Challenges for realising Japan's long-term strategy for decarbonisation under the Paris Agreement, and the role of scenarios

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Abstract

This paper highlights the challenges for realising Japan's long-term strategy (LTS) for decarbonisation, also referred to as the mid-century strategy (MCS), and the role of scenario analysis in the formulation and strengthening of this strategy. Although the government of Japan declared on 26 October 2020 to reduce greenhouse gas (GHG) emissions to net-zero by 2050, this paper analysed the goal of 80% GHG emissions reduction goal by 2050, due to the data availability of the model analysis for the LTS. Materialising the deep societal transformations needed across all economic sectors for realising Japan's LTS goal will be a challenge for Japan, given that changes will need to occur at a speed and scale that are likely beyond anything experienced in the past. Therefore, identifying these challenges is fundamental to assess the feasibility of the LTS. Long-term scenario analysis is also crucial for this assessment, as these scenarios describe the range of possible outcomes from different socio-economic developments in the long term, covering a broad set of aspects in a quantitative and systematic manner. To clarify these challenges, this paper reviews Japan's LTS, and compares the results from model analysis on long-term scenarios (by 2050) against the historical trends and the NDC commitments (by 2030). This knowledge is fundamental for decision-makers in order to assess the uncertainty involved in the formulation and realisation of the LTS.

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Key messages

- For the formulation and realisation of the LTS for decarbonisation, national policymakers and stakeholders need to be informed of the challenges arising from socio-economic transformations driven by decarbonisation.
- The challenges for realising Japan's LTS can be assessed as the difference between past trends and future scenarios in terms of the speed and the scale of changes in major socio-economic indicators: the prevalence of challenges for decarbonisation justify strengthening current efforts for mitigating GHG emissions.
- To realise Japan's LTS goal (80% GHG emissions reduction by 2050), emissions reduction will have to accelerate considerably (from a linear average annual rate of 1.5% between 2013 and 2030, as stipulated in the NDC, to 3.7% per year from 2030). Long-term scenario analysis clearly shows that the LTS goal will involve major challenges for decarbonising final energy consumption across all economic sectors (in particular for the residential sector), expanding the share of low-carbon energy technologies (mainly for renewable energy), and the share of electricity in final energy consumption. Challenges are uncertain for the deployment of nuclear, carbon capture and storage (CCS), and hydrogen, as they depend strongly on the scenario assumptions related to the availability, features and acceptability of these options.
- The current LTS of Japan lacks any mention of long-term scenario analysis, thus, it can be enhanced with insights from this analysis by mentioning scenarios explicitly in relevant documents and discussions, thereby supporting the common understanding among stakeholders of the challenges and alternative measures to realise the LTS, and promoting action towards concrete measures in specific sectors.
- Scenario analysis is fundamental for LTS formulation given that it: 1) helps to understand the challenges and long-term uncertainties surrounding the realisation of the LTS (such as the availability and performance of low carbon measures, and the trends of macroeconomic drivers and energy consumption), as the scenarios inform policymakers and stakeholders with the range of possibilities for the major socio-economic drivers of emissions, in a quantitative and systematic manner; 2) contributes to the transparency of the LTS formulation, as the scenarios provide quantitative evidence supporting the measures considered in the LTS; and 3) enables a common understanding and discussion of the LTS among diverse stakeholders and provides them with robust signals on the need for change on specific aspects.

1. Purpose

To address the climate change issue, Parties to the United Nations Framework Convention for Climate Change (UNFCCC) adopted the Paris Agreement in 2015, which requires nations to set targets for greenhouse gas (GHG) emissions reduction with periodic revisions under a process known as the Global Stocktake (GST) (UNFCCC, 2015). The Paris Agreement included short-term targets that were defined individually by each Party as a national determined contribution (NDC) for the year 2025 or 2030. It also invited nations to submit long-term targets by 2020, also defined independently by each nation, as a long-term strategy (LTS) for decarbonisation by 2050, also referred to as mid-century strategy (MCS). At the time of this paper's publication, 22 nations and one union had submitted LTS to the UNFCCC (UNFCCC, 2020).

In June 2019, Japan submitted its long-term strategy for decarbonisation to the UNFCCC, following the call in Article 4 of the Paris Agreement (The Government of Japan, 2019b). The submission, right before the G20 meeting hosted by Japan, was touted by the Japanese Government as a vision which provides directions for all stakeholders to pursue an "ideal future model" in each area. The LTS includes a national GHG emissions reduction goal of 80% by 2050, without specifying the base year, along with guiding principles for realising this goal. In addition, it mentions the intention of realising a decarbonised society as early as possible in the second half of this century. Previously, Japan ratified the Paris Agreement, and declared in its NDC submission that it intended to reduce its national emissions by 26% by 2030 compared to 2013 levels (Cabinet Office, 2015). Prior to the LTS submission, Japan also expressed its intention to pursue a long-term goal of 80% emissions reduction by 2050, reflecting the initiative by major economies at past G7 meetings, but without any concrete strategy (Cabinet Office, 2016). On 26 October 2020, Prime Minister Yoshihide Suga pledged to reduce GHG emissions to net-zero by 2050 in his first policy speech at the Diet (The Government of Japan, 2020).

The feasibility of the LTS and the alternatives forming the strategy, as well as the potential for increasing the ambition of mitigation, are uncertain. Quantitative analysis based on long-term scenarios can assist in understanding the uncertainties, and help narrow down the range of possible outcomes of key indicators related to decarbonisation, based on scientific knowledge. Even when there are multiple studies assessing Japan's long-term mitigation goals, they are either written up in scientific journals targeting experts, or there is no comprehensive review of their outcomes against past developments. To communicate their findings effectively, scenario analysis needs to be compared to historical trends, and in a format that can be easily accessed by non-expert readers.

The purpose of this paper is to introduce the current status of Japan's contribution to the Paris Agreement to a broad range of policymakers and stakeholders within and outside Japan, elaborating on the challenges to put the LTS into practice, and emphasising the role of scenario analysis. This paper analyses the goal of 80% GHG emissions reduction by 2050, instead of the net-zero goal, due to the data availability of the model analysis for the LTS. Japan is a key player on global action for tackling climate change, as it is currently the fifth largest GHG emitter and the third largest economy in the world. As such, policy dialogues are held with other major emitters, aiming to promote mutual understanding of the national circumstances and the processes leading to the formation of climate change mitigation policy. Such dialogues can invigorate the perspectives and initiatives of stakeholders so that the Paris Agreement can be fully realised. This paper contributes to the policy dialogue between Japan and the EU under the SPIPA (Strategic Partnerships for the Implementation of the Paris Agreement) project, focusing on the challenges for achieving the LTS in light of the current NDC submission, and highlighting the need to strengthen mitigation efforts in specific sectors. While the deliverable to the UNFCCC process is basically the same, the process forming the strategy and the features of the strategy can widely differ between Japan and the EU. Recognising those differences and the gaps/challenges that each country faces in the formulation and future implementation of the strategy are valuable insights to materialise the ambitious emissions reductions needed to achieve global climate targets.

The contents of this paper are as follows. Section 2 summarises the process for the formulation of the LTS and the outline of its contents. Section 3 explains the features of and major insights from long-term scenario analysis used in the assessment of the 2050 emissions reduction goal of Japan. Section 4 describes the challenges for realising the LTS based on the speed of change in major socio-economic indicators from the long-term scenario analysis, the historical trends and the 2030 commitments included in the NDC. This section also explains the role of scenario analysis on the LTS formulation. Section 5 presents the conclusions and provides policy messages. Additional background information is presented in the appendix (the current situation and historical trends of socio-economic drivers of GHG emissions in Japan, and the relevant policies for climate change mitigation; also supplementary data is included).

2. Japan’s long-term strategy for decarbonisation

This section introduces Japan’s LTS submitted in 2019, starting with the process for its formulation.

2.1 Process of Japan’s LTS formulation

Prior to the LTS discussions, the goal to reduce emissions by 80% was mentioned in some official documents such the Basic Environment Plan and the NDC, but there were no concrete strategies put in place to achieve this target. Discussions about Japanese LTS (Figure 1 and Table 1) have been conducted separately since July 2016 by the Ministry of the Environment (MOEJ), the Ministry of Economy Trade and Industry (METI) and Ministry of the Foreign Affairs (MOFA) (METI, 2017; MOEJ, 2017; The Government of Japan, 2019a). On 3 August 2018, the Cabinet Office established a roundtable named “Paris Agreement Long-term Growth Strategy Roundtable (Discussion to formulate a long-term strategy as a growth strategy based on the Paris Agreement)” to discuss the basic concept on LTS (The Government of Japan, 2019c). On 2 April 2019, the Paris Agreement Long-term Growth Strategy Roundtable published its recommendations including the decarbonisation of the energy and material supply process through energy efficiency, renewable energy, hydrogen, nuclear power, carbon capture and storage and utilisation (CCS/CCU), Well-to-Wheel Zero Emissions as well as the Regional Circular and Ecological Sphere (Regional CES) in line with a carbon neutral society.

