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JAPAN 2050 LOW CARBON NAVIGATOR

Overview and Trajectory Setting

Japan 2050 Low Carbon Navigator

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IGES Research Report

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Acknowledgements

Back in 2010, the UK Department of Energy and Climate Change (DECC) developed an innovative simulation tool—the UK 2050 Pathways Calculator (2050 Calculator)—which lets the users to create their own emission reduction pathways and see the impact using real scientific data. The Institute for Global Environmental Strategies (IGES) found that a similar tool for Japan is likely to be very effective in delivering the fundamentals of energy mix and mitigation options for Japan to get wider public access and receive feedback simultaneously. The Japan 2050 Low Carbon Navigator is the result of this initiative. This research report has been prepared to provide an overview of the Japan 2050 Low Carbon Navigator and explain its structure, the calculation procedures as well as the trajectory setting of the covered sectors.

The core team working on the development of the Japan 2050 Low Carbon Navigator received cordial support, valuable comments and sincere encouragements from many people at IGES as well as in other institutions. The authors would like to thank IGES President Hideyuki Mori and Chair of IGES Board of Directors Professor Hironori Hamanaka for initiating this very useful project and for providing overall guidance all the way. We are also indebted to IGES Senior Research Advisor Professor Shuzo Nishioka who actively guided us in every step of the development of the Japan 2050 Low Carbon Navigator, starting from supervising the progress of our work to bringing together the experts for reviewing the tool.

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Foreword

The Synthesis Report of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) sent a clear warning message that if the world maintains its current trend without additional efforts for mitigation and adaptation, global warming is more likely to be 4°C above pre-industrial levels by 2100. This will lead to a high risk of severe, widespread, and irreversible impacts including extreme weather events, substantial species extinction, global and regional food insecurity, all of which can jeopardize the foundations that human society and economy depend on. Scientists also demonstrated that the pathways likely to limit warming to below 2°C require substantial reductions in global anthropogenic GHG emissions by 40% to 70% by 2050 compared to 2010 and emissions levels near zero or below in 2100. These messages urge the politicians to take immediate actions without delay.

Quantitative tools are increasingly becoming essential in effective and informed policymaking processes. It is particularly true for policies related to climate change and sustainable development. Quantitative analytical tools can provide important insights on how and to what extent policies can positively or negatively affect the social, economic and environmental dimensions of sustainability. As developed and developing countries alike are now formulating their intended nationally determined contributions (INDCs), the significance of quantitative tools are even more important in understanding how these INDC targets could be achieved in terms of available technologies, investment options, required behaviour changes and associated economic costs. This is also true for other sustainability issues such as the Sustainable Development Goals (SDGs), where the key concern is identifying—with quantitative evidence—the type of supporting policies needed for achieving the goals.

The Japan 2050 Low Carbon Navigator, a scenario-based simulation tool for understanding the energy and emissions-related choices that Japan faces, offers an ideal example of a quantitative instrument that is aimed at supporting policymaking processes. While the country is committed to a drastic reduction of its greenhouse gas (GHG) emissions, its energy security is at stake as a consequence of the 2011 nuclear disaster. Now Japan is at crossroads in choosing its energy and emissions policies: should it try to reduce energy consumption, or try to focus more on decarbonising the supply side? The country also faces questions relating to technology options as well as means of producing electricity. The Low Carbon Navigator offers users a platform to develop their own energy and emissions pathways/scenarios using real scientific data.

The Low Carbon Navigator for Japan, which is based on the 2050 Pathways Calculator of the United Kingdom, was developed by researchers at IGES and the National Institute for Environmental Studies (NIES). I first came to know about the UK version of the tool when I attended an international workshop in Bangkok in 2012, at which the UK Department of Energy and Climate Change presented the UK 2050 Pathways Calculator. I was impressed with the tool and believed that a similar tool for Japan would be very useful particularly in the context of the country's growing concerns about ensuring energy security and simultaneously achieving its mitigation targets. Subsequently, a research team was established and worked hard for over one year to develop the Low Carbon Navigator for Japan. UK DECC as well as the British Embassy Tokyo provided technical and logistic support, and the Ministry of the Environment of Japan provided financial support. After several discussions and demonstration trials with experts, the Low Carbon Navigator was officially launched in July 2014 during IGES's annual event, the 2014 International Forum for Sustainable Asia and the Pacific (ISAP) held in Yokohama.

The UK version of the tool—the UK 2050 Pathways Calculator—took very little time to become popular among policymakers, sector specialists as well as the general public. Its simplicity, transparency and user-friendliness prompted its wider use. Japan and several other countries followed suit and developed the tool for their respective countries. As in the UK, these national tools including the one for Japan received similar acceptance among the audience in those countries. I would like to emphasize that the use of this kind of quantitative tools must go beyond national governments. Cities, private companies, researchers and academicians also need quantitative instruments to assess their own initiatives and actions. For this, what is needed is a truly transparent and easy-to-operate tool. The Low Carbon Navigator is an attempt to meet these needs. It provides an ideal platform for a shift from the top-down approach in energy and emissions policies by engaging an audience from different spheres of life in dialogues on the challenges and opportunities of the future energy system and the responses to climate change. We are pleased to see an increasing number of universities and institutes in Japan using the Low Carbon Navigator for capacity development purposes.

The current version of the Low Carbon Navigator has been set up in the national context to analyse and synthesize Japanese energy and emissions policies at the country level. However, we plan to further develop and apply similar tools at the city level within and outside Japan.

I would like to take this opportunity to thank UK DECC, the British Embassy Tokyo, NIES, the Ministry of the Environment of Japan and all other institutions and individuals for the cordial support that they rendered to us for developing and improving the Japan 2050 Low Carbon Navigator.

It is with immense pleasure that IGES publishes this research report. This report has been prepared as a supportive document that provides an overview of the Low Carbon Navigator, how it works, and what its assumptions are. In addition, it provides several examples of simulation results under different pathways. I believe that the users of the Low Carbon Navigator will benefit from this report as a quick reference to the assumptions as well as way to gain deeper understanding on how it works.

Hideyuki Mori

President

Institute for Global Environmental Strategies

Preface

The world's carbon budget is already very small and decreasing very fast, and therefore keeping the temperature rise below the 2°C target is indeed a major challenge. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) shows a clear linear relationship between accumulated greenhouse gas (GHG) emissions to date and global temperature rise. We cannot deny that the emissions problem is of anthropogenic nature and if we continue the current rate of emissions, we will have exhausted the available carbon budget entirely within only 25 years. So, we have to use this very limited allocation in our wallet thriftily and wisely from now on, prolonging this 25-year allowance as much as possible, extending it to, for example, fifty or one hundred years, while we safely transform our highly energy-dependent society to a low-carbon society, aiming to eventually achieve a zero emission society. Such extension of this budget, however, is not impossible. The report of IPCC's Working Group 3 suggests that a group of feasible and reasonable pathways do exist for keeping the temperature rise to within 2°C, but roughly halving current emissions by 2050 will be the key.

Calculating from global population projections, this reduction pathway is equivalent to GHG emissions of 2 tons of carbon per capita in 2050 when divided equally throughout the world. Almost all developed countries and major economies in Asia have already exceeded this level. Japan emits 10 tons per capita, China almost 6 tons, Thailand more than 3 tons. Therefore the 2 tons per capita is a common target for us to attain over the next 35 years.

Japan had already set a goal to reduce GHG emissions by 80% by 2050 in its Fourth Basic Environment Plan. However due to the Great East Japan Earthquake and tsunami in 2011, followed by the accident of Fukushima nuclear power plant, Japan is now revising its mid-term energy plan and GHG emissions plan, preparing for a mitigation target to be submitted to the UNFCCC in June this year. Before the Fukushima accident occurred, Japan's energy plan was decided in a top-down manner by the national government together with experts from energy-related industries. But after the nuclear accident, civil society rediscovered the vital role that energy plays in our daily lives and, at the same time, recognised the associated risks to the places where we live and to the climate that we shared as a common issue. As a result, the decision-making procedure has become more multi-layered with dialogues among stakeholders and between layers now required.

Against this backdrop, I am very excited to introduce the UK 2050 Pathways Calculator to Japan and happy to see that the Japan 2050 Low Carbon Navigator was successfully developed jointly by the Institute for Global Environmental Strategies (IGES) and the National Institute for Environmental Studies (NIES). Some of the existing projects and networks built upon the Japan 2050 Low Carbon Society Project which I led assisted the Navigator development team with data-related support. Prior to the official release of the Navigator, we arranged two rounds of meetings with stakeholders where experts from various professional backgrounds reviewed the initial model, particularly the scenario settings. I would like to take this opportunity to express my appreciation for their valuable comments and contributions.

The Low Carbon Navigator can be a good instrument for each individual to deepen his or her thoughts and insights, as well as an effective tool for enhancing discussions within communities, a good partner for national and local decision-makers to think over alternatives, and, hopefully, also a navigator that directs us on the right pathway for reaching consensus at the global level to stabilize the climate. It was with that wish firmly in mind that we named our 2050 Calculator the “Low Carbon Navigator”.

We believe that audience from all spheres of life—policymakers, businesses and companies, educational institutes and academics, researchers and students, as well as the general public—will find the Low Carbon Navigator useful. While the tool is simple and easy-to-operate, this research report further assists the users to understand how it was developed and what the underlying assumptions are. In addition, illustrative examples in the report help the audience to learn about generating scenarios/pathways and interpreting the results. We hope that the users of the Low Carbon Navigator will find this report useful.

Shuzo Nishioka

Senior Research Advisor

Institute for Global Environmental Strategies

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List of Abbreviations

2050 Calculator	UK 2050 Pathways Calculator
CCS	Carbon capture and storage
CO_2	Carbon dioxide
COP	Coefficient of performance
EV	Electric vehicle
FCV	Fuel cell vehicle
GDP	Gross domestic product
GHG	Greenhouse gases
GW	Gigawatt
HEMS	Home Energy Management System
HEV	Hybrid electric vehicle
IGES	Institute for Global Environmental Strategies
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
JPY	Japanese yen
km	Kilometre
LED	Light-emitting diode
Low Carbon Navigator	Japan 2050 Low Carbon Navigator
m^2	Square meter
METI	Ministry of Economy, Trade and Industry of Japan
MIJ	Made-in-Japan Society
MOE	Ministry of the Environment of Japan
MW	Megawatt
NIES	National Institute for Environmental Studies
PHEV	Plug in hybrid electric vehicle
R&D	Research and Development Society
RI	Resource Independent Society
SB	Service Brand Society
SDG	Sustainable Development Goal
Share	Share Society
Solar PV	Solar photovoltaic
ton-km	Tonne-kilometre
TWh	Terawatt-hour
UK DECC	UK Department of Energy and Climate Change
UNFCCC	United Nations Framework Convention on Climate Change
y	Year

I. Introduction

For information:

Web Tool: http://www.en-2050-low-carbon-navi.jp/
Excel version: http://www.2050-low-carbon-navi.jp/web/en/
Website: http://www.2050-low-carbon-navi.jp/web/en/
Inquiry: ge-info@iges.or.jp

Background

Japan is committed to reduce its greenhouse gas emissions by as much as 80% below the 1990s levels by 2050. This has been complicated by the 2011 Fukushima nuclear accident which has raised concerns about ensuring the country's energy security in the coming decades. As a result, Japan is now placed at a crossroads in choosing its energy policies while at the same time achieving its mitigation targets. The choices Japan face now include, among others, whether to focus more on cutting its energy demand or relying more on decarbonising on the supply side, how to generate electricity, and what types of technologies to use.

Against this backdrop, recognising importance of rethinking Japan's energy and power supply policy, the government adopted an updated Strategic Energy Plan (the 4th Basic Energy Plan) in April 2014. This Plan provides a new course for Japan's energy policy. Two basic principles are reflected in this Plan (Hiranuma, 2014). First, it reiterates the "3E+S" focus of the nation's energy policy, emphasising energy security, economic efficiency, and environmental protection without compromising safety. Second, it emphasises the need to look at both supply and demand side options by creating a supply-demand structure that is multi-layered, diversified, and flexible (METI, 2014b). Additionally, Japan also underscores its role in contributing to global efforts in mitigating emissions and combatting climate change. In line with the decision at the 19th meeting of the Conference of Parties (COP19) of the United Nations Framework Convention on Climate Change (UNFCCC), Japan has started preparing the country's Intended Nationally Determined Contributions (INDCs), which are expected to be submitted to the UNFCCC in the summer of 2015. All these developments are critical for the country's social, economic and environmental dimensions of sustainability. There is a growing interest in simplified tools that can provide an easy-to-understand chart of the energy and emission options that Japan now faces, and to communicate on how Japan's policies related to energy and climate change can impact on the country's pronounced "3E+S" objectives and the INDC target. The Japan 2050 Low Carbon Navigator is such a quantitative tool which can support the policymaking process by engaging a wider audience in the energy and emissions debate.

Back in 2010, the UK Department of Energy and Climate Change (DECC) developed an innovative simulation tool—the UK 2050 Pathways Calculator (2050 Calculator)—which lets the users create their own emission reduction pathways by choosing their own combination of scenarios and see the impact using real scientific data. This user-friendly simulation tool received very positive responses from the audience. The 2050 Calculator is now being used by the policymakers as well as the experts and general public for dialogues and education purposes. Many other countries, such as China, Republic of Korea, Wallonia/Belgium, Taiwan and India followed suit and developed the Calculator for their respective countries. In Japan, the Institute for Global Environmental Strategies (IGES) and the National Institute for Environmental Studies (NIES), with the technical support from the UK DECC and the British Embassy Tokyo, jointly started working on developing the Japanese version of the 2050 Calculator in 2013. The prototype of the Japanese version, known as Japan 2050 Low Carbon Navigator (Low Carbon Navigator), was pre-launched during a trial session with different stakeholders in May 2014. The full version was launched for the general public in July 2014 (IGES, 2014).

As a pathways simulation tool, the Low Carbon Navigator helps policymakers, energy producers and consumers (including the public) to understand the energy and emission-related choices that Japan faces. It provides a platform for engaging in dialogues on the challenges and opportunities of the future energy system and the responses to climate change. It allows users to develop their own pathways combinations to achieve emissions reduction and ensure energy security. This transparent and handy tool can help answer the fundamental questions of how the energy system can evolve over the coming decades and its impact on emissions, energy security, land-use, electricity systems, energy development and related costs. It is, however, not a cost optimization model; it compares costs under the selected pathways but does not identify the least-cost pathway.

Description of the model

As the Low Carbon Navigator is a long-term simulation tool, it is reasonable to assume that there will be a significant number of uncertainties. Therefore, the Low Carbon Navigator uses a scenario-based approach to explore potential pathways and to illustrate the likely outcomes under these scenarios. The assumptions under different scenarios are clear, simple and easy-to-understand. All the supply and demand sectors of the Japanese economy have been considered. Instead of combining the sectors together, the Low Carbon Navigator takes a sector-by-sector approach. The sectors covered are given in Table 1.

For each sector, the Low Carbon Navigator sets out a range of four levels/trajectories for the types of changes that might occur. In the case of renewable energy sectors, an additional level 5 is set to reflect the physical potential of those sectors for Japan.

