Energy security in Japan
in the context of a planned energy system transition

Jeffrey B. Kucharski

Energy security in Japan in the context of a planned energy system transition

A dissertation submitted to
the Graduate School of Energy Science of Kyoto University
in partial fulfillment of the Degree of Doctor of Energy Science

by

JEFFREY B. KUCHARSKI

Kyoto, Japan
2016

Acknowledgements

I am very grateful to my supervisor, Prof. Hironobu Unesaki, who provided invaluable support and advice on the research direction of my thesis and made numerous helpful suggestions on the research papers and the thesis itself. His patient ongoing guidance and support is highly appreciated.

I would also like to thank the other members of my doctoral review committee: Prof. Keiichi Ishihara and Prof. Tetsuo Tezuka who provided invaluable comments and suggestions for improvements to the thesis. I also highly appreciate Prof. Benjamin McLellan's valuable comments and help with various research topics and for advice on improvements to research papers.

I would also like to thank Dr. Philip Andrews-Speed for accepting me as a visiting researcher at the Energy Studies Institute at the National University of Singapore in February 2015 and for helping broaden my understanding and appreciation of institutional theory.

This thesis is dedicated to my wife Hideko whose unfailing love, support and encouragement over the past three years sustained me and helped me get through the times when the hurdles seemed insurmountable. Her devotion and sacrifices on my behalf enabled me to complete the work, and for this I am forever grateful.

Extended abstract

The purpose of this thesis is to assess the impact of energy policies and institutions on Japan's energy system in order to identify current energy security issues as well as assess the outlook for energy security in the future. A major premise is that energy security is a function of policy, technology/infrastructure and institutions. While many studies of energy security have examined policies and technologies, relatively few have systematically examined the influence of institutions on energy security. Yet institutions exert a strong influence on how policies are articulated, interpreted and implemented and how the energy system itself evolves and changes.

This thesis uniquely combines an energy security assessment with an institutional analysis to provide the most comprehensive assessment of energy security and change in Japan's energy system since the Fukushima disaster. A novel analytical framework for energy security assessment is developed based on three properties (i.e.: robustness, resilience and adaptability) of a secure energy system. This study also provides the first in-depth analysis of the government's 2014 Strategic Energy Plan arguing that it represents a plan for a major energy transition. A framework for analysis of Japan's energy institutions integrates various institutional and related theories to provide a detailed analysis of the institutional structure for energy and to explain recent changes and the implications for Japan's energy security. Unique insights into the development of Japan's strategic energy plans and energy policymaking were made possible by supplementing the analysis with primary data gathered from interviews with senior government officials.

Energy security has been the fundamental driver of Japan's energy policy since the oil shocks of the 1970's and plays a central role in Japanese energy policy. The Japanese government has historically taken a strong role in regulating the energy sector given the importance placed on stable and reliable supplies of energy to support economic development and trade. Japan views itself as facing a wide range of potential threats to its energy security and virtually no other industrialized economy is as dependent on imports of energy resources as Japan. The shock of the Great East Japan Earthquake, tsunami and nuclear disaster of March 11, 2011 dealt a severe blow to Japan's energy system with far-reaching consequences for Japan's energy security. This "triple disaster" provoked a fundamental review of Japanese

energy policy and energy institutions, resulting in a series of policies and plans that are reshaping the structure and future evolution of Japan's energy system.

The central research question for this thesis is: **how do energy policies affect energy security in Japan?** This question can be further broken down into the following related issues:

- in terms of vulnerabilities to threats and risks facing the energy system;
- in terms of strategies to reduce vulnerabilities;
- in terms of the relationship with other policy objectives;
- in terms of institutional change;
- in terms of the potential impact on energy security in the future.

This thesis therefore seeks to fill a gap in scholarly studies of energy security regarding the impact of energy policies and institutional change on Japan's energy security.

The research questions are answered by assessing policies and institutions in both the pre-Fukushima and post-Fukushima periods through an analytical framework that incorporates a systemic, integrated and comprehensive approach to the analysis of Japan's energy system. It is systemic because the energy system is conceptualized as a socio-technical system that co-evolves with its environment and related systems. It is integrated because an interdisciplinary approach is employed in this study, drawing from systems theory, engineering, economics, risk studies, ecological and sustainability studies, political economy, governance theory and institutional theories. It is comprehensive because it goes beyond narrow definitions of "security of supply" to include analysis of the entire energy supply-demand chain and a broader range of factors impacting on energy security. Such approaches are rarely applied in the energy security literature, which generally tends toward more deterministic conceptions of the energy system and narrow definitions of energy security.

The analytical portion of this thesis is divided into two main sections. The first section is focused on assessing energy security and energy policy in Japan between 2000 and 2013. It consists of three sub-chapters that take quantitative and qualitative approaches to analyzing Japan's energy system in order to evaluate Japan's past and current energy security situation. This analysis is presented in terms of energy security over two distinct periods: the period from 2000 to 2010 leading up to the triple disaster, and the period after the disaster between 2011 and 2013.

Energy Security Vulnerability in Japan focuses on identifying and assessing vulnerabilities to the threats and risks facing Japan's energy system. The results show that between 2000-2010, Japan's overall energy security situation steadily improved in all segments of the supply chain, as measured by a broad suite of indicators of vulnerability. However, the triple disaster made some critical vulnerabilities worse and exposed new ones that posed significant challenges to Japan's long-term energy security and held important implications for policy.

The Impact of Japanese Energy Policies on Energy Security is focused on understanding the extent to which Japanese energy policies served to reduce vulnerabilities through their impact on energy system resilience and adaptability. The results show that between 2000 and 2010, policies and strategies served to strengthen energy system resilience and adaptive capacity, allowing the energy system to recover quickly after the triple disaster. However after the triple disaster, several indicators of energy system resilience and adaptability degraded and Japan's energy system shifted to a less desirable state with overall poorer performance and increased vulnerability.

Energy Security and Sustainability in Japan focuses on examining the government's energy security and sustainability (i.e.: climate change) goals and targets and evaluating the extent to which they were met. Over the 2000-2010 period Japan attempted to balance the "3-E's" of energy security, economic efficiency, and environmental suitability and aimed to achieve both energy security and sustainability objectives simultaneously. Over this period, the findings show that Japan's energy security situation generally improved but a number of key policy targets and objectives were not met. The triple disaster dealt a major blow to the balanced approach to energy policy as energy security and economic efficiency concerns took precedence over sustainability goals as the government sought to protect the economy.

The *Outstanding Issues and Vulnerabilities* sub-chapter summarizes the impact of Japanese energy policies on energy security up to 2013 and identifies and discusses ten energy security vulnerabilities and concerns that remain outstanding in the post-Fukushima period. These include issues related to nuclear power adequacy, low levels of renewables generation, lack of competition in electricity and gas markets, decline in support for nuclear power, inadequate inter-regional electricity and gas interconnections and exchange, electricity frequency conversion bottlenecks, weak demand-side management strategies, regulatory quality issues, and over-investment in electricity and gas infrastructure capacity.

The second section in this thesis consists of two sub-chapters that analyze institutions and institutional change in order to assess the potential impact on Japan's energy security in the future. The first sub-chapter, *Japan's 2014 Strategic Energy Plan: A Planned Energy Transition*, is focused on analyzing and evaluating the government's 2014 Strategic Energy Plan (SEP) in order to understand the nature and magnitude of the changes planned for Japan's energy system and related institutions. The analysis demonstrates that the shock of the triple disaster opened up a window of opportunity in Japan's policy environment for fundamental changes in Japan's energy policies, allowing for major reforms to the energy industrial structure and energy institutions. Given the nature and magnitude of the potential changes implied in the SEP, it is concluded that the 2014 SEP represents a major planned transition of the Japanese energy system.

The second sub-chapter, *An Institutional Analysis of the Japanese Energy Transition*, examines the institutional structure of Japan's energy sector, the changes that have been taking place within it, and the impact of Japanese government policy reforms on the energy sector. The analysis shows that while Japan's energy institutions evolved and changed incrementally between 2000 and 2010, the triple disaster represented a critical juncture in the path of Japan's energy system development, overturning several policy paradigms and provoking major institutional and structural changes in Japan's energy sector. The empirical evidence in this section demonstrates that these changes are consistent with the objectives of the 2014 SEP and suggests that government commitment to fundamental change appears strong. It is therefore concluded that the major energy transition implied in the 2014 SEP has already begun.

The period immediately following a critical juncture is crucial in terms of determining the future path of energy system development. The Japanese energy transition is still in a very early stage as the impacts of various policies and reforms gradually work their way through the energy sector. Developments over the 2016-2020 period are seen as crucial to setting the course and deepening the path of the transition. As momentum for change has accelerated and the effect of more dramatic market and structural reforms have become more evident, energy sector governance in post-Fukushima Japan is evolving to reflect the growing influence of competitive markets and a broader array of energy actors and institutions.

The analysis in this thesis strongly suggests that the policies and institutional changes that have been proposed for reforming Japan's energy sector in the post-Fukushima period are likely to help further reduce energy security vulnerabilities and address outstanding issues as long as they are fully and effectively implemented. Japan appears to be moving toward a more robust, reflexive form of energy governance that prioritizes adaptability and economic efficiency over the emphasis on predictability and stability of the past. While the future is uncertain and unexpected events and developments are sure to occur, the results presented in this thesis suggest that Japan has taken firm steps toward enhancing its energy security for the future.

Table of contents

Chapter 1: Introduction

1.1 Background

Energy security is a policy matter than is primarily concerned with protection from the risk of energy disruptions in an economy. Modern conceptions of energy security emerged in the early nineteenth century in a military context as war ships and military vehicles converted from coal to oil [1]. Energy security concerns rose to prominence during the World Wars, the energy crises of the 1970s, and wars in the Middle East. Over the last several decades energy security has emerged as a distinct area of scholarly studies [2]. As the field has developed, a broader range of issues have been incorporated and the concept of energy security has broadened and deepened [3].

Energy security can be considered a subset of national security, given its importance to the security and economic development of a nation [4], [5]. Governments are therefore deeply involved in policymaking to improve energy security. The governance of energy systems is a critical factor in determining whether and how energy systems can ensure energy security. Governance is not limited to government – it involves a range of actors and institutions. Institutions exert a strong influence on how policies are articulated, interpreted and implemented and how the energy system itself evolves and changes.

This thesis is concerned with energy security and change in Japan's energy system. Japan is third largest economy in the world and a major manufacturing and exporting country with an extremely low rate of energy self-sufficiency. It is the second largest net importer of fossil fuels in the world (after China), the world's largest LNG importer, the second-largest coal importer, and the third-largest net importer of crude oil and oil products [6]. Japan's energy security situation and energy policies therefore have a significant impact on regional and global energy markets.

Japan is an extreme case of vulnerability to energy disruptions and therefore represents an important subject for energy security studies. Other than South Korea, no other industrialized economy is as dependent on imports of energy resources as Japan. The country faces a wide range of potential threats to its energy security ranging from natural disasters to geopolitical events. The oil shocks of the 1970's had a profound impact on Japan's energy system, inflicting considerable damage on the economy and leaving the Japanese feeling very vulnerable to supply disruptions and price shocks. The country is faced with many other challenges, including an increasingly aging and shrinking population, a high national debt and eroding industrial competitiveness.

Energy security has been the fundamental driver of Japan's energy policy since the 1970's. Historically, even though the energy sector has mostly been in private hands, the Japanese government has taken a strong role in shaping the structure of the sector. The country sees its continued economic prosperity as closely tied to its ability to maintain a stable and adequate level of energy supplies and services to its economy. Currently, Japan's policymakers are challenged with managing a wide range of difficult structural reforms in order to improve competitiveness and maintain a high standard of living. Following the Great East Japan Earthquake and Tsunami of March 2011, energy sector restructuring is seen as playing a pivotal role in helping meet the goals of the government's broader economic agenda as well as enhancing future energy security.

1.2 Summary of related scholarly studies

Scholarly studies of energy security assessment have employed various methodological approaches. Many qualitative studies have focused on the political and geopolitical aspects of energy security while many quantitative studies focus on measuring certain dimensions of energy security by using various indicators in order to evaluate energy security performance [2]. The energy security literature tends to be multidisciplinary since most studies employ separate methodologies and therefore often promote differing or even opposing solutions to energy security issues.

Relatively few studies have evaluated Japan's energy security in a comprehensive way, employing a broad conception of energy security and examining the whole energy supply-demand chain, especially post-Fukushima. While studies of energy security have examined the relationship between energy and environmental policies (see: [7]–[13]), nuclear power policy (see: [14]–[17]), security of the electricity grid (see: [18], [19], renewables (see: [20]–[22]) and other specific energy security issues (see: [23]–[27]), only a very few recent studies have taken a broad approach to evaluating overall trends in Japan's energy security (for examples, see: [28]–[31]).

Studies of energy security have been criticized on various grounds, including that they are arbitrary, rarely use a systematic approach to energy security assessment, and cannot be applied universally from country to country [2]. Many studies fail to explain the concept of risk adequately, focus on only one part of the energy system or define the system so narrowly that the range of risks under study is very limited [32]. As a result, the literature lacks frameworks incorporating a broader range of response strategies capable of dealing with the increasing number of risks and uncertainties facing modern energy systems [33].

A recent scholarly review of methodologies used in peer-reviewed energy security studies highlighted a number of issues and gaps in the existing literature along with recommendations for future research (see: [34]). Firstly, the authors noted that most studies of energy security adopt a static perspective on the energy system whereby threats and risks are seen as independent from how the energy system responds. They recommend a systemic approach that focuses more on evaluating system response, including the properties of resilience and adaptive capacity, as strategies to reduce system vulnerabilities. Secondly, the authors note that research on energy security assessment often tends to focus on the behavior of energy subsystems (such as the electricity grid, or petroleum sector) rather than the behavior and performance of the energy system as a whole. As a result, studies that take a "whole of system" perspective to assessing vulnerabilities across the energy supply chain are under-represented in the literature on energy security.

Since energy security is a function of the interactions within an energy system as well as the interactions with other complex systems in its environment, it therefore needs to be assessed from a systemic perspective [35]. While some studies of energy security assessment have conceptualized the energy system in such a way, the author could find no examples that apply this approach to the case of Japan.

Finally, and as already noted, the scholarly literature on energy security assessment is multidisciplinary and very few studies integrate various theories and approaches in order to provide a more holistic evaluation. Consequently, an interdisciplinary approach to the assessment of energy security has been recommended as a way to bridge the gap between various theories and assumptions and improve the evaluation of energy security [34].

Typically, energy security assessment, the analysis of energy institutions and energy transitions are treated separately in the literature. While a number of studies have applied institutional theory to the energy sector, most studies of energy security generally tend to overlook the institutional context within which the energy system is embedded. In addition, few studies have systematically applied institutional theory to energy transitions. The systematic application of institutional theory can provide deeper insights into the impact of policy on energy security and on energy transitions yet few authors have drawn on the institutional literature to frame their arguments [36].

There are very few systematic studies of Japanese energy institutions in the scholarly literature. Samuels [37] analysis of the role of the state, markets and institutions in Japan's energy system is extensive and insightful but is now dated since much has changed since this book was published in 1987. A few recent studies by political economy scholars have included an institutional analysis in their study of the impact of the Fukushima disaster on energy policy and related institutions. Most of these studies come from political economy scholars who generally employ rational choice theory. This approach views institutions as being deliberately constructed by actors so as to promote and protect their own interests [38]. These studies assert that change in Japan's energy system has been effectively blocked by Japan's monopoly utilities, the so-called "nuclear village" and various interests conspiring to preserve the status quo. Whether through institutional resilience (see: [39], [40]), discourses that shape public perceptions (see: [41]–[43]) or the power of vested interests (see: [13], [24], [27], [44]) the dominant perspective of this literature assumes that the public will has been ignored or subverted and that institutional rigidities fostered by cozy relationships among politicians, the bureaucracy and industry vested interests have slowed or prevented change in Japan's energy institutions. One recent study on Japan's energy security that adopts this perspective is Vivoda [28]. This study makes the assertion that even after the Fukushima disaster, Japan's energy institutions and policymaking process "remains dominated by vested interests and centered on METI" [28].

To summarize, the scholarly literature lacks systemic, comprehensive and interdisciplinary approaches to energy security assessment. Other than Vivoda's [28] recent study, there are no examples of broad comprehensive studies that assess the impact of energy policies and institutional change on Japan's energy security in the post-Fukushima period. Given the critical importance of energy security to sustaining the world's third-largest economy, it is important to understand how recent changes in Japan's energy policies and institutions are impacting on its energy system. This thesis therefore aims to fill a gap in the scholarly literature by integrating a broad, systemic energy security assessment with a detailed institutional analysis in order to provide new insights into how energy policies affect energy security in Japan.

1.3 Research purpose and questions

While aspects of Japan's energy system have been studied in detail by a wide range of scholars employing various perspectives on energy security, this study aims to fill a gap in the scholarly literature regarding the impact of energy policies and institutional change on Japan's energy security.

Purpose of this study

The purpose of this study is to assess the impact of energy policies and institutions on Japan's energy system in order to identify current energy security issues as well as assess the outlook for energy security in the future.

Research questions

The central research question for this thesis is: **how do energy policies affect energy security in Japan?** This question can be further broken down into the following related sub-questions:

1. in terms of vulnerabilities to threats and risks facing the energy system;
2. in terms of strategies to reduce vulnerabilities;
3. in terms of the relationship with other policy objectives;
4. in terms of institutional change;
5. in terms of the potential impact on energy security in the future.

These questions will be answered by assessing policies and institutions in both the pre-Fukushima and post-Fukushima periods through an analytical framework that incorporates a systemic, integrated and comprehensive approach to energy security assessment.

1.4 The present research

A major premise of this thesis is that energy security is a function of policy, technology/infrastructure and institutions. An interdisciplinary approach is therefore employed, conceptualizing Japan's energy sector as a socio-technical system where technology and policy options must be considered within the social and institutional context. Defining the energy sector as a socio-technical system enables a systemic and more comprehensive analysis of the energy system by examining how various components of the system interact with each other, and with the system's environment.

Such a conception strongly suggests the use of a framework for analyzing interrelationships between existing structures, actors, perceived problems and possible solutions [45]. Accordingly, this thesis employs an analytical approach to assessing Japan's energy policy and energy security that is systemic, integrated and comprehensive. It is systemic because the energy system is conceptualized as a socio-technical system which is an open system that co-evolves with its environment and related systems. It is integrated because an interdisciplinary approach is employed in this study, including systems theory, engineering, economics, risk studies, ecological and sustainability studies, political economy, governance theory and institutional theories. Finally, it is comprehensive because it goes beyond narrow definitions of "security of supply" to include analysis of the entire energy supply-demand chain and a broader range of factors impacting on energy security. Such approaches are rarely applied in the energy security literature, which generally tends toward more deterministic conceptions of the energy system and narrow definitions of energy security.

An important aim of this study is to further explore the relationships and interactions between actors (both public and private), technologies, infrastructures and institutions at all levels of the energy system so as to gain deeper insights into energy system vulnerabilities as well as into certain properties of systems that may serve to enhance energy security.

The structure of the thesis

This thesis is structured as follows. Chapters 1 and 2 provide an introduction to the thesis and a conceptual review of the concept of energy security. This is followed by the development of an analytical framework and methodological approach that applies primarily to the analyses in Chapter 4.

Chapter 4 consists of three sub-chapters that assess the energy security of Japan's energy system from different perspectives in order to **address the first three research questions** posed by this thesis. These chapters give an **assessment of Japan's past and current energy**

security situation in the pre-Fukushima (2000-2010) and post-Fukushima (2011- 2013+) periods. Chapter 4.1, *Energy security vulnerability in Japan* focuses on identifying and assessing vulnerabilities to the threats and risks facing Japan's energy system. Chapter 4.2, *The impact of Japanese energy policies on energy security* is focused on understanding the extent to which Japanese energy policies and strategies served to reduce vulnerabilities through their impact on energy system resilience and adaptability. Chapter 4.3, *Energy security and sustainability in Japan* focuses on examining the relationship between energy security and related policy objectives and evaluates the extent to which energy security and sustainability goals and targets were met. Chapter 4.4, *Outstanding energy security issues and vulnerabilities* summarizes the findings from the analyses in the three preceding chapters and highlights the energy security policy implications.

Chapter 5 consists of two sub-chapters that describe the current context for institutional change in Japan's energy sector in order to **address the last two questions** posed by this thesis. The focus of analysis is placed on Japan's energy-related policies, plans and institutions in order to assess the potential **impact on Japan's energy security in the future**. Chapter 5.1, *Japan's 2014 Strategic Energy Plan: A Planned Energy System Transition* explains the key features of the 2014 Strategic Energy Plan and analyzes the plan's significance for energy system change. Chapter 5.2, *An institutional analysis of the Japanese energy transition* examines Japan's energy-related institutions, institutional change and the implications for energy system transition and governance.

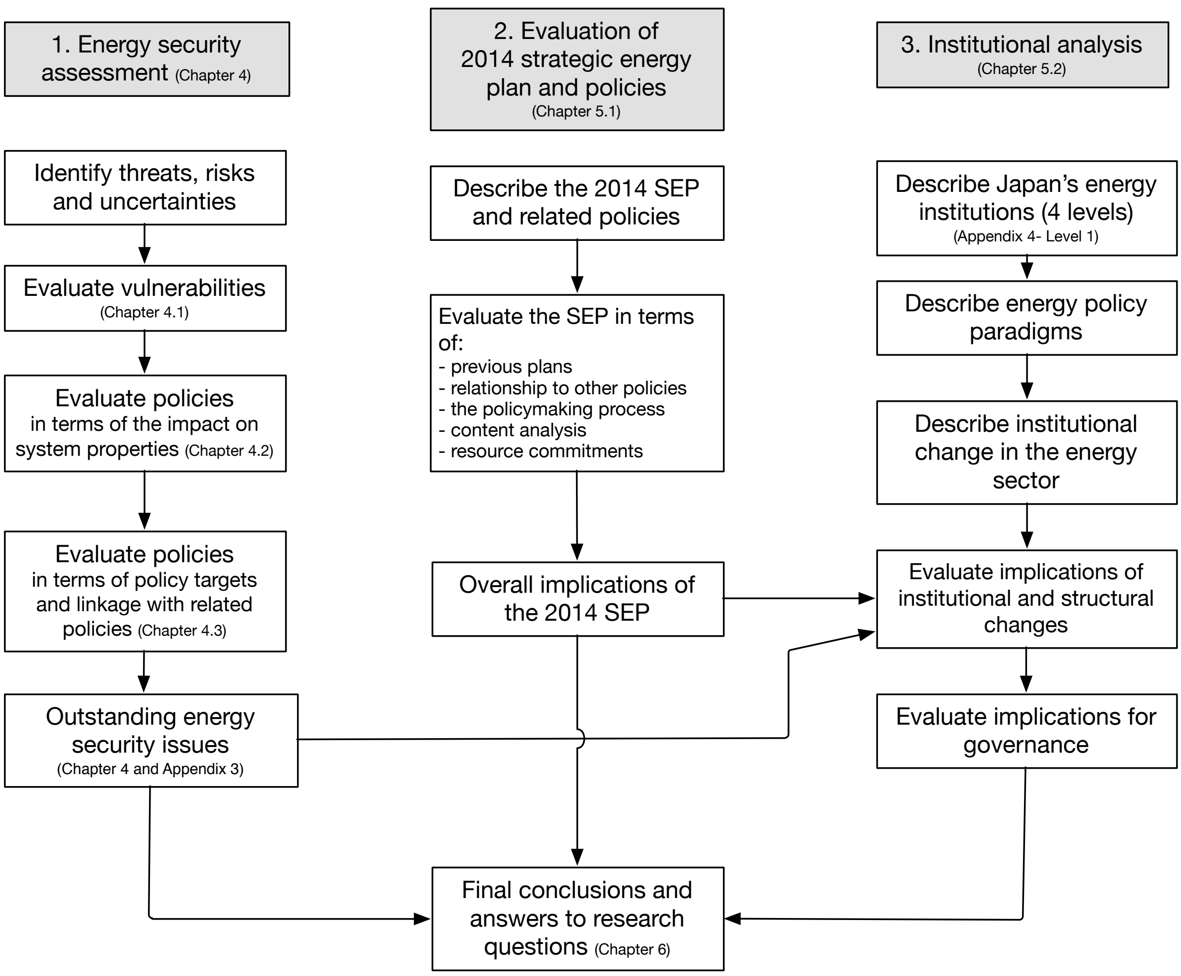
Chapter 6, the concluding chapter, discusses the implications for energy security and transition in Japan's energy system and directly answers the research questions posed in this thesis. Table 1 below relates the research questions to the relevant chapters in this thesis.

The structure of the argument used to address the research questions posed in this thesis is depicted in Figure 1.

Table 1: Research questions and organization of the thesis

Research question: how do energy policies affect energy security in Japan?	**Primarily addressed in:**	**Purpose of analysis**
in terms of vulnerabilities to threats and risks facing the energy system	Chapter 4.1	To produce an assessment of ***Japan's past and current energy security situation***
in terms of strategies to reduce vulnerabilities	Chapter 4.2	
in terms of the relationship with other policy objectives	Chapter 4.3	
Summary of Chapter 4 findings and the policy implications for Japan's energy security	Chapter 4.4	
in terms of institutional change	Chapters 5.1 and 5.2	To produce an assessment of the potential impact on ***Japan's energy security in the future***
in terms of the potential impact on energy security in the future	Chapters 5.1 and 5.2	
Overall conclusions and answers to the research questions	Chapter 6	

Figure 1. Logic diagram of the structure of the thesis



1.5 Definitions and terms

Definitions:

Varying definitions of terms related to the security and vulnerability of systems have been employed in various disciplines including ecology, systems science, management science and the energy security literature. The following definitions have been derived from these various disciplines to provide clarity in the context of this thesis.

Vulnerability –a feature of a system or object that may be susceptible to disturbance.
Threat – anything that can potentially exploit a vulnerability, intentionally or accidentally, and adversely affect an object or system.
Disturbance – a phenomenon, factor, or process, either internal or external to the system, which may cause a shock to or stress in a system.
Polysemic – capable of having many possible meanings, interpretations or dimensions.
Risk[1] – the probability of an unfavorable outcome or event. Risk is a function of threats exploiting vulnerabilities. Risks arise from knowledge of the outcome of a threat and the probability distribution of the threat occurring.
Shock – a sudden, acute, episodic disturbance. Examples of shocks that are internal to the energy system include price spikes, infrastructure failures, and industrial conflict. Examples of shocks arising external to the energy system include market disruptions, geopolitical events, and natural disasters.
Stress – a continuous or slowly increasing pressure. If internal to the energy system, examples include market competition, resource depletion and consumer demand shifts. If external to the energy system, examples include technological or geopolitical changes, climate change and demographic shifts.
Systemic – As relating to a system and the interrelationships in a system. Implies a holistic conception of a problem or issue within the context of a system.
Systematic – Characterized by a methodical plan or step-by-step procedure of how to do something.

[1] Although the term risk has a specific meaning and application as described here, the term is often understood in a general sense to include all types of incertitude, including both risks and threats to a system.

Abbreviations:

Common abbreviations used in this study are summarized below. Others are defined in the text as they appear.

Advisory Committee for Natural Resources and Energy (ACNRE)
Agency for Natural Resources and Energy (ANRE)
Complex adaptive system (CAS)
Distributed generation (DG)
Energy Data and Modelling Center (EDMC)
Federation of Electric Power Companies of Japan (FEPC)
General electric utility (GEU)
Greenhouse gasses (GHG)
International Energy Agency (IEA)
Institute for Sustainable Energy Policies (ISEP)
Japan Renewable Energy Foundation (JREF)
Kilograms of oil equivalent (koe)
Million tons of oil equivalent (Mtoe)
Ministry of International Trade and Industry (MITI)
Ministry of Economy Trade and Industry (METI)
Ministry of Environment (MOE)
Ministry of Land, Transportation and Technology (MLIT)
Megawatts (MW)
New National Energy Strategy (NNES)
Organization for Economic Cooperation and Development (OECD)
Primary energy supply (PES)
Photo-voltaic (PV)
Strategic Energy Plan (SEP)
Socio-ecological system (SES)
Socio-technical system (STS)
The Institute of Energy Economics Japan (IEEJ)
Total primary energy supply (TPES)
Trillion cubic feet (tcf)

1.6 Delimitations of this study

This study takes a broad, interdisciplinary approach to the assessment of energy security in Japan. Out of necessity, the depth to which any single issue can be examined and analyzed is limited. A wide range of theoretical approaches are drawn upon in the interest of taking an integrated approach and therefore no attempt is made to provide a comprehensive literature review of all of the relevant theory. Instead, only those elements of theory that were judged by the author to support the analytical framework and to address the thesis questions are reviewed.

The analytical framework employed in this thesis cannot be exhaustive of all threats, risks and vulnerabilities and only those that were judged to be particularly relevant to the case of Japan have been identified. While this study conceptualizes the energy system as a complex adaptive system with multiple interactions within the system and with other systems, not all possible system interactions can be identified or analyzed and so the choice of which dimensions or elements to analyze is necessarily limited.

The use of indicators in order to "measure" energy security also comes with certain limitations. Indicators cannot measure vulnerability directly; they can only measure changes that can be considered a proxy for the potential risk and/or magnitude of a threat should it actually occur [46], [47]. Complex aggregate indices are not employed in this study due to transparency issues that limit the reliability of such indicators.

With respect to policy, this thesis is focused on the impact of energy policies on the energy system. There is no question that other policies also have some impact as well, including macro-economic policy, fiscal policy, financial policies, innovation policy, climate change policies and so on. However for the purposes of this thesis, these policies are considered exogenous influences on the energy system and for the most part are excluded from the analysis except in instances where their impact is particularly significant.

Chapter 2: Conceptual review of energy security

2.1 What is energy security?

Energy security is primarily concerned with protection from risk. Energy security has been defined broadly as "protection from disruptions of energy systems that can jeopardize nationally vital energy services" [48].

Energy security is a somewhat ambiguous concept and many definitions exist. Although the term is widely used, there is no universally accepted interpretation [49]. The concept of energy security has been described by one scholar as "inherently slippery because it is polysemic in nature" [3].

Definitions of energy security range from very narrow conceptions, such as "security of supply", to broad ones such as "the reliable, stable and sustainable supply of energy at affordable prices and social costs" [50]. The traditional definition of energy security focused on "security of supply" issues, which initially concerned the uninterrupted supply of oil. This was broadened to incorporate other globally traded fuels as well as the price of energy, in recognition of the linkage between the availability of physical supplies and prices. This concept is reflected in the IEA's definition of energy security as, "the uninterrupted availability of energy sources at an affordable price" [51].

The literature suggests that many current definitions of energy security are too narrow to encompass issues that many policymakers and researchers agree are essential to a full and complete definition for current use [52]–[54]. Others have pointed out that a narrow conception of energy security can pose serious challenges to energy policies [55]. Definitions of energy security can also be so broad that they divert attention from what is essential, thus becoming incoherent and hard to differentiate from energy policy in general [3], [56].

In recent years, a broader range of factors beyond "security of supply" have begun to be incorporated into conceptions of energy security. For example, from the perspective of an energy exporting country, energy security is also concerned with "security of demand". Conventional approaches to energy security have also tended to underestimate demand-side risks [53]. Consumers and "prosumers" are increasingly shaping the evolution of energy systems. Demand-side trends and behaviors impact on primary energy sources in the energy mix, on self-sufficiency, as well as on environmental health due to the linkage with GHG emissions. The concept of energy security has therefore expanded to include demand-side issues. *Energy services security* has been defined as "the certainty level of enduring, uninterrupted access of the population in a defined region to affordably and competitively priced, environmentally acceptable energy end-use services" [57].

2.2 Why energy security is important

As energy markets become increasingly global and issues affecting energy systems increase in number and complexity, the concept of energy security is being challenged to accommodate these developments. The increasing demand and competition for energy resources, along with fears of potential resource depletion, high prices and the effects of climate change are at the root of why energy security has become so important recently [52].

Modern energy supply systems are much more complex today than ever before. Increasingly integrated energy transportation and electricity transmission systems, ICT-enabled energy production and transportation control systems, and financial and energy market linkages are some of the factors that have contributed to the increased complexity and interdependence of energy systems and markets, raising the risks and potential impacts of supply disruptions [3], [58].

Energy security is considered by most governments to be an essential aspect of national security due to the important influence it has on the sovereignty and economic development of nations [59]. In extreme cases, energy can be used as a political "weapon" and could pose a serious economic threat to a country [60]. As a result, there are significant geopolitical and national security dimensions to energy. Most governments perceive a need to ensure against potential threats to the energy system including from embargoes, disruptions, cyber-crime, the exercise of market power, war and terrorism.

Economic shocks, price spikes, price volatility and the exercise of market power can have serious implications for energy markets and for energy security. On the other hand, poorly functioning market mechanisms, energy subsidies and over-regulation can distort markets and price signals resulting in inefficient use of energy resources, under-investment in energy infrastructure and stifle innovation and technology development [61].

The energy sector has a significant impact on environmental sustainability and is the source of two-thirds of global greenhouse gas emissions [62] which in turn is the major cause of anthropogenic climate change. Energy production and use has local, regional and global impacts on the environment and consequently climate change is now widely seen as a key driver of future energy policy [63]. As the frequency of extreme weather events increases, energy systems may increasingly be affected. Accordingly, climate change has recently been recognized as a threat to energy security because of the impact it can have on the sustainability of energy systems themselves [64].

Recently, the social/public acceptability aspects of energy activities have risen to prominence. Public attitudes toward energy activities are diverse and issues such as "not in my backyard" (NIMBYism), social justice and public acceptance issues have the potential to restrict or even halt certain energy activities with significant consequences for energy security. Citizens are increasingly demanding involvement in decisions that they feel could impact on them and/or their communities, or even to question decisions after they have been made [65]

Technology is playing an increasing role in assuring energy security. Technology comes with both risks and benefits. On the risk side, technologies are susceptible to risks such as from critical failure, safety issues and unintended consequences of use [66]. On the other hand, technology is critical to energy exploration and development as well as to reducing environmental impacts, improving energy efficiency and developing clean energy solutions [67].

2.3 Short-term vs long-term energy security

While many disruptions to energy supplies or energy services are often of short duration, the persistence of some threats and stresses on the energy system may impact energy system performance over many months and years. Therefore, a distinction is made between short-term energy security (minutes to weeks) and long-term energy security (months to decades) [35].

Short-term energy security is concerned with the disruptive impacts on the function of the energy system as a result of sudden shocks, such as from a price shock or disruptions in energy supplies. Short-term energy security implies a time interval over which the system can respond without fundamentally changing [35].

Governments have tended to place emphasis on short-term energy security concerns, given the obvious political and economic implications of disruptions. Various authors have called attention to the short-term perspective on energy security held by many policymakers, pointing out that short-term disruptions in energy supplies and emergency situations tend to get most of the attention [57], [68], [69].

Long-term energy security as a concept has not been as clearly defined in the literature and various interpretations exist [68]. Many existing approaches associate the concept with “adequacy of supply”, which implies that adequate investments in energy supply capacity and infrastructure are made in a timely fashion [70]–[72]. Underinvestment in energy infrastructure or inadequate market design may lead to increased risk of disruptions. For these reasons, a comprehensive approach to energy security assessment should include the analysis of vulnerabilities in the energy transformation and transmission segment of the energy supply chain. A focus on *infrastructure adequacy and security* issues is therefore warranted.

This thesis considers long-term energy security concerns to be as important as short-term ones. While political attention is often focused on short-term concerns, policies to ensure that adequate and sustainable energy infrastructure is in place when needed and that energy services are sustained over longer time scales deserves attention by policymakers.

Chapter 3: Analytical framework and methodology

Energy security is a policy matter. Therefore, energy security assessment should be policy-oriented and policy-relevant. A policy-oriented approach is one that is inclusive of a broad range of factors that can potentially impact on energy security [73]. A systemic, integrated and comprehensive approach to energy security assessment is therefore called for.

In this chapter, a framework for the assessment of energy security in Japan's energy system is developed in order to meet this objective. This framework applies mainly to the analyses in Chapter 4 which seek to measure and assess energy security for the 2000-2013 period. Methodologies for the analysis of Japan's strategic energy plan and the institutional structure surrounding Japan's energy system are detailed in the relevant sections of Chapter 5.

The analytical framework developed in this chapter is based on an extensive literature review which was conducted using an interdisciplinary approach. This review covered relevant theory from economics, systems science, ecology, international relations, risk management and policy studies as well as from the existing literature on energy security. Where necessary, new interpretations of existing theory are proposed or concepts are modified and/or extended to be made relevant to the approach presented. Case studies have been drawn upon and examples have been employed to illustrate concepts. Concepts are explained and developed in order to address the research questions outlined in the introduction.

3.1 Research methodology

Given the research questions posed, the broad perspective on energy security assumed in this study, and the narrative quality of policy issues, it was decided that a mixed methods approach to the analysis of data would be most appropriate.

A quantitative approach is used principally to measure energy security in Japan's energy system over the 2000-2013 period. Primary data in time series was obtained, formatted and analyzed using various quantitative and statistical methods in Excel. Energy statistics and climate related data were collected from primary or secondary sources including from the Japanese government (especially METI and MOE), the Energy Conservation Center of Japan (EDMC), the Institute of Energy Economics Japan (IEEJ), the IEA, EIA, OECD, World

Bank, UN and other sources. Energy security and sustainability indicators were calculated from IEA, the Energy Conservation Center of Japan (EDMC), and UN data.

A qualitative approach was used to supplement quantitative data when comparable quantitative data was lacking or because of the characteristics of the variable being assessed. In order to understand the Japanese government's policy concerns and priorities and to inform the analysis in this thesis, a survey of Japanese energy policies covering the period from the 1990's up to 2013 was conducted. Major laws and policies governing the energy sector were compiled in order to extract information on goals, objectives, targets and strategies. This information has been collated in Appendix A. Special attention is given to nuclear, electricity and gas sector policies since these sectors have undergone significant changes in recent years. Information on Japanese policies and targets were collected from primary sources including published government reports and policy documents both in English and Japanese. Documents were reviewed to extract information on historical data, including adjustments and revisions that were made during the period under study. Main sources included the Ministry of Economy, Trade and Industry (METI), Ministry of Environment (MOE) the Cabinet Office of Japan, and the IEA's Policies and Measures database. Content analysis was used to analyze energy policy documents and briefs.

3.2 Approach to the analysis of energy security in this thesis

Energy security has multiple dimensions because the energy system is complex, with multiple dynamic vulnerabilities. Energy security is itself a property of the energy system [74]. The energy system therefore needs to be assessed from a systemic perspective, taking into consideration all of the elements and components of the system while pointing out the interactions and interdependencies between them [35].

As energy systems have become more complex and pervasive in societies, the issues arising from the role of energy have increased in number and complexity. As a result, a growing number of authors subscribe to a broader and more comprehensive approach to energy security assessment that considers economic, technological, environmental, social, and geopolitical factors [33], [52], [53], [75], [76].

Many energy security assessment studies provide normatively derived definitions of energy security to suit the purpose of those studies. Such "top-down" approaches focus on what policymakers *should* be concerned with rather than what they actually *are* concerned with. The approach in this thesis follows the perspective that energy security should be concerned with "empirically observed policy concerns" and that top-down definitions cannot claim to be policy relevant [2]. Therefore, this study draws upon a review of government laws, policies and reports in order to identify energy-related policy concerns and priorities (Appendices 1 and 2).

While this thesis argues for a broad, comprehensive approach to energy security assessment, it does not do so by developing a formal definition of energy security. Rather, a bottom-up approach is employed by identifying the threats and risks to energy security perceived by the Japanese government, and by examining energy security concerns embodied in Japanese energy policies.

3.3 The energy system

3.3.1 The energy system as a Complex Adaptive System

A complex adaptive system (CAS) is a special type of system. There are two requirements that make the system both complex and adaptive and differentiate a CAS from other systems. First, a CAS requires a large number of "agents" (e.g.: human beings and technological components) that are able to interact with each other dynamically and in a non-linear fashion. This makes the system complex. The interactions among the agents in the system are not controlled or governed by some central authority; control is distributed throughout the system. Secondly, the agents learn and adapt in response to influences from each other and through feedback from the environment. New patterns, structures and properties for the system as a whole emerge from these self-organizing interactions[2] which tend to increase the system's "success". These emergent responses affect the system's environment which in turn affects the subsequent interactions of the agents, a process known as *co-evolution* [77]–[79].

Since CAS operate far from equilibrium and exhibit non-linear behavior, predicting specific future behaviors of a CAS is virtually impossible with any degree of certainty. Cause and effect relationships between system components in a CAS are far more intricate and difficult to predict than a linear or causal process [80]. While simple linear systems lend themselves to

[2] Self-organization and emergence has been observed in many human and biological/technical systems including in financial markets, open market economies, ecosystems and social movements.

predictions, complex systems can only allow for what have been called "pattern predictions": the general attributes of the behavior that emerge in a system [81]. Examples include macroeconomic patterns such as the business cycle and stock market "boom and bust" cycles.

Socio-technical systems are a special type of complex adaptive system where technologies, institutional arrangements (e.g. laws, regulations, norms), social practices and actor relationships (including producer-consumer relations, intermediary organizations, public authorities) are mutually dependent and are embedded within the broader context of cultural paradigms, norms, values, and socio-economic trends (global energy markets, international institutional frameworks, etc.) [45].

In this study, the energy system is conceptualized as a socio-technical system. Doing so provides a unique perspective on change that is distinct from more linear, deterministic approaches. It acknowledges our inability to predict with any degree of certainty, particularly over the long-term. It also accounts for uncertainty and non-linearity and suggests that energy systems and related systems influence each other and co-evolve in a dynamic and ongoing process of change.

Socio-technical systems are characterized by path dependence and inertia. This means that energy infrastructures and institutions tend to be highly resistant to change. This is because there are significant human and financial investments in these structures and because they have co-evolved together [82].

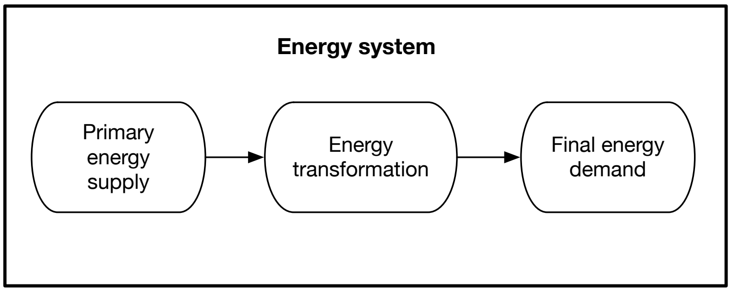
3.3.2 Defining the energy system

The advantage of conceptualizing the energy system as an STS is that it allows for a multi-dimensional perspective on energy security. This necessitates viewing the energy system from various scales.

At the *micro* level, complexity is expressed in terms of a large number of "agents"– human beings or technological components – that interact with each other in a non-linear fashion. The agents learn and adapt their behavior based on these interactions and co-evolve with their environment.

At the *meso* (intermediate) level, a national energy system can be defined as the interconnected components of human systems (including institutions), technology and infrastructure that convert natural sources of energy into energy services and amenities. These components also co-evolve. The energy system can be viewed as a supply chain consisting of three main subsystems: primary energy supply, energy transformation and final energy demand. This view of the energy system is useful for understanding the relationship between subsystems and the flows of energy demand and supply (see Figure 2).

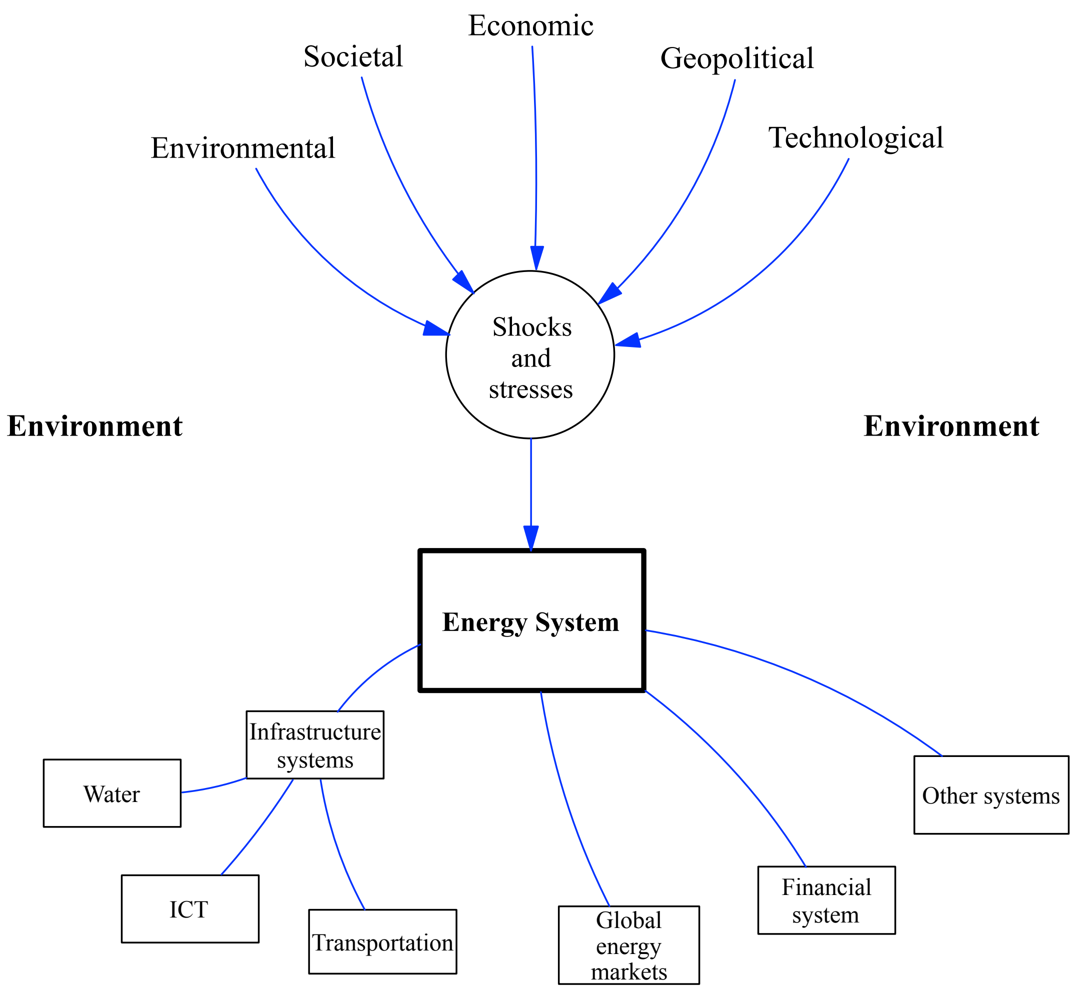
Figure 2: The energy system



At the *macro* level, the energy system can be viewed as a socio-technical "system of systems" that interacts and co-evolves with other complex systems in its environment. These interconnected systems are extremely complex with multiple interdependencies and as a result are vulnerable to a variety of threats, risks and systemic failures [83], [84]. Related but exogenous systems include certain infrastructure systems (e.g.: water, transportation, ICT systems), financial markets, global energy markets, international institutions (e.g.: IEA, UN, etc.), and other systems (See Figure 3).

The principal focus of this thesis is on Japan's national-level energy system (the meso level), however interactions and influences with the micro and macro levels will also be examined where necessary and appropriate.

Figure 3. The energy system as a system-of-systems



3.4 The energy system and risk

3.4.1 Defining risk and uncertainties

The energy system has multiple potential vulnerabilities because it is a dynamic system with complex internal interactions and multiple interdependencies with other complex systems in its environment. Where vulnerabilities are exploited by shocks, stresses and threats there is risk. Risk reflects the potential inability of the energy system to deliver on its essential function.

There is general agreement that energy security is concerned with risks[3] [32], [63]. Furthermore, energy security is about assessing various types of risk in the energy system [69] and developing strategies and policies to manage those risks [58]. It is useful to begin the discussion of risk by describing the difference between risk and other uncertainties.

Stirling [85] described four fundamental categories of "incertitude", each corresponding to different evaluation and response strategies. These categories are derived from two factors: knowledge of the likelihood (or probability) of an event occurring and knowledge about the nature of the outcome (see Table 2).

Table 2: Categories of incertitude and response strategies

Knowledge about Likelihoods	**Knowledge about Outcomes**	
	Well-defined outcomes	*Poorly defined outcomes*
Some basis for probabilities	***Risk*** (apply: probabilistic techniques such as Monte Carlo analysis, portfolio theory, cost-benefit analysis, other risk assessment methods)	***Ambiguity*** (apply: fuzzy logic, expert groups, Delphi methods, multiple perspectives, etc.)
No basis for probabilities	***Uncertainty*** (apply: demand margins, scenario analysis, sensitivity analysis, enhance adaptability)	***Ignorance*** (apply: diversification, redundancy, enhance resilience and adaptability)

Strictly speaking, the use of the term "risk" should only be applied to situations where both the outcome and the probability are well understood. For example, electricity transformers in electricity grids have a well-known failure rate and the impact of such a failure on a grid is also well understood. Risk can be therefore be measured with a high degree of reliability and steps can be taken to manage this risk using well known risk management methods.

Other forms of incertitude do not lend themselves to traditional risk assessment. Treating uncertainties as if they were risk raises serious reliability and validity concerns [86]. Various methods exist, including diversification and other techniques, to hedge against the outcome of uncertainties.

[3] For the remainder of this study, the term "risk" is used in a general sense to describe all types of uncertainty except where specified.

"Uncertainty" applies to situations where there is good information to characterize the outcome of a threat, but little basis for determining the probability of the threat occurring. An example is an earthquake where models exist that can reliably estimate the damage that would be incurred at a given magnitude, but the earthquake itself cannot be predicted with any degree of confidence. "Ambiguity" on the other hand is where an event is predictable but once it has occurred the understanding of what happened or the implications are poorly understood. For example, there was some basis for predicting insurgent warfare would breakout in Iraq in 2014 but an unexpected outcome was that a hydro dam came under the control of the insurgents with consequences that were poorly understood at the time.[4]

Under conditions of "ignorance", a threat is poorly understood or not understood at all, and there is no basis to determine the probability of it occurring. For example, anthropogenic climate change was not recognized as a threat until after its effects began to be felt and researchers began to study the problem.

3.4.2 Types, sources and temporality of risk

Threats and risks to the energy system can be categorized by the following characteristics:

- *Source* - where the threats or risks originate, either internal or external to the energy system
- *Controllability* - the extent to which risks and threats can be managed or controlled
- *Temporality* - in terms of the difference between short-term shocks and long-term stresses

Source and controllability

Internal risks are defined as risks that are generated from within the energy system and are usually controllable. Internal risks include both technical and human risk sources [32]. Technical risks include failures in energy infrastructure such as from a pipeline leak, transformer failure, or control system failure. Human risk sources include those generated from employee errors, poor management decisions or unauthorized actions.

4 "ISIS battling to seize Iraq's largest dam — which can unleash 'a 15-foot wall of water' on Baghdad", National Post, August 5, 2014. http://news.nationalpost.com/2014/08/05/isis-battling-to-seize-iraqs-largest-dam-which-can-unleash-a-15-foot-wall-of-water-on-baghdad/

External threats (also referred to as uncertainties) are defined as events that originate in the external environment and are usually not controllable. They can be further categorized along several dimensions [87], [88]:

- *Economic threats* can arise from volatility in the price of energy products and services, spikes in energy commodity prices including oil price shocks, and the failure of energy infrastructure that can disrupt the supply of energy in the economy.

- *Environmental threats* to the energy system can have both anthropogenic and natural causes. Such threats can be caused by greenhouse gas induced climate change, including severe weather events (floods, storms, fires), natural disasters (earthquakes, tsunami's) water shortages affecting dams and power plants, and damage to energy infrastructure such as pipelines, ports and railways from climate variability.

- *Societal threats* can arise from a lack of public acceptance of energy activities (e.g.: resistance to nuclear power, "fracking", oil pipelines, high voltage overhead transmission wires, NIMBYism), energy poverty and social inequities.

- *Technological threats* can be generated from cyber- crimes ("hacking") that attack energy subsystems and control systems as well as information and telecommunications networks on which energy systems increasingly depend resulting in infrastructure disruptions, data loss and system failures. Also, lack of investment in maintaining and upgrading technology systems and infrastructure that supports energy activities. Nuclear accidents can also threaten other related energy systems.

- *Geopolitical or "strategic" threats* can arise from energy being used as a political "weapon" posing a serious economic threat to other countries. As a result, there are significant geopolitical and military dimensions to energy security. Other potential threats to the energy system include embargoes, wars, terrorism, disruptions to sea lanes and the exercise of market power in countries where energy is subject to political control.

Temporality

Temporality refers to whether disturbances are seen as short-term shocks or long-term stresses. A *shock* is an acute, short-term episodic disturbance. Examples include a sudden spike in energy prices as a result of a war, a natural gas pipeline leak, and damage to a power plant from a typhoon.

A *stress* is driven by a long-term or slowly increasing pressure. The drivers of stress are external to the energy system. Examples include aging or inadequate infrastructure, demographic changes, technological changes and climate change pressures affecting energy production and use.

There are different response strategies for dealing with disturbances to the energy system and these strategies depend upon the type of risk and threat as described above, as well as the location in the supply chain and the time frame in which they occur. These response strategies are discussed in section 3.6.

3.4.3 Systemic risk

Systemic risk is another type of risk that can affect the energy system broadly. Systemic risk has been defined as “a phenomenon in which, through contagion and cascading, failure of a system component leads to the dysfunction of the entire system or large parts of it” [89]. Systemic risk can arise from unpredictable events that can affect large parts of the energy system and include:

- Disruptions to transportation infrastructure (e.g.: terrorist acts and natural disasters affecting pipelines, railways, and other energy infrastructure)
- Technology disruptions (e.g., cyber-crime – computer viruses in the electricity grid, internet attacks on pipeline control systems, etc.)
- Disruptions affecting interdependent energy subsystems. The “Ice Storm of 1998” that caused widespread power outages for millions of people in the northeastern United States and Canada is an example of a systemic risk and highlighted serious vulnerabilities in the integrated North American electricity grid [90].

Measures to reduce vulnerability to systemic risk include reducing the coupling of components and interdependence among systems where the risk of sabotage, theft or terrorism is great [80].

3.5 Energy security assessment and the properties of secure energy systems

The approach to energy security assessment presented in this thesis is systemic, built around evaluating the energy system's ability to withstand, rapidly recover from, and adapt to disturbances, pressures and other constraints. The focus of attention is on three properties that can be said to characterize "secure" energy systems: robustness, resilience and adaptability. These properties have been drawn from the literature on complex adaptive systems, engineering and natural science and they are applied here to the energy system for the purpose of assessing energy security.

A basic assumption in this thesis is that the energy system is a complex adaptive system. As such, it is self-organizing and therefore the future is not simply a function of the past, but is the result of the interactions between various actors and components in the system, making it inherently unpredictable. While some risks can be identified and quantified and dealt with through conventional risk management approaches, many of the threats facing the energy system are assumed to be unknown or beyond the ability to be influenced directly, as noted earlier. The principal vulnerability facing the energy system is therefore the inability to adapt to disturbance and change (whether known or unknown) and the best way to evaluate this type of vulnerability is by employing methods of characterizing the properties of adaptive capacity and resilience [71].

3.5.1 Vulnerability

Vulnerability refers to how a system, an organization, or human performance is degraded if some hazard or threat exploits the vulnerability [91]. It is a measure of the extent to which a system or its components may be affected over the short or long-term [46]. Vulnerability refers to the "normal" or planned states of a system (whether physical, technical organizational or cultural) that can potentially be exploited by a threat and cause damage to that system [92]. A disturbance may cause a system to move out of its "normal" or planned state to an undesirable or unplanned state.

Vulnerabilities are properties of known systems and can be assessed much more readily than threats, which are often unpredictable or even unknown. A system can be vulnerable to certain disturbances and not to others, therefore it is important to define the threats or disturbances under study. Vulnerabilities can be described without quantifying the likelihood of something exploiting them [93].

3.5.2 Robustness

Robustness[5] is a term originating in engineering and natural science and has been defined as "the capacity to withstand internal or external events without degradation in system performance" [95]. A robust system does not experience stress after a disturbance has occurred. A robust system resists disturbance and change without adapting; it endures rather than responds to changes [96].

In this thesis, and consistent with other applications of robustness to energy systems (see: [48]), robustness is viewed as a property of certain major energy subsystems, such as power plants, LNG terminals, and transmission and distribution infrastructure. Therefore, we can refer to the robustness of a power plant against earthquakes, as well as to the robustness of energy supply.

Risks to robustness are seen as arising from natural or technical sources, including infrastructure failures, electricity disruptions and resource scarcity [48], [68]. Improving robustness is primarily about with dealing with risks from predictable and controllable characteristics of energy systems, rather than from unpredictable and uncontrollable threats.

Robustness incorporates the concept of adequacy of supply (i.e.: sufficiency of resources) as well as the reliability of infrastructure and stable and affordable prices [48]. Energy infrastructures are part of the energy system as a CAS (and therefore may change and evolve over time), however for energy security assessment purposes infrastructure robustness is evaluated for a particular point in time, primarily in order to gain insights into the degree to which these infrastructures can meet demand with adequate supply.

[5] Robustness may be considered to include the concept of *stability*, but is a broader concept than stability [94].

3.5.3 Resilience

The *resilience* perspective is based on a view of systems as being complex and non-linear, as in complex adaptive systems. In this view, disturbances arise that are inherently unpredictable and uncontrollable and therefore the most appropriate response is to focus on strengthening characteristics of the system, rather than attempting to mitigate threats over which we have little or no control [2].

Resilience may be defined as the capacity of an energy system to rapidly recover from short-term shocks while retaining its essential function and structure. A commonly used description is that the system "bounces back" to its "normal" functional state.[6] Resilience is widely considered to be a systemic property, applying to the system as a whole. Typically, it implies that the energy system can shift to alternative energy sources or manage demand and recover normal operation relatively quickly, usually within hours, days or weeks [48].

Resilience can be undesirable if it prevents a system from adapting or changing when factors in the environment threaten its normal function [98]. Constant enhancements to the resilience of systems can actually lead to the issue of socio-technical *lock-in,* whereby ongoing benefits from the status-quo lead to institutional and technological rigidity which prevents the movement to superior alternatives [99], [100].

The concept of resilience as applied to socio-ecological systems (SES)(e.g.: a forest or wetlands) has sometimes been used uncritically when applied to socio-technical systems (i.e.: the energy system) in studies of energy security. Unlike in SES, resilience in STS can undermine the shift toward structural configurations that deliver on desired functions and system qualities [101]. In studies of SES, broad definitions of resilience such as the notion of "general resilience" that includes the capacity for structural change (e.g.: infrastructure changes or transitions) risk conflating resilience and adaptive capacity [102] [103]. Such broad definitions of resilience make it difficult to be able to distinguish different system behaviors in response to change.

The perspective in this thesis is that it is important to distinguish clearly between resilience and adaptability as applied to energy systems. As pointed out above, resilience is a system

6 Resilience may be considered to include the concept of *flexibility,* such as the ability to easily alternate between fuel sources in the case of disruptions in electricity generation [97].

property that responds to short-term shocks. However, to explain system behavior in the face of stress and changes in energy system structure over time, we must look beyond resilience to the concept of adaptive capacity.

3.5.4 Adaptive capacity and adaptability

Adaptive capacity has been variously defined depending on its application in various scientific fields. In studies of ecological resilience, adaptive capacity has been defined as the capacity of actors in the system to manage resilience [104]. As applied to socio-technical transitions, it has been defined as the capacity to coordinate resources in response to selection pressures [105].