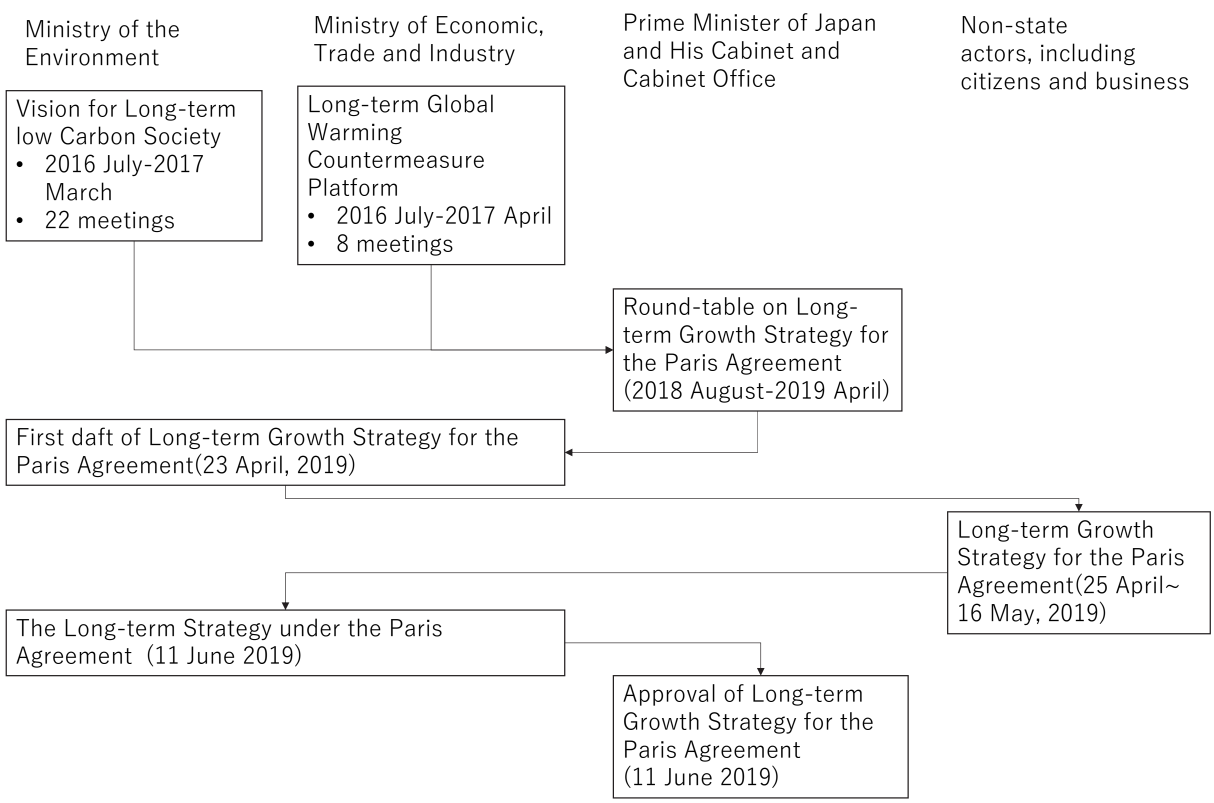

Figure 1 process of development of LTS

Table 1 Schedule and content of the Paris Agreement Long-term Growth Strategy Roundtable

Date	Contents of the Paris Agreement Long-term Growth Strategy Roundtable
3 August 2018	1st Roundtable: Establishment of the Round Table
4 September 2018	2nd Roundtable: Innovation
19 November 2018	3rd Roundtable: Green finance, Green business, Local economy
21 December 2018	4th Roundtable: Comments on the discussion paper developed by the secretariat.
2 April 2019	5th Roundtable with recommendation for the contents of LTS

Source: Authors based on GOJ (2019)

Based on these recommendations, the joint committee by MOEJ and METI published the first draft of Long-term Growth Strategy for the Paris Agreement on 23 April 2019, which opened for public comments during the period from 25 April to 16 May 2019. The final version of LTS was approved by the Cabinet on 11 June 2019, and submitted to the UNFCCC on 26 June 2019.

2.2 Outline of Japan's LTS

On 11 June, 2019, the long-term strategy of Japan was published. The LTS consists of five chapters. Chapter 1 provides basic concepts of the LTS including purpose, long-term vision, basic principles for measures to achieve the strategy and relevant initiatives outside the LTS (e.g. SDGs, innovation, Society 5.0 and Regional Circular and Ecological Sphere). The long-term strategy is described as a "decarbonized society" as early as possible in the second half of the century while aiming for a 80% reduction of GHGs by 2050. Chapter 2 of the strategy describes current status, visions and possible countermeasures for the sectors of energy, industry, transport, lifestyles and LULUCF. Chapter 3 shows major cross-cutting policies to promote each countermeasure discussed in Chapter 2. The LTS identifies three major cross-cutting measures: Promotion of Innovation, Promotion of Green Finance, and Business-led Promotion of International Application with International Cooperation. Chapter 4 mentions relevant policies to complement the major measures including capacity building, formulation of a resilient society to adapt to climate change, just transition and carbon pricing. Chapter 5 refers to the possibility of stakeholder consultation and review after six years. Below, the key contents of each chapter of the strategy are summarised. Details can be found in the official document "Outlines of Japan's Long-term Strategy under the Paris Agreement" (The Government of Japan, 2019d).

Japan's LTS is characterised by a focus on broad, guiding principles expressed mostly in qualitative terms, with a few specific targets (e.g. cost reduction of batteries, penetration of hydrogen production and usage), and with a strong emphasis on the role of technological innovation for production processes in financing in businesses. There is no mention of the regional aspects of the transition in the LTS, and social perspectives are given a secondary role. For instance, there is considerable focus on innovation in technologies related to energy efficiency, carbon capture utilisation and storage (CCUS), hydrogen, renewable energy and related devices (e.g. demand response and battery), as well as nuclear energy. Innovation in non-technology aspects have less emphasis, in particular with respect to changes in societal and organisational systems. Moreover, the role of economic instruments such as carbon pricing is not underscored, and instead regarded as a matter for further discussion in the future.

It is worth noting the absence of any information related to scenario analysis, or any other quantitative framework supporting the elements and priorities presented in the LTS. Instead, the LTS document is based solely on the principles forming the socio-economic plans established by the government (e.g. Basic Energy Plan and Basic Environment Plan). Even though there is a growing amount of literature on national scenarios assessing the feasibility and implications of the LTS goal (80% reduction by 2050), the LTS lacks any reference to such valuable knowledge. The following sections introduce examples of long-term scenario analysis found in the literature, along with a description of the main features of the scenarios, and the messages that can inform the formulation and realisation of the LTS.

3. Insights from scenario analysis of Japan's mitigation goal

This section briefly overviews the long-term scenario analysis used for assessing the mitigation goal of Japan's LTS (80% GHG emissions reduction by 2050), and the main insights from those assessments. The feasibility of achieving this goal along with the NDC has been assessed in studies based on energy models, economic models, or a combination of both (energy-economic and integrated assessment models) with a variety of tools, approaches and assumptions (Kuramochi *et al.*, 2016; Oshiro, Kainuma and Masui, 2016; Oshiro, Masui and Kainuma, 2017; Silva Herran, Fujimori and Kainuma, 2019; Sugiyama *et al.*, 2019). They project the trends of the basic socio-economic drivers of GHG emissions in the long term, using socio-economic, energy and technology parameters. The outcomes of these analyses depend on the assumptions for future availability and characteristics of these parameters, which are encapsulated in a "scenario" describing the potential status of these parameters based on a given narrative or storyline (Nakicenovic *et al.*, 2000; Moss *et al.*, 2010; O'Neill *et al.*, 2014). While there is extensive literature on the feasibility of 2030 mitigation targets (see (Kuramochi, Wakiyama and Kuriyama, 2017) for a review of scenarios), there are only a few studies available to date dealing with a comprehensive analysis of the 2050 target. Here we introduce the outcomes from research conducted by Sugiyama *et al.* (2019) with multiple models from Japanese research organisations (see Figure 2). This research is selected given that all its data is publicly available. We complement those insights by comparing them with historical annual changes of key indicators in the following section.

According to the scenario analysis, achieving the 2050 target will need a much larger share of low-carbon energy sources (renewables, nuclear and CCS) in the energy supply, in particular for the power sector. It will also require lower energy intensities driven by energy efficiency improvements and energy savings, a larger use of electricity by final users, as well as the penetration of high efficiency and electric devices across all sectors.

The mix of energy sources and technologies consistent with the 2050 goal varies across scenarios and models. Several scenarios suggest that in addition to renewables and nuclear, a shift to natural gas and fossil fuels with CCS may prevail in the energy system. The role of certain technologies in the long-term scenarios, in particular of CCS, nuclear and wind, remains uncertain due to the diversity of technological assumptions across models. Different to the power supply, a considerable share of fossil fuels will remain in the industrial and transport sectors. However, it must be noted that some scenarios with a detailed description of these two sectors, indicate that substitution of fossil fuels with hydrogen and electricity will allow for a considerable reduction in emissions. For example, some scenarios depict a large share of the vehicle fleet covered by fuel cell or electric vehicles.