These trajectories are intended to reflect the whole range of potential futures that might be seen in that particular sector. In the energy supply sectors these trajectories represent potential roll-out of energy generation infrastructure. This is slightly different for the nuclear sector where other considerations such as nuclear restart policy have been taken into account. For the energy demand sectors, the trajectories represent more the

Table 1 Japan 2050 Low Carbon Navigator: Sectoral coverage

Energy supply sectors	*Energy demand sectors*
Nuclear and conventional power plants	***Transport***
Nuclear power stations	Passenger transport
Conventional power plants	Freight transport
Renewables	***Residential sectors***
Solar PV	Space heating and cooling
Wind (Onshore, offshore and floating)	Hot water supply
Hydropower (Small and medium, and large)	Cooking, lighting and appliances
Geothermal electricity	***Commercial sectors***
Ocean power	Heating, cooling and hot water supply
Biomass energy supply	Cooking, lighting and appliances
Volume of wastes and recycling	***Industry***
Bioenergy production and imports	Manufacturing and construction
Hydrogen production	Agriculture, forestry and fisheries
Hydrogen production for transport	Industrial process emissions
Refineries	Non-energy GHG emissions from agriculture
Coke production	Non-energy fossil fuel consumption in petrochemical industry
Petroleum refinery	
Town gas production	

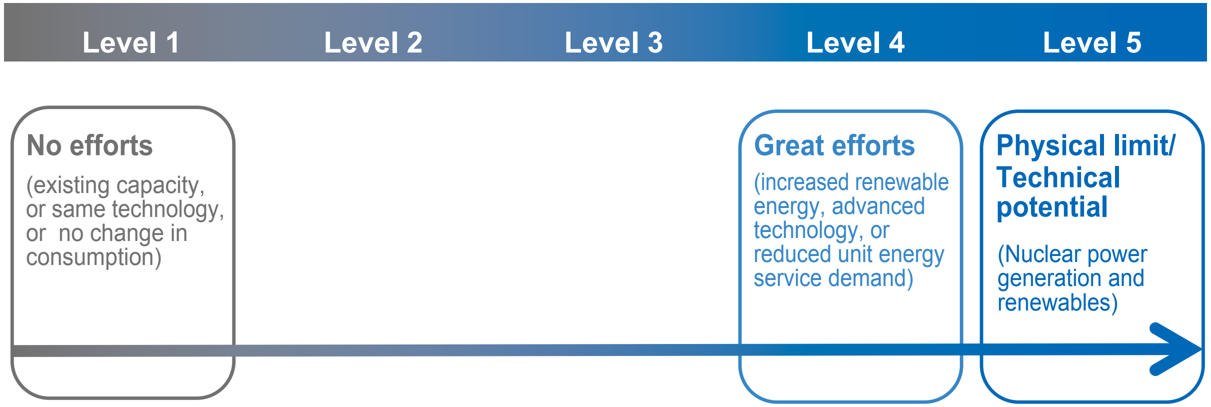
Source: Authors.

behavioural and technological changes. In general, these trajectories are described as "levels" as they indicate scales of change. However, for certain sectors, such as nuclear power stations or domestic and freight transport, the changes indicate choices rather than scales, and therefore are described as "trajectories" or "options".

The levels/trajectories have been set up on the basis of progressively higher efforts toward transition to a low-carbon society (Figure 1). For example, Level 1 represents low efforts and continuation of existing capacity and technology or no change in consumption behaviour, whereas Level 4 represents great efforts leading toward increased use of renewable energy and advanced technology, or reduction of energy service demand. Level 5 in nuclear power generation and renewable energy sectors represent the physical limit/technological potential. All these trajectories/levels have been developed after rigorous review of existing literature and then through feedback from several expert review meetings. It is, however, important to note that by default, the Low Carbon Navigator just provides a wide range of possibilities, but it does not make estimated projections or cost optimisations. Box 1 presents some of the key questions that the Low Carbon Navigator can address.

This research report has been prepared to provide an overview of the Low Carbon Navigator, how it works, and what its assumptions are. Section II explains the fundamental model, its structure as well as the calculation procedures. Section III describes the underlying society scenarios (i.e. the

Figure 1 Levels/trajectories setting



Source: Authors.

Box 1: Questions that the Low Carbon Navigator can address

- *How far can Japan reduce emissions while meeting energy needs?*
- *How much energy can we supply from different energy technologies?*
- *How much energy do different sectors use and how can we change this?*
- *Which sectors are the ones we should focus on? Which are less important?*
- *What could happen to our energy dependency and security?*
- *Without nuclear, what will be the energy mix for Japan to achieve the 80% emissions reduction target by 2050?*
- *How much CO_2 reduction can be achieved using the most ambitious renewable energy scenarios? At what cost?*
- *What is the full potential of CO_2 reductions in Japan? At what cost? What does the low-carbon pathway look like?*

Source: Authors.

assumed structure of the economy and society) that will affect Japan's energy consumption and greenhouse gas (GHG) emissions. Sections IV and V explain the trajectories/levels that have been set out for the supply- and demand-side sectors[1]. The users of the Low Carbon Navigator will be able to quickly refer to these sectoral descriptions to see the assumptions and outcomes under each level. Each sectoral description provides an introduction to inform the audience about the current status of the sector. This is followed by illustrative definitions of the trajectories/levels, including indicative results by Low Carbon Navigator simulations. The text of the descriptions have been intentionally kept short, simple and specific so that it can be used by a wide range of audience. The associated charts and figures make the descriptions more vivid and easy-to-understand. The users of the Japan 2050 Low Carbon Navigator are recommended to look into these brief descriptions of the sectors to get a clearer idea about the levels/trajectories setting. Section VI provides two example pathways under different levels setting to illustrate how to interpret the results generated by the model. The scenarios are presented side-by-side so that they can be compared easily by the readers. Section VII concludes the report and informs the readers about the limitations of the Low Carbon Navigator.

[1] The Low Carbon Navigator can be accessed at: http://www.2050-low-carbon-navi.jp/web/en/

II. Calculation procedure and model structure

We developed two types of products for the Low Carbon Navigator, the Excel Spreadsheet model[2] and the Web Tool[3]. The Excel Spreadsheet model provides the fundamental model and calculations based on which the Web Tool was developed. The image of the two products is shown in Figure 2.

Using the Excel Spreadsheet model as an example, the calculation procedure consisting of six steps is explained as follows (see Figure 3).

Step 1: The users select their society scenarios and sectoral trajectories for both supply and demand sectors to form one low-carbon pathway (see details in Table 1 and Sections III, IV and V).

Step 2: Sectoral sheets then calculate the outputs based on users' trajectory selections.

Step 3: Energy balance sheets for each defined years (2005, 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045 and 2050) are generated based on sectoral outputs.

Step 4: A summary sheet is generated by compiling all yearly energy balance sheets.

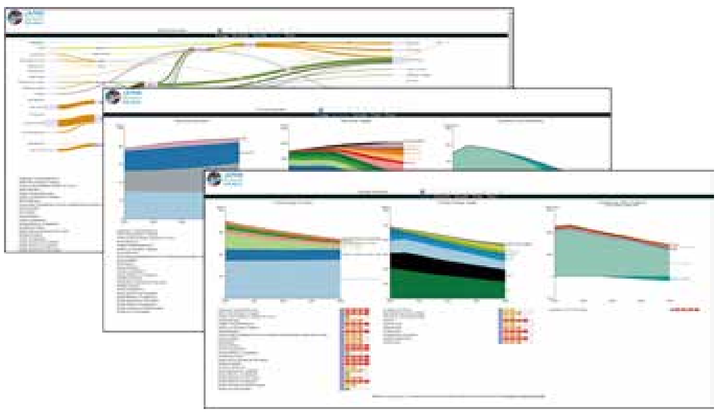
Step 5: Results are presented in charts based on the summary sheet for primary energy supply, total final energy consumption, energy mix for electricity generation, emissions and total incremental costs.

Step 6: The users modify their trajectory selections to simulate another low-carbon pathway.

The structure of the model is shown in Figure 4.

Figure 2 Image of the Excel Spreadsheet Model and the Web Tool

The Excel Spreadsheet model



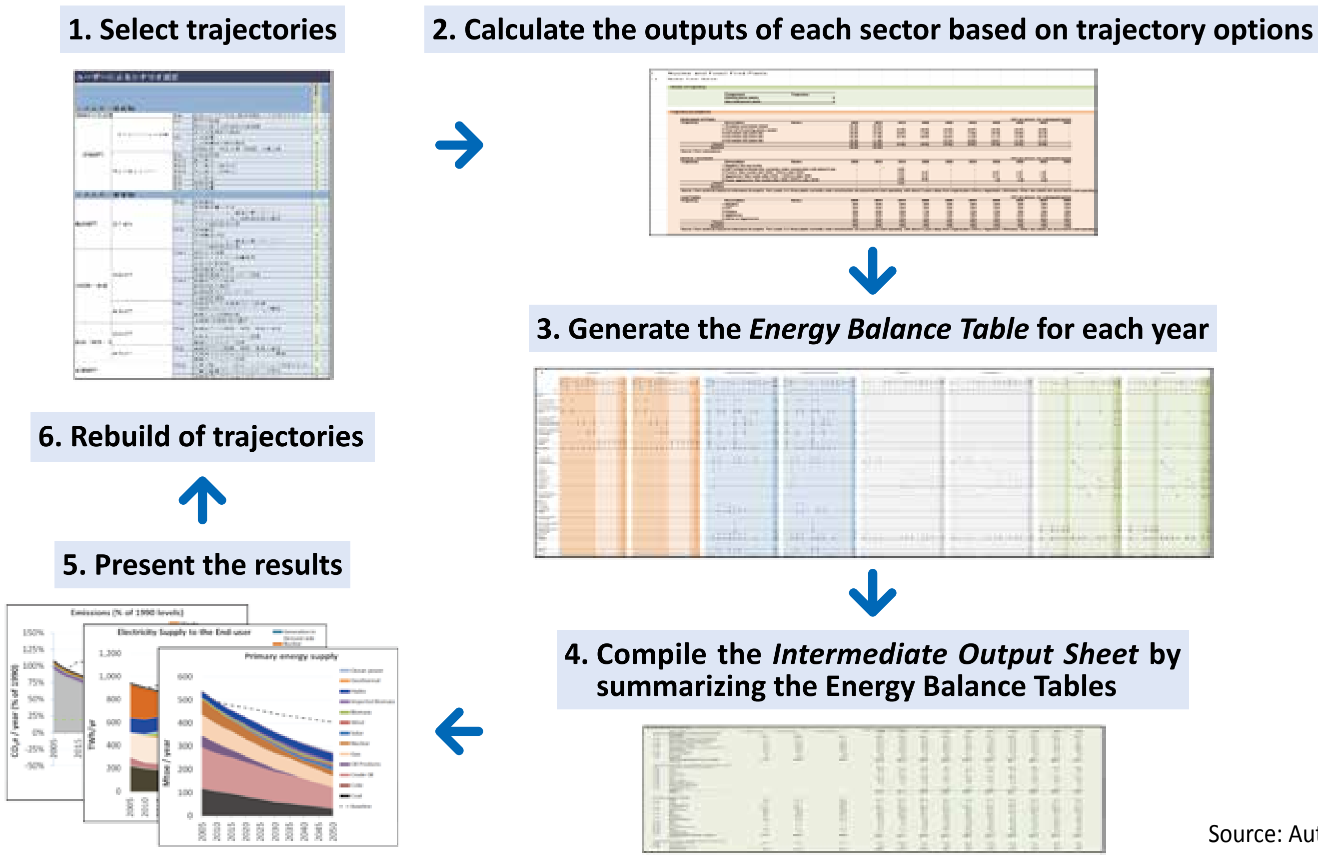
The Web Tool

Source: Authors.

[2] The Excel model can be downloaded at: http://www.2050-low-carbon-navi.jp/web/en/

[3] The Web Tool can be accessed at: http://www.en-2050-low-carbon-navi.jp/

Figure 3 Levels setting under the Low Carbon Navigator

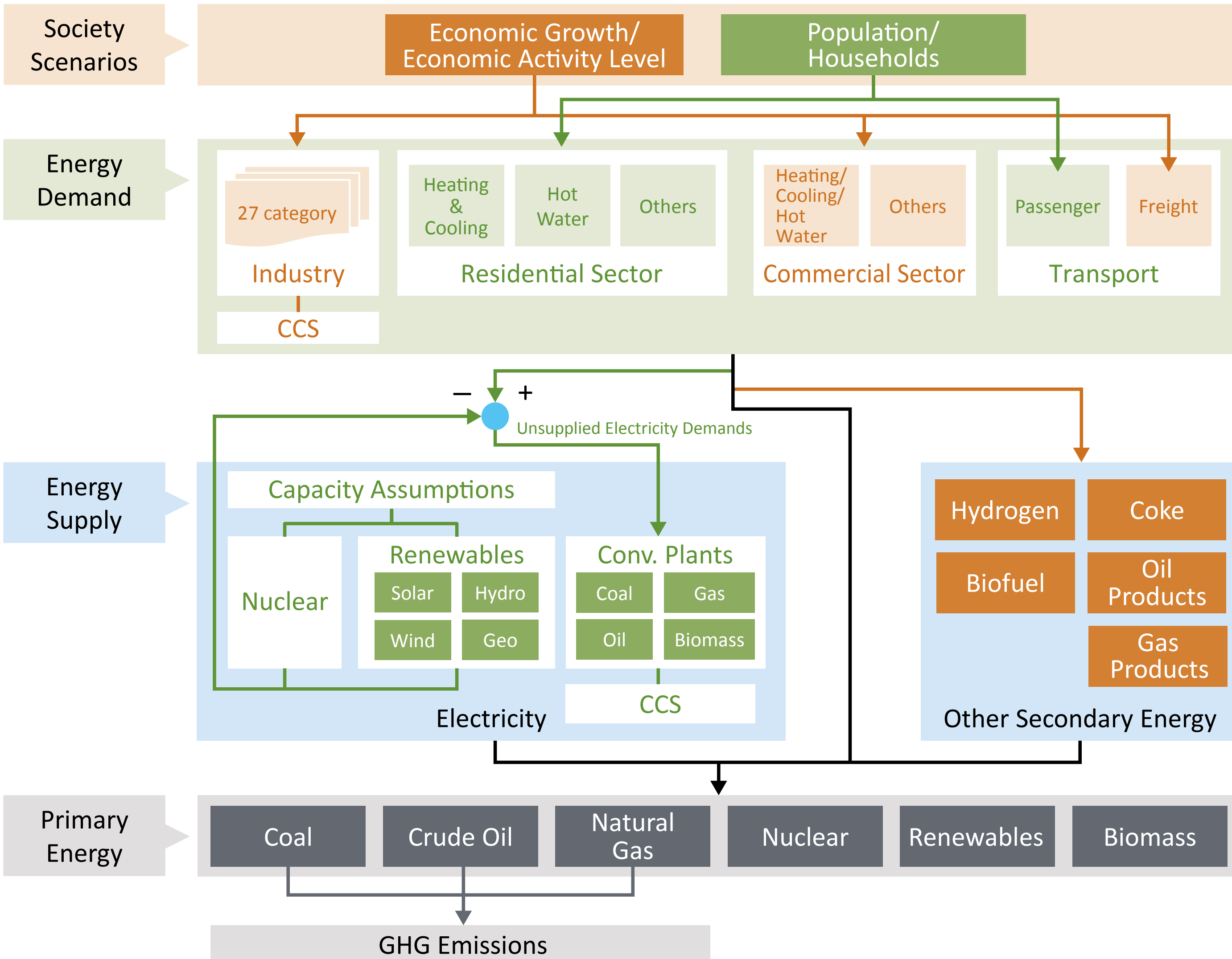


Source: Authors.

