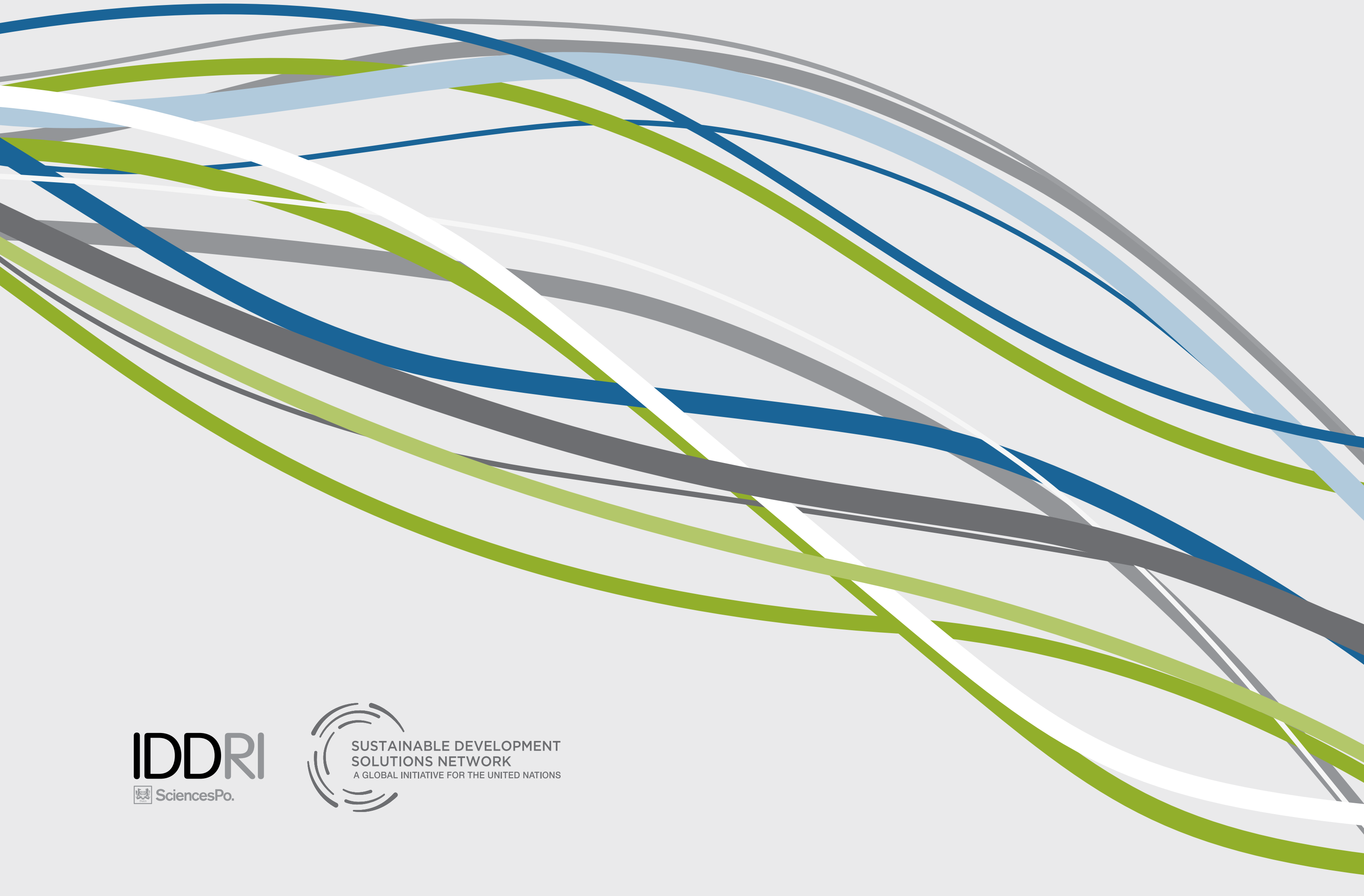
Japan Chapter

pathways to
deep decarbonization

2014 report



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SUSTAINABLE DEVELOPMENT
SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

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Preface

The Deep Decarbonization Pathways Project (DDPP) is a collaborative initiative, convened under the auspices of the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI), to understand and show how individual countries can transition to a low-carbon economy and how the world can meet the internationally agreed target of limiting the increase in global mean surface temperature to less than 2 degrees Celsius (°C). Achieving the 2°C limit will require that global net emissions of greenhouse gases (GHG) approach zero by the second half of the century. This will require a profound transformation of energy systems by mid-century through steep declines in carbon intensity in all sectors of the economy, a transition we call "deep decarbonization."

Currently, the DDPP comprises 15 Country Research Partners composed of leading researchers and research institutions from countries representing 70% of global GHG emissions and different stages of development. Each Country Research Partner has developed pathway analysis for deep decarbonization, taking into account national socio-economic conditions, development aspirations, infrastructure stocks, resource endowments, and other relevant factors. The pathways developed by Country Research Partners formed the basis of the DDPP 2014 report: Pathways to Deep Decarbonization, which was developed for the UN Secretary-General Ban Ki-moon in support of the Climate Leaders' Summit at the United Nations on September 23, 2014. The report can be viewed at deepdecarbonization.org along with all of the country-specific chapters.

