoint of Carbon Neutrality, but also from the viewpoint of improving transportation capacity in response to logistics demand. Additionally, since logistics demand is generated by production, consumption, and other activities of companies, there is a limit to the efforts of logistics companies alone to reduce CO_2 emissions, and therefore cooperation with shippers is also important. For this reason, the "Law Concerning the Rational Use of Energy" requires transporters and shippers that exceed a certain level of fuel consumption and transportation volume to report their energy consumption as well as energy consumption per unit of production, etc. However, it is a challenge to shift to a system in which energy efficiency and conservation efforts made by business operators are appropriately evaluated. Moreover, the improvement in energy consumption per unit of production has been slowing down.

Concerning logistics facilities, the government will take the following actions: (i) efforts to reduce energy consumption, including promoting less-lights and lights-out warehouses thanks to the automation, (ii) energy consumption reductions by promoting introductions of energy-saving equipment with natural refrigerants in refrigerated warehouses, and (iii) to reduce the emissions of fluorocarbons from commercial refrigeration and air conditioning equipment as much as possible. Concerning domestic cargo transportation, truck transportation accounts for about 80% of the total. To solve current traffic issues such as traffic jams, the government should take road traffic flow measures and improve logistics efficiency using double-trailer trucks and other methods.

In depopulated areas, the government should improve transportation efficiency and ensure logistics networks' sustainability by replacing low-loading-efficiency, inefficient transportation/distribution by existing logistics means with unmanned aerial vehicles.

In the railway field, experimental fuel-cell railway vehicles are being developed. However, the current standards and regulations do not envisage the operation of fuel cell railcars, so it is necessary to improve them. In addition to cost reduction, the infrastructure needs to be developed to maximize the potential of stations, which are public transportation nodes, for social implementation.

In the airport field, the government formulated guidelines for realizing eco-friendly airports (Eco Airport Guidelines) and is implementing voluntary efforts toward low carbonization at each airport. In order to achieve Carbon Neutrality by 2050, it is necessary to promote efforts to reduce CO_2 emissions from facilities and vehicles, and to consider the use of renewable energy based on the characteristics of airports.

Besides, until today, the air traffic system has been sophisticated to improve efficiency, however, due to technical limitations and operational challenges for increasing air traffic volume, we need more improve for various social needs such as reduction of CO_2 emissions through reduction of fuel consumption. For this thing, to develop suitable air traffic systems would require synchronizing the sophistication of avionics (on-board equipment on the airline) side with the sophistication of systems on the civil aviation bureau side. To tackle these challenges, based on the long-term vision developed through industry-academia-government collaborations called the "Collaborative Actions for Renovation of Air Traffic Systems (CARATS)",It has been accelerating for implementing various measures to CO_2 reductions through shortened flight routes (i.e., promoting the introduction of RNAV routes) in cooperation with the long-term plans the International Civil Aviation Organization (ICAO).

<Future efforts>

In order to improve the international competitiveness of Japan as a whole and promote sustainable growth, it is necessary to establish a flexible supply chain from production to consumption, share standardized goods and data, and provide efficient logistics services that flexibly recombine transportation modes and routes. Efforts to reduce CO_2 emissions should promote the construction of these ideal logistics networks and contribute to the simultaneous resolution of social issues, such as driver shortages, in addition to stimulating economic activity.

From this perspective, we will combine various elements related to logistics, such as logistics companies and shippers involved in the supply chain, transportation modes, and logistics facilities such as warehouses, as well as promote changes for the future, in order to simultaneously achieve higher efficiency and productivity in logistics, electrification, and decarbonization of fuels.

Specifically, the government will promote modal shifts to transportation modes with lower CO_2 emission intensity, joint transportation and delivery, and consolidation of transportation networks to reduce CO_2 emissions by shortening the distance of cargo transport by trucks, as well as to solve the shortage of drivers by reducing the waiting time for trucks. Also, the standardization of pallets and slips related to logistics will be promoted, as well as the efficiency of transportation throughout the supply chain, leading to a dramatic increase in productivity in the logistics field and the realization of an attractive working environment. Furthermore, the government will strive for the decarbonization of logistics with the help of digitalization, thorough improvement in productivity and loading efficiency through collaboration between cargo owners and business operators (drastic improvement in specific CO_2 emissions), electrified regional transportation/distribution, and fuel decarbonization for long-distance transportation. Additionally, how to appropriately promote energy efficiency and conservation efforts made by shippers and carriers will be studied.

The introduction of automated equipment and systems and renewable energy facilities will promote the conversion of warehouses and other logistics facilities to zero-energy facilities, which will not only reduce CO_2 emissions, but will also contribute to local communities by reducing labor shortages, such as the need to work in warehouses and wait for cargo, and by building uninterrupted supply chains even in the event of a disaster or infectious disease epidemic. At the same time, we will promote replacement with energy-saving equipment filled with natural refrigerants in refrigerated warehouses.

In addition to further promoting traffic flow measures through the development of road networks such as beltways in three metropolitan areas and congestion countermeasures using big data, the efficiency of logistics will be improved by promoting the use of double-trailer trucks. This will facilitate road traffic and save manpower in truck transportation, where there is a serious shortage of drivers.

As for the last mile delivery, we will promote institutional development, technological development, and social implementation for the practical use of drone logistics in depopulated areas. In particular, with regard to social implementation, we will prepare and publish the "Guidelines for the Delivery of Goods and Other Items Using Drones" and promote the full-scale practical and commercialization of drone logistics. In addition, we will promote the development of technology and services for the social implementation of delivery using automated delivery robots.

In the field of railways, for the social implementation of fuel cell rail vehicles, we will review related standards and regulations based on demonstration tests on commercial routes and study the necessary environmental improvements, such as the establishment of integrated hydrogen stations around stations, which are public transportation nodes, and which can be used not only by railways but also by passenger cars, buses, trucks, etc. We will also study the low-carbon hydrogen supply chain, including other fields.

In the airport sector, through the work of the "Study Group on CO_2 Reduction in the Airport Sector", we will promote the introduction of power and air conditioning supply facilities (GPUs) from airports to aircraft, promote the introduction of energy-saving systems such as the use of LEDs in airport facilities, promote the introduction of clean energy vehicles by converting airport vehicles to EVs and FCVs, and promote the conversion of airports into renewable energy centers by encouraging the introduction of solar power generation and other systems.

As stepped-up sophistication, the government will enable more flexible flight route settings and further reductions in holding patterns no later than 2040 by managing and operating the best flight routes in all flight phases from departure to arrival utilizing satellites and data communications. In doing this, the government will consider various factors that may affect aircraft navigation, such as weather conditions that could increase aircraft fuel consumption. Specifically, the government will conduct research and development toward the practical use of critical traffic control systems in cooperation with its international counterparts. In particular, through the work of the "Study Group on CO_2 Reduction in the Aircraft Operation Field," we will consider expanding the number of applicable airports and reviewing the screening criteria in order to promote the spread of new operation methods (RNP-AR, etc.) that contribute to further shortening flight routes, thereby simultaneously reducing CO_2 emissions and strengthening the international competitiveness of aviation-related businesses.

4) Zero-emission infrastructure and urban space

<Current status and issues>

Regarding energy-efficient road lighting, the government is currently changing road lights to LED lights upon road development and equipment renewal. The government still needs to continue to install LED road lights on national highways under jurisdiction of MLIT.

Regarding renewable energy generation in road space, road administrators install solar power generation equipment and others to use the electricity for road administration. The government has been promoting solar power generation equipment by adding it to a list of properties subject to permission for occupancy of roads in 2013.

Regarding EV, the government supports the development of the electric road system, and a social experiment on EV chargers on public roads. As to the electric road system, development of road structures in which a power supply system is embedded, technical standards, and evaluation of EV chargers' impact on road traffic are necessary.

Sewerage and domestic wastewater treatment systems consume about 0.7% of the nation's electricity consumption (about 7.5 billion kWh) and emit about 0.5% of Japan's greenhouse gases (about 5.96 million t-CO_2). Municipalities account for the majority of greenhouse gas emission emitted from their administrative operations, and energy conservation efforts are urgently needed. Sewage heat can be used by the collection of heat within urban areas, but only 32 locations in Japan (as of August 2020) have introduced this technology, and there has needed more cost reduction. In order to promote the utilization of sewage heat, combined use with multiple renewable energy heat sources is necessary, and the lack of information exchange (matching) between the public and private sectors regarding heat use as an issue on promoting heat utilization.

As a means of promoting hydropower generation, the government has been taking measures such as simplifying the procedures for licensing water rights for hydropower generation and publishing river flow data, but it is necessary to further encourage the effective use of hydropower energy.

It is necessary to realize sustainable urban development not only from the perspective of a declining and aging population, but also from the perspective of energy and the environment. Against this backdrop, the number of municipalities that have created "Location optimization plan area" (under the Law Concerning Special Measures for Urban Revitalization) that aim to consolidate residences and urban functions in cooperation with regional public transportation in order to create compact cities is 383 (as of April 1, 2021).

Moreover, in order to strongly promote decarbonization in cities, area-based initiatives are to be implemented in cities in addition to the citywide initiatives.

In addition, of the approximately 110,000 urban parks nationwide, solar power generation has already been introduced in national government parks and some urban parks established by local governments, and it is expected that wind power generation and biomass power generation can also be introduced depending on the characteristics of the location. The introduction of renewable energy in urban parks not only contributes to the reduction of greenhouse gas emissions, but also leads to the revitalization of local communities through improved disaster prevention and economic circulation through local production and local consumption of energy.

With regard to the social implementation of "green infrastructure" that utilizes the diverse functions of the natural environment, it is necessary to simultaneously solve a variety of regional issues, such as the greening of urban spaces that also serve as CO_2 sinks, and disaster prevention and disaster mitigation through rainwater storage and infiltration, in order to realize a sustainable green society. The Ministry of Land, Infrastructure, Transport and Tourism has been conducting cross-disciplinary, public-private surveys and studies on social dissemination of green infrastructure and the technology introduction applied to the green infrastructure in the framework of the "Green Infrastructure Public-Private Partnership Platform" (established in March 2020), in which various entities from the industry, academia, and the government participate. However, the social implementation of green infrastructure has not progressed well. The Ministry of the Environment (MOE) has been promoting the concept of "Ecosystem-based Disaster Risk Reduction (Eco-DRR)," which enhances regional resilience by utilizing the functions of the natural environment, and has been creating "ecosystem function potential maps" to visualize areas suitable for Eco-DRR implementation in river basins since FY2020.

International Horticultural Expo 2027 , Yokohama, Japan (EXPO 2027) is going to be organized at Kamiseya, the site of a former communication station (approx. 242 ha) in the City of Yokohama, and preparations to disseminate the implementation of green infrastructure both domestically and internationally through the Expo 2027 are underway. In order to organize the Expo 2027, approval from the” Association Internationale des Producteurs de of l’Horticultureists” (AIPH) (approved in March 2020) as well as recognition from the “Bureau International des Expositions (BIE)” is required, and efforts toward recognition need to be promoted.

<Future efforts>

In order to realize further cost saving, energy saving, and the sophistication of road lighting, the development of new road lighting technologies will be encouraged, and technological verification and evaluation will be conducted to promote their introduction. At the same time, by FY2025, the standards for the installation of road lighting facilities, etc. will be reviewed to promote the introduction of new road lighting that can further reduce energy consumption. In addition, we will encourage the use of LED road lighting on national highways under jurisdiction of MLIT, taking into account cost effectiveness. These efforts will reduce the road management costs associated with road lighting.

Studies will be undertaken to foster the introduction of renewable energy sources, such as solar power generation, for the electricity required for road management, with the aim of nationwide deployment. This is expected to reduce road management costs and ensure the availability of electricity for road management during power outages.

With regard to electric road systems, the government will support research for the development of the technology and the development of road structures that embed the power supply system, with the aim of starting experiments in the mid-2020s. While conducting verification and evaluation for social implementation depending on the research's progress, the government will study road-related institutions and technical standards, including the installation of EV chargers on public roads. The maintenance of information signs on arterial roads and other roads in areas where there are few EV recharging facilities will also be promoted. These efforts will improve the convenience of charging. By providing incentives for electrified vehicles when using expressways, we will reduce emissions by shifting traffic from roads to expressways and promote the spread of electrified vehicles.

In relation to sewerage, we will develop new technologies such as energy-saving water treatment, and promote further energy saving in water treatment and sludge treatment. In addition, in order to move forward the use of sewage heat in cooperation with the public and private sectors, intensive efforts will be made until FY2025 to reduce the cost of heat utilization systems and to promote the formation of projects for the use of sewage heat in cooperation with the public and private sectors, including the revision of the sewage heat utilization manual.

In order to further promote the effective use of hydroelectric power, the feasibility of improving dam operations, such as releasing floodwater stored in multipurpose dams while using it for power generation as much as possible without interfering with flood response by utilizing the latest weather forecasting technology when lowering the water level in preparation for the next typhoon, etc., will be verified and applied, starting with the initiatives that are deemed feasible.

In order to realize the further promotion of the Compact Plus Network[68], we aim to have 600 municipalities create a "Location optimization plan area" by the end of FY2024.

We will establish a support system, including considering how to set an area and making private funding more accessible, to strongly promote comprehensive area-based initiatives in cities.

Moreover, in order to decarbonize cities, we will conduct studies on the possibility of introducing renewable energy sources such as solar power, wind power, and biomass power to urban parks. In addition, we will promote the introduction of renewable energy sources in urban parks in conjunction with the "Location Optimization Plan" and decarbonization efforts in areas within cities, and build a low-carbon, bustling, and independent living area.

The government will promote technology development relating to the planning, development, and maintenance of green infrastructure (such as urban space greening, rain gardens that combine green and rainwater storage/infiltration, blue carbon, and monitoring using remote sensing). In particular, in order to achieve the new reduction target for FY2030, the government and private sector will collaborate to develop technologies to reduce emissions and enhance sinks through urban greening, including rooftop and wall greening, and to enhance rainwater storage and infiltration functions through rain gardens combined with greenery. Also, in order to promote the demonstration and implementation of green infrastructure technologies, the activities of the "Green

---

[68] Compact Plus Network: In order to maintain the vitality of each region and secure the services necessary for daily life in the midst of a declining population, low birthrate, and aging society, the concept of compact and sustainable urban development is to guide people's residence and necessary urban functions to a number of locations, such as in municipalities, and to connect each location with a regional public transportation network.

Infrastructure Public-Private Partnership Platform" will be expanded to support the establishment of partnerships to match technological needs and seeds, and to promote the formation of leading models for local governments and other organizations that aim to introduce green infrastructure technologies. The formation of leading models for local governments and other organizations that are seeking to introduce green infrastructure technologies will also be promoted. The government will also support the introduction of green infrastructure into the region by conducting regional model demonstrations. Through the expansion of social implementation of green infrastructure technologies, the government will drive green finance and ESG investment utilizing private finance-raising methods such as green bonds. As a result of these efforts, the social implementation of green infrastructure in local communities will be promoted through public-private sector collaboration and cross-sectoral cooperation, which will lead to the realization of sustainable and attractive communities through the combined resolution of diverse local issues, including CO_2 sink measures, ecosystem conservation, disaster prevention and disaster mitigation such as rainwater storage and infiltration, the creation of healthy and comfortable living spaces in the post-pandemic period, and urban development that contributes to a virtuous cycle between the environment and the economy in line with the SDGs. With regard to Eco-DRR, we will also publish a handbook on how to develop ecosystem function potential maps in order to accelerate social implementation by local governments, and contribute to zero emissions in the construction and installation of new infrastructure.

The government proceeds with preparations for obtaining BIE recognition for EXPO 2027 such as the enactment of related laws and the establishment of an association for Expo to serve as the organizer, and makes EXPO 2027 a concrete opportunity to disseminate domestically and internationally models of sustainable urban development that implement green infrastructure and utilize private funds in order to promote initiatives aimed at achieving the SDGs and establishing a green society. The implementation of green infrastructure at EXPO 2027 will promote the spread of green infrastructure both domestically and internationally, and induce technological development by various entities. After EXPO 2027, the government will continue to promote the spread of green infrastructure both in Japan and abroad as a Japanese model.

5) Realizing carbon-neutral construction work

<Current status and issues>

CO_2 emissions from construction work account for 1.4% of the industrial sector's CO_2 emissions (about 5.71 million t-CO_2). If ICT utilization improves productivity at construction sites, it will shorten work time, contributing to reductions in CO_2 emissions. If innovative construction machinery powered by electricity, hydrogen, or biomass is developed and introduced in the future, it will provide opportunities for further CO_2 emission reductions. The government has been reducing CO_2 emissions by introducing ICT-assisted construction (i-Construction) and improving work efficiency at construction sites. Today, the implementation rate of i-Construction (civil engineering) at government-administered construction sites has reached about 80%. However, that implementation rate in local governments stays around only 30%. From now on, local governments should further promote the spread of i-Construction at their construction sites. As to construction machinery, the government has encouraged the introduction of energy-efficient diesel engine-powered vehicles by formulating stepped-up fuel-efficiency standards and equipment certification schemes. The government also supported this approach through government financing. As international efforts to further reduce CO_2 emissions in construction work are currently underway, Japan should also promote the introduction of innovative technology in this field.

<Future efforts>

By promoting i-Construction and other measures, such as the spread of ICT to small- and medium-sized construction companies that are undertaking the construction projects of local governments, we will further improve the efficiency of construction and maintenance management and save manpower and labor to cope with the decrease in the number of skilled workers, etc. We will also promote efforts to improve the productivity of construction sites, including cost reduction through the spread of construction machinery. The objective is to reduce CO_2 emissions by promoting the use of construction machinery with superior fuel efficiency. In terms of the spread of ICT construction to small- and medium-sized construction companies, there are aspects that are difficult to introduce due to cost and human resources. Therefore, in addition to ICT construction equipment, a certification system will be established for ICT construction equipment and technology to perform ICT construction by attaching retrofit parts to existing construction equipment. In addition, a system will be introduced to train ICT leaders within the community to advise companies. In order to achieve Carbon Neutrality in relation to construction, which is the target for 2050, we will establish a certification system for innovative construction equipment (electric, hydrogen, bio, etc.) that drastically reviews the power source, and promote its introduction and adoption. Under this certification system, it is necessary to set up various evaluation items for innovative construction equipment, such as environmental impact, safety and work performance, and to define evaluation indicators for each item through field introduction tests. Therefore, a study group including experts and related organizations will be established to study the social implementation of innovative construction equipment. At this time, while taking into account the various related standards for construction machinery to date, we will work to formulate new standards in light of the international situation, and will also consider making the use of these standards a principle in projects under the direct control of the Ministry of Land, Infrastructure, Transport and Tourism. These efforts are expected to reduce working hours and construction time by up to 30%, and also reduce noise generated by construction work.

(9) Food, agriculture, forestry, and fisheries

Japan's food, agriculture, forestry, and fisheries industries are important carbon sinks in their own right, as demonstrated by the widespread adoption of a "wood culture" with wood products being utilized in the right places for the right purposes, while forests, wood products, cropland, and oceans are expected to play a role as huge sinks for CO_2. In addition, rural districts have significant potential for achieving the carbon neutrality target, as they can not only utilize renewable energy derived from locally available resources such as land, water, and biomass that exist in agricultural, mountainous, and fishing villages, but also reduce greenhouse gas (GHG) emissions, through work optimization using smart technologies emitting less CO_2, and proper fertilization emitting less N_2O.

However, while global warming in Japan continues to progress at a rate of increase nearly twice that of the world average, the frequent occurrence of record-breaking heavy rains, typhoons, etc., and heat waves all across the country have become one of the most serious risks to the agriculture, forestry, and fisheries industries. In recent years, the need for a stable supply of food, and sustainable development of agriculture, forestry, and fisheries, doing no harm to the global environment has been strongly emphasized. In the food, agriculture, forestry, and fisheries industries, which draw on the power of nature and ecosystems, it is a crucial and urgent task to reduce the impact of these activities on the environment and maintain a rich global environment.

To address these issues, the Ministry of Agriculture, Forestry and Fisheries (MAFF) formulated the " Strategy for Sustainable Food Systems, MeaDRI (Measures for achievement of Decarbonization and Resilience with Innovation)" in May 2021 as a policy to strategically address medium- to long-term perspective in order to enhance productivity potentials and ensure sustainability in a compatible manner of the food, agriculture, forestry and fisheries industries through innovation. The strategy aims to promote the development and deployment of innovative technologies and production systems that can be adopted across the entire supply chain, from sourcing production, processing and distribution to consumption, focusing on labor savings underpinned by productivity improvement, utmost use of locally available resources, advancement toward the carbon neutrality target, reduction of chemical pesticides and fertilizers, and conservation and restoration of biodiversity. By addressing these economic, social, and environmental issues in an integrated manner it is expected to achieve significant benefits for building a sustainable industrial base (economic), enriching people's diets as well as increasing employment and income generation opportunities for local communities (social), making a contribution to the achievement of the carbon neutrality and maintaining a global environment as the base for future generations to lead secure lives (environmental).

Furthermore, we will advocate this strategy as a new model of sustainable food system for the Asian monsoon region, where climatic conditions and production structures are different from those of other regions like Europe and North America, and contribute to international dialogues and rule-making fora (e.g., the United Nations Food Systems Summit (September 2021)).

1) Common matters

<Current status and issues>

In light of the fragile production base and the decline of local communities, such as the decrease in the number of producers responsible for agriculture, forestry and fisheries, and the further progress of aging, strengthening the productivity of food, agriculture, forestry and fisheries has become a challenge to overcome. On the other hand, from the viewpoint of maintaining the stability of the global environment, the sustainability of so-called "natural capital" such as land, water, and biological resources, which have been utilized by the food, agriculture, forestry, and fisheries industries, is in great danger, and urgent and bold measures are required.

In order to ensure a stable supply of food and the development of agriculture, forestry, and fisheries in the future, it is urgent to improve labor productivity through labor-saving measures and to expand the range of producers, in view of the further decline and aging of producers and the post-pandemic period. At the same time, there is an urgent need to reduce the burden on the environment by recycling resources, maximizing the use of local resources, and curbing the use of chemical pesticides, fertilizers, and fossil fuels, as well as to promote Carbon Neutrality and the conservation and restoration of biodiversity to build a sustainable food system that is resistant to disasters and climate change.

In addition, at the Climate Summit held in April 2021, Prime Minister Suga declared that he would aim to reduce GHG emissions in FY2030 by 46% from the FY2013 level, and further announced that he would continue to take on the challenge of achieving a 50% reduction. The achievement of this ambitious goal requires concerted national efforts, and the development and dissemination of technologies that contribute to this goal in the fields of food, agriculture, forestry, and fisheries is essential.

To this end, it is necessary to promote the understanding of all parties involved in the challenges facing the food system, to fully draw out the ambitious efforts of agricultural, forestry, and fishery producers, food companies, and consumers, which are not extensions of the past, and to strongly promote innovation involving the public and private sectors to solve the challenges for the future where these are still lacking. In encouraging such efforts, it is important to promote the "visualization" of the effects of sustainable efforts by producers in the agriculture, forestry, and fisheries industries, and to aim for a society in which consumers and related businesses support such efforts together. It is also necessary to disseminate information in an easy-to-understand manner to promote public understanding of the concrete benefits that the introduction of new technologies, etc. can bring, such as improved occupational safety and productivity and higher income.

<Future efforts>

Regarding Carbon Neutrality in the food, agriculture, forestry, and fisheries industries, based on the Green Food System Strategy, we will develop innovative technologies and production systems by 2040, and by 2050, we will promote the "greening of policy measures" based on the development of innovative technologies and production systems, in order to achieve social implementation of Carbon Neutrality in the entire supply chain, from procurement to production, processing and distribution, and consumption, in terms of labor reduction and productivity improvement, maximum utilization of local resources, reduction of chemical pesticides and fertilizers, and conservation and restoration of biodiversity.

In addition, from the perspective of encouraging these initiatives, the "greening of policy measures," which encourages environmentally friendly initiatives by incorporating environmental perspectives into policy guidance methods such as subsidies, investments, loans, taxes, and systems, will be reviewed in stages as follows.

a) While taking into account the contribution to the Paris Agreement and the Post-2020 Biodiversity Framework, the aim is to focus the support of measures on those who engage in sustainable food, agriculture, forestry and fisheries by 2030. Regarding the subsidization project of the Ministry of Agriculture, Forestry and Fisheries, it aims to support Carbon Neutrality by 2040, taking into account the status of technological development.
b) Expand subsidies, enhance the options for environmental impact reduction, and improve cross-compliance requirements as a set with these, and consider a mechanism to verify the continuous implementation of initiatives.
c) From the viewpoint of encouraging the social implementation of innovative technologies and production systems as well as sustainable efforts, review of regulations and new systems necessary at the time, while listening to the opinions of researchers and users, will be considered. In doing so, we will consider mechanisms and support to encourage a shift to sustainable production technologies for agricultural production.
d) Promote environmentally friendly management practices by companies, such as sustainable procurement of raw materials, GHG emissions reduction, waste reduction and resource recycling, and consider specific measures to promote mechanisms to encourage disclosure of such information and to attract ESG investment.

Furthermore, in order to link the innovative ideas and technological seeds that lie dormant in Japan to innovation at an early stage, efforts from R&D to the commercialization of products and services will be seamlessly developed, and the launch of new services and businesses that bring income and employment to local industries through cooperation between agriculture and other industries will be encouraged. In addition, the government will promote the development of innovative technologies with a view to utilizing cross-ministry frameworks such as the Green Innovation Fund and the Moonshot R&D System, the development and dissemination of technologies that benefit producers of agriculture, forestry, and fisheries, as well as local communities, and the efforts of public incentive systems such as the J-credit system.

In terms of overseas development and international collaboration, we will promote bilateral and multilateral international joint research conducted by domestic and overseas research institutes and universities by developing the "4 Per 1000 Initiative," an initiative to promote soil carbon increase through soil management technology, etc., and an international joint research system centered on national research institutes. We will continue to participate in and collaborate with global research networks on GHG reduction in agriculture, and contribute to the reduction of GHG emissions worldwide by deploying Japan's excellent decarbonization technologies in the agriculture, forestry, and fisheries sectors overseas in collaboration with international organizations and through the Joint Crediting Mechanism (JCM). In addition, for the future overseas expansion of Japanese companies and the realization of sustainable procurement of imported raw materials, we will promote the establishment of a sustainable food system in the Asian monsoon region and the introduction of a smart agricultural system that will contribute to it, through demonstration projects including the dispatch of experts and human resource development.

2) Absorption/fixation of CO_2

<Current status and issues>

Forests, which account for 93% of Japan's CO_2 sink measures (fiscal 2019 results), contribute to the prevention of global warming as a source of absorption. In addition to storing carbon for a long period of time, wood produced from forests is a material that consumes relatively little energy during manufacturing and other processes, and it also contributes to the reduction of CO_2 emissions because it replaces fossil fuels through energy use.

In order to maximize the absorption and emission reduction effects of forests and timber, it is important to establish a recycling system of "cutting, using, and planting" for planted forests that have reached the end of their useful life and whose absorption is declining due to the aging, and to expand the use of timber while ensuring the creation of young forests with vigorous growth. In doing so, it is necessary to develop and implement wood utilization technologies that can store large amounts of carbon for long periods of time, such as using wood for construction of high-rise buildings and the development of new wood-based materials. In addition, it is necessary to adopt new technologies for reforestation after main felling, which imposes a heavy burden of cost and labor on forestry companies, etc., and to promote labor-saving and low-cost reforestation.

In recent years, great expectations have also been placed on the carbon sequestration effect of cropland. In many place of Japan, efforts have been carried out for enhancing carbon sequestration effect as well as restoring soil fertility through improving CO2 fixation of crops and applying it in the form of crop residues and biochar. Especially for biochar, the methodology for biochar application to cropland in the J-Credit Scheme has just been developed in Japan, following the addition of the " Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments " to the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and the implementation of reporting using the production volume of charcoal for agricultural use since National Greenhouse Gas Inventory Report of JAPAN in 2020. In light of the carbon sequestration through applying biochar, etc., cropland in Japan has high potential since Japan has vast cropland of 4.37 million hectares. In the future, it will be necessary to maximize this capability through R&D and the establishment of breakthrough technologies.

In organic agriculture, the carbon sequestration effect of applying compost and other fertilizers has been recognized, and it is important to further enhance the carbon sequestration capacity of cropland through this promotion.

Blue carbon (carbon sequestration by marine ecosystems) is expected to have great potential as a sink, and a method is being developed for evaluating CO_2 sequestration by vegetation type for seaweed beds that are not included in the 2013 Supplement to the IPCC Guidelines for National Greenhouse Gas Inventories. In addition, the development of technology for the creation, restoration, and conservation of seaweed beds and tidal flats is underway.

<Future efforts>

In order to achieve Carbon Neutrality by 2050, negative emissions, which cover emission sources with which it is difficult to achieve zero emissions, are essential, and it is necessary to realize long-term and massive storage of carbon in forests and wood, cropland, and oceans.

With regard to forests, in addition to appropriate thinning of planted forests, reforestation after main felling will be promoted by utilizing the "elite tree" species (the "elite tree" species with excellent growth and other characteristics selected from the next generation of individuals obtained through artificial crossbreeding of the "elite tree" species with excellent growth and other characteristics), etc., to ensure the creation of young, vigorous-growing forests, thereby securing and strengthening forest absorption over the medium to long term. To this end, the government will work to efficiently develop the "elite tree" species and expand the production of their seedlings by speeding up the breeding of forest trees, etc. It will also promote low-cost and labor-saving afforestation through the development of automated forestry machines, etc., the transportation of seedlings using drones and forestry machines, and the reduction of the number of undercutting operations using the "elite tree" species and large seedlings, etc. In addition, it will promote the creation of forests with the participation of the public through tree planting, etc. In doing so, the use of the "elite tree" species and other seedlings with excellent growth potential will be targeted at 30% of forestry seedlings by 2030, and at least 90% by 2050. With regard to the use of wood, in addition to promoting using wood for construction of buildings and the use of wood in daily life, the development of wood construction materials and standardization of construction methods that contribute to using wood for construction of high-rise buildings, etc., and the establishment of high-rise wood construction technology by 2040, we will also promote the wide use of new materials such as glycol lignin and CNF, as well as the development and practical application of new wood-derived materials, etc., to achieve long-term, large-volume storage of carbon using wood.

As the risk of meteorological disasters such as torrential rains is expected to increase further with the progress of global warming, the appropriate maintenance and conservation of forests that support the livelihood infrastructure of the people by promoting thinning and reforestation, road network maintenance, and mountain control measures through these initiatives will contribute to the realization of a society where people can live with peace of mind.

For cropland as a carbon sequestration, we improve the functionality, and then develop new type of biochar with as carbon sequestration and soil amendment, revise the biochar standards, and develop technologies to control the decomposition of soil organic matters. In addition, in order to achieve efficient and effective carbon sequestration in cropland, we will develop smart agricultural machinery that can automatically measure the organic matter content and fertility of soil and precisely apply highly functional biochar, etc., in order to both increase carbon sequestration and improve fertility. Additionally, we will develop biodata infrastructure for the development of crops with high CO_2 fixation capacity. Moreover, we will develop a rice husk gasification power generation system and aim to establish a sustainable, high-value-added farming model using biochar derived from local biomass.

With regard to organic agriculture, we aim to establish technologies related to next-generation organic agriculture by 2040, and thereby expand the organic market by 2050, while increasing the ratio of the area under organic farming (organic farming as practiced internationally[69]) to the total area of cultivated land to 25% (1 million hectares). The systematization of practical techniques, the development of labor-saving techniques, and the establishment of next-generation technology systems that many farmers can work with are expected to lead to the strengthening of the production base through the "expansion of the producer base" and other measures, in which diverse human resources from inside and outside the region participate as new supporters of the agriculture, forestry, and fisheries industries.

In addition, in order to increase the consumption of organic agricultural products, it is important to review the selection of products that focus on appearance, and to promote the sales of environmentally friendly agricultural management and high value-added agricultural products through the expansion of a system in which consumers and local residents understand and support organic agriculture, such as community-supported agriculture and interregional exchange.

With regard to blue carbon, we will establish a method for measuring the amount of CO_2 absorbed and stored by seaweed beds by fiscal 2023, and aim to reflect this in the United Nations Framework Convention on Climate Change, etc. At the same time, we will promote further efforts by industry, government, and academia to create, restore, and preserve seaweed/seagrass beds and tidal flats. This will also contribute to the restoration of biodiversity in the coastal zone. We will also promote the development of innovative technologies such as mass cultivation technology of hydrogen-oxidizing bacteria as a new CO_2 sink. Furthermore, we will promote the commercial use of seaweeds and hydrogen-oxidizing bacteria, and monetize them through the carbon offset system to promote autonomous CO_2 absorption.

3) Reduction of greenhouse gas emission — Energy procurement and production to distribution/consumption stages —

<Current status and issues>

Local resources such as land, water, and biomass, which exist abundantly in rural areas, are expected to be utilized as renewable energy resources that can be circulated locally, but they are not fully utilized at present because of their low energy density, wide dispersion, and large seasonal and temporal variations. In addition, the agriculture, forestry, and fisheries industries rely heavily on fossil fuels to heat horticultural facilities, promote photosynthesis, and power agricultural and forestry machinery and fishing vessels.

For this reason, it is necessary to further reduce the cost and improve the efficiency of renewable energy production, collection, and utilization in order to maximize the use of local resources in agricultural, mountainous, and fishing villages and to break away from fossil fuels, and to transform agricultural, mountainous, and fishing villages into sustainable societies of local energy production for local consumption.

The total GHG emissions from the agriculture, forestry, and fisheries sector are about 4%

---

[69] The term "internationally practiced organic farming" refers to organic farming at the level of efforts specified in Organic-JAS. "Organic agriculture" refers to agriculture conducted using agricultural production methods that reduce the burden on the environment derived from agricultural production as much as possible, based on not using chemically synthesized fertilizers and pesticides and not using genetic recombination technology.

domestically, but this is a major source of emissions accounting for about 24% worldwide. In addition, GHG emissions from agriculture, forestry and fisheries in Japan are approximately 50 million tons, of which 34% is CO_2 from fuel combustion and 46% is methane from paddy fields. In Japan, the development of fundamental technologies for reducing GHG (methane, N_2O, etc.) emissions from the agricultural and livestock industries has been progressing, and it is necessary to promote early dissemination of the technologies in the practical use stage and their deployment to the world, especially in the Asian monsoon region.

The food industry has low labor productivity compared to other industries. Therefore, it is necessary to develop and socially implement smart technologies that save labor and optimize the process from production to the distribution and consumption stages.

Wood has a variety of features that make life more comfortable for those who use it, including psychological effects such as warmth and comfort, moisture control, a certain level of heat insulation, and shock mitigation when falling. Furthermore, wood is a material that stores the carbon absorbed by forests for a long time and consumes relatively little energy during production. Moreover, it is an effective substitute for fossil fuels through energy use. Therefore, it is necessary to promote the use of wood through the conversion of high-rise buildings to wooden structures, and to promote the substitution of fossil fuel-derived products such as plastics through the development and diffusion of new materials derived from woody biomass. In addition, with regard to the energy use of woody biomass, from the viewpoint of ensuring the sustainability of forest resources, it is necessary to utilize unused wood, cascade use (multi-stage use through recovery and reuse), and efficient use based on thermal efficiency.

Fisheries production in Japan is on a long-term declining trend. In order to halt this trend and provide a stable supply of fisheries products to the public, the establishment of a new resource management system basically through an output control has just been started.

<Future efforts>

With regard to renewable energy sources, toward the realization of Carbon Neutrality by 2050, we aim to introduce renewable energy in rural areas in a manner that contributes to the sound development of agriculture, forestry, and fisheries, and that keeps pace with the expansion of the introduction of renewable energy sources in Japan. For this reason, in order to realize local production for local consumption type energy systems, technological development will combine different types of renewable energy to build systems that supply energy stably throughout the year and efficient and stable systems that supply renewable energy to other regions under the collaboration of industry, academia, and government. By promoting the introduction of such systems by local governments, local businesses, residents, and other communities, new industries will be created in each region, leading to the creation of jobs and regional revitalization.

For the dissemination of the developed technology, a logo mark will be introduced to visualize the renewable energy initiatives that contribute to the revitalization of rural areas. In addition, in order to accelerate the introduction and expansion of renewable energy in a way that encourages the decarbonization of rural areas, improves the vitality of rural areas, and contributes to the sound development of agriculture, forestry, and fisheries, the government will set new targets for the introduction of renewable energy in rural areas, and promote initiatives for local production and local consumption of renewable energy, such as the introduction of small-scale hydroelectric power generation, locally-produced and locally-consumed biogas power generation facilities, and the promotion of local resource recycling initiatives through the use of bio-liquid fertilizer (digestive liquid, a by-product of biogas power generation) and farm-based solar power generation, as well as reviewing the necessary regulations for the establishment of locally-produced and locally-consumed energy systems in rural areas.

