

Japan's medium- and long-term GHG mitigation pathways under the carbon budget approach

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Abstract:

This paper assessed Japan's "fair" carbon budget consistent with the 2 °C target between 1990 and 2100 under three frequently referred effort-sharing approaches: Converging Per Capita Emissions (CPE); Common but Differentiated Convergence (CDC); and Greenhouse Development Rights (GDRs), as well as the consequent GHG emission pathways up to 2100 for the country to stay within the budget. The calculated carbon budgets were compared with Japan's projected cumulative greenhouse gas (GHG) emissions in case of adhering to the existing national mitigation targets committed for 2020 and 2050 ("Nationally Committed Amount": NCA). The global carbon budget for 1990-2100 was assumed to be 1800 Gt-CO₂e excluding LULUCF.

The remaining carbon budgets for Japan under CPE and CDC (23 Gt-CO₂e and 20 Gt-CO₂e) were found to be about 50%-60% of the amount the country would emit up to 2100 under the reference NCA (39 Gt-CO₂e). If Japan continues to emit GHG at current levels (1.34 Gt-CO₂e/yr in 2012), the budget under CPE and CDC approaches will run out in the early 2030s. Japan's carbon budget under GDRs was found to be negative for 1990-2100, due to the very high responsibility and capability that is determining the results under this approach.

Moreover, the average emissions reduction rate for 2020-2050 based on the government's current mitigation targets was found to be similar to that required under the CPE approach with immediate actions from 2014. If Japan is to consider the carbon budget concept, strengthening the current 2020 target, rather than adhering to the current targets, would allow mitigation rates to remain within a more realistic range and would limit the need to buy international offsets.

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Policy relevance:

To remain below 2°C temperature increase, there is a limit to total GHG emissions that can be emitted globally. Following the Fukushima nuclear disaster, however, many new coal-fired power plant constructions have been planned in Japan, which would “lock-in” a significant amount of CO₂ emissions up to 2050. Nevertheless, the concept of a carbon budget and the equity principles to distribute the budget across countries has seldom been discussed when formulating Japan’s national mitigation targets. This paper quantitatively assesses and discusses the gap between the level of ambition Japan has committed to and what effort-sharing approaches with their different interpretations of equity define.

The views expressed in this working paper are those of the authors and do not necessarily represent those of IGES. Working papers describe research in progress by the authors and are published to elicit comments and to further debate. Their contents may be revised and eventually published in another form.

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1. Introduction

Japan is now at a crossroads with regard to the future direction of energy and climate policies following the Fukushima nuclear disaster of March 2011. In December 2009 at the 15th Conference of the Parties (COP15) under the United Nations Framework Convention (UNFCCC) held in Copenhagen, the Japanese government led by the Democratic Party of Japan (DPJ) pledged to reduce its Greenhouse Gas (GHG) emissions by 25% by 2020 below 1990 levels, which was “premised on the establishment of a fair and effective international framework in which all major economies participate and on agreement by those economies on ambitious targets” (UNFCCC 2009). This Copenhagen pledge by Japan was planned to be achieved mainly by the expansion of nuclear power (METI 2010). After the Fukushima nuclear disaster, however, aggressive decarbonization of the electricity supply through a large expansion of nuclear power has become politically and technically difficult. The 25% target was officially replaced in November 2013 at COP19 held in Warsaw by the current administration led by the Liberal Democratic Party (LDP). The revised 2020 mitigation target (“Warsaw Target”) is to reduce its GHG emissions by 3.8% below 2005 levels, which equals to 3.1% increase from 1990 levels and assumes zero nuclear power generation in 2020. Meanwhile in 2012, a long-term reduction target of 80% by 2050 below 1990 levels was enshrined in the cabinet-approved Fourth Basic Environment Plan (MOE 2012).

Although a large uncertainty exists with regards to Japan’s short-mid energy and climate policies, limiting global climate change is becoming ever more urgent. In October 2013, Working Group I (WGI) of the Intergovernmental Panel on Climate Change (IPCC) released its 5th Assessment Report (AR5), which provides a detailed look at the science of climate change (IPCC 2013). This report conveyed the concept of a “carbon budget”, which is a finite amount of GHG that can be emitted if the increase in global temperature is to be curbed to a certain level. Under

the UNFCCC, countries have agreed to keep the increase in the global mean temperature below 2°C compared to preindustrial levels: the so-called 2°C target. This conveys the importance of managing the total cumulative emissions consistent with a long-term global “carbon budget” for the 2°C target, as well as of assessing national GHG emission reduction targets from the perspective of their consistency with such carbon budget (Tamura 2014).

The distribution of global carbon budget consistent with the 2 °C target across countries under one or more equity principles has been proposed by several research groups (WBGU 2009; Horstmann and Scholz 2011; BASIC Experts 2011). In recent years, country-level carbon budgets under different effort-sharing approaches have been calculated by Ecofys for various countries (e.g., Höhne and Moltmann 2008, 2009) and their implications on national mitigation policies have been assessed and discussed for Australia and the European Union (WWF Australia 2013; de Vos et al. 2014).

Drawing upon a new research, this paper assesses Japan’s “fair” share of global carbon budget consistent with the global 2°C goal under a number of effort-sharing principles and analyzes its implications for Japan’s GHG emissions reductions in 2030 and 2050. In particular, the impact of delayed actions for drastic mitigation on the future emissions trajectories is quantitatively assessed and discussed. In addition, the consistency of current mid- and long-term targets of the Japanese Government with the calculated “fair” carbon budgets for Japan is also examined.

This paper is structured as follows. Section 2 briefly describes the recent GHG emission trends in Japan. Section 3 describes the research methodology used for the analysis. Section 4 presents the calculated carbon budgets and the derived emission trajectories toward 2050 and beyond. Section 5 discusses the policy implications of the results obtained in this study and the limitations of the methodology used. Lastly, conclusions are drawn in Section 6.

2. Japan's GHG emission trends in recent years

This section provides a brief description of Japan's GHG emission trends in recent years (see Kuramochi (2014) for details). For the first commitment period of the Kyoto Protocol (KP-CP1: 2008–12), Japan was committed to reduce its GHG emissions by 6% from 1990 levels. Figure 1 presents Japan's historical GHG emissions between FY1990 and FY2012. It was recently announced that Japan achieved the KP-CP1 target, on average reducing its GHG emissions by 8.4% including net carbon sequestration through land use, land-use change and forestry (LULUCF), and the purchases of Kyoto Units⁵ (MOE 2014). The average annual domestic GHG emissions excluding LULUCF, however, were 1.4% above 1990 levels. The average annual acquisition of Kyoto units was 74 Mt-CO₂e/yr or nearly 6% of 1990 emissions. Figure 2 presents the historical GHG emissions per capita and per GDP (in 2005 international dollars) between FY1990 and FY2012. While per GDP emissions have declined by 13% between 1990 and 2012, per capita emissions have slightly increased.

3. Methodology

This paper stems from the analysis conducted in Höhne and Moltmann (2009) using the Evolution of Commitments tool (EVOC) version 8 developed by Ecofys. The EVOC model, originally developed by Höhne et al. (2003), is a decision support tool to quantify several future international climate regimes. The detailed data and description of the EVOC version 8 can be found in, e.g., Höhne and Moltmann (2009) and Fekete et al. (2013). Höhne and Moltmann (2009) assumed that by 2050, global GHG emissions excluding LULUCF will have reduced by

80% compared to 1990. The estimated emission budget of 1800 Gt-CO₂e for 1990-2100 excluding LULUCF and 1600 Gt-CO₂e including LULUCF, is consistent with the stabilization levels around 400 ppm CO₂e and the 2°C target (Höhne et al. 2014a). To stay within this global budget, the referenced study also assumed that global emissions excluding LULUCF reduce by 30% in 2030 and 80% in 2050 from 1990 levels, respectively. All calculations considered six different scenarios, which include different assumptions on the growth rates of important factors such as GDP and population, from the IPCC Special Report on Emission Scenarios (Nakicenovic et al. 2000).

The country-specific analytical framework used in this study, which is largely based on Fekete et al. (2013) for an Australia case study, is described below.