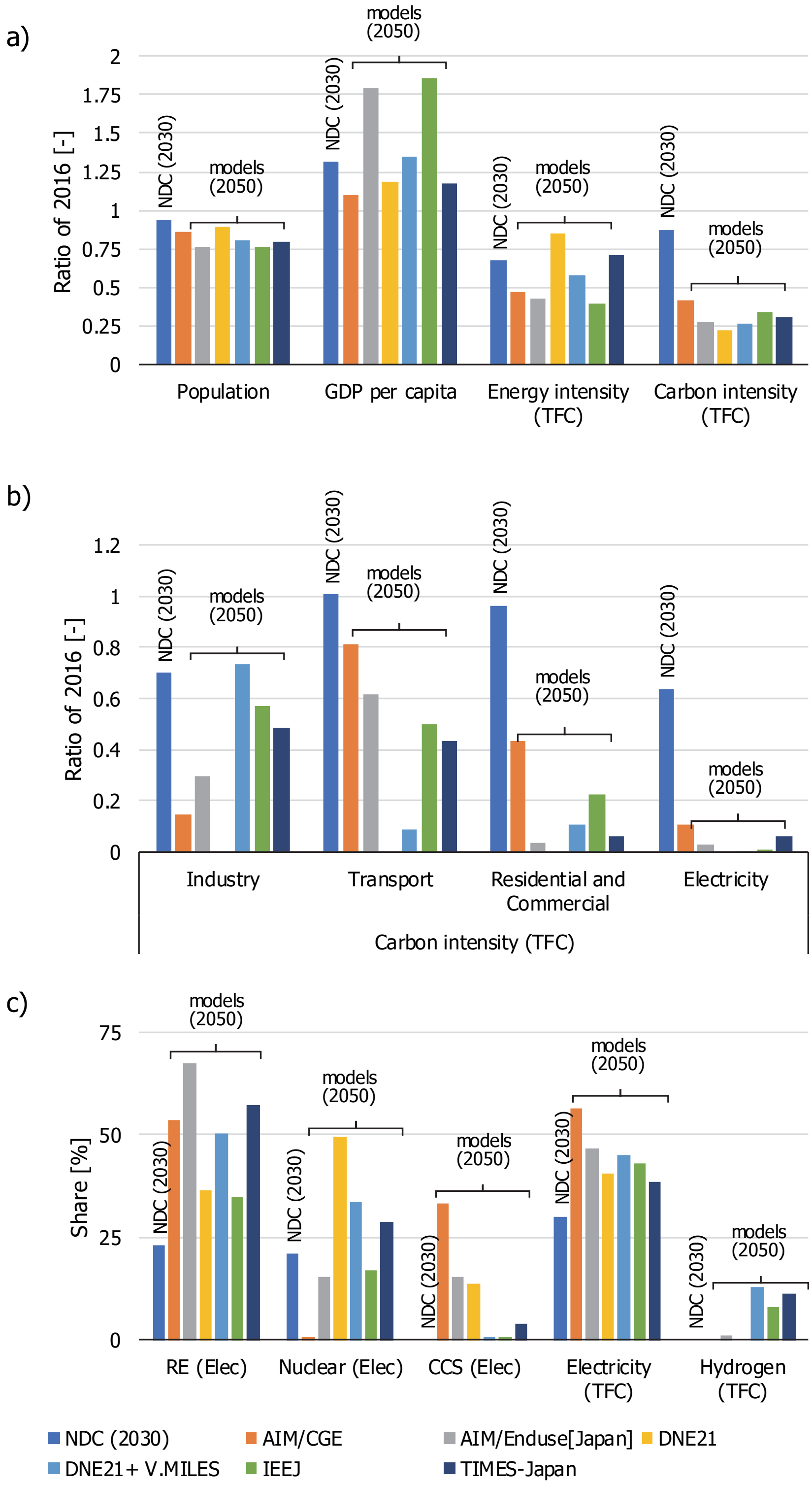

Figure 2 Outcomes in major drivers of emissions in Japan for 2030 (based on the NDC) and 2050 (based on long-term scenario analysis): a) Kaya indicators; b)carbon intensity of final energy consumption; c) share of low-carbon energy technologies (renewables, nuclear and CCS) in electricity supply and of energy carriers in final energy consumption.

Outcomes for 2030 and for 2050 are from the NDC (Government of Japan, 2015) and long-term scenario assessments (Sugiyama et al. Energy 2019), respectively. Carbon intensity by sectors (panel b) for the DNE21 model and hydrogen shares (panel c) for AIM/CGE and DNE21 not shown given they are missing in the data from Sugiyama et al. (2019).

Despite the wide range of outcomes from these scenarios, all studies point out the need to strengthen the infrastructure supporting the large-scale deployment of low-carbon energy sources and technologies. In particular, infrastructure needs to focus on transforming the power system into one that allows for more flexibility on the supply side and is more responsive to changes in demand. This is especially challenging for Japan given the currently small penetration of variable renewables, such as wind and solar, which are expected to grow considerably in scenarios. There should also be more focus on the supply chain for alternative fuels (hydrogen, biofuels, electricity) in the transport and industrial sectors, the transport and storage of CO_2 as well as on the procurement of stable and accessible underground reservoirs (given the large penetration of CCS expected in the scenarios and the limited availability of suitable land in the country). Another common feature of these scenarios is the importance put on improving the market performance of low-carbon technologies, in terms of cost reductions and adoption levels.

The total costs of reducing nation-wide emissions (measured in terms of the marginal abatement cost, the GDP loss, or the additional energy system cost) in Japan by 2050 according to the scenarios, is 1-10% of GDP. Results are relatively higher and more uncertain compared to other countries' assessments, partly because these scenarios constrain 2030 emissions to the level assumed in the Japan's NDC (which is higher than the cost-optimal level), leading to faster emissions reduction post 2030 to meet the 2050 goal, and, thus requiring higher costs in the long-term. The higher costs of low-carbon technologies, and a wider presence of the industry sector in contrast to other industrialised countries, also contribute to this outcome.

Other aspects not quantified in the scenario analysis also become clear, such as the impacts of transition to a decarbonised society on employment and the economic structure. For example, the shift from the current energy supply centralised in large-scale facilities and depending almost entirely on imported fuels will promote jobs with new skills required for renewable energy systems, and diminish the concerns over energy security due to a more diverse portfolio of energy supply options. Moreover, mechanisms will be needed to lessen the economic impacts (especially in the industrial sector, as emissions in this sector are more difficult to mitigate) due to increased fuel and electricity prices and the subsequent decrease in consumption caused by mitigation policies. Thus, it is important to intensify early adoption of energy efficiency measures and technologies, as well as changes in lifestyles. Finally, although not described in the scenario analysis introduced above, enhancement of mitigation measures in non-energy sectors complement the decarbonisation of energy use. Scenario analysis also indicates the need for reducing emissions of non-CO_2 GHGs (such as nitrous oxide, methane and fluorinated gases) from agricultural and industrial activities, as well as carbon from land-use changes (however, the representation of mitigation of these sources of GHG emissions is less comprehensive in most scenarios).

Discrepancies among scenarios are mainly the consequence of: 1) the modelling methodology used to quantify the scenario's outcomes, and 2) the assumptions of parameters used in the model. The methodologies (i.e. models) cover sources of emissions and mitigation alternatives in different approaches and at different levels of detail. Macroeconomic models, such as AIM/CGE, represent market interactions and price change effects on aggregated economic sectors. In contrast, technology-oriented models, such as AIM/Enduse and DNE21, are based on cost optimisation of the supply and demand across sectors with high detail in technologies and consumption services, but without any market interactions. Also, models differ in the coverage of decarbonisation options. For example, IEEJ and TIMES-Japan include several hydrogen technologies, while DNE21 has detailed nuclear energy technologies. The assumptions describing the socio-economic elements of the scenario (e.g. energy resources and technologies, growth rates of consumption) vary according to different rationales and sources of information adopted by the modellers. This is particularly the case for assumptions reflecting long-term developments, which are very uncertain. They refer to different values for key parameters (such as the future energy conversion efficiencies and costs), and in some cases to specific constraints related to the starting year of availability of a new technology (such as CCS), the operation of idle nuclear plants, and the possibility of new nuclear plant installations (as in DNE21) in contrast to a progressive phase-out (as in AIM/CGE).

4. Challenges for realising the LTS and the role of scenario analysis

Building on the contents in previous sections, this section highlights the challenges for realising Japan's LTS, by comparing insights from scenario analyses with the historical trends and the NDC commitment, with respect to key macro indicators relevant to decarbonisation in the long term (i.e. by 2050). Values reported here are based on data from eight historical periods (covering 1960 to 2016), and outcomes of scenario analysis from six models for 2050. Furthermore, the role of scenario analysis in LTS formulation is discussed.

4.1 Results of scenario analysis

Here, we interpret the challenge of decarbonisation as the scale of the pace of transformation needed, compared to the historical trends and the current emissions reduction targets. The long-term target for decarbonisation requires considerable transformations in the drivers of GHG emissions, which contrasts with what has been experienced in the past decades. This contrast can be measured as the differences in the speed of change in key indicators. In terms of emissions, this challenge means that emissions reduction will have to accelerate from a linear average annual rate of 1.5% between 2013 and 2030 (as stipulated in the NDC), to 3.7% per year from 2030 to reach the long-term goal (80% of 2005 GHG emissions by 2050).

The overall picture of decarbonisation is first described by means of the annual rate of change in Kaya indicators, namely population, affluence (GDP per capita), energy intensity of GDP, and carbon intensity of energy consumption (Figure 3). Overall, Japan will need to balance the expectations for sustained positive economic growth with the decrease in population (which already peaked in 2010), the reduction in energy use, and the shift to low-carbon energy supply. While the outcomes by 2050 are diverse for energy intensity and GDP per capita, all scenarios result in fairly rapid reductions in carbon intensity of final energy consumption, several times faster than the expected change from now until 2030 according to the NDC. Among the Kaya indicators, carbon intensity is the central indicator representing the size of the challenge for the LTS. In terms of the carbon content of total final energy consumption (TFC), scenario analysis indicates that reaching the LTS goal would mean a decrease of around 3.6-6.6% per year from NDC levels. These rates are much larger than the decarbonisation rate committed in the NDC (0.9% per year between 2016 and 2030), and larger than any rate experienced in Japan over the last few decades (1.4% at the most).

The rate of transformation of energy intensity towards 2030 expects a considerable decrease in energy consumption due to continuous energy efficiency improvements, like those experienced in the past. Scenarios towards 2050 show diverging possibilities. On the one hand, some scenarios result in a positive rate of change, which means larger energy consumption compared to 2030 (driven by faster economic growth). This outcome is consistent with the long-term decarbonisation goal due to a larger penetration of low-carbon energy sources in the energy supply, in particular of CCS (which can offset the increase in emissions from the additional energy consumption). On the other hand, some scenarios show similar levels to the rate of change of energy intensity by 2030, indicating the sustained role of energy efficiency along with lower expectations for economic growth.