First, at the top of sectoral trajectory setting are the five society scenarios based on which the economic indicators in terms of GDP growth and sectoral output levels, the social indicators in terms of the size of population and number of households will be determined (see details in Section III). The selection among the society scenarios will have impact on energy demand sectors. In particular, the GDP growth and sectoral output levels are linked with the industrial sectors, freight transport sector and commercial sectors, while the population size and the number of households are linked with the residential sectors and passenger transport sector.

Second, for energy demand (for detailed trajectory setting, please see Section V), four categories of energy end users are considered, i.e. industry (including 27 sectors), residential sectors (heating

Figure 4 Structure of the Model



Sourtce: Ashina (2014).

and cooling, hot water, and lighting, cooking and electronic appliances), commercial sectors (heating, cooling and hot water, and lighting, cooking and electronic appliances) and transport sectors (passenger transport and freight transport). For different sectors, the activity levels of the sector, consumption behaviours, technology penetration (technology options) and energy efficiency advancement, etc. will influence the sectoral outputs in terms of energy demand, emissions levels and corresponding incremental costs.

Third, for energy supply (for detailed trajectory setting, please see Section IV), secondary energy supply including electricity generation and other secondary energies are included in the model. Electricity is generated from conventional power plants using fossil fuels (including coal, oil and gas) and biomass, as well as from nuclear power plants and renewable energy (including hydro power, solar PV, wind power, geothermal and ocean power). Other secondary energies include hydrogen production, biofuels, and refinery products (including coke, petroleum and town gas production).

Fourth, primary energy resources include hydrocarbon energy carriers (coal, crude oil and natural gas), nuclear energy, renewable energy, and biomass.

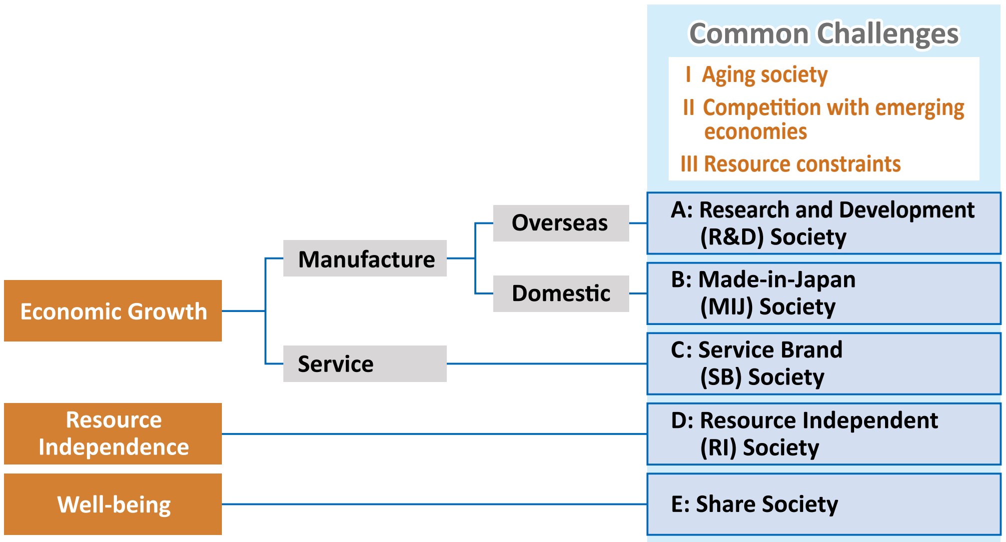
Both secondary and primary energy will be provided to satisfy energy demand. Secondary energies are provided by transforming the primary energy.

Emissions are generated from fossil fuel combustion which is influenced by the way of energy supply and energy demand levels.

III. Society scenarios

The projections of energy consumption and GHG emissions for 2050 can be significantly affected by the structure of economy and society we envision for 2050. For the 2050 Low Carbon Navigator, the user can select from five society scenarios for 2050, which were presented in 2012 for government discussions (MOE, 2012b) and developed based on three important factors to consider for Japan's future: (1) economic growth, (2) resource independence, and (3) well-being. The user choice on this lever affects socioeconomic activity levels (e.g., GDP, number of households, industrial production level, and residential and commercial floor space) (see Figure 6).

Figure 5 Concepts of 2050 society scenarios



Source: Adapted from MOE (2012b).

Notes: The society scenarios consider different but likely future societies in Japan in 2050. The concept of these five scenarios take into consideration the fundamental questions that matter to Japan. The first question related to the type or direction of development that should take place. The direction is then considered from the vantage points of economic growth, resource independence and prosperity. The next question raises the issue of the way to achieve economic growth, i.e. by focusing on manufacturing or on the service sector. The third question, a critical one for Japan, is about the location—within Japan or outside Japan—of manufacturing goods, especially materials.

Against the backdrop of the above consideration, the five society scenarios are developed to emphasis different directions, manner, and location for fostering Japan's growth and development toward a low carbon society. An economic growth-oriented Japan will have to emphasis either manufacturing or service industry. The SB Society can be envisioned when Japan focuses on developing its service industry. On the other hand, If Japan focuses on manufacturing industry, then the question of either producing at home or abroad will come up. Consequently, two different society scenarios can be envisioned—the R&D and the MIJ society, with the latter stressing in Japan production. The other two societies, RI and Shared Society, are directly related to the alternative development directions—resource independence and prosperity-oriented—that Japan may choose.

These society scenarios also help us understand how Japan's trade structure, which is one important underlying factors for CO_2 emissions, may develop. For the R&D and MIJ scenarios, there is a large difference in how much Japan would rely on international trade to sustain high economic growth. In the R&D scenario, the production of goods for overseas customers will move from Japan to overseas close to the market. As production moves outside of Japan, import will also be significant. In the MIJ scenario, Japan will continue to produce goods for overseas customers within Japan and export them. It is assumed that to support production within Japan, higher volume of imports compared to R&D scenario—particularly raw material and intermediate goods—will occur under MIJ scenario. Overall, the energy consumption and related CO_2 emissions from manufacturing sector will be higher for the MIJ scenario than in the R&D scenario.

The RI scenario is similar to the R&D scenario in that they both result in lower levels of international trade compared to the MIJ scenario, but some significant differences can be found, e.g. in the industrial sector. The RI scenario aims for greater use of domestically-recovered secondary steel and larger production from the agricultural sector to improve resource independence, whereas in the R&D scenario continues to depend on imported iron ore for steel production and imported agricultural products.

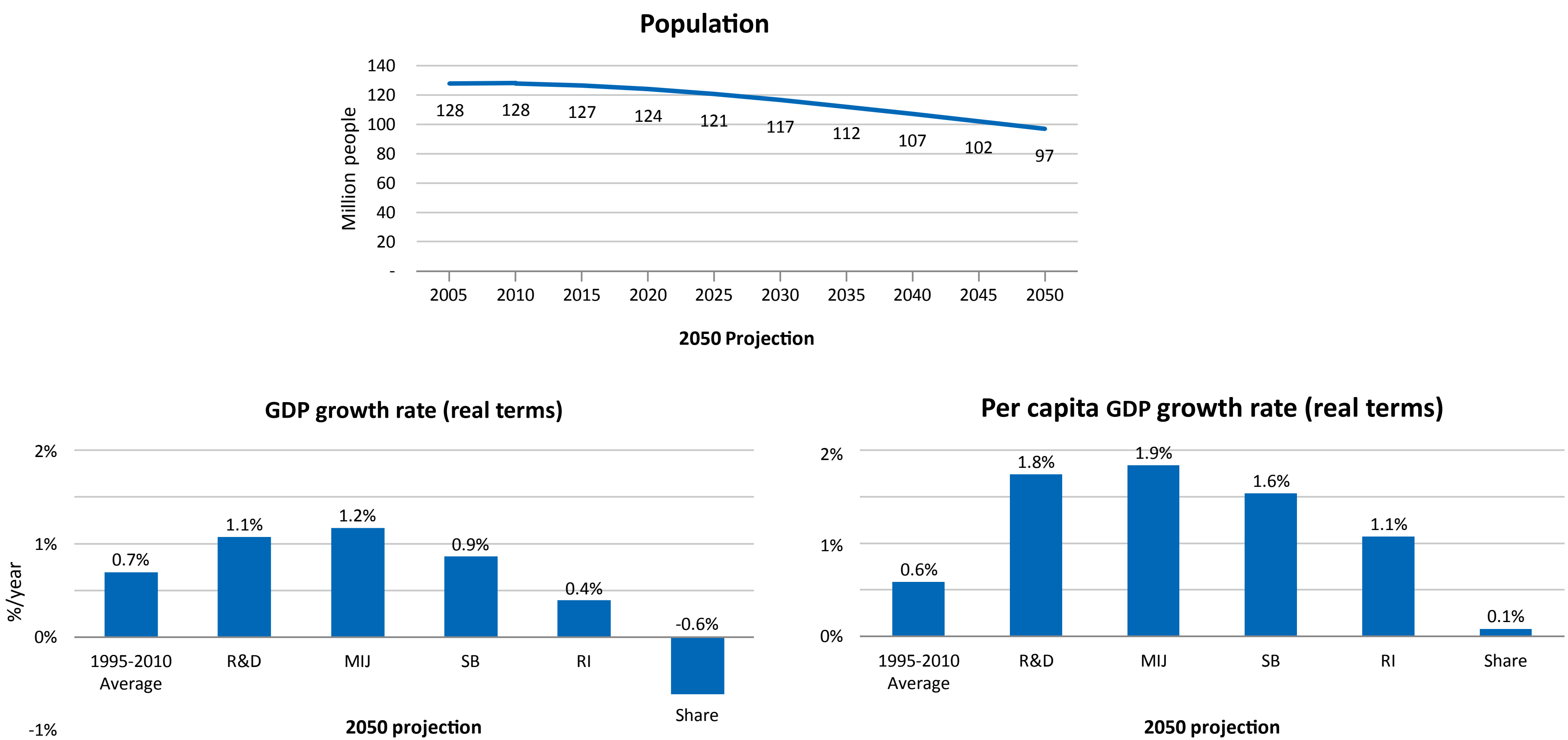
This note is based on MOE (2012b) and Ashina (2015).

Table 2 Overview of 2050 society scenarios

2050 society scenarios	Summary	Pros	Cons
Made-In-Japan (MIJ)	A society in which domestic industrial manufacturing drives high economic growth.	The Japanese economy is boosted by the domestic production of competitive low-carbon technologies and high value-added products for mid-high income customers overseas.	There may be a lack of innovation and the salary level may be kept to low levels to compete internationally. Moreover, the economy will be more vulnerable to changes in currency exchange rates.
Research and Development (R&D)	A society in which the overseas expansion of Japanese manufacturing industries drives high economic growth.	Japan will become the global hub of Research and Development (R&D) for the manufacturing industry including low-carbon technologies. Revenues are generated by sales overseas.	To maintain a technological edge on competitors, the country needs to be successful in a harsh global competitive environment by developing state-of-the-art infrastructure and supporting entrepreneurs and game-changers.
Service-Brand (SB)	A society in which the expansion of high-quality service industry toward foreign customers drives high economic growth.	Japan will achieve high economic growth through expansion of its high-quality service industry toward wealthy foreign customers including tourists.	Large fraction of services provided by the Japanese economy, which target wealthy foreign customers, may not be affordable to average Japanese consumers.
Resource Independent (RI)	A society in which resource independence is considered most important for prosperity.	The society will become more resilient to global resource protectionism by supplying as much food, energy and resources domestically as possible.	Japan needs to bear additional costs for energy and resources to maintain resource independence.
Share	A society in which a well-being and a humble lifestyle is sought for.	Necessary goods and services will be provided domestically, and more laid-back lifestyle will be achieved.	The economy becomes more vulnerable to external factors. Moreover, the sense of community prevails individualism that collective actions and sharing of goods become the basis of daily life.

Source: Adapted from MOE (2012b).

Figure 6 2050 projections for population, GDP growth rates and percapita GDP growth rates under five society scenarios



Source: Authors' calculation based on MOE (2012b).

IV. Energy supply scenarios

Nuclear power

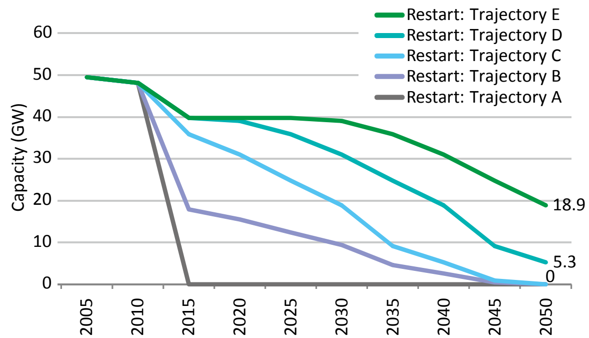
Before the Fukushima Daiichi nuclear accident in 2011, Japan was a leading producer of nuclear power in the world. With a capacity of 49 GW, the country produced around 288 TWh/y of electricity in 2010 which was delivered to the grid (IEA, 2013). However, in the aftermath of the 2011 Fukushima disaster, none of Japan's nuclear power stations are in operation as of 2014. Some drastic changes in the country's nuclear power production were expected. Two major policy decisions will affect the future of Japan's nuclear energy. The first one is related to the restart policy of the existing nuclear power plants. The second issue concerns the impact of new-build policy on future capacity.

Impact of restart policy

Trajectory A

Trajectory A assumes that Japan will shut down all of its nuclear power plants from 2010 onwards and they will never be restarted. In other words Japan will phase out its nuclear capacity completely and focus on other sources of energy.

Figure 7 Impact of restart policy on future capacity (no new build assumed)



Source: Authors.

Trajectory B

Trajectory B for restart policy assumes that only half of the existing nuclear plants will be restarted. With no new-build rate, nuclear capacity will come down from 49 GW in 2010 to below 10 GW in 2030 and to zero by 2050.

Trajectory C

Trajectory C assumes a restart policy where Japan only allows all existing nuclear plants with a 40 year lifespan to operate. With the retirement of exhausted plants and no new-build, Japan's capacity will gradually decline, but at a slower pace than Trajectory B. By 2030, capacity will be around 19 GW and eventually zero by 2050.

Trajectory D

The assumption under Trajectory D is similar to Trajectory C, but here all plants with a 50 year lifespan are allowed to operate and no new plants are built. It will mean that despite the declining trend, Japan will still have limited, 5.3 GW (32 TWh/y electricity) nuclear capacity.

