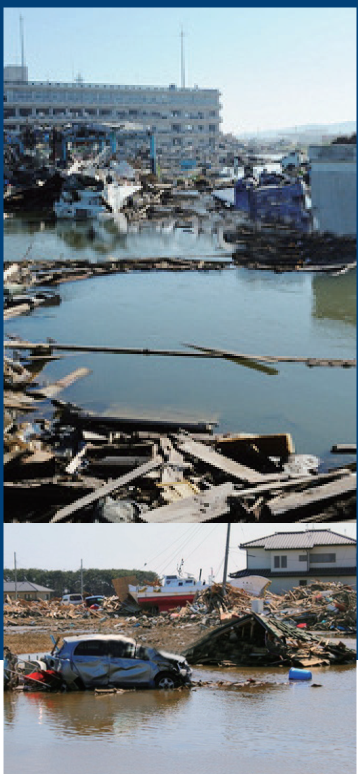
IGES Policy Report No.2012-01

Lessons Learnt from the Triple Disaster in East Japan



Institute for Global Environmental Strategies (IGES)
June 2012

IGES
Institute for Global Environmental Strategies

Lessons Learnt from the Triple Disaster in East Japan

Policy Report

Institute for Global Environmental Strategies
(IGES)

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IGES Policy Report

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IGES Policy Report

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Foreword

The magnitude 9.0 Great East Japan Earthquake that occurred off eastern Japan on March 11, 2011 triggered a massive tsunami of unprecedented size and a catastrophic level-7 (International Nuclear Event Scale) accident at the Fukushima Dai-ichi Nuclear Power Plant, a level not witnessed since Chernobyl. The death toll from the earthquake and tsunami was 15,854 with a further 3,000 still listed as missing. Further, 384,509 buildings were completely or partially destroyed. Presently, one year on from the earthquake, full-fledged recovery initiatives have only just begun, prompting the question: What lessons have been learnt from this major earthquake and nuclear accident?

One month after the earthquake, in April 2011, IGES initiated a line of research tasked with determining what types of measures and policy approaches would be necessary to build a "resilient society"—one that had the ability to rebound after a disaster—as well as developing disaster mitigation systems. In particular, this research analysed and evaluated a long-term scenario involving transition to an energy mix centered on renewable energy instead of fossil fuels in the case where nuclear power in Japan were to be gradually phased out by 2050. A greenhouse gas reduction emission target of 80% being achieved by 2050 was also factored in. We also verified the energy-saving effects in the household sector and the feasibility and policy implications of energy-saving efforts after the Great East Japan Earthquake, as well as actual cases of support carried out in disaster-hit areas during the disaster, and assessed what types of measures could provide the best aid at sites of disasters.

In the present context of increasingly frequent extreme weather events such as floods, typhoons, and droughts, and with predictions that such will increase due to climate change, it becomes readily apparent that there exists a burning need to develop policy approaches geared towards a "resilient and sustainable society" that can respond to disasters in a robust and flexible manner—not just for Japan but for the rest of the world. Laid out herein are the results of our research, which we would like to share with all those throughout the world striving towards the goal of sustainable society.

In compiling the report on the earthquake research, we received valuable advice from Dr. Keywan Riahi and Dr. Oscar Van Vliet, from the International Institute for Applied Systems Analysis (IIASA); Dr. Shuzo Nishioka, Senior Research Advisor of IGES; Dr. Mikiko Kainuma of the National Institute for Environmental Studies; and Prof. Akio Morishima, Special Research Advisor of IGES. I would like to take this opportunity to express my thanks to these individuals. For Chapter 2, the base model and reference case used in this study were developed and are maintained by KanORS/KanLo (www.KanORS-EMR.org/DCM/TIAM_World), for which we would like to thank Dr. Amit Kanudia for his valuable contribution in technical aspects and calibration of the model. I would also like to extend my heartfelt gratitude to the authors of each chapter for their tireless efforts and to those who provided constructive input throughout the entire drafting process: Prof. Hidefumi Imura, Senior Policy Advisor of IGES; Mr. Masaya Fujiwara, Integrated Research Programme Manager of IGES; Mr. Hideyuki Mori, President of IGES; Mr. Kazunobu Onogawa, Senior Fellow of IGES; and Mr. Hirotaka Tachikawa, Secretary General of IGES; as well as to the IGES staff members who provided overall coordination.

It is my sincere hope for this research to take us one step closer towards a resilient and sustainable society.

Hayama, Japan
June 2012

Prof. Hironori Hamanaka
Chair of the Board of Directors,
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The authors would sincerely like to acknowledge the many useful comments received from Board of members, external reviewers, colleagues, and everyone else involved. Especially, we would like to thank the experts listed below for having gone through relevant chapters to provide detailed suggestions.

Chapter 2 - Balancing Japan's Energy and Climate Goals: Exploring Post-Fukushima Energy Supply Options – Report of the Disaster Study Project

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Photo1: Great East Japan Earthquake revealed Japan's vulnerability against natural disaster

Photo 2: Osaka city's water trucks were observed at various sites in Rikuzentakata, Iwate prefecture.

Abbreviations and Acronyms

Bbl	Barel = 117.3 litres
COP	Conference OF Parties of the United Nations Framework Convention on Climate Change
CSP	Concentrated Solar Power
EJ	Exajoule = 10^{18} joule
FDMA	Fire and Disaster Management Agency
FIT	Feed-In Tariff
FY	Fiscal year (in Japan, fiscal year begins on 1 April and ends on 31 March)
GHG	Greenhouse Gasses
GW	Gigawatt = 10^{9} watt
IEA	International Energy Agency
IEEJ	Institute of Energy Economics, Japan
IGES	Institute for Global Environmental Strategies
IPCC	Intergovernmental Panel on Climate Change Green House Gases
JPY	Japanese Yen
JWWA	Japan Water Works Association
kW	Kilowatt = 10^{3} watt
kWh	Kiliwatt-hour
LHV	Lower Heating Values
LNG	Liquid natural gas
LULUCF	Land Use, Land Use Change and Forestry
Mbtu	Metric British thermal unit = $1.055*10^{3}$ joule
METI	Ministry of Economy, Trade and Industry, Japan
MHLW	Ministry of Health, Labour and Welfare
MIC	Ministry of Internal Affairs and Communications
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MoEJ	Ministry of Environment, Japan
MW	Megawatt = 106 watt
NEDO	New Energy and Industrial Technology Development Organization
NGCC	Natural Gas Combined Cycle power plant
NPA	National Police Agency
NPO- REN	Nuclear Phase Out - Renewable energy promotion scenario
NPO- FF	Nuclear Phase Out - Fossil Fuel dependent scenario
NPO-LC	Nuclear Phase Out-Low Carbon scenario
NPU	National Policy Unit, the government of Japan
O&M	Operation and Maintenance
PC	Pulverized Coal power plant
PV	Photovoltaic
RPS	Renewable Standard Portfolio
REF	Pre-Fukushima Reference scenario
REF-LC	Reference-Low Carbon scenario
TEPCO	Tokyo Electric Power Company
TOE	Ton of Oil Equivalent = $41.868*10^{9}$ joules
TWh	Terawatt-hour = 10^{12} kWh
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction
USC	Ultra-SuperCritical
USD	U.S. dollars

Executive summary

Lessons Learnt from the Triple Disaster in East Japan

Main proposals and messages

(1) Balancing Japan's Energy and Climate Goals: Exploring Post-Fukushima Energy Supply Options – Report of the Disaster Study Project

Transition from a fossil-fuel/nuclear dominated energy mix to a renewable energy dominated fuel mix is feasible from the economic point of view. Japan's target of 80% CO_2 emission reduction by 2050 is economically feasible provided certain conditions are met. Achievement of this target relies on 1) faster and greater deployment of renewable energy, 2) advanced technologies of conventional power generation, and 3) deployment of economically viable carbon capture and storage technology. Japan can be cautiously optimistic about achieving its long term emissions reduction target by 2050 if all the enabling policies are put into place in a timely manner.

(2) The Power-saving behavior of the residential sector in the wake of the Great East Japan Disaster

Since the Great East Japan Earthquake, in the region served by Tokyo Electric Power Company (TEPCO), there was an approx. 11.8% reduction (temperature adjusted) in electric power usage in households during summer 2011 (July and August) compared with the preceding year, against a goal of a 15% reduction in power usage. A questionnaire on energy consumption in the household sector conducted in January 2012 in Kanagawa Prefecture, which is served by TEPCO, revealed variations in the actions taken by energy consumers to conserve power depending on gender, age group, size of household, and other factors. To encourage more energy conservation among a broad range of age groups it is important to recommend the most effective methods suited to such households.

(3) Reconsidering Resilience: Vitalisation of Inter-municipality Collaboration in Northeast Japan Earthquake

During the Great East Japan Earthquake, disaster area aid activities by local governments and communities to compensate for the inadequacies in existing disaster countermeasures displayed swiftness of action and the flexibility to respond to a wide range of needs. It will be important, going forward, for cooperation among local governments to complement the vertical aid provided by the national government. It will also be important to strengthen the coordination functions among the local governments in disaster areas and among those providing aid, to ensure that effective support for disaster areas is carried out.

1. Introduction

On March 11, 2011 a deadly succession of an earthquake, tsunami, and nuclear power plant accident led to damage of a catastrophic level being wreaked over a vast expanse of land, concentrated on the northeastern coastal prefectures of Miyagi, Fukushima, and Iwate. Many of the coastal cities, towns, and villages were decimated, bringing local economies to a standstill and the loss of many jobs, homes, property, families and friends. The death toll from the disaster one year later stood at 15,854 (28 March, 2012; National Police Agency). Operations at the nuclear power plants in Fukushima were shut down as a result of this disaster, plunging the entire Kanto region into a power shortage. Businesses had to scale back operations, and households were forced to save power in the face of planned blackouts. The power shortages left post-earthquake Japan with a disjointed economy and society. In order to suppress any such future impacts on the economy and society caused by another major earthquake, we need to formulate appropriate energy policy measures fit for the task. In the societal aspect as well, it is imperative to obtain a clear picture of the needs of those in disaster areas and to construct frameworks that enable a rapid return to stable lifestyles and commerce. It is necessary, via the recovery from this earthquake disaster, to effect a transformation in economic and social systems toward ones that are strong in the face of disasters—to lessen or avoid their impact altogether, with a focus on mitigation to minimise the damage during a disaster.

In April 2011, IGES commenced research on the March 11 earthquake to ascertain what sort of measures and policy approaches would be effective in helping to build a resilient society that is strong in the face of disasters—and to speed up recovery from the destruction wrought by this earthquake. This research aims to review existing energy resources to help ensure a stable supply of energy in Japan, explore solutions (energy-saving actions) that can be implemented at the grass-roots level to limit energy demand, and make policy recommendations through an examination of methods of avoiding or mitigating earthquake risks and rapid recovery measures after an earthquake. To achieve this, a research study was conducted on the following three themes: 1. An analysis of the long-term energy supply options available to post-Fukushima Japan in consideration of Japan's energy mix and greenhouse gas reduction targets; 2. An examination of regional policy measures on effective energy usage learnt from actual emergency energy-saving conditions after the earthquake; and 3. Suggestions for cooperative structures among local governments toward the construction of a society that is resilient to disasters. The results of this research and the associated policy recommendations posit important implications not only for the rapid recovery from the recent Great East Japan Earthquake, but also in exploring an ideal global societal system that is resilient against disasters.

This report was created based on the results of the research study on the above three themes conducted as part of earthquake research. It is hoped that this report will not only raise awareness of disaster prevention but also energy-saving efforts in households and businesses to enable a stable and continuous supply of energy essential for the economy and society at large. It further aims to raise awareness, from a global perspective, of the importance of constructing networks that are indispensable to post-earthquake recovery and in the creation of sustainable societies that are disaster-resilient. The key research results and recommendations from each research theme are given below.

2. Balancing Japan's Energy and Climate Goals: Exploring Post-Fukushima Energy Supply Options – Report of the Disaster Study Project

This chapter assesses the implications of a long term phase-out of nuclear energy supply in Japan toward 2050 and its replacement with renewable energy, based on an assumption that the technicality of intermittency has been overcome. This study performed two sets of energy scenario analyses using the TIMES Integrated Assessment Model (TIAM-WORLD), a technology driven bottom-up energy model. The indicators used for the comparison are: (1) total energy supply system cost, (2) amount of fossil fuel imports, and (3) CO_2 emissions. The first analysis (Analysis I) assesses the implications of the preferred energy choice between renewable energy and fossil fuel to compensate the nuclear power phase-out by 2050 in the absence of a mid- to long-term GHG emissions reduction target. The second analysis (Analysis II) investigates the future energy mix to achieve an 80% reduction in CO_2 emissions by 2050 with and without a gradual phase-out of nuclear power.

The result of Analysis I indicates that the total final energy consumption drops from 310 million tons of oil equivalent (Mtoe) in 2009 to 210-220 Mtoe in 2050, depending on the scenario. The major reasons for such reduction are a steady decline in population, number of households and other demographic factors by 2050 and changes in economic structure due to lower domestic industrial production. The renewable energy dependent scenario is estimated to be only 0.2% more expensive than the fossil fuel dependent scenario in terms of the discounted total energy system costs of each between 2005 and 2050. The incremental energy system cost for the renewable energy scenario is estimated to be around 0.04% of national GDP, while the renewable energy scenario contributes to a national wealth saving by lowering fossil fuel imports significantly to the point of almost complete offset of the total system cost increase.

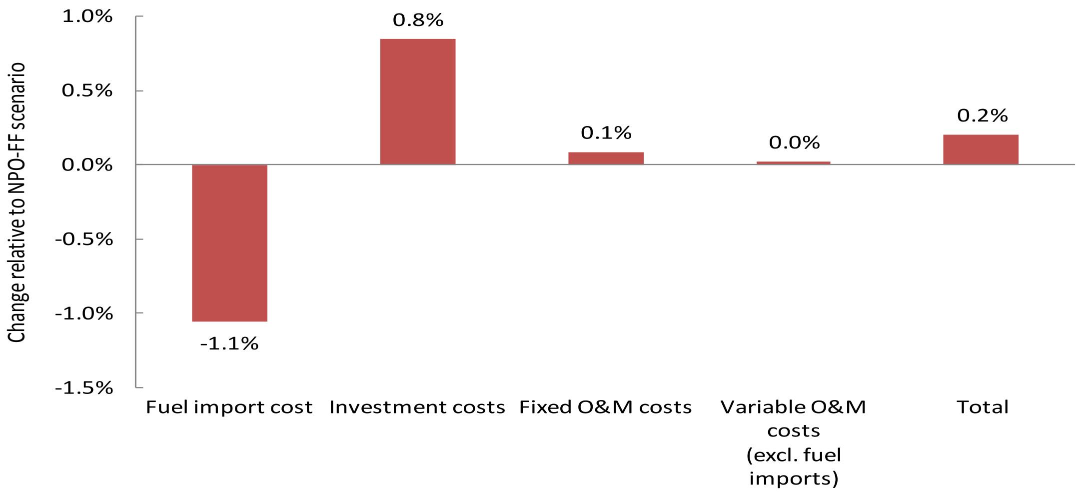

FIGURE 1: ANALYSIS I. DISCOUNTED TOTAL ENERGY SYSTEM COST FOR 2010-2050 FOR THE RENEWABLE ENERGY PROMOTION (NPO-REN) SCENARIO RELATIVE TO THE FOSSIL FUEL-DEPENDENCE (NPO-FF) SCENARIO BY COMPONENT.

NOTE: THE NUMBERS UNDER EACH CATEGORY IN THE FIGURE ARE THE PERCENTAGE CHANGES OF A PARTICULAR COST COMPONENT. THEREFORE, SIMPLE ADDITION OF THE PERCENTAGE VALUES FOR INDIVIDUAL COST COMPONENTS DOES NOT OBTAIN THE TOTAL PERCENTAGE CHANGE.

Analysis II shows that final energy consumption drops to 200 Mtoe in 2050 under both scenarios of with and without a gradual phase-out of nuclear power, reflecting a more stringent CO_2 emissions reduction compared to Analysis I. Most of the final energy consumption shifts from primary fuel to decarbonised electricity added with carbon capture and storage (CCS) to achieve the 80% target without the use of nuclear power. In the nuclear phase-out scenario, wind and solar power plants are expected to be installed to the capacity limit of 80 GW and 176 GW respectively, by 2050. The CCS requirement is doubled in the nuclear phase-out scenario compared to the pre-Fukushima energy plan (i.e., nuclear-based) achieving the 80% CO_2 reduction target. The additional need for CCS is estimated to be around 170 Mt/yr in 2050 over the pre-Fukushima energy plan. The increase in discounted total energy system costs for 2010-2050 for the nuclear phase-out scenario compared to the pre-Fukushima nuclear scenario was found to be 1%. In annual terms, the average energy system cost increase was found to be about 0.13% of national GDP.

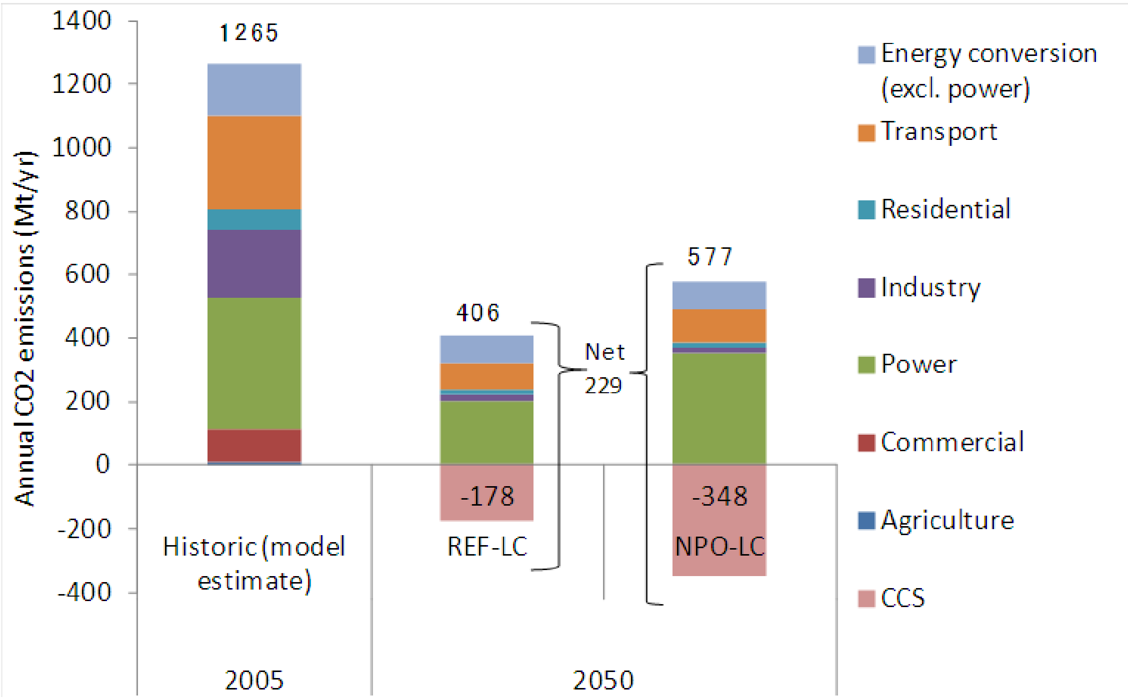

FIGURE 2: ANALYSIS II. BREAKDOWN OF CO_2 EMISSIONS IN 2050 FOR THE SCENARIOS WITH MID- TO LONG-TERM CO_2 EMISSIONS REDUCTION TARGETS. HISTORIC EMISSIONS DATA FOR 2005 IS ALSO GIVEN FOR REFERENCE.

The study brings forth a set of policy measures that can be prioritised in Japan in order to ensure long term energy security while meeting the long-term CO_2 reduction target. The key messages of this study are: i) that transition from a fossil-fuel/nuclear dominated energy mix to a renewable energy dominated fuel mix is feasible from an economic point of view, and ii) Japan's target of an 80% CO_2 emission reduction by 2050 is economically feasible provided certain conditions are met. Whether or not this target is met hinges on an escalated deployment of renewable energy, use of advanced technologies for conventional power generation, and deployment of economically viable CCS technology. The study concludes with the opinion that Japan can be cautiously optimistic about achieving its long term emissions reduction target by 2050 if all the enabling policies are put into place in a timely manner. In order for Japan to reduce its dependence on nuclear power and to increase renewable energy supply, it is critical to develop alternative energy technology, to promote regulatory and institutional reform in the power sector, and to require implementation of policy tools such as the Feed-In Tariff scheme. It is also necessary to promote investment for building CCS facilities, which requires the government to take the initiative and set up a long-term plan for CCS technology development and deployment. At the same time, a shift from coal to natural gas and further control of energy demand are also needed to reduce the heavy reliance on CCS.

3. The Power-saving behavior of the residential sector in the wake of the Great East Japan Disaster

The power shortfall brought about by the Great East Japan Earthquake and its secondary disasters had a substantial impact on Japan's economy and society, including suppressed business and compulsory energy-saving efforts in households. These occurrences not only served to stimulate debate on energy policy measures in Japan, but also spurred a transformation in actions and awareness across all energy consumers. In the heavily energy-dependent household sector, in particular, it has constituted a wake-up call of sorts. It is important to incorporate the behavior patterns of energy consumers, including the household sector, and reforms of social infrastructure to enable energy-saving measures to be taken, in the formulation of a new energy strategy for Japan.

This research compiles recommendations on the appropriate orientation of continued and efficient energy consumption lifestyles from an assessment of the actual conditions of energy usage in the household sector in Kanagawa Prefecture. To achieve this, a survey was conducted of 1,000 married citizens in Kanagawa Prefecture in January 2012 via the Internet. The research compiled recommendations to contribute to energy-saving measures based on the actual conditions gleaned from this internet survey.

According to the trends in power sold in the area served by TEPCO, it was reported that there was an approx. 11.8% reduction (adjusted for temperature differences; the target was a 15% reduction) in electric power usage in households during summer 2011 (total for July and August) compared with the preceding year. To compare this figure, the summertime energy-saving effect per household in Kanagawa Prefecture was calculated. The result, as shown in Figure 3, reveals that an 11.0% energy saving compared with the previous year was also obtained in Kanagawa Prefecture, which agrees with the year-on-year reduction in power sold in the area served by TEPCO. The quantity of power saved by each household during summer in Kanagawa Prefecture was approximately 87 kWh, and estimating the total energy-saving effect for all households in the prefecture based on this figure gives a power saving of 328 GWh during the two-month period of summer 2011. However, in and after October when the energy-saving campaign ended the energy-saving effect began to decline, partly because air conditioner usage times decreased. In terms of age groups, the rate of energy-saving was large for the 50–60 age group, but low for the 20–30 age group (almost half), thus appeals to the younger group will be important in further promoting energy-saving measures in the future.

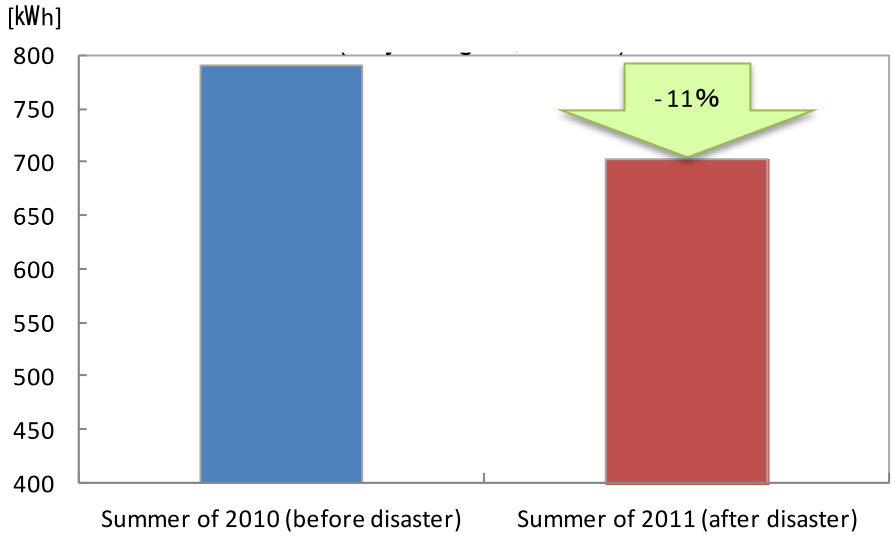

FIGURE 3: YEAR-ON-YEAR CHANGE IN POWER USE PER HOUSEHOLD IN SUMMER (JULY-AUGUST; N = 961)

Variations are seen in the power saving efforts of energy consumers due to gender, age group, size of household, and other factors. In order to encourage energy-saving among a broad range of age groups it is important to disseminate, permeate, and establish more appropriate modes of usage that produce the maximal effect through the combined effect of small efforts by all. The most effective means of doing this is by expert-led public awareness-raising, the content of which would be based on the household and numerical data contained in this research with specific focus on identifying target age groups. Moreover, new means of energy efficiency can be obtained through dissemination and establishment of household energy-saving practices that have emerged since the earthquake. Replacing appliances with more energy-efficient models improves lifestyle comfort, but has an economic effect for households because most of the initial investment in such appliances can be recovered. In light of the actual energy usage situation in households, there is a need for information provision and mechanisms to encourage the actions of consumers. Providing economic incentives, such as subsidies, and disseminating information regarding cost-benefit analyses of energy-saving investment would help permeate a more favorable mindset geared towards saving energy.

Due to variations in energy consumption in different households and age groups, as well as at different times of the year, it is also important to identify what energy-saving information is appropriate, and tailor such for a target group. Formulating policy to clarify energy consumption features, approaches to find specific policies for local governments and municipalities, and assessment schemes after policy implementation, etc, would establish such initiatives and pave the way for households to set into motion appropriate energy-saving lifestyles.

4. Reconsidering Resilience: Vitalisation of Inter-municipality Collaboration in Northeast Japan Earthquake

As an earthquake-prone country Japan has suffered numerous natural disasters since ancient times and has drawn upon this past experience to set in place disaster prevention and disaster response measures. However, the Great East Japan Earthquake of March 2011, together with the massive tsunami and catastrophic nuclear power plant accident that followed, inflicted damage in many sectors over an extensive area. Therefore, an awareness is spreading that it is not only necessary to establish hardware and systems to prevent disasters but also to strengthen resilience against disasters to enable rapid recovery and reconstruction.

The Japanese government has historically instituted measures categorised by the type of disaster, rules on the application of laws to promote mutual support agreements (cooperation frameworks) between regional governments, and other related aid measures and implementation plans. The cities, towns, and villages in each metropolis and prefecture have also formulated regional disaster prevention plans that include necessary post-disaster actions and mutual support agreements with other local governments. During the Great East Japan Earthquake as well, the disaster countermeasures of the national and local governments that were already in place were put into effect, and at the same time intensive support activities were carried out to compensate for any inadequacies in the existing disaster countermeasures. Regional governments and local communities in particular were noteworthy for the speed of their support and the flexibility in meeting a broad range of needs in the relief and recovery stages. This study looks at cases of actual aid provided to disaster areas during the Great East Japan Earthquake and recommends policy measures that would enable more effective disaster area support.

Carrying out effective disaster area support through cooperation among local governments requires coordination between the disaster-struck local governments and the aid-providing ones, which can be classified into: 1) the central government playing a major role (fire-fighting, police), 2) existing national-level coordination organisations assuming coordinating functions during disasters in liaison with the central government (water and sewage, staff dispatches from local governments), 3) mutual support agreements among local governments during disasters, and 4) autonomous aid activities by local governments carried out immediately after a disaster.

It is naturally preferable for aid to the disaster areas to be provided quickly after a disaster occurs, to be flexibly aligned with the diverse needs of the disaster area, and to be carried out in a sustained manner until the disaster area is well on the road to recovery. To meet these conditions coordination at three stages is required: 1) "twinning" (pairing disaster-hit local governments with aid-providing ones), 2) coordinating the services and supplies sought in the disaster area with that available on the supplier side, and 3) coordination to enable sustained support by lightening the burden on the aid-providing side. This study examined the prerequisites for coordination at these three stages to be effectively carried out, as well as the hurdles that were faced, based on an examination of aid activities witnessed after the Great East Japan Earthquake. Aid to disaster areas is fundamentally provided from the national government, but this sort of vertical aid by itself may not be fast enough or suit the actual conditions on the ground. To complement such aid, horizontal cooperation among local governments is required (refer to Figure 4).

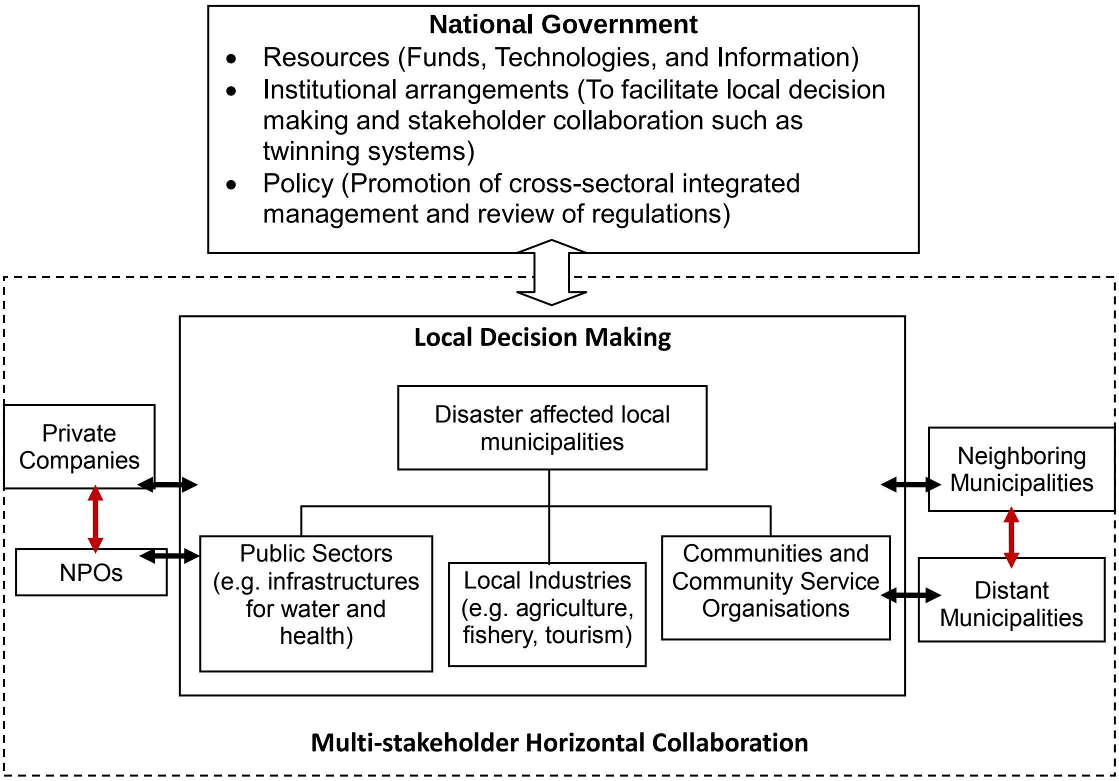

FIGURE 4: FLOW OF MUTUAL SUPPORT DURING A DISASTER

Finally, considering the coordination functions at the three stages required for disaster area support, the following five recommendations are given to ensure that speedier, more flexible, and more sustained aid activities are provided during future disasters. The recommendations are: 1) promotion of mutual support agreements with stakeholders (private businesses, citizen groups) other than local governments, 2) establishment of mutual support agreements with a broad geographical base of local governments, 3) creation of frameworks executable in an emergency, e.g., temporary legal flexibility, 4) strengthening of coordination functions to ensure swift cooperation, and 5) support from the national government to invigorate mutual support. The recommendations given here are thought to be applicable across the globe, and comprise regional governments equipped to provide a fast, flexible, and sustained cooperation framework during a disaster, thus forming the preconditions for recovery.

5. Conclusion

We have learnt many lessons from the Great East Japan Earthquake. Among these, the reconsideration of Japan's medium- to long-term energy policy following the Fukushima Dai-ichi Nuclear Power Plant accident, which IGES selected as a research theme, is an unavoidable issue in determining the long-term picture for Japan's future. In addition to energy supply the issue of how energy demand can be controlled going forward is also important in respect of medium- to long-term energy policy measures. Furthermore, it is crucial to strive to create a resilient and sustainable society that incorporates further disaster mitigation and prevention measures to prepare for major disasters that are bound to occur in the future.

Japan's future energy mix will be substantially influenced by the formulation of energy policy measures based on changes in the nuclear power industry and targets set for long-term climate change countermeasures. Achieving greenhouse gas reduction targets and responding to energy demands while phasing-out nuclear power generation will require considerable policy accommodation to strengthen the energy sector. Policy measures are likely to include the establishment of organisational mechanisms for promoting renewable energy, promotion of effective demand-side management, improvement of the country's energy system for the integration of standards, and the integration of energy plans at the regional and national levels.

Regarding energy usage, as Japan's nuclear power plants have had to be taken offline in succession for testing and inspections since the Fukushima Dai-ichi Nuclear Power Plant accident on 11 March, 2011, with power generation at all 54 nuclear power plants (including the four defunct Fukushima nuclear power plants) suspended on 5 May, 2012, the country is still faced with the need to greatly suppress its energy demands. Saving power in the diverse household sector is complex, but policy measures that take account of differences among age groups, household sizes, and other unique characteristics of energy consumption, as well as consideration of effective local government measures and assessment of any policy that is implemented will be key issues Japan will have to face.

Although this study focused on mechanisms for mutual support witnessed in the one year period following the Great East Japan Earthquake, there is a need to further consider mechanisms that are not influenced by the conditions of each group long-term for aid that represents a growing burden on the aid provider as well. There are also support issues, which couldn't be covered in this paper, that are relevant in Japan and overseas, stemming from the experiences of the Great East Japan Earthquake. For instance, as the role played by local governments is limited in terms of financial assistance under the existing system, it will be very important to consider initiatives to respond to urgent funding demands in the future. It is also preferable to spread cooperation and partnerships abroad as well as domestically (regional governments, employers, medical groups, NGOs, etc.) going forward. Moreover, there are likely cases in developing countries where international organisations and international NGOs have the potential to support mutual aid.