3.1. Sharing the mitigation effort among countries

While many different effort-sharing approaches have been investigated in the literature, they are often based on one or more of the following four basic dimensions: (i) responsibility (historical emissions), (ii) capability (capacity to pay for mitigation), (iii) equality (emission rights per person), and (iv) cost-effectiveness, of which the first three are explicitly equity principles (Höhne et al. 2014a). In addition to the above four, a comparative assessment of over 40 studies that analyzed future GHG emissions allowances or reduction targets across regions (Höhne et al. 2014a) identified the following three effort-sharing categories that combine two or more of the above four dimensions: (v) responsibility, capability, and need (combines (i) and (ii)); equal cumulative per capita emissions (combines (i) and (iii)); and (vi) staged method (combines (i) – (iii)).

⁵ Kyoto units⁵ is a collective term for emission allowances that are generated, cancelled, acquired or transferred through LULUCF Activities and through participation in the Kyoto mechanisms (UNFCCC 2008).

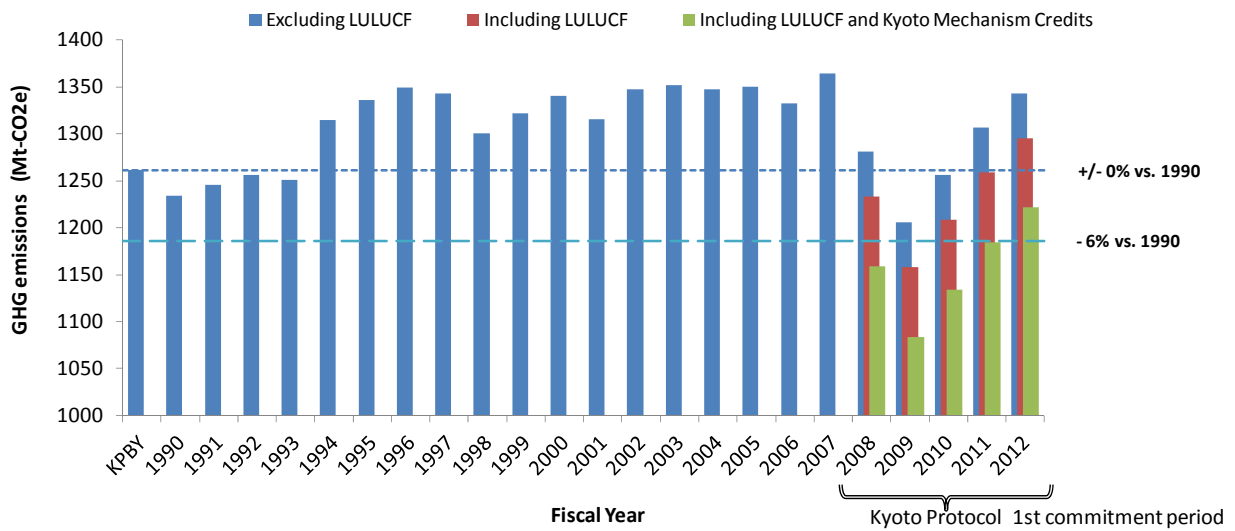


Figure 1: Annual total GHG emissions excluding and including LULUCF in Japan between fiscal years (FY) 1990 and 2012. The annual Kyoto Units are assumed to be a 5-year average of total units acquired between 2008 and 2012. Source: Kuramochi (2014), based on GIO (2014).

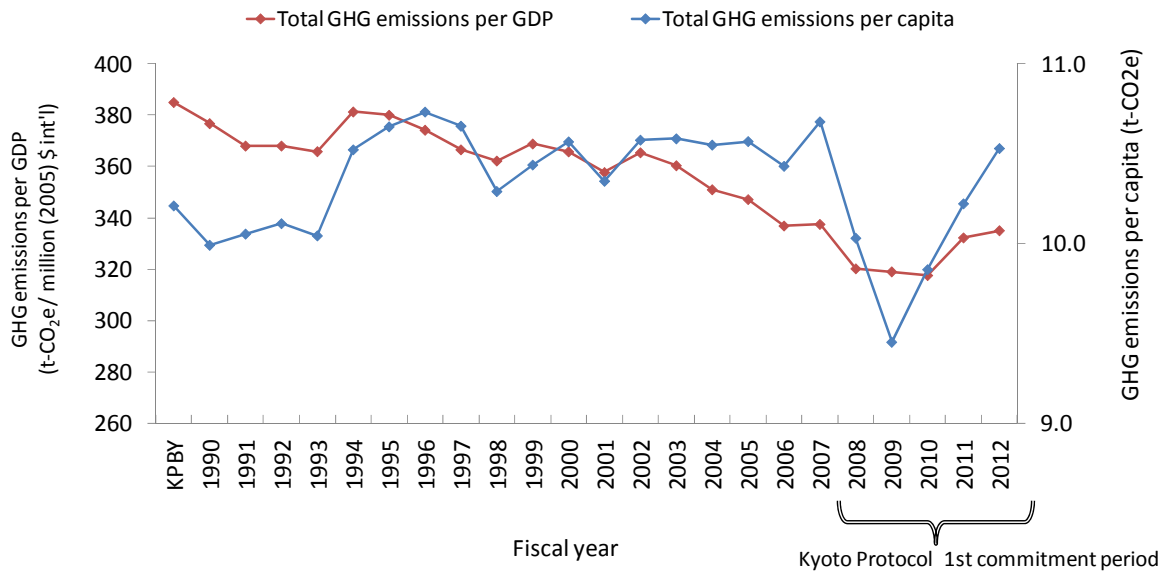


Figure 2: Total GHG emissions per capita and per GDP (PPP) in Japan between FY1990 and 2012. GDP data are in adjusted for purchasing power parity (PPP) and reported in constant 2005 international dollars. Source: Kuramochi (2014), based on GHG emissions data from GIO (2014) and population and GDP (PPP) data from World Bank (2013).

This paper calculated the carbon budget for Japan using three different effort-sharing approaches: Converging Per Capita Emissions (CPE),⁶ Common but Differentiated Convergence (CDC) and Greenhouse Development Rights (GDRs), while referring to the classification adopted in Höhne et al. (2014a) and the IPCC AR5 report (IPCC 2014). An overview of the three approaches is presented in Table 1. CPE approach is based on equality principle (category (iii)) alone, whereas the other two are based on multiple equity principles. CDC approach, originally proposed by Höhne et al. (2006), is categorized under “Staged method” and considers all three equity principles as well as “Cost-effectiveness” (Höhne et al. 2014b). GDRs approach was proposed by Baer et al. (2007) and shares the global carbon budget between countries according to two equity principles (capacity and responsibility). The GDRs approach sets a development threshold, below which the countries do not need to contribute to climate change mitigation and adaptation; wealthier and higher emitting countries receive a much smaller share of the budget than poorer and lower emitting countries.

In addition to the aforementioned three effort-sharing approaches, we also calculated a reference amount of cumulative GHG emissions under the current 2020 and 2050 mitigation targets in Japan, which we refer to as “Nationally Committed Amount” (NCA). As mentioned, current GHG emission reduction target is 3.1% increase in 2020 and 80% decrease in 2050 compared to 1990 level. For calculating NCA up to 2100, national GHG emissions were assumed to change linearly between 2013 and 2020 and between 2020 and 2050, and the average GHG emissions between 2050 and 2100 were assumed to be 10% of 1990 levels. This paper treated NCA as a reference because it is not based on any

particular effort-sharing principle.

3.2. Mitigation scenarios, calculation of the remaining budget and the derivation of exemplary emission trajectories

In Höhne and Moltmann (2009), country/region-specific carbon budgets and the emission trajectories up to 2100 were calculated with an assumption that drastic mitigation actions will be taken around the world after 2010. As of 2014, many countries including Japan are not taking mitigation efforts that are consistent with their respective carbon budgets. Therefore, we investigated how the delayed actions affect the emission trajectories up to 2100. This study calculated the emission trajectories under the following two scenarios with regard to the starting year of aggressive mitigation actions:

Scenario A – “Immediate action from 2014”: This scenario assumes that from 2014 onward the emissions will be reduced at a pace that allows Japan to stay within its carbon budget. This scenario aimed to describe what the emissions pathways look like under given carbon budgets if the mitigation efforts are taken from 2014 onward, despite being already 4 years delayed compared to the original analysis in Höhne and Moltmann (2009).

