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MILES (Modelling and Informing Low Emissions Strategies) Project - Japan Policy Paper:

A joint analysis of Japan's INDC

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The current report details the Japanese contribution to the report "Beyond the Numbers. Understanding the Transformation Induced by INDCs" prepared by the MILES project Consortium under contract to DG CLIMA (No. 21.0104/2014/684427/SER/CLIMA.A.4).

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In parallel with the publications of countries' Intended Nationally Determined Contributions (INDCs) at 2030 horizon, the "Modelling and Informing Low-Emission Strategies" (MILES) project is an international research project bringing together 16 leading research teams from US, China, Japan, EU, Brazil and India in order to build capacity and knowledge on low-emissions development strategies (http://www.iddri.org/Projets/MILES-%28Modelling-and-Informing-Low-Emission-Strategies%29). Under the coordination of French Institute IDDRI (http://www.iddri.org/), the project aims at providing informed and transparent narratives for low-emission development strategies at national levels. Following the publication of the MILES report "Beyond the Numbers. Understanding the Transformation Induced by INDCs" aggregating all teams' contributions in October 2015, the current report co-written by Japanese teams RITE and NIES provides the detailed material for the analysis of Japan's situation on the eve of the COP21.

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1. Introduction

In the run up to COP21, the Japanese INDC was submitted to the secretariat of the UNFCCC on July 17th, 2015. This paper analyses the potential impacts of the Japanese INDC on the Japanese energy system, including the energy mix and the changed induced in the final energy consuming sectors. It offers quantitative analysis of Japan's INDC from the different perspectives of two Japanese research institutions (RITE (Research Institute of Innovative Technology for the Earth) and NIES (National Institute for Environmental Studies)) and discusses policy implications and challenges to achieve the INDC from an economic point of view.

2. Qualitative Description of the INDC

The Japanese government announced its INDC to be a 26% emission reduction by 2030 compared to 2013 levels which corresponds to a 25.4% reduction compared to 2005 (the emissions target in 2030 is 1.042 $GtCO_2eq$.). The detailed breakdown by type of gas in the government INDC is shown in Table 1. The targeted greenhouse gases are CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3. All sectors emitting these greenhouse gases are covered by the Japanese INDC.

Table 1: Japanese INDC for 2030

	Compared to 2013（compared to 2005）
Energy-related CO2	-21.9% (-20.9%)
Other GHGs (except energy -related CO2)	-1.5% (-1.8%)
Removal by LULUCF	-2.6% (-2.6%)
Total GHG	-26.0% (-25.4%)

It can be seen from Table 1 that reductions in energy-related CO2 are the principal component of the Japanese INDC. Given this link with energy policy and the INDC, the INDC was decided in line with the Government's strategic energy plan for 2030. The INDC was considered through discussions open to the public at the Joint Experts' Meeting of the Central Environment Council (Subcommittee on Global Warming Measurement after 2020, Global Environment Committee) and the Industrial Structure Council (INDC WG, Global Environment Subcommittee, Committee on Industrial Science and Technology Policy and Environment). At the same time, energy policies and the energy mix were considered through open discussions at the Advisory Committee for Natural Resources and Energy.

Based on the discussions, the Global Warming Prevention Headquarters (ministerial decision-making on global warming countermeasures: the chair is the Prime Minister) developed a draft INDC on June 2, and public comments were received from June 3 to July 2. Finally, after going through public comment procedure, the Global Warming Prevention Headquarters made a final decision on the INDC, and it was submitted to the UNFCCC on July 17.

In the Japanese context, the Great East Japan Earthquake and the accident at the Tokyo Electric Power Company's Fukushima Dai-ichi Nuclear Power Station on March 11, 2011, have obviously had a tremendous impact on Japan's energy policies and thus on the determination of the INDC. After long discussions, the Strategic Energy Plan was decided in April 2014, highlighting the basic principles known as the 3E+S: *energy security, economic efficiency, environment*, and *safety.* Regarding specific numbers for the energy mix for 2030, however, the Strategic Energy Plan only mentioned that the Japanese government would make an announcement quickly regarding each energy source in the energy supply-demand structure. A draft vision for the energy mix for 2030 with specific numbers (primary energy, final energy, power supply) was proposed in June, 2015 just before the decision on the draft INDC. The vision for the energy mix in primary energy was designed with these three major objectives, and also a general objective of safety:. 1) The self-energy sufficiency ratio should be higher than prior to the Great East Japan Earthquake (around 25% in primary energy). 2) The electricity cost should be reduced compared to the current level. 3) Greenhouse gas emissions should be reduced as to make Japan a leading example for the rest of the world and with levels at least equivalent to those of the EU and the U.S. The INDC was in turn determined based on the energy mix and possible measures for GHG emissions reduction.

3. Quantitative, detailed description of the INDC

This section describes the outlook for the energy mix and INDC officially shown by the Japanese government; all figures and graphs in this section are from official governmental sources. The government's plan regarding the energy mix and INDC is based on the macro-economic assumptions regarding population and GDP growth below. The average annual growth rate of GDP is 1.7% between 2013 and 2030: this GDP outlook corresponds to the 'economic recovery' case. Not only the INDC but also the most of the domestic policies by the government are developed based on this GDP outlook.

Table 2: Demographic evolution assumption for Japan (Source: METI/ANRI, 2015; National Institute of Population and Social Security Research, 2012)

Year	2013 (historical data)	2030
Population	127 million	117 million

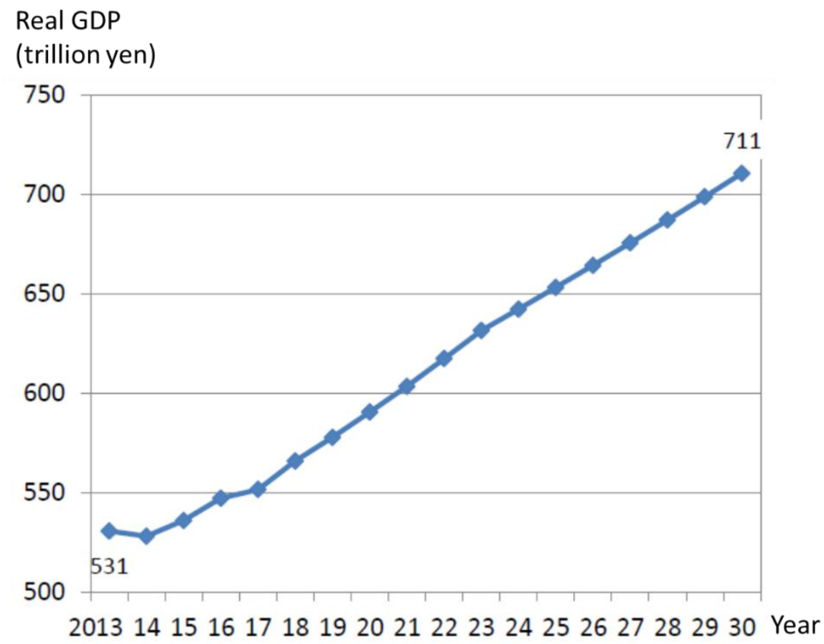

Figure 1: Estimation of middle and long-term GDP evolution (economic recovery case) (Source: METI/ANRI, 2015; Cabinet Office, Government of Japan, Feb. 12, 2015)

Approximately 90% of Japanese GHG emissions are energy-related CO2. The INDC implementation is closely linked therefore to the implementation of the 2030 vision for the energy mix. The two following paragraphs detail the government's proposition regarding energy supply measures and end-use measures by sector in order to build a well-balanced energy future based on the 3E+S objectives.

INDC and the energy mix

In order to ensure the achievability of the INDC, the government elaborated the breakdown targets by bottom-up calculation based on the energy mix with concrete policies, measures and individual technologies. Table 3 shows the estimated energy-related CO2 emissions in 2030 by sector.

Table 3: The expected energy-related CO2 emissions by sector for achieving the INDC
(Source: METI/ANRI, 2015)

	2005	2013	2030
Industry	457	429	401
Commercial and other	239	279	168
Residential	180	201	122
Transport	240	225	163
Energy conversion	104	101	73
Energy-related CO2 Total	1219	1235	927

[Value: million t-CO2]

Note: Emissions by sector include indirect emissions (e.g., electricity consumptions). Emissions from energy conversion is those of own use and losses in energy conversion.

The primary energy supply and final demands, and electricity supply in the energy mix is shown respectively in Figures 1 and 2. In the estimation, the government assumed the GDP growth of 1.7% per year between 2013 and 2030. A significant improvement of energy efficiency is expected in the energy mix:

- A cut of 13% in energy consumption compared to baseline (50.3 million kL (crude oil equivalent))
- A cut of 17% in electricity consumption compared to baseline (196.1 TWh)

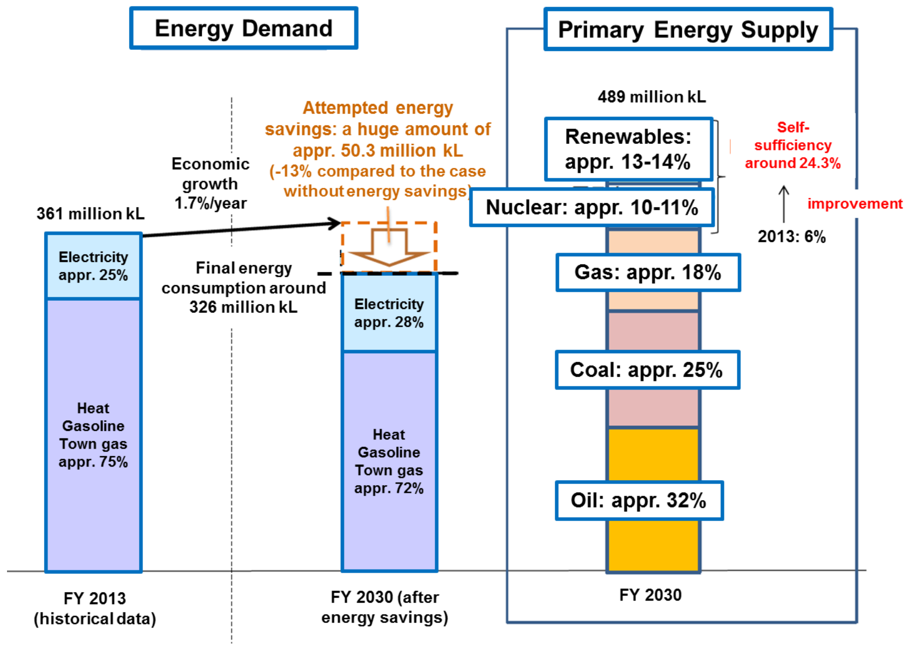

Figure 2: Final energy demand and primary energy mix in 2030 (Source: METI/ANRI, 2015)

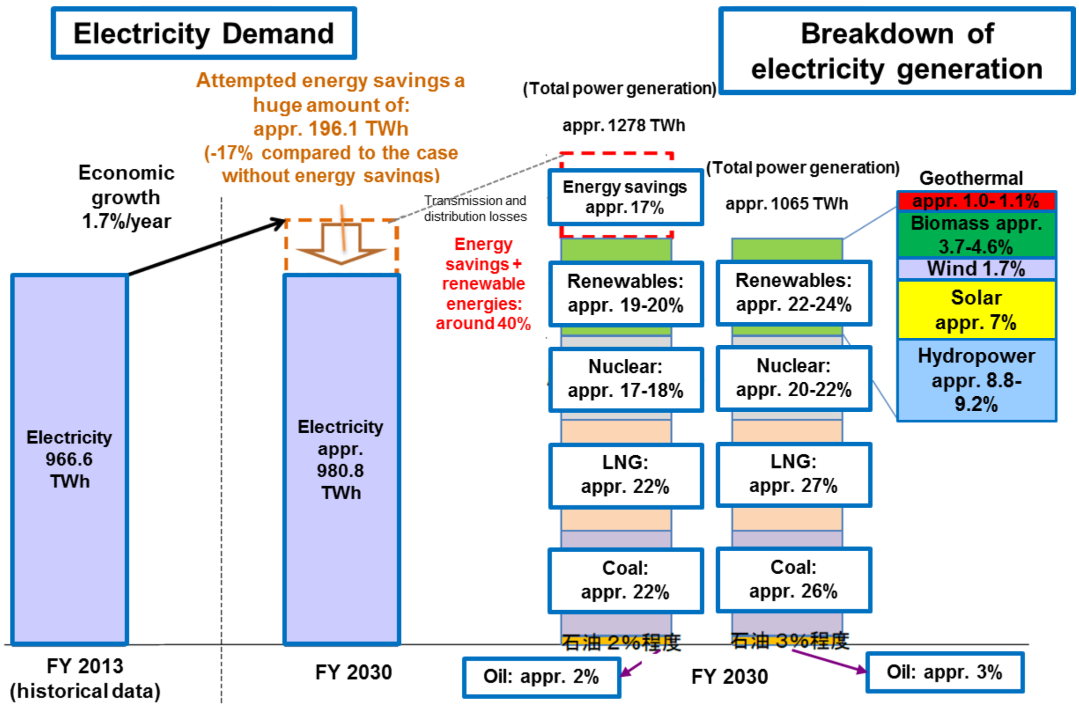

Figure 3: Electricity mix in 2030 (Source: METI/ANRI, 2015)

The government intends to reduce the dependence on nuclear power compared with the share of nuclear power before the accident. On the other hand, all of the nuclear reactors are stopped as of the end of June 2015[1], and large amounts of CO_2 are emitted by fossil fuel power substituting nuclear power. The government introduced a feed-in tariff after the nuclear power accident to strongly promote renewable energies, and has already achieved a significant introduction of photovoltaics in particular. However, the electricity costs are increasing. The government intends to reduce both CO_2 emissions and electricity costs. The well-balanced electricity mix was determined to include the restart of nuclear power, renewable energy increases (well-balanced increases in energy sources within renewables), and increases in efficiency of fossil fuel power in order to achieve both a reduction in CO_2 emissions and electricity costs (see Figures 3 and 4). In this case, the self-sufficiency of energy is expected to be 24.3% which nearly corresponds to that before the nuclear power accident.