In this thesis, *adaptive capacity* or *adaptability*[7] is defined as the potential, capability or ability of a system to adapt, either in reaction to or in anticipation of stress. Adaptability is a characteristic of complex adaptive systems, and some parts of a system will be more or less adaptable than others. Systems can adapt to changes in their environment in two basic ways. They can adapt autonomously to gradual changes and changes in variability. Human systems (including the energy system) can also adapt by planning and implementing strategies to reduce potential vulnerabilities or take advantage of emerging opportunities [106].

Adaptive capacity is related to the ability of systems to recognize and reduce vulnerabilities to perceived threats [107]. The greater the adaptive capacity of the system, the less vulnerability it will have and the more effective it will be in responding to pressures. Adaptability is often defined in relation to vulnerability; adaptations are a way of reducing vulnerability [108]. Adaptations do not occur instantaneously and a system needs time to realize its adaptive capacity as adaptation. Therefore, adaptability results from adaptive capacity realized in the past which determines current levels of vulnerability [109].

While resilience remains important in the short-term, adaptability is particularly relevant to long-term energy security through the ability to adjust to long-term stresses, enduring threats and evolution in energy infrastructure[8] [32]. Over the long-term, energy systems may be

---

7 In this study, the term adaptability and adaptive capacity are used interchangeably.

8 Instead of applying the concept of adaptive capacity or adaptability to long-term system change, some scholars have used the term "transformability". Transformability has been defined "the capacity to create a fundamentally new system when ecological, economic, or social structures makes the existing system untenable" [104]. Since transformability has been employed more as a term of convenience and lacks a strong

impacted by a number of secular *stresses* and slowly changing factors in the energy system's environment. This may include energy demand shifts, changing infrastructure requirements, technology evolution, climate change pressures and policy changes. A system must be adaptable so that it can alter its structure, function and interactions and in response to these stresses and pressures. Thus, adaptive capacity holds significant implications for long-term energy security and energy policy, given the important role it plays in the evolution of energy systems and in energy transitions.

In an energy transition or transformation, sufficient adaptive capacity must be employed to overcome the resilience that can arise from path dependence [110]. A good example is the shift from fossil fuel-based energy systems (which are highly resilient to change) to low-carbon systems. Adaptive capacity is therefore particularly relevant to long-term energy security and energy transitions because it is the property that enables the system to evolve its structure and function over time.

3.5.5 Relationships among system properties

The properties of vulnerability, resilience, adaptive capacity and robustness are linked concepts. Vulnerability, resilience and adaptive capacity have been discussed in detail by Gallopin [102], Cutter [111] and Engle [112] who pointed out the wide range of views and lack of agreement on the relationships among these properties in different research disciplines. These and other scholars do agree that adaptive capacity and resilience both serve to reduce vulnerability. However, the relationship between resilience and adaptive capacity is less clear cut. The literature on resilience, socio-technical transitions and energy security suggest that adaptive capacity plays a significant role in enhancing resilience, at least in the short-term.

While vulnerability is clearly a negative system property, resilience is generally considered positively, allowing the system to return to normal function after a shock. However, as already discussed, resilience can also be negative when it becomes resistance to change. Similarly, robustness is also generally viewed as positive especially when applied to

---

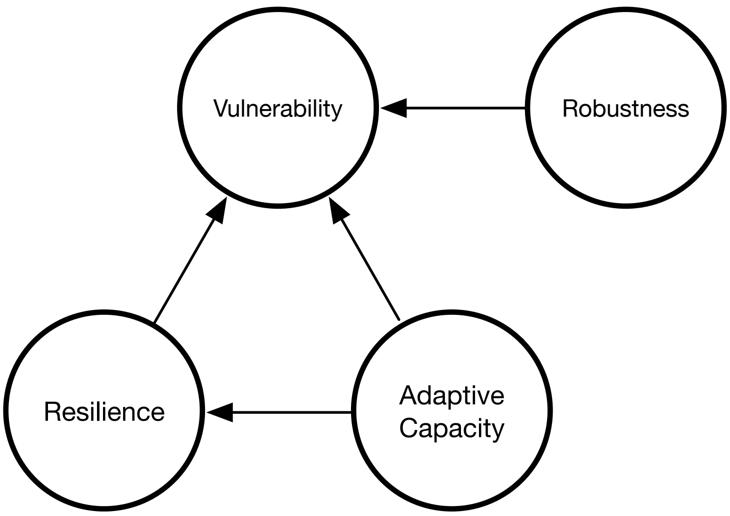
theoretical basis in the scientific literature, this study builds on the traditional definition of adaptive capacity from natural science and systems science and applies it to the energy system.

infrastructures, but robustness can also impede change. On the other hand, adaptive capacity has been characterized as being universally positive[9] [112].

Drawing from the literature on resilience, environmental change and energy security (see: [102], [111], [112]), a conceptual framework of system properties can be constructed for the purposes of this thesis. The framework proposed here extends the frameworks proposed by these other scholars and applies it to the energy system, adding the dimension of robustness and expanding on the dimension of adaptive capacity. Engle's framework rightly suggests that adaptive capacity is an element of both vulnerability and resilience, however in this thesis I distinguish adaptive capacity further by adding the important role adaptive capacity plays in energy transitions.

The framework depicting the relationships among the four properties of vulnerability, resilience, adaptive capacity and robustness is shown in Figure 4.

Figure 4. Relationships among vulnerability, resilience, adaptive capacity and robustness.



Vulnerability is linked to resilience, adaptive capacity and robustness in different ways. The arrows in Figure 4 represent the influence of one property on another. The level of adaptive capacity influences both resilience and vulnerability, with higher levels of adaptive capacity

9 Increases in adaptive capacity may not always be positive. There may be a point where increased investments in adaptive capacity may result in diminishing returns and increased costs resulting in economic inefficiency.

increasing resilience and reducing vulnerability. Robustness, primarily a property of energy infrastructure, impacts on vulnerability as well but it is not linked directly to the systemic properties of resilience or adaptive capacity.

These relationships can be illustrated using the case of a major shock, such as a tsunami, affecting a power plant. If the robustness of the power plant is overcome by the wave, the plant fails. This may or may not cause vulnerability of the system as a whole to increase (e.g.: susceptibility to blackouts), depending on how resilient and adaptable the system is. Adaptive capacity supports the system's built-in resilience, allowing it to reorganize and return to normal function after a shock (i.e.: accessing emergency generation capacity, power transfers from other regions, etc.). Adaptability can also reduce vulnerability directly (e.g.: voluntary electricity conservation, installing new sources of power, etc.). If, however resilience is overcome due to the severity of the shock, the system changes its functional state and may become more vulnerable than before (e.g.: power shortages, widespread blackouts, increased GHG emissions, etc.).

Adaptive capacity is also important apart from resilience when applied to socio-technical transitions. This will be addressed in Chapters 5.1 and 5.2.

3.6 Strategies to strengthen energy security

Strategies and actions for the reduction of system vulnerability have been discussed in detail by Stirling ([97]) who described the relationship between temporality of disturbance (whether a shock or stress), the type of disturbance, and the style of action. The temporality and types of disturbances have already been discussed in Section 3.4.2.

Style of action refers to the method of responding to the drivers of disturbance. A *control* style of action implies that the *causes* of threats can be influenced by deliberate intervention. Vulnerabilities must be determinate, predictable and controllable and therefore risk-based strategies are appropriate. Risk implies that there is a clear understanding of the outcome or impact of a threat as well as a firm basis for estimating its likelihood.

A *response* style of action implies acting on the emergent *consequences* of a threat or disturbance. This is because threats are seen as either unknowable or unpredictable and therefore cannot be acted upon, or the investment of time and resources required to deal with them are not available. In such cases, the focus of response is on strengthening characteristics of the system itself in order to enhance its ability to deal with threats.

3.6.1 Strategies to enhance robustness

Strategies to improve robustness are control actions which lend themselves to conventional risk management approaches. They include include ensuring system *adequacy* (i.e.: meeting demand with sufficient capacity) which implies that adequate investments in energy supply capacity and infrastructure are made in a timely fashion [70]–[72]. Adequacy is related to market design and performance, including price setting, managing supply-demand balances and providing incentives for infrastructure investment. Other strategies to improve robustness include switching to more abundant energy sources [48].

3.6.2 Strategies to enhance resilience and adaptive capacity

Strategies to improve resilience are response actions. Diversification is generally acknowledged as the most appropriate "system level" response strategy for dealing with uncertainties [86]. For energy resource importing countries such as Japan, diversification can be implemented along several dimensions including primary energy sources (e.g.: coal, oil, electricity, natural gas), geographic region, transit routes in order to avoid choke points (e.g.: Strait of Hormuz, Suez Canal, Malacca Strait), electricity generation sources, and transportation modes (e.g. pipeline, rail, ship, grid interconnects). In addition to diversification, other strategies include the utilization of domestic energy sources such as renewables, distributed generation, creating emergency stockpiles of essential fuels, and maintaining reserve margins of electricity generation capacity [71], [113]. Certain strategies designed to address so-called "sovereignty concerns" (see: [68]) can also be considered as potentially resilience-enhancing. Such energy security strategies are usually designed to provide some "insurance" against energy disruptions caused by the actions of external actors in foreign countries. These strategies are discussed in the next section.

Strategies to enhance adaptive capacity are also response actions. They center on learning and the acquisition of knowledge, stimulating innovation, undertaking risks through experimentation, resolving problems and learning from failures (i.e.: "lesson's learned") [114], [115]. With regard to the energy system, specific strategies include investments in innovation and technology development, liberalized market mechanisms (which help stimulate timely investments in energy infrastructures and services), improving regulatory quality, transition management, instituting participative stakeholder processes, scenario planning, and utilizing expert groups.

3.6.3 Resource (energy) security strategies and risk

Another approach some governments use to deal with potential threats is through the use of certain externally-directed geopolitical strategies. To the extent that countries are not confident that markets can ensure long-term energy security, they may choose to employ *resource (or energy) security strategies*[10] [116], [117]. The use of such strategies derives from a "sovereignty" perspective on energy security that is concerned with power and influence over energy resources and the behavior of various actors in the energy system that might compete for, limit or even disrupt access to energy resources [71]. This perspective has also been referred to as the "strategic" or "geopolitical approach[11]" (see: [117]–[119]). Nations that are highly dependent on energy imports, including Japan, may employ various resource security strategies either directly or through state supported actors (including domestic energy companies and state-owned enterprises). State-directed or state supported resource security strategies may be considered to include the following:

- Energy (or resource) diplomacy.[12] For example, building stronger linkages with key supplier countries through politically negotiated relationships, rather than through market mechanisms.
- Government guarantees (financial, commodity) to underwrite energy investments or "strategic" energy projects.
- Investments by state-owned enterprises in foreign markets to secure resource access, energy technologies and expertise.
- Energy cooperation agreements between governments (e.g., creating buyers' groups, securing long-term supply agreements or joint purchasing agreements, etc.).
- Energy (or resource) access clauses in free trade agreements.

---

[10] A typical view of energy security in Northeast Asia is exemplified by a comment made to the author by a policy advisor to the Japanese government that "energy security is too important to be left solely to the marketplace". Personal communication.

[11] As Daniel Yergin has said, "the major risk to supplies over the next decade or two is not geology but geopolitics" [58].

[12] This can be defined as the attempt to leverage diplomatic assets to hedge risks to energy security [116].

Energy security strategies are a kind of hedge or "insurance policy" in the face of risks or threats to energy security and therefore can be considered a method of enhancing resilience. However, a number of authors have pointed out that they have questionable effectiveness and may have negative consequences for international energy markets by "locking up" energy supplies, promoting anti-competitive behavior and reducing openness and transparency [61], [120].

3.7 A basic framework for energy security assessment

This study draws upon a broad range of theoretical approaches in order to develop a systemic, integrated and comprehensive framework for analysis of energy security. A major premise of this thesis is that such an approach to energy security assessment is necessary in order to account for the broad range of factors impacting on a modern energy system that operates within a dynamic and unpredictable international environment.

This chapter has defined the energy system and described various types of risk and uncertainty, including the consequences for energy system vulnerability. A comprehensive energy security assessment should consider the type, source and temporality of threats and risks, the location of vulnerabilities within the system, and the appropriate system property to be strengthened. When risks are within the ability to control, they can be managed using well-established risk management approaches and strategies to improve robustness. When risks are not controllable, as in the case of most external threats, then strategies to enhance resilience and adaptability are most appropriate.

A comprehensive energy security assessment framework should utilize appropriate indicators to identify and measure vulnerabilities so that the appropriate strategy can be applied in order to secure the energy system. Indicators should be related to the characteristics or properties of the system that are to be measured.

The various analyses in the following chapter, *Assessing energy security and policy in Japan*, build on the concepts and the basic framework outlined in this chapter by supplementing with additional concepts and theories as appropriate to each analysis.

Chapter 4: Assessing energy security and policy in Japan: 2000-2013

This chapter consists of three sub-chapters and a concluding section that analyze and discuss Japan's energy policies and energy security from different perspectives.

Energy security vulnerability in Japan focuses on identifying and assessing vulnerabilities to the threats and risks facing Japan's energy system. *The impact of Japanese energy policies on energy security* is focused on understanding the extent to which Japanese energy policies served to reduce vulnerabilities through their impact on energy system resilience and adaptability. *Energy security and sustainability in Japan* focuses on examining the government's energy security and sustainability goals and targets and evaluating the extent to which these goals and targets were met. The final section, *Outstanding issues and vulnerabilities* identifies outstanding energy security issues and concerns and discusses the implications for policymaking institutions.

Chapter 4.1: Energy security vulnerability in Japan

4.1.1 Introduction

The purpose of this chapter is to identify and assess energy security vulnerabilities facing Japan's energy system. Building upon existing theories and approaches to energy security assessment, a systemic and comprehensive evaluation of Japan's energy system vulnerabilities is presented. This analysis goes beyond short-term energy supply security concerns to include long-term system adequacy issues as well as demand-side concerns. The principal threats facing Japan's energy system are identified and a series of quantitative and qualitative indicators and measures are developed in order to assess energy security vulnerabilities across all segments of the energy system, providing new insights into Japan's energy security situation post-Fukushima. The chapter concludes with a discussion of the implications for Japanese energy policies.

A key motivation of this study is the view that a comprehensive analysis of energy system vulnerability trends leading up to the March, 2011 disaster is required in order to better understand the challenges the country faces as it begins major energy system reform initiatives post-Fukushima. In many ways, Japan will be dealing with the consequences of the disaster for many years to come so a better understanding of how the energy system has performed in recent years, and the challenges it faces today, will be foundational to further research on assessing the trajectory of its evolution in the future.

4.1.2 Background, concepts and analytical framework

1) Japan's perspective on energy security

Japanese energy policy embodies a broad approach to energy security that pays particular attention to long-term issues. While the government has not issued a formal definition, the aim of energy security in Japan has been described by the country's leading energy policy research institute as: "to secure sufficient energy supplies at reasonable prices for the achievement, pursuit and maintenance of maximum economic and social welfare and for the sustainable development of the national economy and citizens" [121].

Japan’s energy policies are conditioned by its sensitivity to external threats and risks as a result of its extremely low energy self-sufficiency and the experience of the two oil shocks of the 1970’s. Despite a substantially liberalized market for energy in Japan, the government considers energy as a strategic sector that is essential to Japan’s long-term security and economic growth and one that justifies a degree of government intervention.[13]

2) Threats, risks and vulnerabilities

Threats and Risks

A starting point for an assessment of long-term energy security is the identification of key threats to an energy system [35]. The number and severity of threats facing increasingly complex, interdependent systems appears also seems to be increasing. The IEA recently noted that the global energy system is undergoing severe stress from various long-term issues including ongoing turmoil in the Middle East, conflict in major supplier countries and transit routes (such as pipeline gas supplies between Russia and Europe), uncertainty surrounding nuclear power, increasing concentration of fossil fuel supplies in a few countries, long-term demand growth in developing countries, and other issues [122]. It acknowledges that such threats are not readily controllable and require concerted action among policymakers, industry and other stakeholders. Thus the focus of energy security concerns is increasingly shifting to long-term issues.

Vulnerability

Since a system can be vulnerable to certain disturbances and not to others, it is important to define the threats or disturbances under study. Since it is not possible to take into consideration all possible threats, focus is placed on those identified by the Japanese government as well as those mentioned in Chapter 3.4.2 that present a reasonable likelihood of causing interruptions to energy supplies, energy infrastructure or to the provision of energy services.

[13] This view was summed up by a Japanese official who commented to the author that “in Japan, energy is too important to be left solely to the markets” .

3) Energy security: the government's perspective

Based on a comprehensive evaluation of key threats and risks to energy security sponsored by METI in 2006 [123], the government identified a number of threats and risks to Japan's long-term energy security including:

- *Political conditions in the Middle East* - the destabilization of Iraq, the threat of terrorism, tensions with Iran and general political instability in the region were seen as a threat to oil security, and potentially to natural gas as well.
- *Terrorism, natural disasters and accidents* - the threat of terrorist acts since 9-11, intentional "misconduct" in the energy supply chain, risks to marine transport in critical sea lanes and damage to refineries and energy infrastructure from hurricanes, typhoons and other natural disasters.
- *Reduction of investments from supply nations* - the tendency of some supplier nations toward increasing control over domestic energy resources may serve to reduce investments in energy supply.
- *Trends in energy consuming nations* - increased energy demand in emerging economies such as China and India leading to resource competition and high prices, particularly if these nations act to secure resources in a way that hinders international energy supplies.
- *Issues facing the energy industry* - including risks from insufficient development of upstream supply but also the lack of capacity in transportation and distribution infrastructure in Japan. While structural changes arising from market liberalization were expected to improve market efficiency, uncertainties may also arise leading to intensified domestic competition and the risk of reduced investment in large-scale energy infrastructure.

Of the threats and risks identified in METI's report, many appear to be biased toward *external*[14] sources. This study will take a balanced approach and will attempt to measure vulnerabilities to both external and internal sources of threats and risks.

---

[14] External risk sources arise from outside the energy system whereas internal risk sources arise from within the energy system itself.

4) Vulnerability assessment framework

The approach used in this study is to assess potential vulnerabilities in Japan's energy system comprehensively and systematically, by employing an analytical framework grounded in the literature on energy security. Vulnerabilities include those arising from the various threats and risks mentioned in the previous section but also those arising from other sources, including from the interactions and inter-relationships among different segments of the energy supply chain.

The Framework and indicators

The approach to the assessment of vulnerability in Japan's energy system used in this study is adapted from the method presented here [48], [71], where each segment of the supply chain is analyzed as well as the overall (systemic) security of the system. Vulnerability trends are assessed by applying suitable indicators ex-post using time series data (where such data is available) in order to determine the direction and magnitude of trends that could impact on energy security.

In order to perform a comprehensive and systemic vulnerability analysis, indicators have been chosen for their relevance to Japan's energy system, and for their ability to measure vulnerability in several dimensions (see Table 3). The first dimension includes the physical segments of the energy supply chain, including primary energy supplies, energy transformation/transmission, and final energy demand. A second dimension is the temporality of energy security, including short-term, long-term or all periods. Indicators have also been chosen to reflect conditions in various sectors of the energy system (such as industry and households) as well as the various sources of energy supply (such as fossil fuels, nuclear, renewables, etc.). In addition, several "systemic" or cross-sectoral indicators are used to evaluate vulnerability and resilience to both systemic shocks and long-term stresses affecting the energy system as a whole [48], [49]. This approach is intended to provide a more integrated and comprehensive analysis of vulnerabilities in the energy system. While most vulnerabilities can be assessed using indicators available in time series, aspects of some vulnerabilities were assessed using other quantitative and qualitative data.

Table 3. Indicators for vulnerability assessment

	Indicators	Short-term Indic. (S) Long-term Indic. (L)	Impacts on Energy Supply/Demand Chain: Primary Energy Supply	Energy transformation & transmission	End-use/ Services	Systemic
1	Oil reserves	S	✔			
2	Natural gas reserves	S	✔			
3	Coal reserves	S	✔			
4	Import dependency for oil	S	✔			
5	Import dependency for gas	S	✔			
6	Import dependency for coal	S	✔			
7	Middle East Reliance	S	✔			
8	Choke point share	S	✔			
9	Thermal and nuclear power plants and service years	L		✔		
10	Electricity demand	L		✔		
11	Capacity factor of nuclear reactors	L		✔		
12	Electricity generation reserve margins	S		✔		
13	Electricity T&D losses	L		✔		
14	Public acceptance impact: high-level radioactive waste	L		✔		
15	Environmental impact: carbon intensity	L		✔		
16	Final energy consumption by source and share	L			✔	
17	Growth in final energy consumption by sector	L			✔	
18	Final demand for oil by sector (share)	L			✔	
19	Indices of end-use prices for industry: total energy	L			✔	
20	Indices of end-use prices for households: total energy	L			✔	
21	Indices of end-use prices for industry: electricity	L			✔	
22	Indices of end-use prices for households: electricity	L			✔	
23	Self sufficiency	S-L				✔
24	Import cost of fossil fuels	S-L				✔
25	Share of energy sources in TPES	S-L				✔
26	Primary energy intensity	L				✔
27	Electricity generation mix by fuel	S-L				✔
28	Final energy consumption per capita	L				✔

This study aims to select indicators that measure vulnerabilities as simply and directly as possible in an effort to get at "root causes" of energy insecurity in Japan's energy system. Indicators of diversification are also avoided in this analysis as they are better employed as measures of resilience and to evaluate the effectiveness of policies, although some studies have used them as a proxy for vulnerability.

4.1.3 Analysis

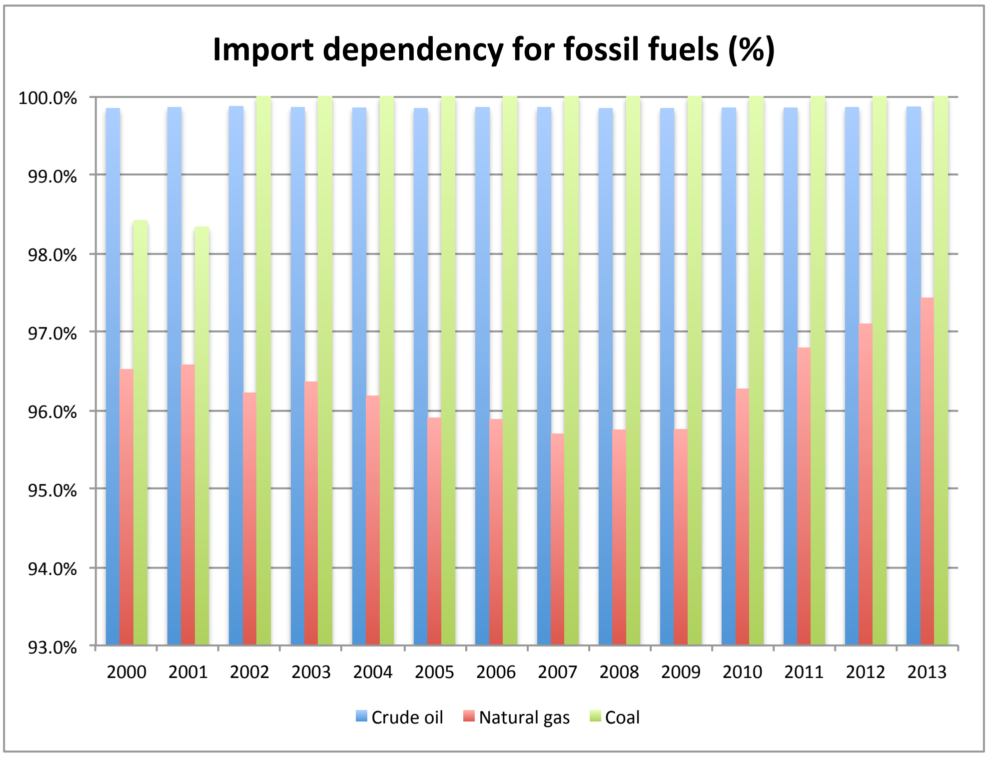
This section presents the results of the quantitative and qualitative data, analyzes the results and discusses the implications for vulnerability in each of the major segments of the energy system. Data for indicators is presented in graphic form as indicated in the text.

1) Energy supply security vulnerabilities

Import dependency and self-sufficiency

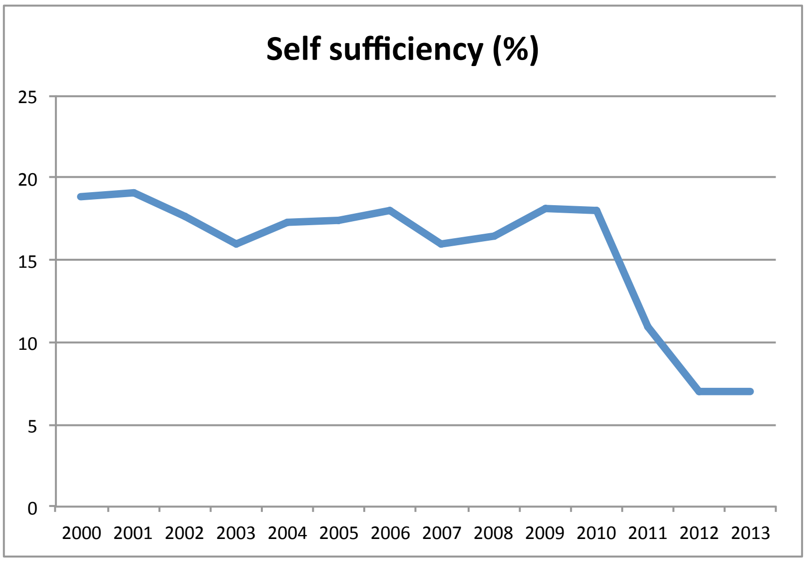
Japan produces only very small quantities of oil, coal and natural gas from an extremely small base of proven reserves and is therefore almost completely reliant on imports of crude oil, coal and natural gas (see Figure 5). This makes Japan among the largest importers in the world for these commodities.

Figure 5. Import dependence for crude oil, coal and natural gas



In Japan the self-sufficiency indicator typically includes the production of nuclear power which is considered a "quasi-domestic" energy source since uranium can be stockpiled and used for many years after it is imported [124]. During the 2000-2010 period, self-sufficiency was fairly stable at between 16-19% (see Figure 6). However, after the triple disaster[15] of March, 2011 Japan's nuclear reactors were gradually shut down for safety checks. Thus by 2013, Japan could only meet about 7% of its total primary energy supply[16] from domestic sources (including nuclear and renewables) and only 1.2% of its fossil fuel supply [125]. As a result, Japan's self-sufficiency ratio is the lowest among all industrialized countries [125].

Figure 6. Self-sufficiency



Supply vulnerabilities arising from geopolitics and transport routes

Japan maintained a very high dependence on the Middle East for its crude oil imports over the 2000-13 period, averaging more than 85% over the period (see Figure 7). Dependence began to decline slightly after 2009 but has remained well above 80%.

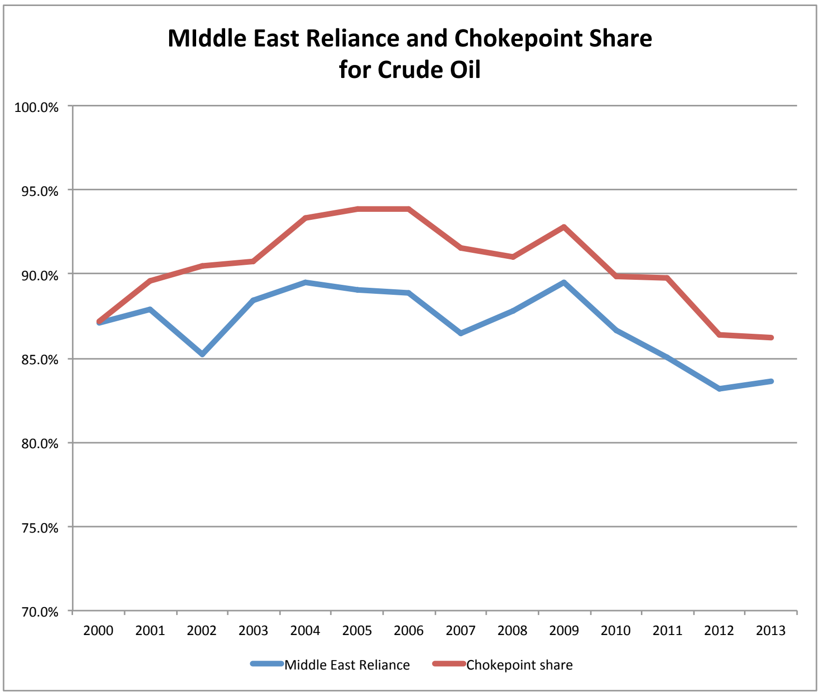
Much of Japan's oil imports are transported from regions with unstable countries where Japan has limited influence, through vulnerable sea lanes and "chokepoints" that it doesn't control. This exposes Japan to increasing levels of both price risk and geopolitical risk [126]. Key chokepoints that had potential to impact Japan during 2000-2012 period included the

---

[15] Japan's "triple disaster" refers to the earthquake and tsunami that struck Japan's Tohoku region on March 11, 2011 and the resulting nuclear accident at the Fukushima nuclear power plant.

[16] On an energy equivalent basis (Kcal).

Figure 7. Middle East dependence and choke point share



Strait of Hormuz, Bab el-Mandab and the Strait of Malacca.[17]. Over the period of 2000-2013, between 86-94% of Japan's imports of crude oil passed through one or more of these chokepoints (see Figure 7).

Systemic vulnerabilities

The price of oil rose sharply and steadily three times during the 2000-2013 period: once from April 2003 to July 2006, again from January of 2007 to July 2008 and finally from December 2008 to April of 2011 (see Figure 8). These upward price trends are reflected in Japan's import cost of fossil fuels in corresponding years (see Figure 9).

Between 2010 and 2013, import prices for crude oil and LNG in Japan rose by 52% and 66% respectively, while the price of coal fell by 1.2% [125]. As a result, spending on net imports of fossil fuels as a ratio of nominal GDP rose from 3.4% in 2010 to 5.3% in 2013 (figures for China and the U.S. in 2013 were 3.1% and 1.5% respectively), exacerbated by currency depreciation that began with monetary easing in April of 2013 [127].

[17] The Panama Canal played a limited role in crude oil shipments during the period due to size restrictions that excluded large oil tankers from passing through.

Figure 8. Crude oil prices, 2000-2015

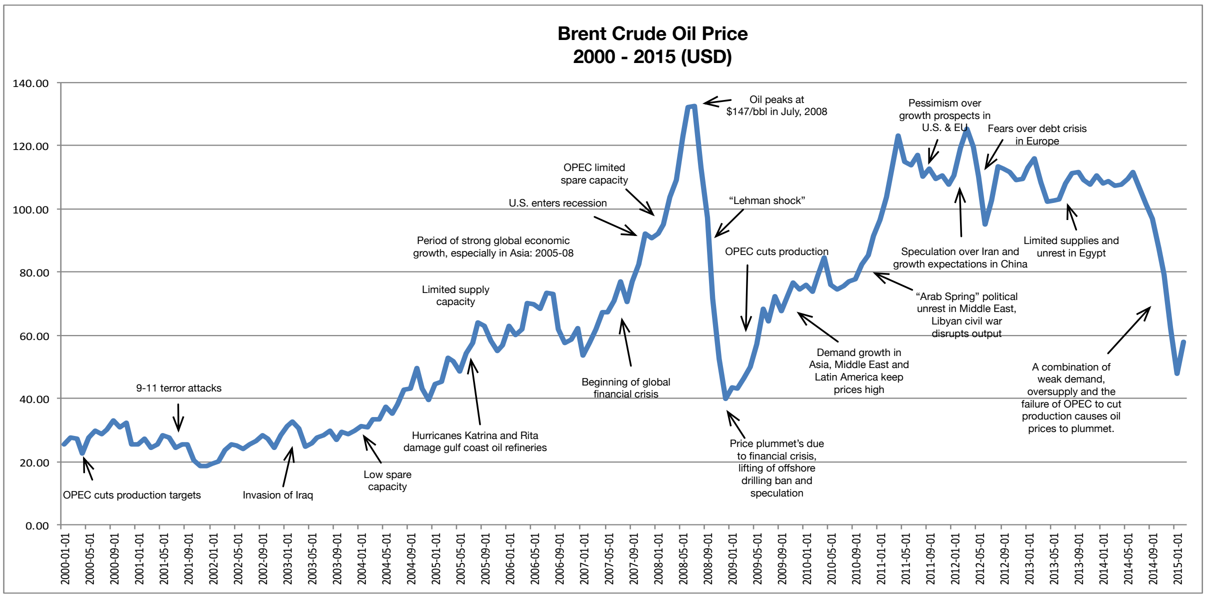
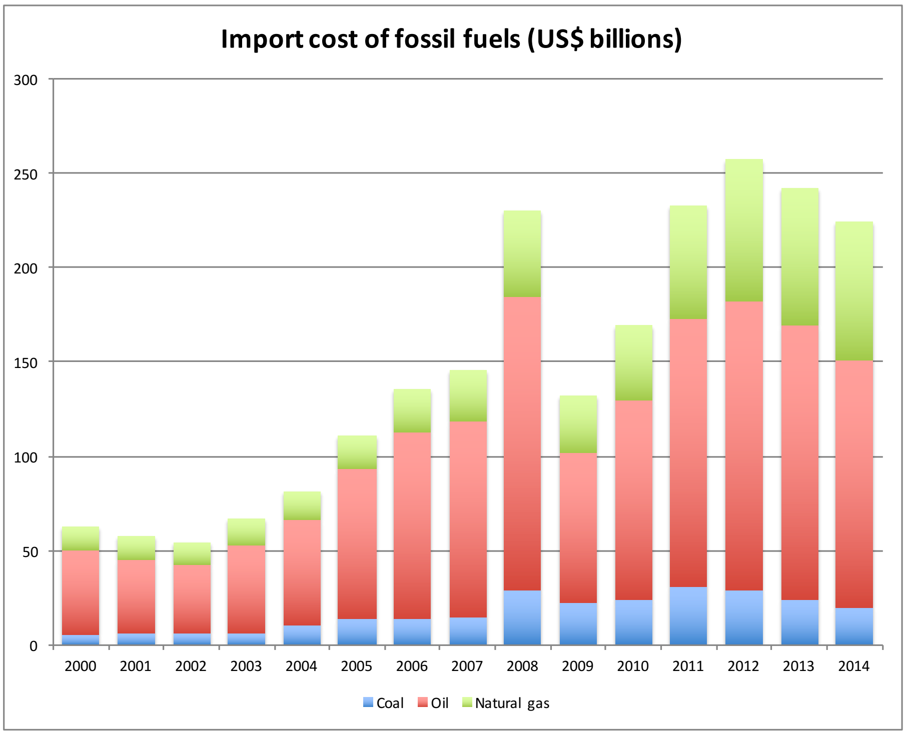


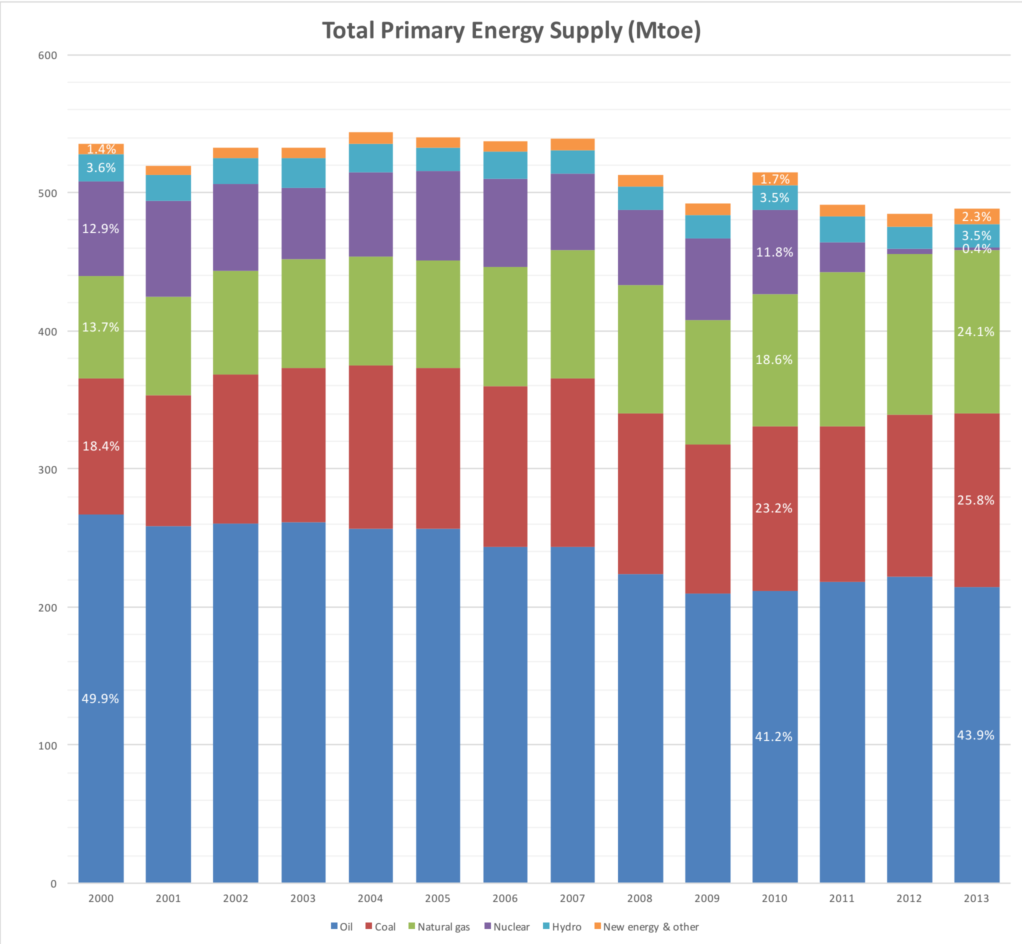
Figure 9. Import cost of fossil fuels



While the total share of fossil fuels in the primary energy mix remained almost unchanged between 2000 and 2010, the shares of individual fuels changed significantly. Oil's share declined by a total of 21% while coal and natural gas increased to fill the gap (see Figure 10).

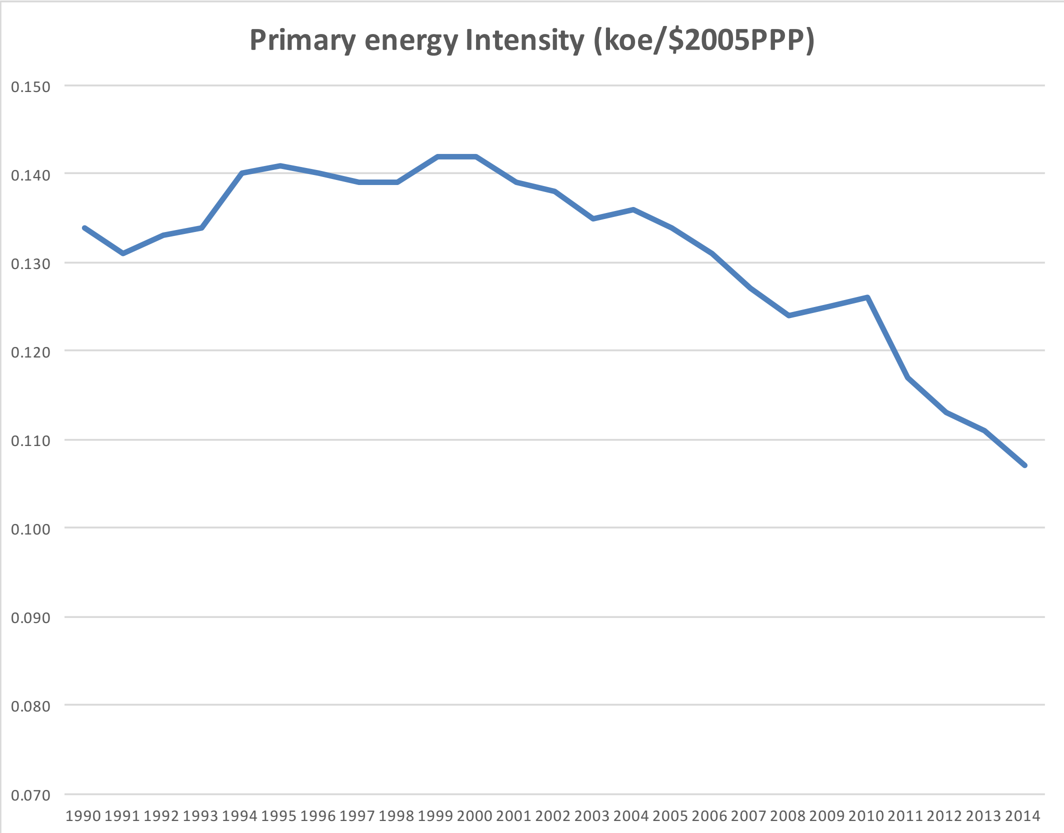
After the triple disaster, nuclear power rapidly declined and natural gas (LNG) and coal increased even more to fill the gap left by nuclear. This left Japan reliant on fossil fuels for almost 94% of its total primary energy supply in 2013, up from 82% in 2000 and exposing it to greater supply and price risks.

Figure 10. Total primary energy supply



Since the oil shocks of the 1970's, Japan has had policies in place to improve energy efficiency in manufacturing and other sectors and as a result, has one of the lowest rates of energy intensity in the world. The big gains in energy efficiency improvement were made in the 1970's and 80's, with the rate stabilizing over the 1990's up to 2000. Starting around 2001, energy intensity began to decline again (see Figure 11). While it is difficult to attribute direct causes to the decline, a combination of energy efficiency and conservation programs, the movement of energy-intensive manufacturing offshore and the recession following the global financial crisis in 2008-09 were likely contributing factors.

Figure 11. Primary energy intensity



2) Infrastructure adequacy and security vulnerabilities

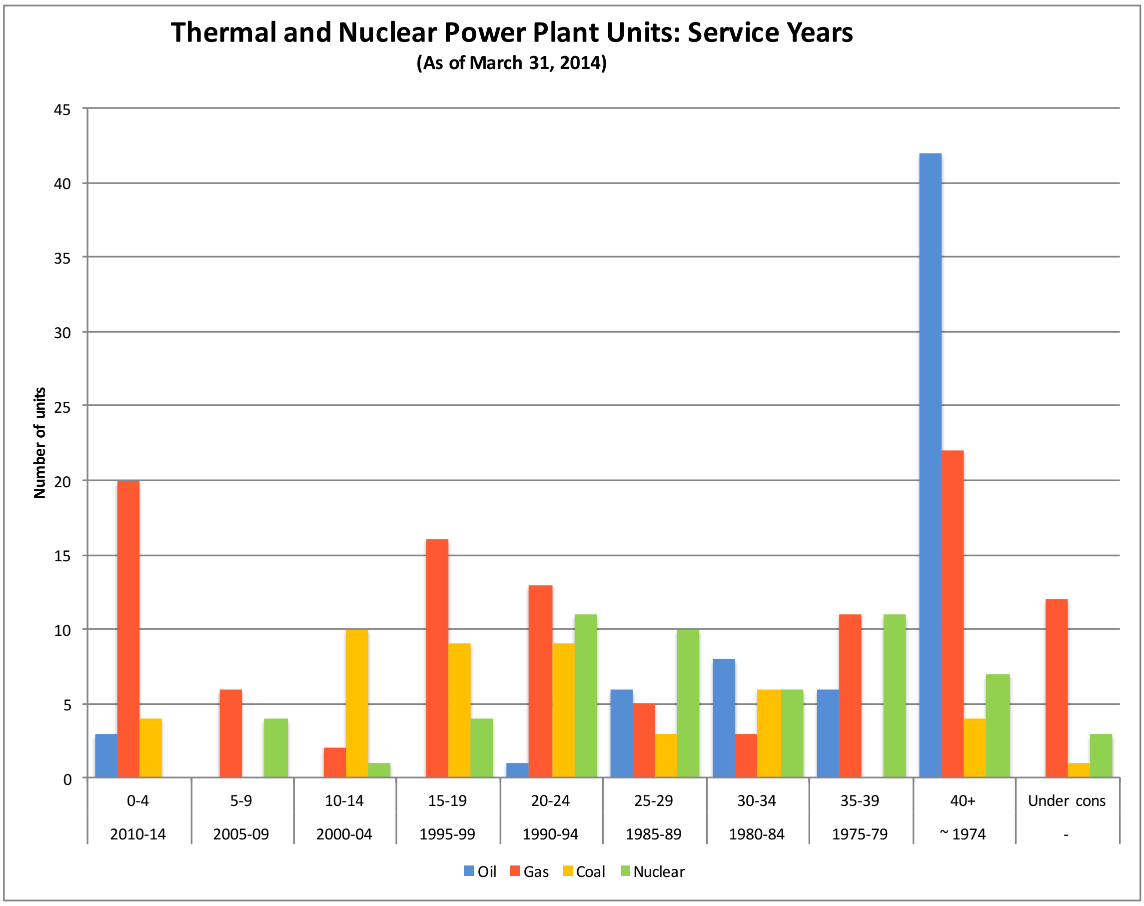
The assessment of Japanese infrastructure adequacy and security during the period was especially impacted by the tragic events resulting from the triple disaster. On March 11, 2011 a magnitude 9.0 earthquake and tsunami hit the Tohoku region of northeastern Japan. The disaster caused heavy damage to both nuclear and thermal power plants and other energy infrastructure. The earthquake and tsunami, and the ensuing destruction and meltdown of the Fukushima Dia-ichi nuclear reactors combined to make up a single large and complex disaster and is regarded as the costliest natural disaster in history [128].

(i) Electricity infrastructure adequacy

Age of thermal and nuclear power plants

Japan has about 1,800 hydro, thermal, nuclear and other power plants, 1,414 of which were owned by the ten GEU's [129]. There are a total of 61 power plant sites[18] each with a total capacity of over 1000 MW or more that contain one or more generating units [130]. Figure 12 shows the number and age of nuclear and thermal power plant units that have been commissioned in Japan. Of the 188 power units built since 1975 (and thus 40 years old or less), 40% were gas-fired, 25% were nuclear, 22% were coal-fired and 13% were oil-fired. A total of 109 or 58% of all thermal and nuclear power plant units were 20 years or older as of 2014.

Figure 12. Thermal and nuclear power plant units and service years

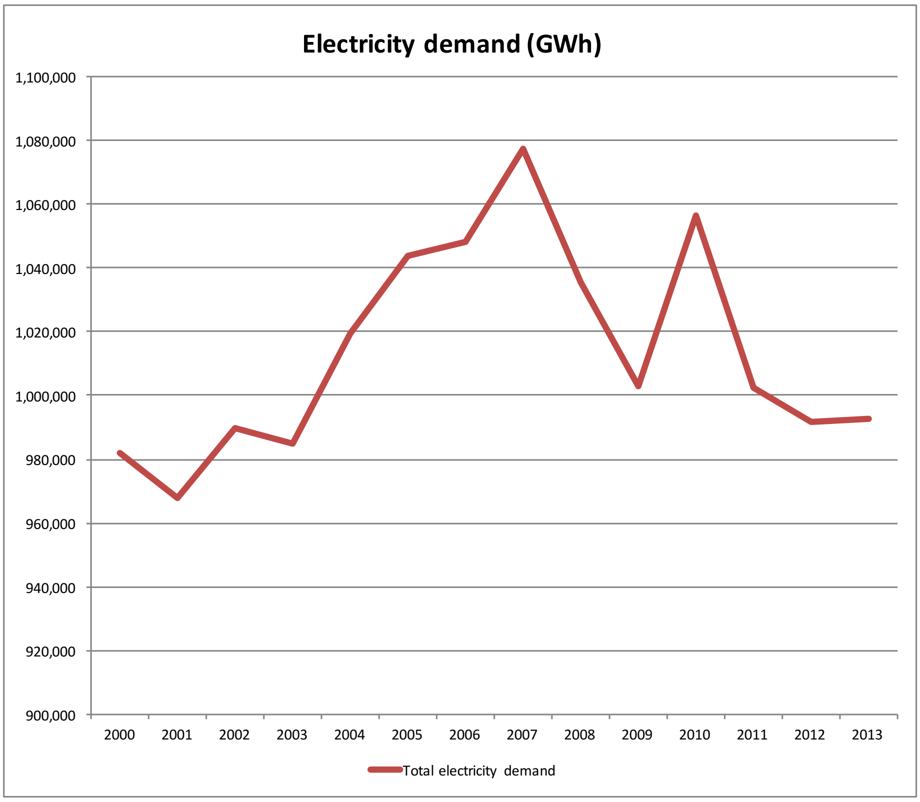


Between 1975 and 1999, electricity demand grew fairly steadily, at about 5% annually [125]. The number of power plants built over this same period also steadily rose, with the period 1985-1999 showing the highest number of new units commissioned. Electricity demand

18 Excludes geothermal power plants, all of which have a generating capacity of less than 100MW.

peaked in 2007 and then fell at an average rate of about 1% a year up to the end of 2013 (see Figure 13). The fall in demand coincided with the period 2005-09, which saw the fewest number of new units built compared to anytime in the previous 30 years.

Figure 13. Electricity demand



Thermal power plants

The ten GEU's together operated 83 thermal power plants as of 2014 [131]. J-Power, a major independent power company operates 7 plants. In terms of fuel type, crude oil and fuel oil generating units make up the largest number of power units in Japan. However, as the country steadily reduced its reliance on oil, few of these units were built after 1994 and the vast majority are now 30 years old or more. Coal power plant construction peaked in the 2000-04 period and only 4 coal units were built over the following ten years. Natural gas fired power plants represented the largest number of power plants built over the 1975-1999 period. In the wake of the triple disaster and the uncertainties surrounding the restart of nuclear power plants, utilities embarked on a rapid build of 27 new thermal power plants, of which 20 were gas-fired turbines.

Nuclear power plants

The 20-year period between 1975 and 1994 was the height of nuclear power plant building in Japan as the country sought to diversify away from oil. During this period, 38 nuclear units were built. However, the pace of construction fell steeply between 1995 and 2009 when only 9 units were completed. No new nuclear units have been commissioned since Tomari No. 3 unit was started up in 2009.

In 2010, Japan had a total of 54 nuclear power units in operation. After the Fukushima accident in March 2011, all 6 units of Fukushima Dai-ichi power plant were decommissioned. Out of the 48 reactors remaining, 5 additional units are scheduled to be de-commissioned[19] (as of March, 2014). This will leave Japan with a total of 43 nuclear units in the fleet.

In April 2015, the Japanese government announced new targets for its electricity generation mix with nuclear targeted to make up between 20-22% of electricity generation by 2030. To meet this target, it is estimated that Japan must have approximately 40-44 reactors operating in 2030.[20] However, as Figure 12 shows, 23 out of the remaining 43 nuclear units – or over half of the fleet – will reach the service life limit of 40 years between 2014 and 2030[21]. The government limited the service life of nuclear reactors to 40 years after the Fukushima disaster, however operators can obtain a one-time 20-year life extension if the reactors are refitted and pass inspections from the Nuclear Regulation Authority (NRA). Three reactors were being reviewed for life extensions by the NRA as of April, 2015.[22] However as more than half of Japan's nuclear reactors will reach their 40 year service life over the next 15 years, they must pass inspections and receive life extensions or will be decommissioned.

In October 2015 and more than four years after the Fukushima disaster, only two nuclear reactors with a total capacity of 1780 MW had been restarted and only 21 of Japan's 43 operable reactors were undergoing NRA safety reviews [133]. At the same time, three

[19] Based on NRA data and other public sources.

[20] Based on the Japanese government's estimate of total electricity generation in 2030 of 1,065,900 GWh, multiplied by the share of nuclear targets for 2030 (20% & 22%) divided by the average annual nuclear reactor output of 5.34 GwH (based on 2010 figures).

[21] As of March 20, 2015 based on data compiled by Japan Atomic Industrial Forum (JAIF) and other public information as of March 20, 2015 [132].

[22] Kansai Electric (KEPCO)'s Mihama No. 3 and Takahama 1 and 2.

reactors were under construction but as of March 2014 only one[23] had applied for approval to start up, with full operations expected only in 2021 [134]. If these three reactors are eventually built, it would mean that Japan will either need to build between 17 and 21 additional new reactors between 2015 and 2030 assuming older reactors are not given life extensions[24], grant life extensions to the same number assuming no additional new plants are built, or implement a combination of life extensions and new plants.[25]

There is no guarantee that all nuclear power plants will either pass the NRA's safety inspections or be granted life extensions. Some reactors may never be approved because they lie on or near active earthquake faults and several nuclear plants are threatened by closure for this reason[26] [136]. Post-Fukushima regulations also require additional safety measures to reduce the risk from threats such as earthquakes and tsunami's and required modifications may take several years to implement. Although not legally required, local government and community approvals are also regarded as necessary before reactor's can be restarted. Any one or several of these factors may potentially delay the restart of some power plants and compound the risks to adequacy of nuclear power by 2030.

Renewables

Japan's GEU's operated 1,200 hydroelectric power facilities as of 2014 with a total capacity of 36.8 GW [131]. Japan has already exploited all potential sites for large-scale hydroelectric facilities, and so newer plants have been on a smaller scale [131].

Power companies continue to develop pumped-storage facilities to meet peak demand requirements. Electric utilities own 25 major pumped storage plants[27], and 3 more are under construction [130]. Conventional hydro (run-of-river and dam type) accounted for over 90% of hydro generation over the 2000-13 period, with pumped storage accounting for the

---

23 J-Power's Oma plant.

24 The Japanese government limited the service life of nuclear reactors to 40 years after the Fukushima disaster. However operators can obtain a one-time 20-year life extension if the reactors are refitted and pass inspections from the Nuclear Regulation Authority.

25 In June 2015 the Japanese government announced that 35 reactors would need to be in operation by 2030 in order to meet the country's target of 20-22% electricity generation from nuclear power by that date [135].

26 Reactors that may have to be closed include Tsuruga, Higashidori, Mihama, and Shika, as well as the fast breeder reactor, Monju.

27 "Major" plants with 360 MW generating capacity or above in 2014. Figure is for GEU's and J-Power.

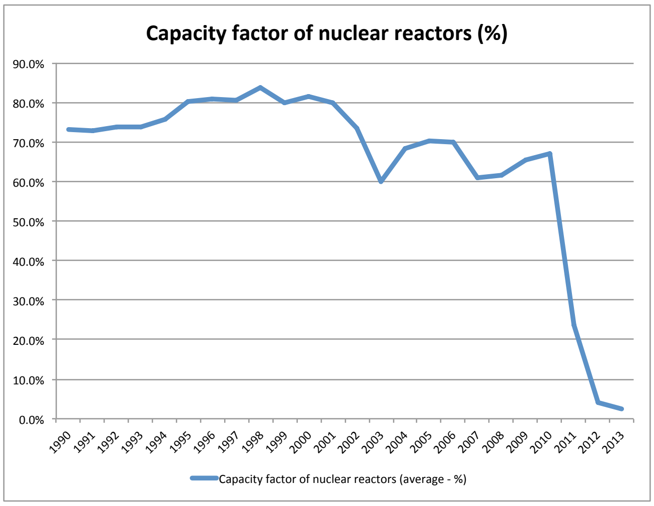
remainder. Unlike thermal and nuclear power plants, hydro facilities have an indefinite service life.

As of April 2014, there was about 30 GW of other types of renewables capacity, including residential PV (6.9 GW), commercial/utility-scale PV (8.3 GW), small hydro (9.6 GW), wind (2.7 GW), geothermal (0.5 GW) and biomass (2.4 GW) [137]. Capacity increased steadily from very low levels after 2000 but the pace of capacity installations increased rapidly after the implementation of a feed-in tariff system in 2012.

Capacity factor

The capacity factor of Japan's nuclear power reactors averaged more than 80% between 1995 and 2001. However, a series of scandals and accidents over the years caused regulators to increase the number of inspections and lengthen inspection times for nuclear reactors [138]. As a result, the average capacity factor[28] of nuclear reactors rarely exceeded 70% between 2001 and 2010, and fell to 2.4% in 2013 as a result of the shutdown of most of Japan's nuclear fleet (see Figure 14). As far back as 2003, the IEA noted Japan's low capacity factors and recommended more attention be paid to shortening the statutory and other outage periods as well as reducing their frequency [139]. By comparison, the average capacity factor of U.S. nuclear power plants in the 2006-12 period was 88.7% [140], [141].

Figure 14. Capacity factor of nuclear reactors



28 The capacity factor of a power plant is defined as its average power output divided by its maximum power output.

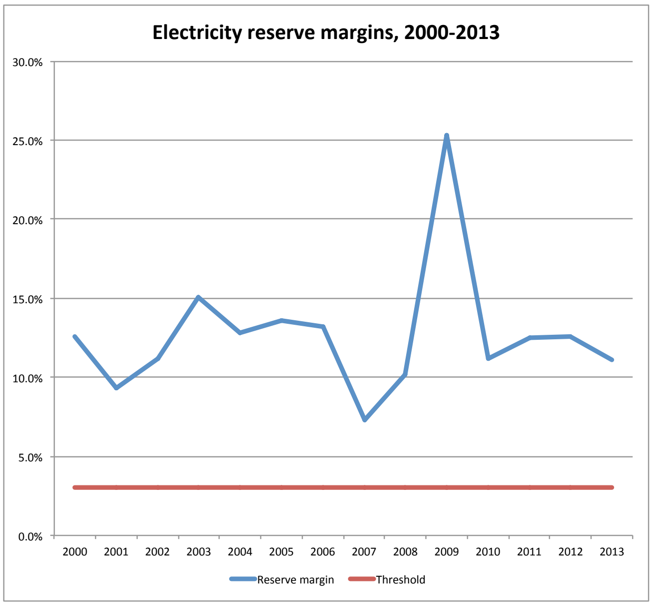
(ii) Electricity infrastructure security

Reserve margins

In Japan, a reserve margin of 3% is required by METI as the minimum level to ensure stable electricity supply.[29] Reserve margins for the country as a whole were well above the threshold for the entire period (see Figure 15). Margins spiked in 2009 because of a sharp drop in electricity consumption due to the economic crisis and again in 2011 as a result of the triple disaster and subsequent restrictions on electricity use [142].

The reserve margin data for the country is an average of all utilities so does not give an accurate picture of changes in specific regions where conditions may be more severe. For example, prior to the triple disaster the Kansai and Kyushu regions relied on nuclear power to supply 27% and 26% of electricity demand respectively [130]. After the triple disaster and the loss of capacity, these regions suffered from negative reserve margins [143]. Since 2011, they have struggled to meet the 3% minimum reserve margin required by METI, especially in the summer peak demand months. They therefore have had to rely on newly installed generation facilities, restarting idled plants and power purchases from private companies [144].

