Decarbonisation pathway of Japan

Where are we?

In 2016, Japanese GHG emissions were 1,307 Gt-CO$_2$-eq, most of which came from energy use (88.3%) and industrial processes (7.3%). CO$_2$ emissions made up 92.2% of the total GHG emissions. The submitted Japanese NDC pledges a 26% reduction in GHG emissions by 2030 compared to 2013 levels. In addition, the government expressed its intention to pursue efforts for 80% GHG emission reduction by 2050. The former Japanese decarbonisation plan heavily relied on nuclear energy. However, after the event of Fukushima-Daiichi nuclear power plant in 2011, all nuclear power plants were shut down. To date, only a few plants have resumed operations and no new construction plan is running.

The population of Japan (127 million in 2016) is now decreasing after peaking in 2008 and is expected to be around 102 million by 2050. The economic activity (measured in terms of Gross Domestic Product) in 2016 was 4.8 trillion USD, the GDP per capita was 37,960 USD, and the annual economic growth rate in the last decade fluctuated around 1-2% with very low and even negative values following the global financial crisis, the 2011 Great East Japan Earthquake, and the rise of consumer taxes in 2014. Implemented decarbonisation policies are mainly based on voluntary actions targeting energy efficiency in private sectors. The feed-in tariff for renewable energies introduced in 2012 has led to a significant increase in the capacity of solar PV.

The AIM/Enduse [Japan] energy system model is mainly used in the analysis. This is a partial equilibrium, dynamic recursive energy system model with detailed descriptions of energy technologies in the end-use sectors as well as the energy supply sectors in Japan. It describes the characteristics of energy supply and demand across 10 sub-regions in Japan, broadly coinciding with the areas of power supply firms.

Where do we want to go?

It is noted that the government claims Japan’s NDC for 2030 is consistent with the Paris Agreement target of well-below 2 °C, but how to realise the ambitious 2050 goal (GHG reduction by 80%) remains an open question. The NDC emission reduction target (GHG reduction by 26% in 2030 from 2013 levels) is regarded feasible by the extension and strengthening of current policies and actions. On the other hand, the 2050 GHG reduction goal is seen as challenging without structural innovations both in energy demand sectors (transport, industries, buildings) and energy supply systems.

The AIM/Enduse [Japan] model is used to assess three scenarios: a scenario assuming only current policies in place (Baseline); a scenario introducing a decarbonisation path towards 2050 that is in line with the NDC (2030) target (NDC); and a low-carbon scenario assuming immediate decarbonisation towards an 80% emission reduction by 2050 (Immediate). The Japanese low-carbon scenario presented here is considered to be in line with the objective to limit global warming to well-below 2 °C, as Japanese cumulative CO$_2$ emissions are 28 Gt in the 2010-2050 period; this is well within the range projected by a number of global models for cost-optimal scenarios assuming a global carbon budget of 1000 Gt CO$_2$ considered equivalent to likely below 2 °C.

1 We acknowledge funding from the COMMIT project, Climate Policy assessment and Mitigation Modeling to Integrate national and global Transition pathways. The project is financed by the European Commission’s Directorate-General for Climate Action (DG CLIMATE). More info on: https://themasites.pbl.nl/commit/
2 METI. The Strategic Energy Plan of Japan. In: Meeting global challenges and securing energy futures—(Revision June 2010) [Summary], Ministry of Economy, Trade and Industry, Tokyo, Japan; 2010.
4 Japan’s NDC includes targets for the share of RES technologies in power generation for 2030, but here we only analyse the NDC emission reduction target.
According to the model-based analysis, keeping the same mitigation effort needed for the NDC target until mid-century (2050) contributes to large emissions reductions compared to the Baseline scenario, but leaves a gap of around 100 Mt CO$_2$eq with the pathway that assumes immediate action to achieve the long-term 80% GHG emission reduction target by 2050 (Figure 1).

Japan has not yet submitted a Mid Century low-carbon Strategy. Discussion on the long-term low-carbon strategy led by the government has just begun in August 2018. ‘Simultaneous solution’ is the key notion forming the Japanese decarbonisation strategy, e.g., low-carbon society and economic growth, energy security, sustaining local communities, and resilience to climate disasters. They are also linked to Japanese national Sustainable Development Goals (SDGs). A sense of urgency to be left behind from the global trend of decarbonisation is becoming common particularly among large international companies.

