IN COLLABORATION WITH ACCENTURE

Shaping the Future of Energy and Materials
System Value Framework – Japan Market Analysis

May 2023
Executive Summary

SHAPING THE FUTURE OF ENERGY AND MATERIALS
System Value framework and the clean energy transition in Japan

The System Value framework more holistically evaluates economic, environmental, social and technical outcomes of potential energy solutions across markets. The framework aims to shift political and commercial focus beyond cost to include value.

Using the System Value framework, the World Economic Forum, supported by Accenture and a group of global electricity companies, conducted analysis across several geographies as part of market evaluations that examined recovery opportunities to accelerate economic growth and the clean energy transition. The flexible nature of the framework allows inclusion of both quantitative and qualitative analysis.

The relevance of system value dimensions may vary by geography and over time horizons.

Economic, environmental, societal and energy value
# Executive Summary

## Market Analysis

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG Reduction Target</td>
<td>60%</td>
</tr>
<tr>
<td>Energy Self-sufficiency Rate</td>
<td>11%</td>
</tr>
<tr>
<td>Renewable Energy Installed Capacity</td>
<td>28%</td>
</tr>
<tr>
<td>GHG Emissions Reduction Target</td>
<td>46%</td>
</tr>
<tr>
<td>Energy Efficiency Ranking</td>
<td>4th</td>
</tr>
<tr>
<td>Target Ratio of Power Supply</td>
<td>59%</td>
</tr>
<tr>
<td>Energy Generated by Renewables</td>
<td>16%</td>
</tr>
</tbody>
</table>

- **46%**: Reduction target of GHG emissions by 2030 from 2013 levels. Japan will continue challenge towards 50%.
- **648 Mt**: GHG reduction target amount by 2030.
- **60%**: Percentage of installed capacity of thermal power generation in 2022.
- **28%**: Percentage of renewable energy installed capacity in 2022 (hydro/solar/wind/biomass).
- **59%**: Target ratio of power supply by non-fossil power by 2030.
- **100%**: Japan to achieve net-zero emissions across the economy by 2050.
- **76%**: Percentage of power generated by thermal power generation in 2022.
- **16%**: Percentage of electricity generated by renewable energy in 2022 (hydro/solar/wind/biomass).
- **4th**: Energy efficiency ranking of Japan among OECD member countries.
Purpose of this report

With the realization of carbon neutrality in 2050 in mind, this report evaluates the system value of the measures for 2030. In the course of the System Value analysis, an analysis was conducted based on interviews with relevant parties.

Gather inputs from stakeholders
Conducted interviews related to measures to realize carbon neutrality and derived the thoughts of stakeholders.

Prioritize measures to “net zero”
Based on the contents of the interview, conducted analysis and set the priority of measures for carbon neutrality based on the System Value.
Solutions to accelerate the transition in Japan to achieve 2030 target

**Renewables as a main power supply**

To achieve carbon neutrality by 2050, bringing the renewable energy up to main power sources is one of the main solution as mentioned in the 6th Strategic Energy Plan. Specifically, energy mix in 2030 consists of solar power is expected to generate 1,290-1,460 kWh (14-16%), wind power 510 kWh (5%), geothermal power 110 kWh (1%), hydro power 980 kWh (11%) and biomass 470 kWh (5%)

122-168 Mt CO₂ reduction in 2030

26.1/8.2-11.8 yen LCOE is to be 26.1 yen/kWh for offshore wind and 8.2-11.8 yen/kWh for solar

Increased renewable energy and the use of storage batteries lead to maximize energy productivity and efficiency

24.9 K - 62.1 K Additional jobs in 2030

**Utilizing nuclear power capacity**

Following the Fukushima accident, the treatment of nuclear power was being redefined in Japan and all over the world. In response to the current trend toward carbon neutrality and the energy crisis triggered by Ukraine crisis, the Japanese government announced plans to restart up to 17 reactors after the summer of 2023, and also expressed its intention to consider building new or replacing next-generation reactors, including innovative light water reactors at the GX Conference in August 2022.

32-116 Mt CO₂ reduction in 2030

11.7 yen LCOE is to be 11.7 yen/kWh for nuclear

Increasing capacity leads to improve resiliency to energy system and make the price close to affordable price

**Deployment of hydrogen & ammonia**

Hydrogen can be a key technology to accelerate carbon neutral in Japan. In Japan, imports from overseas are expected to be the main sources, and the establishment of a supply chain is urgently needed. For this purpose, it is important to provide sufficient political support and establish the predictability of demand side, such as power generation, fuel cell vehicles, use in industrial fields, etc.

8 Mt LCOE is to be 26.1 yen/kWh for offshore wind and 8.2-11.8 yen/kWh for solar

30 yen/Nm³ Target hydrogen price in 2030 is 30 yen/Nm³

Developing new supply chain produces various job opportunities

**Deployment of CCS/CCU**

CCS and CCU are key technologies that will lead to virtually zero CO₂ emissions not only from thermal power generation in the electric power sector, but also in the non-electric power sector (especially in the industrial sector).

120-240 Mt CO₂ storage in 2050

Target capturing cost is 2,000 yen/t-CO₂ level for low pressure gas and 1,000 yen/t-CO₂ level for high pressure gas

Developing new industry produce various job opportunities
EXECUTIVE SUMMARY

System Value of Japan’s clean energy transition to achieve 2030 target

<table>
<thead>
<tr>
<th>Economic, environmental, societal and energy value</th>
<th>GHG Emissions</th>
<th>Jobs and Economic Impact</th>
<th>Water Footprint</th>
<th>Air Quality and Health</th>
<th>Equitable Access</th>
<th>Energy Productivity and Systemic Efficiency</th>
<th>Resilience and Security</th>
<th>Foreign Direct Investment</th>
<th>Reliability and Service Quality</th>
<th>Flexibility</th>
<th>System Upgrade</th>
<th>Cost and Investment Competitiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewables as a main power supply</td>
<td>122-168 Mt CO₂ reduction in 2030</td>
<td>24.9K-62.1K Additional jobs in 2030</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>26.1 yen/kWh for offshore wind and 8.2-11.8 yen/kWh for solar in 2030</td>
</tr>
<tr>
<td>Utilizing nuclear power capacity with safety assurance and domestic consensus building</td>
<td>32-116 Mt CO₂ reduction in 2030</td>
<td>2.8K Additional jobs in 2030</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>LCOE is to be 11.7 yen/kWh for nuclear in 2030</td>
</tr>
<tr>
<td>Decarbonization of industrial sector</td>
<td>10 Mt CO₂ reduction in steel and chemical industry by energy efficiency in 2030</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>10 trillion yen for steel and 7 trillion yen for chemical industry toward 2050</td>
</tr>
<tr>
<td>Transformation of transportation</td>
<td>9 Mt CO₂ reduction by EV/FCV/PHV/HV for in 2030</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>1.8 trillion yen for electric car, 1 trillion yen for R&amp;D and 0.2 trillion yen for infrastructure in 2030</td>
</tr>
<tr>
<td>Deployment of hydrogen &amp; ammonia</td>
<td>8 Mt CO₂ reduction by FCV, FC bus, steel manufacturing and home FC in 2030</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>Target hydrogen price in 2030 is 30 yen/Nm³</td>
</tr>
<tr>
<td>Deployment of CCS/CCU</td>
<td>OCS is to start operation in 2030</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>Target capturing cost is 2,000 yen/t-CO₂ level for low pressure gas and 7,000 yen/t-CO₂ level for high pressure gas</td>
</tr>
</tbody>
</table>

Analysis performed for given System Value dimension and recovery solution. For more detail, please see specific solution and/or relevant System Value dimension slide(s).

System Value dimension not as relevant to geographic market or not considered with given recovery solution.

Relative System Value dimension benefit for given recovery solution within market:

- High benefit
- Medium benefit
- Minimal-to-no benefit

Priority System Value dimension with qualitative analysis
Market Analysis

SHAPING THE FUTURE OF ENERGY AND MATERIALS
Overview

Overview of emissions and reduction targets

Japan has set a goal of reducing GHG emissions by 46% from 2013 levels by 2030 and achieve carbon neutrality by 2050. Its energy landscape is expected to change dramatically, with the share of non-fossil sources in its power mix more than doubled by 2030.

- **By 2030  46%**
  
  Reduction in GHG emission from 2013 levels, with continuous efforts towards a 50% reduction goal

- **By 2050  100%**
  
  Japan to achieve net-zero emissions across the economy

Power Generation Mix

<table>
<thead>
<tr>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>20%</td>
</tr>
<tr>
<td>Coal</td>
<td>31%</td>
</tr>
<tr>
<td>LNG</td>
<td>6%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>37%</td>
</tr>
<tr>
<td>Renewables</td>
<td>20%</td>
</tr>
<tr>
<td>Hydrogen and ammonia</td>
<td>2%</td>
</tr>
</tbody>
</table>

By 2030:
- Fossil: ~76%
- Non-fossil: ~24%

By 2050:
- Fossil: ~41%
- Non-fossil: ~59%
Overview of emissions and reduction targets

Japan has set a goal of reducing GHG emissions by 46% from 2013 levels by 2030 and achieve carbon neutrality by 2050. Its energy landscape is expected to change dramatically, with the share of non-fossil sources in its power mix more than doubled by 2030.