It is hoped that Japan's experiences in the Great East Japan Earthquake, the earthquake research of IGES in light of Japan's experiences, and the recommendations based on these will reach as wide an audience as possible. It is also hoped that this research will be a notable addition toward building a sustainable society that is resilient in the face of disasters and that incorporates disaster mitigation and prevention measures.

Chapter 1 - Introduction

Chapter 1 - Introduction

Aya Watarai, Ikuko Matsumoto, and Hideyuki Mori

On March 11, 2011 a deadly succession of an earthquake, tsunami, and nuclear power plant accident led to damage of a catastrophic level being wreaked over a vast expanse of land, concentrated on the northeastern coastal prefectures of Miyagi, Fukushima, and Iwate. Many of the coastal cities, towns, and villages were decimated, bringing local economies to a standstill and the loss of many jobs, homes, property, families and friends. The death toll from the disaster one year later stood at 15,854 (28 March, 2012), with 3,276 still listed as missing (as of 1 March, 2012). Buildings and residences numbering 384,509 were partially or completely destroyed (National Police Agency public relations document). Even now, some 344,000 people are being forced to live as evacuees, with about 390 existing in shelters (Reconstruction Agency). As of 26 March, 2012, 53,077 temporary housing units had been constructed, but this is still 239 short of the number required (Ministry of Land, Infrastructure, Transport and Tourism). This natural disaster was of unprecedented scale, and led to the lives and livelihoods of so many people being lost, and full-fledged initiatives toward reconstruction have only just begun.

When viewed from a global scale, the Great East Japan Earthquake can be seen as one of many earthquakes, tsunamis and hurricanes that have scourged the planet over the past several years. The major Aceh earthquake in 2004 and subsequent giant tsunami took the lives of more than 230,000 over 14 countries, including neighbouring Sri Lanka, Thailand, and India. Hurricane Katrina, which struck the south-eastern United States in 2005, resulted in at least 1,836 dead and total damages of 81 billion USD. An estimated 68,000 also died as a result of the major earthquake in 2008 in China's Sichuan Province. A further 100,000 lives were lost to a cyclone in Myanmar in 2008. Hundreds of thousands in Bangladesh suffer the impact of floods on a yearly basis. In 2011, 13.6 million were also affected by serious flooding in the central region of Thailand, with a damage estimate of 45.7 billion USD. The Asia Pacific region suffers from more natural disasters than any other region on the planet, and it is believed that weather disasters will be further aggravated by climate change in the future.

The impact of natural disasters is often more serious in developing countries that lack adequate societal infrastructure or administrative functions (UNFCCC 2007). Further, the effects of the large-scale natural disasters in recent years have had repercussions not just in the developing countries themselves but throughout the world. Due to the nature of globalisation the occurrence of localised natural disasters impacts heavily on the global economy, in which disruptions in one place may have an effect in countries far away, such as the large-scale flooding caused by heavy rains in central Thailand in 2011 which disrupted the supply chain of automotive and electrical equipment manufacturing industries throughout the world.

The Great East Japan Earthquake caused immense and widespread damage of a degree never before experienced in Japan, despite the country's apparent familiarity with earthquakes and tsunamis. This most recent earthquake disaster has on the one hand prompted a transition toward focusing on disaster mitigation, in which damage from future disasters is minimised, as well as promotion of communities that are robust in the face of disasters (Reconstruction Headquarters in response to Great East Japan Earthquake, Reconstruction Agency 2011), and on the other raised questions about the state of Japan's disaster preparedness. It has also revealed inadequacies in the speed and flexibility of Japan's response to emergencies and its safety measures concerning nuclear power generation in the event of natural catastrophes. In the broader context, with the damage from floods, hurricanes, droughts, and other disasters mounting in countries worldwide, it is important for Japan to share its recent experiences with the world with a view to both forestalling the damage caused by such disasters to the extent possible and to encourage a swifter recovery after a disaster.

Until the recent disaster Japan's system of concentrated power supply had enabled stable power production and supply, but this model was turned on its head after the nuclear power plant accident at Fukushima as has led to a power shortfall, especially during the summer in eastern Japan when demand peaks. This has affected all sectors, from households to industry, which have had to limit their power usage. One consequence of this was that on 26 August 2011 a special act was passed which implemented a fixed-price purchasing system to promote the introduction of renewable energy (Act on Special Measures concerning the Procurement of Renewable Electric Energy by Operators of Electric Utilities). In light of the March 11 earthquake and Fukushima accident, operations at nuclear power plants throughout the country are also witnessing successive suspensions of operations due to periodic inspections. In response, the Japanese government (National Policy Unit, Cabinet Secretariat) undertook a review of the current mode of energy production, which also embraced greenhouse gas reductions in the medium and long term. It held the 1st Energy and Environment Council on 22 June 2011 with the aim of formulating innovative short-term and medium- to long-term strategies for energy and the environment, and had held six further meetings as of 31 March 2012. As a result, progress is being made toward a comprehensive and long-term review of energy policy.

The word *kizuna* (bonds) has received much attention during the aftermath and recovery from the earthquake, and it has been underscored that connections among people and communities are indispensable to speeding up reconstruction and to aid the lives of the many victims in disaster-hit areas. Various aid activities by NPOs, voluntary organisations, and individuals have played an important role in advancing support tailored to the needs of disaster victims throughout all processes—from immediately post-quake to reconstruction. Aid through local governments across Japan also enables the provision of essential water, food, clothing, sanitary goods, and other relief supplies. Further, even when transportation networks failed aid managed to get through via community networks of neighbouring local governments and associations, NPOs, and other organisations, which played a crucial role in assisting the recovery.

To minimise the risk of or totally prevent natural disasters and other large-scale catastrophes, it will in the future be necessary to build a society that promotes swift relief from any damage, advances effective medium- to long-term recovery, and is highly resilient to disasters. A resilient society is a sustainable society that can achieve rapid recovery following a disaster, while maintaining disaster prevention systems that can mitigate the damage. IGES commenced the current research last year, in April 2011, in order to disseminate the circumstances surrounding the recovery to a wider audience, to mitigate and prevent future disasters, and also to identify effective measures for constructing a resilient society and the policy approaches that will be required. Through this research, we hope to contribute to a stable supply of energy in the face of disasters, sustainable energy policy measures that focus more on the demand side, swift recovery from the damage wrought by earthquakes, and the development of policy approaches that help mitigate and prevent disasters at the outset.

The research in our report covers three main themes. The first is an analysis of the long-term energy supply options available to post-Fukushima Japan; the second is an examination of household energy-saving measures and policy measures to promote energy-saving; and the third is an examination of policy measures aimed at building a new societal system that would aid in reconstruction in disaster areas. These three themes are key elements that support daily life, economic activity, and societal infrastructure development, and we believe these policy suggestions will enable a speedy and efficient framework to be constructed toward recovery in disaster-struck areas, including restoration of the foundations of society and the economy. Moreover, these themes are relevant for all countries across the globe and are recently gaining importance in the context of the rise in frequency of large-scale natural disasters and the related risk management. Awareness of unforeseeable disasters needs to be raised and a disaster-prevention mindset needs to be instilled throughout the world. For these reasons as well, in view of the Great East Japan Earthquake, it is important to disseminate the results of research on disaster preparedness, recovery from disaster, and the construction of a sustainable and resilient society.

Based on the above three points, IGES has compiled a body of information on the societal system elements that will be required to mitigate damage from disasters to the highest extent possible and to recover swiftly from any damage incurred. It is our view that incorporating these elements into policy measures will enable a resilient society to be constructed that responds flexibly to natural disasters—which are likely to become more severe going forward—and enable society to continue on a stable footing.

Debate on the safety and sustainability of nuclear power generation spurred by the Great East Japan Earthquake was the pretext IGES used to introduce in Chapter 2 a scenario where nuclear power is completely phased out by 2050. Use was made of the TIMES Integrated Assessment Model (TIAM-WORLD) to economically analyse a long-term transition to an energy mix centered on renewable energy in comparison with a scenario reliant on fossil fuels, including situations predicated on achieving a greenhouse gas reduction of 80% by 2050. We also examined post-Fukushima energy supply options based on this analysis.

In Chapter 3, we report on a questionnaire survey conducted in the household sector in Kanagawa Prefecture on the actual state of energy consumption, covering the tricky field of civil energy demand, from the perspective that a bottom-up approach from local governments and communities is important to the formulation of strategies regarding energy, on which debate has been invigorated by the Great East Japan Earthquake. We also report on the survey responses related to the factors that would enable energy-saving in the household sector after the earthquake in order to maintain normal modes of living.

In Chapter 4, we analysed the role coordination among local governments played during the Great East Japan Earthquake, identified the characteristics of such coordination, and compiled information on how local governments can improve in this respect, with the aim of constructing a society that is resilient to disasters. Coordination among local governments, in both the affected regions and unaffected regions, played a major role in not only relief measures during the emergency but also medium- to long-term recovery support measures. Lateral relationships among local governments also played a substantial role in building new societal systems that are resilient, to help prevent and mitigate disasters. The study summarises the suggestions made in the returned surveys in the context of executing faster, more flexible, and more sustainable aid activities during a potential future disaster.

As mentioned above, along with the increase in large-scale natural disasters has been a rise in risk-management and disaster-prevention consciousness worldwide with regard to unforeseeable disasters. This report sheds light on disaster prevention measures that have heretofore been inadequate in Japan, based on experiences in the Great East Japan Earthquake, and particularly in terms of aspects in which development toward the construction of a resilient society has been insufficient, while at the same time aims to offer policy suggestions to strengthen a preparedness framework. It is our hope that the vast body of experience gained from Japan's recent catastrophe will provide pointers towards building a more resilient and sustainable society that is prepared for large-scale natural disasters.

We believe that the information contained in this IGES earthquake research paper will be of the most benefit if disseminated to as wide an audience as possible, and, as such, would like to believe it could spark the beginnings of a new global mindset that embraces resilient new societal systems that incorporate measures to mitigate and prevent disasters.

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Chapter 2 – Balancing Japan's Energy and Climate Goals: Exploring Post-Fukushima Energy Supply Options – Report of the Disaster Study Project

Chapter 2 – Balancing Japan's Energy and Climate Goals: Exploring Post Fukushima Energy Supply Options – Report of the Disaster Study Project[1]

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1. Introduction

1.1 Background

As one of the largest primary energy consumers in the world Japan has relied heavily on nuclear power not only to meet a significant share of its electricity demand but also to minimise the cost of petroleum imports. Japan is endowed with only a negligible quantity of fossil fuel resources compared to how much it consumes. Despite the key role Japan played in developing renewable energy technology in the preceding decade[2] (Japan Renewable Energy Policy Platform, 2009, 2010), fossil fuels and nuclear energy have maintained their dominance, leaving the renewables sector on the sidelines.

This was so until the nuclear disaster at Fukushima, which has led to some inevitable changes in Japan's domestic energy policy framework towards a higher reliance on alternative supply sources. Allied with this deep shift in energy policy are concerns surrounding the availability, affordability and sustainability of transitioning to an alternative energy supply.

In order to comprehensively reformulate Japan's energy and environmental strategies, the government set up the inter-ministerial Energy and Environmental Council under the National Policy Unit in June 2011, which is tasked with developing an "Innovative Strategy for Energy and Environment" (hereafter, "Innovative Strategy") before summer 2012 (NPU, 2011a). The three core principles of the Innovative Strategy are:

1. Realisation of a new best mix of energy sources
   - Draw up a scenario of reduced dependence on nuclear energy
   - Utilise a clear and strategic schedule to avoid energy shortfalls and price rises
   - Conduct a thorough review of nuclear power policies and operate under a new framework
2. Realisation of new energy systems
   - Distributed energy system (as opposed to the current centralised energy system dominated by local monopoly-based power utilities)
   - Seek to make an international contribution as an advanced problem-solving nation
3. Formation of national consensus
   - Stimulate national discussions to overcome the confrontation between nuclear proponents and opponents
   - Verify objective data
   - Formulate innovative energy and environmental strategies while maintaining dialogue with a broad range of national figures

1 Report of the Disaster Study Project conducted jointly by Economy and Environment Group (EE) and Climate Change Group (CC)

2 Japan's renewable energy market has remained frozen due to market policies for renewables not being sufficiently examined or implemented. Solar and wind power sectors reflected annual growth of more than 30% between 2000 and 2004, but slowed down due to discontinuation of subsidies.

Issues surrounding the feasibility and public acceptability of the continued reliance on nuclear power are hot debate topics in present day Japan. One thing is clear, however, and that is that the new energy policy framework is unlikely to follow that outlined in the 2010 Strategic Energy Plan (METI, 2010), which advocated an almost two-fold increase (26% to 50%) in nuclear power usage from that in Fiscal Year (FY) 2007.

Going forward, the resulting reduced dependence on nuclear power may also have significant consequences on Japan's greenhouse gases (GHG) reduction strategy. Regarding the medium term GHG emission reduction target following the first commitment period of the Kyoto Protocol, Japan made a pledge at the 15th UNFCCC Conference of Parties (COP15) to reduce its GHG emissions by 25% by 2020 compared to the 1990 level, which is "premised on the establishment of a fair and effective international framework in which all major economies participate in an agreement by those economies on ambitious targets" (Government of Japan, 2010). The 25% target has also been enshrined in the Bill of the Basic Law on Global Warming Countermeasures, together with an 80% reduction compared to the 1990 level by 2050. METI also presented its mid- to long-term[3] plan on GHG emissions reduction (30% by 2030 and 80% by 2050 compared to 1990 level) in the 2010 Strategic Energy Plan, which is heavily reliant on increased input from the nuclear sector. The Bill of the Basic Law on Global Warming Countermeasures will likely be resubmitted to the Diet after the Innovative Strategy is developed. However, in the current political climate it is unclear whether the quantitative reduction targets for 2020 and 2050 will be enshrined in the Bill.

1.2 Rationale and Objectives

There are a number of reports to date covering the consequences of reducing the share of nuclear energy in Japan's energy mix, electricity generation costs, and CO_2 emissions (IEA, 2011a; IEEJ, 2011). These studies indicate that the shortfall in power will be met by increased fossil fuel-based power generation, but with the role of renewable sources limited at least in the medium term (to around 2030)[4] and possibly also in the long term[5].

Such observations, however, do not account for the many benefits of adopting renewable-energy based systems. First, considering the supply cost, transition to a renewable-based electricity system will likely be more expensive in the short term due chiefly to high investment costs. However, renewables will provide a significant fuel cost saving when hikes in fossil fuel prices are factored into the long term (e.g., IEA, 2011). Second, Japan is likely to pursue a course of significant decarbonisation of its economy over the long term and the costs for emitting CO_2 will likely rise too. Under such circumstances, it is apparent that renewable energy technologies become that much more economically attractive. Third, with regard to Japan's dependency on imported fossil fuels, there are challenges in terms of supply security and an additional burden on the energy bill. The use of renewables over fossil fuels has the potential to avoid such risks.

The objective of this study is to assess the technical and economic implications of a long-term phase-out of nuclear energy supply in Japan by 2050, with emphasis on

[3] In this study, "mid- to long-term" refers to the period between 2020 and 2050.
[4] In this study, "medium term future" and "medium term" refers to the period between 2020 and 2030.
[5] In this study, "long term" refers to the period between 2040 and 2050.

increasing the supply from renewables. The research posits the following questions:

1) If nuclear is to go by 2050, what are the implications for its replacement(s) (renewable energy or fossil fuel), on the energy mix, total energy supply system cost, fossil fuel imports and CO_2 emissions?
2) To achieve mid- to long-term (2020-2050) CO_2 emission reduction targets, what are the impacts of a gradual phase-out of nuclear by 2050 on the energy mix, total energy supply system cost, fossil fuel imports and CO_2 emissions?

The energy-economic analysis presented in this study was performed via the TIMES Integrated Assessment Model (TIAM-WORLD), a bottom-up technology-driven energy systems model. This paper first provides the rationale behind this research in Section 2. Following this, the research methodology used for energy-economic modelling is described in Section 3. The results are presented in Section 4. Section 5 discusses the implications of the results and the limitations of this study. Finally, conclusions are drawn and policy recommendations are made in Section 6.

2. Context Surrounding this Study

This section covers Japan's energy supply system and the implications of the Fukushima accident on the future energy supply in Japan.

2.1 Overview of Japan's Energy Supply System

Being one of the largest energy consumers in the world Japan has acted as a major catalyst in the global energy supply market. A lack of domestic fossil fuel reserves and high dependency on imports tightly tethered the country to the global energy market. As well as the scientific gains of developing Fast Breeder Nuclear technology and participation in the International Thermal Experimental Reactor (ITER), the role played by Japanese industry in developing and promoting nuclear technology also aided in placing Japan on the map as a safe country in terms of civil nuclear energy.

2.1.1 Electricity Sector in Japan

Japan's electricity sector has been guided by the Basic Act on Energy Policy, passed in 2002 (Act No. 71 of June 14, 2002). The three pillars of Japanese energy policy are: 1) securing a stable energy supply; 2) assuring environmental compliance; and 3) utilising market mechanisms with due consideration accorded to energy supply stability and environmental compliance (METI, 2010). The Strategic Energy Plan was formulated in 2003 to articulate the fundamental direction of Japanese energy policy based on the Basic Act on Energy Policy. The electricity mix for 2007 (Figure 1) shows that about 80% of total electricity generation is attributable to liquefied natural gas (LNG), coal and nuclear, with each fuel type accounting for a similar share.

The Strategic Energy Plan was revised for the second time in 2010 to add perspectives on energy-based economic growth structural reform of the energy industry as distinct from detailing the goals to 2030 (METI, 2010). This policy was heavily biased in favour of an increased share of nuclear energy, though unrealistic in nature, in the electricity mix. As shown in Figure 1, an additional 14 nuclear reactors were planned to be added to the existing fleet in spite of the continuous delays in commissioning new power plants.

A projection of this energy mix scenario to 2030 showed noticeable differences in the electricity supply pattern from that in 2007. Renewable electricity generation is also projected to increase, but only up to about 20% of the total.

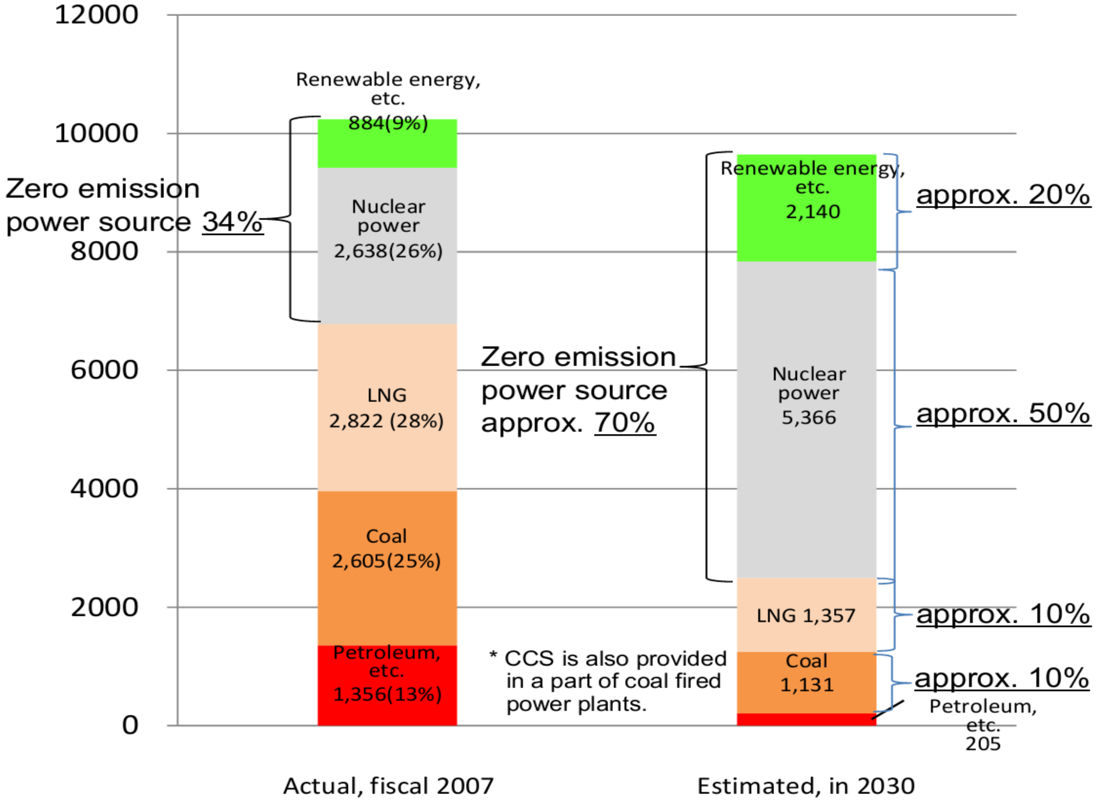

Figure 1: Electricity mix in Japan (in 100 million kWh): 2007 data and the projection for 2030 made in the 2010 Basic Energy Plan (METI, 2010).

2.1.2 Renewable Energy Sources: Resource Availability and Potential

Japan has a huge potential for renewable energy. Table 1 gives the latest estimates (Ministry of the Environment, Japan (MoEJ, 2011a)). As can be seen, although there is significant potential for various renewable electricity sources, this potential has yet to be fulfilled.

Table 1: Estimates on renewable energy potential. Source: Theoretical data obtained from MoEJ (2011) and 2009 capacity data obtained from IEA (2011a). N.A.: not available

Technology		2009 capacity (GW)	Potential (GW) [1]					
				Introduction potential				
			Abundance	Maximum introduction potential	Possible amount of introduction under FIT scenario			
					FIT only	+Tech. Innovation	+Subsidy	+Innovation +Subsidy
PV	Residential (2030)	2.63	207 [2]	45-75 [2]	N.A.	N.A.	N.A.	N.A.
	Non-residential		-	150	0	0.2-72	0-26	69-100
Wind	Onshore	2	-	280	24-140	270	130-260	280
	Offshore			1600	3	140	0.3-330	1200
Small hydro (<30 MW)		1.4 [3]	17	14	1.1-3	4.3	2.7-5.4	7.4
Geothermal		0.54	33 [4]	14	1.1-4.8	5.2	1.5-4.3	4.6
Biomass (100%, no co-firing)		N.A.	N.A.					

1) Definitions of terms used above:
Abundance: the amount of energy resources which can be theoretically estimated by the feasible area for system installation, mean wind velocity, river discharge or other relevant factors. It excludes the amount of energy which is difficult to utilise based on the current technological level and does not take various limiting factors (land inclination, legal restrictions, land use, distance from a residential area and others) into consideration.
Introduction potential: the amount of energy resources which take various limiting factors for energy collection and utilisation into consideration.
Possible introduction amount under scenario: the portion of the introduction potential which can hopefully be realised for actual use under a specific scenario (assumptions) for project viability.
2) The reference quotes NEDO 2004 study for these figures (MoEJ, 2011a).
3) Figure for autoproducers.
4) A survey by the National Institute of Advanced Industrial Science and Technology (AIST) also shows similar estimates that Japan has a potential of 23 GW (Muraoka, 2009).

Regarding research and development (R&D) activities, Japan played a major global role in the development of solar energy from the late 1990s until several years ago. What has been lacking, however, is any substantial policy support for raising the share of renewables in Japan's energy mix, despite a promising government subsidy initiative for domestic PV systems that started in FY1994–a key factor that helped kick-start the solar industry. The subsidies died off from FY2006 to FY2008, however, leaving Japan trailing behind Spain and Germany in total grid-connected PV installed capacity (Japan Times, 2011). Regarding financial incentives for renewables, in 2003 the Renewable sources Portfolio Standard (RPS) act (Act on Special Measures Concerning New Energy Use by Operators of Electric Utilities (Act No. 62, 7 June, 2002)) entered into force with a 12.2 TWh target for 2010—about 1% of total electricity generation. In 2009, the Feed-In Tariff (FIT) scheme for PV electricity was introduced, but the scheme was only applicable to PV installation below 500 kW and to excess electricity generated (net metering). On the surface, Japan appeared to be promoting renewable energy technologies but suffered from a basic lack in implementing such on the ground to generate a worthwhile amount of electricity. Indices on the attractiveness of countries for renewable energy (Ernst & Young (2012)) show Japan's poor performance in this area: Japan ranked 16th out of 40 countries, behind China, U.S., Germany, and India. No awards were received from the

Global Wind Energy Council either, which ranked Japan at the dismal level of 20 in terms of yearly growth of wind capacity in 2011 (GWEC, 2012).

2.1.3 Transmission and Distribution Infrastructure and Legal Facilities

A transmission and distribution infrastructure and its related regulatory and legal facilities are critical for the large scale deployment of renewable energy in the national energy mix. In Japan, a major bottleneck preventing such is a lack of unified transmission and distribution infrastructure that is technically capable of withstanding the intermittency in the grid supply caused by renewable energy and also able to maintain power supply quality. Other major hurdles are the difference in utility frequency between East and West Japan (50 Hz in the east, 60 Hz in the west) and poor interconnectivity among regional power companies. Unified national grid can work as a first tire buffer to gird instability caused by intermittency of power wheeling. Moreover, Japan also lacks market regulation and legal facilities to encourage third party power providers (usually comprised of small-scale independent power producers in remote areas) to harness remote renewable energy resources such as small hydro, small and midsize wind, solar PV, and biomass. Figure 2 shows the Grid interconnectivity in Japan. For example, Tohoku and Hokkaido regions have significant wind power potential but relatively low electricity demand. If large-scale wind power deployment were to take place a large fraction of wind power would have to be exported to other regions such as Tokyo to match supply and demand. This is not currently possible, however, as the transmission capacity between Tohoku and Tokyo regions is very small.

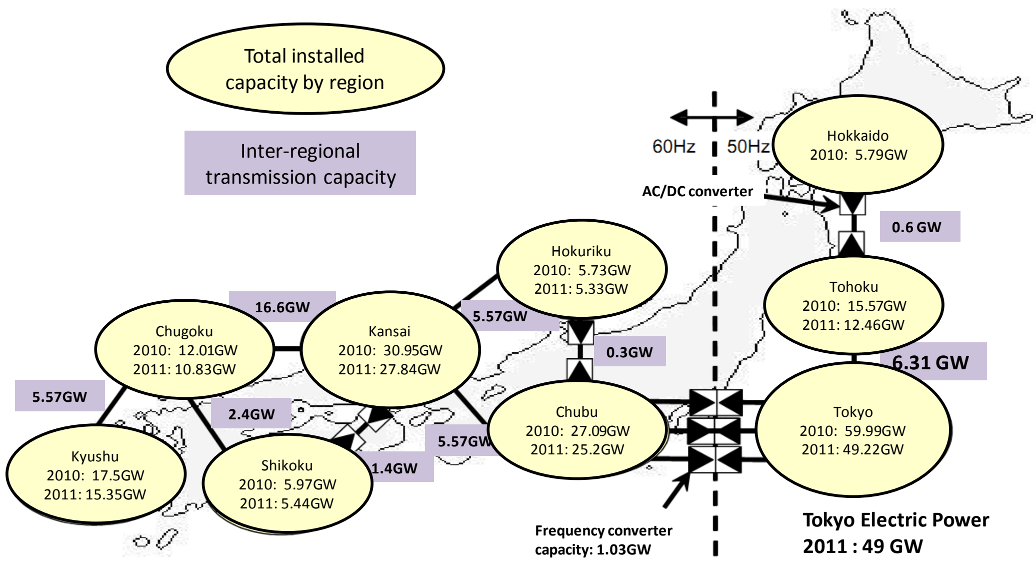

FIGURE 2: GRID INTERCONNECTIVITY IN JAPAN. SOURCE: ADAPTED FROM (METI, 2011).

2.2 Implications of the Fukushima Accident

The Fukushima nuclear accident generated two different sets of global debates: first, the risk of nuclear energy especially for countries like Japan, and second, energy security and corresponding economic impact without nuclear energy. With the increasing public concern over the reliance on nuclear power in Japan and with plans for a nuclear phase-out in Germany[6] a serious policy dilemma is emerging across the world over the long term dependency on nuclear power with the current level of safety and technology. That the dilemma has precipitated into public protests against the nuclear industry in India, Italy and France very vividly highlights this trend. Very recently the IAEA (International Atomic Energy Agency) published its forecast for nuclear power plants based on the impact of the Fukushima nuclear disaster, which is a 7 to 8% drop (depending on the low and high growth scenarios, respectively) in new capacity addition by 2030 compared to the data published before the accident in 2010 (IAEA, 2011).

In contrast, the alternative energy sector has been gaining more policy attention in many countries despite the myths of technical complexity and prohibitive costs. The renewed interest in the alternative energy sector in Japan since the end of last decade[7] and the need for more alternative sources in the aftermath of the Fukushima incident have resulted in renewable energy emerging as a real alternative to the conventional fossil-fuel/nuclear choice.

After Fukushima, much has happened in the arena of renewable energy policy too. For example, the Act on Special Measures concerning the Procurement of Renewable Electric Energy by Operators of Electric Utilities (Act No. 108, 30 August 2011) obliges electric utility operators to purchase all electricity generated (i.e., not net metering) from most renewable energy sources[8] to boost the deployment of renewable sourced electricity. Although the level of renewable electricity deployment largely depends on the FIT levels, which are expected to be determined in the coming months, expectations for large-scale renewable energy deployment in the coming decades are high.

2.2.1 Replacing Nuclear with LNG and Other Fuel Imports: Possible Consequences

The importance of fossil fuel in Japan’s energy mix grew significantly after the Fukushima accident. Further, many of the nuclear reactors over Japan have had to be taken offline for routine inspections and stress tests in order to ensure safety. In such a climate, and as Japan is already a major consumer of fossil fuels, further reliance on them has been seen as a quick fix for the shortfall in nuclear in the supply mix. A higher dependence on fossil fuel in the short term thus has several advantages, such as avoiding immediate cash outflow for *green field* projects for alternative energies, utilising existing supply infrastructures at full capacity and using the same technical expertise and human resources without any additional costs for training on new technologies. However, the basic math of substituting around 250 TWh of nuclear energy by fossil fuels mainly via LNG represents a mammoth task for the utility companies. Fortunately, Japan has sufficient infrastructure to import, process and transport additional LNG import; Japan’s LNG import capacity is currently around 180 million tons and in FY2010 it imported around 70 million tons. Following the outage of nuclear reactors demand for LNG mainly for power generation has surged many times over. In the first quarter of FY2011 Japan imported around 20% more LNG compared to the same period of FY2010 (METI, 2011). The Institute of Energy Economics in Japan (IEEJ) estimated that

[6] Though the nuclear phase-out plan in Germany was not a direct response to the Fukushima incident, Fukushima has undeniably catalysed greater anti-nuclear public sentiments in Germany.
[7] Interest in renewables rose at the end of last decade due to various reasons. At the G8 Summit in Tokyo, Solar Power was recognised as a potential long-term supply source for the country. This has paved the way for Japan to more proactive support of solar PV (Japan Renewable Energy Policy Platform, 2010).
[8] Includes wind, solar, small hydro (<30MW), geothermal and biomass that does not affect existing industrial processes such as pulp and paper production.

an additional supply of 6.2–8.6 million tons of LNG was required for the whole year of 2011. Though Japan is already the largest LNG importer in the world (35% of the world's total tradable LNG in 2010 (pre-Fukushima)) and has sufficient reserve capacity for additional LNG imports, the financial burden placed on post-Fukushima Japan of importing the necessary LNG would be crippling to its economy. It thus appears the major impact of the post-Fukushima energy import scenario would be in the realm of economics rather than technical feasibility. Continuous rises in LNG imports also lead to market price hikes (the spot price in Asia stood at 13.5 $/MBtu at the end of May compared to 10 $/MBtu pre-Fukushima (Hashimoto and Shimao, 2011)) which can only lead to steeper costs for energy imports. Simply adding an adverse Yen value on world markets into the equation could easily tip the trade balance. Not surprisingly, by the end of FY2011 Japan had recorded its lowest ever current account balance in 20 years. The Long-term implications for continued fiscal weakening can only lead to currency devaluation, downgrading of the country's credit rating and could even precipitate a sovereign debt crisis, as is currently being witnessed in Europe.

2.3 Priority and Risks Associated with Various Energy Sources

The quest for the best mix of energy sources has always been a challenge for Japan. Table 2 presents the Priority-Risk matrix for different fuel type options. The assessment used here is indicative in nature to illustrate commonly held perceptions concerning what each type of fuel represents in terms of its effects on the country. The matrix helps evaluate the suitability of these fuel types in Japan based on the factors of energy security, climate goal, self-reliance, and public acceptance.

In terms of prioritising GHG emissions, fossil fuel dependency is of low priority and is high risk for a country having high fossil fuel dependency.[9] If energy security is prioritised, dependence on low cost fossil fuels is important and is low risk. However, the advantages of fossil fuels do not fully compensate the risk of its price fluctuation in the international market, which is often beyond the control of any individual country. Nevertheless, fossil fuels are expected to a play major role in the energy supply market in the foreseeable future. In contrast, renewable energy is high priority if GHG mitigation targets are prioritised, regardless of problems of intermittency in supply and the front-loading capital cost structure. Renewable energy hence demands continuous policy support on all fronts–technology, finance, and market regulation. Nuclear is similar in nature to renewables in terms of its front-loaded capital cost structure but differs in technological and regulatory issues. Historically, Nuclear energy in Japan has benefitted from steady policy support from the Government in terms of technology development and regulation, and no perception of risk had materialised prior to Fukushima. Presently, the most noticeable challenges for nuclear energy are a lack of public acceptance, concerns over spent fuel management, radiation issues, and seismic sensitivity.

[9] A country that depends on the fossil fuel sources to run its economic activities. With regard to a consumer country the terminology can be used if fossil fuels serve as the major source of energy to fuel its domestic economic activities or more precisely if the share of fossil fuels is higher than other primary energy sources the country depends on. For a producer country the terminology 'fossil fuel-based economy' can be used if that serves as the largest source of national revenue.

TABLE 2: PRIORITY - RISK MATRIX FOR DIFFERENT FUEL TYPES IN THE JAPANESE CONTEXT.