Scenario B – “Delayed action”: For the second scenario we assume that Japan will reach the Warsaw Target and will only thereafter start reducing emissions at a pace that allows the country to stay within its carbon budget. This scenario aimed to illustrate the level of effort needed by Japan after 2020 if it decides to adhere to the Warsaw Target.

The details of the derivation of emissions trajectories for different scenarios under given calculated carbon budgets are described in Fekete et al. (2013). Figure 3 shows how the carbon budget is distributed over the years. GHG

⁶ This approach is inspired by the “Contraction and Convergence” approach of the Global Common Institute (GCI). <http://www.gci.org.uk/cbat-domains/Domains.swf>

Table 1: Description of the three effort-sharing approaches. Source: Höhne and Moltmann (2009), Höhne et al. (2014a).

Effort-sharing approach	Description	Equity principles		
		Responsibility	Capability	Equality
Converging Per Capita Emissions (CPE)	All countries, regardless of their development or emission levels, agree to converge their per capita emissions from the current level to a level equal for all countries by a predefined year (set at 2050 in Höhne and Moltmann (2009)), ensuring that global aggregated cumulative emissions remain within the global carbon budget. Some developing countries with very low per capita emissions today would be allocated allowances more than a Business-As-Usual (BAU) pathway.			X
Common but differentiated convergence (CDC)	Originally proposed by Höhne et al. (2006), all countries converge at the same per capita emissions levels by 2050 as with the CPE, but non-Annex I countries are required to commit to a specific target only when their per capita emissions reach a threshold, which is defined as a certain percentage of the gradually declining global average. The delayed participation of non-Annex I countries accounts for the differences across countries on per capita emissions, economic development levels, and historical contributions to global GHG emissions. No countries receive more allowances than BAU because countries participate only when their per capita emissions are above the threshold.	X	X	X
Greenhouse development rights (GDRs)	GDRs approach shares the global emissions budget between countries according to two equity principles: capacity (income) and responsibility (for historical emissions since 1990). These two data sets are combined to calculate each country's share of the global carbon budget. Wealthier and higher emitting countries receive a much smaller share of the budget than poorer and less emitting countries. The level for the development threshold, which is a per capita income level, is set at 7,500 US\$ ₂₀₀₅ per year as suggested by Baer et al. (2007).	X	X	

emissions were assumed to decrease linearly from the base year (t_{base}), which is scenario-specific, to a year of convergence (t_{con}). The year of convergence is then optimised to match remaining budgets. GHG emissions were assumed to remain stable after the year of convergence until 2100 (t_{end}). The level of stabilisation was taken from the model runs in Höhne and Moltmann (2009) and differs depending on the effort-sharing approach.

The calculations in Höhne and Moltmann (2009) were based on earlier versions of Japan's GHG emissions inventory and other data sources, which differ from the latest official emissions data (GIO, 2014). The remaining carbon budget at the base year was, therefore, calculated following the approach taken in Fekete et al. (2013). The carbon budgets calculated in Höhne and Moltmann (2009) based on old datasets were used as they are and the

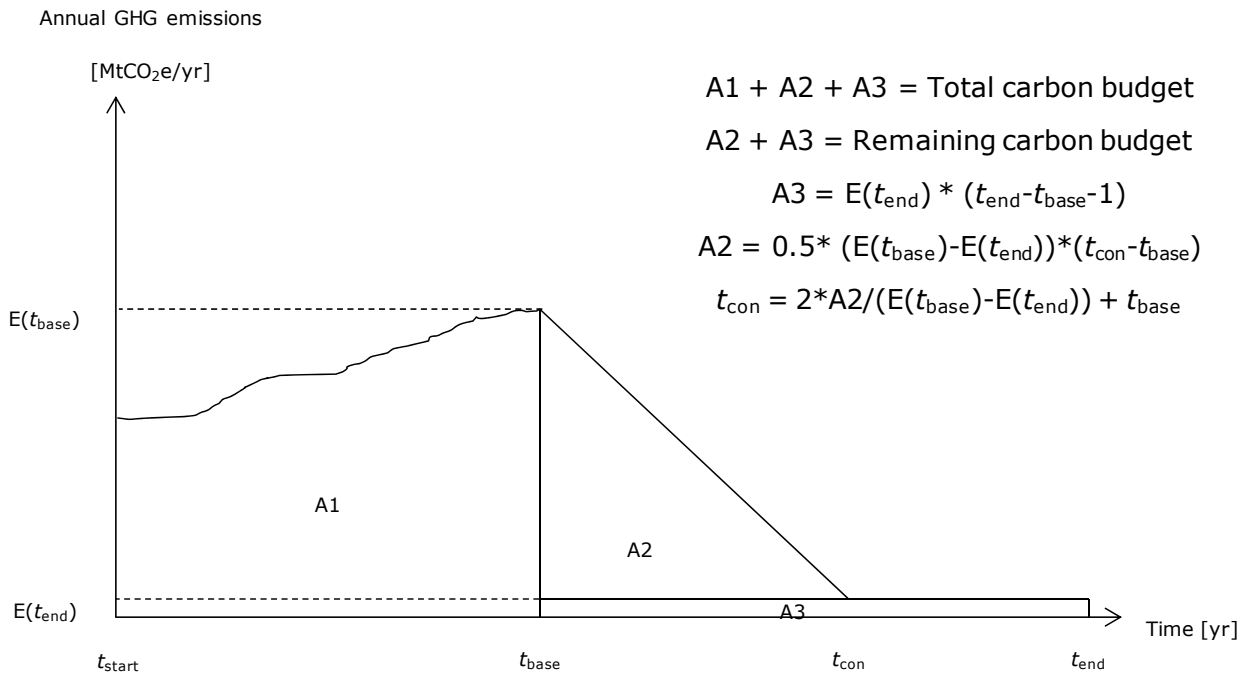


Figure 3: Illustration of approach to development of exemplary emissions trajectories. Source: adapted from Fekete et al. (2013).

latest national GHG inventory report (GIO 2014) was used to calculate the budget spent between 1990 and 2012. The Warsaw Target was recalculated to exclude emissions reduction through LULUCF, based on the Biennial Report submitted to the UNFCCC (Japanese Government 2013).⁷ If the emissions reductions through forest

sinks are excluded, the Warsaw Target translates into 1337 Mt-CO₂e/yr or a 1% reduction from 2005 levels including overseas credits. The BAU GHG emissions between 2012 and 2020 were estimated by linear interpolation between 2012 historical emissions data and the 2020 mitigation target emission levels.

⁷ The targeted forest sequestration for 2020 was reported to be 38 Mt/yr (GoJ, 2013).

4. Results

4.1. Calculated carbon budget

Table 2 presents the carbon budget allocated and remaining for Japan under three effort-sharing principles. Between 1990 and 2013 Japan emitted about 32 Gt-CO₂e of GHG emissions. Results show that Japan has already used 57%-61% of its 'fair share' of the global carbon budget under the CPE and CDC approaches, which were calculated to be 51 Gt-CO₂e and 54 Gt-CO₂e, respectively. If Japan keeps on emitting GHG at the 2012 level (1343 Mt-CO₂e excluding LULUCF and Kyoto units), the remaining budget would be consumed by 2031 at the latest.

Under the GDRs approach, in contrast, total budget (1990-2100) allocated to Japan is already below

zero in 1990 (-25 Gt-CO₂e) and the budget remaining for 2014-2100 is -59 Gt-CO₂e. This result signifies that the average annual emissions reductions required on the basis of capability and responsibility up to 2100 is larger than the current emission levels because of Japan's very high responsibility and capability. Since it is not easy to generate policy-relevant discussions based on a negative carbon budget, no further analysis for GDRs approach is conducted hereinafter in this paper.

For the reference NCA, which assumes that Japan adheres to the current mitigation targets for 2020 and 2050, the cumulative GHG emissions between 1990 and 2100 were calculated to be 70 Gt-CO₂e. This is 16 Gt-CO₂e and 19 Gt-CO₂e more than the carbon budgets under CPE and CDC approaches.

Table 2: Japan's Carbon budget allocated, used and remaining (excluding land use change and forestry) for four effort-sharing approaches.