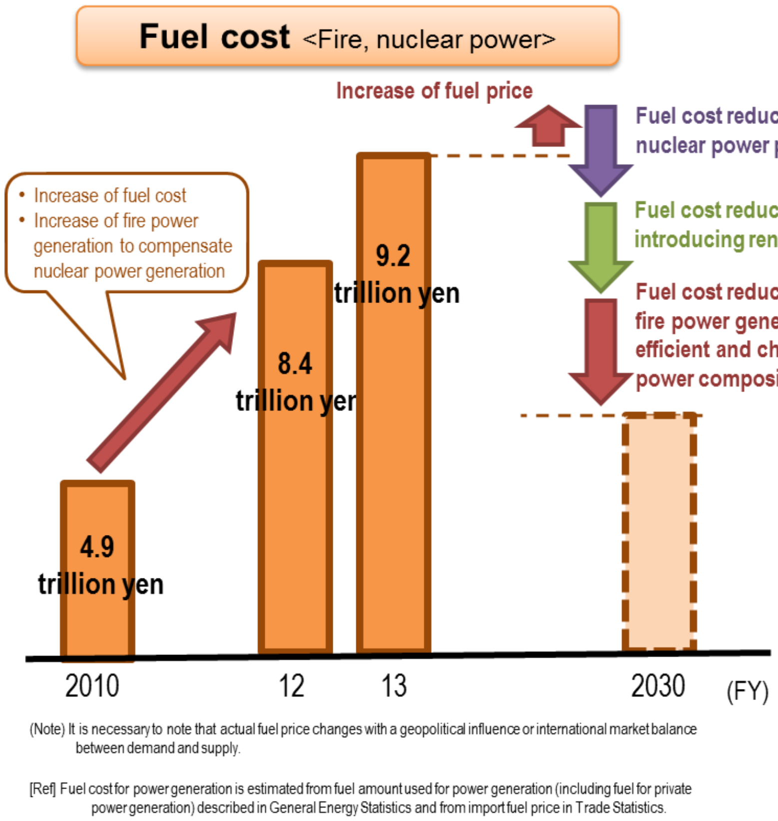

Figure 4: Expected fossil fuel and expected expenses in 2030 (Source: METI/ANRI, 2015)

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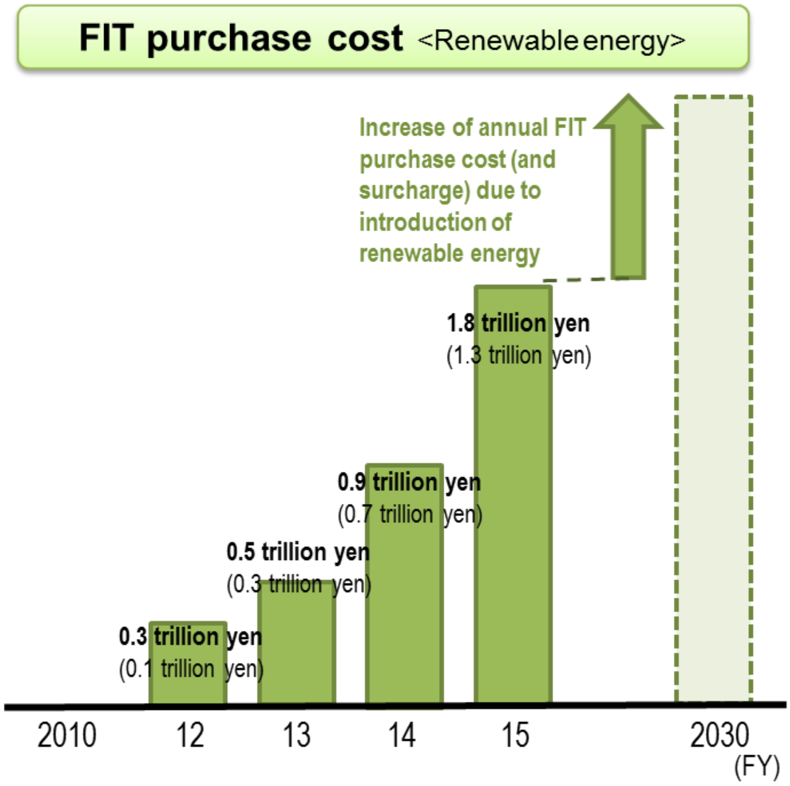
[1] The unit 1 of Sendai nuclear power station was restarted on August 11, 2015. In addition, the evaluations by the Nuclear Regulation Authority under the new regulations after the Fukushima Dai-ichi Nuclear Power accident for the unit 2 of Sendai nuclear power station, the units 3 and 4 of Takahama nuclear power stations, and the unit 3 of Ikata nuclear power station were finished as of August 11, and are prepared to be restarted. 20 reactors are under the evaluation processes by the Nuclear Regulation Authority.



(Note) Purchase cost = surcharge + avoided cost + office expense at cost burden management agency
Purchase cost and surcharge are not actual but estimated ones.

Figure 5: Renewable expenses trends and expected expenses in 2030 (Source: METI/ANRI, 2015)

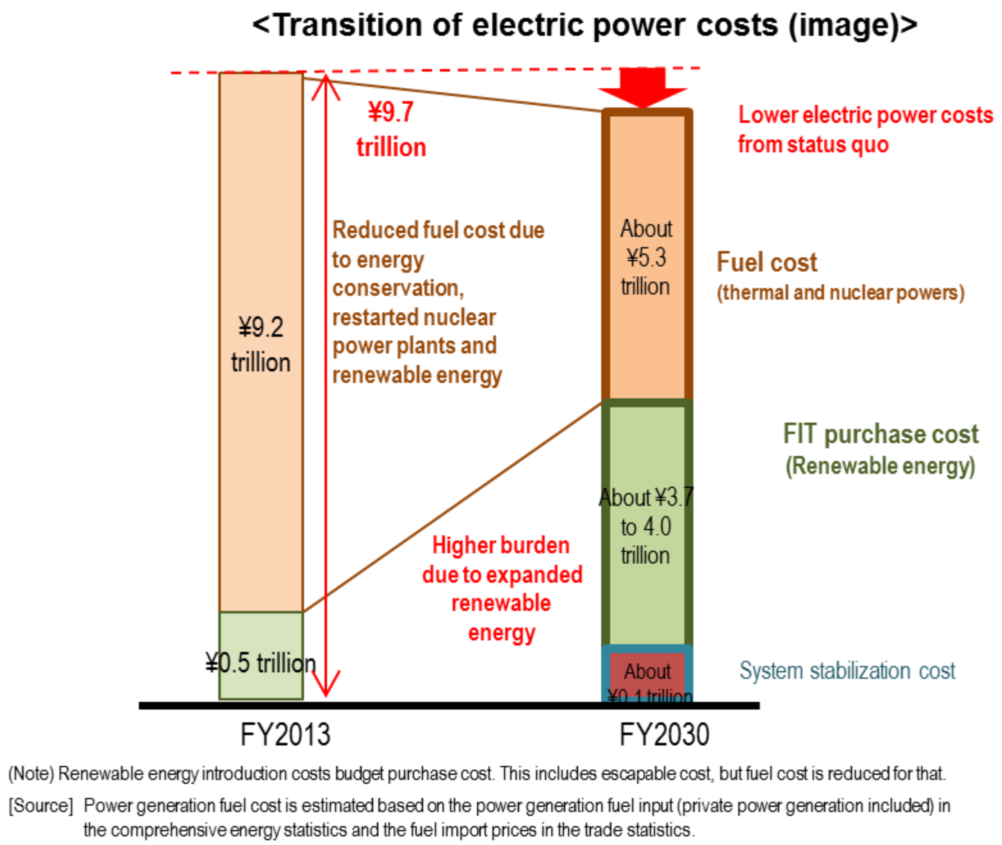


Figure 6: Structure of national expenses for electricity in 2013 and 2030 (Source: METI/ANRI, 2015)

Sectoral disaggregation of INDC

The government submitted a detailed plan for the measures to be implemented to reach the INDC: examples are listed inthe following tables, while the full tables are available in appendixes.

Table 4: Examples of measures for energy-originated CO_2 (source: Submission of Japan's INDC)

Energy-originated CO2	
Industry sector	□ Promotion and enhancement of the industries' action plans towards a low carbon society Iron and steel industry □ Introduction of innovative processes: coke making process (SCOPE21), ironmaking process (Ferro Coke), environmentally harmonized steelmaking process (COURSE50) Chemical industry □ Introduction of technology which uses CO2 as a feedstock □ Introduction of technology for using waste (e.g. waste plastic, etc.) as alternative thermal energy, waste water processing with microbe catalysis Cross-sectoral/Other □ Introduction of high-efficient air conditioner, industrial HP (heating-drying), industrial light, industrial motor... □ Introduction of hybrid construction machine, etc.
Commercial and other sectors	□ Promotion of compliance of energy saving standards for newly constructed buildings □ Introduction of commercial-use water heater (latent heat collection water heater, commercial-use heat pump water heater, high-efficient boiler) □ Introduction of highly efficient light □ Introduction of refrigerant control technology (F-gases) □ Expansion of shared use of energy □ Promotion of measures for energy efficiency and conservation of/energy generation from sewerage systems, in water business
Residential sector	Promotion of compliance of energy saving standards for newly constructed housing □ Promotion thermal insulation in renovation of existing houses □ Introduction of high-efficient water heater (CO2 refrigerant HP water heater, latent heat collection water heater, fuel cell, solar water heater) □ Introduction of high-efficient light □ Promotion of nationwide campaigns (thorough promotion of Cool Biz/Warm Biz, and encouragement of purchase of upgraded, Home CO2 advisor) □ Increasing Johkasou energy efficiency and conservation
Transport sector	Improvement of fuel efficiency □ Promotion of next-generation automobiles □ Other measures in transport sector (traffic flow improvement, promotion of public transport, modal shift to railway, ...)
Energy conversion sector	□ Expanding renewable energy introduction to the maximum extent possible □ Utilizing nuclear power generations whose safety is confirmed □ Pursuit of high efficiency in thermal power generation (USC, A-USC, IGCC, etc.)
Cross-sectional strategies	□ Promotion of the J-Credit Scheme

Energy-originated CO_2	
Industry sector	□ Promotion and enhancement of the industries' action plans towards a low carbon society Iron and steel industry □ Efficiency improvement of electricity-consuming facilities □ More chemical recycling of waste plastic at steel plants □ Introduction of next-generation coke making process (SCOPE21) □ Improvement of power generation efficiency □ Enhanced energy efficiency and conservation facilities □ Introduction of innovative ironmaking process (Ferro Coke) □ Introduction of environmentally harmonized steelmaking process (COURSE50) Chemical industry □ Introduction of energy efficiency and conservation process technology in petrochemicals □ Introduction of energy efficiency and conservation process technology in other chemical industry □ Introduction of energy efficiency and conservation technology using membranes for distilling process □ Introduction of technology which uses CO_2 as a feedstock □ Introduction of chemical product production technology with inedible plant-based material □ Introduction of electricity-generating waste water processing with microbe catalysis □ Introduction of sealed plant factory Ceramics, stone and clay products industry □ Introduction of conventional energy efficiency and conservation technologies (waste heat power generation, slag crusher, air-beam cooler, separator improvement, vertical roller coal mills) □ Introduction of technology for using waste (e.g. waste plastic, etc.) as alternative thermal energy □ Introduction of innovative cement production process □ Introduction of glass melting process Pulp/paper/paper products manufacture industry □ Introduction of high-efficient pulp production technology using old paper □ Introduction of high-temperature and pressure recovery boilers Cross-sectoral/Other □ Introduction of high-efficient air conditioner □ Introduction of industrial HP (heating-drying) □ Introduction of industrial light □ Introduction of low-carbon industrial furnace □ Introduction of industrial motor □ Introduction of high performance boiler □ Direct use of recycled plastic flakes
Commercial and other sectors	□ Promotion of compliance of energy saving standards for newly constructed buildings □ Energy efficiency and conservation buildings (remodeling) □ Introduction of commercial-use water heater (latent heat collection water heater, commercial-use heat pump water heater, high-efficient boiler) □ Introduction of highly efficient light □ Introduction of refrigerant control technology (F-gases) □ Improvement of energy efficiency and conservation performance of equipment by the top runner program, etc. □ Thorough implementation of energy management in commercial sector with BEMS and energy efficiency diagnosis □ Efficient use of light □ Promotion of nationwide campaigns (thorough promotion of Cool Biz/Warm Biz, repair of local government buildings) □ Expansion of shared use of energy □ Promotion of measures for energy efficiency and conservation of/energy generation from sewerage systems □ Promotion of measures for energy efficiency and conservation/renewable energy in water business □ Promotion of activities based on action plans of local governments (administrative business section) □ Promotion of sorted collection and recycling of plastic containers and packaging □ Low-carbonization of cities by improving urban thermal environments through measures against the urban heat island effect □ Promotion of inter-ministry collaborative measures following the Roadmap of Global Warming Counter-measures, etc.