Fuel Types / Policy targets	Fossil Fuel Dependency		Renewable Dependency		Nuclear Dependency	
	Priority	Risk	Priority	Risk	Priority	Risk
Climate Targets	Low (Due to High emissions)	High (high emissions damage environment)	High (cleaner energy supply)	Low (Low environmental damage)	High (low GHG emission)	Low (low GHG emission)
Energy Security	High (currently constitutes <80% of Primary energy mix)	High (supply security, geopolitics resource extinction)	High (self-reliance in supply if developed adequately)	Medium (intermittency concerns)	High (less dependency on fossil fuel, meeting demand in key sectors)	Low (fuel & technology are relatively less vulnerable to geopolitics)
Self-reliance	Low (overseas dependency)	High (reliance on politically volatile supply sources)	High (Low overseas dependency, enhanced domestic supply capabilities)	Low (domestic supply)	Medium (Higher role in electricity supply)	Medium (domestic technology but overseas fuel dependency)
Domestic economy	High (currently constitutes <80% of Primary energy mix, indicates greater role played in domestic economic activities)	High (High energy bill)	High (Low overseas dependency)	Medium (if equipment and services outsourced, high capital cost, intermittency)	High (major supply sources for domestic economic activities)	High (expenses on spent fuel management, overseas dependence for reprocessing, need for long term fuel imports, etc.) pose burdens on economy
Public Acceptance	High (no major challenge compared to nuclear dependency)	Low (no major challenge compared to nuclear dependency)	Medium (perception of low vulnerability to external challenges, perception of no fuel cost)	High (perception of high electricity cost)	Low (perception of radiation effect, historical perception based on WWII experience)	High (radiation hazards to environment and human health, vulnerable to major natural disasters, seismic sensitivity)

Note: The table is indicative based on perceptions of risk and priority of each fuel type.

3. Modelling Methodology

This section describes the methodology underpinning the modelling analyses performed in this study. We used the 16-region TIMES Integrated Assessment Model (TIAM-WORLD) with a primary focus on Japan's energy supply system. Major attention was given to the electricity supply system of Japan as we deal with the issue of nuclear energy displacement in the supply system. More precisely, in this model we assumed uniform energy supply and demand for all other regions, except for systematic endogenous changes modelled at the base level linked to the supply and demand drivers and other factors.

This section describes the energy system techno-economic model used for the analyses (TIAM-WORLD), then the modelling assumptions on energy demand drivers, energy supply scenarios and energy conversion technology data.

3.1 General Description of the Model Used in this Study

The TIMES Integrated Assessment Model (TIAM-WORLD) is used in this study to project energy mix, energy costs and CO_2 emissions (see, e.g. Loulou, 2007; Loulou and Labriet, 2007; KanORS, 2012 for more details on TIAM-WORLD). TIAM-WORLD is developed, maintained, and utilised in various EU and other international projects, and served as the starting point for the global energy system model used by the Energy Technology Program (ETP) at the IEA (KanORS, 2012). TIMES is a technology-rich model that integrates the entire energy/emission system of the world, divided in 16 regions (one of which is Japan), including the extraction, transformation, trade, and consumption of a large number of energy forms. The economic paradigm of TIMES is the computation of an inter-temporal partial equilibrium on energy and emission markets based on the maximisation of total surplus, defined as the sum of suppliers and consumer surpluses. TIMES is designed to arrive at a minimal discounted total energy system cost for the entire modelling period. The total energy system cost includes capital cost, and variable and fixed operation and maintenance (O&M) costs on both the demand and the supply sides. The detailed technological modelling of the energy system of TIAM-WORLD allows energy flows, prices, technology uses, net GHG emissions and concentrations (Loulou, 2007; Loulou and Labriet, 2007; KanORS, 2012) to be computed.

Figure 3 is a schematic flow diagram of the TIMES/MARKAL model family. TIAM-WORLD comprises the following four components: energy service demands, energy supply, techno-economic data of energy technologies, and policy scenarios.

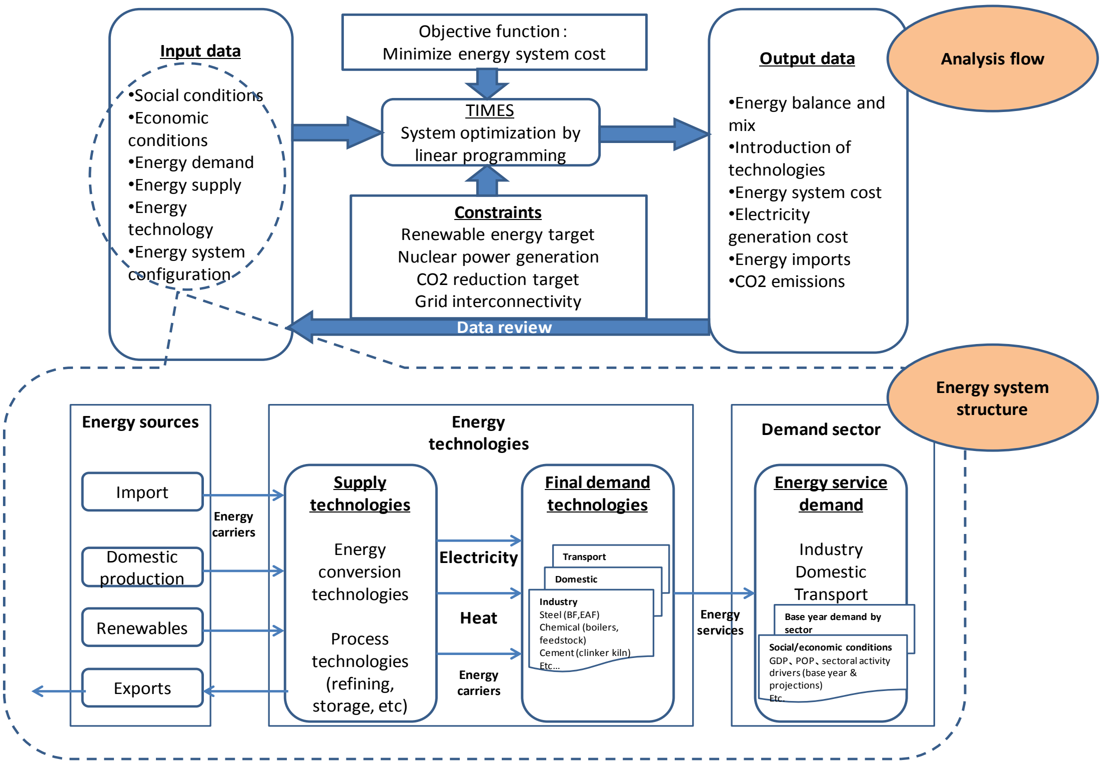

FIGURE 3: SCHEMATICS OF ANALYSIS FLOW AND ENERGY SYSTEM STRUCTURE OF THE TIMES MODEL (ADAPTED FROM SATO, 2005).

Energy service demands are calculated based on the quantified activity drivers and elasticities of demands to their respective drivers. Elasticity represents how strongly the demand follows the changes of the driver. Energy technologies convert primary energy sources to energy services; TIMES contains technical and economic descriptions of more than 1,500 technologies and several hundred commodities in each region. Primary energy resources are disaggregated by type and multi-stepped supply curves are generated for each primary energy form, with each step representing the potential of the resource available at a particular cost. Lastly, regarding policy scenarios, TIAM-WORLD enables incorporation of various policy scenarios, including renewable energy installation capacity targets and CO_2 emission caps (Loulou and Labriet, 2007).

3.2 Key Modelling Assumptions

The model calculation was performed for the period 2005-2050 at the 2050 time horizon. All cost figures related to TIAM-WORLD are expressed in USD_{2000}, unless otherwise stated. When cost data expressed in other currencies or USD from other years is used for the model, the cost data is firstly converted to USD of the current year, then converted to USD_{2000} by applying an inflation index. In this study two sets of inflation indexes are used for different commodities. For power plant capital cost data, the IHS CERA Power Capital Costs Index (IHS CERA, 2012) was used. For other commodities, the U.S. Consumer Price Index (U.S. Bureau of Labor Statistics, 2012) was used. See Appendix A for more details. Regarding the cost optimisation in the model, the discounted total energy system cost for 2010-2050 is calculated using a discount factor of 5% and the selection of energy technologies is based on an internal rate of return (IRR) of 10% in this study[10].

[10] IRR and pay-back time are not directly comparable, but the rule of thumb is that projects with a lifetime of 15 years or

3.2.1 Energy Demand Drivers

TIAM-WORLD calculates future energy service demands based on the projections of various demand drivers such as national and per capita GDP, population, number of households and sectoral production growth rates. In this study, we refer to the set of macroeconomic drivers presented in the Post-2013 Mid- to Long-Term Policymaking Subcommittee of the MOEJ Central Environment Council's Task Force on Global Environment (hereafter, "Post-2013 Subcommittee") (MoEJ, 2011b). The selected set of demand drivers is based on an assumed extended growth case from the activity projections used to generate the 2020/2030 emissions roadmap in FY2010 (MoEJ, 2011b). The demand driver set used in this study also takes into account the energy demand reduction due to behavioural changes. Note that the demand drivers and the future energy service demands depend largely on how the future society, economy, and technology development are envisioned.

Table 3 shows the assumptions on key energy service demand drivers and the exogenous fossil fuel prices used in the model. All the demand drivers are exogenous inputs to the model; dynamic effects such as changes in economic growth due to CO_2 emissions constraints are ignored. With regard to fuel prices, TIAM-WORLD calculates the energy prices at each step of the flow towards the end use. Final energy prices used in the model are endogenously determined based on the cost at the well and pit head. We intentionally used a certain price mark-up to adjust the final price of the primary fuels to the level of IEA projections published in the IEA World Energy Outlook 2010 (IEA, 2010a). This price adjustment is then used as a system profile for the rest of the analysis. The drivers for other energy service demands used in this study are presented in Appendix B.

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more have a slightly higher IRR than the inverse of the pay-back period (Blok, 2006).

TABLE 3: KEY MACROECONOMIC DRIVERS USED FOR SERVICE DEMAND PROJECTION AND FUEL PRICES USED IN THIS STUDY

	Values			
	2010 (Historic data)	**2020**	**2030**	**2050**
Macroeconomic Drivers (all relative to 2005 level; based on MOEJ 2012d)				
GDP (real terms)	1.00	1.21	1.37	1.55
Population (POP)	1.00	0.97	0.91	0.76
Number of households (HOU)	1.04	1.07	1.05	0.96
GDP per capita (GDPP)	0.99	1.25	1.50	2.04
Ethylene production	1.00	0.93	0.91	0.59
Crude steel production	0.98	1.06	1.06	0.75
Passenger transport (person-km)	0.98	0.95	0.93	0.87
Freight transport (ton-km)	0.92	1.06	1.10	1.20
Commercial floor space (m^2)	1.04	1.10	1.09	1.08
Benchmark Fuel prices [absolute values, based on IEA (2010)]				
Steam coal ($\$_{2005}$/GJ LHV)	3.1	3.5	3.6	3.6
Crude oil ($\$_{2005}$/bbl LHV)	75	106	120	162
Natural gas ($\$_{2005}$/GJ LHV)	9.3	11.7	13.1	12.6

3.3 CO_2 Emission and Energy Supply Scenarios Investigated in this Study

We performed two sets of analyses in this study. The first (Analysis I) addresses the first research question by comparing two electricity supply scenarios for nuclear phase-out without mid- long-term CO_2 targets: (1) Fossil fuel-dependent scenario (NPO-FF), and (2) Renewable energy-promotion scenario (NPO-REN). For general reference, the report also assessed (3) a scenario with continuation of pre-Fukushima power supply conditions along with certain targets for nuclear energy promotion and LNG power supply in the system. This scenario (REF) has no CO_2 reduction targets and no explicit energy demand control measures until 2050 and is also very specific to this study (conducted by IGES). Therefore, Analysis I aims to compare the choice between renewable energy and fossil fuels under conditions that the technical and economic implications of the choice on energy supply become most apparent.

With regard to scenarios, the NPO-FF scenario assumes a gradual phase-out of nuclear by 2050 and replacement with fossil fuels and no deployment of renewables. The NPO-REN scenario assumes a gradual phase-out of nuclear by 2050 as in the NPO-FF scenario, and replacement with renewables, mainly wind and solar. In order to factor-in the external cost of CO_2 emissions, the same CO_2 emissions reductions were used for FF and NPO-REN scenarios. The benchmark emission reduction level is derived from the simulation of the NPO-REN scenario and is input to the NPO-FF scenario as a constraint. Scenario REF assumes a continued pre-Fukushima energy supply policy based on the 2010 Basic Energy Plan.

The second analysis (Analysis II) addresses the second research question by assessing and comparing two scenarios in which CO_2 emissions (excl. LULUCF) are reduced by 80% by 2050 compared to the 1990 level, which was 1144 Mt/yr (Government of Japan, 2010b). One scenario (NPO-LC) assumes the gradual phase-out of nuclear power, as described in Table 4 below. The reduction level of nuclear power is more aggressive than in other studies, assuming that part of the remaining capacity in the future will not be utilised due to factors such as local opposition. The other scenario (REF-LC) assumes the continued dependence on nuclear power as in the REF scenario. In this analysis, no comparison of fossil fuel-dependent and renewable energy promotion scenarios is performed. This is because an 80% reduction target would involve the maximum deployment of various decarbonisation measures in order to achieve the target, rendering the comparison meaningless. No renewable energy deployment targets are set for NPO-LC and REF-LC scenarios; only upper limits are set in order to account for physical, technical, economic and social constraints.

Table 4 presents the key assumptions used for the three scenarios investigated in this study.

TABLE 4: KEY ASSUMPTIONS USED FOR THE SCENARIOS INVESTIGATED IN THIS STUDY.

Assumptions on mid-to long-term CO_2 emissions reduction targets		Without targets (Analysis I)			With targets (Analysis II) [3]	
Scenario		Pre-Fukushima plan for nuclear power (REF)	Nuclear phase-out, renewable energy promotion (NPO-REN)	Nuclear phase-out, Fossil fuel-dependence (NPO-FF)	Pre-Fukushima plan for nuclear power (REF-LC)	Nuclear phase-out (NPO-LC)
Future CO_2 emissions reduction targets		No targets		Constrained to annual emissions identical to NPO-REN scenario	Minimum reduction compared to 1990 level: 2020: 17%, 2030: 40%, 2040: 60%, 2050: 80%	
Power generation technologies						
Nuclear (share in total electricity production)		Gradual increase in line with the 2010 Basic Energy Plan 2020: 40%, 2030: 50% and 2050: 65% [1] 85% capacity factor	Gradual reduction corresponding to the following [1]: -Decommissioning of all Fukushima Daiichi reactors - No restart of Fukushima Daini reactors Shutdown of all plants after 40 years operation - No construction of new power plants - Only 60-70% of the remaining capacity operating at 70% capacity factor for all time periods - Complete phase-out in 2050		Same as with REF scenario	Same as with NPO-REN and NPO-REF scenarios
Natural gas/oil-fired		Minimum share constraint in total electricity generation of 20% [2]				
Renew-able	Wind (onshore and offshore)	No targets	Gradual increase with lower & upper bounds 2020: 15-20 GW, 2030: 25-30 GW, 2050: 80-90 GW	Total of wind and solar limited to maximum 10% of total electricity production	Maximum capacity cap (upper bound) - 2020: 20 GW, 2030: 30 GW, 2050: 90 GW	
	Solar		Gradual increase		Maximum capacity cap	

Assumptions on mid-to long-term CO_2 emissions reduction targets		Without targets (Analysis I)			With targets (Analysis II) [3]
			with lower & upper bounds2020: 25-30 GW 2030: 45-50 GW;2050: 175-180 GW		(upper bound) - 2020: 30 GW, 2030: 50GW, 2050: 180 GW
	Hydro (all scale, excludes pumped storage)	Maximum capacity: 30GW (upper bound)			
	Geothermal	Limited to maximum 14GW (upper bound)			
Other assumptions on key technologies					
Biofuels: Upper bound [4]	Transport sector	2020: 27PJ, 2030: 60PJ, 2040: 100PJ, 2050: 150PJ			
	Other sectors	2020: 50PJ, 2030: 230PJ, 2040: 400PJ, 2050: 570PJ			
CCS	Year of introduction	2020			
	Capacity constraints	No constraints are set			

[1] The maximum installed capacity is expected to be around 50-60 GW by 2050 for the pre-Fukushima scenarios. For the nuclear phase-out scenario 0% supply of electricity in the grid means 0 kWh generation by nuclear power plants by 2050. We used the percentage of nuclear power supply in the scenario rather than absolute amount of generation or installed capacity mainly for ease of understanding the scenario and also to technically avoid even a minute amount of nuclear power supply coming from the existing installed capacities in the system and within their technical lifetime Scenarios with absolute amounts of supply can be misleading to readers as it may increase the supply ratio of nuclear under the case where total electricity supply drops. With a percentage scenario we are able to make the supply mix 100% nuclear-free.
[2] A minimum share of natural gas/oil-fired power generation needs to be set in order to secure an intermediate-peak load supply, which cannot be done by coal-fired plants or renewable electricity plants due to their inflexible operation. Considering historic data, 20% is the minimum gas supply required to maintain grid stability at peak times.
[3] All targets are for net domestic reductions excluding LULUCF. Therefore, actual emissions reductions will be large when LULUCF and emission credits purchased abroad are taken into account.
[4] Biofuels include bioethanol and biodiesel. The upper limits for biofuel introduction are based on the assessment presented in the MoEJ Post-2013 Subcommittee (MoEJ, 2012a).
5) Note that CO2 capture from CO2-intensive industrial processes such as blast furnace and cement clinkers is not included. The prospects for CCS in the industry are presented in, e.g., Kuramochi et al. (2012).

3.3.1 Assumptions on Renewable Energy Potential

Solar Photovoltaic

Japan has set more ambitious targets for solar power deployment compared to other renewable technologies. The Ministry of Economy, Trade and Industry (METI) has an ambitious target for solar power technology; 28 GW by 2020 and 53 GW by 2030 (METI, 2008). Moreover, the PV Roadmap 2030+ published by NEDO (2009) quotes a higher potential of 150-200 GW in the domestic sector, 150-200GW in the transport sector and about 150 GW in the industrial sector by 2050.

Our assumption on maximum installed capacity until 2050 (180 GW) is conservative compared to the aforementioned estimates and is in agreement with the estimates presented in the MoEJ Post-2013 Subcommittee (MoEJ, 2011b), which estimated the range of 200-250 GW for 2050 based on various studies and expert opinion. The capacity targets for 2020 and 2030 are taken from (MoEJ, 2011b).

Wind power

As presented in Table 1, Japan has a large wind power potential, most of which lies in the Tohoku and Hokkaido regions (MoEJ, 2011a). Despite the large potential, Japan currently lags behind many other major wind power producing countries due in particular to the limited progress made in the field in the past few years. The main limiting factors for wind power deployment in Japan include grid stability, mountainous geographical conditions and various environmental restrictions, particularly the protection of Golden Eagles. These factors have adversely affected the wind power sector's development plans and are likely to remain as potential bottlenecks in the future.

Our assumption on maximum installed capacity up to 2050 (90 GW) generally agrees with the estimates presented at the MoEJ Post-2013 Subcommittee (MoEJ, 2011b) that the maximum deployment of wind power in 2050 would be about 70 GW based on various studies and expert opinion.

Geothermal Power

Although Japan currently has only 18 geothermal power plants with a total capacity of about 550 MW (MoEJ, 2011a), geological estimates (see Table 1) show that ample exploration opportunities exist. Japan is ranked third worldwide in geothermal resources behind Indonesia and the United States (Muraoka, 2009). Geothermal is also considered to be already economically competitive with conventional fossil fuel-fired technologies (NPU, 2011b). The main constraint for geothermal power is that many of the promising heat sources are in environmentally sensitive areas such as nature reserves, where installation is prohibited.

In this study, geothermal power capacity is restricted to a maximum of 14 GW for 2010-2050 based on the maximum introduction potential estimated by MoEJ (see Table 1).

Hydropower

As of 2009, Japan had a hydropower capacity (excluding pumped storage) of 22 GW (IEA, 2011b). While much of this has been exploited via large hydropower facilities, the MoEJ survey has identified noticeable potential for developing small-medium hydropower (less than 30 MW) generation facilities (see Table 1). Similarly to the MoEJ estimate presented in Table 1, METI also estimates that there is about 12 GW of potential hydropower capacity over 2,700 locations that may be technologically and economically feasible.

Considering the aforementioned potential for small-medium hydro and the existing potential, the maximum total hydropower capacity (excluding pumped storage) was assumed to be 30 GW.

3.4 Techno-economic Performance Data for Energy Conversion Technologies

Techno-economic data for energy conversion technologies is the default data from the TIAM-WORLD database, except for power generation technologies.

3.4.1 Fossil Fuel-Fired Power Technologies

For fossil fuel-based power generation technologies, we updated the TIAM-WORLD database on new power plants by adopting a consistent technical and economic dataset for new fossil fuel-fired power plants with and without CO_2 capture from van den Broek et al. (van den Broek et al., 2008). Since the economic data is mainly based on American and European plants, capital costs are multiplied by a factor of 1.4 to account for the Japanese situation. The details are presented in Appendix D.

3.4.2 Wind and Solar Power Technologies

Table 5 shows capital cost data for wind and solar power technologies used in this study. For wind and solar power plants, the economic data was updated based the authors' calculations. The capital cost data for wind and solar power generation technologies used in this study includes both the plant capital cost and the capital costs for grid stabilisation measures to deal with intermittency.

TABLE 5: WIND AND SOLAR POWER PLANT CAPITAL COSTS INCLUDING GRID STABILISATION MEASURES (IN USD2000/KW) (SELECTED TECHNOLOGIES ONLY). (SOURCE: OWN CALCULATIONS BASED ON IEA, 2010B; MOEJ, 2012B)

Technology/ Year	2010	2020	2030	2040	2050
Solar PV-decentralised	4750	2310	1640	1620	1390
Solar PV-centralised	3270	1640	1190	1250	1100
Solar CSP	4570	3960	3350	2950	2340
Wind onshore	1460	1380	1300	1420	1340
Wind offshore	2590	2400	2220	2230	2050

Plant capital costs are based on (IEA, 2010c) for solar PV technologies and (IEA, 2010b) for other technologies. The cost figures presented in the referenced report are representative of U.S. plants. In TIAM, all capital costs of power generation technologies for Japan are assumed to be 40% higher than those for the U.S. Therefore, we also applied a similar adjustment for the ETP 2010 cost projections. Incremental capital costs per kW of installed capacity for grid stabilisation to cope with the intermittency of solar and wind power are derived from the short- to medium-term estimates (2012-2030) by (MoEJ, 2012b).

The additional cost for grid stabilisation is from 6 to 35% for solar and 5 to 24% for wind energy over the next 40 years. Grid stabilisation costs are lower in the medium term future (until 2030) compared to the long term (between 2030 and 2050). Increasing the supply of renewable energy in the grid demands more investment in the grid stabilisation infrastructure and facilities, thus a slight increase in capital costs between 2030 and 2040 is observed. Appendix C gives details of the calculations.

3.4.3 Nuclear Power Technologies

Table 6 presents the cost data for nuclear power plants used in this study (NPU 2011). All costs for nuclear power technologies are assumed to remain unchanged for the entire period covered by this study. In addition to the O&M costs included in the TIAM-WORLD technology database, we also account for cost components such as fuel cycle costs, policy-related costs and disaster compensation costs. The cost figures are taken from the NPU (2011). These additional costs add up to about 2 JPY/kWh. A conservative real interest rate of 3% was used to calculate decommissioning costs and fuel cycle costs per kWh of electricity generated.

TABLE 6: KEY COST DATA FOR NUCLEAR POWER PLANTS ASSUMED IN THIS STUDY. DECOMMISSIONING COSTS AND NUCLEAR FUEL CYCLE COSTS ARE CALCULATED FOR 3% REAL INTEREST RATE AT 80% CAPACITY FACTOR. SOURCE: COST EXAMINATION COMMITTEE OF THE NATIONAL POLICY UNIT (NPU, 2011B).

Cost component	Units	Value
Capital cost	$/kW	3200
Extra cost for disaster compensation [1)]	$/kWh	0.005
Policy-related costs**, advertisement costs and donations	$/kWh	0.01
Decommissioning cost	$/kWh	0.001
Nuclear fuel cycle cost	$/kWh	0.01

1) The extra costs for the disaster compensation include additional decommissioning costs, compensation for victims and some decontamination costs, but do not include various costs regarding human health, costs due to the designation of no-fly zones, damage to local government properties, area decontamination costs, facility costs for intermediate storage of contaminants, and costs for final treatment of the contaminants.

2) Policy-related costs include financial support of the local governments hosting nuclear power plants and R&D costs (e.g., for the sodium-cooled Monju fast-breeder reactor).

4. Results and Discussions

This section presents the results of two modelling analyses in terms of final energy consumption, electricity mix, CO_2 emissions and total energy system cost (including fuel import costs).

4.1 Analysis I: Comparison of Scenarios with CO_2 Emissions Benchmarking

This analysis primarily focuses on the pros and cons of the renewable and fossil fuel dependent long-term energy scenarios in Japan under an experimental CO_2 benchmark cap, for meaningful comparison.

4.1.1 Final Energy Consumption

It is assumed that the trends in final energy consumption are similar across all scenarios up to 2050 as there are no exogenous constraints on final energy use to reduce consumption via conservation.

Figure 4 compares final energy consumption by sector and by energy type projected for the three scenarios with no long-term CO_2 emissions reduction target. Final energy consumption is projected to drop by about 30% compared to the 2009 level. The breakdown of final energy consumption by sector shows a big reduction for the transport sector (35-40%) and commercial and industrial sectors (both about 30%), and a smaller reduction in the residential sector (about 15%). The breakdown figure by fuel type shows considerably less coal consumption for the NPO-FF scenario compared to other scenarios primarily due to the CO_2 emissions constraint applied to the scenario. Electricity consumption is projected to decrease by 5% in 2030 and 24% in 2050 compared to the 2010 level.

Regarding the breakdown by energy source, the results obtained in this study show lower electricity consumption compared to IEEJ (2011) and IEA (2011) estimates of 20-25% compared to the 2010 level. This is attributed to an assumption that excludes targets for specific advanced end-use technologies, which are often electricity-driven.

Thus, the electrification rate of final energy use slows down in our study compared to the other studies.

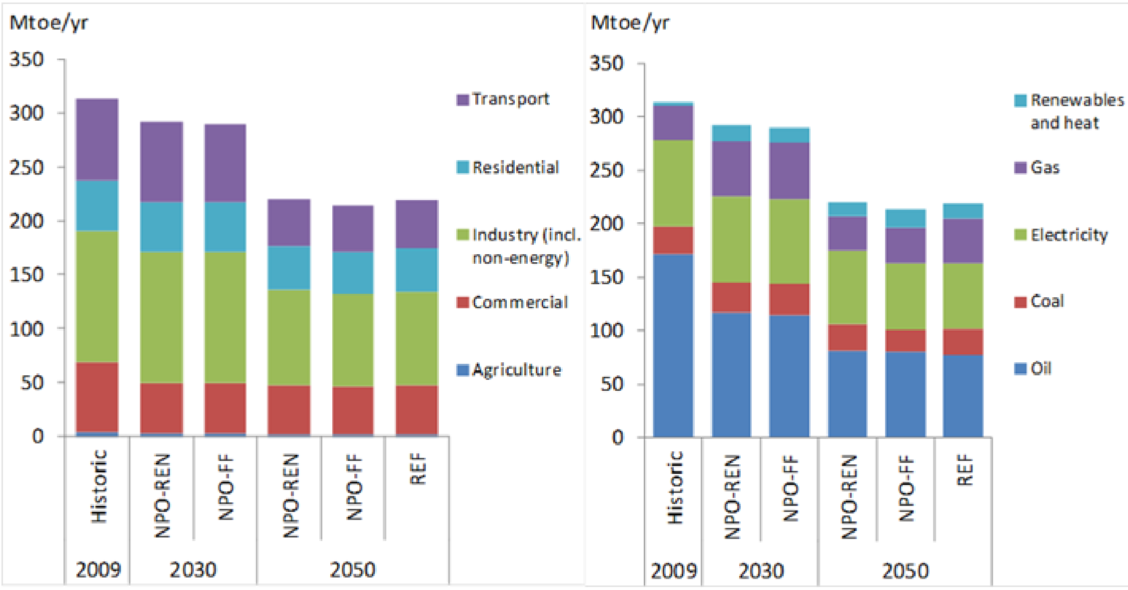

FIGURE 4: COMPARISON OF FINAL ENERGY CONSUMPTION BY SECTOR (LEFT) AND BY FUEL (RIGHT) PROJECTED FOR THE THREE SCENARIOS WITHOUT EXPLICIT MID- TO LONG-TERM CO_2 EMISSIONS MITIGATION TARGETS.

4.1.2 Electricity Supply Portfolio

The breakdown of total electricity production by energy source toward 2050 for REF, NPO-REN and NPO-FF scenarios is presented in Figure 5. In REF, nearly half of total electricity generation in 2050 is generated by nuclear power plants. In NPO-REN, both coal-fired power and gas/oil-fired power increase in the medium term (until around 2030) when renewable power capacity cannot compensate for the reduction in nuclear power. Coal-fired power maintains the larger share (above 20%) until 2050, while gas/oil-based electricity becomes gradually replaced by the growing renewable electricity.

With regard to NPO-FF, the electricity mix up to 2030 is very similar to that for NPO-REN. After 2030, however, NPO-FF maintains its large dependence on gas-fired power in order to maintain the same CO_2 emissions level as for NPO-REN. The results for NPO-REN and NPO-FF strongly indicate that coal-fired power will remain as one of the major sources of power in Japan in nuclear phase-out scenarios with no long-term CO_2 emissions reduction target. Moreover, the security of additional natural gas supply in the mid- to long-term (up to 2050) will be crucial if Japan is to reduce its dependence on nuclear power, particularly if renewables deployment remains slow.

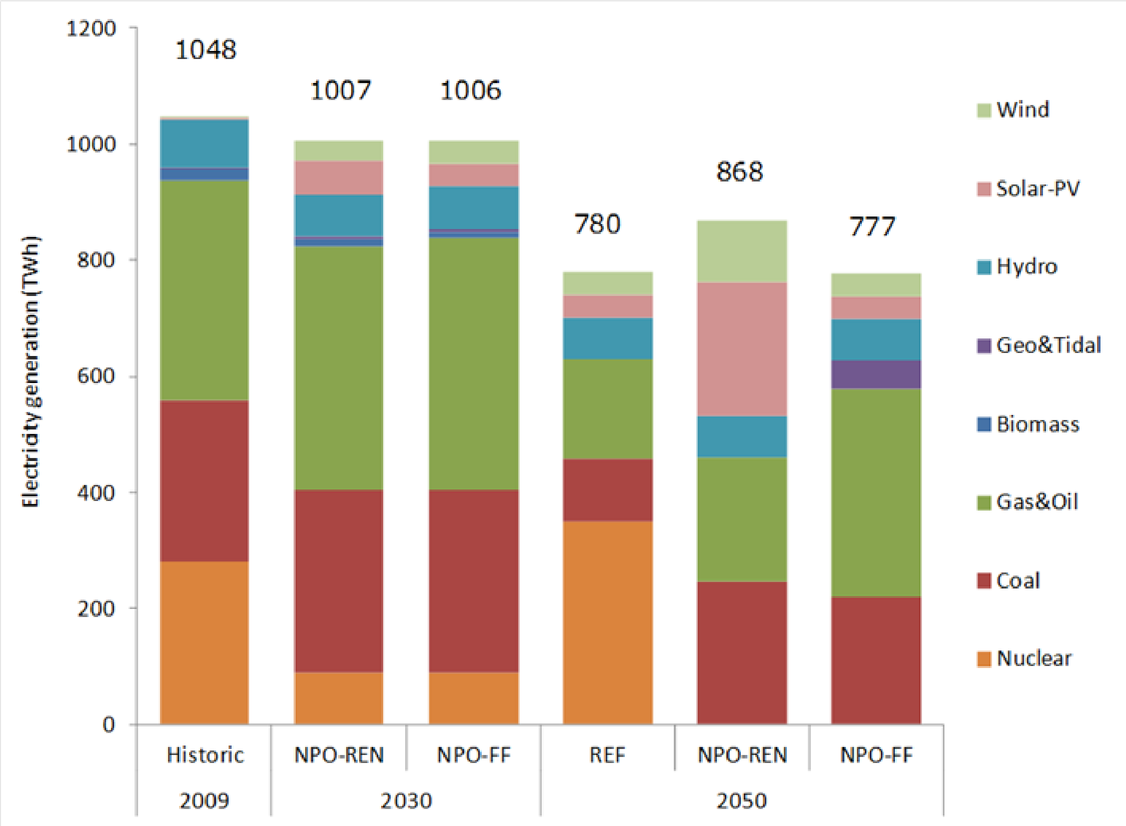

FIGURE 5: ELECTRICITY SUPPLY PORTFOLIO IN JAPAN FOR SCENARIOS WITHOUT EXPLICIT MID- TO LONG-TERM CO_2 EMISSIONS REDUCTION TARGETS BETWEEN 2010 AND 2050.

4.1.3 Energy-related CO_2 Emission Pathway for the Renewable Energy Scenario

Figure 6 shows total CO_2 emissions for NPO-REF and NPO-REN scenarios in 2030 and 2050. NPO-REN is projected to reduce total national CO_2 emissions by 12% in 2030 and 40% in 2050 compared to the 1990 level, though showed higher CO_2 emissions than REF throughout the period covered by this study. Since there are no explicit CO_2 emission targets, no CCS is deployed in REF or NPO-REN.

For NPO-FF, there are several factors that contribute to the reduction of CO_2 emissions to the NPO-REN level including: (1) lower share of coal and higher share of natural gas, (2) larger renewable energy consumption, (3) lower total primary energy and final consumption, as well as (4) some CCS (after 2040, 18 Mt/yr in 2050).

Compared with previous studies, the medium term (around 2030) CO_2 emission projections for REF (890 Mt/yr in 2030) are about 100 Mt/yr lower than those projected in pre-Fukushima studies (986 Mt/yr in 2030 and 950-1000 Mt/yr in 2035 according to IEA World Energy Outlook 2010 ‘Current Policies Scenario’ and IEEJ (2011) base case scenario, respectively). This difference is mainly due to the more conservative projections of macroeconomic drivers and their corresponding impact on reduced final energy consumption.