Effort-sharing approach	Total budget allocated to Japan for 1990-2100 (Gt-CO ₂ e)	Share of budget spent 1990-2013 (31 Gt-CO ₂ e)	Remaining budget 2014-2100 (Gt-CO ₂ e)	The year the budget runs out if 2012 emission levels* continue
Converging Per Capita Emissions (CPE)	54	57%	23	2031
Common but Differentiated Convergence (CDC)	51	61%	20	2028
Greenhouse Development Rights (GDRs)	-25	Overspent	Overspent	Overspent
Nationally Committed Amount (NCA; reference)	70	45%	39	2042

* 1343 Mt-CO₂e excluding LULUCF and Kyoto units.

4.2. Exemplary emission trajectories under the calculated carbon budget

Our analysis highlights the wide gap between the emission trajectories calculated from the carbon budgets under CPE and CDC approaches and the reference NCA (Figure 4, Table 3, Figure 5). For CPE and CDC approaches, the Scenario A results indicated that Japan's "fair" mitigation commitments for 2020 ranged between -22% (CPE) and -27% (CDC) below 1990 levels. For 2030, Japan's emissions need to be reduced by 54% below 1990 levels by 2030 even under the CPE approach, which is the least stringent effort-sharing approach for Japan among the three approaches in this analysis. These results are also far more stringent than the results of the technology-based bottom-up assessment conducted by an expert committee of the Ministry of the Environment (MOE, 2012), which estimated that 39% emissions reduction by 2030 from 1990 levels can be achieved assuming a nuclear power share of 35%. For 2050, the results for CPE and CDC approaches show that the emissions need to be reduced by 95% regardless of the starting year for drastic mitigation.

Scenario B results for CPE and CDC approaches, moreover, showed that the emissions would need to be reduced by 95% from 1990 levels before 2040 for both effort-sharing approaches. The average annual emissions reduction amounts ranged between 89 Mt-CO₂e/yr and 136 Mt-CO₂e/yr, which is larger than the major drop observed between 2007 and 2008 in Japan due to the global economic crisis (83 Mt-CO₂e/yr) as shown in Figure 1. These results strongly indicate

that keeping Japan's GHG emissions within the carbon budget calculated under CPE and CDC approaches would be extremely difficult if actions for drastic mitigation are delayed until 2020.

Under the reference NCA, Scenario A results show that the emissions reduction trajectory could be significantly relaxed if drastic mitigation actions are taken immediately from 2014, rather than adhering to the current national mitigation targets for 2020 and 2050. Table 3 shows that if Japan can reduce its emissions by 12% from 1990 levels by 2020, then the country would only need to reduce emissions by 69% by 2050 from 1990 levels to stay within this reference carbon budget.

Another interesting observation comparing Figures 4 and 5 is that the required emissions reduction rate under the reference NCA in Scenario B (36 Mt/yr) is fairly close to that for the CPE approach in Scenario A (41 Mt/yr). By lowering the ambition level of the 2020 mitigation target announced at COP19 in Warsaw, Japan has forced itself to reduce GHG emissions after 2020 at a rate that is extremely difficult to achieve. The results highlight that if Japan is to take the carbon budget concept, it would make more sense to strengthen the current 2020 mitigation target, rather than sticking to the current one, in order to keep the average mitigation rate after 2020 within a more realistic range. It is worth noting, however, that the average emissions reduction rates discussed above are still similar to or larger than the CO₂ emissions reduction rate observed for the Soviet Union after its collapse (2%-4% per year) and in Sweden and France after the oil crisis (2%-3% per year) (Riahi et al., 2014).

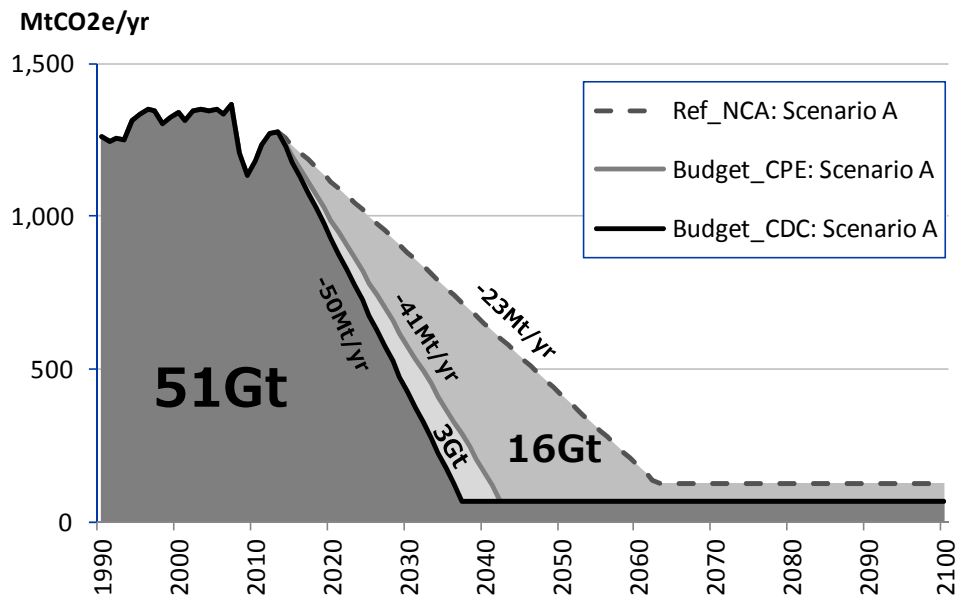


Figure 4: Japan’s exemplary GHG emission pathways for scenario A (immediate action from 2014) under the carbon budget calculated for two effort-sharing approaches (CPE and CDC) and a reference (NCA) approach.

Table 3: Comparison of Japan’s current mitigation targets and necessary mitigation levels implied by two effort-sharing approaches (CPE and CDC) and the reference Nationally Committed Amount under Scenario A (immediate action from 2014).

Target year	National target	CPE			CDC			NCA		
	vs. 1990 (%)	vs. 1990 (%)	vs. 2005 (%)	vs. 2010 (%)	vs. 1990 (%)	vs. 2005 (%)	vs. 2010 (%)	vs. 1990 (%)	vs. 2005 (%)	vs. 2010 (%)
2020	+3.1	-22	-27	-21	-27	-31	-26	-12	-17	-11
2030	N.A.	-54	-57	-54	-66	-68	-66	-30	-35	-30
2050	-80	-95	-95	-95	-95	-95	-95	-69	-71	-67

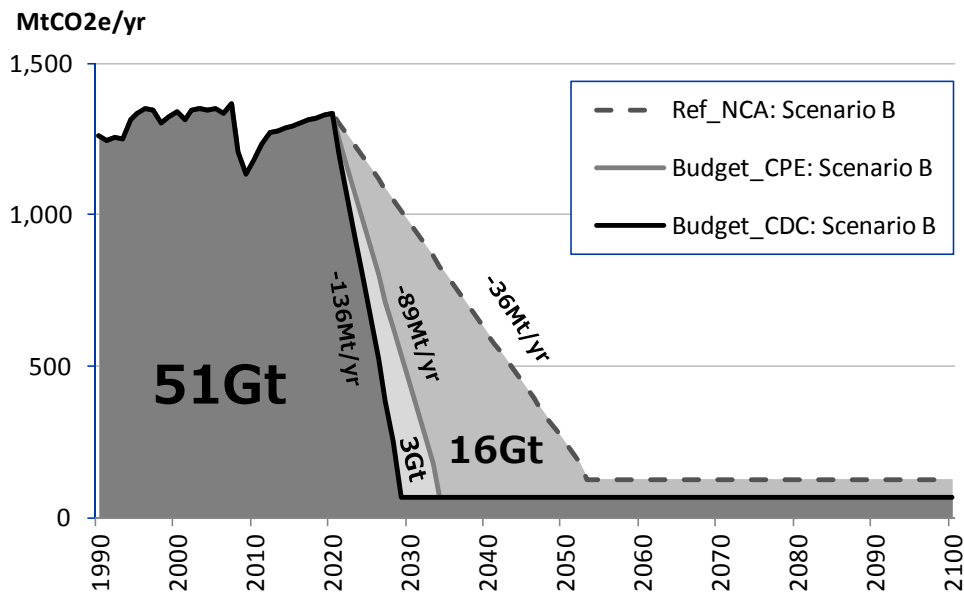


Figure 5: Japan's exemplary GHG emission pathways for scenario B (delayed action until 2020) under the carbon budget calculated for two effort-sharing (CPE and CDC) approaches and the reference Nationally Committed Amount (NCA).