Table 5: Measures for non-energy-originated CO2 (source: Submission of Japan's INDC)

Non energy-originated CO2	Expansion of blended cement use Reduction of municipal solid waste incineration
CH4	Measures to reduce CH4 emissions from agricultural soils (reduction of CH4 emissions from paddy rice fields) Reduction of municipal solid waste disposed of by direct landfill Introduction of semi-aerobic landfill system for final disposal site of municipal solid waste
N2O	Measures to reduce N2O emissions from agricultural soils (reduction of N2O emissions originated from fertilizer application) Promote the advanced technologies in the sewage sludge incineration facilities
Fluorinated gases	Measures to control overall emissions of fluorinated gases (Act on Rational Use and Proper Management of Fluorocarbons, emission control through industries' voluntary action plans, etc.)
LULUCF sector Forest management Cropland management /Grazing land management Revegetation	Promote measures for greenhouse gas removals through the promotion of forest management/forestry industry measures Promotion of soil management leading to the increase of carbon stock in cropland Promotion of revegetation

Final energy consumption by sector is shown in Figure 7. The energy consumption of the industry sector is expected to increase slightly compared to the current level due to the expected economic growth and fewer opportunities for cost-efficient improvements in energy efficiency. On the other hand, the energy consumption in transportation, residential and commercial sectors is expected to reduce greatly. The structure of final energy consumption is expected to shift as well, as electricity is expected to play a greater role in final energy consumption in most sectors, including plug-in hybrid and electric vehicles in the transportation sector.

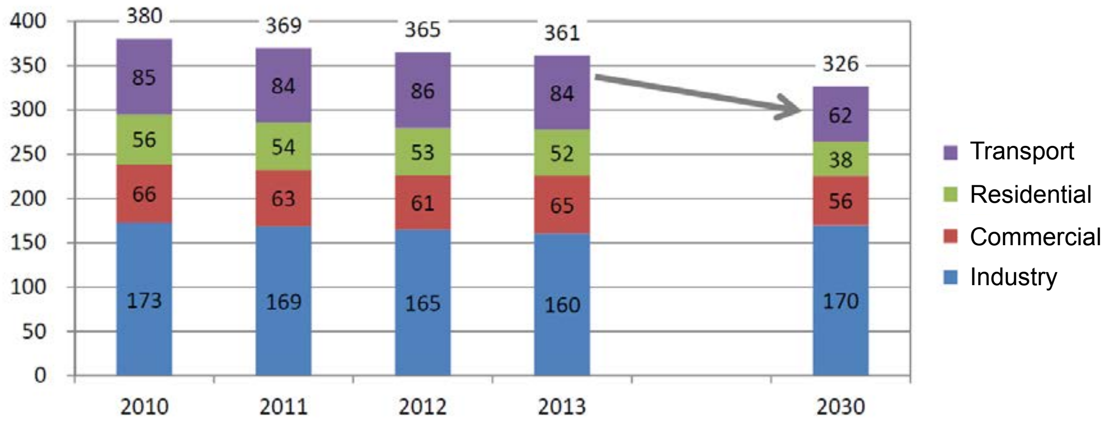


Figure 7: Trajectory of final energy consumption with sectoral disaggregation (-13% in energy consumption compared to baseline) (unit: million kL of oil equivalent per year); source: METI/ANRI, 2015)

The emission outlook is determined not only by CO2 intensity improvements but also by the production and service levels. The government assumes the production levels for major energy-intensive industries to be consistent with the assumption of macroeconomic growth of 1.7% per year (Cabinet Office Outlook). Projections for several main energy-intensive industrial products such as crude steel, ethylene, cement, and paper are shown in Figure 8. Most of the production is assumed to be roughly stable or slightly decrease toward 2030.

For example, for crude steel, the world's economic growth is expected to be centered in Asia in the next decades, and the Japanese production will be driven by both the national demand and the Asian demand[2]. Balancing the effect of growth and efforts towards a low carbon society has lead the government to project stabilized production for several main industrial products such as crude steel.

For cement, although the demand is expected to grow steadily until 2020 due to the post-2011 disaster reconstruction and the 2020 Olympic Games preparation, it should then decrease until 2030.

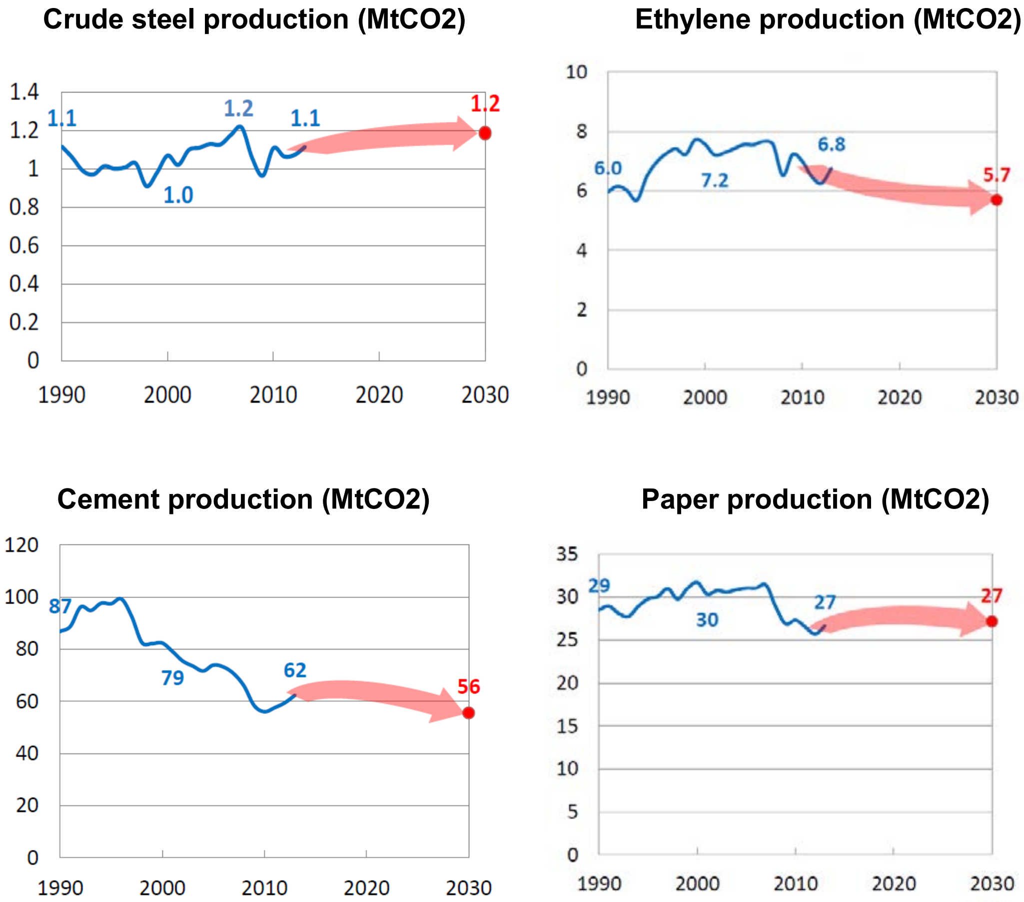


Figure 8: Projection outlook for crude steel, ethylene, cement, and paper productions in 2030 (Source: METI/ANRI, 2015)

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2 According to the 2014 statistics of the Japan Iron and Steel Federation, Japan exports 43 % of their iron and steel products (in metric tons), 77% of which in Asia.

Contributions towards achieving the ultimate objective of the UNFCCC

In the Government's INDC, it is described that Japan's INDC is consistent with the long-term emission pathways up to 2050 to achieve the 2 degrees Celsius goal as presented in the IPCC AR5, and with the goal the country upholds, namely, "the goal of achieving at least a 50% reduction of global GHG emissions by 2050, and as a part of this, the goal of developed countries reducing GHG emissions in aggregate by 80% or more by 2050".

4. Critical analysis

This section presents the critical analysis presented by each institute, NIES and RITE.

The NIES analysis mainly focuses on feasibility and robustness of Government's INDC by 2030 and a consistency with the long-term emission pathways up to 2050 to achieve the 2 degrees Celsius goal. In addition, it assesses a possibility and impact of enhanced action by 2030 toward the 2050 target which is to reduce GHG emissions by 80%.

The RITE analysis evaluates the economic impacts of the government's target on GDP and household consumption, and compares them with scenarios previously developed with RITE models; it assesses their fairness and ambition from an international perspective by comparing indicators such as energy efficiency performances, GHG intensity of GDP, emissions per capita, emission reduction costs per GDP and marginal abatement costs.

4.a NIES Analysis

Methodology

The Asia-Pacific Integrated Model (AIM) is a large-scale computer simulation model developed by the National Institute for Environmental Studies, Kyoto University and Mizuho Information & Research Institute in collaboration with several research institutes in the Asian-Pacific region (Kainuma et al., 2003).

The NIES analysis here uses the AIM/Enduse model which is a dynamic recursive and technology selection model for the mid- to long-term mitigation policy assessment. The model covers both end-use sectors (transport, industrial, residential and commercial) and the energy supply sector. Non-energy sectors (e.g. agriculture, industrial process, waste) are also included and non-CO_2 gases including CH_4, N_2O, hydrofluorocarbon (HFC), perfluorocarbon (PFC) and SF_6 (these emissions are converted into CO_2-equivalents using the GWP based on the IPCC SAR (GIO, 2014)) but NF_3 emission and emission/carbon sink from LULUCF are excluded. In each sector, service demands are given exogenously and technologies are selected in order to minimize total system costs (capital cost, energy cost and carbon price).

The model used for this analysis is a multi-regional version of AIM/Enduse[Japan]. This model explicitly distinguishes 10 regions to assess the regional differences in renewable energy potentials and energy demand characteristics. These 10 regions coincide with the business areas of 10 public power supply firms. For the details of AIM/Enduse[Japan], see Appendix I.

AIM/Enduse[Japan] broadly takes into account the mitigation options of the Government's INDC by 2030. However, some options which contribute to cut service demands, such as energy management in factories, promotion of Cool-Biz/Warm-Biz[3], promotion of public transport and modal shift to railways are not taken into account as mitigation options, since it is difficult for technology selection model to consider the effect of these options. In addition, as the technology selection is determined based on cost minimization, the levels of introduction of each mitigation option are not precisely consistent with those of the Government's INDC.

Scenarios

For NIES analysis, three different scenarios are developed in order to analyze feasibility and robustness of Japan's INDC, and an opportunity for further emission reduction by 2030 toward the 2050 target. In NIES INDC Scenario, the level of GHG emissions is consistent with Government's INDC in 2030 and with long-term reduction target in 2050. In Enhanced Action Scenario, an opportunity for further reduction in 2030 is assessed. In Low-Nuclear Scenario, uncertainty of the availability of nuclear power is considered.

Regarding the long-term GHG emission reduction target, it is described in the Government's INDC that Japan's INDC is consistent with the long-term emission pathways up to 2050 to achieve the 2 degrees Celsius goal and with the goal the country upholds, namely, "the goal of achieving at least a 50% reduction of global GHG emissions by 2050, and as a part of this, the goal of developed countries reducing GHG emissions in aggregate by 80% or more by 2050". In addition, in the Fourth Basic Environment Plan, the target in 2050 is set to reduce GHG emission by 80%. Hence, NIES analysis sets the 2050 target to reduce GHG emission by 80% compared to the 1990 level (Government of Japan, 2013).

For all scenarios, carbon prices are set as a driver for introduction of mitigation options, coupled with the energy efficiency standards for new buildings and houses which is also modelled in the Current Policies Scenario of WEO 2014 (IEA, 2014). However, other policies such as feed-in-tariff for renewable energies, subsidies for low-carbon technologies and fuel economy target for vehicles are not taken into account.

Followings are the detailed descriptions of each scenario.

- NIES INDC Scenario – This scenario sets the target of reducing GHG emissions by 2030 by the same level with the Government's INDC (25.4% reduction with respect to the 2005 level, including reduction in LULUCF and NF_3) and achieving the 80% reduction

[3] The Cool-Biz and Warm-Biz are the public campaigns which encourage people in offices to wear clothes that enable them to set the air conditioner to 28 degrees C in the summer and set the heating to 20 degrees C in the winter, and live comfortably at these room temperatures (the Government of Japan, 2013).

target by 2050 thereafter. Excluding emissions from LULUCF and NF_3, the INDC target of 25.4% reduction by 2030 corresponds to approximately 22.7% with respect to the 2005 level.

In this scenario, availability of nuclear plant is given based on New Policies Scenario developed by IEA's World Energy Outlook 2014 (IEA, 2014); a lifetime of plants built since the mid-1980s is extended to 60 years and limited to 40 years for all others. Complying with this assumption, electricity generation from nuclear plant in 2030 accounts for approximately 232 TWh. It is broadly consistent with the description in the Long-term Energy Supply and Demand Outlook for 2030 which projects between 217 TWh and 232 TWh in 2030 (METI/ANRE, 2015). Extrapolating this assumption toward 2050 without any new construction or replacement of nuclear plant, the electricity supply from nuclear power will be approximately 184 TWh in 2050.

- Enhanced Action Scenario – This scenario illustrates the opportunity for further decarbonization by 2030 from the level of the Government's INDC. In this scenario, carbon prices are increased linearly from 2016 to 2050 in order to achieve 80% reduction target by 2050. This means a carbon price in 2030 reaches roughly a half of the 2050 level. Assumptions on availability of nuclear power are the same as NIES INDC Scenario.
- Low-Nuclear Scenario – Considering the uncertainty of availability of nuclear power plants, all nuclear plants are not assumed to operate more than 40 years in Low-Nuclear Scenario. In this scenario, new constructions and replacements of existing nuclear plants are not considered as well and capacity factor of nuclear plant is fixed up to 70%. In this scenario, the electricity supply from nuclear power will be zero in 2050. Assumptions on GHG emissions constraint are the same as NIES INDC Scenario.