This chapter provides a detailed look at a single Country Research Partner's pathway analysis. The focus of this analysis has been to identify technically feasible pathways that are consistent with the objective of limiting the rise in global temperatures below 2°C. In a second—later—stage the Country Research Partner will refine the analysis of the technical potential, and also take a broader perspective by quantifying costs and benefits, estimating national and international finance requirements, mapping out domestic and global policy frameworks, and considering in more detail how the twin objectives of development and deep decarbonization can be met. This comprehensive analysis will form the basis of a report that will be completed in the first half of 2015 and submitted to the French Government, host of the 21st Conference of the Parties (COP-21) of the United Nations Framework Convention on Climate Change (UNFCCC).

We hope that the analysis outlined in this report chapter, and the ongoing analytical work conducted by the Country Research Team, will support national discussions on how to achieve deep decarbonization. Above all, we hope that the findings will be helpful to the Parties of the UNFCCC as they craft a strong agreement on climate change mitigation at the COP-21 in Paris in December 2015.

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1 Country profile

1.1 The national context for deep decarbonization and sustainable development

The Japanese economy is characterized by low domestic reserves of fossil fuels, which makes it highly dependent upon importations. This situation has raised important energy security issues since the 1950s when Japan has turned from domestic coal and hydro to imported oil to fuel its fast economic growth. After the first oil shock in the 1970s, Japan's energy policy priorities have shifted to be framed around the three pillars of energy security, environment protection, and economic efficiency, with in particular the development of nuclear, liquefied natural gas (LNG), and imported coal to limit the dependency on oil. The focus on energy security and climate change has favored the development of renewables and the domination of nuclear power, which has been the most important energy source until the Daiichi Nuclear Power plant accident in March 2011.

Energy strategies have changed after the 2011 accident. The Innovative Strategy for Energy and the Environment (2012) and the comments on Basic Energy Plan by Advisory Committee for Natural Resources and Energy (ACNRE, 2013) concluded that the dependency on nuclear power should be decreased; consequently, the power generation from nuclear power decreased substantially in 2012 from its level in 2010 and import of fossil fuels, especially LNG, increased in spite of energy efficiency improvement in end-use sector.

To achieve the political GHG mitigation target of reducing 80% emissions compared to the 1990 level by 2050 with lower nuclear dependence, it is utmostly necessary to reduce energy consumption by reducing energy service demands and by increasing the use of energy saving technologies, and to increase the share of renewable energies. As the potential of renewable energies is unevenly distributed, regional electricity exchange is required. The major renewable energy capacity is not located in the major electricity demand regions such as Kanto area but in the rural regions such as Hokkaido and Tohoku areas. However current electricity interconnection capacity between regions is not high in Japan and strengthening interconnections is therefore a crucial issue.

1.2 GHG emissions: current levels, drivers, and past trends

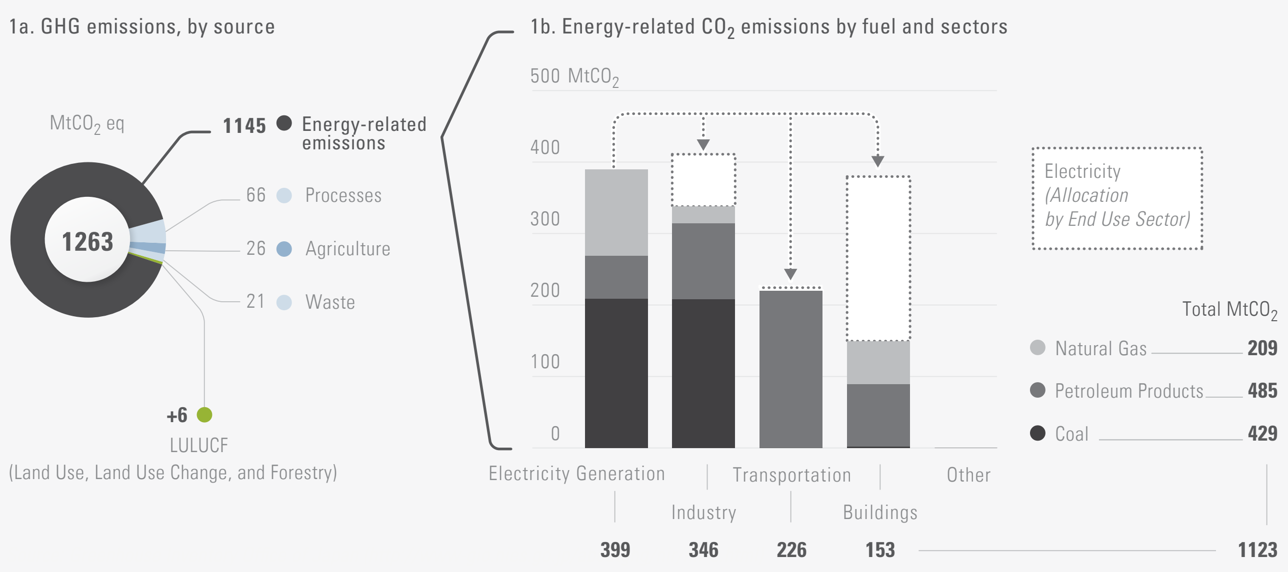
Total GHG emissions in 2010 (excluding LULUCF) amounted to 1,256 $MtCO_2eq$ in Japan of which CO_2 represented a large majority (1,191 $MtCO_2$ or 94.8%) (Figure 1a). The sectoral decomposition shows that three activities were dominantly responsible for these CO_2 emissions at this date (Figure 1b): power generation, notably because the power sector was largely fueled by imported coal and LNG (even in 2010 before nuclear was partly removed from the power generation mix); industry, because the industrial sector plays a very important role in the Japanese economy notably for exports; and transport sector, because the vehicle transports of both passenger and freight traffic were increased. Moreover, although shares of commercial and residential sectors are not large, the emissions from these sectors have increased because of increasing distribution of electrical appliances. At the same time, the emissions from the industry sector have reduced continuously since 1990, and those from the transport sector have reduced since 2000. The trends demonstrate a continuous but moderate increase of total CO_2 emissions over 1990-2007 (+14%) before recent drastic changes (-8% between 2008 and 2010 after the economic crisis and +7% between 2010 and 2012 because the closure of nuclear plants after Fukushima triggered a temporary increase of fossil importations).