4.3. Required additional emission credits to meet the carbon budget

Since the carbon budget concept does not concern actual domestic emissions but emissions rights, Japan can stay within its carbon budget by acquiring emission credits from overseas. In the long-term future Japan's domestic GHG emissions needs to be reduced to near zero, but in the short-to mid-term purchasing international offset credits from overseas can be an important option considering the drastic emission reduction requirements under the investigated scenarios. While the use of international credits could displace domestic mitigation activities, it contributes to lowering the overall cost of achieving targets.

As shown in Table 2, the amount of additional emissions reductions required under CPE and CDC approaches compared to the reference NCA would amount up to 16-19 Gt-CO₂e. Since it is expected that Japan would continue to acquire international

emission credits even for only achieving the current national mitigation targets, which is represented in this study as the reference NCA, this study assumed that all additional GHG emissions reductions under CPE and CDC approaches compared to the NCA are achieved by international emission credits. Figure 6 shows that when they are spread over the period between 2014 and 2100, the average annual acquisition of international credits would range between roughly 180 Mt/yr and 220 Mt/yr, which is equivalent to 14%-17% of Japan's 1990 emissions. When they are spread over the period between 2014 and 2050, the average annual acquisition of international credits would range between 420 Mt/yr and 510 Mt/yr, which is equivalent to 34%-40% of Japan's 1990 emissions. The calculated amount is considerably larger when it is compared with the average Kyoto Units acquired by the Japanese government and the Japanese private sectors (74 Mt-CO₂e/yr) to meet the Kyoto target.

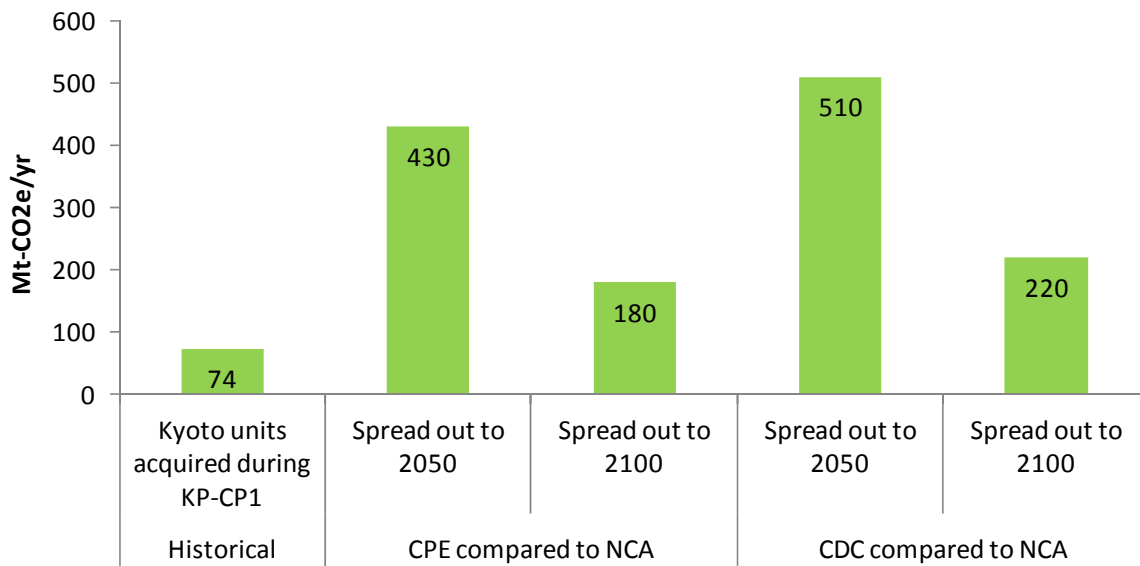


Figure 6: Required emission credits in addition to the reference Nationally Committed Amount (NCA) case to keep Japan’s GHG emissions within the carbon budget under CPE and CDC approaches.

It may be considered unfair to make a comparison with the acquisition of Kyoto Units during the KP-CP1 because it was only a temporal measure to achieve Japan’s mitigation target for 2008-2012, whereas the calculated additional credit requirement concerns a much longer timeframe. Nonetheless, the comparison highlights the significant scale of the additional emission credits required for Japan to stay within the calculated carbon budget.

5. Discussion

This study is one of the first to quantitatively assess Japan’s carbon budgets consistent with the 2 °C target under commonly referenced equity principles in comparison with the country’s current policy targets. This section discusses the policy implications of the results and the limitations of the research methodology taken in this study.

5.1 Significance of the results

The obtained results have shown that the remaining carbon budgets under CPE and CDC

approaches are about half of the amount Japan would emit up to 2100 under the NCA, i.e. if the country does not reduce its GHG emissions beyond its current 2020 and 2050 mitigation targets (19-23 Gt-CO₂e compared to 38 Gt-CO₂e). If Japan continues to emit GHG at current levels, it will already have run out of carbon budget by early 2030s. This result highlights the major gap between the current mitigation commitments by the Japanese government and the mitigation levels that are considered to be a ‘fair share’ of global carbon budget for Japan under different effort-sharing approaches to achieve the 2 °C target.

Moreover, the results of this study have shown the large impact of delayed actions on the emission trajectories that Japan can possibly take. Although the Japanese government is facing difficulties in setting ambitious mitigation plans and actions in the absence of a clear direction on future energy policy after the Fukushima nuclear disaster, this study highlights the importance of taking more aggressive, concrete mitigation actions

immediately towards a transition to low-carbon society. If this is not done, the country will end up generating higher cumulative emissions between 1990 and 2100 with limited mitigation to be achieved by 2050. In particular, serious “lock-in” of carbon-intensive technologies as a result of compensating for the reduced nuclear power generation may have serious consequences on Japan’s future climate mitigation actions (discussed in detail in Section 5.2). Delayed actions may reduce the mitigation burden and associated costs in the near term, but this near-term inaction will lead not only to stronger medium-term emission reductions, but also to “lock-in” and path dependencies, higher overall costs, reduced societal choices and higher climate risks (UNEP 2013). These are important trade-offs between near and long term futures. At the same time, it would become increasingly important for Japan to consider acquiring a fair amount of emission credits from overseas in order to keep its future GHG emissions within the carbon budget assessed in this study in a cost-effective manner. This paper also contributes to domestic discussion over Japan’s post-2020 emission reduction target, by explicitly addressing equity principles and consistency with the 2°C goal which have not been adequately considered so far. The domestic discussion has largely revolved around the notions of technological potential, cost-effectiveness and political acceptance to the domestic constituency, rather than equity principles of responsibility, capability and equality. When the Japanese government first formulated the 2020 mitigation target in 2009, the equal Marginal Abatement Cost (MAC) and equal additional cost per GDP approaches were among the global effort-sharing methods used, and the final target level was roughly consistent with equal additional cost per GDP approach (The Cabinet, 2009). In contrast, the carbon budget approach taken by this paper highlights the equity principles and the long-term consistency of cumulative emissions up to 2100

with the 2°C goal.

Finally, the national carbon budget presented in this paper gives a benchmark to which policymakers can refer when discussing Japan’s mitigation target, and also against which Japan’s mitigation target is assessed. Some may argue that the idea of dividing a global carbon budget into national budgets results in a zero-sum game and gives rise to negative consequences to international negotiations. However, concrete numbers which are regarded “fair” based upon certain equity principles can serve as a benchmark against which the adequacy of individual countries’ pledged targets is assessed.

5.2. Implications on recent energy policy developments in Japan

With regard to recent energy policy developments in Japan, it is important to assess the expected GHG emissions from the new coal-fired power plants currently being planned in the context of Japan’s carbon budget. Following the Fukushima disaster in March 2011, regional electric utilities are planning to increase the capacity of coal-fired power plants, which would cause “lock-in” of GHG emissions.⁸ Recently, five regional Electric Power Companies (Tokyo, Tohoku, Kansai, Chubu and Kyushu) have announced open bids for a total of 11.4GW of new fossil fuel-fired power plant constructions (Kiko Network 2014).⁹ It has been reported that most of these new constructions will be coal-fired and this trend may continue beyond 2020 (Kiko Network 2014; Reuters 2014). If the entire 11.4GW capacity bid is assumed to be coal-fired, the resulting, incremental CO₂ emissions would be about 68 Mt-CO₂ per year, which is equivalent to about 5% of the GHG

⁸ Currently, the Japanese Government is also promoting the export of coal-fired power plants by providing public money through Japan Bank of International Cooperation (JBIC) and Nippon Export and Investment Insurance (NEXI) (Kuramochi et al. 2012; Nakhoda et al. 2013). In contrast, the U.S. government as well as the World Bank has stopped publicly supporting the export of coal-fired power plants.