Assumptions on population and economic growth by 2030 is consistent with the Government's INDC and the Long-term Energy Supply and Demand Outlook. From 2030 to 2050, economic growth is estimated using GDP growth per capita of SSP5, conventional development scenario of Shared Socioeconomic Pathways (IIASA, 2015). Population prospects are taken from the perspectives by National Institute of Population and Social Security Research (IPSS, 2012). Assumptions on socio-economic indicators up to 2050 are summarized in Table 6.

Table 6: Assumptions on population and economic growth for NIES analysis[4]

	2005	2030	2050
Population (Million)	128	117	97
Real GDP (billion US$$_{2005}$)	4,572	6,406	8,285

Assessing feasibility and robustness of Government's INDC

The purpose of this section is to assess feasibility and robustness of Japan's INDC based on the developed three scenarios by 2030 with AIM/Enduse model.

In NIES INDC Scenario and Low-Nuclear Scenario, carbon prices in 2030 are estimated approximately as 187 US$/t-$CO_2$ and 236 US$/t-$CO_2$ respectively in order to cut GHG emissions by approximately 22.7% with respect to the 2005 level. In Enhanced Action Scenario, GHG emissions are reduced furthermore; 25.3% with respect to the 2005 level and the carbon price in 2030 rises to approximately 220 US$/t-$CO_2$ (Figure 9, Table 7). The carbon price in this analysis is directly linked to the marginal cost to achieve the INDC target. However, it should be noted that additional policy tools such as mandatory standards and recycle of carbon tax revenue could help to lower the actual carbon prices.

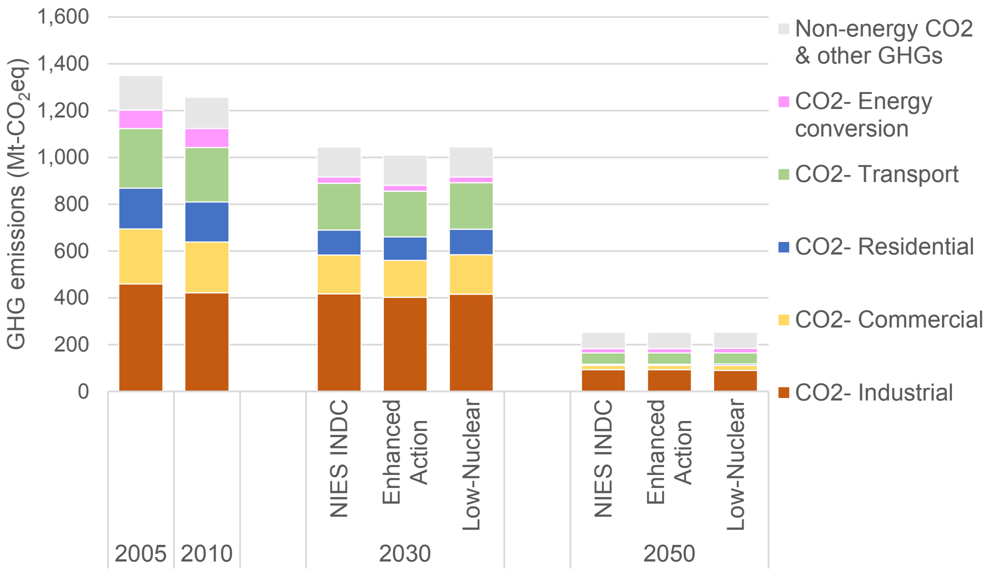


Figure 9: GHG emissions for the different scenarios developed by NIES[5]

[4] The Government of Japan (2015), IIASA (2015), IPSS(2012), METI (2015)

[5] Both direct and indirect emissions are included. The data for FY2005 and FY2010 is taken from historical GHG emission which is based on GWP subjected to IPCC SAR. As the authorized historical data has been changed to the GHG based on GWP_{100} subjected to IPCC AR4 since 2013, the data for FY2013 is not appeared in the figure.

Table 7: Carbon prices for the different scenarios developed by NIES

Scenario	2030	2050
NIES INDC Scenario	187	523
Enhanced Action Scenario	220	514
Low-Nuclear Scenario	236	631

(Unit: US$/t-$CO_2$)

The further reduction in Enhanced Action Scenario by 2030 compared to NIES INDC Scenario is due to a switch from coal to natural gas and an additional deployment of renewable energies mainly in the power sector. As shown in Figure 10, in the Enhanced Action Scenario, power generation from gas fired plants and renewable energies, such as solar PV and biomass, is increased and a share of coal fired plant falls approximately 13%, while it accounts for 17% and 18% in NIES INDC Scenario and Low-Nuclear Scenario, respectively. However, a share of coal fired plants falls to lower level compared to the 2010 level even in NIES INDC Scenario because of high carbon prices, while Government's INDC requires a share of coal at, where it approximately 26% in 2030 in consideration of its stability of supply and economic competitiveness.

In NIES INDC Scenario, a share of renewable energies rises to around 20% in 2030 which is slightly lower than the Government's INDC (22%-24%). The share of renewable energies accounts for approximately 23% and 29% in Enhanced Action Scenario and Low-Nuclear Scenario respectively where the coal fired plants and nuclear power plants are replaced by renewable energies. A share of renewable energies stays below 30% in 2030 even in Low-Nuclear Scenario despite the high carbon prices due mainly to the fragmented potential of renewable energies with narrow interconnection capacity between the 10 regions in Japan (As shown in Appendix I, AIM/Enduse considers the constraints on regional renewable potential and interconnection capacity). Additionally, it should be noted that the additional policies, such as feed in tariff and subsidies for renewable energies, are considered, a share of renewable energies could be increased.

With respect to the 2013 level, total electricity generation in 2030 is almost the same level because of economic growth and electrification in the demand side. This trend is roughly consistent with the Government's INDC.

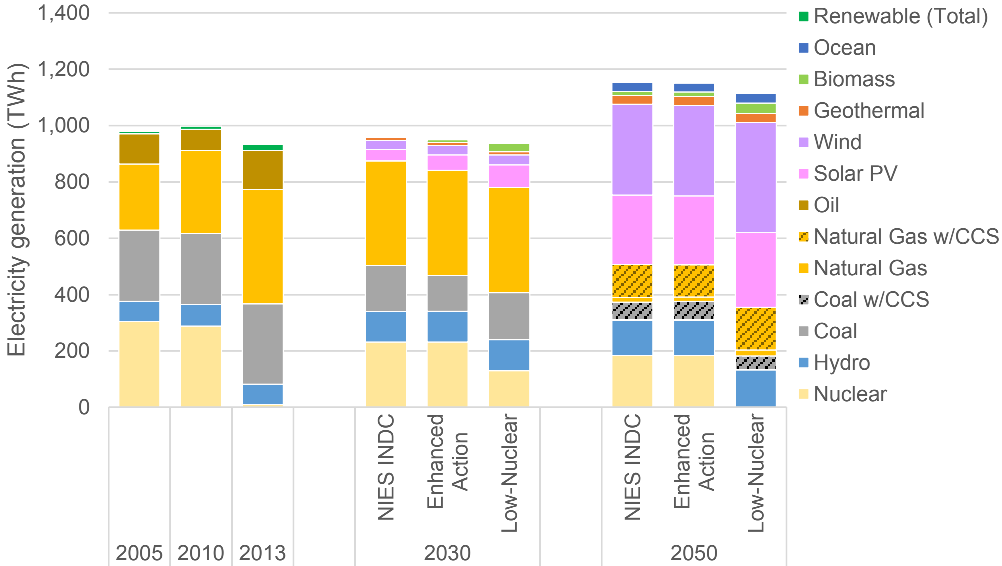


Figure 10: Electricity generation for the different scenarios developed by NIES[6]

Final energy consumption in NIES INDC Scenario is decreased by around 9% with respect to the 2010 level. The level of energy efficiency in the model used for NIES analysis is moderate compared to the Government's INDC which accounts for 14% due mainly to absence of some mitigation options which cut service demand, as it is difficult for technology selection model to take into account the effect of these abatement options.

Even in Enhanced Scenario and Low-Nuclear Scenario, which applies higher carbon prices, final energy consumption in 2030 stays the same level as NIES INDC Scenario. It implies most of cost-effective energy efficiency option is introduced even in NIES INDC Scenario and remaining potential to additional reduction of energy use is insufficient excluding the options which cut service demand. Therefore, it seems that the level of reduction of final energy demand in Government's INDC is appeared to be reasonable considering its high economic growth.

[6] The data for FY2005, FY2010 and FY2013 is taken from historical electricity generation. Electricity generation by autoproducers are excluded in this figure.

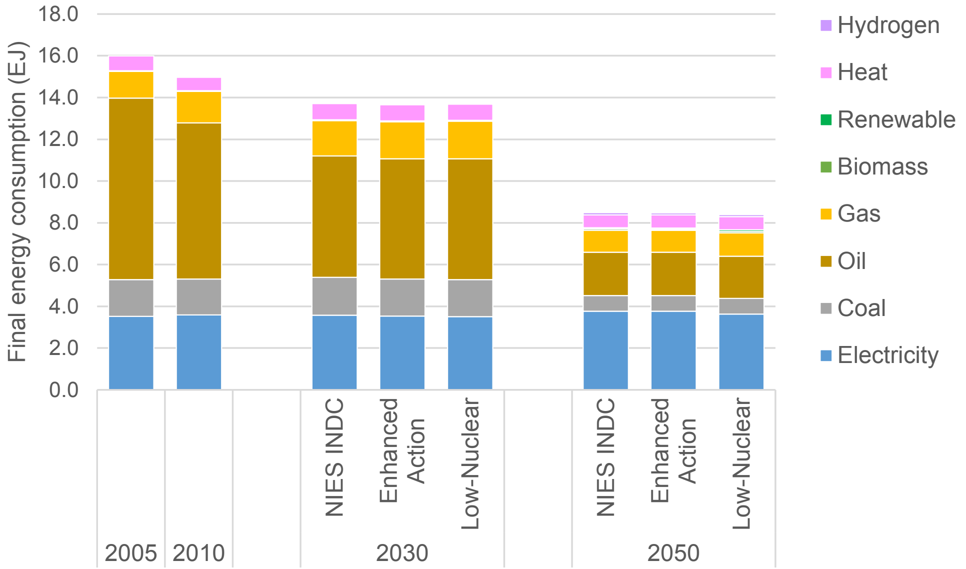


Figure 11: Final energy consumption for the different scenarios developed by NIES[7]

Figure 11 summarizes import bills of fossil fuels in the different scenarios which is estimated based on the perspectives of fossil fuel import prices taken from IEA's Energy Technology Perspectives 2015 (IEA, 2015). In 2030, it falls to approximately 220 billion US$ despite of a rise of crude oil prices. However, import bills in Enhanced Action Scenario stays at the same level as NIES INDC Scenario because the impact on energy costs of a switch from coal to gas nearly compensates that of improvement in energy efficiency and additional deployment of renewable energies. Hence, promotion of early actions especially on gasification by 2030 entails challenges associated with energy security issue and impacts on end-use energy price such as electricity.

[7] The data for FY2005 and FY2010 is taken from historical energy consumption from the energy balance statistics in Japan. As the structure of the statistics has been updated since 2013 in Japan, the data for FY2013 is not appeared in the figure. It should be noted that energy unit is described in HHV complying with the manner of the Energy Balance Statistics.

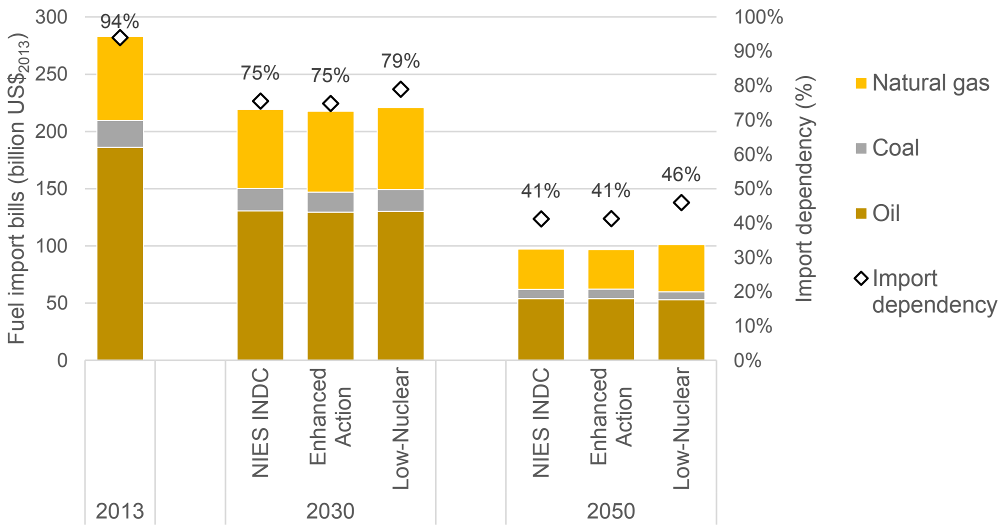


Figure 12: Fuel import bills for the different scenarios developed by NIES

Figure 13 shows the improvements of energy and carbon intensity in the final energy sectors under the NIES INDC scenario. It can be seen that the industry, buildings and passenger transport sectors require significant improvements in energy intensity by 2030 with respect to the 2010 level of approximately 27%, 18% and 27% respectively, while those in freight transport sector stay at around 7% in 2030. Likewise the carbon intensity (including direct and indirect emissions) of energy demand in the industry and buildings sectors improve by 12% and 16% between 2010 and 2030, thanks notably to electrification and gasification. In buildings sector, it can be seen that carbon intensity by 2020 increased by 3% with respect to the 2010 level because of a temporal rise of carbon intensity of electricity due mainly to reduction of nuclear power. By contrast, the carbon intensity of transport fuel declines only by 1% by 2030, reflecting limited electrification and biofuel penetration.