Trajectory E

The assumption under Trajectory E is similar to Trajectories C and D. The difference is that plants with a 60 year lifespan are allowed to operate, though no new plants are built. Thus, though capacity will decline, Japan will still have limited, 18.9 GW (111 TWh/y electricity) nuclear capacity in 2050 as plants with longer lifespan are allowed to operate.

Impact of new-build policy

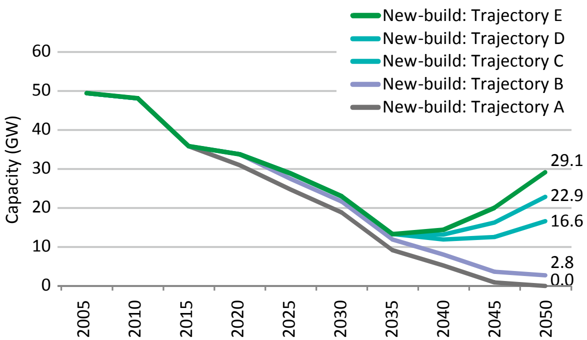
Trajectory A

Trajectory A assumes that no new nuclear plants will be developed and existing plants will retire once their lifespan is over. Assuming a full restart policy with a 40 year lifespan for the plants, Japan's existing nuclear capacity will go down gradually to 19 GW in 2030 and eventually to zero by 2050.

Trajectory B

This trajectory assumes that two of the three plants currently under construction (Ohma No. 1, Shimane No. 3) will be allowed to develop, but with a 5-year delay. . With a full restart policy (40 year lifespan), this trajectory will lead Japan's nuclear capacity to decrease to 2.8 GW in 2050, which will generate 16 TWh/y of electricity.

Figure 8 Impact of new build policy on future capacity (full restart with 40-year life assumed)



Source: Authors.

Trajectory C

In addition to Trajectory A, construction of TEPCO Higashidori No. 1 reactor will start operating with a 5-year delay. Furthermore, the operation of new-builds will take place from 2035 onwards, and Japan will achieve a 1GW/y build rate after 2040. With a full restart policy (40 year lifespan), Japan's nuclear capacity under this trajectory will be 16.6 GW (generating 105 TWh/y) in 2050.

Trajectory D

Trajectory D assumes a more aggressive new-build policy. The operation of new-builds will take place from 2035 with a new capacity installation rate of 1.5 GW/y from 2040 onwards. It will mean that with full restart policy (40 year lifespan) Japan's nuclear capacity will be 22.9 GW in 2050. The resulting generation will be 164 TWh/y.

Trajectory E

Trajectory E assumes the most aggressive new-build policy. The operation of new-builds will take place from 2035 with a new capacity installation rate of 2 GW/y from 2040 onwards. It will mean that with full restart policy (40 year lifespan) Japan's nuclear capacity will be 29.1 GW in 2050. The resulting generation will be 208 TWh/y.

Conventional power plants

Fuel mix for conventional plants

Japan is not well-endowed with conventional energy resources. Limited domestic oil and gas reserves compel Japan to be heavily dependent on imports. As nuclear power generation is suspended due to the Fukushima disaster, imports of conventional fuel has increased sharply in recent years. The user determines the fuel mix for conventional plants (gas, coal and biomass co-fired with coal).

Level 1

Level 1 assumes that the scenario remains similar to the current situation all the way up to 2050. Under this level, gas-to-coal ratio remains at 1:1 accounting for 90% in the fuel mix and there is no introduction of biomass in 2050.

Level 2

Under this level, gas-to-coal ratio increases to 1.8 accounting for 85% in the total fuel mix and biomass electricity share increases to 10% in 2050.

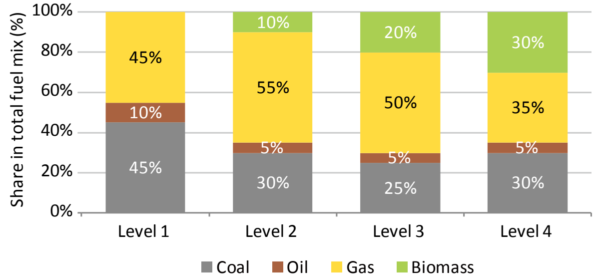
Level 3

For Level 3, gas-to-coal ratio increases to 2, accounting for 75% of total fuel mix and the share of biomass electricity rises to 20% in 2050.

Level 4

Under level 4, gas-to-coal ratio is kept at 1.2, accounting for 65% in the total fuel mix. The biomass electricity share increases to 30% in 2050.

Figure 9 Share in fuel mix for conventional plants in 2050



Source: Authors.

Availability of carbon capture and storage (CCS) technology

Although CCS has not been proven on a large scale, Japan has recently launched its first full-scale CCS demonstration project in Tomakomai, Hokkaido. The deployment of CCS in Japan depends on the availability of geological storage sites. According to a study, the country has a technical potential of 5.2 billion tonnes of CO_2 storage (Ito, 2008). This potential is equivalent to about four times Japan's total GHG emissions in 1990.

Level 1

This level assumes that there is no roll-out of CCS. CCS technology is available only in demonstration plants.

Level 2

Level 2 assumes that 20% of coal-fired power plants and 20% of gas-fired power plants in 2050 are equipped with CCS.

Level 3

In this level, Japan puts significant effort in adopting CCS technology. It assumes that 50% of coal-fired and 50% of gas-fired power plants in 2050 are equipped with CCS.

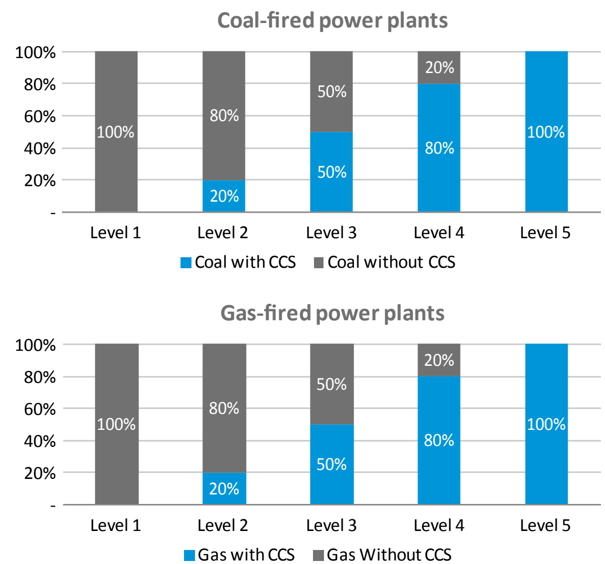
Level 4

At Level 4, Japan undertakes a more aggressive approach for adopting CCS technology. As much as 80% of coal-fired and 80% of gas-fired power plants in 2050 are equipped with CCS facilities.

Level 5

At Level 5, 100% of both coal-fired and gasfired power plants are equipped with CCS facilities.

Figure 10 Japan's CCS installation rate in 2050 (% of net power generation)



Source: Authors.

Solar PV

Figure 11 Japan is a leading producer of solar energy

Source: IGES stock image.

Japan is one of the leading producers of solar panels and the country's use of solar power has been on the increase since late 1990s. In 2010, Japan's electrical capacity from solar PV was 3.6 GW (EDMC, 2014). Japan introduced a renewables portfolio standard (RPS) in 2003, and then In 2009, it introduced a feed-in-tariff system for promoting solar PV (which was further expanded in 2012 to cover other renewable sectors) (METI, 2012). This incentive system has generated immediate results; in the first quarter of 2013 alone, Japan's solar PV installations increased by 270% in gigawatt terms (Song, 2013). In January 2014, the installed capacity reached 13.1 GW (METI, 2014a).

Level 1

Level 1 assumes that the growth of Japan's solar PV sector is rather slow compared to its potential. This is because no additional effort has been made to promote solar PV. Capacity reaches just over 26 GW in 2050, generating 27 TWh/y of electricity. At this level, there is roughly 2.2 m^2 of solar panels per person in Japan, based on an estimate of 8.1 km^2/GW for the area required for solar system.

Level 2

Level 2 assumes that Japan's solar PV receives limited effort, and capacity reaches 47 GW in 2030 and 87 GW in 2050. With this capacity Japan produces 92 TWh/y of electricity in 2050. This is equivalent to roughly 7.5 m^2 solar panels per person.

Level 3

This level assumes that Japan's solar capacity reaches 76 GW in 2030 and 150 GW in 2050. With about 13 m^2 solar panels per person, Japan generates 158 TWh/y of electricity in 2050.

Level 4

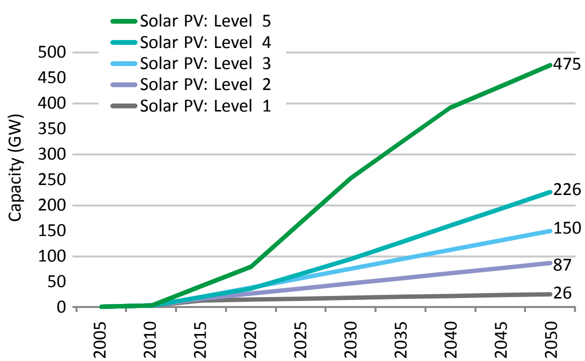
At this level, Japan maximises its efforts in promoting solar PV. This results in capacity increasing to 95 GW in 2030 (producing about 100 TWh/y) and 226 GW in 2050 (producing 238 TWh/y). This is equivalent to roughly 19 m^2 of solar panels per person in Japan.

Level 5

Level 5 represents Japan's physical and economic potential for developing solar PV capacity. At this level, Japan's capacity reaches 475 GW in 2050, which generates 500 TWh/y electricity.

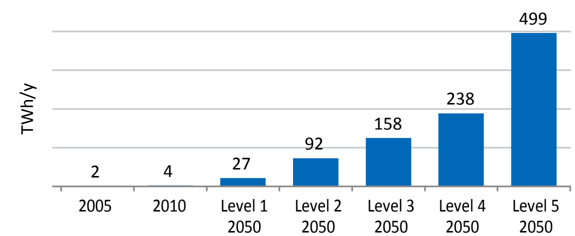
For detailed references related to the level settings, please see the Excel spreadsheet model (Zhou et al., 2014).

Figure 12 Japan's solar PV capacity versus time



Source: Authors.

Figure 13 Solar PV electricity generation under different scenarios



Source: Authors.

Onshore wind

Figure 14 Japan has significant potential to develop its onshore wind sector

Source: IGES stock image.

In 2010 Japan had 2.45 GW of installed onshore wind capacity (JWPA, 2014). The country has significant potential for onshore wind power. Most of Japan's onshore potential is concentrated in Hokkaido, Tohoku and Kyushu regions.

Level 1

Level 1 assumes that Japan gives less priority to onshore wind. Technology is frozen, and there is no expansion of the country's onshore wind capacity. However, the 2.67 GW capacity level of 2014 (METI, 2014a) is maintained up to 2050 by replacing retired turbines. With just over 134 20-MW turbines, Japan's onshore wind sector generates around 4.7 TWh/y of electricity in 2050.

Level 2

In the Level 2 scenario, Japan makes moderate efforts to expand its onshore capacity. The total number of 20-MW onshore turbines reaches over 350 by 2020. Onshore capacity expands to 7 GW by 2020 and this is maintained until 2050. With this capacity, Japan produces 12 TWh/y of electricity in 2050.

Level 3

Level 3 assumes that with significant efforts, Japan will increase its onshore capacity to about 18 GW by 2050. In this scenario, it is estimated that Japan will have approximately 900 onshore wind turbines, which will produce 32 TWh/y of electricity.

Level 4

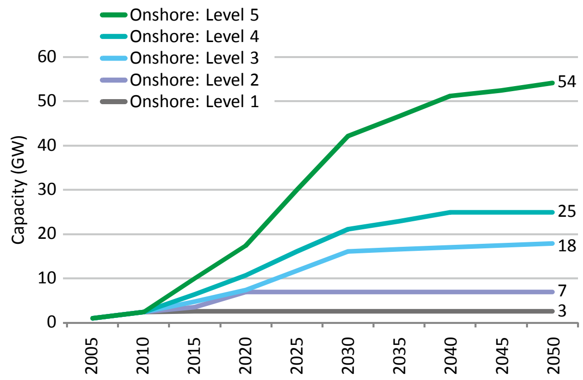
At Level 4, Japan maximises its efforts to promote the country's onshore wind capacity. The country speeds up building new turbines. By 2050, Japan will have about 1250 20-MW turbines. The country's total capacity will rise to 25 GW in 2050, generating 44 TWh/y of electricity.

Level 5

Level 5 represents Japan's physical and economic potential for developing onshore capacity. At this level, Japan's capacity reaches 54 GW in 2050, which generates 95 TWh/y electricity.

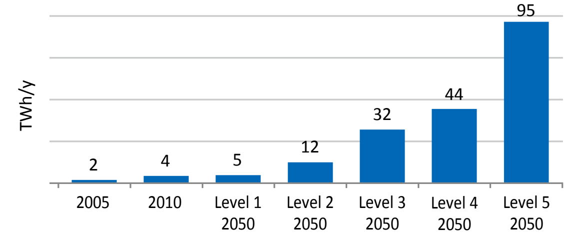
For detailed references related to the level settings, please see the Excel spreadsheet model (Zhou et al., 2014).

Figure 15 Japan's onshore wind capacity versus time



Source: Authors.

Figure 16 Onshore wind electricity generation under different scenarios



Source: Authors.

Offshore wind

Offshore wind development in Japan is relatively new. As of 2010, Japan had negligible offshore capacity. Offshore wind has great potential for catering to Japan's domestic energy demands (JWPA, 2012) and reduce the country's overdependence on conventional energy.

Level 1

Level 1 assumes that Japan's offshore wind capacity does not take off. Technology is frozen, the build rate is zero and thus there is no expansion of the country's offshore wind capacity. The trend continues all the way to 2050 and Japan has negligible offshore capacity of 0.03 GW in 2050.

Level 2

At this level, thanks to limited efforts in exploring Japan's offshore potential, capacity takes off to reach 2.4 GW in 2030 and then a slow but gradual increase continues. By 2050, Japan will have a total of 4.5 GW capacity, which will deliver about 12 TWh/y of electricity.

Level 3

Level 3 assumes that more effort is put into the offshore sector. Improved assessment of potential, offshore site identification and cost reductions lead Japan to gradually expand its offshore wind capacity to 3 GW in 2030 and 6.5 GW in 2050. Under this level, Japan will produce 17 TWh/y of electricity in 2050.

Level 4

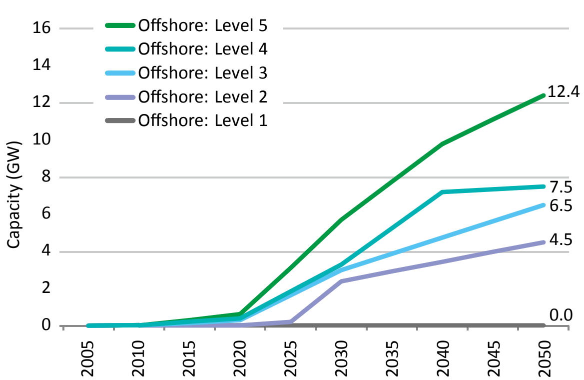
Under the Level 4 assumptions, Japan follows an aggressive strategy towards construction and operation of offshore wind. Capacity reaches to 3.3 GW by 2030 and then to 7.5 GW by 2050. The resulting electricity generation would be roughly 20 TWh/y.

