Perspectives on Climate Change Research in Japan after the Paris Agreement: International Negotiations, Technologies and Countermeasures, Plus Adaptation
Editorial

It is our great pleasure to issue our journal ‘Global Environmental Research’ which aims to disseminate the results of studies on global environmental issues, studies conducted not only in Japan but also in other parts of the world. Many scientists monitor research in their own fields, but communications between scientists are not always easy, because the ranges of their fields are so broad, subjects are so diverse, and reports may not be written in an internationally spoken language. This journal is intended to help to fill these gaps.

In recent years, many reports, publications, and other forms of information have been released relating to Japanese studies on global environmental issues. The main purpose of ‘Global Environmental Research’ is to provide information on Japanese research results to scientists internationally and in a timely manner. We also hope that ‘Global Environmental Research’ will encourage exchanging information among such as the Asian and Pacific regions where local language barriers and limited opportunities exist.

International Geosphere-Biosphere Programme (IGBP), International Human Dimensions Programme of Global Environmental Change (IHDP) and other international and interdisciplinary programmes have produced a lot of important results. A new global research platform ‘Future Earth’ will provide the knowledge required to face risks posed by global environmental changes and to seize opportunities for global sustainability. The results of these studies need to be distributed worldwide. We hope this journal will also make a contribution to this end.

It was said that the title of the third scientific symposium of the IHDP ‘Global Change, Local Challenge’ recognizes that global changes are the results of a variety of local activities shaped by particular cultures, histories, political boundaries, and national policies. We are certain that our ‘Global Environmental Research’ will serve as a transmitter of information on local activities about global change.

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Preface

Key aspects of the Paris Agreement

The COP21 conference of the United Nations Framework Convention on Climate Change (UNFCCC) negotiated and adopted the Paris Agreement. Entering into force in November 2016, this epoch-making agreement united all developed and developing countries for future climate change governance. Essential elements of the Paris Agreement closely linked to the papers in this Special Issue of Global Environmental Research are as follows (UNFCCC Home Page, Decision 1/CP.21).

- The 2 degree Celsius target (Art. 2)—In seeking to strengthen the global response to climate change, the Paris Agreement reaffirms the goal of limiting the global temperature increase to well below 2°C, while pursuing efforts to limit the increase to 1.5°C.
- Global emission pathways (Art. 4)—To achieve the 2°C target, Parties aim to reach global peaking of GHG emissions as soon as possible, and to undertake rapid reductions thereafter in accordance with the best available science, to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century. All parties should formulate and communicate long-term low GHG emission development strategies.
- Sinks and reservoirs (Art. 5)—The Paris Agreement encourages the Parties to conserve and enhance sinks and reservoirs of GHGs including forests.
- Voluntary cooperation/Market- and non-market-based approaches (Art. 6)—The Paris Agreement recognizes the possibility of voluntary cooperation among Parties to allow for higher ambition and sets out principles for any cooperation that involves internationally transferal of mitigation outcomes. It establishes a mechanism to contribute to the mitigation of GHG emissions and support sustainable development, and defines a framework for non-market approaches to sustainable development. For this, the Japanese government has proposed a unique market mechanism called the Joint Crediting Mechanism (JCM).
- Adaptation (Art. 7)—The Paris Agreement establishes a global goal on adaptation – of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change. It aims to significantly strengthen national adaptation efforts, including through support and international cooperation. All Parties should engage in adaptation planning and are expected to submit and periodically update an adaptation communication on their priorities, implementation and support needs, plans and actions.

The Japanese government sets its top priority on taking countermeasures against global warming, having adopted the Plan for Global Warming Countermeasures in May 2016 to fulfill the mandate of the Paris Agreement. It sets a GHG reduction target of 26% by 2030, and long-term GHG reduction goal of 80% by 2050. The Japanese government will promote R&D of innovative technologies in the areas of energy and environment under this plan. Regarding adaptation, in November 2015 the Japanese government adopted the National Adaptation Plan as a Cabinet decision prior to COP21, and in August 2016 it established a platform called A-Plat for supporting adaptation actions under the National Adaptation Plan.

Outline of the Seven Papers of this Special Issue

In this Special Issue of Global Environmental Research, the editors asked Japan’s top scientists and experts in the areas of climate change science and policy to review and consider perspectives in related research fields after the Paris Agreement.

First, Dr. Kameyama of the National Institute for Environmental Studies (NIES) examines key issues for academic experts to prioritize and deal with to support implementation of the Paris Agreement in the post-2020 period. She presents the overall architecture and provisions of the Paris Agreement, maps its major themes, and considers governance issues related to equity and transparency.

Second, Dr. Ashina of NIES discusses transitioning of energy systems and technologies toward achieving the Paris Agreement. In Japan, most GHG emissions come from energy consumption, so de-carbonization of energy systems is crucial and essential. Therefore he underscores the need for technological innovation in energy supply and demand to achieve the target.

Third, Dr. Masui of NIES deals with future scenarios toward achievement of the 2°C target. He introduces
controversial discussions in Japan over the past decade toward the 2°C target, and discusses what will be needed in Japan to realize the 2°C target.

Fourth, Dr. Takahashi of NIES overviews research on climate change impacts and adaptation in Japan, and explains climate risk management based on scientific evidence. Based on this review, he suggests important directions for future research on climate risks such as co-design and co-production of climate risk for decision making and strategy planning, improvement of quantification and communication of uncertainties in climate risk analyses, and so on.

Fifth, Dr. Hara and Shimada of the Center for Environmental Science in Saitama (CESS) discuss recent progress in local governmental planning for climate change adaptation, presenting a typical case in Saitama Prefecture. Some municipalities have formulated their own adaptation plan based on the National Adaptation Plan. The Saitama Prefectural Government plays a leading role in local adaptation planning and its implementation as a good practice.

Sixth, Dr. Yamanoshita et al. of the Institute for Global Environmental Strategies (IGES) explain Japan’s new initiative for reducing emissions from deforestation and forest degradation in developing countries (REDD+). They examine a new bilateral initiative of Japan called JCM REDD+, which would contribute to REDD+ result-based finance. JCM REDD+ is a unique REDD+ activity, and to maximize its potential, modalities and guidelines for transparency and accounting related to REDD+, the Nationally Determined Contributions (NDCs), and Internationally Transferred Mitigation Outcomes (ITMOs) should be clarified under the Paris Agreement.

Lastly, Dr. Kuriyama and Dr. Morita of IGES identify factors for promoting renewable energy projects through the Clean Development Mechanism (CDM), and analyze CDM projects in China, India and ASEAN countries. This paper will be useful in applying the CDM to renewable energy projects in Asian countries.

These seven papers reviewing past research and envisioning future research after the Paris Agreement will be of great help to environmental researchers, experts and policy makers in promoting a variety of studies and surveys to achieve the 2°C target.

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Remaining Research Agendas in the Post-2020 Period under the Paris Agreement

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Abstract

This paper aims at examining key issues that should be prioritized and dealt with by academic experts in the next three to five years, particularly for the purpose of supporting effective implementation of the Paris Agreement in the post-2020 period. The paper starts off with a section briefly illustrating the overall architecture and provisions of the Paris Agreement, followed by a section mapping out major themes under which remaining issues exist that should be overcome before countries start taking actions under Paris Agreement rules after 2020, and how researchers could contribute to resolving these remaining issues. Among the remaining issues, this article takes up the dimension related to governance of the Paris Agreement, covering agendas related to equity and transparency. Other major elements should be further elaborated by other articles in this special issue. The paper concludes with presenting recommendations to a Japanese audience as to how Japan should proceed in the post-2020 period under the Paris Agreement. There are two ways of looking at the world. The first is the traditional image of the 20th century, where the economy is grounded in a stable fossil fuel supply, and emission reduction seems costly. The second is a new image of the 21st century, where emission reduction is considered an opportunity for change. The paper argues that Japanese stakeholders and researchers are affected by the former image of the world, but they need to be aware of the transition, and start taking action today.

Key words: climate change, governance, Japan, nationally-determined contribution (NDC), Paris Agreement

1. Background

The Paris Agreement has opened a new door for the world to respond to climate change. Adopted on the final day of the Twenty-first Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2015, the agreement took less than a year to enter into force in November 2016. While the Paris Agreement has been hailed as a historic diplomatic success (Kinley, 2016), there are loads of remaining issues that need to be tackled for the agreement to be most effectively workable. Many of the remaining agendas require expert knowledge and inputs from the scientific community.

This paper aims at examining key issues that should be prioritized and dealt with by academic experts in the next three to five years, particularly for the purpose of supporting effective implementation of the Paris Agreement. The first section briefly illustrates the overall architecture and provisions of the Paris Agreement. The second section maps out major themes under which remaining issues exist, that should be overcome before countries start taking action under Paris Agreement rules in the post-2020 period, and how researchers might contribute to resolving these remaining issues. Among these remaining issues, this article takes up the dimension related to governance of the Paris Agreement, covering agendas related to equity and transparency. It discusses how Japanese stakeholders are engaging in this aspect. Other major elements of the Paris Agreement are further elaborated by other articles in this special issue. This article concludes with recommendations to a Japanese audience as to how Japan should proceed in the post-2020 period under the Paris Agreement.

2. Architecture and Provisions of the Paris Agreement

The Paris Agreement is the outcome of a four-year negotiation process that was initiated by a decision called “Durban Platform,” that had been agreed to in 2011 at COP17 (Bodansky, 2016). The countries involved under the Durban Platform decided “to launch a process to develop a protocol, another legal instrument or an agreed outcome with legal force under the UNFCCC applicable to all Parties” (UNFCCC, 2011). The process was to include in its work elements related to “mitigation, adaptation,
finance, technology development and transfer, transparency of action, and support and capacity-building.” Thus, the structure and provisions of the Paris Agreement fully reflect the scope set by the Durban Platform.

2.1 Long-term Goals

Unlike the Kyoto Protocol, which set legal obligations on countries to limit or reduce their greenhouse gas (GHG) emissions to targets clearly indicated in the Kyoto Protocol, the Paris Agreement merely obligates each country to periodically prepare nationally determined contributions (NDCs) that it intends to achieve. The agreement does not ensure that the aggregated amount of all countries’ NDCs is sufficient to avoid dangerous consequences of climate change to human beings as well as ecosystems as described in Article 2 of the UNFCCC. The Paris Agreement sets a long-term goal of partially overcoming this deficit. Its Article 2 states, “Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels” would significantly reduce the risks and impacts of climate change. Article 4 follows by further stating, “Achieving a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century” should be aimed for to achieve the long-term target set out in Article 2. The COP decision invites the Intergovernmental Panel on Climate Change (IPCC) to provide a special report in 2018 on the impacts of global warming of 1.5°C and related global GHG pathways.

2.2 Mitigation

Article 4 of the Paris Agreement obligates each country to “prepare, communicate and maintain successive NDCs that it intends to achieve.” The successive NDCs are to represent progression beyond the country’s then current NDC and reflect its highest possible ambition. Developing countries are urged to continue taking the lead by undertaking economy-wide absolute emission reduction targets, while developing countries are encouraged to continue enhancement of mitigation efforts. Many of the first NDCs had already been submitted before COP21, setting targets for years up to around 2025 or 2030. All Parties must also strive to formulate long-term low GHG emission development strategies and communicate them by 2020. Countries may voluntarily use market mechanisms such as emissions trading schemes to achieve their NDCs (Article 6).

2.3 Adaptation, Loss and Damage

Both the UNFCCC and Kyoto Protocol put more weight on mitigation than adaptation, but it has become clear that adverse impacts of climate change are already occurring. Thus, the Paris Agreement aims at striking a balance between mitigation and adaptation. Its Article 7 establishes a global goal also for adaptation to enhance adaptive capacity, strengthen resilience and reduce vulnerability to climate change. Countries are to engage in adaptation planning processes and implement actions, including the development or enhancement of relevant plans, policies and/or contributions. Countries should submit and periodically update adaptation communications in ways that mitigation actions should be communicated.

The concepts of loss and damage already existed from the time of the UNFCCC, but were enshrined as an independent article in the Paris Agreement (Article 8). The Warsaw International Mechanism for Loss and Damage associated with Climate Change Impact shall be subject to the authority and guidance of the meeting of the Parties of the Paris Agreement (CMA).

2.4 Finance

Finance has always been one of central issues of contention in the climate regime. Several financial mechanisms have been established, but financial flows have been insufficient for responding to all the financial needs in developing countries. The Paris Agreement requests not only developed countries but also other countries to voluntarily provide financial resources to help developing countries take actions under the Paris Agreement (Article 9). One COP decision that was adopted with the Paris Agreement states, “Developed countries intend to continue their existing collective mobilization goal through 2025,” and “Prior to 2025 the CMA shall set a new collective quantified goal from a floor of US$100 billion per year.”

2.5 Transparency

Now that countries’ central obligation for the post-2020 period is to set NDCs and update them periodically, it has become more important to verify whether countries are making enough progress to achieve their NDCs. A transparency framework for action has thus become a necessary component of the Paris Agreement in order to build mutual trust and confidence. On the other hand, a series of processes have already been established under the UNFCCC that are related to monitoring, reporting and verification (MRV). Article 13 of the Paris Agreement therefore aims at making the best use of these existing processes in the most efficient manner. Existing reporting requirements are focused mainly on mitigation actions, but with new commitments of the Paris Agreements, actions related to other elements, notably adaptation and finance, should also be subject to the MRV process.

2.6 Global Stocktaking

Global stocktaking is a process inserted into the Paris Agreement to assess the collective progress towards achieving the long-term goals. Countries’ NDCs are nationally determined, which does not ensure reaching the ultimate long-term goal. The first global stocktaking is to be held in 2023, but the procedures’ details have yet to be determined. Somewhat related to the stocktaking process is a facilitative dialogue among countries to be
hold in 2018 to take stock of the collective actions, as
described in the COP decision. This is an important
process because this is just about the only avenue for
countries to assess sufficiency of their own and other
countries’ efforts to curb global GHG emissions towards
reaching the long-term goals.

2.7 Differentiation
Both the UNFCCC and Kyoto Protocol categorized
countries into two distinctive groups called Annex I and
non-Annex I. The Annex I group consisted of developed
countries and countries in transition into a market
economy, such as former Soviet Union countries. Countries
that achieved economic development were expected to shift from non-Annex I to Annex I. This
categorization became outdated as the distinction
between the two groups became vague. The Paris
Agreement precluded categorization of countries and set
common commitments for all countries. This does not
necessarily mean all countries face same level of
stringency. Within each element of commitment such as
mitigation, adaptation and finance, all countries are
expected to take the same actions, but at differentiated
levels. The level of actions is to be determined nationally
and voluntarily.

2.8 Legal Nature of the Agreement
The Paris Agreement takes the form of a treaty. During
the negotiation process, there was a disagreement over the
name of the agreement. Some countries wanted it to be
called a “protocol,” while others preferred “agreement” or
“implementing agreement.” The legal nature of the
agreement is determined not by how it is named, but by
the clauses that form parts of the agreement. Articles on
signing (Article 20), ratification (Article 20), entry into
force (Article 21), and depositaries (Article 26) fulfill
necessary conditions for the agreement to be an
international treaty with official legal status.

2.9 Non-state Actors
The roles of non-state actors are not explicitly stated
in the Paris Agreement itself, but are securely embedded
in the founding basis of the agreement. The Paris
Agreement does not have any teeth in the sense that it
does not determine countries’ GHG emission targets in a
top-down manner. This means that any additional
emission reductions need to occur voluntarily,
independent of national governments’ initiatives. The
COP decision “welcomes the efforts of all non-Party
stakeholders to address and respond to climate change,
including those of civil society, the private sector,
financial institutions, cities and other subnational
authorities.” The Non-State Actor Zone for Climate
Action platform (NAZCA) was established at COP20 to
support various actions taken by the non-state actors.

3. Remaining Issues to be Solved with Support
from Academia
Multilateral agreements usually take at least several
years from adoption to entry into force. The Kyoto
Protocol took eight years for enforcement. The Paris
Agreement was an extraordinary case that entered into
force within eleven months after its adoption. This is a
good sign that the world is supporting the transition into
de-carbonization, but countries had been expecting
several years at least to negotiate detailed rules to
confidently proceed in the post-2020 period. Among
those are elements that require input from scientific
experts.

3.1 Long-term Goals and Emission Budgets
The first set of research questions is related to
long-term emission trajectories and levels of near-term
emission reduction targets. The IPCC has already started
preparing the 1.5°C special report. On the other hand,
monitoring data by NOAA (National Oceanic and
Atmospheric Administration) and NASA (National
Aeronautics and Space Administration) have indicated
that the year 2016 was the warmest year on record
(NASA, 2017). The mean global surface temperature
has already risen more than 1.0°C from the pre-industrial
period, leaving very little room for the world to stay
within the 1.5°C warming path.

“Carbon budget,” or “emission budget,” is a notion
that expresses the amount of carbon, or GHGs, that
could be emitted while aiming to achieve a long-term
temperature goal. If we were to achieve the long-term
goal of 2°C, the total carbon budget since
pre-industrialization would be about 840 GtC of CO2. We
have already emitted about 530 GtC in the past up to 2011
(IPCC, 2014), so there is only about 310 GtC that could
be emitted by future generations in order to keep the
temperature under 2°C. The future budget will be even
smaller if we are to achieve the 1.5°C goal. Calculating a
carbon budget is not an easy task. The amount will
depend on how much CO2 can be sequestered by various
sinks and reservoirs. Emissions of non-CO2 gases also
affect the budget. How much of the carbon budget would
be left for the future world at the global level if we were
to reach the 2.0 or 1.5°C goal? How will it change
according to changes in assumptions regarding levels of
deforestation and CCS (carbon capture and storage)
technologies? These are remaining questions that need to
be answered by researchers.

While global emission pathways are discussed,
others need to focus more on national emission
pathways. Many developed countries have already set
long-term emission goals for the year 2050 at the
national level. This is in line with declarations in 2008
and 2009 among the Group of 8 (G8) member countries
that have called for halving global GHG emission by
2050. In order for these countries to reach deep cuts in
emissions such as 80% reduction by 2050, they would
have to make good progress at reducing emissions in the
years 2030 and 2040 as well. Questions such as “which is the most economically efficient emission pathway for reaching the long-term goal” need to be answered to enable the world to conduct an effective facilitative dialogue in 2018 and global stocktaking process in 2023.

3.2 Mitigation: Hard and Soft, Involvement of Non-state Actors

The second set of research questions is on mitigation over the short to medium term. It is clear that total amount of countries’ NDCs for the years between 2025 and 2030 is insufficient to reach the long-term goal (UNFCCC, 2016). More needs to be done in the area of mitigation to further deepen the targets, and actually reach the targets. But how? There is some opposition to the long-term temperature goals as too idealistic or unrealistic (Pielke, 2009). These opposing views stem from pessimism regarding plausibility of GHG emission reductions. It is true to say no one can live without energy. Energy must continue to be supplied even under the trajectory towards the long-term goals (Rogelij et al., 2015). Carbon dioxide from fossil fuels should be completely phased out by mid-century either by shifting energy sources to renewable energy or nuclear energy, or by using CCS technology alongside fossil fuel power plants. In addition, non-CO₂: GHGs such as methane and fluorocarbons needs to be reduced as much as possible. Remaining emissions should be counterbalanced by sequestration of CO₂ in forests.

While making an energy shift towards de-carbonized sources, the energy demand side also needs to make a huge transition into a less energy-intensive society. Urban planning and infrastructure require more than three decades to make a transition. We need to start making changes from today if we are to complete the restructuring of our cities by mid-century. Buildings and people’s dwellings are also a sector that needs a long-term view to reduce their GHG emissions. Thinking in the long term, we need to take into account various technologies and means that could totally change our way of living. As for transportation, for instance, current automobiles with engines might become a thing of the past. People could continue enjoying mobilization using smarter and lighter vehicles with electric motors. It is thus insufficient to argue against stringent emission targets using only the technologies we have today.

Issues related to mitigation include not only engineering, or the “hard” aspect, but also policy, or the “soft” aspect. Infrastructure and technologies would not exist without relevant policy implementation. All countries have already implemented a wide variety of climate mitigation policies, including regulations, market-oriented mechanisms, and information-oriented tools such as labeling. These policies should be further strengthened and implemented in a speedy manner. Although many policy analyses have already been conducted (Höhne et al., 2017), it is still at too early a stage to conclude which policy instruments are more effective than others. The effectiveness of policies will greatly depend upon each country’s national circumstances, other relevant non-climate policies, and its share of sectors in terms of emission sources.

Engagement of non-state actors in climate change mitigation activities is a prerequisite for achieving deep emission cuts. Technological breakthroughs are achieved by private companies’ R&D. Urban city development is determined by local governments and citizens. The role of policies and measures is to develop enough incentives for these various actors to voluntarily shift to less carbonized behavior. Fossil fuel divestment is a movement that started from NGOs and university students, to divest their holdings of fossil fuel stocks in favor of other climate-friendly alternatives (Ayling & Gunningham, 2016). More research is needed to investigate ways to involve investments by the private sector, as well as actions by local governments.