2007 saw the most GHG emissions for the 1990 to 2010 period, which was a 15% increase from base year under the Kyoto Protocol (KPBY). The total GHG emissions in 2010 decreased by 0.4% compared to the emissions in the base year under KPBY (excluding LULUCF). Since 2010, GHG emissions have resumed to increase and accounted for 1,343 $MtCO_2eq$ in 2012. They increased by 6.5% compared to KPBY. During the 1st commitment period, GHG emissions increased by 1.4% compared to KPBY. On the other hand, if the carbon sink of LULUCF and credit of Kyoto Mechanism are counted, the GHG emissions during the 1st commitment period amount to 1,156 $MtCO_2eq$, a 8.4% decrease from KPBY.

In Figure 2, the decomposition of drivers of changes in CO_2 emission from fuel combustion over 1990-2012 demonstrates that the Japanese economy has experienced a continuous diffusion of energy efficiency permitting an average 0.7% annual rate of production energy intensity decrease. The other Kaya drivers did not have such a consistent effect in that period.

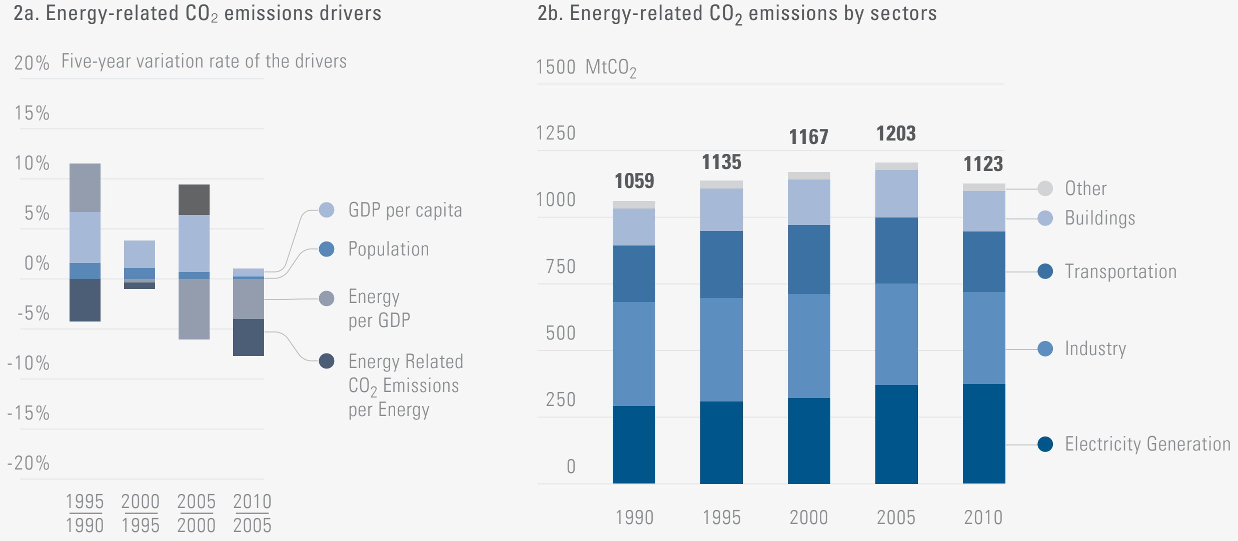
Until 2007, growth of GDP per capita has been the major driver of CO_2 emission increase, while there was a substantial decrease in 2008 and 2009 due to the global economic recession. In 2011 and 2012, the contribution of improvement of energy efficiency was neutralized by the increase of carbon intensity due mainly to the suspension of nuclear plants after the Great East Japan Earthquake in 2011 and the resulting comeback of fossil fuels.

Figure 1. Decomposition of GHG and Energy CO_2 Emissions in 2010


1a. GHG emissions, by source

1b. Energy-related CO_2 emissions by fuel and sectors

Figure 2. Decomposition of historical energy-related CO_2 Emissions, 1990 to 2010


2a. Energy-related CO_2 emissions drivers

2b. Energy-related CO_2 emissions by sectors

② National Pathways to Deep Decarbonization

2.1 Illustrative Deep Decarbonization Pathway

2.1.1 High-level characterization

In line with declining birthrate and growing proportion of elderly people, both total and active Japanese populations are expected to experience a significant decrease between 2010 and 2050, by 24% and 39% respectively as shown in Table 1. Despite the decline in population, the continuous rise of GDP per capita is projected to be sufficient to ensure a steady rise of total GDP (from about 5.38 trillion USD in 2010 to 8.37 trillion USD in 2050).