In horticultural facilities, the aim is to make a complete shift to facilities that do not use fossil fuels by 2050 through the development of ultra-efficient heat storage, transfer, and heat dissipation technologies related to high-speed heating type heat pumps and industrial waste heat, on-site demonstrations to reduce the cost of new technologies, and the development of ultra-precise environmental control facilities that achieve RE100. In addition, we will promote energy-saving measures for forestry machinery, fishing vessels, and drainage systems, and develop technologies for the electrification and hydrogenation of agriculture, forestry, and fishing vessels in cooperation with industry, academia, and government, aiming to establish such technologies by 2040.

With regard to the promotion of sustainable livestock production, efforts will be made to (1) shift from a structure dependent on imported feed through the expansion of self-sufficient feed production, (2) reduce the burden on the environment through the improvement of livestock with high feed utilization, the development of GHG-reducing feed, and labor-saving and precision livestock feed management, (3) circulate resources through the wide-area distribution of livestock waste-derived compost in cooperation with arable farmers, and (4) foster understanding among consumers regarding the efforts of production sites. While utilizing the knowledge and experience of the production sites to solve problems, we will work to spread and establish the system. In addition, we will promote the development of innovative technologies to reduce GHGs from the agricultural and livestock industries by controlling microbial activities, and promote the development, demonstration, and dissemination of smart technologies.

As for the food industry, the government will develop innovative technologies, such as technologies to produce energy, fats, and oils from food residues and food processing residues using microbial saccharification technology, etc., technologies to improve QOL and ultra-long-term storage of food through freezing, thawing, and cooking technologies, data-driven cold chain systems, and new food manufacturing technologies using vegetable proteins, and will also aim to achieve sustainability-conscious procurement of imported raw materials by food companies by 2030. Through these efforts, we will build a smart food chain that will both improve productivity and reduce food loss and CO_2 emissions by linking data not only at the production stage, but also at the distribution and consumption stages.

In order to reduce business-related food loss, a system will be established in which products that lead to the reduction of food loss, such as discontinued products, will be sold with donations, and part of the profits will be used to support food bank activities, etc. In addition, a review of business practices in which manufacturers, wholesalers, and retailers work together will be promoted, such as the establishment of an online matching system that manages information on food providers and receivers for the promotion of food bank activities. By FY2030, the goal is to halve the amount of business-related food loss (compared to the FY2000 level), and by FY2050, the goal is to minimize business-related food loss through technological advances such as AI-based demand forecasting and the development of new packaging materials. In addition, by 2030, the government aims to increase labor productivity by more than 30% (based on 2018 standards) by promoting automation and other measures in the food manufacturing industry, and by 2050, the government aims to further improve labor productivity in Japan's food manufacturing industry, which has a diverse food culture, by realizing fully unmanned food production lines that can handle a wide variety of products through the use of AI.

With regard to the distribution of food and beverage products, we aim to promote rationalization and reduce the ratio of expenses to net sales in the food and beverage wholesaling business to 10% by 2030. In addition, by 2050, the aim is to further reduce costs and CO_2 emissions from trucking, storage, and other distribution activities by using AI, robotics, automation, and other new technologies to reduce labor at all distribution sites.

For the establishment of a sustainable food system that adequately responds to climate change and biodiversity conservation, etc., we will consider how to establish a policy mechanism to expand private investment and encourage behavioral change of each entity in each process from procurement and production to consumption. In addition, in order to expand sustainable production and other activities that contribute to the reduction of environmental impact, we will promote the visualization of the efforts of agriculture, forestry, fisheries, and food businesses through the improvement and upgrading of the "Soil CO_2 Absorption Visualization System".[70]

We will also promote consumer understanding of sustainable food, agriculture, forestry, and fisheries, and changes in purchasing behavior, through the implementation of smart agriculture technologies and the promotion of dietary education, including the "SCAFFF 2030 Project," a platform in which various stakeholders that promote sustainable production and consumption participate.

This will not only realize a stable supply of food to consumers and stabilize prices, but will also lead to the spread of a healthy and nutritionally balanced Japanese-style diet across the nation, making it possible to maintain and improve the health of the entire nation through food, including extending healthy life expectancy.[71]

In order to improve production capacity and reduce environmental impact, the following goals will be achieved. With regard to chemical pesticides, the government will establish and disseminate an integrated pest management system that does not rely solely on chemical pesticides, while gradually promoting the use of smart pest control technology systems and a shift from high-risk pesticides to low-risk pesticides. In addition, the government aims to reduce the risk-weighted use of chemical pesticides by 50% by 2050 through the development of new pesticides and other alternatives by 2040 that replace the need to use conventional insecticides, including neonicotinoid pesticides,

---

[70] The system is operated by the National Agriculture and Food Research Organization (NARO), and allows users to calculate soil carbon storage and greenhouse gas emissions by entering information such as the location and management method.

[71] In a study by Tohoku University on the association between Japanese food patterns and mortality risk (published in the European Journal of Nutrition in 2020), the risk of all-cause mortality was reduced by 14% and the risk of cardiovascular and cardiac mortality was reduced by 11% in the group with a high Japanese food score compared with the group with a low Japanese food score for deaths confirmed during approximately 18.9 years of follow-up.

which are widely used. As for chemical fertilizers, the government aims to reduce the use of chemical fertilizers made from imported raw materials and fossil fuels by 30% by 2050. In relation to the procurement of fertilizers and other products, which account for a large proportion of imports, the shift from imports to domestic production will revitalize related industries, increase exports by improving the reputation of domestic products through the introduction of environmentally friendly production, etc., and improve labor safety and labor productivity through the use of new technologies, leading to the formation of a sustainable industrial base for Japan. Furthermore, the same effect is expected in the promotion of organic farming, as efforts to reduce the use of chemical pesticides and fertilizers will be promoted.

These efforts will not only meet a wide range of consumer needs, but will also lead to the conservation of biodiversity and the prevention of global warming, as production will be based on the natural cycle of the region and the burden on the environment derived from agricultural production will be reduced.

In addition to carbon storage and CO2 emission reduction, the use of wood will be promoted through the verification and dissemination of evidence of the benefits of wood use, such as positive effects on the body and mind[72], popularization of activities such as "Mokuiku" (tree education), and networking with design and construction businesses and companies (clients). Also, the development of wooden building materials and standardization of construction methods that contribute to using wood for construction of high-rise buildings will be promoted. In addition, highly efficient use of woody biomass energy will be promoted through the development of highly functional materials utilizing glycol lignin, CNF, which can replace plastics, and subsequent new wood-derived materials, the establishment of an efficient transport and collection system for unused wood, and the promotion of heat utilization and thermoelectricity supply within each region. At the same time, in order to improve the efficiency of wood production and distribution, which is necessary for these efforts, we will introduce a forest cloud that complies with standard specifications, and develop and disseminate an ICT-based wood production and distribution management system that is consistent with automated machinery and cloud computing.

These efforts are expected to lead to economic cycles that make the most of the various resources in each region, including timber, and to the involvement of a variety of people both inside and outside each region, leading to increased employment and income in each region and the revitalization of local communities.

As for the amount of fisheries production, we aim to recover to the same level as in 2010 (4.44 million tons) by 2030 by promoting the appropriate management of fisheries resources in accordance with the "Roadmap for the Promotion of New Resource Management", including enhancement of scientific resource surveys and stock assessments and expansion of TAC (total allowable catch) managements based on the results of stock assessments.

In addition to achieving a 100% artificial seedling ratio in the cultivation of Japanese eel and

---

[72] For example, studies have shown that increasing the rate of interior wood quality in living spaces can increase sleep efficiency.
(Reference) Japan Society for the Promotion of Science (JSPS), Grant-in-Aid for Scientific Research, "Measurement of Effects of Living Environment on Brain, Circulatory System, Respiratory System, and Locomotor System and Evaluation of Benefits for Disease and Nursing Care Prevention," 2017-2021.

bluefin tuna by 2050, we will convert all of our fish feed to formula feed, aiming to create a sustainable aquaculture production system that does not place a burden on natural resources.

These efforts to restore fisheries resources in waters around Japan will increase the amount of sustainably available fisheries products will halt the decline in fisheries production, establish a stable supplying system, suppress price fluctuations, and thereby support the maintenance of a rich diet. In addition, the recovery of fisheries resources will lead to systematic operations that avoid unnecessary competition and efficient operation of fishing vessels, which in turn will reduce the use of fossil fuels.

In addition to these efforts, through the revision and implementation of the Ministry of Agriculture, Forestry and Fisheries Global Warming Prevention Plan, we aim to achieve zero CO_2 emissions from agriculture, forestry and fisheries by 2050.

(10) Aircraft industry

The International Civil Aviation Organization (ICAO) has adopted a goal of no increase in CO_2 emissions from international aviation after 2020, and this goal will be achieved through a combination of improved flight operations, the introduction of new technologies, alternative fuels, and the use of market mechanisms.[73] Meanwhile, International Air Transport Association (IATA) has set a goal of halving CO_2 emissions from 2005 levels by 2050.[74]

With the increasing demand for low carbon, the development of low carbon related technology is indispensable from the viewpoint of climate change countermeasures, and will contribute to maintaining and strengthening the competitiveness of Japan's aircraft industry.

Therefore, Japan will promote the development of individual technologies and consider concrete measures to promote the introduction of new technologies into aircraft and equipment by reviewing and improving safety and environmental standards, and contribute to the low-carbon aviation sector.

1) Electrification of equipment and propulsion system

<Current status and issues>

As regards the electrification of aircrafts, while, currently, the range of applications is limited, such as installing storage batteries for auxiliary power and power supply when staying on the ground, but in the future, it is expected to be expanded to applications related to power during flight and operation of internal systems. In order to achieve this, it is necessary to dramatically improve the performance of technologies such as batteries and motors.

In recent years, competition has become active for the acquisition of electrification technology and the development of demonstrators, centered on Western aircraft and engine manufacturers. Japanese companies are potentially competitive in elemental technologies in related fields such as batteries and motors, but their current use in aircraft equipment and other products is limited.

In the "Agreement between the Ministry of Economy, Trade and Industry of Japan and The Boeing Company on Cooperation in Aircraft Technology" in 2019, electrification of aircraft is positioned as one of the specific fields of cooperation.[75]

<Future efforts>

In order to establish electrification technology for aircraft, we will continue to promote R&D conducted in cooperation between aircraft-related manufacturers and electrical equipment-related manufacturers, while utilizing the knowledge of the Japan Aerospace Exploration Agency (JAXA) and other national research institutes, and aim to meet the required technological level of domestic manufacturers by the time the technology to be installed in future aircraft is selected. Specifically, we will accelerate the R&D of core technologies for powering aircraft, such as batteries, motors and

---

[73] ICAO "ON BOARD A SUSTAINABLE FUTURE"
（https://www.icao.int/environmental-protection/Documents/ICAOEnvironmental_Brochure-1UP_Final.pdf）

[74] IATA "Aviation & Climate Change Fact Sheet".
（https://www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet--climate-change/）

[75] Ministry of Economy, Trade and Industry News Release (January 15, 2019)
（https://www.meti.go.jp/press/2018/01/20190115007/20190115007.html）

inverters, with the aim of incorporating these technologies in stages from 2030 onwards, while also considering the use of the Green Innovation Fund. On that occasion, the government will utilize and strengthen the framework of cooperation with overseas companies that manufacture aircraft, and aim to incorporate the developed technology into future aircraft. In addition, we will promote international standardization through domestic industry-academia-government collaboration.

It should be noted that electric aircraft are expected to significantly reduce noise by replacing the conventional propulsion system with an electric system. In addition to the elimination of noise originating from the combustor and turbine in the engine, exhaust noise is likely to be reduced due to the lower exhaust velocity compared to conventional engines. In fact, the recent development of small electric aircraft overseas has confirmed a noise reduction of 20-30%. Japan will also actively aim to reduce noise in the development of technologies related to storage batteries, electric motors, etc., and contribute to the realization of low-noise electric passenger planes by 2050 that are acceptable to residents and passengers in the vicinity of airports, even at night, for example.

2) Hydrogen-powered aircraft

<Current status and issues>

In order to realize low carbon in the aircraft field, it is expected that hydrogen fuel will be used in addition to the installation of electrification technology. There are many technical challenges for the realization of hydrogen-powered aircraft, such as a lightweight and safe hydrogen storage tank, and the development of new engine parts when directly burned in a turbine. Additionally, it is also necessary to consider the feasibility of peripheral infrastructure and hydrogen supply chain from the viewpoint of safety and cost.

In addition, in September 2020, Airbus announced that it will bring hydrogen aircraft to the market in 2035. At present, Japanese companies have also started concrete efforts regarding hydrogen aircraft, and it is necessary to accelerate research and development and concrete studies in the future.

<Future efforts>

The government will promote the development of necessary elemental technologies for the realization of hydrogen aircraft. At that time, it will seek cooperation with overseas manufacturers from the initial stage of development, identify issues that will lead to practical use, and focus on them. For example, the manufacturing technology for the fuel tank and engine combustor is an essential core technology for hydrogen aircraft, but it requires a huge amount of R&D costs over the medium to long term because of the extremely high technical hurdles, such as the difficulty of achieving weight reduction as well as safety and reliability. For this reason, we will promote the development of core technologies while considering the use of the Green Innovation Fund and other funds. In addition, the study of civilian facilities at airports for the storage, transportation, and use of hydrogen fuel will be carried out from June 2021 onward in the "Study Group on Airport Peripheral Infrastructure for the Realization of Hydrogen Aircraft (tentative name)" in cooperation with the government, aircraft manufacturers, other related companies, and academics.

3) Weight reduction and efficiency improvement of the airframe/engine

<Current status and issues>

As for aircraft and engine materials, the introduction of new materials that contribute to weight reduction and heat resistance improvement is in progress. In relation to aircraft structures (fuselage, wings, etc.) and interiors (galleys, etc.), there has been a shift from aluminum alloys to carbon fiber composites. Regarding aircraft engines, carbon fiber composites, which are lightweight and have excellent strength, are being applied to fan parts, and ceramics-based composites, which are seen as promising materials that can withstand high temperatures, are being applied to turbine parts.

As the demand for low carbonization increases, it is expected that the needs for applying materials that will lead to further weight reduction and efficiency will continue in the future. At present, Japanese companies have technological advantages in the material field, but it is important to respond to further performance improvement and cost reduction demands in the future.

<Future efforts>

Under the collaboration among domestic material manufacturers, aircraft and engine manufacturers, and national research institutes such as JAXA, the necessary technology development including database development and production technology for advanced materials will be promoted, aiming to meet the required technology level by the time the onboard technology for future aircraft is selected by domestic manufacturers. On that occasion, the government will utilize and strengthen the framework of cooperation with overseas companies that manufacture aircraft, and aim to incorporate the developed technology into future aircraft.

In addition, while carbon fiber composite materials are more energy efficient than conventional metals in terms of weight reduction during operation, they consume more energy than metals during manufacturing. Therefore, in order to increase the emission reduction effect of the entire manufacturing cycle, we will promote the establishment of recycling technology over the medium and long term in cooperation with other fields such as automobiles.

4) Bio jet fuel etc. and synthetic fuel

(a) Sustainable Aviation Fuel (SAF)

<Current status and issues>

With regard to international aviation, a system of "no increase in CO_2 emissions compared to 2019" has been introduced by the ICAO (the system will continue until 2035). With the introduction of the system, the market for SAF is expected to steadily expand, although at present it is almost non-existent.

For this reason, starting with European companies, companies in each country are activating the development of alternative fuels for jet fuel. With regard to the development of multiple SAF technologies, Japanese companies have been developing elemental technologies and have started demonstrations, while other countries are in a state of horizontal competition.

The main production technologies of SAF include gasification FT synthesis technology,[76] ATJ

---

[76] A technology to produce SAF by steaming (gasification) of organic materials such as wood waste and liquefying them with a catalyst (Fischer-Tropsch process).

technology,[77] and microalgae cultivation technology.[78]

At present, it is necessary to establish technology to solve the following production issues: for gasification FT synthesis, crushing treatment technology to equalize the quality of various raw materials; for ATJ, technology to control the catalytic reaction under high temperature conditions; and for the cultivation of microalgae, (1) the algae have low CO_2 absorbing efficiency and the speed of growth is slow (low productivity), and (2) the algae's weak tolerance to the external environment makes it difficult to grow stably (fragile production stability), and this remains at the small-scale demonstration stage (current NEAT[79] production cost 200-1,600 yen/L (existing product: 100 yen/L)).

<Future efforts>

As for the gasification FT synthesis technology, ATJ technology and the microalgae cultivation technology, in order to establish the above-mentioned technologies and reduce costs, R&D and large-scale verification will be carried out to reduce the costs from the current level by around 2030, ahead of other countries. The cost will be reduced from the current 200 ~ 1,600 yen/L to the 100 yen/L level, which is equivalent to existing products, by around 2030 to achieve practical application.

In addition, it is assumed that the production and supply of SAF will progress in other countries after 2025. Therefore, we will promote R&D and social implementation for further cost and CO_2 emission reduction, aiming to quickly establish a low-cost and stable SAF manufacturing and supply system supported by domestic manufacturers at domestic airports, where the total demand is expected to be approximately 250 to 560 billion yen in 2030.

Additionally, demand for SAF is expected to increase significantly in accordance with the international trend toward Carbon Neutrality in aviation. Ensuring international competitiveness in terms of SAF supply and prices in Japan will provide a major economic and social incentive for foreign airlines to operate flights to Japan, which will lead to the enhancement of the status of Japan's international airports in Asia, and eventually to the establishment of a stable international aviation network.

In addition, by developing this technology overseas and supplying SAF for use by foreign airlines, these efforts are expected to contribute to foreign currency acquisition. From this perspective, we will expand the supply of competitive SAF to aircraft in response to trends in the international market for SAF (some of which have already acquired international certification).

(b) Synthetic fuels

<Current status and issues>

Synthetic fuels are produced by synthesizing CO_2 and hydrogen, and can be regarded as carbon-free decarbonized fuels because they reuse the emitted CO_2. In particular, liquid synthetic fuels, which are mixtures of gasoline, kerosene, diesel oil, etc., are aggregates of multiple hydrocarbon

---

[77] Abbreviation for Alcohol-to-Jet. A technology for reforming bioethanol into SAF using a catalyst.

[78] Through photosynthesis CO_2 to produce oil and lipids through photosynthesis. SAF technology to produce This technology produces SAF.

[79] Refers to jet fuel manufactured based on biomass raw materials, etc. before mixing with fossil-derived jet fuel. When using Neat, it is necessary to mix a certain ratio with fossil-derived jet fuel before mounting it on an aircraft.

compounds, or "artificial crude oil," so to speak. In particular, when hydrogen derived from renewable energy is used, it is referred to as e-fuel. Since existing fuel infrastructure and internal combustion engines can be utilized, the introduction cost can be reduced compared to other new fuels such as hydrogen.

Synthetic fuels, like fossil fuels, are liquid fuels and therefore exhibit high energy density and portability. For example, when heavy-duty vehicles and jets are electrified and converted to hydrogen, they will require a larger capacity of battery and hydrogen energy than liquid fuels to travel the same distance. These liquid synthetic fuels will continue to exist as long as there are mobility products that are difficult to replace with electric and hydrogen energy.

The challenges for the commercialization of synthetic fuels are the cost and the establishment of production technology, and it is necessary to improve the efficiency and cost of existing technologies and to develop innovative new technologies and processes.

In addition, since the raw materials of synthetic fuels are CO_2 and hydrogen, their potential as SAF with stable supply can be evaluated from the viewpoint that they can be industrially mass-produced without resource constraints. Therefore, synthetic fuels are expected to contribute to the realization of adequate supply for the demand of SAF, which is expected to increase in the future.

<Future efforts>

For synthetic fuels, in order to establish an integrated production process for commercialization, we will develop innovative new technologies and processes (co-electrolysis, direct-FT, etc.) in addition to improving the efficiency of existing technologies (reverse shift reaction + FT synthesis process) and designing and developing production facilities.

By intensively developing and demonstrating technologies related to these synthetic fuels over the next 10 years, we aim to establish high-efficiency, large-scale production technologies by 2030, expand their introduction and reduce their cost in the 2030s, and achieve independent commercialization (based on environmental value) by 2040.

(11) Carbon Recycling and materials industry

i） Carbon Recycling

Carbon Recycling is a key technology that effectively utilizes CO2 as a resource for realizing a carbon neutral society, and Japan has a competitive edge in this field.

The Carbon Recycling industry is diverse, as shown in the Carbon Recycling Technology Roadmap, which includes major fields such as minerals (concrete products, concrete structures, carbonates , cement, etc.), fuels (microalgae jet fuel, microalgae diesel fuel, synthetic fuel, biofuel, gas fuel from methanation, etc.), and chemicals (polycarbonates, urethanes, biomass-derived chemicals, general-purpose substances such as olefins and paraxylene), etc. Focusing on these major products, the government will promote technology development for cost reduction as well as application development and social implementation, and aim for global development through International Conference on Carbon Recycling.

1) Concrete and Cement

<Current status and issues>

As for concrete, there are companies in Japan that have succeeded in commercializing CO_2 absorption type concrete (CO_2-SUICOM). By producing a material that hardens by absorbing CO_2 from slaked lime produced as a by-product emitted from chemical plants etc., and using this material for concrete production, we can (1) reduce the amount of CO_2 emissions in the manufacturing process, and (2) reduce the amount of cement used. Furthermore, by increasing CO_2 absorption, negative emissions (carbon removal) can be achieved.

Internationally in addition to U.S. companies developing and putting the concrete to practical use with similar technologies, U.K. companies commercialize a type of technology that absorbs CO_2 into aggregates, and each country is in a side-by-side competitive states.

While the market size of CO_2 absorption type concrete is expected to reach about 15-40 trillion yen as of 2030, in anticipation of such market expansion, it is necessary to achieve price reduction at an early stage and acquire market share.

On the other hand, the cost of current CO_2 absorption type concrete is high (i.e., 100 yen/kg, which is about three times that of precast concrete products), and the main issue is to achieve both low cost and increased CO_2 absorption. Another issue is that the steel reinforcement in concrete structures tends to rust (due to easy oxidation by CO_2 absorption), which limits its application. Furthermore, taking into account the fact that concrete has the characteristics of local production for local consumption, it is necessary to establish manufacturing technology that can respond to the regional characteristics such as the procurement situation in the region in order to spread and expand the developed CO_2 absorption type concrete.

As for cement, a large amount of CO_2 is emitted from the calcination reaction that occurs when limestone, the raw material for cement, is burned. In order to cope with this issue, based on the "Environment Innovation Strategy" and other guidelines, we have started R&D on CO_2 capture from exhaust gas from factories, etc. by chemical absorption methods, etc., and carbonation of the CO_2

by fixing it in calcium recovered from waste/fresh concrete and steel slag, etc., thereby promoting efforts for effective utilization of CO_2 from cement production.

Internationally, the cement industry in various countries is developing technologies that will lead to the realization of Carbon Neutrality, such as the development of manufacturing technology to improve cement manufacturing processes and capture CO_2 generated during the combustion process, with funding provided by the EU, and aims to maintain a domestic market scale of 500 billion yen by 2030 in order to secure the future cement market.

At present, several thousand tons of CO_2 are emitted per day from a single cement kiln, and in order to recover a large amount of CO_2 by the chemical absorption method, it is difficult to adapt the method to existing cement plants due to the inevitable increase in the scale of facilities. This makes it difficult to adapt to existing cement plants. In addition, since disaster waste and other materials are used as raw materials for cement, the development of innovative technologies for efficient CO_2 capture and recycling of various raw materials is an issue.

<Future efforts>

As for concrete, by expanding sales channels through public procurement, we aim to achieve the same price as existing concrete (=30 yen/kg) by 2030 as a cost target. For this reason, we have already registered CO_2 absorption type concrete in the database of Ministry of Land, Infrastructure, Transport and Tourism for new technologies (NETIS: New Technology Information System), and will make this widely known to local governments. Additionally, we also aim to expand public procurement by the national and local governments by introducing it at the 2025 World Exposition in Japan and other events. In the global market, the demand for concrete is expected to reach 15 to 40 trillion yen (2030), especially in Asia where economic growth is remarkable. Therefore, we will expand our sales channels in Asia through international standardization and PR at large-scale international exhibitions, etc.

Furthermore, by 2050, while considering the use of the Green Innovation Fund, etc., we will develop and demonstrate new products with rust preventive performance by developing technologies to control the CO_2 absorption range and using alternative materials to reinforcing steel bars. In addition, we will promote social implementation by working on standardization. Moreover, we will develop new technologies and products that combine increased CO_2 absorption with lower costs, establish manufacturing technologies for CO_2 absorption type concrete that can suit to regional characteristics, and utilize licensing business forms through intellectual property strategies such as the acquisition of patents related to these technologies. We will also establish manufacturing technology for gaining and expanding market share in Japan and overseas.

As for cement, in the short term (~2030), the goal is to establish technology to realize large quantities of CO_2 capture at domestic cement plants. Therefore, based on the existing manufacturing process, we will develop a plant that captures nearly 100% of CO_2 emissions from limestone. Specifically, after the first demonstration at a small plant, the construction and demonstration of a large demonstration plant with a production capacity close to that of a commercial plant will be promoted, and at the same time, the development of technology for effectively using various calcium sources, such as waste, as carbonates by reacting them with recovered CO_2 and the demonstration of the commercialization of this technology will be promoted.

In view of the fact that the cement kiln system (NSP kiln) originating in Japan has become the de facto technology in the world, this technology is expected to be adopted not only in Japan but also in other countries. In order to achieve this goal, we will promote the introduction of this technology in 51 cement kilns in Japan from 2030 onwards, as well as in kiln renovations and new construction around the world by 2050, in order to capture and expand our share of the market, which is estimated to exceed 15 trillion yen. In addition, we will promote the introduction of this technology in relation to the refurbishment and construction of kilns around the world by 2050.

In addition to the CO_2 reduction effect, CO_2 absorption type concrete also has the characteristic of increasing the water resistance and durability of concrete by CO_2 absorption. This will lead to a reduction in the frequency of maintenance and replacement of structures that have contact with water, especially river structures, and will rationalize public investment.

Through these efforts, the creation of the market where products and buildings using carbon recycled concrete and carbon recycled cement can be used and the demand side will be enabled to select products and buildings that meet their needs for environmental friendliness and long life.

2) Carbon Recycling Fuel

(a) Alternative aviation fuel (SAF: Sustainable Aviation Fuel) (SAF)

<Current status and issues>

With regard to international aviation, the International Civil Aviation Organization (ICAO) has introduced a system of "no increase in CO_2 emissions compared to 2019" (the system will continue until 2035). With the introduction of the system, the market for SAF is expected to steadily expand, although at present it is almost non-existent.

For this reason, starting with European companies, companies in each country are activating the development of alternative fuels for jet fuel. With regard to the development of multiple SAF technologies, Japanese companies have been developing elemental technologies and have started demonstrations, while other countries are in a state of horizontal competition.

Major production technologies for SAF include gasification FT synthesis technology,[80] ATJ technology,[81] and microalgae cultivation technology.[82]

At present, the production technologies for these fuels are still in the small-scale demonstration stage, as it is necessary to establish technologies to resolve the following issues: for gasification FT synthesis, a crushing treatment technology to equalize the quality of various raw materials; for ATJ, a technology to control catalytic reaction under high temperature conditions; and for cultivation of microalgae, (1) the low efficiency with which algae absorb CO_2 and the slow speed of growth (low productivity), and (2) the difficulty of stable growth due to the weak tolerance of algae to the external

---

[80] A technology to produce SAF by steaming (gasification) of organic materials such as wood waste and liquefying them with a catalyst (Fischer-Tropsch process).

[81] Abbreviation for Alcohol-to-Jet. A technology for yielding SAF from bioethanol using a catalyst.

[82] A technology to produce SAF by stably cultivating large quantities of algae that produce oil and lipids from CO_2 through photosynthesis

environment (weak production stability). (Current Neat[83] production cost 200-1,600 yen/L (ready-made: 100 yen/L))

<Future efforts>

As for the gasification FT synthesis technology, ATJ technology and the microalgae cultivation technology, in order to establish the above-mentioned technologies and reduce costs, R&D and large-scale verification will be carried out to reduce the costs from the current level by around 2030, ahead of other countries. The cost will be reduced from the current 200 ~ 1,600 yen/L to the 100 yen/L level, which is equivalent to existing products, by around 2030 to achieve practical application.

In addition, it is assumed that the production and supply of SAF will progress in other countries after 2025. Therefore, we will promote R&D and social implementation for further cost reduction and CO2 emission reduction, and aim to quickly establish a low-cost and stable SAF manufacturing and supply system by domestic manufacturers at domestic airports, where the total demand is expected to be approximately 250 to 560 billion yen in 2030.

In addition, demand for SAF is expected to increase significantly in accordance with the international trend toward Carbon Neutrality in aviation. Ensuring international competitiveness in terms of SAF supply and prices in Japan will provide a major economic and social incentive for foreign airlines to operate flights to Japan, which will lead to the enhancement of the status of Japan's international airports in Asia, and eventually to the establishment of a stable international aviation network.

In addition, by developing this technology overseas and supplying SAF used by foreign airlines, the initiative is expected to contribute to foreign currency acquisition. From this perspective, we will expand the supply of competitive SAF to aircraft in response to trends in the international market for SAF (some of which have already acquired international certification).

(b) Synthetic fuels

<Current status and issues>

Synthetic fuels are produced by synthesizing CO_2 and hydrogen, and can be regarded as carbon-free decarbonized fuels because they reuse the emitted CO_2. In particular, liquid synthetic fuels, which are mixtures of gasoline, kerosene, diesel oil, etc., are aggregates of multiple hydrocarbon compounds, or "artificial crude oil," so to speak. In particular, when hydrogen derived from renewable energy is used, it is referred to as e-fuel. Since existing fuel infrastructure and internal combustion engines can be utilized, the introduction cost can be reduced compared to other new fuels such as hydrogen.

Synthetic fuels, like fossil fuels, are liquid fuels and therefore exhibit high energy density and portability. For example, when heavy-duty vehicles and jets are electrified and converted to hydrogen, they will require a larger capacity of battery and hydrogen energy than liquid fuels in order to travel the same distance. These liquid synthetic fuels will continue to exist as long as there are mobility products that are difficult to replace with electric and hydrogen energy.

---

[83] Refers to jet fuel manufactured based on biomass raw materials, etc. before mixing with fossil-derived jet fuel. When using Neat, it is necessary to mix a certain ratio with fossil-derived jet fuel before mounting it on an aircraft.

The challenges for the commercialization of synthetic fuels are the cost and the establishment of production technology, and so it is necessary to improve the efficiency and cost of existing technologies and develop innovative new technologies and processes.

<Future efforts>

For synthetic fuels, in order to establish an integrated production process for commercialization, we will develop innovative new technologies and processes (co-electrolysis, direct-FT, etc.) in addition to improving the efficiency of existing technologies (reverse shift reaction + FT synthesis process) and designing and developing production facilities so that the cost of synthetic fuels will be lower than the price of gasoline in 2050.

By intensively developing and demonstrating technologies related to these synthetic fuels over the next 10 years, we aim to establish high-efficiency, large-scale production technologies by 2030, expand their introduction and reduce their cost in the 2030s, and achieve independent commercialization (based on environmental value) by 2040.

(c) Synthetic methane

<Current status and issues>

Synthetic methane is expected to be one of the hydrogen carriers because it is synthesized (methanation) from hydrogen derived from renewable energy sources etc. and CO_2. The main component of city gas (natural gas) is methane, and synthetic methane can replace natural gas by utilizing existing infrastructure and facilities such as city gas pipelines, etc. Therefore, it is expected to contribute to a smoother transition toward Carbon Neutrality in 2050 while keeping costs low. In addition, synthetic methane, which captures emitted CO_2 and combines it with green hydrogen, can be considered carbon neutral because it does not emit any new CO_2. When combined with CO_2 separation/recovery and utilization, etc., it can contribute to the further reduction of CO_2 emissions.

As for methanation technology, NEDO carried out the development of basic technology for methanation in a small-scale test facility from FY2017 to FY2021. In addition, from FY2019 to FY2020, NEDO is also conducting leading fundamental technology development to confirm the elemental technologies necessary for innovative SOEC methanation technology that can produce synthetic methane more efficiently than conventional methanation technology without the need for hydrogen procurement.

In the future, it will be necessary to develop technologies such as larger equipment and higher efficiency for practical use and lower cost of methanation. Methanation requires the procurement of inexpensive hydrogen and CO_2, and so the construction of a supply chain is an issue. Regarding the counting of CO_2 reductions, it is necessary to consider in a direction that contributes to Carbon Neutrality.

<Future efforts>

In 2030, the goal is to inject 1% synthetic methane into existing infrastructure, and to make 5% of gas carbon neutral, along with other measures such as direct hydrogen use. By 2050, 90% of synthetic methane will be injected into the existing infrastructure, and together with other means such as direct use of hydrogen, we aim to achieve the Carbon Neutrality of gas. In addition, we aim to start supplying synthetic methane, etc. as gas fuel for ships around 2030.

We will work on the development of technologies necessary for reducing the cost of water electrolysis equipment required for hydrogen production and increasing the size of methanation facilities, and on the development of innovative technologies necessary for highly efficient methane synthesis and CO_2 separation and recovery.

For the 2025 World Exposition in Japan, a demonstration is proposed that methanation be used to generate synthetic methane from biomass-derived CO_2 generated from food waste at the venue and hydrogen derived from renewable energy sources, and that this be used in facilities at the venue.

A study on counting CO_2 reductions in a direction that contributes to Carbon Neutrality will be promptly conducted.

In addition, in order to achieve Carbon Neutrality in 2050, it is necessary to secure a considerable amount of hydrogen for the generation of synthetic methane. In order to keep the cost of synthetic methane low, it is considered effective to transport synthetic methane generated overseas where the hydrogen cost is relatively low to Japan. Based on the above, we will promote the construction of overseas supply chains for the decarbonization of gas, including the introduction of synthetic methane. We will start transporting synthetic methane from overseas to Japan in the latter half of the 2020s, and expand its introduction nationwide in the 2030s, aiming to achieve commercialization in the 2040s while reducing costs.

In order to promote these efforts, it is important that various stakeholders involved, including private companies on the supply side and demand side, as well as the government, work together. Therefore, the “Public-Private Sector Council for the Promotion of Methanation” was established in June 2021 to promote the study of the decarbonization of gas, through the unified efforts of the public and private sectors.

Through these efforts, we aim to supply 25 million tons of synthetic methane by 2050, and bring the price of synthetic methane to the same level as the current LNG price (40-50 yen/Nm^3).

(D) Green LPG

<Current status and issues>

LP gas is supplied to about 40% of all households, and so it is an essential energy source that supports the lives of the people. It also supports a wide range of fields, including industrial and chemical raw materials, and is expected to maintain approximately 60% of demand by 2050.

In order to achieve Carbon Neutrality, it is necessary to shift from an industry structure in which LP gas, a fossil fuel, is procured from overseas to one that contributes to Carbon Neutrality by establishing technology to synthesize green LP gas (not derived from fossil fuels) from biomass and other resources, thereby creating a green LP gas manufacturing industry.

At present, artificial synthesis using hydrogen and carbon monoxide, and green LP gas synthesis technology using biomass, etc. are assumed, but in the future, development and demonstration of highly durable catalysts, etc. are essential for direct synthesis of LP gas.

The commercialization of this technology is expected to change the structure of the industry and reduce costs through the participation of various players who have not been involved in the LP gas industry in the past.

In Europe, green LP gas derived from biomass has been synthesized as a byproduct of biodiesel fuel, but the quantity is extremely small, and the artificial synthesis is still in the process of basic research worldwide.

<Future efforts>

In order to make LP gas greener, we will establish LP gas synthesis technology by chemical synthesis and biomass, and work on demonstrations, etc. for social implementation in 2030.

By intensively developing and demonstrating technologies for the synthesis of such green LP gas over the next 10 years, we will establish synthesis technologies and achieve commercialization by 2030. The goal is to replace the entire demand with green LP gas by 2050.

3) Carbon recycling chemicals (raw materials for plastics through artificial photosynthesis, etc.)

The market scale of chemical products such as plastics derived from fossil resources is about 10 trillion yen in the Japanese market and several hundred trillion yen in the global market. In such a large-scale market, we aim to acquire and expand our share by establishing artificial photosynthesis technology, etc., which only Japanese companies possess.

a) Plastic raw materials by artificial photosynthesis

<Current status and issues>

Only Japanese companies are developing artificial photosynthesis technology that separates hydrogen from water by sunlight using a photocatalyst and combines hydrogen and CO_2 to produce plastic raw materials. Basic research (labor level) has already succeeded.