3.3 Adaptation and “Loss and Damage”

Adaptation and “loss and damage” is the third pillar of work remaining to be tackled under the Paris Agreement. Adaptation actions are mainly rooted in each country or even further at each local level. As adverse impacts of climate change become more evident, however, the need for more precise estimations of future plausible damage becomes stronger.

As the COP decision accompanying the Paris Agreement requested the IPCC to publish a special report on 1.5°C, climate researchers have already started to elaborate on plausible climate impacts that are expected to occur under the 2°C and 1.5°C scenarios, and how much damage the world could avoid by seeking the higher ambitious temperature goal (Hulme, 2016). This exercise is necessary for comparing the costs required to reduce GHG emissions to reach the 1.5°C goal and the cost required to adapt to a warmer world by 2°C or more and damage associated with higher temperatures. Currently, researchers are making a great effort to estimate the future impact of climate change. Mean precipitation and temperature are the most commonly acknowledged parameters affected by climate change, but it is also important for local people to understand extreme precipitation or temperature events locally in a shorter timeframe.

As for loss-and-damage-related debates, the key will be finding ways to prove direct damage-and-loss consequences from climate change and those considered to be associated with climate change. Attribution of extreme weather patterns and the damage they cause to climate change is a new frontier in climate science. Climate security is a notion that aims at finding potential links between climate change and armed conflict, but few studies have resulted in robust results so far (Ide, 2017). From the legal aspect, responsibility and liability for loss and damage are still under debate (Lees, 2017).

3.4 Finance, and Involvement of Non-state Actors

Finance has always been an issue at stake in climate change negotiation. Three types of financial mechanisms
were established in 2001 at COP7: the Special Climate Change Fund and Least Developing Countries Fund, both under the UNFCCC, and the Adaptation Fund under the Kyoto Protocol. Establishment of these mechanisms was supported by developing countries, but dissatisfaction was soon raised by the same countries, because the amount of financial flow was too meager to fulfill all their needs. To respond to these serious financial demands, the Copenhagen Accord, adopted in 2009 at COP15 included a quantitative target of “US$30 billion for the period 2010-2012 with balanced allocation between adaptation and mitigation” as short-term finance, and “US$100 billion a year by 2020” in the long term (UNFCCC, 2009). The funding sources were not limited to official assistance, but included both public and private, and bilateral and multilateral types of finance. A significant portion of such funding was to flow through a newly established financial mechanism called the Green Climate Fund. The short-term financial goal was reached through huge financial contributions from developed countries. The long-term financial goal is yet to be achieved but the amount of financial flow is certainly on the rise. Much of the growth owes to finance, and “US$100 billion a year by 2020” in the long term (UNFCCC, 2009). The funding sources were not limited to official assistance, but included both public and private, and bilateral and multilateral types of finance. A significant portion of such funding was to flow through a newly established financial mechanism called the Green Climate Fund. The short-term financial goal was reached through huge financial contributions from developed countries. The long-term financial goal is yet to be achieved but the amount of financial flow is certainly on the rise. Much of the growth owes to private companies (CPI, 2015). The Copenhagen Accord only set financial goals up to 2020, and the COP decision in 2015 supplemented the Paris Agreement by stating that developed countries intended to continue their existing collective mobilization goal through 2025, and that a new collective goal from a floor of US$100 billion per year would be agreed upon prior to 2025.

It goes without saying that the amount of financial flow makes a crucial difference in making effective changes towards de-carbonization in both developed and developing countries, but merely talking about quantity is not enough. Financing should be directed towards the most effective technologies and investments. In reality, however, it is difficult to track all financial flows, and there is no assurance that all the financial resources are being used either to mitigate climate change or to adapt to the changing climate (Clapp et al., 2012). Studies are needed to monitor how financial resources have contributed to actual emission reductions or adaptation.

There have been a number of studies that elucidated the financial amounts needed for developing countries to take action against climate change (Kameyama et al., 2016; Bowen et al., 2017). In many cases, most of the financial burden required to make substantial emission reductions occurred at the time of initial investment. Once the facilities were entirely installed, the investors could profit from energy saving for the next two to four decades. Loans and mortgages that leveraged the initial investment cost and avoided costs later on could motivate citizens to invest in less energy-intensive infrastructure and renewable energy.

4. Governance

4.1 Equity: Two Contrasting Images of the World

The Paris Agreement was absolutely successful in attracting most countries to be Parties to the agreement. Nevertheless, the real engagement of countries and other sub-national stakeholders starts today. The agreement does not force countries to reduce GHG emissions to a level indicated by any third-party institutions that take equity into consideration. This means the equity dimension of the climate change problem is not institutionally embedded in the agreement. It is up to each country how much it will consider its own responsibility to respond to the climate change problem and take action voluntarily. This system is completely different from how many researchers used to consider equity—or burden-sharing rules—to determine emission reduction targets for countries (Höhne et al., 2014).

There are two distinctive ways to look at the game of climate change politics. Traditional debates related to equity in the realm of climate change politics are based on the idea that reducing emissions is costly (Barrett, 2006). On one hand, countries agree to reduce GHG emissions globally because they understand climate change is likely to harm all. On the other hand, however, they oppose setting stringent emission reduction targets at the national level, insisting that deep emission cuts would negatively affect their economy. A country that does not participate in the emission reduction regime, often called a “free-rider,” will still be able to enjoy alleviation of adverse impacts of climate change, thanks to other countries’ efforts to reduce GHG emissions. Equity considerations are particularly important under such conditions to avoid allowing countries to become free riders. Burden-sharing rules are investigated to see if any rule could be agreeable to all nations. Emissions per capita and emissions per GDP are major equity rules that have been proposed by countries and researchers (Kameyama, 2004). The Kyoto Protocol’s emission reduction targets were set after long debates on equity. This image is, so to say, the “20th century image” of the world—a fossil-fuel-based economy.

The second way of looking at the game of politics is to see climate-related investment as an opportunity rather than a cost. Fossil fuel is a non-renewable natural resource that will eventually deplete. Coal reserves are relatively large, but oil production could peak out sometime within the next few decades. It is therefore necessary for all countries to start investing in new sources of energy in one way or another for the purpose of energy security. Climate change mitigation has worked as motivation for the private sector to invest in renewable energy and other technologies that would contribute toward moving away from fossil fuel use. The faster companies develop new technologies, the more competitive they become and able to profit by dominating markets. Under the free market of climate investment, countries will not need to compare NDCs across countries or make persistent efforts in the equity
of coal by utility companies. Renewable energy sources, such as wind and solar, are also becoming more competitive (Isadore, 2017).

The two images of the world co-exist today and will stay that way in the next decade. It is likely, however, that the first image will slowly fade away. Not only because of climate change, but also because fossil fuel is a depleting resource and from a sustainable development point of view, we should not depend on non-renewable sources.

4.2 Transparency: Tracking Efforts

Countries’ actions will be assessed by the transparency mechanism set up under the Paris Agreement, but the process is yet to be discussed. Reliable information on mitigation, adaptation and financing is the key to ensuring the agreement’s effectiveness. Many developing countries lack basic data, including GHG emissions and energy consumption. One of the remaining tasks for researchers is to introduce simple ways to collect these data periodically with the simplest methodology.

The transparency system is important for different reasons, depending on the image of the world, each requiring different types of information. In the case of the traditional image of the world, transparency is important because all countries need to be watched to make sure they are really doing what they promised to do. The transparency system should put much effort into tracking actual emission trajectories, and agree on rules in case of noncompliance. In addition, countries need to start discussing possibilities to increase the level of ambition of their future NDCs. This will be a laborious process because no country wants to set stringent emission reduction targets. Developing countries will look at developed countries with an eye on how much the rich countries have adopted “common but differentiated responsibility.”

Meanwhile, in the latter case, transparency is important for sharing information on best practices and performances. Information to be submitted under the transparency mechanism, the verification processes and compliance procedure as a consequence would differ according to which world we assume we are living in. The transparency system could collect various information, such as GDP growth data and policies implemented, to find high-performance policies. Success stories could be duplicated in other countries to enhance best practices.

A number of reporting and verification processes have already been established under the UNFCCC regime, and it has been widely acknowledged that the process should be as simple as possible for all countries to comply with. Some studies have proposed new methodologies to assess countries’ efforts for mitigation by grasping the policies implemented in those countries (Kameyama & Kawamoto, 2016; New Climate Institute et al., 2016). More studies are needed to assess policy packages that result in maximal emission reductions while also striking a balance with healthy economic

dimension of the agreement. Rather, countries would voluntarily implement policies to lead companies to invest in R&D in the area of energy and efficiency, and set ambitious goals, giving incentives. This image is, so to say, the “21st century image” of the world, making huge investments in renewable energy.

Assessments of the effectiveness of the Paris Agreement largely depend on how individuals see today’s status quo, whether it is closer to the former or the latter.

The agreement will have negligible effectiveness in mitigating climate change if the world continues to have the former image of the world. Many developing countries were unhappy about abolishment of the Annex I – non-Annex I division in the Paris Agreement. During the negotiations at COP21, developing countries continuously underscored the importance of the historical responsibility of developed countries for causing climate change and called for the agreement to be based on equity and common but differentiated responsibilities (CBDR) (Ajit, 2015). Developed countries also accepted differentiation, except that they insisted that it be reflected in a dynamic manner, since the world has changed since the time the UNFCCC was adopted. The agreement was still considered fair by most countries, because it was agreed upon by the developed countries that a further financial commitment would be made by the developed countries in the post-2020 period. Efforts to reduce GHG emissions by developing countries are dependent on the amount of financial resources transferred to the developing countries, as well as efforts by developed countries to reduce their own emissions. Now that the current U.S. Trump administration is against the Paris Agreement and overall emission reduction policies at the federal level, it is not likely that developing countries will receive a positive message from the richest and second largest GHG-emitting country in the world.

On the other hand, the Paris Agreement could be considered a level playing field for all stakeholders to shift towards a de-carbonized world, if we could see the world as the latter image. There have already been a lot of signs of the world being steered in this direction. For example, Chinese President Xi Jinping is said to be strongly committed to the Paris Agreement and other climate change mitigation efforts, even if the United States pulls out of the agreement (Phillips, 2017). Saudi Arabia, the largest oil producer, has been making huge investments in solar and wind power plants, with further plans to develop almost 10 gigawatts of renewable energy by 2023 in its vast northwestern desert. It is expected that new development of renewable energy could replace the equivalent of 80,000 barrels of oil a day now burned for power (Dipaola, 2017). In the United States, many judge that coal production will not regain profitability even with full support from President Trump in eliminating all of the regulations set by the former Obama administration, because the falling price of natural gas is the primary reason for the plunge in use of fossil fuels. Renewable energy sources, such as wind and solar, are also becoming more competitive (Isadore, 2017).
growth.

4.3 Japan’s Case

In Japan, many government officials and industries welcome the universal coverage of the Paris Agreement, officially stating that the agreement is “fair” just because it achieved more or less universal participation (MOFA, 2015). Meanwhile, the same individuals also stress that Japan does not necessarily have to endeavor seriously to achieve its NDC, as the commitments elaborated in the Agreement are voluntary and there will be no penalty even if Japan does not achieve its target. Although this interpretation is correct in legal terms, it should be noted that it is based on the traditional image of the world.

One of the events that have been attracting much attention worldwide is the inauguration of President Trump of the United States. He himself has been unwilling to take action against climate change, and intends to pull out of the Paris Agreement (Worland, 2017). Japanese stakeholders also pay much attention to changes in the United States. People who are unwilling to take action to reduce GHG emissions in Japan will welcome President Trump’s actions—or inaction—that almost cancel out what his predecessor, former President Obama, introduced both inside and outside the United States to tackle climate change.

Nevertheless, there are others that see signs of the newer, more proactive image of the world (Kiko Network, 2017). They feel that Japan should be the front runner in a race towards decarbonization for many reasons other than climate change. Foremost, Japan does not own any extraction or production industries within its territory related to fossil fuels and is currently almost totally dependent on energy sources imported from overseas. Nevertheless, the share of fossil fuel within the total primary energy supply was almost 94.6% in 2013, higher than that of most of countries around the world (United States: 83.3%, China 88.1%) (Agency for Natural Resources and Energy, 2016). Replacement of fossil fuel by renewable energy would contribute to reduced payments to overseas countries for fossil fuel imports.

Actions to reduce energy consumption are likely to contribute also toward adaptation to a rapidly aging society. The elderly share of society (ages above 65) is likely to reach almost 40% by 2050 (IPSS, 2012). The size of the Japanese population, currently around 120 million, is expected to decrease to less than 100 million by 2050. As the number of elderly lacking support of family or relatives is likely to expand, more people will be willing to dwell close to each other, with shops and community buildings within walking distance. Less driving of automobiles and more use of public transportation will be welcomed by these people. Energy consumption per person is expected to be much smaller when people live in housing complexes than individual houses (NIES, 2016).

Japan’s NDC for the year 2030 is a “26 percent reduction from 2013.” Although there are controversies over the degree of ambition of the target, it should be achievable if Japan were to aim at an 80% reduction by 2050, as has been indicated by the Global Warming Mitigation Plan adopted as a Cabinet Decision in 2016. Japan needs to start moving in the direction of a decarbonized community by investing in infrastructure and buildings that can last for more than three decades (Central Environmental Council, 2017).

In the international arena at meetings under the UNFCCC, countries are discussing ways for countries to deepen their emission targets. Japan should undertake additional cooperation with other countries, specifically in Asia, and develop effective projects for reducing emissions jointly. One such Japanese initiative is a mechanism called the Joint Crediting Mechanism (JCM). The JCM develops GHG emission reduction projects in developing countries and uses Japanese financial assistance to install facilities to reduce emissions and at the same time enhance sustainable development (JCM, 2017). Seventeen developing countries have signed onto partnership agreements with Japan on JCM projects. The effectiveness of the mechanism is yet to be seen, but some projects initiated by the JCM could flourish to become bigger and more effective projects in the future.

5. Conclusion

We see today evidence of increasing temperatures and more frequent extreme weather patterns. Even if any scientific uncertainty still remains, there is nearly a consensus that climate change and its impacts are human induced at a level serious enough for all countries to start taking action. The Paris Agreement should not be another excuse for delaying actions just because the achievement of emission reduction targets is not legally binding, or because the level of the targets could be set according to each country’s preference. Rather, the Paris Agreement should be the founding basis for wider cooperation among countries, local governments, the business community, and citizens. That said, researchers are expected to supply the various stakeholders with data sets and information to enable them to find the best, most effective and least costly solutions obtainable, that also invite other co-benefits related to sustainability.

Japanese stakeholders should not confine themselves to the traditional way of looking at the world, assuming stable prices, with the prices of fossil fuels continuing at their current level into the future, thinking emission reduction to be costly. People should be aware that GHG emission reduction actions bring about opportunities to invest in reconstructing new ways of living in the 21st century.

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Transitions of Energy Systems and Technologies toward Achieving the Paris Agreement in Japan

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Abstract

In order to achieve the targets in the Paris Agreement, it is important to reduce greenhouse gas (GHG) emissions drastically. Because in Japan most GHG emissions result from energy consumption (88.6% in 2015), de-carbonization of energy systems is crucial, and there are strong hopes for technological innovation in energy supply and demand to help the targets be reached. Japan has already undertaken various kinds of technological development and implementation in society via both the public and private sectors, and these activities have contributed to the reduction of energy consumption and GHG emissions in Japan. For example, the total energy consumption in the latter half of the 1990s and first half of the 2000s was around 550–560 million tons of oil equivalent (Mtoe), decreasing to 502 Mtoe in 2015 through comprehensive energy saving measures and actions to reduce GHGs. Even so, development of innovative technologies is still needed for further GHG emission reductions. In the past, technological measures focused on devices such as those involving hydrogen, carbon capture and storage, or batteries and renewables, but research and development (R&D) is now focused on systemized technologies. One example is energy monitoring systems in conjunction with energy management, and another is local energy networks with renewables and distributed energies such as gas cogeneration and biomass boilers. Low carbonization of energy systems is the key to both GHG emission reduction and achieving a global low-carbon society. Materialization of innovative technologies is also needed for building a low-carbon society, and Japan’s experience and expertise in technological R&D could be the first step in the right direction and will go a long way toward providing a foundation for impressive GHG emission reductions and establishment of a low carbon-society not only in Japan but also all over the world.

Key words: climate change mitigation, emission reduction, energy system, system transition, technology development

1. Introduction: Historical Transition in Japan’s Energy Sector

The value of a “stable climate” as an environmental commodity has increased. An important feature of the climate system is its inertia. Because of past and current greenhouse gas (GHG) emissions, a certain increase in global temperatures is unavoidable, as reported in the IPCC’s Fifth Assessment Report (AR5). Such increases in temperature carry profound risks. Even a small increase in temperature is likely to have significant impacts on ecosystems and species, and might lead to increased droughts or extreme rainfalls, with severe consequences for our society. Measures against global warming need to be taken to ensure sustainable development and a better future for Japan. The scientific information in AR5 and many international agreements and commitments including the Paris Agreement indicate the profoundness of global warming and the need for prompt action. As Japan is no exception, in that it seems to have been affected in various ways by global warming, it is time to implement concrete measures in view of disaster prevention, health, water resources, food, ecosystems, etc., while reducing GHG emissions.

A response to this challenge can be found in technology development, which is Japan’s area of expertise. As such, the perfect opportunity for a new growth driver can be found right before our eyes. Competition has already begun. Competition can be overcome by creating low-carbon technologies and social systems that have no equal. The key is to take positive action and not wait around doing nothing.

In order to cut greenhouse gas (GHG) emissions to achieve the low-carbon society indicated in the Paris Agreement, it is important to understand sources of GHG emissions and identify causes (or driving forces)
of emissions. Based on the IPCC Inventory Guideline, sources of GHG emissions can be divided into six categories: (1) energy use, (2) industrial processes, (3) agriculture, (4) waste, (5) land-use change and forestry (LUCF) and (6) bunker fuels. Among these categories, in Japan, GHG emissions from energy use have a dominant share compared to the other categories. In 2015, 88.6% of Japan’s GHG emissions came from energy use (NIES/GIO 2017). GHG emissions from energy use have a strong relationship with primary energy consumption and level of economic activity, so getting a picture of GHG emissions from energy use is almost equal to understanding energy systems and energy consumption.

1.1 Overview of Energy Profiles in Japan

Figure 1 summarizes energy consumption by primary energy source in Japan from 1880 to 2015. Until around 1880, energy consumption in Japan mainly consisted of traditional biomass such as fuel wood and charcoal. Then coal use started to grow and Japan kept coal as a main source of energy until the end of World War II. Before the two oil crises of 1973 and 1979, energy consumption, especially oil consumption, increased with economic growth. After the latter half of the 80s, i.e., the beginning of the bubble economy, energy consumption started to increase again due to the upturn in economic activity, interfusion with an energy-consuming lifestyle and shift in vehicle preferences to large cars such as land cruisers. After the bubble economy burst in the latter half of the 90s, Japan’s prolonged economic slump led to suppression of energy consumption, and total energy consumption remained at a level of around 550–560 million tons oil equivalent (Mtoe) for a while after that. The bankruptcy of Lehman Brothers and subsequent recession have affected not only economic activity but also energy consumption, and energy consumption in 2009 was 487 Mtoe, down 7% from the 2008 level.

Among energy sources, we should give more attention to nuclear energy in Japan. Nuclear power was a key technology for the electricity supply in Japan after the oil crisis, because Japan’s energy policy aimed to diversify energy sources away from oil. On March 11, 2011, Japan suffered a big earthquake and tsunami. The nuclear power plants in the northern part of Japan’s main island have been now shut down since. On that day, 55 nuclear power units were in commercial operation and 12 units were under construction, as shown in Fig. 2. The total installed capacity was 49,165 MW, and capacity under construction, 16,318 MW. The Okinawa Electric Power Co. (OEPC) has no nuclear power facilities and no future plans to construct any. When the earthquake hit, 15 plants were shut down in response. Subsequently,
the Tohoku Electric Power Co. (Tohoku-EPCO) shut down all its nuclear power plants (Onagawa: 2,174 MW and Higashi-dori: 1,100 MW). The Tokyo Electric Power Co. (TEPCO) also shut down some of its nuclear power plants on account of the earthquake, but only plants on the Pacific side of Japan (Fukushima Daiichi: 4,696 MW and Fukushima Daini: 4,400 MW). By 2014, all of Japan’s nuclear power plants had been shut down for periodical inspection and never restarted within the year. Thus, Japan generated no nuclear-power electricity in the year 2014. Since 2015, some nuclear power plants located in the western part of Japan have been approved for restarting on the condition that they conform to strengthened safety criteria set by the Nuclear and Industrial Safety Agency.