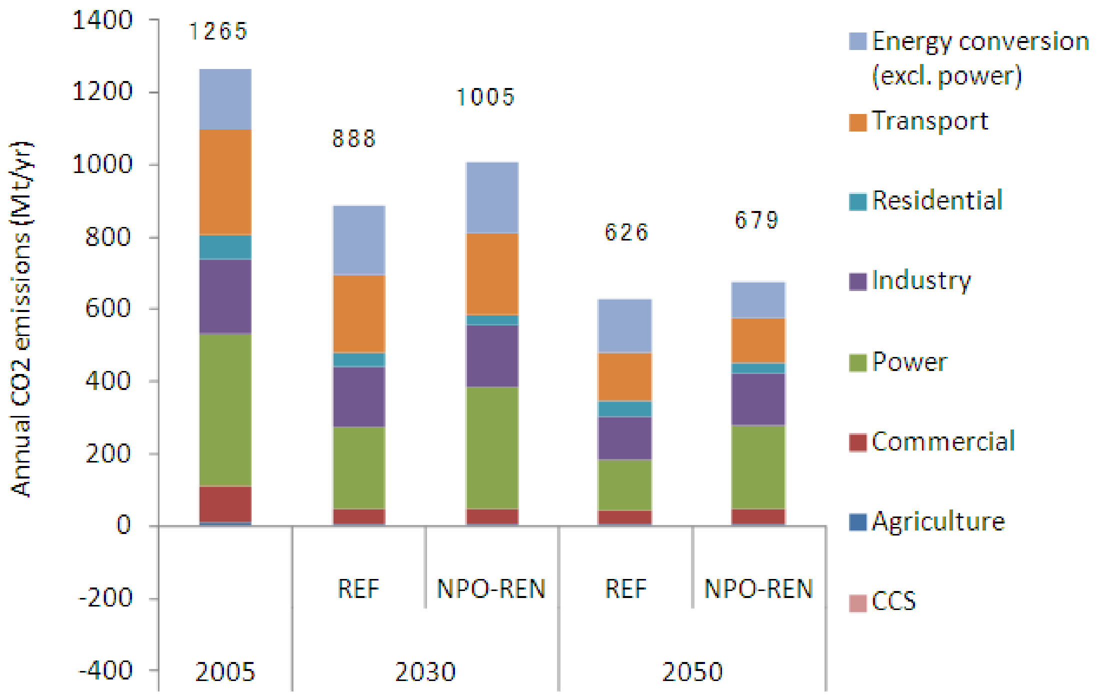

FIGURE 6: TOTAL CO_2 EMISSIONS TRAJECTORY OF THE REFERENCE (REF) SCENARIO AND THE RENEWABLE ENERGY DEPENDENT (NPO-REN) SCENARIO FOR YEARS 2010-2050. HISTORIC EMISSIONS DATA FOR 2005 IS TAKEN FROM THE MODEL TO BE CONSISTENT WITH THE BREAKDOWN OF EMISSIONS.

4.1.4 Total Energy System Cost

Figure 7 shows the discounted total energy system cost for 2010-2050 for the renewable energy promotion (NPO-REN) scenario compared to the fossil fuel-dependence (NPO-FF) scenario by component. Fixed operation and maintenance (O&M) costs are expenditures proportionate to the scale of investment and comprise mostly labour costs, whereas variable O&M costs are proportionate to the amount of energy produced and comprise mostly material costs. The results show that the discounted total energy system cost for NPO-REN is marginally higher than that for NPO-FF (by 0.2%) savings in fuel import costs are outweighed by considerably higher investment costs for deploying renewable power plants. To obtain an order-of-magnitude estimate on the scale of the increase in total energy system cost for NPO-REN compared to NPO-FF, the annual total cost is compared with Japanese GDP. The increase in annual total cost is on average 0.04% of national GDP (0.02%–0.12%, depending on the year).

One significant advantage of NPO-REN over NPO-FF is the fossil fuel import reduction; the estimated reduction in total discounted fossil fuel costs for 2010-2050 is around 20 billion USD_{2000} or around 2 trillion JPY_{2010}[11]. This is equivalent to the current annual total fossil fuel import costs, which are 23 trillion JPY_{2010} (Ministry of Finance, 2012). The results indicate that the large-scale deployment of renewable energy can help place Japan in a better position in terms of energy security. This result further corroborates the

[11] The currency conversion from USD_{2000} to JPY_{2010} was done by first applying the inflation factor, i.e., U.S. Consumer Price Index to update to USD_{2010}, then converting to JPY_{2010} by applying the currency conversion rate for USD_{2010} and JPY_{2010}. These conversion factors are shown in Appendix A.
Caution should be taken in interpreting this monetary value as it is heavily influenced by several external global factors beyond the scope of this study and control of the model.

importance of a basal shift in energy planning from least cost to least risk. Least-risk-based planning can assist Japan to deploy more renewable energy in the system without much additional investment (Bhattacharya and Kojima, 2012).

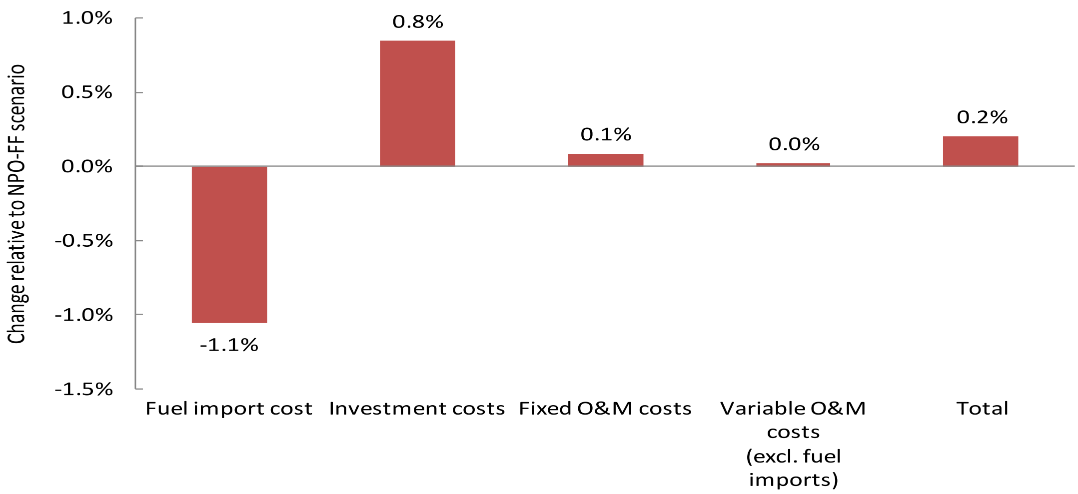

FIGURE 7: DISCOUNTED TOTAL ENERGY SYSTEM COST FOR 2010-2050 FOR THE RENEWABLE ENERGY PROMOTION (NPO-REN) SCENARIO RELATIVE TO THE FOSSIL FUEL-DEPENDENCE (NPO-FF) SCENARIO BY COMPONENT. NOTE: THE NUMBERS UNDER EACH CATEGORY IN THE FIGURE ARE THE PERCENTAGE CHANGES OF A PARTICULAR COST COMPONENT. THEREFORE, SIMPLE ADDITION OF THE PERCENTAGE VALUES FOR INDIVIDUAL COST COMPONENTS DOES NOT OBTAIN THE TOTAL PERCENTAGE CHANGE.

4.1.5 Summary of Analysis I

In Analysis I, the renewable energy promotion (NPO-REN) scenario and the fossil fuel-dependence (NPO-FF) scenario are compared at a benchmarked level of CO_2 emissions by 2050. Total final consumption drops from about 310 million tons of oil equivalent (Mtoe) in 2009 to 210-220 Mtoe in 2050, depending on the scenario. The major reasons for this are a steady fall in population by 2050 and changes in economic landscape due to reduction in domestic industrial production. The biggest drop in final energy use is in the transport sector while the drop is smaller for industry. The results showed that NPO-REN is only 0.2% more expensive than NPO-FF regarding the discounted total energy system cost for 2010-2050. Compared to REF, the increase was only 0.1%. The increase in annual total energy system cost for NPO-REN compared to NPO-FF was on average 0.04% of national GDP. Moreover, NPO-REN also showed significantly lower LNG imports especially after 2030 compared to NPO-FF (about 60% in 2050). The CO_2 emissions reduction in 2050 for NPO-REN was slightly higher than in REF (45% compared to 41% compared to 1990 level.

Overall, the results indicate the importance of renewable energy for Japan under the nuclear phase-out plan for its direct contribution to foreign exchange savings arrived at via less fuel imports, which can provide ample buffer to the national wealth loss in the context of large fluctuations in exchange rates and high LNG spot market prices. In fiscal year 2011 Japan recorded a 19 billion USD trade deficit–the biggest since 1990–caused by the lopsided export-import balance in the energy sector. Fiscal year 2011 also witnessed a 27% yearly increase in LNG usage by all 10 power utilities in Japan[12] due to offline nuclear power plants in the aftermath of the March 11 disaster.

[12] Sourced from a report published by the Federation of Electric Power Companies of Japan, April 2012, and a news

This very heavily underscores the urgent need for Japan to switch its reliance over to indigenous energy resources such as renewables to prevent the financial burden spiraling out of control in the near future. Further, our current estimates of an additional 0.1% cost in the renewable scenario don't consider all the expenses related to spot market premium costs, and foreign exchange fluctuation costs, etc.

4.2 Analysis II: Comparison of Scenarios with mid- to long-term CO_2 Emissions Reduction Targets

This analysis primarily focuses on the pros and cons of the long term energy scenarios in Japan with and without nuclear energy supply and with an overall national target of 80% CO_2 emissions reduction by 2050.

4.2.1 Final Energy Consumption

Figure 8 gives a breakdown of total final consumption[13] for the NPO-LC scenario for 2030 and 2050 by sector and fuel type. The breakdown by energy type shows the use of fossil fuel drops from 73% in 2009 to 41% of total final consumption by 2050, under NPO-LC. Compared to the scenarios in Analysis -I (REF, NPO-REN and NPO-FF), the total electricity consumption in 2050 is considerably higher in NPO-LC, the main reason for this being that in order to reduce CO_2 emissions economically the final energy use, especially in the residential and commercial sectors, has shifted from primary fuels to electricity generated from renewable sources or from fossil fuel power plants with CCS.

The significant reduction in final energy use in the transport sector is due to three factors: First, the fuel economy of petrol- and diesel-driven vehicles is assumed to improve by around a factor of two by 2050 compared to the 2005 level; Second, most of the passenger vehicles will be electric (100% conversion to mechanical energy); and third, the majority of freight trucks will be hydrogen-powered (significantly higher conversion efficiency to mechanical energy than petrol and diesel) by 2050.

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report published in the Japan Times, 17th April, 2012.

[13] Total final consumption is 'the sum of consumption by the various end-use sectors. TFC is broken down into energy demand in the following sectors: industry, transport, buildings (including residential and services) and other (including agriculture and non-energy use). It excludes international marine and aviation bunkers, except at the world level where it is included in the transport sector.' (IEA 2011b)

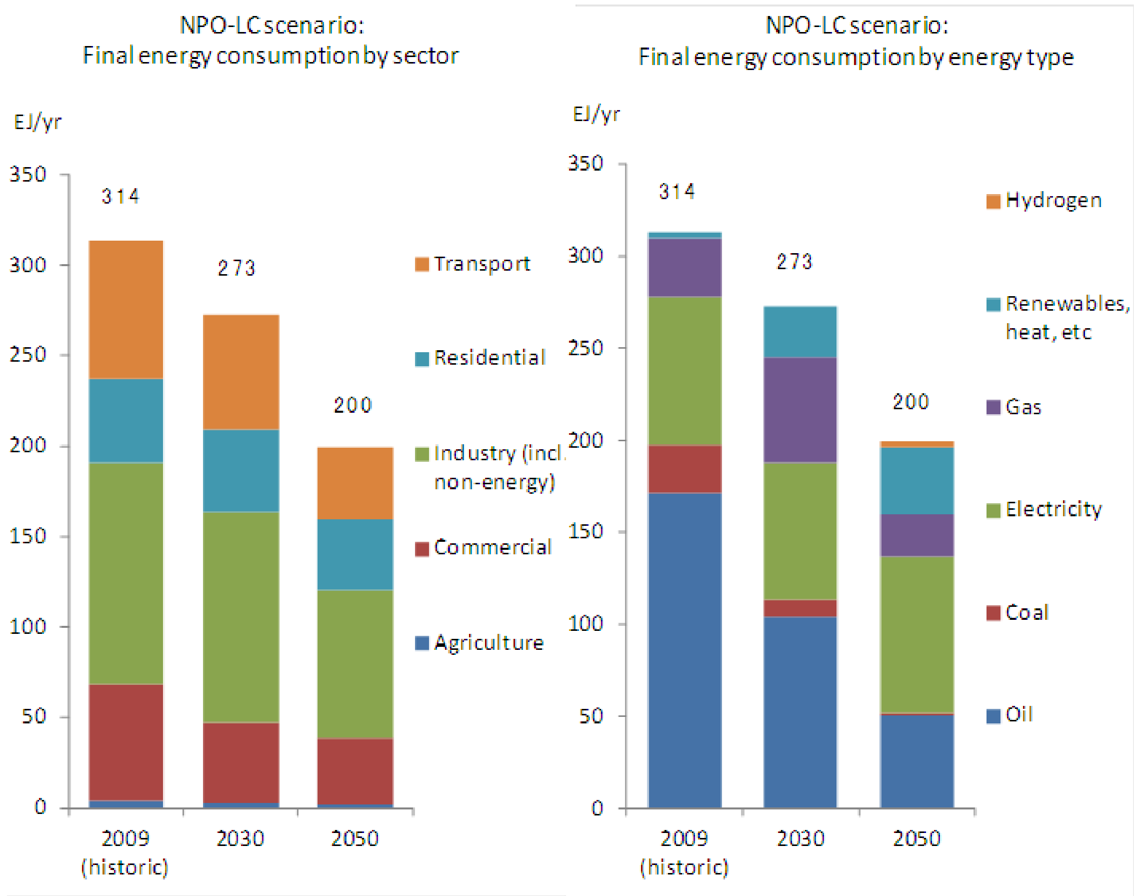

FIGURE 8: FINAL ENERGY SUPPLY IN THE 2050-80% REDUCTION SCENARIO BETWEEN 2010 AND 2050. LEFT: BREAKDOWN BY SECTOR, RIGHT: BREAKDOWN BY FUEL TYPE.

4.2.2 Electricity Supply Portfolio

Figure 9 shows the electricity mix in the NPO-LC and REF-LC scenarios for 2030 and 2050. The increase in electricity generation from 2030 to 2050 is due to the fact that final energy consumption needs to be decarbonised by shifting from primary energy to electricity with CCS to meet the CO_2 emissions reduction target.

Regarding the introduction of renewable electricity, wind and solar power are deployed in NPO-LC to around 80 GW and 176 GW, respectively, approaching their capacity limits (of 90 GW and 180 GW). In REF-LC, on the other hand, wind is relatively high (59 GW) while solar is only 38 GW because of its relatively high pre-Fukushima generation cost relative to other technologies. The nuclear power capacity in REF-LC was found to be 63 GW in 2050.

Up to 2030, Japanese electricity supply needs to rely heavily on gas-fired power plants because gas-fired power generation is the only viable economical option to both make up for the shortfall in nuclear power and reduce CO_2 emissions until adequate capacity can be reached with renewables. Coal-fired power drops drastically in the medium term (up to 2030) for both scenarios to meet the CO_2 target then rebounds after 2030 when the technologies that enable low-cost CO_2 capture are introduced. The results also show that nearly all fossil fuel-fired power generation is decarbonised through CCS. Total electricity production is found to be larger for REF-LC due to a lower marginal electricity generation cost (MEGC).

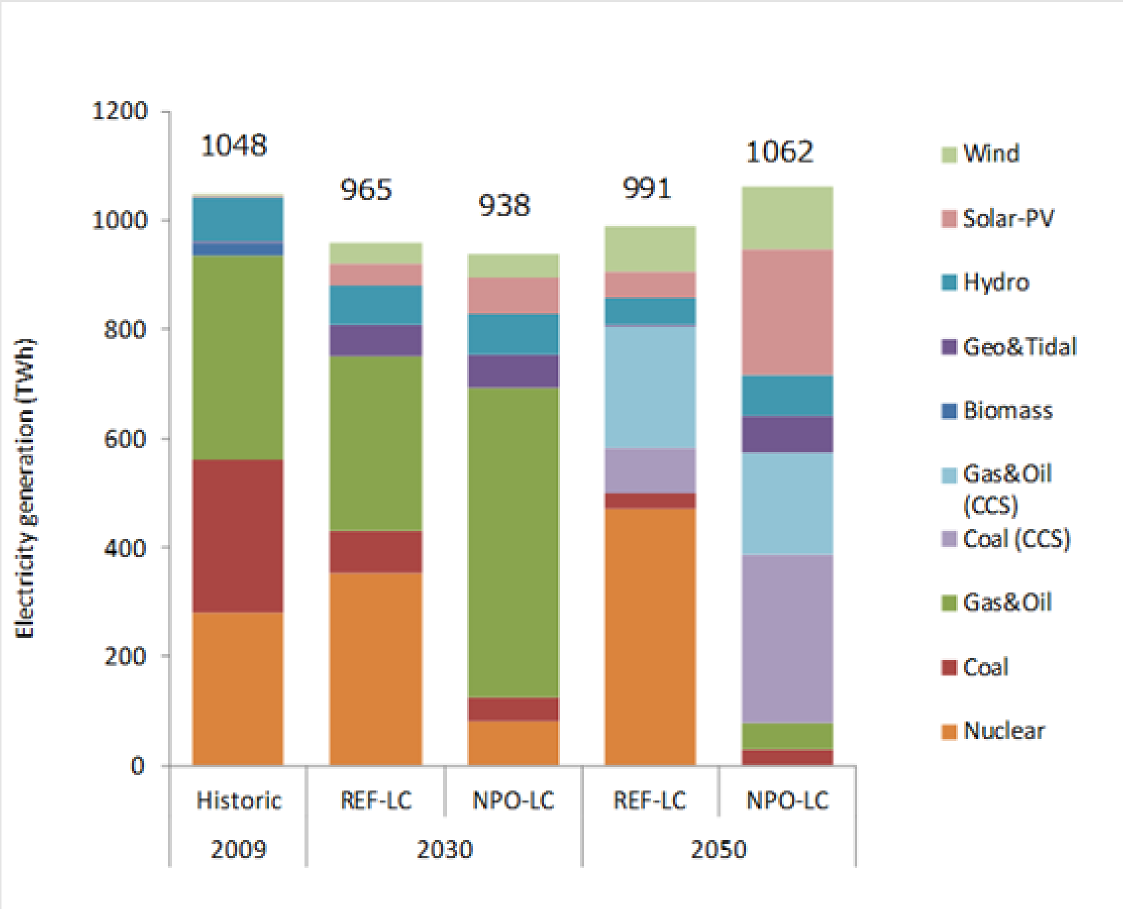

FIGURE 9: ELECTRICITY MIX FOR THE SCENARIOS WITH MID- TO LONG-TERM CO_2 EMISSIONS REDUCTION TARGETS IN 2030 AND 2050.

4.2.3 Energy-related CO_2 Emissions Pathway

Figure 10 gives a breakdown of CO_2 emissions in the NPO-LC and REF-LC scenarios in 2050, together with the historic emissions data for 2005 for reference. The breakdown shows that about two-thirds of total CO_2 generated is attributable to the power sector, with the residential and transport sectors together claiming a large share. Most of the CO_2 generated from power generation is geologically stored using CCS technologies. The results show that additional CCS requirements in 2050 in the case of no nuclear power will be about 170 $MtCO_2$/yr, which equates to annual emissions from coal-fired power plants of around 30 GW capacity.[14]

[14] Assuming a CO_2 emission factor of 95g/MJ LHV for coal, 80% capacity factor and 40% efficiency (LHV) with CCS.

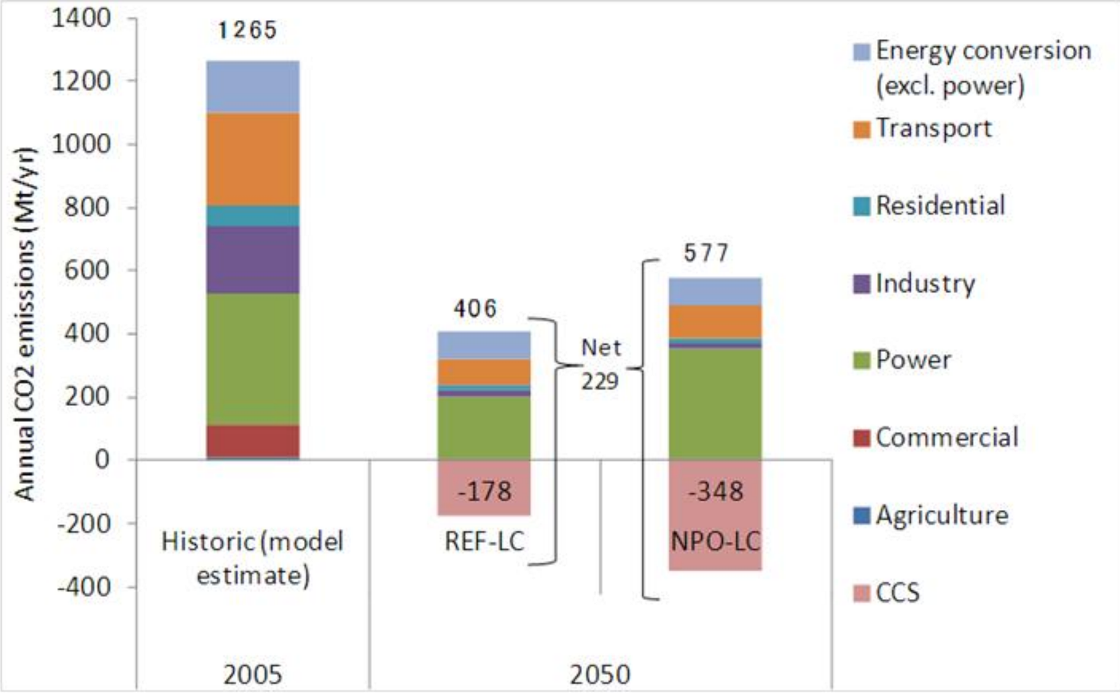

FIGURE 10: BREAKDOWN OF CO_2 EMISSIONS IN 2050 FOR THE SCENARIOS WITH MID- TO LONG-TERM CO_2 EMISSIONS REDUCTION TARGETS. HISTORIC EMISSIONS DATA FOR 2005 IS ALSO GIVEN FOR REFERENCE.

4.2.4 Total Energy System Cost

Figure 11 gives a comparison of the discounted total energy system cost for 2010-2050 between the NPO-LC scenario and the REF-LC scenario. The figure shows that the 80% reduction of CO_2 emissions in 2050 compared to the 1990 level will be more expensive and require higher fuel import costs with no nuclear power utilisation. It has been estimated that the total discounted fuel import costs for 2010-2050 increase by around 90 billion USD_{2000}, which is around 9 trillion JPY at today's value.[15] The major increase in fuel import occurs in the LNG sector in the medium term (until 2030) and then in the coal sector in the long term due to massive use of coal-based CCS technology deployment. It can be seen that LNG imports increase by around 50% by 2030 under NPO-LC compared to REF-LC and the coal imports increase by around 90% by 2050. Finally, the total discounted energy system cost varies by 1% between these two scenarios, which is around 92 billion USD_{2000}. In annual terms, the average energy system cost increase was found to be about 0.13% of national GDP (between 0.35% and -0.1%, depending on the year). Most of this cost increase is attributable to an increase in fossil fuel imports.

[15] Caution should be taken in interpreting this monetary value as it can widely vary due to several external factors in the world beyond the scope of this study and control of the model.

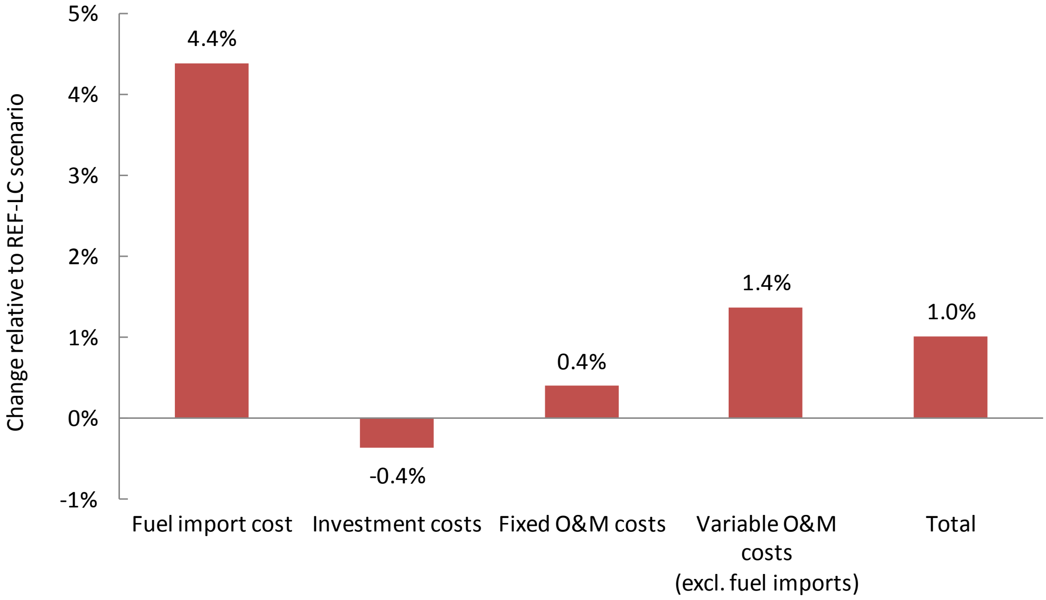

FIGURE 11: COMPARISON OF THE DISCOUNTED TOTAL ENERGY SYSTEM COST FOR 2010-2050 BETWEEN THE NPO-LC SCENARIO AND THE REF-LC SCENARIO. NOTE: THE NUMBERS UNDER EACH CATEGORY IN THE FIGURE ARE THE PERCENTAGE CHANGES OF A PARTICULAR COST COMPONENT. THEREFORE, SIMPLE ADDITION OF THE PERCENTAGE VALUES FOR INDIVIDUAL COST COMPONENTS DOES NOT LEAD TO THE TOTAL PERCENTAGE CHANGE.

4.2.5 Summary of Analysis II

Analysis II investigated the future energy mix toward 2050 when the CO_2 emissions are reduced by 80% in 2050 compared to the 1990 level with and without nuclear power. The results show that for the NPO-LC scenario, wind and solar power plants are installed up to 80 GW and 176 GW respectively, approaching the capacity limits set in this study (90 GW and 180 GW, respectively). Final energy consumption was found to drop by nearly 40%, from about 310Mtoe in 2009 to 200Mtoe in 2050, which was slightly lower than that for the scenarios without explicit mid- to long-term CO_2 emissions reduction targets. Most of the final energy consumption is shifted from primary fuel to electricity with CCS to meet the 80% target. Consequently, electricity generation gradually drops until 2030, but rises again toward 2050. Large-scale deployment of CCS is essential to achieve the 80% target without the use of nuclear power; the results show that the additional need for CCS will be 170Mt/yr, and the total requirement will be 350Mt/yr in 2050 with zero nuclear power. The increase in discounted total energy system costs for 2010-2050 for the NPO-LC scenario compared to the REF-LC scenario was found to be 1%. In annual terms, the average energy system cost increase was found to be about 0.13% of national GDP. This cost comparison is only limited to the energy production, transportation, and consumption-related issues. But such massive quantities of inter-fuel substitution would require changes in end-use technologies, consumption patterns of society and other economic structures. All these actions have impacts on the overall economy. Unfortunately, those costs are not included in this study. However, at best, the no-nuclear scenario is a cautiously optimistic one for Japan.

4.3 Sensitivity Analysis

In this study a sensitivity analysis has been conducted on international fuel price variations. It is observed that fuel prices play a key role in terms of determining the total system cost of a scenario. However, in the TIMES model structure, as the fuel prices are endogenously determined by the model based on the given cost of production at pit or well head, transportation and other transaction costs, different cost parameters of the model are accordingly adjusted to increase the final fuel price in the market by around 20% for LNG, crude oil and coal compared to the standard price used in the reference scenario.

Sensitivity analysis indicates that the renewable energy scenario becomes dearer in a higher fossil fuel price context, which demonstrates the importance of continued efforts to promote renewable energy in the country based on the threat of endless global market price hikes in fossil fuels. If fossil fuel prices increase by 20%, the discounted total system cost differential between FF and REN scenarios becomes only 0.04% compared to the normal price situation, which is around 0.2%. However, for LCS scenarios the cost differential between scenarios with and without nuclear increases to 2% from 1% in the normal price case. This indicates that if the fossil fuel prices (coal, oil and LNG) increase, the cost of achieving a long term CO_2 emissions reduction target of 80% by 2050 without nuclear power supply becomes more expensive, provided all other costs remain unchanged.

5. Policy Implications

The results obtained provide a number of insights into the large-scale deployment of renewable energy and the realisation of a long-term GHG reduction target without dependence on nuclear power. However, the modelling results obtained in this study should be analysed together with overall macroeconomic impacts, risks and public acceptance of nuclear power as presented in Table 2. The study highlights that greater integration of renewable sources into the supply system could provide notable advantages to the country in terms of ensuring energy security and achieving emission reduction targets. Transitioning to a supply system dominated by renewable energy could also set the country on the path to the holy grail of energy independence [16]. Renewable energy development is also critical from the Green Economy Perspective–as echoed in the New Growth Strategy (promulgated by the Japanese government), which states that “green innovation highlights the importance of investing in renewable energy from the Green Economy perspective.” The analysis conducted in this study is also in tune with the policy approaches aimed at by the Japanese government related to science and technology, and employment and human resources, both of which are essential to the country's long term sustained economic growth [17]. The additional discounted total energy system cost for 2010-2050 for the energy transition to achieve the 80% emission reduction estimated in this study was found to be only about 1%, hence should be embraced as being within the parameters of Green economy investment objectives. The sections below discuss certain critical aspects that are vital to examination of the growing importance of renewable energy sources, and also re-examine the relevance of nuclear power in post-Fukushima Japan.

[16] While complete energy independence is a global ideal, the term refers to a much more practical situation where a country eventually reduces the dependence on external sources and relies more on the domestic supply capabilities (Nandakumar Janardhanan, “Rethinking the myth that we cannot make energy independence financially feasible,” Japan Times, June 27, 2011).

[17] The New Growth Strategy: Blueprint for Revitalizing Japan, Government of Japan, June 18, 2010, Accessed: http://www.meti.go.jp/english/policy/economy/growth/report20100618.pdf, 30 March, 2012.

5.1 Increasing Renewable Energy Supply under a Nuclear Phase-out Scenario

Analyses I and II clearly illustrate the significant potential and importance of increasing renewable energy supply in a possible nuclear phase-out. Analysis I shows that the renewable energy promotion scenario is only marginally more expensive than the fossil fuel-dependence scenario—even when the grid stabilisation costs required to overcome the intermittency of renewable sourced electricity are factored in—and significantly reduces fossil fuel imports. The result of Analysis II has shown that in order to achieve an 80% reduction of CO_2 emissions by 2050 compared to the 1990 level without relying on nuclear power, it is necessary to introduce renewable energy to the highest extent possible, which is also economically rational and attractive. These results therefore indicate both a strong incentive and necessity to realise large-scale deployment of renewable energy technologies if Japan is to reduce its dependence on nuclear power.

The realisation of large-scale deployment of renewable energy in Japan's energy system will require the implementation of policy tools such as the Feed-In Tariff (FIT) scheme and ambitious renewable energy targets. In addition, national level support for improving the grid infrastructure for large scale renewable electricity development would be required. Although renewable energy can contribute to the reduction of fossil fuel imports, it may significantly increase the imports of equipment and materials for building renewable energy facilities, including those related to storage technologies, if the domestic renewable energy technology industry is not competitive. Anxiety has already surfaced in Japan's battery manufacturing industry due to heightened market competition with its Korean counterparts (AutoblogGreen, 2011). It is therefore crucial for the Japanese government to support R&D activities in renewable energy technologies, for two key reasons: to protect market competitiveness and enhance energy security.

5.2 Achieving the Long-term GHG Emissions Reduction Target

The results of Analysis II have shown that in order to achieve an 80% reduction in CO_2 emissions by 2050 compared to the 1990 level, the increase in discounted total energy system costs for 2010-2050 for the gradual nuclear phase-out scenario compared to the pre-Fukushima nuclear scenario was found to be 1%. . A substantial increase in fossil fuel imports is also observed for the entire period assessed in this study (2010-2050). However, from the perspective that the long term economic impact on the country may not be negligible (based on the available technology and its cost), drafting of the GHG reduction policy needs to be undertaken with the utmost care. On the other hand, it is also hard to predict over a timespan of two to three decades exactly what technological progress might be made, as a solution to all problems might emerge at a reasonable cost. Thus any market-based policy tools that enable an economically optimal reduction in GHG emissions will be of great importance.

The obtained results also strongly indicate the need for CCS technology development. The 80% reduction scenario without nuclear power (NPO-LC) requires geological storage of 350 $MtCO_2$/yr. Regarding the technical feasibility of such large scale CCS, the geological storage potential in Japan may become a bottleneck. An assessment made by RITE (Ito, 2008) indicates that in Japan the storage potential for relatively reliable reservoirs is about 5.2 $GtCO_2$ with an "ultimately feasible" potential of 146 $GtCO_2$. The NPO-LC scenario in our study showed that the amount of CO_2 that needs to be stored geologically between 2020 and 2050 is about 4Gt, which is nearly 80% of the relatively reliable reservoir capacity. Although technological development will likely expand the potential of geological storage of CO_2, securing feasible sites will become crucial. Large CCS deployment will also require massive investment for infrastructural development, which requires the government to take the initiative and set up a long-term plan for CCS technology development and deployment.