On the other hand, at present, since the conversion efficiency of photocatalysts is low and the manufacturing cost is high, there are technical issues in conducting large-scale demonstrations. In addition, separation membranes such as hydrogen and backbones are required to establish artificial photosynthesis technology. It is also necessary to develop and demonstrate catalysts, etc. required for the synthesis of hydrocarbons as fundamental substances.

<Future efforts>

By developing a photocatalyst with high conversion efficiency in collaboration with the AIST-Global Zero Emission Research Center, the government aims to reduce the cost of plastic manufacturing by artificial photosynthesis by about 20% by 2030. At that time, it is necessary to consider the relevant regulations for optimizing the large-scale demonstration of artificial photosynthesis and its implementation in society, taking into account safety assurance in a series of processes from the generation of low-pressure gas mixed with hydrogen and oxygen by photocatalyst to the separation and recovery of hydrogen and oxygen. In order to prevent Japan from losing its competitive edge due to delays in establishing technologies and implementing them in society, we will work to formulate new safety and security standards with foresight, and to comply with related regulations such as the High Pressure Gas Safety Act, while anticipating future technological trends.

On top of that, a large-scale demonstration of the production of plastic materials by artificial photosynthesis will be carried out in 2050, and the same price as existing products (= 100 yen/kg) will be achieved for general-purpose plastics such as polyethylene and polypropylene.

b) Plastic raw materials such as waste plastic, waste rubber and CO_2 direct synthesis

<Current status and issues>

While waste plastic and waste rubber emit CO_2 when incinerated, it is necessary to take measures based on the fact that they can be reused as a carbon source for chemical products. For example, some efforts are underway to generate synthetic gas (hydrogen and carbon monoxide) from waste plastics, convert it to alcohol, and then use it as a raw material for plastics.

In addition to the need to reduce CO_2 emissions during production, functional chemicals are also required to have high added value by improving functionality such as weight reduction. Additionally, it is important to deal with the heat source required in naphtha cracking furnaces.

<Future efforts>

For functional chemicals based on CO_2 (oxygen-containing compounds such as polycarbonate) and chemicals derived from biomass and waste plastics, we aim to establish manufacturing technology by 2030 and to achieve the same price as existing products by 2050. Further improvements in functionality, such as heat resistance, impact resistance, and weight reduction, will enable the realization of products (automobiles, electronic devices, etc.) with higher added value than current products at the same price.

In addition, we will consider upgrading naphtha cracking furnaces by making the heat sources carbon-free (R&D of burners and cracking furnaces).

c) Utilization of biomanufacturing technology

<Current status and issues>

Bio monozukuri technology is a type of carbon recycling technology. It is possible to produce chemicals such as bioplastics and functional materials from biomass resources and atmospheric CO_2 using microorganisms with enhanced functions through genome editing, etc. In addition, energy-saving effects are expected by means of production processes at normal temperature and pressure, and emission-reduction effects at the livestock production stage are anticipated by manufacturing artificial fibers instead of animal-derived fibers.

The challenge with bio-manufacturing using biomass resources is that the cost is higher than that of existing chemicals, and the types of chemicals that can be produced are limited. In addition, although there are some cases of R&D with a view to commercialization of biomanufacturing using atmospheric CO_2 as a raw material, the development of elemental technologies, such as the development of genetically modified microorganisms and cultivation technologies that enable efficient material production, is an issue.

<Future efforts>

As for bio-manufacturing using biomass resources, development of microorganisms for industrial use by genome editing, etc., and development and demonstration of efficient production processes by AI, etc. will be carried out. Intensive efforts over the next 10 years will be made to reduce costs and expand the types and functions of chemicals that can be produced on a commercial basis by 2035. As for bio-manufacturing that uses atmospheric CO_2 as a raw material, we will establish basic technology by developing microbial strains suitable for cultivation, etc., and aim to put such results to practical use from around 2040.

4) CO_2 separation and recovery facility (separation and recovery of CO_2 in exhaust)

<Current status and issues>

Development and demonstration of CO_2 separation and recovery technology is indispensable to secure the negative emission (carbon removal) of CO_2 emission sources that are difficult to net zero emission and the CO_2 source required for Carbon Recycling. Amid the trend toward decarbonization in countries such as Japan and Europe and the United States, the market size of CO_2 separation and recovery technology will expand to about 6 trillion yen/year in 2030 and to about 10 trillion yen/year in 2050. It is predicted that it will reach about 400 billion yen/year in 2050 in Japan alone.

Japanese companies have completed high-concentration CO_2 separation and recovery equipment from power plants for EOR and chemical applications, and have secured top shear by constructing a CO_2separation and recovery plant. Also, regarding CO_2 separation and recovery technology in Japan, the number of industry-academia patents is large compared to other countries.

On the other hand, low-cost recovery technology from CO_2 emission sources with various concentrations and characteristics is a future development issue.

<Future efforts>

In the future, the government will develop highly efficient CO_2 separation and recovery technology, and in 2030, the government aims to realize further reduction in cost of separation and recovery technology and expansion to applications other than EOR. In doing so, we will establish a standard evaluation technology for CO_2 capture with a view to a wide range of applications, and consider international standardization in order to accelerate the deployment of Japanese technology in Japan and overseas. On top of that, in 2050, it aims to secure 30% of the world's separate collection market of 10 trillion yen annually. In order to promote the development of technologies for social implementation, the use of the 2025 World Exposition in Japan and other venues will be considered in order to conduct technology demonstrations and disseminate the results to the international community.

[Reference] Direct recovery of CO_2 from the atmosphere (DAC: Direct Air Capture)

<Current status and issues>

As regards technology development for DAC (Direct Air Capture), although Western venture companies are accelerating research and development with an eye on commercialization, they are still in the stage of elemental technology development worldwide. In Japan as well, development at the laboratory level has started in 2020.

At present, energy efficiency is low and CO_2 recovery cost from the atmosphere is high.

<Future efforts>

The government will advance technological development on a highly efficient CO_2 recovery method from the atmosphere, realize low cost, and aim for practical use in 2050.

ii） Materials

Chemicals and cement are components of the carbon recycling industry, as well as the materials industry, which also includes metals and paper. These materials (component materials), including steel, are incorporated into all kinds of products that support people's lives, from spacecraft to automobiles, bullet trains, PCs, smartphones, homes, and daily necessities. Even in the carbon-neutral society of 2050, the role of these materials will remain unchanged, and they will continue to be used in all products that support daily lives.

In addition, the industrial structure of manufacturing itself is about to shift from an era in which added value is sought by manufacturing a single product to an era in which solutions to social issues, such as low-carbonization, are proposed and managed for the entire process of other products and services. Against this backdrop, the materials industry is providing a variety of component materials while utilizing chemical reactions in energy-intensive environments such as those characterized by high temperatures and high pressures. Therefore, the materials industry is an industry that can be expected to grow further as it becomes a leader in process management with a view to Carbon Neutrality.

The materials industry, which supplies materials for the products that form the foundation of society, is located upstream in the supply chain and plays a fundamental role in all industries, including infrastructure fields such as resources, energy, civil engineering, and construction, as well as manufacturing industries such as automobiles, electronics, and shipbuilding. At the moment, it employs about 1.64 million people[84] and is a major contributor to the local economy and employment.

However, these material industries are faced with the problem of emitting a large amount of CO_2 in the manufacturing process. In fact, the iron and steel, chemical, ceramic and stone, and clay products manufacturing, as well as paper industries emit relatively more CO_2 than any other industrial sector. In each of these industries, the heat sources must be decarbonized, and the processes themselves must be radically changed. One example of a drastic change in the processes themselves is hydrogen reduction ironmaking, which uses hydrogen instead of coal in the iron ore reduction process, and artificial photosynthesis, which produces plastic materials from water and CO_2. In order to decarbonize and reduce CO_2 emissions at the manufacturing stage and achieve zero-carbon manufacturing, we will lead the world in technology development, demonstration, and implementation to switch to innovative manufacturing methods.

All of the materials manufactured using innovative methods are expected to contribute to resource and energy conservation at the downstream stage by making them lighter and tougher, and demand for these materials is expected to increase for a wide range of applications. Specifically, we will promote the development of carbon fiber (for aircraft and wind turbines), fine ceramics and carbon nanotubes (for innovative storage batteries, innovative photovoltaic power generation, next-generation semiconductors, and other components), and cellulose nanofibers (naturally occurring and contributing to the performance improvement of various components) based on strategies for

---

[84] Total number of employees (as of 2018) in the Ministry of Economy, Trade and Industry's Industrial Statistics Survey (2020).

downstream fields, aiming to expand the use of materials with high environmental performance and capture the market. In addition, we will work to improve the business environment, which is a prerequisite for doing business both in Japan and overseas.

Through these efforts, the industrial base of the materials industry will be strengthened, while accelerating efforts toward Carbon Neutrality toward 2050, with the aim of achieving both further growth and development of Japan's materials industry.

1) Innovative metal materials

<Current status and issues>

In the industrial sector, the development and supply of innovative metal materials is necessary to achieve Carbon Neutrality in various industries such as automobiles, ships, and aircraft. For example, in order to reduce the weight of transportation machinery so as to improve energy efficiency, lightweight and durable metal materials are indispensable. On the other hand, with the expansion of electrification, the development of innovative metal materials is required to improve the performance and reduce the cost of electric powertrains. In addition, to realize an advanced information communication society such as post 5G and 6G, it is necessary to improve thermal properties such as thermal conductivity to save energy used for cooling data centers, etc., which are expected to expand in number in the future. However, there is generally a trade-off between thermal conductivity and strength, and so it is necessary to develop new alloys to improve both properties.

In order to achieve Carbon Neutrality in the infrastructure sector, it is necessary to supply parts materials that correspond to the characteristics of each of the new carbon-free energy sources to broaden their use. For example, for infrastructure such as for hydrogen supply, innovative metallic materials that are resistant to hydrogen corrosion are indispensable because hydrogen embrittlement occurs when metallic materials are exposed to a high-pressure hydrogen environment, causing hydrogen atoms to penetrate into the metallic material and cause degradation. In addition, the supply chain for the main components of offshore wind power generation depends on foreign countries, so the development of structural materials that take into account the unique natural conditions of Japan, such as transportation costs and disasters such as typhoons, earthquakes, and tsunamis, is an issue. Moreover, the expansion of interconnection lines between regions is essential for the spread of offshore wind power generation, etc. The development and supply of materials for interconnection lines with high efficiency and stability is necessary because performance and cost are issues.

From the viewpoint of decarbonization and overcoming resource constraints, it is essential to expand resource recycling and reduce CO_2 emissions during manufacturing by extending the service life of metal materials in all applications, including in the industrial and infrastructure fields. For example, steel and aluminum have excellent recyclability, but the problem is that recycled materials have limited applications. Steel and aluminum are widely relied on in daily life, such as in bullet trains and train bodies, automobiles, construction materials, and beverage cans, because of their high strength and high corrosion resistance. Further development of recycling technology, weight reduction, and improvement of corrosion resistance are expected to have various effects, such as improving the fuel efficiency of trains and automobiles and extending the service life of construction materials. Thus, it is essential to work on metal materials throughout their life cycle.

<Future efforts>

We will develop and supply innovative metal materials to decarbonize end products in the industrial sector, aiming to reduce the fuel consumption of transportation machinery, electrification, and the advancement of an information and communication society. For example, by developing innovative steel plates (ultra-high-tensile steel) that exceed the high-tensile steel plates (high-tensile steel) currently used by the automotive sector, and adhesion and joining technologies that are indispensable for combining multiple materials (multi-materials), we will realize further weight reduction in transportation machinery while maintaining the cost competitiveness that is a characteristic of metal materials. The use of such innovative metal materials to reduce weight and other factors is essential for increasing the speed of transportation machinery, and this has the potential to significantly reduce the cost of transportation and travel time. Therefore, in promoting R&D, we will also pay attention to the way in which components used in high-speed transportation machinery will be implemented in society in the future.

In addition, we will accelerate the development of completely new high-performance materials that can be used in new alloys essential for electrification and aircraft engines with high requirements for heat resistance and other properties. Through the realization of completely new high-performance materials, the weight of next-generation aircraft will be reduced and the fuel consumption of aircraft engines will be improved through higher efficiency. This is expected to reduce CO_2 emissions by 928,000 tons/year in 2040.

Additionally, we will develop new copper alloys and functional alloys that efficiently manage heat, taking advantage of Japan's strengths in both improving thermal conductivity, which is a trade-off, and making products smaller and lighter by increasing strength. The aim is to achieve early realization of the post-5G and 6G societies by promoting power saving in data centers and other facilities.

In the infrastructure field, we will realize high durability and cost reduction of renewable energy-related facilities, etc. through the development and supply of parts materials that correspond to the characteristics of new carbon-free energy. Specifically, we will contribute to the early establishment of hydrogen supply infrastructure by developing innovative metal materials that are resistant to corrosion and less expensive, which are indispensable for expanding the use of new energy sources such as hydrogen and ammonia. The development of high-strength structural materials, cables and other materials for offshore wind power generation that are suitable for Japan's unique natural conditions will help build a domestic supply chain for the offshore wind power industry, which currently relies on overseas sources, and will also help reduce installation and maintenance costs. In order to capture these new markets, we will not merely supply materials, as we have done in the past, but we will build a business model that allows us to propose solutions as a single package by working on everything from manufacturing to installation and maintenance, with the aim of improving our international competitiveness.

2) Innovative smelting, rolling, and melting methods

<Current status and issues>

Metal materials are basic materials essential to daily life and industry, and the metal industry is playing an increasingly important role in the realization of a carbon-neutral society from the aspect of supplying innovative metal materials. However, while the supply of metal materials plays a major role in the realization of a carbon-neutral society, a large amount of CO_2 is emitted in the manufacturing stage of metal materials, and so decarbonization in the smelting and rolling processes is an urgent issue.

For example, in the reduction of iron ore in the smelting process, carbon such as charcoal and coal has long been used to remove oxygen from iron ore, starting with the ancient Japanese "Tatara" iron manufacturing method. However, CO_2 is inevitably generated as a result of the chemical reaction. If the reduction material can be substituted from coal to hydrogen, a significant reduction in CO_2 emissions can be expected. However, while the current reduction with coal (coke) is an exothermic reaction, the reduction reaction with hydrogen is an endothermic reaction that requires heat, and the furnace cools down as the reduction reaction occurs, so it is necessary to compensate for the heat required for continuous reduction. The technical challenges, however, are extremely high, such as how to create a gap in the furnace necessary for the ventilation of the reaction gas due to the reduction of coal, and on top of this the technology for hydrogen reduction ironmaking has not been established worldwide. In addition, it is essential to procure a large amount of hydrogen (about 7 million tons), which is expected to be a decarbonized fuel, at a low cost (about 8 yen/Nm^3) to realize hydrogen reduction ironmaking.

Additionally, by expanding the electric furnace method, CO_2 emissions in the manufacturing process can be significantly reduced compared to the blast furnace method, which emits CO_2 in the reduction process. However, the technology to remove impurities contained in raw materials has not been established in relation to the electric furnace method, and there are various problems such as sorting and pretreatment of raw materials containing various impurities, making it difficult to supply high-grade steel used for transportation machinery, etc. by the electric furnace method alone.

In the rolling and melting process, a huge amount of energy is required for electrolysis and heating, and the burden of energy costs such as electricity charges is a major issue. For example, aluminum smelting requires 13,000 to 14,000 kWh of electricity per ton, and Japan used to have smelting plants, but the oil crisis led to a sharp rise in electricity prices, which in turn led to a decline in international competitiveness as cheap imports flowed into the country. In order to reduce the burden of these energy costs and realize CO_2 emission reductions while strengthening international competitiveness, it is necessary to develop an innovative heating process to reduce the enormous power consumption required for electrolysis and realize significant energy savings.

In addition to this, in order to achieve a virtuous cycle of decarbonization and growth in Japan's metals industry, it is necessary to secure appropriate profit margins for Japanese companies and to ensure that they have the investment capacity for green growth in addition to investment in the refurbishment of aging facilities. It is also necessary to improve the business environment and international cooperation, including the formation of rules that will encourage the acquisition of the global green metal market by appropriately evaluating the excellent decarbonization technologies of Japan's metal industry.

<Future efforts>

As for the steel industry, we aim to capture the market for[85] green steel (total of hydrogen-reduced steelmaking, blast furnace + CCUS/carbon recycling, etc.), which is expected to reach a maximum of about 500 million tons/year (about 40 trillion yen/year) by 2050, by developing and supplying world-leading "zero-carbon steel" technology through the electric furnace method using carbon-free electricity and the blast furnace method using carbon-free hydrogen.

As an effort to achieve this goal, specifically, in the reduction and melting process of the steel industry, we will develop technology that can reduce CO_2 emissions generated in the steelmaking process by effectively utilizing the current blast furnaces with high productivity and energy efficiency, reducing iron ore using hydrogen, and separating and recovering CO_2 contained in blast furnace exhaust gas, converting it into a reducing agent, and utilizing it. Additionally, with a view to realizing "zero-carbon steel" by 2050, we will establish basic technologies for the realization of the "hydrogen direct reduction method," which can reduce iron ore using only hydrogen (e.g., (1) furnace heat compensation technology necessary for the reduction of iron ore, (2) technology to remove impurities contained in raw materials, and (3) technology to upgrade electric furnaces essential for the dissolution of reduced iron). Furthermore, by overcoming the technological constraints associated with the larger size of electric furnaces, which can reduce CO_2 emissions during production compared to the blast furnace method, CO_2 emissions reduction will be achieved while reducing production costs and increasing competitiveness.

In the melting and rolling processes, we will develop technologies to reduce CO_2 emissions from the reheating process during rolling, such as power-saving electrolysis, which requires enormous amounts of electricity, and the electrification of heating using fossil fuels. In general, electrification reduces energy efficiency more than fossil fuels, but energy conservation through improved heat transfer efficiency and other measures will reduce costs during production.

In addition to working to solve the problem of excess production capacity under international cooperation and coordination, we will secure appropriate profits for Japanese companies and secure investment capacity for green growth by promoting measures to increase domestic demand and improve corporate strength. Furthermore, in order to promote the acquisition of the global green metal market, we will foster efforts to formulate and disseminate international standards, etc., to formulate rules for the appropriate evaluation of excellent energy-saving and CO_2-reducing technologies in the manufacturing processes of Japan's metal industry, thereby securing markets mainly in emerging countries and reducing CO_2 emissions worldwide.

3) Effective use of resources

<Current status and issues>

While mineral resources are dependent on overseas sources, the stable supply of metal materials

---

[85] Estimated based on IEA "Energy Technology Perspectives 2020" Sustainable Development Scenario (SDS), etc. (Average steel price: 80,000 yen/ton)

for transportation machinery and infrastructure that contribute to further expansion of resource recycling and Carbon Neutrality require advanced recycling and alternative as well as resource-saving methods that utilize scrap generated in Japan.

For the purpose of extending the service life of structures, steel materials are also used in embankments to prevent river flooding and tsunami countermeasures in ports and harbors for the purpose of strengthening national land. In order to reduce environmental load while ensuring the safety and security of people's lives and to use resources effectively for a long period of time, high-strength steel products with even higher strength and durability are needed.

In addition to this, it is also necessary to form social rules and disseminate evaluation methods that will promote the spread of green metals through international standardization of environmental impact assessment throughout the life cycle, etc., in order to expand the use of Japanese metal materials with excellent environmental performance and, in turn, to reduce CO_2 emissions throughout the life cycle of products utilizing metal materials.

<Future efforts>

Both decarbonization and the reduction of resource constraints will be achieved through the expansion of resource recycling and the reduction of CO_2 emissions during manufacturing by extending service life. For example, as a lightweight material, demand for aluminum is expected to increase for use in automobiles and other applications, and the global market is expected to grow by about 50% to about 140 million tons by 2050. In order to capture this market, we will develop technology to upgrade aluminum scrap into materials that can be used for automobile bodies, etc., thereby contributing to the realization of a carbon-neutral society not only in Japan, but also worldwide. This will enable us to expand the resource recycling rate of aluminum oriented materials from the current 10% to 50% by 2050, meet the growing demand for aluminum against the backdrop of the need to reduce weight, and promote the use of recycled materials, thereby contributing not only to the decarbonization of Japan, but also to the decarbonization of the world. As for steel materials, the supply of high-grade materials such as steel plates for automobiles is limited to manufacturing methods that produce steel from iron ore, but by developing technology to remove impurities, the supply of materials from manufacturing methods that use steel scrap as a raw material will be realized, and the use of recycled materials will be promoted.

In addition, we aim to overcome resource constraints by developing and upgrading technologies to steadily extract, recover, reuse, and recycle rare metals and other metals (rare metals, rare earths, etc.) contained in trace amounts in ores, metal scrap, and the ocean, as well as technologies to reduce the use of rare metals and substitute them with raw materials that are less scarce.

In order to extend the service life of structures, we will develop high-strength steel materials with even higher strength and durability to protect the nation from natural disasters and reduce damage, as well as realize buildings that are not only resistant to earthquakes and other disasters, but also have excellent designs, such as the Skytree and the new National Stadium. These well-designed buildings are valuable as tourism resources and will have a positive impact on regional revitalization, such as by increasing inbound tourism.

Furthermore, in order for the excellent energy-saving and CO_2-reducing effects of Japan's metal products to be properly evaluated, and to achieve a decarbonized society by capturing the global green metal market and contributing to CO_2 reduction in developing countries with low marginal abatement costs, efforts will be made to develop and disseminate international standards for a mechanism to evaluate the environmental impact of products throughout their life cycles.

4) Decarbonization of heat sources

<Current status and issues>

Although the paper industry and some other industries such as glass and ceramics do not emit CO_2 in their manufacturing processes like chemicals and steel, they all require drying and firing at high temperatures, and currently use low-cost fossil fuels. However, there has been no production process using non-fossil fuels in the past, therefore making it a challenge to convert facilities after demonstrating the feasibility of such a process.

<Future efforts>

The goal is to decarbonize by converting to heat sources derived from non-fossil fuels such as hydrogen and ammonia, which do not produce CO_2 when burned. In converting to non-fossil fuels, we will work to convert our manufacturing facilities to accommodate the change in fuel on the premise that non-fossil fuels will be available with a stable supply and at low cost. Specifically, we will develop technologies for large boilers, cogeneration systems, industrial furnaces such as naphtha cracking furnaces, cement kilns, glass melting furnaces, ceramics firing furnaces, and paper pulp drying processes that match the combustion characteristics of hydrogen and other materials.

Through these efforts, we will maintain the competitiveness of the paper industry and other industries that manufacture essential daily commodities, and support the affluent lives of the people.

5) Decarbonization of petrochemical complexes

<Current status and issues>

The petrochemical complexes located in the waterfront areas of Japan support the Japanese economy and people's lives as a supply base for materials and energy, with a concentration of key industries such as petrochemicals, petroleum refining, steel, electric power, and gas. The petrochemical plants and refineries that make up these petrochemical complexes emit a large amount of CO_2 in the processes of their operations. We have been working on energy-saving measures such as the introduction of high-efficiency heat exchangers, but further efforts are required, such as the introduction of decarbonized fuels and the use of decarbonization technologies in manufacturing processes.

<Future efforts>

In order to further decarbonize petrochemical complexes, including the introduction of decarbonized fuels into production processes, the technology development of naphtha cracking furnaces that match the characteristics of fuels such as hydrogen and ammonia will be carried out in petrochemical plants. At refineries, we will promote demonstrations and capital investment to decarbonize, including the use of CO_2-free hydrogen in the refining process and the use of decarbonized fuels for boilers in toppers and cracking equipment. In addition, efforts will be made to decarbonize each petrochemical complex as a whole by promoting cooperation among companies in each complex, such as through heat sharing. Furthermore, by encouraging efforts to make petrochemical complexes centers for the supply of new fuels, such as hydrogen and synthetic fuels, the government aims to ensure that petrochemical complexes continue to play a central role in relation to the energy supply.

(12) Housing and building industry and next-generation power management industry

i) Housing and Buildings

The houses/building field is a key field for Carbon Neutrality in the home/business sector, and once built, becomes a long-term stock; and is a field that should be addressed immediately. The global trend in Europe, United States and other countries, is to aim for Carbon Neutrality through bold investment in heat insulation renovations in houses and buildings and introducing solar-power generation, which creates a market towards employment and economic recovery affected by the corona virus, as well as improving the quality of life by supplying high-quality housings.

Japan has been working on the improvement of energy efficiency performance, the promotion of life cycle carbon minus (LCCM), the conversion to net zero energy houses and buildings (ZEH/ZEB), and the extension of life of houses and buildings, but the progress is halfway through. In order to achieve Carbon Neutrality by 2050, we will promote the spread of LCCM homes and buildings that emit negative CO_2 throughout their entire lifecycle (from construction to demolition and reuse), as well as the spread of ZEH and ZEB, the promotion of energy-saving renovations, the introduction of high-performance insulation materials, high-efficiency equipment, and renewable energy, and the promotion of the use of wood in buildings to the greatest extent possible. With regard to renewable energy, the practical application of thin, lightweight, next-generation solar cells, in which Japan has an advantage, will make it possible to mount solar panels on the roofs of existing houses and buildings, including those with small load-bearing capacity, and on the walls and windows of houses and buildings, which are technically difficult to install with existing solar cells. In addition, it is necessary to use energy management systems (HEMS and BEMS) for homes and buildings to promote energy management that contributes to the adjustment of electricity supply and demand in accordance with the amount of electricity generated by solar power generation systems, etc.

1) Energy management through utilization of AI･IoT and EV etc.

<Current status and issues>

In the field of energy management, the government has been conducting domestic demonstration, joint research and business development with overseas, etc. for market acquisition. On the other hand, lack of evaluation, awareness, and demand are issues upon the efforts for introducing energy management. In particular, incentive design that encourages consumers to change their behavior in response to the power supply and demand situation is an issue for expanding the market such as energy management systems that leads to optimization of energy use on the consumer side. Specifically, control equipment manufacturers, etc. that specialize in energy management have developed systems that can automatically perform optimal control without impairing users' comfortability in response to the demand side equipment such as hot water supply, air conditioning, and lighting, and have put them into practical use. However the incentives to be introduced on the demand side are scarce, and the introduction is not progressing. In addition, usage of power storage system such as EVs plays an important role as energy management. EVs have a large storage capacity, and it has a large potential that will lead to the expansion of the introduction of renewable energy by building a mechanism that enables stored surplus electricity generated by solar power generation during the day to be used at other times. Currently, the government is addressing issues to expand peak shift EV charging through demonstration projects, etc., the future challenges include the examination of incentives that encourage the actions of consumers that leads to the introduction and utilization of EVs.

The expansion of the introduction of renewable energy, etc. entails the concern for the lack of dispatchable power. Promoting efforts to reduce the cost of procuring dispatchable power as well as expanding the resources that are utilized through the establishment of a supply/demand regulation market, and considering measures on the demand side in the event of system instability is necessary. Furthermore, the needs for grid stabilization responding to mass introduction of renewable energy and demand-side energy management due to the mass introduction of reusable energy are increasing overseas as well, and demonstration projects have been carried out in developed countries such as Europe and the United States. It is expected that the needs for introducing these will increase in emerging countries such as ASEAN, and there is a potential for overseas expansion.

<Future efforts>

While energy management within consumers is becoming more widespread, in addition to this, it is expected that some aggregation business that bundles a large number of decentralized energy resources will be activated and the introduction of resources and control systems necessary for it will be expanded with the opening of the supply/demand regulation market, etc., in the future.

In order to achieve this, the government will provide support for the demonstration and introduction of optimal control using big data and AI, as well as consider institutional measures such as the development of standards and criteria and the review of systems (Energy Conservation Law, imbalance fee system, etc.) to strengthen the introduction of energy management, including optimal control of EVs, storage batteries, solar power generation, as well as electric equipment, and the development of related ministerial ordinances under the Electricity Business Act and support for demonstrations in order to promote new businesses such as aggregators and power distribution businesses that use renewable energy, EVs, storage batteries, etc.

As regards of EV utilization, for the time being, while promoting demonstration projects for peak shift of EV charging, the government will consider incentives for EV utilization according to the power supply and demand situation, also, its issues and directions will be organized. Furthermore, as a control that contributes to the adjustment of supply and demand of the equipment itself, automatic control technology for air conditioning according to the load fluctuation of the system has been developed, and incentives will be strengthened to expand the introduction to the market. In addition to these efforts, we will establish methods for visualizing energy use through the use of AI and IoT and for evaluating the effects of energy conservation through optimal control of facilities, with the aim of realizing a society in which people can experience economic benefits and improved living standards.

Furthermore, based on the results of these domestic efforts, and with the aim of acquiring markets in Europe, the United States, and emerging countries, we will support the establishment of systems in partner countries and promote the overseas deployment of Japanese technologies through bilateral dialogue, human resource development projects, and overseas demonstrations (international demonstrations by the New Energy and Industrial Technology Development Organization (NEDO)).

2) LCCM houses and buildings, ZEH/ZEB, and improvements of energy efficiency performance of houses

<Current status and issues>

To promote the spread of energy-efficient houses and buildings including LCCM and ZEH/ZEB, the government has so far introduced both subsidy and regulatory methods (The Building Energy Efficiency Act), and tried to expand the number of providers through the registration system of ZEH builder, etc. About 70% of newly built detached houses have achieved the energy efficiency standards based on the Building Energy Efficiency Act (FY2018). The ratio of ZEH to newly custom-built detached houses reaches about 50% for major ZEH builders, but it is only 20% (13% of all) (FY2019) for all ZEH builders, and to reach the government target of "More than half of custom-built detached houses newly built by house builders become ZEH by 2020." seems to be difficult.

The system, ability, and improving proficiency related to the handling of energy-efficient houses at small and medium-sized builders are issues on the supply side. At the same time, on the demand side, issues include the cost burden for improving energy-efficiency performance of existing houses and buildings, low consumer awareness, low understandings of its merit, and restrictions on energy generation potential in large-scale condominiums, etc. The composition is the same for buildings, and, while Japanese government has been cooperating with stakeholders to develop overseas markets especially for ZEB, further efforts is required. In addition, there is a need to enhance the standards for energy consumption performance of houses and buildings based on the Building Energy Efficiency Act, and reconsider the housing performance display system in which the highest grade of building envelope performance is equivalent to the energy conservation standards.

<Future efforts>

For the time being, we will provide policy support for homes and buildings with high energy-saving performance and energy-saving retrofits to create an environment for self-sustaining dissemination, while considering the introduction of further regulatory measures to improve the rate of compliance with energy-saving standards for housing, based on the status of dissemination.

Specifically, the government will improve energy-saving performance by strengthening regulatory measures such as requiring compliance with energy-saving standards, including for housing; expanding the spread of ZEH and ZEB; enhancing and strengthening existing stock measures, including measures to promote investment in real estate projects that contribute to expanding energy-saving renovation and improving energy-saving performance; and revising the certification standards for excellent long-term housing and a housing performance indication system. In addition, through the promotion of the introduction of photovoltaic power generation and storage batteries, we will achieve the goal of zero energy for homes and buildings. At that time, with the aim of maximizing the potential for energy creation, the government will develop a system to encourage the introduction of renewable energy sources such as photovoltaic power generation, with an eye to the development of next-generation solar cells that can be installed on (1) existing houses and buildings with limited roof load-bearing capacity and (2) walls and windows of houses and buildings, which are difficult on which to install with existing solar cells due to technical limitations, and will also take support measures to expand energy creation in houses and buildings by introducing next-generation solar cells on the walls of buildings. On that occasion, it will also promote advertise and PR its advantages to raise consumer awareness. In addition, from the perspective of CO_2 reduction throughout the entire life cycle, we will promote the spread of LCCM homes and buildings that contribute to CO_2 emission reduction, as well as the extension of the service life of homes and buildings. Through these efforts, we aim to achieve zero or a substantial reduction in utility costs borne by consumers, building owners, and tenants,[86] as well as to reduce health risks by preventing heat shock through improvements in the thermal insulation performance of homes.

Moreover, as for ZEB, the government will, through the activities for formulation of ISO standard etc., further work on demonstration project and horizontal expansion to foreign countries including ASEAN.

Through the above measures, in addition to cultivating demand for forefront houses and buildings such as LCCM housing and buildings and ZEH/ZEB in the domestic market, it also aims to improve quality of life/living. Additionally, for some technologies and products cultivated in the domestic market, government aims to expand them overseas.

3) Wooden buildings that contribute to carbon storage

<Current status and issues>

Wood is reproducible and carbon-storable, will reduce fossil fuel consumption and contribute to reduction of CO_2 emissions therefore it is necessary to promote the use of wood in buildings.

About 80% of low-rise houses are wooden structure, while the ratio of wooden buildings in non-residential, middle/high-rise buildings is still less than 10%. In order to promote the use of wood in non-residential and mid- to high-rise buildings, the following issues need to be addressed: the rationalization of building standards, the spread of new construction methods using CLT and other new materials, the spread of wood technology in new fields such as mid- to high-rise housing, and the training of designers who will be responsible for these projects.

<Future efforts>

The rationalization of building standards, etc. will be studied during 2021, and necessary institutional measures will be taken from 2022. In addition, support will continue to be provided for the development of practical wooden buildings with various uses where leading design and construction technologies are introduced. In addition, it will continue to support efforts to develop information portal sites related to wooden buildings design, such as standard plans and textbooks

---

[86] Based on a trial calculation (based on the results of the FY 2014 Net Zero Energy House Support Project) indicating that it will be possible to reduce utility costs (electricity, gas, and kerosene) from approximately 200,000 yen/year for conventional houses to approximately 40,000 yen/year for detached ZEH, the aim is to achieve zero or a substantial reduction in utility costs for detached houses in 2050 by incorporating solar power generation, peak shifting using storage batteries and EVs, HEMS, etc. It should be noted that zero may not be achieved in cases where there is insufficient solar power capacity, such as in areas with heavy snowfall or in relation to skyscrapers.

for non-residential, middle/high-rise wooden buildings, and efforts to train its architects. In addition, it will promote public procurement in Japan to disseminate and promote the use of timber. These will create a rich architectural space characterized by wood in cities.

4) High-performance building materials/equipment

<Current status and issues>

So far, the government has been improving the performance of equipment and building materials by the Top Runner Program based on the Act on the Rationalization etc. of Energy use, and supporting the demonstration and introduction by subsidies such as the demonstration of next-generation energy saving building materials. On the other hand, introduction of equipment and building materials by consumers has not progressed due to the fact that the performance improvement of equipment and building materials has partially leveled off and the health benefits of performing energy-efficiency remodeling have not been fully recognized. These may be included in the challenges. In particular, remodeling involves a large amount of expenditure, and there are also cost issues.

<Future efforts>

In order to improve the energy-efficiency performance of houses and buildings, including existing ones, it is necessary to expand the spread of building materials such as heat insulating sashes and equipment such as high-efficiency air conditioners. Therefore, for the time being promoting the introduction of forefront equipment and building materials to the market through demonstration projects, etc., and will work together with the public and private sectors to reduce prices. In combination with this effort, in consideration of the expanded introduction of high-performance equipment/construction materials into the markets through these projects, it aims to significantly strengthen the top runner equipment/building material standards and promote so that the supply of high-performance equipment/building materials to the market will become normal.

Furthermore, it aims to establish a display system and performance evaluation system for equipment and building materials that are easy for consumers to understand, including the impact on costs such as electricity charges and gas charges.

ii） Next-generation power management

With the changes in the structure of electricity supply represented by the massive introduction of renewable energy, there are concerns that the spatial gap (distance between large demand areas and suitable power generation areas) and temporal gap (gap between demand and power generation) between electricity demand and supply will expand, and that grid congestion and power quality problems will become more serious. In order to realize a carbon-neutral society while curbing the burden on the public, it is important to maintain and review the necessary regulations in order to effectively respond to these issues, and at the same time, to encourage the development of a "next-generation electricity management industry" that utilizes ever-advancing digital technology and uses more advanced methods for forecasting, operating, and controlling electricity management for business development, through institutional responses including market development and various support measures.

The next-generation power management industry includes businesses that utilize and provide value to distributed energy resources (DERs), such as renewable energy, fuel cells, cogeneration, storage batteries, and demand-side resources, as well as next-generation grid businesses that upgrade the operation of power transmission and distribution systems and form facilities based on the premise of increasing and utilizing DERs. It also includes microgrid businesses as a form of fusion of the two in specific regions, and, in a broader sense, businesses that provide platforms such as systems, equipment, and databases that make these businesses possible. The following is a summary of the current status, issues, and future initiatives for each.

The development of these businesses and industries is expected to bring a variety of benefits to consumers and other electricity consumers. For example, the electricity generated by roof-mounted solar power equipment can be used without waste. Also, the use of electrical equipment in the home can be adjusted to the necessary extent based on electricity supply, demand, and price trends, and the recharging and discharging of EV storage batteries can be managed optimally, leading to savings in electricity bills compared to the situation without such optimal power management. At the same time, advanced use of the increasing number of DERs and the sophistication of various forecasting, operation, and control technologies are expected to help improve resilience by reducing the probability of power outages due to disasters, etc., and the extent of their impact, as well as speeding up the restoration process. In the future, quantitative verification of these effects will also be conducted.[87]

The direction and major initiatives planned for the time being regarding the expansion of the introduction of DERs, the support of related businesses, and the construction of next-generation grids are also indicated in the "Basic Energy Plan." In the future, specific discussions and examinations will continue in the "Advisory Committee on Natural Resources and Energy" and in practical examination forums in which related businesses, etc. participate, and initiatives will be promoted through the cooperation of the public and private sectors.