Figure 15. Reserve margins

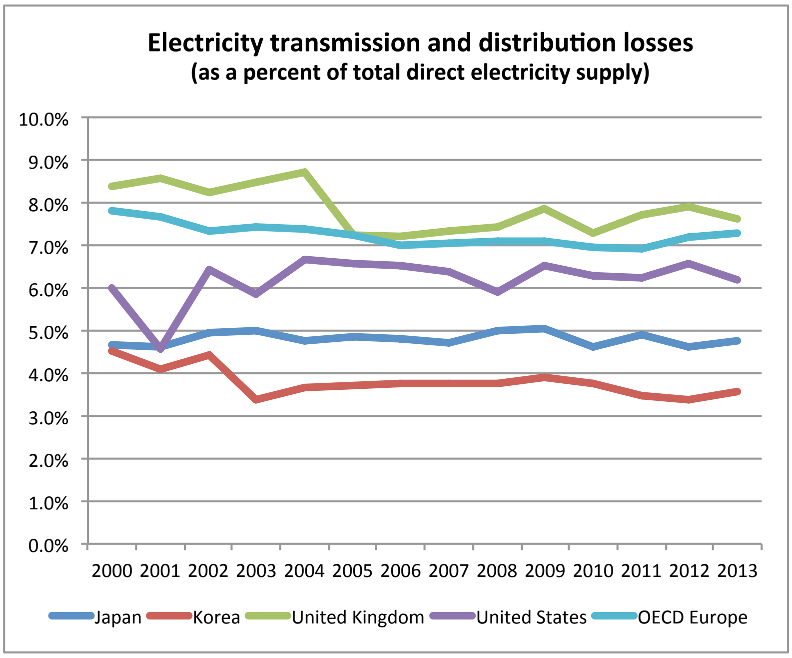


29 While 3% is required, a reserve margin of 8% is considered the level required for normal operation.

Transmission and distribution losses

Japan has a very modern and well-maintained electricity transmission infrastructure and achieved a loss rate of under 5% for most of the 2000-13 period (see Figure 16). This is one of the lowest loss rates in the OECD; the OECD average for Europe ranged between 7-8% over the same period [145]. Japan's performance is due to significant investments in new transmission technology and improvements in capacity factor [139].

Figure 16. Electricity T&D losses



(iii) Public acceptance impacts

Nuclear waste materials and storage

Radioactive waste materials from nuclear power generation present storage and proliferation risks [66]. In a national poll 76% of Japanese respondents said that the fact that disposal sites for radioactive waste from spent fuel had yet to be designated was "significantly problematic" and 19 % said it is "problematic to some degree" [146].

Given the foregoing, the level and trend of high-level radioactive waste materials[30] (HLW) is measured as an indicator of the government's ability to manage nuclear safety issues that impact on public attitudes toward nuclear power and thus on long-term energy security. High-level waste is produced as a byproduct of nuclear power generation and can remain dangerously radioactive for hundreds of thousands of years. Japan currently sends its waste materials to the U.K. and France for reprocessing after which the vitrified waste is shipped back to Japan for permanent storage.[31]

As of 2006, spent nuclear fuel equivalent to 20,400 canisters of HLW was estimated to have accumulated at Japanese power plants and was awaiting reprocessing. Since 2006, the equivalent of about 1,400 canisters of HLW have been produced annually in Japan as a result of nuclear power generation. Thus by 2015, spent nuclear fuel equivalent to an estimated 33,000 canisters of HLW was awaiting reprocessing [148]. However between 1995 and 2015, only 1,470 canisters of HLW had actually been reprocessed and shipped back to Japan [149]. Thus the volume of unprocessed HLW continues to grow annually while issues surrounding Japan's own reprocessing site at Rokkasho and a location for permanent geological storage remain to be solved [150].

(iv) Environmental impacts

Between 2000 and 2010, carbon intensity fell by a total of about 13% indicating the economy as a whole became more efficient at using fossil fuels (see Figure 17). However, carbon intensity of the power sector increased by about 11% over the same period, reflecting the increased use of fossil fuels for power generation.

After the triple disaster, carbon intensity of the economy rose by about 5% but intensity in the power sector spiked up by 21%, due to the replacement of nuclear capacity with fossil fuels after the triple disaster. Per capita carbon emissions were relatively stable up to 2007, but then dipped during the 2007-08, after which they rose rapidly with economic recovery. They have continued to increase steeply since the triple disaster.

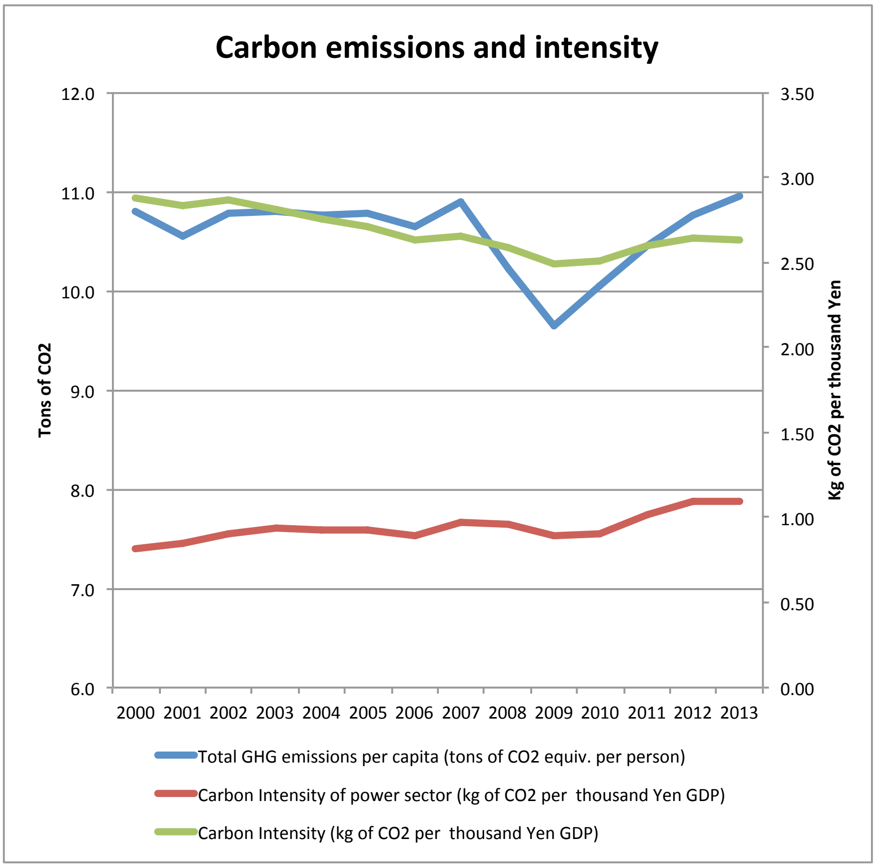
---

[30] High-level wastes take one of two forms: spent (*used*) reactor fuel when it is accepted for disposal, and waste materials remaining after spent fuel is reprocessed [147]. High-level waste makes up only about 3% of the total volume of waste produced from nuclear reactors.

[31] Vitrification is the process by which reprocessed HLW is mixed with melted glass and then encased in stainless steel canisters for long-term storage.

It appeared that improvements in reducing carbon intensity in the economy were large enough to offset some of the increase in intensity in the power sector, while emissions performance of society as a whole (as shown by emissions per capita) ended 2013 at roughly the same level as it started out with in 2000.

Figure 17. Carbon emissions and intensity

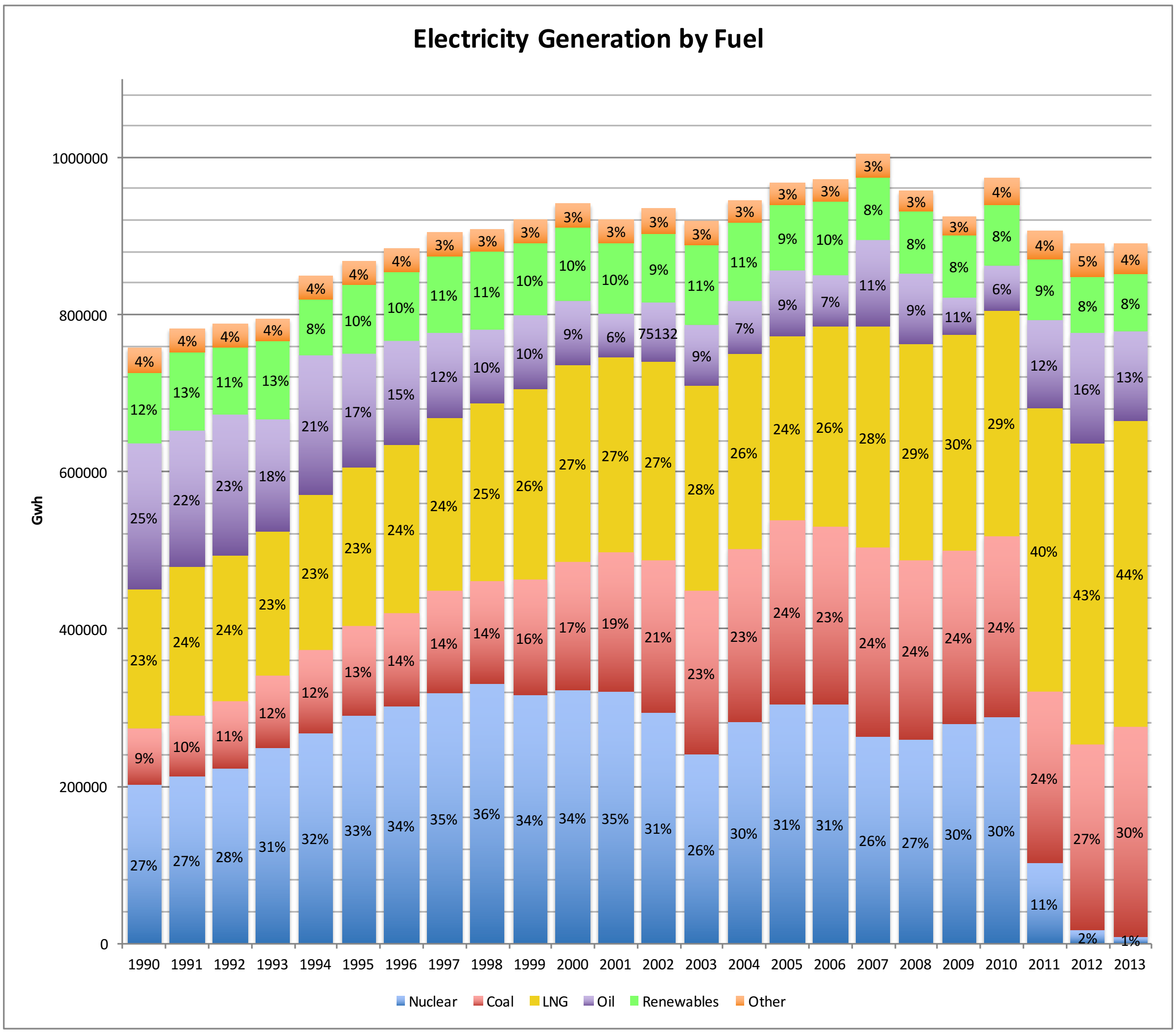


(v) Systemic vulnerabilities in the electricity sector

Electricity generation mix

Electricity generation by fuel (i.e.: generation mix) is an important indicator of energy security vulnerability and resilience in Japan's electricity sector since electricity accounts for a steadily growing share of final energy demand (see Section 4.1.3). Japan had achieved a well-diversified mix of fuel sources and generation technologies up to 2010 with nuclear, coal and LNG making up roughly 25-30% share each. The post 2011 situation has been marked by the virtual absence of nuclear power and a fuel mix that has become much more concentrated on fossil-fuels which made up 87% of total generation in 2013.

Figure 18. Electricity generation by fuel (electricity mix)



Examining the data since 1990, several key trends are evident (see Figure 18). First, electricity generation grew fairly steadily up to 2007 when demand peaked. LNG and coal-fired power generation steadily increased their shares while oil-fired power generation fell significantly up to 2011, reflecting Japan's policy of reducing reliance on oil in power generation and improving energy efficiency. Despite over 30 GW of total installed capacity, the role of renewables in the electricity mix has actually fallen since 1990 both as a share of total generation and in absolute terms. The biggest factors have been a steady reduction in hydro and geothermal generation, with pumped hydro declining by 55% between 2000 and

2013 and accounting for most of the renewables reduction [131]. Utility-scale wind and solar generation was insignificant until 2010, only after which they began to increase.

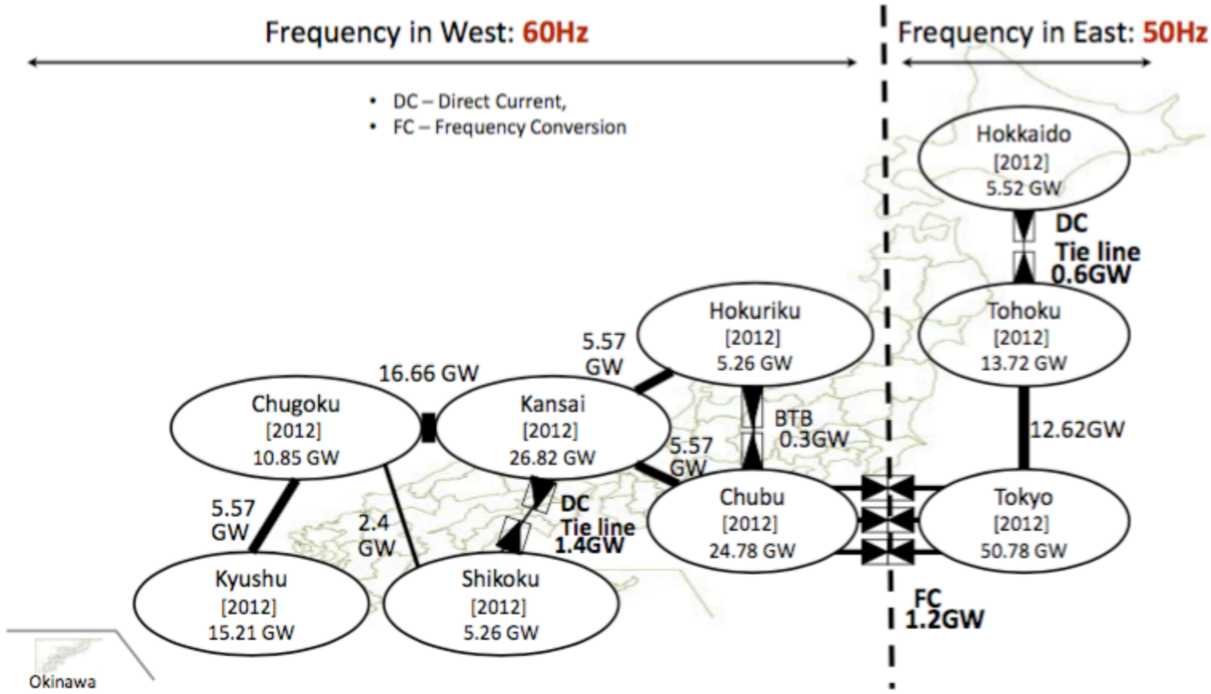
Inadequate inter-regional electricity exchange and load-sharing

The regional GEU's have sole responsibility for transmission and distribution infrastructure within their region (see Appendix A.5 for further information on electricity market structure). There are transmission interconnections between the various GEU's in the 9 main grid systems (with the exception of Okinawa) and therefore regional GEU's can exchange power if required. However in practice, inter-regional power exchange is very limited. Since each GEU builds and operates power plants to service demand in their own region alone, the cost of electricity is higher than it would otherwise be if there was a functioning inter-regional power market [151]. Japan has no electricity connections with other countries.

Historically, all GEU's were required to be self-sufficient in electricity supply within their respective regions, either through their own generation assets or by buying electricity from other generators. Power interconnections between regions were built to improve security of supply rather than for trading power between regions and third-party access was not taken into account in transmission planning. As a consequence, interconnections between some regions are weak, even in the same frequency area [139]. Figure 19 shows both the total transmission capacities in each region as well as the interconnection capacities between regions. In 2003, the IEA noted that the 10-year EPS plans submitted by the GEU's to the government did not include any planned increases in inter-regional transmission capacity up to 2011 [139]. Underinvestment in regional electricity interconnections and frequency converters made national load balancing and emergency response much more difficult after the triple disaster as power could not be efficiently dispatched across regions. This was one reason why Tokyo had to undergo rolling blackouts and some regions suffered negative reserve margins after the triple disaster. Thus, from a national perspective the grid remained fragmented and inefficient, and contributed to high prices.

Japan has yet to develop any electricity or pipeline connections with other countries, even though energy resources are available in neighboring countries such as S. Korea and Russia.

Figure 19. Electricity regions and interconnections in Japan



Electricity frequency conversion bottleneck

A unique aspect of Japan's electricity grid is that frequencies differ between Eastern and Western Japan, namely 50 Hz and 60 Hz respectively. This difference has historical roots in the development of the electricity business in Japan when the Tokyo area adopted German-made generators while Osaka chose US-made ones. As a result, frequency converter facilities are required to connect the eastern and western power grids. However, the capacity of these connections is currently limited to about 1200 MW (see Figure 19). After the triple disaster, the power shortages in eastern Japan could not be sufficiently supplemented by power transfers from western Japan because of the capacity bottleneck at the frequency converter facilities.

Over-investment in electricity infrastructure capacity

Over-capacity in Japan's electricity infrastructure is a function of regulation and market structure. Regulated electricity rates were determined by the "fully distributed cost method" (FDC) where all costs for the construction or expansion of power plants can be passed on to ratepayers, with final approval by METI [152]. As a result, there was a built-in incentive for the GEU's to invest in power plants even when they were operating at below-capacity. As a result, this formula enabled GEU's to invest without sufficient consideration of cost resulting in over-investment and over capacity [153]. When electricity demand was steadily rising in Japan, as in the period up to 2007 when demand peaked [125], this was less of a concern because plants were eventually expected to reach full capacity. However, with demand steadily declining after 2007 and likely to continue to do so, this is not likely to be the case.

It is also notable that during the period covered by this study, capacity factors for Japan's power plants were relatively low compared to international standards, even for newer nuclear and coal-fired plants [154]. Reasons for this include the structure of peak demand where there are large load variations particularly during the hot summer months, as well as inspection periods required for nuclear power plants. However, another significant reason is likely over-capacity.

The effect of over-investment in electricity infrastructure is mixed. On the one hand, the existence of surplus capacity creates idle capacity which can enhance resilience to shocks. On the other hand, the existence of over-capacity is economically inefficient, contributing to higher prices for consumers.

Impact on prices

Due to the unique electricity market structure during the 2000-2013 period as described above, there have been steady investments in electricity infrastructure within Japan's electricity regions but little investment in infrastructure that would increase electricity trade between regions. Consequently, the cost of electricity is higher than it would otherwise be if there was a functioning inter-regional power market [151]. The market structure also did not encourage competition nor the efficient allocation of infrastructure investments to hold down costs but rather acted to maintain a high cost structure. The result was that industrial and household consumers in Japan were paying higher rates for electricity that in most other OECD countries (see Figures 20 and 21).

Figure 20. Industry electricity prices in OECD

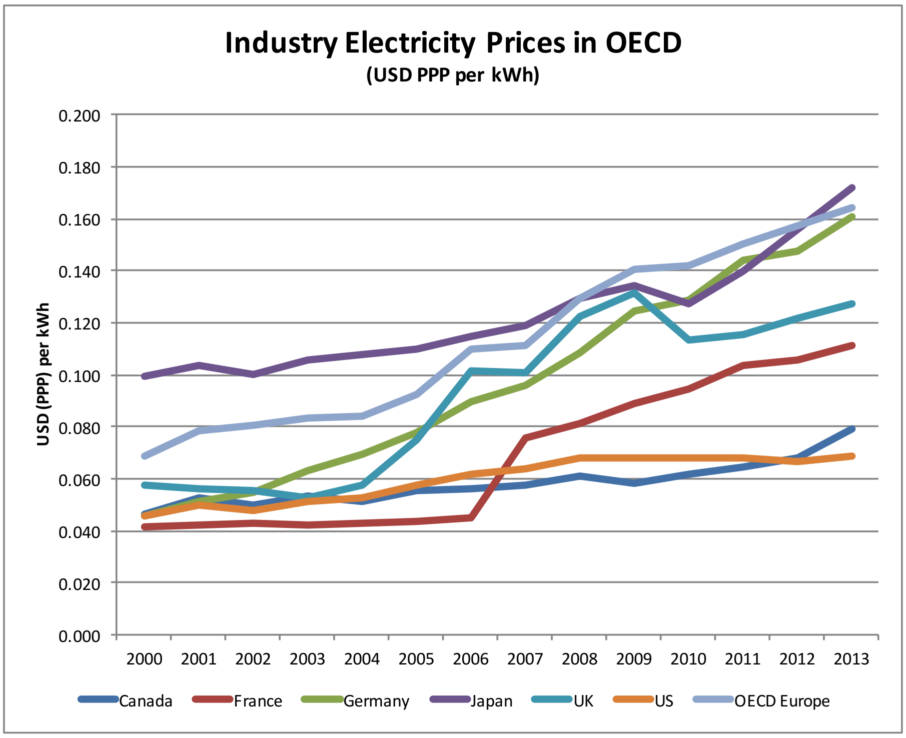
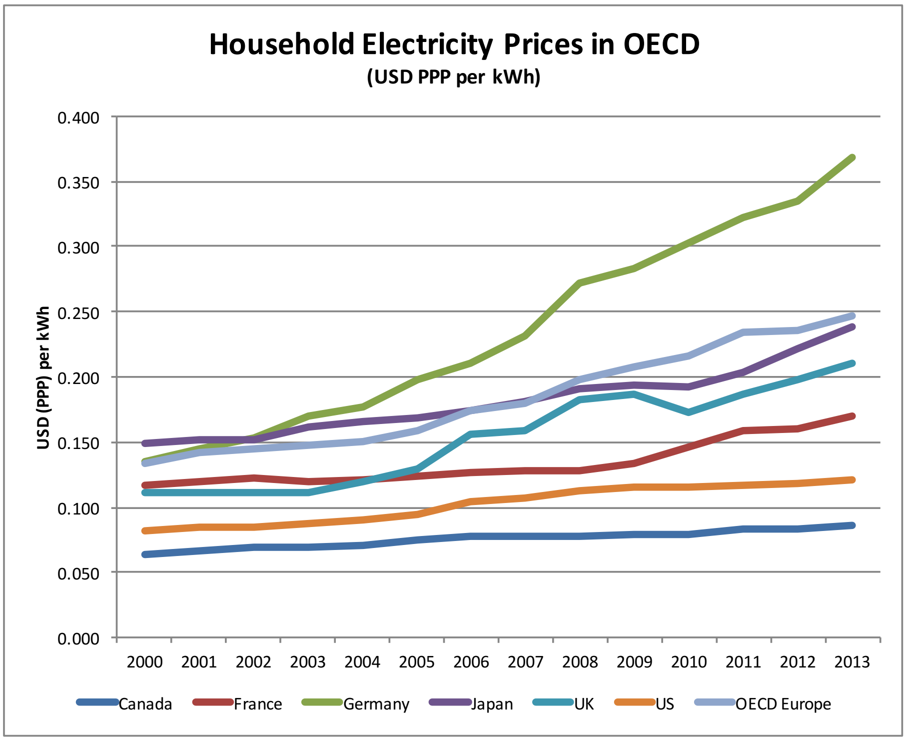


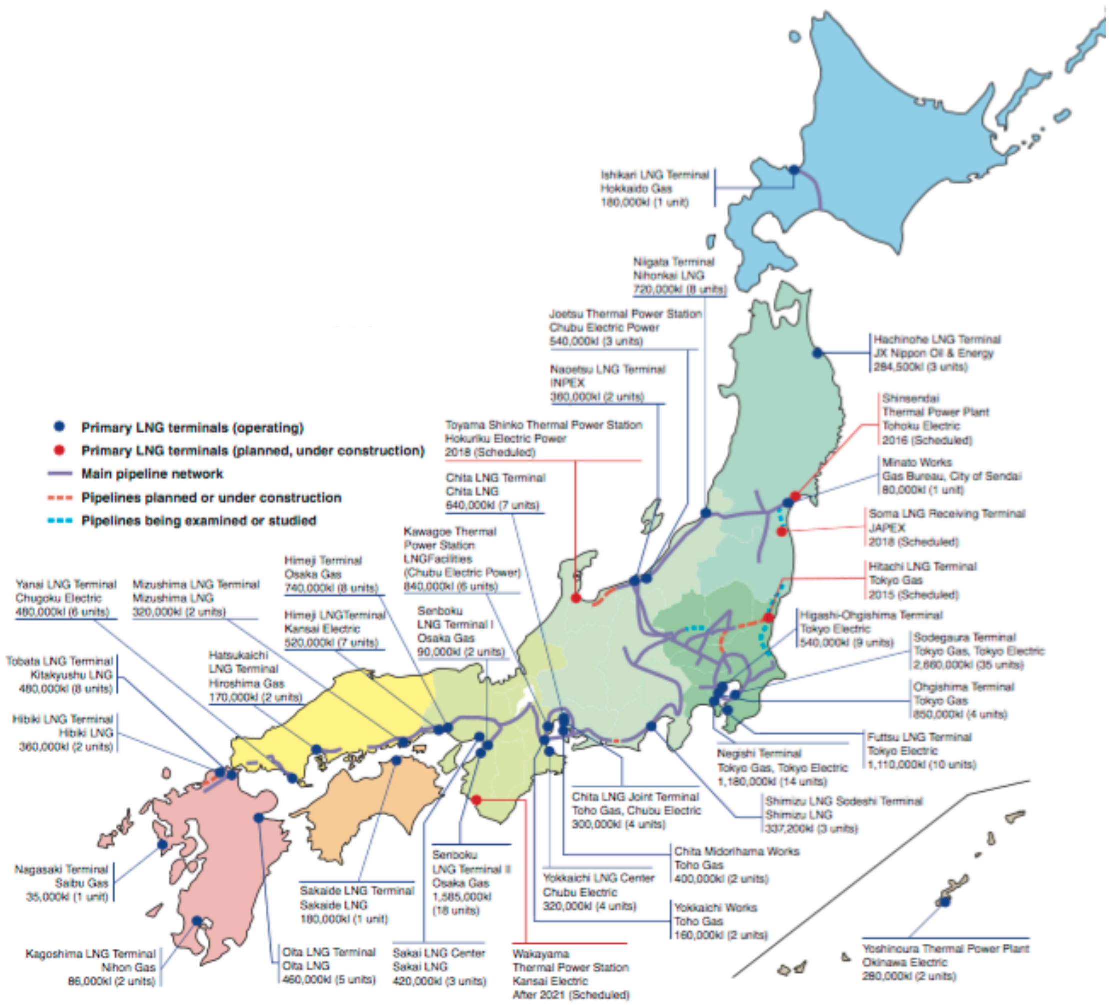
Figure 21. Household electricity prices in OECD



(vi) Systemic vulnerabilities in the gas sector

Given the regional character of energy supply in Japan, virtually all of Japan's gas supply regions have their own LNG receiving terminals and feeder pipeline connections in their respective markets (see Appendix A.6 for further information on gas market structure). There is no single national gas transmission system operator in Japan. About 86% of gas pipelines are used for local gas distribution and there are few interconnections between regions [155] (see Figure 22). Many industrial areas have no natural gas supply due to inadequate pipeline networks.

Figure 22. Gas regions and gas supply infrastructure in Japan[32]



[32] Figure is adapted from the Japan Gas Association ([156]).

Terminals and pipelines are built, owned and maintained by the utilities which supply gas to retail customers under regulated rates. These rates reflect the utility's costs and rate of return. Utilities invest in infrastructure to meet demand within their own region and are not concerned with competition or trade outside their region. As a result, rather than planning from a national perspective that could take into account economic efficiency and inter-regional trade, the regional monopoly approach has incentivized the overbuilding of infrastructure within regions. In 2008, the IEA recommended that Japan increase competition and improve liquidity and economic efficiency in gas markets by linking existing supply areas with trunk lines where feasible [154]. However little has changed to better integrate Japan's gas pipeline infrastructure.

Due to the unique gas market structure in Japan, gas pipeline infrastructure is regionally fragmented and centered around a large number of LNG terminals which are owned and operated by gas utilities, electricity utilities (GEU's), local governments and private companies. To illustrate, in 2005 there were 24 LNG import terminals in Japan [157]. Ten years later in 2015, there were 32 terminals in operation, with an additional 5 terminals scheduled to be completed within the next several years [156]. By contrast, the entire continent of Western Europe had 26 operating LNG import terminals with 8 under construction in 2015 {[158].

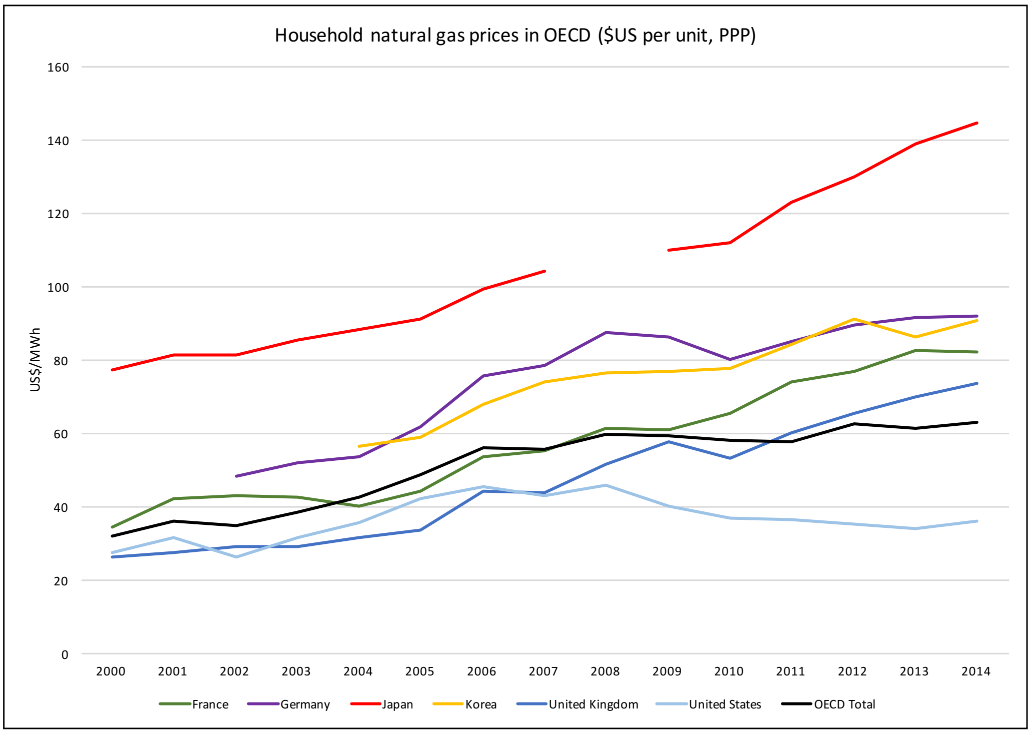
The majority of LNG is imported by electric utilities for power generation. The share of electric utilities in total LNG imports increased from 67% in 2004 to 71% in 2014 [156]. The GEU's have their own LNG import contracts, separate from the city gas industry. Each utility owns and operates its own pipelines. Areas outside major urban centers are underserved by piped gas, and high-pressure pipeline links between major gas markets are under-developed. The gas utilities increased gas pipeline length by 11.3% between 2003 and 2012 with most of the increase being in low and medium pressure pipelines within their regional markets rather than between regions [159], [160].

There are several possible explanations for the heavy investment in regional infrastructure. Japan has made a steady shift to LNG as a source for its city gas and for electricity generation since the first LNG shipments from Alaska began in 1969, so an increase in receiving terminals is partly a response to demand. Having many LNG terminals is viewed as providing flexibility and some insurance against supply disruptions. In addition, there are challenges associated with building trunk lines and connecting regions in Japan. Mountainous terrain and seismic instability make building pipelines more expensive in Japan than in many other countries [139]. However, even taking these issues into account, industry officials acknowledge that over-investment in regional infrastructure is primarily the consequence of the market structure that has been in place for many decades.[33]

Impact on prices

This market structure has undoubtedly contributed to high natural gas prices. In fact, Japan's natural gas prices are by far the highest in the OECD: 1.6 times that of Germany which is the second highest in the OECD, more than 2.3 times higher than the OECD average, and 4 times higher than in the U.S (see Figure 23).

Figure 23. Natural gas prices in the OECD[34]



While the possibility of building a natural gas pipeline from Sakhalin Island in Russia's Far East has been discussed for many years, no natural gas or oil pipeline connections between

33 Interviews with Japan Gas Association officials.
34 There were gaps in the available data for some years in the IEA database, as reflected in the graphs.

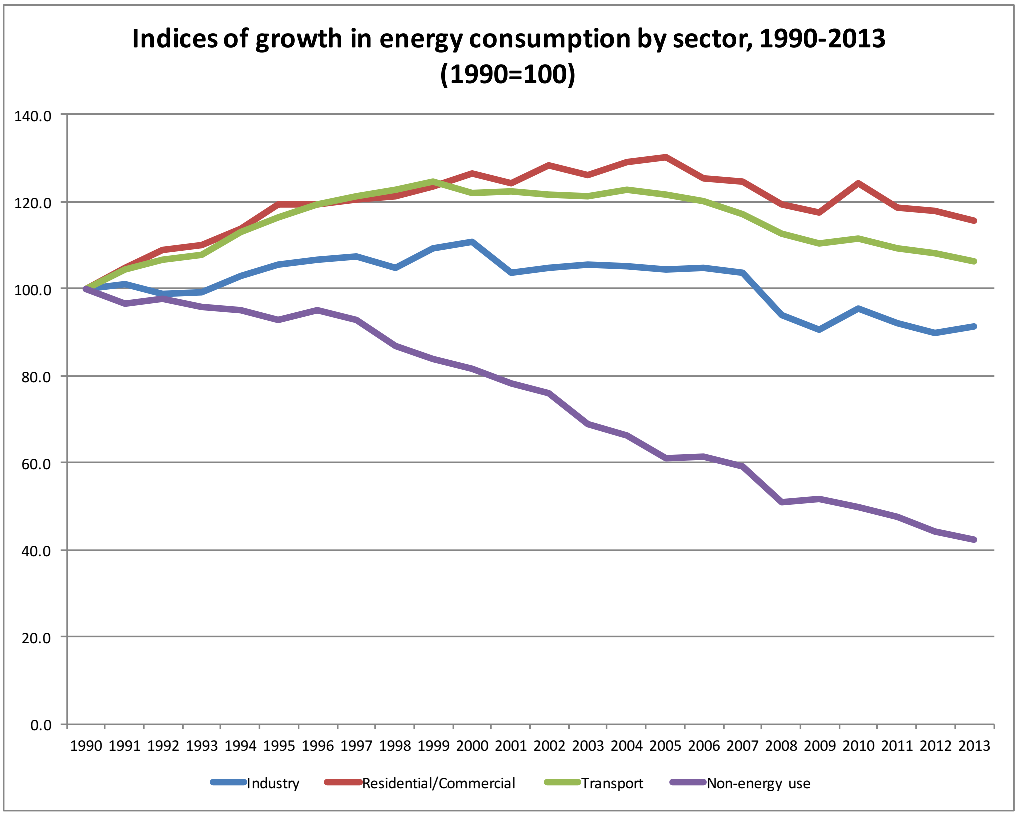
Japan and other regions existed or were planned during the period under study. Thus the country relied on marine vessels and ports to bring required energy commodities to market.

3) Energy services security vulnerabilities

(i) Changes in the structure of demand

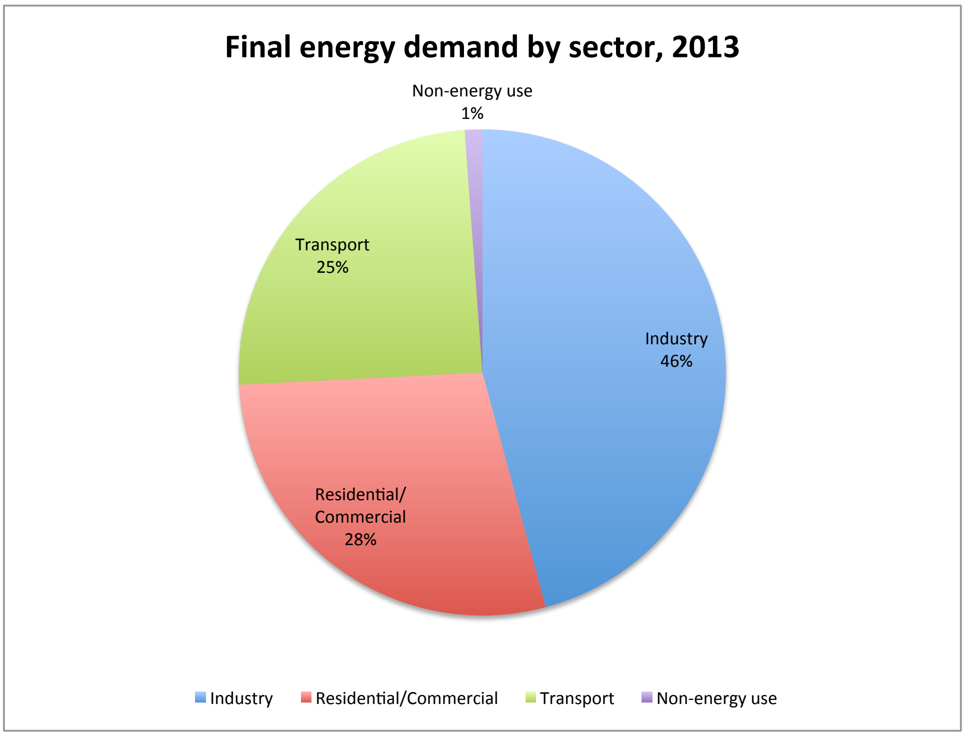
The Japanese economy recorded a slow period of growth in the late 1990's but growth began to pick up starting in 2000. Between 1990 and 2000, total energy consumption increased steadily in the industry, residential/commercial and transport sectors, with residential/commercial consumption rising over 26% (see Figure 24). Between 2000 and 2013, residential /commercial energy consumption grew faster than all other sectors. However, the rate of growth for all sectors started to decline after 2006 with industry and non-energy use declining the most. Over the whole of the 2000-2013 period, Japan's energy consumption declined by 14.6% even as the economy grew by 11.3% [125].

Figure 24. Indices of growth in energy consumption by sector, 1990-2013



The sectoral shares in final energy consumption did not change significantly. Industry consumed the large majority of final demand, followed by residential/commercial and transport (see Figure 25). Significant changes did occur in final energy consumption by source however (see Figure 26). Oil consumption dropped by 26% to represent about half of final consumption, coal consumption fell by over 12% but maintained its share and natural gas consumption grew steadily over the period. Electrification of Japan's economy expanded between 2000 and 2013, however it is notable that final energy consumption was still largely in non-power uses, mainly in the form of heat.

Figure 25. Final energy demand by sector, 2013



The transport sector is particularly vulnerable to changes in the supply and price of fossil fuels and oil plays a particularly important role as a transportation fuel. While overall oil consumption in Japan fell during the period as noted above, its relative importance in the transportation sector increased while consumption in the industry sector fell significantly (see Figure 27).

Figure 26. Final energy consumption by source and share, 2000 and 2013

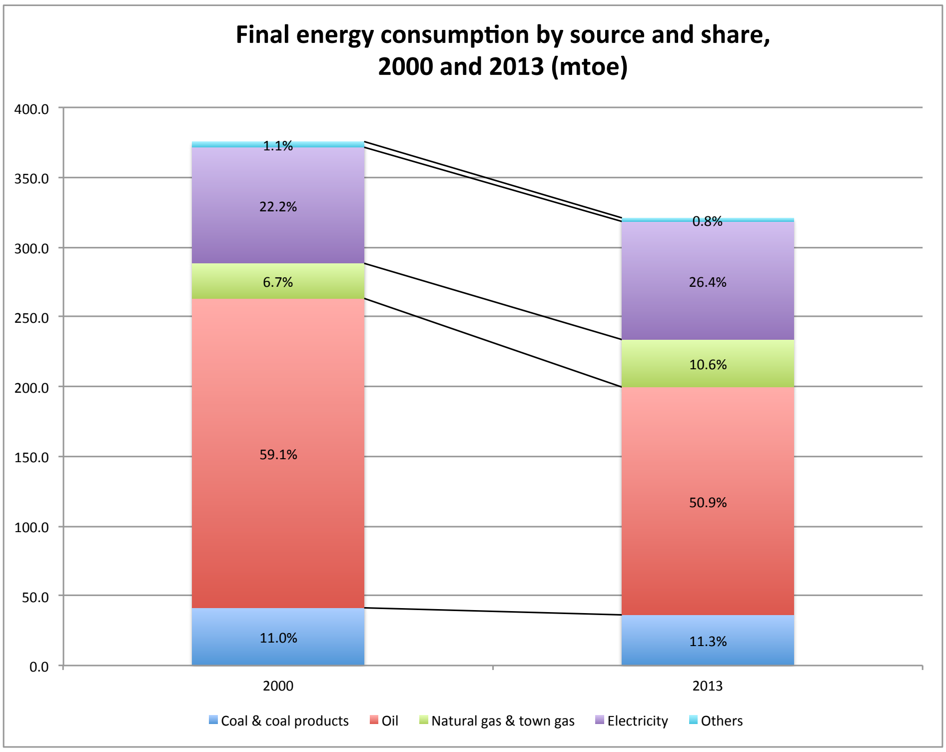
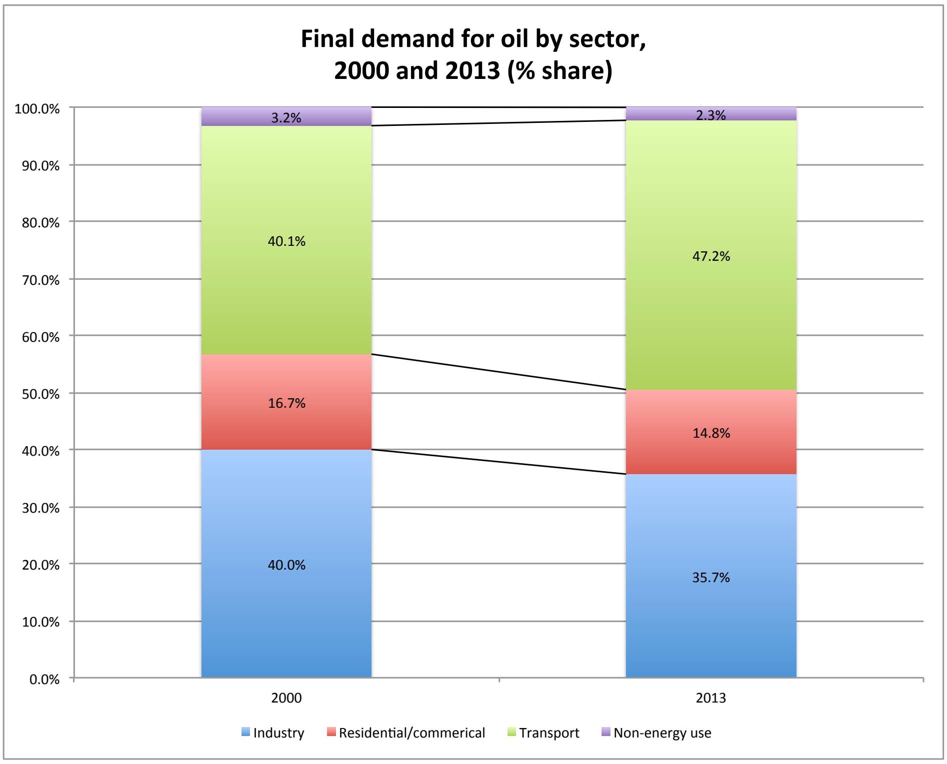


Figure 27. Final demand for oil by sector



(ii) Energy prices and volatility

The index of total energy end-use prices in Japan over the 2000-2013 period showed an upward trend, rising on average about 1.7% annually for households and 3% annually for industry (see Figures 28 and 29). Considering that Japan was experiencing a deflationary trend in overall prices over this period, the increases are significant, especially for industry.

Figure 28. Indices of energy end-use prices for households

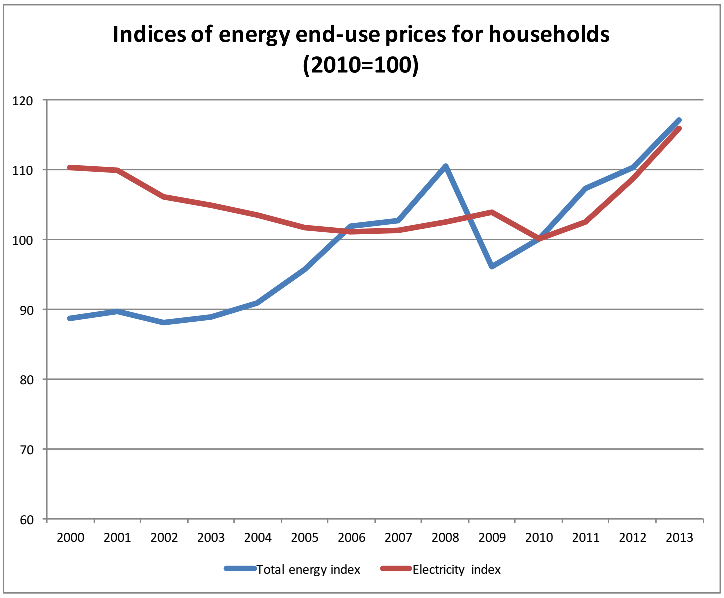
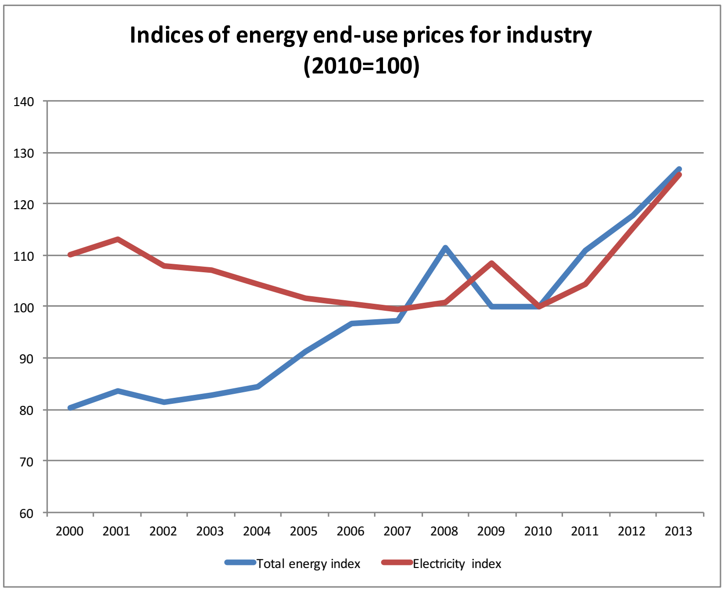


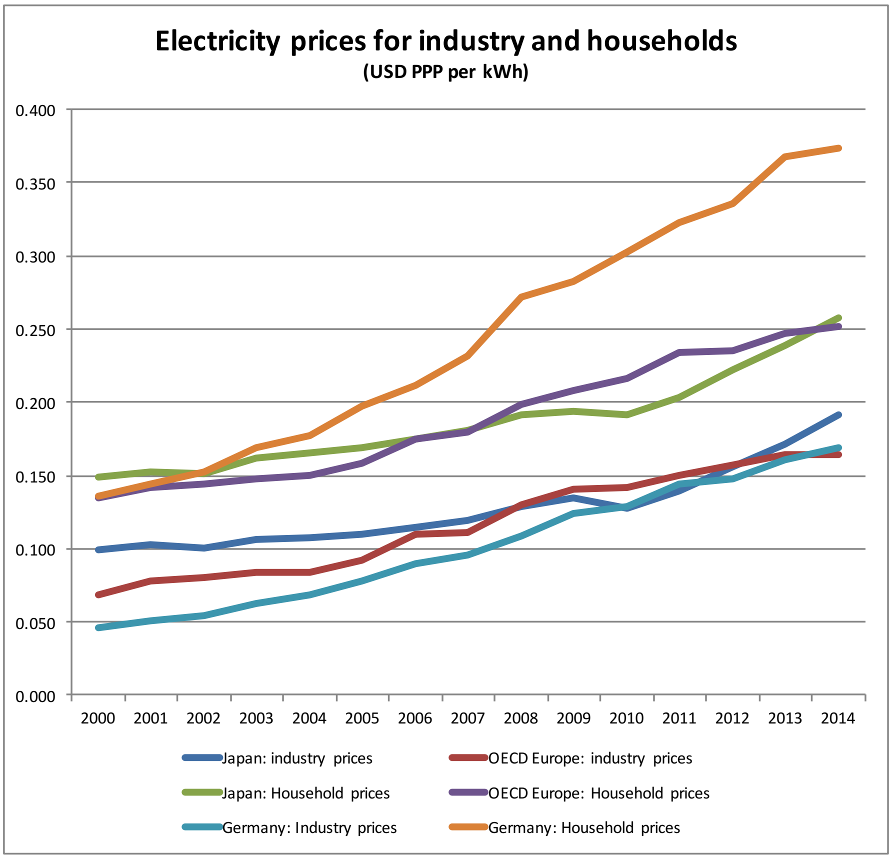
Figure 29. Indices of energy end-use prices for industry



The index for electricity prices showed a mixed trend, with prices declining slightly from 2001-2008 and then rising steeply from 2010. Between 2000 and 2007, prices declined about 1% annually for households and 1.3% annually for industry, primarily due to increased competition brought on by electricity liberalization measures that began in 1995 [161]. However, by 2013 electricity prices for industry were 26% higher than they were in 2010, reflecting the increase in global energy prices. Household prices were 16% higher, having been dampened by regulated rates prevailing in the household sector. The steep price increases arose from the power companies having to deal with the increased costs of fossil fuels after the triple disaster, which also caused declining profitability and financial losses in the GEU's [162], [163].

Comparing industry electricity prices in Japan with OECD Europe countries, Japan's prices were higher up to 2008, after which they tracked European prices closely (see Figure 30). As for household electricity prices, Japan's prices closely tracked OECD average prices and were well under Germany's prices which were among the highest in the world.

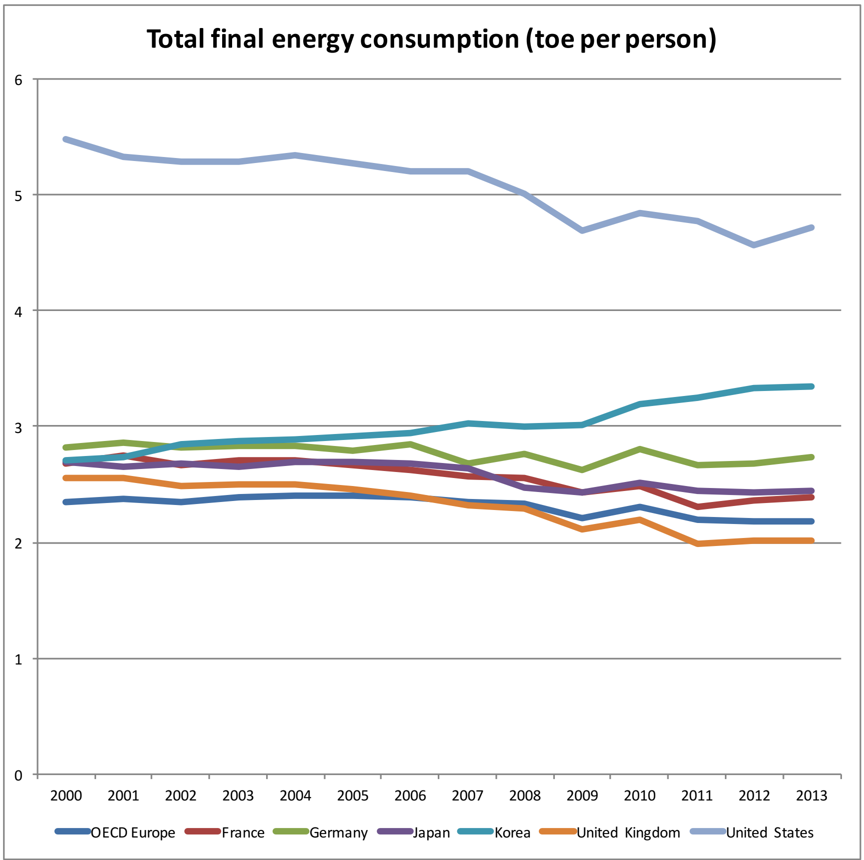
Figure 30. Electricity prices: industry and households in OECD



(iii) Systemic vulnerabilities

Total final energy consumption per capita fell by over 9% over the 2000-13 period, reflecting a steady reduction in energy use by individuals and therefore a reduction in social vulnerability to energy price and supply disruptions. Japan compares favorably with European countries on the same measure and significantly outperforms S. Korea and the U.S. (See Figure 31).

Figure 31. Total final energy consumption per capita



4.1.4 Discussion

1) The 2000 - 2010 period

Japan's efforts since the 1970's to diversify the types of fuels in its primary energy supply mix and reduce reliance on oil helped keep the primary energy mix well diversified. With nuclear power representing about 12% of TPES, Japan was able to maintain the self-sufficiency ratio at around 18% over the 2000-2010 period. Crude oil stockpiles far exceeded the minimum requirements set by the IEA[35] and could supply the country for more than six months, providing resilience in the case of a major disruption.

The share of fossil fuels in Japan's primary energy mix remained high, increasing marginally between 2000 and 2010. Reliance on the Middle East for fossil fuels remained about the same, leaving the country highly vulnerable to instability in that region, and to potential disruptions to vital sea lanes and chokepoints.

Japan built a well-diversified and extensive fleet of thermal, nuclear and hydro power plants over several decades up to 2010. As a result, the country had a well diversified mix of fuel sources in the electricity mix providing flexibility and resilience to possible fuel supply disruptions. On the other hand, Japan's thermal and nuclear power generation fleet was rapidly aging, with almost 60% being at least 20 years old and no new nuclear power plants commissioned since 2009.

Despite positive growth in GDP, the country managed to steadily reduce final energy consumption. The industry sector accounted for almost half of total energy consumption throughout the period and so remained the most heavily exposed to overall energy supply and price risks. Its share of oil consumption fell over period possibly reflecting the effectiveness of energy efficiency measures, an increase in energy-intensive manufacturers moving offshore, or a combination of both factors. These trends were also reflected in the steady reduction in emissions intensity over this period.

Total energy prices showed an upward trend for most of the period, in both the industry and household sectors. However, electricity prices fell steadily between 2000 and 2007 reflecting the effects of competition in the electricity sector. Electricity prices began to rise again in 2008 as the global prices of fossil fuels recovered after the global financial crisis.

In summary, between 2000-2010 Japan's overall energy security situation can be said to have generally improved in all segments of the supply chain, as measured by the indicators used in this study. Despite Japan's almost total reliance on imports for fossil fuel supplies, the primary energy supply mix and electricity mix were relatively well diversified and well

[35] The IEA's minimum stockpile obligation is 90 days.

balanced. The electricity system had sufficient flexibility to accommodate changes in fuel mixtures in response to prices and cushion the effects of shocks. Even though energy prices generally rose over the period, the steady decline in energy consumption and energy intensity along with the increase in electrification served to reduce vulnerabilities to supply disruptions and price risks.

2) The post-Fukushima period

The situation after the triple disaster exacerbated Japan's energy supply vulnerabilities significantly. With the shutdown of almost all its nuclear reactors, primary energy supply became even more concentrated on fossil fuels, particularly LNG and coal which filled the gap left by nuclear. By 2013 fossil fuels made up almost 91% of primary energy supply, a level higher than after the first oil shock in 1973. As a result, self-sufficiency plummeted to 7%, leaving the country much more vulnerable to supply and price shocks and potential instability in the Middle East.

Oil prices and the prices of other commodities linked to oil (such as LNG) rose significantly between 2000 and 2013. In fact, the triple disaster occurred just at the time when oil prices were spiking back toward the $120/bbl level in March, 2011. As a result of Japan's emergency purchases of LNG and other fossil fuels, the total cost of imports rose precipitously impacting the country's balance of payments and severely affecting the profitability of Japan's utilities.

Between 2011 and 2013 prices for energy and electricity rose steeply, impacting on affordability and industrial competitiveness. While the situation was somewhat alleviated by the 50% fall in global oil and natural gas prices that occurred in 2014, the welfare impact of rising energy prices is concerning given that per capita energy consumption has already fallen significantly and further room for energy conservation improvements may be limited. Still, by the end of 2013 prices in Japan were comparable with those of OECD European countries.

The rate of decline in final energy consumption accelerated after the triple disaster in all sectors. Decreases in electricity consumption since 2011 can be attributed to slow economic growth as well as to conservation efforts implemented after the triple disaster which have been sustained by broader Japanese society [164].

While Japan's electricity infrastructure adequately met demand over the whole of the period (with the exception of a few weeks after the triple disaster), an important question is whether it did so in an economically efficient manner. The disaster exposed serious weaknesses in the vertically integrated regional electricity monopoly structure, pointing toward deficiencies in market structure and regulatory oversight. Over-investment in electricity generation capacity has been economically inefficient, with generation assets being allocated on a regional basis rather than a national basis. Thus, regions had more than adequate capacity but as this study has shown, performance at the "national grid" level was inadequate and inefficient, particularly during a major emergency.

Japan's overall energy security situation in the post-Fukushima period can be said to have degraded significantly. The triple disaster revealed a wide range of new or exacerbated vulnerabilities, especially the increased dependence on fossil fuels (and thus exposure to external geopolitical risks), aging electricity generation infrastructure, inadequate inter-regional electricity exchange, an electricity frequency conversion bottleneck, low public acceptance of nuclear power, lack of inter-regional gas pipeline interconnections, over-investment in gas infrastructure capacity, increased GHG emissions, and low levels of non-hydro renewables generation. Over-investment in electricity and gas infrastructure capacity contributed to the increasing cost of energy that threatened industrial competitiveness and affordability. These issues will be discussed further in detail in Chapter 4.4.

4.1.5 Conclusion

In summary, this chapter addressed the first research question posed in this thesis by examining the impact of energy policies on energy security in terms of vulnerabilities to threats and risks facing the energy system. Threats and risks were identified and their impact on energy system vulnerability was analyzed. The analysis demonstrated that between 2000-2010, Japan's overall energy security situation steadily improved in all segments of the supply chain, as measured by a broad suite of indicators of vulnerability. However, the triple disaster made some critical vulnerabilities worse and exposed new ones that posed significant challenges to Japan's long-term energy security and held important implications for policy. These vulnerabilities and their implications will be further discussed in Chapters 4.4 and 6.

Chapter 4.2: The impact of Japanese energy policies on energy security

4.2.1 Introduction

In Chapter 4.1, energy security vulnerabilities in Japan's energy system were assessed for the 2000-2013 period. The purpose of this chapter is to assess Japanese energy policies between 2000-2013 by evaluating their impact on Japan's energy system. The focus is on understanding the extent to which Japanese energy policies served to reduce vulnerabilities through their impact on energy system resilience and adaptability. These policies are covered in detail in Appendix A.

While many energy security studies have assessed resilience in energy systems, very few have attempted to evaluate adaptive capacity. Most studies of adaptive capacity originate in ecology and sustainability studies in the context of climate change. Very few attempts have been made to apply the concept to socio-technical systems or evaluate adaptive capacity explicitly as a dimension of energy security. Adaptive capacity has been little discussed in the context of energy security and usually only in relation to its role in supporting resilience (for an example, see: [165]). As a result, very few studies have employed measures of adaptive capacity in an energy security assessment. In a 2011 study, Sovacool et.al. [56] proposed several indicators to measure adaptive capacity and resilience as part of an energy security assessment framework but did not systematically define or explain the property or its role in energy security.

This study fills a gap in the literature on energy security by clarifying the sources of resilience and adaptive capacity in the energy system and demonstrating how energy policies have impacted on resilience and adaptability in Japan's energy system. It responds to calls for a greater emphasis on evaluating adaptive capacity along with the development of metrics to analyze this property [34], [112], [166]. Since measures of adaptive capacity are particularly relevant to long-term energy security, this study provides new insights into the policies and strategies that enable the Japanese energy system to evolve and change in response to long-term stress.