The transformations indicated above for the whole of Japan are distributed unevenly among economic sectors and low-carbon options (energy technologies and energy carriers). We will now focus on the carbon intensity by major economic sectors, namely buildings (residential and commercial), transport and industry (Figure 4). Overall, by 2030 the NDC expects a moderate decrease in carbon intensity in the industry sector (2.5% per year), and almost no change in other sectors. In contrast, scenarios suggest a considerably high rate of decarbonisation ahead of 2050 in all sectors, in particular for the building and transport sectors (3.9-15.5% and 1.0-11.4% per year respectively). Emissions reduction in buildings needs to occur faster than in other sectors, and remaining emissions by 2050 are concentrated in the industry sector. Also, the speed of decarbonisation is unprecedented across all sectors (i.e. faster than ever experienced in the last few decades). To materialise these transformations, adoption of low-carbon energy carriers and technologies needs to be complemented by less intensive and more efficient energy consumption patterns. Scenario analysis suggest that these measures permeate better in the residential and commercial sectors (for example, through the adoption of more efficient appliances and buildings, and the replacement of fossil fuel-based devices with electric ones). Moreover, changes in lifestyles may result in further reductions in energy consumption. However, these changes are not yet well represented by models used in the scenario assessments, so their actual effect on emissions reduction is likely to be underestimated.

Now we turn our attention to the trends in low-carbon energy technologies (renewables, nuclear and CCS) and energy carriers (electricity and hydrogen) (Figure 5). Given that the power sector is a major source of emissions with major potential for decarbonisation, we focus on the share of technologies in electricity supply, and the share of energy carriers in final energy consumption. The Japanese NDC expects a considerable increase in the share of renewables (from 15% in 2016 to 23% in 2030) along with a recovery of nuclear power to pre-2011 levels (21% in 2030). For 2050, scenario analysis indicates a further increase for renewables (35%-67%), mainly solar, wind and biomass. Increasing the share of renewables with intermittent supply (solar and wind power), which currently is less than 5%, will require new infrastructure to guarantee a stable supply, such as large-scale batteries or other power storage means, grid adjustments, flexible power supply options (such as gas turbines), as well as demand response measures. Moreover, scaling up these technologies will have to overcome restrictions on land-use, posed by the limited availability of flat land in Japan, and whether they will be accepted by local communities. In the case of biomass, a sustainable supply of large amounts of feedstock may prove difficult.

For nuclear power and CCS, scenario analysis shows a variety of possibilities, ranging from no deployment at all to a more than 30% share. These outcomes reflect the diversity of views on the feasibility of these technologies, not only with respect to technological and economic aspects, but also from social and political viewpoints. For instance, the social and political acceptability of nuclear power in Japan is still under debate. Nuclear power supplied 20-30% of the country's electricity between 1990 and 2010, but only 6% in 2018 (IEA, 2019). The 2011 disaster triggered by the Great East Japan Earthquake led to the indefinite closure of most of Japan's nuclear power plants, and a delay in the construction of new ones. For CCS, the only experience in the country are pilot-scale facilities, and questions remain in relation to the availability of underground carbon reservoirs, technical and economic feasibility, and acceptance by local communities.

With respect to energy carriers, all scenarios show a more prominent role played by electricity in final energy consumption, and a range of possibilities for hydrogen. These energy carriers will substitute fossil fuels across all sectors but most likely at different scales. For example, displacing some fossil-fuel based applications in the industry sector (such as cement, and iron and steel) may be more challenging compared to electrifying the entire building sector (residential and commercial). The share of electricity has increased steadily in the past (around 0.2 percentage points per year), and this trend seems to be aligned with the NDC assumption (30% by 2030). However, scenario analysis suggests that the pace of electrification towards 2050 will need to be double or more compared to historical trends (meaning that electricity share should reach 39-57% by 2050). This will require expanding the capacity of the electricity grid, as well as enabling the widespread adoption of electric devices (equipment and appliances) in end-use sectors, and ensuring a larger share of electric vehicles. For the latter, recent progress in the commercialisation of electric vehicles is promising but will need further investment in supporting infrastructure (charging stations). There are also concerns to overcome such as the net impact on Japan's vehicle manufacturing industry. As for hydrogen, the scenario analysis suggests shares of between 0 and 13% of the total final energy consumption. Hydrogen is not yet a mature energy alternative, and assumptions across scenarios vary considerably, but it can complement the realisation of the LTS if produced from carbon-free sources. This implies considerable advances in the performance of hydrogen technologies and the establishment of a widespread infrastructure, which is currently non-existent.

Overall, the analysis shows that realising Japan's 80% reduction target by 2050 depends on significant and fast transformations in the whole economy, as well as the provision and consumption of energy, which is the main source of emissions in the country. The rate of annual change in key decarbonisation indicators needed for transition from the current NDC to the 2050 goal (between 2030 and 2050) is considerably bigger than the past trends. In contrast, the rates of change expected to meet the current NDC (between 2016 and 2030) are very similar to recent trends for many of the indicators. This shows that the current NDC does not fulfil the demand for accelerated efforts for curbing GHG emissions in line with global climate goals, including decarbonisation (i.e. net zero emissions) around the mid-century. This agrees with evaluations of Japan's NDC by authoritative sources, such as the UNEP Emissions Gap Report (United Nations Environment Programme, 2019) and the Climate Action Tracker (Climate Action Tracker, 2019), as well as scenario analysis considering enhanced ambition of the 2030 target (Oshiro, Kainuma and Masui, 2017; Oshiro, Masui and Kainuma, 2017). Therefore, it is fundamental to upgrade the current NDC with a more ambitious mitigation target that bends the recent trends in decarbonisation indicators towards a pathway aligned to the long-term climate goals.

The above analysis is based on key macro indicators and provides an initial outline of the challenges ahead for achieving the LTS, focusing on some major transformations that will need to take place in the supply and consumption of energy. Overall, the scenario analysis provides valuable information for the formulation and evaluation of long-term decarbonisation strategies. At the very least, such analysis are a quantitative basis for an informed discussion of the feasibility and options for a long-term decarbonisation target. While the scenario analysis does not represent a deterministic outcome for the decision-making process, it does clarify and highlight the range of possibilities and uncertainties under a structured set of assumptions.

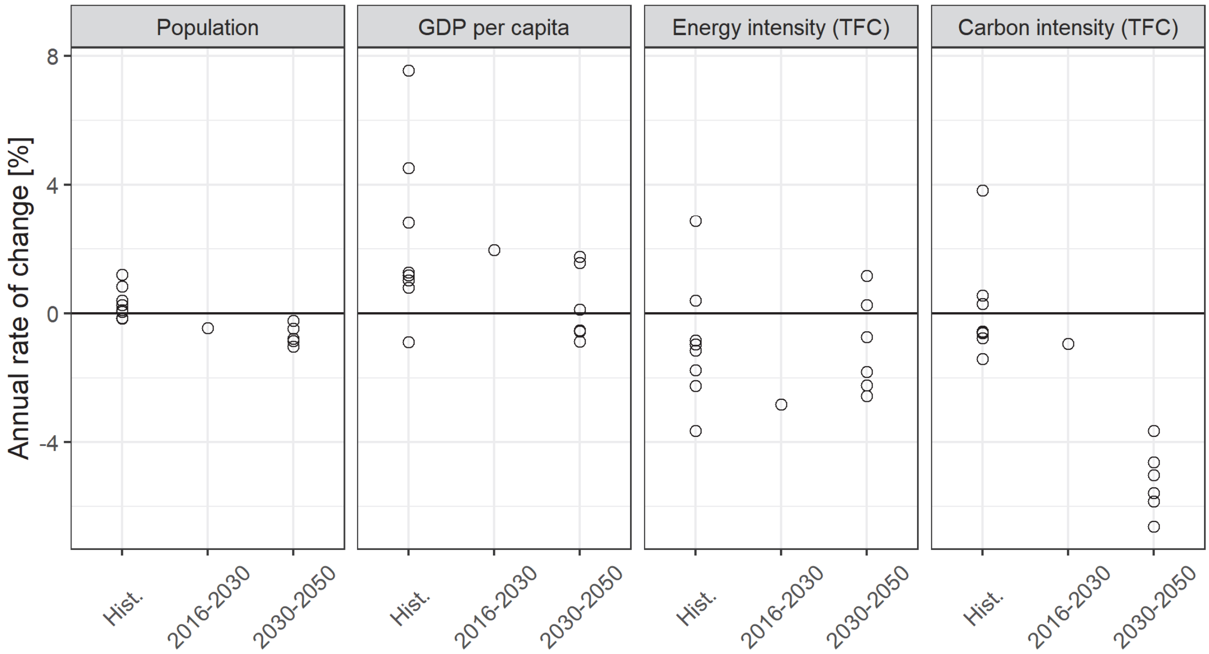

Figure 3 Annual change rate in major drivers of emissions.
"Hist" are values for eight timeframes between 1960-2016. "2016-2030" are based on NDC assumptions. "2030-2050" are values for Japan 80% emissions reduction scenario from six different models. Based on data from Kuriyama et al. (Energy Policy 2019) and Sugiyama et al. (Energy 2019).