⁹ To date, bids have already been closed for a total 0.68 GW called by TEPCO.

emission of Japan in 1990. For the 40-year lifetime, cumulative GHG emissions will be 2.7 Gt-CO₂,¹⁰ which is about 12%-14% of the remaining carbon budget for 2014-2100 under CPE and CDC approaches and 7% of that under NCA.

To minimize the “lock-in” of carbon-intensive technologies, renewable energy deployment and energy efficiency will become crucial. For renewable energy, the recent development under the Feed-In Tariff (FIT) scheme indicate that renewable electricity has the potential to minimize the increase of fossil fuel-fired power generation. Since the FIT scheme started in July 2012, the total renewable power capacity of 69 GW has been approved as of March 2014.¹¹ Assuming the capacity factors reported in a Japanese government report (NPU 2011),¹² the renewable capacity approved under the FIT scheme as of March 2014 could generate 84 TWh/yr when fully operated, which is already close to the amount of electricity that the aforementioned coal-power plants of 11.4GW would generate (about 90 TWh/yr). Considering the large untapped renewable energy potential, the continued policy support for renewable electricity deployment could minimize the future constructions of new carbon-intensive power plants.

Moreover, energy savings, for example, in the residential and commercial sectors could significantly contribute to minimizing carbon-intensive power generation. Figure 7 shows the energy-related CO₂ emissions including indirect emission from electricity consumption by sector during the KP-CP1. The performance of

energy-related CO₂ emissions in the aforementioned two sectors were poor compared to the target emission levels under the Kyoto Protocol Target Achievement Plan (KPTAP), regardless of the impact of the Fukushima nuclear disaster and despite the lower actual GDP growth compared to the projections under the KPTAP (Figure 7).¹³ Since large part of the emissions from the two sectors are attributable to electricity use, the figure indicates that large part of the CO₂ emissions from the aforementioned 11.4GW of coal-fired power plants could be avoided if the two sectors would at least reduce their emissions to the levels targeted under the KPTAP.

In addition, it is also interesting to assess how much the restart of existing nuclear power plants would contribute to Japan’s staying within its carbon budget because stronger climate policy tend to support nuclear power in Japan (Skea et al. 2013). Currently all nuclear reactors have stopped operating, and 19 reactors from 13 plants have submitted applications to the Nuclear Regulation Authority for restart as of August 2014 (NRA 2014). Estimations based on the reactor data (IEEJ 2013) indicate that the operating nuclear capacity in 2015 would be about 36 GW if all 19 reactors restart.¹⁴ Assuming a 40-year lifetime and a 70% capacity factor, the restarted reactors will generate around 2000 TWh from 2015 onward during their lifetime, which could replace roughly 1.5 Gt of CO₂ emissions from coal-fired power plants. The calculated amount is a little more than the total domestic GHG emissions (excluding LULUCF) in 2012, and equals to about 7%-8% of the remaining carbon budget for 2014-2100 under CPE and CDC approaches shown in Table 2. For 2020 and 2030, the displaced CO₂ emissions would be up to 7%

¹⁰ Assumptions for the estimate: CO₂ emission factor for coal is 90.6 g/MJ HHV taken from the METI Comprehensive Energy Statistics (ANRE 2013), average electrical conversion efficiency of 43% HHV (gross) taken from the METI and MOE CO₂ emissions guidelines (METI and MOE, 2013) for USC plants of 900-1100MW capacity, and an average capacity factor of 90%.

¹¹ Note that less than 15% of all approved capacity was in operation as of March 2014 (METI 2014).

¹² 12% for solar photovoltaics, 20% for wind, 60% for small-medium hydro, 80% for biomass (coal co-firing) and geothermal, respectively.

¹³ Some point out that the mitigation target for the industry sector under KPTAP is based on the industry’s voluntary action plan and is not appropriate as a fair target (Joint Statement by Environmental NGOs 2007).

¹⁴ The data excludes all reactors in Fukushima Daiichi and Daini power plants and reactors that reached a 40-year lifetime.

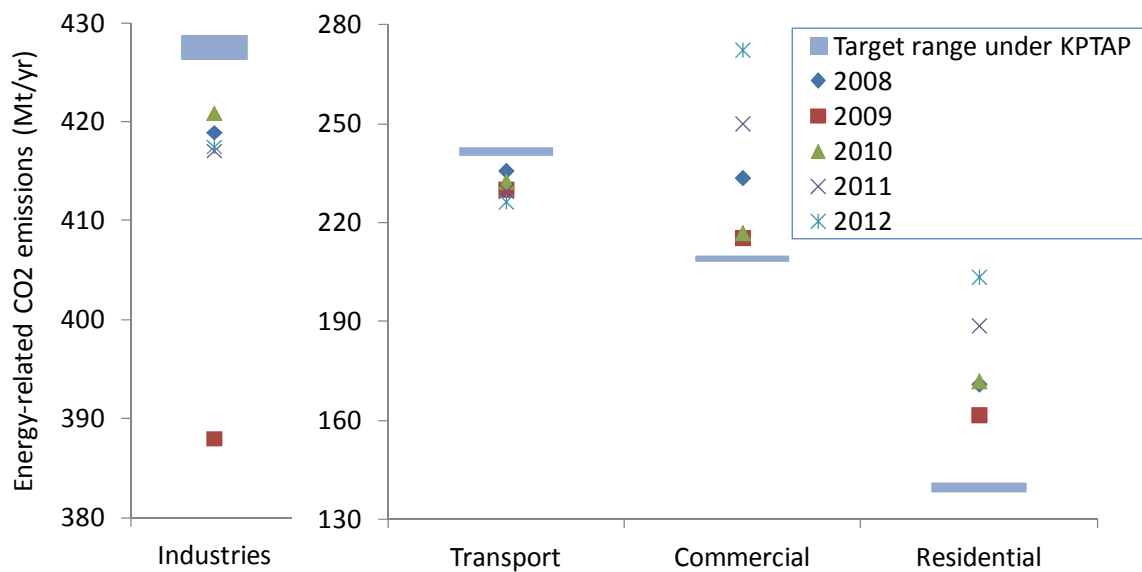


Figure 7: Energy-related CO₂ emissions (indirect emissions from electricity use allocated to final consumers) in Japan during the first commitment period of the Kyoto Protocol: Comparison between planned under the Kyoto Protocol Target Achievement Plan (KPTAP) and actual emissions. Source: GoJ (2008) and GIO (2014).

and 5% of 1990 total GHG emissions, respectively. In a hypothetical case when all 37 reactors that can be restarted operate from 2015, they would generate about 3500 TWh during their lifetime and displace roughly 2.6 Gt of CO₂ emissions from coal-fired power plants.

5.3. Limitations of the research methodology

Two key limitations of this study with regard to the research methodology are identified. First, the global carbon budget used for the analysis (1800 Gt-CO₂e for 1990-2100 excluding LULUCF) is one of the most stringent out of all the literature investigating 2°C emissions pathways (Höhne et al. 2014a). Although it may be argued that the calculated carbon budgets are overly tight, we consider that this reflects the current international climate negotiations under the UNFCCC, in which most vulnerable countries strongly argue for holding global average temperature rise within 1.5°C above pre-industrial levels. Moreover, the use of a tighter global carbon budget serves the purpose of this paper well because one of its aims was to assess and discuss quantitatively the gap

between the current level of national commitments and scientifically calculated “fair shares of efforts” for developed countries under clear definitions of “ambitious”, “fairness” and “equity”. There was little discussion on these concepts in Japan’s policy formulation process.