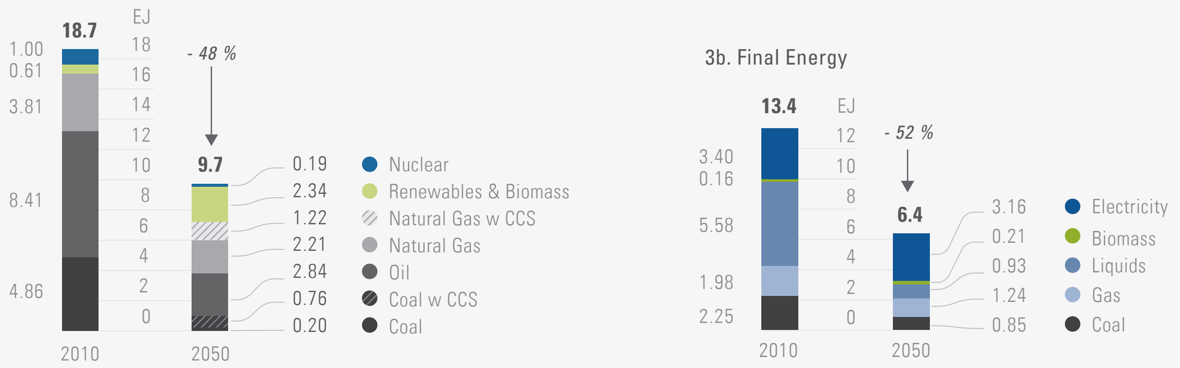
The deep decarbonization pathways in Japan are assessed using AIM/Enduse model.[1] Table 1 summarizes the major socio-economic indicators used in the estimation of deep decarbonization pathways in Japan. The indicators are taken from the assumption by Working Group of Technology Perspective of Central Environmental Council in Japan and the estimation of population by National Institute of Population and Social Security Research. In Japan's illustrative deep decarbonization scenario, the long-term GHG emission reduction target is achieved by large scale energy demand reduction in end-use sector and decarbonization in power

Table 1. Major socio-economic indicators

	2010	2050	Variation 2010/2050
GDP (trillion JPY$_{2000}$)	538	837	+56%
Population (million)	128	97	-24%
Active population (Million)	82	50	-39%
GDP per capita (US$/cap)	38003	82116	+116%

Source: Central Environmental Council, 2012. Report on measures and policies after 2013.

Figure 3. Energy Pathways, by source



3a. Primary Energy

3b. Final Energy

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[1] AIM/Enduse model is a dynamic recursive, technology selection model for the mid- to long-term mitigation policy assessment, developed by the National Institute for Environmental Studies, Kyoto University and Mizuho Information Research Institute. This model has already been applied to assess the mitigation target in Japan. The model applied for the deep decarbonization pathways is a multi-region version of AIM/Enduse model of Japan, that is to say, the model is composed of 10 regions and considers the regional differences in renewable energy potential and energy demand characteristics. The 10 regions almost coincide with the business areas of 10 public power supply firms.

generation sector including deployment of CCS. In parallel with continuous growth in GDP per capita, improvements of both energy efficiency and carbon intensity become the major drivers to substantial CO_2 emissions reductions in the mid and long terms. Total final energy consumption in 2050 decreases substantially and accounts for approximately 50% of the 2010 level (Figure 3, right panel). Particularly in transport sector, the pace of energy demand reduction is the most rapid in the mid- to long terms, followed by residential, commercial, and industrial sectors. The shift to public transport, fuel efficiency improvement, and efficiency improvement of transportation service will promote the reduction of CO_2 emissions in the transportation sector.

Dependency on fossil fuel is reduced substantially compared to the 2010 level due to reduction in energy demand and deployment of renewable energy. In 2050, fossil fuel consumption falls by approximately 60% compared to the 2010 level with an approximate 35% decrease of total primary energy supply and increase in share of renewable energy which accounts for approximately 40% (including hydropower) of total primary energy supply in 2050 despite almost complete phase out of nuclear power (Figure 3, left panel). Among the fossil fuels, natural gas and oil (including non-energy use) exist in 2050 while coal is almost phased out because of its high carbon intensity. Natural gas supply increases in the mid term in place of oil and coal because of its lower carbon intensity, but falls to the 2010 level by 2050 along with energy demand reduction and large-scale deployment of renewable energy. Hence, natural gas without CCS acts as a bridge technology.