Notes: (1) Industry, Commercial and others, Residential, Transport, and Energy conversion refers to energy-related CO2 only, and CO2 emissions from power and heat generation are allocated to each sector based on the consumption of power and heat. (2) Japan also aims to contribute to international emission reductions and removals through the Joint Crediting Mechanism (JCM), with a cumulative goal of ~100 Mt CO2 by 2030, and the acquired credits will be counted to achieve its Nationally Determined Contribution.

Sources: METI, METI, MOE, NIES
Overview

As market liberalization progresses, the Japanese government aims to create a more attractive market for participants.

Electricity market liberalization has been proceeded in Japan since 1995, and the trading environment continues to change. In addition, FIP has started in the sale of renewable electricity in 2022.

<table>
<thead>
<tr>
<th>Electricity Market Liberalization</th>
<th>Trading Environment</th>
<th>FIT/FIP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Liberalization of the power generation market</strong> started in 1995 and the <strong>liberalization of the retail sector</strong> in 2000. The <strong>unbundling of the transmission and distribution sector</strong> started in 2020, with the aim of reducing prices by promoting competition in the electric power business. After the liberalization of the retail sector, many retail companies were launched and price reductions seemed to have progressed, but recently, structural issues of liberalization have come to light, such as <strong>instability in market prices</strong> due to difficulties in balancing supply and demand, and the accompanying bankruptcies of retail companies.</td>
<td><strong>Power generators sell electricity to retailers through bilateral contracts and PX(JEPX).</strong> In addition to the <strong>day-ahead and intraday market</strong>, there are other trading markets such as the <strong>balancing market</strong>. As the physical market becomes more active, <strong>futures trading</strong> has also started. In addition, there is a <strong>capacity market</strong> for trading kW value, and a <strong>non-fossil value trading market</strong> for trading non-fossil value, etc., where various values other than just kWh are traded.</td>
<td><strong>Since the introduction of a FIT (feed-in tariff) in 2012, the diffusion of renewable energy has accelerated in Japan. Furthermore, starting in 2022, an FIP (feed-in premium) was introduced for market integration of renewables.</strong> Under the FIP, the market mechanism is expected to be reflected in the transaction price of renewable energy, as a premium is added to the market price and be settled.</td>
</tr>
</tbody>
</table>

Note: Non-fossil value trading market - a market to trade certificates showing the “non-fossil value” of electricity from non-fossil sources such as renewable energy and nuclear power.

Sources: [METI](https://www.meti.go.jp), [METI](https://www.meti.go.jp)
Overview

As market liberalization progresses, the Japanese government aims to create a more attractive market for participants.

Electricity market liberalization has been proceeded in Japan since 1995, and the trading environment continues to change. In addition, FIP has started in the sale of renewable electricity in 2022.

Installed Capacity (GW)
As of March 2022

- LNG 79 (30%)
- Coal 50 (19%)
- Oil 33 (12%)
- Hydro 50 (18%)
- Nuclear 33 (12%)
- Solar 14 (5%)
- Wind 4 (2%)
- Biomass 4 (2%)
- Others 2 (1%)

269 GW

Power Generation (TWh)
in FY2021

- LNG 356 (35%)
- Coal 321 (31%)
- Oil 76 (7%)
- Hydro 78 (8%)
- Nuclear 71 (7%)
- Solar 86 (8%)
- Wind 9 (1%)
- Biomass 33 (3%)
- Others 3 (0.3%)

1,033 TWh

Note: Non-fossil value trading market - a market to trade certificates showing the "non-fossil value" of electricity from non-fossil sources such as renewable energy and nuclear power.

Sources: METI
Overview

1a. Japan’s Energy Policy

Government agencies in Japan provide directions for policies and promotions related to carbon neutrality. Major administrative agencies and their policies are as follows.

<table>
<thead>
<tr>
<th>Cabinet Office</th>
<th>Ministry of Economy, Trade and Industry (METI)</th>
<th>Ministry of the Environment (MOE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Policy on Economic and Fiscal Management and Reform 2022 sets out the direction of policy reform for Japan’s “New Form of Capitalism,” and GX (Green Transformation) ¹ is one of the focused investment areas. It is estimated that at least 150 trillion yen, in combined public and private investments, will be required in the next decade to realize GX. Basic Policy for the Realization of GX ¹ outlines the government’s approach towards GX*, including some of specific policy measures such as the issuance of GX Economy Transition Bonds (provisional name) worth 20 trillion yen in the next decade to support up-front investment, and the basic concept of a carbon pricing scheme, consisting of an Emissions Trading System (ETS) and a carbon surcharge. Green Growth Strategy through Achieving Carbon Neutrality in 2050, the first major energy/industry-focused national strategy after the declaration of the 2050 carbon neutrality goal, lays out action plans in the 14 priority sectors that have potential for growth, including renewables, hydrogen and fuel ammonia, synthetic methane, carbon recycling (CCU) and resource circulation (e.g. bioplastics). The 6th Strategic Energy Plan, the latest edition of the periodically revised national energy strategy, outlines a path for energy policy to achieve carbon neutrality by 2050 and the 46% GHG reduction goal by 2030 (from 2013 levels). It stipulates key actions for each of energy areas, not only for realizing decarbonization, but also for securing stable energy supply at a competitive price.²</td>
<td>Regional Decarbonization Roadmap focuses on decarbonization at a city-level. MOE will select at least 100 municipalities as the “advanced model regions for decarbonization” by 2030 and support local efforts such as installation of solar power facilities for self-consumption, energy-efficient houses/buildings, etc. MLIT’s Green Challenge summarizes the ministry’s priority areas for decarbonization, including the upgrade of transportation and logistics infrastructure adapted for EVs, the decarbonization of marine transportation (e.g. zero-emission ships) and ports, as well as the promotion of offshore wind power generation, etc.</td>
<td></td>
</tr>
</tbody>
</table>

Note: (1) Green Transformation (GX) is defined as an initiative to “shift the industrial and social structures that have been fossil energy-centered since the Industrial Revolution to clean energy-centered.” (2) Japan’s energy policy has been guided by the principle called “S + 3E (Safety, Energy security, Economic efficiency and Environment),”

Japan’s Policies related to Carbon Neutrality (Non-exhaustive)

Regional Decarbonization Roadmap focuses on decarbonization at a city-level. MOE will select at least 100 municipalities as the “advanced model regions for decarbonization” by 2030 and support local efforts such as installation of solar power facilities for self-consumption, energy-efficient houses/buildings, etc.

Ministry of Land, Infrastructure, Transportation and Tourism (MLIT)
Overview

1b. Time series of installed capacity

The time series shows a steady increase in installed capacity. In particular, renewable energy and LNG have increased in recent years, while oil has decreased.

Sources: METI, METI
Overview

1c. Time series of power generation

The amount of power generation by nuclear power plant decreased significantly after the Fukushima accident in 2011 and thermal increased to fill the gap. Renewables have also increased.

Source: METI
While former GEUs have a strong presence, new entrants have also increased their market share.

Before the unbundling of T&D, most of the regional GEUs were vertically integrated. Currently, retail and generation maintain as one company in most of the regions, whereas T&D is unbundled.

Notes:
(1) GEU: General Electric Utility
(2) OCCTO: Organization for Cross-regional Coordination of Transmission Operators
(3) PPS: Power Producer and Supplier
(4) IPP: Independent Power Producer

Sources: Based on public information
Major Changes

Due to the liberalization of the power generation sector, the surplus of in-house power generation equipment was tendered and wholesaled to electric power companies. In addition, it became possible to supply electricity using its own transmission line instead of TSO.

Since 2000, the retail sector has been liberalized, and at first, supply to large-scale consumers (30% of total demand) began at a deregulated tariff. In addition, the wholesale market (JEPX) was established in 2003 and started trading from 2005.

After the Great East Japan Earthquake (2011), a three-stage reform of the electric power system was presented:

Step1: Establishment of OCCTO (2015)
Step2: Full liberalization of entry to electricity retail business (2016)
Step3: Legal unbundling of transmission & distribution sector (2020)

The Electricity Business Act regulates the operation of the electric power sector in Japan, and the system is being revised in response to changes in the social environment. Until the system reform in 1995, the electric power sector was operated by regions’ vertically integrated general electric utilities (Generation – Transmission & Distribution - Retail).