---

[87] In addition, the International Energy Agency's (IEA) "Digitalization & Energy (2017)" estimates that demand response, referring to managing electricity on the demand side, has the potential to generate 185 GW of regulating capacity, which could save 270 billion dollars in investment in electricity infrastructure.

1) Distributed energy-related industries

<Current status and issues>

DERs subject to management can be broadly categorized as follows:

Power generation resources such as renewable energy, fuel cells, and cogeneration

Storage batteries, EVs, and other energy storage resources

Demand-side resources such as power-hungry factories, water electrolysis equipment (hydrogen production), and energy equipment

As for renewable energy sources, the pace of expansion of solar power generation, which saw the greatest expansion in installation volume under the FIT system, has slowed down as power generation costs have stopped falling and location constraints have become apparent. In addition, the FIP system will be introduced in April 2022, although the process of transitioning to the integration of renewable energy into the electricity market is still currently in progress (i.e., the trading of renewable energy in the same business environment and market price as other power sources). With regard to storage batteries, the market for household storage batteries is one of the largest in the world, and the introduction of storage batteries is increasing at present in response to the emergence of solar power generation for household use after the end of the feed-in tariff period and growing consumer interest in strengthening resilience, but costs remain high compared to overseas markets. Efforts are being made to reuse in-vehicle storage batteries as stationary storage batteries through technological verification and international standardization, and also through technological verification for the use of storage batteries in EVs, but the full-scale use of these batteries is only possible with the further expansion of the introduction of EVs. Demand-side resources have already been used for flexibility by providing electricity transmission and distribution companies with planned demand curtailment by large-scale factories, etc., and were also used when electricity supply and demand tightened in January 2021. The balancing market will be developed in the future, however, the amount of power used in each region varies at present, and is still not fully utilized in terms of quantity compared to Europe and other regions

Aggregators that bundle, operate, and control such DERs, and provide supply and coordination power while utilizing the market as necessary, were positioned as "specified wholesale suppliers" under the Electricity Business Act in June 2020, but the future challenges will be the development of an appropriate market environment and the establishment of forecasting, operation, and control technologies.

<Future efforts>

First, continue to develop regulations and markets to optimize the use of DERs. First of all, with regard to the FIP system, which aims to integrate renewable energy into the electricity market, we will steadily make preparations for the start of the system in FY2022, and after the start of the system, we will set and review the scope of the system in a timely and appropriate manner, taking into account the operation status of the system and the market environment. Under the FIP system, while renewable energy businesses are required to adjust imbalances and conduct sophisticated transactions based on market prices, the aggregation business plays a significant role in bundling and balancing the electricity generated from dispersed renewable energy sources and selling the electricity in accordance with market price trends using storage batteries, etc. In order to promote the business, advanced renewable energy forecasting technology as well as technology to avoid imbalances using storage batteries will be demonstrated. With regard to various markets (spot market, pre-time-basis market, balancing market, forward market, capacity market, renewable energy value trading market, etc.) where DERs can trade their value as supply and adjustment power, as well as their environmental value, we will ensure fair treatment with the large-scale power sources of DERs on the premise that they meet the objective requirements for each market when developing and examining their market participation conditions and measures to stimulate trading, while referring to overseas precedents. At the same time, in order to utilize DERs as flexibility in the balancing market, digital technology will be used to remotely manage and control a variety of resources and to demonstrate the technology for delivering a certain amount of output within a specified time. Furthermore, in order to optimize the use of DERs and to further effectively alleviate grid congestion in the future, it is important to utilize price signals at the local (distribution system) level, and so we will consider the establishment of market transactions while conducting demonstrations, etc.

Second, we will also encourage[88] the use of each DER in business. With regard to storage batteries, in order to reduce the cost of and expand the use of stationary storage batteries, the following measures will be implemented: the introduction and promotion of investment to achieve the price target of 70,000 yen/kWh for residential use in FY2030 (for storage systems including installation costs); R&D and technological verification for technologies to provide flexibility, etc.; the development of international standards for the conversion of vehicle batteries to stationary use; clarification of the position of storage batteries that are directly connected to grids for recharging and discharging under the Electricity Business Act; and the improvement of the operation of JET certification, which will contribute to the facilitation of consultations necessary for grid connection. In addition, we will conduct technological demonstrations of automatic EV recharging and vehicle battery reuse in line with price fluctuations through the use of dynamic pricing linked to wholesale electricity market prices, etc., and promote new businesses that utilize DERs. With regard to demand-side resources, in order to further utilize industrial demand, which is expected to be the main focus for the foreseeable future, dissemination and awareness-raising will be carried out in conjunction with the market development described above. In addition, with the assumption that demand will be utilized for residential and business use in the future, the next-generation smart meters that will be introduced in the mid-2020s will increase the types of data to be collected and the frequency of measurement, and expand the scope of provision beyond general transmission and distribution companies as well as retail electricity companies, thereby promoting demand response and the sophistication of energy management among consumers. Furthermore, based on the specified measurement system, we will promote the use of the measurement functions of EV chargers and power conditioners for solar power generation for trading, expand the scope of trading to smaller resources, and consider the development of verification tests and standards as necessary

---

[88] See "4 (1) Offshore wind, solar, and geothermal industries (Next Generation Renewable Energy)" for initiatives related to solar power generation. See "4 (3) Next-generation thermal energy industry" for initiatives related to fuel cells and cogeneration.

to enable integrated and optimal management and control through the use of big data, AI and IoT. Additionally, since the production of hydrogen by water electrolysis equipment could be used to adjust electricity demand in the future, measures to promote this will also be considered. It has also been pointed out that in order to facilitate the use of various DERs, including EVs, which are expected to be used as "mobile storage batteries" in the future, it is important to develop an environment that allows them to be interconnected quickly and inexpensively, as well as to build a platform that can grasp, collect, manage, and utilize various data, serve as a basis for resource control, and be shared among grid users and operators. Therefore, we will deepen our study on how this should be done.

Through the above-mentioned initiatives, we will boost the growth of the distributed energy industry, with a focus on the aggregation business, which is expected to have an annual market size of approximately 300 billion yen[89] or more by around 2030.

2) Next-generation grid-related industries

<Current status and issues>

As a result of the electricity system reform, a nationwide wide-area power network has been developed and operated, centered on the Organization for Cross-regional Coordination of Transmission Operators, and interregional coordination and the reinforcement of cross-regional interconnection lines have been promoted in times of tight supply and demand. In addition, with the aim of strengthening resilience and making renewable energy the major power source, the Bill for the Act of Partial Revision of the Electricity Business Act and Other Acts, which was enacted in 2020, is leading to the master plan for systematic formation of grid facilities and detailed studies for a revenue cap system (to be introduced in FY2023) to secure investment incentives for power transmission and distribution companies. In January 2021, the main grid began accepting non-firm connections nationwide, which are conditional on the possibility of output control during grid congestion in response to increases in the amount of renewable energy installed.

However, in order to properly respond to the maximum introduction of renewable energy and the acceleration of the pace with a view to Carbon Neutrality, there are many issues that need to be addressed in terms of grid operation and facility formation.

In the distribution system, it will become more difficult to maintain and manage power quality, such as voltage, as a result of the introduction of a large number of variable renewable energy sources, even if they are small in scale. Therefore, it is necessary to take measures including the sophistication of various data monitoring, collection, and management methods. Since a large amount of renewable energy is expected to be introduced into the power grids in an unevenly distributed manner, it will be necessary to systematically develop transmission lines to accommodate the introduction of offshore wind power, etc., while making the most effective use of existing facilities to deal with grid congestion. In addition, an increase in the introduction of variable

---

[89] If we multiply 9 GW of DR and 30 billion kWh of renewable energy, which are estimated as the potential of representative DERs in "Aggregator Market Potential Estimates" (April 22, 2021, Basic Policy Subcommittee of the Advisory Committee for Natural Resources and Energy), by the assumed price of approximately 4,500 yen/kW (simple average of the average winning bid price for DR in the FY 2019-21 public offering of regulating power sources I') and 9.6 yen/kWh (simple average of the spot market price for FY 2018-20), we obtain a total of approximately 330 billion yen.

renewable energy sources, combined with a decrease in thermal power generation, will lead to an increase in the proportion of asynchronous power sources, so it will be necessary to ensure inertia and other factors to stabilize the grids.

<Future efforts>

As for the distribution system, we will promote efforts to upgrade the operation of the distribution system, based on the premise of the mass introduction of DERs, such as variable renewable energy, and the use of digital technology. Specifically, from the perspective of increasing the number of DERs that can be connected to the power distribution system and reducing CO_2 emissions, the introduction of pole-mounted switchgears with sensors that collect data necessary for maintaining the quality of electricity, such as voltage, and the use of next-generation smart meters will be promoted by advancing the sophistication of data analysis technology, such as technology for predicting expected tidal currents and reducing power loss during transmission. In addition, it is an important issue to develop the technology to collect, analyze, and integrate the data necessary for monitoring the status of grids in real time from variable renewable energy sources, storage batteries, and each power facility, and to enable optimal management and control according to fluctuations, while paying attention to security aspects, although this is an initiative that should be studied in an integrated manner in relation to the upper-level grid.

With regard to the power transmission system, we will promote the development of a system that utilizes market functions, the upgrading of grid operations using digital technology, and the formation of necessary facilities. Specifically and first of all, the scope of application of non-firm type connections will be expanded to introduce renewable energy to the maximum extent possible, and the specific method of providing incentives by means of transmission charges, etc. will be studied to induce large-scale demand to the point where it contributes to the improvement of grid congestion. The grid congestion management method should be based on the concept of merit order (priority is given to the order of decreasing marginal cost of power generation). We will solidify the operation policy of the re-dispatch system (grid operators adjust power sources) to be introduced in 2022, and will study the necessary institutional and system aspects so that we can shift to a market-driven system (zone system[90] and nodal system[91]) by the late 2020s or later. Additionally, although this is an initiative that should be considered in tandem with subordinate systems, we will proceed with the development of technologies for next-generation inverters that provide inertia and other functions, as well as their systems, and once we have a clear idea of what needs to be done, we will basically reflect this in grid coding and the opening of markets starting in the 2030s to ensure the necessary and sufficient functions of inertia, etc. In addition, through the demonstration of dynamic rating, which dynamically handles transmission capacity in response to changes in outside temperature, etc., the monitoring and operation technology of transmission and substation facilities will be upgraded.

With regard to the wide-area formation of transmission facilities, based on the master plan to be formulated by the end of 2022, we will steadily develop cross-regional interconnection lines and

---

[90] The system identifies congested transmission lines in advance, prepares for congestion adjustments, and then performs congestion adjustments in the market when congestion occurs.

[91] The system is prepared to perform congestion adjustments for all transmission lines, and when congestion occurs, congestion adjustments are performed based on market bidding information and other factors.

accelerate studies to systematically and efficiently develop a long-distance direct current (DC) transmission system that will enable the transmission of electricity from suitable offshore wind farms in Hokkaido and Tohoku to large demand areas. At the same time, we will promote the development of the technologies necessary to overcome the various difficulties of this system and to realize it more efficiently.

As for the business of providing systems and equipment that support the upgrading of grid operations and the formation of facilities as described above, many countries and regions overseas, including Asian countries, are expected to undergo similar structural changes in the future, and so demand is expected to increase. Therefore, it is important to provide the necessary boost to these countries while taking into account the perspectives of international competitiveness and economic security. For example, with regard to advanced grid operation methods that also utilize digital technology, as well as the systems and equipment that support them, we will encourage overseas deployment based on the fact that "smart grids" were positioned as one of the items for cooperation between Japan and the United States in the Japan-U.S. Summit Agreement of April 2021 and the results of overseas demonstration projects to date. With regard to equipment such as submarine DC cables and AC-DC converters, which are components of long-distance DC transmission systems, we will consider measures to promote domestic capital investment, taking into account the international competitiveness of Japanese companies, the magnitude of the economic effect, and the perspective of economic security.

3) Microgrids

<Current status and issues>

Microgrids, which make effective use of DERs within a region, promote local production and local consumption of energy such as electricity and heat, enable efficient energy use within a region, and can contribute to strengthening resilience by avoiding power outages and mitigating the effects of disasters, as well as to regional revitalization. Microgrids can also be expected to be effective as a topic around which knowledge can be gained for further development by demonstrating new business forms and grid operations described in 1) and 2).

The experience of the budget projects of the Ministry of Economy, Trade and Industry (26 projects to create master plans and 3 projects to construct microgrids were adopted) and other projects that have been conducted so far have revealed issues such as the difficulty of independent grid operation with a high ratio of renewable energy, the difficulty of coordination among consumers, retail electricity providers, grid operators, as well as local governments, and a decline in business feasibility due to high storage costs and grid operation costs.

<Future efforts>

As for microgrids, since the significance of microgrids can be noted as described above, we will work on addressing the challenges in order to promote the introduction of microgrids in regions that are suitable for the local production and local consumption of energy.

Specifically and first of all, the technical knowledge obtained from demonstration projects, such as support for the establishment of microgrids in each region including remote islands, will be shared among the parties concerned in order to establish the basic technologies necessary for adjusting supply and demand within microgrids and to develop best practices. In order to facilitate coordination among related parties, we will clarify the operation of various licenses such as those related to power distribution businesses under the Electricity Business Act by developing guidelines, organize matters to be coordinated with related parties, and share best practices among related parties in relation to the distributed energy platform. Furthermore, in order to improve economic efficiency, we will work on reducing the cost of storage batteries as indicated in 1) above, and in order to encourage the formation of various business models, we will study the effective use of DERs during normal times, the clarification of the value of resilience, the integration of resilience with other public services, and other measures and effects through our experience in various projects in cooperation with local governments.

There is also a movement overseas, mainly in emerging countries, to develop smart cities and industrial parks, and to introduce microgrids, including renewable energy and storage batteries, in island areas. We will support the overseas development of Japanese companies by sharing the technical knowledge and best practices we have developed in Japan with governments, cities, and companies in other countries through human resource development and demonstration projects.

(13) Resource circulation-related industries

Regarding Reduce, Reuse, Recycle, and Renewable, the government is supporting technology development and social implementation through laws and plans. Waste power generation, heat utilization, and biogas utilization have already entered the commercial phase and are becoming more widespread and advanced. In the future, these efforts will be further promoted by advancing technology, improving equipment, lowering costs, etc., based on discussions at the "The Council for National and Local Decarbonization". By 2050, Japan will reduce greenhouse gas emissions as a whole while advancing the transition toward the Circular Economy.

1) Reduce and Renewable

<Current status and issues>

Regarding Reduce, the government is promoting efforts and the Basic Plan based on the Basic Act on Establishing a Recycling Society, and various recycling laws.

Regarding Renewable (biomassization, utilization of recycled materials, etc.), the government is promoting the replacement of plastics derived from fossil resources with renewable biomass plastics, paper, etc. through a demonstration project. In addition, it is promoting the replacement of fossil resource-derived plastics with biomass plastics through the Act on Promotion of Procurement of Eco-Friendly Goods and Services by the State and Other Entities

<Future efforts>

Regarding Reduce, the government will demonstrate a system for sharing necessary information on used products and materials among stakeholders in order to promote efficient resource recycling and CO_2 saving.

In respect of biomassization and utilization of recycled materials, the government will develop and demonstrate technology to promote higher functionality, expansion of application and cost reduction of biomass materials, develop and advance recycling technology, promote equipment maintenance, and demand generation for further expansion of recycling.

In particular, in introducing bioplastics, based on the " Roadmap for Bioplastics introduction" (formulated in January 2021), it is important to develop technologies related to bioplastics that are suitable for introduction in each product area, and the government will promote the development of technologies that contribute to the sustainable use of biomass plastics, such as functional diversity of raw material procurement that also takes into account environmental impact. In addition, in order to achieve the target of introducing approximately 2 million tons of biomass plastic (in 2030), the government will foster a smooth supply by providing examples of advanced initiatives and forecasts of demand, take the initiative in public procurement by the national and local governments based on the Act on Promotion of Procurement of Eco-Friendly Goods and Services by the State and Other Entities, develop international standards to further improve the reliability of methods for assessing marine biodegradation functions, and study new mechanisms for environmentally-friendly design to appeal to consumers and spread awareness.

These efforts are expected to expand the range of choices of environmentally-friendly products in people's lives and reduce CO_2 emissions from waste incineration in each region.

2) Reuse, Recycle, and utilization of exhaust gas

<Current status and issues>

Regarding Reuse and Recycle, the government is promoting efforts and the Basic Plan under the Basic Act on Establishing a Recycling Society, and various recycling laws, and it is promoting the expansion of procurement of recycling products under the Act on Promotion of Procurement of Eco-Friendly Goods and Services by the State and Other Entities. Additionally, the demonstration of the recycling technology, and the introduction support of the equipment for recycling in Japan is in progress.

Regarding the utilization of incineration facility exhaust gas, etc., the CCU plant is already in operation at the waste incineration facility. In addition, a demonstration project to generate methane, ethane, etc. from waste gas generated by incineration and gasification of waste is in progress.

<Future efforts>

Regarding Recycle, in order to further expand recycling, the government will develop and advance high-performance recyclable materials and recycling technology, optimize collecting routes, expand installed capacity, and expand the recycling market. In particular, based on “the Act on Promotion of Resource Circulation for Plastics”, smooth collection and recycling by manufacturers, retailers, municipalities, and waste generators, etc., will be promoted. Similarly, promotion of resource circulation for other materials than plastics will be further considered.

With regard to the utilization of incineration facility exhaust gas, etc., while considering the use of the Green Innovation Fund, efforts will be made to develop innovative technologies, such as combustion control to facilitate the recovery of CO_2 and other substances from waste treatment facilities, and the separation, recovery, and utilization of CO_2 and other substances from low-concentration flue gas containing a variety of impurities, as well as to scale up and reduce costs through demonstration projects, in order to achieve practical application and social implementation.

These efforts are expected to advance sustainable regional development through the creation of a regional recycling symbiosis zone, including industrial development using waste and exhaust gas as regional resources.

3) Waste power generation, heat utilization, biogas conversion, fixation of exhaust gas

<Current status and issues>

In order to avoid the generation of methane due to landfill of organic waste, organic waste is incinerated or bio gasified, and the energy is collected. In addition, trees accumulated in the maintenance and management of rivers and other bodies of water (e.g., felled trees and driftwood) can be used as a renewable energy resource for biomass power generation and other purposes, but the promotion of their effective utilization is an issue.

Regarding waste power generation, Japan has improved the power generation efficiency of waste incineration facilities every year through technology development of boiler materials, etc., and achieved an average of 13.58% in FY2018.

As regards heat utilization, the government is promoting effective utilization by supplying heat generated from waste incineration facilities to nearby utilization facilities through heat pipes.

As regards bio gasification, since the amount of energy collected per amount of waste processed by incineration at small and medium-sized waste treatment facilities is limited, waste energy is collected by bio gasification technology by methane fermentation.

As for the fixation of exhaust gas from incineration facilities, the government is developing technology at the lab level to fix CO_2 separated and recovered from the exhaust gas from waste incinerators.

In addition to the steady decrease in the amount of waste generated per capita and the amount of waste for final disposal due to the promotion of the 3Rs and other factors, the amount of waste generated is expected to decrease further in the future as the population continues to decline, and the capacity of treatment facilities required for waste disposal in Japan as a whole will decrease. On the other hand, there are concerns about the shortage of people to take charge of waste treatment, the increase in the cost of maintenance, management as well as refurbishment of aging social infrastructure, and the inefficiency of waste treatment in various regions. Additionally, in order to promote the development and implementation of the above-mentioned technologies, improve energy recovery efficiency, and reduce costs, it is necessary to develop facilities with a certain level of treatment capacity. For this reason, by notifying prefectures and informing them of the "Guide for Wide-Area Treatment and Consolidation," the government is systematically promoting the development of necessary waste treatment facilities, such as the wide-area treatment of waste and the consolidation of waste treatment facilities, with an eye on the trend of general waste discharge not only in municipalities but also in wide-area regions.

<Future efforts>

As regards waste power generation, the amount of heat generated will decrease due to major changes in the quality of waste in the future (such as an increase in the ratio of kitchen waste due to a decrease in the ratio of plastic waste), and there is a concern that the power generation efficiency will decrease. In addition, in order to promote the use of accumulated trees (cut wood, driftwood, etc.) in the ongoing maintenance and management of rivers, etc. as a renewable energy resource for biomass power generation as a measure to mitigate climate change, the feasibility of solving the problems and improving the efficiency of maintenance and management will be verified based on the issues confirmed in field demonstrations, and the possibility of effective use of general waste treatment facilities will be examined.

The government will proceed with technological development to ensure high-efficiency energy recovery. As for heat utilization, since the location conditions of waste incineration facilities have a large effect on the degree of heat utilization, in addition to improving the operating efficiency of waste incineration facilities, the government will promote improvement of heat storage and transportation technology for supplying heat to distant facilities and cost reduction.

With regard to biogas conversion, we will promote technological demonstration projects with an eye to the large-scale construction of methanization facilities in line with major changes in the quality of waste in the future. In order to expand the use of sewage biomass, we will make intensive efforts until FY2025 to promote the formation of projects among local governments, including the enhancement of the "Sewage Energy promoting Concierge Program."

In addition, by requesting each prefecture to formulate a "Regionalization and Consolidation Plan" by the end of FY2021, we will promote the development of waste treatment facilities with enhanced functions as aspects of regional social infrastructure, such as functioning as regional energy centers by efficiently recovering waste energy, and functioning as disaster prevention bases such as power supply and evacuation centers in times of disaster by promoting the earthquake resistance of facilities and ensuring their resilience so that they do not become inoperable in the event of an earthquake or flood.

These efforts are expected to promote energy conservation and energy creation in relation to local governments, reduce CO_2 emissions, promote industrial use of waste energy, and utilize the facilities as a disaster prevention bases in the event of a disaster through independent and decentralized power and heat supply. The development of facilities that create new value in each region, which will be the core of Circular and Ecological Economy, is expected to advance.

(14) Lifestyle-related industries

In order to promote the spread of technology for decarbonizing life styles, based on discussions at the "The Council for National and Local Decarbonization", etc., the government will work on introduction support, system construction, etc. to promote the total management of housing/transportation (ZEH/ZEB, equipment on the demand side (home appliances, hot water supply, etc.), local renewable energy, EVs/FCVs as moving storage batteries, etc. that are now being put into practical use), behavioral change through ‘nudge’ and sharing, technology development/demonstration that promotes CO_2 reduction credit using digital technology, etc. By means of the above, by 2050, Japan will realize a carbon-neutral, resilient and comfortable life (to an era of earning by energy by switching to a decarbonized prosumer).

* Decarbonized Prosumer: Homes that produce more energy than they consume with renewable energy

1) Total management of housing and transportation (Practical use of combinations of ZEH/ZEB, demand-side equipment, regional renewable energy, EV/FCV, etc.)

<Current status and issues>

Combining ZEH/ZEB, demand-side equipment (home appliances, hot water supply, etc.), local renewable energy, EV/FCV, etc., demonstration and social implementation are currently being carried out in advanced areas and blocks toward ensuring flexibility consistent with the mainstreaming of renewable energy and sector coupling of electricity, heat, and mobility.

<Future efforts>

It is necessary to combine ZEH/ZEB, equipment on the demand side, renewable energy in the region, EV/FCV, etc., and to remotely control a wide variety of equipment for optimization by autonomous control or ICT. It is also necessary to form a market. In addition, in order to further reduce CO_2, it is necessary to promote the spread of renewable energy electricity and heat that is close to demand, and to demonstrate and implement the technology in society. While pursuing networking between houses and buildings by DC power supply, etc., ensuring flexibility consistent with the mainstreaming of renewable energy utilizing hydrogen, etc., as well as demonstrating and social implementation of technology related to sector coupling of electricity, heat, and mobility, a business model needs to be established by designing an appropriate market for popularization.

By promoting these initiatives, we will make effective use of renewable energy, which is a local resource, and in addition to regional decarbonization, we will realize strong and vibrant regional societies that simultaneously resolve regional issues such as building disaster-resistant cities, creating jobs, and improving the quality of life. Specifically, after securing an environment for living and working in homes and buildings with high levels of insulation that are healthy, comfortable, and provide significant energy savings, we will create a new lifestyle in which people first generate their own renewable energy through solar power and other means and then consume it themselves, transforming the conventional lifestyle in which energy is purchased. In addition, by optimizing energy supply and demand through the use of smart technologies such as AI to control demand-side equipment, society will be transformed from one in which fossil fuels are imported and procured outside each region to one in which resources and funds are circulated within each region and jobs are created. This will enable a certain degree of self-sufficiency in electricity and heat even in the event of large-scale disasters, which are expected to become more severe due to climate change, thereby establishing a safe and secure lifestyle. In addition, EVs, FCVs, and other vehicles powered by energy generated in each region will function throughout society as moving storage batteries that buffer the variability of renewable energy.

2) Behavior change by means of nudge, digitalization, and sharing, etc.

<Current status and issues>

(a) Nudge, BI-Tech (Fusion of Behavioral Insights and Tech)

While maintaining Japan's superiority in advocating the concept of fusion of behavioral insights such as nudge and cutting-edge technologies (BI-Tech), the government is implementing demonstration projects for its social implementation, maintaining international cooperation.

(b) Digitization

Using blockchain technology, the government is demonstrating the construction of a market where the CO_2 reduction value (environmental value) of renewable energy of individuals and small and medium-sized enterprises can be traded freely at low cost.

The government is experimentally developing an urban carbon mapping method that visualizes the area/dynamic energy use through digitization of a combination of various statistical data.

(c) Sharing

The government supports the creation of precedent cases related to decarbonized transportation by car-sharing of EVs utilizing regional renewable energy and community-contribution decarbonized logistics utilizing battery exchange type EVs and battery stations.

<Future efforts>

(a) Nudge, BI-Tech

The government will pursue the development/implementation, standardization of more advanced system technology that supports daily life by digitalizing behavioral information in daily life, aggregating and analyzing it, and proposing eco-friendly and comfortable life styles[92] based on behavioral sciences and AI, and incorporate them in business models for sales of products and service.

(b) Digitization

While utilizing the results of the demonstrations so far, the government will try to digitize the

---

[91] A lifestyle that does not compromise comfort as a non-energy benefit, which is important not only for reducing CO_2 emissions, but also for encouraging voluntary behavior change. For example, it refers to the effect of increasing green space, which improves comfort and health by increasing the frequency of walking, and the effect of maintaining comfort while saving energy by controlling air conditioning effectively. In order to realize these goals, the Ministry of the Environment will study methods for R&D, demonstration, and social implementation.

application procedure, simplify and automate the monitoring and credit certification procedures, so that the environmental value can be traded and utilized in a limited time lag in the J-credit system, as well as to consider creating a trading market using block chains and aim to start operation from 2022 at the earliest.

Using the urban carbon mapping method, we will develop a tool that can be used universally by local governments throughout Japan to examine future scenarios and measures for realizing zero-carbon cities through evaluation of the potential for introducing technologies for decarbonization prosumers. It will promote the construction of smart cities equipped with a decentralized energy system nationwide while ensuring security.

(c) Sharing

The government will promote the establishment of business models related to decarbonized transportation by car-sharing of EVs utilizing local renewable energy, and community-contribution decarbonized logistics utilizing battery exchange type EVs and battery stations, and horizontal expansion at the national level.

3) Enhancement of scientific infrastructure related to observation and models

<Current status and issues>

Through the advancement of observation, modeling, and simulation technologies, we aim to elucidate the mechanisms of climate change, reduce uncertainty, and more accurately estimate CO_2 emissions.

The government is building and expanding an observation network based on artificial satellites, aircraft, ships, and ground observations in close cooperation with the international framework.

Through the Data Integration and Analysis System (DIAS)[93], we are making further use of greenhouse gas observation data and climate change projection information.

In addition, not only technological innovation but also innovation of economic and social systems is essential to achieve Carbon Neutrality, and it is necessary to create cross-sectoral knowledge and promote social implementation based on such knowledge. In this way, it will be necessary to promote decarbonization and other initiatives in particular regions, and to expand the practical models to other regions, countries, and throughout the world.

<Future efforts>

In relation to observation and modeling technology, we will improve spatio-temporal resolution, further elucidate the mechanisms of climate change, improve the accuracy of climate change prediction information, continue observation and monitoring, promote further utilization of greenhouse gas observation data and climate change prediction information through DIAS, and enhance scientific infrastructure.

The observation network and analysis system will be integrated to improve spatio-temporal resolution and estimated accuracy. Specifically, we will develop a high-resolution atmospheric model

---

[93] The Japan Agency for Marine-Earth Science and Technology (JAMSTEC), as the representative organization, operates a data integration and analysis system to accumulate and integrate global environmental data.

that can estimate the distribution of emissions in each municipality and maintain an inventory. We will also build a system to continuously observe the urban atmosphere and monitor changes in emissions in time units. In addition, the greenhouse gas budget will be quantified for the entire region, including ecosystems. These systems will make it possible to evaluate the effects of decarbonization efforts in more detail, and will facilitate the evaluation of potential to promote more effective social implementation of technologies.

Through the verification of the greenhouse gas reduction effects of various climate change initiatives and the identification of effective initiatives, the results will be made visible to foster decarbonization awareness among the public and contribute to the improvement of measures and the management of climate change risks. Specifically, we will work on the following.

From April 2021, a study group on climate change research will be convened to discuss the direction of research on the advancement of modeling and simulation technologies and more accurate estimation of the carbon budget, which is the upper limit of cumulative greenhouse gas emissions allowed for temperature targets.

Based on the "Follow-up Report on the Implementation Policy of Japan's Earth Observation for the Next 10 Years" (Earth Observation Promotion Subcommittee, Planning, Evaluation and Subcommittee, Council for Science and Technology, August 2020), relevant ministries and agencies will continue to conduct observation and monitoring, utilizing the framework of GEO (the Intergovernmental Meeting on Earth Observation). The observation subcommittee will confirm the implementation status based on this follow-up report in the summer of the same year.

As for DIAS, the promotion of the utilization of global environmental big data will be promoted in earnest from FY2021 under a new structure.[94]

In order to confirm the implementation status of the Paris Agreement and review the targets, Japan and the governments of each country will provide scientific support for reporting on each country's greenhouse gas emissions and progress toward reduction targets based on the best scientific evidence at the Global Stocktake, which will be held every five years after the first meeting in 2023. We will propose a highly accurate and continuous monitoring system for the greenhouse gas balance and establish a system to verify the transparency of reporting by each country through the "Integrated Study on Multi-scale Monitoring and Model Advancement of Greenhouse Gas Balance" funded by the Comprehensive Environmental Research Fund SII-8.

We will enhance observation and prediction of the atmosphere and oceans by upgrading meteorological satellites and simulation technologies, and work in cooperation with industry, academia, and government to promote the utilization of the results as a scientific basis for climate change countermeasures by companies and public organizations.

By utilizing data from these scientific platforms, we will contribute to the planning of optimal climate change countermeasures within disaster prevention measures and scenario assessments for a decarbonized society by the national government, local governments, and companies. Specifically utilizing these results will contribute to the verification of Japan's decarbonization efforts, including lifestyle industries, and to the study of measures in the public and private sectors for a decarbonized

---

[94] From April 1, 2021, JAMSTEC will take over from the Remote Sensing Technology Center (RESTEC) as the representative organization for DIAS operation.

society in the future.

In addition, in order to promote the decarbonization of each region, we will promote cross-disciplinary R&D from the humanities and social sciences to the natural sciences in order to promote technological innovation and social change from the perspective of backcasting from an image of the future society of each region, and we will enrich the fundamental knowledge related to the formulation of national and regional scenarios and methods of introducing effective technologies and measures from a cross-policy perspective. At the same time, in order to promote the social implementation of such knowledge, we will strengthen cooperation among universities and between industry, academia, and government by forming " University Coalition for Carbon Neutrality 2050," which is an inter-university network that will serve as a place for co-creation by various stakeholders and further strengthen the function of universities, including such centers, as regional "centers of knowledge."

Reference 1: "Growth Strategy Action Plan" (Cabinet Decision of June 18, 2021) (Extract)

Chapter 3: Growth of the Green Sector

1. Green Growth Strategy Through Achieving Carbon Neutrality in 2050

(1) Framework for a Green Growth Strategy based on the 2030 emission reduction target

In an effort to decarbonize, companies are increasingly selecting their supply chain partners on a global scale, and we are entering an era in which responding to global warming will determine the success or failure of growth. We need to maximize the introduction of renewable energy. In order to achieve the high goal of carbon neutrality in 2050, the Green Growth Strategy will be implemented as follows. In doing so, the benefits to each citizen on the demand side, should be communicated in an easy-to-understand manner. We will also consider measures to encourage further necessary investment with a view to the 2030 emission reduction target. In addition, we will continuously follow up on the progress of the strategy and review its contents and areas.

(2) Key cross-sectoral policy tools

① Budget

Government establishes a 2 trillion yen fund which will encourage innovation through continuous support of challenging R&D activities by companies and other organizations over a 10-year period.

② Tax Systems

The Investment Promotion Tax System will promote investment in production equipment for products with high decarbonization potential and equipment which promote decarbonization of production processes, etc.

③ Regulatory reform and standardization

We will overhaul regulations to induce green investment. In addition, we will tighten regulations to create technology demand, relax outdated regulations that do not cover new technology, and work on international standardization that makes it easier for new technologies to be used around the world.

④ International cooperation

The goal is to strengthen the competitiveness of domestic industry by capturing not only the domestic market but also overseas markets such as emerging countries and reducing costs by taking advantage of economies of scale. In addition, through direct investment and M&A, we will bring in foreign capital, technology, sales channels, and management.

(3) Issues and responses by sector

① Offshore wind, next-generation solar, and geothermal industries

Since offshore wind power generation has the anticipated economic ripple effects, the government and the Industry will develop a competitive and resilient supply chain by creating an attractive domestic wind power market to attract domestic and foreign investment. In addition, the government and the Industry will engage in next-generation technology development and international cooperation with an eye to expanding into Asia, and create next-generation industries that can compete on the global stage.

Specifically, the government will continue to award capacity of 10GW by 2030 and 30-45GW, including floating offshore wind, by 2040.

The government will thoroughly support the development of next-generation solar cells and accelerate research and development for performance improvement to achieve commercialization in 2030. It will develop new markets such as building walls with technical restrictions using existing photovoltaic modules.

Since geothermal power generation is expected to provide a renewable energy source that can serve as a base load power source, we will work to significantly expand its introduction through the supply of risk money, review of the operation of regulations under related laws and regulations, and technological development.

② Hydrogen and fuel ammonia industry

Hydrogen is a key carbon-neutral technology that is widely used in power generation, industry, and transportation. By positioning hydrogen as a new resource and involving a wide range of players in addition to automotive applications, we aim to introduce a maximum of 3 million tons by 2030 and expand supply to around 20 million tons by 2050. The goal is to reduce the cost of hydrogen power generation to a level that is sufficiently competitive with fossil fuels in 2050, i.e., to reduce the cost of hydrogen power generation to less than that of gas-fired power generation (hydrogen cost: less than about 20 yen/Nm3).

Ammonia, which does not emit CO2 when burned, is an effective fuel for co-firing in thermal power plants. The goal is to establish co-firing technology early to expand to Southeast Asia and other regions, and quickly establish an international supply chain.

③ Automobile and battery industries

In the automotive sector, comprehensive support measures will be implemented to promote electrification, together with energy decarbonization, with the aim of making the entire supply chain carbon neutral. In addition to promoting the introduction of electric vehicles, fuel cell vehicles, etc., by 2030 at the latest, electrified vehicles will be as economical and convenient as gasoline-powered vehicles through the development of next-generation battery technologies and the promotion of manufacturing facilities as described below, the development of hydrogen stations, and the development of quick charging facilities for electric vehicles.

④ Industry and material industry related to Carbon Recycling

Carbon Recycling is a technology that effectively utilizes CO2 as a resource, and is an important cross-cutting field for the realization of a carbon-neutral society. Japan has a competitive edge in Carbon Recycling and aims to expand globally after cost reduction and social implementation.

Specifically, CO2 absorption type concrete will be priced at the same level as existing concrete (=30 yen/kg) in 2030 through increased demand, and the new product with rust prevention performance will be available for architectural applications in 2050. Technology development and demonstration of synthetic fuels made from CO2 and hydrogen for use in transportation equipment, etc. will be conducted intensively over the next 10 years, with the aim of achieving commercialization by 2040.