In terms of final energy consumption in Japan, total final energy consumption has shown a similar trend to primary energy consumption, as shown in Fig. 3. The industrial sector, especially the manufacturing industry, accounts for a large part of final energy consumption during the entire period covered by the statistics. In 2015, the total final energy consumption was 316 Mtoe, with the industrial sector (manufacturing and nonmanufacturing industries) consuming 149 Mtoe, which corresponds to 47.1% of the total final energy consumption. However, final energy consumption in the industrial sector after the oil crises has remained almost steady at around 150–160 Mtoe and its share of the total final energy consumption has gradually decreased. The increase in final energy consumption has come mainly from increases in final energy consumption in both the residential and passenger transportation sectors.

In 1965, final energy consumption in the residential and passenger transportation sectors was 11 Mtoe and 8 Mtoe, respectively. In 2015, the residential sector consumed 47 Mtoe, which corresponded to 4.4 times the final energy in 1965, and the passenger transportation sector consumed 49 Mtoe, 6.2 times the 1965 level. This is why, especially after the bubble economy started, lifestyles in Japan shifted toward higher energy-consumption, such as greater varieties of home appliances, multiple appliance and vehicle ownership, larger sizes of appliances and trends in vehicle preferences for larger cars. As an illustrative example, changes in ownership rates for typical home appliances (air conditioners, refrigerators, TVs and PCs) from 1970 to 2015 are summarized in Fig. 4 (some statistical data after 2004 are unavailable due to a change in the statistical survey system). More than 100% ownership indicates that the average household has several units of the appliance, e.g., 200% ownership of air conditioners could be interpreted to mean that each household has installed two air conditioning systems at home. The figure clearly shows that except for refrigerators, ownership rates continue to grow. That is, final energy consumption also continues to grow.

1.2 Historical Transitions of the Energy System in Japan

In the 135-year history of energy statistics in Japan, we can find at least two energy system transitions (or technology shifts). Specifically, one occurred after the oil crisis and the other, after the March 2011 earthquake.

The oil crisis triggered the promotion of non-oil energy sources such as gas and nuclear, as described above, and popularization of energy-saving activities, including replacement by energy efficient machines or appliances in all sectors, including industrial, residential, commercial and transportation. Although this transition brought another type of energy system into Japan—the electrified society—that transition is not yet complete, because even now, oil still accounts for around 45% of primary energy consumption in Japan, as shown in Fig. 1. The accidents in Fukushima following the March 2011 earthquake led nuclear power to be shut down for thorough safety review. As a result, nuclear was fully substituted for by fossil fuels in 2014. Some nuclear plants, however, have restarted after safety examinations and approval by the government since 2015, so the energy transition from nuclear to other energy resources was not completed.

From the viewpoint of the energy transition in Japan, even though diversification of fuel sources was promoted after the oil crisis, oil has remained the dominant energy source consistently during the period
from 1965 to now. Before the oil crisis, energy demand growth covered mainly oil. On the other hand, after the oil crisis, promotion of diversified energy sources resulted in both suppression of oil consumption growth and an increased gas and nuclear power supply. In a similar way, before the Fukushima accident, nuclear power was considered a key electricity supply and its capacity grew in line with the Basic Energy Plan designed by the Ministry of Economy, Trade and Industry (METI). On the other hand, the possibility of restarting most nuclear power plants, except for a few such as Fukushima Daiichi and Fukushima Daini, is being explored after the complete examination of facilities.

As shown above, Japan has experienced two energy system transitions triggered by the oil crisis and Fukushima nuclear accident. Now, the Kyoto Protocol, Paris Agreement and subsequent international agreements on climate change mitigation are set to bring about a third energy system transition in Japan. The “low-carbon society” philosophy aims to minimize carbon emissions in all sectors as well as shift to a simpler, higher-quality life and coexistence with nature. In order to realize such a low-carbon society and/or energy system, new, innovative technologies are required not only for the energy system but also the whole social system. The needs for technological development cover wide-ranging aspects, including the energy system, transportation, industry, buildings, energy efficiency, renewable energy, lifestyle changes, education and awareness, governance, forest conservation, waste management, air environmental quality and urban planning. Even though, low-carbonization of the energy system is inevitable, understanding of the energy system as well as actions towards a low-carbon energy system offer hope. This paper presents an outlook on technology development before and after the Paris Agreement.

2. Current Technological Measures and Actions for Climate Change Mitigation in Japan

Japan has tackled GHG emission reduction under a collaborative framework that includes government, local authorities, industries, businesses, citizens and NGOs. In October 1990, the Government of Japan ratified a plan against global warming, named the “Global warming action prevention plan,” in a ministerial conference on global environmental conservation. The plan targeted stabilization of CO₂ emissions at the 1990 level after the year 2000. In 1997, the Third Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) was held in Kyoto where the Kyoto Protocol was agreed upon. In the Kyoto Protocol, the GHG emission reduction target for Japan was set at a 6% reduction compared to the baseline year from 2008 to 2012.

In June 1998, following the Kyoto Protocol agreement, the Global Warming Prevention Headquarters adopted “Guidelines for Measures to Prevent Global Warming – Measures Towards 2010 to Prevent Global Warming.” At the same time, the Law Concerning the Promotion of the Measures to Cope with Global Warming was enacted (Law No.117 of 1998) to set a basic framework for actions to prevent global warming, and other relevant laws and measures, such as the Act on the Rational Use of Energy, was revised. Since then, the government of Japan has implemented various kinds of policy measures, such as imposition of a tax for global warming from 2012 and implementation of a feed-in-tariff (FIT) system for wholly renewable energy from June 2012. In 2016, the Japanese government renewed the National Plan for Coping with Global Warming, and summarized three national GHG reduction targets: a 3.8% or more reduction from the 2005 level by 2020, a 26% reduction from the 2013 level by 2030, and an 80% reduction by 2050.

Under these laws and plans, various kinds of mitigation actions using technology have been promoted. Hybrid vehicles and electric vehicles, for instance, have gradually diffused over these 10 years as shown in Fig. 5. In 1998, 3,428 hybrid vehicles and 638 electric vehicles were in use. The number of hybrid vehicles in 2016 was 5,581,578 units, rising to 16.28 times the 1998 level. Although the increase in electric vehicles was small compared to that in hybrid vehicles, 63,760 units were in use in 2016. Such trends in penetration can be found for other energy efficient technologies, such as LED light bulbs, heat pump water heaters, solar heaters and efficient industrial furnaces.

Japan's government and ministries have also supported the spread of emission reduction technology through policies and measures. For example, METI, the ministry with jurisdiction over energy policy, creates policies and measures for energy conservation, the Kyoto Mechanisms, investment in innovative technology and promotion of nuclear power. The Agency for Natural Resources and Energy promotes a variety of energy policies and measures in conjunction with METI. It has been promoting the adoption of next-generation coke ovens and propagating high-performance industrial furnaces in the industrial sector. The agency has
encouraged steady improvements in energy efficiency equipment in the residential and commercial sectors through a top runner approach, which sets standards for energy efficiency. Under Japan’s Energy Conservation Law, it promotes public relations activities, including eco-labeling. In the transportation sector, it promotes modal shifts and improved logistics efficiency. Renewable energies such as wind and solar are a key element for both energy policy and global warming policy, and the agency has been funding technology development and pilot projects.

In addition, it has also implemented technology development programs. One example is a microgrid demonstration project. Installation of renewables such as solar, wind and biomass contributes to reduction of CO₂ emissions and climate change mitigation. On the other hand, burgeoning renewable generation has a non-negligible negative impact on the grid system. The output of renewable generation, especially solar and wind, is unstable, resulting in voltage and frequency fluctuations in the power grid system. A microgrid (recently termed “smart grid”) is a localized group of generators, storage cells, and electricity users connected to the grid, that can function autonomously. Generators include fuel cells, solar, wind, biomass, micro-gas turbine and so on. In 2003, the New Energy and Industrial Technology Development Organization (NEDO) started three demonstration projects in Aomori, Aichi and Kyoto prefectures under its Regional Power Grid with Renewable Energy Resources Project. These demonstration projects evaluate the feasibility of integrating new energy sources into a local distribution network. In addition to these demonstration projects, several demonstration projects have been conducted by the private sector.

2.1 Three pillars of technological actions and measures: avoid, shift and improve

As just described, Japan has made many efforts to develop and promote technology for GHG emission reduction in both the private and public sectors. These efforts comprise three mainstays. The Kaya identity is a useful tool for understanding GHG emission reduction actions. The Kaya identity is a methodology for expressing CO₂ emissions by multiplying population, activity level per capita, energy intensity and average emission factors as shown in the following equation.

\[ CO₂ = Population \times \frac{Activity}{Population} \times \frac{Energy}{Activity} \times \frac{CO₂}{Energy} \quad \text{Eq.1} \]

The second item on the right-hand side expresses activity level per capita, the third item represents energy consumption per unit activity (energy intensity), and the last item is CO₂ emissions per unit energy consumption (average emission factor). By using the Kaya identity, the level of effort needed to achieve a certain CO₂ reduction can be easily analyzed.

It is assumed that “population” will not change as a result of taking GHG emission reduction actions. Thus, emission reduction can be considered almost equal to improvements in “activity/population,” “energy/activity” (energy intensity) and “CO₂/energy” (average emission factor) created by technology, as shown in Fig. 6. Therefore, based on analysis using the Kaya identity, technological actions can be categorized into the following three categories (mainstays):

1) AVOID the use of energy services
2) SHIFT energy sources to less GHG-intensive ones
3) IMPROVE energy use efficiency

Essential to avoiding the use of energy services is cutting the amount of energy wasted. Changing lifestyles and business-styles also contributes to avoidance of the use of energy services. In order to accelerate actions to avoid the use of energy services, it is also important to monitor and visualize energy consumption.

Shifting energy sources to non-GHG-emitting energy, such as renewable energies and nuclear power could lead to sharp reductions of GHG emissions. Renewables are one of the key technologies for promoting a shift. Renewable energy capacity has steadily grown all over the world as well as in Japan, as shown in Fig. 7. From the viewpoint of energy sources, hydropower is the
dominant technology among renewable resources throughout Japan. After the year 2000, capacities of solar are increasing drastically due to enforcement of a feed-in-tariff (FIT) scheme.

Replacing and/or installing energy efficient technologies have been key actions to improve energy use efficiency heretofore. Increasing air leakage efficiency and strengthening thermal insulation for rooms and spaces are also effective measures to improve energy efficiency. In general, energy efficient technology requires additional costs for installation. Subsidies and tax relief, however, could accelerate actions to improve energy use efficiency. The availability of renewables differs place-by-place.

3. Future Directions of Technology
Development toward the Paris Agreement

Japan has already undertaken development of various kinds of technology and its implementation in society, and these activities contribute to the suppression of GHG emissions in Japan. Figure 8 shows the CO₂ emissions trajectory from 1965 to 2016 by sector. The total CO₂ emissions trend traces a similar pathway to total primary energy consumption as shown in Fig. 1. Before the oil crises, CO₂ emission increases corresponded to the growth of oil consumption, rising from 392.2 MtCO₂ in 1965 to 917.5 MtCO₂ in 1973. After the oil crisis, total CO₂ emissions remained roughly flat at the start of bubble economy in the latter half of the 80s, because energy sources shifted to natural gas and nuclear power, which emit relatively less CO₂ per unit energy than oil, and energy-saving activities had become widely accepted in the industrial sector. In the 90s, total CO₂ emissions showed a similar trend to primary energy consumption, but in the 2000s, the growth rate of total primary energy consumption nearly flattened, while on the other hand, total CO₂ emissions continued to increase, except in 2009, after the global recession. The earthquake and nuclear accident of March 2011 triggered a reduction in CO₂ emissions. Although nuclear power was replaced by fossil fuels such as coal, oil and natural gas, the national power-saving edict, issued on July 1, 2011, led to a change in attitudes among businesses and citizens toward not only electricity consumption but also all other types of energy consumption.

The development of innovative technologies needed for building a low-carbon society by the deadline might depend on the accumulation of whatever technologies have been developed up to that time, changes in systems, the preparation of social infrastructure that can enable these new technologies to be incorporated and other factors. Table 1 summarizes major technologies for achieving sharp GHG emission reductions by 2050 based on Ashina et al., 2012. In order to achieve the Paris Agreement in the long-term, various types of technologies in all sectors should be implemented: energy-efficient air conditioners, LED lights, etc., in the residential sector; energy-efficient boilers and fuel conversion in the industrial sector; hybrid automobiles and electric vehicles in the transport sector; and energy-efficient fossil fuel-fired power generation, CCS-equipped power generation, etc., in the energy supply sector. In addition to these individual technologies,

![Fig. 8 CO₂ emissions by sector from 1965 to 2015 (EDMC, 2017).](image)

<table>
<thead>
<tr>
<th>Major technologies</th>
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<tr>
<td><strong>Residential and commercial sector</strong></td>
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<tr>
<td>Energy-efficient air conditioners, districtwide heating and cooling (cooling/ heating/ hot water), electric heat pump hot water heaters, fuel cell hot water heaters, solar water heaters, energy-efficient lighting, energy-efficient electrical appliances, energy-efficient commercial power equipment, etc.</td>
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<tr>
<td><strong>Transport sector</strong></td>
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<tr>
<td>Electric vehicles, hybrid vehicles, plug-in hybrid vehicles, fuel cell vehicles, improved automobile fuel consumption (lightweight vehicles, etc.), energy-efficient railways, energy-efficient shipping, energy-efficient aviation, biofuels, etc.</td>
</tr>
<tr>
<td><strong>Industrial sector</strong></td>
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<tr>
<td>Innovative steel manufacturing processes, innovative chemical manufacturing processes, increased efficiency for paper and pulp manufacturing processes, increased efficiency for cement manufacturing processes, high-performance industrial furnaces, energy-efficient motors, energy-efficient boilers, increased efficiency for home generators, fuel conversion, etc.</td>
</tr>
<tr>
<td><strong>Energy supply sector</strong></td>
</tr>
<tr>
<td>Energy-efficient coal-fired thermal power generation, energy-efficient gas thermal power generation, nuclear power generation, general hydroelectric power generation, small and medium-scale hydroelectric power generation, geothermal power generation, photovoltaic power generation, onshore wind power generation, offshore wind power generation, biomass power generation, waste power generation, hydrogen production through fossil fuel reforming, hydrogen production through electrolysis, carbon capture and storage technologies, etc.</td>
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technology systems (or energy-system technology) will also be implemented.

Among these technologies and systems, batteries, energy management, and local energy networks are anticipated as innovative technologies for the future. Since early times, Japan has carried out development projects for various technologies expected to contribute to large reductions in GHG emissions in the future, such as hydrogen fuel, fuel cells, and carbon capture and storage (CCS). Some of these technologies have diffused as planned, but others are lagging and have yet to be introduced to the market. We can take fuel cells, a technology first developed by the National Aeronautics and Space Administration (NASA) in 1961, as an example. From 1981 to 1986, scientists in Japan developed the phosphoric acid fuel cell (PAFC) in the Moonlight Project. The basic technologies were demonstrated in the 1990s, and projects such as the New Sunshine Project and the Fixed-type PAFC Millennium Project of the Japan Gas Association were carried out later (2000 to 2004) to highlight the potentials of PAFCs. Yet, as of this writing, fuel cells have only been introduced on a trial basis for demonstration by electric and gas supply companies. Today, nearly 50 years after its conception, the fuel cell is yet to be solidly positioned in the market. The status of CCS, the nuclear fuel cycle, and nuclear power technologies is similar, but technology systems have much room for R&D.

a) Innovative Battery Technologies

Renewables are expected to play a central role in low-carbon electricity supply systems. Photovoltaic systems (PVs) and wind power generators have now been widely adopted around the world as an option for reducing CO₂ emissions, but electricity from renewables, especially solar and wind, has large volatility over time. Renewable electricity supplies vary according to natural conditions, such as solar insolation and wind speed, and the electricity supply from them rarely matches electricity demand. Thus it is important to level the electricity outputs of renewables to match supply-and-demand.

The batteries developed at present can be classified into six types: (1) secondary batteries, (2) capacitors, (3) fly wheels, (4) superconducting magnetic energy storage (SMES), (5) pumped hydro, and (6) compressed air electricity storage. Among these types, secondary batteries can be expected to become popular in future society.

b) Energy Monitoring Systems in Conjunction with Energy Management

To accelerate lifestyle and workstyle changes, it is important to share with all stakeholders information about the effects of energy saving actions and behavioral changes on reducing energy consumption for a low-carbon lifestyle. Japan already has its own statistical system for energy supply and demand, but statistical data are mostly capable of describing the national or prefectural situation, and it is difficult to determine the effects of avoidance actions such as lifestyle changes by each household. On the other hand, a monitoring system could provide a comprehensive picture on how much energy is consumed and for what purposes in houses, buildings and districts, but efforts to address national and/or prefectural energy consumption would face many difficulties if they only relied on a monitoring system. Many companies and research institutions have started developing energy monitoring systems, and some have already been implemented in the real world. The government of Japan also supports R&D of energy monitoring systems in conjunction with energy management systems. Kitakyushu launched a project named “Kitakyushu Smart Community Creation Project” from FY2010 to FY2014, and as a part of the project, smart meters and displays for electricity consumption were installed in houses and offices. Based on the project’s results, installing energy monitoring system could reduce 0.6% of energy use in offices, and introduction of energy management systems and batteries in households could almost halve their energy consumption (Sasakura, 2015).

Energy monitoring systems usually consist of a series of data collection systems involving energy-use monitors for residential, commercial and industrial use; transport monitoring; greenhouse gas inventories; land use maps; demographic assessments; and so on. Figure 9 gives the schematics of an energy monitoring system as an example. The system comprises four functions: (1) electricity monitoring, (2) data transference, (3) data collection and (4) data sharing. Electricity monitoring measures real-time electricity consumption by using sensors installed in the distribution board of each building. Electricity consumption can be monitored minute by minute, and the amount of electricity consumed can be determined by multiplying power current by power voltage.

The monitored data are transferred to a data server using the data transfer system. The system uses two types of data transfer methodology. One system uses a wired or wireless Internet connection and the other uses a mobile line. The system is expected to be installed in offices and commercial buildings which have wired/wireless-Internet connections as well as houses where Internet connections are not always available. The data transfer speed of mobile lines is slow compared to Internet connections in general, but mobile lines are now very common everywhere in Japan, so the system includes both mobile lines and Internet. Mobile lines often fail to transfer data due to poor reception or slow connections. To avoid loss of monitored data, the data transfer system includes temporary data storage that can hold data for 10 days.

The transferred monitoring data are stored at a data server. The server has the function of sharing data via the Internet. Stakeholders such as residents, workers, and staff at monitoring sites can use a browser to access monitoring data. The system provides graphical information systems to users for getting information.
The system also provides summarized information on electricity consumption in certain areas (such as cities and blocks), and shows information on real-time electricity consumption over a public signage system. Figure 10 shows monitoring data from selected sites on March 6 to 12, 2016. The monitoring data clearly show large differences among the monitored sites. Offices and commercial facilities (a shopping mall and cafe) consume electricity mainly during the daytime, while hotels consume electricity both day and night. Electricity consumption in houses is low compared to offices and commercial buildings, and is affected by family structure, lifestyle and travel. In other words, the level of electricity consumption is defined mainly by the number of members staying in the house.

The monitoring data could be used not only for notifying stakeholders of energy use but also for managing energy. The Community Energy Management System (CEMS) is a system for energy management in areas and communities, and is analogous to the Building Energy Management System (BEMS), Home Energy Management System (HEMS) and Factory Energy Management System (FEMS). CEMS could manage the energy balance between supply and demand, leading to efficient use of energy. The evolving capabilities of EMS offer not only effective use of energy in houses and buildings but also new opportunities to automate some parts of the commissioning process, and can generate benefits over the entire lifetime of a building. Developing a detailed systematic automated approach will improve the quality assurance process and may even integrate energy audit capabilities that could improve the overall performance of buildings as well.
c) Local Energy Networks

Local authorities have played an important role in preventing deterioration of the natural environment and combating environmental pollution, and they are often more pioneering than the national government. Chapter 28 of Agenda 21 points out the importance of local authorities in addressing global warming issues. In Japan’s general policy for promoting measures against global warming, basic policy concepts include the importance of promoting collaborative action among the government, local authorities, businesses and citizens; and local authorities play a crucial role in tackling climate change in Japan. Local authorities are expected to set goals and directions for regional actions, promote institutional arrangements and development of social infrastructure for achieving a low-carbon society, and share information among residents and businesses, according to local natural and economic conditions.