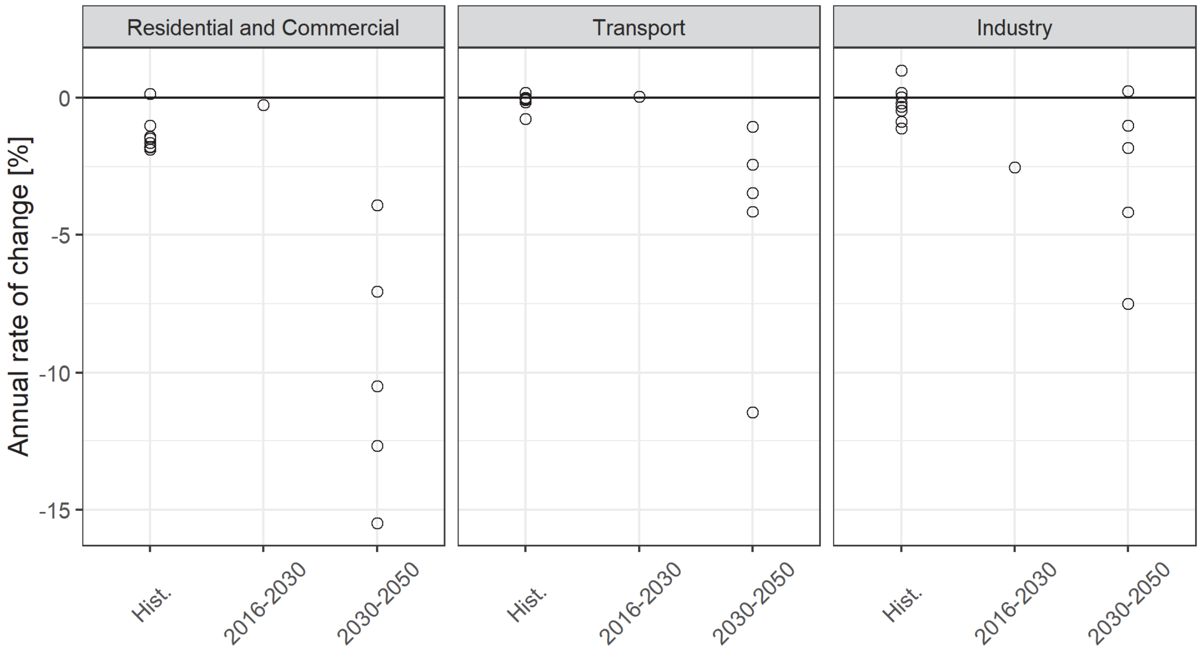

Figure 4 Annual change rate in carbon intensity of energy consumption by aggregated economic sectors.
"Hist" are values for eight timeframes between 1960-2016. "2016-2030" are based on NDC assumptions. "2030-2050" are values for Japan 80% emissions reduction scenario from six different models. Based on data from Kuriyama et al. (Energy Policy 2019) and Sugiyama et al. (Energy 2019).

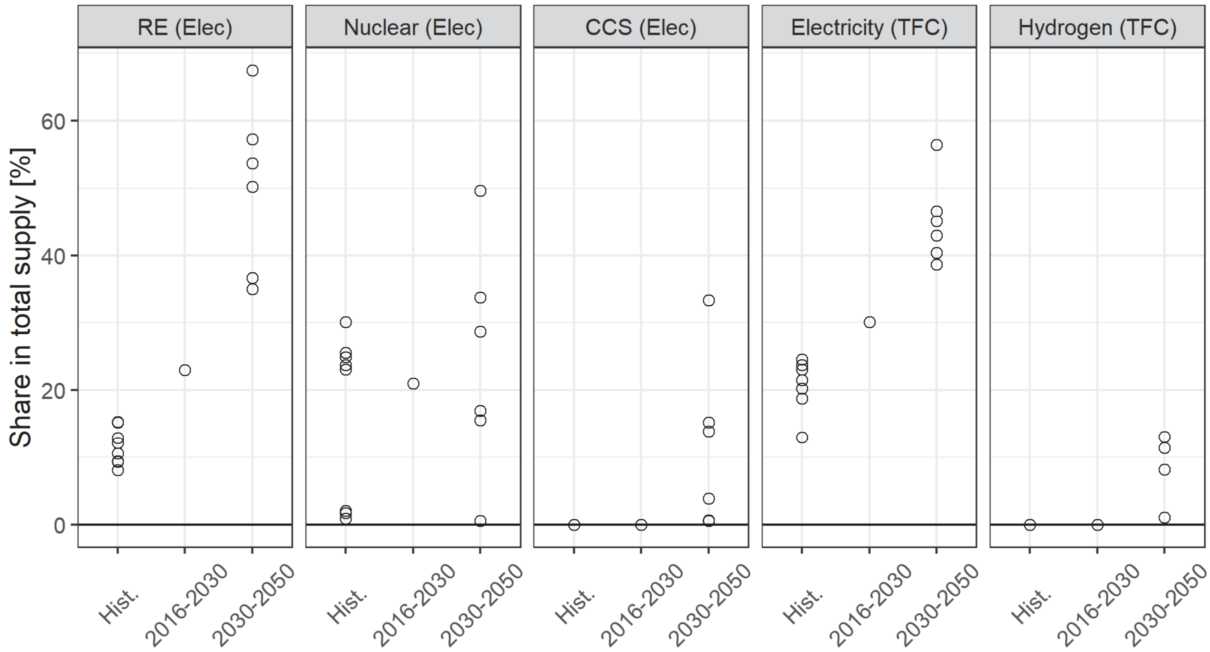

Figure 5 Share of low carbon technologies (RE, nuclear, CCS) in electricity supply, and share of energy carriers (electricity, hydrogen) in total final energy consumption.
"Hist" are values for eight timeframes between 1960-2016. "2016-2030" are based on NDC assumptions. "2030-2050" are values for Japan 80% emissions reduction scenario from six different models. Based on data from Kuriyama et al. (Energy Policy 2019) and Sugiyama et al. (Energy 2019).

4.2 The role of scenario analysis in LTS formulation

To understand the challenges for decarbonisation in the long-term, and supporting the LTS formulation, scenario analysis plays a fundamental role (Iyer *et al.*, 2017; Weitzel *et al.*, 2019). Japan's current LTS lacks any explicit mention of long-term scenario analysis, in contrast to, for example, the vision for decarbonisation forming the basis of the EU's LTS (European Commission, 2018). Below, we elaborate on the role of scenario analysis in enhancing LTS formulation.

First, scenario analysis provides quantitative knowledge on the long-term transformations for a wide range of socio-economic indicators, including those of emission drivers. Moreover, it clarifies the effect of multiple uncertainties surrounding the feasibility of decarbonisation (such as the availability and performance of low-carbon measures, and the trends of macroeconomic drivers and energy consumption), in a systematic and quantitative manner. Although it is not able to perfectly reflect all socio-economic interactions, it does provide quantitative insights on the relative size of transformations in economic sectors and of the penetration of technologies. Therefore, scenario analysis helps identify measures and targets to be considered in the LTS. In contrast, the absence of scenario analysis in the LTS formulation prevents the proper evaluation of multiple alternatives and the definition of quantitative targets, capturing only a partial picture of the socio-economic transformations, and allowing for biased choices without any clear supporting evidence.

A second role for scenario analysis is that it contributes to the transparency of the formulation process. As explained above, the options considered in the LTS can derive from an assessment of multiple scenarios. As scenarios are scientific assessments documented in the research literature, their insights represent science-based evidence supporting the measures and targets established within the LTS. This evidence (including assumptions, rationale and data) can be verified by all stakeholders. If the LTS lacks any information derived from scenario analysis, the basis forming the selection of measures and the setting of targets will be missing, obscuring the justification of the LTS' contents.

A third role of scenario analysis is the promotion of stakeholder engagement when formulating the LTS. This can enrich the basic knowledge that makes up LTS discussions. If scenario information is equally shared among the policymakers and stakeholders during the LTS formulation process, it is possible to enable a common understanding of the alternatives considered in the strategy and their corresponding implications in a broad range of socio-economic aspects. In addition, scenario analysis provides a robust signal to stakeholders of any changes in terms of the scale and timing of changes in specific aspects that are needed for decarbonisation. A lack of scenario analysis will considerably diminish the acceptability of the LTS contents, as the rationale behind the choices within the LTS will be difficult to communicate and discuss among stakeholders.

In addition to the assessment of the LTS, scenario analysis helps to understand the feasibility and implications of diverse socio-economic developments to conform to multiple policy aims. For instance, scenario analysis is also useful for determining near-term mitigation targets, namely the NDC, and revisions in the level of mitigation ambition. Given that periodic revisions of the NDC are stipulated in the Global Stocktake (GST) under the Paris Agreement, scenario analysis should be a basic component of the climate policymaking process. Current NDCs (which in the case of Japan includes a target by 2030) are far from the level of GHG emissions consistent with global climate goals (i.e. 2 degree and 1.5 degree goals). Moreover, the latest NDC submission by Japan on March 2020, kept the same emissions reduction target as the first submission, without any revision of the contents, neither any reference to scenarios (Ministry of Environment of Japan, 2020). Therefore, increasing the ambition of current targets is needed, and scenario analysis can clarify the actions that enable further emissions reductions in specific sectors and technologies. Also, scenario analysis help businesses to evaluate the long-term risks and opportunities posed by the impacts and socio-economic transformations derived from climate change (Task Force on Climate-related Financial Disclosures, 2017).

The benefits of scenario analysis elaborated above depends on the recognition of their limitations. First, scenario analysis is a tool for describing possible futures, and their feasibility based on a range of assumptions and methods. Thus, it should not be misunderstood as an attempt to predict or prescribe the future outcome of policies. Discussion using scenario analysis should consider the underlying assumptions and modelling approaches, in addition to the numerical outcomes. Second, the diversity of modelling approaches should be acknowledged as a feature of scenario analysis rather than a limitation. While a single model focus on a given range of interactions and factors that results in advantages and disadvantages compared to other models, combining the insights from multiple models can extend the coverage of scenario analysis.

5. Summary

The goal envisaged in the LTS for decarbonisation implies a deep transformation for the major drivers of GHG emissions in the long-term. National policymakers and stakeholders involved in the formulation and implementation of the LTS need to be informed about how major socio-economic transformations may evolve in order to meet the LTS goal. While decarbonisation may be well acknowledged as a challenging matter, it is fundamental to explain these challenges in a quantitative manner, and in a context that facilitates the formulation of effective measures with a long-term perspective in mind. The challenge for decarbonisation can be described as the contrast between the pace of socio-economic change needed for the LTS target, and what has been experienced in the past. To measure this, we analysed the difference between past trends and future projections from scenarios, in terms of the speed and scale of change in key indicators relevant to decarbonisation.