The material industry will lead the world in the development and supply of zero-carbon steel technologies, such as the blast furnace steelmaking method using hydrogen, with the aim of capturing the green steel market, which is expected to reach a maximum of 500 million tons per year, or about 40 trillion yen, by 2050.

⑤ Housing and Building Industry, Next Generation Power Management Industry

Housing and buildings are areas that have a significant impact on reducing energy consumption in the consumer sector. While creating a market environment to spread advanced technologies domestically, we also expect to expand our technologies overseas.

Specifically, to strengthen energy efficiency and conservation measures, including regulatory measures, we will develop a roadmap and take other concrete steps to improve energy efficiency and conservation performance by reviewing standards for energy consumption performance of houses and buildings, certification standards for long-life quality housing and the housing performance indication system, and extending the service life of houses and buildings.

In order to eliminate congestion in the electric power system caused by the massive introduction of renewable energy sources, we will build a next-generation power grid that can perform more advanced grid operations by utilizing digital technology. In addition, digital technology will be used to promote businesses that provide services for optimizing the supply and demand of electricity by combining highly variable renewable energy sources such as solar and wind power with storage batteries, etc.

⑥ Next generation heat energy industry

Methane synthesized from hydrogen derived from renewable energy sources, etc., and CO2 can replace natural gas using existing infrastructure such as city gas pipes, and is therefore a key to decarbonizing the gas needed for heat demand.

Regarding synthetic methane, we will continue to develop the technology and aim to start using it by 2030. By 2050, the goal is to use 90% of synthetic methane in the existing gas supply infrastructure, and to achieve decarbonization of gas in combination with direct use of hydrogen and other means.

⑦ Nuclear industry

Nuclear power is a decarbonization option that is in the practical stage. While lowering the dependence on nuclear energy to the extent possible, we will make steady progress in restarting nuclear power plants in Japan with the highest priority on safety. At the same time, Japanese companies with advanced manufacturing capabilities will participate in the development of next-generation innovative nuclear reactors in the United States, the United Kingdom, and other countries to accelerate innovation in various nuclear technologies. We will promote R&D, human resource development, etc. for the future, including the pursuit of reactors with superior safety, etc.

Specifically, by 2030, small modular reactor technology will be demonstrated through international collaboration and component technologies related to hydrogen production for high-temperature gas-cooled reactor will be established, as well as R&D of nuclear fusion will be steadily promoted.

⑧ Semiconductor and information and communication industry

Carbon neutrality will be achieved by a society that is electrified and digitalized in all areas, including manufacturing, services, transportation, and infrastructure. Therefore, the two approaches of (1) improving the efficiency of energy demand through digitization and (2) energy saving and greening of digital devices and information and communication itself will be promoted as two wheels of the same cart. The goal is to make all new data centers 30% energy-efficient by 2030, to convert a portion of the electricity used at domestic data centers to renewable energy, and to make the semiconductor and telecommunications industries carbon neutral by 2040.

⑨ Ship industry

For zero-emission ships using alternative fuels such as hydrogen and ammonia, we will promote technological development and start demonstration projects by 2025, aiming to achieve commercial operation ahead of the previous target of 2028, and to further popularize the technology by 2030.

⑩ Logistics, people flow, and civil engineering infrastructure industries

We aim to achieve carbon neutrality in 2050 in the logistics, people flow, and civil engineering infrastructure industries by making comprehensive efforts to form Carbon-Neutral Ports for hydrogen import, etc., to introduce smart transportation, to promote the introduction of bicycle transportation, to promote green logistics, to make transportation networks, bases, and transportation more efficient and low-carbon, to achieve zero emissions in infrastructure and urban spaces, and to achieve carbon neutrality in construction.

⑪ Food, agriculture, forestry and fisheries

Based on the Strategy for Sustainable Food Systems, called MeaDRI (Measures for achievement of Decarbonization and Resilience with Innovation), we will promote the development and implementation of innovative technologies and production systems throughout the supply chain, from production, processing and distribution to consumption, with the aim of achieving zero CO2 emissions from fossil fuel combustion in agriculture, forestry and fisheries sectors by 2050.

Specifically, the government will strongly promote the electrification and hydrogenation of agricultural and forestry machinery and fishing vessels, the reduction of greenhouse gases from agriculture and livestock sectors, enhancement of carbon storage in farmlands and sea areas for long-term and, large-scale, and the reduction of food loss and waste.

In addition, in order to enhance the CO2 absorption and storage functions of forests and lumber, we will promote using wood for construction of buildings s, including the establishment of technology to construct high-rise wooden buildings, while also working to rejuvenate forests through thinning and reforestation using seedlings with excellent growth.

⑫ Aviation industry

While the International Civil Aviation Organization (ICAO) has decided not to increase CO2 emissions compared to 2020, we aim to establish the technological superiority of Japan’s aircraft manufacturing industry in such areas as electrification and hybrid electrification, alternative fuels such as hydrogen, and carbon fiber composite materials for airframes.

Specifically, the goal is to expand electrification technology after 2030, in line with the timing of the market introduction of future aircraft, and to establish the core technology necessary for hydrogen aircraft, etc. after 2035.

⑬ Resource circulation industries

Regarding the “reduce, reuse, recycle, and renewable” of waste, the technology development and social implementation are being encouraged through the development of laws and plans. Technologies such as waste power generation, heat utilization, and biogas utilization have already entered the commercial phase and are becoming more widespread and sophisticated. In the future, these efforts will be further promoted by upgrading technology, improving facilities, and reducing costs. While promoting the transition to a circular economy, we will reduce overall greenhouse gas emissions to zero by 2050.

⑭ Lifestyle-related industries

We will promote total management of housing and transportation by implementing a combination of ZEH (Net Zero Energy House), ZEB (Net Zero Energy Building), home appliances, hot water supply and other equipment, and electric vehicles as moving storage batteries. We will encourage behavior change through nudging and sharing, and technological development and demonstration, etc. to verify the effects of CO2 reduction.

2. Carbon pricing

Japan will, without hesitation, tackle economic instruments such as carbon pricing, that use market mechanisms and are conducive to growth, so as to strengthen industrial competitiveness and promote innovation and investment.

In light of accelerated expansion of voluntary credit markets internationally, we will take concrete measures to increase the depth of the domestic market (credit market) in Japan in which carbon reduction value can be traded, and thereby promptly respond to the desires of companies that are pioneering climate change measures.

Specifically, in light of the growing corporate demand for credits with carbon reduction value, such as J-Credits and Non-fossil Fuel Energy Certificates, at first we will review the existing credits mechanisms and promote voluntary and market-based carbon pricing.

Furthermore, in terms of carbon taxes and emissions trading systems, we will advance professional and technical discussions on whether it is possible to design a system that will promote investment and contribute to growth in terms of both price signaling and revenue generation, while taking into account the added cost borne by companies. In doing so, we will build upon international trends and domestic circumstance, including current economic situation and the availability of alternative means, efforts of leading local governments, and possible impact on the international competitiveness of domestic industries.

In addition, Japan will fully take the lead in creating fair international rules that strike a balance between free trade and climate change policies, while demonstrating its leadership as a standard-bearer for free trade. On this occasion, we will organize Japan’s basic approach to carbon border adjustment mechanism, and then respond strategically to such mechanisms by paying attention to the trends of discussions in the EU and other countries.

3. Attracting domestic and foreign private capital to carbon-neutral markets

(1) Development of infrastructure for smooth provision of funds

The goal is to attract domestic and foreign environmental investment funds, which are said to amount to 3,000 trillion yen. We will develop guidelines necessary from the perspective of improving the environment for sustainable finance.

We will also develop sectoral roadmaps for transitions in industries with large CO2 emissions such as steel, chemicals, pulp and paper, cement, electricity, gas, oil, etc., and promote transition support in Asia.

We encourage acceptance of the Stewardship Code by corporate pension funds and other institutional investors, signing of the Principles for Responsible Investment (PRI). Furthermore, we encourage enhanced disclosure and other measures in line with the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD), and call for the disclosure of information on investment strategies.

(2) Improvement of the environment for green bond transactions, etc.

The goal is to create a green international financial center where transactions of green bonds and other products are actively conducted. We aim to develop an information infrastructure that is highly convenient from the perspective of financial business practices. We will encourage the establishment of private sector certification frameworks to evaluate the eligibility of green bonds, etc. and the development of evaluation organizations.

(3) Enhancement of sustainability-related disclosure

Through the Corporate Governance Code, etc., we will encourage companies listed on the Prime Market (the market where companies with larger market capitalization and higher governance level will be listed after the TSE’s market reorganization next April) to enhance the quality and quantity of their disclosure based on international frameworks such as the TCFD. In addition, Japan will strategically participate in the development of international standards.

(4) Support for lenders by financial institutions and public-private partnerships

We will promote active dialogue between financial institutions and businesses, and investment and financing based on this dialogue. In order to improve the climate change risk management of financial institutions, guidance will be formulated by the financial supervisory authorities and support for regional financial institutions will be provided by the end of this fiscal year.

4. Regional decarbonization roadmap

Based on the Regional Decarbonization Roadmap, we aim to achieve decarbonization of electricity consumption in the consumer sector by 2030 in at least 100 decarbonization leading areas. In addition, priority measures will be implemented nationwide to achieve decarbonization domino effect with leading areas as the core. In particular, we will concentrate our efforts on the following items over the next five years.

(1) Continuous and comprehensive support for local initiatives

Establish a scheme to provide continuous and comprehensive support for regional decarbonization efforts, including those in leading areas, in order to dispatch and train personnel, share information and technology, and secure necessary funding.

(2) Lifestyle innovation

Develop visualization of CO2 emissions from products and services, incentives to encourage active selection of decarbonized products and services, use of local renewable energy as a homecoming gift for hometown tax payments, social implementation of nudges, and a national movement using ambassadors.

(3) Innovation in rules for decarbonization

Establish a renewable energy promotion zone that contributes to environmental conservation and smooth regional consensus building, as well as to the foreseeability of businesses, and promote renewable energy such as solar power generation that coexists with and contributes to local communities. Consideration of the optimization of environmental assessments to promote wind power generation, etc., and institutional measures to accelerate the development of geothermal power generation in symbiosis with local communities through the implementation of scientific research.

Chapter 4: Realizing New Investments for Green Growth Strategies

1. Industrial structural transformation associated with carbon neutrality

We will support the industrial structural transformation associated with carbon neutrality in 2050. For example, engine parts suppliers will be challenged to manufacture electric parts in line with the shift to electrification of automobiles, and gas stations and maintenance bases will be transformed into new regional human flow, logistics, service bases, and EV stations. At the same time, we will support the movement of labor, without the loss of employment, associated with industrial structural transformation.

2. Electrification and the use of digital technology in conjunction with carbon neutrality

Electrified society is a prerequisite for carbon neutrality. For example, digital control of power networks is important to maximize the introduction of renewable energy. Cars, drones, airplanes, trains, and their automated driving are digitally controlled. Robots will support the workplace in both manufacturing and service. The Green Growth Strategy will be supported by a robust digital infrastructure, and green and digital are two wheels of the same cart. We will promote efficient and effective greening through digitization in environment-related fields. We will lead the world's green industry and create a virtuous cycle between the economy and the environment.

3. Development of hydrogen stations

In anticipation of the widespread use of fuel cell vehicles, fuel cell buses, and fuel cell trucks, about 1,000 hydrogen stations will be constructed by 2030, taking into account human flows and logistics in order to achieve the optimal layout. We will promote the development of hydrogen stations for commercial vehicles such as buses and trucks, including refueling facilities exclusively for business locations.

4. Development of quick charging facilities for electric vehicles

Lack of charging facilities will hinder the spread of electric vehicles. We will strongly promote the installation of 30,000 quick charging facilities to achieve the same level of convenience as gasoline vehicles by 2030 at the latest.

5. Gas conversion of coal-fired private power generation, etc.

Focusing on energy-intensive industries such as steel, chemicals, pulp and paper, and cement, we will promote the conversion of coal-fired private power generation to gas and the upgrading of low-efficiency blast furnaces, coke ovens, industrial furnaces, and other facilities to higher efficiency.

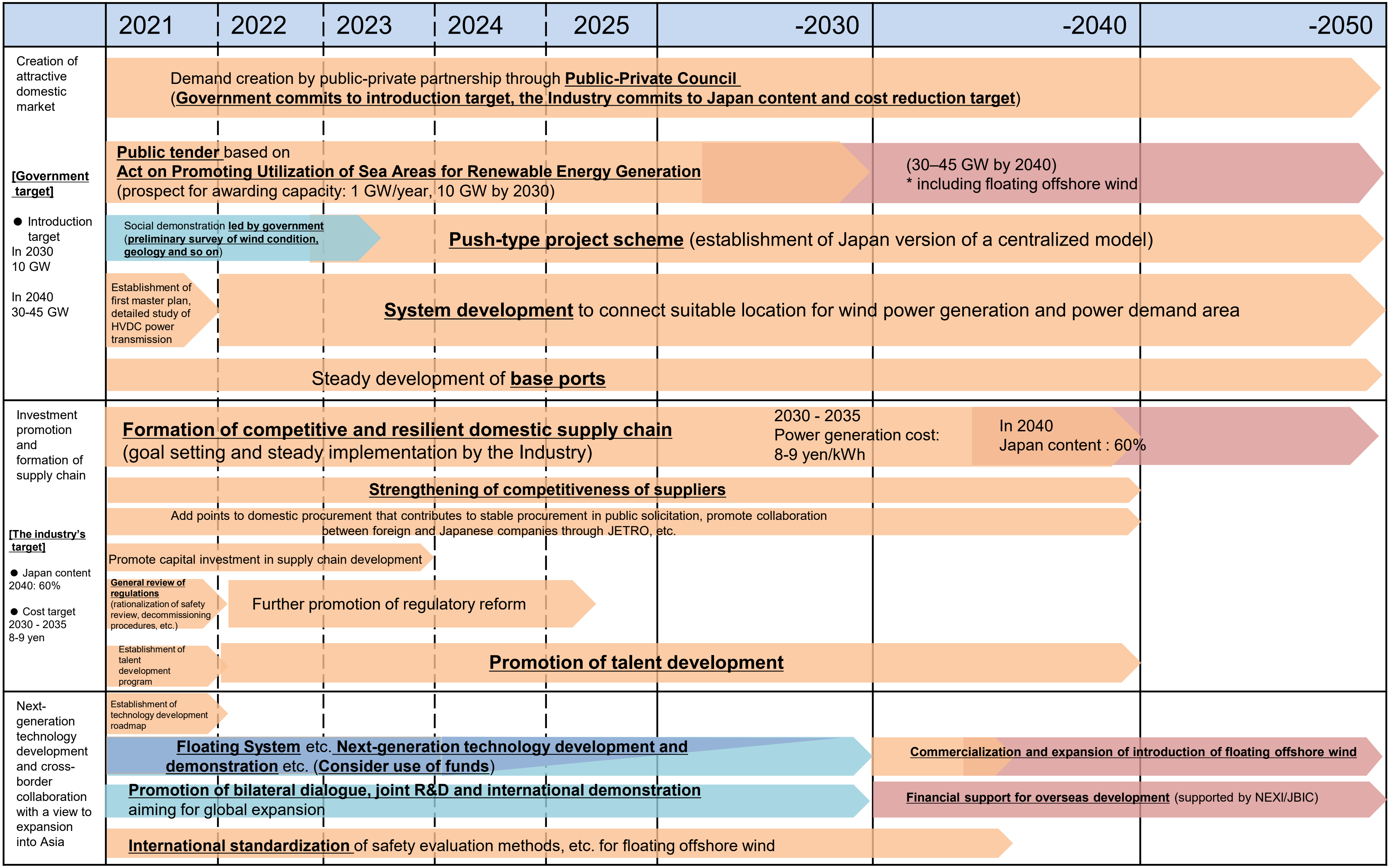
6. Development of transmission line networks to promote renewable energy

In order to accelerate the development of transmission line networks for the spread of renewable energy, we will promote feasibility studies (FS) on submarine transmission lines and capital investment for manufacturing facilities for cables.

Reference 2: "Roadmaps" for key areas

(1) "Roadmap" of Growth Strategies for the Offshore Wind, Solar, and Geothermal Industries (Offshore Wind)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



Creation of attractive domestic market

[Government target]

- Introduction target

In 2030
10 GW

In 2040
30-45 GW

Demand creation by public-private partnership through **Public-Private Council** (**Government commits to introduction target, the Industry commits to Japan content and cost reduction target**)

Public tender based on **Act on Promoting Utilization of Sea Areas for Renewable Energy Generation** (prospect for awarding capacity: 1 GW/year, 10 GW by 2030)

(30–45 GW by 2040)
* including floating offshore wind

Social demonstration **led by government** (**preliminary survey of wind condition, geology and so on**)

Push-type project scheme (establishment of Japan version of a centralized model)

Establishment of first master plan, detailed study of HVDC power transmission

System development to connect suitable location for wind power generation and power demand area

Steady development of **base ports**

Investment promotion and formation of supply chain

[The industry's target]

- Japan content 2040: 60%
- Cost target 2030 - 2035 8-9 yen

Formation of competitive and resilient domestic supply chain (goal setting and steady implementation by the Industry)

2030 - 2035
Power generation cost:
8-9 yen/kWh

In 2040
Japan content : 60%

Strengthening of competitiveness of suppliers

Add points to domestic procurement that contributes to stable procurement in public solicitation, promote collaboration between foreign and Japanese companies through JETRO, etc.

Promote capital investment in supply chain development

General review of regulations (rationalization of safety review, decommissioning procedures, etc.)

Further promotion of regulatory reform

Establishment of talent development program

Promotion of talent development

Next-generation technology development and cross-border collaboration with a view to expansion into Asia

Establishment of technology development roadmap

Floating System etc. **Next-generation technology development and demonstration** etc. (**Consider use of funds**)

Commercialization and expansion of introduction of floating offshore wind

Promotion of bilateral dialogue, joint R&D and international demonstration aiming for global expansion

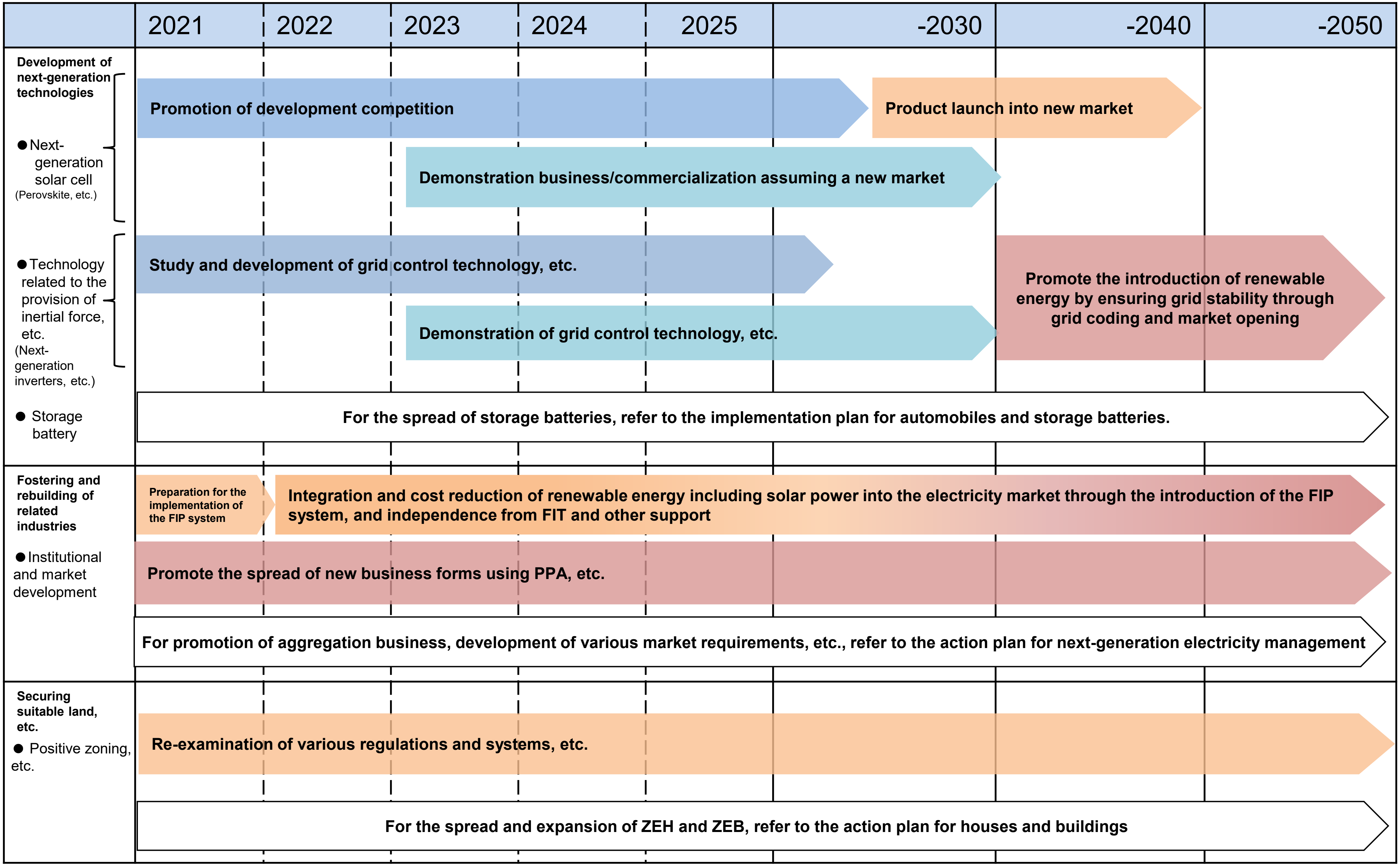
Financial support for overseas development (supported by NEXI/JBIC)

International standardization of safety evaluation methods, etc. for floating offshore wind

(1) "Roadmap" of Growth Strategies for Offshore Wind, Solar, and Geothermal Industries (Solar)

● Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase

● Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

Development of next-generation technologies

● Next-generation solar cell (Perovskite, etc.)

Promotion of development competition

Product launch into new market

Demonstration business/commercialization assuming a new market

● Technology related to the provision of inertial force, etc. (Next-generation inverters, etc.)

Study and development of grid control technology, etc.

Demonstration of grid control technology, etc.

Promote the introduction of renewable energy by ensuring grid stability through grid coding and market opening

● Storage battery

For the spread of storage batteries, refer to the implementation plan for automobiles and storage batteries.

Fostering and rebuilding of related industries

● Institutional and market development

Preparation for the implementation of the FIP system

Integration and cost reduction of renewable energy including solar power into the electricity market through the introduction of the FIP system, and independence from FIT and other support

Promote the spread of new business forms using PPA, etc.

For promotion of aggregation business, development of various market requirements, etc., refer to the action plan for next-generation electricity management

Securing suitable land, etc.

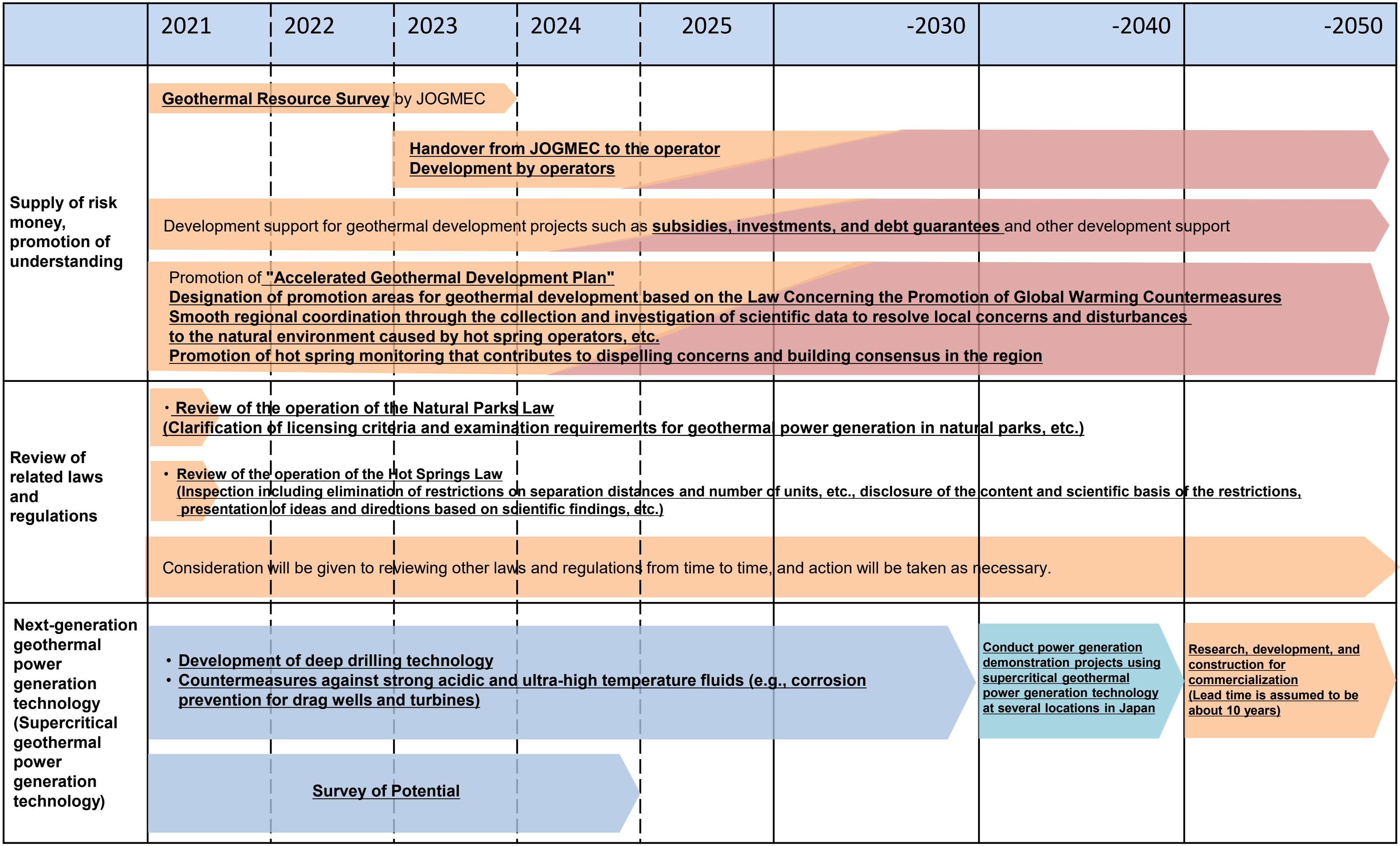
● Positive zoning, etc.

Re-examination of various regulations and systems, etc.

For the spread and expansion of ZEH and ZEB, refer to the action plan for houses and buildings

(1) "Roadmap" of Growth Strategy for Offshore Wind, Solar, and Geothermal Industries (Geothermal)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



Supply of risk money, promotion of understanding

Geothermal Resource Survey by JOGMEC

Handover from JOGMEC to the operator
Development by operators

Development support for geothermal development projects such as **subsidies, investments, and debt guarantees** and other development support

Promotion of **"Accelerated Geothermal Development Plan"**
Designation of promotion areas for geothermal development based on the Law Concerning the Promotion of Global Warming Countermeasures
Smooth regional coordination through the collection and investigation of scientific data to resolve local concerns and disturbances to the natural environment caused by hot spring operators, etc.
Promotion of hot spring monitoring that contributes to dispelling concerns and building consensus in the region

Review of related laws and regulations

- **Review of the operation of the Natural Parks Law (Clarification of licensing criteria and examination requirements for geothermal power generation in natural parks, etc.)**
- **Review of the operation of the Hot Springs Law (Inspection including elimination of restrictions on separation distances and number of units, etc., disclosure of the content and scientific basis of the restrictions, presentation of ideas and directions based on scientific findings, etc.)**

Consideration will be given to reviewing other laws and regulations from time to time, and action will be taken as necessary.

Next-generation geothermal power generation technology (Supercritical geothermal power generation technology)

- **Development of deep drilling technology**
- **Countermeasures against strong acidic and ultra-high temperature fluids (e.g., corrosion prevention for drag wells and turbines)**

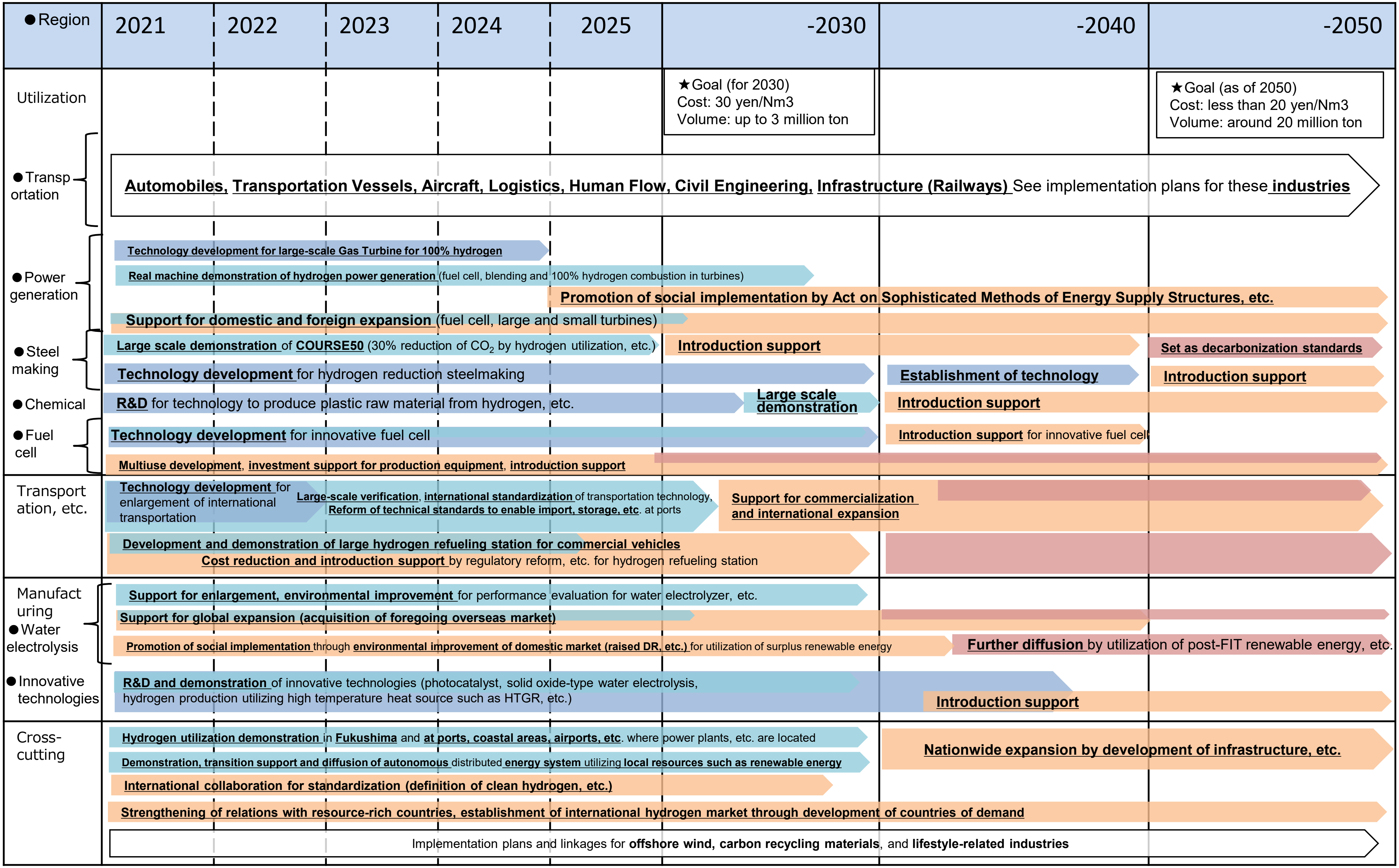
Conduct power generation demonstration projects using supercritical geothermal power generation technology at several locations in Japan

Research, development, and construction for commercialization (Lead time is assumed to be about 10 years)

Survey of Potential

(2) "Roadmap" of Growth Strategies for the Hydrogen and Fuel Ammonia Industries (Hydrogen)

- **Introduction phase:** **1. Development phase** → **2. Demonstration phase** → **3. Introduction and expansion/cost reduction phase** → **4. Autonomous commercialization phase**
- **Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.**



●Region | 2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

Utilization

★Goal (for 2030)
Cost: 30 yen/Nm3
Volume: up to 3 million ton

★Goal (as of 2050)
Cost: less than 20 yen/Nm3
Volume: around 20 million ton

●Transportation

Automobiles, **Transportation Vessels**, **Aircraft**, **Logistics**, **Human Flow**, **Civil Engineering**, **Infrastructure (Railways)** See implementation plans for these **industries**

●Power generation

Technology development for large-scale Gas Turbine for 100% hydrogen

Real machine demonstration of hydrogen power generation (fuel cell, blending and 100% hydrogen combustion in turbines)

Promotion of social implementation by Act on Sophisticated Methods of Energy Supply Structures, etc.

Support for domestic and foreign expansion (fuel cell, large and small turbines)

●Steel making

Large scale demonstration of **COURSE50** (30% reduction of CO_2 by hydrogen utilization, etc.) | **Introduction support** | **Set as decarbonization standards**

Technology development for hydrogen reduction steelmaking | **Establishment of technology** | **Introduction support**

●Chemical

R&D for technology to produce plastic raw material from hydrogen, etc. | **Large scale demonstration** | **Introduction support**

●Fuel cell

Technology development for innovative fuel cell | **Introduction support** for innovative fuel cell

Multiuse development, **investment support for production equipment**, **introduction support**

Transportation, etc.

Technology development for enlargement of international transportation | **Large-scale verification**, **international standardization** of transportation technology, **Reform of technical standards to enable import, storage, etc**. at ports | **Support for commercialization and international expansion**

Development and demonstration of large hydrogen refueling station for commercial vehicles

Cost reduction and introduction support by regulatory reform, etc. for hydrogen refueling station

Manufacturing

●Water electrolysis

Support for enlargement, environmental improvement for performance evaluation for water electrolyzer, etc.

Support for global expansion (acquisition of foregoing overseas market)

Promotion of social implementation through **environmental improvement of domestic market (raised DR, etc.)** for utilization of surplus renewable energy | **Further diffusion** by utilization of post-FIT renewable energy, etc.

●Innovative technologies

R&D and demonstration of innovative technologies (photocatalyst, solid oxide-type water electrolysis, hydrogen production utilizing high temperature heat source such as HTGR, etc.) | **Introduction support**

Cross-cutting

Hydrogen utilization demonstration in **Fukushima** and **at ports, coastal areas, airports, etc**. where power plants, etc. are located

Demonstration, transition support and diffusion of autonomous distributed **energy system** utilizing **local resources such as renewable energy**

Nationwide expansion by development of infrastructure, etc.

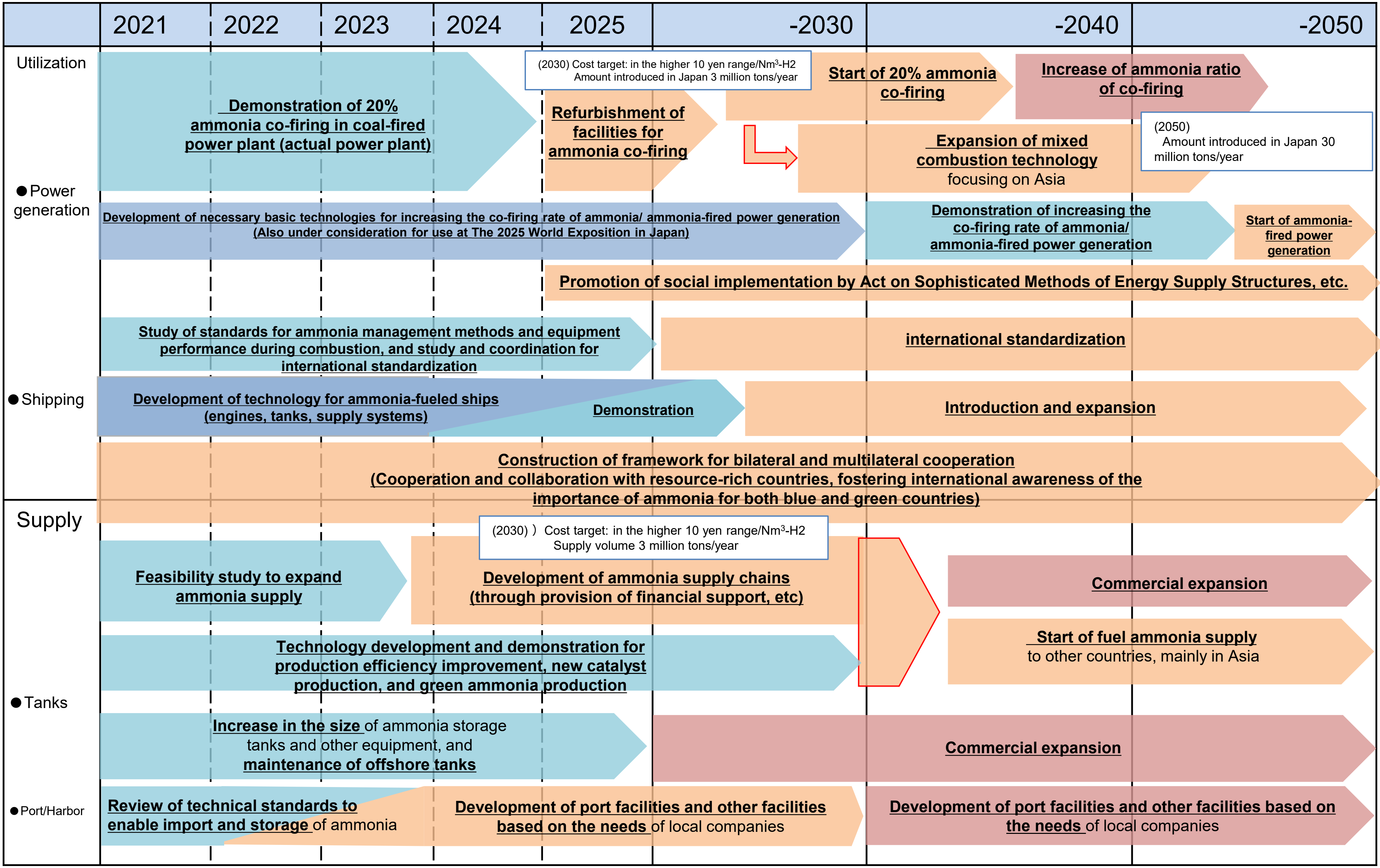
International collaboration for standardization (definition of clean hydrogen, etc.)