Possible options to reduce the heavy reliance on CCS include a further shift from coal to natural gas and tighter control over energy demand. The former option is likely to result in additional costs, even in a society constrained by the reduction of GHG emissions. The latter option (energy efficiency and conservation) may be achieved by more advanced changes in lifestyle and economic structure without necessarily compromising the quality of life.

5.3 Re-examining the Share of Nuclear Power in the Post-Fukushima Energy Mix

The results of this study have shown that achieving significant reductions in CO_2 emissions without nuclear power will be more costly than with nuclear power. However, concerns over the feasibility of continued reliance on nuclear power surged in the aftermath of the Fukushima accident, which necessitates a careful examination of the future trajectory of this sector in the face of the potential danger it presents to society. Measures such as nuclear plant operator liability and additional risk cost[18] are adopted to address the potential risks associated with nuclear power facilities. The nuclear liability law requires the plant operator to pay out about 120 billion JPY as compensation in the event of a nuclear accident. However, taxpayers and electricity users already have a tab of several trillion JPY awaiting them due to the Fukushima accident. The liability law, which specifies that “government will take the responsibility of compensating for the damage in case of extreme cases of natural disasters” holds the general public liable for the damage caused by the 3/11 tsunami. A crucial question that needs raising in this context is “To what extent should the citizens of Japan support a power industry if it presents monetary liability and health hazards?”

The use of nuclear power in Japan depends not only on the central government’s position but also on the local governments and local populations; public opinion will continue to be the determining factor influencing the nuclear policy.[19] Concerns about seismic sensitivities, and the potentially incalculable impact of natural disasters shape the perception of safety of nuclear power facilities. To a notable extent nuclear power has lost credibility[20] among various sections of the society and the anti-nuclear sentiments have reached a level that would make any significant nuclear development

[18] In light of the potential risk of a nuclear accident, a technical committee was established by the Japan Atomic Energy Commission (JAEC) last year to assess the additional risk cost of nuclear facilities, which, based on an operational rate of 80% and 60%, was estimated at 0.006–0.008 JPY/kWh based on radiation release from an existing reactor, or 1.2–1.6 JPY/kWh for one reactor accident every ten years. Risk assessment of nuclear power is complex and depends on the potential accident. While there are tangible measures such as deriving a risk cost based on assumptions about nuclear accident possibility, various intangible components such as impact on society and environmental health remain as unknowables and are thus unquantifiable economically.

[19] Public opinion played a critical role in the building of nuclear power plants over past decades. The siting of a nuclear power plant was cancelled by a local referendum in Maki-machi, Niigata prefecture in 1997 (see Kohta Juraku, Tatsujiro Suzuki, Osamu Sakura, Social Decision-making Processes in Local Contexts: An STS Case Study on Nuclear Power Plant Siting in Japan, East Asian Science, Technology and Society: an International Journal (2007) p-57).

[20] The perception of credibility is based on public anxiety over the continued reliance on nuclear power. Drawing from the experiences of Hiroshima and Nagasaki, there is widespread concern over the adverse impacts of radiation on the

[20] The perception of credibility is based on public anxiety over the continued reliance on nuclear power. Drawing from the experiences of Hiroshima and Nagasaki, there is widespread concern over the adverse impacts of radiation on the environment as well as on future generations. The Fukushima accident has undeniably magnified this perception, which contributes to shaping the credibility of nuclear power facilities.

in the country difficult[21]. According to a recent survey 65% of the respondents opined that Japan should completely abandon nuclear power (Jiji Press, 2012) and 57% opined that nuclear power plants currently under periodical maintenance should not be restarted (Asahi Shimbun, 2012). In addition, according to a survey on the public acceptability of nuclear power conducted by the Institute for Global Environmental Strategies (IGES) in July 2011, more than 65% of the respondents opined that nuclear power is not an acceptable energy option for Japan (Asuka et al., 2011). This reflects the fact that, irrespective of benefits the economy may enjoy, nuclear power is unlikely to have continued support from the citizens of Japan. It is important for the government to take this element into consideration when formulating policy for the nuclear sector.

While Analysis II indicates that under REF-LC scenario the system cost will be lower, the relevance of nuclear power needs to be assessed not only on the basis of any economic advantage it brings but also the risks. Vulnerability of the facilities to a higher magnitude earthquake or tsunami and the potential psychological shock a disaster can cause to populations are important factors that need to be taken into account. Moreover, judging the relevance of nuclear power in any form of assessment must prioritise the inevitable cost in terms of mental suffering and health of future generations related to radioactive fallout. In this context it emerges as an ethical decision rather than a short term economic assessment to decide what sort of trade-off—between reliance on nuclear power and the risks—is more beneficial for the country in the long term.

5.4 Limitations of the study

Although the analysis performed in this study provided many useful insights into the future energy system and CO_2 emissions for a phase-out of nuclear power by 2050 in Japan, there are a number of limitations to the scope of the study.

First, it does not account for the engineering feasibility of large-scale development and deployment of low-carbon technologies such as CCS, wind and solar power. The large-scale development and deployment of these technologies can only be realised step by step over a long period of time with a significant amount of investment ("2050 Japan Low-Carbon Society" Scenario Team, 2009). Although this engineering limitation is beyond the scope of this study and cannot be handled by the existing model, it is a factor of key importance for the realisation of a low-carbon society and therefore should not be underestimated.

Second, this study did not investigate the policy measures required to realise such large-scale renewable energy deployment and long-term CO_2 emissions reduction. Although this is outside of the scope of our research it is important to note that achieving highly ambitious CO_2 emissions reductions and levels of renewable energy deployment wholly depends on the efficacy of policy measures.

Third, the issue of the intermittent supply characteristics of renewable energy that may hinder its use as a base load substitute is not fully covered in this study. This study addresses this important issue by use of two assumptions: (1) setting a minimum level of gas and oil-fired power generation, which enables flexible operation and acts as buffer to the grid instability, and (2) implicitly assuming that batteries are equipped for wind and solar power plants after 2030 to minimise the stress on the grid. However, our

[21] Endo, Tetsuya. (2011), Interview with Ambassador Tetsuya Endo conducted by Nandakumar Janardhanan, 19 October. Tokyo, Japan

approach to the issue has been somewhat simplified and requires future improvements.

Fourth, the energy service demand driver assumptions, which are indicators of lifestyle and economic structure, were not altered for the different scenarios investigated in this study. Under the 80% CO_2 reduction target, further reduction in energy demand is required in order not to rely too heavily on renewables and CCS. Other studies ("2050 Japan Low-Carbon Society" Scenario Team, 2009; MoEJ, 2012c) have demonstrated that the energy mix as well as the level of CO_2 emissions reduction can differ significantly due to differing paths taken by society leading up to 2050. Although this study refrained from controlling energy service demands in any scenario as it was beyond the scope, the implications of future lifestyle and economic structure in relation to the long-term CO_2 emissions reduction require further research.

Fifth, this study does not fully cover the damages related to the Fukushima accident. In this study, about 2 JPY/kWh is assumed to be added to conventional O&M costs to account for cost components such as fuel cycle costs, policy-related costs and disaster compensation costs. The cost figures are taken from the NPU (2011). However, considering the extent[22] of damage a nuclear accident can cause it is practically impossible to quantify the risks in economic terms. Moreover, the continued use of nuclear energy will certainly require large scale investment in ensuring the above mentioned elements. Radiation leaks have immeasurable consequences: impacts on a certain region, effects on the population and future generations, displacement of inhabitants, direct and indirect implications on the agriculture sector and livestock, potential impacts of oceanic resources, concerns regarding the fresh water quality, etc.

There are also a number of limitations regarding the TIAM-WORLD model. First, the model only covers the energy system but not the entire economy. Therefore, the model does not take into account the dynamic effects such as the changes in economic growth rates and energy prices due to CO_2 emissions caps or economy-wide impacts due to the large-scale deployment of renewable energy technologies or the increased use of fossil fuel energy. These factors need to be considered to clarify the economic impacts of whatever energy source is chosen to replace nuclear.

Second, the study did not consider the regional variation of renewable energy potential within Japan, which might have a substantial impact on the overall national long-term energy scenario. Because Japan is modelled as a single regional block in TIAM-WORLD, the potential grid-related bottlenecks in the case of large-scale renewable electricity deployment—such as the limited inter-regional transmission capacity and the utility frequency difference between East and West Japan pointed out in Section 0—are not fully taken into account. This may become particularly important for wind power because there is a large mismatch of regions with high wind power potential and regions with high electricity demand, thus a significant portion of wind power energy may need to be exported to other regions. Although this issue is factored-in for the upper limit for wind power capacity set in the analysis and the incremental capital costs added to new wind and solar power plants, a more detailed analysis that involves splitting Japan into multiple regional blocks would be necessary.

[22] In the wake of the accident about 160,000 people from Fukushima prefecture are still unable to return to their homes permanently. Any quantification of risks in monetary terms will not be able to address such hardships presented to society.

6. Conclusions and Recommendations

This study assessed the implications, for Japan, of a long-term phase-out of nuclear energy supply toward 2050 and its replacement by renewable energy—unhindered by the technical aspects of intermittency. It is assumed that there will be no new commissioning of nuclear power plants and mandatory decommissioning of old power plants at the end of their 40 life. This study performed two sets of modelling analyses using the technology driven bottom-up TIMES Integrated Assessment Model (TIAM-WORLD). The indicators used in the comparison are: (1) total energy supply system cost, (2) amount of fossil fuel import, and (3) CO_2 emissions.

The first analysis (Analysis I) assessed the implications of the choice of energy source: renewable energy or fossil fuel, to compensate for the nuclear power phase-out by 2050. In Analysis I, the renewable energy promotion (NPO-REN) scenario and the fossil fuel-dependence (NPO-FF) scenario were compared in the absence of any long-term GHG target but with same amount of CO_2 emissions, with a view to highlighting the difference between the two options for energy source choice. The results showed that the renewable energy promotion scenario is only 0.2% more costly than the fossil fuel-dependence scenario in terms of discounted total energy system cost for 2010-2050. The increase in annual total energy system cost for the renewable energy promotion scenario compared to the fossil fuel-dependence scenario is on average 0.04% of national GDP. Moreover, the renewable energy promotion scenario also showed significantly lower fossil fuel imports, which increases the national wealth to a value approximating the total increase in system cost.

The second analysis (Analysis II) investigated the scenario with mid- to long-term GHG emissions reduction targets (80% reduction of CO_2 emissions in 2050 compared to 1990 level) and a nuclear phase-out by 2050. The results show that in the nuclear phase-out (NPO-LC) scenario, wind and solar power plants are installed to the capacity limit of 80 GW and 176 GW, respectively. Final energy consumption was found to drop by nearly 35%, from about 310 Mtoe in 2009 to 200 Mtoe in 2050, which was similar to that for the scenarios without GHG targets. The major part of final energy consumption needs to be shifted from primary fuel to electricity with CCS to meet the 80% target. Without the use of nuclear power this points to the necessity of large-scale deployment of CCS to achieve the 80% target, as the additional need for CCS in the nuclear phase-out scenario was projected to be 170Mt/yr in 2050 higher compared to the pre-Fukushima nuclear development scenario (REF-LC scenario). The increase in discounted total energy system costs for 2010-2050 for the NPO-LC scenario compared to the REF-LC scenario was found to be 1%. In annual terms, the average energy system cost increase was found to be about 0.13% of national GDP.

The study demonstrates that transitioning from a fossil-fuel nuclear dominated energy mix to a renewable energy dominated fuel mix is economically feasible and environmentally attractive as the country can achieve an 80% emission reduction at a limited increase in energy system costs. Japan's target of an 80% emission reduction can be achieved with a fuel mix that comprises a higher share of alternative energy sources, advanced energy efficiency technologies and economically viable carbon capture options.

Based on the results obtained, the following recommendations are highlighted in order to ensure long term energy security while meeting the environmental goals:

Achieving 80% with a No-Nuclear Energy Mix is Economically Attractive: Under the 80% emission reduction scenario, the increase in total annual energy system cost is estimated to be on average 0.13% of national GDP. This additional cost is not prohibitively high in light of the financial risk and environmental damage associated with nuclear accidents. Further, renewables offer a long-term economic advantage as well as job creation in the green sector. Considering Japan's commitment to playing a leading role in climate mitigation it is important for the country to give adequate policy attention to a 'no-nuclear – high ambition' energy mix.

Need to Promote Investment for Building CCS Facilities: About 170 Mt/yr of additional CO_2 may need to be buried by 2050 if nuclear energy is not utilised as per the pre-Fukushima plans. Early action in the development of a competitive CCS industry would be required to achieve this target. However, caution should be taken in undertaking such a massive scale of CCS in the country as its geological structure is vulnerable. To avoid a heavy dependence on CCS, it is considered safer and more economically preferable to give emphasis to structural changes in the economy by allowing more renewables, investing more in energy efficiency and conservation measures, investing more in leap-frogging technologies that can reduce emissions, technological risk and energy vulnerability.

Need to Address Socio-political and behavioural Aspects:
The two analyses conducted in this study showed significant reduction in final energy consumption largely due to energy efficiency improvement, energy conservation (partly incorporated in activity drivers) and the switch from primary energy to electrical energy toward 2050. However, these results are based on economical optimization, suggesting that the energy use would be reduced as the model results suggest without any policy because consumer behaviour is not always economically optimal. Therefore, adequate measures need to be taken to realize the energy demand reduction as projected in this modeling study, taking into consideration the behavioural aspects towards how energy is used."

Necessity of Regulatory and Institutional Reform in the Power Sector for Promotion of Renewable Energy: The Analysis shows that a higher level of renewable energy integration is necessary to decarbonise the energy mix, which requires a higher level of investment to exploit all possible alternative energy sources. Renewable energy deployment on a massive scale requires technical, institutional, regulatory and legal changes in the existing age-old system dominating the Japanese energy market. Changes in these areas will be the critical determinants in influencing the investment decisions of private players in the alternative energy sector and the sector's long term stability.

Promote R&D in Alternative and Advanced Energy Technologies: Promotion of R&D on the advanced energy technology front is important in the context of the energy scenarios analysed above. The increase in system cost can be significantly suppressed by promoting innovation and technological development in the alternative energy sector.

Ensure Adequate Supply of Natural Gas: Analysis II shows that Japan's electricity supply needs to switch over to gas-fired power plants, based on their potential to replace nuclear power facilities and reduce CO2 emissions until the point where renewable sources can meet a significant share of demand. Considering the potential adverse impacts due to demand surges in many parts of the world, it is important for Japan to develop strategies to secure reliable natural gas supplies through long-term supply contracts from major producing regions.

Appropriate Changes in Current Lifestyle and Economic Structure Envisaged. Japan is now at a developmental crossroads–with the chance of a new paradigm emerging for the economy, society and environment. The current circumstances thus act as an ideal opportunity for the country to redirect its development down the green economy pathway by promoting not only low-carbon energy technologies but also significantly less-energy intensive lifestyle and economic structure. For example, the way Japan dealt with the shortage of power supply in the summer of 2011, provides a valuable lessons about the realization of a green economy in the long term through controlling energy demand without sacrificing much of desired quality of personal life. Such lesson could be further used in other sectors of the economy, too. Further, the Tohoku reconstruction region could play a key role as a test bed for the whole nation to initiate this green economic revolution.

Build Financial Tools to Support the Alternative Energy Industry: The sustainability of the alternative energy sector heavily depends on continued governmental support in terms of tax incentives and subsidies. This analysis highlights the importance of financial tools such as Feed-In-Tariff (FIT) to promote a significant level of alternative energy integration.

Appendices

Appendix A: Economic Indexes Used in this Study

TABLE A- 1: HISTORIC U.S. CONSUMER PRICE INDEX FOR 2000-2010 (U.S. BUREAU OF LABOR STATISTICS, 2012)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CPI (2000=1.00)	1.00	1.03	1.04	1.07	1.10	1.13	1.17	1.20	1.25	1.25	1.27

TABLE A- 2: HISTORIC CURRENCY CONVERSION RATES FOR 2000-2010 (OANDA, 2011)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
USD/JPY	107.8	121.5	125.2	116.0	108.2	110.1	116.3	117.8	103.4	93.6	87.8	79.7

Appendix B: Energy Service Demands and Drivers for Japan

TABLE A- 3: ENERGY SERVICE DEMANDS AND THEIR DRIVERS FOR JAPAN REGION IN THE TIAM-WORLD MODEL USED IN THIS STUDY (KANORS, 2012). THE DEMANDS WITH ASTERISKS (*) ARE THOSE WITH DEMAND DRIVERS MODIFIED FROM THE ORIGINAL TIAM-WORLD TO TAKE THE JAPANESE SITUATION INTO ACCOUNT.

Demand	Driver	
Transportation		
Passenger transport (all modes) *	person-km	
Freight transport (all modes) *	ton-km	
Residential	After 2050	Before 2050
Space heating	HOU	HOU
Space Cooling	GDPP	HOU
Water Heating	POP	POP
Lighting	GDPP	GDPP
Cooking	POP	POP
Refrigeration and Freezing	GDPP	HOU
Washers	GDP	HOU
Dryers	GDPP	HOU
Dish washers	GDPP	HOU
Other appliances	GDPP	GDPP
Others	GDPP	HOU
Commercial (all demands)*	Total commercial floor space (m^2)	
Agriculture	SPROD-Agriculture	
Industry	All regions	
Iron and steel *	Crude steel production (tons)	
Non-ferrous metals	Crude steel production (tons)	
Chemicals *	Ethylene production (tons)	
Pulp and paper *	SPROD-OEI (average IIP of the two sectors)	
Non-metal minerals *		
Other industries	SPROD-OI	

Abbreviations: HOU: households, POP: population, GDP: gross domestic product, GDPP: GDP per capita, SPROD-X: industrial output of sector X, IIP: Index of Industrial Production

Appendix C: Performance Data for New Wind and Solar Power Plants in Japan

Estimation of incremental capital costs for grid stabilization

Incremental capital costs per kW of installed capacity for grid stabilisation to cope with the intermittency of solar and wind power are derived from the short to medium term estimates (2012-2030) by (MoEJ, 2012b). Table A-4 presents detailed figures of how the costs were derived. The referenced document presents cost estimates using two different approaches: (1) Conventional approach assuming batteries for all installed wind and solar power plants and installations of pumped storage hydropower plants (PSH), (2) Integrated (and more cost-effective) approach for the entire grid system with no battery installation until battery costs drop (2030 in this case) and no additional PSH.

The referenced document indicates that the second approach is considerably cheaper than the first, yet feasible for the targeted wind and solar capacity in 2030 (32 GW and 106 GW, respectively). In this study, we assumed the second approach until 2030 and the first approach after 2030, assuming that the installation of batteries becomes necessary to accept highly intermittent electricity. In addition, it is assumed that after 2030 battery costs decrease to one-third of that assumed for the short to medium term in the referenced document.

TABLE A- 4: ESTIMATION OF INCREMENTAL CAPITAL COSTS FOR GRID STABILISATION MEASURES DUE TO LARGE-SCALE WIND AND SOLAR POWER DEPLOYMENT

Cost component	Unit	Integrated approach (before 2030)	Conventional approach (after 2030)
Solar specific costs	Trillion yen	2.6	2.6
Wind specific costs	Trillion yen	0.1	0
Common costs [1)]	Trillion yen	1.94	6.3 [2)]
of which allocated to solar	Trillion yen	1.48	4.80
of which allocated to wind	Trillion yen	0.46	1.47
Additional capital cost per kW [3)]	Unit	Before 2030	After 2030
Solar	yen/kW	40846	74006
	$\$_{2000}$/kW	273	495
Wind	yen/kW	18515	49093
	$\$_{2000}$/kW	124	328

[1)] Includes costs for batteries, pumped storage hydro plants, operation of fossil fuel power plants for peak-flattening, inter-regional gridlines, etc.
[2)] Battery cost is assumed to be one-third of that assumed in the referenced document. $1USD_{2011}$=$79.7JPY_{2011}$, (year average currency rate; OANDA 2012). $1USD_{2000}$=$1.8USD_{2011}$ (IHS CERA 2012).
[3)] Calculated on the assumption that solar and wind power capacities increase by 100 GW and 30 GW, respectively.

Total capital cost figures used in this study compared to National Policy Unit estimates

Table A-5 shows the capital cost data for wind and solar power technologies used in this study in comparison with the estimates from the National Policy Unit (NPU, 2011b). The estimates from NPU do not include costs related to grid stabilisation. The comparison shows that our costs estimates for wind power are on the lower side of the range indicated by NPU. For solar power, on the other hand, our estimates are higher than the range indicated by NPU.

TABLE A- 5: CAPITAL COST DATA FOR WIND AND SOLAR POWER TECHNOLOGIES USED IN THIS STUDY IN COMPARISON WITH THE ESTIMATES FROM THE NATIONAL POLICY UNIT (NPU, 2011B). NOTE THAT THE ESTIMATES FROM NPU DO NOT INCLUDE COSTS RELATED TO GRID STABILISATION. N.A.: NOT AVAILABLE.

Year	Capital costs (in USD_{2000}/kW)							
	Solar PV		Solar CSP		Wind onshore		Wind offshore	
	This study	NPU	This study	NPU	This study	NPU	This study	NPU
2010	4750	3181-3645	4570	2319-3645	1460	1325-2319	2590	N.A.
2020	2310	1524-1763	3960	1226-1948	1380	1246-2319	2400	1875-4638
2030	1640	1252-1458	3350	1047-1670	1300	1173-2319	2220	1723-4638
2040	1620	N.A.	2950	N.A.	1420	N.A.	2230	N.A.
2050	1390	N.A.	2340	N.A.	1340	N.A.	2050	N.A.

Appendix D: Fossil Fuel Power Plants

Table A-6 presents the key data for fossil fuel-fired power generation technologies used in this study. The performance data presented here is based on that used in the Dutch MARKAL model (MARKAL-NL-UU) developed by Utrecht University (van den Broek et al., 2008). The reason for using MARKAL-NL-UU data instead of that estimated by the National Policy Unit (2011) is because the former uses the technical and economic performance data of existing and advanced technologies collated by Damen et al. (Damen et al., 2006, 2007) for industrialised countries sourced from a wide literature with consistency in terms of, e.g., cost definitions and CO_2 capture rates.

TABLE A- 6: KEY DATA FOR FOSSIL FUEL-FIRED POWER GENERATION TECHNOLOGIES USED IN THIS STUDY. SOURCE: OWN CALCULATIONS BASED ON VAN DEN BROEK ET AL. (2008) AND DAMEN ET AL. (2006, 2007).

	Capital cost ($2000/kW)				Efficiency (%-LHV)			
Technology \ Year	2010	2020	2030	2040	2010	2020	2030	2040
NGCC	840	760	760	760	58.0%	60.0%	63.0%	64.0%
PC (USC)	1980	1850	1770	1670	46.0%	49.0%	52.0%	53.0%
IGCC	2440	2230	2060	1890	46.0%	50.0%	54.0%	56.0%
NGCC-CCS	1420	1260	1160	1040	49.0%	52.0%	56.0%	58.0%
PC-CCS	3100	2850	2600	2350	36.0%	40.0%	44.0%	47.0%
IGCC-CCS	3190	2680	2350	2180	38.0%	44.0%	48.0%	50.0%

Abbreviations - NGCC: natural gas combined cycle, PC: pulverised coal, USC: ultra-supercritical, IGCC: integrated gasification combined cycle, CCS: CO_2 capture and storage.

In order to use the aforementioned MARKAL-NL-UU data in the current Japanese context we took the following steps. First, the original cost data expressed in $€_{2000}$ was converted to USD_{2000} using the conversion rate of 1 $€_{2000}$=0.924USD_{2000}. Second, the cost data was adjusted to take into account the higher cost increase for power plant construction costs compared to the increases in other commodity prices. The adjustment factor is derived by comparing the data with the latest fossil fuel power plant cost estimates (with and without CO_2 capture) from Schlumberger & Worleyparsons (2011), which was discounted from USD_{2010} to USD_{2000} terms by using the U.S. Consumer Price Index (U.S. Bureau of Labor Statistics, 2012). It was found that the GCCSI cost estimates were a factor of 1.22-1.54 higher than the MARKAL-NL-UU data, therefore the adjustment factor of 1.5 was used for this study. In addition, the location factor of 1.2 was applied based on Schlumberger & Worleyparsons (2011) to account for the regional differences in power plant construction costs.

Table A-7 compares the capital cost data used in this study and that estimated by the National Policy Unit (NPU, 2011b) in USD_{2000} terms. The capital cost data used in this study is overall lower than that estimated by the NPU. For NGCC, we consider the NPU estimate to be very conservative. The Kawasaki natural gas power plant built in 2008 is quoted to have 58% efficiency (LHV) and cost 25 billion JPY_{2008} for 420 MW capacity, which is equivalent to 580 USD_{2008}/kW (Inose, 2011). Even if this plant is considered to be an economically optimal case, we consider the NPU estimate to be too pessimistic. For coal-fired power plants, the cost estimates for 2010 show similarity between the two estimates, but our study is more optimistic on future cost reduction and efficiency improvement.

Table A- 7 compares the capital cost data used in this study and that estimated by the National Policy Unit (NPU, 2011b) in USD_{2000} terms. The capital cost data used in this study is overall lower than that estimated by the NPU. For NGCC, we consider the NPU estimate to be very conservative. The Kawasaki natural gas power plant built in 2008 is quoted to have 58% efficiency (LHV) and cost 25 billion JPY_{2008} for 420 MW capacity, which is equivalent to 580 USD_{2008}/kW (Inose, 2011). Even if this plant is considered to be an economically optimal case, we consider the NPU estimate to be too pessimistic. For coal-fired power plants, the cost estimates for 2010 show similarity between the two estimates, but our study is more optimistic on future cost reduction and efficiency improvement.

TABLE A- 7: COMPARISON OF CAPITAL COST AND EFFICIENCY DATA ESTIMATED IN THIS STUDY AND THE NATIONAL POLICY UNIT (2011). NPU ESTIMATES DO NOT DISTINGUISH IGCC AND PULVERISED COAL POWER PLANTS.

Parameter	Year	Data source	Technology		
			NGCC	PC (USC)	IGCC
Capital cost ($\$_{2010}$/kW)	2010	This study	1060	2510	3090
		NPU	1400	2680	N.A.
	2020	This study	960	2340	2830
		NPU	1400	2680	
	2030	This study	960	2240	2610
		NPU	1400	3350	
Efficiency (%-LHV)	2010	This study	58%	46%	46%
		NPU	56%	44%	N.A.
	2020	This study	60%	49%	50%
		NPU	63%	44%	
	2030	This study	63%	52%	54%
		NPU	63%	50%	

Abbreviations - NGCC: natural gas combined cycle, PC: pulverised coal, USC: ultra-supercritical, IGCC: integrated gasification combined cycle, CCS: CO_2 capture and storage.

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Chapter 3 – The Power-saving behavior of the residential sector in the wake of the Great East Japan Disaster

Chapter 3 - The power-saving behavior of the residential sector in the wake of the Great East Japan Disaster

Hidefumi Katayama, and Kazunobu Onogawa

1. Introduction

1.1 Background

The nuclear accident at the Fukushima Dai-ichi Nuclear Power Plant on March 11, 2011 resulted in the shutdown of nuclear power plants in Japan - and by May 5, 2012, all 54 nuclear were offline including the four that had been decommissioned at Fukushima. As a result, Japan is facing formidable energy constraints. In order to resume nuclear power plant operations, regular inspections, stress tests or further safety examinations are required, as well as consent from the local governments. However, the government's safety regulations themselves have now been tarnished, causing distrust among the stakeholders, which has led to deliberation at the national diet on the need to establish a new agency for nuclear safety, as well as new regulations. Japan relies on nuclear power for nearly one-third of its power needs, thus is now facing a crisis in supply, raising not only the issue of stop-gap solution but also the need for fundamental debate on its long-term energy policy towards developing a sustainable society. Currently, the Cabinet's Energy and Environment Council is in the process of developing a new energy and environmental strategy based on discussions at the Advisory Committee for Natural Resources and Energy and the Central Environment Council.

However, the development of any energy-related strategy needs to be addressed from the demand as well as the supply side. For energy demand in the residential and commercial sector in particular - the control of which is complex - a bottom-up approach from local governments, communities, and residents in addition to a top-down approach from the central government is critical. Such a frontline grassroots approach calls for scaling up both steps that can be taken by residents, including those to save energy (especially electric power) at the household level, as well as coordinated governmental support for such efforts, with a focus on public behavior patterns and changes in the technologies available to households.

In terms of energy saving strategies Japan is one of the strictest countries in the developed world, and the government has taken a number of stringent measures, including standardising temperature settings for air conditioners, encouraging sensible use of lighting, and curbing the use of escalators and elevators. Various measures are also in place to support energy saving efforts at the household level, among which are the introduction of the "top-runner" program for home appliances, financial incentives for purchasing high-efficiency home appliances, and incremental power charges, all of which are designed to improve energy use efficiency and curb energy demand. The government also encourages the public to adopt less energy-hungry lifestyles through information campaigns, including a campaign for higher air conditioner temperature settings and "Cool Biz" (cool business) dress modes for summer.

The above efforts, however, have failed to halt the rise in energy consumption in the residential and commercial sector. The figure for FY2009 represents a 140% increase from FY1973—the first “oil shock.” This compares to a 90% increase for the transport sector and a 10% drop in the industrial sector. This big leap in residential and commercial consumption can be attributed mainly to higher standards of living, i.e., more living space and more electric appliances in homes, as well as an increasing number—and shrinking size—of households. Attempting to match the drop in consumption in the industrial sector will thus require more innovative ways to control consumption in the residential and commercial sector.

Power companies in Japan have recently being attempting to kick-start disused LNG, oil and coal power plants in order to fulfill the shortfall in power created by the shutdown of nuclear power plants, yet the supply-demand situation remains serious. To curtail power demand, in the summer of 2011 the government launched an extensive power-saving campaign and imposed a cap on power use for large consumers such as factories. As a result, manufactures shifted operations to the night time and at the weekends, supplemented power with generators, and diversified their supply chains. Railways cut down on suburban and subway trains. Tokyo Electric Power Company (TEPCO) implemented rolling blackouts throughout its service area. In sum, all power consumers exerted maximum efforts in order to navigate the colossal peak of power demand that reared in the summer of 2011.

On May 13, 2011 the government imposed a 15% reduction in power usage across the board to take effect on June 1 (Electricity Supply-Demand Measures in Summer Time) and issued instructions for large and small corporate consumers as well as households. For large consumers (500 kW+), in accordance with Article 27 of the Electricity Business Act, this meant a 15% reduction from the previous summer, for the anticipated peak periods and hours in the summer of 2011. This complemented voluntary action by all power users but also ensured fairness across the board and ensured the necessary amount of power was saved. As a result electric energy sales in TEPCO’s service area in July and August 2011 posted a year-on-year reduction of 14.1% and 15.7% for large and small consumers, respectively.

These experiences represent a major transformation in public awareness and give rise to numerous opportunities for energy saving in Japan; specifically, opportunities that need to be explored in the industrial, transport, and residential and commercial sector. Of these, the latter requires special attention because of the intrinsic difficulty in terms of controlling demand. Accordingly, this sector calls for a unique, multifaceted approach.

For the residential and commercial sector, one aspect to be addressed is regional characteristics if energy supply and demand is to be balanced at the regional level. Assessing the regional characteristics of the climate, residential buildings, and energy-based product ownership will help design a policy geared towards informing consumers to adopt effective and sustainable measures.

The age and household makeup of the target groups constitute another aspect because of how they affect behavioral traits such as commitment to saving energy. Promoting effective energy saving in the residential and commercial sector requires focusing on these themes in assessing a range of behavioral changes towards energy saving. Analysing the inter-relationships between these factors will provide insights into how energy can be used more efficiently to consolidate power-saving practices.

Japan needs both near- and longer-term approaches. In the face of a lack of power supply capacity, the initial approach should be to curtail peak demand to keep it within the supply capacity. Subsequently the focus needs to shift to total energy use, especially if Japan is to strive for sustainable society. This study focuses on this longer-term approach.

2. Analysis of household power-saving behavior in Kanagawa Prefecture

2.1 Fact-finding survey

To analyse the public's power-saving behavior, the authors conducted an on-line survey in January 2012 on 1,000 married adults in 1,000 households in Kanagawa Prefecture. Kanagawa accounts for a large share of energy use in the National Capital Region and is an area with relatively low climactic variation. The survey subjects were carefully selected so that as a group they were consistent with the findings of the National Census in terms of age and sex makeup.

In this survey, the authors obtained from utility company data the monthly consumption figures for electricity, gas, and kerosene over 2010 and 2011 - the period embracing the Great East Japan Earthquake. Surveyed was the use of air conditioners, lighting, and ownership of home appliances, actions that were taken to save power in the summer, winter, and throughout the rest of the year, as well as knowledge of energy-saving. These aspects were summarized in terms of 51 power-saving actions. Also assessed was the extent of awareness of power-saving and energy policies implemented by the central government and Kanagawa Prefecture in the household sector in summer 2011.

2.2 Power consumption and power-saving behavior in the residential sector

Tokyo Electric Power Company (TEPCO) does not disclose data on total power consumption of Kanagawa Prefecture, because its power distribution districts do not coincide with the administrative districts. For this reason, the authors estimated and compared total power consumption of the prefecture in 2010 (pre-disaster) and 2011 (post-disaster) from the data on total power consumption of the households of the 1,000 subjects (Figure 1).