Figure 1a: CO$_2$ emissions from energy supply and demand in alternative pathways (Baseline, NDC, and Immediate pathway). 1b: Greenhouse gas emissions in 2015 and by 2050 in the reference scenario (Baseline), emission reductions between the reference and low-carbon (Immediate pathway) scenarios by sector (energy supply, industry, residential and commercial buildings, transport, non-energy CO$_2$), and 2050 emissions in the low-carbon scenario (consistent with 2 °C)\textsuperscript{6}.

\textsuperscript{6} Non-energy CO$_2$ emissions correspond to those from industrial processes; land use change emissions are excluded.
How do we get there?

A drastic energy system transformation is required to achieve Japan’s NDC for 2030 and the more ambitious long-term decarbonisation goal (immediate pathway). Extensive improvement of energy efficiency and decarbonisation of energy sources in all demand and supply sectors are expected to play key roles in the mitigation effort (Figure 2).

Improvement in energy efficiency is achieved by both supply and demand sides. In the supply side, for example, by means of deployment of high efficiency combined cycle and cogeneration systems. In the demand side, energy efficient cars, appliances, and buildings with energy management systems utilising Internet of Things (IoT) and AI technologies will reduce the final energy consumption, while maintaining the standards of living of Japanese citizens. Decarbonisation of energy sources could be achieved via the large-scale expansion of wind power, solar PV, and geothermal power generation as well as by the development of Carbon Capture and Storage (CCS) technologies (in electricity production and in industrial applications). Nuclear energy may also contribute to decarbonisation in case it overcomes safety issues and becomes accepted by the Japanese society. Required additional (from Baseline levels) energy system investments in 2030 are projected to be 9.4 billion USD and 69 billion USD under NDC and immediate low-carbon pathway, respectively. In 2050, the additional investment requirements increase to 62 billion USD and 86 billion USD, respectively. They would partly be offset by reduced energy import bills induced by a large-scale decline in imports of oil and natural gas.

To lead to decarbonisation of society, economy-wide carbon pricing and support for innovative clean energy technologies would be important as well as enhancement and strengthening of current policies. The integration of nuclear-energy-related issues in the long-term decarbonisation pathway should also be discussed nationwide. Introducing variable renewable energies (solar and wind) is a challenge for the Japanese energy system. Increasing the connectivity of power grids among regions is important as well as developing energy storage technologies (e.g., batteries, fuel cells, or pumped-storage hydropower). Energy security has long been a major concern because Japan relies almost entirely on imported fuels (oil and gas). Increasing the capacity of renewable energies can improve energy security. While the present analysis focuses on Japanese domestic energy system transformation, Japan can also contribute to the decarbonisation of other countries by transferring energy-related technologies, which can be a business opportunity for many Japanese innovation-based companies (like battery manufacturers).
Figure 2a: Energy system transformation towards decarbonisation for each pathway (low-carbon energy includes renewables, nuclear and CCS). 2b: Decarbonisation indicators for the Immediate pathway. Numbers in graph indicate change between 2015 and 2050 (intensity indicators: %, share indicators: percentage points, pp)
The role of nuclear power in the Japanese low-carbon transition

The government's basic energy plan and NDC still rely on nuclear energy, which is projected to maintain a share in the primary energy supply of about 10-11% in 2030. However, after the events of Fukushima-Daiichi nuclear power plant in 2011, all nuclear power plants ceased their operations temporarily (the share of nuclear energy in primary energy supply dropped from 11.2% in 2010, to less than 1% in 2016), and the public opinion against nuclear energy has become dominant. Therefore, it is quite uncertain whether deployment of nuclear energy in the future is possible or not.

To quantify the effect of limited nuclear energy availability in energy system transition towards decarbonisation, additional analysis is conducted under a scenario assuming gradual phase-out of nuclear energy (NDC limited nuclear, Figure 3). Under the limited nuclear scenario, achieving Japan’s NDC can be more challenging. More intensive deployment of renewables and additional investment for energy systems are necessary. On the other hand, it can lead to more energy-efficient society, promote new business opportunities based on local and decentralised energy supply, and reduction in nuclear wastes.

Figure 3: Effects of nuclear energy phase-out in the NDC scenarios. (a) Electricity generation by technology, (b) Investment on energy supply, (c) Changes in final energy consumption from 2010 levels.