Strengthening of relations with resource-rich countries, establishment of international hydrogen market through development of countries of demand

Implementation plans and linkages for **offshore wind, carbon recycling materials**, and **lifestyle-related industries**

(2) "Roadmap" of Growth Strategies for the Hydrogen and Fuel Ammonia Industries (Fuel Ammonia)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

Utilization

● Power generation

Demonstration of 20% ammonia co-firing in coal-fired power plant (actual power plant)

(2030) Cost target: in the higher 10 yen range/Nm³-H2
Amount introduced in Japan 3 million tons/year

Refurbishment of facilities for ammonia co-firing

Start of 20% ammonia co-firing

Increase of ammonia ratio of co-firing

Expansion of mixed combustion technology focusing on Asia

(2050)
Amount introduced in Japan 30 million tons/year

Development of necessary basic technologies for increasing the co-firing rate of ammonia/ ammonia-fired power generation
(Also under consideration for use at The 2025 World Exposition in Japan)

Demonstration of increasing the co-firing rate of ammonia/ ammonia-fired power generation

Start of ammonia-fired power generation

Promotion of social implementation by Act on Sophisticated Methods of Energy Supply Structures, etc.

Study of standards for ammonia management methods and equipment performance during combustion, and study and coordination for international standardization

international standardization

● Shipping

Development of technology for ammonia-fueled ships (engines, tanks, supply systems)

Demonstration

Introduction and expansion

Construction of framework for bilateral and multilateral cooperation
(Cooperation and collaboration with resource-rich countries, fostering international awareness of the importance of ammonia for both blue and green countries)

Supply

(2030)) Cost target: in the higher 10 yen range/Nm³-H2
Supply volume 3 million tons/year

Feasibility study to expand ammonia supply

Development of ammonia supply chains (through provision of financial support, etc)

Commercial expansion

Start of fuel ammonia supply to other countries, mainly in Asia

Technology development and demonstration for production efficiency improvement, new catalyst production, and green ammonia production

● Tanks

Increase in the size of ammonia storage tanks and other equipment, and maintenance of offshore tanks

Commercial expansion

● Port/Harbor

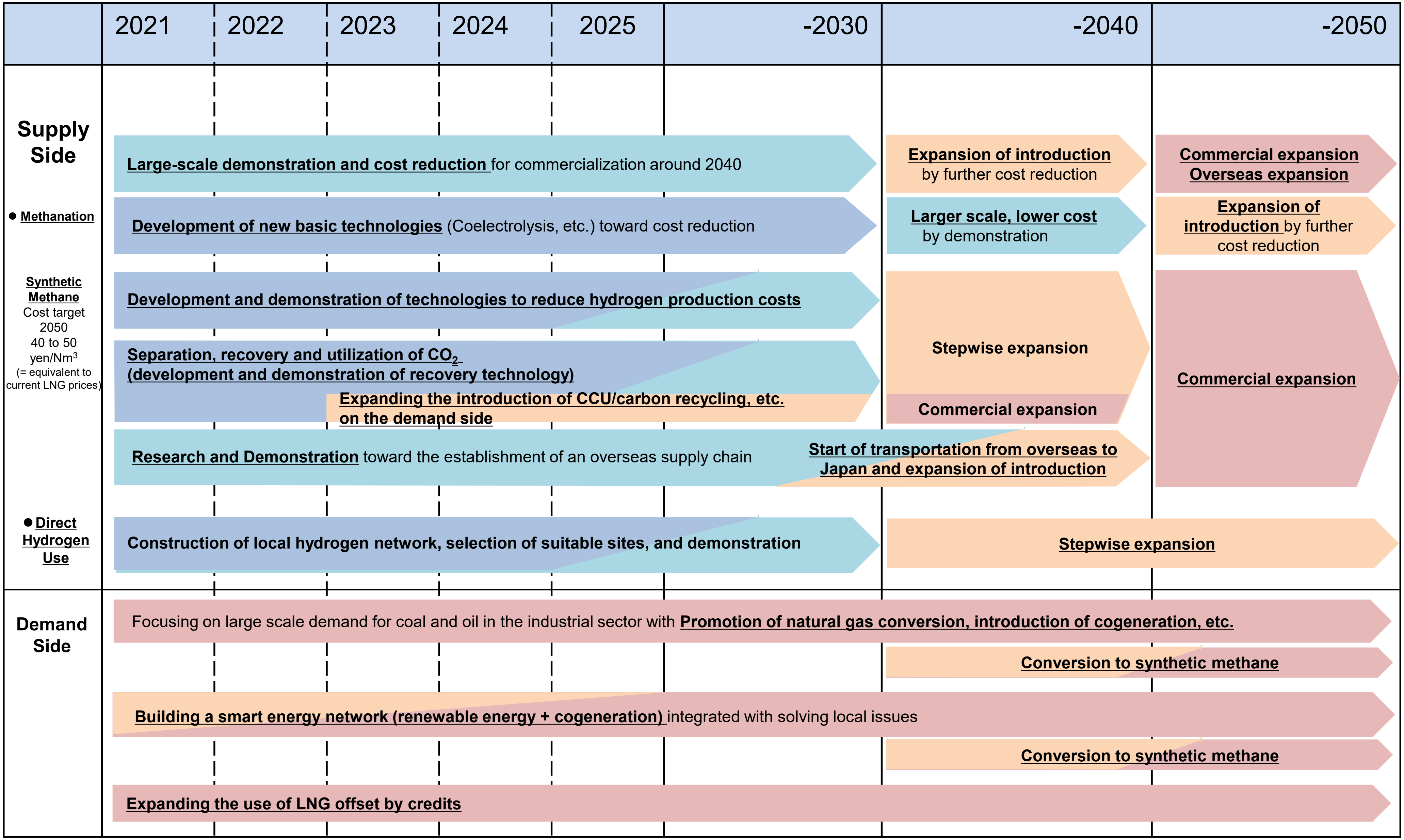
Review of technical standards to enable import and storage of ammonia

Development of port facilities and other facilities based on the needs of local companies

Development of port facilities and other facilities based on the needs of local companies

(3) "Roadmap" of Growth Strategy for the Next-generation Heat Energy Industry

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

Supply Side

- **Methanation**

Synthetic Methane
Cost target 2050
40 to 50 yen/Nm^3
(= equivalent to current LNG prices)

Large-scale demonstration and cost reduction for commercialization around 2040

Expansion of introduction by further cost reduction

Commercial expansion
Overseas expansion

Development of new basic technologies (Coelectrolysis, etc.) toward cost reduction

Larger scale, lower cost by demonstration

Expansion of introduction by further cost reduction

Development and demonstration of technologies to reduce hydrogen production costs

Separation, recovery and utilization of CO_2
(development and demonstration of recovery technology)

Expanding the introduction of CCU/carbon recycling, etc. on the demand side

Stepwise expansion

Commercial expansion

Commercial expansion

Research and Demonstration toward the establishment of an overseas supply chain

Start of transportation from overseas to Japan and expansion of introduction

- **Direct Hydrogen Use**

Construction of local hydrogen network, selection of suitable sites, and demonstration

Stepwise expansion

Demand Side

Focusing on large scale demand for coal and oil in the industrial sector with **Promotion of natural gas conversion, introduction of cogeneration, etc.**

Conversion to synthetic methane

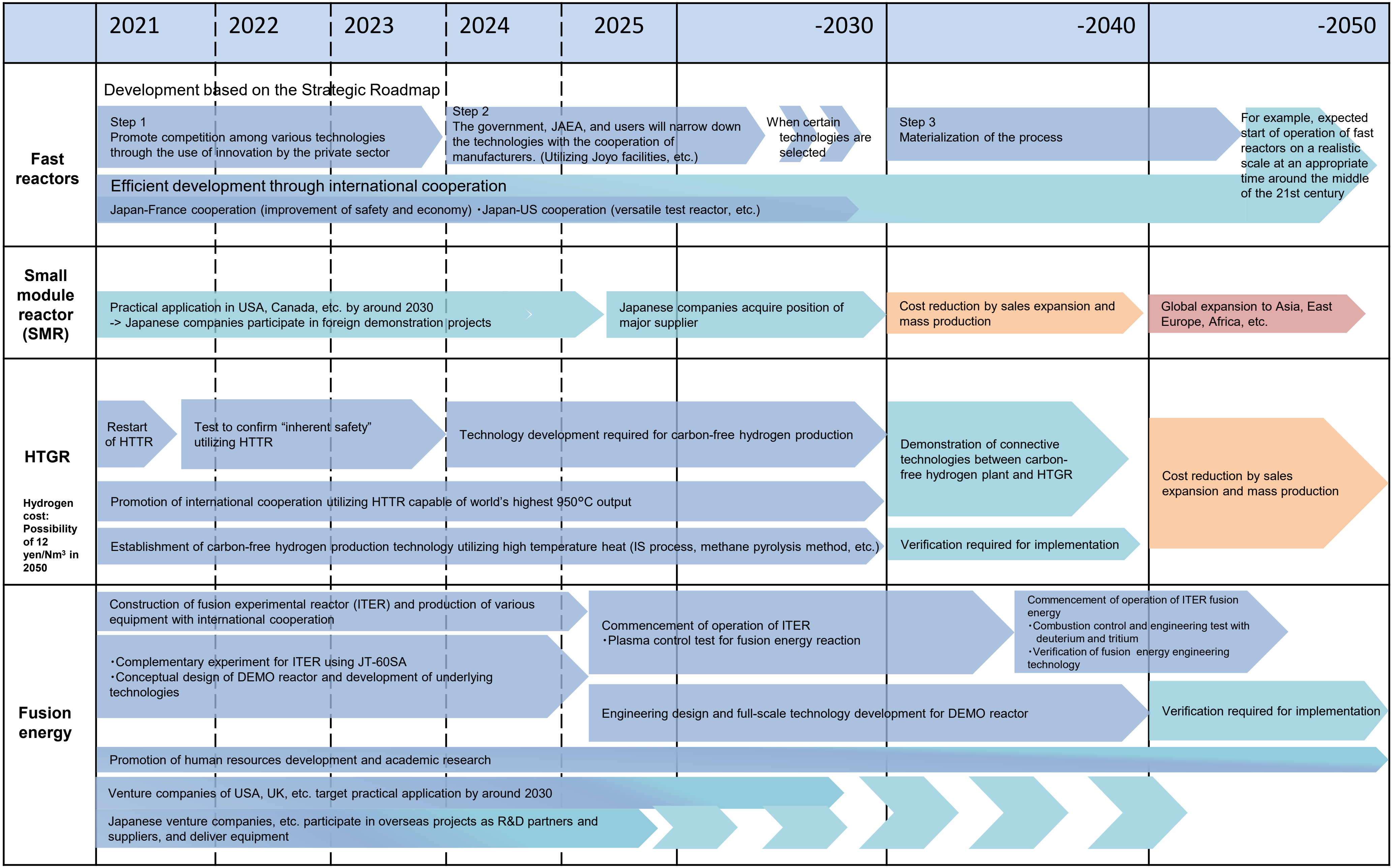
Building a smart energy network (renewable energy + cogeneration) integrated with solving local issues

Conversion to synthetic methane

Expanding the use of LNG offset by credits

(4) "Roadmap" of Growth Strategies for nuclear industry

- **Introduction phase:** **1. Development phase** **2. Demonstration phase** **3. Introduction and expansion/cost reduction phase** **4. Autonomous commercialization phase**
- **Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.**



2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

Fast reactors

Development based on the Strategic Roadmap

Step 1
Promote competition among various technologies through the use of innovation by the private sector

Step 2
The government, JAEA, and users will narrow down the technologies with the cooperation of manufacturers. (Utilizing Joyo facilities, etc.)

When certain technologies are selected

Step 3
Materialization of the process

For example, expected start of operation of fast reactors on a realistic scale at an appropriate time around the middle of the 21st century

Efficient development through international cooperation

Japan-France cooperation (improvement of safety and economy) ・Japan-US cooperation (versatile test reactor, etc.)

Small module reactor (SMR)

Practical application in USA, Canada, etc. by around 2030
-> Japanese companies participate in foreign demonstration projects

Japanese companies acquire position of major supplier

Cost reduction by sales expansion and mass production

Global expansion to Asia, East Europe, Africa, etc.

HTGR

Hydrogen cost: Possibility of 12 yen/Nm³ in 2050

Restart of HTTR

Test to confirm "inherent safety" utilizing HTTR

Technology development required for carbon-free hydrogen production

Demonstration of connective technologies between carbon-free hydrogen plant and HTGR

Cost reduction by sales expansion and mass production

Promotion of international cooperation utilizing HTTR capable of world's highest 950°C output

Establishment of carbon-free hydrogen production technology utilizing high temperature heat (IS process, methane pyrolysis method, etc.)

Verification required for implementation

Fusion energy

Construction of fusion experimental reactor (ITER) and production of various equipment with international cooperation

・Complementary experiment for ITER using JT-60SA
・Conceptual design of DEMO reactor and development of underlying technologies

Commencement of operation of ITER
・Plasma control test for fusion energy reaction

Commencement of operation of ITER fusion energy
・Combustion control and engineering test with deuterium and tritium
・Verification of fusion energy engineering technology

Engineering design and full-scale technology development for DEMO reactor

Verification required for implementation

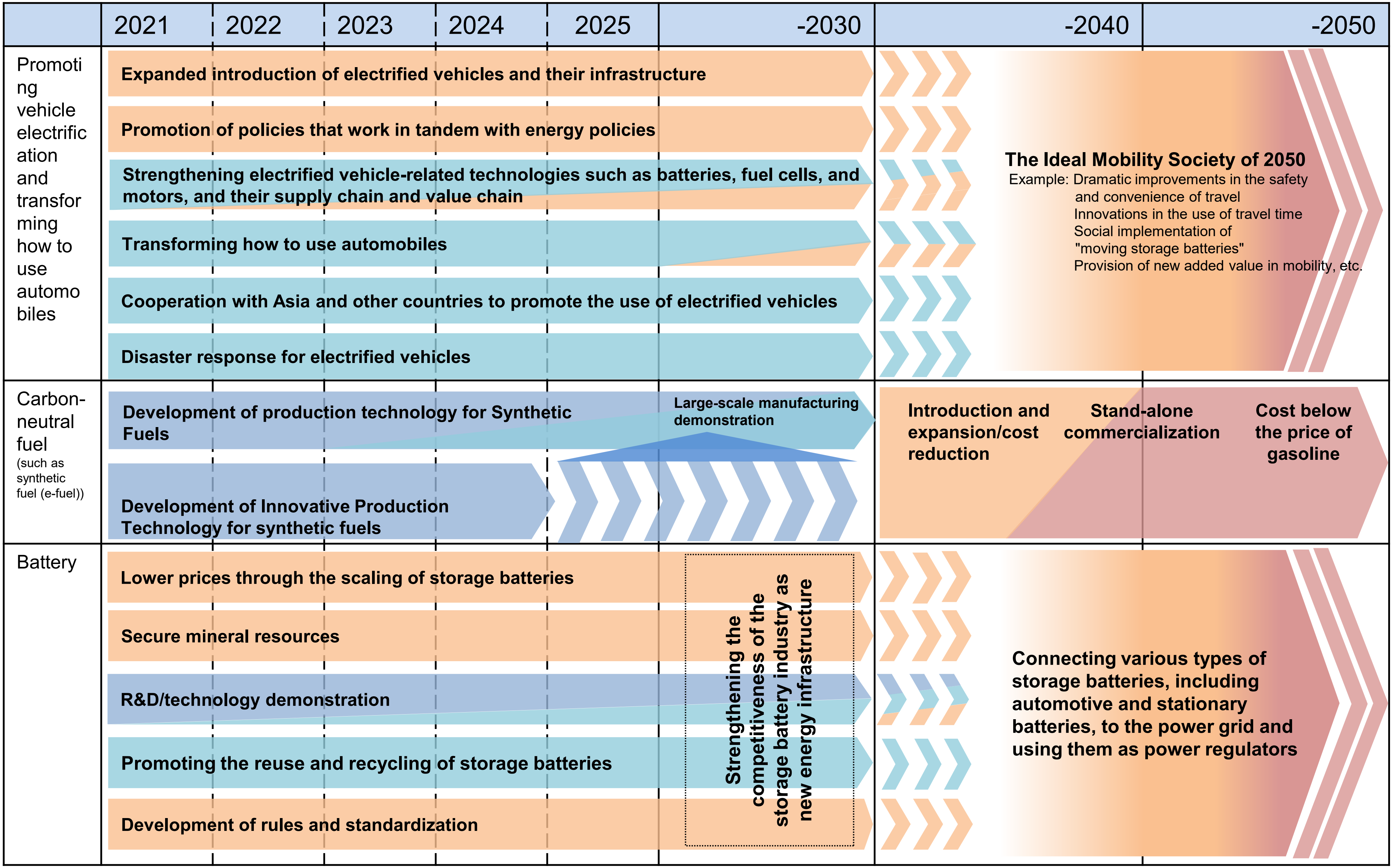
Promotion of human resources development and academic research

Venture companies of USA, UK, etc. target practical application by around 2030

Japanese venture companies, etc. participate in overseas projects as R&D partners and suppliers, and deliver equipment

(5) “Roadmap” of Growth Strategies for Automobile and Battery Industries

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

Promoting vehicle electrification and transforming how to use automobiles

- **Expanded introduction of electrified vehicles and their infrastructure**
- **Promotion of policies that work in tandem with energy policies**
- **Strengthening electrified vehicle-related technologies such as batteries, fuel cells, and motors, and their supply chain and value chain**
- **Transforming how to use automobiles**
- **Cooperation with Asia and other countries to promote the use of electrified vehicles**
- **Disaster response for electrified vehicles**

The Ideal Mobility Society of 2050

Example: Dramatic improvements in the safety and convenience of travel
Innovations in the use of travel time
Social implementation of "moving storage batteries"
Provision of new added value in mobility, etc.

Carbon-neutral fuel (such as synthetic fuel (e-fuel))

- **Development of production technology for Synthetic Fuels**
- **Large-scale manufacturing demonstration**
- **Development of Innovative Production Technology for synthetic fuels**

Introduction and expansion/cost reduction → **Stand-alone commercialization** → **Cost below the price of gasoline**

Battery

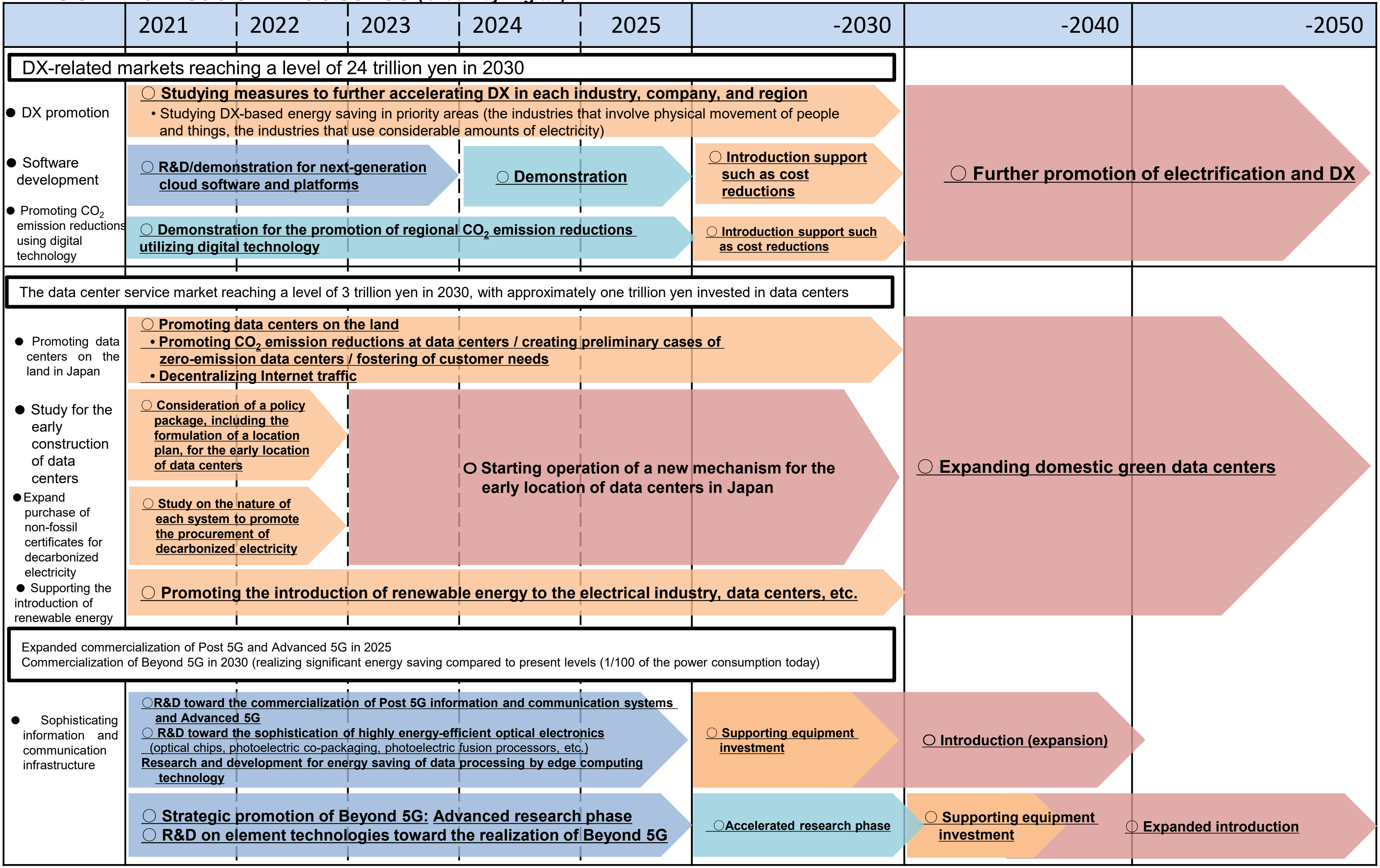
- **Lower prices through the scaling of storage batteries**
- **Secure mineral resources**
- **R&D/technology demonstration**
- **Promoting the reuse and recycling of storage batteries**
- **Development of rules and standardization**

Strengthening the competitiveness of the storage battery industry as new energy infrastructure

Connecting various types of storage batteries, including automotive and stationary batteries, to the power grid and using them as power regulators

(6) "Roadmap" of Growth Strategies for Semiconductor/Information and Communication Industries (Green by Digital)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



DX-related markets reaching a level of 24 trillion yen in 2030

- DX promotion
- Software development
- Promoting CO_2 emission reductions using digital technology

○ **Studying measures to further accelerating DX in each industry, company, and region**
• Studying DX-based energy saving in priority areas (the industries that involve physical movement of people and things, the industries that use considerable amounts of electricity)

○ **R&D/demonstration for next-generation cloud software and platforms**

○ **Demonstration**

○ **Introduction support such as cost reductions**

○ **Demonstration for the promotion of regional CO_2 emission reductions utilizing digital technology**

○ **Introduction support such as cost reductions**

○ **Further promotion of electrification and DX**

The data center service market reaching a level of 3 trillion yen in 2030, with approximately one trillion yen invested in data centers

- Promoting data centers on the land in Japan
- Study for the early construction of data centers
- Expand purchase of non-fossil certificates for decarbonized electricity
- Supporting the introduction of renewable energy

○ **Promoting data centers on the land**
• **Promoting CO_2 emission reductions at data centers / creating preliminary cases of zero-emission data centers / fostering of customer needs**
• **Decentralizing Internet traffic**

○ **Consideration of a policy package, including the formulation of a location plan, for the early location of data centers**

○ **Study on the nature of each system to promote the procurement of decarbonized electricity**

O **Starting operation of a new mechanism for the early location of data centers in Japan**

○ **Expanding domestic green data centers**

○ **Promoting the introduction of renewable energy to the electrical industry, data centers, etc.**

Expanded commercialization of Post 5G and Advanced 5G in 2025
Commercialization of Beyond 5G in 2030 (realizing significant energy saving compared to present levels (1/100 of the power consumption today)

- Sophisticating information and communication infrastructure

○**R&D toward the commercialization of Post 5G information and communication systems and Advanced 5G**
○ **R&D toward the sophistication of highly energy-efficient optical electronics**
(optical chips, photoelectric co-packaging, photoelectric fusion processors, etc.)
Research and development for energy saving of data processing by edge computing technology

○ **Supporting equipment investment**

○ **Introduction (expansion)**

○ **Strategic promotion of Beyond 5G: Advanced research phase**
○ **R&D on element technologies toward the realization of Beyond 5G**

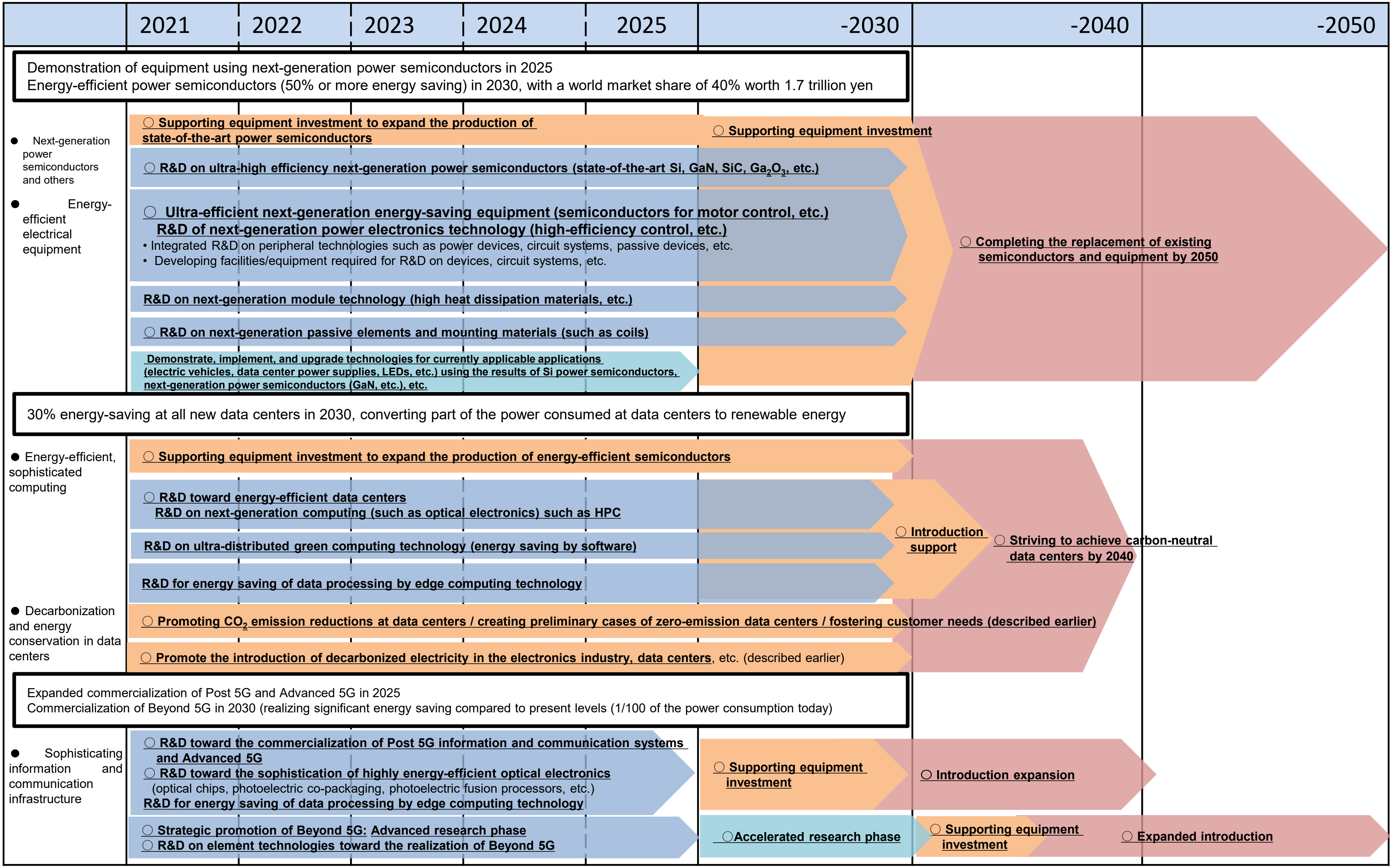
○**Accelerated research phase**

○ **Supporting equipment investment**

○ **Expanded introduction**

(6) "Roadmap" of Growth Strategies for Semiconductor/Information and Communication Industries (Green of Digital)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



Demonstration of equipment using next-generation power semiconductors in 2025
Energy-efficient power semiconductors (50% or more energy saving) in 2030, with a world market share of 40% worth 1.7 trillion yen

- Next-generation power semiconductors and others
- Energy-efficient electrical equipment

○ **Supporting equipment investment to expand the production of state-of-the-art power semiconductors**

○ **Supporting equipment investment**

○ **R&D on ultra-high efficiency next-generation power semiconductors (state-of-the-art Si, GaN, SiC, Ga_2O_3, etc.)**

○ **Ultra-efficient next-generation energy-saving equipment (semiconductors for motor control, etc.)**
R&D of next-generation power electronics technology (high-efficiency control, etc.)
- Integrated R&D on peripheral technologies such as power devices, circuit systems, passive devices, etc.
- Developing facilities/equipment required for R&D on devices, circuit systems, etc.

R&D on next-generation module technology (high heat dissipation materials, etc.)

○ **R&D on next-generation passive elements and mounting materials (such as coils)**

Demonstrate, implement, and upgrade technologies for currently applicable applications (electric vehicles, data center power supplies, LEDs, etc.) using the results of Si power semiconductors, next-generation power semiconductors (GaN, etc.), etc.

○ **Completing the replacement of existing semiconductors and equipment by 2050**

30% energy-saving at all new data centers in 2030, converting part of the power consumed at data centers to renewable energy

- Energy-efficient, sophisticated computing

○ **Supporting equipment investment to expand the production of energy-efficient semiconductors**

○ **R&D toward energy-efficient data centers**
R&D on next-generation computing (such as optical electronics) such as HPC

R&D on ultra-distributed green computing technology (energy saving by software)

R&D for energy saving of data processing by edge computing technology

○ **Introduction support**

○ **Striving to achieve carbon-neutral data centers by 2040**

- Decarbonization and energy conservation in data centers

○ **Promoting CO_2 emission reductions at data centers / creating preliminary cases of zero-emission data centers / fostering customer needs (described earlier)**

○ **Promote the introduction of decarbonized electricity in the electronics industry, data centers**, etc. (described earlier)

Expanded commercialization of Post 5G and Advanced 5G in 2025
Commercialization of Beyond 5G in 2030 (realizing significant energy saving compared to present levels (1/100 of the power consumption today)

- Sophisticating information and communication infrastructure

○ **R&D toward the commercialization of Post 5G information and communication systems and Advanced 5G**
○ **R&D toward the sophistication of highly energy-efficient optical electronics**
(optical chips, photoelectric co-packaging, photoelectric fusion processors, etc.)
R&D for energy saving of data processing by edge computing technology

○ **Supporting equipment investment**

○ **Introduction expansion**

○ **Strategic promotion of Beyond 5G: Advanced research phase**
○ **R&D on element technologies toward the realization of Beyond 5G**

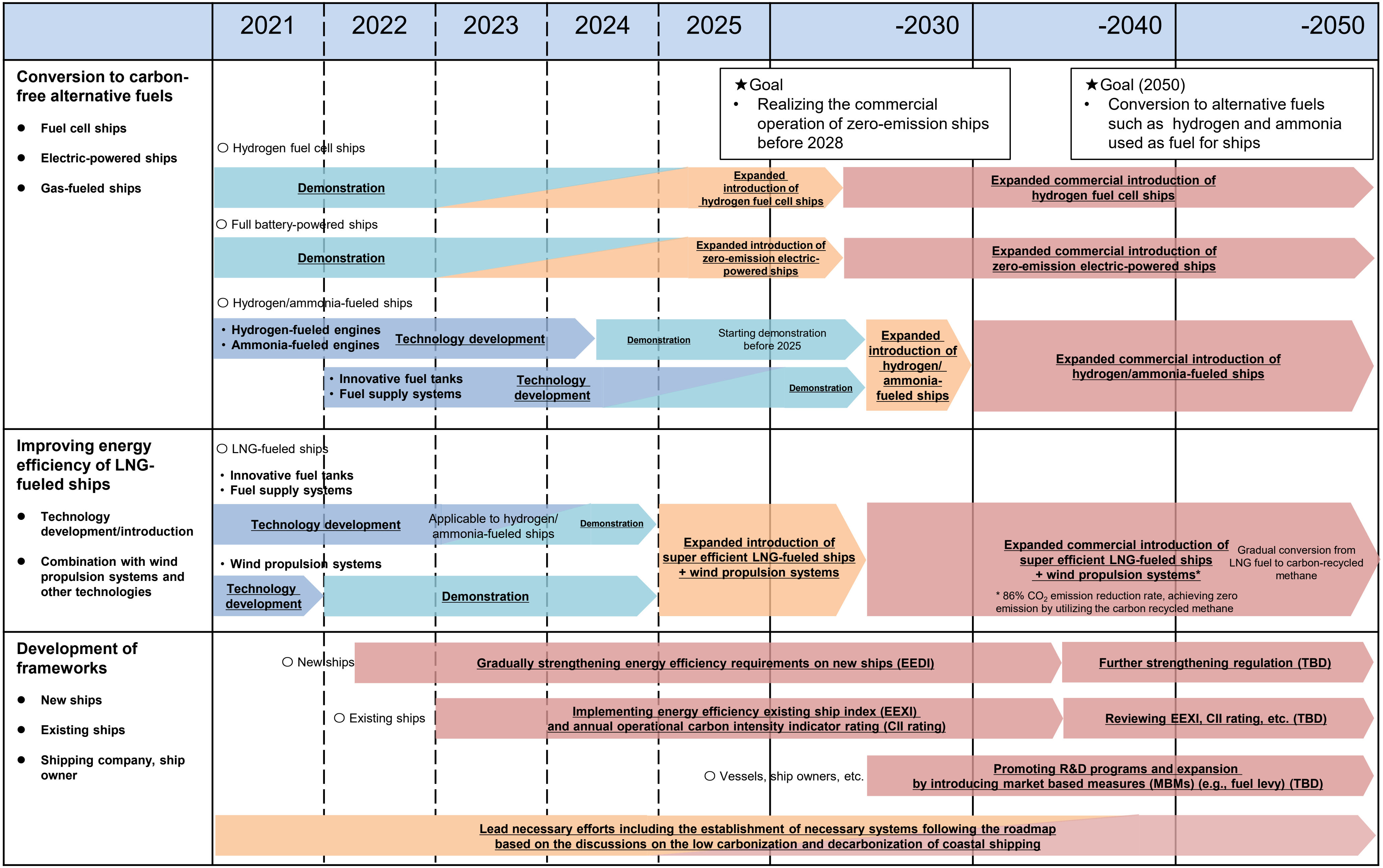
○**Accelerated research phase**

○ **Supporting equipment investment**

○ **Expanded introduction**

(7) "Roadmap" of Growth Strategies for Shipping Industry

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

Conversion to carbon-free alternative fuels

- Fuel cell ships
- Electric-powered ships
- Gas-fueled ships

★Goal
- Realizing the commercial operation of zero-emission ships before 2028

★Goal (2050)
- Conversion to alternative fuels such as hydrogen and ammonia used as fuel for ships