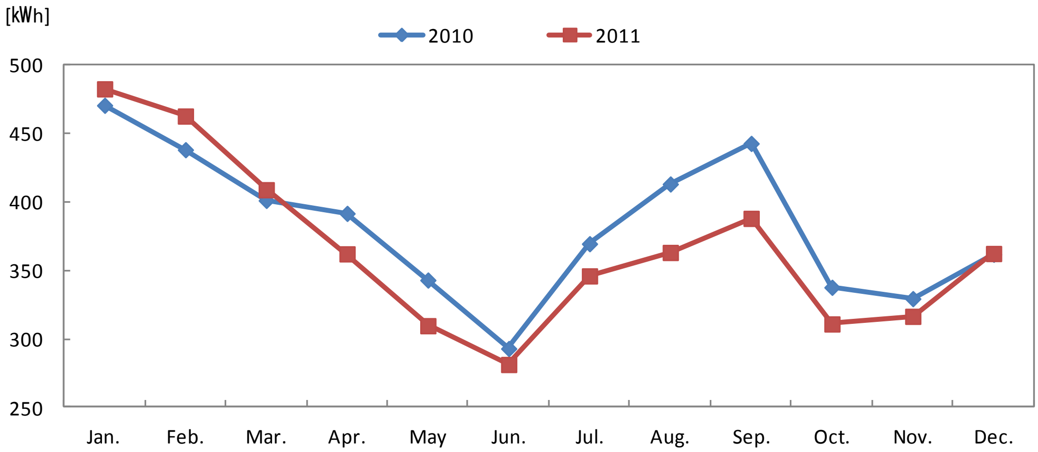


Figure 1: Changes in monthly power consumption per household (corrected for temperature; N=961)

To assess the net effect of the "power demand control" (power-saving) behavior of the public corrections were made for temperature, as this has the greatest impact on power consumption. Temperatures in 2011 were assumed to be equal to 2010.

Figure 1 shows that power consumption was lower in and after April of 2011 - due to tight supply-demand in the aftermath of the March 11th disaster - than in the same period a year earlier. Note that TEPCO implemented rolling blackouts for 10 days starting on March 14, 2011, excluding weekends. As a result, almost all businesses and households in its service area experienced several hours of power outage in rotation. The impact of these planned outages is reflected in the power consumption in March 2011. TEPCO set out a policy not to execute rolling blackouts in April 2011 onwards, citing its assumption that power demand for heating would start to dwindle at the end of March 2011. No planned outage has been implemented since then.

Power consumption was lowest in June. Although power-saving efforts might have played a part, this is due mainly to the fact that the use of air conditioners, considered to account for the largest portion of power consumption, was lowest during this period. Air conditioner usage therefore has a huge influence on the observed changes in power consumption.

The power-saving effect was evident from July to September 2011, due in part to the "power-saving support program" that the government launched in June to raise public awareness and provide incentives for power saving. The power-saving effect began to wane in October, partly because the use of air conditioners was lower in and after October, when the power-saving program ended.

The power-saving support program was quite successful. Efforts by households and others to refrain from using air conditioners - the main focus of the campaign - were so intense as to result in occasional cases of heatstroke, which attracted media attention.

In winter, on the other hand, the power-saving effect was the smallest. Major factors include the lifting on September 9, 2011 of government restrictions on power use that had been imposed in accordance with Article 27 of the Electricity Business Act, and the lowered public awareness in the need for power saving half a year after launch of the campaign.

2.3 Seasonal power-saving effect

The authors analysed the power-saving effect in the summer (July and August) of 2011 and examined the contributing factors. The results are shown in Figure 2.

According to TEPCO, household consumption in its service area in the summer of 2011 (total for July and August combined) recorded an approx. 11.8% drop (corrected for the effect of the temperature) from the same period a year earlier*, as against a target reduction of 15%. In order to compare these values with the power consumption in Kanagawa Prefecture, the formula shown below was used to calculate the power-saving effect in summer per household in Kanagawa Prefecture. As shown in Figure 2, the subject households reduced their power consumption by 11% from the same period a year earlier. This figure was consistent with a year-on-year reduction of 11.8% in electric energy sales of TEPCO in its service area in the corresponding period.

The average household saved about 87 kWh during the summer (July and August) of 2011. This translates as a total saving of some 328 GWh for all 3,784,887 households in the prefecture.

(* TEPCO estimates that the summer temperature of 2010, which was unusually high, had the effect of pushing up power consumption by 3%.)

The power-saving effect is obtained via the following formula:
Power-saving effect in summer per household (%) = (Power consumption in summer of 2010 [corrected for temperature] - Power consumption in summer of 2011) / Power consumption in summer of 2010 x 100

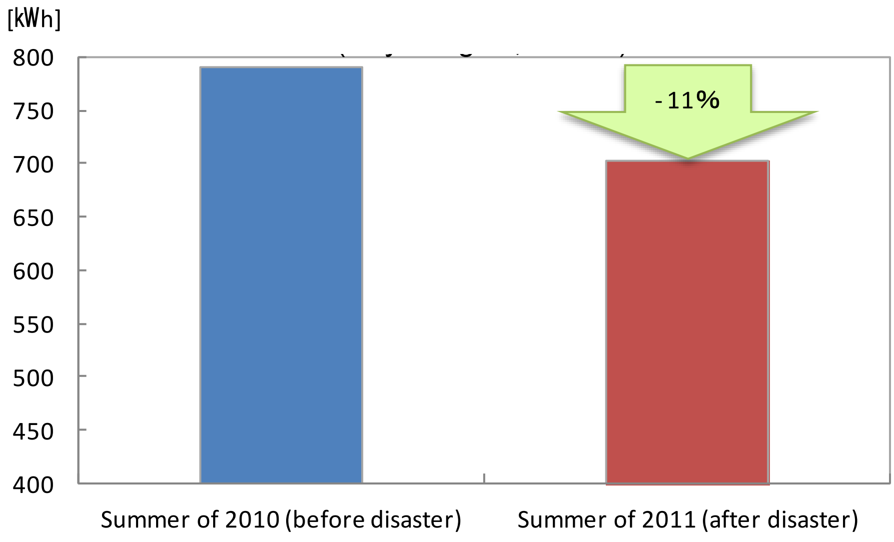


FIGURE 2: YEAR-ON-YEAR CHANGE IN POWER USE PER HOUSEHOLD IN SUMMER (JULY-AUGUST; N=961)

Figure 3 shows the year-on-year change in the amount of power the average household in Kanagawa Prefecture used in the winter. Note that winter, which spans a period from December to February for Kanagawa in terms of average temperature, is represented by December alone because this study covers a period from January 2010 to December 2011.

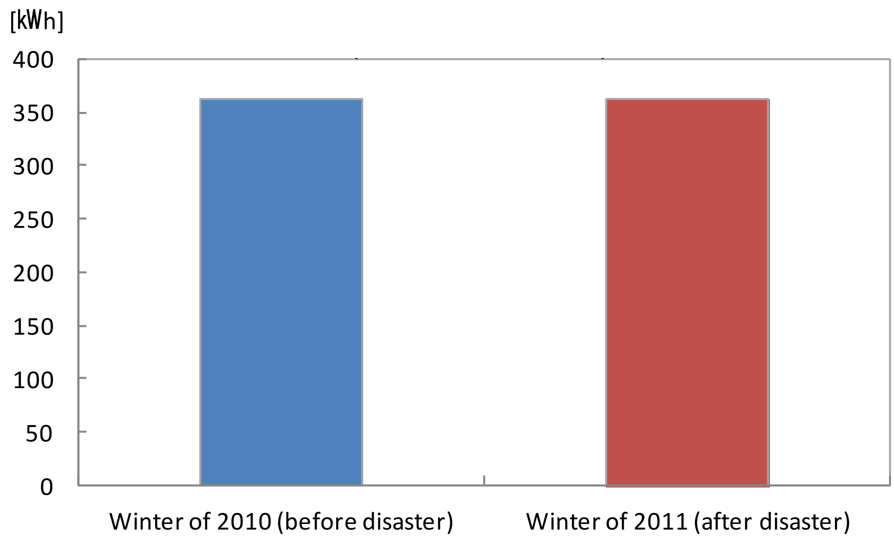


FIGURE 3: YEAR-ON-YEAR CHANGE IN POWER USE PER HOUSEHOLD IN WINTER (DECEMBER; N=961)

As shown in Figure 3, the change from 2010 to 2011 is negligible for December.

2.4 Specific power-saving actions and analysis thereof

The authors then analysed the findings of the fact-finding survey to determine what actions the subject households took to save power. Such actions were diverse, ranging from a change in lifestyles to purchases of energy-efficient equipment and home insulation.

To promote such actions, governments often use financial incentives and regulations. In July 2009, the Japanese government introduced the “eco-point” system, which was designed to encourage consumers to replace their appliances with more energy-efficient ones and upgrade their home insulation. The eco-point system for green home appliances ended in March 2011, the baseline month for this study. It is thus safe to conclude that most of the power-saving actions after the Great East Japan Earthquake stemmed from lifestyle changes.

This study covered 51 energy-saving actions as shown in Table 1. These actions are extracted from those promoted by the central government and Kanagawa Prefecture in their respective power-saving campaigns.

TABLE 1: POWER-SAVING ACTIONS (EXCERPTED FROM THE WEBSITES OF THE GOVERNMENT'S "POWER-SAVING SUPPORT PROGRAM" AND KANAGAWA PREFECTURE, AND OTHER SOURCES)

Action No.	
1	Avoid over-filling the refrigerator.
2	Shut the refrigerator door as soon as possible after opening it.
3	Avoid placing heat emitting objects near the refrigerator.
4	Avoid turning up the TV sound more than necessary.
5	Minimize the number of times to open the refrigerator door.
6	Keep a perimeter space of 5 cm or more on either side and a space of 20 cm or more above the refrigerator.
7	Avoid making the TV screen brighter than necessary.
8	Add seasonal adjustments to the temperature setting of the refrigerator.
9	Watch only TV programs you really want to; avoid watching TV idly.
10	Use a refrigerator curtain to limit the outflow of cold air.
11	Turn off the TV when you are not watching it.
12	Make arrangements so that the liquid crystal TV screen is not exposed to direct sunlight.
13	Use a fan to circulate the cool air indoors when the air conditioner is on in the summer.
14	Avoid watching TV while doing something else.
15	Set the air conditioner at 28 degrees Celsius in the summer.
16	When not watching TV, turn off the master switch.
17	Clean the filter of the air conditioner twice a month or so.
18	Turn off the set top box when it is not in use.
19	Place a shade over the outdoor unit of the air conditioner in the summer.
20	Reduce the radiant heat from the outdoor unit of the air conditioner by connecting to the drain hose another hose with holes on it.
21	Use the air conditioner for cooling only when necessary.
22	Use the air conditioner for heating only when necessary.
23	Wear an extra layer of clothing in winter to stay warm.
24	Try to use a fan in place of an air conditioner for cooling.
25	Keep the cooling time to a minimum with the good use of a timer.
26	Use long, thick curtains or bubble wrap so as not to let the heat out of the windows.
27	Set the air conditioner at 20 degrees Celsius in the winter.
28	Use reed or bamboo blinds, green curtains, or other articles so that the inside walls are not exposed to direct sunlight.
29	Use a fan to circulate the warm air indoors when the air conditioner is on in the winter.
30	Before using the air conditioner, pour cold water over its outdoor unit in the summer.
31	Do the laundry in bulk.
32	Limit the period of the keep-warm mode of the electric rice cooker to four hours.
33	Make sure that power will not be wasted when you are out of town by, for example, deactivating power-on timers.
34	Adjust the power mode of the vacuum cleaner according to floor type.
35	When using an iron, take advantage of its remaining heat.
36	Turn off the hot water dispenser before going to bed.
37	Avoid using the keep-warm mode of the hot water dispenser.
38	In the summer, take a drink out of the refrigerator when it becomes cold enough and pour it into a thermos on the table.
39	Use window insulation sheets.
40	Cook rice on the stove and avoid using an electric rice cooker.
41	Make sure to close the lid of a washing toilet with a built-in heater.
42	Replace the fridge, air conditioner, TV or light with a more energy-efficient one.
43	Take advantage of PC power options to save energy.
44	Prewash the dishes in a bowl of water before putting them into the dishwasher.
45	Avoid using the drying feature of the dishwasher and let the washed dished air-dry.
46	Save standby power consumption by unplugging appliances when not in use.
47	Clean the filter of the air cleaner regularly.
48	Check how much power your home appliances consume to identify those with high power consumption.
49	Check your contracted current supply.
50	Reduce your contracted current supply.
51	Check the total monthly power consumption for your household.

(1) Power-saving behavior and specific actions

Table 1 is a list of 51 electricity power saving actions as suggested by the Japanese government and Kanagawa prefectural government to support power-saving actions in homes during the summer and winter of 2011. This comprehensive list covers major appliances in homes such as air conditioners, fridges and TVs and also actions such as wearing more clothes in winter, as well as behavioural changes through promoting energy efficiency by improving building insulation, checking monthly utility bills and the power ratings of appliances.

Figure 4 summarises the findings from the survey. These exclude appliances that had ownership rates of less than 70% and actions related to these appliances. Of the remaining actions, shown in the Figure are subjects who were unaware of them, did them, or became aware of them post-disaster (probably through power-saving campaigns) but failed to do them.

Power-saving actions with an execution rate of over 50% are those that were already in the public consciousness (Figure 4). A higher execution rate does not necessarily mean a higher power-saving effect since different power-saving actions have different levels of effect. Regardless, a reduction of 11% is the result of all these power-saving actions.

Some of the power-saving actions were known already by over 30% of the public before the March 11th disaster but not carried out anyway. Among them were "Watch only TV programs you really want to; avoid watching TV idly," "Save standby power consumption by unplugging appliances when not in use," "Set the air conditioner at 28 degrees Celsius in the summer, "Avoid watching TV while doing something else," and "When not watching TV, turn off the master switch." Some of these actions may entail a negative impact on such aspects as convenience, comfort, and lifestyle. Others may require a measure of behavior change that involves much time and effort. These difficulties suggest that different approaches are needed to make these rather irksome actions more acceptable among the public. It may be viable, for example, to provide additional incentives on top of the conventional approach of raising public awareness about the need for power saving.

The power-saving actions taken by 70% or more of the subjects can be classified into three types: (i) three highly effective actions of limiting the use of the air conditioner, including substituting it with a fan; (ii) five actions concerning the refrigerator; and (iii) three actions concerning TVs. Actions involving washing machines, refrigerators and other appliances the use of which the subjects can make a difference with on their own initiative tend to have a higher execution rate than actions that affect comfort, including those involving air conditioners. This tendency suggests that the subjects were well aware of the need for power-saving actions—an observation that should be taken into account in addressing future measures.

Many of the power-saving actions with an execution rate of below 50% are those that the public were unaware of before the March 11th disaster. Looking ahead, it is important to raise public awareness of these actions, as they include those with high power-saving potential.

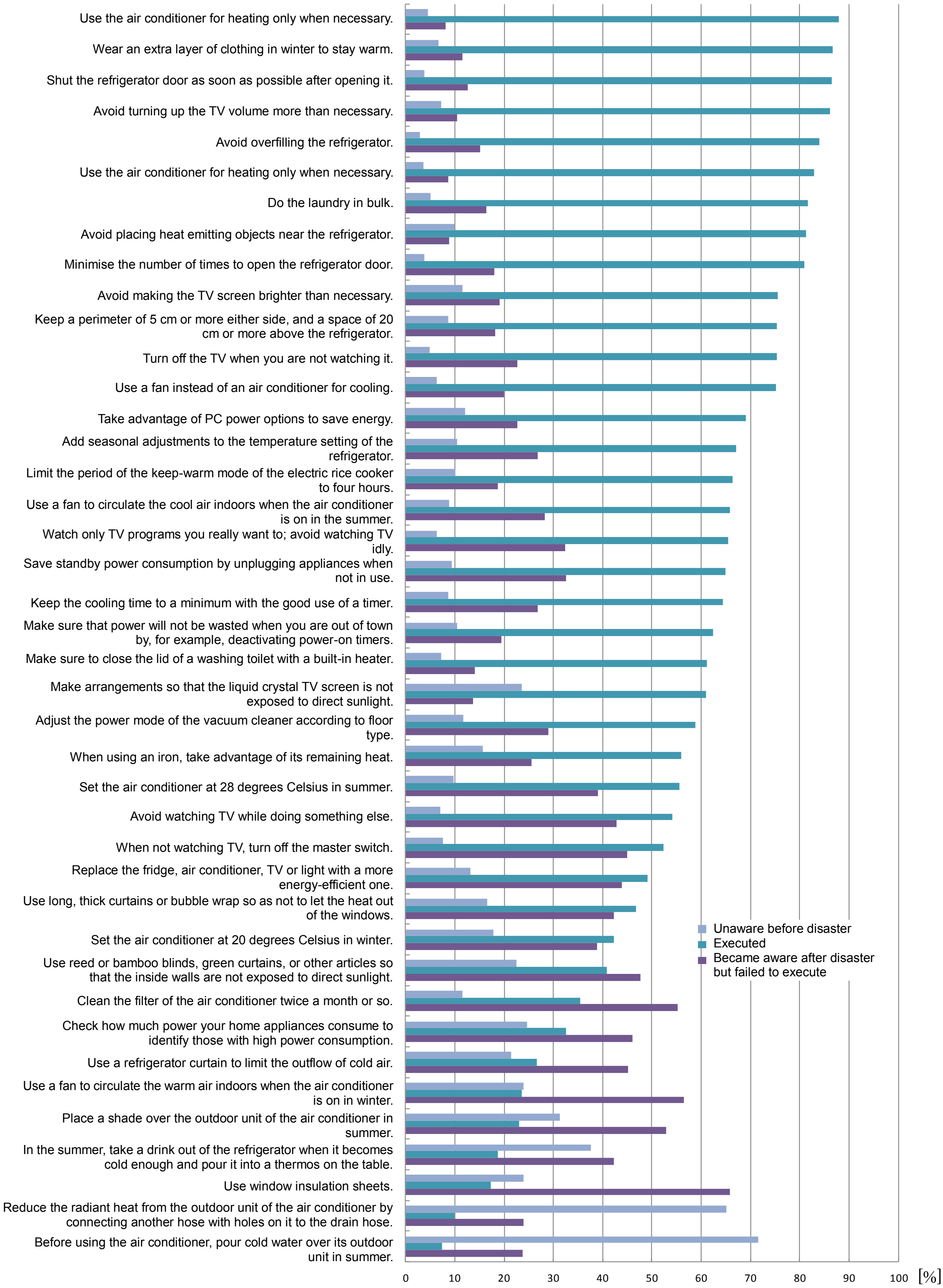


Figure 4: Pre-disaster awareness rate, execution rate, and rate of non-execution despite post-disaster awareness for each power-saving action

(2) Classification of power-saving actions

The power-saving actions are classified into three; A, B, and C depending on the level of cost and time and effort as defined in Table 2 (Figure 5).

TABLE 2: LEVELS OF COST AND TIME AND EFFORT ASSOCIATED WITH POWER-SAVING ACTIONS

Level	1	2	3	4	5
Cost (yen)	0-1000	1001-5000	5001-10000	10001-99999	100000-
Time and effort	Actions that can be taken by one household member once and for all	Actions that need to be taken twice a month and can be taken by one household member	Actions that need to be taken as necessary by all household members	Actions that need to be taken daily and can be taken by one household member	Actions that need to be taken daily by all household members

Most of the 51 power-saving actions are on Level 1 in terms of cost (0–1,000 yen). Only one action, that is, replacing appliances, is on Level 5 (100,000 yen or more), although this could be on Level 4 as energy-efficient appliances costing less than 100,000 yen are now available.

Here, category A is defined as the actions that can be done by the subject alone either once or twice a month, and cost less than around 5,000 Japanese Yen (JPY). Category B covers the actions that require either all of the family to do, or to attempt to do every day in terms of the level of effort, and that cost around 10,000 JPY. Category C is for the actions that cost more than 10,000 JPY, but only require such action once.

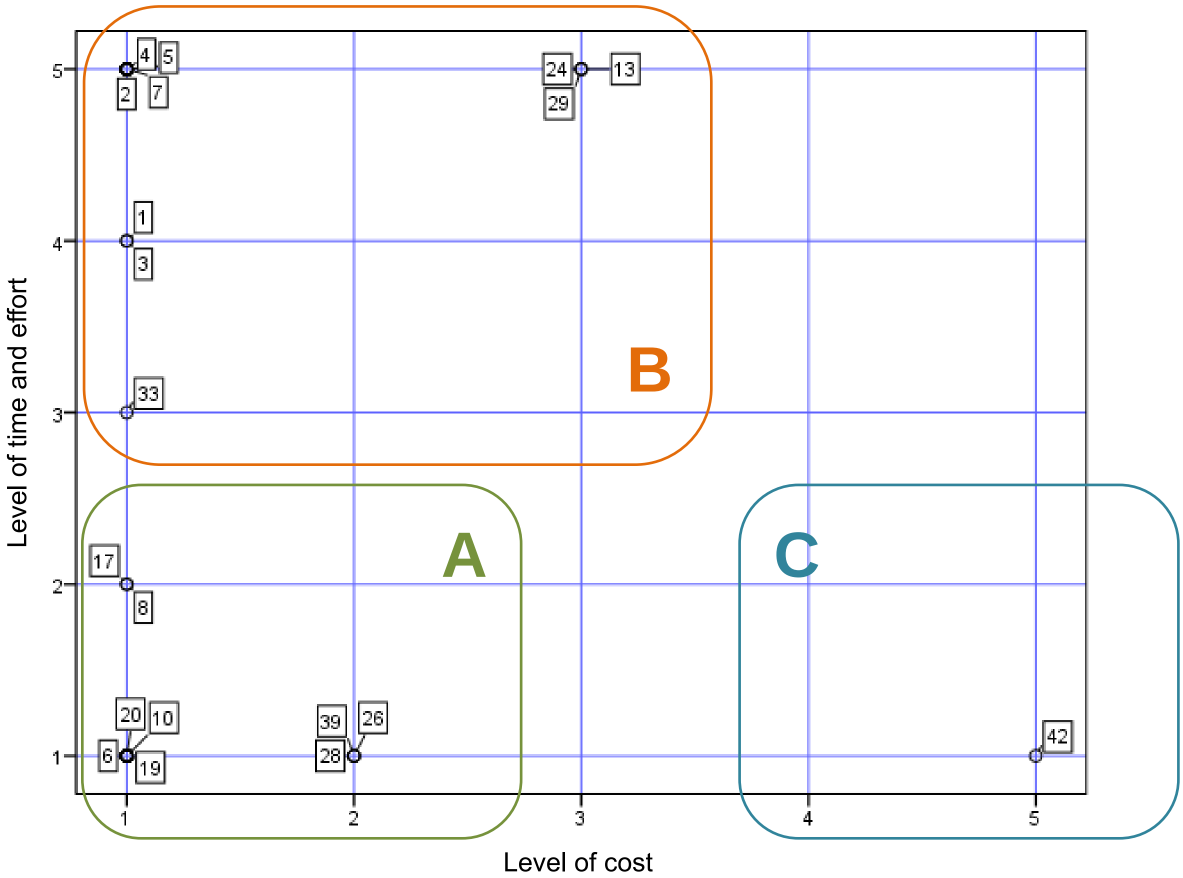


FIGURE 5: RELATIONSHIP BETWEEN COST AND TIME AND EFFORT ASSOCIATED WITH POWER-SAVING ACTIONS

Figure 6 shows the pre-disaster awareness rate, execution rate, and the rate of non-execution despite post-disaster awareness by category for each of the power-saving actions with an execution rate of less than 50%.

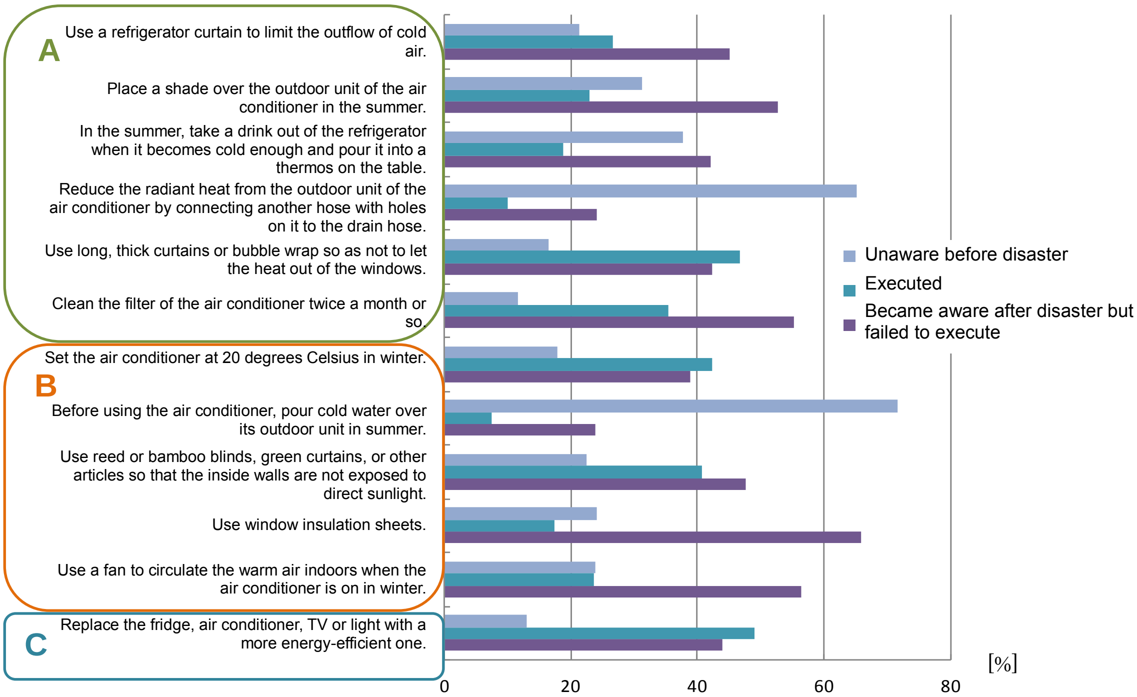


FIGURE 6: PRE-DISASTER AWARENESS RATE, EXECUTION RATE, AND RATE OF NON-EXECUTION DESPITE POST-DISASTER AWARENESS FOR EACH OF THE POWER-SAVING ACTIONS WITH AN EXECUTION RATE OF LESS THAN 50%

The execution rate is not necessarily high for Category A actions even though they are low in both levels of cost and time and effort. One contributing factor may be that the impact of power-saving actions (energy-saving performance) was not fully made known to the public, who consequently failed to understand the real value of behavioral change even though they were aware of such power-saving actions. To address the low execution rates, it is crucial to encourage the public to take steps to address the issue, possibly by the dissemination of numerical targets in order for them to make informed decisions.

Another viable approach is to communicate to the public that combining unpopular actions with popular actions will likely create a synergy effect, e.g., when using the air conditioner, insulate the windows, place a shade over the outdoor unit, and also use a fan to circulate the air better. The low execution rates of actions reflect two aspects: (i) the prospect of a compromise to lifestyles, comfort or convenience; and (ii) an inadequate knowledge of the need to take, or of the actions themselves. The first aspect concerns the lifestyles and preferences of the executors (mostly homemakers). For example, they may have set patterns in doing certain chores or simply dislike laundry piling up. The second aspect is exemplified by the lack of basic knowledge about the power consumption of their home appliances.

These two aspects call for different approaches. The first aspect should be addressed by devising power-saving actions or tips that will not compromise consumer lifestyles, comfort, or convenience. The second aspect should be addressed by developing a power-saving guide that provides basic knowledge of electricity and home appliances as well as power-saving tips. Such a guide should also describe the rationale and expected outcomes of these tips.

Category B actions include those that compromise comfort or call for changes in lifestyle. These actions call for a focused approach that will make up for the downside. It may be viable, for example, to combine actions that require changes in lifestyles with those that bring tangible benefits. For actions that involve air conditioners and thus have high power-saving potential, it may be advisable to promote “Warm Biz” - a campaign for wearing warmer clothes in winter. Technological innovation in the energy-saving business also has a significant role to play in this category. Category B actions also include those that the public was largely unaware of before the March 11th disaster, pointing to the need for information campaigns. Public commitment to power saving depends largely on the cost and ease of power-saving actions, as well as on the level of understanding or awareness of the impact of such actions.

The Category C action represents investment in equipment as highlighted by the replacement with more energy-efficient home appliances. The case in point is government subsidies that were designed to frontload such energy-saving investment. Looking ahead, it is important for home appliance manufactures to provide information on the life cycle costs of their products as well as to promote top-runner standards and consistent energy-efficiency labeling programs. Such information will allow consumers to better understand the cost-effectiveness of home appliances.

Among such subsidies which were those involving “eco-point” programs. In this system consumers gained “eco points” when they bought power-efficient home appliances and obtained a subsidy that corresponded with the number of such points under a special program (Program to Promote the Spread of Green Home Appliances by Utilising Eco-Points). Within a space of nearly two years (July 1, 2009 - May 31, 2011) nearly 0.634 trillion eco points had been collected by the public, and over 10.1 billion by corporations (August 7, 2009 - May 31, 2011).

The above case indicates the significant impact of providing economic incentives, thus should be born in mind at the time energy saving measures are required. The policy of providing economic incentives in energy-saving promotions via the government or other agencies should therefore be examined if energy-saving measures that entail personal investment are to be promoted.

(3) Power-saving behavior by age group

Power-saving behavior differed depending on the age group. Figure 7 shows the power-saving rate by age group for summer, the peak period for air conditioner use. The older the age group the greater the power-saving rate was, with the exception of the 70s group.

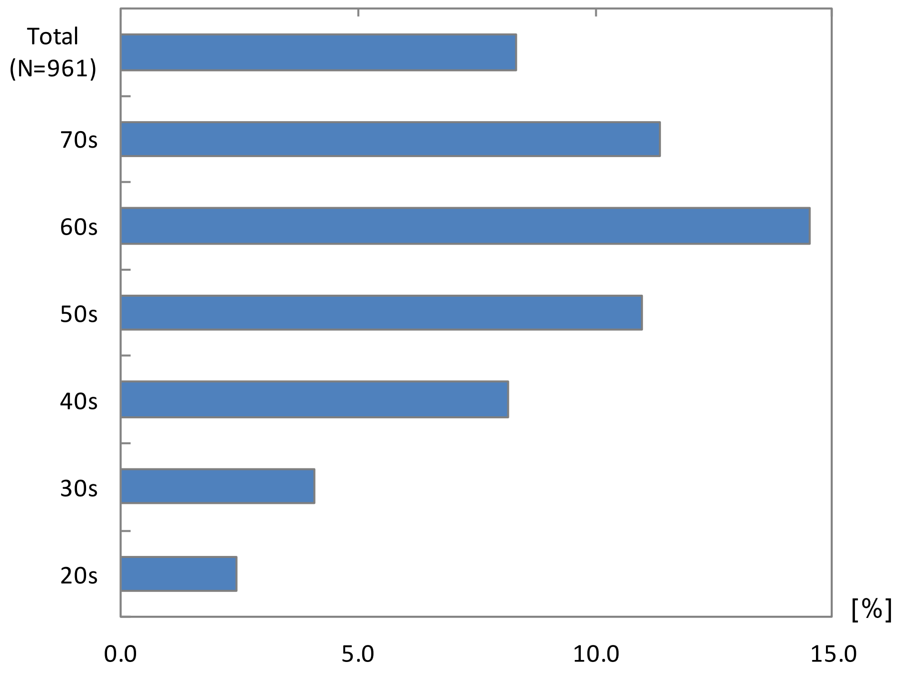


FIGURE 7: POWER-SAVING RATES DURING SUMMERTIME (JULY-SEPTEMBER) BY AGE GROUP

The power-saving rate for the 20s and 30s age brackets was less than half of the average. Looking ahead, the key is to address the younger generation.

Likewise, Figure 8 shows the power-saving effect during the year, including the winter when the power-saving campaign ended. The pattern for the year resembles that for the summer, pointing to the need to raise efforts to consolidate power-saving practices by the younger generation. Those in the 20-29 age bracket even increased their power consumption for the year. This highlights the need to encourage this age group to practice power-saving throughout the year.

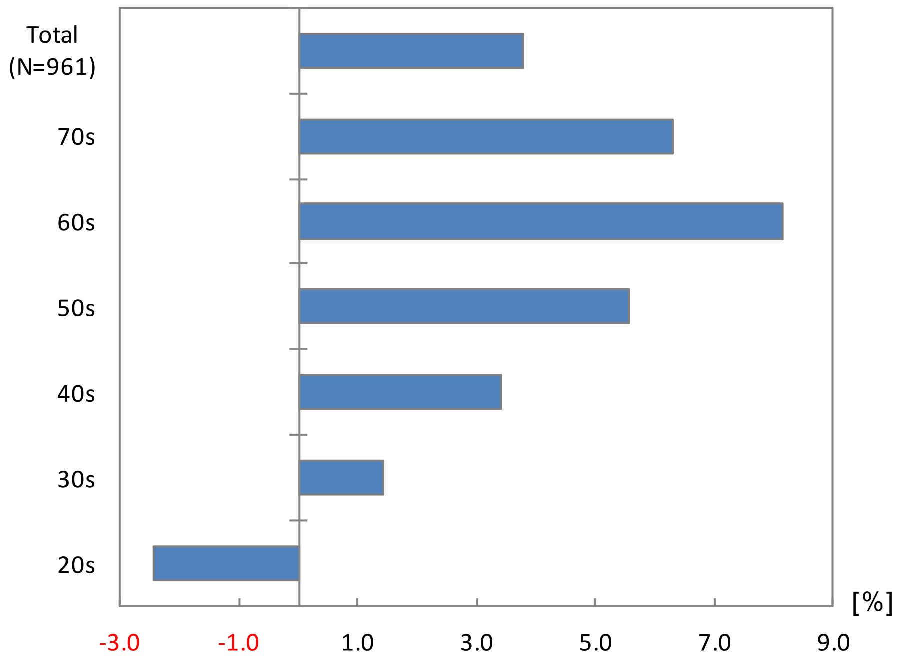


FIGURE 8: POWER-SAVING RATES DURING THE YEAR BY AGE GROUP

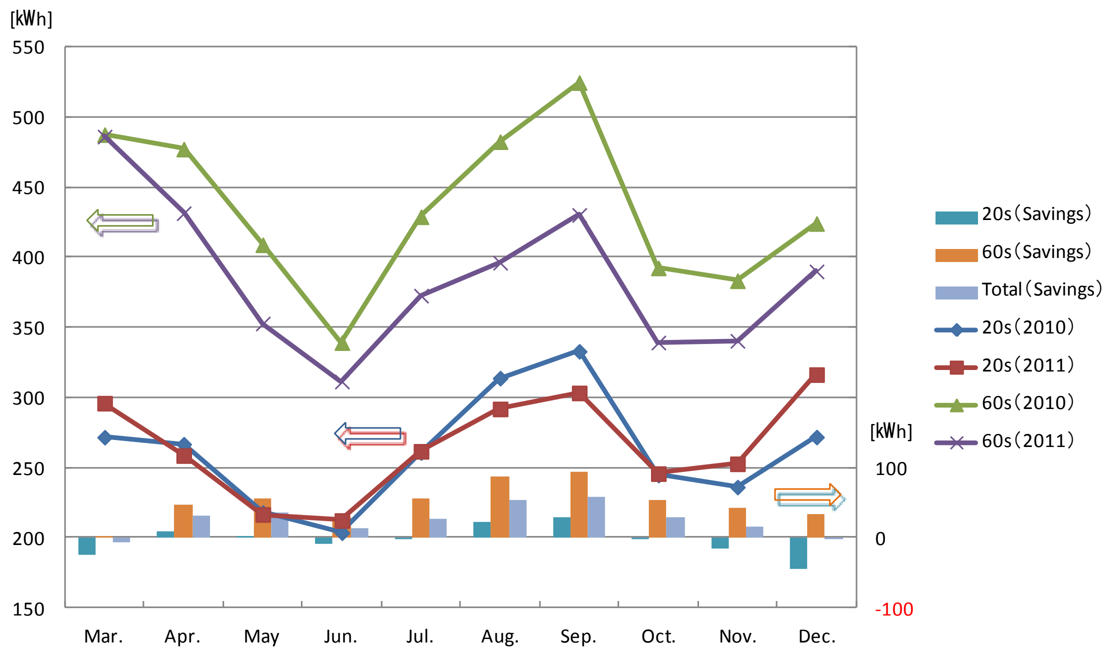


FIGURE 9: POWER CONSUMPTION AND POWER-SAVING AMOUNT IN MONTHLY TRANSITION PER HOUSEHOLD

Figure 9 shows total monthly electric power consumption compared to the previous year, and the energy saving amount for 2011, for the households represented by the respondents in their 20s and 60s. A tendency for those in their 20s and 60s to make efforts to save energy from July to September in summer can be seen; however, such efforts decreased from September to December. In particular, those in their 20s increased their consumption over the previous year, thus a negative energy saving amount arises in December. Conversely, the 60s group shows a consistency tendency to maintain energy saving throughout the year (though only the data for December is available for winter).