Each prefecture has established its own plan to prevent global warming. In each plan, a CO₂ reduction target is set for 2020 and/or 2030, and concrete policies and measures to achieve the target are revealed. Examples of these policies and measures include acquiring ISO 14001, an environmental management system, to reduce the environmental impacts from carrying out needed business; or introducing their own environmental management system. Moreover, in order to promote voluntary actions against global warming by residents, some regions have enacted their own environmental management standards.

In general, GHG emission reduction actions by local authorities focus mainly on energy demand-side sectors, including the industrial sector, residential and commercial sector, and transportation sector, although the largest GHG emitter in Japan is the power sector, a supply-side sector. Given this situation with the energy end-use sectors, it can be pointed out that in order to reduce GHG emissions at the local scale, it will be important to accelerate diffusion of energy-efficient technologies among the energy demand-side sectors as well as to construct a low-carbon energy supply system within each region.

Progress in designing and implementing local energy systems involves many difficulties. For example, each region has different issues that need to be resolved. The town of Shinchi, which is located in the northern part of Fukushima Prefecture and has a population of 8,000, was selected as an “environmental future city” by the Cabinet Office in 2012. In Shinchi, a gradual population decline after 2005 led to a reduced labor force in both primary industry and the construction industry, and lower industrial output. The tertiary industry labor force continued to grow until 2015, but has started to decrease now. These shrinking and aging population issues are common among rural areas in Japan, and efforts to implement local energy systems in such areas should aim to reduce GHG emissions and to solve the problem of decreasing population. Another difficulty is the availability of energy sources. Energy systems differ from region to region, and the availability of technology also differs. The northern part of Japan relies heavily on kerosene heaters and hot water supply equipment, while the southern regions rely on hot water supply equipment using town gas and/or electricity. Implementing gas-based energy systems in the northern area could decrease GHG emissions but would need investment and new construction of gas infrastructure. For areas rich with resources in renewables such as solar, wind and geothermal, installation of renewables is a key action for low-carbonization of the area, while for areas located close to industrial complexes, utilization of waste heat would be a possible option. Although improvement of energy efficiency will be the key to low-carbonization in all regions, it is important to formulate plans and actions for a low-carbon society based on regional characteristics.

Some cities in Japan have launched new challenges for achieving energy transition. Shinchi, again, in northern Fukushima Prefecture revised its city development plan after the Fukushima accident. Figure 11 gives an outline of Shinchi’s future development plan. The city has LNG tanks and industrial parks, and it recently started a new town development around Shinchi Station. Using these resources, the city is trying to shift from traditional city development sustained by oil and fossil-fueled electricity to an innovative development plan sustained by natural gas and renewable energies.

4. Summary

Even before the Kyoto Protocol, Japan was organizing various kinds of technological development in both the public and private sectors, and in addition to reducing GHG emissions, these technologies have contributed to energy saving and diversification of energy sources after the oil shock. Even so, continuous technology development will be needed for achieving the Paris Agreement.

For example, Fujino et al. (2008) notes that in order to achieve a 70% reduction in Japan’s CO₂ emissions by 2050, the coefficient of performance (COP) for household air conditioners should be improved to COP8 on a stock basis. In 2007, the COP for household air conditioners on a stock basis was 4.26 for heating and 3.85 for cooling (EDMC, 2017), so technological advances able to double these figures will be needed in order to achieve the required performance by 2050. Such technological innovation and market penetration processes will require public and/or private funding for R&D as well as consumers’ (including companies’ and businesses’) support through the market.

Obviously, some technologies could be deployed immediately, such as a fuel shift to imported biofuels and co-firing of woody biomass in coal-fired plants. In most cases, however, dissemination would require from several years to several decades. Even if innovative technology is successfully launched in the market with the support of R&D investments and/or policies, if
consumers do not choose them when they appear on the market, subsequent technological innovations will become less certain to be carried out and further innovative technologies will be prevented from appearing on the market, e.g., fuel cells, electric vehicles and solar heaters.

Technology is a key element of efforts toward a low-carbon society, but technologies and R&D alone cannot attain it. Realizing GHG emission reduction with only technological countermeasures would be costly, but a combination of policies and countermeasures, such as lifestyle changes, good institutional arrangements and reassembling the transportation system, would lower the costs. Taking early action could lead to cost-effective ways to achieve emission reductions. For that, a large investment is needed in the initial stage, but it is likely that early market entry of technologies will lead to reduced costs of future technologies due to the "learning-by-doing" effect, and the additional investments will be balanced by the sum of reduced technology and fuel costs. Learning-by-doing effects can be detected for many commodities and technologies when observing markets. Rubin et al. (2015) presented a literature review on learning-by-doing effects (or the "learning curve") for electricity supply technologies, including renewables. Based on their research, the learning rate of solar PV is in the range of 10%–47%, and that of offshore wind, 5%–19%.

Moreover, infrastructure cannot be built immediately, making it difficult to switch suddenly to a low-carbon type just before 2050. In addition, planning of GHG reduction policies and actions with both technology and non-technology options is a key action, and it is also important to implement and monitor the policies and actions. Planning, implementation and monitoring based on the PDCA (Plan-Do-Check-Act) cycle should be established, so the continuous running of the PDCA cycle can open the door to the low-carbon society, in which society achieves immense reductions of GHG emissions while maintaining quality of life.

The development of a low-carbon society in Japan is crucial for tackling climate change issues. The impacts of climate change affect everyone around the world, and Japan is no exception. Policies and actions that do not contribute to low-carbonization will bring benefits in the short term, but result in damage to the environment, nature, economy and life in the long run. In addition, considering that the global trend is toward achieving a low-carbon society, a country may lose an opportunity for green growth and its future international competitiveness in low-carbon technologies if it fails to shift to a low-carbon approach because other nations will achieve green growth and export low-carbon technologies and experience first.

Low-carbonization of the energy system is a key to GHG emission reduction as well as achieving a low-carbon society globally. Development of innovative technologies is also a necessary part of building a low-carbon society, and to meet deadlines it may be necessary to accumulate whatever technologies have been developed up to that time, change systems, prepare a social infrastructure that will enable these new technologies to be incorporated, and take other measures. Japan’s experience and expertise in technological R&D could go a long way toward taking the first step in the right direction. It will provide a foundation for sharp GHG emission reductions and establishment of a low-carbon society not only in Japan but also all over the world.
Acknowledgements

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Research Perspectives on Future Scenarios toward Achievement of the 2 Degree Target

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Article 2 of the Paris Agreement describes the global average temperature target as follows: “Holding the increase in the global average temperature to well below 2°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.”

Article 4 of the Paris Agreement mentions the global emission pathways as follows: “In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.” Moreover, that “All Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies, mindful of Article 2, taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances” is also mentioned (COP, by decision 1/CP 21, paragraph 35, invited the Parties to communicate by 2020 to the secretariat, mid-century, long-term low greenhouse gas emission development strategies in accordance with Article 4, paragraph 19, of the agreement). That is to say, in order to achieve climate targets such as the 2°C target, global GHG emissions will need to peak-out as soon as possible, and show a negative trend during the latter half of the 21st century.
2. The 2 Degree Target and INDCs

Prior to COP21, all countries had to submit their own intended nationally determined contributions (INDCs) to the UNFCCC. All the submitted documents are listed on the UNFCCC’s website (http://www4.unfccc.int/submissions/indc/Submission%20Pages/submissions.aspx). The INDCs cover not only the targets for GHG mitigation reductions but also the targets for adaptation in each country. Some developing countries focus on climate change impacts and adaptation rather than GHG reduction targets.

Table 1 shows the mitigation targets of major countries and regions of the world. From Table 1, it can be seen that the GHG mitigation targets reflect the situation of each country. Most of the developed countries have adopted absolute targets for GHG emissions. On the other hand, many developing countries have adopted intensity targets or relative reduction of their emissions in a BaU (business as usual) case. Moreover, some developing countries such as Indonesia and Thailand have adopted two types of targets: one unconditional target and a separate conditional target contingent on other countries’ support.

The UNFCCC (2016) has summarized the all

<table>
<thead>
<tr>
<th>Country</th>
<th>Target</th>
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<tbody>
<tr>
<td>China</td>
<td>To reduce carbon intensity by 60% to 65% by 2030 below 2005 levels.</td>
</tr>
<tr>
<td>India</td>
<td>To lower emission intensity of GDP by 33% to 35% by 2030 below 2005 levels.</td>
</tr>
<tr>
<td>Indonesia</td>
<td>An unconditional 2030 GHG emission reduction target of 29% below BaU including land use, land-use change and forestry (LULUCF) emissions, and a conditional 41% reduction below BaU by 2030 (with sufficient international support).</td>
</tr>
<tr>
<td>Japan</td>
<td>To reduce emissions by 26% below 2013 emission levels by 2030.</td>
</tr>
<tr>
<td>Korea</td>
<td>To reduce GHG emissions by 37% below BaU by 2030.</td>
</tr>
<tr>
<td>Malaysia</td>
<td>To reduce GHG emission intensity of GDP by 45% by 2030 relative to the emissions intensity of GDP in 2005.</td>
</tr>
<tr>
<td>Thailand</td>
<td>An unconditional 20% reduction in emissions by 2030 compared to BaU levels. This could increase to 25%, conditional upon international support.</td>
</tr>
<tr>
<td>Vietnam</td>
<td>An 8% reduction in emissions by 2030, compared to BaU. This could be increased to 25% conditional upon international support.</td>
</tr>
<tr>
<td>USA</td>
<td>To reduce economy-wide emissions by 26% to 28% below 2005 domestically.</td>
</tr>
<tr>
<td>EU</td>
<td>To reduce GHG emissions by at least 40% domestically below 1990 levels by 2030.</td>
</tr>
<tr>
<td>Russia</td>
<td>Limiting anthropogenic GHG to 70−75% of 1990 levels by 2030.</td>
</tr>
<tr>
<td>Brazil</td>
<td>To reduce GHG emissions by 37% below 2005 levels by 2025.</td>
</tr>
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</table>

Source: UNFCCC (2015)

Fig. 1 Comparison of global emission levels in 2025 and 2030 resulting from the implementation of the INDCs and under other scenarios. Source: UNFCCC (2016)
proposed GHG reduction targets. Figure 1 shows the various global GHG emission pathways, including emissions upon achieving the INDCs. This figure shows that the INDCs can reduce GHG emissions compared to no GHG reductions in the world by 2025 and 2030, but very large gaps remain in GHG emissions between the INDCs and the 1.5°C / 2°C scenarios. In order to achieve the 2°C target after following the INDCs, very steep GHG emission reductions will be needed after 2030. That is to say, more ambitious targets in 2030 will be needed to achieve the 2°C target according to this figure. The Paris Agreement mentions the “global stocktake” which assesses collective progress towards achieving the purpose of the Paris Agreement and its long-term goals. For each country, “Each Party’s successive nationally determined contribution will represent a progression beyond the Party’s then current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.”


The Paris Agreement requests each Party to submit a “long-term low greenhouse gas emission development strategy” by 2020. As of the end of June 2017, a total of six countries had submitted their own strategies: the USA, Mexico, Canada, Germany, France and Benin. Among these countries, the USA, Mexico, Canada, Germany and France have indicated long-term GHG emission reduction targets, as shown in Table 2. Although the benchmark years are different, many countries have indicated GHG reductions of more than 75% by 2050. In particular, Germany mentions a 95% reduction by 2050 compared to its emissions in 1990.

4. Discussion on Japan’s Long-term Strategy

The Government of Japan (2015) approved Japan’s INDC at a Cabinet meeting on July 17, 2015. The GHG reduction target for 2030 was set at a 26% reduction compared to the 2013 level. After that, Japan also approved a Climate Action Plan at a Cabinet meeting on May 13, 2016. The Climate Action Plan stipulates an 80% reduction of GHG emissions in Japan by 2050. Figure 2 shows previous trends and future targets for GHG emissions in Japan. Although Japan achieved its GHG mitigation target during the 1st commitment period (2008 – 2012) by using carbon sinks and credits, no sharp GHG reduction could be observed from 1990 to 2015. In order

![Graph showing GHG emission trends through 2015 and future emission targets in Japan. Source: Greenhouse Gas Inventory Office of Japan (2017) and Government of Japan (2015)
to achieve the GHG emission targets for 2030 and 2050, a real break in this trend will be needed from now on.

Although the Climate Action Plan mentions an 80% reduction of GHG emissions in Japan by 2050, a detailed concrete roadmap to achieve the 80% reduction target has yet to be quantified. To discuss the long-term target for Japan, the Sub-committee on Long-term Low-Carbon Vision was organized under the Central Environment Council in July 2016. In March 2017, the sub-committee presented its long-term low-carbon vision (2017). In this vision, “simultaneous solution” of economic and social problems such as aging of society and climate change is regarded as a background issue. The long-term GHG reduction target for 2050 is clearly set at 80%, and in order to achieve this target, the vision stresses improved energy efficiency, increased low-carbon energy supply, and a switch to low-carbon energies in end-use. In addition to that, the “carbon budget” concept is introduced, in which the global mean temperature change is related to cumulative GHG emissions from the pre-industrial level, and it gives the clear message that the time to act is “Now.” If infrastructure and large-scale facilities including coal thermal power plants, which have long life times, are introduced now, the CO₂ emissions may remain high over time. Such “lock-in” effects will have to be avoided to keep the GHG mitigation opportunity as high as possible. The vision points out that development and deployment of new innovations are key to long-term significant GHG emission reductions. Not only innovation in technology, but also innovations in economic and social systems and lifestyles will be needed to realize drastic GHG emission reductions. The transformation will contribute to emission reductions both in Japan and worldwide. To support the various actions toward a low-carbon society, the role of “carbon pricing” will be very important. Carbon pricing will provide the necessary information and a good incentive to reduce the GHG emissions.

5. Is an 80% Reduction of GHG emissions in Japan by 2050 Achievable?

There have been several studies assessing 80% reduction of GHG emissions in Japan by 2050. The first of these was the Japan Low Carbon Society (LCS) Scenarios toward 2050 Project (2050 Japan Low-Carbon Society Scenario Team, 2008). This was a research project of the Global Environmental Research Fund (S-3) of the Ministry of the Environment, Japan. In this project, two types of socio-economic scenarios were proposed, and by using the Asia-Pacific Integrated Model (AIM), it found quantitatively that a target of 70% reduction of CO₂ emissions by 2050 compared to the 1990 level in both scenarios would be achievable. Later the GHG mitigation target for 2050 was changed from 70% to 80%, and the new target was also found to be realizable.

The Deep Decarbonization Pathways Project (DDPP) is another example of a quantitative analysis. The Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI) initiated it to demonstrate how countries could transform their energy systems by 2050 to achieve a low-carbon economy and significantly reduce the global risk of catastrophic climate change. The project currently comprises 16 country research teams, composed of leading research institutions from countries representing about 70% of global GHG emissions and at very different stages of development.

From Japan, the AIM project team is participating in this project, and by using the AIM/Enduse [Japan] (a dynamic recursive technology selection model for mid-to long-term mitigation policy assessment in Japan), it assesses GHG emission pathways in Japan through 2050 (Kainuma et al., 2015). It has prepared three scenarios to assess 80% GHG emission reduction in Japan by 2050: a mixed scenario in which all technology options are available; no nuclear scenario; and limited carbon capture and storage (CCS) scenario, in which 100 MtCO₂/year of CCS is allowed, i.e., half the amount considered in the mixed scenario.

Figure 3 shows the CO₂ emission reductions for these three scenarios in 2050. The DDPP shows the three pillars of decarbonization as a whole: energy efficiency, decarbonization of electricity and electrification of end-uses. In the case of Japan, these pillars are also important, and the report concludes that “With largescale diffusion of low-carbon technologies, Japan’s long-term GHG emission reduction target is technically feasible, even if the availability of nuclear power and/or CCS is limited.” Although the marginal costs of CO₂ reduction in the no-nuclear and limited CCS scenarios are more expensive than that in mixed scenario, these three scenarios can achieve the 80% reduction of GHG emission by 2050.

6. How can Japan Contribute to the 2°C Target?

From the existing quantitative analyses, the 80% GHG emission reduction in Japan by 2050 is a
technologically feasible target, but to realize this target, we face many challenges. From Fig. 2, no sharp GHG emission reduction can be observed in Japan from 1990 to 2015. This means that the general level of engagement with climate change mitigation is still slow.

To ensure the 2°C target is reached, an 80% reduction in Japan by 2050 is inevitable. From the existing studies, the 80% reduction target can be achieved using the existing and forecasted technologies. Various innovations of technologies and socio-economic systems can help implement the mitigation actions.

It is important to show how to support implementation of the mitigation technologies in the actual world. For example, if the payback period can be considered long, that is to say, decision making with a long-term viewpoint can be realized, the mitigation costs decrease, and more mitigation technologies including energy saving technologies and renewable energies will be able to be introduced.

Climate change measures to achieve the 2°C target will have to continue more than 100 years, and strengthen year by year. On the other hand, the year 2050 is not the distant future. The target of 80% reduction will have to be realized before high school students at this moment reach 60 years of age. A long-term perspective during the decision making process can help avoid lock-in effects. The research also will have to contribute to implementation of GHG mitigation technologies in the real world to provide a concrete roadmap. For that purpose, in addition to mitigation technologies, socio-economic activities in the future will have to be discussed, and more detailed analyses taking into account the local circumstances and stakeholders’ conditions will be needed in addition to macroscopic analyses.

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Overview of Studies in Japan on Climate Change Impacts and Adaptation: Towards Climate Risk Management Based on Scientific Evidence

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Abstract

Persistent efforts to improve scientific understanding of climate risks and countermeasures against them are indispensable for keeping strong momentum of coordinated climate risk management efforts. For example, the long-term climate target for the global mean temperature increase from the pre-industrial period of less than 2 degrees Celsius in the Paris Agreement is not fresh-off-the-farm but has a long history of political discussion supported by the science available at any given time. On another front, Japan published its first national adaptation plan in November 2015. When we look at domestic climate policies, rapidly growing attention to adaptation in Japan also revolves around the intensified public perception of existing and anticipated climate impacts. Based on the above, the primary purpose of this article is to give an overview of previous, ongoing and future studies on climate impacts and adaptations in Japan with regard to domestic and international policy support. This overview of the studies provides suggestions for some important directions or aspects of future research on climate risks. These include the importance of co-design and co-production in fields of study to support decision making and strategy planning against global environmental problems; improvements to quantification and communication of uncertainties in climate risk analyses; the importance of participation in internationally coordinated research activities, including impact model inter-comparison projects; archiving and management of tools and data developed for risk analysis for portability and transparency; and responsibility of researchers in the iterative process of periodic climate risk assessment.

Key words: adaptation, climate change impacts, risk management, long-term target, sustainability

1. Introduction

Persistent efforts to improve scientific understanding of climate risks and countermeasures against them are indispensable for keeping strong momentum of coordinated climate risk management efforts. The Paris Agreement, agreed upon among the parties to the UNFCCC (United Nations Framework Convention on Climate Change) in December 2015 and effective from November 2016, explicitly manifests its central aim for strengthening the global response to the climate change threat by keeping the global temperature rise this century well below 2 degrees Celsius over pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. This long-term climate target is not fresh-off-the-farm but has a long history of political discussion supported by the best science available at any given time. Most recently, the referential scientific treatises include the Fifth Assessment Report of the IPCC (Intergovernmental Panel on Climate Change) published in 2013-2014 and further scientific evidence communicated between researchers and policymakers at the SED (Structured Expert Dialogue) process for the periodic review of the long-term target by the UNFCCC (Fig. 1, a chronological summary of events on international/domestic climate policy and relevant research projects in Japan, that are discussed in this article).

If we look at domestic climate policies, rapidly growing attention to adaptation in Japan also revolves around the intensified public perception of existing and anticipated climate impacts. In November 2015, the Japanese government formulated its first national plan for adaptation to the impacts of climate change (NAP) with the purpose of promoting adaptation to climate change impacts systematically and comprehensively. Prior to the NAP’s formulation, the Central Environment Council (an advisory body of the Japanese Cabinet) assessed the existing and potential impacts of climate change on seven major sectors (agriculture, forestry and fisheries; aqueous environments and water resources; natural ecosystems; natural disasters and coastal areas;
human health; industrial and economic activities; lives of citizenry and urban life) and compiled the *Report on Assessment of Impacts of Climate Change in Japan and Future Challenges* in March 2015 with the participation of academic experts from a broad range of disciplines. The first NAP emphasized continuous enhancement of scientific findings, as one of the basic strategies it listed, through implementation of observation and monitoring, projection and assessment, and promotion of studies and research. Based on the first NAP, the Central Environment Council discussed governmental efforts necessary for supporting a review of climate risk assessment planned before or around 2020 and published an interim report titled *Policies and Procedures for Efforts on Scientific Knowledge and Climate Risk Information to Promote Climate Change Adaptation* in March 2017.