4.2.2 Energy security assessment framework

This study builds on the conceptualization of the energy system as a socio-technical system. A mixed methods approach, combining both quantitative and qualitative measures and indicators is used to evaluate energy security by assessing the impact of various Japanese energy policies on the systemic properties of resilience and adaptive capacity.

1) Assessment challenges and limitations

The assessment of vulnerability, resilience and adaptive capacity in energy systems presents various challenges. Vulnerabilities are relatively easy to identify and assess because the system's response can be measured or simulated against specific hazards and threats. On the other hand, the sources of resilience and adaptive capacity in complex systems can be much more difficult to isolate, identify and evaluate. Complex interrelationships among system elements and between the energy system and other related systems makes it more difficult to relate system response to specific causes or policies.

Moreover, the assessment of resilience, and particularly adaptive capacity, can be highly context-specific with the energy systems of various countries having varying attributes that are not easily generalizable between contexts. As already discussed, it is also important to note that the properties of resilience and adaptive capacity are to some extent overlapping and policies that serve to strengthen either resilience or adaptive capacity may each serve to reduce vulnerability.

Adaptive capacity is difficult to assess because of its latency; its effect may only be apparent after the system has responded to a specific disturbance. One method of assessing adaptive capacity is through *measurement*. Measurement attempts to assess adaptive capacity directly for a particular point in time by examining the various system responses surrounding a disturbance in order to identify the possible sources of adaptive capacity. If the system was able to adapt to the disturbance, then the capacity to do so must have existed [112].

Another method of assessing adaptive capacity relies on *characterization*. Characterization is an indirect method of assessing adaptive capacity that often involves using various indicators derived from a set of assumptions about the theoretical determinants of adaptive capacity (the determinants of adaptive capacity in energy systems will be discussed in Section 4.2.2) [108].

Characterization may also make use of a variety of methods including case studies, survey techniques, and examining the system for the presence of certain attributes and mechanisms that the literature has suggested enhance adaptive capacity [112].

The measurement of resilience poses similar challenges to that of adaptive capacity since resilience often cannot be measured directly and must be inferred from the presence of certain characteristics in a system. In this study, a mixture of qualitative measures, quantitative indicators and reference cases are employed in order to characterize and measure resilience and adaptive capacity in Japan's energy system.

2) Analytical framework

The framework used in this study employs a "bottom-up" approach to the analysis of Japanese energy policies and was undertaken in several steps. First, policies and energy plans in effect between the late 1990's and 2013 (see Appendix A) were reviewed and analyzed for common themes and objectives. On the basis of this review, policies were categorized into seven broad policy areas:

- Diversification
- Increase domestic supply sources
- Energy efficiency and conservation
- International energy relationships and investments
- Energy innovation and technology development
- Market structure and liberalization
- Public engagement

Each of these policy areas can be further distinguished by the specific strategies associated with them, as articulated in Japan's energy plans. These strategies were then related to the corresponding property of the energy system that is potentially affected, based on the theoretical determinants of resilience and adaptive capacity discussed in the next section.

The assessment of the impact of Japan's energy policies on resilience and adaptive capacity necessitates the choice of a limited set of qualitative and quantitative measures and indicators.

These have been selected based on the appropriateness to each policy area or strategy and on the availability of data. Table 4 summarizes the relationships between policy areas, strategies, system properties and indicators.[36]

This framework is supplemented by reference cases in order to evaluate characteristics of the energy system that are difficult to evaluate using only quantitative measures. This is discussed further below.

(i) Resilience measures and indicators

The sources of resilience in systems may derive from many factors. In his widely cited research on diversity, Stirling argued that the energy sector is dominated by uncertainty and argued that the best measures of resilience in an energy system are diversity indicators [71], [85]. He also showed that diversity is an appropriate "system level" response strategy for dealing with uncertainties [86].

In addition to diversity, other strategies for enhancing the resilience of energy systems have been much discussed in the energy security literature and include: maintaining sufficient idle capacity, emergency stockpiles of energy resources, utilizing domestic energy sources such as renewables, demand-side efficiency improvements, distributed generation, maintaining reserve margins of electricity generation capacity and promoting intra-regional trade and energy cooperation. Such strategies have been shown to be effective in strengthening the system's ability to respond to short-term shocks [54], [71], [86], [113].

Diversification

Diversification promotes resilience by providing alternatives in the case of disruptions to energy supplies. For energy resource importing countries such as Japan, diversification can be implemented along several dimensions including primary energy sources (e.g.: coal, oil, electricity, natural gas), the diversity of supplier countries (including by region), diversity of fuel type in electricity generation and diversity in the location of electricity generation (i.e.: distributed generation).

[36] It should be noted that although these policy areas broadly represent and describe Japan's energy policies over the 2000-2013 period and can be related to various strategies and system properties, the relationships depicted in this study do not necessarily reflect how the Japanese government itself viewed them.

Table 4. Policies, strategies and indicators

Energy policy areas	*Strategies*	*System property affected*	*Indicators and Measures*
Diversification	Electricity mix targets Diversify location of electricity supply Diversify fuel type in primary energy supply Diversify supplier countries	Resilience Resilience Resilience Resilience	Electricity mix Distributed generation SWI HHI
Increase domestic supply sources	Promote domestic sources of fuels Promote renewables Oil and LPG stockpiles Idle capacity	Resilience Resilience Resilience Resilience	Domestic E&P activity, power generation efficiency Renewables capacity and generation Number of days supply Capacity
Energy efficiency and conservation	Energy efficiency and conservation	Resilience	Energy intensities, indices of energy use
International energy relationships and investments	Resource security strategies	Resilience	Activities implemented
Innovation and technology development	Investment in energy technology R&D Experimentation/demonstration projects Innovation and commercialization	Adaptive capacity Adaptive capacity Adaptive capacity	Government investments in energy R&D, energy-related patent applications Reference case on "Smart Communities" Reference case on Ene-farm fuel cells
Market structure and liberalization	Deregulation Electricity liberalization Gas market liberalization	Adaptive capacity Adaptive capacity Adaptive capacity	Regulatory quality Share of new entrants in electricity markets Share of new entrants in gas markets
Public engagement	Engagement on energy issues	Adaptive capacity	Attitudinal studies and public polls

Distributed generation

Distributed generation[37] (DG) can be considered as diversification based on location (of power sources) as well as diversification in distribution mode.[38] DG adds flexibility to national power supplies and can help reduce the load on centralized transmission and distribution networks during peak demand periods. DG can help overcome the high cost of building centralized transmission infrastructure, lower costs and relieve pressure on main grids, and reduce the potential for power outages [167]. DG systems also enhance resilience because they are less exposed to cascading failures of centralized networks [168].

Domestic supply sources

Japan has expended efforts over many years to improve domestic supplies of energy resources. Domestic sources are considered to include indigenous fossil fuels and renewables. Although nuclear power can be viewed as "quasi-domestic[39]", it is considered under diversification strategies. Improvements in the efficiency of energy production and use have also been considered as a "source" of domestic energy since such improvements can reduce reliance on imports. Stockpiles are an additional source of energy supplies in the event of emergencies, providing a buffer to supply and price shocks. Similarly, idle capacity represents electricity generation capacity in excess of that required to ensure adequacy and not currently in operation. The amount of idle capacity is an indicator of electricity system resilience since idle capacity represents a potential buffer in the case of disruptions to the operational fleet.

Increasing the level of renewables offers several potential advantages for enhancing resiliency including [88]:

---

[37] For the purposes of this study, distributed generation (DG) is defined as decentralized electricity generation technologies that are demand-side connected, and that may or may not be grid-connected.

[38] DG systems are typically located close to the load they serve. Distributed generation systems include renewable energy sources (small hydro, biomass, biogas, solar PV, wind, and geothermal) as well as co-generation (including CHP) systems. DG systems offer the benefit of enhanced energy efficiency since power generation losses and transmission losses are minimized, and higher flexibility since power is available even if there is an outage in the main grid.

[39] Nuclear power is viewed in Japan as "quasi-domestic" because uranium can be imported from friendly supplier countries and stockpiled, providing many years of secure supply.

- Reduced dependency on imports of fossil fuels and therefore to vulnerability to supply disruptions.
- Enhanced energy security since they are they are generally not scarce and may even be inexhaustible (e.g.: geothermal and solar).
- Reduced risk of price shocks and price volatility.
- Suitability for rural and isolated regions where centralized grid access may be lacking or expensive to build.
- Helping achieve emissions targets since they are low-carbon energy sources.

Energy efficiency and conservation/Demand-side management

Demand-side management (DSM) is a portfolio of measures to improve energy systems performance on the consumption side. It includes energy efficiency improvements (e.g.: energy efficiency standards for household appliances, transportation vehicles, buildings), energy conservation, smart grids, smart meters, demand response and load balancing. All of these measures serve to enable more efficient energy use, therefore reducing reliance on energy imports and increasing resiliency.

Resource (energy) security strategies

Nations that are highly dependent on energy imports, such as Japan, may employ various resource security strategies either directly or through state supported actors (including domestic energy companies and state-owned enterprises). Various types of state-directed or state supported resource security strategies were discussed in Chapter 3.6. Energy security strategies may act as a hedge or "insurance policy" in the face of risks or threats to energy security and therefore can be considered a method of enhancing resilience. Since Japan actively employed such strategies over the period under study, they are included in the analysis.

(ii) Adaptive capacity measures and indicators

The strategies and measures outlined in this section can be considered to act as a*daptive mechanisms* within the energy system. The presence of adaptive mechanisms serves to enhance adaptation processes by increasing diversity (variation), improving feedback or enhancing learning and innovation in systems [169]. Adaptive mechanisms can reinforce the proactive aspect of adaptability by aiding in the selection and reinforcement of behaviors that tend to improve system performance even in the face of uncertainty [170].

Market structure and liberalization

Energy markets have been described as complex adaptive systems that enable the coordination of actors and resources across multiple scales [171]. Market mechanisms can improve the efficiency of adaptation, particularly where goods or commodities such as energy are traded [172]. A competitive market that adjusts supply and demand dynamically in response to price signals is more economically efficient that a purely regulated system because it can respond faster and with greater flexibility, although it may not always do so in ways that satisfy the public interest. On the other hand, state-dominated and highly regulated governance models can produce biased feedback due to distorted information flows, multiple veto points and institutional rigidities making them less adaptive [173].

Long-term energy security requires timely and adequate investment in energy production and transportation facilities [88], [174]. Market structures that are not conducive to stimulating timely investments in critical energy system infrastructures can increase system vulnerability and degrade long-term energy security [47]. Monopolistic or oligopolistic structures are associated with the negative effects of market power which can affect the adequacy of energy infrastructure [47]. Both under-investment and over-investment in energy infrastructure can be signs of inadequate market structure.

Regulatory quality

A major goal of regulatory reform is to improve economic performance as well as to enhance the ability to adapt to change [175]. Governments wish to ensure that “regulations operate efficiently to boost economic growth, social welfare and environmental standards” [176]. Prescriptive regulations and regulatory inflexibility can stifle innovation and act as a barrier to change [177]. Long-term threats to energy security include regulatory risks since the regulatory environment shapes the context for the operation of markets, and plays an important role in providing certainty, predictability as well as flexibility in making energy related investment decisions.

Innovation and technology R&D

The literature on socio-technical transitions has emphasized the role of technological innovation and the use of experiments, learning and adaptation in enabling system change [107], [178] [179].

The ability to develop and employ advanced energy technologies can serve to improve adaptability to various energy security risks including from increasing resource prices, changes in the structure of demand, and climate change pressures. Technologies include those in the supply, transformation and demand segments as well as related technologies including information and telecommunications technologies which are increasing integrated into modern energy systems.

The level and trend of government budget expenditures on energy R&D can be used as a proxy measure for the capacity to innovate and adapt to emerging technological challenges associated with climate change and energy production and use. While a direct correlation between government spending on R&D and the ability to deal with technological change is difficult to establish, it is reasonable to assume that a country that spends more on energy R&D will have better long-term energy security and environmental outcomes.

Patents provide an excellent measure of the location and intensity of innovative activity. The empirical evidence shows that there has been a sharp increase in global patent filings in energy technologies since around 2000 [180]. The number of patents registered by a country can be used as a proxy indicator for the capacity to develop and employ energy technologies [47].

Experimentation/Demonstration projects

Strategies to enable system change include linking technological and social innovation, promoting “learning by doing”, involving broader constituencies of stakeholders and networks, and experimentation and diversity of innovations [181]. In the literature on technological innovation, the importance of large-scale demonstration projects as a strategy to facilitate the diffusion of emerging energy and environmentally-related technologies has been extensively documented (for examples see: [182], [183]).

Public/stakeholder engagement

Complex adaptive systems rely on reciprocal feedback for adaptation [184]. In systems where government has employed control-oriented approaches there is sometimes the tendency to develop a policy agenda first and then present it to stakeholders and the public without first having developed shared learning and understanding or built sufficient trust relationships. Once contentious issues that require public support move into the public arena, stakeholder positions can become polarized and negotiation becomes difficult [185]. Engagement with stakeholders and the public can therefore be an effective adaptive mechanism in helping deal with uncertainty and shaping change [186].

4.2.3 Analysis

In this section Japanese government energy policies that were in place over the 2000-2013 period are evaluated by employing the framework developed in the previous section and employing both quantitative and qualitative analysis.

1) Assessing resilience

(i) Diversification

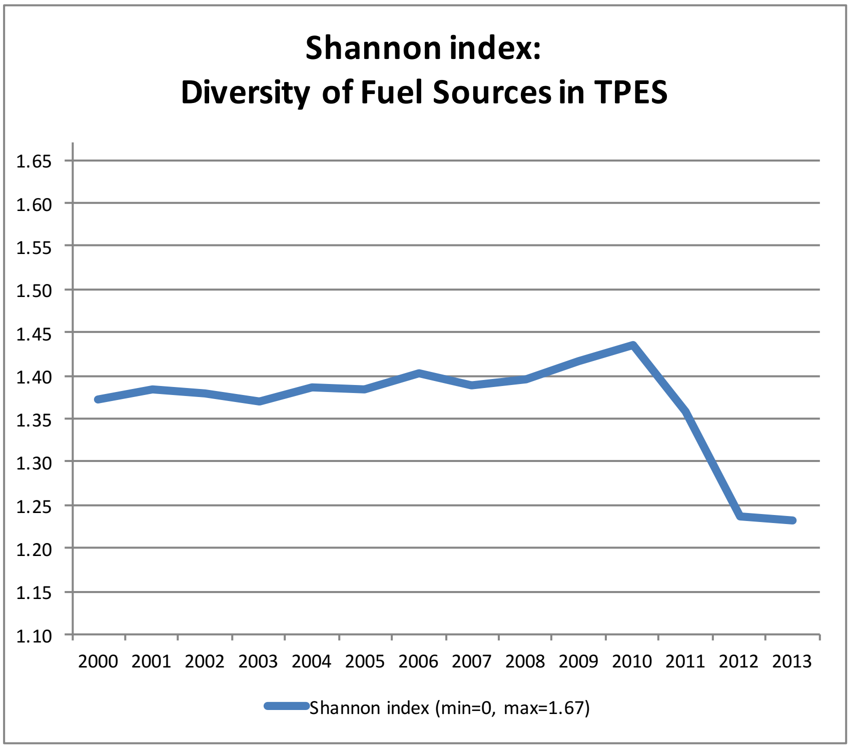
In the 2000-13 period, Japan's diversification policies were primarily centered on reducing the dependence on oil in primary energy supply, developing new sources of fossil fuel supplies outside of the Middle East and striving for a "best energy mix" in electricity generation [187].

Primary energy supply diversification

As a measure of the effectiveness of fuel source diversification policies, the Shannon-Weiner Index is used. Stirling [85] has demonstrated that the Shannon index is transparent and best reflects the qualities of both variety and balance in diversity [69]. It is applied here to measure the degree of diversification in primary energy supply (see Figure 32).

The Shannon-Weiner diversity index was computed for the five primary energy sources in TPES over the period (i.e.: coal, crude oil, natural gas, nuclear and renewables). The values range from zero to 1.67 with higher values representing greater diversity. The results show that Japan was achieving rising levels of diversity in terms of fuel variety and balance in TPES up to 2010. In the 2011-13 period however, the triple disaster caused the index to plummet as a result of the shutdown of almost all of Japan's nuclear power and the increased reliance on fossil fuels.

Figure 32. Shannon-Weiner index: Diversity of Fuel Sources in TPES



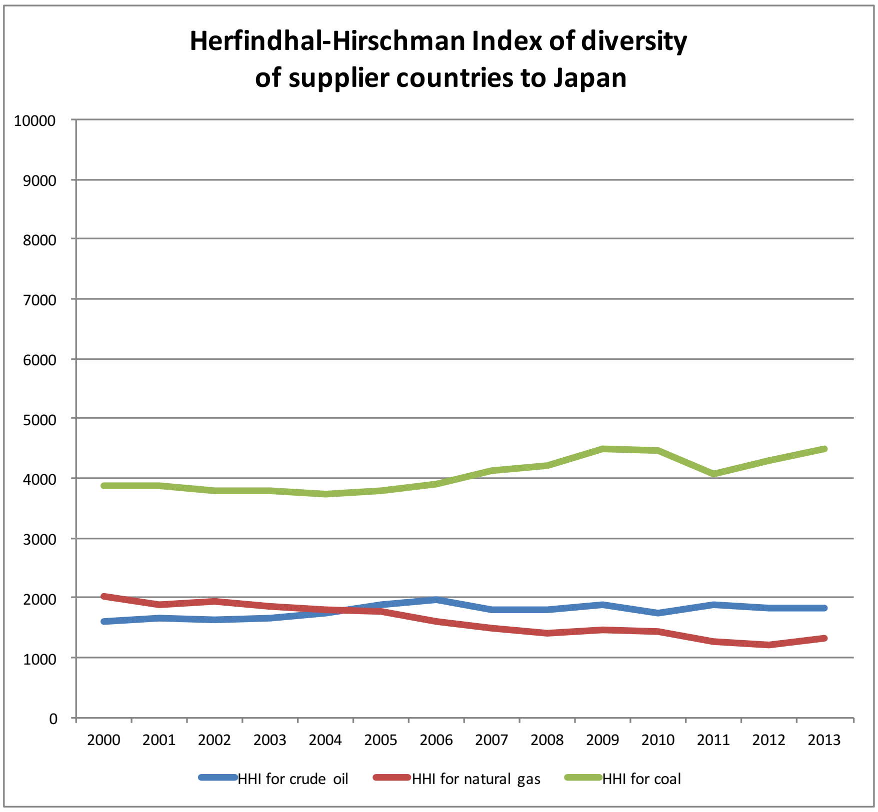
Trends and changes in the composition of primary energy supply were discussed in detail in Chapter 4.1. It was noted that between 2000 and 2010, Japan's reliance on fossil fuels remained essentially the same at around 81%. As a result of the shutdown of nuclear power plants after the Triple Disaster, fossil fuel reliance increased to 94% with natural gas supply increasing by over 20% between 2010 and 2013.

Supplier diversification

Japan's ongoing efforts to diversify fuel types extends to the diversification of supplier countries. The Japanese government has made resource diplomacy with various supplier countries one of its key foreign policy priorities since the oil shocks of the 1970's and will be discussed further detail below. Japan has maintained imports from a broad range of countries and regions in order to reduce the risk from the exercise of market power and to help insure against political or other disruptions (such as from the Middle East).

The Herfindhal-Hirschman Index (HHI) is used here as a measure of diversification in supplier countries for each of Japan's major import fuels. The HHI is a well-established method of measuring market concentration and is commonly used by governments to assist in assessing market power [63]. The HHI takes into account both the number of countries supplying the market as well as their respective market shares.[40]

Figure 33: Herfindhal-Hirschman Index for Supplier Countries



The HHI for crude oil, coal and natural gas were calculated and the results are presented in Figure 33. Values for the index range from 0 where there is perfect competition with innumerable suppliers, to 10,000 where the market is supplied exclusively by a single supplier. Given that these two extremes are highly unlikely in the real world, Japan's index values for crude oil and natural gas can be judged to be moderately low, indicating a

40 The HHI is determined by calculating the market shares of all supplier countries for each imported fuel and then summing the squares of these ratios.

relatively high degree of diversification. In the case of crude oil however, the value would be significantly higher if imports from Middle Eastern countries were summed together and considered as a single “country”. The trends for these two fuels over time have been relatively flat, with diversification for natural gas improving slightly over time.

With regard to coal, the index is judged to be moderately high, reflecting an increasing level of concentration in importing countries. In particular, imports of coal from Australia increased by 41% between 2000 and 2013 and Australia’s share of Japan’s coal imports rose from 60% in 2000 to 64% in 2013. While Australia and Japan enjoy good political and economic relations, the concentration by a single supplier poses economic risks including price risks and the risk of strikes.

Fuel diversification in electricity generation

Changes in the shares of fuel types in Japan’s electricity mix over the 2000-13 period were discussed in Chapter 4.1.3. Here, the major trends are summarized as illustrated in Figure[41] 34. For purposes of assessing resilience, two trends are noteworthy. The first is the large increases in coal and natural gas-fired generation in 2013 that made up for the shortfall in nuclear generation after the triple disaster. The second is that in spite of various policies to promote renewables over the period, they made up only 8% of Japan’s electricity mix in 2010 and 2013, which actually represented a decline from 2000.

Distributed generation

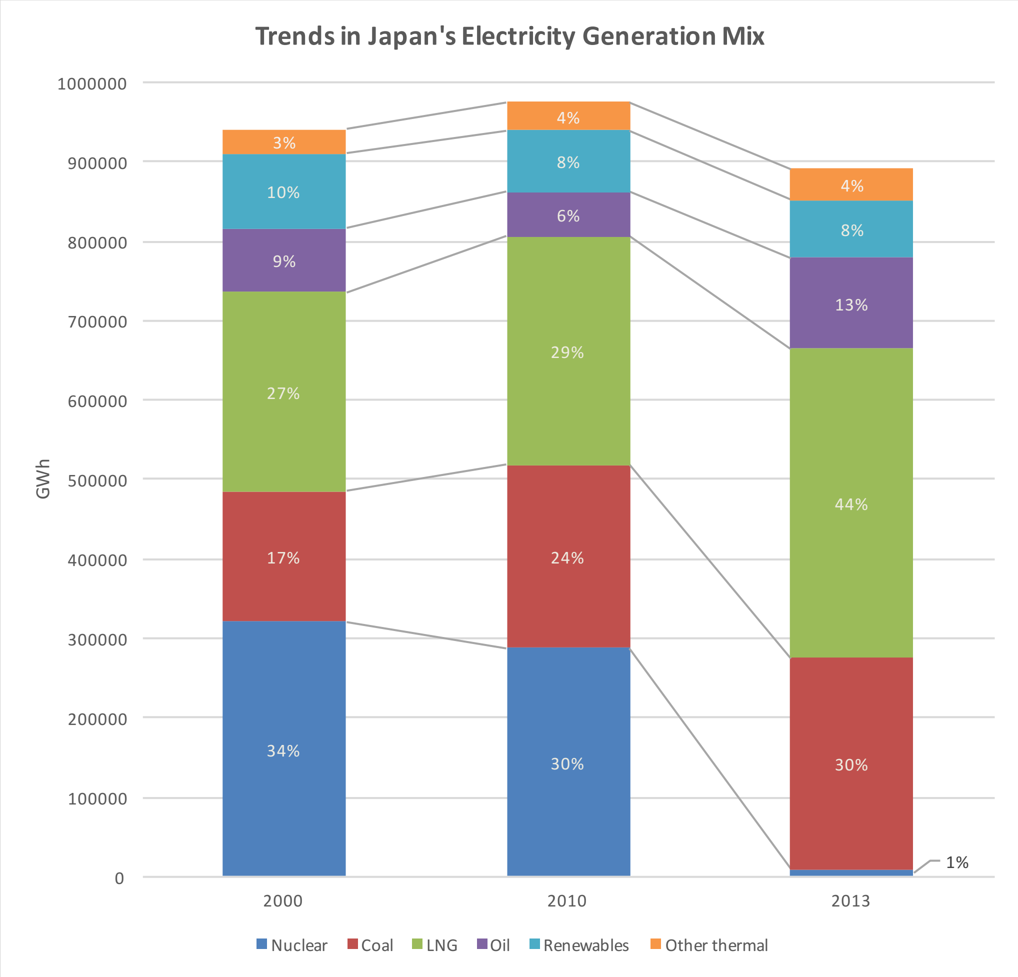
In Japan, the promotion of distributed generation (DG) is centered on renewables (especially geothermal, solar PV and wind) and combined heat and power (CHP) co-generation systems. There are no official statistics published on distributed generation in Japan despite the fact that increasing the level of distributed generation is a stated government policy goal. For the sake of providing a rough estimate, most renewables (except for large scale hydro and non-residential PV) and co-generation facilities can be considered to meet this definition. The majority of these installations prior to 2012 were small to medium scale facilities at the

---

[41] There are slight discrepancies in the percentage shares between Table 11 and Figure 33 due to different data sources. Figure 33 data is from the IEA (OECD, Electricity and Heat Generation database) while Table 11 data is from METI.

residential/commercial/industrial level. Figure 35 provides an estimate of the trend of distributed generation in Japan from 2000-2013.[42]

Figure 34: Trends in Japan's Electricity Generation Mix: 2000 - 2013



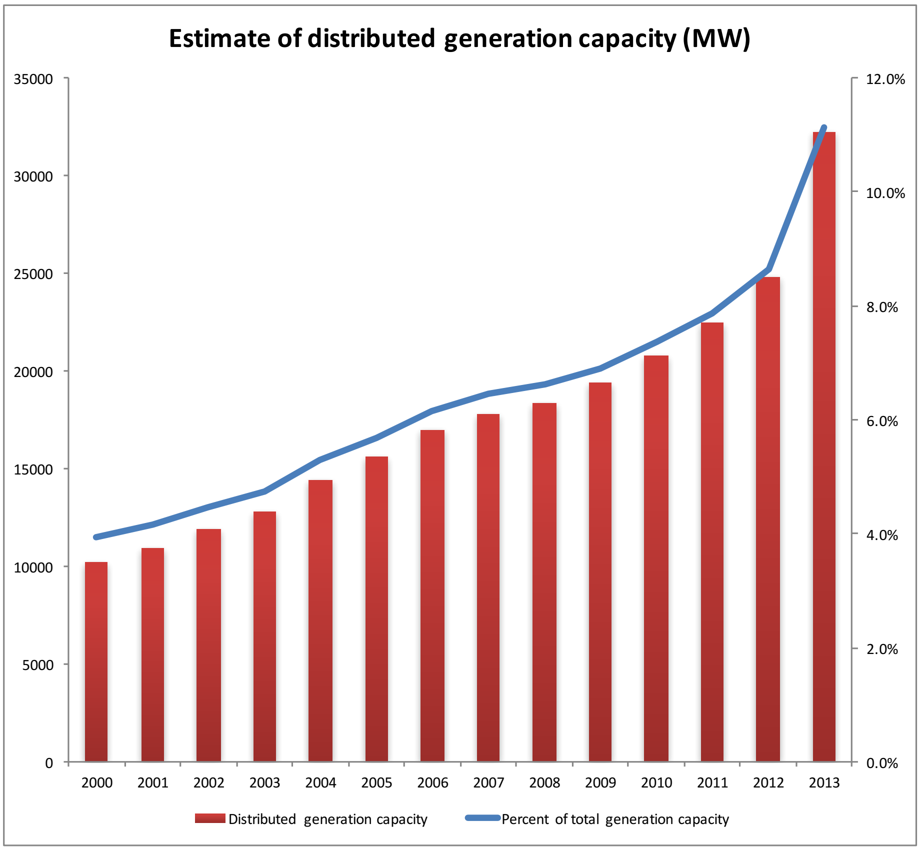
There was 10,300 MW of renewables capacity meeting the definition prior to the implementation of the 2012 FIT scheme[43] and 1,546 MW to June 30, 2013 [137], [188]. These figures include PV (10 kW or less), wind, hydro (1000 kW or less), biomass and

[42] The data used to construct this table are estimates based on total renewables generation capacity figures from JREF that exclude hydro (both small and large scale) but may include utility scale PV and wind. Co-generation figures are from EDMC. Total generation capacity data is from EDMC and is for all electric utilities but does not include renewables generation or auto producer plants.

[43] Prior to the start of the FiT program in July 2012, accumulated Japanese PV capacity amounted to 5.6 GW of which 84 percent of total capacity was small-scale PV systems for residential purposes (Hahn 2014, JPEA 2014).

geothermal power. Co-generation installed capacity in FY2013 was 10,042 MW[44] [189]. Therefore the estimated distributed generation capacity in Japan as of 2013 was 32,189 MW, representing about 11 % of total generation capacity (2013) in Japan.[45]

Figure 35. Distributed generation trend in Japan



CHP generation rose almost 80% between 2000 and 2013 to about 10GW [125]. In 2013, industrial users represented approximately 79% of the total installed CHP capacity and natural gas represented more than 53% of the CHP fuel [125]. However, capacity additions slowed in the late 2000's due to higher LNG prices in relation to the slower rate of increases in electricity prices. Still, the Japanese government has set a goal for CHP to supply 15% of Japan's total demand for electricity by 2030 [160]. Micro co-generation systems (primarily

[44] Made up of:
Commercial- 2,070 MW (hospitals, schools, hotels, commercial buildings, etc.)
Industrial - 7,972 MW (factories, refineries, etc.)
Total: 10,042 MW (of the total, 5,342 is natural gas, 3,150 oil, LPG 429, others 1,121)
Source: Advanced co-generation and energy utilization center of Japan

[45] Estimated based on total generation capacity of 231,219 MW in FY 2012, excluding auto producer plants.

the “Ene-farm” system) are also seen as an integral component of METI’s vision for “smart communities” [190].

(ii) Increase domestic supply sources

Over the 2000-2010 period, Japan’s strategic choices in terms of enhancing resilience were focused on increasing domestic supplies of energy. This included nuclear power, considered in Japan as a “quasi-domestic” power supply source. Nuclear power was discussed in Chapter 4.1 as a component of electricity infrastructure adequacy.

Other domestic sources include renewables, building crude oil and LPG stockpiles and developing Japan’s domestic fossil fuel resources. Japan’s electricity idle capacity is a legacy of METI’s electric power supply planning and market structure policies.

Renewables capacity and generation

As a result of various policies to promote the introduction of renewable in the electricity mix over the 2000-2013 period, renewables generation capacity has steadily risen since 2000, albeit from very low levels. Total capacity for all renewables except for large hydro is estimated[46] and illustrated in Figure 36.

Renewables generation capacity grew from about 5.8 GW in 2000 (representing 2.2% of total generation capacity) to 24.2GW (representing 8.4% of total generation capacity) in 2013. In 2013, solar PV made up the largest share of renewables capacity (excluding large hydro) at 59% followed by biomass (14%), small hydro (13%), wind (11%) and geothermal (2%).

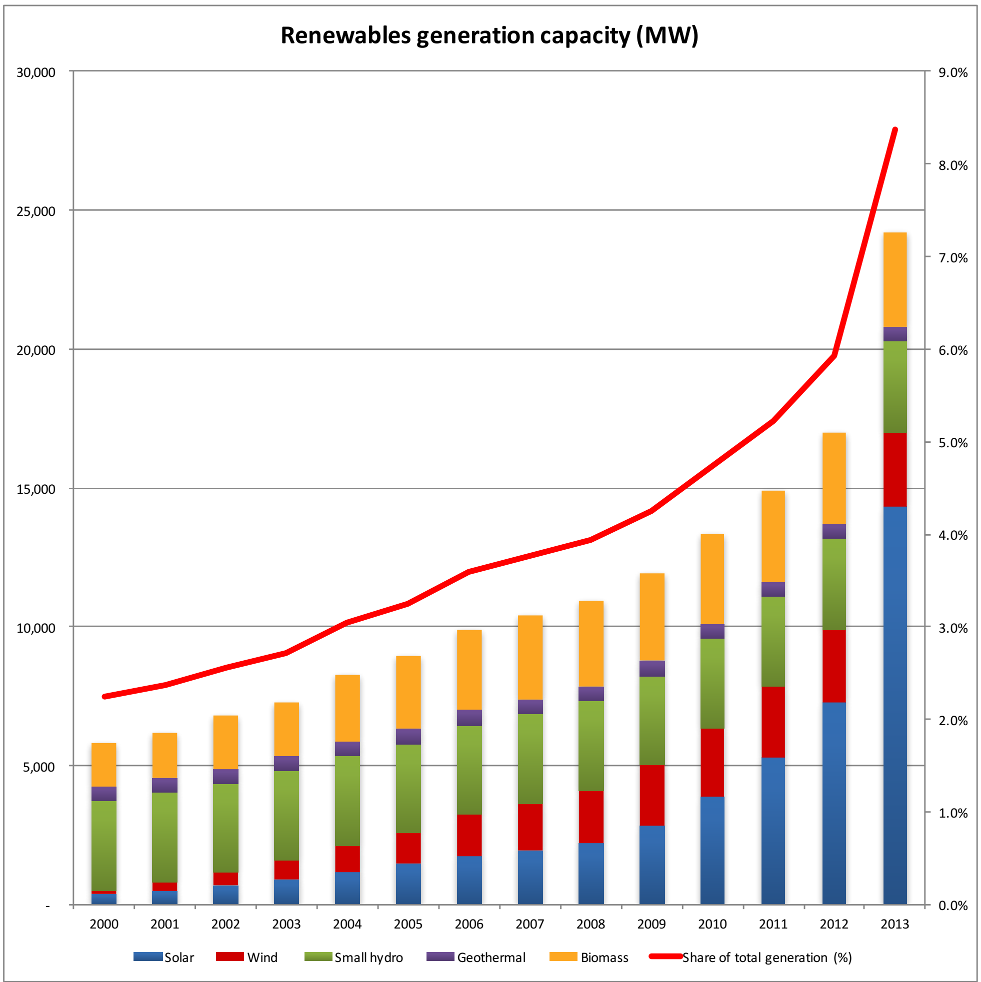
In 2013, small hydro[47] still made up the largest proportion of renewables generation (32%) followed by solar PV (28%), biomass (25%), wind (9%) and geothermal (6%). The share of renewables (excluding hydro) in total electricity generation increased very slowly rising from about 1% in 2000 to about 4.4% in 2014. The share including hydro was about 14% which

[46] The share of renewables in total generation capacity is an estimate based on ISEP capacity figures divided by total generation capacity in Japan which is sourced from EDMC statistics. The latter figures include only the capacity of electric utilities and auto producers.

[47] Small hydro is defined as facilities with generation capacity of 10MW or less. Most such facilities in Japan are run-of-river type and were built before 1990 [191].

ranked comparably with some other OECD countries such as Italy[48] (11%), the U.K. (12%) and the U.S. (13%) but less than France (16%) and Germany[49] (25%) [167].

Figure 36: Renewables generation capacity

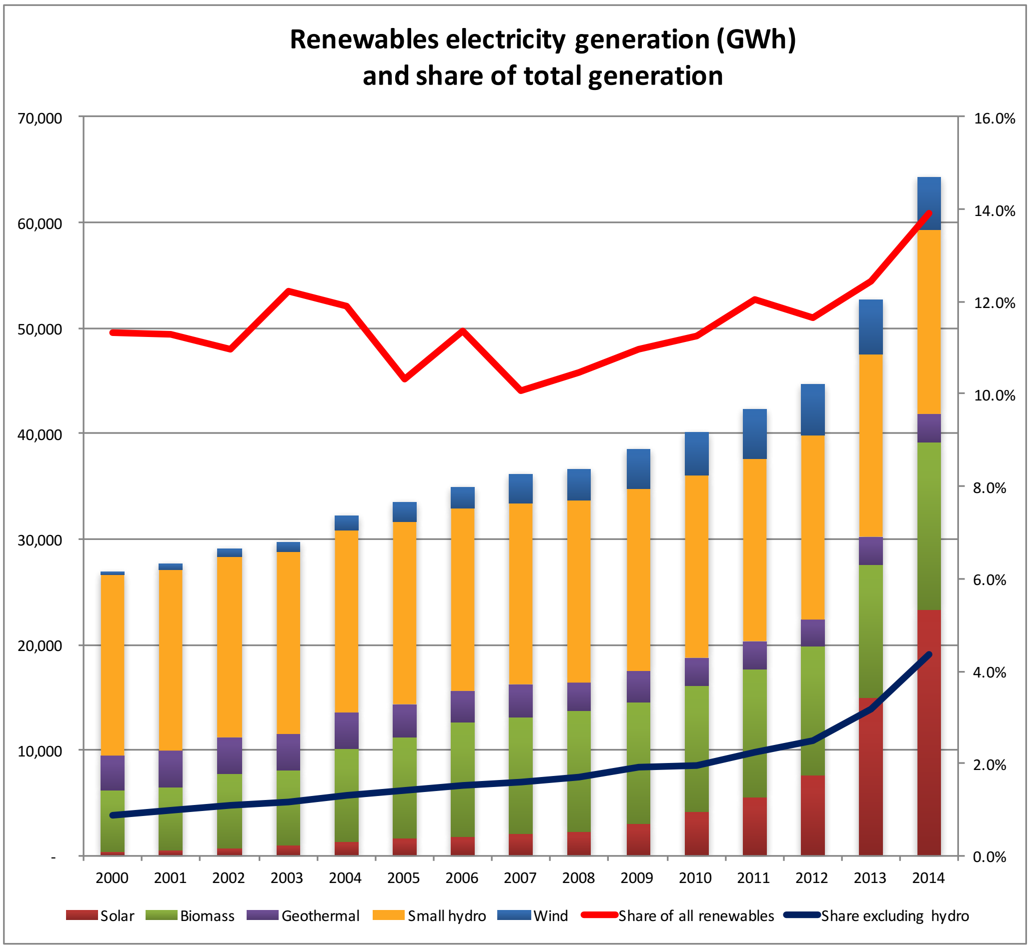


By the end of the 2000-2013 period, the share of renewables electricity generation (excluding large hydro) remained small in relation to total generation, having changed very little over the period (see Figure 37). This was despite the steady increase of renewables capacity additions, particularly in the case of solar PV as already noted. While the GEU's committed to "aggressively" expand utility-scale renewables with a plan to develop about 30 "mega-solar" plants with a capacity of approximately 140 MW by FY2020 [192], these plans were extremely conservative in comparison to several independent large-scale solar PV projects

48 Figure is for 2011
49 Figure is for 2013

that began operations soon afterward. This included a 70MW plant in Kagoshima[50] and an 82MW plant in Oita Prefecture[51] (both of which sell the power to Kyushu Electric). In April 2014, General Electric announced its investment in a 230 MW solar PV plant in Okayama Prefecture[52] which will be completed in 2018.

Figure 37: Renewables electricity generation



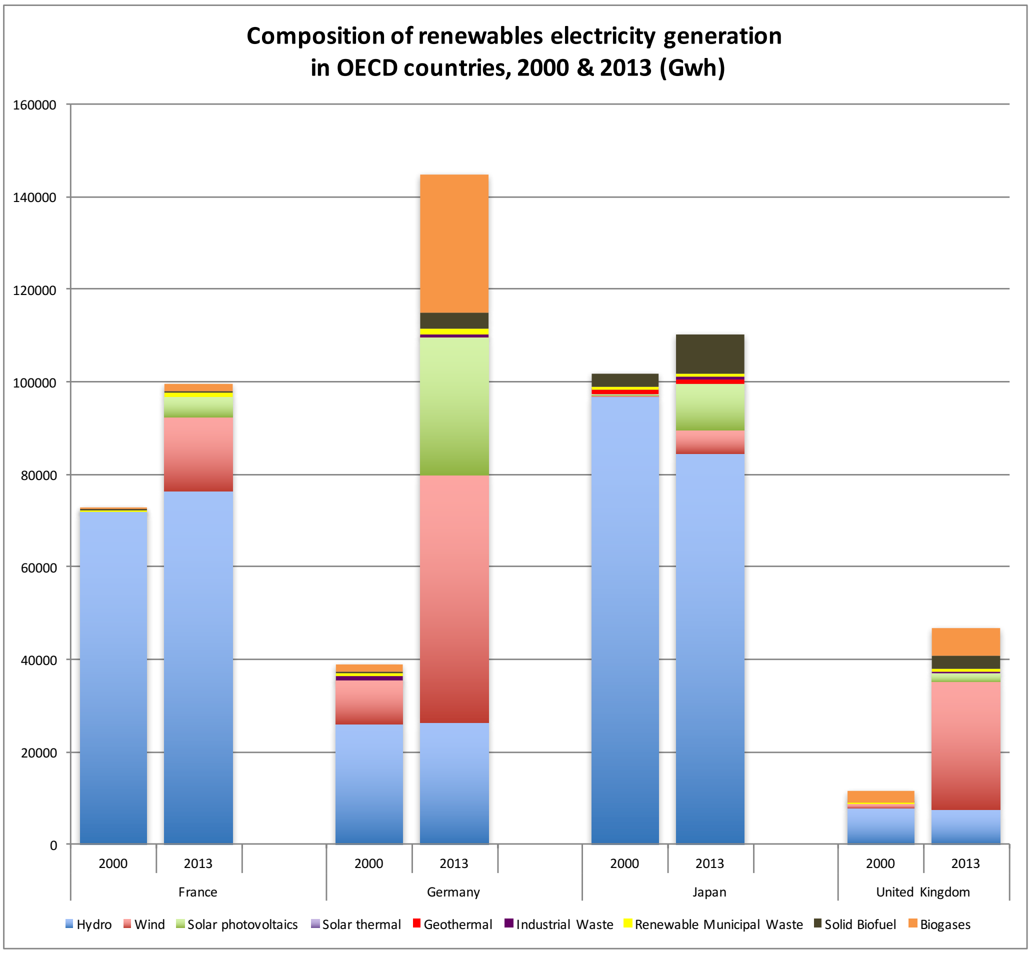
Looking at the growth of renewables generation in Japan and comparing it with the growth in other OECD countries over the 2000-2013 period, Japan's overall performance has lagged some of its peers (see Figure 38).

50 The Kagoshima plant is operated by Kyocera and went online November 1, 2013 (see: KYOCERA Starts Operation of 70MW Solar Power Plant, the Largest in Japan; Clean, safe electricity generated will provide equivalent power for roughly 22,000 average households | News Releases | KYOCERA)

51 The Oita plant is operated by Marubeni and went online on March 12, 2014 (see: Marubeni mega-solar plant goes online in Japan: pv-magazine)

52 See: GE Financially Backing 230 MW Solar PV Power Plant In Japan | CleanTechnica

Figure 38: Renewables generation in OECD countries, 2000-2013



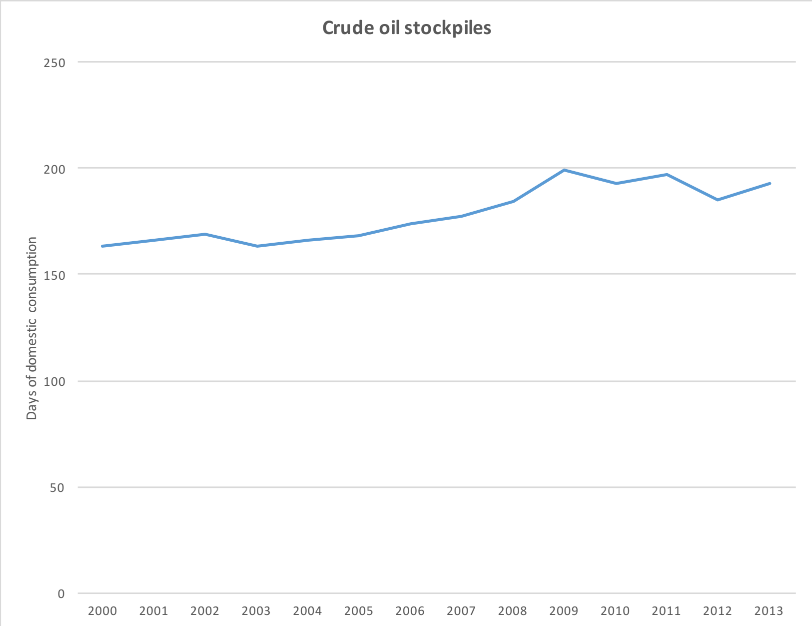
Further information on the issues constraining renewables expansion in Japan are covered in Appendix C.

Stockpiles

Japan maintained both crude oil and LPG stockpiles throughout the period. As of March, 2014 stockpiles of crude oil and oil products stored in public and private facilities totaled 193 days of domestic consumption (see Figure 39). Japan's crude oil stockpiles far exceeded the minimum requirements set by the IEA[53] and could supply the country for more than six months, providing resilience in the case of a major disruption.

[53] The IEA's minimum stockpile obligation is 90 days.

Figure 39: Crude oil stockpiles



Stockpiles of liquified petroleum gas (LPG) stored in public and private facilities totaled approximately 89 days of imports. JOGMEC, a state-owned enterprise, manages the government-owned crude oil and LPG stockpiles and facilities [193].

Domestic sources of fuels

Oil and gas deposits exist in offshore areas around Japan. However, exploitation of these deposits has been hampered by the high cost of recovery, technical hurdles and, in the case of the East China Sea, territorial disputes with China.

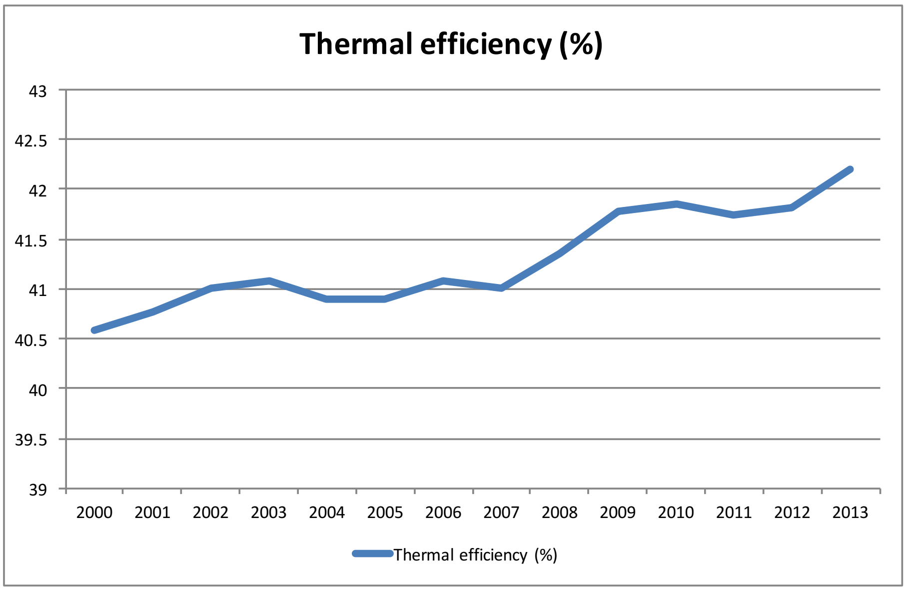
A major discovery of methane hydrate was made in the Nankai Trough off the East coast of Japan in 2012. Estimates are that there is approximately 40 tcf in place which is equivalent to around eleven years of the amount of LNG imported into Japan in 2012 [194]. In early 2013, the government announced that it had successfully extracted gas from a deposit of methane hydrates in the Nankai Trough for the first time [195]. Subsequently, METI announced that Japan would increase efforts to extract methane hydrates from FY 2015 with the aim of commercializing it by 2023 and allocated ¥2 billion toward these efforts in the FY2014 supplementary budget [196].

Onshore resources are also being developed using “fracking” technology. JAPEX is a Japanese exploration and production company that currently operates 11 domestic onshore and offshore oil and gas fields in Hokkaido, Akita, Yamagata and Niigata prefectures. It began the first fracking project in Japan in 2012 in Yurihonjo City, beginning full-scale commercial production of tight oil in 2014 [197].

Power generation efficiency

As a result of employing new technologies in thermal generation, including super-critical and ultra super-critical technologies for coal, and combined-cycle gas and steam turbines (CCGT) for natural gas, thermal efficiency of fossil fuel-fired power generation has steadily improved (see Figure 40).

Figure 40. Efficiency of thermal generation

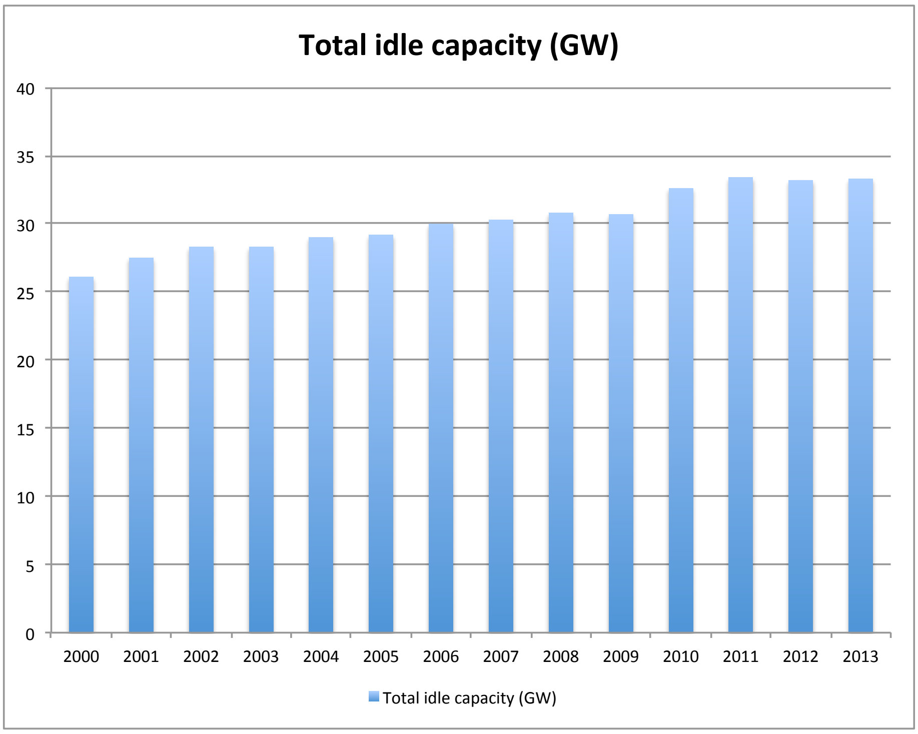


According to an independent study, Japan maintained an average efficiency of over 43% in its thermal power plants during the 2000-2011 period, the second highest level in the world after the UK [192], [198], [199]. Japanese utilities claim that their state-of-the-art CCGT power plants have achieved the world’s highest level of thermal efficiency at 59% [199].

Idle capacity

As of 2013, Japan had about 33 GW of total idle capacity, almost all of which was thermal generation (see Figure 41). Japan's idle capacity represents about 12% of total installed capacity. This is a substantial amount but includes many plants that are well over 40 years old. Some of these plants were restarted after the triple disaster as utilities scrambled to fill the gap caused by the immediate loss of capacity and the mandated shutdown of nuclear reactors for safety inspections.

Figure 41. Idle capacity



In most cases, restarting a long idled power plant cannot be done immediately and restarted plants often require much maintenance and are prone to breakdowns. Tokyo Electric Power Company (TEPCO) and Tohoku Electric both restarted idled thermal power plants soon after the earthquake, however it was expected to take several months before they could be brought back on-line [200], [201].

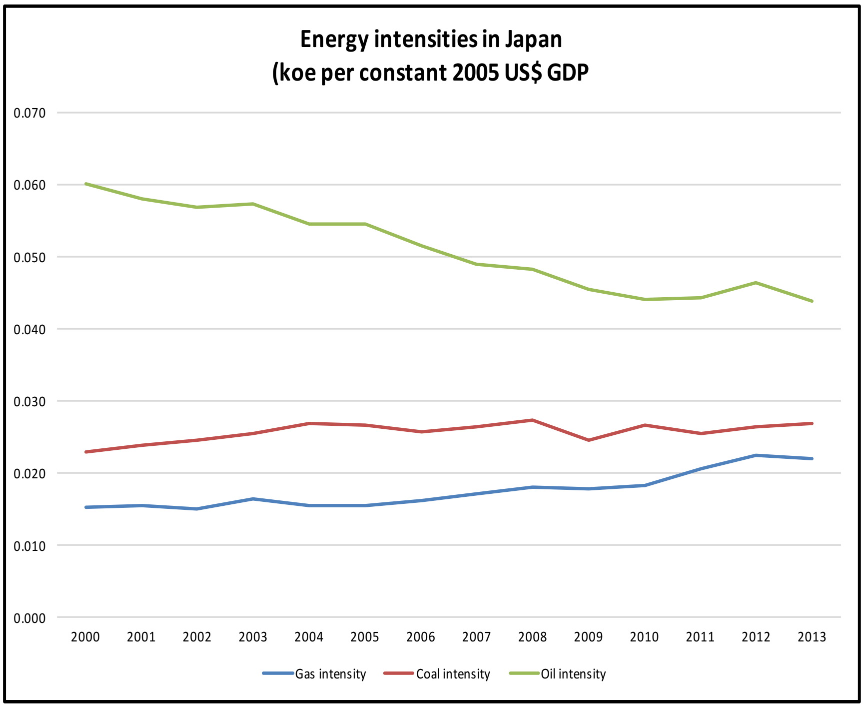
(iii) Energy efficiency and conservation

Japan has one of the lowest energy intensities in the world among developed economies due largely to various policy measures which have enabled Japan to achieve a 40% reduction in energy intensity since the oil crises of the 1970's [202]. In this section, energy efficiency and conservation measures are assessed in order to determine their impact on resilience.

Over the 2000-2013 period, Japan's GDP grew by 11.1% (in 2005 $U.S.) while total final energy consumption fell by 14.6%. Improvements varied by sector with the largest reductions in industry (17.5%) and transport (12.8%) while the residential/commercial sector fell by 8.6% [125].

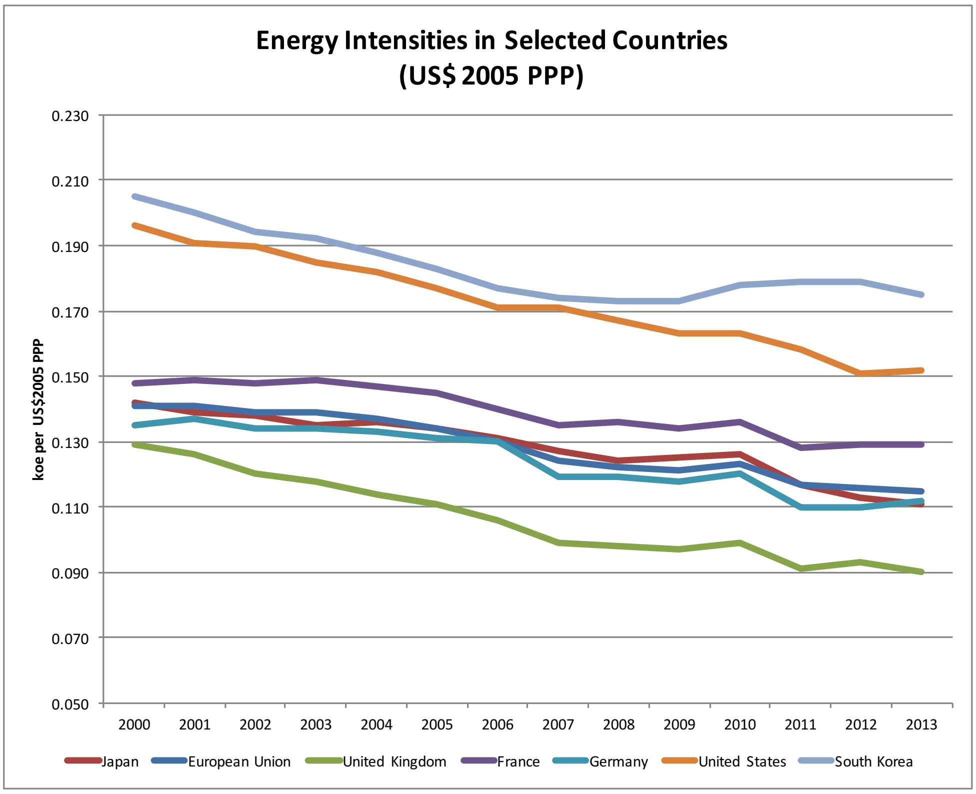
While primary energy intensity has been falling since 2000 (see Figure 11), the trend in fuel intensities is divergent (see Figure 42). Oil intensity has been steadily falling while coal and gas intensities have been relatively stable. However, after the triple disaster, both coal and gas intensity increased slightly reflecting increased use of these fossil fuels.

Figure 42. Energy intensities in Japan



Comparing Japan's energy intensity performance with those in selected developed economies shows that Japan compared favorably (see Figure 43). Another study has shown that energy intensity in Japan was the ninth lowest and less than two-thirds of the average of all OECD countries [203].

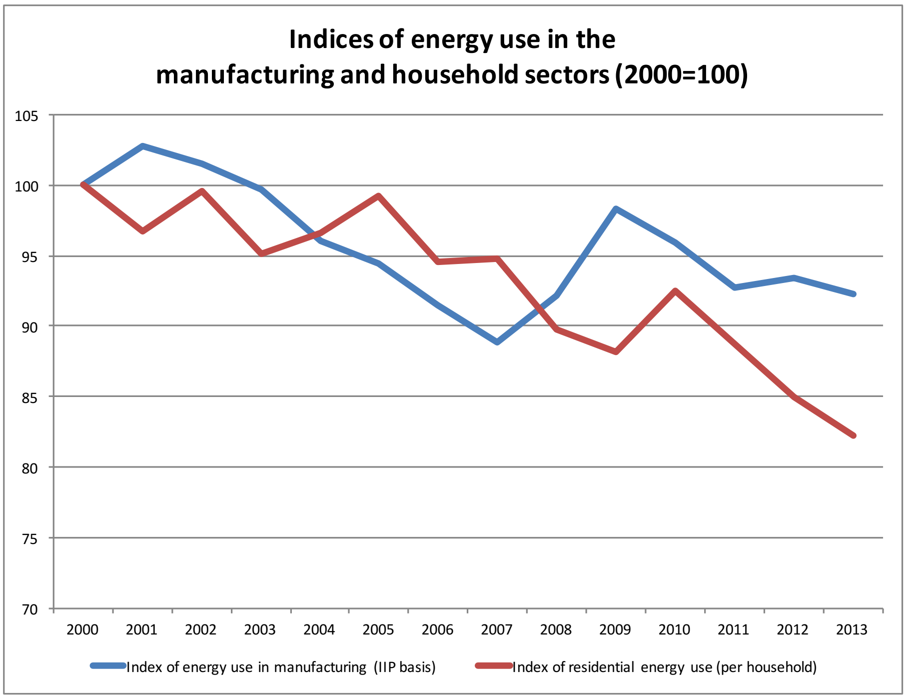
Figure 43. Energy intensities in OECD Countries



These results demonstrate that Japan's energy efficiency policies have been very successful in the aggregate. However, energy efficiency performance is uneven across different sectors. Much of the credit for Japan's performance on energy efficiency can be attributed to the industrial (manufacturing) sector which improved its energy efficiency by an average of about 1.2%[54] a year between 1979 (when the Energy Conservation Act was introduced) and 2000. Energy use declined in the manufacturing and residential sectors over the 2000-2013 period with residential consumption falling faster than the manufacturing sector especially since 2008 (see Figure 44).