Figure 5. Energy-related CO_2 Emissions Pathway, by Sector, 2010 to 2050

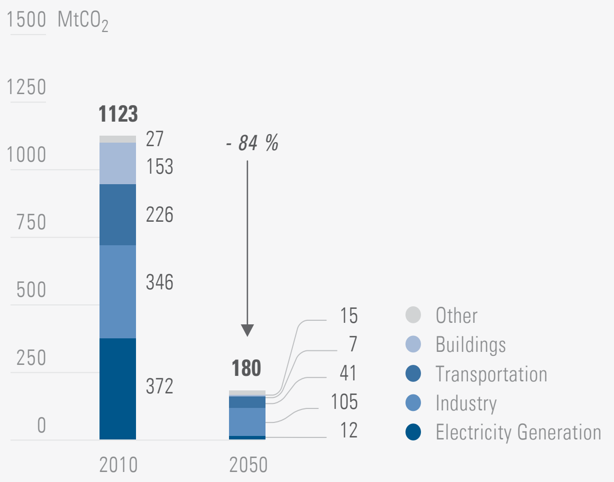
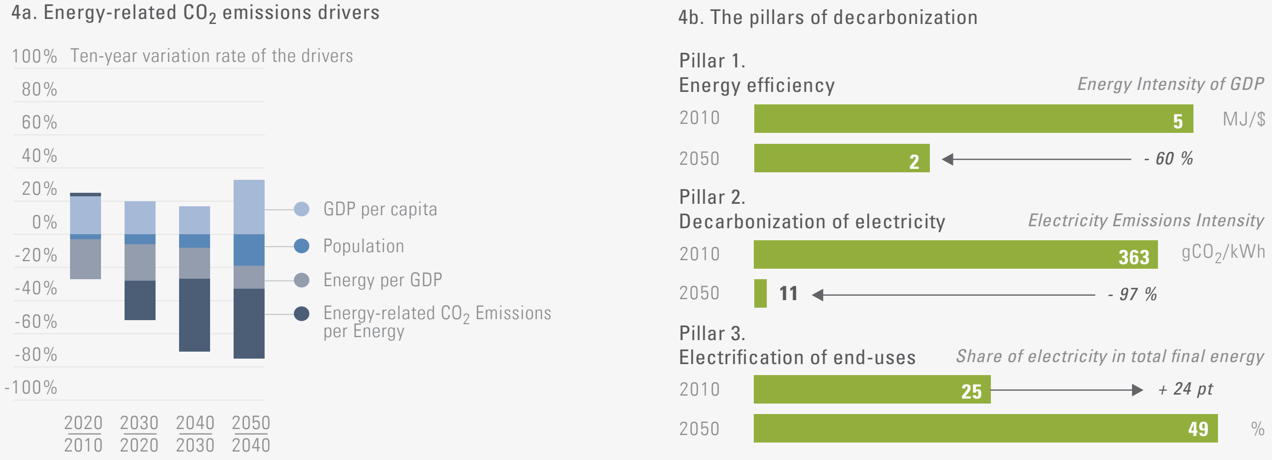


Figure 4. Energy-related CO_2 Emissions Drivers, 2010 to 2050


4a. Energy-related CO_2 emissions drivers

4b. The pillars of decarbonization

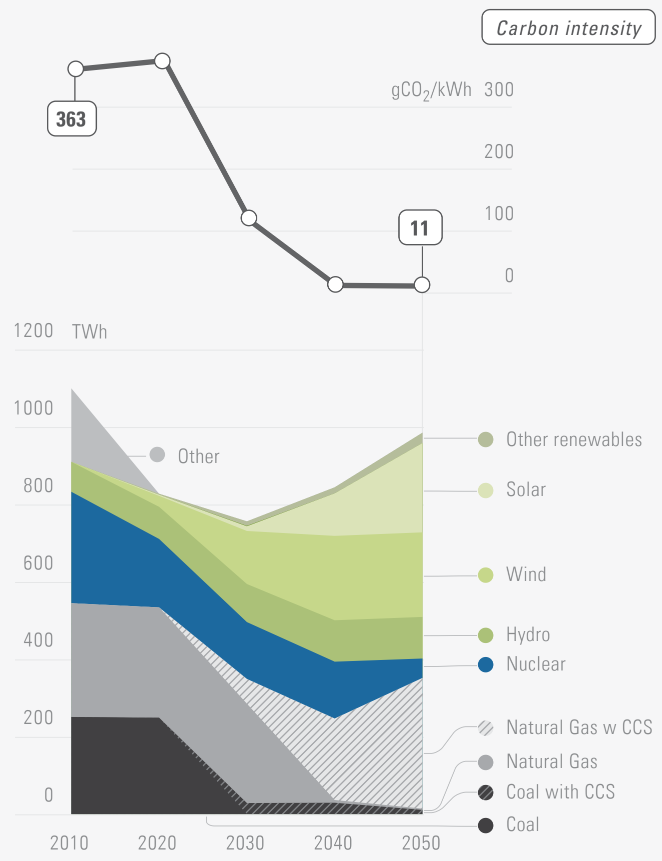
2.1.2 Sectoral characterization

Power sector

The nuclear power is assumed to be phased out gradually (see next section for more extensive discussion) and electricity generation from coal without CCS is entirely phased out by 2050. Renewable energy is developed over the mid to long terms and reaches approximately 59% of total electricity generation through large-scale deployments of solar PV and wind power (Figure 6). In addition, natural gas (equipped with CCS) is developed to ensure balancing of the network and reaches about a third of total electricity generation in 2050. Due to large-scale deployment of renewable energy and natural gas equipped with CCS, carbon intensity of electricity falls to nearly zero in 2050.