3. Conclusions and suggestions

This chapter examined the electric power consumption and power saving behaviour of 1,000 households in Kanagawa Prefecture, Japan, during the two years that included the great disaster in 2011. It analysed the energy saving actions during the summer in 2011 triggered by the great disaster, regarding energy efficiency promotion measures in the household sector, which is a more complex sector than the others.

The authors found that during the summer (July and August) of 2011, the subject households reduced their power consumption by 11% from the same period a year earlier. This figure was consistent with a year-on-year reduction of 11.8% in electric energy sales witnessed by TEPCO in its service area in the corresponding period. The power-saving effect increased until September 2011 when the government campaign ended. It declined in October onwards when the need to control peak demand dropped. Changes in monthly power consumption show that the power-saving effect was smallest in June and November, in which the use of air conditioners was low. This indicates that reduced use of air conditioners played a major role in saving power in the residential and commercial sector. The amount of power saved in December was negligible. However, the data at the beginning of winter indicates a tendency for the 60s households to consistently save electricity throughout the year, as opposed to the practice of those in their 20s.

Power-saving actions that can be taken by households are diverse, ranging from a change in lifestyles to buying energy-efficient equipment and insulating homes. To understand what actions households took to save power based on experience, the authors analysed the power-saving behavior in Kanagawa Prefecture. The traditional energy-saving actions that had long been recommended publicly were taken by more than half of the households, increasing the effect of recent power-saving efforts. The effect of power-saving actions, which maintained its importance in the summer of 2012 as well, can be increased by promoting the insufficiently performed actions, especially those with a low rate of pre-disaster awareness, and ensuring that other power-saving efforts will be maintained, in order to bring about a synergistic effect from the whole population.

Providing information that raises the popularity of power-saving efforts is important, as is identifying the age brackets that need targeting, as any such efforts are meaningless unless households are aware of them. The level of commitment that results from the household sector thus depends largely on the level of understanding of the impact of power-saving actions, as well on the cost and ease of carrying out such actions. It is therefore necessary to focus resources on encouraging power-saving actions that are inexpensive, require minimal lifestyle changes, and have a high potential to actually save power.

Household energy consumption is influenced by four major factors: climate and natural features, housing characteristics, equipment specifications, and household characteristics, including energy use behavior. This study found that age structure plays a part in energy consumption and the power-saving effect. It is already known that both total consumption and the consumption structure will change over life stages. Consequently, power and energy-saving measures should be designed in accordance with the target groups and adjusted for the age segment in question.

The purchase of energy-efficient home appliances for replacement is highly effective in saving energy as a sustainable measure. It is therefore desirable to promote a two-pronged approach of providing economic incentives such as subsidies and raising the level of understanding on the part of the public by, for example, providing information on the power-saving effect vis-a-vis the investment cost. It is a formidable task to promote energy and power saving in the residential and commercial sector, as it has such a diverse makeup. Looking ahead, important issues to be addressed may include devising ways to assess the characteristics of energy consumption more accurately, formulate concrete measures to be taken by the central and local governments, and evaluate any such measures taken.

Chapter 4 – Reconsidering Resilience: Vitalisation of Inter-municipality Collaboration in Northeast Japan Earthquake

Chapter 4 – Reconsidering Resilience: Vitalisation of Inter-municipality Collaboration in Northeast Japan Earthquake

Shinano Hayashi, Atsushi Watabe, Izumi Tsurita, Robert Kipp, and Hideyuki Mori

1. Introduction

1.1 Background

The massive magnitude 9 earthquake that occurred in the Pacific Ocean off the coast of Japan's Tohoku region on March 11, 2011 caused an enormous tsunami that subsequently struck over a wide area. This brought about significant damage to the four prefectures in the Tohoku region and resulted in the loss of nearly 20,000 lives. The sequence of disasters dealt an enormous blow to Japan's society. Japan, a country well-acquainted with earthquakes, has prided itself on having set in place disaster prevention and disaster response measures that have been honed from past experience. But it has become clear that its tsunami defenses, response to wide-ranging damage, and disaster mitigation measures to minimise damage over both hard and soft aspects were not necessarily fit for the task (Cabinet Office, 2012). The damage from the earthquake and tsunami also had an impact on the operations of not only Japanese manufacturers but those of other countries as well, severing supply chains of goods such as automobiles and electrical machinery. The nuclear accident caused power shortages over an extensive area that encompassed Tokyo, which plagued homes and businesses for a period of several months. Efforts for medium to long-term resettlement and for reviving the local economy have also not proceeded very smoothly.

In the aftermath, local municipalities and volunteers provided an incredible degree of assistance in post-disaster relief. Upon a directive issued by the Ministry of Internal Affairs and Communication on March 22, prefectures and municipalities from all over Japan dispatched large numbers of personnel and supplies to the affected municipalities (Ministry of Internal Affairs and Communications, 2011) (summary of personnel support (Ministry of Internal Affairs and Communications,2012) summary of material support (Ministry of Internal Affairs and Communications,2012)). At the same time, the volunteer activities that had flourished ever since the Great Hanshin-Awaji Earthquake also grew in intensity as the enormity of the Great East Japan Earthquake became apparent to the outside world, and these provided a significant contribution in supporting the affected regions. Over the two months after March 2011 as many as 216,800 people carried out support activities through the intermediation of volunteer centers in different regions (Japan National Council of Social Welfare, 2012).

1.2 The role of local municipalities in disaster resilience

Ever since the Great Hanshin-Awaji Earthquake of 1995 Japan has adopted a philosophy of disaster mitigation that minimises damage based upon the presupposition that it would be impossible to completely avoid damage from earthquakes and other natural disasters. Japan has made progress with setting in place hardware such as coastal levees in order to protect populations from tsunamis. Further, structures that minimise the damage from disasters and promptly rebuilding after them have been increasingly recognised by the international community in recent years, along with the concept of disaster resilience. Resilience is a concept that was coined by ecologists in the 1970s in discussing the recuperative ability of ecosystems, but since the 1990s it has expanded in meaning to embrace the interrelationship between humans and nature and also the response by social and economic systems to disasters (Carpenter, et. al. 2001). The philosophy of disaster resilience has also been emphasised by the international community in natural disaster initiatives, and in 2005 it was explicitly stated in the Hyogo Framework for Action, under the United Nations International Strategy for Disaster Reduction (UNISDR). The Hyogo Framework for Action defines disaster resilience as "The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure."(UN/ISDR, 2005) It goes on to say that whether a society is equipped with disaster resilience "…is determined by the degree to which the social system is capable of organising itself to increase this capacity for learning from past disasters for better future protection and to improve risk reduction measures." One of the three strategic goals established by the Framework for its programme from 2005 to 2015 is "The development and strengthening of institutions, mechanisms and capacities at all levels, in particular at the community level, that can systematically contribute to building resilience to hazards."(UN/ISDR, 2005)

There are two reasons why the framework emphasizes "… at all levels, in particular the community level." To begin with, in many communities local governments are responsible for services that are more closely connected to daily life than national governments, thus during emergencies they are assumed to have the capacity to determine the extent of the damage and quickly provide relief, medical care, evacuation shelters, lifelines and supplies, and information in situ. Furthermore, this is also because in cases where necessary information such as disaster risks and methods of evacuation and aid provision is shared at the local community and household level, this further boosts the efficacy of the emergency response and rebuilding support provided by the national and local governments.

On occasions, however, depending on the scale of the disaster, local governments and community organisations themselves suffer enormous damage, rendering them incapable of functioning in the areas of damage assessments and support provision. Yet even in such cases relief activities and medical care must be provided and citizens need to continue with their day-to-day lives. It is here that the support of other local governments, communities, or civil organisations that are still functioning directly plays a major role. From this perspective, support for affected regions that is based in the municipalities is an important theme in discussing resilience.

Photo1: Great East Japan Earthquake revealed Japan's vulnerability against natural disaster

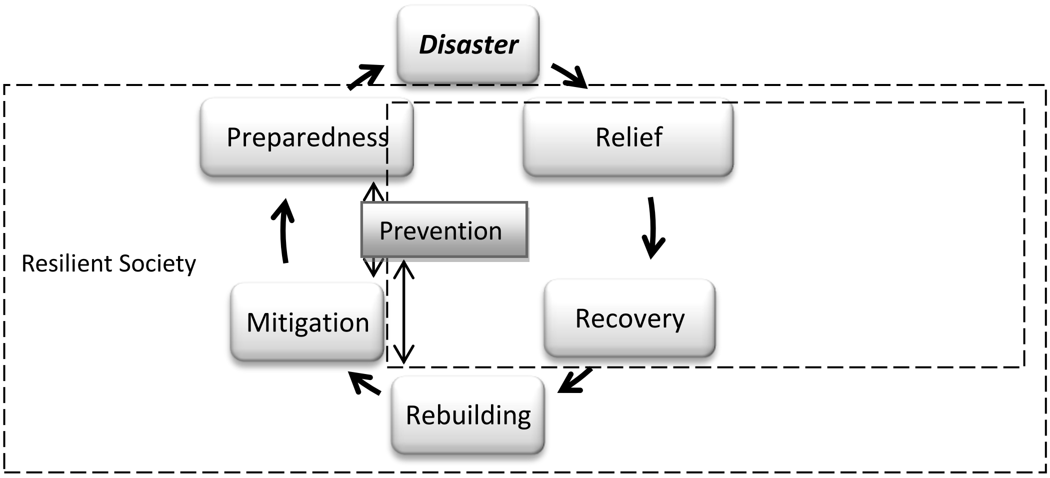
1.3 Objectives and methodology

As mentioned previously, the majority of the services required when disasters strike—such as fire-fighting, first aid, and water supply and sewage—are managed at the municipal level during times of normalcy in Japan. Therefore the physical and material resources as well as the experience that municipalities possess must be utilised effectively in order to accurately assess aspects such as the extent of damage in the locality and which sectors require support when disasters strike, while also providing prompt, on-going support.

Since many local governments (municipalities) were compromised during the March 11 2011 earthquake, support from "unaffected municipalities" inside and outside of the region played a significant role in ensuring the personnel and supplies required for the emergency response. While support for and cooperation with the affected regions by municipalities has shown to be effective it has also revealed a number of important themes, such as coordination between the receivers and providers of support. For example, immediately after the disaster, municipalities all over Japan offered support such as in dispatching personnel and shipping supplies to the affected prefectures. However, the affected prefectures were not necessarily capable of mounting a finely tuned response tailored to the diverse and constantly changing needs in each of the municipalities within the prefectures, and further, many of the municipalities had previously concluded mutual aid agreements for emergencies with neighboring municipalities, but since such a vast region was affected, none of the municipalities could aid their allotted partners, effectively nullifying the potential of such agreements in many cases.

From these examples it becomes apparent that more appropriate coordination needs to be carried out before and after a disaster occurs in order for the municipalities in the affected regions to effectively provide their support to other municipalities. This paper analyses the support for the affected regions that utilised municipal partnerships after the Great East Japan Earthquake, and will also consider the coordination functions needed for resolving problems pertaining to such partnerships, and draws on records in a municipal support database (Ministry of Internal Affairs and Communications, 2012) and local interview surveys conducted in June and November, 2011. This investigation is expected to strengthen the aspect of "community participation" (advocating specific disaster prevention policies at the community level with strategic utilisation of volunteer resources, etc.) as mentioned in the Hyogo Framework for Action.

Disaster management is generally understood as consisting of six phases: relief, recovery, rebuilding, mitigation, preparedness, and prevention (Figure 1). Roughly one year has elapsed since the Great East Japan Earthquake, and for the response to it the relief and recovery stages have been completed, and rebuilding has begun. Therefore, the mutual partnerships between local governments that will be taken up in this paper will be limited to those carried out during the stages of relief, recovery, and rebuilding. However, it is hoped that the themes and lessons observed in these stages will be harnessed when it comes to building new municipal partnerships in the stages of mitigation, preparedness, and prevention that come after the rebuilding stage.



* Developed from Miththapala 2008[23]

Figure 1: Disaster management cycle

2. Institutions for disaster support

When disasters occur in Japan the emergency response is the responsibility of the municipality with jurisdiction. But if it is difficult for the affected municipality to mount a response, another municipality, or the prefecture as a whole provides support. In such cases support from other municipalities[24] is coordinated by the prefecture. If the prefecture containing the affected municipality cannot provide support, or if this support is inadequate, other prefectures or municipalities in other prefectures provide support via central government coordination.

[23] Miththapala. S (2008). Integrating environmental safeguards into Disaster Management: a field manual Volume 2: *The Disaster Management Cycle Colombo*: Ecosystems and Livelihoods Group, Asia, IUCN.

[24] Legally speaking, aid to the affected region is termed "assistance," but this paper uniformly refers to it as "support."

Support from prefectures and municipalities for the affected regions is usually laid out in national government laws related to disaster prevention measures, and in Japan's laws is based primarily around the Basic Act on Disaster Control Measures of 1961. The laws are tailored to each type of support measure[25] such as emergency countermeasures, restoring livelihoods, and financial assistance; laws stipulated for each sector for prevention, including for construction, forests, roads, and rivers; and laws based on type of disaster, such as those for earthquakes, volcanoes, typhoons, and nuclear disasters. Of these, the Basic Act on Disaster Control Measures requires that local governments conclude mutual aid agreements[26] but does not explicitly define such mutual assistance.

2.1 Categories of support for the affected regions

This section gives a general overview of the support received by the affected regions following the Great East Japan Earthquake, as well as the flow of operations from support request through to support provision.

First the pre-earthquake institutional support framework is discussed. Although the coordinators and chains of command differ according to the content of support, the support can be roughly categorised into three types.

In the first type the national government plays a major role in coordinating support, such as with fire-fighting and relief. For fire-fighting, the governor of the prefecture in which the affected region is located requests support from the Commissioner of the Fire and Disaster Management Agency, who issues requests to other prefectural governors to mobilise emergency fire-fighting and relief teams to the affected regions. In other words, three organisational heads—the prefectural governor of the affected region, the national government (Fire and Disaster Management Agency), and the governor of the supporting prefecture—assess the needs and provide support to meet them. It is a structure that emphasises speed by prioritising the dispatch of fire-fighting and relief teams.

The emergency fire response team system mentioned above was established based on lessons learnt from the Great Hanshin-Awaji Earthquake (1995). During large-scale disasters there are many aspects an affected prefecture cannot handle through its own fire-fighting and relief capabilities. Even though fire-fighting and first aid support was received from other prefectures during the Great Hanshin-Awaji Earthquake, there were some cases where guidelines, manuals, and the like concerning initial responses and other activities were missing. Problems were also found with the chain of command and information sharing. Thus in June 1995 the emergency fire response team system was launched with the goal of smoothly facilitating mutual assistance between fire departments around the country. The legal framework supporting the system, after undergoing revisions in 2003, was realised as the Fire Service Organization Act, and

[25] The Disaster Relief Act (1947), the Act Concerning Support for Reconstructing Livelihoods of. Disaster Victims (1998), and the Act on Special Financial Support to Deal with a Designated Disaster of Extreme Severity (1962) which offers disaster rehabilitation works and fiscal and monetary policy, among others.

[26] Article 4, Paragraph 2 of the Basic Act on Disaster Control Measures stipulates mutual cooperation between prefectures, while Article 5, Paragraph 2 of the law stipulates mutual cooperation between municipalities and prefectures, and Article 8, Paragraph 2-12 calls for the conclusion of agreements related to mutual assistance by local governments.

was passed into law in April 2004. With regards the emergency fire response team's commanding unit, it is the task of the Commissioner of the Fire and Disaster Management Agency to request mobilisation of units from unaffected prefectures to affected regions, in line with the request from the governor of the affected prefecture (Article 44, Paragraphs 1, 2, and 3 of the Fire Service Organization Act). The same Commissioner can also independently issue an order for mobilisation (Article 44, Paragraphs 4 and 5 of the Fire Service Organization Act) if necessary. With such a system and chain of command, support services can be mobilised rapidly; Government figures (Fire and Disaster Management Agency under the Ministry of Internal Affairs and Communications) show that in FY2010 nearly three times as many units as those from the time of system instigation were mobilized (Ministry of Internal Affairs and Communications, 2010).

In the second type of support, coordinating organisations related to services at the national level execute coordinating functions via partnering with national governmental ministries and agencies; the services including water supply, sewage, and personnel support (dispatching municipal personnel). These national organisations were created to provide services during times of normalcy and for information sharing, i.e., they were not designed to respond to disasters.

With respect to water supply, water supply utilities from the affected regions request support from their local prefectures, who then refer to the central government (Japan Water Works Association and the Water Supply Division, Health Service Bureau, Ministry of Health, Labour and Welfare). The government (Japan Water Works Association and the Ministry of Health, Labour and Welfare) then contacts prefectures outside of the affected regions and other local water supply utilities to request support. For sewage, however, the process resembles that for water supply but is more complicated. The prefecture that receives a request for support from a municipality sets up its own headquarters for sewer system measures and requests support from external prefectures and municipalities while partnering with the central government (Sewerage and Wastewater Management Department, Ministry of Land, Infrastructure, Transport and Tourism). During the Great East Japan Earthquake, however, there was much confusion, and multiple support routes existed; for example, in some cases support requests were delivered directly to other prefectural governors and municipal leaders through the National Governors' Association or the Japan Association of City Mayors, in addition to those through the basic chain of command, causing confusion among the municipal entities receiving the requests (Ministry of Land, Infrastructure, Transport and Tourism, 2011). The two coordinating organisations for dispatching support in the form of municipal personnel (the Japan Association of City Mayors and the National Association of Towns & Villages) handled the vast majority of the coordination related to dispatches of personnel. On April 13, 2011, one month after the earthquake, there were offers for some 2,500 personnel in response to requests for 673 (Komatsu, 2011).

Photo2: Osaka city's water trucks were observed at various sites in Rikuzentakata, Iwate prefecture.

There have also been cases in which national governmental ministries and agencies have served as contact points whereby requests for the dispatch of specialised personnel have been made to prefectures outside of the affected regions through the National Governors' Association (Ministry of Internal Affairs and Communications, 2012).

This period of over-subscription of support personnel was, however, quite brief (Table 1). Conversely, from the breakdown (Table 2) of the planned personnel dispatches (including both short and long-term) for FY2012 as of March 18, 2012, approx. one year after the earthquake, it can be seen that a large percentage of the personnel support was provided by municipalities. However, it also shows that the overall rate of assistance in the affected prefectures fluctuates, and that support for Fukushima Prefecture in particular has been extremely low, a fact attributed to the Fukushima Dai-ichi Nuclear Power Plant accident. From FY2012 onward personnel support was hoped to consist of long-term support; however, as of January 30, 2012 support comprised of the dispatch of 550 medium- to long-term personnel, with only about 300 coming from municipalities outside the affected regions Japan Association of City Mayors, 2012).

For the sectors mentioned above, specialised knowledge and skills, materials, and so on must be supplied over the medium to long term from the time of the emergency for each of the services requiring support. Having organisations at the national level that are specialised in such sectors serve as coordinators makes it possible to provide flexible support tailored to the needs of the affected regions and the support capacity of the regions on the supporting side. On the other hand, for sectors that require ongoing support, comprehensive coordination that factors-in the burdens imposed on the supporting side over the long term is desired.[27] For example, when personnel are dispatched over the long term the burden on the municipalities providing support and on

[27] From the interviews with personnel in Iwate Prefecture and others (June 7 and November 10, 2011 at Rikuzentakata City Hall)

the dispatched personnel should be eased in terms of payment of wages, welfare benefits, family relations, and health concerns.

Table 1: Actual wide-area personnel support by municipalities outside the affected regions

	Iwate Prefecture	Miyagi Prefecture	Fukushima Prefecture	Others	Total
Prefectures	5625	13981	7618	951	28175
Ordinance-designated cities	3931	9215	1197	132	14475
Municipalities	9607	20203	5833	814	36457
Total	19163	43399	14648	1897	79107

* Ministry of Internal Affairs and Communications. “Status for Local Public Employees Dispatched to Local Governments in the Affected Regions for the Great East Japan Earthquake,” press materials (February 17, 2012)

Table 2: Planned wide-area personnel dispatches by municipalities outside the affected regions for FY2012 (as of March 14, 2012)

	Iwate Prefecture	Miyagi Prefecture	Fukushima Prefecture	Total
Prefectures	139	210	200	549
Municipalities	217	380	91	688
Total	356	590	291	1237

* The Kahoku Shinpo (March 18, 2012)

The third type consists of support based upon mutual aid agreements for emergencies concluded between prefectures and each municipality (not coordinated by the National Governors’ Association). During the Great East Japan Earthquake a number of supply routes existed for support materials sent from other municipalities to the affected regions. These included cases where such materials were provided in accordance with aid agreements concluded ahead of time with the cooperation of the Japan Self-Defense Forces, and cases where ad hoc shipping routes were established. The advantages with this method are that the affected regions and the supporting side confer on the support needs, the capacity of the supporting side, and the aid supply routes. Further, providing information such as the types and details of the anticipated supplies in mutual aid agreements concluded ahead of time (including those with private companies and civil organizations, as well as with municipalities) shortens the time between procurement and shipment. If both of these conditions are satisfied, flexible support can be provided that satisfies both sides to a greater extent than through inter-agency/ministerial coordination at the national level.

The three patterns mentioned above constitute the support mechanisms that existed prior to March 2011. After the Great East Japan Earthquake, however, other support activities emerged. For example, roughly 20,000 of the 344,345 evacuees (as of March 22, 2012; includes those who changed residences) had moved in with family or acquaintances. The remainder have been accepted in temporary housing, evacuation shelters, hospitals, and other facilities in 1,220 municipalities over 47 prefectures (Nishinippon Shimbun, 2012). This acceptance of the earthquake victims was implemented voluntarily by the municipalities immediately after the earthquake, and had significant results as a form of short-term support.

Other unique means of support included the securing of land for temporary housing, as well as orders for house construction (Sumita Town, Iwate Prefecture), and the procurement of some services (emergency medical teams from other countries, etc.) that could not be procured domestically (Kurihara City, Miyagi Prefecture). Municipalities also dispatched personnel to neighboring affected municipalities ahead of instructions from the prefectural governors' association or municipal associations, and also worked together to restore functionality.

This unprompted support for the affected regions by municipalities is a new phenomenon. As the range of the damage precipitated by the Great East Japan Earthquake was so vast, each municipality tended to adopt support measures that were adaptable to the changing circumstances. Initiatives such as municipalities building temporary housing and contacting overseas medical teams appear to be at odds with the Disaster Relief Act, and achieved a certain measure of success. Such examples are not to be thought of as merely unorthodox steps in times of emergency—they highlight the importance of such independent institutional thinking as a factor that needs to be expanded upon in order to enable local municipalities to act quickly and flexibly in the event of a disaster.

2.2 Mutual aid agreement mechanisms

Modalities for mutual aid are referred to in the nation's laws in broad terms, yet conversely, prefectures and municipalities often incorporate specific support content and processes between other local governments and civil groups into their regional disaster prevention plans. Such content focuses mainly on clarifying the targets of support and people in charge when it comes to mutual cooperation, as well as the proportion of any financial burdens and other matters.

Regarding emergency mutual aid agreements concluded among local governments , some are "bilateral" in that they are simply concluded between two groups. Other agreements also exist, such as those concluded by large numbers of groups over a wide range and agreements in which prefectures all over Japan take part. The groups that conclude the agreements and the scope of the agreements can be broadly classified as follows:

a. Mutual aid agreements between prefectures
    - a.1 Aid agreements for wide-area disaster prevention (aid agreement divided into blocks for each prefecture)
    - a.2 Agreements concerning Wide-Area Aid during Disasters for Prefectures Nationwide (National Governors' Association)

b. Mutual aid agreements between major cities
    - b.1 Agreements concerning mutual aid during disasters by 20 major cities (ordinance-designated cities)

c. Mutual aid agreements between municipalities
    - c.1 Consolidated aid agreements targeting all municipalities within a prefecture
    - c.2 Aid agreements targeting municipalities outside of a prefecture

c.3 Aid agreements between sister cities

d. Agreements between municipalities and the public sector

d.1 Agreements between municipalities and public enterprises

d.2 Agreements between municipalities and volunteer groups

Agreements for wide-area disaster prevention (a.1 above, hereafter referred to as "block agreements") refer to agreements that bring together neighboring prefectures into a wide-area block. Upon the occurrence of a disaster within this block the unaffected prefectures provide support based upon a request from the affected prefecture. At present, agreements have been concluded for seven blocks nationwide, including the "Agreement on Mutual Aid between Eight Prefectures in Hokkaido and Tohoku for Large-Scale Disasters."(Cabinet Office, 2007) Affected prefectures can request aid by designating prefectures in their block adjacent to them. The block agreements stipulate which prefectures are to coordinate the aid ahead of time so that this aid-related coordination can be carried out smoothly. If the affected prefecture is prevented from requesting aid due to the severity of the damage, or when the coordinating prefecture lacks the time to handle the coordination, then another prefecture from within the block can mobilise emergency aid on its own initiative (Figure 2). The costs required for mobilising the aid are generally borne by the affected prefecture.

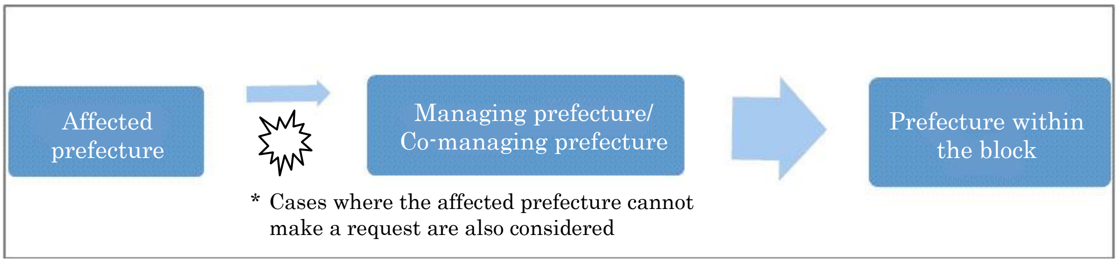


Figure 2: Flow for support requests based on aid agreements for wide-area disaster prevention

All 47 prefectures are cosignatories to the Agreement concerning Wide-Area Aid during Disasters for Prefectures Nationwide (a.2 above; referred to as the "nationwide agreement"), which was concluded in July 1996 by the National Governors' Association in the aftermath of the Great Hanshin-Awaji Earthquake (then revised in 2007 following the Niigata-Chuetsu Earthquake). This agreement is regarded as a supplementary arrangement for providing aid in the event that an adequate response cannot be mounted through the block agreements and bilateral agreements. The main purport of the nationwide agreement is "to provide physical and material support, facilities, or services related to rescue and relief; emergency disaster and reconstruction measures; and rebuilding measures in the affected region, or intercessions to this effect. (National Governor's Association, 2007)"

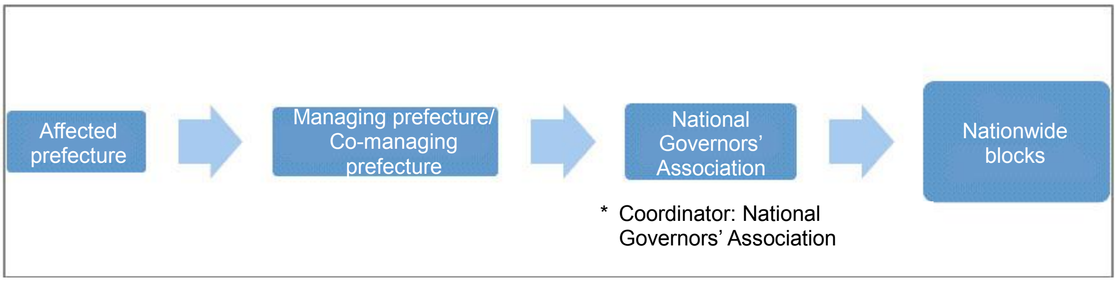


Figure 3: Flow for support requests based on the nationwide agreement

Both the block agreements and the nationwide agreement incorporate the following content: (1) goals, (2) types of aid, (3) procedures for requesting aid, (4) voluntary mobilisation of aid, (5) cost burden for aid, (6) contact points, and (7) information sharing.(Funaki, et al. 2005)

Bilateral mutual aid agreements (c.2 and c.3 above) (Yamagata Prefecture, 2006) are arrangements where one municipality provides aid to another municipality if affected by a disaster.

The four prefectures that were affected by the Great East Japan Earthquake (Iwate, Miyagi, Fukushima, and Ibaraki) all incorporated mutual cooperation agreements with prefectures, municipalities, fire departments, the public sector (broadcasting stations, Japan Red Cross Society, medical associations, convenience stores, shipping companies, and volunteer centers), and other bodies into their regional disaster prevention plans. The mutual cooperation that took place in the four prefectures' regional disaster prevention plans and challenges faced in the Great East Japan Earthquake are discussed in the second half of Section 3.

3. The spread of mutual aid agreements

It is readily apparent that mutual aid agreements between local governments played an important role during the emergency, especially for those municipalities that had concluded such prior to the 1990s.[28] A notable characteristic of them is that they have been successively modified in the aftermath of multiple earthquakes that have occurred over the past two decades (1995 Great Hanshin-Awaji Earthquake, 2004 Niigata-Chuetsu Earthquake, etc.). As a result the national government's Basic Act on Disaster Control Measures underwent a dramatic overhaul following the Great Hanshin-Awaji Earthquake, in that provisions concerning mutual cooperation between municipalities and prefectures were added, with the aim of promoting cooperation between local governments (Article 5, Paragraph 2: "Local governments must make efforts to cooperate with one another when necessary to fully discharge their responsibilities set forth in Article 4, Paragraph 1 and Paragraph 1 of the preceding article").

The number of municipal and prefectural mutual aid agreements has substantially risen

[28] The Mutual Aid Agreement for Disaster Prevention between Okayama Prefecture and Kagawa Prefecture (signed May 10, 1973) is one such example.

in recent years. In 2000, the figure was around 70%, by 2006 it was over 80%, and since 2008 it has stood at or above 90% (Figure 4). As of April 2011, 1,476 municipalities (91.2% of the total) had concluded aid agreements of one form or another.

The assumption underpinning these aid agreements is that they will secure the primary relief and recovery stages in the disaster management cycle mentioned above. If a disaster is of a large-scale then medium to long-term support such as employee dispatches also occurs over the rebuilding stage. Regarding the agreements, some are related to fire-fighting while others to disaster reconstruction (including the dispatch of personnel) or the provision of supplies. Of these, those related to disaster reconstruction had increased from 392 to 662 in the five years between 2003 and 2007, while those related to supplies had increased from 562 to 794 during the same period. Considering that over this time period the number of municipalities was roughly halved (3,200 to less than 1,800) under the Great Heisei Consolidation, such figures have even more meaning.[29] Prefectural agreements over the same period also show a similar uptrend—from 37 to 43, while those related to supplies increased from 34 to 44.[30]

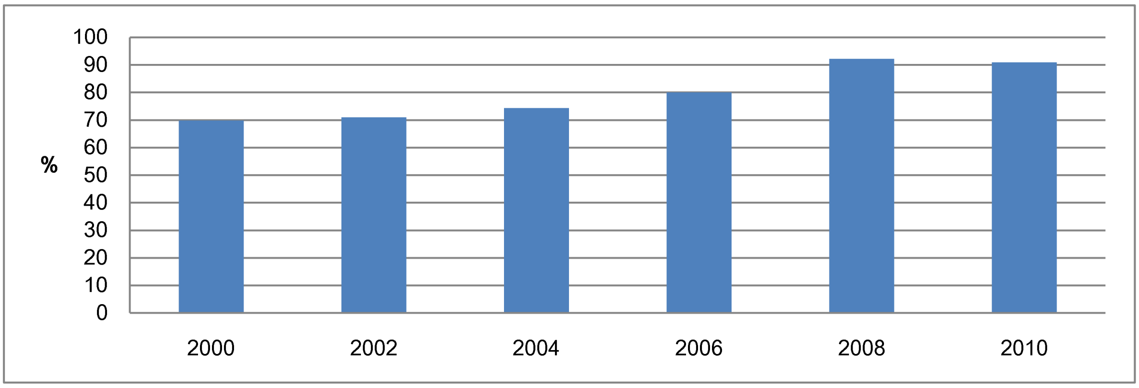


Figure 4: Trends in municipal aid agreements (calculated from the previous fiscal year's white paper on fire and disaster management issued by the Ministry of Internal Affairs and Communications)

It is worth noting, however, that in many cases the counterparties to the mutual aid agreements were municipalities and groups within the same prefecture (more than 90% of the municipalities nationwide had concluded aid agreements with other municipalities, whereas only 51.3% had agreements with municipalities outside of their prefecture (Ministry of Internal Affairs and Communications, 2011)), which had important ramifications after the Great East Japan Earthquake as the damage was so widespread it compromised aid provision as all had suffered damage. As a consequence, three of the four affected prefectures are now considering concluding mutual aid agreements with external parties to provide a broader range cover in the future.