54 On an Index of Industrial Production (IIP) basis.

Figure 44. Indices of energy use in the manufacturing and household sectors



Certain policy actions such as the Setsuden[55] program that was initiated in July 2011 played a role in reducing residential peak electricity demand [204]. A recent study that surveyed households and companies showed that while electricity savings achieved in 2013 were lower than the level achieved in 2011, reductions in electricity usage have remained around 10% lower than in 2010 and cited the use of higher efficiency equipment as a contributing factor [205].

Most of the reductions in Japan's final energy consumption can reasonably be credited to enhancements to ongoing energy efficiency and conservation programs. This includes enhanced standards for buildings, housing and updates to the Top Runner and the Front Runner programs which have been highly evaluated as having successfully achieved or exceeded their targets [206], [207].

55 Measures included mandatory electricity demand restrictions for large businesses while small businesses and households were encouraged to take voluntary measures through the "Setsuden" campaign. Various actions were taken to conserve energy including changing working hours, installing cogeneration, setting thermostats higher in summer, switching off lights, and reducing the frequency of trains and subways. As a result, a 15% reduction in peak power demand in East Japan was achieved [202].

(iv) International energy relationships and investments

Under the priority of "securing a stable supply of energy and mineral resources at reasonable prices", the government plans, supports and undertakes "strategic resource and energy diplomacy" in order to diversify supplier nations, strengthen relationships with major resource suppliers, while monitoring developments in the shale revolution in countries such as the U.S. [208], [209].

Japan has a long history of using diplomacy to enhance energy security. To ensure sufficient supplies of uranium, the Japanese government signed nuclear cooperation agreements with the U.S. and UK in 1958; and with Canada in 1959 [210]. Successive government administrations have expended much effort to forge strong relationships with supplier countries, especially in the Middle East and Southeast Asia. With rising resource prices and resource competition from China, Japan significantly stepped up its energy diplomacy efforts under the Abe administration. Prime Minister Abe, Foreign Minister Kishida and others have visited major resource-rich countries in North America, the Middle East and Africa, Latin America and the Caribbean, and the Asia Pacific [208].

Some of Japan's energy diplomacy efforts have had a positive impact on Japan's energy security while others hold potential for the future. For example, following the triple disaster, Japan was able to quickly access additional supplies of LNG by relying on supplier relationships. The Russian prime minister Vladimir Putin ordered that Russian LNG supplies to Japan be increased, and Indonesia and Qatar also substantially increased LNG supplies to Japan [211]. This allowed Japan to rapidly fill the gap in power supply created by the shutdown of nuclear power plants.

Despite U.S. restrictions on LNG exports to countries with which it has no free trade agreement, Japan was able to get the U.S. government to approve export licenses for four of six export terminals in the U.S. LNG bound for Japan [208]. These approvals were thought to have been helped by Japanese investments in LNG facilities in the U.S.[212].

Certain energy cooperation agreements may serve to enhance resilience by forging closer relations among buyers of energy commodities or with supplier countries. For example, Japan and Australia signed an energy cooperation agreement in 1985 and since then have significantly upgraded their energy relationship [213]. In 2012, Inpex Corporation (partially owned by the Japanese government), together with Japanese gas utilities and Total Corporation, announced a US$34 billion investment in the Ichthys gas-export development project in Australia which will export LNG to Japan starting in 2017. The Inpex project is expected to provide 10% of Japan's annual LNG demand [214]. Japan has also signed energy cooperation agreements with the U.S., Canada and other resource supplier countries as well.

In order to improve its self-sufficiency and reduce the risk of imports from politically volatile regions, the government formerly set targets to increase "independently developed crude oil resources" [124]. With the 2014 Strategic Energy Plan the government no longer sets such targets[56] but it continues to provide financial and other supports for overseas investments in upstream energy projects. For example, in 2013 the METI minister announced a program to diversify Japan's LNG supplies by supporting Japanese company's (including electric power and gas utilities) involvement in upstream development projects in Russia, Canada, Mozambique and other countries [215]. Subsequently, the government announced that it would provide financial guarantees through JOGMEC for up to 75% of the amount of loans taken out by Japanese energy firms that help reduce Japan's import fuel costs [216], [217].

As of the end of June, 2013 Japanese firms were reported to be involved in over 140 oil and gas development projects overseas, of which about 70 have reportedly "performed well in commercial production[57]". The share of such crude oil and gas development projects represents about 22% of Japan's total domestic demand [218].

2) Assessing adaptive capacity

(i) Innovation and technology development

Investment in energy technology R&D

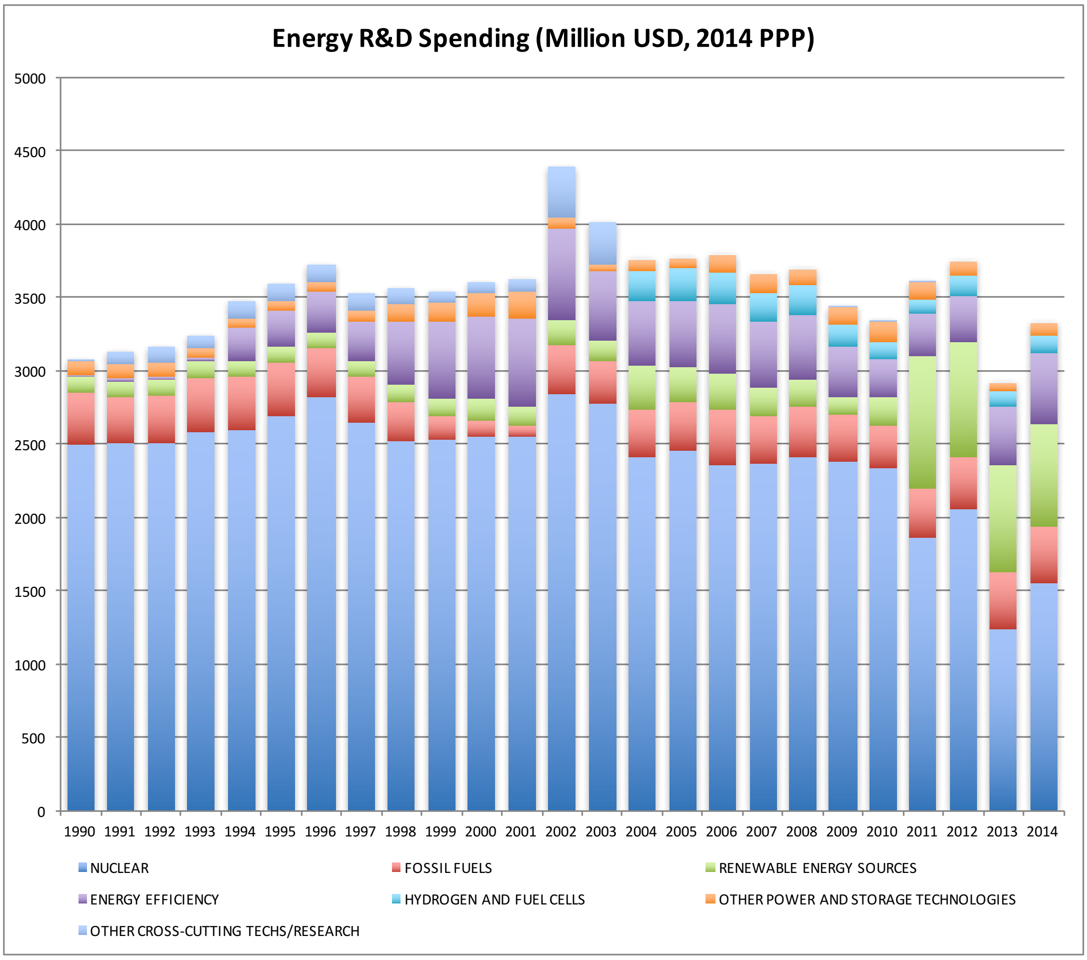
Japan has made substantial government and private sector investments in various energy technologies for many years and spending remains at a high level. Between 2000 and 2010, nuclear power R&D accounted for 60-70% of total government energy R&D spending.

[56] A METI planning official confirmed to this researcher that the targets set in previous energy plans for independently developed resources would no longer be set.

[57] It is important to note that despite the investments made by Japanese companies in overseas energy projects, not all of them supply energy resources directly to Japan.

However, after the triple disaster nuclear's share of spending fell steeply to under 50% while spending on other energy technologies increased significantly. A stronger policy priority on renewables technology development starting after the triple disaster likely accounts for the sharp rise in renewables R&D which accounted for only 6% of total spending in 2010 but rose sharply to account for 25% in 2011 (see Figure 45).

Figure 45. Government spending on energy R&D in Japan

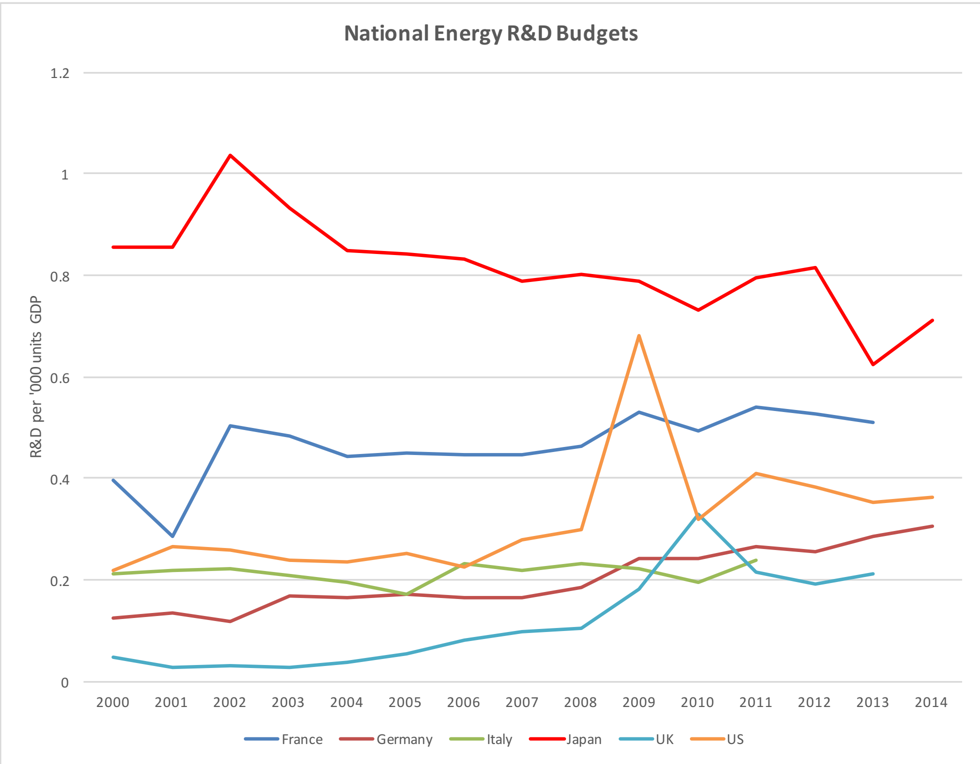


Japan's energy R&D spending compares favorably with other OECD countries. Between 2000 and 2014, the level of Japan's energy R&D spending trended downward, however the government still spent more on energy R&D than other major OECD countries over the period (see Figure 46). Japan has been well ranked globally on measures on capacity for innovation and it ranked first in the world according to a recent survey [50].

Energy related patent applications

In 2010, residents of Japan filed the largest number of applications relating to solar energy and fuel cell technologies in the world, while residents of Germany and the US had the largest numbers of applications relating to geothermal and wind energy, respectively. For the 2006-2010 period Japan had the highest share of applications related to solar energy (29.2%), followed by the Republic of Korea (17.2%) and the US (14.3%). Japan accounted for 52.9% of all patent applications for fuel cell technology, 9.4% in wind energy (following the U.S. and Germany) and 10.5% in geothermal energy technology (following Germany, the U.S. and S. Korea) [219].

Figure 46. National energy R&D budgets in OECD countries



In a study conducted by MIT that reviewed energy-related patents between 1970 and 2009, Japan led all other countries in total (cumulative) patents filed for all energy technologies. Japan also led in patent filings in all energy categories except for coal, hydroelectric, biofuels, and natural gas. Japan led in solar, wind, geothermal, biofuels, nuclear fusion, nuclear fission, and oil [180].

(ii) Experimentation/demonstration projects

Reference case on Japan's "Smart Communities"

In Japan, smart grid development has been incorporated within a broader and more systemic approach known as 'smart community". The smart community concept began with the establishment by METI of the "Conference on the Next-generation Energy and Social System" as an interdepartmental project team in November 2009. Subsequently, based on the recommendations of this body, applications were solicited from cities willing to be sites for the testing of smart grid and smart city-related systems and technologies [220]. Four cities were then designated as smart communities: Yokohama, Toyota City, Keihanna Science City (Kyoto Prefecture), and the City of Kitakyushu. The program was expanded in 2012 with the addition of 10 communities designated in Fukushima and other prefectures where reconstructions and renewal has been prioritized [221]. In addition, the Eco-model city initiative of 2008 supports communities that seek to transition to a low-carbon society [222]. As of 2013, 23 cities including Kitakyushu, Kyoto, Sakai and Yokohama have been designated under the program. A related initiative arising from *The New Growth Strategy* launched in June 2010 by METI is the Future City Initiative (FCI) which has approved 11 cities as of March 2014 [223]. While the FCI has a broader set of social objectives, renewable energy, energy efficiency and smart technologies are also features of FCI community projects. Whereas the original four smart community projects received large subsidies from METI, the other programs are less generously subsidized by the central government and are supported more at the local level [224].

In cooperation with various Japanese companies, NEDO has taken the lead in developing the original "smart communities" concept and providing support for related technologies. NEDO defines a smart community as "a mechanism to use energy intelligently by sharing data in both directions between the supply and demand sides of the system using ICT" [225]. METI prefers the term "smart community" to "smart grid" in order to emphasize the demand-side focus through the creation of energy efficient communities. The smart community paradigm includes not only technological components, but also the social aspects of how human beings interact with technology to improve energy use. Therefore, the lifestyles of the residents of these communities is an important aspect of determining the form smart communities actually take [225], [226].

Each smart community is focused on demonstrating somewhat different aspects of the smart community paradigm by exploring both the technological and social aspects of energy use. Smart communities attempt to integrate various technological systems including: cogeneration systems (including micro-CHP systems using fuel cells such as Ene-Farm), renewable energy sources for generating heat and electricity, smart meters and demand response, home energy management systems (HEMS), hot water systems, energy storage (including batteries and accumulators), electric vehicles (EV's and HEV's) and charging stations [190].

The aim of the demonstration projects being undertaken in the four communities is to identify the optimum form for smart grids and smart cities in Japan [220]. At the same time, the improvements and refinements resulting from the demonstration projects are expected to contribute toward helping Japan shape international standards for smart grids and other smart technologies and to promote Japanese technologies to the rest of the world. In his vein NEDO, in collaboration with Japanese technology companies and local organizations is supporting smart community demonstration projects in various countries including in the United States, France, Spain, Indonesia and the United Kingdom [225]. In 2012, METI announced additional support to Japanese companies for feasibility studies for integrated smart community projects in several Asian countries as well as Russia [227].

In anticipation of the business opportunities arising from the growing interest in smart communities, the Japan Smart Community Alliance (JSCA) was established in April 2010. The association has 322 member companies and organizations from a broad range of sectors including from the electricity, gas, automotive, ICT, electronics, construction and trade industries, as well as from academia and local government. The aim of the association is to promote collaboration between public and private entities and to collect and share information with its members [225]. NEDO administers JSCA's activities and maintains close coordination with METI in order to encourage participation in various working groups and projects, deal with common issues and to promote global collaboration by participating in initiatives like the Global Smart Grid Federation [225].

The smart community concept demonstrates the use of experimentation and demonstration projects as a mechanism to promote technology development, commercialization and industry development. "Learning by doing" plays a major role as the concept was designed to be improved and adapted based on the experience and feedback generated in the four smart communities. At the same time, the program has taken a proactive approach to introducing the smart community concept to foreign countries for the purpose of adapting it to different conditions, helping Japanese companies gain experience in foreign markets and influencing future international standards.

While it is still too early to assess the impact of the program on Japan's long-term energy security and whether the benefits will outweigh the costs, preliminary results appear to show that for community residents, significant energy savings and efficiencies can be realized. For example, following the triple disaster smart community projects took on a more demand driven approach with the introduction of demand response programs such as in Kitakyushu where as much as a 20% reduction in energy consumption was achieved during peak periods [228]. For companies, the demonstration projects enable technologies to be refined and adapted to improve their commercial feasibility based on the practical needs and feedback gained through the experiments in the communities. Considering the ongoing participation by community residents, support by a broad range of Japanese companies and local governments and expansion of the program to foreign countries, it seems reasonable to conclude that participants recognize at least some benefits.

One recent study of Japan's smart communities concluded that Japan's smart grid model has achieved a significant degree of success which has been enabled through the way in which the government-business-community partnership model demonstrated effective project governance and enabling capacities. However, the authors also noted some weaknesses, including the failure by the government to take up a major regulatory role, the absence of large utilities in the project and the limited participation of the broader business community and consumers [229].

In summary, the smart community program can be considered an important adaptive mechanism for Japan's energy system since it is clearly focused on improving the efficiency of energy end-use by encouraging adaptive behaviors by end-users (primarily through demand response), allows multiple technologies to be integrated at a community level so as to improve energy and environmental performance, and provides an important forum for technology developers and users to interact in finding more efficient and effective methods of utilizing energy in the future.

(iii) Innovation and commercialization

Reference case on stationary fuel cell development

The government has been supporting research and demonstration projects in fuel cell technologies since the “Moonlight Plan” in 1981, the “New Sunshine Plan” in 1992 and the “Millennium Project” of 2000 [230]. Japan’s strategic energy plans have also included strategies to support further development of hydrogen technologies including stationary fuel cells and fuel cell vehicles.

In 2001, METI decided to put an emphasis on stationary fuel cells. Following four years of demonstration projects and customer trials, the scheme was commercialized in 2009 with the announcement of a micro-CHP fuel cell system called “Ene-farm”. Ene-farm units (700W-1kW capacity) produce electricity and heat by means of a hydrogen fuel cell that is supplied by city gas or LPG. These units have been targeted primarily at homes and apartment buildings as well as office buildings.

The fuel cell units were developed jointly by city gas and LPG companies in collaboration with Japanese manufacturing companies such as Panasonic, Toshiba, Aisin Seiki and JX Oil and Energy. Constant improvements in the product has improved efficiency and lowed costs and as a result, sales have steadily increased. METI has promoted the technology to end users by granting subsidies on the purchase of units but the subsidies have been steadily reduced as unit costs have fallen. Unit sales rose from zero at the beginning of the program in 2009 to over 100,000 units in 2014. The greatest increase in sales came after the Triple Disaster as residential customers sought to insure against future power disruptions, save on power bills and reduce their environmental impact. The government has set a goal of 5.3 million residential units to be operating by 2030 [231], [232].

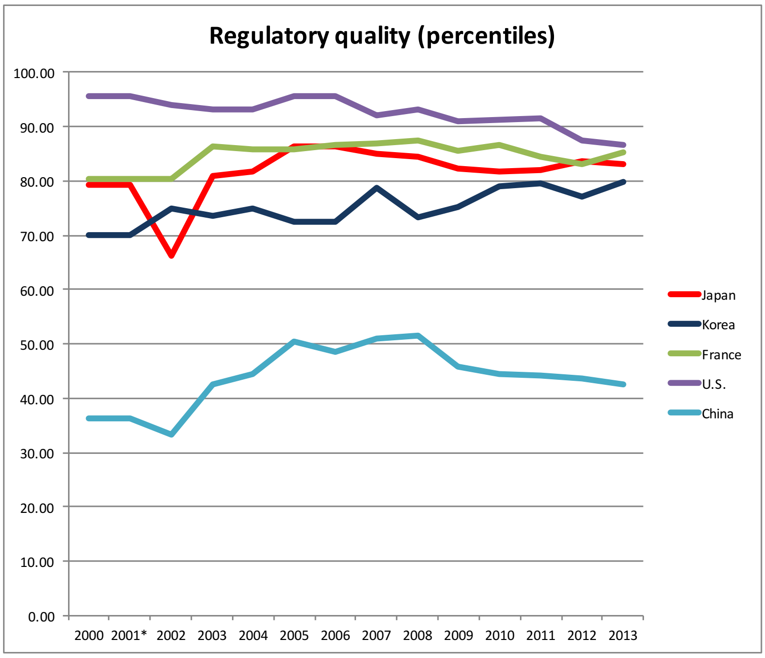
Ene-farm appears to represent a successful innovation that arose through a model of government-industry collaboration. This approach can be considered an example of an adaptive mechanism that has successfully commercialized and introduced a new technology that promises to improve energy efficiency while lowering operating costs and carbon emissions. Ene-farm units have also been integrated into Japan’s smart communities as part of a flexible and integrated approach to energy management. With the success in Japan, the Ene-farm technology is also being expanded to Europe and other countries. Both Panasonic and Aisin have partnered with European technology firms to adapt the technology and develop products suited to the European market [231].

(iv) Market structure and liberalization

Regulatory quality

Since there are no appropriate indicators of regulatory quality that are specific to the energy sector, the World Bank's indicator of regulatory quality is used as a proxy measure. This indicator employs an extensive survey method to provide an estimate of overall regulatory quality in countries expressed in units of a standard normal distribution (i.e. ranging from approximately -2.5 to 2.5). It is intended to capture perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. The results show that Japan's scores over the 2000-12 period were mostly in the 80-85th percentile range. Japan's performance compares favorably with other OECD countries including those where nuclear power is a significant component of the electricity mix[58] (see Figure 47)[233].

Figure 47. Regulatory quality



58 The range (i.e.: of best and worst scores) of scores for regulatory quality among all countries in the WGI database in 2012 was: +1.96 and - 2.53

While the results above suggest that Japan has maintained a high level of regulatory quality in comparison with its peers, this indicator is a general one and not specific to energy. With respect to energy regulation, the disaster at the Fukushima nuclear power plant can be used as a measure of regulatory quality as well.

Several official investigations were conducted into the Fukushima disaster. These investigations documented a wide range of regulatory failures, implicated nuclear regulators, exposed weaknesses in the regulatory system and recommended major changes. As a result of these reports, a major review of nuclear regulation was undertaken in Japan and a new regulatory agency was established in order to help rebuild trust in the regulation of nuclear power (see Appendix C for additional details).

Electricity market liberalization

The effectiveness of electricity market liberalization measures can be assessed using two key indicators: the share of electricity demand that has been liberalized (i.e.: opened to competition), as well as the share of demand supplied by new entrants into electricity markets.

Between 1995 when electricity market liberalization measures were first introduced, and 2013 when a new 3-step policy toward a fully liberalized market was announced (see Appendix A), the government took a very incremental and gradualist approach. After 18 years, the residential market still remained under regulation (see Table 5).

In 2013, about 86% of total electricity demand in both regulated and deregulated markets was supplied by electric utilities, 12% by industry-owned auto producer plants and 2% by other suppliers [125]. Approximately 63% of total electricity demand was open to competition as of 2013 (see Table 5). The remaining portion of demand was represented by the residential sector (users with demand of 50kW or less) and was served solely by the GEU's under regulated rates.[59]

[59] In the regulated sector, utilities pass on the costs of generation including the cost of building and operating power plants and T&D infrastructure to users, with rates subject to approval from METI.

Table 5. Summary of electricity market reforms

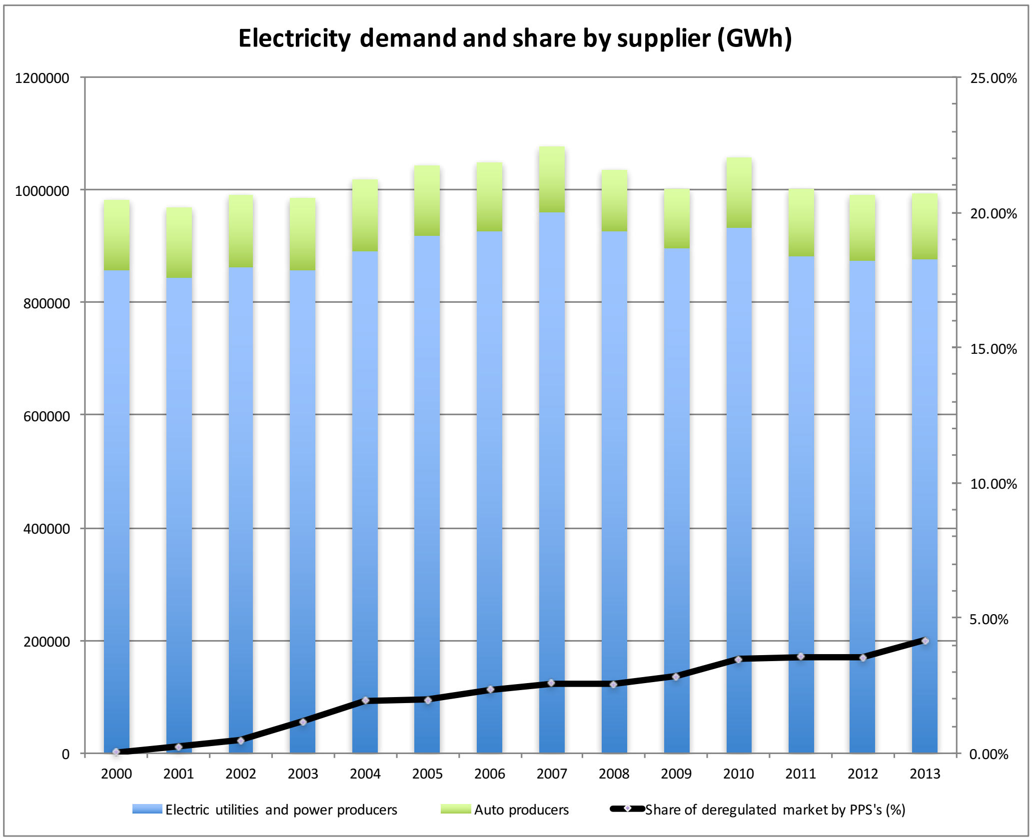
Stage	Year	Percent of retail market liberalized	Status/Policies implemented
	Before 1995	0%	Electricity markets highly regulated and market entry restricted. No competition. Regulated rates approved by MITI with GEU's passing on costs to ratepayers according to the full-cost recovery scheme.
1	1995	0%	Independent Power Producers (IPP) market introduced.
2	2000	26%	Partial retail competition introduced for high-demand, large-scale industrial and commercial end users. Accounting separation of the transmission and distribution sector.
3	2004	40%	Retail competition expanded to include high-demand medium-scale factories and commercial facilities.
4	2005	63%	Retail competition expanded to include high-demand small-scale factories and commercial facilities.
5	2013	63%	Establishment of "3-step" electricity reforms to achieve full liberalization by 2020.
6	2015	63%	Ist step: Establishment of "OCCTO".
7	2016	100%	2nd step: Full retail competition. Liberalization expanded to include small-scale factories, convenience stores and households. Maintain regulated rates for residential end-users until 2020.
8	2020	100%	3rd step: Legal unbundling of transmission and distribution. Abolish regulated rate.

Source: METI ([234], [235])

Electricity sector liberalization measures were intended to increase competition in the deregulated segment, thus lowering prices. However, the share of privately owned power producers and suppliers (PPS[60]) who supply directly to the deregulated market has grown only very slowly and is still extremely small at about 4% as of 2013 (see Figure 48). This situation stimulated concern from the Japan Fair Trade Commission and suggests that the market power of the GEU's has been inhibiting competition in the sector [151].

[60] PPS stands for "Power Producers and Suppliers" which is a Japanese government designation for privately owned power producers and suppliers who supply the deregulated segment of the market.

Figure 48. Electricity demand and share by supplier



Gas market liberalization

The effectiveness of gas market liberalization measures can be assessed using two key indicators: the share of gas demand that has been liberalized (i.e.: open to competition) as well as the amount of gas supplied by new entrants into the gas market.

Over the 2000-2013 period, the percentage of the retail market that was liberalized increased in several stages, moving from 53% in 1999 to 63% as of 2013 (see Table 6). As of 2015, 37% of the market representing the residential sector remained under regulated rates. Full third-party access to gas pipelines was completed in 2004. Full retail competition is currently scheduled to be complete in April, 2017 (see Appendix A).

Table 6. Summary of gas market reforms

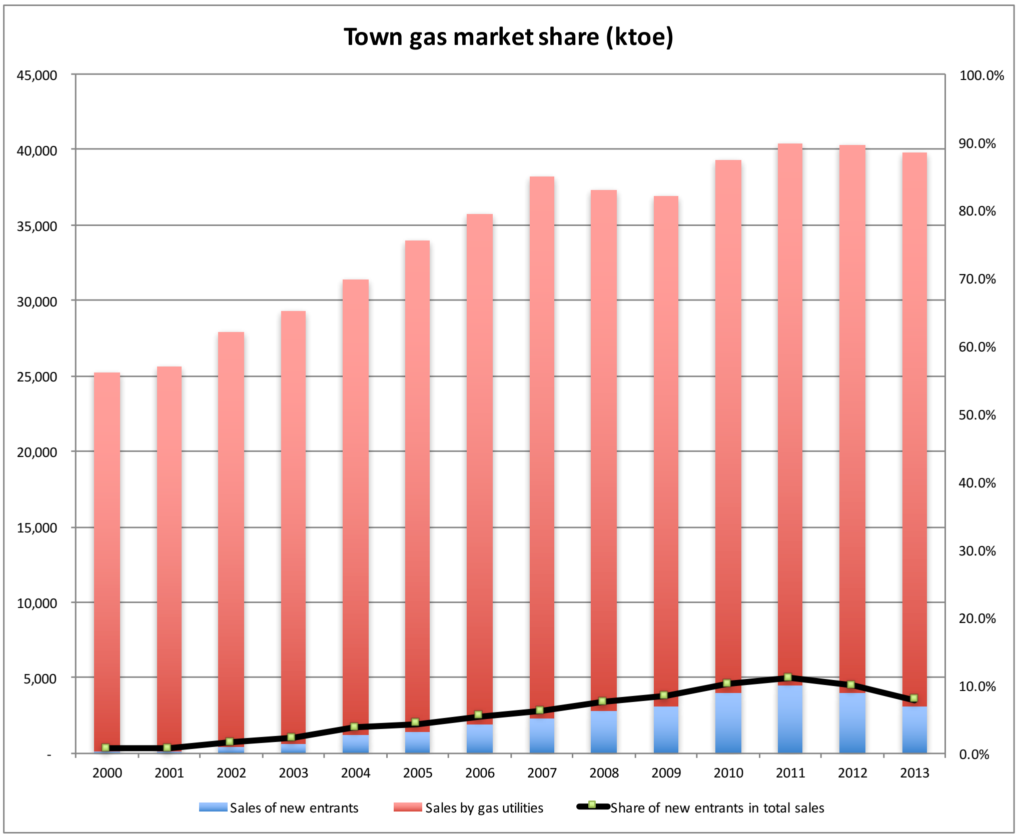
Stage	**Year**	**Percent of retail market liberalized**	**Status/Policies implemented**
	Before 1995	0%	Gas markets highly regulated and market entry restricted. No competition. Regulated rates approved by MITI.
1	1995	48%	Regulated rates abolished for large-volume industrial users (2 million m^3 and above). Introduction of third-party access to pipelines and fuel cost adjustment system.
2	1999	53%	Regulated rates abolished for large-volume industrial users (1 million m^3 and above). Regulated rate system changed to notification only. Changes to make new market entry easier. Third-party access to pipelines made mandatory (four major utilities only)
3	2004	56%	Regulated rates abolished for medium-volume industrial users, hotels, and other commercial facilities (0.5 million m^3 and above). Third-party access to pipelines made fully mandatory.
4	2007	63%	Regulated rates abolished for small-volume industrial and commercial users (0.1 million m^3 and above).
5	2017	100%	Regulated rates abolished for all users. Full retail competition. Third-party access to LNG terminals.
6	2022	100%	Legal unbundling of gas supply business from pipeline services.

Source: METI ([236], [237]), [238]–[240]

The data for town gas sales between 2000 and 2013 shows that sales by the incumbent gas utilities dominated the market despite liberalization measures. Town gas supplied by new entrants increased from less than 1% of total sales in 2000 to about 11% in 2011, but has been decreasing since 2011 (see Figure 49) [125].

Although third-party access to gas distribution pipelines started in 1995, the transportation tariffs for gas are still relatively high and this serves to restrict access by new entrants to the gas business. As of 2013, only 99 (or 31%) out of a total of 320 new entrants to the commercial gas supply business planned to use the gas transportation network [152].

Figure 49. Sales of town gas and market share



(v) Public engagement on energy issues

Public discourse and attitudes toward energy issues can have a significant impact on the ability to effectively implement energy policies. Among energy-related national public issues in Japan, nuclear power is by far the most contentious and long-standing. Having experienced nuclear war and its aftermath as well as a series of accidents and scandals involving nuclear facilities over the past 30 years including the meltdown in the Fukushima Dai-ichi reactors, the Japanese people have a particularly sensitive and complex relationship with nuclear power.

The traditional approach of the Japanese government to public engagement on energy policy issues has been largely "one way" in that it tries to influence public opinion in order to bring it in line with the government's policy goals [17]. Other than the extensive engagement with local communities that host nuclear power plants, there has been relatively little "two-way" communication with the broader public on energy policy issues.

As a measure of public engagement on energy issues, public attitudes toward nuclear power are evaluated on the basis of attitudinal studies and public polls. A 2005 study of public attitudes toward nuclear energy sponsored by the IAEA [241] was undertaken in 18 countries around the world, including Japan. The study found that in 2005, only 21% of Japanese respondents approved of building new nuclear power plants but that 61% wanted to keep existing plants operating. The same study found that a high percentage of Japanese (at 71% – the highest in the countries polled) also felt that the risk of terrorist acts involving radioactive materials and nuclear facilities is high because of insufficient security.

The same study reported the results of time-trending polls. In the case of Japan, public support for nuclear energy generally increased from about 30% in the early 1990's to about 40% by 2010, except for dips after the Monju and JCO accidents. Those Japanese who opposed nuclear energy dropped from around 43% in 2000 to about 35% by 2010.

Since the Fukushima nuclear disaster, resistance has built against restarting nuclear power plants in Japan. Polls taken by the Asahi newspaper in April 2011 immediately after the Fukushima disaster show that 51% of respondents (down from 53% in 2007) reported that they wanted to keep existing plants operating [242]. However, a nationwide poll conducted in March of 2012 showed that 80% of respondents did not trust the government's nuclear safety measures and 57% were opposed to restarting Japan's nuclear reactors [243]. Polls conducted by Asahi Shimbun in July and September of 2013 showed similar results with 59% of respondents opposed the restart of nuclear reactors [244].

3) Reference case on resilience and adaptability: energy system recovery after the triple disaster

On March 11, 2011 a magnitude 9.0 earthquake and tsunami hit the Tohoku region of northeastern Japan. The disaster left almost 20,000 people killed or missing and inflicted heavy damage to infrastructure throughout the region. About 32 GW of power was knocked-out in northeastern Japan, including 10 nuclear power plants (14 GW capacity) and 25 thermal power plants (18 GW capacity). Most notably, damage to the reactor cooling system at Fukushima No. 1 power plant caused a meltdown of the reactor cores and release of radiation [211], [245].

The damage and disruption in Eastern Japan was varied and extensive. The power shortages resulting from damage to power plants and transmission lines caused TEPCO to institute a program of rolling blackouts lasting from March 14 to 28, affecting 70 million people in Eastern Japan [245]. In the gas sector, about 420,000 customers had their gas supplies cut off or disrupted in Eastern Japan. LNG terminals and pipelines were damaged making it impossible to receive LNG supplies. LPG supplies to 1.6 million customers were also cut off, and 2.3 million customers suffered water outages. Oil refineries were also damaged, coal uploading facilities collapsed and coal carrying barges sank, affecting fuel supplies. About 1.5 million barrels per day (mmb/d) of refining capacity representing nearly one-third of the nation's total refining capacity was disrupted [200], [211].

In spite of the magnitude of the earthquake, all nuclear power plants other than the 4 units at Fukushima No. 1 were successfully shut down. Electricity services were fully restored to customers in TEPCO's service area by March 18^{th} and to customers within Tohoku Electric's area (except those affected by the tsunami) by March 19^{th}. Damaged thermal power capacity other than nuclear power was repaired and brought back online very rapidly so that by July, all of TEPCO's thermal power plants (about 12 GW) had been brought back online [211]. On the other hand, 8.9GW of nuclear power capacity remained offline due to damage or shutdowns.

Measures taken by TEPCO included restarting idled power plants, utilizing pumped hydro, purchasing power from private generators and installing "emergency" capacity ahead of the high demand season. Tohoku Electric took similar measures so that by the summer, the two companies were able to bring capacity back to 69 GW, compared to the 80 GW of thermal and nuclear power that were in operation before the disaster. However, a 5-6 GW shortfall relative to peak load of 60 GW was expected in TEPCO's service area during the summer [211]. Unfortunately, due to limited inter-regional transmission capacity and frequency differences between east and west Japan, only about 1 GW of power could be supplied to the TEPCO and Tohoku regions from neighboring regions.

To help make up the difference, the government imposed a 15% mandatory power use restriction on large industrial users of electricity. As a result, peak load was reduced by 15.8% in the Tohoku region and by 18% in the Tokyo region. Various campaigns were also run across Japan to encourage other users to voluntarily reduce consumption, including the

Setsuden program. As a result of these mandatory and voluntary efforts, electricity demand in all of Japan fell by 11.8% in August. Consequently, the deficit created by the shutdowns of nuclear power plants was substantially covered by reductions in demand, with the result that the actual electricity shortfall was much less than anticipated. Over the summer of 2011, Japan made up for the remaining gap between restored capacity and reduced demand by relying on fuel oil and crude oil-fired power plants as well as LNG-fired power plants. As for fuel supplies, the country relied on its relationships with other LNG buyers in Asia as well as on existing suppliers who increased supplies for Japan [211], [245].

The ability of Japan's energy system to adapt to the shock of the disaster and quickly recover is impressive and reflected a number of adaptive behaviors. First, the rapid response of electricity and gas system workers who were able to reroute energy supplies and repair energy infrastructure. Secondly, Japanese society showed a high level of adaptability by adjusting consumption behavior to conserve power and reducing demand sufficiently so that further rolling blackouts were avoided even in the summer peak periods since April, 2011. Thirdly, the country's deep reservoir of idle capacity was drawn upon to help make up for shortfalls stemming from damaged nuclear and thermal generation. Fourthly, in the weeks and months after the disaster, reserve margins were sufficiently ample in certain regions that on a limited basis, the system was able to supply some regions with low reserves from regions with surpluses. Finally, the ability to rapidly deploy emergency power generation facilities and new natural gas turbines helped increase capacity to fill the gap left by the shutdown of most of Japan's nuclear fleet.

Taking all these factors into consideration, it is reasonable to conclude that Japan's energy system must have possessed a high degree of resilience and adaptive capacity prior to the triple disaster since electricity, gas and other energy services were quickly restored in spite of the magnitude of the shock of the disaster. Had these measures not been taken or implemented ineffectively, it is very likely that rolling blackouts would have been experienced not only during the summer of 2011 but also in subsequent years as nuclear power plants remained shut down and reserve margins were dangerously low.

While Japan's electricity system recovered quickly from the shock of the triple disaster, it suffered a functional shift that degraded its overall performance. Whereas before the disaster nuclear power provided about 30% of electricity demand, the loss of nuclear power after the disaster has caused the cost of power and carbon emissions to rise and diversity in the electricity mix to decline with the result that overall energy security has degraded. The system proved to be resilient and adaptable, but it has shifted to alternate, less desirable state.

4.2.4 Discussion

Policy impacts on energy system resilience

Japan employed a wide range of diversification strategies and this study used four key measures of diversification. The results showed that variety and balance in primary energy supply sources and electricity supply sources were generally very good up to the triple disaster but degraded thereafter. Distributed generation is steadily increasing in Japan and provides resilience in case of disruptions to the main grid.

Various policies to decrease reliance on imports by increasing domestic supply sources also showed improvement. Stockpiles of crude oil and LPG were large and could provide several months of supply in case of disruptions. Domestic sources of fossil fuels have historically been very limited in Japan, however large reserves of methane hydrates have recently been discovered which holds future potential to increase self- sufficiency. Improvements in thermal efficiency are world class and continue to show steady improvement, further reducing the reliance on imports. Japan's deep reserve of idle capacity proved important after the triple disaster, improving the ability to recover from damage to operational power plants. On the other hand, renewables capacity and generation remained at low levels despite a wide range of policies designed to enhance renewables share during the period up to 2011. After the triple disaster and the implementation of the new FIT program, solar PV capacity and generation have sharply increased. However, the share of non-hydro renewables generation remains very low.

On the demand side, Japan already achieved dramatic improvements in energy efficiency in the industrial/manufacturing sector up to 2000 and improvements continued during most of the period up to the triple disaster despite sharp increases in the price of oil. Japan's policies combined with significant investments in energy efficiency R&D can be credited with making it a global leader in this area. However, performance in the household/commercial sector lags the industrial sector. Japan's continued improvements in energy efficiency and conservation have served to lower reliance on fossil fuels, lower carbon emissions and improve resilience.

The analysis in this chapter shows that at least some of Japan's resource security strategies have contributed to enhancing energy system resilience by bringing Japan closer to its trade and security partners, potentially allowing it to rely on these suppliers in times of an energy emergency. While it is difficult to measure the cost or effectiveness of the broad range of these strategies, some success has been demonstrated. The fact that Japan continues to employ such strategies suggests that the government perceives that the benefits for energy security are seen to outweigh the costs. Resource security strategies are therefore assumed in this thesis to exert a neutral or positive impact on energy system resilience.

Policy impacts on energy system adaptability

The indicators and measures used to assess the capacity for energy innovation and technology development in Japan all showed strength and steady improvement. Investment in energy technology R&D is high by international standards, although much of it was concentrated in the nuclear sector throughout the period in line with Japan's priorities of expanding the use of nuclear power up to 2010. Spending on energy efficiency, fossil fuels and hydrogen R&D remained relatively steady throughout the period, but after the triple disaster nuclear spending was significantly reduced while spending on renewables has seen the largest increase. Japanese energy-related patent filings lead the world in most categories and particularly in solar and fuel cell technologies. These indicators show that Japan has a strong commitment to developing its adaptive capacity in a variety of energy technologies.

The reference cases on Japan's smart communities and Ene-farm fuel cells demonstrate how the effective use of adaptive mechanisms can help the energy system evolve toward improved performance and more efficient outcomes. As a large-scale demonstration project, the smart communities project serves as a protected niche experiment where different energy and social technologies can be combined to make more efficient use of energy on both the supply and demand sides. It also provides a model for how Japanese communities could evolve more sustainably in the future, while also serving as a launching pad for Japanese technology firms to refine their products and services before entering global markets. As a project arising out of government funded hydrogen and fuel cell R&D programs, the Ene-farm project has demonstrated successful commercialization.

Not all investments in innovation and technology development will necessarily be successful and while the examples cited in this study are necessarily limited in number, the results suggest that Japan has provided strong policy support for innovation and technology development and some of these investments appear to be bearing fruit. The various strategies and projects noted serve as useful mechanisms for gradually adapting the energy system to the constraints facing the country, including high fossil fuel prices, high reliance on imports and climate change pressures.

With respect to market structure and the effectiveness of energy liberalization and deregulation polices, the analysis showed that while overall regulatory quality in Japan is very high and on a level with its OECD peers, there were specific areas of concern particularly with respect to nuclear power. In the electricity market, the share of new entrants in electricity demand remains very low despite a series of liberalization measures taken over a period of 18 years. This indicates that the policy has fallen short of achieving its primary aims. Similarly, the share of new entrants in gas markets also is relatively low, and the share of new entrants since 2011 has actually been falling. These two indicators strongly suggest major weaknesses in the government's policies and/or their implementation such that the regionally-based monopoly structure of these markets remains heavily dominated by the incumbent utilities, while benefits in terms of lower prices have largely failed to materialize.

The level and quality of public engagement on nuclear-related issues is also important to the future of Japan's energy security. If policies and programs cannot adapt to active and strong resistance from the public and local communities, the future of nuclear power in Japan will be increasingly cast in uncertainty, impacting on the ability to restart nuclear plants, creating uncertainties for investors and making the achievement of electricity diversification targets problematic in the future.

Despite several shortcomings, Japanese energy policies up to 2011 can generally be judged to have been successful in reducing vulnerabilities by building resilience and adaptability in the energy system, as reflected in the indicators and reference cases, and as exemplified in the energy system's rapid recovery after the triple disaster. Japan's energy system has been able to meet demand in every year since the disaster without the benefit of any significant amount of nuclear power. It has done so however by shifting to an alternative state that is much less desirable in terms of overall performance. In particular, the increased reliance on fossil fuels and the impact on carbon emissions have negatively impacted both energy security and sustainability.

4.2.5 Conclusion

In summary, this chapter addressed the second research question posed in this thesis by examining the impact of energy policies on energy security in terms of strategies to reduce vulnerabilities. The results show that over the 2000-2010 period, policies and strategies served to strengthen energy system resilience and adaptive capacity, allowing the energy system to recover quickly after the triple disaster. However after the disaster, several indicators of energy system resilience and adaptability degraded and Japan's energy system shifted to a less desirable state with overall poorer performance and increased vulnerability. Various outstanding vulnerabilities and energy security concerns identified in this chapter will be further discussed in Chapters 4.4 and 6.

Chapter 4.3: Energy security and sustainability in Japan

4.3.1 Introduction

Energy security and sustainability policies have developed in different research streams and tend to be treated separately even though the two policy areas are intimately related and increasingly co-dependent [88]. The climate change/sustainability literature has tended to ignore energy security issues in low-carbon scenarios [246], and greater attention to the trade-offs and synergies between energy security and climate change mitigation policies has been called for [247]. For policymakers, energy security is often considered a near-term, national issue, whereas climate change is viewed as a global, long-term problem [248]. Given the increasing importance of achieving both sustainability and energy security goals simultaneously over the long-term, integrated approaches that assess the interactions between both concepts are necessary [88].

This chapter reviews Japan's long-term energy security and sustainability (i.e.: climate change) policy targets and goals. As a country with few non-renewable natural resources, Japan is highly reliant on imports of fossil fuels to power its economy. As a result, energy security issues occupied a prominent place in Japan's policy priorities. Sustainability policy also rose to prominence in the period after Japan acceded to the Kyoto Protocol in December 1997. In order to meet Japan's climate targets within the first commitment period (2008-2012) major changes in Japanese energy policy were implemented in the lead-up to the agreement coming into force.

Despite the obvious linkage between energy security and sustainability policies, there are a limited number of studies in the literature that take an integrated approach to their assessment [248]. Very few studies have examined the effectiveness of Japan's approach to energy security and sustainability over a longer time frame. The purpose of this study is therefore to review Japanese long-term energy security and sustainability policy targets in the 2000-2013 period and to assess how effective government policies were in achieving these targets, including the extent to which they promoted a balanced and integrated approach to the enhancement of long-term energy security and sustainability.

4.3.2 Methodology

Information on Japanese policies and targets were collected from primary sources including published government reports and policy documents. Documents were reviewed to extract information on historical data, including adjustments and revisions that were made during the period under study. Sources included the Ministry of Economy, Trade and Industry (METI), Ministry of Environment (MOE) and the Cabinet Office. Energy statistics and climate related data were collected from primary or secondary sources including from the Japanese government (especially METI and MOE), Institute of Energy Economics Japan (IEEJ), the IEA, UN and other sources. Energy security and sustainability indicators were calculated from IEA, IEEJ [125], and UN data.

4.3.3 Energy security and sustainability policies in Japan

1) Responsibility for energy and sustainability policies

As an island nation dependent on exports of manufactured products, energy security has been a dominant theme in Japanese energy policy particularly since the two oil shocks of the 1970's. Japan has almost no domestic sources of fossil fuels or uranium and imports virtually all of its non-renewable energy resources. Consequently, over the period under study energy was treated as a strategic and important national security issue [28]. In Japan, the role of government is seen as essential to shaping the development of the energy system in order to ensure long-term energy security.

Energy policy in Japan is primarily the responsibility of METI (prior to 2001, the Ministry of International Trade and Industry, MITI). A key tool for METI's energy policy planning was the Long-term Energy Supply and Demand Outlook. The outlooks were prepared by the Advisory Committee for Natural Resources and Energy, a committee whose role is to advise the Ministry of Economy, Trade and Industry. The outlook was meant to provide guidance for policy and plans by setting targets for Japan's energy mix, including energy demand by sector, primary energy supply, electricity generation and CO2 emissions [249]. The outlook is best viewed as a scenario of Japan's energy policy aspirations, rather than as a forecast [139]. Even so, policymakers, industry and other stakeholders used the outlook as a basis for forward planning. Targets for components of primary energy supply were reflected in long-term energy supply and demand outlooks issued in 2001, 2005 and 2008.

Climate and environmental policies are primarily the responsibility of the MOE and are expressed mainly through the Basic Environment Law (enacted in 1993) and the Basic Environment Plan which sets out the measures to be taken by the national and local governments, citizens, businesses and organizations. In Japan, sustainability goals are often included in or linked to energy policies. For example, in developing its “intended nationally determined contribution” (INDC) for global climate change negotiations, Japan links its proposals to national energy policies [250].

2) Balancing the 3-E’s

During the 2000-10 period, the Japanese government itself identified a number of risks threatening its long-term energy security including: instability in the Middle East, resource competition, increasing resource prices, natural disasters, insufficient investment in upstream energy supplies and uncertainties arising from market liberalization [123]. In line with these developments, Japan took a major step toward a more comprehensive approach to energy policy planning with the enactment of the Basic Act on Energy Policy in 2002. The Act stipulated that energy policy development should be based on three fundamental principles known as the “3-E’s”: energy security, environmental protection and economic efficiency. Based on these principles, the government issues a Strategic Energy Plan at least once every three years [251]. Other energy-related plans published during the period included the New National Energy Strategy (NNES) of 2006 which placed a strong focus on energy security issues and outlined a series of measures the country would take to address perceived threats [252].

Energy security and sustainability policies have had a strong linkage ever since the oil shocks of the 1970’s. Energy efficiency and conservation policies implemented since then resulted in a 42% reduction in energy consumption per unit of GDP between 1973 and 2012 [125]. Sustainability issues rose to prominence in 1997 as the country sought to exert global climate leadership by hosting international climate talks in Kyoto. The resulting Kyoto Protocol was the first international climate change agreement to include binding GHG commitments. Japan ratified the Kyoto Protocol in 2002 and it entered into force in February 2005. Under the Protocol, the country committed to reduce its greenhouse gas emissions by 6% from 1990 levels. The Kyoto Protocol Target Achievement Plan implemented in 2005 was the guiding plan for Japan to reach its commitments. A number of other policies were implemented to achieve sustainability goals during the period. These included:

- A voluntary emissions trading scheme and a domestic offset scheme for small businesses to enhance their efficiency and lower emissions in 2005.
- Various measures in the NNES including energy conservation programs such as the Frontrunner Plan and energy efficiency technology development.
- The Cool Earth 50 policy announced in May 2007 that was aimed at reducing global GHG emissions by 50% by 2050.
- The so-called "Fukuda Vision" that included plans for the development of advanced and innovative technologies to significantly reduce greenhouse gases by 2050.

4.3.4 Analysis of policy objectives and targets

In order to meet the Kyoto Protocol's targets within the first commitment period (2008-2012) and address growing energy security concerns, the Japanese government set 2010 as a target year to achieve a range of energy security and sustainability policy objectives that were reflected in the outlooks. In the following sections Japanese government energy and sustainability (climate change) policies and targets in place over the 2000-2013 period are identified and analyzed.

1) Energy policies and targets, 2000-2010

The Long-term Energy Supply and Demand Outlook of July, 2001 consisted of two scenarios, the base case and the policy case with targets set for 2010. For versions of the outlook spanning 2001 to 2008, the target scenarios were based on FY 2010 because Japan had committed to goals under the Kyoto Protocol and achieving its emissions targets within the first commitment period (2008-2012) was an important policy goal for Japan. The base case was a "business as usual" case that incorporated all the energy efficiency and environmental measures that had been implemented up to 2001. The policy case targets incorporated the additional policies and measures needed to meet the Kyoto targets as well as meet energy security goals, including a well-balanced energy supply and electricity mix. The policy case included the following objectives [139]:

- Total final consumption would be reduced below current levels.
- Oil supply would be reduced below current levels through diversification and energy conservation measures.
- Coal use would be reduced through fuel conversion and other measures.
- Natural gas supply would be increased from current levels through fuel conversion and other measures.
- Nuclear power supply would reach 42% by 2010 by building new plants (the government targeted 10-13 reactors by 2010 in addition to the 52 commercial units that existed in 2002) and improving load factors.
- The supply of new and renewable energy sources would be increased by a factor of three.

In order to assess Japan's performance over the 2000-2010 period, actual performance can be compared against the above objectives and the policy case targets that the government set. Table 7 summarizes components of Japan's primary energy supply (PES) targets. Table 8 summarizes the actual amounts. Data have been converted to standardized units (in millions of kiloliters of oil equivalent) for comparability.

Table 7. Long-term energy supply and demand outlooks: targets, 2000-2013

	2010 Targets		
M kl of oil equiv.	**(2001 Outlook)**	**(2005 Outlook)**	**(2008 Outlook)**
Fossil fuels:	468	457	462
Oil	271	244	232
Coal	114	105	117
Natural gas	83	108	113
Nuclear	93	85	83
Hydro	20	21	19
Geothermal	1	1	1
New energy	20	21	20
Domestic Supply of Primary Energy	**602**	**584**	**584**

Source: Long-term Energy Supply-Demand Outlooks

Primary energy supply targets, 2000-2010

Analysis of targets and actual results shows that total primary energy supply in 2010 declined about 3% from the level in 2000 and fell more than levels targeted in the outlooks. Also, total final energy consumption fell by 9.7% compared to 2000 [125]. While it is difficult to attribute direct causes to the reduction in energy demand, energy efficiency and conservation programs and the recession following the global financial crisis in 2008-09 may have been contributing factors [253].

Table 8. Long-term energy supply and demand outlooks: actual amounts, 2000-2013

M kl of oil equiv.	**2000 (actual)**	**2010 (actual)**	**Change (2010/2000)**	**2013 (actual)**	**Change (2013/2010)**
Fossil fuels:	477.6	466.0	-2.4%	500.0	7.3%
Oil	288.1	228.0	-20.9%	233.0	2.2%
Coal	108.5	128.7	18.5%	135.6	5.4%
Natural gas	80.9	109.3	35.1%	131.4	20.2%
Nuclear	74.2	64.4	-13.2%	2.1	-96.8%
Hydro	20.1	18.4	-8.5%	17.5	-4.8%
Geothermal	0.8	0.6	-23.3%	0.6	0.0%
New energy	15.2	20.5	35.4%	22.4	9.3%
Domestic Supply of Primary Energy	**587.8**	**569.9**	-3.0%	**542.7**	-4.8%
Total GHG emissions (Mt of CO2 equiv.)	1370	1286	-6.1%	1395	8.5%

Source: Long-term Energy Supply-Demand Outlooks

In the 2001 outlook, METI aimed to reduce oil dependency to about 45% by the year 2010 which would be achieved mainly by increasing the use of nuclear power and modest increases in "new energy[61]". Looking at specific components of PES over the 2000-10 period it is noteworthy that by 2010 Japan had successfully reduced its reliance on oil by about 21%, more than targeted in 2001.

The failure to reach nuclear power plant targets (discussed below) by a wide margin only resulted in a 13% fall in the share of nuclear power in PES because of the unexpectedly large reduction in domestic supply of primary energy. While the government aimed to reduce coal's share by 2010, it's share in PES actually increased significantly during the period. Natural gas also increased its share. Both of these fuels increased to fill the gap left by the reduction in nuclear power generation (see below). Meanwhile, hydro and geothermal remained almost unchanged over the period.

[61] "New energy" is a term used in Japan and includes the following energy sources: photovoltaic (PV), wind power, solar thermal, waste power, thermal utilization of waste, fuel production from waste, temperature difference energy, natural gas cogeneration and fuel cells.

Electricity mix targets, 2000-2010

Nuclear power was targeted to play a key role in helping Japan improve its long-term energy security, diversify away from oil and achieve its Kyoto commitments. The government viewed nuclear power as a low-carbon energy source and as an important "quasi-domestic" source of energy given that uranium can easily be stockpiled and the fuel cycle would allow plutonium to be enriched and recycled, thereby improving efficiency and reducing waste material. However, despite the ambitious targets set in the outlooks, Japan had to revise down the number of reactors from 10-13 in the 2001 outlook, to 6 in the 2005 outlook. By 2010, a total of only five reactors had actually come online and the share of nuclear power in the electricity mix actually fell. By 2010 the share of nuclear power was well short of the government's original goals and reflected the loss of public confidence in nuclear power as a result of a series of accidents and scandals [254].

Coal steadily increased its share of the electricity mix, increasing its share significantly over the target. In the 2000-2010 period the coal market in Japan was fully liberalized, coal prices were cheap relative to other fossil fuel alternatives and utilities made independent investment decisions on power generation technologies. The increase in coal's share can also be attributed to the uncertainty surrounding the extent to which nuclear generation could actually increase in the face of public concerns over nuclear safety. Imports of thermal coal thus increased steadily over the period while gross thermal power generation efficiency also improved with Japan gaining global leadership in clean and efficient coal-fired generation technologies [255]. The increase in LNG over the period can be attributed to several factors, including the need to diversify the fuel mix, lower CO2 emissions, and the need to meet demand peaking requirements [256].

In 1996 and 2001, as part of efforts to promote "zero-emission" electricity generation, the Japanese government set an overall target for new energy (excluding hydro and geothermal) of 3.1% in total primary energy supply by fiscal 2010. This very modest target was exceeded, representing 3.6% of primary energy supply in 2010 (see Table 9). However, about 89% of electricity from new energy was produced from biomass and waste materials in 2010, while renewables such as solar PV and wind power had only about 1% share. Renewables and co-generation capacity additions fell well short of 2010 targets in all cases (see Table 10).

Table 9. Share of actual amounts and targets in primary energy supply, 2010-2013

	2000 (actual)	2001 (Outlook)	2010 (actual)	2001 Outlook vs 2010 actual	2013 (actual)
Fossil fuels:	81.2%	77.7%	81.8%	-0.4%	92.1%
Oil	49.0%	45.0%	40.0%	-15.9%	42.9%
Coal	18.5%	18.9%	22.6%	12.9%	25.0%
Natural gas	13.8%	13.8%	19.2%	31.7%	24.2%
Nuclear	12.6%	15.4%	11.3%	-30.7%	0.4%
Hydro	3.4%	3.3%	3.2%	-8.1%	3.2%
Geothermal	0.1%	0.2%	0.1%	-40.6%	0.1%
New energy	2.6%	3.3%	3.6%	2.7%	4.1%
Domestic Supply of Primary Energy	100.0%	100.0%	100.0%	-5.3%	100.0%

Source: Long-term Energy Supply-Demand Outlooks

Table 10. Renewables and co-generation capacity targets and actual amounts (MW)

Source	2000	2010		
	Actual	Target	Actual	Diff. from Target
PV	330	4820	3620	-33%
Wind	144	3000	2442	-23%
Biomass & Waste	1100	4500	2404	-87%
Natural gas co-generation	2814	4988	4043	-23%

Source: Long-term Energy Supply-Demand Outlooks

2) Energy policies and targets, 2011-2013

In the Strategic Energy Plan of 2010, the government reaffirmed that nuclear power would play a major role in helping meet Japan's climate change targets. In addition to a new target of 9 additional nuclear power plants to be completed by 2020, and 14 by 2030, the plan called for raising the "zero-emission power source ratio" to about 70% (from 38% in 2010) and cutting CO2 emissions in the residential sector by 50% [257].