In 2050, approximately 199 $MtCO_2$ is captured by CCS technologies and cumulative captured CO_2 reaches about 3,096 $MtCO_2$. This represents about 60% of the potential of CO_2 storage in an anticlinal structure (the well and seismic exploration data for Japan is estimated by RITE).[2]

Figure 6. Energy Supply Pathway for Electricity Generation, by Source



Industrial sector

The industrial sector is the largest emitter: its CO_2 emissions represent about 40% of total GHG emission in 2050 because fuel demand for high temperature heat is hardly replaced by low-carbon sources. Activity levels demonstrate a moderation of activity in energy-intensive sectors in line with restructuring of the Japanese industry: -23% for crude steel production (from 111 Mt in 2010 to 85 Mt in 2050) and -11% for cement (from 56Mt in 2010 to 50 Mt in 2050). Combined with energy efficiency, this ensures a reduction of final energy consumption by more than 30%. Fuel switching, and notably the phase-out of coal without CCS, contributes to improve significantly the carbon intensity of energy in the mid to long terms (Figure 7a).

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[2] The potential storage of CO_2 in an anticlinal structure where well and seismic exploration data accounts for about 5.2 Gt. In addition, the potential storage in existing oil/gas fields represents about 3.5 Gt. Moreover, the total potential storage capacity can be 146 Gt including the storage in geological structure with stratigraphic trapping, etc. (http://www.rite.or.jp/English/lab/geological/survey.html). According to the report by Central Environmental Council in Japan, it is suggested that about a half of the potential capacity can be economically attractive by 2050 (http://www.env.go.jp/council/06earth/r064-03/ccs.pdf (in Japanese)).

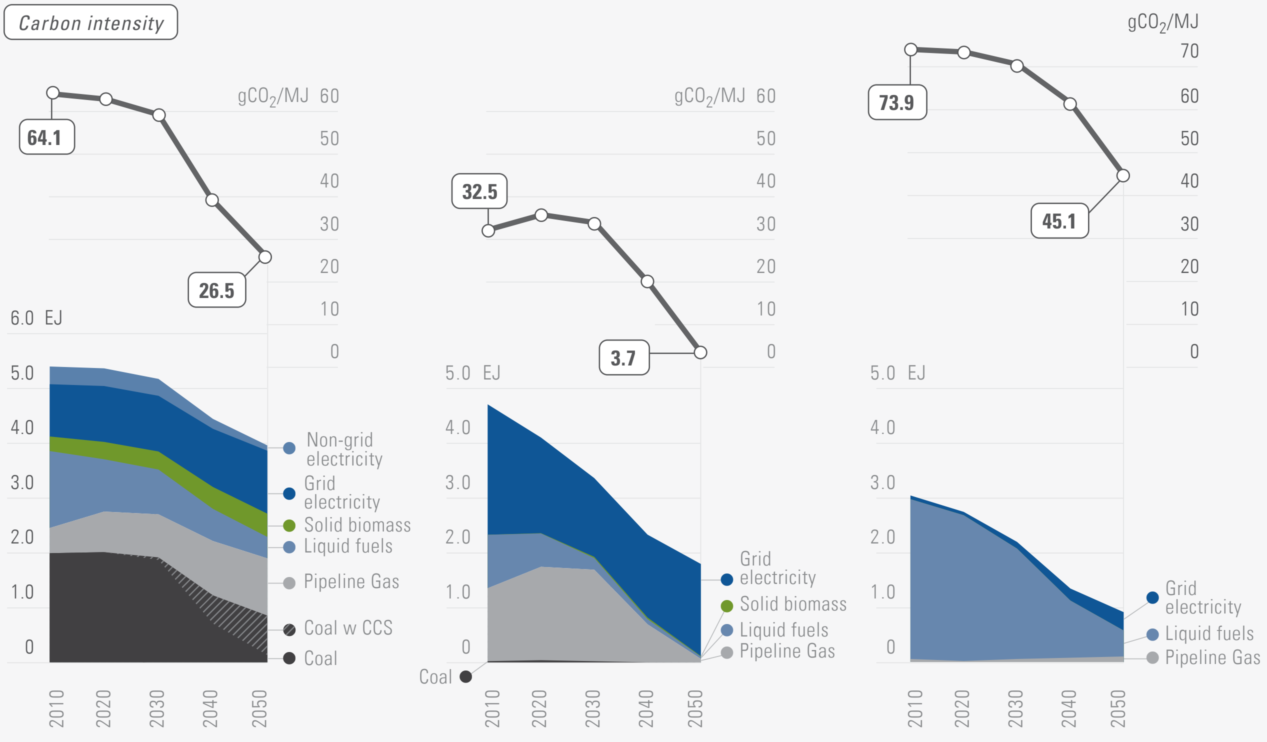
Building sector

In residential and commercial sectors, final energy demand is reduced by approximately 60%, in line with a stability of commercial floor space (+3% only, from 18,3 Mm^2 in 2010 to 19 Mm^2 in 2050) and a 17% decrease of the number of households, hence reducing energy service needs in the residential sector. It is worth noting that fossil fuels (notably gas) remain important in the transition (until 2030), thus explaining a temporary rise of the carbon intensity before electricity becomes the dominant energy over the long term, hence ensuring a significant decrease of the carbon intensity in this sector in 2050.