Based on the information noted above, the primary purpose of this article is to provide an overview of previous, ongoing and future studies on climate impacts and adaptations in Japan in regard to domestic and international policy support. Section 2, below, provides a brief review of previous major scientific efforts (relatively large research projects) on climate change impact and adaptation analysis. Section 3 explains urgent research themes for supporting adaptation policy that have been identified in recent reports by the Central Environment Council. Section 4 introduces ongoing activities of new research on impacts and adaptation in Japan. Lastly, Section 5 concludes the article with a discussion of prospects for impact and adaptation studies in Japan.

## 2. Previous Climate Impact and Adaptation Analysis Efforts in Japan

While impact studies on specific sectors already existed in 1990s, coordinated analyses of climate impacts on comprehensive sectors in Japan didn’t emerge until FY2005. As a research project funded by Japan’s Ministry of the Environment (MOE). The project, titled “Project for Comprehensive Projection of Climate Change Impacts” (commonly known as the “GERF S-4 project”; FY2005-2009) contained a wide range of research teams from national research institutes and universities and conducted coordinated scenario analyses of climate impacts on water resources, human health, agriculture, ecosystems, and natural disasters. Key findings of the project were summarized in two research reports published in 2008 and 2009 (http://www.nies.go.jp/s4_impact/English/seika-e.html), and were also utilized intensively in a ministerial report of the MOE, titled *Wise Adaptation to Climate Change—Report by the Committee on Climate Change Impacts and Adaptation Research*, published in June 2008 (http://www.env.go.jp/en/earth/cc/wacc_080618.pdf).

The basic research structure of the GERF S-4 project was taken over by the succeeding project, called the “GERF S-8 project” (“Comprehensive Study on Impact Assessment and Adaptation for Climate Change”; FY2010-2014) funded by the MOE for further emphasis on adaptation analysis and explicit consideration of future climate uncertainty. In parallel with the GERF S-8...
project, the RECCA project (“Research Program on Climate Change Adaptation”; FY2010-2014; https://www. restec.or.jp/becca/eng/) funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) tackled sophistication of adaptation analyses in specific regions and sectors for supporting decision makers in local governments. In addition to the research projects noted above, progress was achieved toward sophistication of hazard analyses relevant to natural disaster prevention mainly by the KAKUSHIN program (“Innovative Program of Climate Change Projection for the 21st Century”; FY2007-2011) and the succeeding SOUSEI program (“Program for Risk Information on Climate Change”; FY2012-2016) funded by MEXT under a strong partnership with global/regional climate modeling teams in Japan. The research findings obtained through the projects above conducted during this decade were intensively utilized in compiling the Central Environment Council report published in March 2015 and the first NAP published in November 2015, both of which were mentioned above.

For global scale analyses of climate change impacts, in the 1990s, there were a few sectorial analyses in Japan, some of which were conducted for the development of a global integrated assessment of climate policies (e.g., Harasawa et al., 2003). The GERF S-5 project (“Integrated Research on Climate Scenarios for Policy Support and Public Awareness”; FY2006-2010) made the first effort toward coordinated analyses of global climate impacts in Japan, aiming to interpret the latest climate projections available during the period to depict expected climate risks mainly to natural systems. The GERF S-5 project’s risk analyses highlighted uncertainty in the climate projections and the implications regarding future climate impacts. Some of the global climate risk analyses in the GERF S-5 project were succeeded by the GERF S-10 project (“Integrated Climate Assessment – Risks, Uncertainties and Society (ICA-RUS)”; FY2012-2016; https://www. nies.go.jp/ica-rus/en/index.html), where they were made more comprehensive for discussing and developing global climate risk management strategies. The primary purposes of the GERF S-10 project included comparing (i) sector climate risks expected under the long-term climate targets for global mean temperature increases from the pre-industrial period not exceeding 1.5, 2.0 or 2.5 degrees Celsius and (ii) mitigation efforts required for achieving these respective targets.

The large research projects presented above tended to be self-contained and were conducted independently without substantial collaboration with other research projects. That may have resulted in inefficiencies such as duplicated data collection that might have been avoided through cooperative efforts. This deficient collaboration was more remarkable among projects funded by different ministries or funding agencies. Some concrete measures have been tried for enhancing organic integration of projects. One was establishment of a task group for climate scenarios, which was co-managed by the MOE-funded GERF S-5 project (risk analyses) and MEXT-funded KAKUSHIN Program (climate projections). The task group was expected to support efficient data transfer from the climate modeling community to the impact projection studies. Periodic task group meetings were held for exchanging the latest research information and discussing the efficient sharing and transfer of large archives of climate model outputs. Publication of Synthesis Report on Observations, Projections, and Impact Assessments of Climate Change – Climate Change and its Impacts in Japan in 2009 and 2012 through inter-ministerial collaboration among the JMA (Japan Meteorological Agency), MEXT and MOE also worked as a link for improving organic connections among the research projects funded by any of those ministries/agencies.

3. Urgent Research Themes Identified in Governmental Committee Reports

As discussed in Section 2, major governmental reports on adaptation policy have tended to be linked with and based on outputs of the coordinated research projects for studying multi-sector impacts at the national/local scale. The first NAP stresses the importance of improved scientific evidence for supporting periodic climate risk assessment, and the interim report (Policies and Procedures for Efforts on Scientific Knowledge and Climate Risk Information to Promote Climate Change Adaptation), which was compiled in March 2017 as a follow-up activity to the NAP, suggested research themes and areas that should be prioritized for supporting periodic risk assessment. While not all the suggestions derived from political needs may be realized due to limited financial and technical resources, the suggestions in the report will affect the direction of research conducted in Japan in the coming years. Thus this section summarizes the urgent research themes indicated in the committee report.

The report advises the Japanese government to promote climate change risk analysis and implement adaptation through cooperation among relevant ministries and partnerships with a wide range of stakeholders. The MOE has been advised by the report to work on (1) enhancement of scientific knowledge, (2) promotion of understanding and cooperation of stakeholders through the effective provision of climate risk information, (3) promotion of adaptation policy at a regional scale, (4) promotion of international cooperation and contribution. More specifically, regarding (1), enhancement of scientific knowledge, the following five policy directions are presented.

i. Continual observation and monitoring of climate change and its impacts

- Review of climate impact observation and monitoring of implementation plans by relevant ministries
- Securing long-term sustainable observation/monitoring activities supporting adaptation plan
ii. Projection of climate change and its impacts
- Review of climate scenarios and other settings for impact projections by relevant ministries
- Promotion of studies on tools for developing national/regional SSPs that are consistent with global SSPs

iii. Enhancement of investigative research on climate impacts
- Promotion of studies to develop indices and methods for evaluating vulnerability, exposure and adaptive capacity
- Promotion of assessments of vulnerability and exposure at a regional scale

iv. Evaluation of effects of overseas climate impacts on Japan
- Investigative research focusing on the international supply chain and global food demand and supply

v. Periodic assessment of climate risks
- Collection and transmission of the latest scientific knowledge on sector impacts through the establishment of expert working groups in a planned and consistent way
- Improvement of evaluation criteria for significance, urgency and confidence of climate risks based on new scientific findings, as needed

With regard to policy direction (i) itemized above, for prioritizing, promoting and realizing adaptations urgently needed for mitigating climate risks in sensitive sectors, an accurate understanding of the present state of vulnerability and exposure as well as hazards is crucial. Scientific evidence of emerging climate impacts would be a strong motivation for people and society to implement the necessary urgent adaptation measures. Moreover, continuous monitoring of relevant factors for climate risks will be crucial for enhancing understanding of the problems' mechanisms, which would also increase public perception of the problems and promote implementation of the measures. Among various governmental policies regarding observation and monitoring of changes in the natural environment and ecosystems, “Monitoring Site 1000” (http://www.biodic.go.jp/moni1000/) and “Ikimono-Log” (https://ikilog.biodic.go.jp/) operated by the MOE are unique for their reliance on reporting by non-experts as well as experts to increase the temporal and spatial coverage of monitoring as well as the sense of participation by the stakeholders. Under “Monitoring Site 1000,” the MOE set up about 1000 locations for long-term monitoring of various types of ecosystems and is trying to catch quantitative and qualitative deterioration of natural environment at an early stage. For sustainable long-term observation, networks among universities, research institutes, experts, regional NPOs and volunteers have been constructed, and monitoring activities are being implemented. The collected data are processed and publicized swiftly for enhanced information sharing among stakeholders and expedited conservation actions.

A portal website for statistics relevant to climate change impacts (http://www.nies.go.jp/occcco/statistics_portal/index.html) is also operated by the MOE with the support of the OCCCCO (Office for Coordination of Climate Change Observation) at NIES (National Institute for Environmental Studies). The portal site was developed and launched based on recognition that climate change impacts had already been manifesting in many places and sectors and it was important to detect those manifesting impacts quickly enough for the purpose of adapting to them in a timely manner. With the cooperation of relevant ministries and agencies, statistical data recorded and consolidated by various institutions for their own respective purposes are collected extensively from the viewpoint of relevance to climate impacts and put in order at the portal site. The data list in the portal site contains not only statistical data on impacts directly attributed to recent climate change but also other statistical data that may be informative for understanding climate change impacts better. Continuous updating of the list is planned.

Policy direction (ii) highlights proper formulation of scenarios for climate, socio-economic and other environmental factors to be assumed in impact projections. For global or terrestrial climate scenarios, not only climate projections with the domestically developed global climate models but also climate projections supplied by the foreign modeling teams need to be collected, evaluated and utilized efficiently. For impact analyses targeting Japan, spatial downscaling is a key procedure and should be carefully considered. While regional climate models have been improved steadily during recent decades, how to process the outputs of regional climate models is also a crucial consideration for developing climate scenarios suitable to each impact analysis.

Development of national/regional socio-economic scenarios for assuming future vulnerability and exposure is also an urgent task, since it will be an important element in coordinated climate risk analyses. For global scale impact analysis, SSPs (Shared Socio-economic Pathways) have been developed to be commonly used, especially in research aiming at contributing to IPCC-AR6 (Riahi et al., 2017). National/regional socio-economic scenarios do not necessarily need to be consistent with the global SSPs. If consistency is maintained, however, the results of climate risk assessment in Japan can be better linked or compared with global assessments or assessments conducted in other countries based on similar assumptions. While developing quantitative downscaling methods for land-use, population and other factors is essential to development of a national/regional socio-economic scenario, bottom-up visioning of the future by local stakeholders and experts is also valuable and should be considered. Regarding the downscaling of the SSPs, some precedent research exists, conducted mainly by research teams in Europe and the U.S. (e.g., Absar &
Regarding policy direction (iii), more attention has been paid recently to the need for research on vulnerability and exposure with relevance to development of national/regional socio-economic scenarios as mentioned above. While there have been many projections of impacts on natural systems such as hydrological state, vegetation and crop yields so far, climate impacts on social systems have been less studied and understood. Even in projections of socio-economic impacts, there has been a tendency to assume that vulnerability, exposure and related adaptive capacity remain constant (no change in

Preston, 2015).
the future from the present state).

This limited consideration of future change in socio-economic conditions is not merely the case just in Japan but more universally. IPCC-AR5 highlighted the importance of considering vulnerabilities and exposure for assessing and managing risks (Fig. 2; IPCC, 2014) as well as hazards. The Reasons for Concern (RFC) diagram was also claimed to be improved by considering future change and uncertainties in vulnerabilities and exposure more explicitly (Fig. 3; Oppenheimer et al., 2014). The determination of key risks as reflected in the RFCs has not previously been distinguished across alternative development pathways (left plate in Fig. 3). The RFCs, however, represent risks that are determined by both climate-related hazards and the vulnerability and exposure of social and ecological systems to climate change stressors.

The right plate in Fig. 3 illustrates this dependence on vulnerability and exposure in a modified version of the burning embers diagram. Literature published before IPCC-AR5 (before 2014) was insufficient for supporting confident assessment of specific RFCs using the illustrated approach. While this limitation has been a major concern for many years, intensive efforts to overcome it will be made with support of the SSPs in the years to come before the next IPCC-AR6. Not being left behind by the international frontline of research efforts is quite important to the Japanese research community for attaining proper, realistic adaptation policies as well as for increasing its presence in the internationally competitive research community.

Policy direction (iv), evaluating the effects of overseas climate impacts on Japan, poses a traditional frequently asked question that has yet to be answered sufficiently. Conceptually, this type of risk was already a concern even at the initial stage of climate policy discussion. A typical example is the effect of crop yield changes in other countries which are propagated through international food trade. However, after Thailand experienced a huge flood in 2011 causing severe disruption to international industries, including global car manufacturers, people began calling for a more serious discussion. The fragility of the global commercial supply chain was recognized more concretely than before. Beyond the hypothetical and qualitative indications of indirect potential risks from impacts outside Japan, quantitative analyses need to be improved. Recently, impacts on national security affected by changes in migration patterns caused by climate change and rising occurrences of conflicts caused by increases in extreme climate events have also been a concern (e.g., Burke et al., 2015). From the practical viewpoint of model simulation, coherent downscaling of the climate and socio-economic scenarios discussed above is also related to the feasibility of the analyzing knock-on effects of climate change impacts in other countries on Japan.

Finally, regarding policy direction (v), as found in the IPCC process for global circumstances, it should be remembered that promotion of academic research and periodic scientific assessment of available knowledge are interdependent. Since researchers know that research results are surveyed and assessed periodically for supporting policymaking processes, they can plan their research so that it will be useful and timely for those processes. Otherwise, without the improved understanding provided by the research, periodic climate risk assessment cannot be conducted effectively. The explicit signal from the government that suggests a need for periodic assessment of the latest scientific understanding will increase motivation among researchers to conduct relevant studies, especially if the signal is embodied within prioritized provision of research funding. Regarding improving evaluation criteria for climate risks, continuous efforts to improve risk communication based on stakeholders’ views will become more important.

To promote the understanding and cooperation of stakeholders through the effective provision of climate risk information, prioritized policy (2) listed above, the A-PLAT (“Climate Change Adaptation Platform”; http://www.adaptation-platform.nies.go.jp/en/index.html) established by the MOE in 2016 is expected to function as a bridge for interactive communication between the science community, which provides evidence, and stakeholders such as public citizens, the private sector and local governments. The platform is designed to contain and provide data and tools for supporting adaptation decisions, like simplified climate risk models and risk maps. It also contains guidance materials for promoting adaptation actions by individual stakeholders, including summary reports of good practices in the private business sector. The platform is also planned to be equipped with the additional function of supporting adaptation policy developments in developing countries in the Asia-Pacific region, to be extended to the AP-PLAT (“Asia-Pacific Adaptation Information Platform”) by 2020, based on the statement by Minister of the Environment Koichi Yamamoto at COP22 in 2016 on support from Japan’s government for the development of infrastructure to share climate risk information regionally. In a word, any adaptation-related studies conducted in Japan are encouraged to utilize the platform as an outlet for research deliverables, and this will surely affect research proposals on adaptation issues in the coming years.

Other policy initiatives related to enhancing adaptation at a local scale as well as in developing countries in the Asia-Pacific region also give researchers full play. For example, promotion of adaptation at a local scale will be supported by the “Consortiums for Local Scale Adaptation,” consisting of the national government, local authorities and research organizations. The consortiums are expected to conduct climate risk analyses based on collaboration among relevant stakeholders and evidence-based adaptation planning. It would be quite a new challenge for researchers to work on research themes based on direct discussion and
collaboration with potential audiences (i.e., co-design and co-production proffered in FutureEarth). A similar approach is also applicable to collaborative work with Asia-Pacific countries. For example, some projects for supporting adaptation policy planning in Asia-Pacific countries have been conducted through collaboration among local stakeholders who have the ability to affect local policies, local researchers who understand the local problems best and have good access to proper data, and experts from Japan who bring tools like impact analysis models as introduced in Section 4.

4. New and Ongoing Research Projects on Climate Impact and Adaptation Analysis

Here, it is worth summarizing ongoing major research projects on climate impacts and adaptation to get an overview of present research interests and directions in Japan and to consider their potential contribution to achievement of the Paris agreement.

Regarding global-scale analyses of climate impacts, the GERF S-14 project (“Strategic Research on Global Mitigation and Local Adaptation to Climate Change”; FY2015-2019; http://s-14.iis.u-tokyo.ac.jp/eng/) funded by the MOE has been working on analysis of mitigation and adaptation in an integrated manner. It also contains a research module that aims at linking a global economic model (AIM-CGE) with sector impact models to improve economic analysis of climate change impacts. For example, Takakura et al. (2017) estimated the economic cost of heat-related illness prevention through worker breaks associated with climate change under a wide range of climatic and socioeconomic conditions using the AIM-CGE linked with a worktime reduction impact model. The study showed that GDP losses in 2100 will range from 2.6 to 4.0% compared to the current climate conditions under the highest emission scenario while the losses could be less than 0.5% if the 2.0°C goal is achieved. To discuss long-term climate targets and mitigation pathways, accurate economic analysis of climate change impacts will be crucial. The analyses’ comprehensiveness (coverage of the impacted sectors), however, is still insufficient for such a discussion. By expanding the sectors for which economic impacts can be estimated, studies conducted by the project will be able to contribute to policy discussions of long-term global climate targets. The project also aims at better consideration of adaptation in impact projections, so it would fill one of the key research gaps in this research field.

The SI-CAT program (“Social Implementation Program on Climate Change Adaptation Technology”; FY2016-2020; https://si-cat.jp/en/staticpages/index.php/about) funded by MEXT collaborates with local governments in developing technologies that comprehensively assess precise near-term climate projections and the effectiveness of countermeasures against climate change impacts in Japan, considering respective regional characteristics. The keyword and ultimate target of the project is “social implementation.” It aims at either avoiding or reducing the damage caused by climate change by reflecting these technologies in planning for urban development, agriculture and other industries. The SI-CAT program conducts technological development to find adaptation measures needed for the future in collaboration with researchers in geoscience, social science and the humanities, and officials of local governments for protecting the security of residents and their property from climate change threats. It will contribute to the development of adaptation plans by local governments and the creation of new enterprises in consideration of steady adaptation of various needs to climate change.

As discussed in Section 2, improvement of climate models and future climate projections have been conducted mainly in successive large research projects supported by MEXT. The latest ongoing project is called the TOUGOU Program (“Research Program for Improving Integrated Climate Models”), which was launched very recently in May 2017. The program consists of four research themes: global climate projection and development of basic models for the projection, improved understanding of the carbon cycle and climate sensitivity, integrated projection of climate change, and integrated projection of hazards. This research program can be considered a successor to MEXT-funded research projects for the development and improvement of climate models that have utilized the Earth Simulator (high-speed super computer) since FY2002. After several system updates to reflect computer technology improvements, the ES3 (the 3rd generation Earth Simulator) has been operational since June 2015. Based on the accumulated research knowledge and resources, the new program is going to tackle novel tasks such as provision of climate projections suitable for adaptation analyses with fine spatial resolution (a few km); decreasing the uncertainty regarding the carbon cycle, nitrogen cycle and climate sensitivity so that a scientific basis can be formed for mitigation policy; and gaining further insight into tipping elements. These new features would be useful for supporting the development of national disaster prevention plans and ambitious mitigation policies. It is also worth noting that the project also aims at producing climate projections useful for assessing adaptation not only inside Japan but in other East Asian countries, following governmental policy to support adaptation in the region.

Here, let us also look at existing or anticipated international collaboration. For global scale analyses of climate impacts, the importance or necessity of participation in model inter-comparison projects is becoming well recognized in Japan as well. For example, four Japanese impact models were considered in the fast-track analyses of the ISIMIP project (Inter-Sectoral Impact Model Inter-comparison Project) and contributed to papers surveyed in IPCC-AR5 (Warszawski et al., 2014). Furthermore, in ongoing consecutive rounds of the project, larger number of Japanese modeling teams
are participating. It seems that uncertainty in impact projections caused by the choice of analytical methods (models) have been proven to be no less than the uncertainty caused by future climate and socio-economic scenarios. As previously experienced in the global climate model development process, engagement in international model inter-comparison projects will be beneficial for providing insight into the frontline of the research. It will also increase the presence of the participating modeling teams in the international academic community.

Contribution to the IPCC is highly recognized in the Japanese research community. This should not be limited to elevating active researchers to the report writing teams, but there should be various other ways to contribute as well. Generally, research funds granted by government ministries require the recipients to produce output that directly benefits the ministerial services. In some cases, however, citations of published literature by IPCC reports are also highly appreciated as contributing to a governmental service, as they may be considered international contributions from the Japanese government.

As discussed in Section 3, support of Asia-Pacific countries for policy planning and implementing adaptation is also a prioritized policy direction explicitly mentioned in the first NAP. Concrete policy actions have been initiated as a follow-up to the NAP. The plan of launching the AP-PLAT introduced in Section 3 is one of the typical efforts for supporting adaptation policies in these countries. Bilateral collaborative projects are also being conducted for adaptation analysis, planning and implementation.