○ Hydrogen fuel cell ships

Demonstration → Expanded introduction of hydrogen fuel cell ships → Expanded commercial introduction of hydrogen fuel cell ships

○ Full battery-powered ships

Demonstration → Expanded introduction of zero-emission electric-powered ships → Expanded commercial introduction of zero-emission electric-powered ships

○ Hydrogen/ammonia-fueled ships

- Hydrogen-fueled engines
- Ammonia-fueled engines

Technology development → Demonstration (Starting demonstration before 2025)

- Innovative fuel tanks
- Fuel supply systems

Technology development → Demonstration

→ Expanded introduction of hydrogen/ ammonia-fueled ships → Expanded commercial introduction of hydrogen/ammonia-fueled ships

Improving energy efficiency of LNG-fueled ships

- Technology development/introduction
- Combination with wind propulsion systems and other technologies

○ LNG-fueled ships

- Innovative fuel tanks
- Fuel supply systems

Technology development → Applicable to hydrogen/ ammonia-fueled ships → Demonstration

- Wind propulsion systems

Technology development → Demonstration

→ Expanded introduction of super efficient LNG-fueled ships + wind propulsion systems → Expanded commercial introduction of super efficient LNG-fueled ships + wind propulsion systems*

Gradual conversion from LNG fuel to carbon-recycled methane

* 86% CO_2 emission reduction rate, achieving zero emission by utilizing the carbon recycled methane

Development of frameworks

- New ships
- Existing ships
- Shipping company, ship owner

○ New ships: Gradually strengthening energy efficiency requirements on new ships (EEDI) → Further strengthening regulation (TBD)

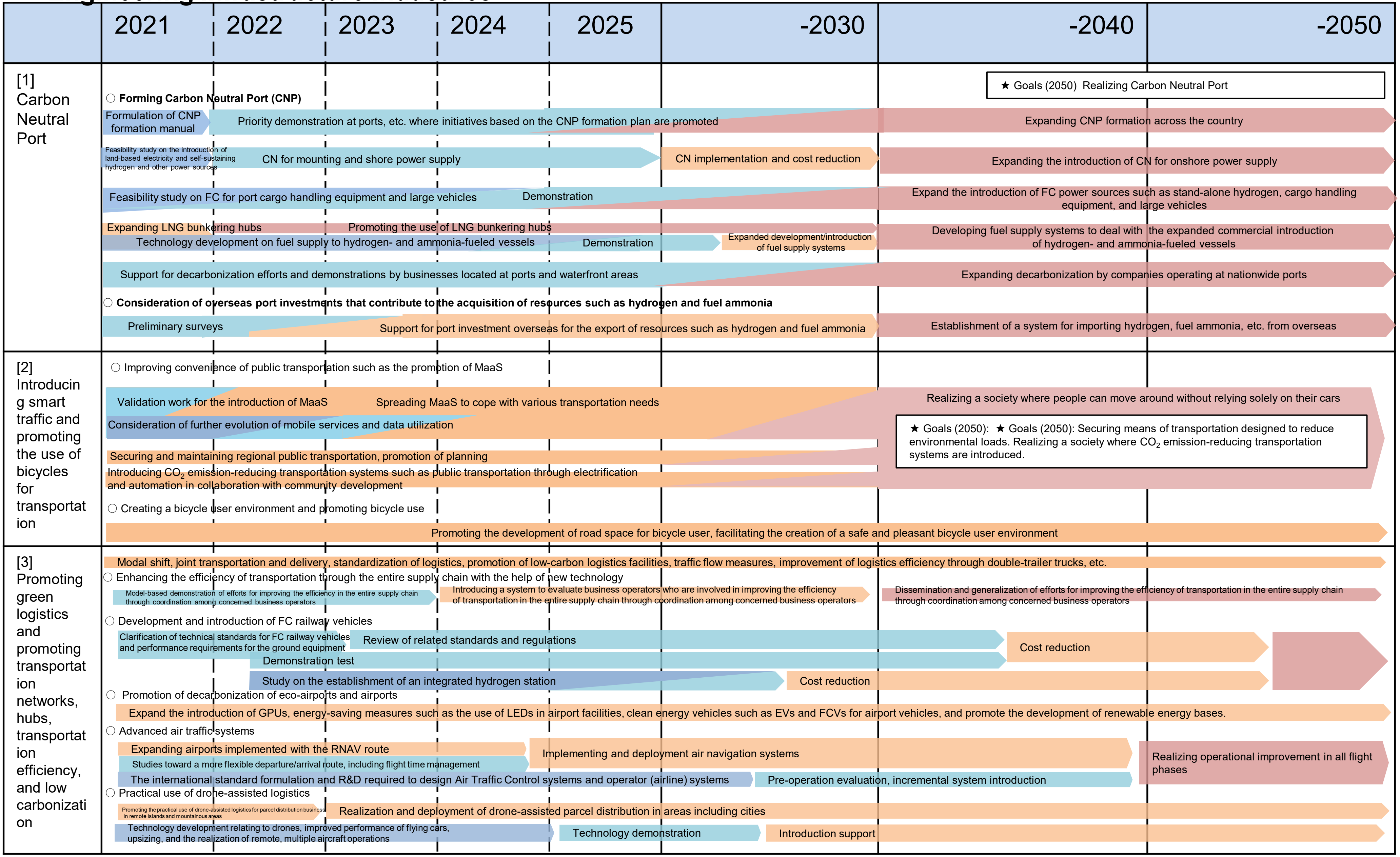
○ Existing ships: Implementing energy efficiency existing ship index (EEXI) and annual operational carbon intensity indicator rating (CII rating) → Reviewing EEXI, CII rating, etc. (TBD)

○ Vessels, ship owners, etc.: Promoting R&D programs and expansion by introducing market based measures (MBMs) (e.g., fuel levy) (TBD)

Lead necessary efforts including the establishment of necessary systems following the roadmap based on the discussions on the low carbonization and decarbonization of coastal shipping

(8) "Roadmap" of Growth Strategies for Logistics, People Flow, and Civil Engineering Infrastructure Industries

- **Introduction phase:** **1. Development phase** → **2. Demonstration phase** → **3. Introduction and expansion/cost reduction phase** → **4. Autonomous commercialization phase**
- **Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.**



[1] Carbon Neutral Port

★ Goals (2050) Realizing Carbon Neutral Port

○ **Forming Carbon Neutral Port (CNP)**

Formulation of CNP formation manual → Priority demonstration at ports, etc. where initiatives based on the CNP formation plan are promoted → Expanding CNP formation across the country

Feasibility study on the introduction of land-based electricity and self-sustaining hydrogen and other power sources → CN for mounting and shore power supply → CN implementation and cost reduction → Expanding the introduction of CN for onshore power supply

Feasibility study on FC for port cargo handling equipment and large vehicles → Demonstration → Expand the introduction of FC power sources such as stand-alone hydrogen, cargo handling equipment, and large vehicles

Expanding LNG bunkering hubs → Promoting the use of LNG bunkering hubs

Technology development on fuel supply to hydrogen- and ammonia-fueled vessels → Demonstration → Expanded development/introduction of fuel supply systems → Developing fuel supply systems to deal with the expanded commercial introduction of hydrogen- and ammonia-fueled vessels

Support for decarbonization efforts and demonstrations by businesses located at ports and waterfront areas → Expanding decarbonization by companies operating at nationwide ports

○ **Consideration of overseas port investments that contribute to the acquisition of resources such as hydrogen and fuel ammonia**

Preliminary surveys → Support for port investment overseas for the export of resources such as hydrogen and fuel ammonia → Establishment of a system for importing hydrogen, fuel ammonia, etc. from overseas

[2] Introducing smart traffic and promoting the use of bicycles for transportation

○ Improving convenience of public transportation such as the promotion of MaaS

Validation work for the introduction of MaaS → Spreading MaaS to cope with various transportation needs

Consideration of further evolution of mobile services and data utilization

Securing and maintaining regional public transportation, promotion of planning

Introducing CO_2 emission-reducing transportation systems such as public transportation through electrification and automation in collaboration with community development

→ Realizing a society where people can move around without relying solely on their cars

★ Goals (2050): ★ Goals (2050): Securing means of transportation designed to reduce environmental loads. Realizing a society where CO_2 emission-reducing transportation systems are introduced.

○ Creating a bicycle user environment and promoting bicycle use

Promoting the development of road space for bicycle user, facilitating the creation of a safe and pleasant bicycle user environment

[3] Promoting green logistics and promoting transportation networks, hubs, transportation efficiency, and low carbonization

Modal shift, joint transportation and delivery, standardization of logistics, promotion of low-carbon logistics facilities, traffic flow measures, improvement of logistics efficiency through double-trailer trucks, etc.

○ Enhancing the efficiency of transportation through the entire supply chain with the help of new technology

Model-based demonstration of efforts for improving the efficiency in the entire supply chain through coordination among concerned business operators → Introducing a system to evaluate business operators who are involved in improving the efficiency of transportation in the entire supply chain through coordination among concerned business operators → Dissemination and generalization of efforts for improving the efficiency of transportation in the entire supply chain through coordination among concerned business operators

○ Development and introduction of FC railway vehicles

Clarification of technical standards for FC railway vehicles and performance requirements for the ground equipment → Review of related standards and regulations → Cost reduction

Demonstration test

Study on the establishment of an integrated hydrogen station → Cost reduction

○ Promotion of decarbonization of eco-airports and airports

Expand the introduction of GPUs, energy-saving measures such as the use of LEDs in airport facilities, clean energy vehicles such as EVs and FCVs for airport vehicles, and promote the development of renewable energy bases.

○ Advanced air traffic systems

Expanding airports implemented with the RNAV route

Studies toward a more flexible departure/arrival route, including flight time management

→ Implementing and deployment air navigation systems → Realizing operational improvement in all flight phases

The international standard formulation and R&D required to design Air Traffic Control systems and operator (airline) systems → Pre-operation evaluation, incremental system introduction

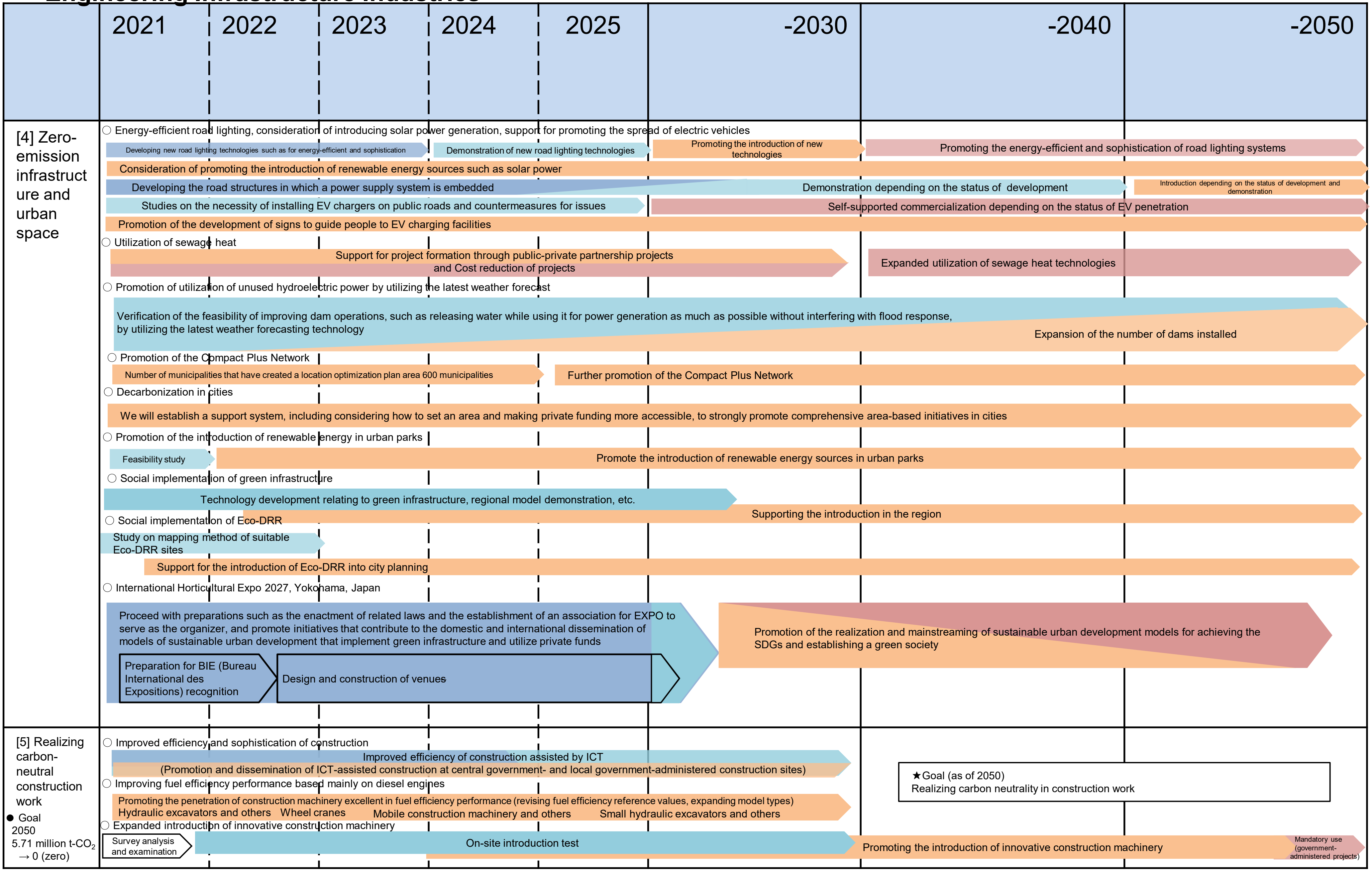
○ Practical use of drone-assisted logistics

Promoting the practical use of drone-assisted logistics for parcel distribution business in remote islands and mountainous areas → Realization and deployment of drone-assisted parcel distribution in areas including cities

Technology development relating to drones, improved performance of flying cars, upsizing, and the realization of remote, multiple aircraft operations → Technology demonstration → Introduction support

(8) "Roadmap" of Growth Strategies for Logistics, People Flow, and Civil Engineering Infrastructure Industries

- **Introduction phase:** **1. Development phase** **2. Demonstration phase** **3. Introduction and expansion/cost reduction phase** **4. Autonomous commercialization phase**
- **Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.**



2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

[4] Zero-emission infrastructure and urban space

○ Energy-efficient road lighting, consideration of introducing solar power generation, support for promoting the spread of electric vehicles

Developing new road lighting technologies such as for energy-efficient and sophistication

Demonstration of new road lighting technologies

Promoting the introduction of new technologies

Promoting the energy-efficient and sophistication of road lighting systems

Consideration of promoting the introduction of renewable energy sources such as solar power

Developing the road structures in which a power supply system is embedded

Demonstration depending on the status of development

Introduction depending on the status of development and demonstration

Studies on the necessity of installing EV chargers on public roads and countermeasures for issues

Self-supported commercialization depending on the status of EV penetration

Promotion of the development of signs to guide people to EV charging facilities

○ Utilization of sewage heat

Support for project formation through public-private partnership projects and Cost reduction of projects

Expanded utilization of sewage heat technologies

○ Promotion of utilization of unused hydroelectric power by utilizing the latest weather forecast

Verification of the feasibility of improving dam operations, such as releasing water while using it for power generation as much as possible without interfering with flood response, by utilizing the latest weather forecasting technology

Expansion of the number of dams installed

○ Promotion of the Compact Plus Network

Number of municipalities that have created a location optimization plan area 600 municipalities

Further promotion of the Compact Plus Network

○ Decarbonization in cities

We will establish a support system, including considering how to set an area and making private funding more accessible, to strongly promote comprehensive area-based initiatives in cities

○ Promotion of the introduction of renewable energy in urban parks

Feasibility study

Promote the introduction of renewable energy sources in urban parks

○ Social implementation of green infrastructure

Technology development relating to green infrastructure, regional model demonstration, etc.

Supporting the introduction in the region

○ Social implementation of Eco-DRR

Study on mapping method of suitable Eco-DRR sites

Support for the introduction of Eco-DRR into city planning

○ International Horticultural Expo 2027, Yokohama, Japan

Proceed with preparations such as the enactment of related laws and the establishment of an association for EXPO to serve as the organizer, and promote initiatives that contribute to the domestic and international dissemination of models of sustainable urban development that implement green infrastructure and utilize private funds

Preparation for BIE (Bureau International des Expositions) recognition

Design and construction of venues

Promotion of the realization and mainstreaming of sustainable urban development models for achieving the SDGs and establishing a green society

[5] Realizing carbon-neutral construction work

● Goal
2050
5.71 million t-CO_2
→ 0 (zero)

○ Improved efficiency and sophistication of construction

Improved efficiency of construction assisted by ICT
(Promotion and dissemination of ICT-assisted construction at central government- and local government-administered construction sites)

★Goal (as of 2050)
Realizing carbon neutrality in construction work

○ Improving fuel efficiency performance based mainly on diesel engines

Promoting the penetration of construction machinery excellent in fuel efficiency performance (revising fuel efficiency reference values, expanding model types)
Hydraulic excavators and others Wheel cranes Mobile construction machinery and others Small hydraulic excavators and others

○ Expanded introduction of innovative construction machinery

Survey analysis and examination

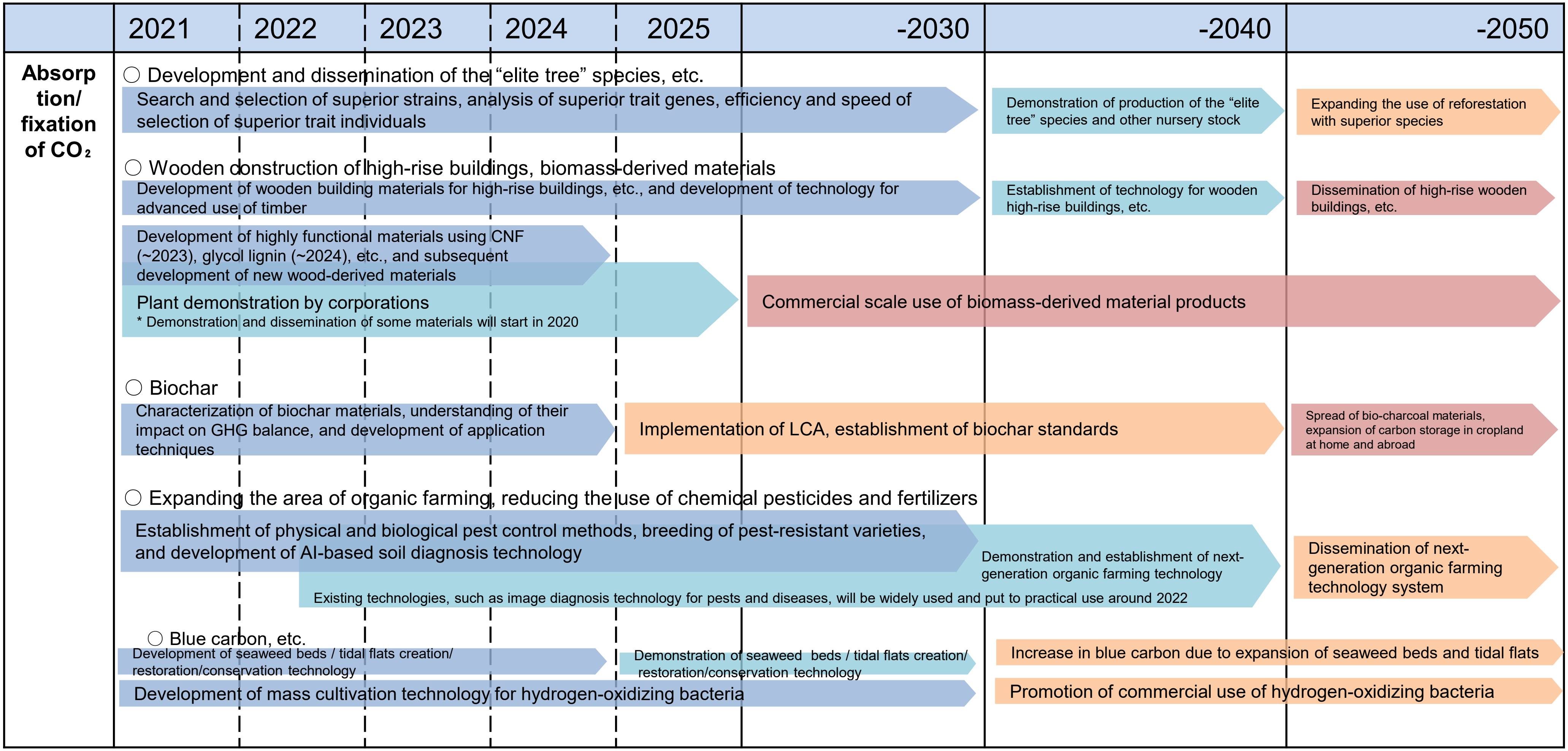
On-site introduction test

Promoting the introduction of innovative construction machinery

Mandatory use (government-administered projects)

(9) "Roadmap" of Growth Strategies for Food, Agriculture, Forestry and Fisheries

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



Absorption/ fixation of CO_2

○ Development and dissemination of the "elite tree" species, etc.

- Search and selection of superior strains, analysis of superior trait genes, efficiency and speed of selection of superior trait individuals
- Demonstration of production of the "elite tree" species and other nursery stock
- Expanding the use of reforestation with superior species

○ Wooden construction of high-rise buildings, biomass-derived materials

- Development of wooden building materials for high-rise buildings, etc., and development of technology for advanced use of timber
- Establishment of technology for wooden high-rise buildings, etc.
- Dissemination of high-rise wooden buildings, etc.
- Development of highly functional materials using CNF (~2023), glycol lignin (~2024), etc., and subsequent development of new wood-derived materials
- Plant demonstration by corporations
  * Demonstration and dissemination of some materials will start in 2020
- Commercial scale use of biomass-derived material products

○ Biochar

- Characterization of biochar materials, understanding of their impact on GHG balance, and development of application techniques
- Implementation of LCA, establishment of biochar standards
- Spread of bio-charcoal materials, expansion of carbon storage in cropland at home and abroad

○ Expanding the area of organic farming, reducing the use of chemical pesticides and fertilizers

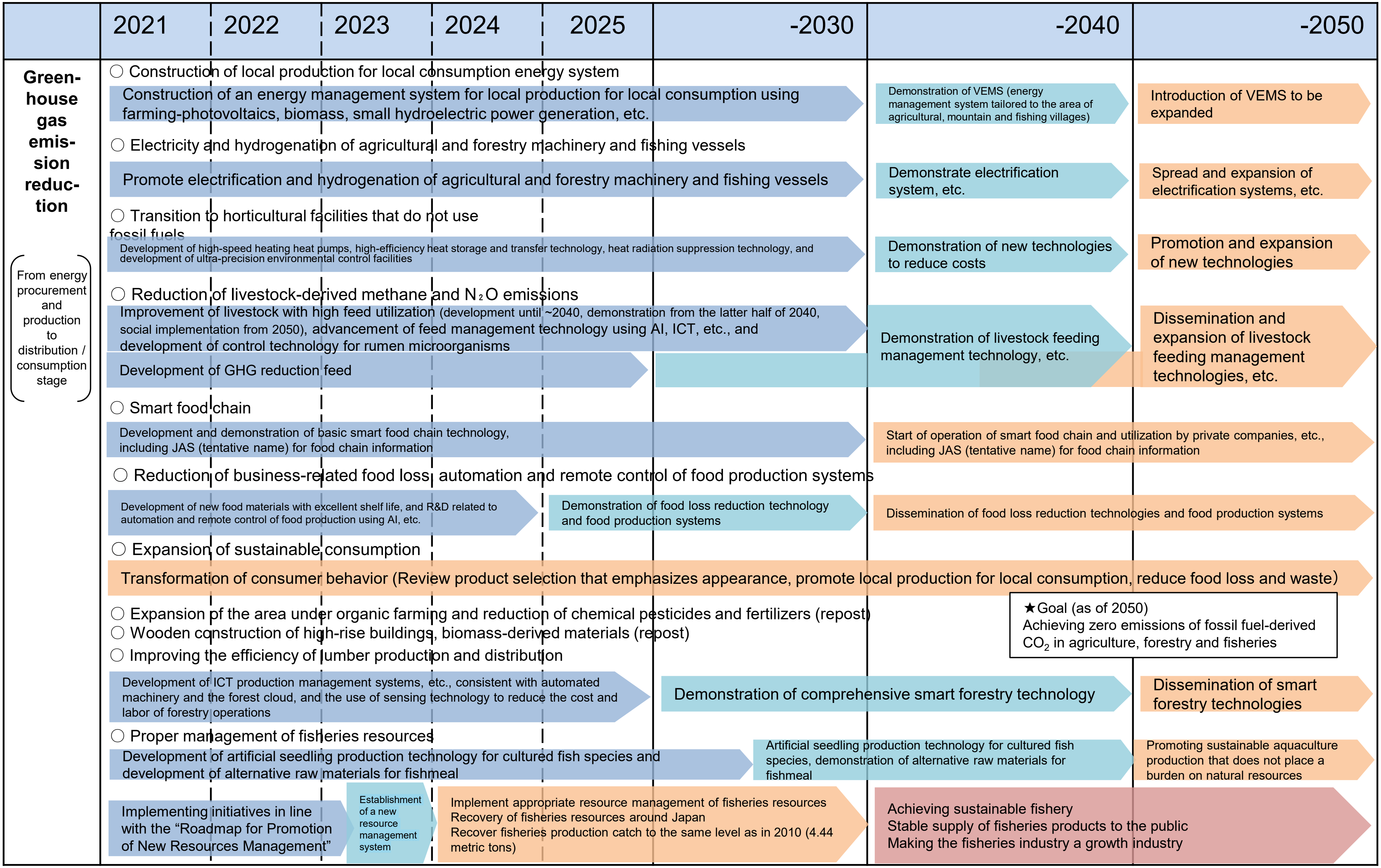
- Establishment of physical and biological pest control methods, breeding of pest-resistant varieties, and development of AI-based soil diagnosis technology
- Demonstration and establishment of next-generation organic farming technology
  Existing technologies, such as image diagnosis technology for pests and diseases, will be widely used and put to practical use around 2022
- Dissemination of next-generation organic farming technology system

○ Blue carbon, etc.

- Development of seaweed beds / tidal flats creation/ restoration/conservation technology
- Demonstration of seaweed beds / tidal flats creation/ restoration/conservation technology
- Increase in blue carbon due to expansion of seaweed beds and tidal flats
- Development of mass cultivation technology for hydrogen-oxidizing bacteria
- Promotion of commercial use of hydrogen-oxidizing bacteria

(9) "Roadmap" of Growth Strategies for Food, Agriculture, Forestry and Fisheries

- **Introduction phase:** **1. Development phase** **2. Demonstration phase** **3. Introduction and expansion/cost reduction phase** **4. Autonomous commercialization phase**
- **Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.**



2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

Greenhouse gas emission reduction

From energy procurement and production to distribution / consumption stage

○ Construction of local production for local consumption energy system

Construction of an energy management system for local production for local consumption using farming-photovoltaics, biomass, small hydroelectric power generation, etc.

Demonstration of VEMS (energy management system tailored to the area of agricultural, mountain and fishing villages)

Introduction of VEMS to be expanded

○ Electricity and hydrogenation of agricultural and forestry machinery and fishing vessels

Promote electrification and hydrogenation of agricultural and forestry machinery and fishing vessels

Demonstrate electrification system, etc.

Spread and expansion of electrification systems, etc.

○ Transition to horticultural facilities that do not use fossil fuels

Development of high-speed heating heat pumps, high-efficiency heat storage and transfer technology, heat radiation suppression technology, and development of ultra-precision environmental control facilities

Demonstration of new technologies to reduce costs

Promotion and expansion of new technologies

○ Reduction of livestock-derived methane and N_2O emissions

Improvement of livestock with high feed utilization (development until ~2040, demonstration from the latter half of 2040, social implementation from 2050), advancement of feed management technology using AI, ICT, etc., and development of control technology for rumen microorganisms

Development of GHG reduction feed

Demonstration of livestock feeding management technology, etc.

Dissemination and expansion of livestock feeding management technologies, etc.

○ Smart food chain

Development and demonstration of basic smart food chain technology, including JAS (tentative name) for food chain information

Start of operation of smart food chain and utilization by private companies, etc., including JAS (tentative name) for food chain information

○ Reduction of business-related food loss, automation and remote control of food production systems

Development of new food materials with excellent shelf life, and R&D related to automation and remote control of food production using AI, etc.

Demonstration of food loss reduction technology and food production systems

Dissemination of food loss reduction technologies and food production systems

○ Expansion of sustainable consumption

Transformation of consumer behavior (Review product selection that emphasizes appearance, promote local production for local consumption, reduce food loss and waste)

○ Expansion of the area under organic farming and reduction of chemical pesticides and fertilizers (repost)
○ Wooden construction of high-rise buildings, biomass-derived materials (repost)
○ Improving the efficiency of lumber production and distribution

★Goal (as of 2050)
Achieving zero emissions of fossil fuel-derived CO_2 in agriculture, forestry and fisheries

Development of ICT production management systems, etc., consistent with automated machinery and the forest cloud, and the use of sensing technology to reduce the cost and labor of forestry operations

Demonstration of comprehensive smart forestry technology

Dissemination of smart forestry technologies

○ Proper management of fisheries resources

Development of artificial seedling production technology for cultured fish species and development of alternative raw materials for fishmeal

Artificial seedling production technology for cultured fish species, demonstration of alternative raw materials for fishmeal

Promoting sustainable aquaculture production that does not place a burden on natural resources

Implementing initiatives in line with the “Roadmap for Promotion of New Resources Management”

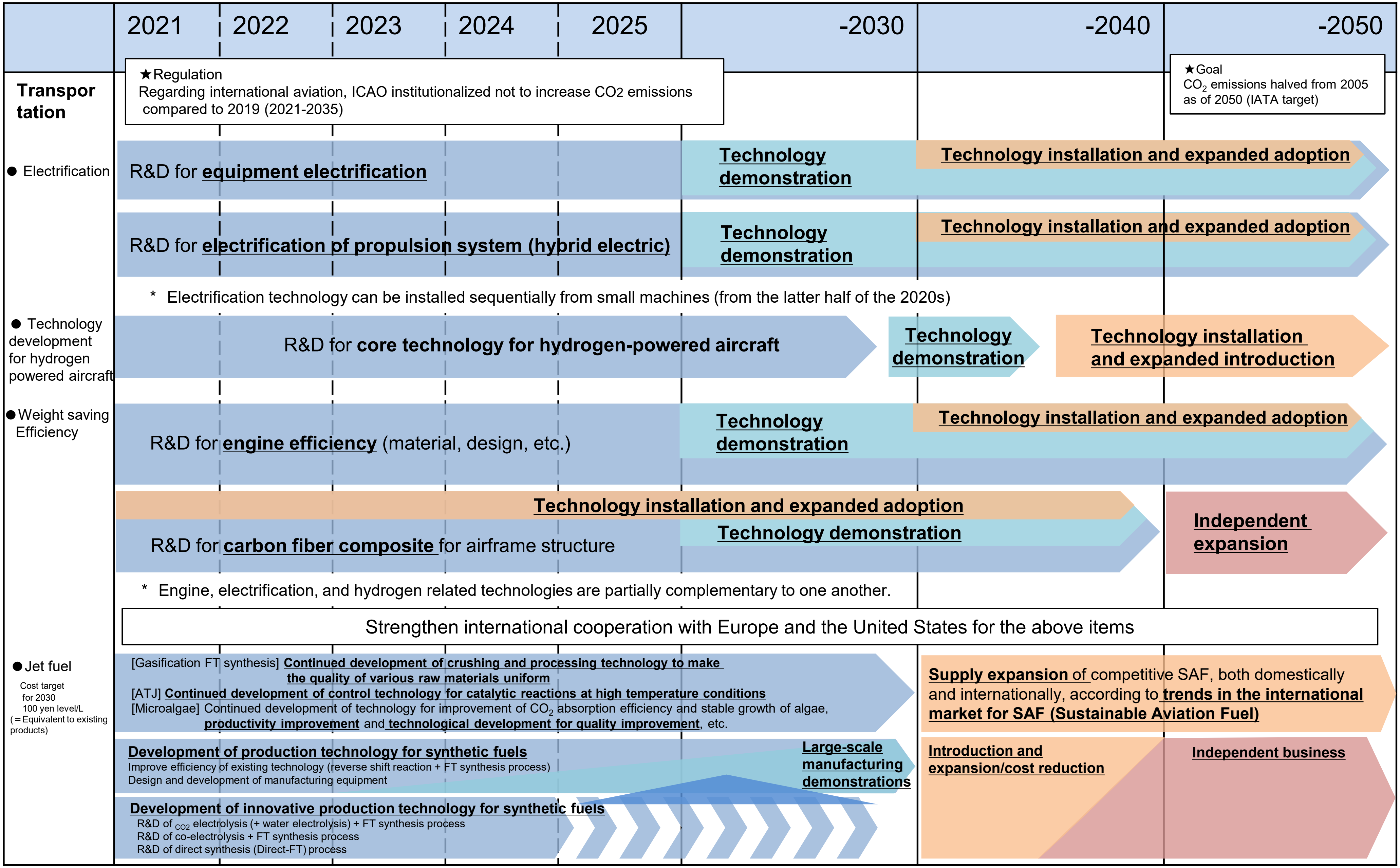
Establishment of a new resource management system

Implement appropriate resource management of fisheries resources
Recovery of fisheries resources around Japan
Recover fisheries production catch to the same level as in 2010 (4.44 metric tons)

Achieving sustainable fishery
Stable supply of fisheries products to the public
Making the fisheries industry a growth industry

(10) "Roadmap" of Growth Strategies for aircraft industry

- **Introduction phase:** **1. Development phase** → **2. Demonstration phase** → **3. Introduction and expansion/cost reduction phase** → **4. Autonomous commercialization phase**
- **Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.**



	2021	2022	2023	2024	2025	-2030	-2040	-2050

Transportation

★Regulation
Regarding international aviation, ICAO institutionalized not to increase CO2 emissions compared to 2019 (2021-2035)

★Goal
CO_2 emissions halved from 2005 as of 2050 (IATA target)

● Electrification

R&D for **equipment electrification** → **Technology demonstration** → **Technology installation and expanded adoption**

R&D for **electrification pf propulsion system (hybrid electric)** → **Technology demonstration** → **Technology installation and expanded adoption**

* Electrification technology can be installed sequentially from small machines (from the latter half of the 2020s)

● Technology development for hydrogen powered aircraft

R&D for **core technology for hydrogen-powered aircraft** → **Technology demonstration** → **Technology installation and expanded introduction**

● Weight saving Efficiency

R&D for **engine efficiency** (material, design, etc.) → **Technology demonstration** → **Technology installation and expanded adoption**

Technology installation and expanded adoption

R&D for **carbon fiber composite** for airframe structure → **Technology demonstration** → **Independent expansion**

* Engine, electrification, and hydrogen related technologies are partially complementary to one another.

Strengthen international cooperation with Europe and the United States for the above items

● Jet fuel

Cost target
for 2030
100 yen level/L
(＝Equivalent to existing products)

[Gasification FT synthesis] **Continued development of crushing and processing technology to make the quality of various raw materials uniform**
[ATJ] **Continued development of control technology for catalytic reactions at high temperature conditions**
[Microalgae] Continued development of technology for improvement of CO_2 absorption efficiency and stable growth of algae, **productivity improvement** and **technological development for quality improvement**, etc.