Level 5

Level 5 represents Japan's physical and economic potential for developing offshore capacity. At this level, Japan's capacity reaches 12.4 GW in 2050, which generates 33 TWh/y electricity.

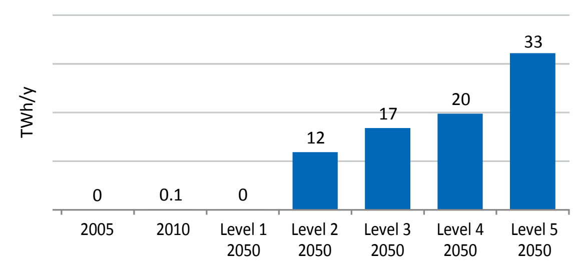
For detailed references related to the level settings, please see the Excel spreadsheet model (Zhou et al., 2014).

Figure 17 Japan's offshore wind capacity versus time



Source: Authors.

Figure 18 Offshore wind electricity generation under different scenarios



Source: Authors.

Floating wind

Japan's narrow continental shelf makes it difficult to develop bottom-mounted offshore wind turbines (GWEC, 2014). Therefore, the country is also exploring floating wind turbines. As of 2010, Japan does not have any floating offshore wind capacity, but it has been recognised that floating offshore wind has vast potential for Japan (JWPA, 2012).

Level 1

Level 1 assumes that Japan's floating wind sector is deprioritised and therefore capacity does not take off. Technology is frozen, the build rate is zero and there is no expansion of the country's floating wind capacity. The trend continues all the way to 2050 and Japan has no floating wind capacity in 2050.

Level 2

In the Level 2 scenario, Japan puts limited efforts into its floating wind sector from 2020 onwards. By 2025, the country's offshore capacity reaches 1.4 GW which nearly doubles over the next five years. Total capacity thus reaches 7.5 GW, which generates over 20 TWh/y of electricity.

Level 3

Level 3 assumes that thanks to policy measures, Japan's floating wind takes off sooner than predicted in Level 2, with capacity reaching 0.1 GW in 2020, 4.1 GW in 2030 and then 16.5 GW in 2050. Under this level, Japan will produce 43 TWh/y of electricity in 2050.

Level 4

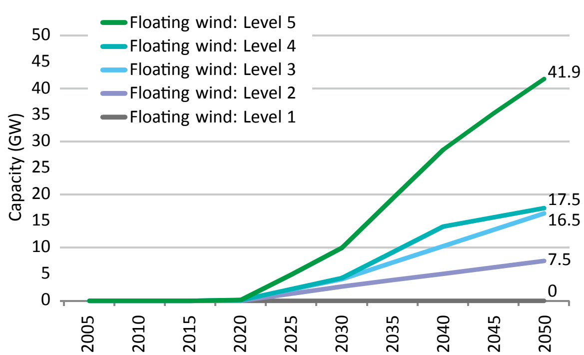
At this level, Japan undertakes an aggressive floating capacity development plan. Early take-off, improved technology and a fast build rate of turbines lead to a capacity rise from zero in 2010 to 4.3 GW in 2030 and 17.5 GW in 2050. At this level, Japan generates over 46 TWh/y of electricity in 2050.

Level 5

Level 5 represents Japan's physical and economic potential for developing floating wind capacity. At this level, Japan's capacity reaches 42 GW in 2050, which generates 110 TWh/y electricity.

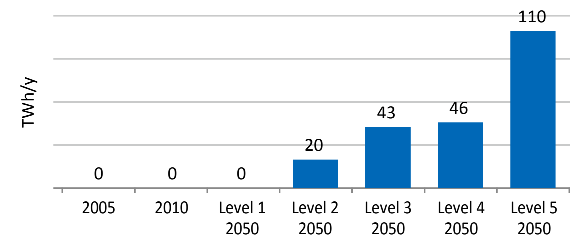
For detailed references related to the level settings, please see the Excel spreadsheet model (Zhou et al., 2014).

Figure 19 Japan's floating wind capacity versus time



Source: Authors.

Figure 20 Floating wind electricity generation under different scenarios



Source: Authors.

Small-medium hydropower

Figure 21 Japan has a century-long experience in hydropower generation

Source: IGES stock image.

For over a century, hydroelectricity has served as one of the major sources of energy for Japan. Hydropower has proved to quite stable in terms of supply and generation costs. The country operates various types of hydropower plants: large (> 100 MW), medium (10 – 100 MW), small (1 – 10 MW), mini (0.1 – 1 MW) and micro (<0.1 MW). As of 2010, Japan's small-medium hydropower capacity stood at 10.46 GW, generating 55 TWh/y of electricity (MOE, 2012a).

Level 1

Level 1 assumes that Japan's 2010 small-medium hydropower capacity is sustained up to 2050 without any further efforts. With this 10.46 GW capacity, Japan generates around 55 TWh/y of electricity in 2050.

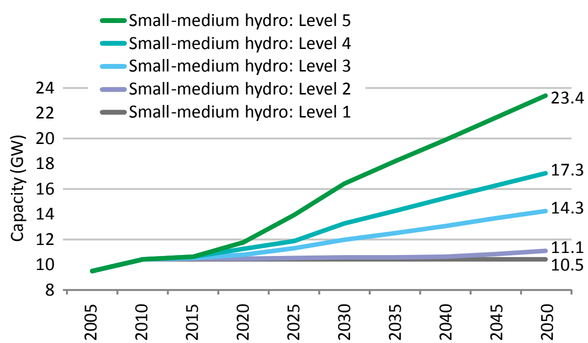
Level 2

Level 2 assumes that Japan makes low efforts to enhance its small-medium hydropower. Installed capacity rises to a little less than 11 GW in 2030 and then to over 11 GW in 2050. At this level, around 58 TWh/y of electricity is generated.

Level 3

Under Level 3, moderate efforts from the government lead to an increase of installed capacity to 12 GW in 2030 and then to 14.3 GW in 2050. At this level, Japan generates 75 TWh/y of electricity in 2050.

Figure 22 Japan's small-medium hydropower capacity versus time



Source: Authors.

Level 4

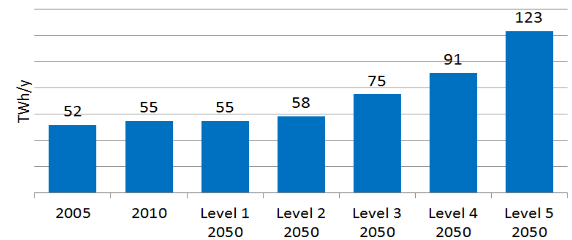
With great efforts, Japan's small-medium hydropower capacity under Level 4 rises to 13 GW by 2030. Capacity is further increased to 17 GW by 2050, which generates 91 TWh/y of electricity.

Level 5

Level 5 represents Japan's physical and economic potential for developing small-medium hydropower capacity. At this level, Japan's capacity reaches 23.4 GW in 2050, which generates 123 TWh/y electricity.

For detailed references related to the level settings, please see the Excel spreadsheet model (Zhou et al., 2014).

Figure 23 Small-medium hydroelectricity generation under different scenarios



Source: Authors.

Geothermal electricity

Geothermal energy uses heat from hot dry rocks from underground to generate electricity. With about 120 active volcanoes, Japan has quite high potential for developing geothermal energy (GRSJ, undated). Indeed, Japan has the world's most advanced technologies for exploration, development, use and monitoring of geothermal power. The first geothermal power generation experiment in Japan dates back to 1925, although commercial exploitation has only taken place since 1966 (GRSJ, undated). In 2010, Japan had 0.5 GW of installed capacity for geothermal energy (EDMC, 2013), generating 3 TWh/y of electricity. After the Fukushima disaster, however, there has been renewed interest among relevant Japanese companies to explore and invest in geothermal power.

Level 1

Level 1 assumes that because of its high development costs and potential adverse effects on national parks and resorts, Japan focuses on other energy sources and no additional geothermal capacity is added. The 2010 level of 0.5 GW capacity is maintained all the way to 2050, generating around 4 TWh/y electricity.

Level 2

Under this level, low efforts from Japan lead to a capacity increase, which reaches 2 GW in 2030 and then 4.3 GW in 2050. With this capacity, Japan generates 30 TWh/y of electricity in 2050.

Level 3

At Level 3, Japan makes moderate efforts and its geothermal installed capacity reaches 2.1 GW in 2030 and further expands to 6.4 GW in 2050. 45 TWh/y of electricity is produced in 2050.

Level 4

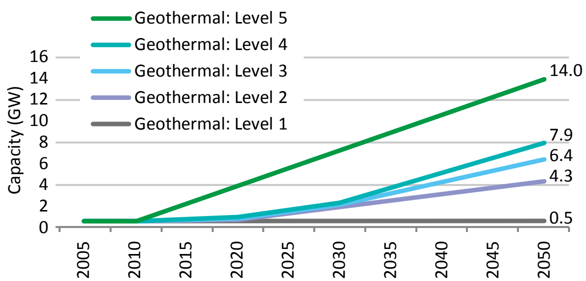
Level 4 assumes that Japan puts great efforts into expanding its geothermal capacity. By 2030, the capacity reaches 2.3 GW but by 2050 it rises to about 8 GW, which generates 56 TWh/y of electricity.

Level 5

Level 5 represents Japan's physical and economic potential for developing geothermal capacity. At this level, Japan's capacity reaches 14 GW in 2050, which generates 98 TWh/y electricity.

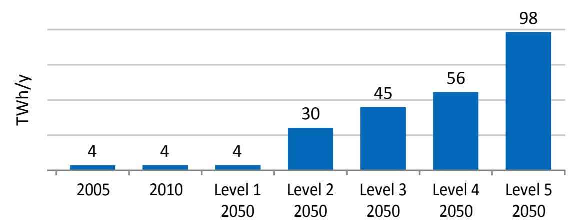
For detailed references related to the level settings, please see the Excel spreadsheet model (Zhou et al., 2014).

Figure 24 Japan's geothermal power capacity versus time



Source: Authors.

Figure 25 Geothermal electricity generation under different scenarios



Source: Authors.

Ocean power

Although Japan is surrounded by ocean, little attention has so far been given to utilising ocean energy. As of 2010, Japan had no installed capacity for generating power from ocean sources (wave generation, tidal stream and tidal range. However, in the post-Fukushima period, the country is taking initiatives to tap energy from alternative sources. Indeed, as an island country, Japan has very good potential to generate power from the kinetic energy of waves (Johnston, 2011). Some experimental projects were initiated in 2013. Unlike solar or wind power, ocean energy is believed to be less fluctuating to weather conditions. Technologies are being developed to tap both wave and tidal power.

Level 1
Level 1 assumes that Japan continues to give little or no attention to ocean energy. With no investment in ocean energy technology, Japan will have no capacity for generating power from the ocean.

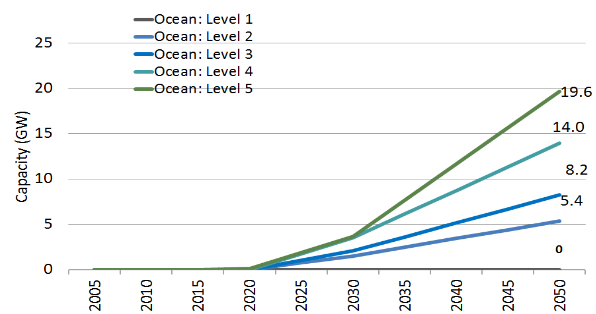
Level 2
Level 2 assumes that there is some, although low, efforts in this sector, which leads the country to increase its combined ocean energy capacity to 1.5 GW in 2030 and 5.4 in 2050. At this level, Japan will produce 42 TWh/y of electricity in 2050.

Level 3
Under Level 3, it is assumed that moderate efforts are made to enhance ocean capacity. By 2050, capacity increases to more than 8 GW, which generates 65 TWh/y of electricity.

Level 4
Level 4 assumes that Japan maximises its efforts to deploy ocean energy and by 2050 the country's installed capacity increases to 14 GW (12.03 GW for wave energy and 1.92 GW for tidal energy). This capacity will generate 110 TWh/y of electricity in 2050.

Level 5
Level 5 represents Japan's physical and economic potential for developing ocean power capacity. At this level, Japan's capacity reaches 20 GW in 2050, which generates 155 TWh/y electricity.

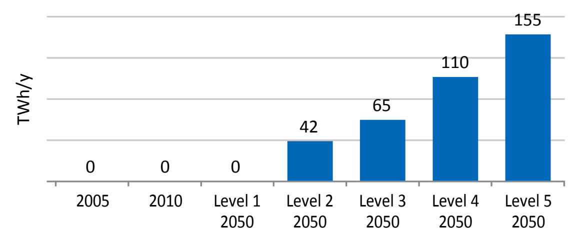
Figure 26 Japan's ocean power capacity versus time



Source: Authors.

For detailed references related to the level settings, please see the Excel spreadsheet model (Zhou et al., 2014).

Figure 27 Ocean electricity generation undre different scenarios



Source: Authors.

V. Energy demand scenarios

Domestic passenger transport behaviour

Today an average person in Japan travels domestically around 10,640 km per year (2010)[4]. 59% of this distance is by passenger car, 29% by rail, 6% by bus, 0.2% by ship and 5% by air.

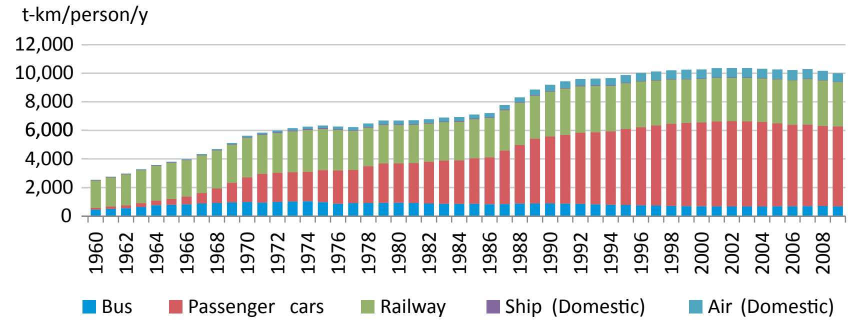
Figure 28 Japanese individuals travel more than 10 thousand kilometres per year domestically

Source: IGES stock image.

Level 1

Level 1 assumes that by 2050 each person in Japan travels 1,766 km per year more than today. The mode of transport is the same as of today, with passenger cars (59%), trains (29%), buses (6%), ships (0.2%) and airplanes (5%).

Figure 29 Volume of domestic transport in Japan



Source: Data provided by NIES.

Level 2

Level 2 assumes that by 2050, each of us travels 883 km per year more than today. Less travel is by road (54%) and more by rail (32%), and air (8%).

Level 3

Level 3 assumes that by 2050, each of us travels the same distance as today but with a substantial shift away from cars (49%) towards rail (35%) and air (10%).