We reviewed the implications of Japan's LTS goal (80% reduction by 2050) with respect to the Kaya indicators (population, income per capita, energy intensity, carbon intensity of energy consumption), and selected indicators related to decarbonisation (energy intensity by aggregated sectors, share of low-carbon energy supply, share of electricity and hydrogen in final energy), and highlighted the challenges for realising this goal based on the analysis of past trends, current commitments for 2030 (as stated in Japan's NDC) and the insights from long-term scenario analysis. Major challenges identified include:

- Emissions reduction will have to accelerate considerably (from a linear average annual rate of 1.5% between 2013 and 2030, as stipulated in the NDC, to 3.7% per year from 2030), meaning rates of decarbonisation of final energy consumption at least three times larger than compared to the largest rate in the past and the current NDC assumption.
- Final energy consumption must be decarbonised across all economic sectors, in particular for the residential and transport sectors (at a pace at least two and 1.2 times faster than past trends respectively), expanding the share of low-carbon energy technologies (mainly for renewable energy) at levels considerably higher than the NDC assumption, and the share of electricity in final energy consumption at levels 1.3 times larger than ever experienced in the past.
- With less certainty, there should be deployment of nuclear, CCS and hydrogen, as they depend strongly on the scenario assumptions related to the availability, features and acceptability of these options.
- Overall, the rapid socio-economic transformations needed for a transition to the 2050 goal from the current NDC are in contrast with those needed to meet the current NDC, which are similar to past trends. Thus, upgrading the NDC with a more ambitious target is essential to downsize the challenge for reaching full decarbonisation of society in the long-term.

In the current LTS of Japan, long-term scenario analysis is absent, and it only presents limited quantitative information justifying the measures and targets therein. Japan's LTS can be considerably enhanced using insights from scenario analysis that are already available in the scientific literature. The role of scenario analysis becomes even more essential following the declaration by Japan's government in October 2020 to aim for net-zero GHG emissions by 2050. In this paper we introduced a representative study including multiple models; however, there is a growing amount of literature on the assessment of long-term decarbonisation targets in Japan and other countries. These insights should be mentioned explicitly in relevant documents and discussions contributing to LTS formulation, in order to support the common understanding among stakeholders of the challenges and alternative measures to realise the LTS, and promote action towards concrete measures in specific sectors.

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References

ANRE (2007) *Energy White Paper 2007 (in Japanese)*. Agency for Natrual Resources and Energy, Tokyo.

Cabinet Office (2015) *Submission of Japan's Intended Nationally Determined Contribution (INDC)*. Tokyo.

Cabinet Office (2016) *Chikyu Ondanka Taisaku Keikaku (Plan of Global Warming Countermeasures, in Japanese)*. Cabinet Office, Tokyo.

Climate Action Tracker (2019) *Climate Action Tracker - Countries*, *Climate Action Tracker*. Available at: https://climateactiontracker.org/countries/ (Accessed: 30 June 2020).

European Commission (2018) 'A Clean Planet for all - A European long-term strategic vision for a prosperous , modern , competitive and climate neutral economy', *Com(2018) 773.*

Fujinami, T. (2014) 'Oil Shock no Keikenwo Ikashi Setsuden wo Wagakuino Seityo no Baneni (Saving electricity consumption during the oil crisis contributed economic growth, in Japanese)', *JRI review*, 9(19), pp. 14–34.

IEA (2017) *World Energy Outlook 2017*. Paris, France.

IEA (2019) 'IEA Electricity Information 2019'. Available at: https://www.iea.org/subscribe-to-data-services/electricity-statistics.

IEEJ (2017) *Heisei 28 Nendo Energy Shiyou Gourika Sokushin Kiban Seibi Jigyo (Project for promotions of energy conservation innovation, in Japanese)*. Institute of Energy and Economics, Japan, Tokyo.

IPSS (2017) *Population Statistics*. National Institute of Population and Social Security Research, Tokyo.

Iyer, G. *et al.* (2017) 'Measuring progress from nationally determined contributions to mid-century strategies', *Nature Climate Change*. doi: 10.1038/s41558-017-0005-9.

Kuramochi, T. *et al.* (2016) 'Comparative assessment of Japan's long-term carbon budget under different effort-sharing principles', *Climate Policy*. doi: 10.1080/14693062.2015.1064344.

Kuramochi, T., Wakiyama, T. and Kuriyama, A. (2017) 'Assessment of national greenhouse gas mitigation targets for 2030 through meta-analysis of bottom-up energy and emission scenarios: A case of Japan', *Renewable and Sustainable Energy Reviews*. doi: 10.1016/j.rser.2016.12.093.

Kuriyama, A. and Abe, N. (2018) 'Ex-post assessment of the Kyoto Protocol – quantification of CO 2 mitigation impact in both Annex B and non-Annex B countries-', *Applied Energy*, 220, pp. 286–295. doi: 10.1016/j.apenergy.2018.03.025.

Kuriyama, A., Tamura, K. and Kuramochi, T. (2019) 'Can Japan enhance its 2030 greenhouse gas emission reduction targets? Assessment of economic and energy-related assumptions in Japan's NDC', *Energy Policy*, 130, pp. 328–340. doi: 10.1016/j.enpol.2019.03.055.

METI (2017) *Long-term global warming countermeasure platform (Choki chikyuondankataisaku purattofomu) in Japanese*. Tokyo.

Ministry of Environment of Japan (2020) 'Submission of Japan's Nationally Determined Contribution (NDC)'. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Japan First/SUBMISSION OF JAPAN'S NATIONALLY DETERMINED CONTRIBUTION (NDC).PDF.

MOEJ (2017) *Tyouki Teitanso Bijyon (Vision for Long-term Low Carbon Society) in Japanese*. Tokyo.

Moss, R. H. *et al.* (2010) 'The next generation of scenarios for climate change research and assessment', *Nature*. doi: 10.1038/nature08823.

Nakicenovic, N. *et al.* (2000) *Special report on emissions scenarios (SRES)*, *Working Group III of the Intergovernmental Panel on Climate Change IPCC*.

O'Neill, B. C. *et al.* (2014) 'A new scenario framework for climate change research: The concept of shared socioeconomic pathways', *Climatic Change*. doi: 10.1007/s10584-013-0905-2.

Oshiro, K., Kainuma, M. and Masui, T. (2016) 'Assessing decarbonization pathways and their implications for energy security policies in Japan', *Climate Policy*. doi: 10.1080/14693062.2016.1155042.

Oshiro, K., Kainuma, M. and Masui, T. (2017) 'Implications of Japan's 2030 target for long-term low emission pathways', *Energy Policy*. doi: 10.1016/j.enpol.2017.09.003.

Oshiro, K., Masui, T. and Kainuma, M. (2017) 'Transformation of Japan's energy system to attain net-zero emission by 2050', *Carbon Management*. doi: 10.1080/17583004.2017.1396842.

Silva Herran, D., Fujimori, S. and Kainuma, M. (2019) 'Implications of Japan's long term climate mitigation target and the relevance of uncertain nuclear policy', *Climate Policy*. doi: 10.1080/14693062.2019.1634507.

Sugiyama, M. *et al.* (2019) 'Japan's long-term climate mitigation policy: Multi-model assessment and sectoral challenges', *Energy*, 167, pp. 1120–1131.

Task Force on Climate-related Financial Disclosures (2017) *Technical Supplement. The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities*.

The Government of Japan (2017) *Japan's Third Biennial Report under the United Nations Framework Convention on Climate Change*. Tokyo.

The Government of Japan (2019a) *2nd round, material 1-3. In"Round-table on Long-term Growth Strategy for the Paris Agreement (Pari kyotei choki seicho senryaku kondan-kai)" in Japanese*. Available at: https://www.env.go.jp/earth/earth/ondanka/mat001_3.pdf.

The Government of Japan (2019b) *Japan's Long-term Strategy under the Paris Agreement*. The Government of Japan, Tokyo.

The Government of Japan (2019c) *Round-table on Long-term Growth Strategy for the Paris Agreement (Pari kyotei choki seicho senryaku kondan-kai) in Japanese*.

The Government of Japan (2019d) *The Long-term Strategy under the Paris Agreement The Government of Japan*. Tokyo. Available at: https://unfccc.int/sites/default/files/resource/The Long-term Strategy under the Paris Agreement.pdf.

The Government of Japan (2020) 'Policy Speech by the Prime Minister to the 203rd Session of the Diet. October 28, 2020'. Available at: https://japan.kantei.go.jp/99_suga/statement/202010/_00006.html.

UNFCCC (2015) *Paris Agreement*, *Conference of the Parties on its twenty-first session*. doi: FCCC/CP/2015/L.9/Rev.1.

UNFCCC (2020) *Communication of long-term strategies*, *UNFCCC Sites and platforms*.

United Nations Environment Programme (2019) *Emissions Gap Report 2019*. Nairobi.

Wakiyama, T. and Kuramochi, T. (2017) 'Scenario analysis of energy saving and CO2 emissions reduction potentials to ratchet up Japanese mitigation target in 2030 in the residential sector', *Energy Policy*, 103, pp. 1–15. doi: 10.1016/j.enpol.2016.12.059.

Weitzel, M. *et al.* (2019) 'Model-based assessments for long-term climate strategies', *Nature Climate Change*. doi: 10.1038/s41558-019-0453-5.

APPENDIX

Status of Japan GHG emissions and current climate policy

Current trend of emissions and their drivers (socio-economic, energy use)[1].

The historical trend of GHG and CO_2 emissions in Japan is presented in Figure 6. Energy-related CO_2 emissions are used as a proxy for GHG emissions, since they constitute the best representation of total emissions (around 90% since 1990). After a rapid increase, CO_2 emissions remained at around 850 $MtCO_2$ between 1973 and 1987. After 1988, emissions increased again until 2013 with a temporary decline during 2008-2010 due to the economic crisis. The current trend of CO_2 emissions is on the decline.