Apart from the abovementioned restriction in counterparties concluding agreements, the aid implemented by local governments during the Great East Japan Earthquake laid bare a number of challenges, such as in the content of pre-existing agreements,

[29] Ministry of Internal Affairs and Communications' website. (http://www.fdma.go.jp/html/hakusho/h19/h19/search/search.html), confirmed in April 2012.
[30] Ministry of Internal Affairs and Communications, same as above.

coordination mechanisms, and the types of aid supplied. A number of improvements have since been deemed necessary to the way in which existing mutual disaster prevention agreements are structured in order to overhaul future disaster prevention systems. With respect to the regional disaster prevention plans of the four affected prefectures, it is apparent that each of the prefectures was compromised to certain extent in the state of preparedness for and the utilisation of mutual aid.

Even though Iwate Prefecture had referred to mutual aid agreements in its regional disaster prevention plan, ambiguities remained as to how it would actually coordinate them. As an example, no clear mention was made of which section or department would coordinate the dispatch of municipal employees outside the prefecture, which hindered the response when it came time to dispatching personnel during the Great East Japan Earthquake. As such, Iwate Prefecture is currently redrafting its disaster prevention plan. The revisions include clarifying the positioning of the prefectural disaster response headquarters and procedural rules concerning the handling of personnel dispatches outside the prefecture. Iwate also intends to promote agreements related to mutual aid with distant prefectures and municipalities that are equipped for not only mutual coordination within the prefecture but also large-scale disasters over a broad area (Iwate Prefecture, 2012).

Prior to the Great East Japan Earthquake, Miyagi Prefecture had concluded 97 aid agreements. The wide-ranging content of these agreements encompassed medical aid (hospitals and medical associations, etc.), civil engineering, construction, and housing (Japan Civil Engineering Contractors Association, etc.), waste disposal (Cooperative Association for Environmental Improvement Projects, etc.), provisions of supplies (convenience stores, etc.), provisions of supplies (real estate companies, etc.), shipping of supplies (trucking associations, etc.), broadcasting (broadcasting stations, etc.), administration (heads of local governor associations, etc.), and other factors (establishment and operation of volunteer centers, etc.). In the overhaul of its disaster prevention plan following the Great East Japan Earthquake no particular revisions were made to its aid agreements. However, as its prior agreements had been concluded between municipalities within the prefecture they did not function very well in the Great East Japan Earthquake for the same reason as mentioned above in relation to damage to an extensive area. Likewise, it would be deemed prudent for it to form future mutual disaster prevention agreements with municipalities, companies, and civil groups over a broader area.

Fukushima Prefecture had also specified comparatively detailed content with respect to mutual aid agreements in its disaster prevention plan prior to the Great East Japan Earthquake, which as in the Miyagi case were also unrevised after the earthquake. However, by way of future measures it is promoting the conclusion of disaster agreements with other prefectures and groups, and from a support and wide-area perspective between municipalities, and endorses support for the conclusion of disaster agreements between municipalities (Fukushima Prefecture, 2012).

Ibaraki Prefecture revised its Prefectural Regional Disaster Prevention Plan on March 26, 2012, just after the earthquake. Notable points are: (1) The plan strengthens cooperative structures based upon specific measures such as relief, cooperative structures, the conclusion of agreements, the preparation of manuals, and conducting drills and sharing information during times of normalcy together with other prefectures, municipalities, organisations concerned with disaster prevention, and other bodies; and (2) As a means of setting in place a wide-area mutual aid structure it clearly lays out that when large-scale disasters strike (including later reconstruction and rebuilding measures), mutual aid structures are to be established not only with neighboring prefectures and municipalities but also with local governments over a broader area.

The four prefectures that suffered damage had all incorporated items related to mutual aid agreements into their disaster prevention plans prior to the Great East Japan Earthquake, yet problems appeared in their emergency responses when the earthquake struck with respect to the capacity for aid cooperation and operational aspects pertaining to the coordination of people and supplies (inability to handle the demands of the affected regions that changed over time, etc.). The allocation and training of human resources to manage these systems for coordination had been inadequate, as in Iwate Prefecture in managing the deployment of its personnel. As a result, there were many instances where support in the form of supplies and manpower that had been acquired from all over Japan could not be efficiently directed to the regions requiring it.

Coordinating the available manpower and supplies provided through mutual aid agreements was also a bottleneck in the initial response stage in the Niigata-Chuetsu Earthquake (Funaki, et al. 2006), which points to the need for improvements to be made in the future. What is apparent is that quality as well as quality is important—it is not only the number of mutual aid agreements but also how they are applied that should be focused on henceforth. Examples of such include making preparations between counterparts outside the local prefecture and allocating and training a human resource body that can respond quickly during emergencies.

4. Consideration of the support structures for the Great East Japan Earthquake

4.1 Coordination and support within the affected regions

The presence of mutual aid agreements between the affected regions and the supporting side and the high level of potential support offered does not, however, guarantee the optimum support when it is needed–there may be times when the types or volume of the support supplied fail to meet the needs of the affected regions or the victims, or delays in the affected municipalities receiving deliverables such as evacuation shelters, as was observed in the Great East Japan Earthquake.

In terms of the process of delivering the supplies and services straight to the affected regions and victims, factors such as assessments of the local needs and types and volumes of support that can be provided near the affected regions, and then allocating support as needed are keys to effective support. With reference to the Great East Japan Earthquake, which caused devastation over such a wide area and led to a high number of deaths, coordinating capacity at locations close to the receiving side was of paramount importance. Municipalities in the affected regions brought together affected regions with those outside, thereby effectively serving as support bases, playing a major role in the emergency response.

As an example, Tono City, Iwate Prefecture, suffered relatively light human casualties of the municipalities in the prefecture, but even though it suffered damage to nearly 400 homes (totaling about 2.7 billion JPY), destruction of public facilities, water outages, severed roads, and other devastation (Tono City Disaster Response Headquarters, 2011), it still proactively carried out logistical support for six neighboring municipalities. During the initial response, it dispatched municipal personnel, as well as medical supplies, food, water, and other emergency supplies to the affected municipalities. It also set up a system whereby it could receive police, Self-Defense Force, and other personnel at public and private facilities, thereby serving as a logistical support base within the affected region. Support from local governments as well as civil NPOs and private companies was the first to arrive on the scene after the earthquake. Tono City could assume the role as a hub for this volunteer network because the logistical support structures were already in place. The content of this logistical support was wide-ranging and included providing facilities and land to serve as bases for the relief supplies, the Self-Defense Force, police, municipalities providing support, medical teams, volunteers, and so on, as well as personnel support for such. Supplies shipped from 42 municipalities from all over Japan also passed through Tono before arriving at affected regions along the coast. A breakdown of this reveals that there were 315 shipments of relief supplies, including 64 tons of rice, 128,000 two-liter bottles of drinking water, 178,000 items of clothing and bedding, and 25,365 support personnel and volunteers (Asahi Shimbun, 2011). These logistical support activities could be carried out quickly based on the historical impetus generated by its experience with the inland earthquake in Iwate and Miyagi three years previous, which resulted in a heightened awareness of disaster prevention in the city and its frequent disaster prevention drills. This heightened awareness of disaster prevention extended from the local government to the public, and resulting in Tono City being not only able to quickly assess the damage in its own locality but also smoothly transition over to act as a platform for support for neighboring regions. The city of Tono thus set in place support structures for nearby municipalities (hard aspects of facilities and supplies, as well as soft aspects such as personnel support structures and information collection) from its position adjacent to regions that had suffered significant damage, and in doing so not only played a key role as a support base, but also in ascertaining the needs of regions that had suffered greater damage and in offering its own support.

Kurihara City in Miyagi Prefecture experienced the greatest seismic intensity during the Great East Japan Earthquake. The city determined the extent of damage within its locality over several days and provided support to neighboring municipalities. With the continuous power and water outages it had difficulty securing fuel for its hospitals and facilities, and in tasks such as damage assessments, however, it concurrently became aware that neighboring Minamisanriku Town had suffered very heavy damage from the tsunami so set out to provide immediate logistical support. As with Tono City, Kurihara City had capitalised on its past experience with the inland earthquake in Iwate and Miyagi in strengthening autonomous organisations in the region, such as neighborhood councils. This enabled it to minimise potential damage within the city and perform the crucial act of accurate information gathering. At the same time, Kurihara City had also installed a satellite phone system that allowed smooth communication after the earthquake, through the support of Keio University (based on interviews with the officials in charge in Kurihara City[31]). Smooth communications are crucial in the immediate aftermath of disasters as the communications networks are usually in a state of chaos. Kurihara City could thus provide support via the dispatch of an Israeli medical team to neighboring municipalities right after the earthquake struck, as well as in building temporary facilities and housing. It also constructed a temporary government building in order to restore the administrative functions of Minamisanriku Town, and dispatched numerous experts in crisis management and other such human resources. The expedited dispatch of the medical team was enabled by a very efficient mayor, which included using the city's own channels to negotiate with the Israeli Government without having to go through a government ministry (Ministry of Foreign Affairs).

Sumita Town, Iwate Prefecture, which is adjacent to the affected regions along the coast (such as Rikuzentakata City, Iwate Prefecture), began construction work on temporary housing for the victims three days after the disaster struck. The town's mayor decided that Sumita Town would accept not only Sumita residents but also those from neighboring Ofunato City and Rikuzentakata City to the temporary housing it had built using its own budget. This decision ran counter to the stipulations of the Disaster Relief Act,[32] which states that temporary housing is to be built by the prefecture while municipalities are in charge of securing and managing the land. When the disaster hit the town's mayor displayed clear leadership, which was positively received in the affected regions (Chunichi Shimbun, 2011).

Shiwa Town, Iwate Prefecture, was also ahead of its neighboring municipalities in taking in evacuees (Asia PPP Institute, 2011). Since this town had put an elementary school exchange program into practice with another local municipality it was aware of the other's circumstances, making it relatively easy for them to communicate. This appears to have been beneficial for the sake of adopting an accurate support structure during emergencies, such as via initiatives for rapidly opening evacuation shelters and clarifying who the support recipients were.

As indicated above, there were cases in which municipalities that had suffered comparatively light damage made a functional switchover to providing support to neighboring regions that had suffered more damage. Such instances reveal that the leadership of those in charge and body of experience from past disasters proved beneficial. Such leadership is also influenced by chance to a considerable degree, and local governments in seemingly similar circumstances could not necessarily respond in the same way. For example, Tome City, Miyagi Prefecture is situated next to the aforementioned Kurihara City, and suffered a similar extent of damage as Kurihara. But aside from the NPO1 organisation which supplied centers for the affected regions along the coast, the city did not engage in any noteworthy logistical support activities. Further, it is believed that Tome City was able to focus its response within the city based on

[31] Interview survey with Mr. Manabu Suzuki, Planning Division, Planning Department, Kurihara City (July 20, 2011).
[32] Outline for the Handling of Disaster Relief Affairs. "3. Items concerning Providing Legally-Sanctioned Aid, (2) Providing Temporary Emergency Housing."

information gathering carried out by Kurihara City and Kurihara's utility as a support base.

Some municipalities—despite being in the affected regions themselves—played a role as support bases by either supporting municipalities in their surrounding areas or accepting support from outside of the region. Disregarding factors such as the individual characteristics of these municipalities or their accumulated experience, such municipalities have certain elements in common that enabled them to quickly assess the situation and provide support. Namely, they quickly determined the magnitude of the damage within their jurisdiction, built close relationships with neighboring municipalities during times of normalcy, and ensured means of communication that functioned during emergencies. These three points can be regarded as preconditions for ensuring a rapid and appropriate disaster response by local governments and support for other regions.

4.2 "One-on-one" responses by the affected municipalities and the municipalities providing support

Thus far the process from the request for aid from the affected regions through to the provision of supplies and services via coordination has been covered. Basically, supplies and services for support are provided to the affected regions (or close by) based on coordination by the national government or coordinating organisations throughout Japan, or based upon prior arrangements with the municipalities providing support, depending on the type of support requested by the affected municipalities. Further, support bases located in or near the affected regions carried out coordination for delivering supplies and services to the areas and victims requiring them within the affected regions. Next we deal with support that differed from the above, and in this section give cases in which corresponding relationships between the municipalities providing support and the affected municipalities were set up rapidly after disaster struck, thus leading to effective support.

Shizuoka Prefecture's disaster prevention efforts were geared towards the event of an earthquake in the Tokai Region, thus initially its intention had been to lend support to Fukushima Prefecture, but after a request from the governors' association its area of responsibility was also diverted to Iwate Prefecture, to which it provided its support. It established a field headquarters for support coordination in Tono City, Iwate Prefecture, where it stationed over 20 personnel and dispatched support units as many as eight times.[33] Owing to its experience in conducting support activities during the Great Hanshin-Awaji Earthquake, it stipulated that the content of its activities would consist of: (1) support in sending supplies and personnel to areas afflicted by major damage, (2) the acceptance of evacuees into Shizuoka Prefecture, and (3) the acceptance and distribution of material support and physical support from Shizuoka Prefecture (and its municipalities).(Asia PPP Institute, 2011) Further, it recognised the importance of disaster agreements concluded during times of normalcy, and so was prepared when it came to providing and transporting supplies and personnel by calling on municipalities, companies, and civil groups within the prefecture.

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[33] Not many supporting municipalities established field headquarters. Further, the majority of the field headquarters other than that of Shizuoka's were established in Morioka City, Iwate Prefecture which is the seat of the prefectural capital.

Municipalities that had accumulated knowledge on disaster countermeasures, like those in Shizuoka Prefecture, were capable of initiating support activities soon after the disaster struck. Moreover, the knowledge and experience gained through their support activities will be helpful for preparing Shizuoka Prefecture itself against future disasters. In this manner, initial coordination should be carried out immediately after disasters strike in order to harness the capabilities of municipalities that are endowed with knowledge and experience.

The Union of Kansai Governments formed teams of municipalities in order to enable multiple prefectures to provide support to the three prefectures in the Tohoku Region that had suffered major damage. The Union of Kansai Governments is a public body that was tasked with the objective of promoting decentralisation, and is composed of the seven prefectures in the Kansai Region. This Union implemented support via the “twinned support” (See Appendix 1) the Chinese Government had adopted after its massive earthquake in Sichuan, whereby support was promoted by pairing each municipality with an affected municipality on a one-on-one basis. Two days after the earthquake on March 13, the decision was made on the allocations for the responsible prefectures, whereby the three prefectures of Hyogo, Tokushima, and Tottori would support Miyagi Prefecture; Kyoto and Shiga Prefecture would support Fukushima Prefecture; and Osaka and Wakayama Prefecture would support Iwate Prefecture. The prefectures in charge of support for the three Tohoku prefectures that suffered damaged established field contact offices, in addition to which Osaka and Wakayama Prefecture established the Union of Kansai Governments Field Office in Iwate Prefecture and stationed personnel there (Union of Kansai Governments, 2011).

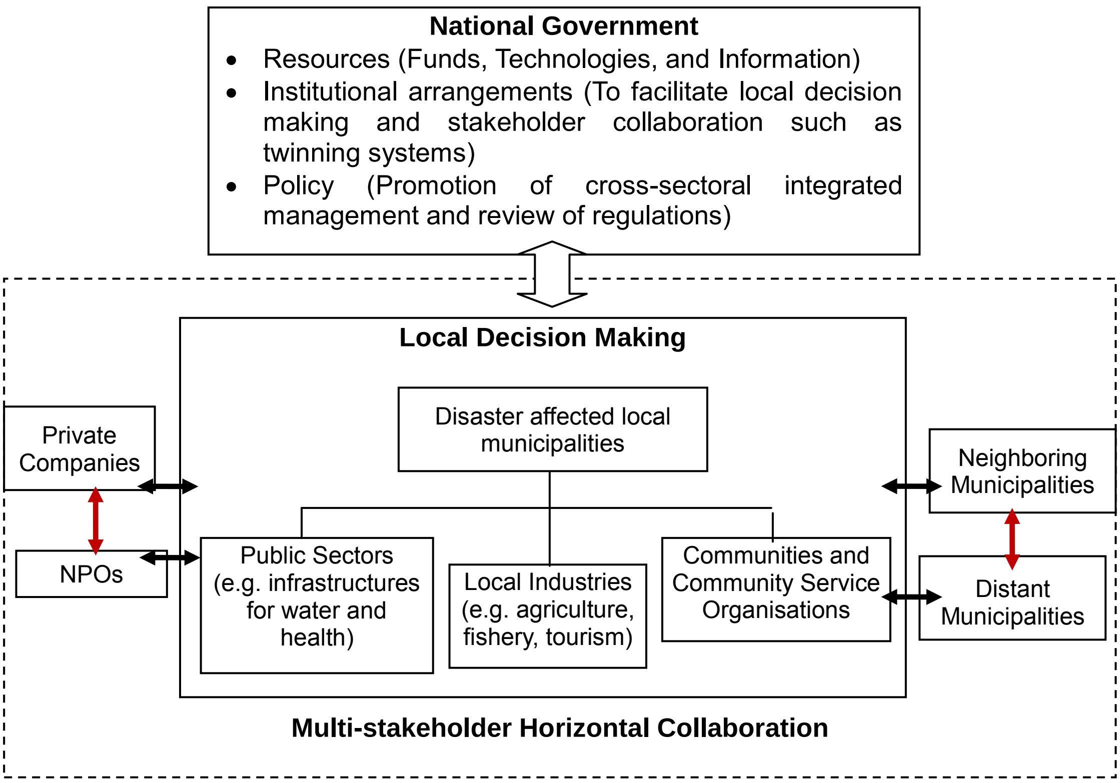
One noteworthy point concerning the support from the Union of Kansai Governments is that a support structure for meeting the counterparts’ needs was quickly enabled by clearly specifying the target of the support and maintaining one-on-one relations. However, consistency in the content of and means for the support activities was not always guaranteed, as such was left to the discretion of each prefecture. Had they shared information in a better way and been able to modify the above content after they had been quickly paired with the support recipients, more effective support might have been possible.

With the twinned support in China the national government created the pairings between the affected regions and the municipalities providing support, with the paired municipalities both forming a single team that competed against the other teams over the level to which the affected municipalities were rebuilt. It was pointed out that by doing this rebuilding would be accelerated in a visible manner in areas such as the reconstruction of infrastructure, for example, but that conversely it could lead to a slipshod response such as in the form of shoddy construction work (Yin et al. 2009). The one-on-one response by the Union of Kansai Governments simply involved the municipalities providing support in line with the actual circumstances in the affected regions by identifying the municipalities that had suffered damage. No competitive elements were incorporated into the support and the project benefitted from the positive aspects of support via this one-on-one response.

As has been seen from the above, various scenarios existed in which corresponding relationships between the municipalities providing support and the affected municipalities were rapidly set in place immediately after the earthquake, thereby leading to effective support. Outside coordination has been required for pairing municipalities up with the affected municipalities and for deciding on the content of the support methods. This holds true for both cases where support activities were carried out at the municipal level and by associations of municipalities.

5. Factors for strengthening support coordination functions

The support for the affected regions explained in Section 4 was implemented by the parties involved, as shown in Figure 5. While support from the national government forms the foundation, the possibility exists that this vertical support alone will not be able to quickly and accurately cope with the actual circumstances in the affected regions (see Table 3). Horizontal cooperation between the municipalities is also needed to supplement this. Preferably, support will be provided promptly after disasters occur, be flexible in matching the needs of the affected regions, and be carried out in an ongoing manner. To enable such, it is important to have coordinating functions working effectively at a number of different levels. The following three stages are essential for coordination related to support during emergencies.



* Created by the authors

Figure 5: Flow of mutual aid during emergencies

1) Twinning: Pairing the affected local governments with those providing support

Pairing the supporting side and the receiving side in the chaotic period immediately after a disaster is frequently wrought with difficulties. The system in Japan is set up so that the prefectures in which the affected municipalities are located perform coordination when the coordination functions of said municipalities do not work, or the national government performs this coordination when the prefectures cannot. But this can complicate the coordination process, depending on the content of the services and supplies provided. Confusion is particularly prone to arise in situations where multiple request routes exist, as was seen with sewage support. It is indispensable for the routes for requesting and providing support, departments to serve as contact points, and the people in charge to be clearly specified ahead of time—before disasters strike. After a disaster has occurred coordination can be carried out quickly through the intermediation of higher-level organisations, such as the Union of Kansai Governments or the Chinese Government during the Wenchuan Earthquake.

2) Coordination related to supply and demand: ascertaining the needs of the affected regions and arranging and allocating support

There were cases during the Great East Japan Earthquake of neighboring municipalities providing support and achieving results despite having suffered damage. The fact of their proximity, which enabled them to easily ascertain the needs of the support recipients, is thought to be one factor behind their success. Furthermore, examples of support bases such as the one managed by Tono City, in which coordination of both assessments of needs and allocation of supplies from outside supporting countries and local municipalities either within the affected regions or close to them took place, existed. Smoother support can be achieved when these support bases are functioning normally. When the constantly changing needs of the affected regions are not ascertained then this produces mismatches in supply and demand, leading to situations of an excess of non-critical support supplies and shortage of required items. To avoid these mismatches it is important to obtain and share accurate information. When municipalities provide support within affected regions, or when cross-municipality interactions operate in times of normalcy, coordination can be carried out more efficiently at this stage.

3) Coordination for ensuring ongoing support: Mitigating the burden on the side providing support over extended periods of time

The ideal is for an increase in municipal disaster prevention agreements (including those made with distant municipalities) to occur in the future. However, effective and ongoing support cannot be carried out without consideration of the allocation of physical and material resources on the supporting side. Following the Great East Japan Earthquake, personnel from other municipalities that exceeded the number requested by the affected regions were initially dispatched, but one year after the earthquake the dispatched personnel fell short of those required. Compared to the national government and the Union of Kansai Governments, municipalities face limitations in terms of their resources in terms of providing ongoing support on their own. Consideration must be given to integrated approaches, such as partnering with multiple municipalities and businesses to mitigate the burdens on personnel dispatches and contributions of supplies. Preferably, resource coordination should take place on the supporting side in advance, at the stage at which municipal disaster support agreements are prepared, before disaster strikes.

When local governments provide support to the affected regions during a disaster the three stages of coordination mentioned above are executed. These three stages of coordination must be carried out correctly to provide timely, flexible ongoing support.

Discussed next, for reference, are the cases of China and New Zealand in relation to post-disaster support provided outside of Japan. With the local government partnerships that were carried out during the Wenchuan Earthquake in China (Appendix 1), instructions from the government sped up the twinning (in item 1 above). Conversely, the results of the rebuilding by teams from the affected region and the supporting side took the form of a competition. Because of this the quality of support was seen to be lacking. For example, the construction of housing and other structures was rushed and overlooked the weakened state of the ground following the earthquake, which reportedly triggered landslides later on (Parker, et al. 2011). With the response to the earthquake in Christchurch, New Zealand, since considerable progress has been made with decentralisation, the public and the community had a strong awareness of disaster prevention, thus voluntary support activities sprang up from within the city itself (Mamula-Seadon, 2011). On the other hand, no large-scale partnerships with other local governments were seen. The damage to Christchurch differed from that in the Great East Japan Earthquake in that it was localised. Further, no twinning-type coordination was demonstrated, nor partnerships, since they were deemed unnecessary.

As regards support from local governments in emergencies, innovative schemes will presumably be needed to strengthen and facilitate the three areas of twinning, supply and demand coordination, and coordination for ongoing support.

6. Conclusions and recommendations

This paper has focused on mutual aid via local governments during emergencies as a factor for boosting disaster resilience, and discussed how aid agreements for disasters between local municipalities have grown in popularity in Japan, particularly since the 2000s. We have also argued that problems were seen in the three stages of coordination of twinning, supply and demand relations for support, and coordination for ongoing support during the Great East Japan Earthquake of 2011. Based on observations to date, we here propose the following measures for setting in place the conditions for local governments to provide support in a timely, flexible, and ongoing manner when disasters strike, as well as undertaking emergency responses and rebuilding. These measures are deemed to be relevant and beneficial for any country.

6.1 Mutual aid involving various stakeholders

Mutual aid by local governments and businesses plays a critical role during disasters. Numerous mutual aid agreements must be concluded ahead of time with not only municipalities but also private sector companies and civil groups that provide various services.

6.2 Establish support systems across a wider area

The thinking is that it will be necessary to promote multiple agreements with not only neighboring local governments but also groups that are more distant and spread out over a broader area. This will ensure responses can be mounted rapidly even in cases where damage affects large regions.

6.3 Create support structures prior to disasters

The conditions for providing prompt, appropriate support include setting in place structures for determining the magnitude of any damage and the extent of such in a certain jurisdiction (creating networks with local neighbors, etc.), building close relationships with neighboring local governments during times of normalcy (exchanges through schools and other activities, etc.), and ensuring means of communication that can be used during emergencies. Since it is difficult to set these in place after a disaster has occurred they must be set in place in advance. Means for coping with emergencies must also be put in place such as through the practice of drills and training.

Providing municipalities with discretionary powers that would enable them to carry out prompt, flexible activities limited to times of disasters and emergencies could also be considered. For example, the Disaster Relief Act stipulates that prefectures are to build temporary housing, but it could also permit municipalities to build temporary housing immediately after a disaster to secure housing for the survivors. At the same time, amendments to the Basic Act on Disaster Control Measures and the Disaster Relief Act should be considered to enable affected municipalities to independently request support from overseas and to enable neighboring municipalities to independently initiate support in areas such as food and first-aid.

6.4 Strengthen coordination functions for providing timely support

When disasters strike a highly disparate range of services and supplies are needed, on top of which various needs arise according to the characteristics of the damaged region and the extent of the damage. When mutual aid agreements are concluded, the types of services and supplies for which cooperation is to be given, details on advance preparedness, and the support process must be clearly specified. The following points should also be kept in mind, and ideally coordination structures for emergencies will be set in place ahead of time.

- Strengthen functions for twinning, coordination for the needs of the side receiving support, and coordination for the supporting side’s supply capacity. In particular, it may be difficult for the affected municipalities to perform the coordination themselves, so examples have been noted where back-up coordination by intermediary organisations or the supporting side has proven effective.

- There will be differences in the magnitude of the damage even within affected regions. Support through municipalities that have set up logistical support structures, as with Tono City, Iwate Prefecture, is effective at facilitating support.

- Making use of municipalities and municipal associations that have a strong awareness of disaster prevention is effective when it comes to providing support to the affected regions. Therefore, support by municipalities immediately after disasters occur as well as that as detailed in disaster agreements should also be taken into consideration. The experiences from partnerships between municipalities immediately after the devastation hit during the Great East Japan Earthquake (Shizuoka Prefecture, Union of Kansai Governments) has highlighted the need for twinning coordination and coordination for ongoing support to be carried out by the supporting side. Further, day-to-day disaster prevention measures, training, and information sharing that take advantage of regional characteristics, and cooperative structures besides those for disaster prevention must be revamped and harnessed for disaster prevention in order to boost the capacity of affected regions in information collection and transmission for when disasters strike.

6.5 Strengthening the role of higher-level organisations such as countries that assist with municipality-level support

The majority of the support for the affected regions dealt with in this paper was not ordered or designated by the national government, but rather was voluntary. The national government can play a major role in mutual aid relationships—such as in intermediation for twinning and financial assistance—in order to ensure that the cooperation between local governments is prompt and sustainable. Factors such as coordination functions and mechanisms for mitigating the burden on the supporting side should be strengthened.

6.6 Conclusion

This study focused on the reciprocal support systems between municipalities that were observed in the roughly one-year time period immediately following the Great East Japan Earthquake. As for long-term support that amplifies the burden on the municipalities providing support, which was not dealt with in this paper, further investigation and consideration will be needed on mechanisms that cannot be swayed by the circumstances with the organisations which are stakeholders involved in supporting activities in disaster affected areas.

Table 3: Strengths and weaknesses of actors in emergency responses

Actors	Scale	Agility	Flexibility	Stability
National Government	Large	Slow	Least	Stable
Local Governments	Medium	Medium	Medium	Medium
Non-Government Organisations	Smaller (in most cases)	Quickest (in most cases)	Most flexible	Less stable in some cases

*Created by the authors

Table 3 shows the types of roles played by the support for municipalities discussed in this paper. While the government's support for the affected regions was large in scale and stable, it was lacking in agility and flexibility. Conversely, support by NPOs (which has become a key aspect since the Great Hanshin-Awaji Earthquake) and other volunteers was replete with agility and flexibility, but suffered from uncertainty over its scale and stability. Support for the affected regions from local municipalities features agility and is also relatively adaptable to the needs of the affected regions. This suggests that if a form of composite support could be provided by multiple municipalities then this would make it possible to improve its scale and stability. An examination of the problems with municipal partnerships and the means for resolving them dealt with in this paper is a matter that requires debate at the national level by policymakers and officials involved in disaster prevention as a means of responding to future disasters. We hope that the content of this paper proves useful in the disaster countermeasures of those countries that are vulnerable to natural disasters.

Although they could not be dealt with in this paper, aspects of support derived from the experiences of the Great East Japan Earthquake that could potentially be universalised exist. We feel that the factors for support to the affected regions listed below must be considered in greater depth, and we intend to continue to conduct research into such factors.

For example, with respect to financial assistance, the role of the municipalities is limited under the current system as it is not geared for flexible financing. Demand for funds is not being handled by national or municipal mechanisms, particularly in time-critical matters. Going forward, various initiatives for resolving these issues (financial assistance schemes such as risk insurance that utilises financial markets and quasi-investment type financial assistance from the private sector, etc.) will have to be taken up in order to consider their potential.

Furthermore, the fact that Kurihara City, Miyagi Prefecture rapidly sent out requests for support not only within Japan but also overseas merits attention as an actual example of transnational support for the affected regions. Ideally, partnerships and collaborations with domestic as well as overseas organisations (local governments, businesses, medical groups, NGOs, etc.) will be broadened in the future, and platforms for debating the potential for this will be needed.

Finally, instances in which organisations such as international agencies and international NGOs have the potential to underpin mutual support within developing countries clearly exist. This merits further study in terms of the types of non-governmental capabilities and functions, which would be aided by further debate over the creation of effective cooperative structures.

Appendix

Appendix 1: China: Twinning Assistance in Post-Wenchuan Earthquake

On 12 May, 2008, a magnitude 8.0 (Richter) earthquake struck Sichuan Province in south western China. Developed soon after the earthquake struck, the twinning assistance programme was an innovative and important component of the recovery and reconstruction model for its role in mobilising financial resources, transferring technology and materials, for sharing and developing technical expertise, and for timely relief and recovery. In the arrangement an unaffected city, county, or province was “twinned” with an affected area to provide recovery and reconstruction support. Initially the arrangement was referred to as “counterpart assistance” and was comprised of 19 partner provinces, counties, and cities selected to provide assistance to counterparts in the disaster affected area, with the requirement to offer assistance equal to at least 1% of their ordinary budget revenues (NDRC 2008). The programme was eventually expanded to 20 donor municipalities and provinces that worked with 18 cities and counties in Sichuan province in addition to the disaster-stricken areas in Gansu and Shaanxi provinces (IRP 2010) for a total of 20 partner areas.

Within a week of the earthquake, the Ministry of Housing and Urban-Rural Development initiated their response to the loss of millions of homes by arranging for the construction of one million pre-fabricated homes to serve as temporary housing for a 2-3 year period while permanent, earthquake resilient homes were being built (IRP 2010). With support from government subsidies, partnership assistance was organised in consultation with local groups and residents (NDRC 2008); the arrangements made in this programme were to serve as a model for subsequent twinning arrangements (IRP 2010).

Twinning arrangements were based on key sectors including rural and urban housing, healthcare and education, public utilities, employment and income generation, and environment and ecosystem restoration in addition to twinning arrangements for sharing best practices for disaster recovery and rebuilding (IRP 2010). Each sector included development of both “hardware recovery” and “software upgrading” in the form of tangibles such as buildings and other infrastructure including schools and hospitals in addition to upgrading the technical capabilities of the locale to improve services during and after the recovery phase. Capacity development was achieved by dispatching expert personnel from unaffected areas to conduct on-the-job training with local staff; conversely, local staff bodies were used for upgrading skills in the donor areas. Overall, these twinning programmes contributed to a broader recovery and reconstruction framework under the guidance of the National Development and Reform Commission and to longer-term regional development.

Table 1: Examples of Twinning Assistance Programme in China

Sector	Donors	Partners	Outputs
Health and Education	Beijing Municipal District	Shifang City, Sichuan Province	Disaster risk reduction education and training via e-learning for teachers and joint activities for students (evolved into a long term partnership)
	Shandong Province Shanghai Municipality	Beichuan County Dujiangyan City	Practical and on-the-job training for teachers, doctors, and managers
	Liaoning Province	Anxian County	Replacement of damaged and sub-standard school buildings with a new middle school constructed according to strict guidelines for earthquake safety
Public Utility Recovery and Reconstruction	Guangdong Province, Hunan Province, Shanxi Province, Jiangxi Province, Anhui Province, Shandong Province	Sichuan Province: Wenchuan County, Lixian County, Maoxian County, Xiaojjin County, Songpan County, Beichuan County	Power supply facilities repaired in the six counties, benefiting 87,000 households
Employment and Income Generation	Heilongjiang Province Hunan Province Shanxi Province	Jiange County Lixian County Mioaxian County	Job fairs in donor provinces to recruit human resources from affected areas for Twinning Assistance-funded reconstruction projects

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