Second, this study did not investigate all of the seven effort-sharing categories identified by Höhne et al. (2014a). As described above, Japanese policymakers may favor effort-sharing based on “Cost-effectiveness” principle and “Capability” principle represented by equal MAC and equal additional cost per GDP, respectively, because Japan is one of the efficient countries in terms of energy use per GDP.¹⁶ The literature indicates that while all three effort-sharing approaches investigated in this study lead to more stringent mitigation targets than the cost-effectiveness and capability approaches for countries like Japan, CPE and CDC approaches can be considered

¹⁶ Höhne et al. (2014b) clarifies that the equal cost GDP approach is categorised under “Capability” principle.

among the moderate of the seven effort-sharing categories described in Section 2.1. Höhne et al. (2014a) compared emission reductions reported in over 40 studies for the seven effort-sharing categories for “Japan, Australia and New Zealand” region. The mitigation target range was found to be by far the most stringent for “Responsibility, Capability and Need” category (represented by the GDRs approach in this study), while the range for “Capability” category was the least stringent, although the range was also wide. The mitigation target range for “Equality” and “Staged” categories, represented by CPE and CDC approaches in this study, was found to be in between the above two and around the lower end of the emissions reduction ranges for “Cost-effectiveness” and “Capability” categories. For example, Hof et al. (2012) calculated that the emissions reduction targets for Japan in 2030 under equal MAC and equal cost per GDP would be 36% and 34% from 1990 levels, respectively, while the reduction target under CPE approach was found to be roughly 10%-points more stringent at 45%.

Nonetheless, it should be noted that Cost-effectiveness is not recognized as a “fair” effort-sharing approach in IPCC AR5 (Chapter 6), in which it is referred to only as a reference, because Cost-effectiveness does not represent any of the three equity principles: responsibility, capability and equality. Moreover, it is important that a comparative assessment of effort-sharing results for 2020 and 2030 based on equal MAC from several bottom-up models shows that the results differ significantly across models due to various differing assumptions on articulating the MAC Curve for each model (Hanaoka and Kainuma 2012).

6. Conclusions

This paper assessed Japan’s “fair” carbon budget between 1990 and 2100 under three commonly referred effort-sharing approaches: CPE, CDC, and

GDRs, and the consequent GHG emission pathways up to 2100 for the country to stay within the budget. The calculated carbon budgets were compared with Japan’s projected cumulative GHG emissions up to 2100 in case of adhering to the existing national mitigation targets committed up to 2050, denoted by NCA.

Japan’s carbon budget for the period 1990-2100 under CPE and CDC approaches were calculated to be 51-54 Gt-CO₂e, of which about 31 Gt-CO₂e had already been used by 2013. This study also showed that cumulative GHG emissions in Japan between 1990 and 2100 for the reference NCA would be about 70 Gt-CO₂e, exceeding the aforementioned carbon budget by 16-19 Gt-CO₂e. It is also worth noting that the remaining carbon budgets under CPE and CDC approaches were found to be about half of the amount the country would emit up to 2100 under the reference NCA (20-23 Gt-CO₂e compared to 39 Gt-CO₂e). If Japan continues to emit GHG at current levels, it will run out of its carbon budget by 2032 at the latest. In addition, Japan’s carbon budget under the GDRs approach was found to be negative for 1990-2100, due to the very high responsibility and capability that is determining the results under this approach.

The emission pathways calculated for the two effort-sharing approaches (CPE and CDC) showed that Japan needs to reduce emissions immediately and drastically. The mitigation levels of Japan in 2020 range between 22% and 27% below 1990 levels (excl. LULUCF) assuming that immediate actions were taken after 2013 (Scenario A), which is far more stringent than the revised 2020 mitigation target announced in the Warsaw COP and similar to the Copenhagen Pledge. For 2030 the results indicated a target range of 54% - 66% reduction from 1990 levels under Scenario A and 95% for Scenario B, in which aggressive mitigation actions are delayed until 2020. The results for Scenario B has shown that the average

annual emissions reduction rate needs to be equal to or faster than the large reduction observed in Japan between 2007 and 2008 due to the global economic crisis. The results have also shown that the average annual mitigation rate between 2020 and 2050 based on the government's mid- and long-term mitigation targets (reference NCA, Scenario B) is similar to the mitigation rate required between 2014 and 2050 under the CPE approach with immediate actions from 2014 (Scenario A).

This study also calculated the amount of international emission credits that needs to be additionally acquired compared to the reference NCA case for Japan to stay within the carbon budget under CPE and CDC approaches. The results were found to be substantial; the average annual requirement amounted to 14%-17% of 1990 emissions when spread out until 2100 and 34%-40% of 1990 emissions when spread out until 2050.

Although it is not clear which country will use what criteria for their "fair" effort-sharing, it is quite possible that each country will argue from their own perspectives. This may result in a non-transparent situation in which the collective ratcheting-up of the commitment would be difficult. Therefore it is crucial that intensive reviews on the contribution pledged by each of the Parties will be implemented by the Parties, researchers and NGOs (Tamura et al. 2013). It is expected that the analysis conducted in this paper as well as the various studies mentioned in this paper will serve as points of reference to assess the "fairness", "adequacy" and "appropriateness" of the pledges made by the Parties and will contribute to the advancement of the international efforts to tackle climate change.

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References

- ANRE, 2013. Comprehensive Energy Statistics 2013. Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry. Tokyo, Japan.
- Baer, P., Athanasiou, T., and Kartha, S., 2007. The right to development in a climate constrained world. The Greenhouse Development Rights framework. Heinrich-Böll-Foundation, Christian Aid, EcoEquity and the Stockholm Environment Institute. Berlin.
- BASIC Experts, 2011. Equitable access to sustainable development: contribution to the body of scientific knowledge, Beijing.
- The Cabinet, 2009. “Chikyuu Ondanka No Chuuki Mokuhyou No Sentakushi” (Options for the Mid-Term Climate Mitigation Target). In Japanese. Tokyo, Japan: Cabinet Secretariat, 2009. http://www.kantei.go.jp/jp/singi/tikyuu/kaisai/dai07t_yuuki/siryou1_honbun.pdf.
- Fekete, H., Hagemann, M., and Höhne, N., 2013. “Australia’s carbon budget based on global effort sharing, Technical report”, Ecofys Project number: CLIDE13854, Date: 30 May 2013. http://awsassets.wwf.org.au/downloads/fs067a_australia_carbon_budget_based_on_global_effort_sharing_24oct13.pdf [Accessed September 10, 2014].
- GIO, 2014. National Greenhouse Gas Inventory Report of JAPAN. Ministry of the Environment, Japan, and Greenhouse Gas Inventory Office of Japan. April, 2014.
- GoJ, 2008. Kyoto Protocol Target Achievement Plan (Totally revised March 28, 2008), Government of Japan, 2008.
- GoJ, 2013. Japan’s First Biennial Assessment under the United Nations Framework Convention on Climate Change. The Government of Japan. December, 2013.
- Hanaoka, T., and Kainuma, M., 2012. Low-carbon transitions in world regions: comparison of technological mitigation potential and costs in 2020 and 2030 through bottom-up analyses. Sustainability Science, Volume 7, Issue 2, pp 117-137.
- Höhne, N., Galleguillos, C., Blok, K., Harnisch, J., and Phylipsen, D., 2003. Evolution of Commitments under the UNFCCC: Involving Newly Industrialized Countries and Developing countries. Research Report 20141255, UBA-FB 000412. Ecofys, Berlin, Germany.
- Höhne, N., den Elzen, M.G.J., and Weiss, M., 2006. Common but differentiated convergence (CDC): a new conceptual approach to long-term climate policy. Climate Policy 6 (2), pp. 181–199.
- Höhne, N. and Moltmann, S., 2009. “Sharing the effort under a global carbon budget”. Ecofys report, commissioned by WWF International.
- Höhne, N., den Elzen, M., and Escalante, D., 2014a. Regional GHG reduction targets based on effort-sharing: a comparison of studies, Climate Policy, Vol. 14, No. 1, 122 –147.
- Höhne, N., Fekete, H., Ellermann, C., and Freitas, S., 2014b. Differentiated mitigation commitments in a new climate agreement. LDC paper series. Updated January 2014.
- Hof, A., Brink, C., Mendoza Beltran, A., and den Elzen, M., 2012. Greenhouse gas emission reduction targets for 2030: Condition for EU target of 40%, PBL Netherlands Environmental Assessment Agency Policy studies. http://www.pbl.nl/sites/default/files/cms/publicaties/PBL_2012_Greenhouse-gas-emission-reduction-targets-for-2030_500114023.pdf [Accessed September 10, 2014].
- Horstmann, B. and Scholz, I., 2011. Burden-Sharing and Allocation Criteria under the UN Climate Regime – Neither Fair nor Effective. Briefing Paper 15/2011. German Development Institute.
- IEEJ, 2013. EDMC Handbook of Energy & Economic Statistics. 2013 Edition. Edited by The Energy Data and Modelling Center, The Institute of Energy Economics, Japan, and the Energy Conservation Center, Japan.
- IPCC, 2013. Climate Change 2013: The Physical Science Basis, Working Group I contribution to the 5th Assessment Report, Intergovernmental Panel on Climate Change.
- IPCC, 2014. “Climate Change 2014: Mitigation of Climate Change”, Working Group III contribution to the 5th Assessment Report, Intergovernmental Panel on Climate Change. <http://www.mitigation2014.org/>
- Joint Statement by Environmental NGOs, 2007. “Chuuchyouki mokuhyou no moto ni bapponteki na seisaku dounyuu de Kyoto giteisho mokuhyou tassei wo!” (Achieve the Kyoto Protocol Target through the introduction of drastic policy measures under mid-long term mitigation targets!). In Japanese. <http://www.kiconet.org/iken/kokunai/archive/release20070525.pdf>
- Kiko Network, 2014. Fears of a Japanese Coal Rush Now a Reality: Utility Companies Announce Electricity Supply Plans.