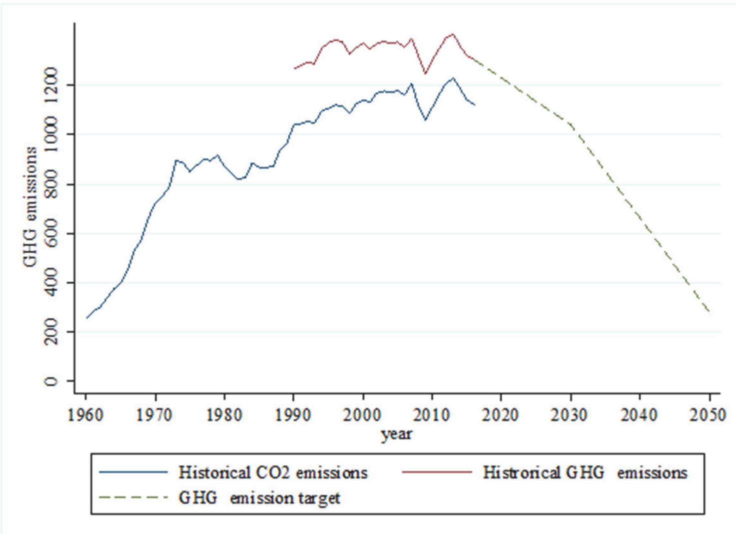


Figure 6 Historical GHG emissions and GHG emission target of Japan

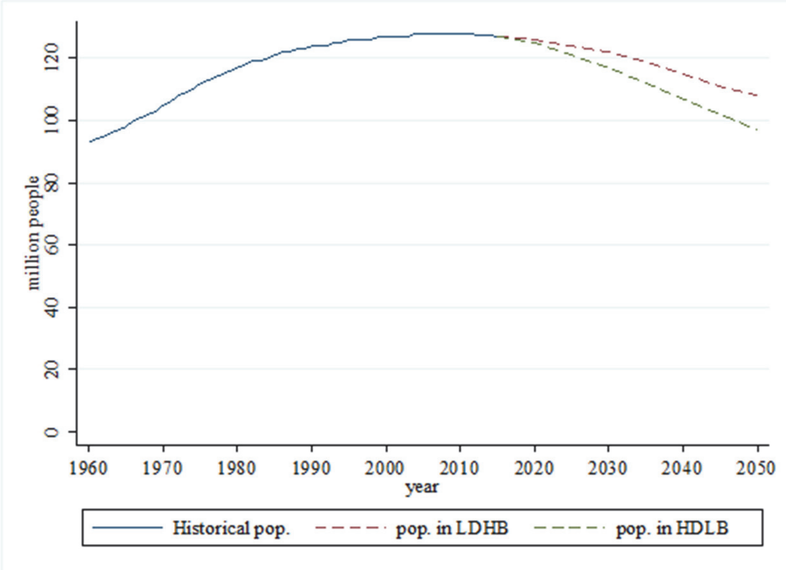
The drivers of CO_2 emissions can be analysed based on the Kaya identity (Eq.1), which includes population, GDP per capita, energy intensity (final energy consumption per GDP) and carbon intensity (CO_2 emissions per final energy consumption).

CO_2=POP × GDP/POP × TFC/GDP × (CO_2)/(Energy) (Eq. 1)

Figure 7, Figure 9, and Figure 11 show the historical data of these indicators between 1960 to 2015, as well as long-term projections up to 2050 for population, and up to 2030 for the other indicators. Population data are taken from IPSS (2017). Other indicators are based on IEA Energy Outlook (IEA, 2017).

[1] This section is based on Kuriyama et al., (2019).

The population of Japan peaked at 1.28 billion in 2010, and it is estimated that it will decrease to between 1.16 and 1.22 billion by 2030 as shown in Figure 7.



LDHB: Low death rate and high birth rate
HDLB: High death rate and low birth rate
Figure 7 Historical and prospective population in Japan

Figure 8 shows the trends of GDP (based on 2010 Japanese yen). During the economic boom created by the Tokyo Olympic Games up to 1964, real GDP grew at an average of 10.3% a year, and thereafter it grew an average of 8.0% a year during the period from 1965 to 1972, including the Izanagi economy. GDP then slowed to 3.9% between 1973 and 1984, a period of time that included the first oil shock in 1973 and the second oil shock in 1978. During the bubble economy (1986-1991), GDP growth improved slightly (4.9%), but dropped sharply (1.4%) thereafter during the Izanami economy (2002-2007), and has remained at similar levels until now (1.3% between 2012-2015) despite the fiscal policy of the second Abe Cabinet (i.e. Abenomics).

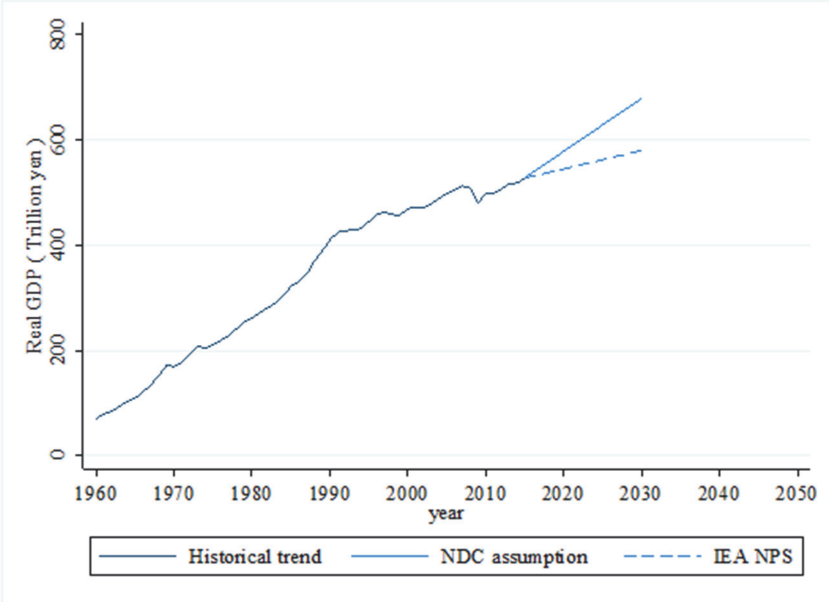
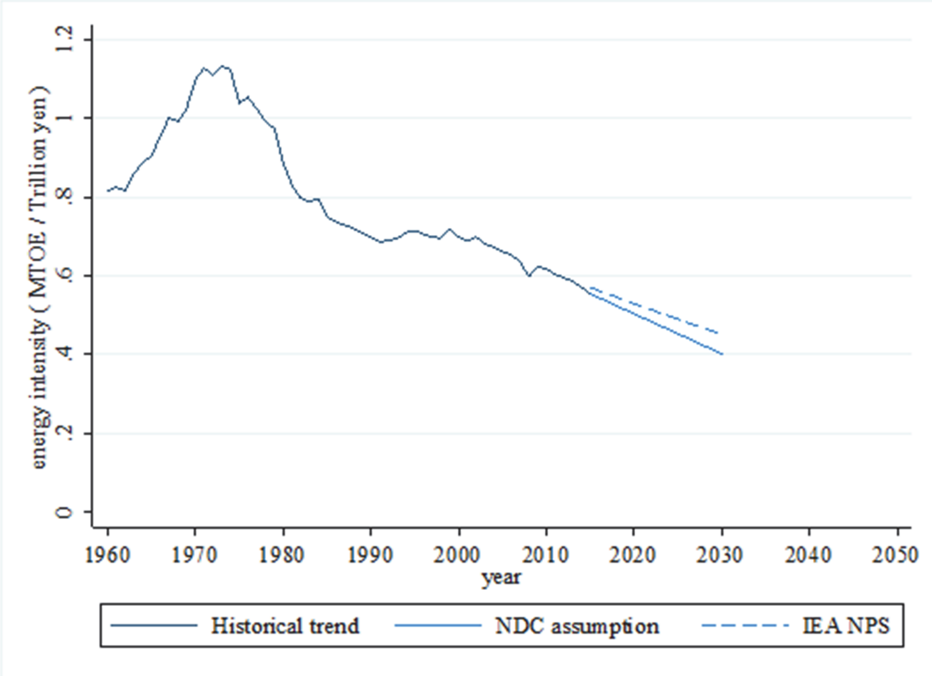


Figure 8 Historical and prospective real GDP (based on 2010 Japanese yen) in Japan

As shown in Figure 9, energy intensity increased at a rate of 2.6% annually until 1973 when the first oil crisis occurred. After that, it continuously decreased until 2015 and included rapid changes between 1973 and 1986 influenced by the sharp decline in oil price, which was due to the increase in crude oil production by Saudi Arabia (ANRE, 2007). The government of Japan enacted the Petroleum Supply and Demand Adjustment Act in 1973, which enforces temporary measures to limit the oil usage of companies. Due to the increased price signals, this policy incentivised voluntary measures in companies, including energy efficiency improvement (Fujinami, 2014). The improvement of energy intensity from 1986 to 1991 and from 1991 to 2000 stagnated at −1.4% and +0.3%, respectively. Between 2000 and 2007 energy intensity improved to −1.5% annually thanks to the introduction of the top runner programme through the amendment of the Energy Conservation Law in 1999 and Japan's ratification of the Kyoto Protocol in 2002 (Fujinami, 2014; IEEJ, 2017). This political movement raised awareness about energy efficiency improvement. From 2010 to 2013 and from 2013 to 2015, reductions in energy intensity accelerated further to −1.8% and −2.7% per year, mainly as a result of energy-saving efforts in the residential sector following the Great East Japan Earthquake and the replacement of old electrical appliances (Wakiyama and Kuramochi, 2017), and to a lesser extent due to changes in economic structure (Kuriyama and Abe, 2018). The NDC assumes that energy intensity towards 2030 will decrease at an average rate of −2.1% per year.