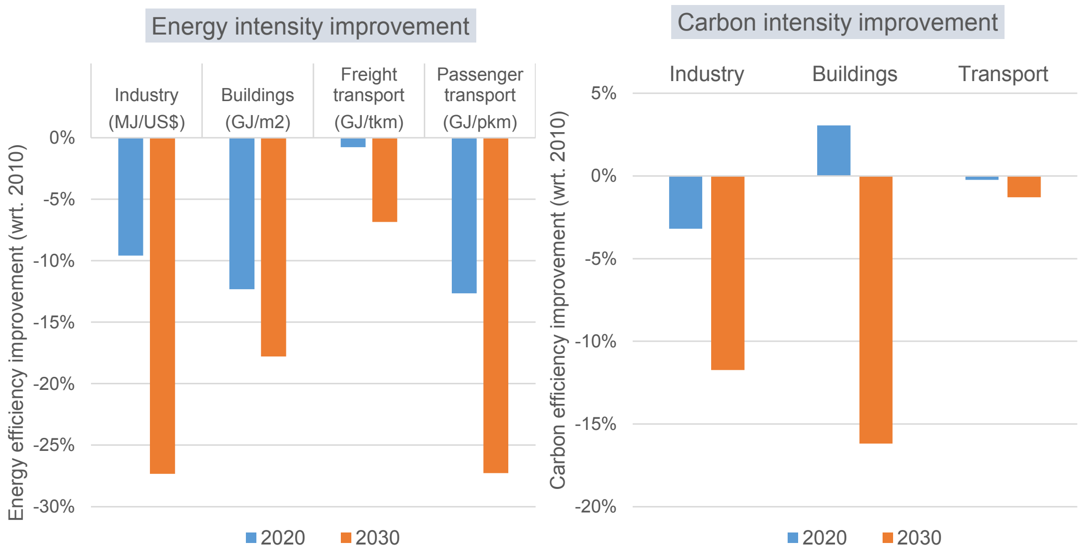


Figure 13: Improvement of energy and carbon intensity by sector in NIES INDC Scenario

Implications for the long-term decarbonization pathway

This section mainly focuses on the implications for the long-term target by 2050 which is to reduce GHG emission by 80% with respect to the 1990 level.

In NIES INDC Scenario, GHG emission reductions in 2050 reach80% due mainly to improvement in energy efficiency, electrification and decarbonization of electricity. Final energy consumption in 2050 is nearly halved compared to the 2005 level and electrification in demand side rises to more than 40% from 22% in 2005 (Figure 11). In addition, electricity is almost decarbonized because of both a large scale deployment of solar PV and wind power and a substitution from unabated coal/ gas fired plant to CCS equipped plant (Figure 10).

By 2050, a carbon price in NIES INDC Scenario rises to approximately 523 US$/t-$CO_2$. As it is not so far from the level of Enhanced Action Scenario, in which a carbon price in 2050 accounts for approximately 514 US$/t-$CO_2$, it is implied that the 80% reduction target is still technically feasible even if GHG emissions reduction in 2030 stays the same level as the Government's INDC.

In all scenarios assessed in NIES analysis, power generation from unabated coal fired plant is almost substituted by low carbon sources while unabated gas fired plants plays still important role as flexible resources in order to integrate variable renewable energies (VREs) in the long-term. Though, the switch from coal to gas in early stage entail the challenge associated with energy security, it could contribute to effective mitigation in the long run because they avoid lock-in of high carbon intensity plant.

Technical uncertainty associated with nuclear power

In Low-Nuclear Scenario, the 2030 target which reduces GHG emission to the level of INDC is still feasible with additional deployment of natural gas and renewable energies, which substitute nuclear power with low-carbon resources (Figure 9). However, a carbon price rises to 236 US$/t-$CO_2$ up to 2030 and import bills of fossil fuels become approximately 221 billion US$, which are 1.5 billion US$ higher than NIES INDC Scenario. The 80% reduction target in 2050 is also technically feasible with the entire phase out of nuclear power, with the deployment of CCS equipped as well as renewable energies, though carbon price reaches approximately 631 US$/t-$CO_2$ in 2050 in order to promote additional deployment of renewables, particularly VREs, and CCS-equipped natural gas plant as alternative low-carbon energies.

4.b RITE Analysis

The economic impacts and feasibility of the emission reduction target

Before the government provided the draft of INDC, RITE analyzed several scenarios of different electricity mix and CO2 emission reduction levels with RITE's economic models (a technology-rich energy systems model DNE21+ and a CGE-type energy-economic model DEARS: see Appendices for a detailed overview of each model). Compared with the analyses for the assumed scenarios by RITE, the GDP loss and consumption loss for the submitted INDC is expected to be substantial. The electricity mix (relative share by primary energy) proposed by the government is well-balanced enough not to trigger important economic losses. However, as to the absolute amount, substantial energy savings are expected, and therefore a relatively high economic impact is estimated to meet these goals.

According to DNE21+ model, the marginal abatement cost for the INDC is about 380$/tCO2eq for the 26% reduction of GHGs compared to 2013 and about 260$/tCO2eq for the 21.9% reduction of energy-related CO2 compared to 2013.

According to DEARS model, achieving these targets will require considerable costs on GDP and households consumption as shown in Figure 14.

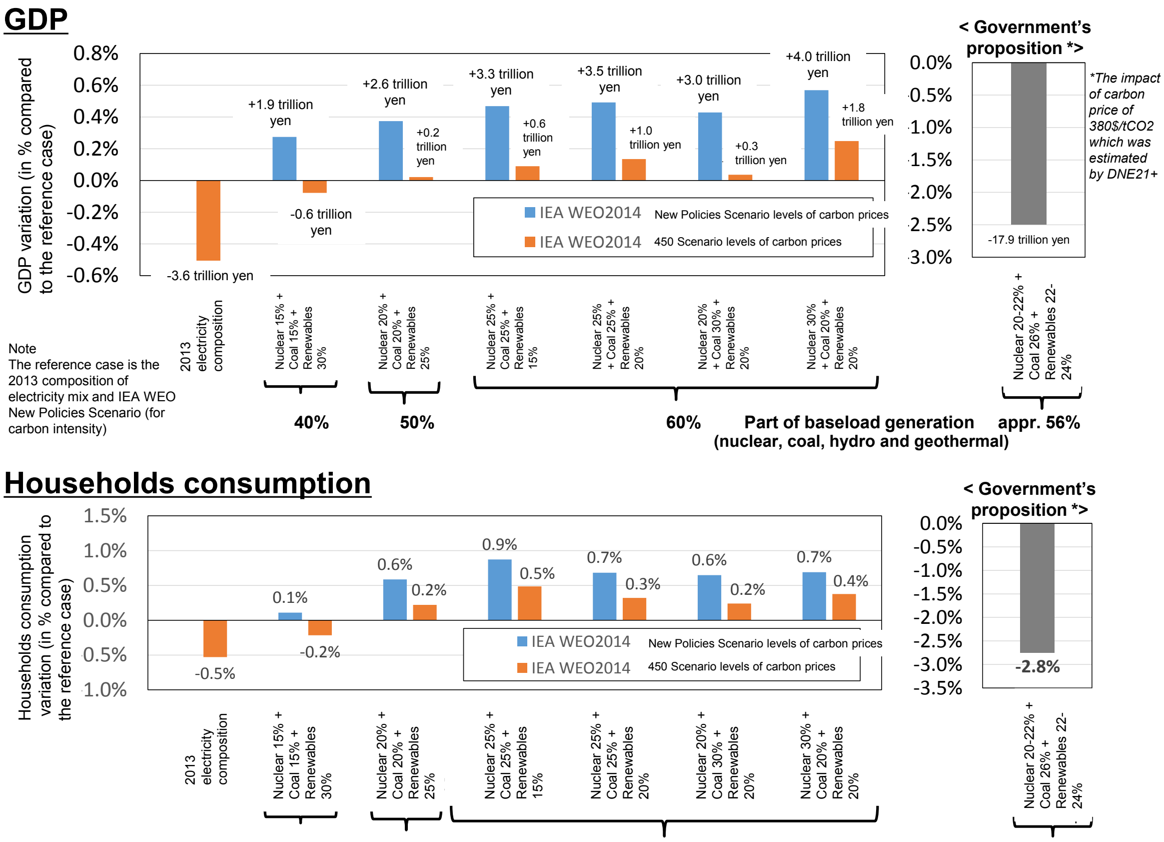


Figure 14: GDP and households consumption losses for the different scenarios assumed by RITE and for the INDC

As described in Section 3, in the government's proposition, despite a high GDP growth rate (1.7%/year) projection, the power generation after GHG reduction measures is anticipated to be almost constant. The GDP elasticity of electricity after the reduction measures is 0.05 between 2013 and 2030. The elasticity between 2000 and 2010 is nearly 1.0 in Japan. The elasticity will decrease gradually toward 2030 due to population decrease and industry structure changes (our estimates of the elasticity for 2013-2020 and 2020-2030 are respectively 0.8 and 0.6; the elasticity of IEA WEO2014 Current policy scenario for 2012-2030 is 0.7). However, the expected electricity generation in 2030 in the government's proposition is too small compared to the GDP outlook. In addition, the price elasticity is relatively small according to the historical records not only in Japan but also in EU countries. Japanese government has a priority to reduce electricity costs compared to the current level (around 30% increase compared to that before the nuclear power accident). Such large electricity savings should be achieved under a high GDP growth and reductions of electricity cost. Such a challenge should have important economic impacts as shown above.

Figure 15 and **Figure 16** show the energy mix and electricity mix for the different scenarios developed by DNE21+ model and for the INDC. For primary as well as electricity, the disparity between the government's proposed energy amount and the total amount in all other scenarios estimated by RITE shows how ambitious the government's objectives in terms of energy savings are.

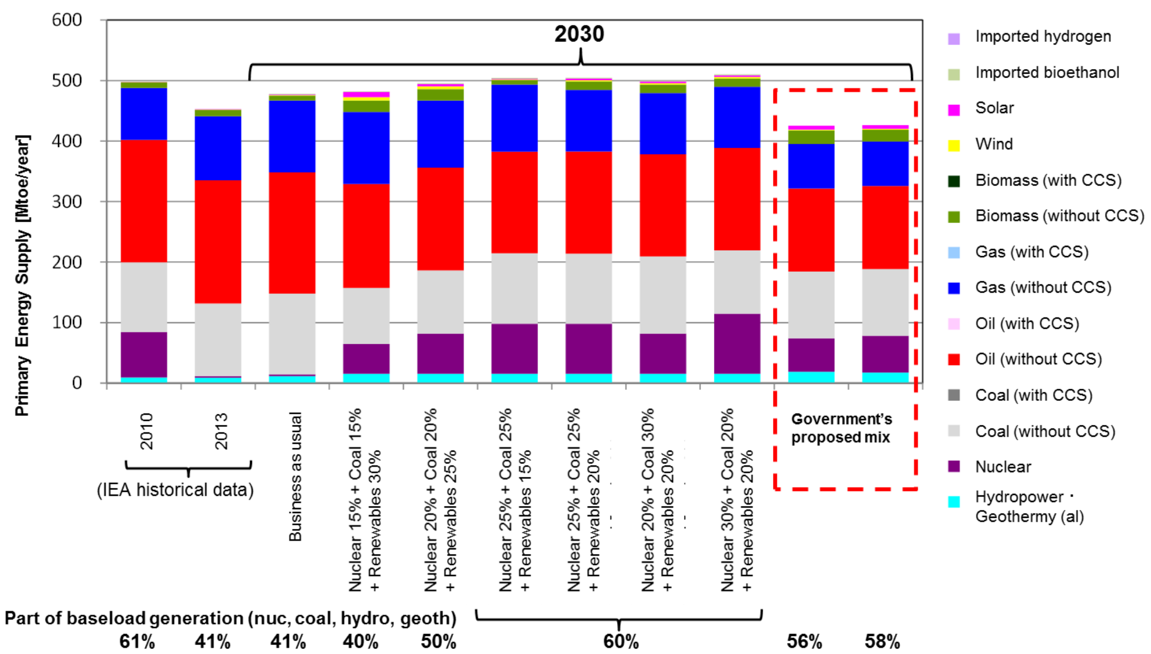


Figure 15: Primary energy mix for the different scenarios developed by RITE and for the INDC. The carbon prices for the RITE scenarios are assumed to be the same level of the Current Policies Scenario of IEA WEO2014 (37$/tCO2 in 2013 price which corresponds to 23$/tCO2 in 2000 price).