5. Conclusion

The above-given summary of recent research activities on climate risk analysis, brought up some important directions or aspects of future research.

First, “co-design” and “co-production,” highlighted in FutureEarth, are becoming more and more important in the field of study to support decision making and strategy planning in response to global environmental problems (as discussed in Section 3). They also apply to climate risk analysis and adaptation assessment. Involvement of stakeholders at the initial stage of research planning is crucial. This might not be achieved effectively by voluntary efforts of researchers alone, and research funding systems may also need to change to promote interaction between the research community and potential study audiences.

Second, while quantification and communication of uncertainties in climate risk analyses have become better recognized in the previous decade, further improvement is still needed. The availability of new scenarios such as SSPs for socio-economic change and new climate scenarios will help us analyze future uncertainties in a more comprehensive manner (as highlighted also in the interim report introduced in Section 3). Spatial downscaling of those global scenarios to national/local scale impacts and adaptation analyses will also be important.

Third, there are internationally coordinated activities aiming to improve impact analysis and adaptation assessment, which include model inter-comparison projects (as discussed in Section 4). Constant active participation in such activities would increase the quality of risk analysis conducted in Japan, which would ultimately increase their international presence. As a shorter-term task, contribution to scientific assessments conducted by the IPCC and dialogues between policymakers and researchers in the UNFCCC may be prioritized, since they can provide direct input to international negotiation processes. What would be even more beneficial would be to contribute during the framing stage of internationally coordinated activities.

Fourth, climate risks and adaptation options needed for managing the risks are generally region-specific and need to be analyzed considering individual and unique local conditions. Tools, models and some types of data for quantitative analysis of the risks, however, could be generic to some degree. For efficiently increasing the coverage of analyses, tools and data developed and accumulated during the process of adaptation analysis in a specific region should be archived and maintained properly to be utilized for analyses in other regions. Such an archive of tools and data would be also effective for maintaining scientific rigor by increasing the feasibility of their validation. Previously, it often occurred that tools and data developed in a research project or governmental survey were not maintained very well after the project ended and valuable products were not efficiently used again. Fortunately, it seems ongoing large research projects and policy initiatives for data management and distribution (e.g., A-PLAT, explained in Section 3) have been conducted with more careful consideration to data management issues.

Finally, the first national adaptation plan has explicitly shown a need for periodic risk assessment based on the best tools and data available in each period. Researchers are expected to support the process through sustainable efforts for improving risk assessment methods. To improve the performance of analyses, it is naturally the responsibility of researchers to develop and improve analytical tools such as more accurate and precise impact simulation models. More active participation in international model comparison may be an effective step for steady improvement of analytical methods as discussed above. Long-term, continuous, repetitive investigation using the tools developed may not be considered academic research, but it might be considered routine investigation or a monitoring task. Appropriate interpretation of long-term repetitive assessments, however, will be a situation where researchers’ expertise is crucial.
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References


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Recent Progress in Local Governmental Planning for Climate Change Adaptation in Japan: A Case of Climate Change Adaptation in Saitama Prefecture

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Abstract

The surface air temperature in Japan continues to rise, as can be seen from observations beginning in the 1890s. This temperature rise has been caused not only by urbanization but is also greatly affected by climate change. Under these circumstances, efforts toward adaptation to climate change have recently begun in Japan among local governments. Since the national climate change adaptation plan was issued in 2015, formulation of adaptation plans by local governments has steadily progressed. This is partly attributable to support from national projects for the development of local government adaptation plans, availability of a climate change adaptation information platform launched by the Ministry of the Environment, and easier access to climate change adaptation information. In this paper, we survey and review the present state of climate change adaptation planning in local governments in Japan. We also describe the current progress toward climate change adaptation in Saitama Prefecture as an example of climate change adaptation planning by a local government.

Key words: climate change adaptation, local government, thermal environment

1. Introduction

It has been pointed out that climate change due to anthropogenic forcing already affects nature and human society, and there is a high possibility that serious, widespread irreversible effects will occur if the degree of global warming increases in the future (IPCC, 2013). Even if future greenhouse gas emissions are reduced to zero, the globally-averaged surface air temperature will rise, and the risk of climate change is expected to increase toward the end of the 21st century.

The Japan Meteorological Agency has been conducting more detailed future climate forecasts for the Japanese region (Japan Meteorological Agency, 2013 & 2017). They postulated the Representative Concentration Path (hereafter, RCP) 4.5 scenario in Global Warming Prediction Information, Volume 8, and the RCP 8.5 scenario in Volume 9. The temperature increase in the region around Japan is predicted to be 2.5°C–3.5°C under the RCP 4.5 scenario and 3.3°C–4.9°C under the RCP 8.5 scenario. It is predicted that the number of days with hot weather, when the daily maximum surface air temperature exceeds 35 °C, will be much higher than at present.

In the Paris Agreement signed at the United Nations Framework Convention on Climate Change, 2015 (COP 21), moves have been made to restrict the global average temperature increase to less than +1.5°C or +2.0°C in the future as compared with the preindustrial climate. It is difficult to predict the future temperature increase because there is great uncertainty not only in climate prediction but also in the prediction of socioeconomic and technological innovation. For this reason, in order to reduce the impact of climate change, we should plan not only “mitigation,” to control greenhouse gas emissions, but also “adaptation” to the effects that have already become apparent and the unavoidable effects in the near and distant future.

Observation, surveillance, prediction / evaluation, investigation, etc., of climate change and its impacts are underway around the world. Particularly in recent years, adaptation measures have progressed remarkably in Japan. In 2015, the Ministry of Agriculture, Forestry and Fisheries (2015) and the Ministry of Land, Infrastructure, Transport and Tourism (2015) announced adaptation plans. Based on these plans and research results on recent adaptations, the
Central Environment Council evaluated the impact of climate change with the participation of experts from a wide range of fields at the Central Environment Council for the government’s adaptation plan formulation. In November 2015, the government’s first adaptation plan for the impacts of climate change as adopted by Cabinet decision (Government of Japan, 2015).

The National Plan for Adaptation to the Impacts of Climate Change explains that one of the basic strategies is to promote regional adaptation: cooperation between the national agency and local governments through the promotion of climate change impact assessments, adaptation planning, and capacity building within local governments. The scale and range of vulnerability due to climate change depend greatly on regional characteristics such as climatic, geographical and social conditions in the affected area. In addition, it is important for local governments to develop their own local communities and societies based on regional characteristics in order to adapt to future climate change. Therefore, each local government should play an active role in tackling climate change adaptation, because adaptation strategies should depend on the locality.

2. Adaptation Planning in Local Governments in Japan

Global warming strategies of local governments, especially at the prefectural and designated city level, are mostly based on mitigation. Each local government has its own action plan for global warming mitigation (Ministry of the Environment, 2017a) and is executing its own action plan to reduce greenhouse gas emissions. After the Paris Agreement in 2016 (UNFCC, 2016), climate change adaptation on a local scale became one of the main issues in the environmental divisions of local governments, even in Japan. Therefore, some local governments have recently made their own action plans for climate change adaptation.

Some national projects to support creation of climate change adaptation plans by local governments have been planned and implemented since 2010 in Japan. Table 1 gives a list of past and current national projects related to climate change adaptation planning by local governments. Twenty-one prefectures and five designated cities have been supported by those national projects since 2010.

Under two national projects, the Comprehensive Study on Impact Assessment and Adaptation for Climate Change, S-8, of the Environment Research and Technology Development Fund (Ministry of the Environment) and the Research Program on Climate Change Adaptation (RECCA) (Ministry of Education, Culture, Sports, Science and Technology (MEXT)) implemented from 2010 to 2014, national research institutes and universities share information with local governments partaking in the projects, and work together to create climate change adaptation plans for local governments. The Support Project for Impact Assessments and Adaptation Planning for Climate Change (Ministry of the Environment, 2017b), which was executed from 2015 to 2016, provided information about climate change adaptation plans in other local governments in Japan and other countries. Additionally, the Social Implementation Program on Climate Change Adaptation Technology (MEXT), an ongoing project, provides information on climate change adaptation.

The SI-CAT project is targeting some local governments, called “Model Municipalities,” and attempting to apply advanced technology and information to implement a climate change adaptation strategy. The project is also examining how to use advanced technology and information in local governments at the prefecture level and making guidelines to establish a climate change adaptation plan.

Table 2 shows the status of climate change adaptation plan-making in prefecture-level local governments as of May 2017. Seven prefectures and one designated city had established their own climate change adaptation plans, and 30 prefectures and 11 designated cities had added a climate change adaptation strategy to their climate change mitigation plans, environmental action plans or

<table>
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<tr>
<th>Name of project</th>
<th>Period</th>
<th>Municipalities involved in the project</th>
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Environmental white papers. Seventy-nine percent of prefectures (37/47) and 60% of designated cities (12/20) had described their approach to climate change adaptation in their official documents. Among local governments that were supported by the national projects mentioned above, over 90% of prefectures (19/21) and 100% of designated cities (3/3) had described their own plans in official documents. This shows that the national projects have strongly supported climate change adaptation planning by local governments.

The climate change adaptation platform (A-Plat) built by Japan’s Ministry of the Environment in 2016 (Ministry of the Environment, 2017c) makes it easier for local governments to access integrated and comprehensive information about climate change adaptation. A-Plat is an important tool for local governments in considering how to plan for climate change adaptation.

3. History of Climate Change Adaptation Planning in Saitama Prefecture

Saitama Prefecture established a climate change adaptation plan in 2016. The prefecture has been receiving assistance from the national projects and is proceeding earlier than other local governments to reflect climate change adaptation in its prefectural climate change adaptation plan. Table 3 lists events in the history of efforts toward climate change adaptation in Saitama Prefecture. In 2008, an impact assessment of global warming in Saitama Prefecture was published. Information was added on climate change adaptation to Saitama Prefecture’s mitigation action plan in 2009 (Saitama Prefecture, 2009a). In 2012, a committee was set up on global warming adaptation promotion in Saitama Prefecture, which has shared climate change information since then among all divisions in the prefectural government. In 2016, a climate change adaptation plan for Saitama Prefecture was established and published. Impact assessments are given, and current public policies and plans for each sector such as agriculture, forestry, fisheries, water resources, ecology, natural hazards, human health and urban environments are described in the plan. There are four issues (paddy rice, floods, heat stroke, and thermal environment) of particularly high concern that are listed as pioneering subjects in the prefecture.

Figure 1 outlines the management process of Saitama

Table 2 Distribution of local public entities (prefectures and designated cites) that had established an adaptation strategy as of May 2017. Red letters indicate local governments supported by the national projects.

<table>
<thead>
<tr>
<th>Method of establishing plan</th>
<th>Municipalities</th>
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<tbody>
<tr>
<td></td>
<td>Designated city: Kawasaki City</td>
</tr>
<tr>
<td></td>
<td>Designated cities: Sendai City, Chiba City, Yokohama City, Sagamihara City, Shizuoka City, Kobe City, Hiroshima City, Fukuoka City, Kitakyushu City, Kumamoto City, Miyazaki City</td>
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Table 3 History of climate change adaptation in Saitama Prefecture.

<table>
<thead>
<tr>
<th>Year</th>
<th>Events</th>
</tr>
</thead>
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<tr>
<td></td>
<td>The Saitama Prefecture Ordinance on the Promotion of Global Warming Countermeasures effected. Climate change adaptation is described in the ordinance.</td>
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<tr>
<td>2010 – 2014</td>
<td>Involved in Comprehensive Study on Impact Assessment and Adaptation for Climate Change, S-8 (Ministry of Environment) .</td>
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<tr>
<td>2012</td>
<td>Committee on the global warming adaptation promotion in Saitama Prefecture established.</td>
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<td>The 4th environmental planning in Saitama Prefecture revised and climate change adaptation information added.</td>
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<td>”Council on the Global warming adaptation in agriculture” held with Department of Agriculture and Forestry and Department of Environment.</td>
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<td>2015</td>
<td>The Global warming strategy action plan in Saitama Prefecture revised and climate change adaptation information added detailed (Saitama Prefecture, 2011).</td>
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<td>Climate change adaptation plan in Saitama Prefecture published.</td>
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<tr>
<td>2015.12 – 2019</td>
<td>Involved in Social implementation Program on Climate Change Adaptation Technology (Ministry of Education, Culture, Sports, Science and Technology) as a Model Municipality.</td>
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Prefecture’s climate change adaptation plan. Saitama Prefecture publishes, manages, executes, verifies and revises its climate change adaptation plan following a process described in Shimada et al., 2016, which is based on “adaptive management” as suggested in Sirai et al., 2017.

4. Strategy for Improving the Thermal Environment in Saitama Prefecture

The Tokyo Metropolitan area (dominating the southern part of the Kanto district) is known as one of the hottest places in summer in Japan. The area contains more than 38 million people and is the world’s largest megalopolis. The amplitude of diurnal variation of the surface air temperature (SAT) is especially large in Saitama Prefecture (just north of Tokyo), where the daily maximum SAT sometimes reaches 40 ºC.

Figure 2 shows the annual mean SAT at the Kumagaya Meteorological Observatory. The trend from 1897 to 2016 has been a rise of 2.07°C /century. This trend is relatively larger than in the rural region because it contains not only the impact of global warming but also that of the urban heat island effect.

Figure 3 shows histograms of the daily maximum and minimum SATs at the Kumagaya Meteorological Observatory. Both histograms show a shift to the warmer side from the 1980s to 2007-2016. The number of days during which the maximum SAT exceeded 35°C increased rapidly, from 73 days in the 1980s to 199 days from 2007 to 2016. The number of the days during which the minimum SAT exceeded 25°C from 2007 to 2016 was 3.79 times of the number in the 1980s.

Thus, in the past decade, the summer heat environment in Japan has grown worse, and the number of emergency transportations due to heat stroke has rapidly increased. Therefore, people are concerned about the summertime thermal environment in Saitama, and the prefectural government has established various measures for adaptation to a hotter environment.

Saitama Prefecture established “Heat island report in Saitama Prefecture” on its heat island effect in March 2006 (Saitama Prefecture, 2007). The Saitama Prefectural Department of the Environment compiled and analyzed many kinds of surface air temperature data, such as the Automated Meteorological Data Acquisition System (AMeDAS) established by the Japan Meteorological Agency and air pollution monitoring stations managed by Saitama Prefecture. The document shows long-term trends, seasonal variations, land use/land cover effects and estimated anthropogenic heat, revealing the main factors in the heat island effect. The impact assessment of global warming in Saitama Prefecture, published in 2008, reported that the summertime thermal environment was getting worse in urban areas. Stop Global Warming Saitama Navigation 2050, published in February 2009 (Saitama Prefecture, 2009a), is a mitigation action plan, but it also includes an adaptation policy, including countermeasures to the heat island effect and summertime thermal environment. A guideline for heat island countermeasures in Saitama Prefecture was also published in 2009 (Saitama Prefecture, 2009b) and the document describes specific plans to implement effective measures against the heat island effect.

Stop Global Warming Saitama Navigation 2050 was revised in 2015 (Saitama Prefecture, 2015). The document includes not only heat island countermeasures but also a comprehensive policy for climate change adaptation in Saitama Prefecture. The Department of Environment, Saitama Prefectural Government also started a model residential area project for advanced measures against the heat island effect to mitigate the heat island effect that year.

As mentioned in the previous section, the recent SAT rise in Saitama Prefecture was caused not only by global warming but also by enhancement of the urban heat island due to urbanization. Figure 4 shows the urban fraction of the Tokyo metropolitan area in 1976 and 2009 and the difference between them, estimated for a three-kilometer grid. We cannot find any differences in the center of Tokyo, because the urban fraction was already saturated by 1976, but we can see urban fraction trends sprawling into western Tokyo, Kanagawa, Saitama and Chiba.

Thus, the summertime thermal environment in Saitama Prefecture is getting worse. Figure 5 shows mortalities from heat stroke in Saitama Prefecture. After...
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(a) Urban fraction in 2009
(b) Urban fraction in 1976
(c) Difference between (b) and (a)

Fig. 3 Histogram of daily maximum (left) and minimum (right) SAT at Kumagaya Station. Orange bars indicate histogram from 1980 to 1989, blue bars indicate histogram from 2007 to 2016.

Fig. 4 Urban fraction of Tokyo metropolitan area. The urban fraction is calculated from land utilization segment mesh data obtained through a national land numerical information downloading service in 3-km grid boxes.

Fig. 5 Mortalities due to heat stroke in Saitama Prefecture. (Population Census, Ministry of Health, Labour and Welfare)

Fig. 6 Population time series in Saitama Prefecture. (Population data were provided by Statistics Division, Department of General Affairs, Saitama Prefecture.)
2000, casualties began increasing, and in 2010, the hottest summer in recent decades, they exceeded 120. Mortalities from heat stroke are much higher than those from other natural hazards such as floods, snow disasters or landslides in Saitama Prefecture.

The population of Saitama Prefecture is still increasing as of January 2017 (Fig.6), though populations in most prefectures are decreasing. Casualties from heat stroke strongly depend on age. The population’s average age is rising drastically: in 2000, 12.8% of the population was over 65 years old; in 2017, that figure had increased to 25%.

5. Example: Local-scale Adaptation in Saitama Prefecture

In this section, we describe one example of Saitama Prefecture’s advanced climate change adaptation measures. To reduce the impact of future heat waves in summertime, the Saitama Prefectural Government is introducing some effective measures against heat at the Kumagaya Sports and Culture Park, where major rugby and football matches often take place.

MEXT launched the Social Implementation Program on Climate Change Adaptation Technology (SI-CAT) in 2015, the goal of which has been social implementation of climate change adaptation on a local government scale. In the project, national research institutes and universities provide their advanced adaptation information and technology to local governments. Saitama Prefecture is one of the “Model Municipalities” of SI-CAT. We established a working group for thermal environment adaptation, consisting of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), the University of Tsukuba, Ibaraki University, Rissho University and the Center for Environmental Science in Saitama, and performed in situ observations and fine-scale numerical simulations.

In August 2016, we performed a set of in situ observations to evaluate adaptation measures quantitatively, to verify numerical simulations and to spread information to citizens and prefectural officers on Saitama Prefecture’s climate change adaptation strategy. Figure 7 shows a map of the Kumagaya Sports and Culture Park. The numbers show the locations of installed observation instruments.

The observations were made on August 9, 10, and 19, 2016. The weather was clear and hot on the observation target days. To share the methodology and information from the thermal environment observations with scientists and policy makers, people from several sectors such as national research institutes, universities and local governments took part in the observations. The daily maximum SAT exceeded 33°C on all the observed days. The highest temperature, 36.9°C, was observed at the Kumagaya Meteorological Observatory on August 9.

The Kumagaya Sports and Culture Park is located at 139.4040 degrees east and 36.1669 degrees north, 3.5 kilometers north of Kumagaya Station on the JR Takasaki Line. The park area is about 100 ha, the longitudinal size is 2 kilometers, and the latitudinal size is 3 kilometers. The park contains the “Sainokuni Kumagaya Dome” (a multipurpose dome), three rugby courts and two athletic tracks.

Figure 7 shows the observation locations. The P1 site was located at the center of a grass-covered field. We set that point as a super site and installed an automated weather station there that could measure air temperature, humidity, pressure, black bulb temperature and three-dimensional supersonic wind speed. We also installed an aspiration psychrometer (Assmann type) and a radiometer that could observe upward and downward, longwave and shortwave, and four radiation components. The situation was ideal for general meteorological observation. We also took thermography, temperature and pressure observations in the lower boundary layer using a drone and radiosonde. Figure 7(b) shows the P1 observation site, (c) shows diurnal variations in SATs in the park, and (d) provides a thermographic and visible image. Such efforts are important not only for improving numerical models by using observational data but also for educating the prefectural government about the impact of climate change.

6. Summary/Discussion

As of 2017, some advanced local governments had already published their own climate change adaptation plans. National projects, which support creation of climate change adaptation plans by local governments, are very effective, and most of the local governments supported by these could form their own climate change adaptation plans. The national projects play a crucial role in propagating local government plans for climate change adaptation. Risks due to climate change and factors that increase climate change vulnerability depend on geographical and social conditions. Climate change adaptation plans should differ for each local government. Climate change mitigation by local governments is mandated by law (Act on Promotion of Global Warming Countermeasures) in Japan, but as of 2017, adaptation has not been mandated by any laws, so there is less motivation to make climate change adaptation plans.

As mentioned in the Introduction, most local governments supported by the national projects could make their own adaptation plans. A-Plat is a helpful tool for local governments for making climate change adaptation plans. It is important to maintain, add and update data to facilitate climate change adaptation more widely.

For local governments to achieve the next stage of climate change adaptation, support for those unable to make their own adaptation plans will be essential.