- <http://sekitan.jp/en/info/article20140507/> [Accessed August 15, 2014]
- Kuramochi, T., Shimizu, N., Nakhooda, S., and Fransen, T., 2012. The Japanese Fast Start Finance Contribution. Working Paper. World Resources Institute, Overseas Development Institute, and the Institute for Global Environmental Strategies.
- Nakhooda, S., Fransen, T., Kuramochi, T., Caravani, A., Prizzon, A., Shimizu, N., Tilley, H., Halimanjaya, A. and Welham, B., 2013. Mobilising International Climate Finance: Lessons from the Fast-Start Finance Period. Overseas Development Institute, World Resources Institute, and the Institute for Global Environmental Strategies.
- Kuramochi, T., 2014. GHG Mitigation in Japan: An Overview of the Current Policy Landscape. WRI Working Paper. World Resources Institute and the Institute for Global Environmental Strategies.
- METI, 2010. The Strategic Energy Plan of Japan. -Meeting Global Challenges and Securing Energy Futures- (Revised in June 2010) [Summary]. Ministry of Economy, Trade and Industry. Tokyo, Japan.
- METI, 2014. FIT facility approval statistics (as of March 2014). Agency of Natural Resource and Energy (ANRE), Ministry of Economy, Trade and Industry. 2014.
- http://www.enecho.meti.go.jp/category/saving_and_new/saiene/kaitori/dl/setsubi/201312setsubi.pdf [Accessed May 15, 2014].
- METI and MOE, 2013. “Tokyo denryoku no karyokudengen nyuusatsumi ni kansuru kankei kyokuchoukyuu kaigi torimatome” (Summary report of the director-general level conference concerning the Bids on Thermal Power Generation Facilities of TEPCO). Ministry of Economy, Trade and Industry, and the Ministry of the Environment, Tokyo, Japan.
- MOE, 2011. Japan’s National Greenhouse Gas Emissions for Fiscal Year 2010 (Final Figures). Ministry of the Environment, Japan. Retrieved from: <http://www.env.go.jp/en/headline/headline.php?serial=1580> [Accessed May 15, 2014].
- MOE, 2012. 2013 Nen Ikou No Taisaku Sesaku Ni Kansuru Houkokusho (Heisei 24 Nen 6 Gatsu). Chikyuu Ondankataisaku No Sentakushi No Gen-an Ni Tsuite (Report on the Global Warming Countermeasures beyond 2013. Proposal of Options. June 2012). In Japanese. Global Environment Committee, Central Environment Council, Ministry of the Environment, Japan, 2012.
- <http://www.env.go.jp/earth/report/h24-03/index.html> [Accessed May 15, 2014].
- MOE, 2014. Japan’s National Greenhouse Gas Emissions in Fiscal Year 2012 (Final Figures). Ministry of the Environment, Japan. Retrieved from: http://www.env.go.jp/en/headline/file_view.php?serial=571&hou_id=2077 [Accessed May 15, 2014].
- Nakicenovic, N., Alcamo, J., Davis, G., de Vries, B., Fenhann, J., Gaffin, S., Gregory, K., Grubler, A., Jung, T. Y., Kram, T., Emilio la Rovere, E., Michaelis, L., Mori, S., Morita, T., Pepper, W., Pitcher, H., Price, L., Riahi, K., Roehrl, A., Rogner, H., Sankovski, A., Schlesinger, M., Shukla, P., Smith, S., Swart, R., van Rooyen, S., Victor, N., and Dadi, Z., 2000. Special report on emissions scenarios. Cambridge, UK: Cambridge University Press.
- NPU, 2011. Final Report of the Cost Verification Committee. Cost Review Committee, National Policy Unit, the Cabinet. 2011.
- http://www.npu.go.jp/policy/policy09/pdf/20111221/hokoku_kosutohikaku.pdf [Accessed May 15, 2014].
- NRA, 2014. “Shinkisei kijuntekigousei ni kakawaru shinsa (genshiryoku hatsudensho)” (Examination of compliance to the new regulatory requirements (nuclear reactors)). In Japanese. Nuclear Regulation Authority.
- http://www.nsr.go.jp/activity/regulation/tekigousei/p_ower_plants.html [Accessed August 10, 2014].
- Pauw, P., Steffen B., Carmen R., Clara B., and Hanna S., 2014. Different Perspectives on Differentiated Responsibilities: a State-of-the-Art Review of the Notion of Common But Differentiated Responsibilities in International Negotiations, Discussion Paper 6/2014, German Development Institute.
- Reuters, 2014. “Japan Steps up Shift to Coal, Gas amid Nuclear Shutdowns,” March 28, 2014. <http://www.reuters.com/article/2014/03/28/japan-utilities-plant-idUSL4N0MN1X520140328>, published on 28 March, 2014. [Accessed August 15, 2014].
- Riahi, K., Johnson, N., Bertram, C., Hamdi-Cherif M., and Méjean, A., 2014. Implication of near-term policies for long-term stabilization: The role of path dependency in energy systems for mitigation pathways, The AMPERE Consortium, 2014.
- Skea, J., Lechtenböhmer, S., and Asuka, J., 2013. Climate policies after Fukushima: three views. Climate Policy, Vol. 14, No. S01, S36-S54.

- Tamura, K., 2014. The IPCC Report and a New Global Climate Regime, JAPAN SPOTLIGHT. September/October 2014.
- Tamura, K., , Kuramochi, T., and Asuka, J., 2013. A Process for Making Nationally-determined Mitigation Contributions More Ambitious, Carbon and Climate Law Review, 4/2013: pp. 231-241.
- UNEP, 2013. The Emissions Gap Report 2013. United Nations Environment Programme, Nairobi.
- UNFCCC, 2008. Kyoto Protocol Reference Manual On Accounting of Emissions and Assigned Amount. United Nations Framework Convention on Climate Change. Bonn, Germany.
- UNFCCC. 2009. Communications Received from Parties in Relation to the Listing in the Chapeau of the Copenhagen Accord. Edited by the United Nations Framework Convention on Climate Change. Copenhagen Accord. Bonn, Germany. https://unfccc.int/files/meetings/cop_15/copenhagen_accord/application/pdf/japan_cphaccord_app1.pdf
- de Vos, R., van Breevoort, P., Höhne, N., Winkel, T., and Sachweh, C., 2014. Assessing the EU 2030 Climate and Energy targets, A Briefing Paper, Ecofys Germany. <http://www.ecofys.com/files/files/ecofys-2014-assessing-the-eu-2030-targets.pdf>
- WBGU, 2009. Solving the climate dilemma: the budget approach: Special Report. German Advisory Council on Global Change (WBGU), Berlin, Germany.
- World Bank, 2013. World Development Indicators. World Bank, Washington DC, USA. <http://data.worldbank.org/data-catalog/world-development-indicators>, accessed on 12 October, 2013.
- WWF Australia, 2013. Avoiding dangerous climate change: Defining Australia's carbon budget, WWF policy brief, 2013. http://awsassets.wwf.org.au/downloads/fs067_policy_brief_avoiding_dangerous_climate_change_defining_australia_carbon_budget_25.pdf [Accessed September 5, 2014].