→ **Supply expansion** of competitive SAF, both domestically and internationally, according to **trends in the international market for SAF (Sustainable Aviation Fuel)**

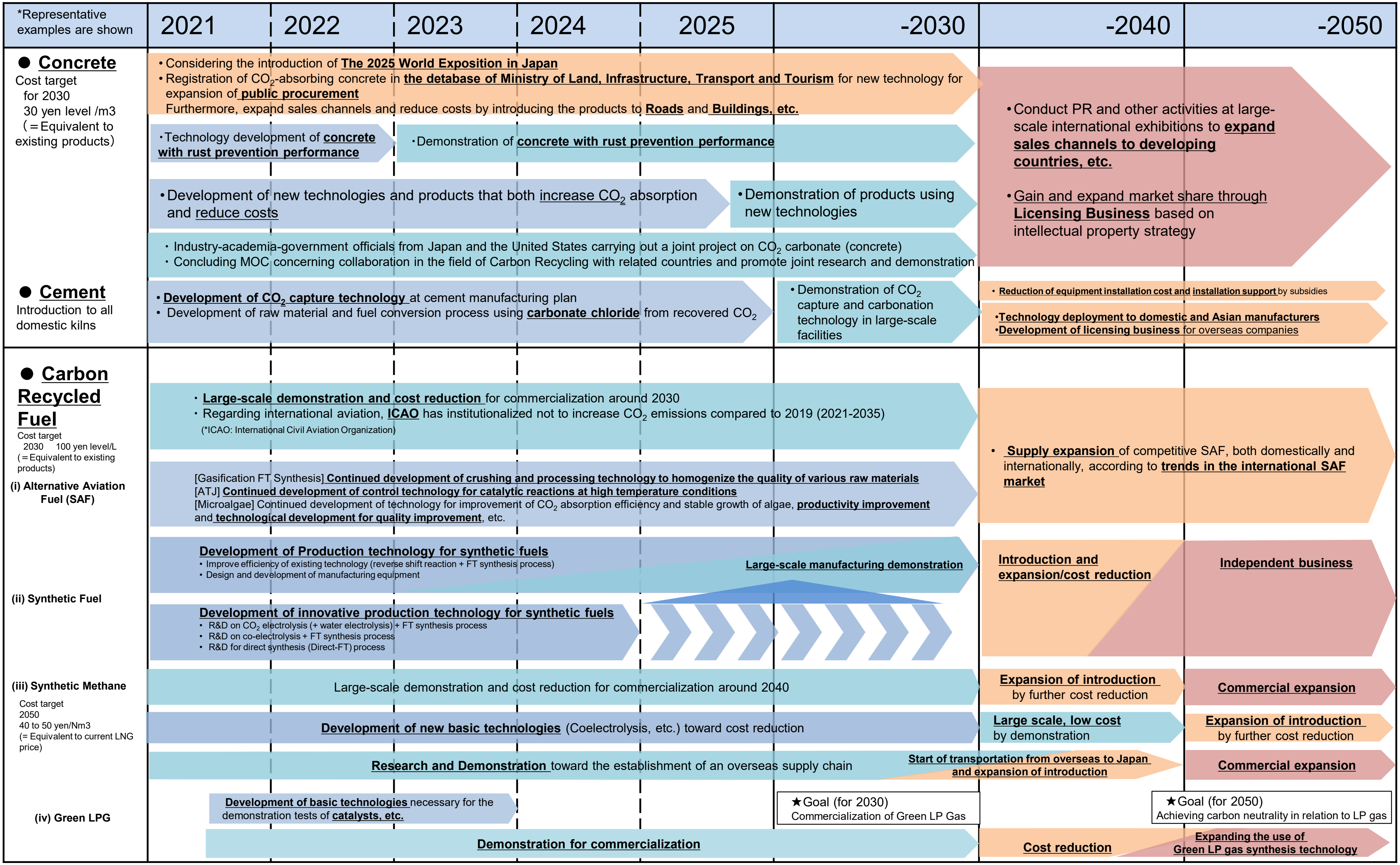
Development of production technology for synthetic fuels
Improve efficiency of existing technology (reverse shift reaction + FT synthesis process)
Design and development of manufacturing equipment

Development of innovative production technology for synthetic fuels
R&D of $_{CO2}$ electrolysis (+ water electrolysis) + FT synthesis process
R&D of co-electrolysis + FT synthesis process
R&D of direct synthesis (Direct-FT) process

→ **Large-scale manufacturing demonstrations** → **Introduction and expansion/cost reduction** → **Independent business**

(11) "Roadmap" of Growth Strategies for the Carbon Recycling and Materials Industries (Carbon Recycling)

- Introduction phase: 1. Development phase | 2. Demonstration phase | 3. Introduction and expansion/cost reduction phase | 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



*Representative examples are shown	2021	2022	2023	2024	2025	-2030	-2040	-2050
● **Concrete** Cost target for 2030 30 yen level /m3 (＝Equivalent to existing products)	• Considering the introduction of **The 2025 World Exposition in Japan** • Registration of CO_2-absorbing concrete in **the detabase of Ministry of Land, Infrastructure, Transport and Tourism** for new technology for expansion of **public procurement** Furthermore, expand sales channels and reduce costs by introducing the products to **Roads** and **Buildings, etc.**						• Conduct PR and other activities at large-scale international exhibitions to **expand sales channels to developing countries, etc.** • Gain and expand market share through **Licensing Business** based on intellectual property strategy	
	・Technology development of **concrete with rust prevention performance**		・Demonstration of **concrete with rust prevention performance**					
	• Development of new technologies and products that both increase CO_2 absorption and reduce costs				• Demonstration of products using new technologies			
	・ Industry-academia-government officials from Japan and the United States carrying out a joint project on CO_2 carbonate (concrete) ・ Concluding MOC concerning collaboration in the field of Carbon Recycling with related countries and promote joint research and demonstration							
● **Cement** Introduction to all domestic kilns	• **Development of CO_2 capture technology** at cement manufacturing plan • Development of raw material and fuel conversion process using **carbonate chloride** from recovered CO_2					• Demonstration of CO_2 capture and carbonation technology in large-scale facilities	• **Reduction of equipment installation cost and installation support** by subsidies •**Technology deployment to domestic and Asian manufacturers** •**Development of licensing business** for overseas companies	
● **Carbon Recycled Fuel** Cost target 2030 100 yen level/L (＝Equivalent to existing products) **(i) Alternative Aviation Fuel (SAF)**	・ **Large-scale demonstration and cost reduction** for commercialization around 2030 ・ Regarding international aviation, **ICAO** has institutionalized not to increase CO_2 emissions compared to 2019 (2021-2035) (*ICAO: International Civil Aviation Organization)						• **Supply expansion** of competitive SAF, both domestically and internationally, according to **trends in the international SAF market**	
	[Gasification FT Synthesis] **Continued development of crushing and processing technology to homogenize the quality of various raw materials** [ATJ] **Continued development of control technology for catalytic reactions at high temperature conditions** [Microalgae] Continued development of technology for improvement of CO_2 absorption efficiency and stable growth of algae, **productivity improvement** and **technological development for quality improvement**, etc.							
(ii) Synthetic Fuel	**Development of Production technology for synthetic fuels** • Improve efficiency of existing technology (reverse shift reaction + FT synthesis process) • Design and development of manufacturing equipment				**Large-scale manufacturing demonstration**		**Introduction and expansion/cost reduction**	**Independent business**
	Development of innovative production technology for synthetic fuels • R&D on CO_2 electrolysis (+ water electrolysis) + FT synthesis process • R&D on co-electrolysis + FT synthesis process • R&D for direct synthesis (Direct-FT) process							
(iii) Synthetic Methane Cost target 2050 40 to 50 yen/Nm3 (= Equivalent to current LNG price)	Large-scale demonstration and cost reduction for commercialization around 2040						**Expansion of introduction** by further cost reduction	**Commercial expansion**
	Development of new basic technologies (Coelectrolysis, etc.) toward cost reduction						**Large scale, low cost** by demonstration	**Expansion of introduction** by further cost reduction
	Research and Demonstration toward the establishment of an overseas supply chain					**Start of transportation from overseas to Japan and expansion of introduction**		**Commercial expansion**
(iv) Green LPG	**Development of basic technologies** necessary for the demonstration tests of **catalysts, etc.**					★Goal (for 2030) Commercialization of Green LP Gas		★Goal (for 2050) Achieving carbon neutrality in relation to LP gas
	Demonstration for commercialization						**Cost reduction**	**Expanding the use of Green LP gas synthesis technology**

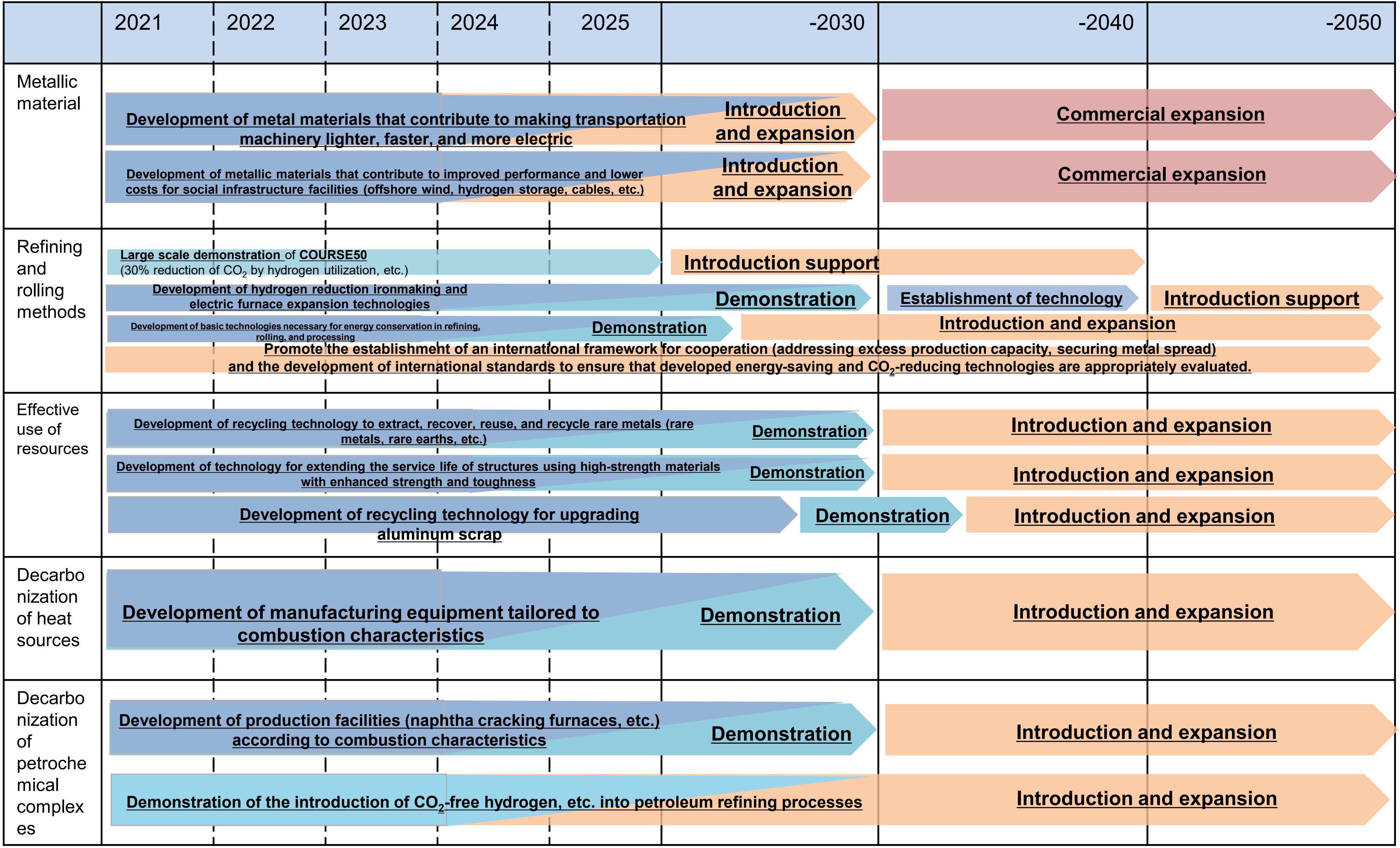
(11) "Roadmap" of Growth Strategies for the Carbon Recycling and Materials Industries (Carbon Recycling)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.

*Representative examples are shown	2021	2022	2023	2024	2025	-2030	-2040	-2050
● **Carbon Recycling Chemicals** Cost target 100 yen/kg for 50 years (= equivalent to existing products) (Plastic raw materials by artificial photosynthesis)	•**Development of highly productive photocatalyst** for large-scale demonstration of plastic raw material production •Study on security and safety standards for related regulations						•**Large-scale demonstration**	**Cost reduction**, **introduction support** through subsidies, etc.
Cost target Equivalent to existing products (Plastic raw materials such as waste plastic, waste rubber, and CO_2 direct synthesis)	•Development of technology to produce more functional chemicals from waste plastic, waste rubber and CO_2						**Cost reduction**, **introduction support** through subsidies, etc.	
Cost target Equivalent to existing products (Biotech Chemicals)	•Development of biomanufacturing technology using biomass resources as raw materials					•Demonstration	Introduction and expansion/ cost reduction	Commercial expansion
	•Development of bio-manufacturing technology to directly manufacture chemicals from atmospheric CO_2						•Demonstration	Introduction and expansion/cost reduction Commercial expansion
● **Separation recovery** Cost target (/CO_2t) Low pressure gas: 30 years 2,000 yen High pressure gas: 30 years 1,000 yen DAC: 50 years 2,000 yen Target scale 50 years about 2.5 billion $_{CO2}$ tons worldwide	○ Derived from exhaust gas •Developed **highly efficient CO_2 separation and capture technology to reduce costs**			•**Large-scale demonstration**			•**Expanding introduction** by further cost reduction	
	○ Derived from atmosphere (DAC) •R&D for **technology of direct CO_2 capture from the atmosphere (DAC)** (Enhancement of energy efficiency, **cost reduction**) through utilization of the moonshot type R&D system, etc.						•Further cost reduction through **demonstration**	• **Expanding introduction** through further cost reduction and subsidy etc.

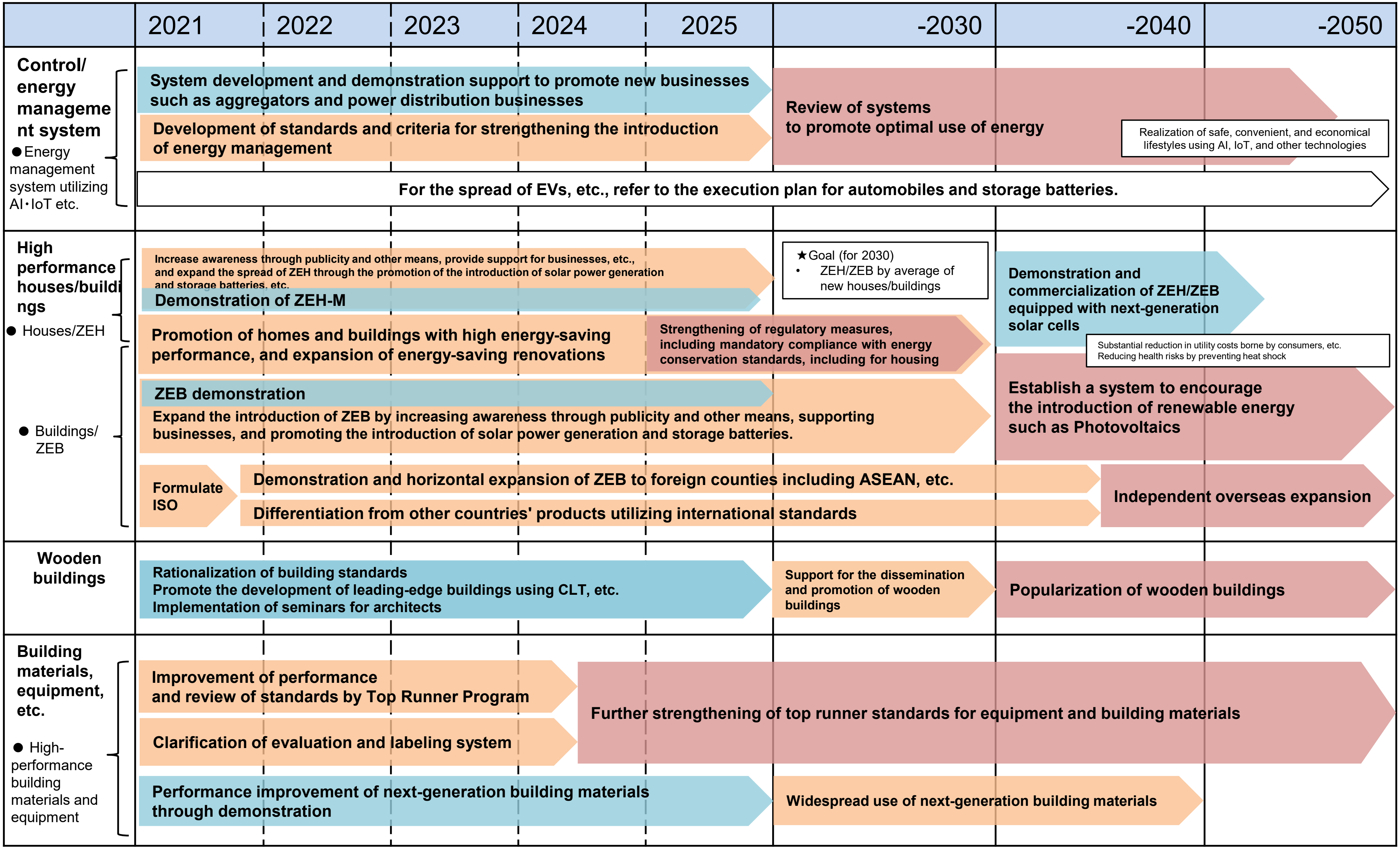
(11) "Roadmap" of Growth Strategies for the Carbon Recycling and Materials Industries (Materials)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



(12) "Roadmap" of Growth Strategies for the Housing and Building Industry and the Next-generation Power Management Industry (Housing and Building)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



2021 | 2022 | 2023 | 2024 | 2025 | -2030 | -2040 | -2050

Control/ energy management system
- Energy management system utilizing AI・IoT etc.

System development and demonstration support to promote new businesses such as aggregators and power distribution businesses

Development of standards and criteria for strengthening the introduction of energy management

Review of systems to promote optimal use of energy

Realization of safe, convenient, and economical lifestyles using AI, IoT, and other technologies

For the spread of EVs, etc., refer to the execution plan for automobiles and storage batteries.

High performance houses/buildings
- Houses/ZEH
- Buildings/ ZEB

Increase awareness through publicity and other means, provide support for businesses, etc., and expand the spread of ZEH through the promotion of the introduction of solar power generation and storage batteries, etc.

Demonstration of ZEH-M

★Goal (for 2030)
- ZEH/ZEB by average of new houses/buildings

Demonstration and commercialization of ZEH/ZEB equipped with next-generation solar cells

Substantial reduction in utility costs borne by consumers, etc.
Reducing health risks by preventing heat shock

Promotion of homes and buildings with high energy-saving performance, and expansion of energy-saving renovations

Strengthening of regulatory measures, including mandatory compliance with energy conservation standards, including for housing

ZEB demonstration

Expand the introduction of ZEB by increasing awareness through publicity and other means, supporting businesses, and promoting the introduction of solar power generation and storage batteries.

Establish a system to encourage the introduction of renewable energy such as Photovoltaics

Formulate ISO

Demonstration and horizontal expansion of ZEB to foreign counties including ASEAN, etc.

Differentiation from other countries' products utilizing international standards

Independent overseas expansion

Wooden buildings

Rationalization of building standards
Promote the development of leading-edge buildings using CLT, etc.
Implementation of seminars for architects

Support for the dissemination and promotion of wooden buildings

Popularization of wooden buildings

Building materials, equipment, etc.
- High-performance building materials and equipment

Improvement of performance and review of standards by Top Runner Program

Clarification of evaluation and labeling system

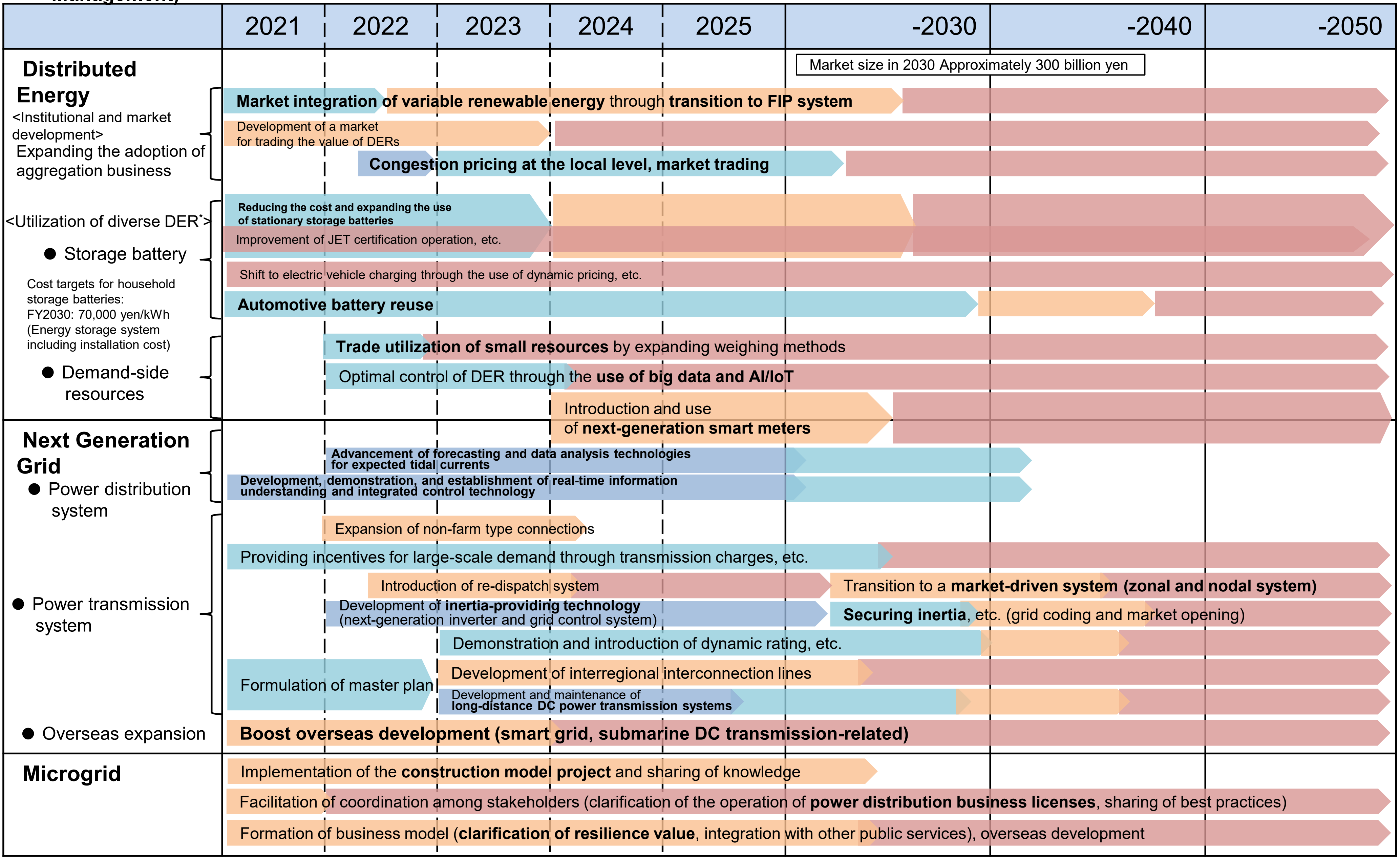
Further strengthening of top runner standards for equipment and building materials

Performance improvement of next-generation building materials through demonstration

Widespread use of next-generation building materials

(12) "Roadmap" of Growth Strategies for the Housing and Building Industry and Next-generation Power Management Industry (Next Generation Power Management)

- Introduction phase: 1. Development phase → 2. Demonstration phase → 3. Introduction and expansion/cost reduction phase → 4. Autonomous commercialization phase
- Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.



Distributed Energy

Market size in 2030 Approximately 300 billion yen

<Institutional and market development>
Expanding the adoption of aggregation business

- **Market integration of variable renewable energy** through **transition to FIP system**
- Development of a market for trading the value of DERs
- **Congestion pricing at the local level, market trading**

<Utilization of diverse DER*>

● Storage battery

Cost targets for household storage batteries:
FY2030: 70,000 yen/kWh
(Energy storage system including installation cost)

- Reducing the cost and expanding the use of stationary storage batteries
- Improvement of JET certification operation, etc.
- Shift to electric vehicle charging through the use of dynamic pricing, etc.
- **Automotive battery reuse**

● Demand-side resources

- **Trade utilization of small resources** by expanding weighing methods
- Optimal control of DER through the **use of big data and AI/IoT**
- Introduction and use of **next-generation smart meters**

Next Generation Grid

● Power distribution system

- Advancement of forecasting and data analysis technologies for expected tidal currents
- Development, demonstration, and establishment of real-time information understanding and integrated control technology

● Power transmission system

- Expansion of non-farm type connections
- Providing incentives for large-scale demand through transmission charges, etc.
- Introduction of re-dispatch system → Transition to a **market-driven system (zonal and nodal system)**
- Development of **inertia-providing technology** (next-generation inverter and grid control system) → **Securing inertia**, etc. (grid coding and market opening)
- Demonstration and introduction of dynamic rating, etc.
- Formulation of master plan
- Development of interregional interconnection lines
- Development and maintenance of **long-distance DC power transmission systems**

● Overseas expansion

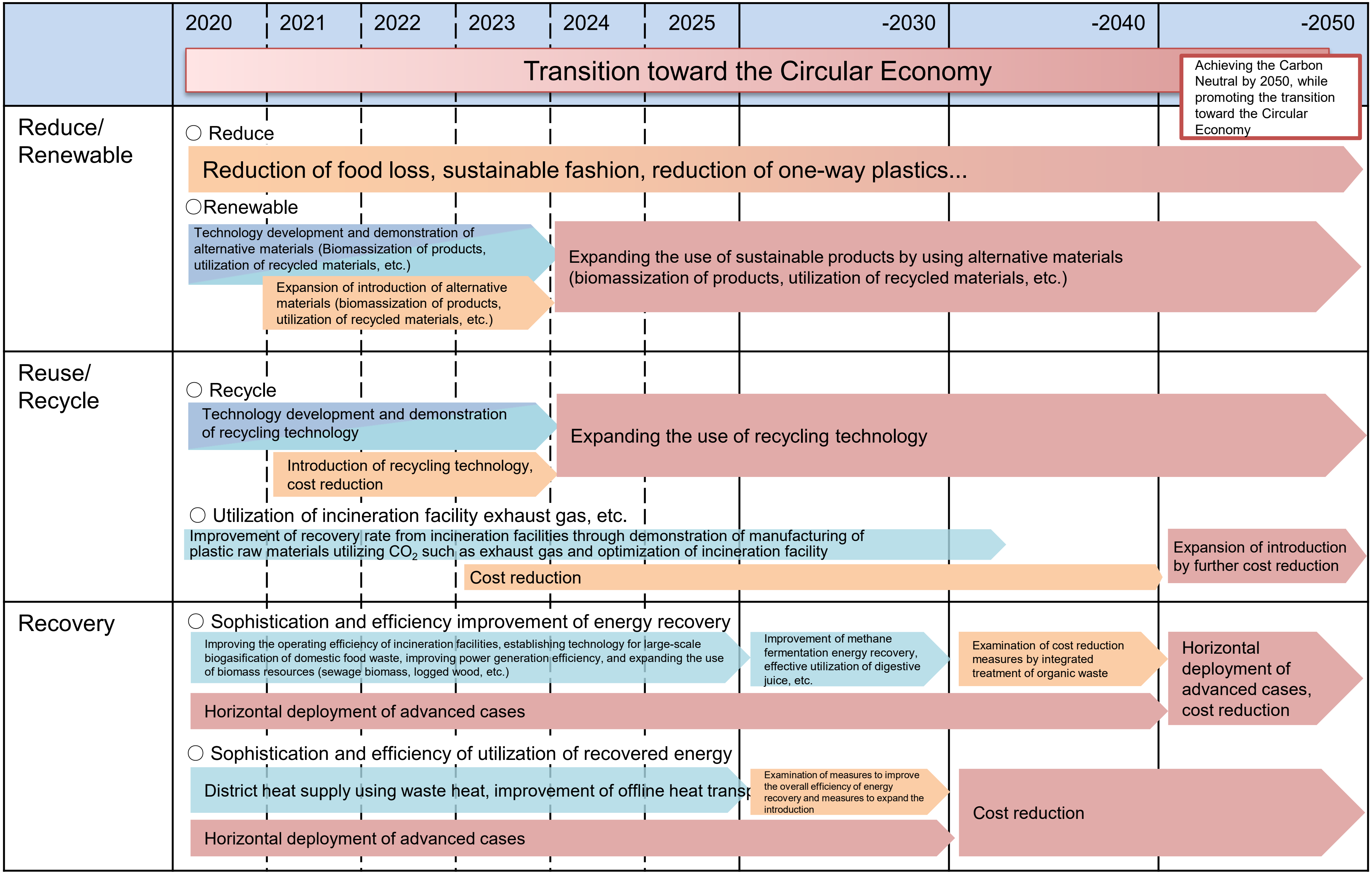
- **Boost overseas development (smart grid, submarine DC transmission-related)**

Microgrid

- Implementation of the **construction model project** and sharing of knowledge
- Facilitation of coordination among stakeholders (clarification of the operation of **power distribution business licenses**, sharing of best practices)
- Formation of business model (**clarification of resilience value**, integration with other public services), overseas development

(13) "Roadmap" of Growth Strategies for resource recycling- related industry

- **Introduction phase:** **1. Development phase** → **2. Demonstration phase** → **3. Introduction and expansion/cost reduction phase** → **4. Autonomous commercialization phase**
- **Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.**



Transition toward the Circular Economy

Achieving the Carbon Neutral by 2050, while promoting the transition toward the Circular Economy

Reduce/ Renewable

○ Reduce

Reduction of food loss, sustainable fashion, reduction of one-way plastics...

○Renewable

Technology development and demonstration of alternative materials (Biomassization of products, utilization of recycled materials, etc.)

Expansion of introduction of alternative materials (biomassization of products, utilization of recycled materials, etc.)

Expanding the use of sustainable products by using alternative materials (biomassization of products, utilization of recycled materials, etc.)

Reuse/ Recycle

○ Recycle

Technology development and demonstration of recycling technology

Introduction of recycling technology, cost reduction

Expanding the use of recycling technology

○ Utilization of incineration facility exhaust gas, etc.

Improvement of recovery rate from incineration facilities through demonstration of manufacturing of plastic raw materials utilizing CO_2 such as exhaust gas and optimization of incineration facility

Cost reduction

Expansion of introduction by further cost reduction

Recovery

○ Sophistication and efficiency improvement of energy recovery

Improving the operating efficiency of incineration facilities, establishing technology for large-scale biogasification of domestic food waste, improving power generation efficiency, and expanding the use of biomass resources (sewage biomass, logged wood, etc.)

Improvement of methane fermentation energy recovery, effective utilization of digestive juice, etc.

Examination of cost reduction measures by integrated treatment of organic waste

Horizontal deployment of advanced cases

Horizontal deployment of advanced cases, cost reduction

○ Sophistication and efficiency of utilization of recovered energy

District heat supply using waste heat, improvement of offline heat transp

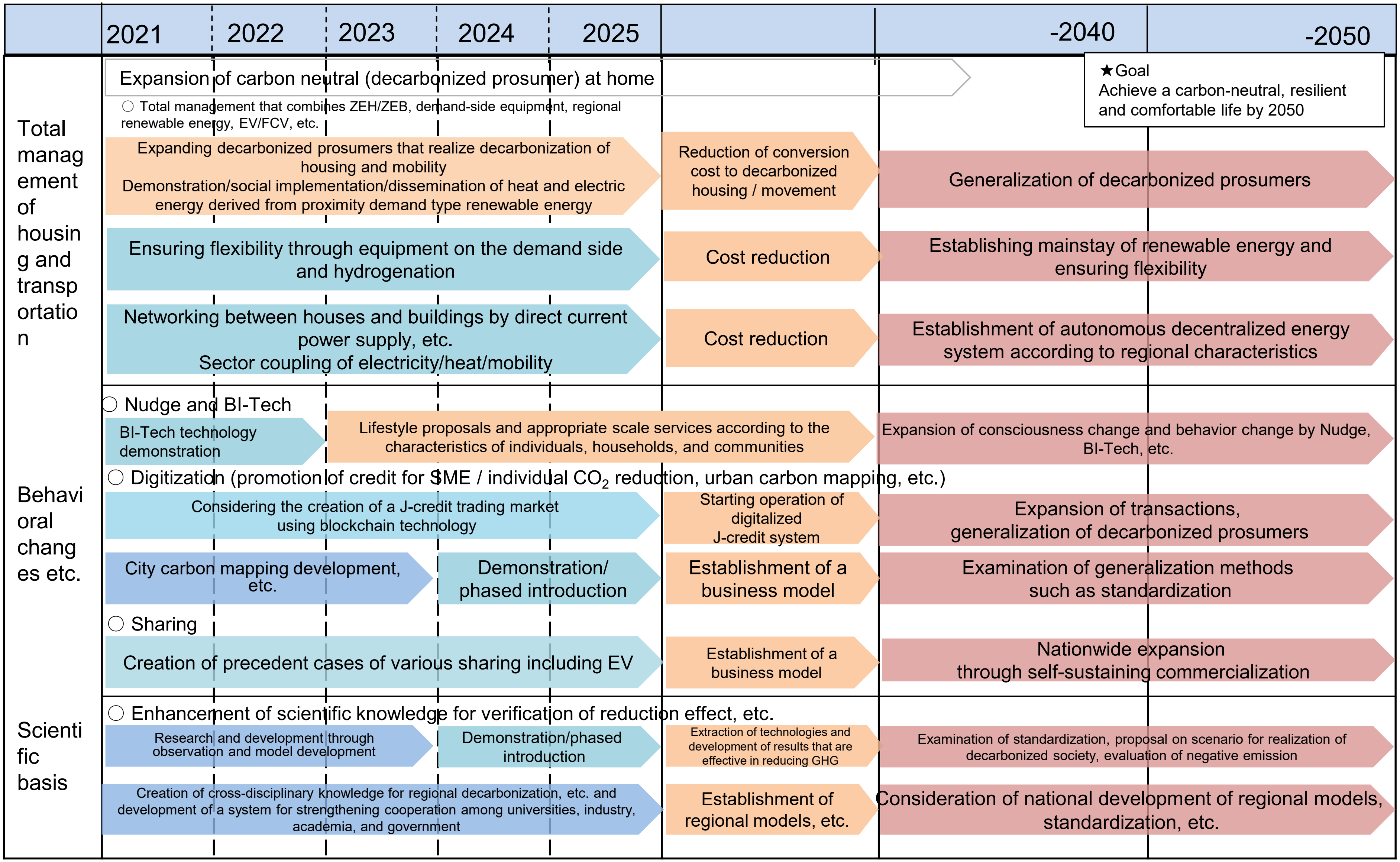
Examination of measures to improve the overall efficiency of energy recovery and measures to expand the introduction

Horizontal deployment of advanced cases

Cost reduction

(14) "Roadmap" of Growth Strategies for lifestyle-related industry

- Introduction phase: **1. Development phase** → **2. Demonstration phase** → **3. Introduction and expansion/cost reduction phase** → **4. Autonomous commercialization phase**
- **Policy means to be substantiated: [1] goals, [2] legal systems (such as regulatory reform), [3] standards, [4] tax systems, [5] budget, [6] finance, [7] public procurement, etc.**



2021 | 2022 | 2023 | 2024 | 2025 | -2040 | -2050

★Goal
Achieve a carbon-neutral, resilient and comfortable life by 2050

Total management of housing and transportation

Expansion of carbon neutral (decarbonized prosumer) at home

○ Total management that combines ZEH/ZEB, demand-side equipment, regional renewable energy, EV/FCV, etc.

Expanding decarbonized prosumers that realize decarbonization of housing and mobility
Demonstration/social implementation/dissemination of heat and electric energy derived from proximity demand type renewable energy → Reduction of conversion cost to decarbonized housing / movement → Generalization of decarbonized prosumers

Ensuring flexibility through equipment on the demand side and hydrogenation → Cost reduction → Establishing mainstay of renewable energy and ensuring flexibility

Networking between houses and buildings by direct current power supply, etc.
Sector coupling of electricity/heat/mobility → Cost reduction → Establishment of autonomous decentralized energy system according to regional characteristics

Behavioral changes etc.

○ Nudge and BI-Tech

BI-Tech technology demonstration → Lifestyle proposals and appropriate scale services according to the characteristics of individuals, households, and communities → Expansion of consciousness change and behavior change by Nudge, BI-Tech, etc.

○ Digitization (promotion of credit for SME / individual CO_2 reduction, urban carbon mapping, etc.)

Considering the creation of a J-credit trading market using blockchain technology → Starting operation of digitalized J-credit system → Expansion of transactions, generalization of decarbonized prosumers

City carbon mapping development, etc. → Demonstration/ phased introduction → Establishment of a business model → Examination of generalization methods such as standardization

○ Sharing

Creation of precedent cases of various sharing including EV → Establishment of a business model → Nationwide expansion through self-sustaining commercialization

Scientific basis

○ Enhancement of scientific knowledge for verification of reduction effect, etc.

Research and development through observation and model development → Demonstration/phased introduction → Extraction of technologies and development of results that are effective in reducing GHG → Examination of standardization, proposal on scenario for realization of decarbonized society, evaluation of negative emission

Creation of cross-disciplinary knowledge for regional decarbonization, etc. and development of a system for strengthening cooperation among universities, industry, academia, and government → Establishment of regional models, etc. → Consideration of national development of regional models, standardization, etc.