Transport sector

In the transportation sector, CO_2 emissions in 2050 reduce by almost 80% compared to the 1990 level and account for about 17% of Japan's GHG emissions, as shown in Figure 4. In a context of a reduction of passenger total mobility (-10% of passenger transport demand) corresponding to an increase of mobility per person, the 18% decoupling of freight transport relative to production is made possible by a combination of energy efficiency, electrification of the fleet, as well as hydrogen and a small diffusion of gas-fueled vehicles (for freight), reaching in total almost 50% of energy consumed, substitute for oil-based fuels and ensuring a continuous decrease of the carbon intensity of fuels in 2050 (Figure 7c).

Figure 7. Energy Use Pathways for Each Sector, by Fuel, 2010 – 2050



7a. Industry

7b. Buildings

7c. Transportation

Note: Carbon intensity shown in Figure 7 for each sector includes only direct end-use emissions and excludes indirect emissions related to electricity or hydrogen production.

2.2 Assumptions

Low-carbon technology options

A wide range of low-carbon technologies is taken into account in Japan's illustrative scenario, and include:

- In electricity supply: efficiency improvement of power generation, coal and gas with CCS, reduced T&D (Transmission & Distribution) line losses, wind power, solar PV, geothermal, bioenergy.
- In industry: energy efficiency improvement, electrification wherever feasible in industrial processes, natural gas use, CCS for iron making and cement lime, fuel economy improvement of agricultural machine, bioenergy use, nitrogen fertilizer management.
- In buildings: improvement of the energy efficiency performance of buildings, high-efficiency equipment and appliances, electric heat pump water heaters, energy management system.
- In transport: energy efficiency improvement, gas-powered heavy duty vehicles (HDVs), vehicle electrification, hydrogen vehicles.

Nuclear power

As future availability of nuclear power is still uncertain in Japan, electricity generation from nuclear plants and availability of nuclear power is based on the premises of New Policies Scenario of World Energy Outlook 2013 published by International Energy Agency. According to the illustrative scenario, nuclear plants' lifetime is limited to 40 years for plants built up to 1990 and 50 years for all other plants, and during 2013 to 2035 an additional 3 GW nuclear plants capacity is included. Subject to these assumptions and maximum capacity factor of 70% for all plants, electricity generation from nuclear plants represents about 50 TWh in 2050.

Geologic carbon storage potential

Complying with previous studies, CCS technologies are assumed to be available from 2025 and annual CO_2 storage volume is assumed to increase up to 200 $MtCO_2$/year in 2050. The potential of storage of CO_2 is set to be around 5 $GtCO_2$. CCS technology can be applied to both power generation and industrial sectors. In the power generation sector, both coal plants and natural gas plants can be equipped with CCS technology, but bioenergy with CCS (BECCS) is excluded in this analysis. For industrial use, CCS technologies are available in iron and steel and cement sectors. In 2050, the amount of captured CO_2 in the iron and steel sector and the cement sector reaches about 60 $MtCO_2$ and 20 $MtCO_2$, respectively. A maximum capture rate of CO_2 by CCS technologies is assumed to be 90% for all CCS technologies.

Electricity interconnection

In Japan, as the regions with large potential of renewable energy are different from the ones with large electricity consumption, reinforcement of interconnection capacity would be helpful to facilitate more effective use of local renewable sources. In the illustrative scenario, due to reinforcement of electricity interconnection, carbon price to achieve 80% reduction target is reduced by about 9% because power generation from renewable energy in Hokkaido and Tohoku regions becomes available in Tokyo region, the largest electricity consumer in Japan. The capacity of interconnection between Tohoku and Tokyo region is tripled during 2010 to 2050.

Demand-side management

Deployment of battery electric vehicle (BEV), heat pump water heater, and converting electricity into hydrogen can provide flexibility to electricity system through implementation of demand side management. In 2050, electricity peak demand in daytime becomes higher relative to off-peak demand, and this necessitates integration of substantial solar PV into electricity system.

2.3 Alternative pathways and pathway robustness

Decarbonization pathway without nuclear power

The Illustrative Pathway considers a gradual phase-out of nuclear but it still represents 19% of electricity generation in 2030 and 5% in 2050. However, no nuclear plant has been in operation since the end of 2013, though some nuclear plants have been put under safety inspection by the Nuclear Regulation Authority, and it is possible that a complete phase-out is decided. Therefore, it is worth considering a pathway that would consider a complete phase-out of nuclear to assess robustness of deep decarbonization pathways. In this scenario, no nuclear plant is assumed to restart in the entire period of estimation after 2014.

In such an alternative pathway, higher carbon intensity is experienced during the transition period where coal and gas without CCS compensates the gap caused by the phase-out of nuclear. But the impact of nuclear phase-out as compared to the illustrative scenario is relatively small in the long term, given the small share of nuclear in 2050 in any case. An 80% emission reduction in 2050 is still feasible with additional deployment of renewable energy and natural gas equipped with CCS.

Decarbonization pathway with less deployment of CCS

As the feasibility of deep decarbonization pathways crucially depends on the availability of CCS, a Limited CCS Scenario is prepared to assess further robustness. In this scenario, CO_2 storage volume is limited to 100 $MtCO_2$/year (half of the volume assumed in the Illustrative Scenario) and cumulative captured CO_2 reach about 1,550 $MtCO_2$.