IEA NPS: IEA New Policy Scenario

Figure 9 Historical and prospective energy intensity in Japan

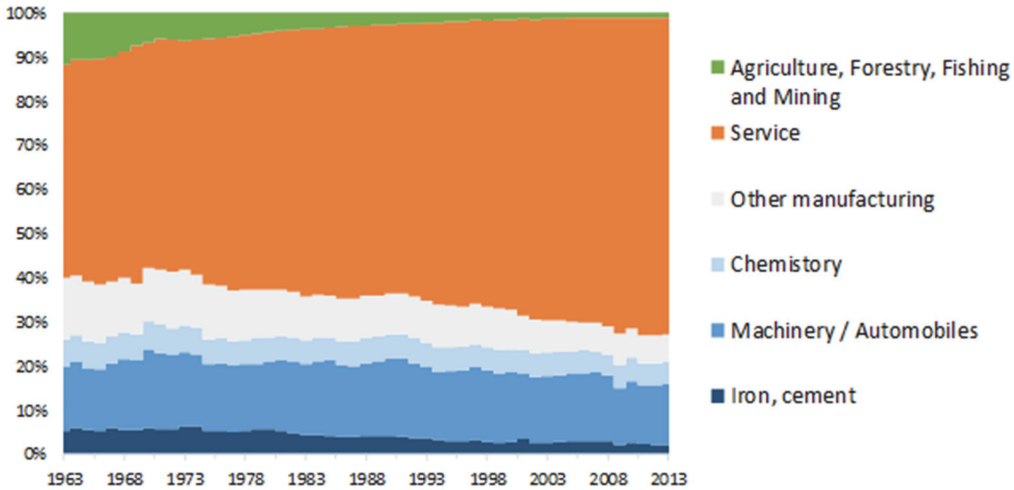
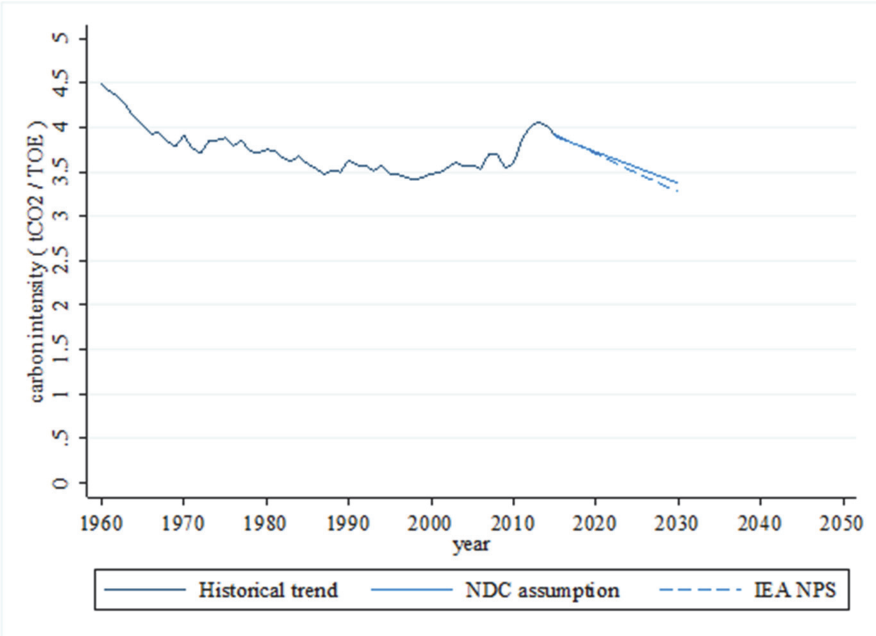


Figure 10 Change of economic structure in Japan

Carbon intensity declined at an annual average of −1.6% from 1960 to 1973, driven by the shift from coal to oil in the non-electricity sector, as shown in Figure 11. From 1973 to 1986 when the reverse oil crisis occurred, carbon intensity decreased at 0.3% annually. During this period, the electricity supply from nuclear power plants and gas-fired power plants increased following the implementation of three electricity-related laws (for details, see Kuriyama et al., 2019). During the periods of 1986–1991 and 1991–2000, the annual change in carbon intensity fluctuated between +0.2% and −0.6%, respectively. The improvement in carbon intensity in these periods was influenced by increases in the share of gas in the non-electricity sector, expansion in the electricity sector of both gas and nuclear power, and improved efficiency of fossil-fuel power plants. These gains in carbon intensity were counterbalanced by the growth of coal's share in the electricity supply (for details, see Kuriyama et al., 2019). From 2000 to 2007, carbon intensity increased once again (0.9%), mainly influenced by the growing share of coal-fired power, among other factors. It then decreased (0.9%) between 2008 and 2010 owing to the addition of gas-fired power supply. From 2010 to 2013, carbon intensity rapidly increased (4.1%) owing to the halt of nuclear power plants after the Great East Japan Earthquake, but later decreased (1.7%) from 2013 to 2015.



IEA NPS: IEA New Policy Scenario

Figure 11 Historical and prospective carbon intensity in Japan

Relevant policies for climate mitigation

The policy landscape for climate change mitigation is encapsulated in the Plan for Global Warming Countermeasures established in 2016. This plan pictures the realisation of 2030 and 2050 mitigation goals through decarbonisation of the energy supply, promotion of innovation of technology and lifestyles, a transformation in the socio-economic structure, and the reduction of energy intensity through technological progress and energy savings. As a whole, the elements forming the national government's position towards long-term mitigation are aligned with the Growth Strategy 2018, the Basic Energy Plan 2018, the 5th Basic Environment Plan 2018, and the Integrated Innovation Strategy 2018.

To achieve those mid-term and long-term goals for climate policies, several climate and energy legislations are in place. Regarding carbon pricing, Japan introduced the Global Warming Countermeasure Tax in 2012. The rate of taxation had been gradually increased to JPY289 per tonne CO_2 by 2016. Although the level of carbon pricing is lower compared to the other countries, all tax revenue will be allocated to reduce energy-originated CO_2 emissions. An emissions trading system was introduced in Tokyo Metropolis in 2010 and in Saitama Prefecture in 2011.

In addition to climate policies, energy policies have strong connections with mitigation measures since energy-related CO_2 has c.a. 90% share of GHG emissions. For the power sector, the feed-in tariff scheme implemented under the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities (2011, Act No. 108) is accelerating renewable energy (The Government of Japan, 2017). In addition there was an announcement in July 2015 on the voluntary framework for the power sector in which major business operators participate, as well as the Industry's Action Plan toward a Low-carbon Society. This Action Plan aims to achieve about 0.37 kg-CO_2/kWh as the emission factor that matches the national energy mix and the CO_2 reduction target. The Electric Power Council for a Low Carbon Society was launched in February 2016. The Council established individual reduction plans, and announced mechanisms and rules for the entire industry to implement PDCA. The liberalisation of the electricity market in 2016 provided additional stimulus for businesses initiatives promoting renewable energy such as RE100.

The Energy Conservation Act has played an important role in promoting energy efficiency. The act came into force in 1979 and has been amended several times in 1983, 1993, 1998, 2005, 2008 and 2013. Through those revisions, it has gained a periodical reporting system, the Top Runner Program (benchmark scheme) for machinery, home appliances, automobiles and building materials, as well as energy efficient standards including mandatory compliance with energy efficiency standards for large construction projects.

Against this policy landscape, multiple challenges persist for materialising climate change mitigation actions. Energy supply, which is the largest source of emissions, has a dependency rate of more than 90% on imported fossil fuels, and deployment of nuclear power, which constituted a countermeasure to improve energy self-reliance and carbon emissions, has been significantly limited after the 2011 Fukushima disaster. Moreover, the power supply consists of regional monopolies of power utilities that are vertically integrated, slowing the penetration of renewables. In terms of policymaking, government discussions on climate mitigation have been limited to small committees, and it is unclear how assessments of climate mitigation policies are considered in the process.

Supplementary data

Table A-1 Historical and expected changes in key indicators relevant for decarbonisation goals (based on average annual rates of change for specific periods).

Aspect/indicator	Historical data [1]		NDC assumption (2016 to 2030) [2]	LTS based on scenario analysis (2030 to 2050) [3]	
	Low	High		Low	High
	Average annual rate of change (%)				
Population	-0.2	1.2	-0.4	-1.0	-0.2
GDP per capita	-0.9	7.5	2.0	-0.9	1.8
Energy intensity: Final energy/GDP	-3.6	2.9	-2.8	-2.6	1.2
Carbon intensity: CO2/Final energy	-1.4	3.8	-0.9	-6.6	-3.6
CO2/Final energy Industry	-1.1	1.0	-2.5	-7.5	0.2
CO2/Final energy Transport	-0.8	0.2	0.0	-11.4	-1.0
CO2/Final energy Residential and Commercial	-1.9	0.1	-0.3	-15.5	-3.9
	Share in each timeframe (%)				
Renewable energy in electricity supply	8.1	15.3	23.0	35.0	67.4
Nuclear energy in electricity supply	0.9	30.1	21.0	0.5	49.7
CCS in electricity supply	0.0	0.0	0.0	0.6	33.3
Electricity in final energy	13.0	24.6	30.1	38.7	56.5
Hydrogen in final energy	0.0	0.0	0.0	1.1	13.1

1 Values for selected timeframes between 1960-2016 according to Kuriyama et al. (Energy Policy 2019).
2 Based on NDC assumptions (Government of Japan, 2015).
3 Values for Japan 80% emissions reduction scenario from different models. Based on data from Sugiyama et al. (Energy 2019).

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