In the wake of the Fukushima disaster, Japan's nuclear reactors were progressively shut down for safety inspections by the newly established Nuclear Regulation Authority (NRA). By the end of 2013 nuclear power's share of PES had dropped by almost 97%. As a result, Japan's power generation mix became heavily concentrated, with the share of fossil fuels (especially coal and LNG) in PES increasing from about 81% in 2010 to more than 92% in 2013.

3) Sustainability policies and targets

At preliminary UN climate talks in Bangkok in 2009, Japan announced it would target a 25% reduction in GHG's over 1990 levels – the most ambitious target proposed by any major developed nation at the conference [258]. Japan reaffirmed this target at the UNFCC Copenhagen conference in 2009. It premised this commitment on an agreement with ambitious targets and where all major economies participate. However, at climate talks in Cancun in 2010, Japan (and three other countries) refused to agree to an extension of the Kyoto Protocol on the grounds that it did not include major emitters such as the U.S. and China.

After the March 2011 disaster, and in a major departure from its previous commitment, Japan proposed to reduce its carbon emissions by 3.8% by 2020 compared to 2005 levels at climate talks in Warsaw in November 2013 [259]. Since emissions in the country grew about 7% between 1990 and 2005, this actually represented a 3.1% increase over 1990 levels. Japan was widely criticized for taking this position. The reasons it gave for lowering the level of ambition were attributed to the impact of the indefinite shutdown of all of the country's nuclear reactors and the "zero-base review" of earlier policies that followed the 2011 disaster [259]. After Fukushima, old oil-fired thermal power plants had been brought back online and new gas-fired plants were built to make up for the loss of electricity generation. As a result, by the end of 2013 Japan's GHG emissions had risen to 1,395 Mt CO2, an increase of 8.5% (about 110 million tons) over 2010 levels, with all of the increase coming from the power sector (see Table 8). This was the highest level since comparable data became available in fiscal 1990.

Subsequently, in July 2015 as momentum started to rebuild toward forging a substantive agreement at COP 21 in Paris, Japan announced that it would reduce its GHG emissions by 26% over 2013 levels by 2030 [260]. This proposal was made in consideration of the government's plan for the electricity generation mix, which was released in April, 2015. Japan's electricity sector is substantially liberalized but through its regulatory authority, the government still exerts significant influence over system adequacy and long-term planning. Thus, nuclear generation was targeted to reach 20-22% of the mix while renewables were targeted to make up 22-24%. In total, the government expected “zero-emissions” generation to account for up to 44% of the generation mix by 2030. On the heels of this announcement, Japan’s Federation of Electric Power Companies also made a voluntary commitment to reduce CO2 emissions by 35% per kWh by 2030 [261].

4.3.5 Discussion

In order to more fully assess Japan’s policy outcomes, several indicators are used to measure trends in energy security and sustainability over the 2000-13 period. Since import dependence for fossil fuels exceeded 95% over the whole period, Japan is highly vulnerable to disruptions in energy supplies. The country faces a wide variety of potential threats and uncertainties to its energy security over which it has little influence. In his seminal work on diversity, Stirling [85] showed that diversification is the best method of building resilience in energy systems that are exposed to incertitude.

In order to measure the trend in energy security in Japan, two well-established indices of diversity are used. The first is the Shannon-Weiner index (SWI) which has been shown to appropriately reflect both variety and balance in the portfolio of fuel types in primary energy supply [85]. In this thesis, SWI measures diversity in five primary fuels: crude oil, coal, natural gas, nuclear and renewables. The range of values for the indicator are between 0, which represents 100% reliance on a single fuel, and 1.67 which represents a primary energy mix which is fully diversified and balanced among the five main fuel types. Therefore, the higher the index value the more diversified the fuel mix is. The results (see Table 11) show that, in absolute terms, Japan's diversity of primary energy supply up to 2010 was very good at a level averaging about 1.4. However, the trend after the Fukushima disaster in 2011 was sharply lower.

Japan also faces potential threats from disruptions to fuel imports from supplier countries, including from political turmoil, wars, piracy, sea lane blockages and the exercise of market power. The Hirfendhal-Hirschman Index (HHI) has been used in several studies to measure the diversity of energy supplier countries and to assist in assessing the market power of suppliers [63]. Values for the index range from 0 where there is perfect competition with innumerable suppliers, to 10,000 where the market is supplied exclusively by a single supplier. The results are found in Table 11.

Table 11. Energy security and sustainability indicators

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Hirfendhal-Hirschman Index (HHI):	3890	3879	3784	3784	3743	3786	3899	4138	4223	4498	4470	4079	4310	4486
HHI for coal	1614	1668	1640	1670	1747	1899	1977	1804	1803	1881	1737	1900	1820	1828
HHI for crude oil	2032	1888	1944	1852	1790	1781	1608	1484	1399	1464	1427	1281	1224	1317
HHI for nat gas														
Shannon-Weiner Index (SWI)	1.37	*1.38*	*1.38*	1.37	1.39	1.38	1.40	1.39	1.40	1.42	1.44	1.36	1.24	1.23
Carbon intensity (kgCO2/2005 $US PPP)	0.32	*0.31*	*0.32*	0.32	0.31	0.31	0.30	0.30	0.28	0.28	0.28	0.30	0.30	0.30
CO2 emissions per capita (tCO2)	9.12	*9.00*	*9.26*	9.30	9.31	9.36	9.25	9.54	8.88	8.41	8.79	9.21	9.54	9.70

Given that these two extreme values for the HHI are highly unlikely in the real world, Japan's index values for crude oil and natural gas can be judged to be moderately low, indicating a relatively high degree of diversification. The trends for these two fuels over time have been relatively flat, with diversification for natural gas improving slightly over time. With regard to coal, the index is judged to be moderately high, reflecting an increasing level of concentration. In particular, imports of coal from Australia increased by 41% between 2000 and 2013 and Australia's share of Japan's coal imports rose from 60% in 2000 to 64% in 2013 [262].

With respect to sustainability, two indicators are calculated: carbon intensity which is a measure of carbon use in the economy, and carbon emissions per capita which is a measure of carbon use in society as a whole. The results (see Table 11) show that both carbon intensity and carbon emissions per capita declined steadily up to 2011. While intensity increased slightly after 2011, per capita emissions increased significantly. The changes after 2011 were due largely to the increased reliance on fossil fuels in the power sector, which were required to replace nuclear power.

Our analysis demonstrates that even though not all the outcomes underlying the policy case in the 2001 outlook (see section 4.3.4) were achieved, Japan managed to maintain a relatively high level of energy security over the 2000-2010 period. It did this primarily by reducing dependence on oil and maintaining a large share of nuclear power in Japan's primary energy supply mix. Total final energy consumption in 2010 was 3% lower than in 2000 [125]. By 2010, the diversity of fuel sources in Japan's electricity generation mix was better than in 2000 (see Tables 11 and 12). Despite these achievements, the share of fossil fuels in PES remained unchanged over the period ending at 81% – the same as it was in 2000.

Table 12. Electricity mix targets and actual amounts for 2010

Source	2000 Actual	2001 Outlook	2005 Outlook	2010 Actual
Thermal	56%	47%	49%	60%
Coal	18%	16%	17%	23%
LNG	26%	26%	25%	31%
Oil	11%	5%	7%	5%
Nuclear	34%	42%	39%	31%
Hydro	10%	10%	11%	8%
Geothermal	0.4%	0.4%	0.4%	0.3%
New Energy	0%	1%	1%	1%
Total	100%	100%	100%	100%

Source: Long-term Energy Supply-Demand Outlooks

Ambitious targets for expanding nuclear power were never reached despite the targets being revised down multiple times. The modest targets set for new energy (including renewables) in PES were met and slightly exceeded. However, renewables and co-generation capacity additions fell well short of targets (see Table 12). As a result, the share of fossil fuels in the electricity generation mix increased to 60% by 2010. Coal and natural gas generation increased to help cover the steady growth of peak load over much of the 2000-2013 period and also helped increase reserve margins. Given various physical and regulatory constraints, hydro and geothermal power were unable to grow during the period.

Due to various factors including energy efficiency and conservation measures and falling energy demand, Japan managed to reduce its total CO2 emissions and emissions intensity over the 2000-2010 period. However, the inability to meet nuclear targets and the weak policy support for renewables expansion made the challenge to reach the Kyoto targets that much more difficult since the growth of other low-emission sources including hydro, geothermal and new energies were relatively insignificant. As a result, while GHG emissions were lower in 2010 that in 2000, they were still higher than in 1990. However, under the Kyoto Protocol Target Achievement Plan the objective to meet the 6% target was to be met by reducing domestic GHG emissions by 0.6% annually compared to base year (1990) combined with 3.8% from a forest sink and 1.6% by employing other Kyoto mechanisms. Due to slow GDP growth and the use of the Kyoto mechanisms, Japan was able to meet its Kyoto Protocol commitments [63].

In the wake of the Fukushima Daiichi nuclear power plant accident in March 2011, the attention of policymakers turned to investigating the causes of the accident and putting in place regulatory and policy reforms to enhance the safety and security of nuclear facilities. Given the magnitude and consequences of the disaster and the importance in addressing an extremely wide range of issues from disaster relief to regulatory reform, the attention and resources of the government shifted to dealing with the most urgent issues for much of this period. One of the major consequences of the disaster was the rapid increase in GHG emissions associated with the increase in fossil fuel power generation, which served to compromise Japan's climate mitigation efforts.

It is not surprising that given the circumstances, the Japanese government sought to avoid major new climate change commitments while it assessed the impact of the disaster on the future of the energy system. Energy security concerns took precedence as rising energy costs led energy-intensive industries to close down or move offshore while capital investments were postponed [263]. In particular, uncertainty surrounding the restart of nuclear power plants and public concerns over nuclear power complicated energy policymaking and led to a four-year period lasting from March of 2011 to April of 2015 in which the government provided no firm guidance or targets for the electricity generation sector. Without a signal as to whether and how much nuclear power would be allowed to restart, decisions on constructing nuclear power plants were delayed and new fossil-fuel based thermal generation expanded to fill the gap in generation capacity, with negative consequences for Japan's balance of payments. As a result, efforts to balance the 3-E's + S ("S" for safety was added after the Fukushima disaster) were compromised as the country found itself having to prioritize energy security and economic efficiency over sustainability in order to protect the economy and continue to provide essential services to its citizens.

While Japan was widely criticized by environmental advocates for lowering its level of ambition in the Warsaw proposal and in its recent COP 21 proposal, its stance is understandable in light of the realities of the post-Fukushima situation with a reduced reliance on nuclear power, a need to limit energy price increases that would further reduce Japan's competitiveness, and an ongoing concern with energy security issues. With the reduced role planned for nuclear power, the government appears to believe that Japan's ability to achieve deeper reductions in GHG emissions beyond what has already been proposed is limited in the short-term, especially given the continued commitment to balancing the 3-E's. Given Japan's already impressive improvements in energy efficiency, there appears be is little room to achieve further dramatic cuts. In 2012, Japan's carbon intensity performance remained among the best in the developed world at 220 t/$US million, 18% less than the OECD average [125].

By 2013 the most urgent post-disaster recovery measures had been taken, regulatory changes for nuclear power had been implemented and a number of government sponsored study groups and committees had reported on recommendations for changes to Japan's energy policies. The most significant and long-awaited announcement concerned the targets for Japan's electricity mix, which were finally announced in April, 2015. The targets reflected a reduced role for nuclear power compared to the pre-Fukushima period but an increase over some low-nuclear scenarios that had been debated soon after the disaster (see: [264]). At the same time, the desire to restrain increases in energy costs that would reduce Japan's export competitiveness combined with efforts to maintain a well-diversified energy mix in order to improve energy security meant that the government saw an important ongoing role for fossil fuel-fired generation (including coal and LNG), as reflected in the electricity mix targets. While renewables have received a strong policy boost from the feed-in tariff scheme of 2012 and capacity additions for solar PV have been dramatic, constraints including the lack of grid connections, limited load sharing among Japan's regions and grid stability concerns associated with intermittency remain issues to be addressed over the longer-term.

Soon after the electricity mix targets were released, the new climate change targets were also announced that proposed more significant emissions reductions than previous proposals (see section 4.3). The government's climate change policy objectives are also being supplemented through the increased use of the UNFCC's Clean Development Mechanisms (CDM). This includes introducing clean energy technologies (such as clean coal technologies and high efficiency gas turbines) in foreign countries and gaining offset credits for GHG reductions achieved. This strategy serves to meet the government's goals of both stimulating energy technology development in Japan as well as expanding Japan's exports. In addition, Japan has committed U.S.$1.5 billion to the UNFCC's Green Climate Fund which will fund programs to reduce overall emissions and enhance climate change adaptation in developing countries [265]. Taken together, these developments suggest that sustainability issues have regained a prominence in energy policymaking that had been lost after Fukushima.

Given the increasing urgency in dealing with the effects of global climate change, the quickest and most cost-efficient method of reducing GHG emissions from power generation in Japan seems to be to safely utilize the country's existing capacity of nuclear power. This would allow Japan to reduce reliance on thermal generation from fossil fuels, lower related price risks (i.e.: reduced exposure to fossil fuel price changes) and improve its sustainability performance significantly in the short-medium term while renewables capacity is scaled up and grid stabilization and integration issues are addressed over the longer-term. Considering the significant investments that have already been made in nuclear technology in Japan, the fact that it is a low-emissions "quasi-domestic" power source and is cost competitive, a strong argument remains for its continued use as long as outstanding safety issues and local concerns are addressed. Japan is faced with energy security challenges that are unlike those of virtually any other developed economy.

4.3.6 Conclusion

In summary, this chapter addressed the third research question posed in this thesis by examining the impact of energy policies on energy security in terms of the relationship with other policy goals. Energy security and climate change policies and targets from the 2000-2010 period indicate that Japan attempted to balance the "3-E's" of energy security, economic efficiency, and environmental suitability and aimed to achieve both energy security and climate change objectives simultaneously. Over this period, the findings show that Japan's energy security situation generally improved but a number of key policy targets and objectives were not met. After the triple disaster, energy security and economic efficiency concerns took precedence over sustainability goals as the government sought to protect the economy. The implications of these findings will be further discussed in Chapters 4.4 and 6.

Chapter 4.4: Outstanding energy security concerns and vulnerabilities

This chapter summarizes the current (to 2013) energy security situation in Japan, synthesizes the findings of the analyses in the previous three chapters and identifies ten energy security vulnerabilities and concerns that remain outstanding in the post-Fukushima period. The policy implications of the issues raised in Chapter 4 are also discussed.

Overall, despite the robustness of Japan's energy infrastructure and improvements in energy system resilience and adaptability up to 2011, the triple disaster was a shock of such magnitude that the energy system shifted to an alternative, less desirable state as indicated by much greater reliance on fossil fuels, worsened diversification in both primary energy supply and in the electricity mix, elevated levels of carbon emissions and increased uncertainty surrounding the future of nuclear power.

The analyses in Chapter 4 identified a number of energy security concerns that emerged after the triple disaster and remain to be addressed. These concerns continue to negatively impact both energy security and sustainability in the post-Fukushima period and several are analyzed in more depth in Appendix C. Here, they can be summarized as follows:

Robustness concerns:

- *Electricity infrastructure* – Including inadequate inter-regional electricity interconnections and exchange, electricity frequency conversion bottlenecks, over-investment in electricity infrastructure capacity, and sustained high prices for electricity.
- *Nuclear power adequacy* – Includes the aging of nuclear power plants and the uncertainty surrounding approvals for restarts, creating risk to nuclear adequacy in future.
- *Gas infrastructure* – Including lack of inter-regional pipeline connections, over-investment in gas infrastructure, lack of pipeline connections to foreign sources of supply, and sustained high prices for gas services.

Resilience concerns:

- *Increased dependence on fossil fuels* – The shutdown of nuclear power plants led to a sharp increase in dependence on fossil fuel imports, especially from the Middles East and exposing Japan to higher geopolitical risks.
- *Issues constraining renewables expansion* – The very low level of non-hydro renewables generation, weak policy commitment to increasing renewables generation up to 2012, and significant barriers that limit their increase.
- *Weak demand-side management strategies* – Low level of demand-side measures aimed at the residential/commercial sector.

Adaptive capacity concerns:

- *Regulatory quality* – The establishment of the NRA may not be able to fully address all outstanding nuclear regulatory issues. A new electricity and gas market regulator has been established in ANRE but fairness, neutrality and transparency issues that existed up to 2013 in electricity and gas markets remain as issues to be fully dealt with.
- *Structural issues in electricity markets* – The regional monopoly structure and weak commitment to reforms up to 2011 resulted in the continued dominance of the GEU's in their regions, limiting competition and creating barriers for new entrants.
- *Structural issues in gas markets* – The regional monopoly structure and weak commitment to reforms up to 2011 resulted in the continued dominance of gas utilities in their regions, limiting competition and creating barriers for new entrants.
- *Decline in public support for nuclear power* – Issues concerning public acceptance of nuclear power have created uncertainties about the level and pace of plant restarts and therefore about the ability reach the 2030 electricity mix targets.

There is a qualitative difference between the risks that are within the power of Japan to control directly, and uncertainties that can only be addressed through strategies designed to enhance system response. The robustness-related concerns described above are risks that arise internally, from within the energy system and therefore are controllable. It is well within the ability of the government and industry to address them fully if there is the resolve and commitment. On the other hand, the concerns related to resilience and adaptive capacity represent opportunities to improve system response to the possibility of external threats which are uncertain and cannot be controlled. It would be prudent for the government to give priority to addressing robustness concerns first, because these are the ones that are most likely to reduce risk and provide significant improvements to Japan's energy security in the near to medium term.

Between 2012 and 2014, the Japanese government began to introduce various policies and plans that would potentially address many of the vulnerabilities and concerns noted above. A new Strategic Energy Plan issued in April 2014 put many of Japan's energy security challenges into a broader context, setting the stage for significant changes in Japan's energy system in the years ahead. The policies and implications of the 2014 SEP will be examined in detail in the next chapter.

Finally, climate change policies are an important consideration in energy policy planning. Japan's energy policy framework attempts to balance among the 3-E's of energy security, economic efficiency, and environmental protection. The 2000-2010 period was marked by a relatively balanced approach that retained a strong focus on achieving the Kyoto Protocol targets. This was to be achieved by expanding the fleet of nuclear power plants, improving energy efficiency and developing technologies to reduce energy consumption. Energy policy reconsiderations after the triple disaster greatly disrupted the balance between the 3-E's as nuclear reactors shut down and the country's priorities turned to dealing with the effects of the disaster and the severe challenges to Japan's energy security and international competitiveness. As a result, environmental (climate change) goals played a less prominent role in energy policy planning between 2011 and 2013 and these factors have made reaching Japan's long-term international climate change commitments even more challenging.

Chapter 5: Assessing change in Japan's energy institutions

Energy security is a function not only of the performance of energy infrastructure systems and the effectiveness of energy policies, but also the institutional structure that governs the system. Institutions and institutional change are important and relevant to energy security and therefore worthy of study. This chapter consists of two sub-chapters that are focused on examining Japan’s energy related institutions and assessing the implications of changes in these institutions.

Japan’s 2014 Strategic Energy Plan: A Planned Energy System Transition explains the key features of the 2014 Strategic Energy Plan and analyzes the plan’s significance for energy system change in Japan. *An institutional analysis of the Japanese energy transition* examines Japan’s energy-related institutions, institutional change and the implications for energy system transition and governance.

Chapter 5.1: Japan's 2014 Strategic Energy Plan – a planned energy system transition

5.1.1 Introduction

On April 11, 2014, the Japanese Cabinet approved the 2014 Strategic Energy Plan (SEP). This was the fourth such plan to be issued by the government. In a statement accompanying the announcement of the plan's approval, the government stated that the 2014 plan would form "the basis for the orientation of Japan's new energy policy, considering the dramatic changes in energy environments inside and outside Japan, including those caused by the Great East Japan Earthquake and the subsequent accidents at TEPCO's Fukushima Daiichi Nuclear Power Station" [266]. As the first plan to be issued after the disastrous events of March 2011, the 2014 plan embodies the most comprehensive and systematic changes ever proposed for Japan's energy system.

While many studies have examined aspects of Japanese energy policy, there have been very few analyses of Japan's strategic energy plans. Duffield and Woodall [267] described Japan's 2010 Basic Energy Plan (BEP[62]) in detail and analyzed the appropriateness and feasibility of its goals and targets using a descriptive approach.

In the period preceding the development of the 2014 SEP, a number of studies examined the implications of the Fukushima disaster for Japanese energy policy, including [14], [27], [28], [268]–[272].

Some studies have examined specific policies in the context of the 2014 SEP including fuel cell and hydrogen development policies [273], [274], the implications for climate change [8], [275], [276], nuclear power policy [14], [15], and energy system resilience [268].

Despite the fact that the 2014 SEP represents a major revision compared to previous energy plans and proposes groundbreaking energy system reforms, there has not yet been any detailed analysis of the 2014 plan or its broader implications for energy system change in the academic literature. The purpose of this study is therefore to explain the key features of the

[62] The terms "Basic Energy Plan" (BEP) and "Strategic Energy Plan" (SEP) are interchangeable. The Japanese government's English translation uses "Strategic Energy Plan" which is the term used in this study.

2014 Strategic Energy Plan and to provide an analysis that explains its significance for energy system change in Japan.

The structure of this study begins with a summary of the key drivers, goals, strategies and policy instruments proposed in the plan. This is followed by a discussion of relevant theory and the development of a theory-based analytical framework for the analysis. This framework relies upon the literature on socio-technical transitions and theories of policymaking as social learning. The analysis itself begins by comparing the 2014 plan with previous plans and discusses the relationship to other government plans and policies. A background to the development of the plan, including the key motivations and drivers that shaped its development is provided followed by a content analysis that discusses the nature and degree of change implied in the plan. Finally, the overall significance of the 2014 SEP for energy system change and the implications for structural and institutional reform in Japan's energy sector are assessed and discussed.

A unique aspect of this study is that it draws upon in-person interviews conducted with senior government officials who were directly involved in the formulation of the SEP, providing new insights into Japan's energy policy planning process.

5.1.2 The 2014 Strategic Energy Plan

The 2002 *Basic Act on Energy Policy* prescribes that a basic energy plan be issued at least every 3-4 years. The first such plan was issued in 2003, and subsequent plans were issued in 2007, 2010 and 2014. The 2014 strategic energy plan[63] is therefore the fourth such plan to be issued and is by far the most detailed and comprehensive to date. This section reviews the major policies, strategies and elements of the 2014 SEP.

1) Key assumptions and drivers of policy

The introductory section of the plan begins by laying out a wide array of potential threats and challenges facing Japan's energy system. The plan stresses the "harsh" environment threatening Japan's energy security and states that Japan faces a "fundamental vulnerability" as a result of its need to import almost all its energy resources. Energy security concerns

[63] The term "basic energy plan" and "strategic energy plan" are interchangeable, with the latter being the government's preferred English translation since 2010.

include increased dependency on the Middle East for fuel imports, resource competition and rising fuel prices, and increased greenhouse gas (GHG) emissions. Domestic challenges include those related to nuclear power plant safety, rising electricity prices and structural issues in electricity markets.

The plan views the Great East Japan Earthquake, tsunami and accident at the Fukushima Daiichi nuclear power plant as a major turning point, stating that an affordable and stable electricity supply cannot be secured simply by maintaining the electricity supply system of the past. It acknowledges that the circumstances surrounding energy "changed drastically" after the disaster, leading to a "new direction" for Japanese energy policy. It acknowledges the "safety myth" that was prevalent in Japan's nuclear establishment, the lack of attention to safety that led to the failure to prevent the Fukushima disaster, and the ongoing need for recovery and reconstruction efforts in Fukushima.

The stated intent of the plan is to give policy direction for changes in Japan's energy system over the medium to long-term (20 years). The plan mentions that Japan will "minimize its dependency on nuclear power" as a "starting point" for the reformulation of Japan's energy policy. The period between 2018 and 2020 is seen as a period of intensive structural reform in the energy sector as domestic electricity reform measures take hold and new, more stable and secure supplies of energy resources become available (i.e.: shale gas).

2) Principles and objectives

The SEP is built around two key principles that guide energy policy. These principles are premised on the notion that Japan's economic development cannot be sustained without "establishing an energy supply-demand structure that realizes a stable energy supply system which imposes a light burden on society".

In this vein, the "3E + S" principle emphasizes the primacy of ensuring energy security while also improving economic efficiency and environmental "suitability", with safety (S) as a basic premise. This principle is already embodied in Japan's *Basic Act on Energy Policy* and its inclusion in the SEP is a reconfirmation of its role in guiding energy policy development.

The second principle is aimed at building a "multi-layered, flexible and diversified energy supply-demand structure". This is primarily concerned with establishing a well-diversified and well-balanced portfolio of energy sources in the electricity generation mix whereby the strengths and weaknesses of various fuels are combined to achieve maximum efficiency and low cost.

3) The energy supply-demand structure

In addition to the two basic principles, the strategy outlines the government's perspective on the primary and secondary energy supply-demand structure.

Regarding the *primary energy supply structure*, various energy sources are prioritized and positioned mainly in terms of their role as electricity supply sources. The plan views nuclear and coal generation as "base-load" power sources, natural gas as an "intermediate" power source, and oil and pumped hydro as "peaking" power sources.

The *secondary energy structure* is defined primarily in terms of demand-side issues. Here, the government acknowledges the central role of electricity generation and the expansion of electrification in the economy, emphasizing the need to "maximize" efficiency by conducting further research into the efficient conversion of energy into electricity and heat while reducing waste and losses. Hydrogen is also seen as playing a major role a secondary energy carrier in the future. The plan reiterates Japan's "inability" to exchange power with neighboring countries, and calls for establishing a well-balanced wide-area grid so that electricity can be utilized more efficiently on a national basis. The plan also anticipates that major structural changes will be required in electricity markets in order to meet the principles and objectives of the plan.

4) Long-term measures and strategies

A series of ten long-term policy measures/strategies are proposed in order to address energy security issues and concerns. These measures are summarized as follows:

1) *Promoting secure and stable energy supplies* – The goal is to establish a "multi-layered" energy supply system by creating an "optimal portfolio" of energy sources and securing them in a stable and economical manner. Self-sufficiency is to be enhanced by promoting domestic energy sources including nuclear power, renewable energy and fossil fuels.

2) *Realizing an "advanced energy saving society"* – The goal is to create a "demand-side led energy supply-demand structure" and accelerate energy efficiency initiatives in all industry sectors in order to better "rationalize" the energy supply-demand structure and reduce greenhouse gas emissions.
3) *Accelerating the introduction of renewable energy* – Increase the introduction of renewables to higher levels than in previous plans and to continue efforts to enhance electricity grids, pursue deregulation, and reduce power generation costs.
4) *Re-establishing nuclear energy policy* – This strategy acknowledges the many failures in nuclear policy leading up to the Fukushima accident, leading to a loss of public trust. It puts restoration and reconstruction of Fukushima as the starting point for rebuilding energy policy. It acknowledges the stringent safety requirements of the newly established NRA and commits to restarting nuclear reactors that the NRA approves.
5) *Enhancing the environmental performance and efficient and stable use of fossil fuels* – Improve structural and performance efficiencies in the thermal power sector.
6) *Promoting structural reforms in the energy sector* – The goal is to realize a more efficient industrial structure in the energy sector. The regionally-based vertical electricity monopoly structure is viewed as inadequate to respond to evolving demands, therefore a more horizontally integrated structure is desired that allows new entities (including firms, local governments and non-profit organizations) to supply energy services.
7) *Enhancing the resilience of domestic energy supply networks* – The aim is to enhance the capability of energy supply and demand side systems to respond to crises and emergency situations.
8) *Further developing the secondary energy supply-demand structure* – The goal is to develop additional methods of transporting and storing energy so as to diversify the secondary energy supply structure. A "hydrogen society" will also be promoted.
9) *Creating new energy services businesses, "smart communities" and expanded global markets for Japan's energy technologies* – The aim is to leverage energy sector institutional reforms to trigger a "major transformation of the structure of the energy industry", establish new "smart communities", create new energy services companies, and increase participation by Japanese companies in international energy markets.
10) *Building comprehensive international energy cooperation frameworks* – Japan will better respond to international developments affecting the energy sector through strategic energy cooperation with countries and organizations closely related to Japan.

5) Other key elements

Promoting energy technology development

In order to reach the country's energy security and GHG emissions goals as well as reduce reliance on fossil fuels in the energy supply-demand structure, the plan calls for introducing "revolutionary" energy technologies throughout society. To achieve this, a long-term approach to energy R&D as well as institutional reforms will be required. The government will therefore develop an energy technology roadmap by the summer of 2014 in order to carry out various technology development projects.

Enhancing energy related communication and education

The government seeks public understanding of energy-related issues and Japan's overall energy circumstances. It will therefore provide information and "conduct public relations" in an "objective and transparent manner based on facts and scientific knowledge". It also commits to establishing mechanisms to promote "two-way" communication and dialog, particularly with respect to nuclear power and its risks.

5.1.3 Concepts and analytical framework

The previous section outlined the key principles, objectives and strategies in the SEP. In this section, we draw upon the literature on socio-technical transitions and theories of the state in order to develop a framework for the analysis of the SEP. This framework will be used to explain the significance of the SEP for energy system change in Japan.

The structure of this section proceeds as follows. First, socio-technical regime theory is reviewed, followed by a discussion of the literature related to socio-technical transitions. A major premise of this study is that energy systems are socio-technical systems, and so a macro-level understanding of such systems and how they evolve is essential to interpreting the overall magnitude of system change called for in the SEP.

In order to understand the implications of specific policies and strategies contained in the SEP in greater depth, an analytical framework also requires a theory for interpreting the nature and magnitude of change at the meso, or policymaking level. This is achieved by presenting key concepts from the literature on theories of the state, with a specific focus on the concept of policymaking as social learning.

1) Socio-technical systems and regimes

Energy systems can be conceptualized as socio-technical systems (STS). STS are a special type of complex adaptive system where technologies and infrastructure, institutional arrangements (e.g.: regulations, norms), social practices and actor relationships (e.g.: producer-consumer relations, industry associations, public authorities) are mutually dependent and are embedded within the broader context of cultural paradigms, norms, values, and socio-economic trends [45].

A refinement to the STS concept is that of a *socio-technical regim*e, which has been defined as a relatively stable configuration of institutions, technologies and infrastructures [277]. What distinguishes a regime is its stability, which is derived from the linkages between heterogeneous groups of actors and institutions which are aligned and coordinated with each other through rules, routines and practices [278].

Japan's energy system can be described as a regime. Its configuration has been shaped by the unique characteristics of its institutions, infrastructure and technologies. Regimes, including Japan's energy regime, evolve along *technological trajectories* as rules and actor behavior move technological development in the same direction through incremental improvements, creating stability but also path dependence [278], [279].

2) Regime transitions

Regime transitions are processes that involve a shift from the dominant regime to a new state of dynamic equilibrium by transforming rules, established technologies and societal practices – a gradual process that can take many decades [181], [280]. Studies of past energy transitions that have occurred throughout world history show that they are protracted affairs [281].

The transitions literature acknowledges that regimes are embedded within a broader environmental, social and economic "landscape". Changes in a regime are a function of selection pressures arising from various levels including the landscape, technological “niches” and from within the regime itself [282]. Socio-technical transitions necessarily require the coordination and marshaling of a wide range of actors, institutions, policies and resources, irrespective of whether changes are the result of planned or emergent processes [283]. Thus politics and the state have an important role to play in terms of committing resources, altering regulatory frameworks, balancing varied public interests and acting as a “channel” for society to exert selection pressures designed to change the regime in desired ways [181].

Smith et al. [105] argue that the governance of regime transitions is a function of two factors: (1) *selection pressures* acting on the regime, and the manner in which these selection pressures are expressed. Selection pressures may take the form of government policies, regulations, liberalized markets, niche innovations, public debates, etc., (2) the *coordination of resources*, whether available within or external to the regime, in order to adapt to selection pressures. Resources include material resources and infrastructure as well as financial, social and human (knowledge and skills) capital. The capacity to coordinate resources across regime elements comprises the *adaptive capacity* available for the regime transition [107].

Socio-technical systems are shaped by particular configurations of selection pressures acting on the regime. Regime transitions can be differentiated by whether changes are planned or autonomous. Planned transitions are coordinated through a “top-down” process of applying selection pressures in the form of deliberate policy interventions. Transitions may also result from a “bottom-up” emergent process that is shaped autonomously by agents in the system and the system’s own built-in rules [107], [284]. Examples of autonomous change in energy markets may result from inter-firm competition and technological change. In reality, energy transitions are a combination of both planned and autonomous changes.

Technological innovation plays a major role in energy transitions since it provides the basis for a new direction of system evolution. The creation of experiments and stimulating ‘variations’, as well as the application of selective pressures can help shape the trajectory of change [181]. Since regimes tend toward stability and are path dependent, the governance of transitions should be directed toward moving innovation activities onto a desired paths and away from less desirable ones.

3) Social learning, policy paradigms and change

It has been argued that policymaking is a form of reflection by policymakers on "what to do" on society's behalf in the face of uncertainty [285]. This in turn implies that policy is the output of a learning process and where, in pursuing the national interest, state actors "decide what to do without serious opposition from external actors" [286]. The concept of social learning asserts that ideas are central to policymaking and that policymakers work within an interpretive framework of ideas and mental models that specify the goals, instruments and nature of the problems they are trying to address.

Hall [287] defined the concept of *social learning* as "a deliberate attempt to adjust the goals or techniques of policy in response to past experience or new information". The process of social learning has three essential elements. The first is that the most important influence on new policies are the policies that existed previously. Secondly, the key agents of policy change are those people who are either in privileged positions working in government or in positions where they can exert influence on government. Thirdly, while non-state actors certainly influence the policymaking process, states have the capacity to act autonomously and independently of other social actors and societal pressures [287].

According to Hall, policymaking can be thought of as a process that typically involves three key variables: the goals and objectives that guide policy, the policy instruments that are used to achieve these goals, and the adjustments made to the policy instruments. Accordingly, Hall specified three orders of change in policymaking. *First-order change* involves adjustment of the means or instruments of policy; how existing policy tools are adjusted or fine-tuned. *Second-order change* is where the goals of policy remain the same but the instruments used to attain them are changed without changing a given policy paradigm. *Third-order change* involves changes in the goals and instruments of policy and a change in the paradigm itself. *Policy paradigms* shape the nature of policy choices and have a strong influence over policy development. This has been borne out in studies of China (see: [288]) and the United Kingdom [289]. Paradigms tend to be resistant to change as long as they continue to fulfill expectations but they can break down in response to significant policy failures.

While first and second-order changes involve social learning within the state, paradigm shifts result from social learning across society. However, while first-order changes are incrementalist and second-order changes are more strategic, neither of them necessarily lead to third-order changes. Changes to a policy paradigm require radical changes to the prevailing policy discourse and necessarily require political leadership, skillful persuasion and effective marshaling of resources [287].

The perspective on social learning outlined here is particularly applicable to state-centric forms of governance and elevates the influence of the bureaucracy over that of politicians in policy change due to the continuity and stability of bureaucratic institutions. This perspective seems suitable for application to a country such as Japan where the state, and bureaucracies in particular, have played an influential role in energy policy development and change. The notion of orders of change and policy paradigms seems particularly suited to the analysis of a national energy plan given that such plans embody policies and strategies designed to effect change in the energy system.

4) Methodological approach

The interpretive framework presented in this section integrates theories of socio-technical change at the macro-level of the energy system with a meso-level perspective on social learning that emphasizes the role of goals, policy instruments and paradigms in the policymaking process. This framework is applied to the content of the 2014 SEP as well as the policymaking process that led to its development in order to provide insights into the significance of the plan for energy system change. The analysis centers on the 2014 version of Japan's Strategic Energy Plan as published by the Japanese government in English.

In order to provide more in-depth insights into the development of the SEP and the role of Japan's bureaucracy in its formulation, a series of in-person semi-structured interviews were conducted with senior government officials from the Ministry of Economy, Trade and Industry (METI) who are or were directly involved in the development and implementation of the SEP and related policies. The interviews were conducted in person in late February and early March, 2016. Background information leading up to the formulation of the plan also relied on various analyses published in both Japanese and English.

5.1.4 Analysis

1) Comparison of the 2014 SEP with previous energy plans

Since the establishment of the Basic Act on Energy Policy, several national energy plans have been issued by the government. These are described below.

2006 NNES and 2007 BEP

The New National Energy Strategy of 2006 (NNES) [252] was crafted during a period where fossil fuel prices were rapidly rising and fears of resource competition, arising particularly from increasing Chinese demand, were of concern to Japan. The NNES was essentially a preliminary template for the 2007 BEP and was clearly focused on energy security. It was founded on 3 objectives:

- strengthening energy security
- a comprehensive approach to both energy and environmental issues (i.e.: sustainability)
- a commitment to working with Asian nations to avoid resource competition.

The 2007 BEP included 4 key strategies [290]:

- Promotion of energy conservation and energy efficiency and establishing a resource-saving socio-economic structure.
- Diversification of energy sources with a particular focus on nuclear power and the nuclear fuel cycle.
- Promotion of strategic and comprehensive measures for securing a stable supply of fossil fuels and uranium.
- Engaging in energy diplomacy and environmental cooperation with other countries and supporting the independent development of resources overseas by Japanese companies.

2010 SEP

The 2010 version of the SEP reconfirmed the 3-E's of Japanese energy policy but added two new goals that did not appear in previous plans. These were "energy-based economic growth" and "reform of the energy industrial structure". The plan states that Japan will "fundamentally change its energy supply and demand system by 2030". An explicit link to Japan's broader economic growth priorities was also added, stating that the plan was formulated so as to be "consistent with Japan's "New Growth Strategy".

Specific measures in the 2010 BEP included: energy cooperation and resource diplomacy initiatives to increase Japan's self-sufficiency ratio; enhancing the supply structure by expanding renewables, promoting nuclear power, implementing low-carbon technologies, building the "world's most advanced interactive grid network by the 2020's", realizing a "low-carbon energy demand structure", developing smart grids and hydrogen infrastructure, support for energy technology and innovation, resource diplomacy and measures to reduce carbon emissions.

Even though the 2010 plan set reform of the energy industrial structure as a new goal, the plan itself failed to include any significant deregulation or structural reform measures. Other than promoting hydrogen use and some new technology programs, most the strategies and measures in the plan were incremental and directed toward expanding on existing policies and programs.

The 2014 SEP differs from the 2010 version in several important respects:

- It commits to major structural and institutional reforms with specific policies. Energy sector reforms are to act as a lever to promote competition, stimulate changes in the energy industrial structure and promote new energy services businesses.
- Nuclear power is to play a less prominent role in the future – its use is intended to be "minimized".
- Renewables generation is targeted for significant expansion over previous SEP's and promoting distributed generation is added for the first time.
- It commits to link all of Japan's regional electricity grids into a national grid system.
- A wider range of demand-side initiatives are emphasized and calls for a "demand-led" energy structure.
- Coal is affirmed as an important base-load energy source and clean coal technologies will be promoted in electricity generation.
- Specific steps toward building a "hydrogen society" are highlighted.

- Externally focused strategic energy security initiatives play a more prominent role.
- A commitment to energy education and public engagement concerning energy related issues is included for the first time.

In summary, the NNES, and the 2007, 2010 and 2014 SEP's all share a primary focus on enhancing energy security. The NNES mentions building a "state-of-the-art energy supply-demand structure" and the 2010 SEP mentions "reform of the energy industrial structure". Although there are some similarities with the "multi-layered, flexible and diversified energy supply-demand infrastructure" of the 2014 SEP, both the NNES and the 2010 SEP incorporated policies that are best described as incremental. By contrast, the 2014 SEP takes a comprehensive and systematic approach to energy system change and includes specific policy goals and strategies designed to stimulate fundamental reform in Japan's industrial structure and energy institutions.

2) Relationship to other government policies

The government clearly views energy system reforms as a significant potential driver of new economic growth [291]. The *Japan Revitalization Strategy* (JRS) – also known as the "Growth Strategy"– was first released in June 2013 as part of the "three arrows" approach of "Abenomics" whose intent is to "put the economy back onto a full growth path". As such, the JRS represents the overarching plan for the "third arrow" of structural reforms and contains various policies and actions with specific goals and performance measures, and was revised in 2014 and 2015.

The Strategic Energy Plan of 2014 plays an important role within the JRS and the government's broader plans for "revitalizing" the Japanese economy. As part of the *industry revitalization action plan* within the JRS, energy sector reforms are positioned as contributing toward enhancing the international competitiveness of the industry sector. In particular, completing electric system reform "by 2020 at the latest" is highlighted as a key performance indicator. In addition, many of the strategies mentioned in the SEP are affirmed in the JRS as well and some include specific performance indicators. With an eye on the 2020 Olympics in Tokyo, the 2015 revision of the JRS adds an emphasis on developing distributed generation ("distributed energy resources") as a public-private project meant to showcase Japanese technology and know-how [292].

3) Policymaking and the development of the 2014 SEP

As early as October 2011, several months after the triple disaster, revisions to the 2010 BEP were being discussed and considered by Advisory Committee Natural Resources and Energy, Fundamental Issues Subcommittee [293]. The subcommittee stated that as a consequence of the disaster and the vulnerabilities it exposed, Japan's energy policy was "approaching a major turning point" and that a revised plan was to be formulated from a "zero-base". Furthermore, the committee stated that the energy supply structure needed to be "fundamentally revised" and that an "ideal" energy mix along with measures to achieve it would be required. In particular, the committee said that the ambitious targets for nuclear power made in the 2010 BEP would have to be fundamentally altered without eliminating nuclear power entirely, in order for the country to maintain its technical infrastructure and specially trained staff.

Despite the vulnerabilities exposed by the triple disaster and the deliberations of METI energy subcommittees, the Democratic Party of Japan (DPJ) government did not issue an early revision of the SEP, likely due to its preoccupation in dealing with disaster recovery and other urgent issues arising as a result of the triple disaster. After the election of the Liberal Democratic Party (LDP) in December 2012, the new Abe administration decided on January 25, 2013 to undertake a "zero-based review" of the previous administration's energy and environmental strategies for the purpose of establishing a "responsible energy policy which also ensures a stable supply of energy and reduced energy costs". At the same time, dependence on nuclear power generation would be reduced "to the extent possible" [294].

Meanwhile, deliberations on electricity system reforms had been proceeding for some time. The *Electricity System Reform Expert Subcommittee*[64] was formed by METI in February 2012 and held 12 meetings, delivering a final report with recommendations on February 8, 2013 . The Committee's report (see: [295]) provided a detailed analysis of the weaknesses of the Japanese electricity system. The report noted that electricity market and institutional reforms introduced starting in 1995 did manage to reduce electricity prices but that despite these reforms, "no significant change has occurred in the market structure of the current electricity system". In particular, the regional monopoly system was singled out for being insufficiently competitive.

[64] The committee was chaired by Motoshige Ito, a professor of economics at the University of Tokyo and the 10 other members who were mostly academics from various Japanese universities.

The report details a number of problems with Japan's electricity system that were revealed by the events surrounding the triple disaster including: a lack of options for consumers to choose their own suppliers, the inability to utilize generation in merit order, the lack of connection of renewables to the grid, the need for a more diverse range of power sources, the lack of national grid integration, and the need for fair and neutral access to the electricity grid. The report stated that a stable and secure energy supply could not be assured simply by maintaining the vertically integrated regional monopoly supply system and that a "paradigm shift" in Japan's power supply structure would be necessary. The report concluded that major electricity reform efforts were required and provided detailed recommendations on changes [295]. Based on this report, the Abe cabinet approved the *Policy on Electricity System Reform* on April 2, 2013 and made a number of recommendations including a three-step electricity liberalization plan [295], [296].

From the summer of 2013 METI officials began to be concerned about the growing number of energy security threats facing Japan, including the possibility of oil supply disruptions resulting from a threatened attack on Iran's nuclear facilities by Israel, the stability and security of energy supplies from the Middle East in general, and rising energy prices[65]. It was around this time that the government also began to consider stepping up efforts to obtain energy supplies from more secure sources and sea lanes, particularly North America. In view of energy security threats, nuclear power was seen as essential to assuring that Japan had a diversified, stable and robust domestic energy supply. But without a new energy plan, bureaucrats felt that they could not defend the policies they felt were necessary to address Japan's energy security issues from public criticism. METI officials felt they needed an "integrated policy management architecture" that incorporated clear policy principles – a kind of "constitution for energy policy[66]".

The process of producing the SEP normally involved a "bottom-up" process where various committees and subcommittees under the Advisory Committee Natural Resources and Energy (ACNRE) develop "policy packages", and then move them up the main committee (ACNRE) for discussion and integration.[67] However, METI felt that the usual subcommittee process would "not be useful" in the turbulent and politically-charged atmosphere that

65 Based on interviews with senior METI officials.
66 Interview with a senior METI official directly involved with compiling the strategic energy plan.
67 As of April, 2014 there were 36 such committees under ACNRE. The minutes of committee deliberations are normally made available to the public.

prevailed post-Fukushima. It was therefore decided to engage only with the main ACNRE committee.[68] METI's strategy for the SEP was to develop a comprehensive policy framework built around a set of principles, thus minimizing the opportunity for special interests to influence the outcome. Once the plan received Cabinet approval, it could not be derailed.[69]

Before the work on developing the SEP began, a number of energy policy initiatives had already begun under the DPJ government in response to the urgency of the issues facing the nation after the triple disaster. This included the creation of the NRA, the work of the *Electricity System Reform Expert Subcommittee*, the introduction of the new feed-in tariff (FIT) program for renewables, and other measures. The SEP had to incorporate these ad-hoc measures within a comprehensive energy policy framework.

METI planning officials were charged with developing a draft of the plan, working in consultation with the Chairman of the ACNRE, Mr. Akio Mimura (former Chairman of Nippon Steel Corp.). The recommendations from the *Report of the Electricity System Reform Expert Subcommittee* would play a central role in the reforms embodied in the plan. Actual discussions began on August 27, 2013 after which the Strategic Policy Committee[70] working directly with ACNRE developed a "Draft Opinions on the Basic Energy Plan" document [297]. A consensus on a first draft of the plan (developed largely by METI officials) was reached by the committee on December 13, 2013[71], after which the document was released for public comment. After the public comment period ended, a final draft of the plan was completed by METI on February 25, 2014 and then moved through the political process. After receiving approval by the cabinet, the final document was released to the public on April 11, 2014.

In summary, unlike previous strategic energy plans that were consolidated from the work of a large number of specialized subcommittees over a long period of gestation, the 2014 plan was developed relatively quickly by a very small group within ANRE's policy planning group in consultation with the ACNRE committee alone. This fact helps explain why the 2014 plan reads as a more cohesive and comprehensive document, reflecting the priorities of METI in

68 Interview with a senior METI official directly involved with compiling the strategic energy plan.
69 Interview with a senior METI official directly involved with compiling the strategic energy plan.
70 The Strategic Policy Committee is the most important committee under ACNRE and can be considered as a functional part of the ACNRE.
71 Interview with a senior METI official directly involved with compiling the strategic energy plan.

the post-Fukushima period where energy security concerns and a sense of urgency heavily influenced the policy environment in which the plan was developed.

4) Content analysis

In analyzing the narrative in the plan, a number of references to making transformational changes in Japan's energy system can be found. For example, the plan states that a "major transformation of the structure of the energy industry to be triggered by institutional reforms" (SEP, p. 73). The plan refers to making "institutional reforms" and promoting "structural reforms" (i.e.: oil refining, electricity and gas markets) numerous times. The term "reform" appears 69 times mostly in reference structural reforms, while the term "institutional" appears in tandem with "reform" 15 times. According to METI officials, the term "structural reform" is used to refer to policies designed to change the energy industrial structure[72] (i.e.: the regional monopoly energy utilities). This also includes the petroleum refining and retailing sector since METI wants a more sustainable and efficient oil refining industry in light of steadily declining petroleum demand in Japan.[73] This element of reform is also one that has not been seen in previous versions of the SEP.

The term "institutional reform" refers to deregulation and liberalization policies. These are aimed primarily at the electricity sector since institutional reforms in the petroleum sector were undertaken in the 1990[74]'s. Since the electricity sector is still heavily regulated by the Electricity Business Act, institutional reforms were deemed as necessary. Thus METI's perspective on institutional reforms includes the dismantling of the regional monopoly structure and the fixed price (regulated prices) system.[75] Other institutional reforms include changes to the renewables policy, including a bill to amend the FIT system.

Levels of change in the SEP

Many of the policies and strategies mentioned in the SEP can be classified as first-order changes since they build on existing strategies and plans but enhance them by reinforcing current programs (such as energy cooperation and resource diplomacy efforts, exploiting

72 Based on interviews with senior METI officials.
73 Based on interviews with senior METI officials.
74 Based on interviews with senior METI officials.
75 Based on interviews with senior METI officials.

domestic non-renewable resources, enhancing energy efficiency), or increasing their scope (such as including energy efficiency requirements in the Top Runner program for residential and commercial buildings). Innovation and technology development is a strong theme running through the SEP and, while the plan is short on details, many of these initiatives appear to be first-order changes that are directed toward strengthening or expanding existing policy initiatives.

The realization of a “hydrogen society” can be considered a second-order change. Achieving a “hydrogen society” was mentioned in the 2006 NNES and hydrogen infrastructure and technologies are also prioritized in the 2010 SEP. However, the 2014 SEP elevates the prominence of this goal and introduces a number of new policy instruments meant to achieve it including developing a comprehensive “roadmap” to coordinate efforts and investing in projects to produce hydrogen overseas for export to Japan. The creation of a hydrogen society clearly appears to be more of a technology development strategy rather than a paradigm-shifting vision for the future of Japan’s energy system.

Strategies related to the acceleration of renewable energy sources are another example of second-order change. Japan had been promoting the introduction of renewables for many years through various programs with only marginal success up to 2012. With the introduction of the new FIT program in 2012, renewables (especially solar) capacity has rapidly increased. However, the SEP states that “higher levels” of renewable power will be pursued. In line with this change, the release of energy mix targets in 2015 set renewables generation targets significantly higher than the targets in previous plans [298]. The SEP also proposes a new policy instrument, the “Related Minister’s Cabinet Meeting on Renewable Energy” to promote cooperation and coordinate efforts in support of renewables across ministries.

An example of third-order change is centered on creating a more *efficient energy industry structure*. Although steps toward partial liberalization in the electricity sector had been rolled out in previous years, the SEP affirms the recommendations of the 2013 *Report of the Electricity System Reform Subcommittee* which addressed a number of energy system vulnerabilities exposed after the triple disaster and developed a comprehensive three-step “roadmap” for electricity system reform. The SEP expands on this with a broad vision for the future energy industrial structure which it sees as moving from one that is vertically segmented by market to one that is horizontally integrated across energy segments.[76] This is to be accomplished by "eliminating market barriers through institutional reforms", as well as the introduction of new technologies and management practices. This includes the "creation of comprehensive energy companies through market integration", allowing energy-related companies to enter each other's market segments.[77]

A second example of third-order change is the creation of a *demand-side led energy system*. This is a new goal that includes some policy instruments not seen previously. The SEP talks about finding an "optimal energy supply-demand structure for Japan[78]". It mentions a number of problems with the current structure, including its lack of flexibility in providing demand-side pricing and services options[79] and calls for end-user participation in the energy system.[80] Enabling demand-side participation is seen as determining the type and scale of energy sources in the market (i.e. the energy mix) and enhancing system stability. This is to be achieved through strategies such as implementing demand-response systems, smart grid technologies, smart communities, and promoting a distributed energy system.[81] This vision represents a major paradigm shift from a centralized, supply-side focused energy system to one that is distributed and demand-responsive.[82] It also implies a much smaller role for government and the regionally-based General Electric Utilities (GEU's) in determining the energy mix, leaving this largely up to markets.

5) Resource (budget) commitments to the plan

In addition to the regulatory reforms and liberalization measures that have already been implemented, the seriousness of the commitment to energy system reform can be evaluated by looking at government budget allocations to programs and initiatives aligned with the goals and policies of the SEP.

Table 13 has been adapted from METI data and shows METI's annual budgets for FY2013-FY2016. In FY 2014, the same year the revised SEP was issued, METI's total energy-related

76 SEP, p. 60
77 ibid., p. 73, 74
78 ibid. p. 6
79 ibid. p. 12
80 ibid. p. 16
81 ibid. p. 42, 66, 75
82 ibid. p. 19-20, 40-41

budget[83] (including the supplementary budget) of ¥1,224 billion was increased by almost 40% over the previous year and FY2015 budgets have been maintained at a similar level. A budget breakdown shows that the increases are closely aligned with the strategies and initiatives outlined in the SEP. In 2015, significant new funding has been allocated to measures to improve energy efficiency and conservation, expand renewables generation, develop domestic energy resources, build resilience in the energy supply chain and conduct R&D related to energy and environmental technology [299]. Based on METI's 2016 budget requests, it is likely that energy budgets will increase again. As a result, energy-related budgets now represent about 78% of METI's total budget.

Table 13. METI budget allocations (billions of Yen)

Item	FY2013	FY2014	FY2015	FY2016 (requested)
General account	329.9	337.0	338.3	395.3
Energy resources special account[a]	783.3	872.7	796.5	975.7
Subtotal	1113.1	1209.7	1134.7	1371.0
Supplementary budget for energy measures[b]	93.0	351.5	382.6	N/A
Grand Total	1206.1	1561.2	1517.3	N/A
Energy related only (a+b)	876.3	1224.2	1179.1	N/A
Change in energy-related budget over previous year	N/A	39.6%	-3.7%	N/A
Share of energy-related budget to total budget	72.7%	78.4%	77.7%	N/A

Source: METI

Other ministries have requested increases for energy-related programs as well. For FY2016, the MOE requested an increase of 175.7 billion yen for energy-related measures (i.e. energy conservation and renewables) representing a 62% increase over the 2015 budget request [300].

In summary, the initiatives laid out in the 2014 SEP have been backed up by substantial funding in government budgets. While it is not possible to say whether funding at these levels is adequate to achieve the goals in the SEP or whether the funds will be effectively spent, it seems reasonable to conclude that there has been a serious effort to provide substantial resources even within a tight fiscal environment.

83 The "energy-related" figures given here do not include allocations related to Fukushima reconstruction and two special accounts for patents and trade reinsurance.

5.1.5 Discussion: a planned energy transition

Several scholars have argued that the triple disaster served as an “exogenous shock”, moving Japan’s energy system toward a new post-disaster mode [301], or even toward a “low-carbon transition” [275]. After the disaster, many Japanese observers viewed the catastrophe as an opportunity for a major transition in the energy system [41]. Indeed, the SEP itself mentions that the triple disaster caused “drastic changes” in the circumstances surrounding Japan’s energy system leading to a “new direction” for Japanese energy policy. The government itself has stated that the SEP represents a fundamental rethink of Japanese energy policy undertaken from a “zero-based review”.

Socio-technical transitions typically unfold over many years or decades. However, certain events may conspire to accelerate the type, rate and magnitude of changes. The shock of the triple disaster opened up a window of opportunity in Japan’s policy environment for a fundamental change in Japan’s energy policy.[84] This allowed for major and fundamental reforms to the energy industrial structure and energy institutions that were not possible in previous plans due to the predominance of the regional monopoly electricity structure policy paradigm and political resistance from entrenched interests. The Strategic Energy Plan of 2014 embodies policies that would potentially result in the most comprehensive and significant changes to the energy system since the early 1950’s.

Given the nature and magnitude of the potential changes already described, we can conclude that the 2014 SEP is a major planned transition of the Japanese energy system. The most significant factors supporting this assertion can be summarized as follows:

- The dismantling of a policy paradigm that had been in place for over 60 years – the regional monopoly electricity supply structure– and its replacement with a new paradigm: a “multi-layered and diversified flexible energy supply demand structure”.
- The “top-down” government-led process that was employed to develop the SEP and secure its approval.
- The comprehensive and systematic approach to addressing system-wide vulnerabilities and issues as reflected in the plan.

[84] Interview with a senior METI official directly involved with compiling the strategic energy plan.

- Third-order changes that point to significant changes to the energy industrial structure and energy-related institutions.
- Significant budget enhancements to support programs that are aligned with the objectives of the SEP.
- Specific long-term goals and targets included in the plan or in closely related policy documents (such as the electricity mix targets issued in 2015).

Similar to the German energy transition (*Energiewende*), the Japanese energy transition implies not only technological/infrastructure changes but also fundamental social and institutional changes. However, unlike the German case where the transition is driven primarily by sustainability goals with an emphasis on renewables, the Japanese transition gives priority to energy security and its vision for a "multi-layered and diversified flexible energy supply demand structure". As demonstrated in this study, the majority of the policies and third-order changes embodied in the SEP support an energy security driven paradigm, with sustainability-related strategies playing a lesser role and leading only to first and second-order changes. Thus, the 2014 SEP can best be characterized as a major "energy transition" rather than as a "low-carbon transition".

5.1.6 Conclusion

In summary, this chapter partially addressed the fourth and fifth research questions posed in this thesis by analyzing the 2014 Strategic Energy Plan and assessing its significance for institutional change and potential impact on the energy system and for energy security in the future. The analysis showed that the shock of the triple disaster opened up a window of opportunity for fundamental change in Japan's energy policies with the potential for significant changes to the energy industrial structure and to energy-related institutions. Given the nature and magnitude of the potential changes implied in the SEP, it is concluded that the 2014 SEP represents a major planned transition of the Japanese energy system. The implications of these findings will be further discussed in Chapters 5.2 and 6.

Chapter 5.2: An institutional analysis of the Japanese energy transition

5.2.1 Introduction

Energy security is a function not only of technology and policy, but also the institutional structure that governs the system. Institutions and institutional change are important and relevant to energy security and therefore worthy of study. This chapter focuses on institutions and institutional change since the energy system is embedded within an institutional context which impacts on the energy system and on energy security.

Japan's energy sector has been undergoing gradual change since the first liberalization efforts were begun in the petroleum sector in the 1980's and in the electricity sector starting in the 1990's (see Appendix A). As discussed earlier in this thesis, a number of laws, policies and plans were issued over the 2000-2010 period designed to further advance liberalization in Japanese electricity and gas markets, but with mixed results. After the triple disaster, a number of energy security vulnerabilities and issues were exposed or became more acute. In response to the disaster, the government formulated the 2014 SEP which proposed major institutional and structural reforms and provided a policy framework that can be described as a plan for a major energy transition.

A question that remains to be addressed is, how effective will these recently introduced policies and plans be in addressing energy system vulnerabilities and will they lead to improved energy security in the future? The application of institutional theory to Japan's energy system can serve as a powerful interpretive framework for understanding the factors that drive or constrain change in the energy sector and for exploring how various policies might impact on the energy system as actors and institutions react and respond to policy measures.

This chapter aims to provide a better understanding of the institutional structure for energy in Japan, how that structure has been changing, and the implications for the energy system and energy security. In order to achieve this objective, an overview of institutional theory is given followed by an in-depth examination of the embedded institutions, institutional environment and institutions of governance that help shape the way the energy sector in Japan changes and evolves. Current developments and changes in Japan's energy-related institutions are also described and related to recent Japanese energy policies. Outstanding energy security issues are examined in the context of institutional change in Japan. Finally, the chapter discusses the implications of institutional changes on governance of the energy transition.