1d. Market deregulation in Japan

The retail sector has been liberalized, and at first, supply to large-scale consumers (30% of total demand) began at a deregulated tariff. In addition, the wholesale market (JEPX) was established in 2003 and started trading from 2005.

After the Great East Japan Earthquake (2011), a three-stage reform of the electric power system was presented:
The business environment for nuclear power generation has changed significantly after the Fukushima accident

The accident at the Fukushima Daiichi Nuclear Power Plant in March 2011 completely changed Japan’s nuclear energy policy. Since the accident almost 10 years ago, there has been a gradual move toward utilizing nuclear power plants.

Overview
The Great East Japan Earthquake that occurred on 11 March 2011 triggered the Fukushima Daiichi Nuclear Power Plant accident. Since then, all nuclear power plants in Japan, including those other than the Fukushima Daiichi Nuclear Power Plant, have been forced to shut down, and the issue is still being debated as one of the most important issues for Japan’s energy supply. As of 2022, some nuclear power plants are in operation, mainly in western Japan. More than 10 years after the accident, treatment of nuclear power plant have been gradually changing by movement of carbon neutral and energy crisis.

Key items after the accident

<table>
<thead>
<tr>
<th>Impact of Accident</th>
<th>Safety Enhancement</th>
<th>Restarting Operation/Building New Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>The earthquake shut down many power plants in east Japan. As a result, there was a shortage of power supply and blackouts were carried out in rotation. Plus, radioactivity was diffused due to the hydrogen explosion after the nuclear accident, and residents were forced to evacuate.</td>
<td>The accident led to the establishment of the New Regulatory Requirement, which strictly review safety requirements in 2013. The requirement also require operators to respond to severe accidents and aircraft collisions, etc.</td>
<td>The treatment of nuclear power has been changing due to the carbon neutral movement and the power shortages. In August 2022, the government announced that it will restart up to 17 reactors by the summer of 2023. The government also mentioned the construction of new power plants, including the development of innovative reactors.</td>
</tr>
<tr>
<td>The power source mix has become dependent on thermal power, and the availability of LNG thermal power has increased, making the procurement of LNG an urgent task for GEUs. In addition, the review of Japan’s energy policy and the reform of TEPGO proceeded.</td>
<td>10 power plants including those that are shut down have passed this requirement and already restarted, including plants undergoing inspection and shutdown (as of November 2022).</td>
<td>In addition, discussions are underway to extend the operating period of plants (currently 40 years, with a maximum of 60 years if extended).</td>
</tr>
</tbody>
</table>
Challenge

Low energy self-sufficiency rate among the G20 countries

Japan’s low energy self-sufficiency is always a subject of debate, as Japan is an island nation with no grid connections to other countries and relies on imports for much of its energy demand.

Energy self-sufficiency* of the G20 Countries (excluding EU) in 2020 (%)

Notes: *Energy self-sufficiency is calculated as primary production divided by total energy supply.
Sources: IEA, UNSD
Challenge

While Japan depends on the Middle East for crude oil, it relies on imports from the Asia-Pacific region for LNG and coal.

Oil is mostly imported from the Middle East, and LNG and coal from Australia; Japan is less dependent on Russia compared to European countries.

Notes: *Energy self-sufficiency is calculated as primary production divided by total energy supply.
Sources: METI

**Japan’s Fossil Fuel Import Partners (2019)**

- **Crude oil**
  - Total import: 1.09 billion barrels
  - degree of dependence: **99.7%**
- **LNG**
  - Total import: 77.33 million tons
  - degree of dependence: **97.7%**
- **Coal**
  - Total import: 110.92 million tons
  - degree of dependence: **99.5%**
Challenge

Misallocation of installed renewables and existing demand. Transmission capacity expansion is needed for additional installation.

While much renewable energy potential exists in the Hokkaido and Tohoku area, there is a shortage of transmission capacity, so the enhancement of interregional grid is essential. On the other hand, although Kyushu has a lot of renewable energy potential, it is difficult to consume electricity only within Kyushu, and it is necessary to transmit power to Chugoku, ...

Fig 1
Potential of renewable energy by region

Sources: MOE, MOE, NIKKEI, METI, TEPCO PG
Challenge

Misallocation of installed renewables and existing demand. Transmission capacity expansion is needed for additional installation.

While much renewable energy potential exists in the Hokkaido and Tohoku area, there is a shortage of transmission capacity, so the enhancement of interregional grid is essential. On the other hand, although Kyushu has a lot of renewable energy potential, it is difficult to consume electricity only within Kyushu, and it is necessary to transmit power to Chugoku, but it is difficult to use up the renewable energy potential due to restrictions on transmission capacity.

Sources: MOE, MOE, NIKKEI, METI, TEPCO PG
Challenge

1e. Japan’s energy grid

OCCTO released the analysis results in 2021 to realize the mass introduction of renewable energy (wind and solar) and the strengthening of the power network toward carbon neutrality goal set by the Japanese government. However, discussions to materialize the master plan is currently in progress, and the plan has not yet been finalized.

Note: The above information is as of 2021. Figures in ( )s for each area are forecast figures for maximum three-day average power consumption in FY2021. Okinawa is omitted because the cross-regional interconnection line is not connected.

Sources: Based on public information

Capacity of Cross-regional Interconnection Lines

60Hz area

- Hokuriku (4.92GW)
- Chugoku (10.35GW)
- Kansai (27.25GW)
- Chubu (24.33GW)
- Shikoku (4.92GW)
- Kyushu (15.21GW)

50Hz area

- Hokkaido (4.15GW)
- Tohoku (12.93GW)
- Tokyo (53.29GW)
### Challenge

#### 1e. Japan’s energy grid

OCCTO released the analysis results in 2021 to realize the mass introduction of renewable energy (wind and solar) and the strengthening of the power network toward carbon neutrality goal set by the Japanese government. However, discussions to materialize the master plan is currently in progress, and the plan has not yet been finalized.

**Note:** The above information is as of 2021. Figures in ( )s for each area are forecast figures for maximum three-day average power consumption in FY2021. Okinawa is omitted because the cross-regional interconnection line is not connected.

**Sources:** Based on public information
Challenge

Japan is one of the most advanced countries in energy efficiency, which is one approach to achieving carbon neutrality.

While real GDP is growing, efficiency of energy consumption has been improved in Japan. In addition, Japan has identified energy efficiency as one of the measures necessary to become carbon neutral by 2050. There is not much room left for simply improving energy efficiency, and approaches and technologies that provide breakthrough are needed.

Note: "Energy efficiency is calculated as primary energy supply divided by real GDP, indicating the amount of primary energy required to produce one unit of GDP."

Sources: METI, World Bank, OECD

Transition of Real GDP and Energy Efficiency* in Japan

International Comparison of Energy Efficiency* (2020) (Japan = 1.00)
Challenge

Efforts to carbon neutrality under energy crisis conditions

Following the Ukraine crisis, many countries including Japan are suffering from an energy crisis. As such, Japan reaffirms its commitment to maximize the use of renewable and nuclear power from the perspective of energy security.

Responding to energy crisis caused by Ukraine crisis

Japan decided to follow the G7 announcement regarding an embargo on Russian crude oil and decided to take a phased fade-out step.

This has caused oil prices, which have been on the rise since the second half of 2020, to continue to further rise. Combined with the weak yen, Japan’s crude oil and crude oil imports continue to rise.

Wholesale power prices (day-ahead/intra-day prices) are also rising as the prices of fossil fuels, which Japan relies on imports from abroad, are rising; most GEUs are making the decision to raise retail prices in regulated sectors by more than 30%.

While steering energy away from Russia, the government has approached the Mitsui and Mitsubishi corporations about maintaining their interests in Sakhalin 2, an oil and natural gas development project in the Russian Far East, in response to soaring energy prices. From Sakhalin 2, Japan imports about 9% of LNG demand (equivalent to 3% of total power generation). Both companies responded to the government suggestion, and the Russian government approved Mitsui on 30 August 2022 and Mitsubishi on 31 August 2022.

In light of this situation, Japan has expressed its commitment to maximize the use of renewable energy and nuclear power, not only as a decarbonized power source, but also from the perspective of energy security.

Note: (1) CIF (Cost, Insurance and Freight) price includes the cost of the fuel at the origin plus the cost of insurance and freight to deliver it to its destination. (2) The price hike in March 2022 was mainly due to an earthquake.

Sources:
Prime Minister’s Office of Japan, METI, NIKKEI, World Bank, JEPX, MOF, Naiko-Soren
In parallel with long-term carbon neutrality, there is a need to address the reserve margin shortage.

In the summer of 2022, an event occurred in which the supply and demand of electricity became tight. In response to this event, the Japanese government is considering measures to prevent further tightening of power supply and demand in the future.