Acknowledgments

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Fig. 7 Example of a thermal environment observation at the Kumagaya Sports and Culture Park. (a) map of observation sites (map data are from http://openstreetmap.org), (b) picture of one observation site, (c) our observed SATs and data from the Kumagaya Meteorological Observatory, Japan Meteorological Agency, located about 2 km southwest of the park, and (d) visible and infrared images of observation site P2.
Program on Climate Change Adaptation Technology (SI-CAT), MEXT. Observations of the thermal environment at the Kumagaya Sports and Culture Park were supported by members of the Thermal Environment Working Group of SI-CAT, MEXT.

References


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Japan’s New Initiative for REDD+ Results-based Financing: Opportunities and Challenges

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Abstract

Article 5 of the Paris Agreement specifies implementation of REDD+ (reducing emissions from deforestation and forest degradation) through results-based payments. Currently, however, REDD+ results-based financing is insufficient for incentivizing full implementation of REDD+ by developing countries. In this article, we examine how a new bilateral initiative of Japan called JCM REDD+ could contribute to REDD+ results-based financing. JCM REDD+ is unique as a CDM-like mechanism providing ex-ante funding to project-based REDD+ activities and issuing credits later for emission reductions achieved which can be used for both countries’ NDCs. The features of JCM REDD+ would complement other existing payment-on-delivery mechanisms. JCM REDD+ supports activities on the ground which directly affect drivers of deforestation. It also has the potential to exploit financial sources from the private sector, in which involvement in REDD+ remains low. JCM REDD+, however, would have no significant positive influences immediately on the landscape of REDD+ results-based financing, as its scale of implementation is restricted in terms of number of projects in the pipeline and available funding sources. To maximize the potential of JCM REDD+, modalities and guidelines for transparency and accounting relevant to REDD+, Nationally Determined Contributions and internationally transferred mitigation outcomes should be clarified under the Paris Agreement. At the same time, we find it is crucial to consider policy designs in developed countries that would enhance investment in REDD+.

Key words: internationally transferred mitigation outcome (ITMO), Joint Crediting Mechanism (JCM), Nationally Determined Contribution (NDC), reducing emissions from deforestation and forest degradation (REDD+), results-based payment

1. Introduction

Article 5 of the Paris Agreement clearly states that the parties should take action to conserve and enhance the function of forests as sinks and reservoirs of greenhouse gases. It also encourages the parties to implement and support REDD+ (reducing emissions from deforestation and forest degradation), the framework for which was adopted in 2013 as the Warsaw Framework for REDD+ as a result of a decade of negotiations at the UNFCCC (United Nations Framework Convention on Climate Change). One distinctive feature of REDD+ under the UNFCCC is that it employs results-based payment for financing. Results-based financing is a financing approach where payments are made only after a quantified outcome has been verifiably achieved (Voigt & Ferreira, 2015). In the context of the UNFCCC, results-based financing generally refers to payments made for REDD+ activities that demonstrate real reductions in emissions from the forestry sector, as well as consistency with other performance criteria such as the REDD+ safeguards (Wilder, 2014).

The Warsaw Framework for REDD+ specifies the requirement for developing countries to implement REDD+ to access results-based payments. It requires them to establish a national strategy or action plan for REDD+, national forest reference emissions level and/or forest reference level, national forest monitoring system and safeguard information system. To help developing countries meet these requirements, REDD+ has adopted a phased approach, which is another prominent feature of REDD+. In the first phase, a country prepares to implement REDD+, for example by developing a national REDD+ strategy and capacity building for monitoring, reporting and verification (MRV) for REDD+. The second phase is for more advanced readiness, focusing on...
REDD+ implementation with demonstration activities, and in the third phase, the country is compensated for its REDD+ activities through results-based payment (Wertz-Kanounnikoff & Angelsen, 2009). The phased approach allows countries at different levels of capacity to participate in REDD+ and ultimately access REDD+ results-based financing.

International financial support for REDD+ has to be in line with the phased approach to materialize this concept. The Warsaw framework for REDD+ affirms that developed country parties are urged to support development of the first and second phases through multilateral and bilateral channels from public and private sectors, which provide adequate and predictable support for all phases (Wildier, 2014). Financial support has been provided in parallel with negotiations on the rules for REDD+ at the UNFCCC. Donor countries pledged US$5.0 billion through bilateral agreements between 2006 and 2014 and US$3.2 billion through six multilateral funds targeting REDD+ and sustainable forest management between 2008 and 2014, and 58% of the finance has been channeled to readiness activities such as capacity building, training workshops, strengthening of in-country institutions and development of national REDD+ policies and strategies (Norman & Nakhooda, 2014). As a result of this readiness support, we note a list of 25 countries who have submitted their forest reference levels to the UNFCCC, one of the requirements for accessing REDD+ results-based payments (UNFCCC, 2017a). On the other hand, results-based funding for Phase 3 to date is still at an initial stage and its scale is still limited. Adequate, predictable and sustainable financing will be crucial for full implementation of REDD+ and scaling up of the REDD+ results-based financing is required.

Japan is the 5th largest donor to REDD+ following Norway, the US, Germany and the UK and has provided REDD+ support mainly through bilateral channels for the purpose of promoting REDD+ readiness among developing countries, especially in building capacity for monitoring, reporting and verification (Norman & Nakhooda, 2014). There is a new unique initiative under development in Japan to support REDD+ in an approach similar to results-based payments. This article examines Japan’s new initiative, called the JCM (Japan Crediting Mechanism) REDD+, for its positive influence on REDD+ results-based financing. We first review the initiative, then discuss its opportunities and challenges.

2. Review

2.1 Current Landscape of REDD+ Results-based Financing and Japan’s Contribution

The funding for the results-based payments of REDD+ remains at 42% of the total pledge to REDD+ as mentioned above. Norway has made a significant contribution, providing over US$3 billion of its pledge, which is more than 70% of its total pledge, through bilateral channels (Norman & Nakhooda, 2014). Norway signed agreements on payment for emission reductions with Brazil, Guyana and Indonesia. We have to say, however, that the scale of financing for REDD+ results-based payments in Phase 3 is not sufficient. For example, Brazil, one of the largest emitters in the forest sector and the pioneer of REDD+, reported to the UNFCCC in their Biennial Update Report that the emission reduction from their REDD+ activities in the Amazon during the period from 2006 to 2010 was 594 million CO₂ eq per year (UNFCCC, 2017b). To compensate fully for the achievement of this one country, it would cost about US$3 billion per year based on simple estimations using the unit price negotiated between the Forest Carbon Partnership Facility (FCPF) Carbon Fund and developing countries (approximately US$5/CO₂ eq). Recently, there have been other bilateral pledges for results-based REDD+ at the Climate Summit in New York in 2014. Germany, the UK and Norway pledged US$5 billion in total between 2016 and 2020 through multilateral and bilateral channels and they notably utilize the REDD Early Movers program (REM), an initiative under Germany’s official development assistance (ODA) with a fund size of EUR€65 million (Ehringhaus & Streck, 2015; Germany et al., 2016; NDC Partnership, 2016). REM is a program to reward the emission reduction performance of countries who are already taking the initiative themselves in REDD+ (GIZ, 2012).

The Green Climate Fund (GCF) is considered the main funding source within the UNFCCC. Forty three state governments have made a pledge of US$10.3 billion in total to the GCF (GCF, 2017b) but it is not yet clear how much will be allocated to REDD+ results-based funding. Discussions on developing funding modalities for REDD+ results-based funding are still underway at the GCF board meetings as of June 2017 (GCF, 2017a) and it is expected to start calling for proposals by late 2018 at the earliest (Leonard, 2017). Outside of the UNFCCC, the FCPF Carbon Fund of the World Bank has initiated results-based funding for REDD+, with capital of about US$390 million (FCPF, 2013a). It provides payments for verified emission reductions from REDD+ activities in countries which have made significant progress in their REDD+ readiness endeavors (FCPF, 2013b), and has selected four programs in Chile, Costa Rica, Democratic Republic of the Congo and Mexico for its portfolio, with 15 programs in the pipeline (FCPF, 2017).

Japan has been supporting REDD+ mainly through ODA projects conducted by the Japan International Cooperation Agency (JICA) and providing technical cooperation to 12 countries (Shishido, 2015). From 2006 to 2016, the government of Japan reported that the amount of aid provided for REDD+ has reached US$1.7 billion (FAO, 2017). Through multilateral channels, Japan contributed US$14 million to the FCPF’s Readiness Fund, US$60 million to the Climate Investment Funds’ Forest Investment Program (FIP) and US$3 million to UN-REDD (Government of Japan, 2017a). So far, Japan has never supported results-based REDD+ but has been developing
a new scheme for results-based funding. It seems at present that this scheme is the sole instrument Japan has for contributing to results-based REDD+ financing and that there are no other options like the German government’s REM utilizing ODA for REDD+ results-based payment under consideration.

2.2 JCM REDD+

The government of Japan is promoting a bilateral mechanism called the Joint Crediting Mechanism (JCM), which is implemented under a bilateral agreement between Japan and partner countries. As of May 2017, 17 countries have signed the agreement. The purpose of the JCM is to facilitate diffusion of leading low-carbon technologies as well as to implement mitigation actions, contribute to sustainable development in developing countries and use those emission reductions or removals, appropriately evaluated in a quantitative manner, to achieve the emission reduction targets of the countries involved (Government of Japan, 2017b). In the first nationally determined contribution (NDC) of Japan it was stated that “the Joint Crediting Mechanism (JCM) is not included as a basis for bottom-up calculation of Japan’s emission reduction target, but the amount of emission reductions and removals acquired by Japan under the JCM will be appropriately counted as Japan’s reduction.” This is expected to achieve 50 to 100 million tCO₂ eq of emission reduction by 2030 through JCM programs undertaken within the government’s annual budget (Government of Japan, 2015).

Under the JCM, private companies in Japan together with local companies jointly implement a project by transferring low-carbon technology, then conservatively calculate the emission reduction achieved following the JCM guidelines and issue JCM credits. The JCM is a scheme similar to the Clean Development Mechanism. A Joint Committee (JC) consisting of representatives from both countries takes a role like that of the CDM Executive Board such as developing rules and guidelines, approving methodologies and project registration, and deciding the amount of credit to be issued (Government of Japan, 2017c). The governments of both countries issue credits based on notifications from JC and establish and maintain a registry. There were 16 projects registered to the JCM and 105 projects in pipeline as of May 2017. As business investment costs are the major burden for a company starting a project, Japan’s government provides several subsidy programs. One program under the Ministry of the Environment (MOE) named “JCM Model Projects” supports a maximum of 50% of the initial investment for a JCM project and requires the subsidized project to deliver back more than 50% of the credit issued by the project to the government (Asakawa, 2016). The MOE prepared approximately US$60 million for FY2017 for this program. REDD+ is within the scope of the JCM, and guidelines for JCM REDD+ are under development and to be agreed upon with partner countries. There were two subsidized projects among the JCM Model Projects in Laos and Indonesia in 2016. They were the projects with the largest estimated emission reductions in the subsidy program (Koakutsu et al., 2016).

The distinctive feature of JCM REDD+ is that it adopts a project-based approach rather than the national approach that the JCM have followed in the wake of the CDM. The Warsaw Framework for REDD+ and related decisions in the UNFCCC recognize that REDD+ is implemented at a national scale, and subnational activities can be implemented as an interim measure (UN-REDD Programme, 2016). Most of the results-based payment mechanisms currently implemented prefer to adopt a national or jurisdictional (e.g., provincial) scale for implementation in line with UNFCCC decisions. In the cases of JCM REDD+ Model Projects in Laos and Indonesia, the project proponents provide technical support for local households in the project area for changing current agricultural practice such as slash and burn cultivation, which was identified as a deforestation driver. The project areas cover 30,000 ha and 89,000 ha, respectively (GEC, 2016a, 2016b). The Japanese government’s methodological guidelines draft for JCM REDD+ provides methods for setting project-specific reference levels and calculating achieved emission reductions, although it also accepts national or sub-national reference levels and monitoring systems if the partner country submits them to the UNFCCC (Government of Japan, 2017c). The timing of the payment is a notable point. The JCM provides up-front payment for the costs of REDD+ activities while other results-based payment mechanisms pay for outcomes that are monitored and verified ex-post. Another remarkable feature of JCM REDD+ is that the scheme issues credits and Japan’s government intends to use the credits allocated to it based on the level of contribution, to achieve Japan’s emission reduction target (NDC). Other bilateral funding schemes have no intention of issuing or receiving credits in return.

3. Discussion

3.1 JCM REDD+ Opportunities

JCM REDD+ is based on the CDM scheme and would be classified as a results-based financing scheme providing ex-ante payment via market mechanisms. It supports the initial costs of implementing REDD+ activities. With payment-on-delivery schemes such as the FCPF Carbon Fund, the host country has to initiate and cover the cost of REDD+ activities. That might lead to non-participation of lower-income countries or impoverished subnational regions or socioeconomic groups (Wong et al., 2016). In an interview we conducted with a government officer in a country participating in the FCPF Carbon Fund we learned that it was very difficult to secure domestic funding for the activity implementation they had listed in the proposal they had submitted to the Fund.

The FCPF Carbon fund sets a fixed price for reduced emissions through negotiations for a purchase agreement...
with the recipient country in advance, but it would be difficult to set the price adequately, as the cost of emission reductions varies even within the same country. When the set price is low, the REDD+ activities will be implemented only in areas where the cost is lower than the price, and this will often be where forests are least threatened (Wong et al., 2016). On the other hand, through the JCM REDD+ approach, a project can target forests with high conservation value or areas that will create co-benefits from forest protection such as livelihood improvement for local communities. It is possible, however, for the emission reduction amount achieved in the project to be much lower than expected. The investors have to take the risk of emission reduction activity underperformance, unlike in the case of results-based financing with ex-post payment.

Supporting activity implementation on the ground for REDD+ through projects is important. Even a developed country can improve and develop legislation and institutional arrangements for REDD+ through past national level readiness support that may previously have been insufficient as a measure to prevent deforestation, especially when the deforestation driver was linked to livelihood practices of local communities. For example, if the newly established limits reduce the area for shifting cultivation per household, direct action for the local community is absolutely necessary, such as capacity building for alternative livelihoods and this is where JCM REDD+ would be able to contribute. A mix of up-front and ex-post payment will be required for financing of REDD+ (Angelsen, 2017).

Funding sources for results-based REDD+ from the public sector have been limited, but JCM REDD+ has the potential to enhance investment from the private sector for REDD+. It was reported that 94% of US$30 million in transacted forest carbon offsets to buyers in 2015 in the voluntary market was from the private sector, who rely on a positive reputation to do business (Goldstein & Ruef, 2016). These private companies might prefer to invest in individual projects rather than be one of many investors in a large-scale fund for national-scale REDD+, because it enables them to explain clearly that their investment contributes to emission reductions as well as conservation of important forests and improvements to local society as part of their corporate social responsibility.

3.2 Challenges of JCM REDD+

We classified JCM REDD+ as a scheme using market mechanisms in the previous section, but JCM credits are not currently tradable (Government of Japan, 2017b), though discussions to make them tradable are ongoing among JCM partner countries. Even if they become tradable, it seems there is no market existing for trading them, as private Japanese companies have not set any GHG emission caps. The accelerated progress of JCM development seems to be backed up by the attractiveness of the government subsidy program, which supports initial business investments for introducing energy efficient equipment and requests a share of the credits generated by the project in return. On the other hand, the REDD+ project has high potential for large emission reductions but it is not directly linked to companies’ business. Thus, companies’ interest in JCM REDD+ seems to remain rather low. In addition, the subsidy prepared for JCM REDD+ is limited because the main source of the subsidy program is the global warming tax, the use of which is restricted to emission reduction activities in the energy sector.

Internationally under the UNFCCC, the market mechanism is recognized as a necessary tool to meet the “2 degree Celsius target,” and Article 6 under the Paris Agreement allows for the creation of an international carbon market. The JCM is a cooperative approach under the article, meeting its important criteria, namely involvement of internationally transferred mitigation outcomes (ITMOs) towards NDCs (Koakutsu et al., 2016). The rules for operationalizing Article 6 are currently under negotiation, including on their scope, accounting and the nature of the ITMOs (Marcu, 2017). In terms of REDD+, and JCM REDD+ as well, although the necessary rules and guidance for implementation have been determined under the Warsaw Framework for REDD+ and results-based payment is allowed in Article 5 of the Paris Agreement, it is not yet clear how REDD+ will be treated in discussions on the ITMOs. Future decisions on the broader architecture of the Paris Agreement, including NDC accounting and transparency and cooperative approaches, will have a significant impact on REDD+ and that is why both developing and developed countries hesitate to mainstream REDD+ in their climate change policies, especially using results-based payment (Graham, 2017). A country like Indonesia that has a clear, ambitious emission reduction commitment in the NDC and identifies forest management as an important sector for reducing emissions would inevitably be careful about accepting international support for REDD+ involving transfer of REDD+ outcome. Indonesia, in fact, has yet to sign the letter of intent for the FCPF Carbon Fund, which is the first step in the fund’s emission reduction purchase agreement (FCPF, 2017).

The challenge for developing countries involved in the ITMOs after relevant decisions are made will be shaping their domestic policies and taking actions to prevent the risk of double counting at the national level. The JCM has taken measures to prevent such risks in its scheme by establishing rules, guidelines and a registry system. If there are plural mechanisms, however, in which some transfer credits within the country and some do not, the national government has to be able to manage a centralized registry for reporting their NDCs adequately. Moreover, registry management may become complex if the mechanisms adopt different methodologies. The methodologies of JCM REDD+ and the FCPF Carbon Fund will differ, for example.

Diversity in approaches to supporting full implementation of REDD+ will be important. To
leverage complementary relationships among different funding schemes, further studies will be required to identify and compare the strengths and weaknesses of each approach and lessons learned from past experience. That would help identifying the role of JCM REDD+ and ways to coordinate with other financing schemes.

4. Conclusions

The “2 degree Celsius target” will be unachievable if emission reductions from deforestation remain unaddressed (Goldstein & Ruef, 2016). More than 100 countries have mentioned REDD+ in their NDCs (Leonard, 2017), but results-based REDD+ has not yet been fully operationalized and REDD+ results-based financing must be scaled up. From our review of REDD+ in this article, we have to conclude that there are few contributions JCM REDD+ would immediately make toward changing the landscape of REDD+ results-based financing at the current stage. At the same time, however, we have also identified the possibility of JCM REDD+ complementing the existing results-based funding with payment-on-delivery as it supports the initial costs of activities linked directly to deforestation drivers on the ground. As it seeks a market-based approach, JCM REDD+ has a potential to open up sources from the private sector. The involvement of the private sector has been widely recognized as an important source of funding for REDD+ but concrete breakthroughs have yet to occur. To maximize the potential of JCM REDD+, modalities and guidelines for transparency and accounting relevant to REDD+, the NDCs and ITMOs should be clarified under the Paris Agreement, and these should not force developing countries to choose between whether they receive international support or show ability to comply with their NDCs. Furthermore, it is crucial to consider new policy designs in developed countries to enhance investment for preventing deforestation in developing countries and to scale up REDD+ financing, which has not been actively discussed in the ODA-dependent REDD+.

The limitation of this study is that our discussion goes no further than the potential opportunities and challenges of JCM REDD+ as its implications are still under negotiation with certain JCM partner countries. Further study on its actual impact will be necessary once the JCM REDD+ project is operationalized.

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Identifying Factors for Promoting Renewable Energy Projects through the Clean Development Mechanism in China, India and ASEAN Countries

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Abstract
This study analysed the greenhouse gas (GHG) abatement cost of renewable energy projects developed through the Clean Development Mechanism (CDM) in China, India and ASEAN countries. The results from this study show that the average abatement cost for all renewable energy technology including biomass, hydro, wind and solar renewable energy in ASEAN countries was the highest among these three countries due to the absence of a “scale of economy,” lower penetration rate of new technology such as PV and wind power, and lower magnitude of grid emission factors. To encourage the implementation of renewable energy in ASEAN countries towards a decarbonised economy, the following research topics could be examined in the future. First, it will be necessary to analyse the “learning curve” for new types of technology, i.e., PV and wind power technology. Second, effective mitigation mechanisms and incentives need to be examined because as the results of this study imply, the magnitude of grid emission factors could affect the abatement cost and business conditions for investments in renewable energies through mitigation mechanisms. Lastly, it is important to discuss the overall policy arrangements since ASEAN countries implement not only feed-in-tariffs for renewable energy, but also subsidies for fossil fuels, which provide some advantages to fossil-fuel power plants and affect estimations of CO₂ abatement costs. Apparently, climate policies interact so closely with energy policies that it is worth proposing comprehensive climate and energy policies with analytical insights into energy-related technologies and policies in ASEAN countries.

Key words: abatement cost, ASEAN, China, India, renewable energy, scale of economy

1. Introduction
In December 2015, the Conference of Parties (COP) adopted the Paris Agreement to strengthen the global response to the threat of climate change, aiming to keep the global temperature rise this century to well within two degrees Celsius over pre-industrial levels. The Paris Agreement requires all countries including developing countries to make their best efforts to implement mitigation actions through nationally determined contributions (NDCs).