In a recent study, Andrews-Speed pointed out that while the term "institution" appears in various studies of socio-technical transitions, the term is rarely defined nor explained adequately [36]. In addition, most studies of energy security and policy generally tend to overlook the institutional context and its impacts on energy security. A comprehensive post-Fukushima analysis of Japan's energy institutions is lacking in the literature, despite the significant changes that Japan's energy sector is undergoing. Moreover, a detailed institutional analysis of Japan's energy transition, as implied in the 2014 SEP, has not yet been examined in the literature. One study (see: [274]) has suggested that Japan may be transitioning to a "hydrogen society" based on a review of policies and programs to support hydrogen and fuel cells. However, this conclusion is not supported by most of the goals and objectives in the 2014 SEP and the analysis in this thesis argues that a different kind of transition is underway.

There are very few systematic studies of Japanese energy institutions in the scholarly literature. Samuels [37] analysis of the role of the state, markets and institutions in Japan's energy system is extensive and insightful but is now dated since much has changed since this book was published in 1987. A few recent studies by political economy scholars have included an institutional analysis in their study of the impact of the Fukushima disaster on energy policy and related institutions. Many of these studies come from political economy scholars who generally employ rational choice theory. This approach views institutions as being deliberately constructed by actors so as to promote and protect their own interests [38]. These studies assert that change in Japan's energy system has been effectively blocked by Japan's monopoly utilities, the so-called "nuclear village" and various interests conspiring to preserve the status quo. Whether through institutional resilience (see: [39], [40]), discourses that shape public perceptions (see: [41]–[43]) or the power of vested interests (see: [13], [24], [27], [44]) the dominant perspective of this literature assumes that the public will has been ignored or subverted and that institutional rigidities fostered by cozy relationships among politicians, the bureaucracy and industry vested interests have slowed or prevented change in Japan's energy institutions. One recent study on Japan's energy security that adopts this perspective is Vivoda [28]. This study makes the assertion that even after the Fukushima disaster, Japan's energy institutions and policymaking process "remains dominated by vested interests and centered on METI" [28].

This study takes a different approach and, as will be demonstrated, reaches very different conclusions than the studies noted above. Rather than adhering to single model of institutional analysis, the approach in this study is broad and systematic, integrating various economic, political and sociological perspectives on institutions with primary data gathered from in-person interviews in order to develop a more balanced and holistic approach to the analysis.

5.2.2 Background and theory

In this section, theories of the state, institutionalism and governance theory are presented in order to lay the foundation for the development of a framework for the analysis of energy institutions and institutional change in Japan which will be presented in the next section.

A theory of the Japanese state is required in order to understand the broader context of the economic system within which Japan's energy institutional structure has evolved and how actors in the system influence the institutional structure. Institutional theories provide a firm foundation for the analysis of Japan's energy institutions and institutional change at various levels. A theory of governance that is relevant to the energy system as a socio-technical system is necessary in order to understand the unique aspects of governing such systems.

1) Varieties of capitalism

To assist in understanding the institutional similarities and differences within developed capitalist economies, Hall and Soskice [302] developed the *Varieties of Capitalism* theory of the state. Their major premise is that government plays a major role in setting the regulatory frameworks that determine the shape of institutional structures. Their approach is focused on the role of multiple actors – whether individuals, firms, producer groups, or governments – who seek to advance their interests in a rational way while interacting with other actors. Companies are viewed as the key actors since they determine the adjustments made in the economy in response to competitive forces and technological change.

Following from this, they describe two major types of capitalist economies: *liberal market economies* and *coordinated market economies*. These are viewed as two ideal types that are situated at both ends of a spectrum along which nations may be categorized. In liberal market economies (LME), firms coordinate their activities mainly through hierarchies and competitive markets. Actors adjust supply and demand in response to price signals through market mechanisms. Market mechanisms therefore serve as the primary mechanism for coordinating the actions of economic actors.

In coordinated market economies (CME), companies are much more dependent on non-market relationships to coordinate their actions with other actors. Such non-market coordination involves deeper and broader relationship contracting, networking, the exchange of private information and greater reliance on collaborative relationships. Whereas in LME's firm behavior is largely determined in response to demand and supply conditions in competitive markets, the outcomes of firm behavior in CME's are also determined through strategic interaction among companies and other actors.

Following from this, institutions are viewed as facilitating relationships among firms in order to help resolve coordination problems. In LME's, market mechanisms are viewed as the key institutions that support coordination, characterized by arm's-length relationships and high levels of competition. In CME's, markets and hierarchies remain important but an additional set of *coordinating institutions* serve to reduce uncertainties among actors so that behavior is more predictable, allowing actors to make reliable commitments to each other. These institutions play a role in facilitating the exchange of information among actors, monitoring actor behavior, and providing sanctions against firms that display uncooperative behavior. Examples include industry associations, trade unions, networks of cross-shareholdings, and legal or regulatory frameworks that are designed to facilitate coordination, collaboration and information-sharing.

The concept of coordination discussed in socio-technical transitions literature and in the Varieties of Capitalism literature are similar and compatible. Energy transitions depend on the ability to coordinate resources (energy technologies, infrastructure, financial and human resources, etc.) across a wide variety of actors and institutions. At the same time, coordinating institutions serve to increase information sharing, collaboration and predictability while reducing uncertainty. Therefore, coordinating institutions can play an important role in facilitating an energy transition.

In CME's, institutions that facilitate cooperative behavior may do so through the use of *deliberative institutions* that encourage relevant actors to engage in collective discussion in order to reach consensus or agreements with each other. Such agreements may serve to reduce uncertainty about the behavior of actors through the exchange of information, to distribute the risks and/or gains from collective endeavors (such as collaborative research) and to enhance the collective capacity to respond to exogenous shocks or new and unfamiliar challenges. These institutions thus serve to enhance strategic capacities that would be unavailable to a single firm operating alone.

Culture, norms and informal rules play a particularly important role in determining outcomes in the economy. A nation's institutions are a product of its history in the sense that they are created both through explicit and deliberate actions (such as through laws and regulations) as well as through more informal norms, rules and sets of common expectations that allow actors to more effectively coordinate with each other. The institutional structure of a country serves to influence and shape the behavior of firms, rather that fully determine it.

Hall and Soskice categorized a range of capitalist economies according to the degree of non-market coordination and the value of stock market capitalization in the economy. Among large OECD nations, six were classified as LME's (the USA, Britain, Australia, Canada, New Zealand, Ireland) and ten were classified as CME's (Germany, Japan, Switzerland, the Netherlands, Belgium, Sweden, Norway, Denmark).

2) Institutional theory

Neo-institutionalism

Neo-institutionalism is a body of institutional theories that include economic, political and sociological perspectives [38]. Institutions have been defined as the laws, norms, and rules that underlie economic activity. Institutions are seen as central to the understanding of economies because they serve to structure systems of incentives and constraints, thus shaping the way the economy changes and evolves [303].

Various approaches to neo-institutional theory can be identified among three mainstream disciplines of economics, political science and sociology [38]. It is important to recognize that while these approaches emphasize different perspectives on institutions, they are not mutually exclusive and overlap to varying extent.

In the field of economics, the *transaction cost economics* approach was pioneered by Ronald Coase (1937) and more recently developed by Oliver Williamson. In this conception, and in contrast to classical economics, individuals are faced with uncertainty about the future, have access only to incomplete information and are limited by "bounded rationality". They therefore incur transaction costs in order to acquire information. Human beings therefore create institutions in order to reduce risks and transaction costs.

Whereas Williamson's view of transaction costs is focused at the level of exchange among individual actors, Douglass North [115] focused his analysis on the higher level cultural, political and legal structures that impact on economic performance. For North, human beings impose structure on their environment to reduce uncertainty and this results in a complex mixture of formal and informal constraints. Such constraints are an inherent part of the culture of a society, including its norms, beliefs and physical artifacts. The beliefs of a society are a key determinant of the institutional structure, which includes rules, norms and enforcement mechanisms.

While classical economics is concerned with the allocation of scarce resources to maximize utility, the structure that is imposed on competitive markets determines whether the outcome will be efficient or not. Institutions are defined as the "rules of the game" that constrain human behavior (North 1990). A complex structure of institutions is created to determine not only the rules but also how the rules are applied. Changing the rules will change the way the game is played. The way that institutions function and change therefore holds significant implications for economic and political performance (North 2005).

In the field of political science, *rational choice theory* developed as an extension to neo-institutional theory in economics. This theory is founded on the premise that actors are rational. Rational choice theorists recognize the importance of property rights, rent-seeking and transaction costs in the function and development of institutions. However, rational choice theory argues that economic approaches must be modified if they are to be applied to political systems. This approach views institutions as being deliberately constructed by actors so as to promote and protect their own interests. Actors are said to have a fixed set of preferences or expectations, act in a manner so as to realize or maximize these preferences, and do so in a strategic way that involves extensive calculation about how other actors are likely to behave. Institutions serve to structure interactions among actors, shaping the range and type of alternative choices as well as providing information in order to reduce uncertainties and influence the behavior of actors so as to better achieve social outcomes [304].

Another approach in political science is *historical institutionalism* which focuses on the nature of political systems and the way that political and economic institutions shape the nature and outcome of conflict such that some interests are promoted while others are demoted [304]. As such, this approach focuses more broadly at a higher level of the institutional structure, especially on how actor behavior is shaped by the interplay between the institutional structure, economic conditions and the diffusion of ideas, in contrast with rational choice theorists who are more focused on individual actor behaviors and their influence on institutions.

Historical institutionalism emphasizes three key features. Firstly, the way in which power is distributed across social groups is asymmetric such that some group's interests are favored over others. Secondly, although institutions are created by individual actors, they may evolve in ways that are unintended. Finally, institutional development is shaped and conditioned by choices made in the past – it is *path-dependent*. Given the foregoing, analysis has focused on how such paths are produced in response to national challenges.

A fourth perspective on institutions is offered by *sociological institutionalism*. This perspective grew out of the field of organization theory and argues that institutional development is more the result of the transmission of cultural practices than from some rational process of calculation and utility maximization. Institutions are seen as symbolic systems that have a reality of their own that exert a coercive power over individuals [305]. DiMaggio and Powell emphasize the importance of the cognitive rather than the rational aspects of behavior, emphasizing that individuals are influenced more by the routines and tacit expectations in organizations than by a rational calculus [38].

While some sociological institutional analyses have focused on individual organizations, much of the focus of recent scholarship has been at the level of *organizational fields*. An organizational field has been defined as “the set of interdependent populations of organizations participating in the same cultural and social subsystem [306]. The energy sector is an example of an organizational field. The focus of analysis is thus at a systemic level on the field of organizations rather than on individual organizations themselves which are seen as players within the field [307]. Analysis is focused on determining the reasons for certain institutional forms, rules and procedures and the reasons for the diffusion of such practices within the field.

Williamson [308] developed an integrative scheme that identifies four levels of institution. Each level imposes constraints on the level immediately below and the institutions at each level change at different rates. At the highest level (“Level 1”) are informal *embedded institutions* particular to the society in question, including customs, beliefs, norms, mental models and paradigms. These change only extremely slowly, on the order of centuries or millennia. The second level (“Level 2”) is the *institutional environment* which is constrained by the first level and includes formal rules and structures such as constitutions, laws, political systems, government bureaucracies. This level also includes systems of property rights, contracts and dispute resolution as well as policymaking and civil society. At this level change occurs over decades. “Level 3” consists of the *institutions of governance* which sets the rules that govern individual transactions and where actors and organizations (especially firms) seek to minimize transaction costs. This level includes policies, regulations, firms, markets, networks, and various hybrid organizations and structures. Adjustments at this level typically takes years. Finally, “Level 4” is the level of *individual transactions* as specified in contracts which determine prices and output in the economy on a continuous basis.

Institutional change

Institutional change has been addressed in neo-institutional theory as well as in governance theory and the literature on socio-technical transitions. The following section elaborates on some relevant concepts relating to institutional change.

According to North [303], institutions change by interacting with organizations in a competitive environment. In this conception, institutions are the rules of the game and organizations are the players. Organizations such as firms, industrial associations, political parties and government bureaux are made up of individuals bound together by common objectives. Institutions and individuals compete to take advantage of opportunities available under the given institutional structure. If organizations see greater opportunities under a different set of rules, they may induce institutional change by altering the rules if they perceive a reasonable chance of success.

Within the institutional literature, many scholars focus on the role of governments and the state in institutional change. Governments specify the rules and individuals and organizations engage in collective action to try to influence the rules to their advantage. The extent to which governments are seen to drive institutional change can be put on a continuum ranging from a playing a minor role to being a decisive factor. The extent of government's role in shaping the institutional environment is a function of the political structure within a given national context, as well of other economic, social and historical factors [309].

Path dependence

The subject of *path dependence* originally developed out of studies of technological change [99]. The future cannot be understood apart from the past and the current state is closely related to past developments. A path-dependent process occurs when "positive feedback" rewards developments in the same direction. Over time, positive feedback increases the cost of switching to alternatives, deepening path dependence. In the energy sector, fossil fuel energy systems have persisted due to technology lock-in and other self-reinforcing processes, despite negative impacts on climate.

Path dependence has been applied to institutions as well [115]. Human societies attempt to shape the future, yet institutions constrain the pace and direction of change. Over time, increasing returns from learning, coordination and the expansion of formal and informal rules tends to produce organizations that reinforce buy-in from actors in the system. As a result, organizations develop a resistance to change and will expend resources to preserve themselves in the face of threats to their survival.

Institutions are shaped by a combination of path dependence and the nature of competitive markets. According to North [303], vigorous competition is likely to lead to improved efficiencies and rapid institutional change while muted competition leaves little incentive to invest in new knowledge and skills, resulting in a more stable institutional environment. Non-competitive markets are characterized by high transaction costs and poor information feedback, leading to imperfect institutions and accounting for economies that display persistently poor performance [115].

The historical perspective sees institutional development as consisting of periods of continuity that are sometimes punctuated by *critical junctures*, or points in history where the path of institutional development may be altered and move onto a different path [304]. Critical junctures are a point in time when political agency and choice can play a decisive causal role in institutional arrangements [310]. An important characteristic of path-dependent processes is that in early stages they are relatively "open" to more than one possible outcome, whereas in later stages the path becomes well-established and relatively "closed" or "coercive". In later stages, the path becomes institutionalized as a result of positive feedback and self-reinforcing processes [311].

Institutional complementarities

The analysis of institutional change is complex because institutions do not evolve in a vacuum, they interact and co-evolve with other institutions at various levels. Thus, the causes of change are multiple and difficult to distinguish. *Institutional complementarities* exist when one institution reinforces the impact and characteristics of another institution [312]. Aoki [313] analyzed Japanese economic institutions and found that institutional complementarity plays a central role, producing institutional structures that are internally coherent and robust, but not necessarily efficient. Institutional complementarities tend to reinforce path dependence; reforming one institution will only be fully effective if its complementary institutions are also reformed, and this is very challenging to undertake [314].

3) The governance of CAS

In the preceding sections, theories of the state and institutional theory were reviewed in order to provide a foundation for the analysis of Japan's institutional structure. However, the process of governance is also important and relevant to energy security over the long term. In this section, the application of governance theory to complex adaptive systems is elaborated on in order to explain the unique aspects of governing the energy system.

Governance can be defined as "the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social norms and institutions" [315]. It is important to point out that *governance* as defined here is not synonymous with *government.* The process of governance (or the "governance system") potentially involves a broad set of actors and institutions including citizens, companies, industry associations, government bureaux, non-governmental organizations (NGO's) and international organizations.

This thesis has conceptualized the Japanese energy system as a socio-technical regime. A regime is a relatively stable configuration of institutions, technologies and infrastructures [277]. A regime transition has been defined as a gradual process of structural change involving a shift in technologies and institutions that takes place over a long period of time (typically decades). Transitions can potentially be managed or governed so that they evolve along a desired pathway, but consistent with CAS theory it must be recognized that the ability to anticipate or fully determine the future remains very limited. Planned transitions necessarily imply an important role for government which has the unique authority to apply regulations, taxes, subsidies and other policy instruments in order to shape or steer the transition [181].

In their discussion of the governance of complex adaptive systems, Duit and Galaz [173] argued that different forms of governance have a strong influence on system change and can play a decisive role on how the system reacts to disturbances and unanticipated events. They acknowledge the critical role adaptive capacity plays in system change, arguing that the adaptive capacity of a governance system is a function of the trade-off between *exploration* and *exploitation*. Exploitation refers to the ability to plan, implement, produce or select while exploration refers to ability to experiment, innovate and discover. As a result, there is a trade-off between control on the one hand (policies, plans, regulations and the capacity to implement) and autonomy on the other (experimentation, innovation and autonomous adaptations within the system). Society creates institutions and establishes norms of cooperation and in order to achieve predictability, stability and to lower transaction costs. However, the tradeoff for stability is rigidity as institutions become path dependent and resistant to change. It has been suggested that organizations (or nations) can explore and exploit the governance landscape between these two thresholds [316], [317].

Duit and Galaz defined four governance types based on the level of exploitation and exploration present in the system. Their conclusion was that the ideal type of governance is a *robust governance type* that combines a high capacity for exploration with an equally high level of capacity for exploitation and is the only type that has sufficient adaptive capacity to effectively deal with the complexity and unpredictability of a CAS. By contrast a *rigid governance type* maximizes stability while lacking in flexibility. Response to change is slow and incremental due to either biased or weak feedback mechanisms. This type is said to be characteristic of state-centric forms of governance, with France, Singapore and Japan (in the mid 2000's) being described as examples. Rigid, state-centric forms of governance are seen as performing well when change is slow and predictability is high, while robust forms of governance are said to perform well regardless of the level of predictability and rate of change [173].

Adaptive capacity and adaptive efficiency

Various scholars within the neo-institutional literature have employed concepts from socio-technical theory and evolutionary theory to help explain how institutions change and evolve over time.

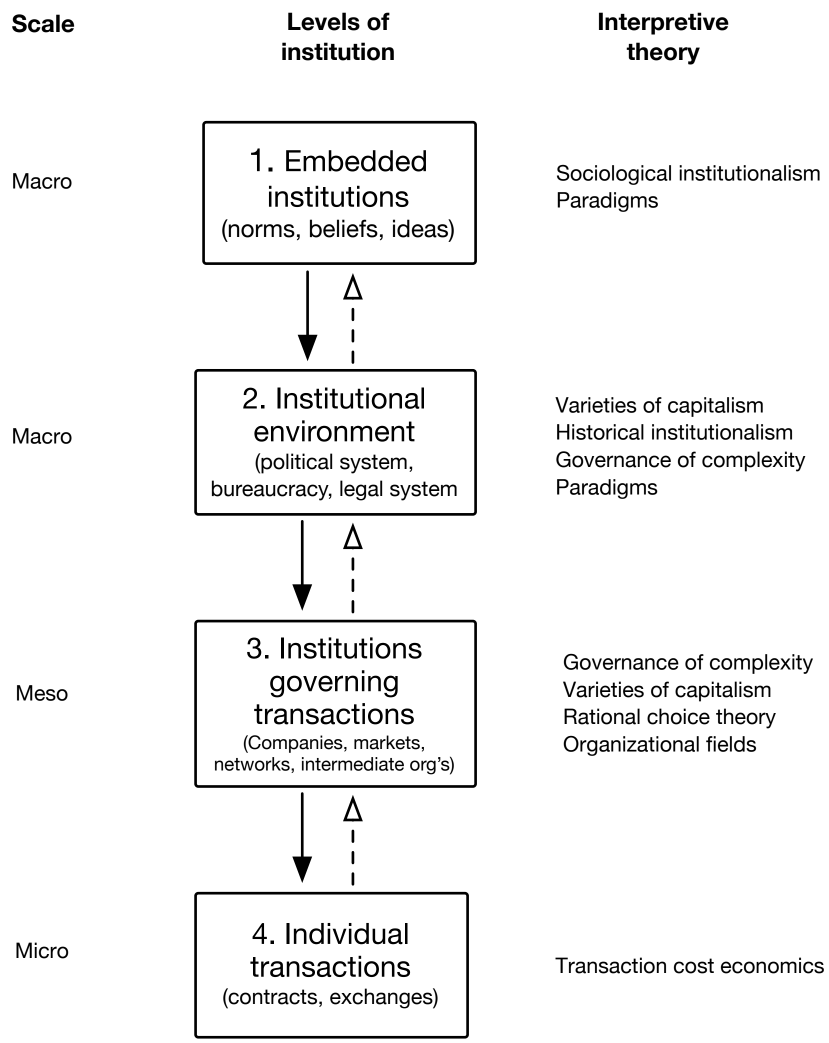
North [303] defined *adaptive efficiency* as the ability of a society to flexibly adjust in the face of shocks and uncertainty while evolving its institutions in order to respond to change. For North, successful economic development is predicated on a societal belief system that has created the conditions for that society to adapt to novel events and experiences. The adaptive efficiency of a society implies an ongoing ability to create or modify institutions in order to deal with problems and challenges as they emerge and to eliminate institutional adaptations that fail to resolve new problems. He characterized the U.S. and western Europe as embodying institutions that were adaptable and flexible in the face of shocks and disturbances allowing them to remain successful over the long run whereas the inflexibility and rigidity of Soviet institutions contributed to that country's ultimate downfall.

The concept of *adaptive capacity* from socio-technical transitions theory is consistent with the notion of adaptive efficiency from neo-institutionalism and the two concepts can be integrated. In this study, the term adaptive efficiency is used to refer to the ability of institutions to adapt, whereas adaptive capacity is used to refer to the ability of the energy system to adapt and transition.

5.2.3 Analytical framework and methodology

This study builds on concepts from the Varieties of Capitalism literature, neo-institutionalism, the governance of complexity and theories of institutional change to construct a framework for the analysis of institutions and institutional change in Japan's energy system.

Figure 50: Integrative institutional framework



Source: Adapted from Williamson [308] and Andrews-Speed [36].

The framework employed in this study consists of several elements drawn from the review of institutional theories provided in Section 5.2.2. First, the analytical approach developed by Andrews-Speed which applies socio-technical transitions theory, the notion of policy paradigms, and a broad perspective on neo-institutionalism to energy system transitions is employed as a foundation [36]. This approach employs an integrative framework based on four levels of institution developed by Williamson and described in Section 5.2.2. The advantage of this scheme is that it can accommodate elements from all the major approaches to institutionalism within the 4 levels (see Figure 50 – Arrows indicate the influence of one level on another, with the dashed arrows representing a weaker influence.)

This study builds on the basic framework described above by adding several additional elements that can be applied to the case of Japan's energy system.

With its contention that government plays a major role in setting the regulatory frameworks that determine the shape of institutional structures, the *Varieties of Capitalism* approach to political economy seems particularly suited to the Japanese case. Hall and Soskice described Japan as a coordinated market economy (CME) where non-market relationships play a major role in coordinating the behavior of actors [302]. This perspective is therefore incorporated into the analytical framework and applied to the Japanese case in order to help explain the changing role of government in shaping Japan's energy transition as well as the way in which forms of coordination are evolving in the Japanese energy sector.

Given that this thesis has defined the energy system as a socio-technical system that is also a system of systems, the framework examines institutions at different scales. This is implicit in the levels of institution described in Figure 50.

Embedded institutions and the institutional environment play an influential role in shaping the balance between exploration and exploitation and therefore the type of governance in the system. Therefore, Japan's energy governance will be examined in terms of the level of exploitation and exploration present in the energy system. The institutional literature also suggests that *market and non-market coordination* and *institutional complementarities* are two factors that should be included in the analysis of energy transitions.

Finally, the concepts of *path dependence* and *critical junctures* are used to explain institutional resistance to change and the conditions under which a shock may cause a system to shift onto a new developmental trajectory.

The analysis proceeds as follows. First, Japan's energy institutions are identified and described according to the various levels in the framework. Institutional changes are described and assessed for two periods: the period up to the end of 2010, and the post-Fukushima period from 2011 onward, with a special emphasis on the policies embedded in the 2014 Strategic Energy Plan. The analysis includes an assessment of the impact of post-Fukushima institutional and structural reforms on Japan's industrial structure and the implications for governance and long-term energy security.

While this basic framework is suitable for an analysis of Japan's energy institutions at various levels and explains how institutions at higher levels shape the behavior of institutions below, it has several limitations. First, it does not adequately account for how institutional change at lower levels exert influence on institutions at a higher level. Secondly, although institutional complementarities are discussed, the framework cannot fully explain the interactions *between* institutions and how these interactions serve to enhance or impede energy transitions. Thirdly, this framework has been tailored to apply to the particular context of the Japanese energy system. No two societies and institutional structure are alike. Due to its history and location, the Japanese energy system has some especially unique characteristics that bear on its institutions and on institutional change.

Although the general character of Japan's embedded institutions is described (see Appendix B), the analysis of institutional change will primarily focus on selected institutions at Levels 2 and 3. It is beyond the scope of this study to analyze the full spectrum of Japan's energy institutions. Instead, the focus will be on those institutions judged to be most critical to changes in those segments of Japan's energy system that are currently being liberalized: electricity and gas markets.

Research methodology

Qualitative data for this study was collected from scholarly journals and published works, government reports and websites (primarily from METI and the Cabinet Office), newspaper reports (for recent data on company and industry developments) and online databases.

A series of semi-structured interviews were held with senior METI officials on February 29 and March 1, 2016 for the purpose of gathering primary data for this study. A second set of interviews were undertaken with NEDO, the Japan Gas Association and other industry association officials in Tokyo on March 22nd and 23rd, 2016. The interviewed officials were either currently or formerly directly responsible for or engaged in the issues referenced in this thesis. Interview questions were prepared in advance in both English and Japanese and interviews were held in Tokyo. Interviews were approximately 1- 1½ hours long and voice-recorded. Proceedings were later transcribed in English.

5.2.4 Energy and related institutions in Japan

1) Japan's embedded institutions (Level 1)

Among the three levels of institution pointed out in Section 5.2.3, the highest level is composed of societal traditions, customs, norms and beliefs. These institutions exert a strong influence on lower levels of institutions as portrayed in Figure 50.

As important and influential as these institutions are, the primary objects of analysis in this study are at Levels 2 and 3. Refer to Appendix D for a discussion of embedded (Level 1) institutions.

2) Policy paradigms

In this section, several distinctive paradigms are proposed in order to help explain the framing of energy policy development in Japan. While any number of paradigms might be formulated to help explain Japanese energy policies, the three developed here would appear to have direct relevance to Japanese energy policies developed over recent years. However, a word of caution is in order. The paradigms described here are only one approximation for interpreting Japanese policies; many others are possible and equally valid. There is a danger of oversimplifying a complex reality by using such heuristics; reality is far more complex with overlapping causes. Paradigms also suggest a static rather than a dynamic explanation of policy, but this may be appropriate at least for the period under question given that paradigms are normally rather stable, although they sometimes shift or are overturned, as this analysis will demonstrate.

Of the three paradigms proposed, *Japan as a vulnerable "island nation"* is a "high-level" paradigm that operates at the level of embedded institutions and can be expected to change only very slowly. The other two paradigms, *regional monopoly electricity supply structure* and the *"safety myth"* are operative at the level of the institutional environment and have recently been severely challenged by the triple disaster and major changes in the policy landscape.

Japan as a vulnerable "island nation" – This paradigm views Japan as an "island nation", harboring a fundamental sense of insecurity driven by a long history of natural disasters, Japan's physical and cultural isolation, perceived external threats from foreign competitors, and anxieties about the lack of domestic natural resources. The "island-nation theory" (*shimaguniron*) suggests that the Japanese maintain a general perception of a threatened people living in a fragile land [318]. Japanese security policies play an important part in this paradigm since energy insecurity can be considered a subset of a wider national security discourse. After World War II, Japanese security policy took on a very restrictive defense posture as a result of the new constitution. The "peace-state security identity" prevailed in Japan up to the time of the end of the Cold War when Japan's security policies began to include a wider vision for its military as part of the U.S.-Japan security relationship. This transformation toward an "international-state security identity" continues up to the present, moving security policy from a domestic focus to more of an international one that includes a responsible role in international peace and security operations [319]. This paradigm drives energy policy toward such goals as reducing reliance on external sources of energy supplies, increased investments in energy projects in stable supplier countries, establishing energy cooperation initiatives with foreign partners, and strengthening external economic, military and security alliances.

Regional monopoly electricity supply structure – Under this paradigm, 10 regionally-based privately-owned utilities (GEU's) with near monopoly control over power generation, transmission and distribution built large-scale centralized generation facilities to provide one-way electricity services to customers within their regions. The current structure was put in place by the American Occupation authorities in 1951 and remained basically unchanged until very recently. Due to their size and influence at both the regional and national levels, the GEU's have been able to successfully fend off greater state intervention by acceding to regulation (particularly over rates) in exchange for maintaining stable power services over the span of the country's economic development. As a result, this supply-side paradigm has become institutionalized. At the same time, the state assumed the technological and financial risks associated with the development of nuclear power but entrusted the building and operation of nuclear power plants to the regional utilities [37]. This paradigm continued to have a strong influence on electricity policy up to the triple disaster, after which sweeping electricity market liberalization initiatives were announced that would cause major reforms to the regional monopoly structure, severely weakening and perhaps marking the eventual breakdown of this paradigm.

***The "safety myth"* –** was driven from a narrative that suggested that the absolute safety of nuclear power technology could be guaranteed. One possible reason that proponents of nuclear power embraced and promoted this safety myth was because contemporary Japanese society has been characterized as generally risk averse (or at least, highly "risk-aware", see: [320]) and was resistant to, or at least ambivalent toward, nuclear power up to the time of the Fukushima disaster. As post-disaster investigations have shown, the nuclear establishment, both in the private sector and in government minimized the risks of nuclear power to the public, were overconfident in Japanese nuclear technologies, failed to adequately develop and enforce safety requirements, did not maintain up to date advances in knowledge and technology and failed to take adequate preventative measures. The triple disaster exposed this paradigm to public scrutiny and it was thoroughly discredited both in the official reports on the disaster as well as in the public discourse [321]–[323].

3) The institutional environment (Level 2)

The second level is the institutional environment which includes formal rules and structures such as constitutions, laws, political systems, government ministries and regulators. This level also includes systems of property rights, regulations, policymaking and civil society. At this level change generally occurs over decades.

Under the 1946 constitution that was crafted during the Allied Occupation, Japan became a constitutional monarchy with a bicameral parliament based on the Westminster system, and a system of civil law. The emperor as monarch is the head of state but holds no political power. The parliament (National Diet) is the highest organ of state power and the sole law-making organ. Members of the House of Representatives and the House of Councillors are elected by universal suffrage. The House of Representatives (or "lower house") is the more powerful of the two houses, and can override vetoes on bills passed by the House of Councillors with a two-thirds majority. The lower house can be dissolved either by the Prime Minister or as a result of a non-confidence motion. The House of Councillors (or "upper house") can delay but not block bills, and cannot be dissolved. The Diet elects the Prime Minister usually from the party that holds the majority of seats.

The Prime Minister is the head of government, and the head of Cabinet, being appointed by the Emperor as directed by the Diet. The Prime Minister appoints members of Cabinet who then are in charge of the various ministries of government.

Politics of Japan are conducted within a framework of a multi-party representative democracy. Several political parties exist but politics has primarily been dominated by the Liberal Democratic Party (LDP) since 1955 with the exception of 2009-12 when the Democratic Party of Japan (DPJ) held power.

Judicial power is vested in the Supreme Court and lower courts, and sovereignty is vested in the Japanese people by the Constitution. The Chief Justice of the Supreme Court is appointed by the Emperor while other Justices are appointed by the Cabinet.

Bureaucratic organizations responsible for national energy policy

Energy policy is primarily the responsibility of the Ministry of Economy, Trade and Industry (prior to 2001, the Ministry of International Trade and Industry, MITI). Within METI, the Agency for Natural Resources and Energy (ANRE) is responsible for energy policy and planning issues, including policies to promote energy security. The ministry is made up of a number of sectoral "policy bureaus" that cover various industrial, manufacturing and trade related sectors. Energy policy and programs are divided between three departments[85] within ANRE, with the Commissioner's Secretariat responsible for energy planning (e.g. the Strategic Energy Plan) and international energy affairs [324].

Other ministries with roles relating to energy policy included the Ministry of Environment (MOE) which was responsible for environmental policy, the Ministry of Land, Infrastructure and Transport (MLIT) which was responsible for transport policy and building regulations

[85] These departments are: the Energy Conservation and Renewable Energy Department, the Natural Resources and Fuel Department, and the Electricity and Gas Industry Department.

and the Ministry of Foreign Affairs (MOFA) which was responsible for enhancing Japan's energy security through diplomatic and international energy cooperation efforts.

The Advisory Committee for Natural Resources and Energy is one of three deliberative councils (*shingikai*) that provides policy advice, analysis and recommendations to METI and is made up of about 36 specialized subcommittees[86]. ACNRE consists of about 30 part-time members drawn from industry, academic and non-governmental institutions who are appointed for two-year terms (which can be renewed) [326], [327].

METI shares responsibility for certain energy efficiency policies with the Ministry of Land, Infrastructure, Transport and Tourism. MLIT is responsible for promoting low-emissions vehicles, vehicle emissions standards, energy efficiency and conservation measures for the built environment, infrastructure to support the "realization of a hydrogen society", and promotion of renewables and "energy harvesting" technology in public infrastructure [328]. MLIT and METI jointly administer vehicle fuel efficiency programs. METI also works with the Ministry of Environment (MOE) which is responsible for environmental policy and promotes energy conservation and renewables programs, and the Ministry of Foreign Affairs (MOFA) which is responsible for enhancing Japan's energy security through "resource diplomacy" and international energy cooperation efforts. The Ministry of Internal Affairs and Communications (MIC) coordinates a number of renewable energy and energy efficiency initiatives at the local government level, and the Ministry of Agriculture, Farms and Forestry (MAFF) has an interest in the promotion of renewables through biomass initiatives and agricultural land use (wind energy).

(i) Energy policymaking

Long-term energy policy planning became more formalized starting in 1967 when the Long-Term Energy Supply and Demand Outlook was first published by MITI. The Demand-Supply Subcommittee of the Advisory Committee for Natural Resources and Energy was tasked with developing the Outlook. The outlook is updated every three or four years as warranted by changing circumstances.

[86] The Advisory Committee for Natural Resources and Energy was reorganized in 2013, reducing the number of sub-committees from 84 to 36 and making changes to the mandates and names of several subcommittees [325].

In 2002, Japan took a major step toward a more comprehensive and systematic approach to energy policy by passing the Basic Act on Energy Policy (Act No. 71 of June 14, 2002) [251], [267]. This law set up a framework to guide energy policy based on three fundamental principles, commonly known as the "3-E's":

- ensuring a stable supply of energy (energy security)
- reducing the burden on the environment (environmental protection)
- applying market principles (economic efficiency)

Based on these principles, the law directs that the government develop a Basic Energy Plan (also called the Strategic Energy Plan) at least once every three years. The Minister of Economy, Trade and Industry must formulate a draft of the plan and consult with the heads of relevant government ministries and the Advisory Committee for Natural Resources and Energy, and then seek a cabinet decision on the draft.

The "best mix" of energy sources is an often mentioned phrase used to describe the optimum mix of energy sources that help Japan to meet the "3-E's + S" principles[87] of energy policy [329]. The best mix has typically taken the form of a statement on desired targets for each source in electricity generation and is usually reflected in the Outlooks. It therefore serves as a policy signal to Japan's power sector to aid in future planning. Targets for Japan's electricity generation mix are typically developed within the Advisory Committee for Natural Resources and Energy (ACNRE) which receives technical input and advice from various groups and then makes recommendations to the government.

The Electric Power Supply Plan (EPS Plan) is an annual plan compiled by METI (ANRE) that sets out plans for new power plants by Japan's 10 electric power companies (GEU's) and two wholesale power companies. It is compiled based on the supply plans submitted by each of the power companies in accordance with the provisions of the Electricity Utilities Industry Law. The supply plans lay out the utility's plan for electric power supply for the next 10-year period and include plans for the installation and operation of electricity supply facilities during that time. METI can recommend changes or alternations to these plans. The Nuclear Power Development Plan (NPD Plan) is a subsection of the EPS Plan. During the 2000-12 period, targets and plans for the construction of nuclear power plants in the NPD were amended a number of times.

[87] The "S" for safety was added after the triple disaster.

Cabinet

In recent years, and particularly after the triple disaster, the Prime Minister and the Cabinet Office have become much more engaged in leading and driving reform efforts, setting high-level goals and ensuring policy coordination within government. The Cabinet Office includes the Council on Economic and Fiscal Policy chaired by the Prime Minister which drives high-level economic policy direction and reforms, including the "three-arrows strategy" and the Growth Strategy of which energy sector reform plays an integral part [330]. In January 2013 the first meeting of the Regulatory Reform Council took place. The purpose of this council is to provide advice and opinion to the Prime Minister regarding measures and policies related to economy and to provide advice and analysis on regulatory reform so as to carry out structural reforms in the economy and society [331].

The current government has taken a new and unique approach to regulatory reform, positioning it as a "top priority" and necessary to Japan's continued economic growth and competitiveness. The purpose of regulatory reform is therefore to revitalize the economy, to achieve economic growth and create employment. In line with this view, significant structural changes in the energy sector, enhancing labor market flexibility and other previously controversial subjects are now being actively considered and implemented [332].

With a stronger Cabinet office driving overall reform efforts, ministries try to shape the implementation of such reforms. With its mixture of industry promotion, regulatory and policy bureaux, METI combines the role of advocate, policymaker and regulator which makes for complex negotiations and compromises both internally and with industry in order to structure bargains across affected industries [333]. While METI has changed considerably from the days of bureau-pluralism and industrial policy, it still reflects a perspective that continues to recognize a key role for government in the economy. METI's own "mission" document states that "striking an effective balance between competition and cooperation is at the heart of effective industrial policymaking." It goes on to say that: "The concepts of 'public' and 'private' are definitely not mutually exclusive. METI aims to team up with the private sector to create public-private partnerships that unleash Japan's full potential" [291].

Deliberative councils (shingikai)

Deliberative councils (*shingikai*) are bodies consisting of members from outside government which are set up for the purpose of discussing policy issues, providing information and analysis and formulating policy recommendations for the government. While these councils play a major role, particularly in advanced stages of the policy development process, the government has no obligation to adopt their recommendations. At the same time, since Ministries determine the mandate and membership of the councils and their subcommittees, they have influence over the balance of interests that shape the outcome of these deliberations. Transparency of the deliberations of these council meetings has been greatly increased in recent years with summaries of discussions, member rosters and agendas being freely available to the public.

The role of the deliberative councils in shaping energy policy in the post-Fukushima era is illustrated by two recent examples. In September 2015, METI established a new subcommittee under ACNRE entitled the *Subcommittee for Reforming Systems Related to Introduction of Renewable Energy.* The mandate of this committee is to discuss and recommend mechanisms to further increase the share of renewables in the electricity system in line with the energy mix targets and the goals for renewables set in the SEP (2014). This committee is to consider ways to overcome various technical issues that have arisen that are hindering the further expansion of renewables in the electricity system. Member of this committee are all industry "outsiders", being made up of academics, a consulting firm, a journalist, an NPO and a consumer group [334]. In October 2015, the *Basic Policy Subcommittee on Electricity* was established by METI to review and verify the progress and results of electricity system reform measures and to discuss issues related to electricity market competitiveness both in domestic and global markets. Members of this committee are mostly academics and other industry "outsiders". The electricity industry (i.e. FEPC) is represented with observer status only [335].

Civil society

In recent years, there has been greater pluralism in civil society including those that seek to influence public policy. Although citizens' movements (*shimin undō)* and resident's movements (*jūmin undō*) have been active for many years, policy advocacy groups have generally been weaker and less strident than their western analogs [336]. With the introduction of the NPO Law in 1998, NPO's have proliferated including some that advocate for or against various energy issues including nuclear power, renewables policies, and sustainability policies. It has been noted that the NPO Law has enabled "Japan to reduce the influence of government bureaucrats and have citizens take the public interest into their own hands" [337]. Yet the bureaucracy appears to be working with NPO's in many cases; METI itself has been a strong supporter of NPO activities that advocate for economic revitalization and structural reforms [338] and representatives from NPO's have increasingly been included in some of METI's deliberative councils.

(ii) Changes in the institutional environment

The institutional environment up to 1990

Japan's rapid growth between the 1950's through the 1980's and its rise as a wealthy modern economy was called an "economic miracle". The institutional factors behind this impressive performance has been extensively studied and includes several complementary elements: the lifetime employment system, main bank relations, cross-shareholdings, keiretsu groupings, industrial policy with extensive government support and intervention, bureau-pluralism, close cooperation between industry associations and the bureaucracy, and strong government support for technology development.

Although postwar Japanese economic development was built on an institutional foundation of guaranteed property rights and a market-based economy, the government set goals, developed plans and intervened in the market to promote economic growth. Chalmers Johnson argued that the Japanese bureaucracy, specifically the Ministry of International Trade and Industry (MITI), played a central role in an "iron triangle" consisting of politicians, big business and the bureaucracy in shaping Japan's industrial development in the decades since 1945. He described Japan as a "developmental state" where policymaking power was in the hands of a few within the iron triangle and that rapid decisions could be made by MITI in concert with the relevant firms to pursue industrial policy objectives [339].

Johnson's analysis has been criticized for giving far too much weight to bureaucratic power and its ability to shape and control the policy process. Scholars pointed out that politicians, interest groups, the mass media and other actors also played an important role. Others have pointed out that firms and their industrial associations played an integral role in contributing to policy development by lobbying the government, coordinating the activities of their members and ensuring compliance with policies and plans [340], [341].

In the energy sector, Samuels [37] proposed that governance in Japan is characterized by "reciprocal consent" whereby state and market interests are mutually accommodated such that firms accept government intervention in exchange for support and stability. This is exemplified in the electricity sector where the government has supported regional monopoly control by the GEU's in exchange for stable supplies of electricity to fuel Japan's economic growth [37].

By the late 1980's, a rapid acceleration of asset prices and overheated economic activity led to the so-called "bubble economy" which finally burst in 1990 leading to a long economic decline that lasted more than a decade. This prolonged economic slump undermined the legitimacy of the postwar economic model, causing the nation to examine its system and look toward other countries such as the U.S. for alternative models. This in turn was the main driving force behind several significant institutional changes in Japan starting in the 1990's [333].

Changes since 1990

In the 1990's, the bursting of the bubble economy, a series of policy failures and the subsequent economic downturn led to calls for administrative reform. Bureaucratic infighting and rigidities had impeded policymaking responsiveness for some time and the reputation of the bureaucracy had degraded in the eyes of the public. These issues resulted in a number of major administrative and bureaucratic reforms designed to increase policy responsiveness and efficiency and to increase the authority of politicians over policy setting. A major step was the restructuring of the bureaucracy in January 2001 which consolidated the number of ministries and instituted a number of administrative reforms to increase transparency and accountability and bring the bureaucracy under greater political control [341].

Another major change resulting from this restructuring was the establishment of a Cabinet Office (Naikakufu) consisting of the Cabinet Secretariat and the Cabinet Office administration. The new Cabinet Office merged various bodies including the Economic Planning Agency, which gave the Prime Minster access to economic issues independent of the ministries. These changes have enabled the Cabinet to wield much greater influence over vested interests both within and outside of government while enabling the advancement of deregulation, privatization and other reforms [336]. Along with the government reorganization in 2001, new coordinating mechanisms such as inter-ministerial councils and liaison groups were introduced, requiring ministries and bureaus to coordinate their policies where issues and responsibilities overlap. The Cabinet Office assumed comprehensive policy coordination functions over and above these ministerial mechanisms [342].

As an example of the Cabinet's new emphasis on driving energy sector reforms, it announced in April 2014 that it would establish a "Ministerial Meeting on Renewable Energy to be headed by the Chief Cabinet Secretary. The purpose of this group is to enhance the government's oversight of renewable energy policy and to promote inter-ministerial cooperation so as to maximize the introduction of renewables. To this end, it will also establish a new Director-General level liaison group to ensure coordination at the bureaucratic level [343].

The bureaucracy

As a result of the administrative reforms, the former MITI was renamed to METI, the Ministry of Economy, Trade and Industry. It's mandate in economic planning was broadened with its absorption of the old Economic Planning Agency and it shifted from a strong focus on industrial policy and promoting exports to advancing structural reforms and encouraging investment. METI also began to take environmental issues into consideration more than before, working closely with MOE to coordinate aspects of energy and environmental policy. As METI's regulatory functions have gradually been reduced, it has shifted toward being a strong proponent of deregulation and liberalization, including in industries that it formerly regulated [341]. METI's own mission statement stresses its role as a champion of regulatory reform [291].

METI has evolved from a ministry that regulated the "energy and exit" of firms in the electricity industry to one that promotes shifting economic decision-making to the markets. In the 1990's, a number of factors including increased global competition, high electricity rates and the strength of the yen negatively impacted Japan's competitiveness, increasing the pressure for electricity reform. METI became a strong proponent of energy deregulation, taking a series of liberalization steps beginning in 1995 with amendments to the Electricity

Utility Law that allowed firms to enter the wholesale power market and the retail market for large power users.

After the triple disaster, responsibility for nuclear power regulation was transferred from METI to the independent NRA (see below) and other aspects of electricity regulation have been transferred to independent agencies and organizations (e.g. OCCTO and EMSC) in line with recommendations made by various advisory committees. Meanwhile, electricity market liberalization measures have continued to move forward, including the announcement of full power market liberalization slated for 2020 (see above).

Deregulation and liberalization

Energy reforms up to 2011 were gradual and incremental. The government began to introduce reforms to the monopoly structure of electricity sector in 1995 but meaningful changes only began to be realized around 2000 when partial retail competition was introduced in electricity markets. A wholesale power exchange was not established until 2005 and even then it was little used due to the regionally-based monopoly structure of the electricity system. Despite deregulation measures taken throughout the 2000's, there were very few new entrants to Japan's energy markets and the regional monopoly electricity supply paradigm continued to predominate.

After the triple disaster, the pace and level of both electricity and gas sector reforms picked up considerably. In April, 2013, the Cabinet approved the "Policy on Electricity System Reform" which was a paradigm-breaking report that called for making a "drastic change" in the electricity sector [344]. Motoshige Itoh, the Chairman of the Electricity System Reform Expert Committee on which the policy was based noted that the GEU's had exerted "very strong power" to resist reforms for over the previous 10 years but that the triple disaster and the shutdown of Japan's nuclear reactors had forced the country to push forward with reforms "all at once". The Abe administration accepted all the recommendations of the report (even though it had been commissioned and completed under the former DPJ government), even incorporating them as a component of its broader economic "Growth Strategy" [345].

Japan's three-step process of completing power sector reforms announced in April, 2013 consists of the establishment of OCCTO (completed in 2015), transition to full retail competition in the residential sector starting in 2016, and legal unbundling of power generation from transmission/distribution in 2020. A revision to the Electricity Business Act will finalize these steps. Regulations on household rates are expected to be abolished sometime after April 2020. Taken together, these institutional reforms are intended to move Japan to a competitive electricity market with prices set by supply and demand by 2020 [237].

Gas market liberalization has fallen closely on the heels of the electricity reforms. While the market serving large factories and gas users is currently liberalized, the Gas Business Act will be amended to liberalize the retail gas market (residential and small business customers) by 2017, opening up a ¥2.4 trillion retail market to competition. Gas pipeline infrastructure held by the three major gas utilities is to be legally unbundled by 2022 and regional monopolies for managing and building new pipelines will be maintained under regulated tariffs [237].

New institutions

As a result of the electricity reforms, two new institutions were formed out of an amalgamation of previous bodies and given new powers and authorities: the Nuclear Regulation Agency (NRA) and the Electricity Market Surveillance Commission (ESMC).

The NRA was established as an independent body under the Ministry of Environment in order to remove a conflict of interest between nuclear regulation and promotion within METI and to unify nuclear safety regulation. Regulatory functions in the former Nuclear & Industrial Safety Agency (NISA) were removed from METI in October 2012 and transferred to the newly established NRA. The Nuclear Safety Commission (NSC) under the Cabinet Office was also incorporated within the NRA at the same time, and the Japan Nuclear Energy Safety Organization (JNES) was merged with the NRA in March 2014 [346].

With local governments and citizens exerting more influence over the siting and operations of nuclear power plants and the establishment of the NRA with its independent regulatory powers, control over the timing and number of NPP's in operation has shifted from politicians and bureaucrats to regulators and local officials. These developments inject a high degree of risk into the government's plans and targets for nuclear power in the electricity mix with implications for other energy sources and capacity planning.

The EMSC was established as an agency within METI on September 1, 2015. The Chairman and Commissioners are appointed by and report to the METI minister. The purpose of the ESMC is to improve the monitoring of electricity markets and to enforce regulations in order to ensure fairness and neutrality in line with newly announced electricity reforms. The Commission also provides advice and recommendations to the METI minister regarding network tariffs and electricity suppliers. [347], [348].

4) Institutions that govern transactions (Level 3)

Third-level institutions consist of the “institutions of governance” which set the rules that govern individual transactions. This level includes specific policy instruments and regulations, companies, markets, networks, and various hybrid organizations and structures. Energy policies, regulations and market reforms have already been covered in other chapters of this thesis. Companies and markets are the most important institutions at this level as they are the ones that play a decisive role in actual transactions. Besides companies, other institutions that may play an influential role at this level include semi-governmental “intermediate” organizations, industry associations, local governments, and non-governmental/non-profit organizations (NGO/NPO).

Companies

The industrial structure of Japan’s energy system tends to be dominated by large, vertically integrated firms. While the petroleum sector operates in a liberalized competitive environment, the electricity and gas sectors remain partially regulated and dominated by regionally based utilities. Japan’s private electricity utilities an example of path dependence that began in the Meiji period. In the early days of electricity, private power companies established themselves before regulators evolved to regulate them. Over the ensuing decades, Japanese power companies were able to fend off state control through a process of “reciprocal consent” whereby state and market interests are mutually accommodated. The government supported regional monopoly control by the GEU’s in exchange for stable supplies of electricity to fuel Japan’s economic growth [37]. The gas supply sector has followed a similar pattern with the market dominated by three large regional gas utilities who own and operate their own gas pipeline and propane delivery infrastructure.

Intermediate institutions

For the purposes of this study, intermediate organizations are defined as institutions that provide information, support and/or coordinating services to market participants (companies) but do not participate directly in markets themselves. Several intermediate organizations have played and are likely to continue play key roles in helping influence the pace and shape of Japan's energy transition.

OCCTO

As part of the government's electricity reform plans, the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) was established on April 1, 2015. The purpose of OCCTO is to promote the development of electricity transmission and distribution networks, including for cross-regional electricity use, and to enhance the ability of the national grid to adjust the supply-demand balance of electricity in normal times and in emergency situations [349]. OCCTO also reviews the electricity supply plans for all power producers can make changes if necessary. All electricity producers and suppliers are obliged to be a member of OCCTO.

OCCTO absorbed the former Electric Power System Council of Japan (ESCJ) which was established in 2004 to set and enforce grid rules, but was ineffective. All power suppliers must participate in OCCTO and it possesses the authority to compel the GEU's and other power suppliers to curb demand for power or increase power supplies in order to balance supply and demand across regions. OCCTO thus appears equipped to play a critical role in addressing a major vulnerability identified after the triple disaster – a fragmented power grid with virtually no power exchange.

The establishment of OCCTO is also expected to help increase the penetration of renewables because the larger platform for managing power supplies should make it easier to balance loads on a national basis by leveling the intermittency of wind and PV power across the various grid regions. About one third of OCCTO's staff have initially been seconded from the GEU's, and as it will also screen applications from power suppliers for access to the grid, the new organization will have to ensure fairness and avoid conflicts of interest [350]. With the abolishment of the regional monopoly electricity paradigm, this new institution will play a key role in electricity system reform as it represents the move toward a new paradigm that incorporates the idea of a “national grid”. Much will depend on how effectively, fairly and efficiently OCCTO can carry out its mandate.

JEPX

In 2005 wholesale electricity transactions commenced on the Japan Electric Power Exchange (JEPX) to provide spot and forward trading for its members. JEPX members are made up of the GEU’s, wholesale electric companies, power producers and suppliers, and others.

Although the first steps toward electricity liberalization began in 1995, only about 2% of total market volume of electricity transactions is currently traded on JEPX.[88] In addition to the regional monopoly system, the lack of power exchange between regions is at least partially reflective of the fact that participation in JEPX is voluntary and companies can only offer at prices that reflect their marginal cost of power. Thus GEU’s with high marginal costs have only been offering their most expensive thermal power, keeping their lowest-cost power (i.e.: nuclear) for themselves.[89] JEPX will introduce a new “1-hour-ahead market” in April 2016. Under this system, power can be traded on the exchange up to one hour before the power is sent to the grid. This is expected to give power producers more flexibility in their supply-demand plans, address shortages, sell demand reductions (negawatts) and enhance demand response [351].

NEDO and AIST

Two intermediate organizations that fall under METI’s overall authority and are intended to support the achievement of innovation and technology development goals in the SEP are The New Energy and Industrial Technology Development Organization (NEDO) and the National Institute of Advanced Industrial Science and Technology (AIST).

NEDO is an administrative agency that organizes and funds R&D programs related to the development and diffusion of energy and environment technologies, and industrial technologies. It is involved in developing photovoltaic, wind power, biomass and waste, geothermal power, thermal utilization, fuel cell and energy conservation technologies. The National Institute of Advanced Industrial Science and Technology (AIST) is one of Japan’s

---

88 Based on interviews with senior METI officials.
89 Based on interviews with senior METI officials.

largest public research organizations. AIST aims to bridge the gap between innovation and commercialization by focusing on developing practical applications of technologies. The Energy and Environment department of AIST is focused on technologies related to renewable energy, energy storage, energy conservation, energy efficiency and environmental risk reduction.

Both of these organizations act as coordinating institutions between the government (which sets priorities and provides funding) and industry, academic, and public research organizations. They also tend to undertake projects that would otherwise not be undertaken by the private sector due to high cost and risk factors [352]. The projects that NEDO funds are evaluated in the pre-project, interim, post-project and follow-up stages. The first three are evaluated against targets and follow-up stages are evaluated on economic and social impact [182].

Industry associations

Energy industry associations in Japan have generally not been strong advocates of energy sector reform. The Federation of Electric Power Companies of Japan (FEPC), established in 1952 along with the regional monopoly system, is an association of Japan's regional GEUs that coordinates activities with its members, disseminates information on the power sector and lobbies on behalf of the interests of its members. The FEPC is closely allied with the Keidanren, Japan's broader industry federation, and both organizations have been a strong advocates for maintaining the status quo in Japan's electricity sector. Keidanren and FEPC have consistently opposed major changes in Japan's regional monopoly structure, lobbied strongly for nuclear power, and opposed a significant increase in renewables generation in Japan's energy mix. In its proposal to the energy mix committee under ACNRE, Keidanren said that it was unrealistic for Japan to have ambitious renewables targets, should increase reliance on nuclear power and proposed that renewables should make up no more than 15% of the power generation mix [333], [353].

The Japan Gas Association (JGA) represents Japan's gas utilities. Its three largest utility members have been opposed to the unbundling of gas pipelines from the utility business on the grounds of possible safety issues. The JGA has also has been active in coordinating efforts among its members and partners to accelerate the adoption of Ene-Farm stationary fuel cell systems and has set a target of installing 5.3 such systems in residential homes by 2030 [354].

Interest groups/NPO's

In recent years, in increasing number of non-profit organizations (NPO's) have been engaged by METI, MOE and others to advise on energy and environmental policy matters. This is evidenced by the more diverse membership on various government deliberative councils. For example, ISEP has participated on a number of METI (including ACNRE), MOE and other ministerial and Cabinet level committees, providing advice and input on renewables and sustainability issues [355]. Another NPO, the Japan Renewable Energy Foundation (JREF), was founded by Masatoshi Son of SoftBank after the Fukushima disaster in 2011, is financially backed by him and includes prominent foreign sustainability activists such as Amory Lovins and David Suzuki on its Board. It conducts research on renewables, provides policy advice to the government and advocates for renewable technologies [356].

Local governments

Local governments have been increasingly engaged by the central government in local revitalization programs that focus on development of renewable energy projects. In particular, MIC has set up a well-funded special program to promote biomass district heating and cooling projects, put local governments in charge of leading energy initiatives, and provided support for local energy businesses. These initiatives are seen as essential to enhancing resiliency by building a decentralized/distributed energy system [357].

Japanese cities have started to set up community-owned electric utilities through public-private partnerships to advance renewables. In 2012, Shizuoka created a local electric utility that launched renewable community power projects in 2013 through a micro-citizens fund of around USD 200,000 (JPY 20 million) with 204 community investors. Similarly, Odawara created a local utility that became operational in 2013, and Fukushima launched a fund in early 2014 to support local renewable electricity projects [167].

(i) Changes in the institutions governing transactions

Japanese energy companies can be expected to adopt positions in response to changes to energy policy that reflect the character of Japan's institutional environment. Although there are exceptions, the business sector in general has not tended to advocate for more liberal market reforms and the few firms that have done so have been rather ambivalent about such reforms in any case [333]. This has certainly been true of the incumbent GEU's and gas utilities who until very recently have lobbied against reforms in the energy sector. Up to the triple disaster, the Japanese government had generally tended to carefully craft policy reforms to preserve core energy institutions and to leverage the advantages of the existing institutional structure as much as possible.

The triple disaster represents a critical juncture in Japan's energy system evolution, enabling major energy sector reforms to be introduced. As was argued Chapter 5.1, the reforms embodied in the 2014 SEP represent a major planned transition of the Japanese energy system. The magnitude of the changes has overturned some long-held policy paradigms and hold the potential for moving the energy system onto a different path of development. In fact, empirical evidence from recent developments in electricity and gas markets demonstrates that structural changes have already begun.

Existing energy companies and new entrants to the electricity and gas sectors have been positioning to take advantage of the changes. The Japanese power market is valued at about ¥18.2 trillion (US$151.7 billion), of which the regulated sector, valued at ¥8.1 trillion (US$67.5 billion), will be open to competition starting in 2016 [237], [358]. This provides a powerful incentive for existing firms to realign themselves to the new institutional landscape and for new companies to enter into newly liberalized markets.

In a sign of the breakdown of the regional monopoly system, Chubu Electric, a regional GEU, was the first company to break an unwritten rule among the regional utilities not to compete in each other's markets. It purchased Diamond Power Corp, a Tokyo-based independent electricity supplier and will build a coal-fired power plant near Tokyo and supply the Tokyo market with power. Similarly, Kansai Electric acquired an LNG-fired power plant in Chiba Prefecture, in the greater Tokyo area, in order to supply power to that region [359].

Japan's GEU's are also starting to partner with each other for the first time. JERA is a joint venture company set up in April 2015 by TEPCO and Chubu Electric and is intended to be an integrated energy supply and services company covering the entire energy supply chain, from upstream investments and fuel procurement through power generation and energy services. In February 2016, in a move highly unusual for Japanese power companies, JERA appointed an American attorney as Chairman to help steer the company through electricity deregulation and expand their energy investments overseas [360].

At the same, the number of new entrants into the electricity supply market rose sharply after the triple disaster and the establishment of the new FIT scheme for renewable power. From only about 30 new companies in 2010, the number of new companies entering the power market soared to over 3,200 in 2014, although many of these have yet to obtain contracts and actually sell power into the grid [361]. In anticipation of full retail competition starting in April, 2016, many of these new suppliers are small start-up firms seeking to take advantage of the FIT and others are large, established firms that are new to the electricity market.