Achieving long-term emission reduction target proves to be still feasible with substantial increase of renewable energy, particularly solar PV and wind power, in the long-term electricity supply, in place of natural gas equipped with CCS. In the scenario, the share of renewable energy in electricity supply reaches approximately 85% in 2050 and intermittent renewable energies account for about 63% in electricity generation in 2050, hence imposing a further challenge for integration into the electricity system. The utilization of the technologies that provide the desired flexibility, such as pumped hydro plants and demand side management using battery electric vehicles can be helpful to integrate large amount of variable renewable energies (VREs).

2.4 Additional measures and deeper pathways

The following measures should be considered for deeper decarbonization.

Further development and diffusion of innovative low-carbon technologies

The technologies listed in Table 2 are proven energy-saving technologies up to 2050. On the other hand, further improvement in energy efficiency of low-carbon technology beyond the levels assumed in the scenario analysis and development of innovative technology provide additional potential to reduce emission, especially in the industrial sector. In addition, system technologies such as reinforcement of electricity interconnection and demand side management system would be helpful for effective deeper decarbonization.

Change of lifestyle to reduce energy service demand while maintaining standard of living

Both in the illustrative scenario and in alternative pathways, substantial change in lifestyle and reduction of energy service demand is not considered. However, behavioral change has further potential to reduce energy demand affordably while maintaining the standard of living. For example, the material stock in developed countries is likely to saturate, and developing countries will also catch up with the developed countries in the future. The enhancement of service economy or stock economy will be able to reduce the material demand, and as a result, energy demand will reduce. Analyzing these effects could help with more refined assessment of deeper pathways.

Change of material demand and its energy service demand

Both in the illustrative scenario and in alternative pathways, substantial change in material production is not considered. However, with existing stock level of infrastructure and decline in future population, a small amount of material production to maintain the stock level is likely to be sufficient. For example, stock of steel in developed countries is estimated to be 4.9-10.6 ton per capita. If the quantities of material production are controlled, the energy service demand in industrial sector could be reduced further, and as a result, CO_2 emissions also could reduce.

Redevelopment of cities designed to consume less energy

Further reduction in emission and energy demand in cities can be achieved by change in urban form favoring even more important shift from private vehicles to public transport and reuse of waste heat. In addition, mitigation actions in cities often provide multiple co-benefits.

Relocation of industrial firms where unused energies are easily available

Though reinforcement of electricity interconnection is taken into account as an option in the scenario analysis, relocation of industrial firms would contribute to more effective use of heat from renewable sources and waste heat. Especially, at present most of the low temperature heat is disposed of. Though the locations of various industries and locations between industries and residential areas are well organized, there is a potential to improve energy efficiency and utilization of heat by reorganizing the locations, thereby further reducing CO_2 emissions.

2.5 Challenges, opportunities, and enabling conditions

Energy system transformation

Deep decarbonization in Japan requires a large scale transformation in the energy system. In particular, there is a huge challenge to integrate VRE, such as solar PV and wind power, into the electricity system. Additional plants that can provide flexibility, such as pumped hydro storage, are built to complement large-scale deployment of VREs in the scenario analysis. In addition, demand side management would be an effective option but may not be implemented by a market mechanism alone, therefore, additional policy instruments such as dynamic pricing of electricity would be needed.

Promoting public acceptance of deep decarbonization pathways

The pace of deploying low-carbon technology is strongly influenced by public acceptance. In general, higher discount rates provide further opportunity to diffuse low-carbon technologies. Public acceptance of technologies may also involve social issues as well as economic barriers, because there are a wide range of possible co-benefits and adverse side effects that can be caused by diffusion of low-carbon technologies.

2.6 Near-term priorities

Avoiding lock-in of high carbon intensity infrastructure

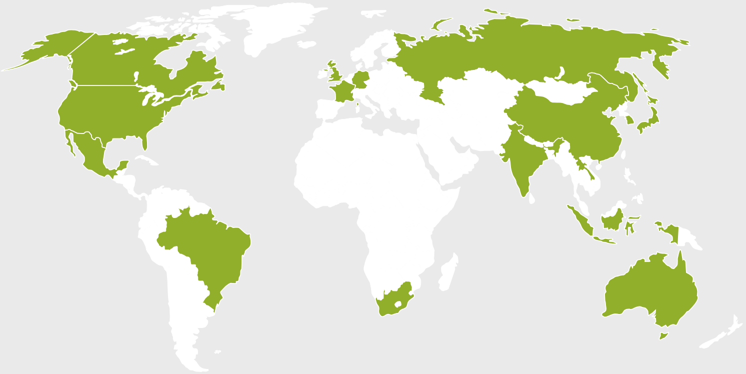
Some infrastructures such as power plants and buildings entail considerable lock-in risks because the majority of those introduced in the near term would remain in 2050. As some gas combined-cycle plants as well as coal plants have to be equipped with CCS in 2050, newly built plants should be CCS-ready in addition to the introduction of the best available technology.

Continuation of electricity saving

After the Great East Japan Earthquake in 2011, electricity use had been reduced in order to avoid blackouts due to the Fukushima accident and the suspension of other damaged power plants. Continuing these actions could be helpful for deep decarbonization.

Reducing near-term impact of energy import price

Since 2011, fossil fuel import values have increased in Japan due to the rise in global crude oil price, the depreciation of Japanese Yen, and the suspension of nuclear plants. Immediate actions for deep decarbonization that decrease fossil fuel demand can contribute to reducing the impact on the economy in the near term.



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