Among the developing countries, China and India emitted 9.1 billion tonnes and 2.0 billion tonnes of CO₂, respectively, from fossil fuel combustion in 2014, accounting for 34% of the world’s total CO₂ emissions from fossil fuel combustion in 2015. Also, among the Association of Southeast Asian Nations (ASEAN) countries, Indonesia, Thailand, and Malaysia had GHG emissions positioned within world’s top 30 (World Bank, 2015). Furthermore, the final energy consumption of the whole ASEAN region is expected to increase by 2.2% per annum, which indicates an increase from 549 Mtoe in 2011 to 1,004 Mtoe in 2035. The Asian Development Bank (ADB) (2013) has forecasted the amount of electricity generation to increase to 1,879 TWh in 2035 from 696 TWh in 2011, which indicates a 4.2% annual increase. In particular, it is expected that the use of coal will increase in Viet Nam, the Philippines and Lao PDR which have not used fossil fuels as electricity sources in the past (ADB, 2013). Therefore, it is important to take the best actions for mitigation in the electricity sector, especially in ASEAN countries, in order to achieve the ultimate goal of the Paris Agreement.

Until the end of the first commitment period of the Kyoto Protocol in 2012, the Clean Development Mechanism (CDM), which is a baseline and credit

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mechanism in developing countries authorised under the Kyoto Protocol, provided significant incentives to promote mitigation measures in developing countries. By the end of May 2014, the CDM had registered 7,490 projects and issued 1.5 billion tons of certified emission reductions (CERs) (IGES, 2016).

Figure 1 illustrates trends of annually estimated emission reductions through CDM project activities. As shown in Fig. 1, project developers promoted energy efficiency CDM projects mainly for waste heat recovery, hydropower generation, methane recovery and avoidance, and fossil fuel substitution by using biomass and industrial gases such as HFC and N₂O from 2004 to 2007. From 2007 onwards, registration of those project types has become less active, while renewable energy project types such as wind power and photovoltaic power have increased. As a result, renewable energy projects accounted for 64% of the total registered projects that had been developed by 2014. In particular, China and India hosted 60% and 27% of those renewable energy projects, respectively. This indicates that China and India hosted 38% and 17%, respectively, of all CDM projects. This result can be explained by looking at the business incentives for CDM project developers. In other words, most project developers were interested in a project that would bring a higher profit, or in a country where the business market could be expected to expand. Regarding the attractiveness of the investment for host countries, Jung (2006) evaluated the potential of CDM project formulations from three aspects: reduction potential in each country, institutional framework in host countries, and investment in climate change. Among Asian countries, Jung (2006) concluded the assessment for China, India, Thailand, Indonesia, Mongolia and Malaysia was “very attractive” or “attractive.” Oleschak & Springer (2011) also evaluated the attractiveness of project investments in the host countries from three aspects: the institutional framework for the Kyoto

Mechanism, legal regulations in host countries, and economic activity. As a result, India was evaluated as the most attractive country for investment by project developers, with China in second place. Winkelman and Moore (2011) also state that total GHG emissions, the emission intensity of the economy, domestic human capital and increased electricity demand are important factors in hosting a CDM project.

Indeed, ASEAN countries including Indonesia, Thailand and Viet Nam have a high potential to host a considerable number of CDM projects because those countries have sufficient institutional capacity and a huge potential for GHG emissions reduction owing to the rapid increase in economic activity. However, as Fig. 2 shows, CERs in the electricity sector have not been issued there in contrast to India and China when it comes to considering the ASEAN countries’ share of CO₂ emissions in the power sector. A possible factor hindering the development of CDM projects in those countries could be high GHG abatement and transaction costs in ASEAN countries since, generally speaking, the
cost issue is one of the major concerns for CDM project developers. This study, however, focuses solely on analysing GHG abatement costs because the transaction costs for renewable energy projects account for only 14.4% of the total (Michaelowa & Jotzo, 2003).

As shown in Equation (1), the CO₂ abatement cost per ton can be calculated by dividing the abatement cost by the amount of emission reductions (Rahman et al., 2009). The abatement cost is defined as the difference between the baseline cost and the project cost, and emission reduction is identified by the difference between baseline emissions and project emissions.

\[
\text{Average GHG emission abatement cost} = \frac{\text{Project cost} - \text{Baseline cost}}{\text{Baseline emission} - \text{Project emission}} \tag{1}
\]

The cost of a CDM project consists of investment costs and operating costs for the project. The baseline cost is defined as the cost of generating electricity using conventional power plants that would be operated in the absence of the CDM. For a renewable energy project, the baseline cost is defined as the selling price of electricity (Rahman et al., 2012). The effect of technological innovation can also be considered, in which the cost of GHG reduction falls in proportion to the decrease in the cost of the project. (Lantz et al., 2012; IEA, 2014b).

A review of past studies reveals that there are few studies analysing the CO₂ abatement costs using data from actual projects in China, India and ASEAN countries. Rahman et al. (2012) calculated the GHG abatement cost for all CDM projects that had been registered up to 2011 in Annex B countries but which did not have any focus on ASEAN countries. Simon et al. (2016) investigated the abatement cost structure of CDM projects in India. Therefore, this study analyses the reasons ASEAN countries failed to harness a considerable number of CDM projects compared to their mitigation potentials, from the two perspectives of “scale of economy,” which causes the average cost of producing something to fall as the volume of its output increases, and renewable energy technology type. The discussion section analyses possible impact by level of grid emission factors.

Section 2 introduces data preparation for project costs and abatement costs. Section 3 discusses the analytical approach, Section 4 describes the analytical results, Section 5 draws conclusions and discusses them, and Section 6 remarks on prospects for further studies.

2. Data

This study developed data for analysing CO₂ abatement costs for renewable energy projects under the CDM, based on the information used in the investment analysis to demonstrate additionality. This information is provided in the project design documents (PDDs) for each renewable energy project. In a review of existing literature, Rahman et al. (2012) define the abatement cost as the difference between the project cost and baseline cost, charged for supplying the same amount of electricity in the absence of the renewable energy technology proposed under the CDM. In particular, Castro and Michaelowa (2010) and Wetzel and Linden (2007) define the baseline cost as the net present value of electricity sales, and the project cost as the net present value consisting of investment costs and operation costs. When project developers calculate the net present value, they can usually use the discount rate as a value for their business. Therefore, this study follows the same approach to identifying the abatement cost of CDM projects using the benchmark rate as shown in Equation (2). GHG emission reductions are referred to by the numbers described in each PDD. Using the project period outlined in the PDDs, emission reductions during the assessment period are calculated using Equation (3). The duration used in evaluating the net present value is same as the project period for each project.

\[
\text{AC}_i = I + \sum_{n=1}^{n} \frac{OMC_{i,t}}{(1+r)^n} + \sum_{n=1}^{n} \frac{FC_{i,t}}{(1+r)^n} + \sum_{n=1}^{n} \frac{OTC_{i,t}}{(1+r)^n} - \sum_{n=1}^{n} \frac{IE_{i,t}}{(1+r)^n} \tag{2}
\]

\[
ER = \text{Annual emission reduction} \times n \tag{3}
\]

where “t” denotes the year of the project activity starting date, “n” represents the project period, “i” denotes in project serial number, and “r” indicates the discount rate defined by the value of the benchmark described in the PDDs. “ACᵢ” represents the net present value of GHG abatement costs without social costs for project i. “OMCᵢ” denotes the operation cost of project i at time t, “FCᵢ” represents the fuel costs of project i at time t, “OTCᵢ” represents other costs of project i at time t, such as water usage rights and insurance. “IEᵢ” represents income from electricity sales of project i at time t.

For projects which do not provide a benchmark value, this study uses the lending interest rate given by the World Bank (2015). To collect cost data, this study examines each PDD that is made available on the UNFCCC website. Since the PDDs provide cost data using several currencies, this study unified all the cost data into USD for the year 2013 using the exchange rate and consumer price index provided by the World Bank (2015). Table 1 summarises the basic statistics for all the data.

“Abatement Cost” indicates the GHG abatement cost. “Abatement” denotes the amount of emission reduction during the project period. “Biomass,” “pv_solar” and “wind” represent the dummy variables of biomass power, PV or solar power and wind power projects, respectively. The numbers for 2006 to 2012 denote the dummy variables for each year. “Project Duration” indicates project operation period. “India” and “ASEAN” denote the country dummy variables.
3. Methodology

The cost function for emissions abatement through CDM refers to existing studies on pollution abatement costs. Hartman et al. (1997), Goldar et al. (2001), and Rahman et al. (2012) note that the abatement costs of projects under pollution control can be explained by the first and second powers of emission reduction of pollutants as shown in Equations (4) and (5). If the coefficient of the second power of emission reduction is negative, the result can imply that the abatement cost has a scale of economy.

\[
\ln(A_{Ci}) = \alpha + \beta \ln(A_{i}) + \sigma X_i + \epsilon_i \\
\ln(A_{Ci}) = \alpha + \beta \ln(A_{i}) + \gamma [\ln(A_{i})]^2 + \sigma X_i + \epsilon_i
\]  

where “ACi” denotes the abatement cost (USD) derived by Equation (2), “Ai” represents the amount of emission reduction during the project period (tCO₂), “Xi” denotes explanatory variables and “εi” denotes the error term.

4. Estimation Results for Abatement Costs in China, India and ASEAN Countries

Table 2 presents the estimation results of this study. Model 1 shows the results for all of the countries including China, India and ASEAN countries. The coefficient of abatement is positive at a significance level of 1% while the coefficient of squared abatement is negative at a significance level of 5%. This result implies that abatement costs in all of the countries have a scale of economy. All the models include the dummy variables of project types, which enable us to discuss the impact of cost increases compared to the base project. Hydropower is selected as the base project because it is the only type of renewable energy technology that is widely implemented across the regions in this study. Regarding abatement cost differences by project type, abatement costs for biomass power, PV and solar thermal power (hereinafter, solar) and wind power CDM projects are around 30%, 16% and 64% higher than the cost of hydropower projects, respectively. Considering the effect of the project starting year, the abatement cost has increased over the years. Looking at the country’s effect on CO₂ abatement costs, the abatement cost of a CDM project in India is 12−16% higher than in China. On the other hand, the abatement cost in ASEAN is estimated to be 47−48% lower than in China. This result is consistent with the consequences of investment in CDM projects, whereby China and India host a large number of CDM projects and ASEAN countries have had less investment through the CDM despite their mitigation potential as discussed in Section 1.

Models 2, 3 and 4 show the country-specific results. For China, the coefficient of abatement in Model 2.1 is estimated to be 0.745 at a 1% significance level. In Model 2.2, however, the coefficient of abatement and squared abatement are not significant. This result implies that renewable energy projects in the CDM did not have a scale of economy. The cost of biomass, solar and wind power projects in China are 103−106%, 181−183% and 71−73% higher than the cost of hydropower projects, respectively. The abatement costs of renewable energy projects have been continuously increasing over the years.

For India, the coefficient of abatement in Model 3.1 is estimated to be 0.985 at a 1% significance level. Also, in Model 3.2 the coefficient of abatement is 1.941 at 1% significance levels while the coefficient of squared abatement is −0.036 at 5% significance levels. This result implies that renewable energy projects in India have a scale of economy effect. The cost of biomass power is 52−55% lower than the cost of hydropower plants, while the cost of solar and wind power plants are 97−100 and 42% higher than the cost of hydropower plants, respectively. Regarding the dummy variable of a project’s starting year, variables for 2007, 2008 and 2011 are positively significant. The weak trend of increasing CO₂ abatement costs as years pass is consistent with past studies conducted by Simon et al. (2016).

Regarding ASEAN countries, the results do not indicate a scale of economy effect. This can be seen in Model 4.2, where neither the coefficients of abatement nor squared abatement are significant. Compared to the results in China and India, the abatement costs of solar and wind power plants in ASEAN countries are more than 200% higher compared to the cost of hydropower plants. This result implies that solar and wind power in ASEAN countries are still much more costly than conventional renewable technology such as hydropower and biomass power. Unlike the results for China and
India, none of the year variables of ASEAN countries were significant, meaning that the abatement costs in ASEAN countries have not increased over the years.

5. Discussion and Limitations of This Study

As discussed above, mitigation by renewable energy projects under the CDM was higher than the costs in China and India. Three reasons can be considered for this result. First, scale of economy could have resulted from both the lower CO₂ abatement costs of renewable energy and the lower baseline emissions of renewable energy projects which has been implemented in China and India. Second, the incremental cost of renewable energy projects in these two countries is lower than those in India and China. In fact, the cost of solar technology in ASEAN countries is higher than the cost in China and India. This result could be explained by the fact that CDM project developers have implemented a large number of solar and wind power projects in these two countries. On the contrary, the cost of wind power technology in ASEAN countries is 207% greater than the cost of hydropower plants. Similarly, the cost of solar technology in ASEAN countries is higher than the cost in China and India. This result could be explained by the fact that CDM project developers have implemented a large number of solar and wind power projects in these two countries. In fact, China had hosted 1,427 wind power projects and 118 solar projects by 2014. India had hosted 570 wind power projects and 20 solar projects by 2014. Therefore, China and India could benefit from the “learning curve” from such technological innovation, which has contributed to a reduction in the initial cost of renewable energy technologies.

Third, the grid emission factor of ASEAN countries is higher than that of the incremental costs in China and India. The results from our empirical model show that the cost of wind power technology in India is only 42% higher than the cost of hydropower plants. On the contrary, the cost of wind power technology in ASEAN countries is 207% greater than the cost of hydropower plants. Similarly, the cost of solar technology in ASEAN countries is higher than the cost in China and India. This result could be explained by the fact that CDM project developers have implemented a large number of solar and wind power projects in these two countries. In fact, China had hosted 1,427 wind power projects and 118 solar projects by 2014. India had hosted 570 wind power projects and 20 solar projects by 2014. Therefore, China and India could benefit from the “learning curve” from such technological innovation, which has contributed to a reduction in the initial cost of renewable energy technologies.

Note: Each model shows the results both with and without the variable of Squared Abatement (Log). For all models, the base technology is hydropower. For Models 1.1 and 1.2, the base country is China.

Table 2 Estimation results for all countries and by country.

<table>
<thead>
<tr>
<th>Abatement Cost (Log)</th>
<th>ALL (Model 1)</th>
<th>CHINA (Model 2)</th>
<th>INDIA (Model 3)</th>
<th>ASEAN (Model 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1.1 Coef.</td>
<td>0.368 ***</td>
<td>0.745 ***</td>
<td>0.985 ***</td>
<td>0.933 ***</td>
</tr>
<tr>
<td>Coef.</td>
<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Model 1.2 Coef.</td>
<td>1.446 ***</td>
<td>0.081</td>
<td>1.941 ***</td>
<td>1.006</td>
</tr>
<tr>
<td>Coef.</td>
<td>(0.23)</td>
<td>(0.48)</td>
<td>(0.39)</td>
<td>(0.81)</td>
</tr>
<tr>
<td>Model 2.1 Coef.</td>
<td>0.745 ***</td>
<td>0.985 ***</td>
<td>1.941 ***</td>
<td>1.006</td>
</tr>
<tr>
<td>Coef.</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.05)</td>
<td>(0.81)</td>
</tr>
<tr>
<td>Model 2.2 Coef.</td>
<td>0.985 ***</td>
<td>1.941 ***</td>
<td>1.006</td>
<td></td>
</tr>
<tr>
<td>Coef.</td>
<td>(0.03)</td>
<td>(0.05)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 3.1 Coef.</td>
<td>0.933 ***</td>
<td>1.006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coef.</td>
<td>(0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 3.2 Coef.</td>
<td>1.006</td>
<td></td>
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</tr>
<tr>
<td>Coef.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 4.1 Coef.</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Coef.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 4.2 Coef.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coef.</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Number of obs. 3,360 2,403 697 260
Adjusted R² 0.61 0.61 0.52 0.61 0.61 0.61
displace electricity from electricity grids are obtained by multiplying the amount of electricity generation (MWh) by the grid emission factor (tCO₂/MWh). For example, the average grid emission factors in China and India are 0.90 tCO₂/MWh and 0.88 tCO₂/MWh, respectively, which are higher than those of other CDM project host countries according to data from IGES (2015). On the other hand, the grid emission factors of Indonesia, Viet Nam and Thailand are 0.76 tCO₂/MWh, 0.56 tCO₂/MWh and 0.55 tCO₂/MWh, respectively, which are mid or lower level among the host countries. The differences in grid emission factors among China, India and ASEAN countries mean that CDM project developers in China and India gain 1.6 times the CERs compared to ASEAN countries even though they generate the same amount of electricity by renewable energy. Thus, even if the power generation costs per kilowatt hour are at the same level among those countries, CO₂ abatement costs from renewable energy are not uniform owing to differences in GHG emission reductions. While the magnitude of grid emission factors could have a significant impact on the abatement costs of renewable energy, there is no sophisticated method for identifying grid emission factors, and in fact there is room for improvement. In fact, Hawkes (2014) pointed out that quantification of CO₂ emissions from electricity use is usually accomplished using short-run emission factors, but these short-run factors do not take account of structural changes in power systems. He also suggested that long-run marginal emission factors need to be analysed to quantify CO₂ emissions. In particular, although the “tool to calculate the emission factor for an electricity system” (UNFCCC, 2013) takes into account structural changes in the electricity system, it does not consider how the newly-built or avoided power stations would have operated in the absence of the CDM. Harmsen and Graus (2013) pointed out that an average CO₂ intensity approach cannot be used to estimate future electricity savings in situations where the change in both electricity generation and the emission intensity occur simultaneously. In this case, they recommend applying a marginal CO₂ intensity approach with a scenario-based analysis.

Indeed, the result of our model also supports the fact that ASEAN countries have enormous potential to implement renewable energy because the abatement costs using renewable energy technology in China and India have increased over the years while the cost in ASEAN countries has not increased. Also, as discussed above, if the project costs of renewable energy decrease further owing to the scale of economy, or methods for identifying CO₂ emission reduction from electricity use are improved to take into account possible increases of fossil-fuel power plants, then the abatement costs of renewable energy in ASEAN countries would decrease.

6. Prospects for Climate and Renewable Energy Policies in ASEAN Countries

In this concluding section, this study identifies possible research topics to be examined in the future. First, it would be interesting to examine the learning effect or learning curve of a new type of technology, e.g., PV and wind power technology. As predicted by various research (Taylor, et al., 2015), the levelised cost of electricity (LCOE) for that technology would be lower than for conventional power plants. However, there are still few studies on how technology has been developed using actual data.

Second, an effective mitigation mechanism that provides appropriate incentives in line with long-term emission reduction goals needs to be examined. The results of this study imply that the degree of the grid emission factor could affect the abatement cost advantage. The limitation of current grid emission factors, however, is that they can only reflect historical CO₂ emissions or short-term trends in electricity sectors as discussed in Section 5. The number of fossil fuel-fired power plants, including coal-fired power technology, however, is expected to increase in ASEAN countries. In this case, the mitigation impact by renewable energy could be higher if it takes into account long-term energy forecasts. Therefore, an appropriate method that promotes renewable energy technology at an early stage as possible needs to be considered to fulfill the two-degree target, which is the ultimate objective of the Paris Agreement.

Third, it is necessary to discuss a comprehensive policy framework. In order to calculate CO₂ abatement costs in this study, the abatement cost was defined as the difference between project and baseline costs. The baseline cost was determined by the electricity sales, consisting of electricity generation and tariffs. In fact, those elements could be affected by certain energy policy interventions. For example, if a government implemented feed-in tariffs, the baseline cost would increase. As a consequence, the abatement cost would decrease. On the other hand, some ASEAN countries have introduced fossil fuel subsidies for energy, especially for oil prices. In this case, the fuel cost for electricity generation is lower than that of business-as-usual. As a consequence, the electricity price is lower than the normal level, and tariffs for electricity also decrease. In this case, though, abatement costs increase.

Above all, the mitigation costs of renewable energy depend on the level of technology development, the design of mitigation mechanisms and incentives, and policy arrangements. Renewable energy for ASEAN countries, however, is critical for achieving a decarbonising society, so the development of these technologies should be constantly promoted with stable policy support. For that reason, a policy proposal based on analytical policy research and fundamental policy discussion would have a significant impact on promotion of steady mitigation actions in ASEAN countries.
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Akihisa Kuriyama obtained his master’s degree in Japan from the Graduate School of Science and Engineering (International Development Engineering), Tokyo Institute of Technology on environmental economics and econometrics. After that, he worked for IGES to implement capacity building programs for mitigation activities in Asian countries including Cambodia, Lao PDR, the Philippines and Indonesia. He also conducts quantitative research on the Kyoto mechanisms and CO2 emissions from the electricity sector.

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