Overview
In the summer of 2022, the reserve ratio of electricity fell below the minimum 3% required for a stable supply due to the retirement of old thermal power stations and soaring resource prices. In addition to short-term measures, such as securing fuel and power-saving requests, resolving structural issues in Japan’s electricity market is required.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Supply</th>
<th>Short term</th>
<th>KW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Issue</td>
<td>Demand</td>
<td>Short term</td>
<td>KW</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
<td>------------</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Thermal power plants shut down due to earthquake in March 2022
- Pre-summer inspection suspension of thermal power plants
- Soaring fuel prices and reduced imports due to the invasion of Ukraine and other factors
- Exit of highly aged oil-fired power plants
- The rainy season ended much earlier than usual
**Challenge**

In parallel with long-term carbon neutrality, there is a need to address the reserve margin shortage.

In the summer of 2022, an event occurred in which the supply and demand of electricity became tight. In response to this event, the Japanese government is considering measures to prevent further tightening of power supply and demand in the future.

### Plans to Solve the Issue

<table>
<thead>
<tr>
<th>Supply</th>
<th>Short term</th>
<th>KW</th>
<th>Long term</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Activate a power plant that is not currently in operation by public offering of kW by TSO</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Encourage power generators to start the thermal power plants currently under trial as soon as possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Secure resources through upstream LNG investment with Asian countries and the development of a framework for sharing LNG among companies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Promote development of non-fossil fuel power sources such as renewable energy (especially for offshore wind and solar), nuclear (exiting and new development), non-fossil fuel thermal, etc. (e.g. design rules to encourage new investment)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Secure power sources that contribute to stable supply (e.g. steady operation of capacity market)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maintain and strengthen pumped storage power, utilize distributed power sources such as storage batteries, and develop inter-regional lines</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Secure resources by strengthening support for upstream and midstream development and enhancement of the entire supply chain</td>
</tr>
<tr>
<td>Demand</td>
<td>Short term</td>
<td>KW</td>
<td>Long term</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Electricity conservation (electricity conservation points, market-linked plans, and usage restriction orders and rolling blackouts, etc.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Promote energy efficiency (e.g., subsidies for insulating materials/energy-efficient appliances)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Promote storage batteries and DR</td>
</tr>
</tbody>
</table>
**Opportunity**

**Establishing a hydrogen and ammonia supply chain with high priority**

The Japanese government aims to actively promote hydrogen and ammonia power generation by positioning it in its power supply mix for 2030. For this purpose, it is necessary to reduce the cost as soon as possible.

**Japan’s Numerical Target for Hydrogen**

The target of hydrogen and fuel ammonia generation in total power generation is set at 1% in 2030 and 10% in 2050 (the value in 2050 is positioned as a reference value to deepen the discussion).

The cost of supply will be reduced to 30 yen/Nm³ (CIF price) in 2030 and below 20 yen/Nm³ (CIF price) in 2050, and in the long term, the cost will be reduced to the same level as that of fossil fuels (100 yen/Nm³ at a typical hydrogen station in 2021).

**Supply**

<table>
<thead>
<tr>
<th>Production</th>
<th>Distribution</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercialization of hydrogen production by water electrolyzers utilizing surplus renewable energy, etc. by 2030</td>
<td>Realization of an international hydrogen supply chain by 2030</td>
<td>Consideration of the use and development of financing schemes by financial institutions and JOGMEC that contribute to resource development and reduction of risks associated with the development of ports of loading and unloading</td>
</tr>
<tr>
<td>Scaling up and modularization of water electrolyzers</td>
<td>Increase in size of various transportation and supply facilities including hydrogen carriers</td>
<td>Establish a system to promote the use of low-cost electricity such as surplus electricity</td>
</tr>
<tr>
<td>Research support for innovation such as hydrogen production using photocatalysts and high-temperature heat sources such as high-temperature gas reactors</td>
<td>Improvement of reception environment at ports</td>
<td></td>
</tr>
</tbody>
</table>

Sources: Cabinet Secretariat, METI, METI
Opportunity

Establishing a hydrogen and ammonia supply chain with high priority

The Japanese government aims to actively promote hydrogen and ammonia power generation by positioning it in its power supply mix for 2030. For this purpose, it is necessary to reduce the cost as soon as possible.

### Demand

<table>
<thead>
<tr>
<th>Power Generation</th>
<th>Transportation</th>
<th>Household/Office</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of combustor for exclusive use and demonstration of power generation using large combustors</td>
<td>Expansion of FCVs with development of hydrogen stations</td>
<td>Widespread use of pure hydrogen fuel cells for households/office buildings</td>
<td>Utilization as a heat source for industrial raw materials and high temperatures required in industrial processes</td>
</tr>
<tr>
<td>Appropriate evaluation of non-fossil value together with ammonia in the Sophisticated Methods of Energy Supply Structures, etc. leading to social implementation by 2030</td>
<td>Technology development and demonstration for the expansion of fuel cell applications to trucks, ships, rail vehicles, etc.</td>
<td></td>
<td>Large-scale conversion of manufacturing processes, including hydrogen-reduced ironmaking</td>
</tr>
<tr>
<td></td>
<td>Development of stations with large-scale filling capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Support for development of SAF fuel with hydrogen</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Opportunity

Hydrogen is being considered for use in a wide range of applications, not just power generation in Japan.

In addition to hydrogen power generation, hydrogen is expected to be used in the transport, residential, commercial and industry sectors, with a future annual demand of 20 million tons of hydrogen.

Notes: (1) Total quantity includes hydrogen and ammonia, where ammonia is converted to tonnes in hydrogen equivalent. (2) From the viewpoint of improving predictability of hydrogen suppliers, etc., the government will fully or partially compensate the difference between the total cost of production and supply and the selling price for 15 years (maximum 20 years). (3) Just one of the scenario as a reference. (4) Only includes demand for FC truck. (5) Only includes demand for hydrogen reduction steelmaking. Chemical industry and others have additional demand.

Sources: Cabinet Secretariat, METI, METI, METI, Cabinet Secretariat, METI, METI

<table>
<thead>
<tr>
<th></th>
<th>Present</th>
<th>2030</th>
<th>2050/Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Quantity &amp; Cost</td>
<td>~20 million tons 100 yen/Nm³</td>
<td>3 million tons (incl. 0.42 million tons of clean hydrogen) 30 yen/Nm³</td>
<td>20 million tons 20 yen/Nm³</td>
</tr>
</tbody>
</table>

Power Generation

<table>
<thead>
<tr>
<th></th>
<th>Phase of Demonstration</th>
<th>Hydrogen/ ammonia-fired Power Generation</th>
<th>17 yen/kWh</th>
<th>12 yen/kWh</th>
<th>Potential demand: 5-10 million tons/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>As of 2022</td>
<td>H₂ station</td>
<td>~180 sites</td>
<td>H₂ station</td>
<td>320 sites</td>
<td>H₂ station</td>
</tr>
<tr>
<td>As of 2025</td>
<td>H₂ station</td>
<td>320 sites</td>
<td>H₂ station</td>
<td>900 sites</td>
<td>H₂ station</td>
</tr>
<tr>
<td>Transport</td>
<td>FCV</td>
<td>~7,500 units</td>
<td>FCV</td>
<td>200K units</td>
<td>FCV</td>
</tr>
<tr>
<td>Residual &amp; Commercial</td>
<td>FC Forklift</td>
<td>~400 units</td>
<td>FC Forklift</td>
<td>10K units</td>
<td>FC Forklift</td>
</tr>
<tr>
<td>Industry</td>
<td>Home Fuel cell</td>
<td>~450K units</td>
<td>Home Fuel cell</td>
<td>5,300K units</td>
<td>Home Fuel cell</td>
</tr>
<tr>
<td></td>
<td>Synthetic methane</td>
<td>Mix 1% with existing gas</td>
<td>Synthetic methane</td>
<td>Mix 90% with existing gas</td>
<td>Synthetic methane</td>
</tr>
</tbody>
</table>

For example, the market size of green steel is estimated to be up to ~500 million tons/year (~40 trillion yen/year).
Opportunity

Positive efforts toward implementation of CCS/CCU

The Japanese government has indicated its intention to promote technological development and cost reduction in order to realize CCS by 2030 and to promote CCU products such as carbon recycling.

Japan’s Numerical Target for CCS

In the 6th Strategic Energy Plan and the interim report of the CCS Long-Term Roadmap, the government mentioned to start CCS projects by 2030, and to achieve this, (1) start FS, etc. from FY2023 and (2) make a final investment decision by FY2026.

It is assumed that an annual storage volume of 120 million tons (240 injection wells) to 240 million tons (480 injection wells) will be achieved by 2050.

Action plan projected by the Japanese government

| Separation and Absorption | Research and demonstrate technologies for CO₂ capture and storage, with the aim of establishing a CO₂ capture and storage system and continuous operation for 10,000 hours by 2030.
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Promote R&amp;D of storage technology, refinement and automation of monitoring, and cost reduction of drilling, storage, etc.</td>
</tr>
<tr>
<td></td>
<td>Accelerate material development by establishing evaluation protocols for separation materials by 2030.</td>
</tr>
<tr>
<td></td>
<td>Achieve competitive cost of DAC and complete pilot demonstration that DAC is effective from the LCA perspective.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transport and Storage</th>
<th>Establish energy-saving and low-cost CO₂ transportation and storage methods that are compatible with CO₂ emission sources and applications by 2030 (e.g., demonstration tests of liquefied CO₂ ship transportation).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Promote research on reservoir potential evaluation, etc., while taking economic efficiency and social acceptability into consideration.</td>
</tr>
</tbody>
</table>

| Utilization | Focus on carbon recycling for reuse as materials and fuels through mineralization and artificial photosynthesis, etc. Aiming for widespread use in chemicals (polycarbonate, etc.), fuels (bio-jet fuel, etc.), and minerals (concrete products such as road curb blocks, cement, etc.) from around 2030.
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In 2040 and beyond, to aim further cost reduction and promote widespread use in carbon recycling products that require hydrogen supply.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Common</th>
<th>Develop an environment for commercialization of domestic CCS based on trends in overseas CCS projects, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Promote the construction of public-private joint model bases for network optimization (hubs and clusters) between CO₂ emission sources, reuse and storage accumulation sites.</td>
</tr>
</tbody>
</table>

Sources: Cabinet Secretariat, METI, METI
Solutions

SHAPING THE FUTURE OF ENERGY AND MATERIALS
# System Value of Japan’s clean energy transition to achieve 2030 target

<table>
<thead>
<tr>
<th>Economic, environmental, societal and energy value</th>
<th>Energy Productivity and Systemic Efficiency</th>
<th>Resilience and Security</th>
<th>Foreign Direct Investment</th>
<th>Reliability and Service Quality</th>
<th>Flexibility</th>
<th>System Upgrade</th>
<th>Cost and Investment Competitiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>01. Renewables as a main power supply</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>261 yen/kWh for offshore wind and 8.2-11.8 yen/kWh for solar in 2030</td>
</tr>
<tr>
<td>02. Utilizing nuclear power capacity with safety assurance and domestic consensus building</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>LCDB is to be 11.7 yen/kWh for nuclear in 2030</td>
</tr>
<tr>
<td>03. Decarbonization of industrial sector</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10 trillion yen for steel and 7 trillion yen for chemical industry toward 2050</td>
</tr>
<tr>
<td>04. Transformation of transportation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.8 trillion yen for electric car, 1 trillion yen for R&amp;D and 0.2 trillion yen for infrastructure in 2030</td>
</tr>
<tr>
<td>05. Deployment of hydrogen &amp; ammonia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Target hydrogen price in 2030 is 30 yen/Nm³</td>
</tr>
<tr>
<td>06. Deployment of CCS/CCU</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Target capturing cost is 2,000 yen/t-CO₂ level for low-pressure gas and 7,000 yen/t-CO₂ level for high-pressure gas</td>
</tr>
</tbody>
</table>

Analysis performed for given System Value dimension and recovery solution. For more details, please see specific solution and/or relevant System Value dimension slide(s).
This report focuses on solutions to reduce energy-related CO₂ emissions, which occupy 77% of total GHG emissions in Japan. Solutions for both the power sector and non-power sector have been built.

**GHG emissions in 2020 (MtCO₂eq)**

- Power Sector (38%)
- Industrial Sector (23%)
- Transportation Sector (16%)
- Consumer Sector (10%)
- Non Energy CO₂ (7%)
- GHGs other CO₂ (5%)

**Pathways to net zero**

- **Power Sector**
  - Focus on renewable energy and nuclear from the aspect of reduction of CO₂ emission and energy security (to raise energy self-sufficiency).
- **Industrial**
  - Each sector needs to build solutions such as electrification, use of renewable energy, CN of fuels and processes, energy efficiency, etc.
  - Estimated percentages for reduction of CO₂ emission toward 2030 are industrial sector: 38%, commercial sector: 51%, transportation sector: 35% (compared with 2013).
- **Transportation**
  - Focus on hydrogen and CCUS, which are key enablers of reducing CO₂ emission both in power sector and non-power sector.

**Solutions**

- **01** Renewables as a main power supply
- **02** Utilizing nuclear power capacity with safety assurance and domestic consensus building
- **03** Decarbonization of industry sector
- **04** Transformation of transportation
- **05** Deployment of hydrogen & ammonia
- **06** Deployment of CCUS/CVCC
3 and 4 are premised on progress in decarbonization of power sources. It is also necessary to develop a hydrogen/ammonia supply system and establish CCS/CCU technology. While confirming the feasibility of 1, 2, 5 and 6, proceed with 3 and 4.
The role of renewable energy is important in promoting the decarbonization and electrification of sectors that consume large amounts of electricity. The enhancement of the grid system is also needed.

01 Renewables as a main power supply

Overview
To achieve carbon neutrality by 2050, bringing the renewable energy up to main power sources is one of the main solution as mentioned in the 6th Strategic Energy Plan.

Challenge
To realize the large-scale introduction of renewable energy (such as solar and wind power), it is necessary to reinforce the power grid system in order to increase the free capacity of the grid system. As described in the “Market Analysis” chapter, in addition to intra-area enhancements, inter-area grid enhancements are also planned.

Although the rule for utilizing storage battery is being developed, there are still some issues for operators. For example, although recharging and discharging from the grid is now possible, participation is only allowed in the balancing market and not in the capacity market.

Opportunity
Solar has been the most widely adopted renewable energy source in Japan due to the introduction of the feed-in-tariff in 2012 (total of 55.8 GW installed as of 2021). Recently, the PPA (power purchase agreement) model, which is a mechanism for providing power generated by a company that owns and manages PV equipment to power users at the facility, has spread, and the installation of PV systems has increased. In addition, there are also expectations for the expansion of the installation of PV systems through installing on abandoned farmland by rule revision.

Expected growth by 2030: 26.2GW/32.6TWh (sum of ground-mounted and roof-top PVs)

Offshore wind has the greatest potential compared to European countries in Japan’s renewable energy development. In terms of manufacturing, although foreign manufacturers currently dominate the manufacturing of wind turbines, Japan has an advantage in some parts such as gears and electronic components, and it is important to maintain its superiority. To promote the spread of offshore wind power, market participants are expecting government responses such as (1) shorter bidding process, (2) developing base ports, and (3) expediting wind farm certification.

Expected growth by 2030(Onshore): 4.4-6.9GW/8.3-13.2TWh (total of 4.2GW installed as of 2021) Expected growth by 2030(Offshore): 1.0-3.0GW/2.9-8.7TWh (total of 0.01GW installed as of 2021)

In addition to strengthening the grid, the spread of storage batteries will play an important role in increasing solar and wind power. Therefore, there are high expectations for the development of rules that will increase the transparency of business predictability using storage batteries. In addition, storage batteries installed in the grid system can participate in both balancing market and the capacity market auction. But, if storage batteries are installed in a solar power generation, they can only participate in balancing market. It is believed that expanding participation in trading market will also lead to the spread of storage batteries.
01 Renewables as a main power supply

The role of renewable energy is important in promoting the decarbonization and electrification of sectors that consume large amounts of electricity. The enhancement of the grid system is also needed.

**Increasing Power Generation by Renewables (TWh)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Biomass</th>
<th>Wind (Onshore)</th>
<th>Wind (Offshore)</th>
<th>Geothermal</th>
<th>Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>2</td>
<td>69</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td></td>
<td>98</td>
<td>17</td>
<td>34</td>
<td>11</td>
</tr>
</tbody>
</table>

**System Value Impacts of Renewable Power Generation**

- **122-168 Mt**
  
  CO₂ reduction in 2030

- **24.9 K - 62.1 K**
  
  Additional jobs in 2030

- Increased renewable energy and the use of storage batteries lead to maximize energy productivity and efficiency; plus add reliability to grid

- Increasing capacity leads to improve resilience

- **26.1/8.2-11.8 yen**
  
  LCOE is to be 26.1 yen/kWh for offshore wind and 8.2-11.8 yen/kWh for solar

**Notes:**

1. The range of figure includes three scenarios shown by government: maintaining current effort, strengthening policy, and ambitious goal
2. Target LCOE to achieve by 2030
The Japanese government has also indicated that Japan will continue to use nuclear power generation. While ensuring safety, it is necessary to ensure business predictability for FID and resolve issues related to the final disposal of radioactive waste, etc.

Overview
In response to the current trend toward carbon neutrality and the energy crisis triggered by the Ukraine crisis, the Japanese government announced plans to restart up to 17 reactors after the summer of 2023, and also expressed its intention to consider building new or replacing next-generation reactors, including innovative light-water reactors at the Realizing Green Transformation Meeting.

Challenge
Safety assurance is the most important and prerequisite for restarting and building new nuclear power plants. A new safety standard, which includes requirements for terrorism, aircraft collision and severe accident response, in addition to enhancements exiting items was enforced in 2013.

The environment surrounding nuclear power has changed since the accident. Specifically, market liberalization has progressed in the power generation and retail sectors, and a significant capacity of renewables, mainly solar power, have been installed, which is making system operation difficult.

10 years after the accident, maintaining human resources has become an issue; lack of opportunities for plant construction decreases experienced workers and chances to pass on skills.

In total, more than 80,000 people are employed in the Japan’s nuclear industry. Due to the impact of the earthquake, the revenue of plant manufacturers and construction companies are said to have fallen to between 20% and 80% of what they were before the earthquake, and it is believed that the number of employees working at these plants has fallen accordingly.

Opportunity
To decarbonize under the market liberalization of power generation, the recent shutdown of thermal power plants has caused a lack of energy supply and threatened stable supply in Japan. From the perspective of securing a stable supply of energy and promoting the decarbonization of electricity to achieve carbon neutrality, there is a growing awareness among the public that it is necessary to restart existing nuclear power plants whose safety has been confirmed.

Innovative reactors development needs to be considered for mid to long-term energy strategy in Japan. In addition, accelerating the process of reprocessing, decommissioning and final disposal is needed. In February 2023, the prime minister declared that as part of Japan’s energy policy, the government would consider rebuilding innovative reactors on the premises of nuclear power plants that had been decided to decommission on the premise of ensuring the safety of the region.

In addition to the development of innovative reactors, it is also necessary to pursue business profitability and predictability caused by environmental change for nuclear power business. Since nuclear power business requires large-scale investment, predictability of long-term income is essential for FID of manufacturers and power generators.
Utilization of Nuclear Power (TWh)

<table>
<thead>
<tr>
<th>Year</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010 (Before Fukushima Accident)</td>
<td>271</td>
</tr>
<tr>
<td>2021</td>
<td>68</td>
</tr>
<tr>
<td>17 plants will operate (Equipment utilization rate=80%)</td>
<td>120</td>
</tr>
<tr>
<td>2030</td>
<td>197</td>
</tr>
</tbody>
</table>

The Japanese government has also indicated that Japan will continue to use nuclear power generation. While ensuring safety, it is necessary to ensure business predictability for FID and resolve issues related to the final disposal of radioactive waste, etc.

System Value Impacts of Nuclear Power Generation

- **32-116 Mt CO₂ reduction in 2030**
- Increasing capacity leads to improved resiliency to the energy system and makes the price close to affordable price
- Nuclear with stable power output contributes to T&D stability
- **11.7 yen** LCOE is to be 11.7 yen/kWh for nuclear

Notes: (1) The range of figure includes energy mix shown in the 6th Strategic Energy Plan, scenario with assuming 10 power plants already reoperated and scenario with 17 power plants mentioned in Realizing Green Transformation Meeting. (2) The figure is calculated with equipment utilization rate=70%. The rate might be lower in the future caused by the change of energy market environment. Target LCOE to achieve by 2030 which is 0.2 yen/kWh higher than 2020.
The industrial sector emits 1/3 of Japan’s total CO₂ emissions, and decarbonization of this sector is a critical issue for Japan.

Overview
In 2020, the industrial sector contributed to 37% of the energy-related CO₂ emissions in Japan, with the steel and chemical sectors accounting for more than half of the industrial emissions.

Challenge
Unlike the transport and residential sectors, a substantial portion of industrial heat demand cannot be easily electrified due to the high temperature required. For example, a naphtha cracker for primary chemicals production is heated up to ~850°C by using the off-gas (e.g. methane) as fuel.

Decarbonization of hard-to-abate industries requires a significant shift from existing production routes to innovative new low-emission routes. For example, Japan’s steel sector, which produces 75% of crude steel in blast furnaces today, is faced with the need to transform its asset base with hydrogen reduction steelmaking, scrap-based electric arc furnaces and CCUS, which would cost roughly 10 trillion yen in total.

Opportunity
Hydrogen and its derivatives (e.g. ammonia and synthetic methane) will play a key role in Japan’s industrial decarbonization through various applications, including hydrogen reduction steelmaking and an ammonia-fired naphtha cracker. There is a growing momentum to develop hydrogen/ammonia hubs at industrial complexes, where potential suppliers and users are co-located; Kawasaki (hydrogen) and Shunan (ammonia) are leading the way.

Synthetic methane, or e-methane, is also regarded as a viable alternative for fossil fuels, as existing gas infrastructure can be utilized.

Systemic efficiency and circularity are other key elements to help decarbonize the industry. Japan’s steel and chemical sectors are among the most energy-efficient in the world, but the collaboration among companies can unlock further potential. In the Kashima Industrial Complex, a plastic-to-oil conversion business has been jointly launched by an oil company and a chemical company.

Direct electrification and renewable heat receives relatively little attention in the industrial sector due to limited applicability. However, replacing a boiler with a heat pump, for example, would half the CO₂ emissions even with Japan’s current power generation mix, and the reduction impact would increase as the emission intensity of electricity improves in the future. The potential of electrification can be maximized through extending the range of applicable temperature.

CCUS will be necessary to offset the CO₂ emissions, and Japan’s industry has been working on various technologies, such as production of basic substances (e.g., methanol), chemicals, and fuels from CO₂. One of the unique technologies is artificial photosynthesis, which produces chemicals from water and captured CO₂. A feasibility study of a CCS project to capture CO₂ at a steel plant in Japan and transport them to CCS facilities overseas is also being conducted.

Sources: NIES, worldsteel, JSIF, Kawasaki city, Idemitsu, Mitsubishi Chemical, CHEP, Nippon Steel
03 Decarbonization of the industrial sector

The industrial sector emits one third of Japan's total CO₂ emissions, and decarbonization of this sector is a critical issue for Japan.

- **Industry (37%)**
- **Commercial and others (19%)**
- **Energy conversion (8%)**
- **Transport (19%)**
- **Residential (17%)**
- **Steel (37%)**
- **Machinery (13%)**
- **Pulp and paper (6%)**
- **Other industries (16%)**
- **Chemical (15%)**
- **Cement and other ceramics (8%)**
- **Food and beverages (5%)**

Source: NIES, worldsteel, JISF, Kawasaki city, Idemitsu, Mitsubishi Chemical, CRIEPI, Nippon Steel

Energy-related CO₂ Emissions by sector in 2020 (Mt CO₂)

- 967 Mt
- 166 Mt
- 182 Mt
- 185 Mt
- 250 Mt
- 78 Mt
- 10 Mt

Improving energy efficiency, not only at a company level, but also through collaboration among co-located industries, helps to maximize overall energy productivity.

10 Mt CO₂ reduction in steel and chemical industry by energy efficiency in 2030

Note: CO₂ emissions from power and heat generation are allocated to each sector based on the consumption of power and heat. Other industries includes agriculture, construction, textile, non-ferrous metals, etc.
04 Transformation of transportation

Since the automobile industry is positioned as an important part of Japanese industry as a whole, it is necessary to promote efforts toward decarbonization while combining various technologies and approaches.

Overview
In the transportation sector, automobiles account for 86% of CO₂ emissions (15% of total Japan emission). The Japanese government has announced a policy that 100% of new passenger car sales will be electric vehicles (EV, HV, PHV, FCV) by 2035, and 2-30% of new commercial vehicle sales will be electric vehicles by 2030, targeting small vehicles of 8 tons or less. The government positions carbon-neutral fuel as one of the important technologies, and R&D including decarbonization of existing vehicles is underway.

Challenge
The Japanese government aims to make all cars sold electrified by 2035. However, it is important to evaluate the effectiveness of all approaches leading to carbon neutrality, rather than focusing on individual technologies such as EVs and FCVs.

For EVs and FCVs, it is necessary to decarbonize the basis of power (electricity, hydrogen, etc). Carbon neutral fuel is also an important technology for achieving carbon neutrality.

Regarding mobility, it is important to aim for carbon neutrality throughout the life cycle, which means it is necessary for raw materials and disposal processes to become carbon neutral as well.

Opportunity
For promoting the wide spread of electric vehicles, LCC reduction is essential: as of November 2022, the price in Japan is 3.7-4.2 million yen for the Nissan LEAF (EV) and 7.1-8.6 million yen for the Toyota MIRAI (FCV). Subsidies are applied to promote the spread (e.g., EV: 850,000 yen, FCV: 1.45 million yen). In addition, the promotion of decarbonization of power sources and hydrogen is related to the spread of EVs and FCVs.

Infrastructure such as charger and hydrogen stations is also being installed. Subsidies are also being applied to promote the development of infrastructure.

Storage batteries production in Japan is also an important topic. To this end, it is necessary to R&D all-solid-state lithium ion batteries to establish a large-scale production site for battery and material and to consider the policy framework based on battery passports.

Improving the efficiency of truck transportation, which accounts for the majority of land transportation, is an important topic in promoting transportation efficiency. Efforts to improve transportation and loading efficiency using AI are being promoted mainly by technology companies.

The use of drones and automated delivery robots are another initiative that could contribute to decarbonization. Currently, social implementation of drone logistics is being considered, especially in depopulated areas.

Sources: METI, Nissan, Toyota, METI, METI, IEA, METI, New Bureau of Taxation, JADA
Since the automobile industry is positioned as an important part of Japanese industry as a whole, it is necessary to promote efforts toward decarbonization while combining various technologies and approaches.

### System Value Impacts of Transformation of vehicle and efficiency improvement

- **9 Mt** reduction by EV/FCV/PHV/HV in 2030*
- Use of EV as storage leads to maximize energy efficiency
- Widely use of EV produce flexibility of electricity
- Widely use of EV contributes to T&D stability

#### 1.8 trillion yen
- 1.8 trillion yen for electric car, 1 trillion yen for R&D and 0.2 trillion yen for infrastructure in 2030

*The figure includes only passenger car*
With the aim of accelerating the introduction of hydrogen and ammonia into Japan, the government has indicated measures to support the cost of building a hydrogen and ammonia supply chain and infrastructure development.

Overview
As mentioned in Green Growth Strategy, hydrogen can be a key technology to accelerate carbon neutral in Japan. In Japan, imports from overseas are expected to be the main sources, and the establishment of a supply chain is at the top of the agenda. To achieve this goal, the Japanese government presented policies on February 2023 to support the establishment of supply chains and building hydrogen/ammonia facilities.

Challenge
For hydrogen and ammonia suppliers to grow their business steadily, it is necessary to have stable demand; to reduce the cost of hydrogen and ammonia, developing large-scale demand is mandatory. Having stable demand is also important in establish a supply chain.

Steps to establish supply chain: in the early stages, not only green hydrogen but also gray hydrogen should be supported for a limited term, then gradually shift to blue, and finally the supply of green hydrogen will be ready. It is important to shift to green hydrogen and ammonia as soon as possible in order to avoid pressure from domestic and foreign shareholders and financial institutions.

Opportunity
Power sector: The Japanese government says hydrogen and ammonia will account for 1% of the power supply mix in 2030.

Non-power sector: In the industrial sector, hydrogen is expected to be used to decarbonize manufacturing processes, such as blast furnace hydrogen reduction and DRI in the steel industry, and to meet demand for heat at high temperatures where electrification is difficult. In addition, with the decarbonization of gas through methanation and the spread of fuel cells, hydrogen is expected to be used in the business, residential, and transportation sectors as well.

The Japanese government will use the total cost of manufacturing and supplying hydrogen and ammonia to be sold to consumers by suppliers of hydrogen and ammonia as the standard price, and will support all or part of the difference between the price and the selling price to consumers. In principle, the support period will be 15 years.

The Japanese government believes that it is necessary to create large-scale demand for hydrogen and ammonia and to build an efficient supply chain, and will provide support for infrastructure development. Regarding specific bases, the Japanese government and the private sector will cooperate to select and develop three large-scale bases and five medium-scale bases over the next 10 years. Creating actual use cases based on the policy published by the Japanese government will help spread hydrogen and ammonia in the future.
With the aim of accelerating the introduction of hydrogen and ammonia into Japan, the government has indicated measures to support the cost of building a hydrogen and ammonia supply chain and infrastructure development.

### Target Volume and Cost for Hydrogen and Ammonia

- **Introduced volume (Mt H₂eq)**
- **Supply cost (yen/Nm³)**

### System Value Impacts of Hydrogen / Ammonia

- **18 Mt**
  - CO₂ reduction by FCV, FC bus, steel manufacturing and home FC in 2030
- **Developing new supply-chain produce various job opportunities**
- **30 yen/Nm³**
  - Target hydrogen price in 2030 is 30 yen/Nm³
The Japanese government has decided to start the CCS project in FY2030, start a feasibility study from FY2023 and plans to make FID by FY2026.

**Overview**

CCS and CCU are key technologies that will lead to virtually zero CO₂ emissions not only from thermal power generation in the electric power sector, but also in the non-electric power sector (especially in the industrial sector).

In the 6th Strategic Energy Plan and the interim report of the CCS Long-Term Roadmap Study Group, the Japanese government has mentioned the need to start CCS projects by 2030, and to achieve this, it is necessary to (1) start FS, etc. from 2023 and (2) make a final investment decision by 2026.

In the future, the government aims to achieve an annual storage capacity of 120 million tons (240 injection wells) to 240 million tons (480 injection wells) by 2050.

**Challenge**

The scope of responsibility for semi-permanent underground sequestration of CO₂ in CCS projects is currently unclear. It is one of the most important issues to clarify the scope for operator and the government, leading to improve the visibility of business predictability.

CCS and CCU are not profitable by itself and represent only an additional investment for companies. Therefore, it is imperative to create a mechanism to provide incentives for these efforts and to consider how costs should be borne.

While many industry clusters in Japan that emit CO₂ are located on the Pacific Ocean side, it is also believed that the opposite side, the Sea of Japan, is more suitable for storing CO₂. This is due to the possibility that the Pacific side is more likely to be affected by earthquakes. Therefore, how to transport CO₂ is also an important issue.

**Opportunity**

**Separation and capture:** How to reduce this cost is important to promote social implementation. Currently, the cost of CO₂ separation and capture is estimated to account for the majority of CCS costs.

**Storage:** To accelerate the implementation of CCS/CCU, it is necessary to establish rules for explore and use of suitable sites by operators. Specifically, the establishment of rules regarding reservoir exploration and CO₂ injection storage rights will be necessary first.

**Utilization:** To commercialize CCS/CCU, it is necessary to anticipate a large demand related to CCS/CCU and to reduce the cost accordingly.

Sources: METI, METI, METI
The Japanese government has decided to start the CCS project in FY2030, start a feasibility study from FY2023 and plans to make FID by FY2026.

Target CCS Amount

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual CCS Amount (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2030</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2031</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2032</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2033</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2034</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2035</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2036</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2037</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2038</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2039</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2040</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2041</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2042</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2043</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2044</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2045</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2046</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2047</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2048</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2049</td>
<td>120Mt/yr</td>
</tr>
<tr>
<td>2050</td>
<td>240Mt/yr</td>
</tr>
</tbody>
</table>

Japan aims to start CCS projects in 2030

Note: Estimate by METI, based on CCS required globally in 2050 (simulated in IEA’s WEO2021) and the proportion of Japan’s CO2 emissions. The graph indicates a linear increase from 2030 to 2050, but the increase in initial years is expected to be smaller in reality.

System Value Impacts of CCS / CCU

- **120-240 Mt CO2 storage in 2050**
- Developing CCS/CCU industry produce various job opportunities
- Target capturing cost is 2,000 yen/t-CO2 level for low pressure gas and 1,000 yen/t-CO2 level for high pressure gas

Sources: METI, METI, METI
Appendix
SHAPING THE FUTURE OF ENERGY AND MATERIALS
# System Value Dimension

## Jobs and economic impact

<table>
<thead>
<tr>
<th>Solution</th>
<th>Jobs and Economic Impact</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewables as a main power supply</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Utilizing nuclear power capacity with safety assurance and domestic consensus building</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Decarbonization of industrial sector</td>
<td>In promoting decarbonization, it is assumed that NO new employment will be created based on the current employees and employees of affiliated companies.</td>
<td><img src="#" alt="Contributes to job creation significantly" /></td>
</tr>
<tr>
<td>Transformation of vehicle (EV/FCV etc.) and efficiency improvement of transportation</td>
<td>It is assumed that NO new employment will be created in manufacturing EVs, FCVs, etc. On the other hand, a certain amount of employment will be created from the standpoint of installing charging stations and hydrogen stations and maintaining and operating them.</td>
<td><img src="#" alt="Contributes to job creation to some extent" /></td>
</tr>
<tr>
<td>Deployment of hydrogen &amp; ammonia</td>
<td>It is assumed that the use of hydrogen and ammonia in 2030 will be centred on power generation, and NO new jobs will be created at power plants. On the other hand, a certain amount of employment will be created in the installation of infrastructure facilities for storing hydrogen and ammonia.</td>
<td><img src="#" alt="Contributes to job creation to some extent" /></td>
</tr>
<tr>
<td>Deployment of CCS/CCU</td>
<td>There are job creations in implementing CCS and CCU.</td>
<td><img src="#" alt="Contributes to job creation significantly" /></td>
</tr>
</tbody>
</table>
## System Value Dimension

### Air quality and health

<table>
<thead>
<tr>
<th>Solution</th>
<th>Air quality and health</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewables as a main power supply</td>
<td>The decrease in the share of thermal power generation due to the expansion of renewable energy (FY2030: assumed share of renewables is 36%-38%) will greatly reduce the adverse effects of harmful substances such as SOx and NOx on health and the natural environment.</td>
<td><img src="image" alt="Circle" /></td>
</tr>
<tr>
<td>Utilizing nuclear power capacity with safety assurance and domestic consensus building</td>
<td>The decrease in the share of thermal power generation due to the use of nuclear power generation (FY2030: assumed share of nuclear is 20%-22%) will greatly reduce the adverse effects of harmful substances such as SOx and NOx on health and the natural environment.</td>
<td><img src="image" alt="Circle" /></td>
</tr>
<tr>
<td>Decarbonization of industrial sector</td>
<td>Decrease in the use of power derived from thermal power generation due to further efforts to save energy, decarbonization of fuel (hydrogen, ammonia, etc.) for heat demand in factories will greatly reduce the adverse effects of harmful substances such as SOx and NOx on health and the natural environment.</td>
<td><img src="image" alt="Circle" /></td>
</tr>
<tr>
<td>Transformation of vehicle (EV/FCV etc.) and efficiency improvement of transportation</td>
<td>Decrease in gasoline vehicles due to the expansion share of EVs and FCVs will greatly reduce the adverse effects of harmful substances such as SOx and NOx on health and the natural environment.</td>
<td><img src="image" alt="Circle" /></td>
</tr>
<tr>
<td>Deployment of hydrogen &amp; ammonia</td>
<td>Decrease in the share of fossil fuel-based thermal power generation due to the spread of hydrogen and ammonia power generation (FY2030: assumed share of hydrogen/ammonia is 1%) will reduce the adverse effects of SOx, NOx, and other harmful substances on health and the natural environment to some extent. Decrease in the number of gasoline-powered vehicles due to the spread of FCVs will reduce the adverse effects of CO, NOx, PM, CO2, etc. to some extent.</td>
<td><img src="image" alt="Circle" /></td>
</tr>
<tr>
<td>Deployment of CCS/CCU</td>
<td>CCUS is an approach to CO2 and does not contribute to the reduction of harmful substances such as SOx, NOx and PM2.5.</td>
<td><img src="image" alt="Circle" /></td>
</tr>
</tbody>
</table>
## System Value Dimension

**Energy productivity and systemic efficiency**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Energy productivity and systemic efficiency</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewables as a main power supply</td>
<td>The expansion of renewable energy sources (FY2030: assumed share is 36%-38%) is expected. Among them, by expanding the introduction of storage batteries, we are in the process of providing the stability of solar and wind power output.</td>
<td>![Circle]</td>
</tr>
<tr>
<td>Utilizing nuclear power capacity with safety assurance and domestic consensus building</td>
<td>Restarting or building new nuclear power plants (FY2030: assumed share is 20-22%) will significantly increase energy supply capacity, but will not contribute to improving productivity or efficiency.</td>
<td>![Circle]</td>
</tr>
<tr>
<td>Decarbonization of industrial sector</td>
<td>Thorough pursuit of energy efficiency in the industrial sector (e.g. recycling of waste plastics in the steel industry, high-efficiency in-house power generation, etc.) will restrain energy demand to some extent.</td>
<td>![Circle]</td>
</tr>
<tr>
<td>Transformation of vehicle (EV/FCV etc.) and efficiency improvement of transportation</td>
<td>Since EVs have the aspect of storage batteries, their spread will greatly increase the adjustment capability.</td>
<td>![Circle]</td>
</tr>
<tr>
<td>Deployment of hydrogen &amp; ammonia</td>
<td>The expansion of hydrogen and ammonia power generation (FY2030: assumed share is 1%) will increase energy supply capacity to some extent.</td>
<td>![Circle]</td>
</tr>
<tr>
<td>Deployment of CCS/CCU</td>
<td>CCUS is an approach to CO₂ and does not contribute to improving the productivity and efficiency of the energy system.</td>
<td>![Circle]</td>
</tr>
</tbody>
</table>
### System Value Dimension

#### Resiliency and security

<table>
<thead>
<tr>
<th>Solution</th>
<th>Resiliency and security</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewables as a main power supply</td>
<td>Increased supply capacity/improved self-sufficiency rate through the expansion of renewable energy greatly contributes to the improvement of resilience and security by raising the energy self-sufficiency rate.</td>
<td>☑️</td>
</tr>
<tr>
<td>Utilizing nuclear power capacity with safety assurance and domestic consensus building</td>
<td>Increased supply capacity/improved self-sufficiency rate by restarting or newly constructing nuclear power plants will greatly contribute to improving resilience and security by increasing the energy self-sufficiency rate.</td>
<td>☑️</td>
</tr>
<tr>
<td>Decarbonization of industrial sector</td>
<td>The industrial sector is the demand side and does not contribute to resilience or security improvement.</td>
<td>⬜️</td>
</tr>
<tr>
<td>Transformation of vehicle (EV/FCV etc.) and efficiency improvement of transportation</td>
<td>EVs do not have the ability to generate electricity on their own. On the other hand, EV has the aspect of a storage battery, expansion of EVs is useful for continuous power supply and recovery from failures and disasters, and contributes to improving resilience.</td>
<td>⬜️</td>
</tr>
<tr>
<td>Deployment of hydrogen &amp; ammonia</td>
<td>Hydrogen has a power storage aspect, so its widespread use is useful for the continuous supply of power and recovery from failures and disasters, and contributes to the improvement of resilience.</td>
<td>☑️</td>
</tr>
<tr>
<td>Deployment of CCS/CCU</td>
<td>CCUS is an approach to capture CO₂ and does not contribute to improved resilience or security.</td>
<td>⬜️</td>
</tr>
</tbody>
</table>
### System Value Dimension

**Flexibility**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Flexibility</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewables as a main power supply</td>
<td>Renewable energy itself is a variable power source. However, considering that renewable energy is becoming a target for curtailment of output, and that the use of storage batteries is expected to spread, it is expected to contribute to the provision of flexible power to some extent.</td>
<td><img src="https://via.placeholder.com/15" alt="Medium" /></td>
</tr>
<tr>
<td>Utilizing nuclear power capacity with safety assurance and domestic consensus building</td>
<td>Nuclear power generation is positioned as a baseload power, and it is said that it cannot be adjusted by output control at present. This solution does not contribute to providing flexibility.</td>
<td><img src="https://via.placeholder.com/15" alt="Null" /></td>
</tr>
<tr>
<td>Decarbonization of industrial sector</td>
<td>The industrial sector is the demand side and does not contribute to providing flexibility.</td>
<td><img src="https://via.placeholder.com/15" alt="Null" /></td>
</tr>
<tr>
<td>Transformation of vehicle (EV/FCV etc.) and efficiency improvement of transportation</td>
<td>Since EVs have the aspect of storage batteries, their widespread use will contribute to the provision of flexibility on a large scale.</td>
<td><img src="https://via.placeholder.com/15" alt="Medium" /></td>
</tr>
<tr>
<td>Deployment of hydrogen &amp; ammonia</td>
<td>Hydrogen/ammonia have potential as a storage method for surplus power generated by renewable energy. On the other hand, the future positioning of hydrogen as a balancing power is unknown.</td>
<td><img src="https://via.placeholder.com/15" alt="Medium" /></td>
</tr>
<tr>
<td>Deployment of CCS/CCU</td>
<td>CCUS is an approach to capture CO2 and does not contribute to providing flexibility.</td>
<td><img src="https://via.placeholder.com/15" alt="Null" /></td>
</tr>
</tbody>
</table>
Renewables as a main power supply

Renewable energy itself is a variable power source. However, considering that renewable energy is becoming a target for curtailment of output, and that the use of storage batteries is expected to spread, it is expected to contribute to stabilized the grid system to some extent.

Utilizing nuclear power capacity with safety assurance and domestic consensus building

Nuclear power turbines are capable of rated output and contribute significantly to grid stabilization.

Decarbonization of industrial sector

The industrial sector is the demand side of the energy system, and if the introduction of DER progresses in the future, it can be expected to contribute to a certain extent.

Transformation of vehicle (EV/FCV etc.) and efficiency improvement of transportation

Since EVs have the aspect of storage batteries and generate adjustment power, their spread will greatly contribute to the stabilization of the grid.

Deployment of hydrogen & ammonia

As with storage batteries, it has potential as a method of storing surplus power generated by renewable energy, so it will contribute to the stabilization of the grid to some extent. On the other hand, the future positioning of hydrogen as a balancing power is unknown.

Deployment of CCS/CCU

CCUS is a capturing CO2 approach and does not contribute to providing stability to the grid.