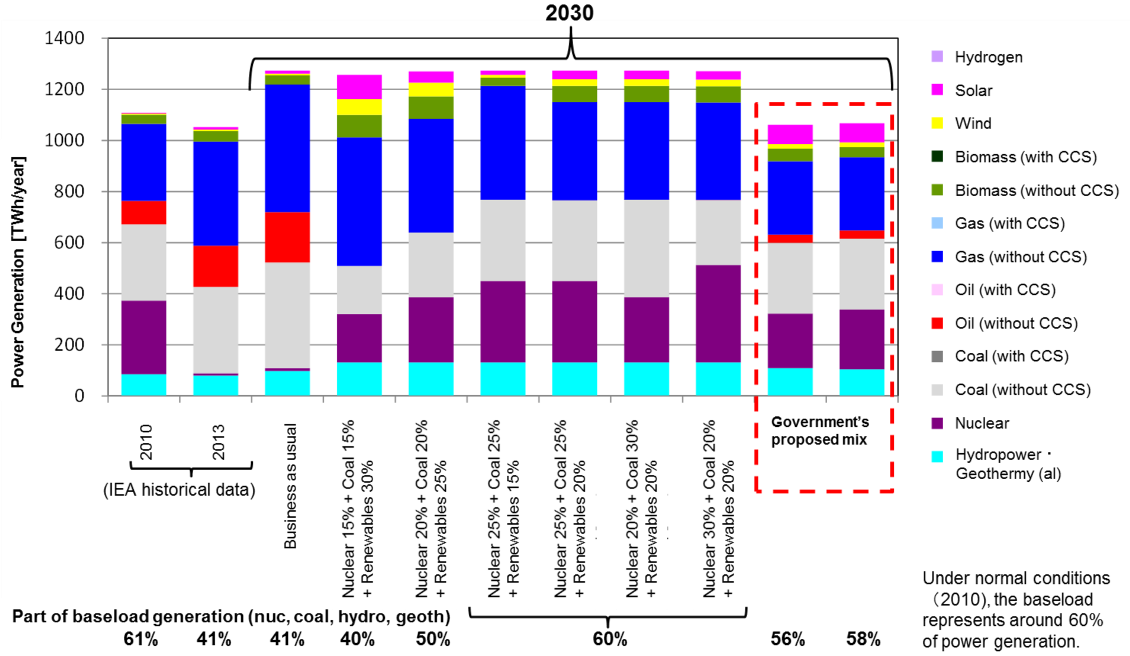


Figure 16: Electricity mix for the different scenarios developed by RITE and for the INDC. The carbon prices for the RITE scenarios are assumed to be the same level of the Current Policies Scenario of IEA WEO2014 (37$/tCO2 in 2013 price which corresponds to 23$/tCO2 in 2000 price). Also, the analysis with DNE21+ includes autoproducers in total power generation (unlike NIES analysis).

International Context: Fairness and Ambition

Japan's submitted INDC aims at achieving fairness and ambition regarding levels among world countries. This paragraph discusses quantative analyses on fairness and ambition in the international context.

Current energy efficiency performances in Japan

As discussed in Section 3 and in the previous paragraph, the government proposition has high targets in terms of energy savings. The government proposition especially counts on energy efficiency equipments to achieve these targets. A close look on energy performances in electricity generation and industrial sectors is given below. The energy efficiency for coal and gas power generation is shown in Figure 17 and Figure 18, respectively. Energy efficiency for coal power generation in Japan has been the highest among major countries for more than 20 years. The room of efficiency improvements is not large in Japan for this reason. According to Figure 18, energy efficiency for gas power generation is not the highest although it is very high compared to world levels. Replacements of existing old gas power stations to state-of-art gas combined power plants will be expected, and in the government's proposition, the efficiency improvements and the emission reduction effects are considered.

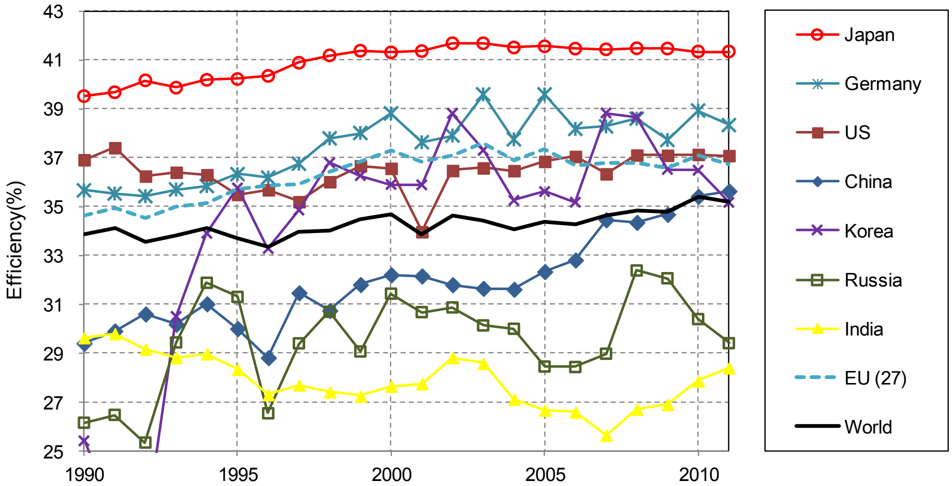


Figure 17: Efficiency of coal power generation. Source: RITE, 2014 (estimation based IEA data, 2013)

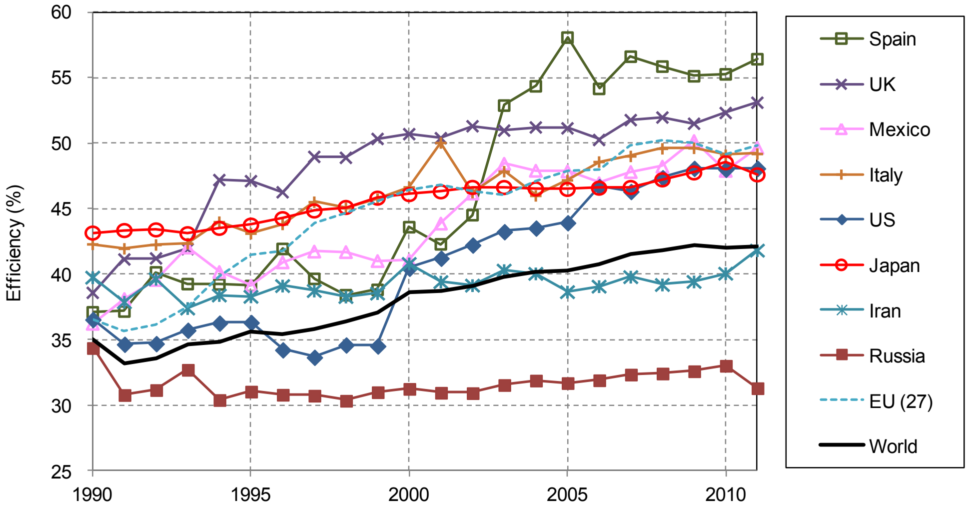


Figure 18: Efficiency of gas power generation. Source: RITE, 2014 (estimation based IEA data, 2013)

Figure 19 and Figure 20 show energy efficiencies for crude steel productions in the iron and steel sector and for clinker productions in the cement sector, respectively. According to both figures, Japan has the best performances among many countries. In these energy-intensive sectors, the room for efficiency improvements is not large in Japan.

Since electricity consumption is expected to decrease in the residential and comercial sectors rather than in the industry, the energy effiency will thus need apply to home appliances and optimizing individual consumption. Such a conclusion is however pretty consistent with the fact the government did not project a decrease in energy consumption for the industry sector. Innovative technology developments are required for further efficiency improvements in the power and industry sectors.

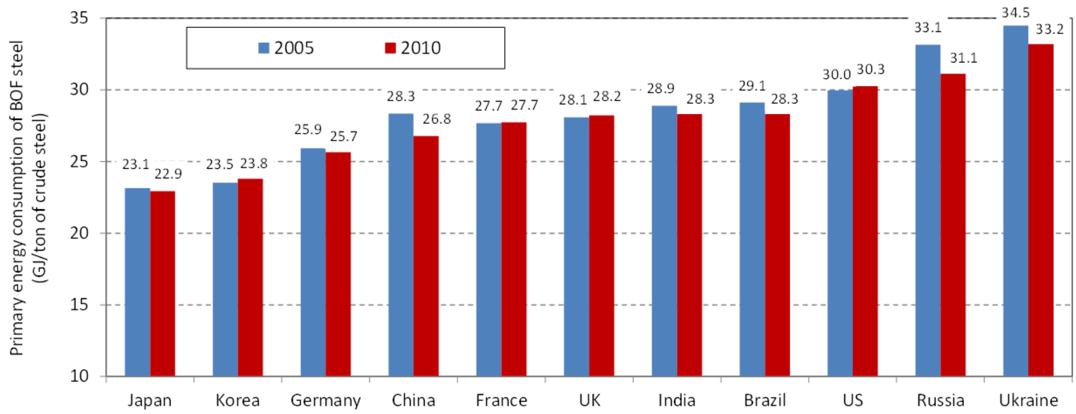


Figure 19: Energy consumption in the iron and steel sector (BOF steel). Source: Oda et al. 2012; RITE, 2012. Note: The efficiency in some countries in 2010 worsen compared to in 2005 mainly due to the decrease in the operation ratios.

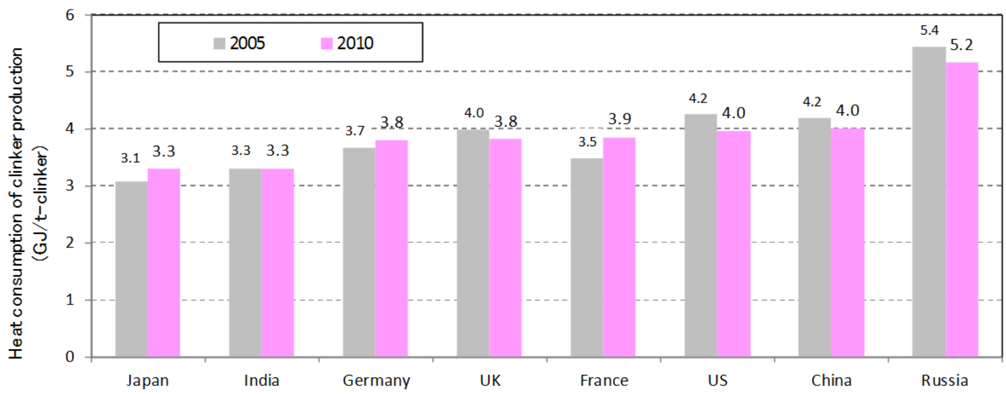


Figure 20: Heat consumption in the cement sector (clinker). Source: RITE estimate based on WBCSD/CSI data. Note: The efficiency in some countries in 2010 worsen compared to in 2005. Main reasons are increases in waste energy use and the decrease in the operation ratios.

Comparison of the level of ambition of Japan's INDC with other countries

Comparing the Japanese INDC to other submitted INDCs can be one way of putting them into perspective and assessing their relative ambition. The comparison in particular allows to explain why the Japanese government estimated their proposition to be appropriate given the already submitted INDC.

Table 8 shows the INDC for Japan, US, and EU, with the reduction rate from 1990, 2005, and 2013. The underlined figure represents the official announcement by the country.

Table 8: INDC for Japan and major economies

	Emissions reduction ratio from base year		
	From 1990	From 2005	From 2013
Japan: in 2030, -26% from 2013 levels	-18.0%	-25.4%	<u>-26.0%</u>
US: in 2025, about -26 to -28% from 2005 levels	-14 to -16%	<u>-26 to -28%</u>	-18 to -21%
EU28: in 2030, -40% from 1990 levels	<u>-40%</u>	-35%	-24%

According to the chosen base year, the apparent value of INDC changes; for instance, with 2013 as a base year, EU28 and Japan have relatively close INDC. Japan will need large emission reduction efforts toward 2030 to achieve the INDC. However, the existing energy efficiency is different among countries as shown in the previous paragraph, different expected economic growth rates etc., and therefore it is difficult to make a relevant comparison between INDC in terms of ambition from the emission reduction rates from a base year. Several indicators are required for measuring the ambition. This report shows the Japanese INDC in the international context by assessing them through a few significant indicators: the GHG intensity of GDP, the emissions per capita, the marginal abatement cost, and the emission reduction cost per GDP. Cost indicators have large uncertainties but also help to have a global view of the effort implied by the INDC.

Figure 21 shows the GHG intensity of GDP trajectories induced by the announced INDC in Japan, EU28, United States, Korea, China and Russia. We can see that developed countries aim at levels that are rather close, EU28 and Japan in particular. Japan is the lowest-carbon economy among the considered countries and remains so with the announced INDC.

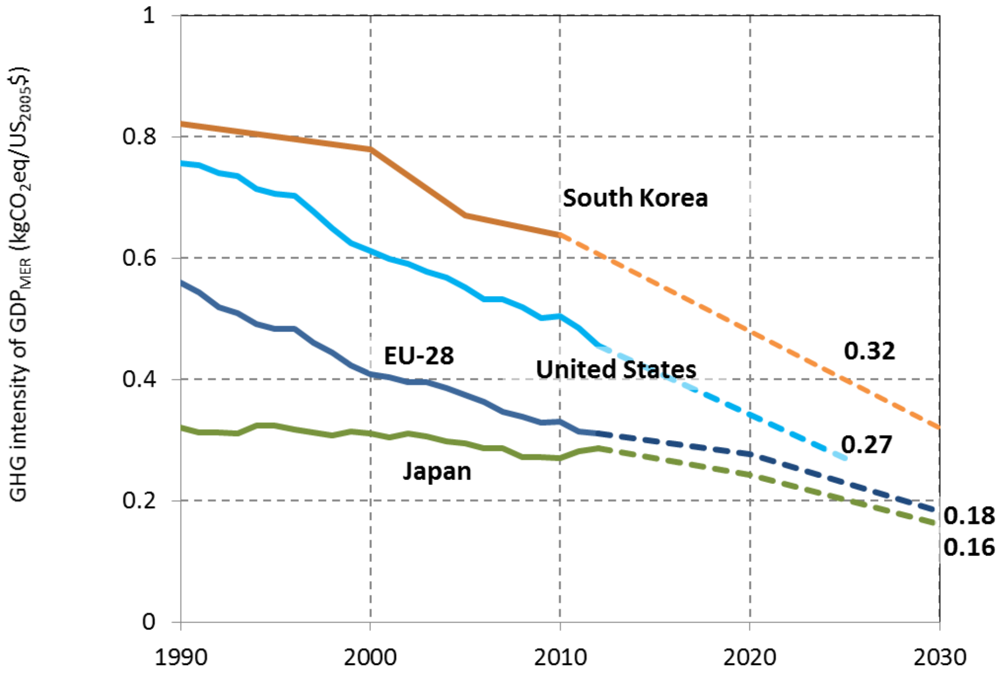


Figure 21: Evolution of GHG intensity of GDP_{MER} ($kgCO_2eq/US_{2005}\$$)

Figure 22 shows the emissions per capita trajectories induced by the submitted INDC in Japan, EU28, United States, Korea, China and Russia. Again, Japanese and European trends are the most alike: the INDC projects a progressive reduction of per capita emissions. EU28 has the lowest per capita emission objective. The INDC for the United States implies a more aggressive decrease given the current levels of emissions per capita. Population of Japan is expected to decrease toward 2030. Under the population reduction, the reduction rate of emission per capita is smaller than that of emission.