Large established companies such as gas utilities and manufacturers are also moving into the power business. Ennet Corporation, formed in 2000, is jointly owned by Tokyo Gas, Osaka Gas and NTT. It is Japan's largest independent electricity supplier and was originally set up to supply power to large customers in the deregulated market. Although the share of independent suppliers in Japan’s electricity market is still under 5%, Ennet controls about half of this market [362]. Ennet managed to double its customer base in two years by offering cheaper prices and more flexible contracts. Automobile makers Honda and Nissan have also registered as electricity retailers. Honda will be the first Japanese automaker to sell electricity to utilities from its own factory roof-top solar panels. Panasonic Corp. and Epco Co., an energy-management company, set up a joint venture to purchase solar power from residential rooftops at premium rates while also providing energy-saving information [363].

There is a rapidly emerging trend of energy companies partnering with telecom providers to provide a broad range of integrated energy and telecommunications services to their customers. TEPCO and SoftBank, a major telecommunications company, signed a business partnership agreement in October 2015 to jointly sell electricity, telecommunications and internet services to customers [364]. Similarly, in September 2015, JX Nippon Oil & Energy announced a partnership with KDDI, another telecom company to offer bundles of electricity and cell phone services [365]. Tokyo Gas is partnering with various internet providers to provide service packages for individual consumers.

The number of new entrants into the electricity retail market increased sharply from 8 in October, 2015 to 291 as of April 28, 2016 [366]. In a sign that Japanese consumers are looking for ways to cut costs or enhance the services they receive about 54,000 power customers decided to switch power providers as companies compete to lower prices [367]. Thus, various types of new business partnerships are aimed at gaining market share by providing convenience and lower costs for customers. Osaka Gas partnered with NTT Docomo to offer electricity and telecom services to their gas customers in the Kansai region and aim to reduce their prices by 5% or more over Kansai Electric [368]. TonenGeneral Sekiyu, an oil refining company, began offering electricity services plans that claim to be 3-6% cheaper than those offered by TEPCO [369]. Independent power suppliers are employing novel strategies to gain advantage over the GEU's by accepting lower profit margins, selling power management systems, electricity trading and utilizing power purchase agreements with other firms [370].

The large Japanese utilities are not standing still and are starting to invest in power businesses overseas in anticipation of greater competition at home. For example, Chugoku Electric Power plans to invest a Malaysian power plant together with a Japanese trading company and a local Malaysian utility [371].

In line with the goals in the SEP and the government's efforts to encourage consolidation in the petroleum refining and distribution business, Idemitsu Kosan and Showa Shell Sekiyu agreed to a merger in November 2015. This was quickly followed by the announcement that JX Holdings and TonenGeneral Sekiyu, Japan's two biggest oil refiners, intend to merge in April 2017. These mergers are expected to allow the industry to cut its costs and improve profitability in the midst of declining demand for gasoline in Japan. However, the JX Holdings-TonenGeneral Sekiyu merger will enable it to gain control of more than half the country's gasoline market [372].

Foreign energy companies have also entered the Japanese market to pursue opportunities arising from deregulation, particularly in the solar power market. Companies such as Canadian Solar and other suppliers of solar panels including Chinese and Taiwanese companies have become strong competitors in the Japanese market. Others are investing in large-scale solar power projects including General Electric, Shanghai Electric, SPI Solar, and others. For example, SPI Solar plans to invest in 500 MW of solar power generation projects and GE Energy Financial Services is investing in a 230 MW solar farm in Okayama Prefecture that is slated to begin operation in 2018 [373]–[375].

The triple disaster also accelerated efforts by electricity services providers to better manage the demand side of the market. METI is mandating a broad number of changes on the demand side of the grid as well. Much of this is focused on developing smart grid standards, smart grid technologies (such as smart meters) and demand management. In 2011, Toshiba acquired Landis+Gyr, a leading global provider of smart grid and energy management technologies. Subsequently, Toshiba partnered with TEPCO to create a city-wide energy management system in Tokyo that will link smart meters, utility enterprise platforms and smart devices in homes and businesses. Given that the government has taken a top-down approach to setting standards for smart devices in Japan, the TEPCO strategy is relying on these standards to maximize the interoperability of various technologies and create an integrated approach to smart grid deployments. It is hope that if this approach is successful, it will help Japanese companies expand into smart grid markets in Asia and elsewhere [376].

5.2.5 Discussion: Japan's energy transition

In this section, recently observed changes in the institutional environment and the institutions of governance as noted in Section 4 are examined in order to assess how institutional change is reshaping Japan's energy system. The question of whether these changes support the contention of this study that a major energy transition is already underway in Japan will also be addressed.

The purpose of this discussion is to address the following questions:

- What institutional and structural changes can be observed to have taken place in Japan's energy sector since the triple disaster?
- Are these changes consistent with new policies implemented since the triple disaster, including those in the 2014 SEP?
- What are the institutional implications of Japan's outstanding energy security issues and vulnerabilities?
- How will institutional changes affect governance of the energy transition and impact on energy security?

1) Institutional change in Japan’s energy sector

Institutional change up to 2010

The path of Japan’s energy sector development up to the triple disaster had been shaped by three important policy paradigms. The *Japan as a vulnerable “island nation” paradigm* has served as the primary driving force for Japanese energy policy since the oil shocks of the 1970’s, as evidenced by the primacy of energy security in Japan’s strategic energy plans and policies throughout this period. Since the early 1950’s and up to the time of the triple disaster, the *regional monopoly electricity structure paradigm* shaped the path of institutional and structural development in Japan’s electricity system, limiting competition but providing stable and reliable power for Japan’s economic development. The “*safety myth” paradigm* also prevailed up to the triple disaster and helped facilitate the expansion of nuclear power in Japan despite ongoing concerns over risks in an earthquake-prone country and a series of nuclear scandals and minor accidents over the years.

Until very recently, Japanese policy reform has been slow and incremental; the result of delicate compromises with those most affected, with generous compensation provided to the losers in reform efforts [333]. Japan has been ambivalent about the wholesale adoption of foreign models and has instead developed a unique pattern of policy and structural reform. Specifically, Japan evaluated the costs and benefits of various existing institutions and then designed reform approaches to suit the Japanese institutional context. In particular, the impact on existing institutions and long-term relationships were an important part of these considerations. Rather than a purely rational calculus that considered only transaction costs and benefits, culturally constructed norms, values, beliefs and perspectives also needed to be considered [377]. Japanese firms would rather renegotiate the terms of their relationship with their partners than abandon the relationship altogether. Firms made a cost-benefit calculation as they were confronted with new situations and policies and would only abandon existing relationships when the marginal benefits of doing so outweigh the large fixed costs that have already been invested in those relationships [333].

In the post-war period, reforms have generally been designed not to radically change existing institutions but rather to help them adapt while building on their strengths [333]. Since Japanese institutions have been relatively successful in supporting Japan’s long-term economic development, society had been reluctant to change them unless sufficient pressure or a major shock forces change [341].

In contrast to this broader explanation of institutional change up to 2010, other scholars have taken a narrower approach, focusing on rational choice theory and asserting that institutional change has been blocked by powerful vested interests such as the “iron triangle”, the “nuclear village”, keiretsu enterprise groups and other collusive networks. These narratives suggest that structural change in the Japanese economy, and the energy sector specifically, has been stymied by a set of rigid and inflexible institutions that seek only to preserve their own interests. The most prominent example advanced in many of these studies is a collusive triangle of nuclear power industry interests, politicians and bureaucrats that perpetuate Japan’s nuclear power industry, euphemistically referred to as the “nuclear village”. The nuclear village narrative has been used to explain how the government crafted a broad set of policy instruments designed to manipulate public opinion and further its nuclear power goals [17], [39].

Various policy measures to enhance energy security were introduced during the period leading up to the triple disaster (see Appendix A). Electricity and gas market liberalization measures were implemented in phases starting in 1995 and programs such as the RPS scheme (2003) to increase the share of renewables in electricity generation and a solar FIT program introduced in 2009 were also implemented. However as demonstrated in this chapter and in Chapters 4.2 and 4.3, actual results in many cases either fell short of targets or stimulated only incremental changes. While these policies did not engender major structural and institutional reforms, they did help set the stage for much more significant measures that would help accelerate the rate of change after the triple disaster.

Institutional change in the post-Fukushima period

Political agency can be said to have played a decisive role in helping overturn the *regional monopoly electricity structure* and *“safety myth” paradigms* and stimulating major institutional and structural reforms in Japan’s energy sector after the triple disaster. As described earlier in this study, significant institutional changes began under the DPJ government soon after the disaster and the scope and pace of change has only increased under the LDP. The triple disaster stimulated a fundamental rethink of Japanese energy policy – a “zero-based review”. Following various investigations and policy reviews, the first paradigm to go was the "safety myth", which provoked major nuclear regulatory reforms and the creation of a new regulatory institution, the NRA.

Narrow rational choice perspectives on institutional change must now be revised in light of the significant institutional and structural changes emerging in the post-Fukushima period. While keiretsu groupings still exist, they are far less influential that they used to be and their role in the economy has diminished considerably as cross-shareholdings have been unwound. As Japan began to introduce liberal market reforms in earnest the 1980's and 1990's and embarked on major administrative reforms starting in 2000, notions of the "iron triangle" and developmental state theory have steadily lost relevance. At least one study has acknowledged that the explanatory power of the "iron triangle" developmental state model has been seriously eroded in the face of the inability of the nuclear power industry to resume "business as usual" after the triple disaster and in light of fundamental changes in state-society relations [378]. The power "nuclear village" appears to have been seriously diluted, if not rendered inert by the recent reforms.

Following the introduction of a renewables feed-in tariff and the establishment of a nuclear regulator and new electricity institutions, changes in industry structure have begun to reshape energy markets. The movement by some of the GEU's to compete on others' turf is a clear sign that the regional monopoly paradigm has begun to break down. If TEPCO, the FEPC and the nuclear village were in a strong position to resist change and influence electricity policy in the pre-Fukushima period, the balance of power appears to have shifted decisively in the post-Fukushima period. This is exemplified by the commitment of the government to reduce the role of nuclear in the electricity mix, the effective nationalization of TEPCO, and TEPCO's subsequent about-face in aligning itself with the government's reforms. The power of complementary institutions to resist change – especially the FEPC and the remaining GEU's – has diminished considerably.[90] The number of new entrants into the power market has sharply increased, especially in renewables generation. At the same time, the number of new entrants into the electricity and gas retail market has risen to around 200 and existing firms are forging new partnerships in order to offer new combinations energy services, particular electricity and gas but increasingly other services as well. Taken together, these

[90] In interviews with METI officials, it was stated that the government's control over TEPCO since the Fukushima disaster has effectively eliminated the FEPC's political influence and with it the main source of resistance to the electricity reforms.

changes are a strong indication that reforms are beginning to reshape Japan's energy industrial structure.

The evidence presented in this thesis argues that the shock of the triple disaster created a critical juncture in the path of Japan's energy system development. The disaster exposed significant weaknesses and critical vulnerabilities in Japan's energy system, overturned key policy paradigms, and opened up political space to initiate major reforms to Japan's energy sector. A new paradigm has been proposed in the 2014 SEP to replace the old regional monopoly paradigm and can be described (from the SEP) as: a *multi-layered and diversified flexible energy supply demand structure*. The policies outlined in the 2014 SEP, together with empirical evidence of institutional and structural changes already taking place support the view that Japan's energy system has embarked on a transition to a new path of energy system development.

2) Are the recent changes consistent with the SEP?

Many of the policy measures proposed in the SEP have already been institutionalized through the passing of new laws or amendments to several existing laws. A legal framework continues to be built that would provide a system of incentives and/or constraints for achieving the objectives in the plan.

While it is still too early to make definitive conclusions about whether all the policies and objectives in the SEP are achieving their intended results, the empirical observations in the previous section and an examination of some recently observed institutional and structural changes can serve as an indication.

Institutional and structural changes such as those detailed earlier in this chapter can be analyzed in terms of whether they align with key policy objectives of the SEP. Table 14 summarizes six key objectives from the SEP and matches these to some observed changes in Japan's energy sector.

The data presented in Table 14 indicates that structural and institutional changes consistent with the objectives of the SEP have either begun or are likely to begin soon in response to policy measures. As discussed in Chapter 5.1.4, recent budget allocations demonstrate that financial resources are being aligned with the strategies and initiatives outlined in the SEP. In

2015, significant new funding was allocated to measures to improve energy efficiency and conservation, expand renewables generation, develop domestic energy resources, build resilience in the energy supply chain and support R&D related to energy and environmental technology [299]. Taken together these data suggest that policy measures to effect intended changes in Japan's energy system are being implemented and resourced.

Table 14. Table of alignment between SEP objectives and institutional changes

SEP objective	Examples of observed institutional and structural changes in Japan's energy sector
Creating a supply structure with diverse energy sources in order to establish a "multi-layered" energy supply system.	Release of electricity mix targets and a commitment to adjusting incentives and regulatory framework to promote their achievement
Promoting a resilient energy supply structure across the primary and secondary energy supply chains.	2015 budget enhancements directed toward resilience improvement measures
Implementing structural reforms in the electricity sector and allowing for new entities (including firms, local governments and NPO's) to supply energy services	"Three-step" electricity deregulation being implemented, gas market liberalization being implemented, establishment of OCCTO, weakened influence of FEPC, increased competition for power and gas customers on each other's "turf", new entrants into generation and retail markets, tie-up's between power utilities and other firms offering new combinations of energy services
Creating a demand-side led energy supply-demand structure through demand-response and other measures designed to increase flexibility for end-users.	Establishment of community-owned electric utilities and renewables projects, accelerated plans for smart meter installations, projects to further develop demand response in Japan's "smart communities"
Improving energy self-sufficiency by promoting domestic energy sources including nuclear power, renewable energy and fossil fuels.	Rapid increase in solar capacity, wind power projects, gradual re-start of nuclear power plants
Reducing global greenhouse gas emissions through utilization of Japan's environmental technologies and know-how.	The government has committed to reduce GHG emissions by 26% by 2030 over 2013 levels, and by 80% by 2050. METI will also require utilities to bring the ratio of renewable energy and nuclear power combined to 44 percent or larger by fiscal 2030 in order to limit thermal power generation.

3) Energy security issues and institutional implications

While Japan's energy system displayed high levels of robustness, resilience and adaptive capacity prior to the triple disaster as demonstrated in the analyses in Chapter 4, the ten energy security concerns identified as outstanding after the triple disaster have important implications for Japanese energy policy, institutional change and the energy transition going forward.

While energy policies introduced after the triple disaster have been designed to address many of these concerns, there are underlying institutional issues that will impact on whether policies will be effective in resolving them. These issues are closely linked and can be grouped by underlying theme.

Lack of government commitment to structural reforms – Despite recommendations from the IEA and the government's own analysis, the analysis in this thesis suggests that there was hesitation in tackling obstacles to reform in oil and gas markets and the pace of change remained slow and cautious. For example, the government clearly lacked a strong level of commitment to following through on structural reforms despite mounting evidence over the 2000-2010 period that the goals it set were not being achieved. Despite various new laws and policies to liberalize retail markets, promote competition, and resolve infrastructure issues, market structure remained relatively unchanged and the major utilities maintained their dominant position in their respective regions.

Ineffectiveness of policy implementation – Over the 2000-2010 period, competition in electricity and gas markets evolved only very slowly and incrementally and with limited success. Inter-regional connections and power exchange remained minimal. Renewables expansion was held back by weak enforcement of grid access policies. The JEPX power exchange remained under-utilized. Nuclear accidents and scandals repeatedly occurred and public support for nuclear power declined. Significant regulatory issues arose during the period, particularly with respect to nuclear power following a series of scandals and accidents. Barriers to electricity and gas infrastructure access by third-parties were ongoing issues, raising questions about neutrality, transparency and the quality of regulatory oversight.

Lack of public engagement on energy issues – Japanese government engagement with the public on energy policy issues has largely been focused on seeking public "understanding" of its policy goals. Up to the time of the triple disaster, energy policy was typically formulated by relying on internal committees and *shingikai* advisory groups composed mainly of industry insiders and academics. While there was extensive consultation with local communities on nuclear power plant siting and related issues, broader public input on nuclear issues has historically been lacking and industry perspectives appear to have predominated. The Fukushima disaster appears to have widened the gap between what the government sees as important energy security priorities and what large portions of the public see as the risks of nuclear power. Consequently, nuclear power plant restarts and the future of nuclear power in general has been cast into doubt and the resulting uncertainty has made long-term power generation planning much more challenging.

Institutional changes impacting on energy security concerns in the post-Fukushima period

With respect to government commitment to reforms, this Chapter has shown that major reforms including the 3-step process of electricity reform, the 2012 FIT program and many of the policies and strategies embodied in the 2014 SEP have already been implemented or scheduled. The government has also committed to substantial increases in budgets to resource the reforms. Interviews with METI officials support the view that the government is committed to continuing with the reforms, albeit with "adjustments" that may be required depending on market conditions. In this vein, METI indicates that minor changes to the SEP may be required in 2017 in order to reflect changes in energy markets, but policy targets for the electricity mix will remain largely intact not least because Japan's commitments at the COP21 meeting are considered binding.[91]

Since the energy transition is currently underway, it is too early to evaluate its overall effectiveness but the empirical evidence cited in this study demonstrates that significant structural changes in Japan's energy markets have already begun to take shape in electricity and gas markets. Since the analysis indicates that these changes are well-aligned with the government's policies, this can be regarded as an early indication that policies are having the desired effect.

There is as yet little evidence that public engagement in two-way communication on energy policy issues as mentioned in the 2014 SEP is taking place. Nuclear power and nuclear power plant restarts remain the most contentious public policy issue but since the triple disaster the government has delegated nuclear safety and decisions on restarts to the NRA. Meanwhile, local governments and communities advocate various positions on energy issues and have

[91] Based on interviews with senior METI officials.

enacted policies or mounted legal challenges at the local level that are sometimes at odds with national energy goals.

To summarize, the evidence presented in this study suggests that issues related to the government's commitment to reforms and the effectiveness of policy implementation are in the process of being addressed. However, public engagement on energy issues remains an outstanding issue. The future of nuclear power and meeting the country's overall energy targets in particular may well depend on how effectively the government manages this issue in the future.

4) Governance and the energy transition

The evidence and analysis in this thesis suggests that the governance of energy is moving away from the state-centric, control-oriented form that predominated up to 2010. This form of governance relied on policymaking processes heavily influenced by the regional monopoly paradigm and industry vested interests. This paradigm served Japan well during its rapid economic development up to the early 1980's, but the weaknesses and vulnerabilities of this structure gradually became apparent during the period covered by this thesis.

As argued in this thesis, the triple disaster served as a critical juncture in the path of energy system development, opening up a window for the introduction of policies that would substantially reform existing energy system institutions and market structures. As a result of these changes, governance of the energy system appears to be moving toward a more open, flexible and robust form that involves a broader set of actors and institutions, including non-utility private companies, local governments, communities, NPO's, and others.

At the same time, the government will not take a completely "hands-off" approach to the energy sector. While institutional reforms will see markets become the major driver of energy system change in the future, the government will need to continue to play an important role in balancing the public interest and ensuring energy security. As already discussed, Japan's energy system has shifted to a less energy-secure post-disaster mode characterized by a number of outstanding energy security concerns. The government will therefore need to address these concerns and the institutional issues that underlie them. It will also need to continue to implement policies to strengthen the properties of robustness, resilience and adaptive capacity in order to bring energy system security to a level that meets the objectives set in the 2014 strategic energy plan.

While METI's role has evolved from a controller of change to a facilitator of change, it remains the principal driver and champion of the transition. While the government has lost some of the means of coordination that it relied in the past on to help ensure energy targets and goals were met, it has fostered the creation of new coordinating institutions. The most significant change is the shift to a greater reliance on competitive markets in determining entry and exit, energy supply and demand, and prices. Coordinating institutions in the "old regime" have been adapted (e.g.: *shingikai* membership), undermined (e.g.: FEPC) or eliminated (e.g.: NISA, ESCJ) and new coordinating institutions have been created (e.g.: NRA, OCCTO). Thus, while Japan's energy sector can still be described as "coordinated", new forms of coordination are shifting authority away from government entities to intermediate institutions that are closer to firms and markets. These changes suggest that the adaptive efficiency of Japan's energy institutions is likely to improve. The government will need to monitor existing and new institutions to ensure they are effective in their roles and make adjustments if they fail to support the goals of the transition.

The government so far appears strongly committed to carrying out the reforms in the 2014 SEP. It has proceeded to implement the reforms over the protests and complaints from the GEU's and gas utilities and has provided substantial resources to fund the policies contained in the SEP. It has maintained large budget commitments to energy R&D and is increasing funding for technology commercialization and other adaptive mechanisms in the SEP (i.e.: "exploration" activities) that together should serve to enhance adaptive capacity in Japan's energy system.

Reaching the targets for the electricity mix stated in the 2015 version of the Long-term Energy Supply-Demand Outlook will be critical for achieving the vision of a resilient, flexible and multi-layered energy supply-demand structure. The government is therefore likely to institute policies to ensure a "level playing field" between different electricity generation sources.[92] Interviews with METI officials indicate that the government stands

[92] Based on interviews with senior METI officials.

ready to utilize a range of policy tools (including taxes, subsidies and regulations) should they be needed in order to help achieve its goals.[93]

Notwithstanding the government's stronger commitment to proceeding with energy sector reforms, the importance of maintaining access to stable and reliable supplies of energy mean that it is likely that Japanese policymakers will be cautious about allowing energy reforms to destabilize the incumbent GEU's or make them financially or structurally unviable. This is especially so since the government wishes to maintain the size and market power of at least some of these incumbents so that they can effectively execute procurement transactions in international energy markets with sufficient leverage.[94] The GEU's are also counting on sufficient nuclear power coming back online to make their business models profitable and viable. Should this not be the case, the energy policy reforms could be put at serious risk.[95] It is therefore likely that the government will try to find a balanced approach between the incumbent GEU's and new entrants by encouraging mergers and tie-ups to promote efficiencies while ensuring that new entrants are treated fairly under the newly liberalized regime.[96]

The governance of Japan's energy transition involves a dynamic process of interaction and decision-making among a broader range of energy-related institutions than in the past. The shift to greater reliance on competitive markets therefore implies less predictability and more ambiguity around reaching the goals of the transition. Based on the government's commitment to proceeding with major reforms, the significant institutional and structural changes already taking place, the alignment of these changes with the objectives of the SEP, and the significant resources allocated to transition policies and strategies, it can be concluded that Japan's energy system transition is well underway. If the goals of the transition can ultimately be achieved, the payoff should be a more robust, resilient and adaptable energy system that is better able to respond to the inherent uncertainties of unpredictable energy markets.

---

93 Based on interviews with senior METI officials.
94 Based on interviews with senior METI officials.
95 Based on interviews with senior METI officials.
96 Based on interviews with senior METI officials.

5.2.6 Conclusion

In summary, this chapter addressed the fourth and fifth research questions posed in this thesis by analyzing the institutional structure for energy in Japan, describing how that structure has been changing, and assessing the implications for the energy system and energy security. The analysis shows that while Japan's energy institutions evolved and changed incrementally between 2000 and 2010, the triple disaster represented a critical juncture in the path of Japan's energy system development, overturning several policy paradigms and provoking major institutional and structural changes in Japan's energy sector. These changes demonstrate that a major energy transition is currently underway. The governance of Japan's energy system is moving toward a more robust and reflexive form that should serve to better enable the energy system to respond to the inherent uncertainties of unpredictable energy markets. The implications of these findings will be further discussed in Chapters 6.

Chapter 6: Conclusion - Energy security in Japan in the context of a planned energy system transition

6.1 Addressing the research question: How do energy policies affect energy security in Japan?

This thesis has addressed the central research question by proceeding from the view that energy security is a policy matter and that energy security assessment should be policy-oriented and policy-relevant. Consequently, a broad range of factors impacting on Japan's energy security were considered and a comprehensive, integrated and systemic approach to energy security assessment was employed.

This purpose of this study was to assess the impact of energy policies and institutions on Japan's energy system in order to identify current energy security issues as well as assess the outlook for energy security in the future. In this concluding chapter, the main research question and sub-questions are reiterated and answered, drawing on the analysis and discussion in previous chapters.

6.1.1 How do energy policies affect energy security in Japan in terms of vulnerabilities to threats and risks facing the energy system?

During the 2000-2010 period, Japan was exposed a wide range of potential threats and risks to energy security. Given its almost total dependence on imports of fossil fuels and uranium, the country faced a number of significant supply-side vulnerabilities. Japan's high reliance on the Middle East especially for oil makes it vulnerable to instability in that region. Long sea lane supply routes through various "chokepoints" exposes it to geopolitical risks. Infrastructure adequacy vulnerabilities included aging thermal and nuclear power plants. On the demand side, the transport sector in particular was vulnerable to prices of fossil fuels. Residential/commercial end use prices were already high and they generally rose over the period.

Although Japan did reduce oil dependence between 2000 and 2010, it was still highly vulnerable to price risks. Nonetheless, between 2000-2010 Japan met many of its policy targets and the overall energy security situation improved in all segments of the supply chain as measured by indicators of vulnerability.

After the triple disaster, this study found that several existing vulnerabilities worsened while new ones emerged. The shock of the triple disaster shifted the energy system to a new, less desirable state characterized by degrading energy security and sustainability performance. Vulnerabilities that were exacerbated included increased dependence on fossil fuels (and thus exposure to external geopolitical risks), nuclear power adequacy issues, low levels of renewables generation, the lack of competition in electricity and gas markets, and the further decline in public support for nuclear power. Vulnerabilities that became newly apparent included inadequate inter-regional electricity and gas interconnections and exchange, electricity frequency conversion bottlenecks, weak demand-side management strategies, regulatory quality issues, and over-investment in electricity and gas infrastructure capacity which contributed to the increasing cost of energy that threatened industrial competitiveness and affordability.

6.1.2 How do energy policies affect energy security in Japan in terms of strategies to reduce vulnerabilities?

Japan employed a wide range of policies and strategies designed to address energy security issues and vulnerabilities over the 2000-2013 period. The impact of energy policies on the properties of a secure energy system can be summarized as follows.

Robustness

Over the 2000-2010 period, Japan's energy system was robust. The country had an extensive and diverse fleet of power generation plants and LNG terminals and a reliable electricity and gas transmission/distribution infrastructure. Electricity and gas infrastructure adequately met demand over the whole of the period with the exception of a short period immediately after the triple disaster. However after the disaster, a number of robustness-related policy issues became evident. The shutdown of virtually all of Japan's nuclear reactors created an issue of the future adequacy of nuclear power. Policies to address electricity and gas interconnections, a frequency "bottleneck" and over-investment in electricity generation capacity were lacking or inadequate, making recovery from the disaster more difficult. High and rising end-use prices were a concern over the whole period and the analysis showed that policies related to market structure contributed to high energy prices in Japan.

Resilience

Between 2000 and 2010, resilience in Japan's energy system improved by a number of measures, and many of the government's energy security and sustainability targets were achieved. By the end of the period the country had reduced its reliance on oil and it had a well-diversified primary energy supply mix and electricity generation mix. As a result of substantial investments in electricity infrastructure over several decades Japan possessed a deep reservoir of idle capacity, and together with ample reserve margins and emergency stockpiles of oil and LPG, the country had access to significant buffers. Ongoing policy commitments to energy efficiency and conservation led to improvements on an already impressive record and carbon intensity and emissions per capita steadily declined. Japan's resource security strategies contributed to resilience, proving helpful immediately after the triple disaster and in helping secure energy supplies in the future. However, the triple disaster exposed the weak policy commitment to increasing renewables generation up to 2012, and significant barriers continued to limit their increase. Policies to address residential energy consumption were shown to be weak in the period leading up to the disaster.

Adaptive capacity

Adaptive capacity generally improved over the 2000-2013 period as Japan maintained a level of investment and commitment to energy technology R&D that was very high by international standards. The country also employed various innovation and technology development strategies and projects which served as adaptive mechanisms in helping improve energy security outcomes. With regard to market structure and liberalization, various measures were taken over the period to streamline regulations and increase competition in electricity and gas markets and, while a number of significant issues remain, some progress was achieved in moving toward competitive markets. Nonetheless, the triple disaster exposed some serious policy deficiencies with respect to market structure and regulatory oversight, which contributed to the worsening robustness-related vulnerabilities in regional electricity and gas markets mentioned above. The decline in public support for and even active resistance against nuclear power has worsened since the disaster and put the onus on government to more effectively engage in public discussion and exchange in order to build support and understanding for its policies.

Outcome for energy security

Based on the evaluation of Japan's energy policies and their impact on the properties of a secure energy system, it can be concluded that policies were effective in reducing overall vulnerability and improving robustness, resilience and adaptability over the 2000-1010 period. Japan's energy system proved to be highly resilient and adaptable in spite of the magnitude and extent of the shock delivered by the triple disaster, demonstrating that even a country with almost no natural sources of conventional energy can employ strategies to significantly reduce vulnerabilities to threats and risks. Although the disaster caused great loss of life and exposed some major weaknesses and shortcomings, Japan's framework of energy policies together with the capabilities of the various human actors in the system can be credited with helping make the impact on the energy system far less severe and the recovery much more rapid than might otherwise have been the case.

Japan's overall energy security situation in the post-Fukushima period can be said to have degraded significantly. The analysis in this thesis showed that in the post-disaster period a number of pre-existing vulnerabilities were exacerbated and other vulnerabilities and issues were revealed, exposing deficiencies in the energy security policy framework. In the wake of the disaster, the government undertook a "zero-based" review of its energy policies and identified many of the vulnerabilities and related issues discussed in this thesis. This led to the development of the 2014 SEP which has proposed a more comprehensive and integrated approach to addressing energy security issues.

6.1.3 How do energy policies affect energy security in Japan in terms of the relationship with other policy objectives?

With the "3-E's+S" principles of energy policy, Japan aims for a balanced and integrated approach to the enhancement of long-term energy security and sustainability. This study's analysis of Japanese long-term energy security and sustainability policy targets over the 2000-2013 period showed that Japan maintained a relatively high level of energy security over the 2000-2010 period while at the same time managed to reduce its total CO2 emissions and emissions intensity. Still, the inability to reach nuclear and renewables targets contributed to making CO_2 emissions higher in 2010 than in 1990. Nonetheless, Japan did meet its Kyoto targets in 2013 by utilizing Kyoto mechanisms.

After the triple disaster, there was a rapid increase in GHG emissions associated with the increase in fossil fuel power generation. Energy security concerns took precedence over sustainability goals, which served to compromise Japan's climate mitigation efforts and lower the country's international climate change commitments. Uncertainty surrounding the restart of nuclear power plants and public concerns over nuclear power complicated energy policymaking and led to a four-year period in which the government provided no firm guidance or targets for the electricity generation sector. As a result, new fossil-fuel based thermal generation expanded to fill the gap in generation capacity, locking in increases in CO_2 emissions. As a result, efforts to balance the 3-E's + S were compromised as the country found itself having to prioritize energy security and economic efficiency over sustainability in order to protect the economy and continue to provide essential services to its citizens.

By April, 2015, Japan had finalized its energy mix targets which allowed it to revise upward its earlier commitments to GHG emission reduction targets for COP 21 in Paris. However, with uncertainty over nuclear power plant restarts, it was unclear at the time of completing this thesis whether Japan could meet these new emissions targets.

6.1.4 How do energy policies affect energy security in Japan in terms of institutional change?

Institutions shape the way that energy policy is formulated and implemented and therefore they exert a significant influence on energy security. This study has examined Japan's energy institutions in detail and noted the changes that have taken place over the 2000-2013 period.

In the post-war period, Japan's institutional reforms have generally been gradual and incremental, designed not to radically change existing institutions but rather to help them adapt while building on their strengths. However, the shock of the triple disaster has engendered a critical juncture in Japan's energy system development stimulating rapid structural and institutional changes and serving to shift the course of Japan's energy system development onto a new path.

Institutional change in Japan's energy sector is driven both by evolution and design. Change occurs endogenously driven by competition, innovation, and technological change as well as exogenously through policies and various kinds of threats and pressures arising in the energy system's environment. While political and bureaucratic actors may play an influential role in shaping the energy transition, transition initiatives are being implemented primarily in the private sector and in society.

Japan's institutional structure helps shape the pattern of change in the energy sector, but the structure itself is evolving. As government's role has shifted toward promoting deregulation and liberalization and relying on competitive markets, institutional change is likely to be increasingly shaped by endogenous competitive pressures at the level of firms and markets, with government gradually playing a less control-oriented role in managing the system. This is already evident from the empirical data presented in this thesis which demonstrates that significant structural changes are already taking place in Japan's energy markets.

As recent energy system reforms take hold and as an increasing number of new firms enter Japan's power generation and retail markets and are exposed to market forces, the cost-benefit calculation for energy firms is changing as they evaluate the threats and opportunities presented by the changes. The evidence presented in this chapter demonstrates that existing relationships, networks and partnerships are being re-evaluated in light of new circumstances. It can be expected that cost-benefit calculations will take on a more a more economic-rational character as firms struggle to survive in an increasingly competitive environment.

This thesis identified three institutional issues underlying outstanding energy security vulnerabilities and concerns: a lack of government commitment to structural reforms, ineffectiveness of policy implementation, and lack of public engagement on energy issues. With the release of the 2014 SEP and recent observed institutional and structural changes, the question remains how energy security will be affected by these changes?

It is encouraging that the government has begun to implement policies designed to address, at least in part, many of the energy security issues raised in this thesis. On the issue of commitment to reform, this thesis has argued that the impact of the triple disaster created a critical juncture in the path of Japan's energy system development where major energy sector reforms became possible. While the 2014 SEP builds upon and accelerates certain policy measures introduced in the period leading up to the disaster, the plan incorporates significant new reform measures that set the stage for a major energy transition. The government's rapid passing of legislation, the development of robust and detailed plans along with budget increases for proposed initiatives strongly suggests that political and bureaucratic commitment to pushing forward with transition initiatives has been significantly strengthened.

In terms of the effectiveness of policy implementation, the empirical evidence presented in this thesis shows that significant structural and institutional changes in Japan's energy sector have already begun. These changes were shown to be well-aligned with the government's policies, and this can be regarded as an early indication that policies are having the desired effect. Existing energy sector relationships, networks and partnerships are being re-evaluated in light of new circumstances and cost-benefit calculations appear to be more market-driven as utilities and other firms form new partnerships and alliances and compete in each other's markets for the first time.

Few of the outstanding energy security issues identified in this thesis can be dealt with quickly since most of them require significant policy adjustments and/or structural changes, although infrastructure robustness issues should be addressed as a priority since they are more readily controllable. Japan's has significant sunk costs invested in the old regional monopoly paradigm and overcoming institutional and structural rigidities will take many years and significant resources. Japan's energy institutions have co-evolved with the energy sector and the ones that survive the reforms and the new ones that are created will require time to adjust to the new institutional environment.

In summary, the policy measures and structural changes that have been made to date, the movement toward a greater reliance on markets, and a stronger willingness to advance the reforms outlined in the 2014 SEP suggest that Japan is taking firm steps toward dealing with its outstanding energy security challenges.

6.1.5 How do energy policies affect energy security in Japan in terms of the potential impact on energy security in the future?

Theory suggests that the period immediately after a critical juncture is crucial in terms of determining the future path of system development. While policies and political agency have played an important role in setting the general direction of the transition, actual changes in energy markets, competitive pressures, public attitudes and technology developments will also be instrumental in future system evolution. The Japanese energy transition is still in a very early stage as the impacts of various policies and reforms gradually work their way through the energy sector.

A planned transition implies that system evolution must be closely monitored and adjustments made in order to help guide the system toward the vision of a multi-layered system. Policy tools such as administrative signals, incentives for renewables, measures to ensure adequacy of power generation, and measures to achieve electricity mix targets and climate change goals will still be essential. In a competitive market environment, stimulating private investment in energy generation and infrastructure will require new forms of coordination in order to reduce political and regulatory uncertainties and reassure investors about prospective financial returns in the future.

Assuming the government stays the course and avoids policy retrenchments, the period between 2016 and 2020 will be crucial to achieving the objectives in the SEP. As 2020 approaches and the pace of structural change begins to slow, the outlines of the new energy system configuration should become more clear. As the market gradually finds a new dynamic equilibrium, theory suggests that positive feedback will begin to reinforce the new paradigm and deepen the path taken by the new regime.

A potential risk to the transition can be found in Japanese history. Other major transitions including the rapid industrialization of the Meiji period and the period of reforms during the post-war U.S. Occupation saw Japan's embedded institutions re-assert themselves after a few years of experimentation and change. The experience of Japan's telecom liberalization in the 1990's also suggests that while the number of new entrants into generation and retail markets has increased sharply, intensifying competition for market share is likely to result in a fewer number of players over time. The government will need to continue to closely monitor for market failures, including the possibility that the sector may come to be dominated by an oligopoly of horizontally integrated energy services firms, rather than the regionally-based vertical monopolies existing today. It remains to be seen the degree to which Japan's embedded institutions will continue to influence the future institutional structure.

Energy sector reforms have begun to move Japan away from the state-centric, rigid type of energy governance that prevailed in previous decades. Since the triple disaster, as momentum for change has accelerated and the effect of more dramatic market and structural reforms have become more evident, energy sector governance has evolved to reflect the growing influence of competitive markets and a broader array of energy actors and institutions. The analysis in this thesis suggests that Japan is moving toward a more robust and reflexive form of governance that prioritizes adaptability and economic efficiency over predictability and stability.

One policy area that creates potential risks to the achievement of Japan's 2030 energy policy targets is the continued lack of "two-way" public engagement on energy issues, as called for in the 2014 SEP. In the absence of a national dialog, local governments and communities have been advocating various positions on energy issues and have enacted policies or mounted legal challenges at the local level that are sometimes at odds with national energy goals. It remains to be seen whether public attitudes toward issues such as nuclear power will stiffen, or whether the safe restart of reactors will gradually allay fears and lower public resistance.

More generally, if the goals of the 2014 SEP are realized and the energy system evolves into the multi-layered energy structure that the 2014 SEP envisions, Japan will have created a more resilient and adaptable energy system – one that is more capable of reducing vulnerability to a broader range of unpredictable threats and risks. While the future is uncertain and unexpected events and developments are sure to occur, Japan appears to have taken firm steps toward enhancing its energy security in the future.

6.2 Novelty in this research study

This study fills a number of gaps in the scholarly literature on energy security and makes several novel contributions.

- Few studies have taken a comprehensive approach to the overall state of Japan's energy security, especially post-Fukushima. This study integrates an energy security assessment with an institutional analysis and compares the pre and post Fukushima energy security situations, taking a systemic approach to assessing vulnerabilities across the whole energy supply chain. Consequently, this study provides the most comprehensive assessment of energy security in Japan since the Fukushima disaster.

- There are a limited number of studies in the literature that take an integrated approach to the analysis of the energy system. This study integrates concepts from systems theory, economics, risk studies, sustainability studies, political economy, governance theory and institutional theories to provide a more holistic perspective on energy security and change in Japan's energy system.
- A novel analytical framework for energy security assessment based on three properties (i.e.: robustness, resilience and adaptability) of a secure energy system was developed and applied in this study.
- While there are many energy security studies that have evaluated resilience in energy systems, very few studies have applied the concept of adaptive capacity to socio-technical systems or have evaluated adaptive capacity as a dimension of energy security. This study differentiated the property of adaptive capacity from resilience and other system properties, described its key role in enhancing energy security and applied it to the case of Japan.
- Despite the fact that the 2014 SEP represents a major revision compared to previous energy plans and proposes major energy system reforms, there has not yet been any detailed analysis of the 2014 plan or its broader implications for energy system change in the academic literature. This study provides the first in-depth analysis of 2014 Strategic Energy Plan arguing that it represents a major energy transition and provides unique insights into the development of the plan based on interviews conducted with senior METI officials.
- A detailed post-Fukushima analysis of Japan's energy institutions is lacking in the literature, despite the importance of these institutions to changes in Japan's energy sector. More specifically, a detailed analysis of institutional change in Japan's energy sector post-Fukushima has not been examined in the literature. This study uniquely relies on data collected from interviews with officials from government, intermediate organizations and industry associations to strengthen the institutional analysis.
- This study employs a unique framework for institutional analysis that integrates several economic, political and sociological perspectives on institutions. This enables an in-depth analysis of the institutional structure that shapes energy policy in Japan, providing insights into current and past policy developments as well as how energy policies may evolve in the future. This will be foundational to further research on assessing the trajectory of the evolution of Japan's energy system in the future.

6.3 Future research directions

This study represents a contribution toward filling a gap in the scholarly literature regarding the impact of energy policies and institutional change on Japan's energy security. As such, it integrates an energy security assessment with an analysis of institutions in order to make conclusions about how energy policies affect energy security in Japan.

The research in this study suggests several avenues of future research that could be explored. With respect to energy security assessment techniques and approaches, more work should be done to develop suitable indicators for adaptive capacity. While this thesis developed the notion of adaptive mechanisms, further research into developing a taxonomy of adaptive mechanisms and suitable measures would be invaluable to a broader assessment of energy security. Similarly, measures and indicators for assessing the effectiveness of energy security strategies are also needed, recognizing that the type of energy security strategies and the extent of their use will differ depending on the country being analyzed.

More research could be performed on assessing the effectiveness of Japanese energy policies in general, especially their cost-effectiveness. The number and breadth of Japanese energy policies is extensive and ever-changing and it is difficult to evaluate their effectiveness either individually or collectively. Although reports on the programs contained in its energy plans and polices are published annually (i.e.: White Papers), they do not provide detailed program or policy evaluations and are more descriptive in nature.

Finally, while the framework and methodology employed in this thesis has been developed and tailored for Japan's specific energy security and institutional situation, it could be easily modified to provide a basis for a broader and more comprehensive approach to energy security assessment for almost any developed country energy system.

References

[1] B. K. Sovacool and M. A. Brown, "Competing dimensions of energy security: An international perspective," *Annu. Rev. Environ. Resour.*, vol. 35, pp. 77–108, 2010.

[2] A. Cherp and J. Jewell, "The three perspectives on energy security: intellectual history, disciplinary roots and the potential for integration," *Curr. Opin. Environ. Sustain.*, vol. 3, no. 4, pp. 202–212, 2011.

[3] L. Chester, "Conceptualising energy security and making explicit its polysemic nature," *Energy Policy*, vol. 38, no. 2, pp. 887–895, Feb. 2010.

[4] W. L. Filho and V. Voudouris, *Global Energy Policy and Security (Lecture Notes in Energy)*, 2013 edition. Springer, 2013.

[5] L. Fuerth, "National security, energy, climate change: new paradigm; new strategy; new governance," in *Energy and security: strategies for a world in transition*, J. H. Kalicki and D. L. Goldwyn, Eds. Woodrow Wilson Center Press, 2013, pp. 499–514.

[6] EIA, "Japan - International - U.S. Energy Information Administration (EIA)," 2015. [Online]. Available: http://www.eia.gov/beta/international/country.cfm?iso=JPN. [Accessed: 20-Jan-2016].

[7] S. Chowdhury, U. Sumita, A. Islam, and I. Bedja, "Importance of policy for energy system transformation: Diffusion of PV technology in Japan and Germany," *Energy Policy*, vol. 68, pp. 285–293, May 2014.

[8] T. Kuramochi, "Review of energy and climate policy developments in Japan before and after Fukushima," *Renew. Sustain. Energy Rev.*, vol. 43, pp. 1320–1332, Mar. 2015.

[9] T. Homma and K. Akimoto, "Analysis of Japan's energy and environment strategy after the Fukushima nuclear plant accident," *Energy Policy*, vol. 62, pp. 1216–1225, Nov. 2013.

[10] B. C. McLellan, Q. Zhang, N. A. Utama, H. Farzaneh, and K. N. Ishihara, "Analysis of Japan's post-Fukushima energy strategy," *Energy Strategy Rev.*, vol. 2, no. 2, pp. 190–198, Sep. 2013.

[11] R. Matsuhashi, K. Takase, K. Yamada, and H. Komiyama, "New energy policy and low-carbon society in Japan after the Great East Japan Earthquake," *Chin. J. Popul. Resour. Environ.*, vol. 11, no. 1, pp. 62–68, Mar. 2013.

[12] E. Mizuno, "Overview of wind energy policy and development in Japan," *Renew. Sustain. Energy Rev.*, vol. 40, pp. 999–1018, Dec. 2014.

[13] E. Moe, "Vested interests, energy efficiency and renewables in Japan," *Energy Policy*, vol. 40, pp. 260–273, Jan. 2012.

[14] V. Vivoda and G. Graetz, "Nuclear Policy and Regulation in Japan after Fukushima: Navigating the Crisis," *J. Contemp. Asia*, vol. 0, no. 0, pp. 1–20, 2014.

[15] T. N. Srinivasan and T. S. Gopi Rethinaraj, "Fukushima and thereafter: Reassessment of risks of nuclear power," *Energy Policy*, vol. 52, pp. 726–736, Jan. 2013.

[16] T. Masuda and R. Komiyama, "Positioning of Nuclear in the Japanese Energy Mix," 2012.

[17] D. P. Aldrich, "Post-crisis Japanese nuclear policy: from top-down directives to bottom-up activism," 2012.

[18] J. Portugal-Pereira and M. Esteban, "Implications of paradigm shift in Japan's electricity security of supply: A multi-dimensional indicator assessment," *Appl. Energy*, vol. 123, pp. 424–434, Jun. 2014.

[19] J. Portugal Pereira, G. Troncoso Parady, and B. Castro Dominguez, "Japan's energy conundrum: Post-Fukushima scenarios from a life cycle perspective," *Energy Policy*, vol. 67, pp. 104–115, 2014.

[20] M. Esteban and J. Portugal-Pereira, "Post-disaster resilience of a 100% renewable energy system in Japan," *Energy*, vol. 68, pp. 756–764, 2014.

[21] K. Morita and K. Matsumoto, "Renewable energy-related policies and institutions in Japan: before and after the Fukushima nuclear accident and the feed-in tariff introduction," *Leg. Issues Renew. Electr. Asia Reg. Recent Dev. Post-Fukushima Post-Kyoto Protoc. Era*, pp. 3–28, 2014.

[22] A. Semmler, "Renewable Energy in Japan: New Competition in the Energy Market after Fukushima," Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 2124157, Apr. 2012.

[23] H. Hatayama and K. Tahara, "Evaluating the sufficiency of Japan′s mineral resource entitlements for supply risk mitigation," *Resour. Policy*, vol. 44, pp. 72–80, Jun. 2015.

[24] F. Umbach, "The energy security of Japan after Fukushima 3/11," in *The Political Economy of Renewable Energy and Energy Security: Common Challenges and National Responses in Japan, China and Northern Europe*, E. Moe and P. Midford, Eds. Palgrave Macmillan, 2014.
[25] M. Hayashi and L. Hughes, "The Fukushima nuclear accident and its effect on global energy security," *Energy Policy*, vol. 59, pp. 102–111, Aug. 2013.
[26] S. H. Lesbirel, "The Insuring State: Japanese Oil Import Security and the Middle East," *Asian J. Polit. Sci.*, vol. 21, no. 1, pp. 41–61, Apr. 2013.
[27] V. Vivoda, "Japan's energy security predicament post-Fukushima," *Energy Policy*, vol. 46, pp. 135–143, Jul. 2012.
[28] D. V. Vivoda, *Energy Security in Japan: Challenges After Fukushima*. Ashgate Publishing, Ltd., 2014.
[29] B. K. Sovacool, "An international assessment of energy security performance," *Ecol. Econ.*, vol. 88, pp. 148–158, Apr. 2013.
[30] K. Koyama and I. Kutani, "Study on the development of an energy security index and an assessment of energy security for East Asian countries (Part I)," Economic Research Institute for ASEAN and East Asia (ERIA), 2012.
[31] K. Takase and T. Suzuki, "The Japanese energy sector: Current situation, and future paths," *Energy Policy*, vol. 39, no. 11, pp. 6731–6744, Nov. 2011.
[32] C. Winzer, "Conceptualizing energy security," *Energy Policy*, vol. 46, pp. 36–48, Jul. 2012.
[33] B. Johansson, "A broadened typology on energy and security," *Energy*, vol. 53, pp. 199–205, May 2013.
[34] A. Mansson, B. Johansson, and L. J. Nilsson, "Assessing energy security: An overview of commonly used methodologies," *Energy*, 2014.
[35] F. Gracceva and P. Zeniewski, "A systemic approach to assessing energy security in a low-carbon EU energy system," *Appl. Energy*, 2013.
[36] P. Andrews-Speed, "Applying institutional theory to the low-carbon energy transition," *Energy Res. Soc. Sci.*, 2016.
[37] R. J. Samuels, *The business of the Japanese state: Energy markets in comparative and historical perspective*. Cornell Univ Pr, 1987.
[38] W. R. Scott, *Institutions And Organizations*, 4 edition. Los Angeles: Sage Publications, 2013.
[39] J. Kingston, "Japan's nuclear village," in *Critical issues in contemporary Japan*, Routledge, 2013.
[40] Andrew DeWit, "Japan's renewable power prospects," in *Critical issues in contemporary Japan*, Routledge, 2013.
[41] R. J. Samuels, *3.11: Disaster and Change in Japan*. Ithaca, NY: Cornell University Press, 2013.
[42] P. J. Scalise, "Who controls whom? Constraints, challenges and rival policy images in Japan's post-war energy restructuring," in *Critical Issues in Contemporary Japan*, J. Kingston, Ed. 2013, p. 92.
[43] P. Midford, "The Impact of 3–11 on Japanese Public Opinion and Policy Toward Energy Security," *Polit. Econ. Renew. Energy Energy Secur. Common Chall. Natl. Responses Jpn. China North. Eur.*, p. 67, 2014.
[44] A. DeWit, I. Tetsunari, and K. Masaru, "Natural Disaster and Nuclear Crisis in Japan," in *Fukushima and the political economy of power policy in Japan*, J. Kingston, Ed. na, 2012.
[45] H. Rohracher, "Transforming energy systems toward sustainability: critical issues from a socio-technical perspective," *Int. J. Environ. Technol. Manag.*, vol. 9, no. 2, pp. 144–161, 2008.
[46] H. G. Brauch, "Concepts of Security Threats, Challenges, Vulnerabilities and Risks," in *Coping with Global Environmental Change, Disasters and Security*, H. G. Brauch, Ú. O. Spring, C. Mesjasz, J. Grin, P. Kameri-Mbote, B. Chourou, P. Dunay, and J. Birkmann, Eds. Springer Berlin Heidelberg, 2011, pp. 61–106.
[47] J. Greenleaf, R. Harmsen, and T. Angelini, "Analysis of impacts of climate change policies on energy security," European Commission, 2009.
[48] A. Cherp, A. Adenikinju, A. Goldthau, L. Hughes, J. Jewell, M. Olshanskaya, J. Jansen, R. Soares, and S. Vakulenko, "GEA-Chapter 5 - Energy and security," in *Global Energy Assessment: Toward a Sustainable Future*, 2012, pp. 325–383.
[49] B. Kruyt, D. P. van Vuuren, H. J. M. de Vries, and H. Groenenberg, "Indicators for energy security," *Energy Policy*, vol. 37, no. 6, pp. 2166–2181, Jun. 2009.

[50] WEF, “World Competitiveness Report - 2012,” World Economic Forum, 2012.
[51] IEA, “What is energy security?,” 18-Oct-2015. [Online]. Available: https://www.iea.org/topics/energysecurity/subtopics/whatisenergysecurity/. [Accessed: 18-Oct-2015].
[52] V. Vivoda, “Evaluating energy security in the Asia-Pacific region: A novel methodological approach,” *Energy Policy*, vol. 38, no. 9, pp. 5258–5263, 2010.
[53] D. von Hippel, T. Suzuki, J. H. Williams, T. Savage, and P. Hayes, “Energy security and sustainability in Northeast Asia,” *Energy Policy*, vol. 39, no. 11, pp. 6719–6730, 2009.
[54] D. Yergin, “Ensuring Energy Security,” *Foreign Aff.*, vol. 85, no. 2, p. 69, 2006.
[55] J. Shin, W.-S. Shin, and C. Lee, “An energy security management model using quality function deployment and system dynamics,” *Energy Policy*, vol. 54, pp. 72–86, Mar. 2013.
[56] B. K. Sovacool and I. Mukherjee, “Conceptualizing and measuring energy security: A synthesized approach,” *Energy*, vol. 36, no. 8, pp. 5343–5355, Aug. 2011.
[57] J. C. Jansen and A. J. Seebregts, “Long-term energy services security: What is it and how can it be measured and valued?,” *Energy Policy*, vol. 38, no. 4, pp. 1654–1664, Apr. 2010.
[58] D. Yergin, “Energy Security and Markets,” in *Energy and security: strategies for a world in transition*, Second., J. H. Kalicki and D. L. Goldwyn, Eds. Woodrow Wilson Center Press Washington, 2013, pp. 69–87.
[59] M. C. Chuang and H. W. Ma, “An assessment of Taiwan’s energy policy using multi-dimensional energy security indicators,” *Renew. Sustain. Energy Rev.*, vol. 17, pp. 301–311, Jan. 2013.
[60] E. Kropatcheva, “He who has the pipeline calls the tune? Russia’s energy power against the background of the shale ‘revolutions,’” *Energy Policy*, vol. 66, pp. 1–10, Mar. 2014.
[61] J. H. Keppler, “International Relations and Security of Energy Supply : Risks to Continuity and Geopolitical Risks,” European Parliament, Feb. 2007.
[62] IEA, “World Energy Outlook-2013,” International Energy Agency (IEA), 2013.
[63] IEA/OECD, “Energy Security and Climate Policy: Assessing Interactions,” International Energy Agency (IEA), 2007.
[64] IEA, “IEA initiates dialogue on the energy security impacts of climate change,” 2012. [Online]. Available: http://www.iea.org/newsroomandevents/pressreleases/2012/november/name,33311,en.html. [Accessed: 06-Feb-2014].
[65] WEC, “World Energy Scenarios: Composing energy futures to 2050,” World Energy Council, 2013.
[66] C. Pascual and J. Elkind, *Energy security: economics, politics, strategies, and implications*. Brookings Institution Press, 2010.
[67] Economic Commission for Europe, UN, *Emerging Global Energy Security Risks*, vol. 36. United Nations Publications, 2007.
[68] J. Jewell, “Energy security and climate change mitigation: The interaction in long-term global scenarios | Center for Climate Change and Sustainable Energy Policy,” 2013.
[69] J. C. Jansen, W. G. Van Arkel, and M. G. Boots, *Designing indicators of long-term energy supply security*. Energy research Centre of the Netherlands ECN, 2004.
[70] IEA, “Energy security,” 2013. [Online]. Available: http://www.iea.org/topics/energysecurity/. [Accessed: 30-Dec-2013].
[71] A. Cherp and J. Jewell, “Measuring Energy Security - From universal indicators to contextualized frameworks,” in *The Routledge Handbook of Energy Security*, B. K. Sovacool, Ed. 2010, p. 330.
[72] C. Egenhofer, K. Gialoglou, G. Luciani, M. Boots, M. Scheepers, V. Costantini, F. Gracceva, A. Markandya, and G. Vicini, “Market-based Options for Security of Energy Supply,” Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 593824, Sep. 2004.
[73] J. Kucharski and H. Unesaki, “A policy-oriented approach to energy security,” *Elsevier Procedia Environ. Sci.*, vol. 28, pp. 27–36, 2015.
[74] M. Barrett, M. Bradshaw, A. Froggatt, C. Mitchell, Y. Parag, A. Stirling, J. Watson, and C. Winzer, “Energy security in a multi-polar world,” *Energy Secur. Multipolar World*, 2010.
[75] APERC, “A quest for energy security in the 21st century,” Asia Pacific Energy Research Center-APERC, 2007.

[76] J.-M. Chevalier, “Security of energy supply for the European Union,” *Eur. Rev. Energy Mark.*, vol. 1, no. 3, pp. 1–20, 2006.
[77] M. M. Waldrop, *Complexity: The emerging science at the edge of order and chaos*. Simon and Schuster, 1993.
[78] B. Zimmerman, C. Lindberg, and P. Plsek, *Edgeware: Lessons from Complexity Science for Health Care Leaders*. Irving, Tex.: V H A, Incorporated, 1998.
[79] G. Eoyang, “A Complex Adaptive Systems (CAS) Approach to Public Policy Decision Making,” 1998.
[80] C. Perrow, “Organizing to Reduce the Vulnerabilities of Complexity,” *J. Contingencies Crisis Manag.*, vol. 7, no. 3, pp. 150–155, Sep. 1999.
[81] F. A. Hayek, “The theory of complex phenomena,” *Crit. Approach Sci. Philos.*, pp. 332–349, 1964.
[82] A. Goldthau, “Rethinking the governance of energy infrastructure: Scale, decentralization and polycentrism,” *Energy Res. Soc. Sci.*, vol. 1, pp. 134–140, Mar. 2014.
[83] R. J. Glass, “Complex adaptive systems of systems engineering,” Sandia National Laboratories, 2010.
[84] S. M. Rinaldi, J. P. Peerenboom, and T. K. Kelly, “Identifying, understanding, and analyzing critical infrastructure interdependencies,” *Control Syst. IEEE*, vol. 21, no. 6, pp. 11–25, 2001.
[85] A. Stirling, “On the economics and analysis of diversity,” *Sci. Policy Res. Unit SPRU Electron. Work. Pap. Ser. Pap.*, vol. 28, pp. 1–156, 1998.
[86] A. Stirling, “The diversification dimension of energy security,” in *The Routledge handbook of energy security*, B. K. Sovacool, Ed. Taylor & Francis, 2010, pp. 146–175.
[87] WEF, “Global Risks 2014 Nineth Edition,” World Economic Forum, 2014.
[88] A. Checchi, A. Behrens, and C. Egenhofer, *Long-term energy security risks for Europe: a sector-specific approach*, vol. 309. CEPS, 2009.
[89] C. Orwat, C. Büscher, and O. Raabe, “Governance of Critical Infrastructures, Systemic Risks, and Dependable Software,” Technical Report. Karlsruhe Institute of Technology. Karlsruhe, 2010.
[90] C. Macdonald, M. Oldreive, and E. Pegolo, “Managing Current Complexity: Critical Energy Infrastructure Failures in North America,” Dalhousie University, 2012.
[91] Y. Y. Haimes, “On the Definition of Vulnerabilities in Measuring Risks to Infrastructures,” *Risk Anal. Int. J.*, vol. 26, no. 2, pp. 293–296, Apr. 2006.
[92] Y. Y. Haimes, “On the Definition of Resilience in Systems,” *Risk Anal.*, vol. 29, no. 4, pp. 498–501, Apr. 2009.
[93] J. Johansson, “Risk and vulnerability analysis of interdependent technical infrastructures,” *Lund Univ. Dept Meas. Technol. Ind. Electr. Eng.*, 2010.
[94] E. Jen, “Stable or robust? What’s the difference?,” *Complexity*, vol. 8, no. 3, pp. 12–18, Jan. 2003.
[95] N. Suri and G. Cabri, *Adaptive, Dynamic, and Resilient Systems*, 1 edition. Boca Raton: Auerbach Publications, 2014.
[96] A. Wieland and C. M. Wallenburg, “Dealing with supply chain risks: Linking risk management practices and strategies to performance,” *Int. J. Phys. Distrib. Logist. Manag.*, vol. 42, no. 10, pp. 887–905, 2012.
[97] A. Stirling, “From sustainability, through diversity to transformation: towards more reflexive governance of technological vulnerability,” *Vulnerability Technol. Cult. New Dir. Res. Gov. MIT Press Camb.*, 2013.
[98] S. A. Levin, S. Barrett, S. