# CHAPTER 8

# Japan
# Main Report

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# 1. Introduction

In October 2020, the Government of Japan declared its goal to be carbon neutral by 2050. Then in 2021, the government updated its Nationally Determined Contribution (NDC) for 2030 to 46% below 2013 greenhouse gas (GHG) emissions. The government previously declared an emission target of just 26% below 2013, and the target has gotten a far more ambitious one. The 6th Strategic Energy Plan, which was approved by the cabinet the same year as the NDC update, outlines these quantitative targets and the actions to be taken in each energy sector to reach carbon neutrality by 2050 and NDC by 2030 (Ministry of Economy, 2021a).

While Japan works toward carbon neutrality, the current energy mix in the country heavily depends on fossil fuels. In 2020, fossil fuels made up 85% of the primary energy supply (Ministry of Economy, 2021b). Power generation is a relatively decarbonised sector, yet generation from coal, oil, and natural gas covers 74% of total power generation. Japan has to substitute these fossil fuel demands or capture and storage the emissions from fossil fuels in order to neutralise the GHG emission.

To consider energy supply and demand in Japan, this report presents a business-as-usual (BAU) scenario, in which similar energy policies are currently taken; an alternative policy scenario (APS) scenario, which considers more powerful measures for climate issues (these two are forecast scenarios); and an LCET scenario, a backcast scenario for carbon neutrality. This scenario analysis will show the difference between Japan's carbon neutrality and the forecast scenarios and summarise the challenges to achieving it.

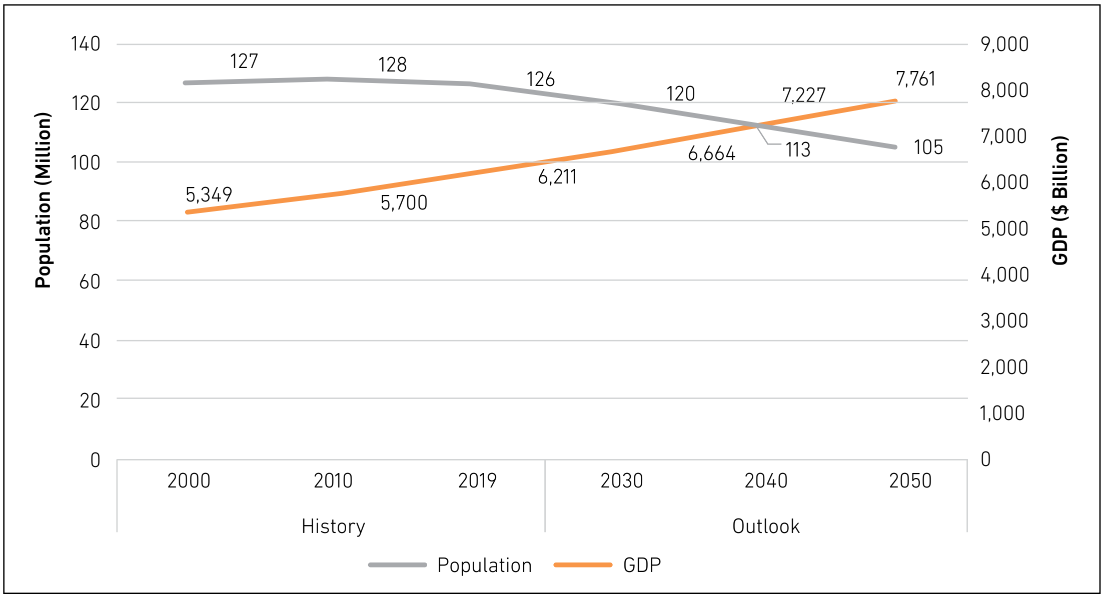
# 2. Modelling Assumptions

## 2.1. Macro-Economy

Recently, gross domestic product (GDP) in Japan has continued a moderate and steady growth, at 1.0% per year between 2010 and 2019. On the other hand, in 2020, GDP declined 4.8% from the previous year due to the economic damage from the coronavirus disease (COVID-19) pandemic. In this outlook, the economy is projected to restart a slow and steady growth so that its GDP is assumed to have an average annual growth rate (AAGR) of 0.8% from 2021 to 2050.

Population in Japan peaked around 2010 and has been declining since then. In the outlook period, population will decline by about 0.6% per year due to a low birth rate. Consequently, population is projected to decline from 126 million in 2020 to 105 million in 2050. Figure 8-1 shows the assumptions of GDP and population in this outlook.

**Figure 8.1** Population and Gross Domestic Product Prospect




GDP = gross domestic product.

Sources:

1. International Monetary Fund, 2021.
2. United Nations Population Division, 2019.

In this outlook, energy supply and demand are projected in three scenarios. First, the BAU scenario incorporates the expected effects of past tends and extends the energy and environmental policies and technologies to date. In the APS scenario, intensive reduction measures for carbon dioxide ($CO_2$) emissions are expected based on social opportunities and acceptability. Energy conservation will accelerate from current trends, and fuel substitution and renewable energy will be introduced within techno-economic limits. In Japan, several nuclear power plants have been suspended since the Great East Japan Earthquake happened in 2011. This scenario considers the restart of nuclear power plants that are confirmed safe and which have been operating within 60 years.

Additionally, the LCET scenario is a backcasting scenario that assumes carbon neutrality in 2050. In the scenario, necessary efforts to achieve it will be made (regardless of the economy). Since Japan has a very limited carbon capture storage (CCS) potential, it is hardly considered in the BAU and the APS scenarios. However, the LCET scenario assumes CCS penetration into existing thermal power plants and industrial processes due to the need for carbon neutrality.

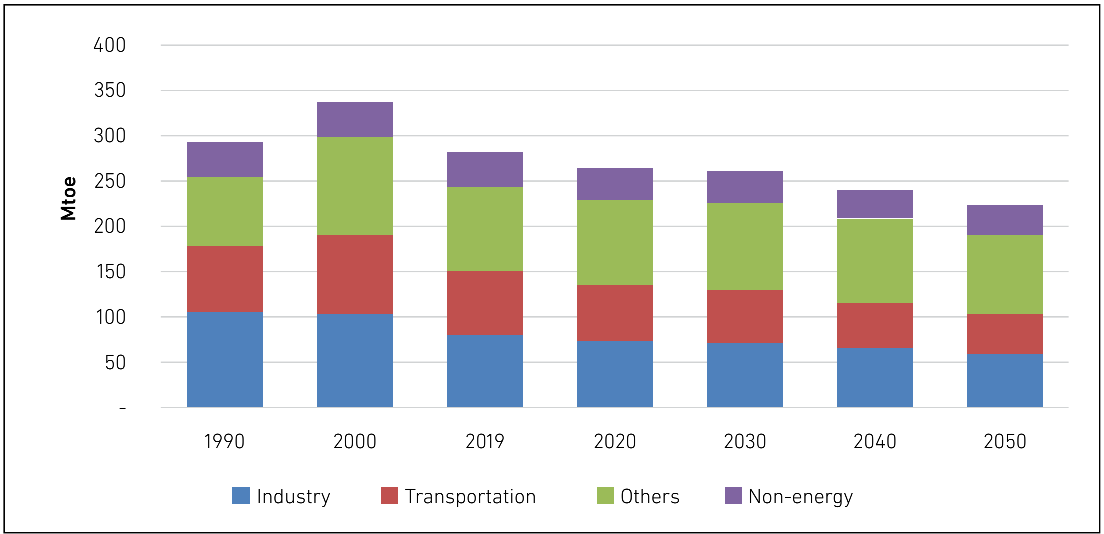
# 3. Outlook Results

## 3.1. Business-As-Usual Scenario

### 3.1.1. Final Energy Consumption

Japan's total final energy consumption (TFEC) will continue to decline through 2050 (Figure 8.2). Transportation sector demand will especially decrease at an AAGR of 1.5% from 2019 to 2050 mainly due to the vehicle shift from conventional gasoline vehicles to gasoline hybrid vehicles and electric vehicles, improving fuel economy. Industry sector demand will also decline at an AAGR of 0.9% during the same period because of the industrial structure change and further energy conservation along with existing policies.

**Figure 8.2 Final Energy Consumption by Sector, Business-as-Usual, 1990–2050**
(Mtoe)

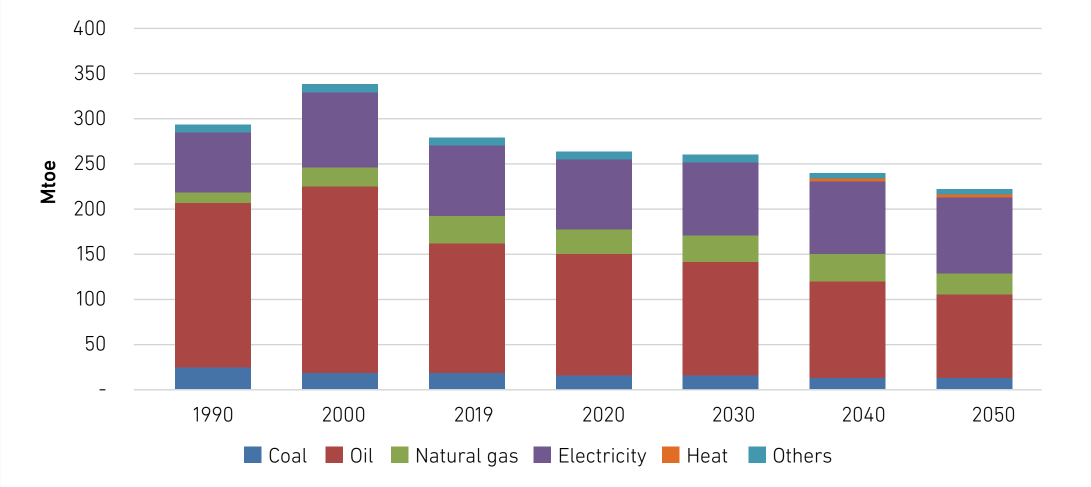



Mtoe = million tonnes of oil equivalent.

Source: Authors' calculation.

In terms of the TFEC by source, coal and oil consumption will decrease at an AAGR of 1.5% and 1.4%, respectively, due to reduced demand from the transportation and industry sectors (Figure 8.3). In contrast, electricity demand will increase at an AAGR of 0.7% due to further electrification on the demand side.

**Figure 8.3** **Final Energy Consumption by Source, Business-as-Usual, 1990–2050**
(Mtoe)



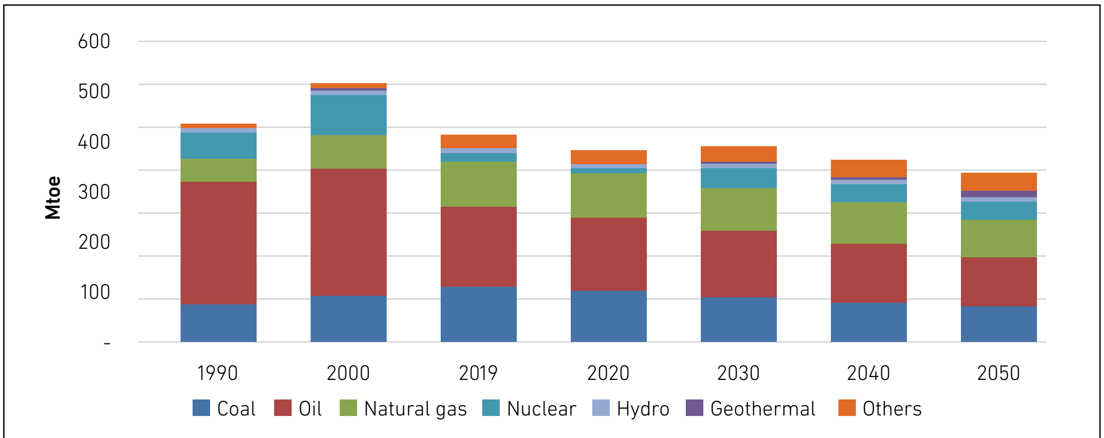

Mtoe = million tonnes of oil equivalent.

Source: Authors' calculation.

### 3.1.2. Primary Energy Supply

Because of energy conservation led by existing policies, total primary energy supply (TPES) will decline at an AAGR of 0.6% through 2050 (Figure 8.4). Oil, coal, and natural gas will decrease at an AAGR of 1.5%, 1.4% and 0.6%, respectively, due to the decline in fossil-fuel use in the TFEC and the power sector. On the contrary, renewables like solar photovoltaics (PV), wind, and geothermal will increase since the power sector particularly utilises more renewables according to existing policies.

**Figure 8.4** **Primary Energy Supply, Business-as-Usual, 1990–2050**
(Mtoe)



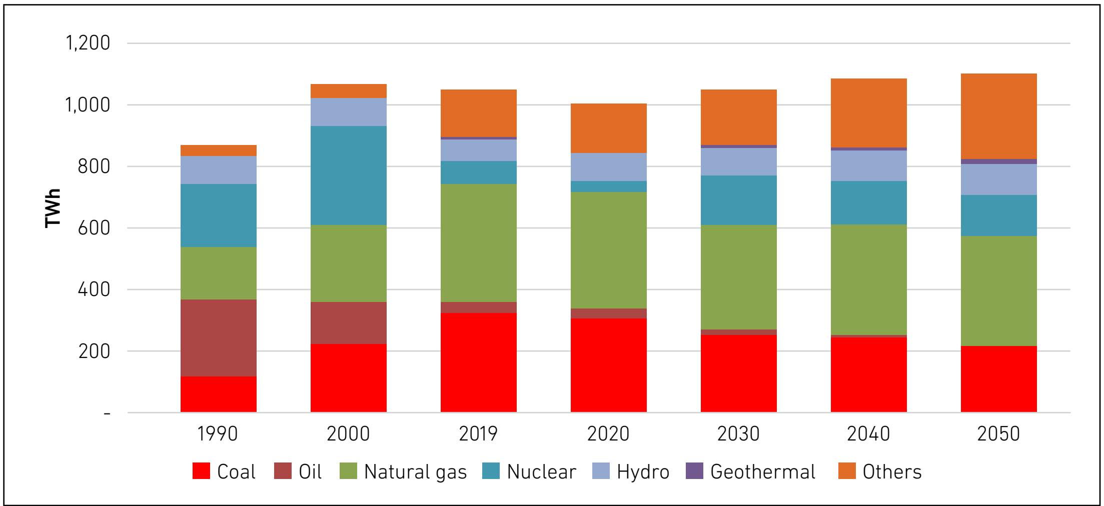

Mtoe = million tonnes of oil equivalent.

Source: Authors' calculation.

### 3.1.3. Power Generation

Total power generation dropped in 2020 due to the COVID-19 pandemic but would increase again through 2050 (Figure 8.5). While fossil-fuel fired power generation will decrease, renewables such as solar PV, wind and geothermal and nuclear will increase along with existing policies. In the BAU scenario, over 45% of power generation will come from non-fossil fuels in 2050.

**Figure 8.5 Power Generation, Business-as-Usual, 1990–2050**
(TWh)



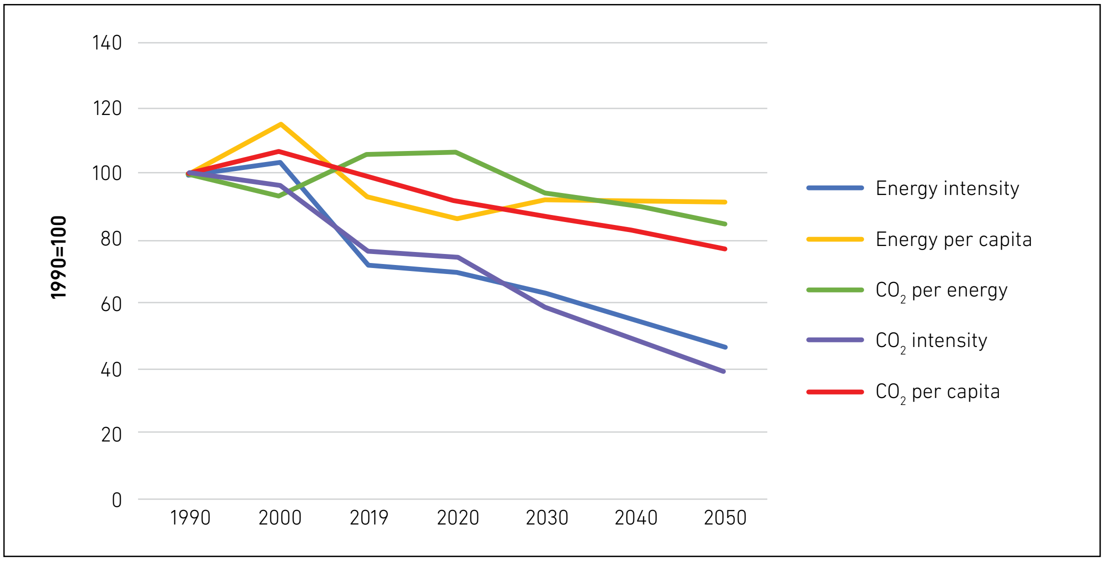

TWh = terawatt-hour.

Source: Authors' calculation.

### 3.1.4. Energy Indicators

Energy intensity, or primary energy supply per GDP, and $CO_2$ per energy will decline at an AAGR of -1.4% and -0.7%, respectively (Figure 8.6). As a result, $CO_2$ intensity will decrease at an AAGR of -2.1% through 2050.

**Figure 8.6** Indices of Energy and Carbon Dioxide Intensities, Energy Per Capita, and Carbonisation Rate, Business-as-Usual, 1990–2050




$CO_2$ = carbon dioxide.

Source: Authors' calculation.

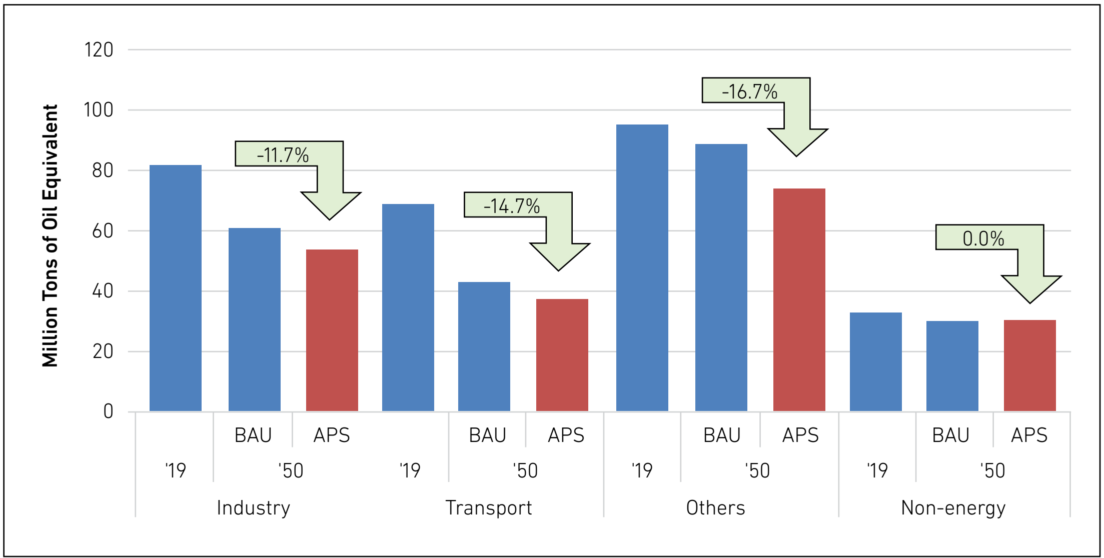
## 3.2. Energy Saving and Carbon Dioxide Reduction Potential, Alternative Policy Scenario

### 3.2.1. Final Energy Consumption

The total final energy consumption (TFEC) for the APS scenario will decrease by 12.7% in 2050 from the BAU level (Figure 8.7). For the APS in 2050, demands will decrease by 16.7% for the 'Others' sector, which includes residential and commercial; 14.7% for transport; and 11.7% for industry from the BAU levels in 2050. In the APS, energy conservation will proceed more aggressively than the BAU with powerful policies for climate issues.

**Figure 8.7 Total Energy Consumption, Business-as-Usual and Alternative Policy Scenario, 2019 and 2050**

(Mtoe)




APS = alternative policy scenario, BAU = business-as-usual.

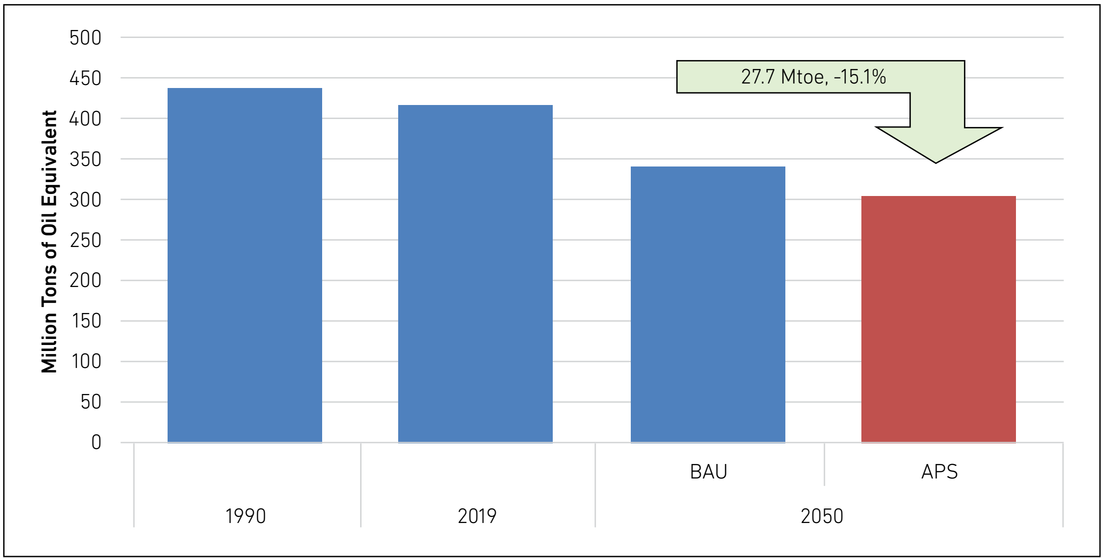
Source: Authors' calculation.

### 3.2.2. Primary Energy Supply

The total primary energy supply (TPES) for the APS scenario would decrease by 15.1% in 2050 from the BAU level, mainly due to energy conservation in final energy consumption and efficiency improvement in the power sector (Figure 8.8).

**Figure 8.8** **Total Primary Enregy Supply, Business-as-Usual and Alternative Policy Scenario, 1990, 2019, and 2050**

(Mtoe)




APS = alternative policy scenario, BAU = business-as-usual, Mtoe = million tonnes of oil equivalent.

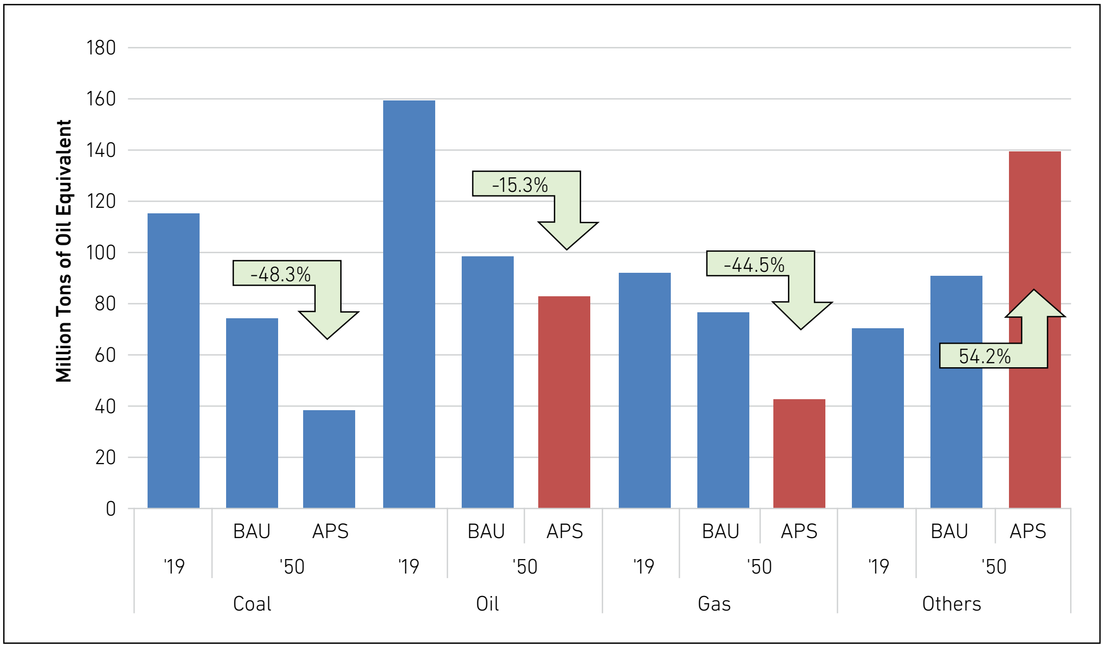
Source: Authors' calculation.

### 3.2.3. Projected Energy Saving

Fossil fuel consumption for the APS in 2050 will considerably decrease from BAU levels, while other energy sources, such as renewables, will increase (Figure 8.9). The APS scenario in 2050 sees a 48.3% reduction in coal demand from the BAU level, followed by 44.5% in natural gas and 15.3% in oil. In contrast, the APS will increase other energy sources including renewables by 54.2% from the BAU level. In the APS, energy sources will shift to more non-fossil fuels with more energy conservation than the BAU.

**Figure 8.9** Primary Energy Supply by Source, Business-as-Usual and Alternative Policy Scenario, 2019, and 2050

(Mtoe)



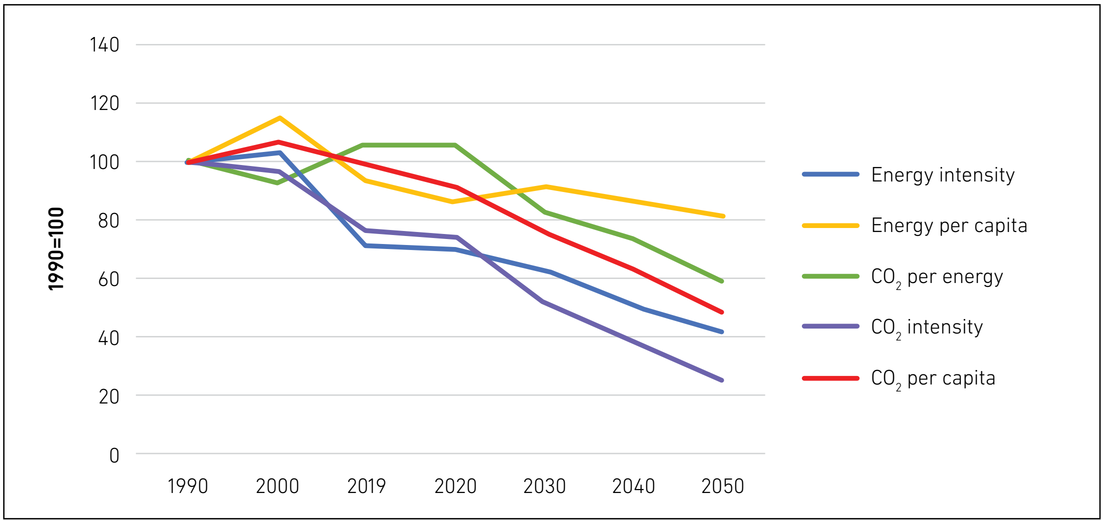

APS = alternative policy scenario, BAU = business-as-usual, Mtoe = million tonnes of oil equivalent.

Source: Authors' calculation.

### 3.2.4. Energy Indicators

In the APS, energy intensity will decrease by an AAGR of 1.7%, while $CO_2$ per energy demand will decrease at an AAGR 1.9% (Figure 8.10). Compared to the BAU, the decreasing rate of $CO_2$ per energy demand will be remarkable due to more non-fossil fuel diffusion. As a result, $CO_2$ intensity, which is $CO_2$ emission per GDP, will drop at an AAGR of 3.5% from 2019 to 2050. Reflecting on the 24% improvement of $CO_2$ intensity from 1990 to 2019, the 67% improvement from 2019 to 2050 would be extraordinary.

**Figure 8.10** Indices of Energy and Carbon Dioxide Intensities, Energy Per Capita, and Carbonisation Rate, Business-as-Usual, 1990–2050



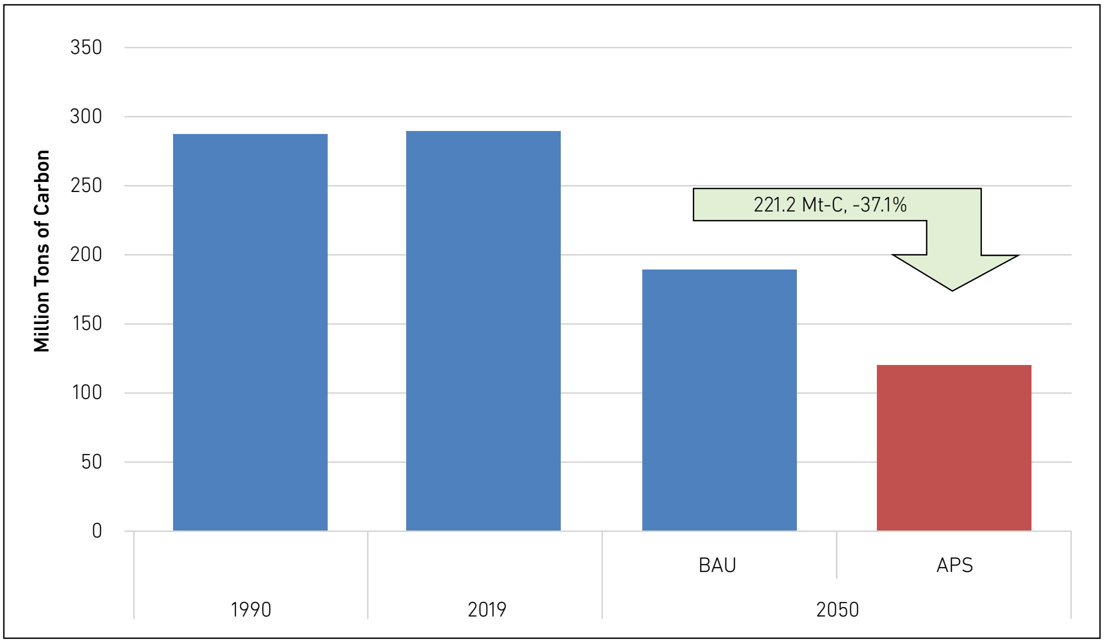

$CO_2$ = carbon dioxide.

Source: Authors' calculation.

### 3.2.5. Carbon Dioxide Emission Reduction

The $CO_2$ emission reduction rate for the APS will be 37.1% from the BAU level in 2050 (Figure 8.11). The total $CO_2$ emission will be 435 Mt-C in 2050, which is only 41% of the 2019 emission level. Still, the APS will not achieve net-zero emissions by 2050, which is the new national target of Japan.

**Figure 8.11 Carbon Dioxide Emissions from Fossil Fuel Combustion, Business-as-Usual and Alternative Policy, 1990, 2019, and 2050**
(Mt-C)




APS = alternative policy scenario, BAU = business-as-usual, Mt-C = million tonnes of carbon.
Source: Authors' calculation.

## 3.3. Low Carbon Energy Transition Scenario, Carbon Neutral

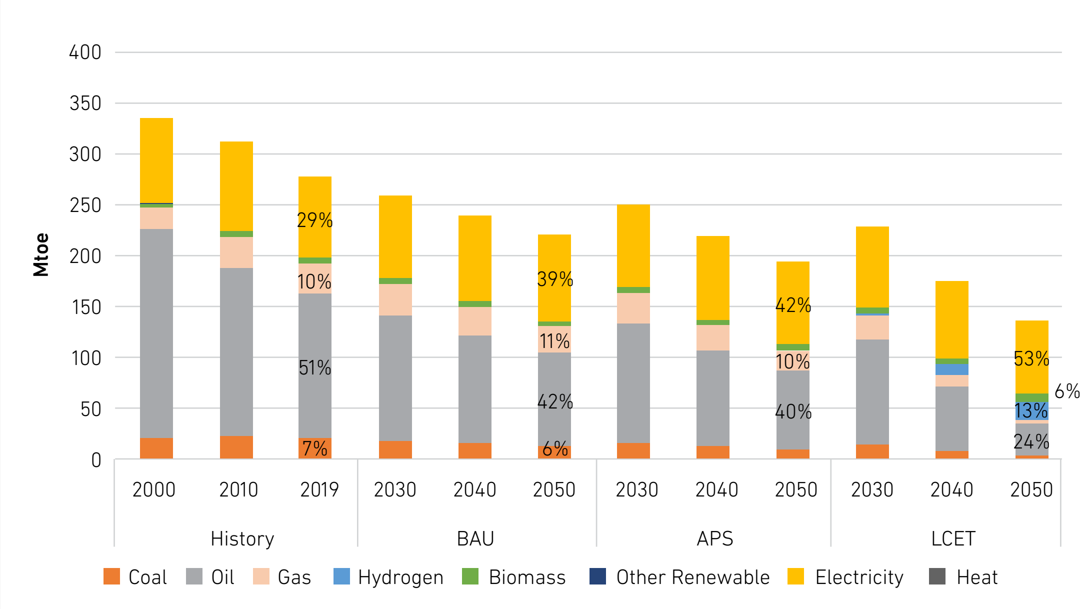
In this section, the results of the LCET scenario will be described compared to the BAU and the APS scenarios.

### 3.3.1. Final Energy Consumption

In the LCET, the TFEC will decline approximately 2.5 times faster than the BAU, falling to 136 Mtoe in 2050, or 61% of the BAU level (Figure 8.12). To achieve carbon neutrality, significant energy transition from fossil fuels to electricity and hydrogen is necessary. Fossil-fuel share will decrease drastically, from 69% of energy in 2019 to 28% in 2050. The share of electricity will increase from 29% in 2019 to 53% in 2050.

**Figure 8.12 Final Energy Consumption by Source, Business-as-Usual, Alternative Policy Scenario, and Low Carbon Energy Technology Scenarios, 2000–2050**

(Mtoe)




APS = alternative policy scenario, BAU = business-as-usual, LCET = Low Carbon Energy Technology, Mtoe = million tonnes of oil equivalent.

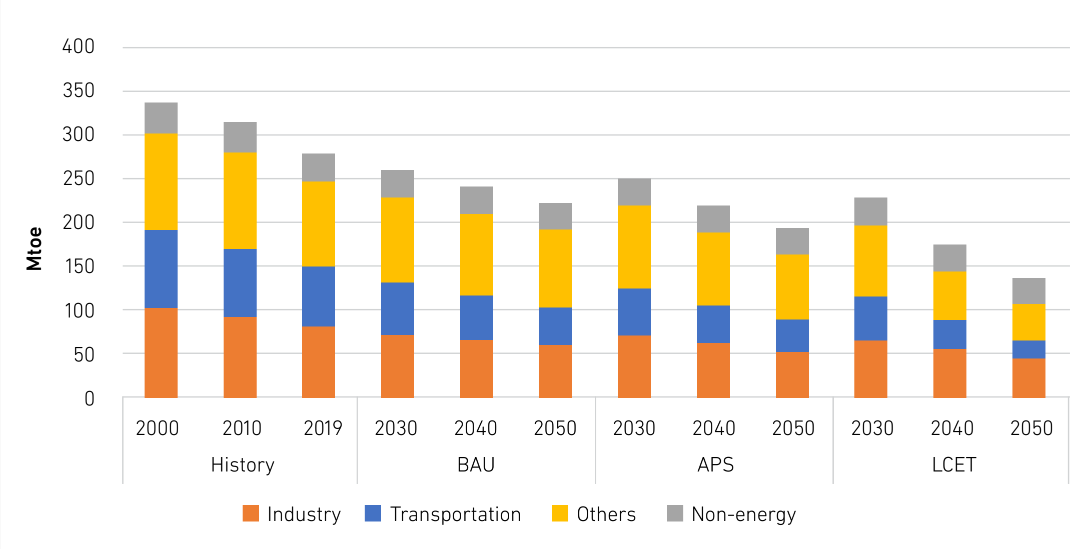
Source: Authors' calculation.

In transport and the 'Other' sector, demands will be shrink due to intensive energy conservation efforts and electrification, which will boost energy efficiency (Figure 8.13 and Table 8.1). Meanwhile, decline will be limited in industry. In this sector, it will be difficult to substitute all of fossil-fuel demand to electricity or hydrogen, due to the need for high-temperature heat sources and lock-in effect of existing machinery.[1] Instead, carbon capture and storage (CCS) would be implemented to reduce $CO_2$ emissions.

[1] A *lock-in effect* refers to a situation where fossil fuel consuming facilities that have already been built will continue to emit $CO_2$ in the future.

**Figure 8.13** Final Energy Consumption by Sector, Business-as-Usual, Alternative Policy Scenario, and Low Carbon Energy Technology Scenarios, 2000–2050

(Mtoe)




APS = alternative policy scenario, BAU = business-as-usual, LCET = Low Carbon Energy Transition, Mtoe = million tonnes of oil equivalent.

Source: Authors' calculation.

**Table 8.1** Change in Final Energy Consumption by Sector, 2019 to 2050

| | BAU | APS | LCET |
|---|---|---|---|
| Industry | -25% | -34% | -44% |
| Transport | -38% | -47% | -69% |
| Others | -7% | -23% | -59% |
| **Total** | **-21%** | **-31%** | **-51%** |

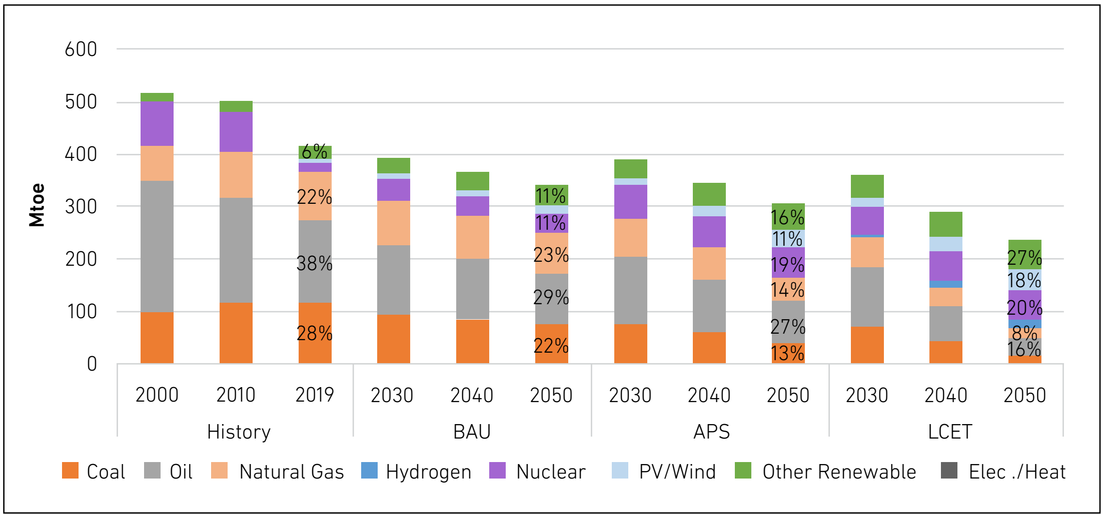
APS = alternative policy scenario, BAU = business-as-usual, LCET = Low Carbon Energy Technology.

Source: Authors' calculation.

### 3.3.2. Primary Energy Supply

In the LCET scenario, primary energy supply will decline as significantly as final energy demand declines. The primary supply in 2050 is projected to be 226 Mtoe, 67% of the BAU level (Figure 8.14). In addition, the share of fossil fuels, which accounted for 88% of primary energy supply in Japan 2019, will shrink to 32% in 2050. Nevertheless, even in such a progressively decarbonised scenario, demands for fossil fuels will not disappear, and efforts for a stable supply in fossil fuels will remain as one of the key energy policies in Japan.

**Figure 8.14 Primary Energy Supply, Business-as-Usual, Alternative Policy Scenario, and Low Carbon Energy Technology Scenarios, 2000–2050**



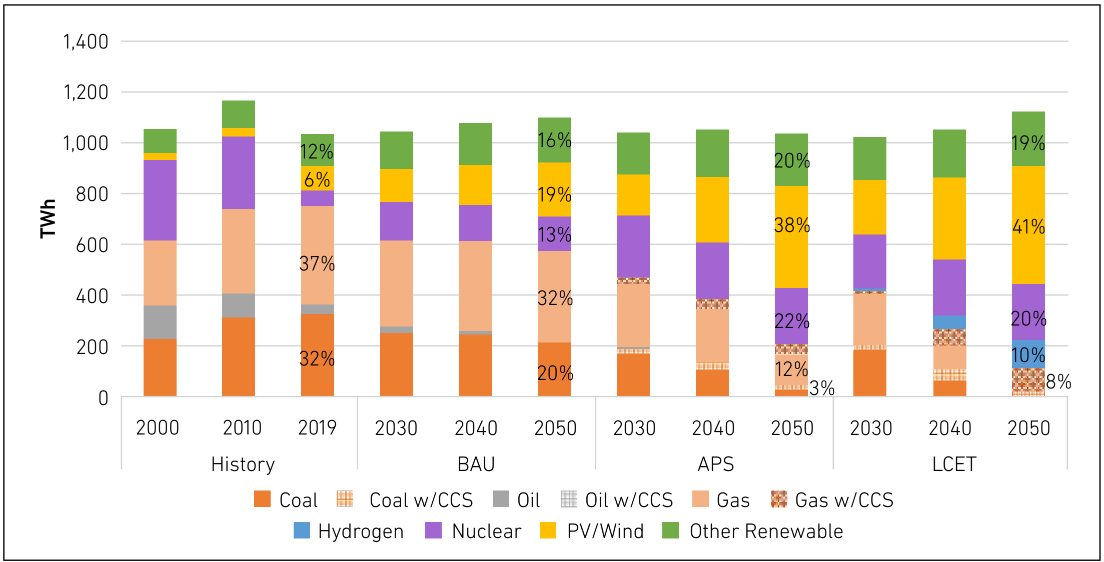

APS = alternative policy scenario, BAU = business-as-usual, LCET = Low Carbon Energy. Technology, Mtoe = million tonnes of oil equivalent.

Source: Authors' calculation.

### 3.3.3. Power Generation

Power generation for the LCET scenario in 2050 is projected to be 1,136 TWh. Due to the rapid progress of electrification and demand for green hydrogen, the generation for the LCET in 2050 will be larger than those in the other two scenarios (Figure 8.15). The share of solar PV and wind power would be 41%. Since output from these variable renewable energies is unstable, backup storages and expansion of the grid will be necessary. Other renewables (hydro, geothermal, and biomass) will account for 19%. Nuclear energy covers 20% of total generation. The remaining 20% is thermal power, of which another 10% is hydrogen and 10% is coal and natural gas with CCS.

**Figure 8.15** **Power Generation, Business-as-Usual, Alternative Policy Scenario, and Low Carbon Energy Technology Scenarios, 2000–2050**



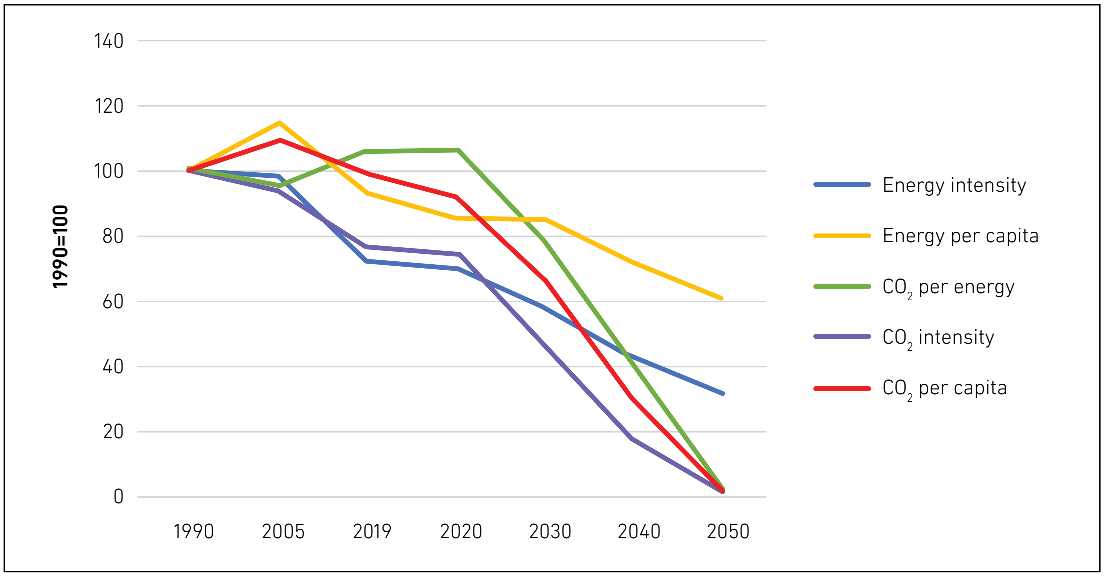

APS = alternative policy scenario, BAU = business-as-usual, LCET = Low Carbon Energy Technology, TWh = terawatt-hour.

Source: Authors' calculation.

### 3.3.4. Energy Indicators

In the LCET scenario described so far, the energy indicators will improve at a faster pace compared to BAU (Figure 8.16). Between 1990 and 2019, energy intensity improved at the pace of 1.1% per year. In this scenario, electrification and other efficiency improvements are expected to play a significant role, contributing to the energy intensity improvement by 2.5% per year between 2020 and 2050, leading to about a half of the 2019 level.

**Figure 8.16** Indices of Energy and Carbon Dioxide Intensities, Energy Per Capita, and Carbonisation Rate, Low Carbon Energy Technology, 1990–2050



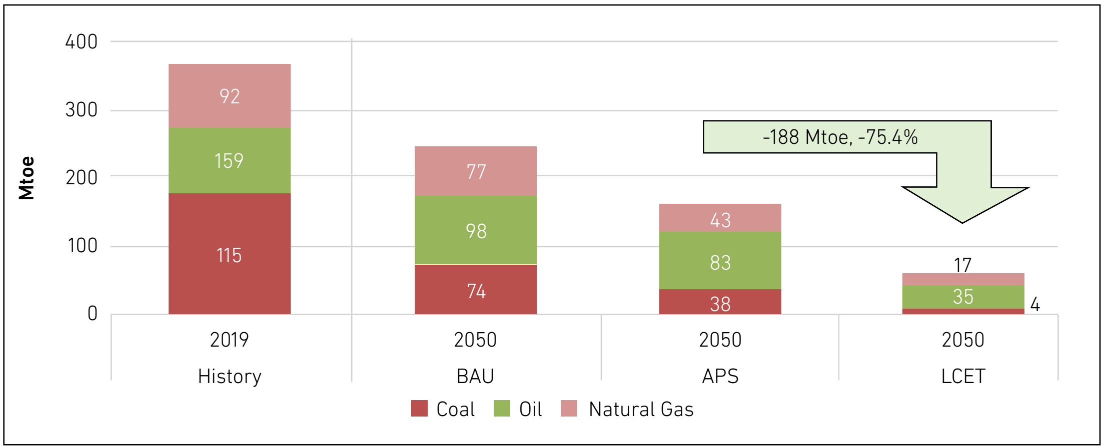

$CO_2$ = carbon dioxide.

Source: Authors' calculation.

### 3.3.5. Saving on Fossil Fuel Consumption and Carbon Dioxide Reduction

In the LCET scenario, fossil-fuel consumption will be about 25% of the BAU scenario, which will reduce consumption by 188 Mtoe (Figure 8.17). Amongst fossil fuels, other energy sources in industry and power sectors mostly replaced coal, with demand of only 4 Mtoe in 2050. On the other hand, oil demand will linger relatively even in 2050, which is used mainly in industry and non-energy sectors.

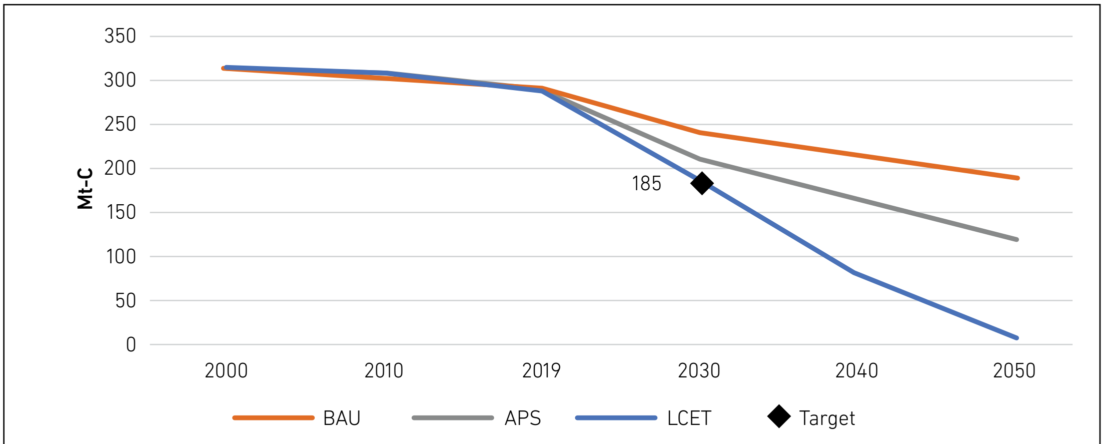
**Figure 8.17 Fossil-Fuel Reduction in Primary Energy Supply, Business-as-Usual, Alternative Policy Scenario, and Low Carbon Energy Technology, 2019 and 2050**
(Mtoe)




APS = alternative policy scenario, BAU = business-as-usual, LCET = low carbon energy transition; Mtoe = million tonnes of oil equivalent.
Source: Authors' calculation.

When the BAU, the APS, and the LECT scenarios are compared for $CO_2$ emissions, the BAU shows a decline along with the historical trends, the APS scenario shows a faster decline than the trend, while the LCET shows even faster reductions than the APS (Figure 8.18). Japan's new NDC target of energy-related $CO_2$ emissions for 2030 is 185 Mt-C (a 45% reduction from the 2013 level, which is the base volume). The LCET scenario will be consistent with the NDC target.

**Figure 8.18 Carbon Dioxide Emissions from Fossil Fuel Combustion, Business-as-Usual, Alternative Policy Scenario, and Low Carbon Energy Technology, 2000–2050**
(Mt-C)




APS = alternative policy scenario, BAU = business-as-usual, LCET = Low Carbon Energy Technology, Mt-C = million tonnes of carbon.
Source: Authors' calculation.

# 4. Implications and Policy Recommendations

According to Japan's net-zero policy, energy demand and $CO_2$ emissions can be reduced. However, the net zero emission will not materialise in the BAU and the APS scenarios. In the BAU, $CO_2$ emissions in 2050 are 65% of 2019 levels. The APS assumes faster energy efficiency improvements than the trend due to the progress in restarting nuclear power plants and massive introduction of renewable energy, reducing $CO_2$ emission to 41% of the 2019 level. Although they are decent improvements, the results are still far from carbon neutral. They show that carbon neutrality requires further $CO_2$ reduction efforts than assumed in the forecast scenarios, such as the BAU and the APS scenarios. In contrast, the LCET scenario will complement this concern, which is a back-casting scenario that assumes carbon neutrality in 2050, as defined.

Nonetheless, $CO_2$ reduction is not the only focal point of energy policy. The "3E+S" (Environment, Energy Security, Economic Efficiency + Safety) is a fundamental principle in Japan's energy policy. While the LCET is a scenario that pursues environment, the scenario shows some challenges in terms of the two remaining E's – energy security and economic efficiency.

### Energy Security

While fossil fuel will be reduced to 32% of the primary supply in the LCET scenario, it would remain a necessary energy source. It is essential to continue efforts to ensure its stable supply, from upstream investments to downstream infrastructure maintenance.

Though electricity and hydrogen will be largely deployed to replace fossil fuels, challenges for energy security for these energies are also inevitable. Stable electricity must be supplied in greater quantities than at present and without $CO_2$ emissions. In the LCET scenario, the amount of power generation in 2050 is about 8% greater than today. The Government of Japan has set renewable energy as its main power source. It is essential to develop the dispatchable capacity and adjust the capability for output fluctuation of renewables. Currently, investment in thermal power generation to provide this adjustment is difficult due to volatile wholesale electricity prices and decarbonisation policies. However, policy efforts must continue to ensure sufficient capacity through 2050 and in the interim.

Hydrogen is expected to be supplied mainly through water electrolysis and imports in Japan because of scarce fossil-fuel resources. It is necessary to build good relationships with countries that supply hydrogen and to form an international market, in the same way we currently do for a stable supply of fossil fuels. Despite these challenges, efforts toward carbon neutrality will increase the energy self-sufficiency rate. It will improve from 15% in 2020 to 65% in 2050 under the LCET scenario.

## Economic Efficiency

Energy costs are also a significant issue. Although the costs of solar PV and wind power, which accounts for a significant share of electricity, is declining, additional costs will arise for investments in batteries to regulate their output, transmission lines to power generation facilities, and so on. As the share of variable renewable energies increases, the cost per kWh itself increases cumulatively. Therefore, it is necessary to utilise other power sources such as nuclear, hydrogen, and fossil fuels with CCS to reduce costs, rather than relying too heavily on renewable energy.

Carbon neutral is exceedingly difficult to achieve with a combination of existing and mature technologies, and the LCET scenario incorporates developing technologies such as CCS and hydrogen. Financial and technical supports from the government for these technologies are significant. In addition, in the transition period, around 2040, current technologies and facilities will be mixed with these developing technologies including hydrogen and CCS. It is essential to replace existing technologies with the new technologies prudently so that stable energy supply will not be compromised.

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