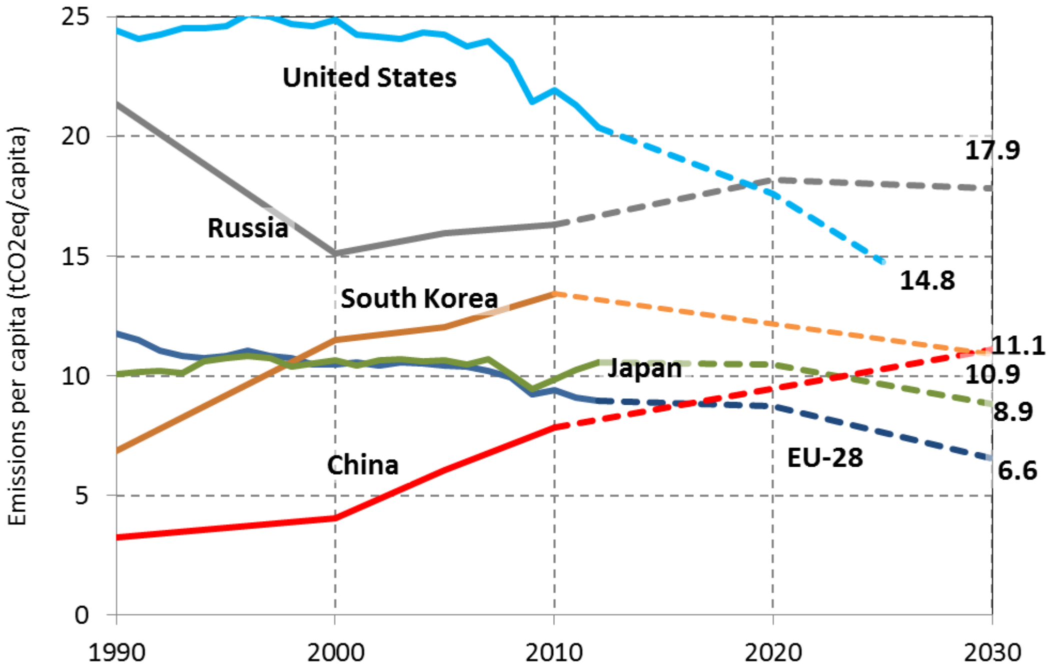


Figure 22: Emissions per capita (tCO2eq/capita)

According to DNE21+ model, the marginal abatement costs induced by the INDC are strikingly higher for Japan than for other countries. Japan's marginal abatements costs are estimated about 380 $/tCO2eq, while around 166 $/tCO2eq for EU28 and between 60 $/tCO2eq (low case) and 69 $/tCO2eq (high case) for the US. The main cause would be that high energy savings are expected in the INDC despite good performances in energy efficiency in Japan. To limit such costs, innovation, whether purely technological or not (related to lifestyle), would be highly needed.

The emission reduction cost per GDP induced by the INDC for Japan is 0.7% in 2030, and that for EU is 0.77%, and almost same level. The cost for the U.S. is 0.34-0.40% in 2025.

In total, the Japanese INDC is evaluated from several possible appropriate indicators to have fairness and ambition in the international context.

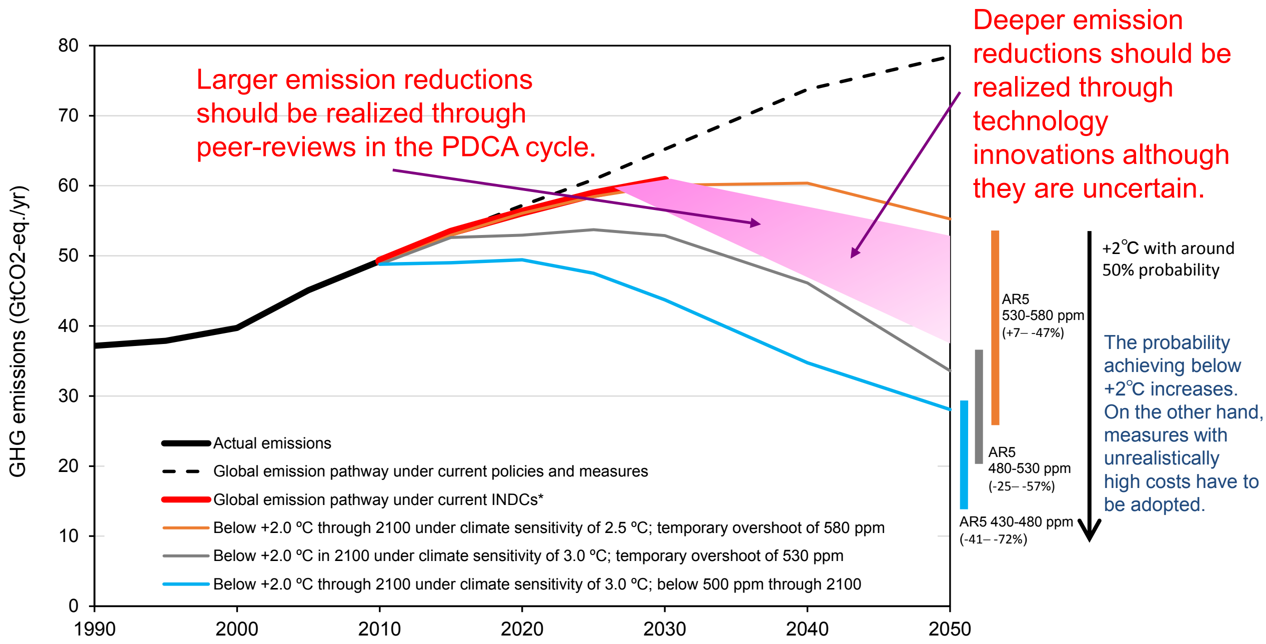
Contribution towards achieving the 2 °C target

The Japan's INDC describes "The Japan's INDC is consistent with the long-term emission pathways up to 2050 to achieve the 2 degrees Celsius goal". This paragraph discusses the analyses on the consistency of the 2°C target, including both Japanese INDC and other INDC submitted so far – since achieving the 2°C target can only be the result of a collective long-term effort.

Consistency achieving the 2℃ target

Actually, as shown in Figure 23, it turns out that there are large gaps between the expected global emission under current INDC and the emission pathway to 2°C target under climate sensitivity to a doubling of CO2 estimated at 3.0°C, However, the INDC are consistent with 2°C target if climate sensitivity is 2.5°C. Even if we assume to stay within a 2°C warming compared to preindustrial levels, there is great uncertainty regarding the actual outcome due to climate sensitivity; based on the latest expertise of the IPCC Fifth Assessment Report, the emissions pathways for the “+2°C” target present a high flexibility (The climate sensitivity was changed from 2.0-4.5°C in the IPCC AR4 to 1.5-4.5°C in the IPCC WG1 AR5.). The INDC submitted so far, including the Japanese ones, are within the pathway range to meet the 2°C target as long as the expected value is used (under a climate sensitivity of 2.5°C). However, the consistency of 2°C target depends strongly on the requirement of the expectation probability achieving the target and the climate sensitivity knowledge.

The framework of the processes to induce future emission reductions is more important than the levels of INDC decided in COP21. In a long-term perspective, we should keep enhancing the INDC through the enforcement of PCDA (Plan-Check-Do-Act) cycles and development of innovative technologies.



* INDCs of US, Canada, EU28, Norway, Switzerland, Japan, Russia, China, Mexico, and South Korea are considered. For other countries, emission pathways under current policies and measures are adopted.

Figure 23: Relationship between climate sensitivity and global emission pathways for 2°C target, and outlook on INDC

Equity of emission reduction cost burden between 2030 and 2050

Emission reduction costs in 2030 and 2050 were compared, applying INDC emissions reduction for 2030 and assuming a cut by half of world total energy-related CO_2 emissions in 2050 compared to 2005 levels as a long-term goal (Marginal abatement costs are assumed to be equal across countries in 2050.).The expected marginal abatement cost is 431$/t$CO_2$ in 2050 for the long-term goal. At that time, the Japanese emissions are assessed to be about half of 2005 emissions levels under the equal marginal abatement costs, and the ratio of emissions reductions costs compared to GDP to be 0.74%. In other words, the economic burden of Japanese INDC for 2030 is about the same level as the cut by half of emissions worldwide in 2050.

Table 9: GHG emission, marginal abatement costs, ratio of emissions reduction costs compared to GDP for Japan

	2030	2050 (Reduction by half of world total energy-related CO2 emissions after equalization of marginal abatement costs)
GHG emissions (compared to 2005 levels)	-25.4%	-50%
Marginal abatement cost ($/tCO2)	381	431
Ratio of emissions reduction costs compared to GDP (%)	0.72	0.74

Note 1: In the case of below +2°C through 2100 under climate sensitivity of 2.5°C, the required GHG emission for Japan in 2050 is -32% compared to 2005, and the marginal abatement cost is 40$/tCO2; the emissions reduction costs per GDP is 0.22%.

Note 2: In the case of below +2°C in 2100 (overshoot of temperature) under climate sensitivity of 3.0°C, the required GHG emission for Japan in 2050 is -48% compared to 2005, and the marginal abatement cost is 360$/tCO2; the emissions reduction costs per GDP is 0.65%.

5. Conclusions

The Japanese INDC was submitted to the secretariat of UNFCCC on July 17th, 2015. The GHG emission target for 2030 is 26% reduction compared to 2013, which corresponds to 25.4% compared to 2005. This target is consistent with the energy mix planned for 2030 given the conditions after the accident at the Tokyo Electric Power Company's Fukushima Dai-ichi Nuclear Power Station, and was developed by bottom-up calculation with concrete policies and measures. The energy mix was developed based on the basic principles known as the 3E+S, namely: controlling electricity costs, reducing CO2 emissions, ensuring energy security and stability of supply, while ensuring safety at all levels.

As described in Section 3, in the government's proposition, despite a high GDP growth rate (1.7%/year) projection, the power generation after GHG reduction measures is anticipated to remain almost unchanged. The GDP elasticity of electricity after the reduction measures is 0.05 between 2013 and 2030, while the elasticity between 2000 and 2010 was nearly 1.0 in Japan. A high energy efficiency improvement is assumed in the INDC.

As for GHG emissions reduction targets, the estimated marginal abatement costs (carbon prices) are about 187 US$/tCO2 and about 260 US$/tCO2 by the NIES and RITE models, respectively, to achieve the 22% reduction of energy-related CO2 emissions in 2030 (which corresponds to the 26% reduction of GHGs according to the government outlook). However, since these ambitious targets are based on high expectations from the energy savings policy (corresponding marginal abatement costs in Japan are exceedingly high compared to other countries) and on great efforts of restarting of nuclear power with extensions to sixty years operation for some nuclear power stations, it will not be easy to achieve such ambitious target. For example, the marginal abatement cost increases by about 26% in 2030 under the nuclear power limitation scenario according to the NIES model. Further reductions in emissions, fuel switch from coal to natural gas and an additional deployment of renewable energies are cost effective under such high carbon price measures. The high costs for society could be limited by breakthrough innovation, whether purely technological or not (related to lifestyle).

More concrete policies and measures are desired to achieve such an ambitious target at the domestic level, and the further contributions of emission reductions all over the world including the Joint Crediting Mechanism (JCM) which has been proposed by the Japanese government are expected. For that, high energy efficiency technologies from Japanese firms are to be helpful to the world.

Acknowledgements (NIES)

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Appendix I: overview of NIES model

AIM/Enduse [Japan]

AIM/Enduse [Japan] model is a partial equilibrium, dynamic recursive technology selection model for the mid- to long-term mitigation policy assessment (Kainuma et al., 2003). The model covers both end-use sectors (industrial, residential, commercial and transport) and energy supply sector. In addition, non-energy sectors (e.g. agriculture, industrial process, waste) are also included.

Technology selection is formulated by linear programming algorithms that minimize the total system cost subject to several constraints, such as satisfying service demands which are specified exogenously, maximum/minimum shares of technologies and constraint of GHG emissions or explicit carbon prices. A detailed formulations and data of the model can be found in Kainuma et al. (2003). As end-use and power generation sectors are mutually interlinked, technology selection in power generation sector is implemented subject to electricity demand derived from end-use sectors. Technology selection is implemented year by year time step, over a time horizon from 2010 (base year) to 2050.