Table 3 Total travel demand per person under different scenarios

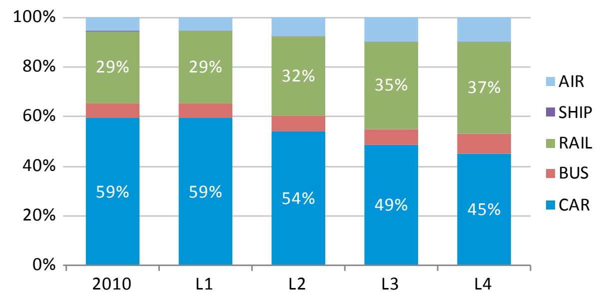
	2010	2050 Level 1	2050 Level 2	2050 Level 3	2050 Level 4
km travelled/ person/ year	10,641	12,407	11,524	10,641	10,324

Source: Authors.

Level 4

Level 4 assumes that in 2050 each of us travels 317 km per year less than today. There is a major shift away from cars to public transport: 45% passenger car, 37% rail, 8% bus, and 10 % air.

Figure 30 Transport mode shares in Japan under different scenarios



Source: Authors.

4 Calculated based on the total volume of transportation (in million passenger-km) and the population size in 2010 (EDMC, 2013).

Shift to zero emission transport

In 2010, almost all of Japan's domestic passenger transport was powered by Internal Combustion Engines (ICE; petrol or diesel). There were only a limited number of electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs) and fuel cell vehicles (FCVs), with their combined share accounting for less than 0.0002% of the total[5]. Zero emission transport includes battery electric (EVs) or FCVs, and electrified domestic rail, all of which have zero emissions at the tailpipe. Hybrid (HEVs) or PHEVs have both petrol/diesel engines and electric motors, and are therefore not zero emissions.

Level 1

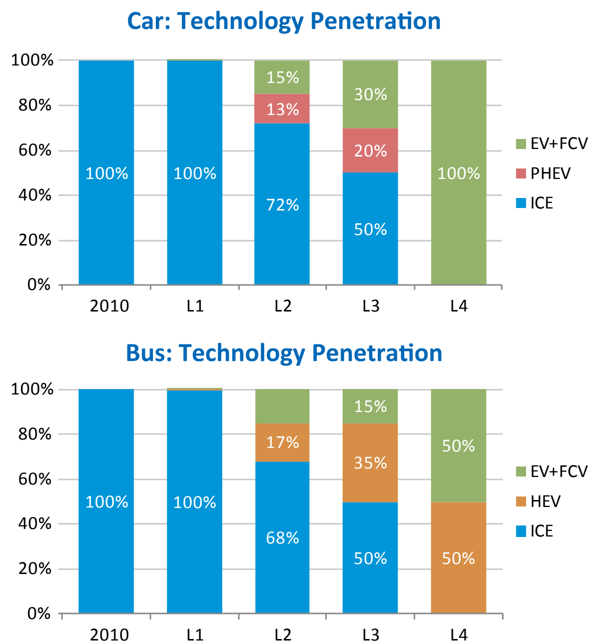
Level 1 assumes that by 2050, nearly 100% of passenger vehicle and bus transport is still ICE (including HEV). 90% of passenger railway travel is electrified.

Level 2

Level 2 assumes that by 2050, about 72% of passenger-km are travelled in conventional ICE/HEV. 13% are PHEVs and 15% are zero emission vehicles (EVs/FCVs). About 68% of all bus transport is powered by ICEs, and HEVs and EVs/FCVs account for 17% and 15%, respectively. Passenger railway travel is 100% electrified.

[5] Calculated based on the data of estimated number of EVs, PHEVs and FCVs in use and total number of passenger vehicles in use in 2010 provided by the Next Generation Vehicle Promotion Center (2012, 2014).

Figure 31 Passenger transport technology penetration under different scenarios



Source: Authors.

Level 3

Level 3 assumes that by 2050, only 50% of passenger-km are travelled in conventional petrol or diesel engine cars. 20% are PHEVs and 30% are zero emission vehicles (EVs/FCVs). 35% of all buses are hybrids (HEVs) and 15% are EVs/FCVs. Passenger railway travel is 100% electrified.

Level 4

Level 4 assumes that by 2050, 100% of car travel is powered by EVs/FCVs. For bus travel, 50% is powered by EVs/FCVs and another 50% is powered by hybrid diesel-electric engines (HEVs). All passenger trains are electrified.

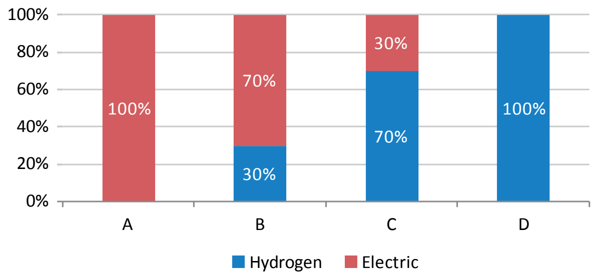
Figure 32 More and more people are likely to shift to zero emission transport

Source: IGES stock image.

Choice of zero emission vehicle technology

The 'Shift to zero emission transport' option allows users to specify the proportion of zero emission cars in the vehicle fleet. Under the choice of zero emission vehicle technology, Options A to D allow the user to choose the proportion of those zero emission vehicles that would be either fully electric, or using hydrogen fuel cells. In practice other technologies such as 'hybrid' electric-hydrogen cars (hydrogen fuel cell range extender) could exist, using all-electric for short journeys and hydrogen for long journeys. However, the Low Carbon Navigator currently only models fully battery electric or hydrogen fuel cell vehicles.

Figure 33 Zero emission vehicle technology options



Source: Authors.

Option A

Option A assumes that by 2050, 100% of domestic vehicles will be fully electric and there will be 0% hydrogen fuel cell vehicles.

Option B

Option B assumes by 2050, 70% of vehicles will be fully electric and 30% will have hydrogen fuel cell vehicles.

Option C

Option C assumes by 2050, 30% of vehicles will be fully electric and 70% of vehicles will have hydrogen fuel cells.

Option D

Option D assumes in 2050, all domestic vehicles will be powered by hydrogen fuel cells.

Domestic freight

Figure 34 Domestic freight transport in Japan is heavily dependent on road transport

Source: IGES stock image.

In 2010, 63% of all Japan's freight tonne-kilometres were by road, 33% by water, 4% by rail and 0.2% by air (EDMC, 2013). Except for rail transport, almost all other freight transport was powered by Internal Combustion Engines (ICEs; petrol or diesel engine) (Next Generation Vehicle Promotion Center, 2012 and 2014). All rail transport is electric. The total amount of goods-movement was 543 billion ton-km (EDMC, 2013). That equates to 4,244 ton-km per person in 2010 (see Figure 35). Domestic freight transport demand will be determined by the five society scenarios of the Low Carbon Navigator. In addition, there are three levers: transport mode share, zero-emission vehicle penetration and biofuel blending rates for conventional fuels.

Level 1

For zero-emission vehicle penetration, 95% of all the road freight transport will be powered by ICEs, with the remaining 5% being HEVs. For biomass blending in ICE fuels, no biofuels will be used in 2050.

Level 2

For zero-emission vehicle penetration, all the road freight transport will be HEVs. For biomass blending in ICE fuels, 5% will be fuelled by biofuels.

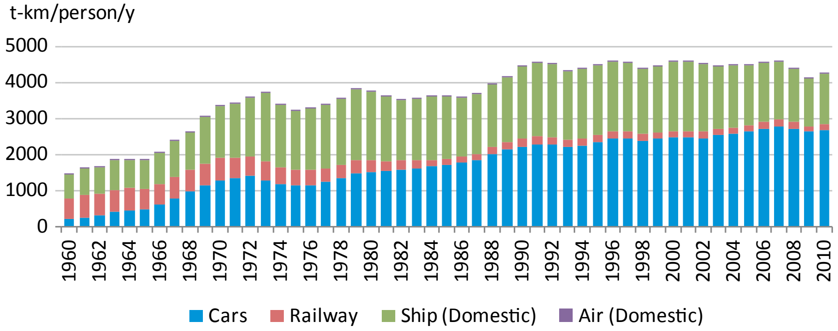
Level 3

For zero-emission vehicle penetration, 50% will be HEVs, 15% EVs and 35% FCVs. For biomass blending in ICE fuels, 10% will be fuelled by biofuels.

Level 4

For zero-emission vehicle penetration, FCVs will take over the market (100% share). For biomass blending in ICE fuels, 50% will be fuelled by biofuels.

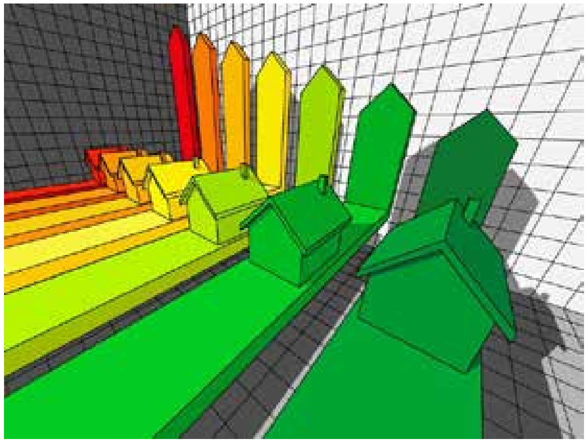
Figure 35 Volume of domestic freight transport in Japan



Source: Data provided by NIES.

Residential heating and cooling

Figure 36 Residential space heating and cooling demand in Japan is high



Source: IGES stock image.

In 2010, residential heating and cooling energy demand was about 133 TWh/year, which is roughly a quarter of the total residential energy consumption. The Japanese climate requires that homes have both heating and cooling facilities. Consequently the ownership rate of air conditioners in households is as high as 90% (2011 estimates) (EDMC, 2013).

The Japan 2050 Low Carbon Navigator considers several factors that critically affect household heating and cooling energy use. These levers vary significantly across the four levels. These levers and their levels settings are explained below.

Installation of Home Energy Management System (HEMS)

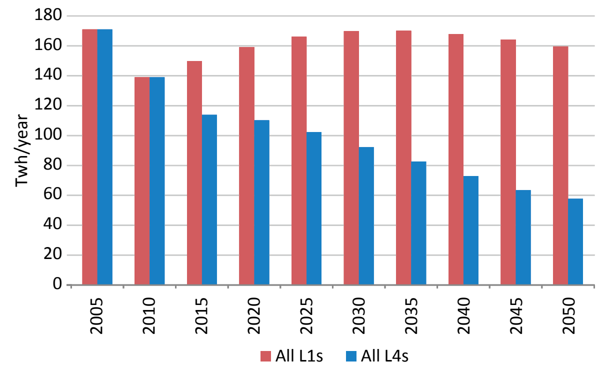
HEMS is a networked system that helps manage the residential power supply to reduce energy consumption (Umer et al., 2014). Currently the use of HEMS is negligible but it is expected that with proper policies, more households will be equipped with HEMS over time. HEMS also applies to residential hot water supply.

Level 1 assumes that no HEMS is installed in the households and thus no energy demand reduction takes place. **Levels 2, 3 and 4** assume domestic heating/cooling energy demand reduction at 7%, 9% and 10% rates respectively compared to **Level 1**, thanks to progressively higher rate of HEMS installation.

Home insulation

Heating and cooling energy demand is affected by the quality of insulation of the facility concerned. In 2010, about 6% of houses met the current insulation standard set in 1999. More than half of all houses only meet the pre-1980 standard, which is less than half as energy efficient as the 1999 standard. Under **Level 1**, it is assumed that there will be negligible reduction in domestic heating and cooling through insulation. **Levels 2, 3 and 4** assume progressively increased and more efficient use of insulation, which will lead to 35%, 38% and 40% energy demand reduction respectively in 2050.

Figure 37 Residential heating and cooling energy demand



Note: Society scenario is set at R&D under both all L1s and all L4s scenarios.

Source: Authors.

Home heating/cooling electrification

Under **Level 1**, electrification rate will remain at 2005 levels all the way to 2050. For this level, 50% of heating appliances are electricity-based, and 28% are gas-based with the remaining using kerosene (22%).

For **Level 2**, the proportion of new domestic heating systems using electricity will increase to 60% in 2050. This share will further increase to 70% and 80% under the assumptions in **Level 3** and **Level 4**.

Energy efficiency

For **Level 1**, the coefficient of performance (COP) for heating and cooling air conditioners keep the same level of 2010, and energy efficiency of gas and kerosene boilers remains the same level of 2010. Under **Levels 2, 3 and 4**, COP for heating and cooling air conditioners increases (1.66 times increase for heating air conditioners and 1.95 times increase for cooling air conditioners, compared to 2010 levels) over time up to 2050, but energy efficiency remains more or less the same for gas and kerosene boilers.

Residential hot water supply

Heating water for domestic purposes consumes about 28% of total residential energy requirements (2010 estimates) (EDMC, 2013). Current electrification rate for water heating is quite low, just over 13%. In recent years, the installation rate of high efficiency water boilers using heat pump techniques such as Panasonic's "EcoCute" is attracting attention, but its diffusion rate is still negligibly small today.

Several factors (described below) that affect domestic hot water energy use have been considered in the Low Carbon Navigator:

Installation of Home Energy Management System (HEMS)

Level 1 assumes that no HEMS is installed in the households and thus no energy demand reduction takes place. **Levels 2, 3 and 4** assume domestic hot water energy demand reduction at 7%, 9% and 10% rates respectively, thanks to progressively higher rate of HEMS installation with more advanced energy management features.

Choice of technology

Under **Level 1**, half of hot water is supplied by advanced gas boilers. In Level 2, gas-fired fuel cogeneration replaces gas boilers. Electric heat pumps share remains relatively low at 10% in both **Level 1** and **Level 2**. However, major electrification takes place under **Level 3**, where half of hot water is supplied by electric heat pumps. **Level 4** assumes that these electric pumps supply 70% of domestic hot water.

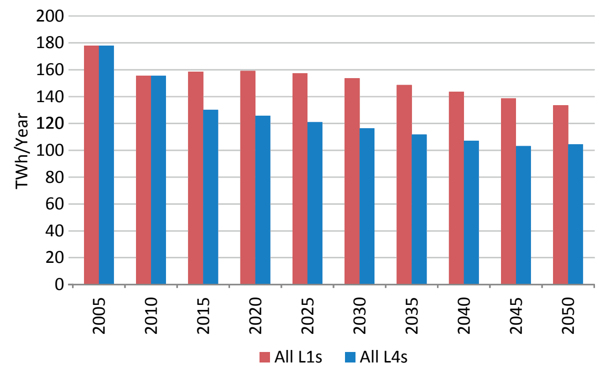
Energy efficiency of appliances

Energy efficiency is not assumed to change over time under **Level 1**. In **Level 2**, COP for heat pump/electricity increases moderately. This trend is also assumed for **Levels 3 and 4**. Overall, FC cogeneration technology increases over time. Efficiency for electricity generation FC cogeneration increases substantially in **Levels 2, 3 and 4**. Energy efficiency of conventional electricity boilers does not change across the levels but increases for kerosene and gas boilers.

Solarthermal boilers

At **Level 1**, the current number of 2.4 million units of solarthermal boilers is installed in 2050, which is about 5% of total households in 2050. In **Level 2**, solarthermal boiler installations count 14 million units in 2050, which is more than 30% of total households in 2050. Similarly, in **Levels 3 and 4**, boiler installations increase to 21 million units (45% households) and to 26 million units (55% of total households).

Figure 38 Residential hot water energy demand



Note: Society scenario is set at R&D under both all L1s and all L4s scenarios.

Source: Authors.

Residential cooking, lighting and appliances

Lighting, cooking and appliances account for more than 40% of Japan's total residential energy consumption (EDMC, 2013). At present in Japan all lighting and most of the appliances are powered by electricity. This is not the same for cooking because there is a choice between gas and electricity. In 2010, only 26% domestic cooking was electrified, with the rest being gas-powered (both town gas and LPG) (EDMC, 2013).

For domestic cooking, lighting and appliances, the Low Carbon Navigator considers the following two factors:

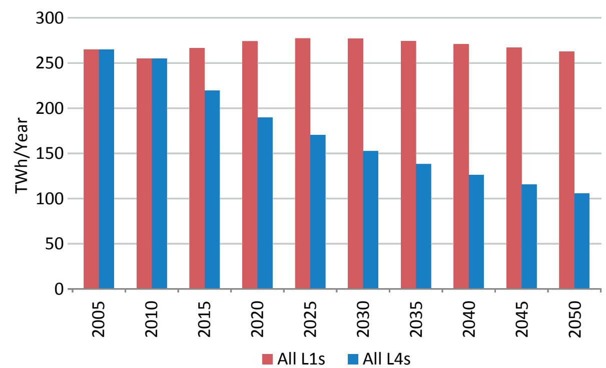
Energy Service Demand per Household

Level 1 assumes that in 2050, energy service demand per household for cooking, lighting and appliances increases by 20% compared to 2010 level. At **Level 2** the energy service demand increases but the increase rate is 10%. **Level 3** assumes that the energy service demand remains the same as 2010 level. At **Level 4**, the energy service demand decreases by 20% in 2050 compared to 2010 levels.

Energy Efficiency of Appliances

Level 1 assumes that energy efficiency of appliances does not change much over time until 2050. Under **Level 2**, there will be only a moderate increase in the efficiency for cooking appliances. Other power appliances are assumed to experience a significant increase. However, a massive increase in efficiency is anticipated for lighting appliances. The relative value of lighting appliances energy efficiency increases from 79% in 2010 to 233% in 2050. **Levels 3 and 4** are assumed to be the same as **level 2**.

Figure 39 Residential lighting, cooking and other appliances energy demand under all L1s and all L4s scenarios



Note: Society scenario is set at R&D under both all L1s and all L4s scenarios.

Source: Authors.

Commercial heating, cooling and hot water supply

Figure 40 Commercial heating, cooling and hot water is heavily dependent on kerosene

Source: IGES stock image.

The Low Carbon Navigator considers eight technologies for heating and six technologies for cooling in the commercial sector. In 2005, more than 80% of commercial heating was supplied from kerosene boilers, followed by gas boilers (15%) and packaged air conditioners (3.7%). Predominant appliances for cooling were gas-based absorption refrigerators (54%) and packaged air conditioners (30%). For water boilers, the predominant appliances were conventional kerosene (53%) and gas boilers (42%) (NIES, 2014).

Factors that are taken into consideration in the Japan 2050 Low Carbon Navigator as affecting commercial energy use for heating, cooling and hot water supply are energy service demand, building insulation, and choice of appliances.

Floor space for commercial activities

Commercial energy use is directly related to the amount of floor space in use for commercial activities. This is affected by Japan's economic activities. The social scenarios (R&D, MIJ, SB, RI, and Share Society), which are reflected in the top lever of the Low Carbon Navigator, allows for selection from among various levels of economic growth and industrial activities. In the R&D scenario, commercial floor space requirement shows a very slow decreasing trend, going down from 1834 million m^2 in 2010 to 1789 million m^2 in 2050. In MIJ scenario, it increases to 1980 million m^2 in 2050. In SB scenario, the requirement increases to 1901 million m^2, whereas in RI scenario, it decreases to 1646 million m^2. Finally, in the Share scenario, it is assumed that there will be a sharp decline to 1386 million m^2 in commercial floor space.

Energy service demand per floor space

Level 1 assumes that in 2050, energy service demand per floor space for heating, cooling and hot water generation increases by 20% compared to 2010 level. This increased rate is relatively small for **Level 2**, i.e. only 10% compared to 2010 level. Under the assumptions in **Level 3**, energy service demand per floor space remains the same in 2050 as 2010 levels. Finally, **Level 4** assumes that energy service demand per floor decreases by 20% compared to 2010 levels.

Building insulation

Heating and cooling energy demand is affected by the quality of insulation of the facility concerned. **Level 1** assumes that there are negligible reductions in commercial heating and cooling through insulation. **Level 2** assumes a 20% reduction in heating and cooling demand through insulation in 2050. A higher reduction rate is assumed under **Levels 3** (42%) and **Level 4** (44%).

Choice of appliances

Choice of appliances is assumed to vary significantly across the levels, with low to high degree of shifts from carbon-intensive to low-carbon technologies.

Level 1: The share of electric heating air conditioners (central and packaged) will increase from 3.7% in 2005 to 12% in 2050. For cooling, heat pumps will account for 18% of total appliances, up from 3% in 2005. Additionally, the use of energy efficient boilers for hot water will also increase, which will hold 20% share in 2050 compared to zero in 2005.

Level 2: At this level, the share of air conditioners for heating will rise even more, reaching 16% in 2050. Similar trend will be seen for heat pumps for cooling and energy efficient boilers for hot water, with their shares reaching 22% and 30% respectively in 2050.

Level 3: The increasing trend of air conditioners for heating, heat pumps for cooling, and energy efficient boilers for hot water continue in level 3. Their shares reach 20%, 26% and 40% respectively in 2050.

Level 4: At this level, the share of air conditioners for heating reaches 24%, while heat pumps for cooling holds 30% share. In case of hot water supply, energy efficient boilers become predominant, holding 50% of the total share.

Table 4 Choice of appliances in 2050

Choice of appliances in 2050						
Space heating appliances						
Code	**Mode**	**2005**	**1**	**2**	**3**	**4**
ELECTRICITY	Central Electric air conditioner	0.0%	6.0%	8.0%	10.0%	12.0%
ELECTRICITY	Package Air Conditioner	3.7%	6.0%	8.0%	10.0%	12.0%
KEROSENE	Absorption Refrigerator	0.0%	7.0%	8.0%	9.0%	10.0%
GAS	Absorption Refrigerator	0.0%	7.0%	8.0%	9.0%	10.0%
KEROSENE	Heat pump	0.9%	6.0%	7.0%	8.0%	9.0%
GAS	Heat pump	0.0%	6.0%	7.0%	8.0%	9.0%
KEROSENE	Kerosene boiler	80.3%	25.0%	22.0%	20.0%	15.0%
GAS	Gas boiler	15.1%	37.0%	32.0%	26.0%	23.0%
	Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Cooling Appliances						
Code	**Mode**	**2005**	**1**	**2**	**3**	**4**
ELECTRICITY	Central Electric Air Conditioner	0.0%	30.0%	28.0%	26.0%	24.0%
ELECTRICITY	Package Air Conditioner	29.5%	30.0%	28.0%	26.0%	24.0%
KEROSENE	Absorption Refrigerator	13.3%	11.0%	11.0%	11.0%	11.0%
GAS	Absorption Refrigerator	54.3%	11.0%	11.0%	11.0%	11.0%
KEROSENE	Heat pump	2.0%	9.0%	11.0%	13.0%	15.0%
GAS	Heat pump	1.0%	9.0%	11.0%	13.0%	15.0%
	Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
	Subtotal (excl. Elect)	71.0%	40.0%	44.0%	48.0%	52.0%
Hot Water Supply						
Code	**Mode**	**2005**	**1**	**2**	**3**	**4**
ELECTRICITY	Heat Pump	0.0%	0.0%	5.0%	10.0%	20.0%
KEROSENE	Energy efficient Kerosene boiler	0.0%	10.0%	15.0%	20.0%	25.0%
GAS	Energy Efficient Gas Boiler	0.0%	10.0%	15.0%	20.0%	25.0%
ELECTRICITY	Electric Boiler	5.0%	5.0%	5.0%	5.0%	5.0%
KEROSENE	Conventional Kerosene Boiler	53.0%	30.0%	20.0%	15.0%	10.0%
GAS	Conventional Gas Boiler	42.0%	45.0%	40.0%	30.0%	15.0%
	Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Authors.

Commercial cooking, lighting and appliances

Commercial ownership of lighting and appliances such as refrigerators, ovens, TVs, computers and related equipment is steadily increasing. Over the years, technological advancement has made many of these gadgets much more energy efficient. Major manufacturers in Japan have put significant efforts into producing energy efficient appliances. For example, Toshiba's E-core LED lighting system is assumed to use 80% less energy than incandescent lamps (Toshiba, 2014).

Commercial lighting and appliance sector's future energy use is influenced by the five society scenarios of the Low Carbon Navigator. In addition, energy use for lighting and appliances is determined by several factors: total floor space required for commercial activities, energy demand per floor space, and energy efficiency of appliances.

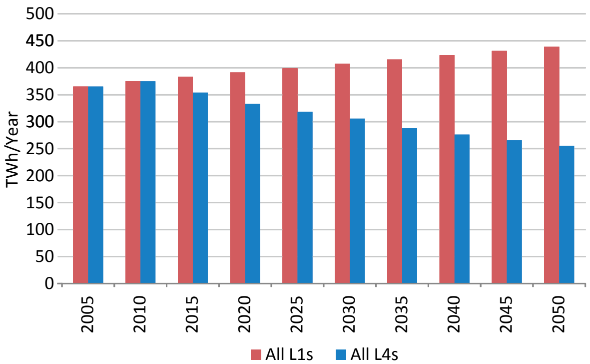
Energy service demand per floor space

Energy service demand per floor space for cooking, lighting and appliances vary across the levels in terms of its degree of increase or decrease. Under **Level 1**, it is assumed that in 2050, energy service demand will increase by 20% compared to 2010 level. A similar increase but to a lesser degree—10% compared to 2010 level—is assumed for **Level 2**. On the other hand, **Level 3** holds that energy service demand will remain the same as 2010 levels. Finally, **Level 4** assumes that energy service demands will decrease by 20% compared to 2010 levels.

Energy efficiency of appliances

Under the assumptions of **Level 1**, energy efficiency of appliances in 2050 will remain the same as 2010. **Levels 2, 3 and 4** assume that efficiency will be improved depending on technologies.

Figure 41 Commercial lighting, cooking and appliances energy demand under all L1s and all L4s scenarios



Note: Society scenario is set at R&D under both all L1s and all L4s scenarios.

Source: Authors.

Figure 42 Commercial use of various appliances is on an increse in Japan

Source: IGES stock image.

Industry

Figure 43 Japan's move to low carbon economy will be affected by its industrial activities

Source: IGES stock image.

Considering Japan's industrial structure, the Low Carbon Navigator incorporates five components:

- Energy use and related GHG emissions in manufacturing and construction;
- Energy use and related GHG emissions in agriculture, forestry and fisheries;
- Non-energy GHG emissions from industrial processes (from cement industry, other ceramics, ammonia and soda, petro chemical, other chemicals, electric furnace, non-ferrous metal, machinery);
- Non-energy GHG emissions in agriculture; and
- Non-energy fossil fuel use in petro-chemical industry.

In 2005, value addition of these industries was around 20 trillion JPY, or about 4% of national GDP (MOE, 2012b).

In the Low Carbon Navigator, industrial sector's future energy use is determined by several factors: economic growth and industrial activity; energy intensity per industrial output, and energy mix in the industry.

Economic growth and industrial activity

Economic growth and industrial activity levels are determined by the user's choice on 2050 society scenarios.

The activity levels of all the five components are affected by the choices of society scenarios.

For details, please see the Excel Model (Zhou et al. 2014).

Energy intensity per industrial output

The energy-related GHG emissions are affected by energy intensity per industrial output. Two opposite scenarios are developed for this factor. In the first one, energy intensity per industrial output remains at base year level up to 2050.

The second scenario under this factor, which assumes the opposite of the first scenario, holds that energy intensity continues to reduce toward 2050 at reasonable levels determined by a group of experts.

Energy mix in the industry

Energy carrier mix in the industry affects the manufacturing and construction subsector, and the agriculture, forestry and fisheries subsector. Four different levels of energy carrier mix have been assumed in the Low Carbon Navigator. Under **Level 1**, the energy mix remains the same as in the base year. On the other hand, for **Level 4**, energy mix shifts toward minimising direct emissions through, e.g. electrification, promotion of renewables and shift from coal to gas, that is consistent with the national efforts to achieve 80% emissions reduction by 2050, determined by a group of experts (MOE, 2012b).

Installation of carbon capture and storage (CCS) technology in the industry

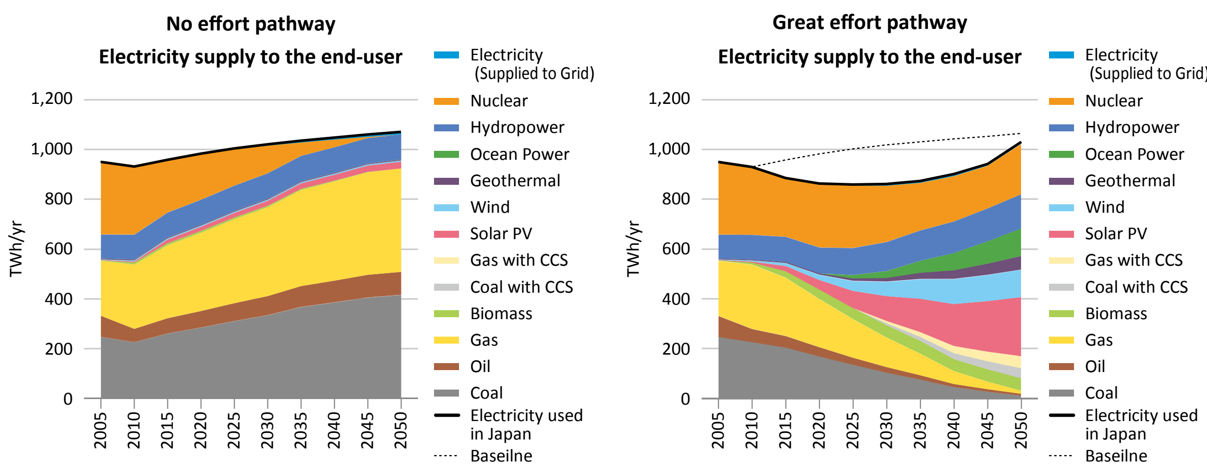
CCS technology is relatively new and its deployment in the industry is still limited to demonstration projects. However, a great amount of research work is being conducted on the actual deployment of this technology. The Low Carbon Navigator therefore includes a lever on the installation of CCS technology across industries in Japan. Similar to the CCS lever for conventional power plants, **Level 1** in the industrial CCS lever assumes that no CCS will be installed in the industry up to 2050. Only limited number of pilot projects will have CCS installed. **Level 2** assumes that Japan puts limited effort in initiating industrial CCS roll-out. Under this level, 20% of the energy CO_2 emissions from chemical, ceramics and steel sectors as well as 20% of non-energy CO_2 emissions from industry are removed by the deployed CCS technology. **Level 3** increases the efforts more, and results in 50% removal of energy CO_2 and non-energy CO_2 from these sectors by CCS. Under great efforts in **Level 4**, the share of emission removal increases further to 80%.