The model explicitly distinguishes 10 regions in Japan with their regional differences in renewable energy potential and energy demand characteristics (Oshiro and Masui, 2015). These 10 regions are coincide with the business areas of 10 public power supply firms.

A wide range of low carbon technologies are taken into account in AIM/Enduse [Japan]. Shares in electricity, such as coal, natural gas, oil and renewable energies, are endogenously determined based on cost minimization, though maximum potentials are set for renewable energies. Electricity generation from nuclear plant is exogenously given based on different assumptions on their lifetime, capacity factor and possibility of new construction. CCS technologies are also included in power sector and industrial sector, though they are assumed to be available after 2030 in NIES analysis.

For end-use sectors, technology selection is also implemented based on cost minimization. However, considering their pace of replacement, maximum share of introduction of energy efficient technologies particularly in industrial sector are exogenously fixed complying with the Long-term Energy Supply and Demand Outlook (METI/ANRE, 2015a). In addition, costs of electricity generation is updated for MILES Project and consistent with the report published by Power Generation Cost Verification Working Group under the Subcommittee on Long-term Energy Supply-demand Outlook which was held in 2015 (METI/ANRE, 2015b).

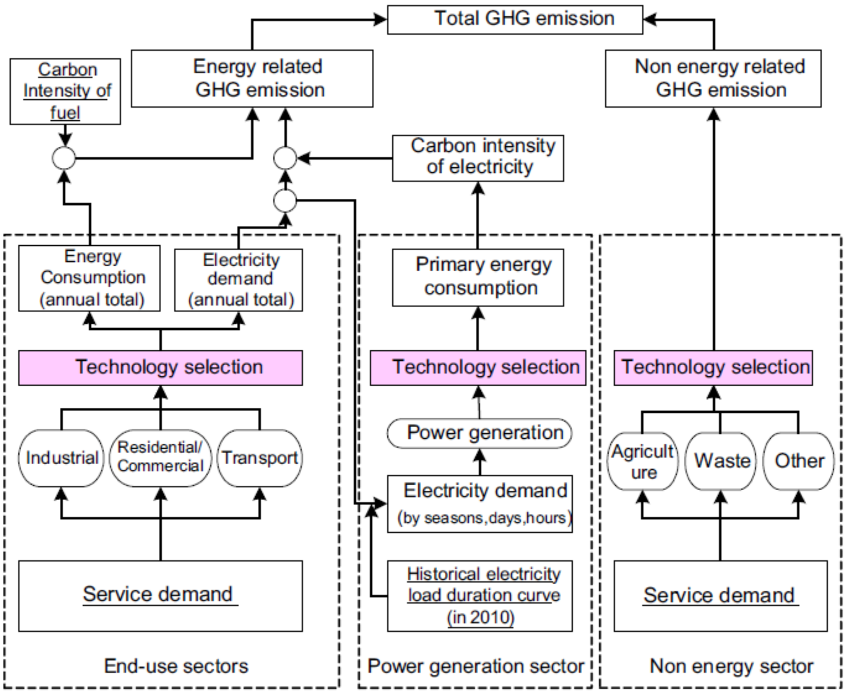

Figure 24: Outline of AIM/Enduse[Japan]

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Appendix II: overview of RITE models

DNE21+ model

The DNE21+ model (Akimoto et al. 2010) is an inter-temporal linear programming model for assessing global energy systems and global warming mitigation. In this model, the sum of the discounted world total energy systems costs is minimized. The model covers the first half of the 21st century as a time range, with 2000, 2005, 2010, 2015, 2020, 2025 2030, 2040, and 2050 as representative time points.

The energy supply sectors are connected to the energy end-use sectors, so that assessments are made while maintaining complete consistency across energy supply and demand levels. For the energy supply sectors and several groups of the energy end-use sectors (energy intensive industries, road transportation, and several kinds of appliances in residential and commercial sector), various technology options are explicitly modeled with assumptions of costs, energy efficiencies, and life times of facilities. Activity amounts of the energy end-use sectors (e.g., crude steel production in iron and steel sector, passenger or freight transport service in road transportation) are exogenously assumed as a scenario. Other sectors in the energy end-use sectors are modeled in a top-down fashion; final energy demands are exogenously assumed as a scenario by energy carrier. Energy-saving effects in these sectors are evaluated using long-term price elasticity. The model specifies energy systems whose costs are minimized and which meet the assumed scenarios and other requirements (e.g, carbon taxes).

The world is divided into 54 regions. To take into consideration the transportation of energy and CO2, large countries such as the United States, Canada, Australia, China, India, and Russia are further disaggregated into several regions. This detailed regional segregation enables us to perform our analysis while taking regional differences into consideration.

About 300 specific technologies, including carbon dioxide capture and storage (CCS) technologies and CO2 fixation by afforestation, are explicitly modeled as the technology options. This enables us to assess CO2 emission reduction measures in detail.

The model has been developed based on the study by Hyman et al. (2003), and with some modifications considering new insights for non-CO2 GHGs, it is used for assessment of non-CO2 GHGs emissions and reductions. The non-CO2 GHGs assessment model calibrates the recent historical emissions of non-CO2 GHGs (Akimoto et al. 2010).

In this evaluation on the Japan's INDC, electricity generation mix is exogenously assumed to be same with that in Japan's INDC (Oil: 3%, Coal: 26%, LNG: 27%, Nuclear: 20-22%, Renewables: 22-24%). However, shares in renewable electricity are endogenously evaluated through cost optimization.

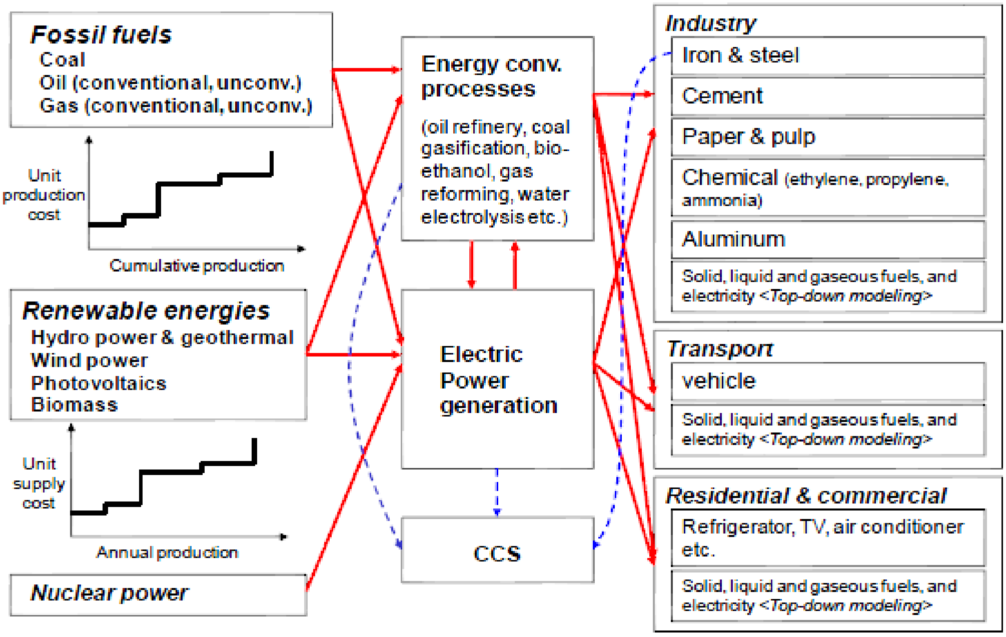

Figure 25: Outline of energy flows in DNE21+

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DEARS (Dynamic Energy–economic Analysis model with multi-Regions and multi-Sectors) model

The DEARS (Homma and Akimoto 2013) is an intertemporal optimization model, which maximizes global discounted consumption utilities up to the middle of this century with 10-year time steps and a computable general equilibrium (CGE) model. The model evaluates the impacts of energy and CO2 emissions reduction policies on economic systems with consideration of international industrial relationships.

The DEARS model has two modules. One is the economic module, which represents explicitly industrial structures of production, consumption, and trade by region and by sector in terms of monetary units, which are required for sectoral analysis on climate policies. The other is the simplified energy systems module, which represents explicitly energy flows in terms of physical units. The two modules are completely linked. The model includes 18 regions and 18 non-energy sectors. The model has nested model structures in the non-energy sectors. The macro production functions for the regional whole economies are based on the Cobb–Douglas function. The summations of GDP and energy inputs in a region are formulated as a Cobb–Douglas function consisting of capital, labor and energy. The three factors are substituted to each other in the function. On the other hand, each sectoral production function for the non-energy sector is based on the Leontief function. The production function for the energy sectors are also based on the Leontief function as primary energy is inputted to the relevant secondary energy.

The model also includes twelve energy sources with eight types of primary energy (coal, crude oil, natural gas, biomass, hydro power, wind power, nuclear power, and photovoltaics) and four types of secondary energy (solid, liquid and gaseous fuels, and electricity). These various types of electricity generation and carbon dioxide capture and storage (CCS) technology are modeled. The energy-saving effects are evaluated using long-term price elasticity. The main economic datasets of DEARS are based on the GTAP database (Hertel, 1997) for economic systems. The input–output tables of the model starting time for 1997 are based on GTAP version 5 and the input–output tables for 2007 are based on the other versions. The energy-related datasets are based on IEA energy balances and datasets of other models (Akimoto et al., 2010) for energy systems. Since the information on the energy supply and the power generation sector is not sufficient in the input–output table, we conduct bottom-up modeling taking relevant technologies into account and make adjustments to achieve consistency with IEA statistics and others, which allows consistent analyses and assessments of energy and the economy. Such bottom-up modeling is able to analyze economic impacts with full consideration of differences in electricity generation shares and their costs.

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Appendix III: INDC measures

Table 10: Measures for energy-originated CO2 (source: Submission of Japan's INDC)

Energy-originated CO2	
Industry sector	□ Promotion and enhancement of the industries' action plans towards a low carbon society Iron and steel industry □ Efficiency improvement of electricity-consuming facilities □ More chemical recycling of waste plastic at steel plants □ Introduction of next-generation coke making process (SCOPE21) □ Improvement of power generation efficiency □ Enhanced energy efficiency and conservation facilities □ Introduction of innovative ironmaking process (Ferro Coke) □ Introduction of environmentally harmonized steelmaking process (COURSE50) Chemical industry □ Introduction of energy efficiency and conservation process technology in petrochemicals □ Introduction of energy efficiency and conservation process technology in other chemical industry □ Introduction of energy efficiency and conservation technology using membranes for distilling process □ Introduction of technology which uses CO2 as a feedstock □ Introduction of chemical product production technology with inedible plant-based material □ Introduction of electricity-generating waste water processing with microbe catalysis □ Introduction of sealed plant factory Ceramics, stone and clay products industry □ Introduction of conventional energy efficiency and conservation technologies (waste heat power generation, slag crusher, air-beam cooler, separator improvement, vertical roller coal mills) □ Introduction of technology for using waste (e.g. waste plastic, etc.) as alternative thermal energy □ Introduction of innovative cement production process □ Introduction of glass melting process Pulp/paper/paper products manufacture industry □ Introduction of high-efficient pulp production technology using old paper □ Introduction of high-temperature and pressure recovery boilers Cross-sectoral/Other □ Introduction of high-efficient air conditioner □ Introduction of industrial HP (heating-drying) □ Introduction of industrial light □ Introduction of low-carbon industrial furnace □ Introduction of industrial motor □ Introduction of high performance boiler □ Direct use of recycled plastic flakes
Commercial and other sectors	□ Promotion of compliance of energy saving standards for newly constructed buildings □ Energy efficiency and conservation buildings (remodeling) □ Introduction of commercial-use water heater (latent heat collection water heater, commercial-use heat pump water heater, high-efficient boiler) □ Introduction of highly efficient light □ Introduction of refrigerant control technology (F-gases) □ Improvement of energy efficiency and conservation performance of equipment by the top runner program, etc. □ Thorough implementation of energy management in commercial sector with BEMS and energy efficiency diagnosis □ Efficient use of light □ Promotion of nationwide campaigns (thorough promotion of Cool Biz/Warm Biz, repair of local government buildings) □ Expansion of shared use of energy □ Promotion of measures for energy efficiency and conservation of/energy generation from sewerage systems □ Promotion of measures for energy efficiency and conservation/renewable energy in water business □ Promotion of activities based on action plans of local governments (administrative business section) □ Promotion of sorted collection and recycling of plastic containers and packaging □ Low-carbonization of cities by improving urban thermal environments through measures against the urban heat island effect □ Promotion of inter-ministry collaborative measures following the Roadmap of Global Warming Counter-measures, etc.

Table 11: Measures for non-energy-originated CO2 (source: Submission of Japan's INDC)

Non energy-originated CO2	□ Expansion of blended cement use □ Reduction of municipal solid waste incineration
CH4	□ Measures to reduce CH4 emissions from agricultural soils (reduction of CH4 emissions from paddy rice fields) □ Reduction of municipal solid waste disposed of by direct landfill □ Introduction of semi-aerobic landfill system for final disposal site of municipal solid waste
N2O	□ Measures to reduce N2O emissions from agricultural soils (reduction of N2O emissions originated from fertilizer application) □ Promote the advanced technologies in the sewage sludge incineration facilities
Fluorinated gases	□ Measures to control overall emissions of fluorinated gases (Act on Rational Use and Proper Management of Fluorocarbons, emission control through industries' voluntary action plans, etc.)
LULUCF sector Forest management Cropland management /Grazing land management Revegetation	□ Promote measures for greenhouse gas removals through the promotion of forest management/forestry industry measures □ Promotion of soil management leading to the increase of carbon stock in cropland □ Promotion of revegetation