VI. Example pathways

Two example pathways

By using the Low Carbon Navigator, the users can choose a combination of society scenarios, energy supply trajectories, and energy demand trajectories to create the pathways for reducing emissions and ensuring energy security. They can experiment by making different selections and see what kind of efforts will be needed to achieve Japan's 80% emission reduction target. A range of trajectories/ levels has been developed for each of the energy demand and energy supply sectors, which allows for creating thousands of pathways. To explain how to understand and interpret the results from the Low Carbon Navigator, this report presents two example pathways/ scenarios in a comparative manner. The pathways have been chosen to illustrate two opposing futures for Japan under different degrees of efforts toward emissions mitigation. The first pathway demonstrates what is likely to happen if no effort is put into mitigating emissions and combatting climate change, while the second one shows what could happen if Japan puts great efforts toward transitioning to a low-carbon society.

Figure 44 Energy mix for electricity generation



Source: Authors' compilation based on simulation results generated by the Japan 2050 Low Carbon Navigator.

Under the "no effort" pathway, all the sectors are locked at Level 1 setting, reflecting the continuation of existing capacity, technology or no change in consumption behaviour. There is an exception for the restart policy of existing nuclear capacity, which is set at Trajectory C (where Japan only allows all existing nuclear plants with a 40 year lifespan to operate). In the "great effort" pathway, all the sectors (including the nuclear lever on restart policy) are locked at Level 4 setting, reflecting increased use of renewable energy, advanced technology, or reduction of energy service demand. For ease of comparison, the society scenarios under both example pathways are set as R&D Society. Table 5 provides a quick overview of society scenario setting as well as the assumptions under the two pathways.

The results under these two pathways are explained below.

Energy mix for electricity generation

Energy mix varies significantly under the two scenarios (Figure 44). In the "no effort" pathway,

Table 5 Specifications of the example pathways

2050 society scenario: R&D; Population: 97.1 million; No. of Households: 44.5 million; GDP growth rate: 1.1%; Per capita GDP growth rate: 1.8%		
	No effort pathway	**Great effort pathway**
My choice	All L1s, except for the restart of existing nuclear capacity (Trajecgtory C)	All L4s

Source: Authors.

the use of fossil fuels, particularly coal and gas, increases over the years. This is particularly because Japan's nuclear capacity gradually decreases and reaches to zero in the 2040s. On the other hand, in the "great effort" scenario, Japan still generates a significant amount of electricity from nuclear sources. In addition, the share of all renewables and biomass increases significantly whereas the use of fossil fuels gradually comes down and becomes quite small in 2050. This shift to renewable energy sources will facilitate the development of a low-carbon economy in Japan.

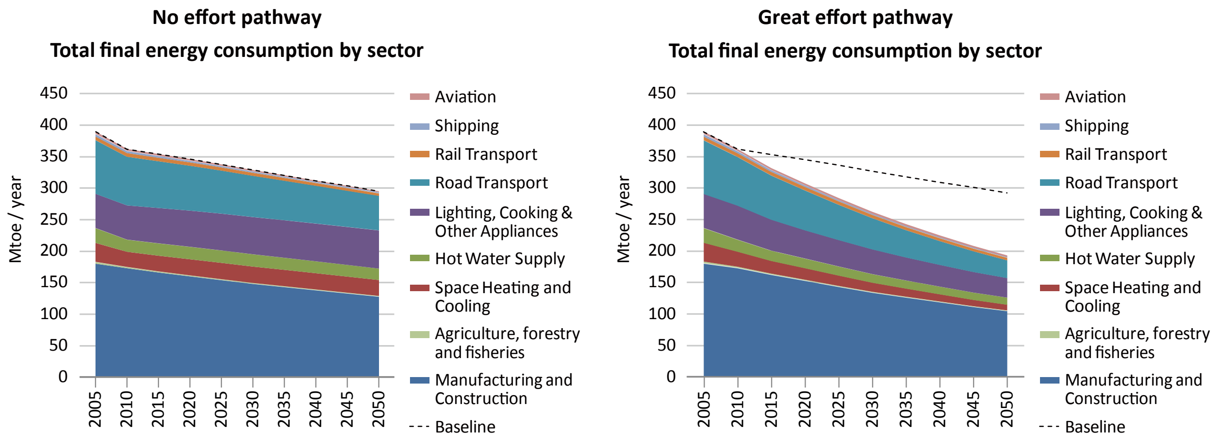
Energy used by end consumers

The overall total final energy consumption reduces over the years until 2050 under both pathways, but the degree of reduction is significantly higher under the "great effort" scenario (Figure 45). A combination of factors, including policy intervention, efficiency enhancement as well as behavioural change, is reflected in the greater reduction of energy consumption. In terms of comparison among the sectors, major changes are seen in the energy consumption for road transport; lighting, cooking and appliances; and space heating and cooling. More and more people will use public transports such as buses, and nearly 100% of privately-owned vehicles will be zero-emission ones. For space heating and cooling, the changes are due to both enhanced efficiency of appliances and people's habitual changes in using these appliances.

GHG Emissions

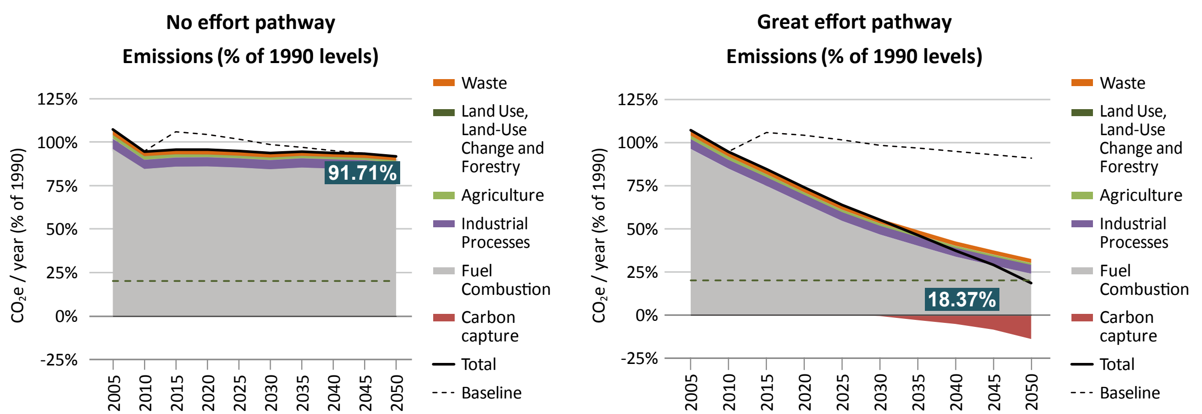
Under the "no effort" scenario, Japan is far from achieving its committed 80% reduction of GHG

Figure 45 Energy used by end-consumers



Source: Authors' compilation based on simulation results generated by the Japan 2050 Low Carbon Navigator.

Figure 46 Comparison of emission reduction under the two scenarios



Source: Authors' compilation based on simulation results generated by the Japan 2050 Low Carbon Navigator.

emissions. The emissions are reduced only to a limited level, reaching around 90% of 1990 levels. Under this pathway, Japan is stuck with frozen technology, and consumption patterns do not change much. The reduction is basically due to the reduced size of the population. On the other hand, thanks to efforts made by the policymakers as well as the people of Japan, the country achieves the targeted 80% reductions by 2050. As can be seen in Figure 46, emissions come down in all the sectors individually as well as together to the targeted level. The use of low-carbon technologies significantly enhance efficiency and reduce emissions.

Key messages

The two example pathways explained above show that some very important insights on Japan's energy and emissions options can be analysed using the Low Carbon Navigator. Thousands of similar pathways can be developed and analysed. Nonetheless, some of the key messages that can be derived from the Low Carbon Navigator are summarised below:

- Many chances exist to achieve the most ambitious reductions which are about 87% of the 1990 levels under "Share" society scenario.
- CCS technologies will be critical for Japan to achieve 80% reductions in 2050.
- Without nuclear, 80% reductions from the 1990 levels can be achieved in 2050 if renewable energy is fully expanded together with massive adoption of CCS.
- Renewable energy is more expensive in the short run, which is not necessarily the case if the price of oil experiences an upsurge in the long run.
- Keeping all options at Level 1, 9% reductions from 1990 levels can be achieved due to the projected downward trend in Japan's population by 2050.
- Shifting from one type of society to another will substantially influence the emissions level. Under "Share" society scenario, 28% reductions from 1990 levels can be achieved by keeping all options at Level 1s ("no effort pathway"). To keep all options at Level 4 ("great effort pathway"), 87% reductions from 1990 levels can be achieved.
- An economy-wide approach integrating both supply side and demand side efforts is necessary to achieve the long-term target of 80% reductions.

VII. Concluding remarks

Realising a low-carbon economy requires not only clear directions and actions but also needs the participation of Japanese citizens. An integrated approach is needed to build confidence to act, make long-term planning, be innovative, and gradually change behaviour. For this, the people need to understand the implications of the decisions that are made now. The Low Carbon Navigator provides a platform to facilitate such multi-stakeholder discussions and better understanding of the fundamentals of different energy mixes and mitigation options for Japan, to give wider public access and receive feedback simultaneously.

The Low Carbon Navigator can also reinforce the "3E+S" (energy security, economic efficiency, environmental protection and safety) objectives explicitly included in the 2014 Basic Energy Plan of the Government of Japan. Table 6 explains how the Low Carbon Navigator helps analyse these issues.

Using the energy security issue as an example, the Web Tool of the Low Carbon Navigator (accessible at: http://www.en-2050-low-carbon-navi.jp/) provides a "Security" page where two indicators on energy security are presented. The first indicator explains Japan's "dependence on imported energy" in terms of an index compared with 2010 levels, whereas the second indicator shows the country's "diversification of energy sources" in terms of the share of different energy sources in Japan's total primary energy supply. For example, the Low Carbon Navigator suggests that under the "great effort pathway" as explained earlier, the index value of Japan's "dependence on imported energy" is roughly 33% lower in 2050 than the level in 2010, indicating much more dependency on indigenous energy. Under the same pathway, Japan's energy mix, as represented by the "diversification of energy sources" indicator, is very different in 2050 compared to 2010: one can see a much lower share of fossil fuels but a significant increase of renewables.

The economic efficiency objective in "3E+S" can also be reflected in the Low Carbon Navigator through proxy indicators of energy system-wide costs and expenses related to power supply under the "Costs" page. In the "great effort pathway", additional cost to the society, measured in terms of yen/person/year in 2050 compared to "no effort pathway" (all at Level 1) would be around JPY160,000. This information is presented on the "Costs: In context" page. Detailed comparison of costs related to power supply under pre-set pathways and chosen pathways are also generated on the "Costs: Compared" page. One should, however, note that the coverage of Low Carbon Navigator's energy system-wide costs is wider than the similar costs in the "3E+S" objective. In addition, the Low Carbon Navigator's costs related to power supply do not include fuel costs.

The environmental protection objective of the 2014 Basic Energy Plan can be discussed using the Low Carbon Navigator through emissions indicators (total GHG emissions as % of 1990 levels) on the "Energy" and "Electricity" pages. For instance, simulation results show that emissions can come down to around 18% of 1990 levels in 2050 under the "great effort pathway", which otherwise suggest that there is a chance that Japan can achieve its previously-committed 80% emissions reduction target.

Finally, the last of the "3E+S" objectives—safety—can be reflected in the Low Carbon Navigator through various options for nuclear power

Table 6 The Low Carbon Navigator reinforces "3E+S"objective

	2014 Basic Energy Plan's 3E+S objectives			
	Energy security	Economic efficiency	Environmental protection	Safety
Indicators in the Low Carbon Navigator	Dependence on imported energy Diversification of energy sources	Energy system-wide costs Expenses related to power supply	Total GHG emissions Emissions from the power sector	Various options for nuclear power generation

Source: Authors.

generation (although there is no agreed metric for "safety"). The users can reflect their respective views by choosing from multiple options under two nuclear sector indicators, restart of existing nuclear power plants and building of new plants. Last but not least, the Low Carbon Navigator can also help communicate alternative pathways and means on how to achieve Japan's INDCs.

Although the Low Carbon Navigator gives the audience an option to look ahead to understand what would happen and what could be done, like all simulation tools, this approach also has certain limitations. It is worth noting these caveats to be able to understand what the Low Carbon Navigator can do and what it cannot.[6]

The Low Carbon Navigator demonstrates the scale of changes that are likely to be required for Japan to make the transition to a low-carbon economy, as well as the choices/trade-offs available to the country. However, it does not make predictions or projections for the future. In other words, while the Low Carbon Navigator is helpful in exploring a range of available pathways, none of these generated pathways should be prejudged as optimal.

The Low Carbon Navigator does not adopt a cost-optimisation approach. Instead of focusing on identifying the least-cost pathway to meet Japan's 2050 target, it looks at what might be achievable in each of the covered sectors under different assumptions. Nonetheless, the Low Carbon Navigator does acknowledge the significance of costs in making choices. It allows the users to see the incremental cost to the society of their chosen pathways, and make sensitivity analysis by comparing the costs of their selected pathways with other pathways.

The model has been developed exclusively focusing on Japan, its emissions mitigation and energy security options. It does include associated data (but no trajectories) on Japan's importation of bioenergy and hydrocarbons, and the exportation of petroleum and petrochemical products. Additionally, the analysis under this model considers emissions credits for bioenergy but does not provide trajectories. It does not include emissions from international aviation and shipping assigned to Japan.

The underlying data for the Japan 2050 Low Carbon Navigator comes from various sources such as estimates from governmental authorities and research institutes. The model describes how the trajectories might look like under various assumptions. Relevant developments, such as the 2011 Fukushima nuclear accident and the renewed focus on alternative and renewable energy sources, have been taken into consideration. Thus the analysis under this model looks at what might be possible to deliver in the coming years up to 2050, but does not propose or identify the required policy decisions to ensure this future. In other words, the Low Carbon Navigator does not provide a detailed policy framework and the trajectories should not be considered as projections based on policy decisions.

We believe that the Low Carbon Navigator can be a handy educational and communication tool that will not only help the general audience to better understand the situation, but also assist policymakers in the consultation and decision-making processes. We expect wide application of this tool and feedbacks from the users.

[6] The Low Carbon Navigator is based on the UK 2050 Pathways Calculator. The discussions on the caveats are based on UK DECC (2010).

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Information

For accessing to the Web Tool version: http://www.en-2050-low-carbon-navi.jp/
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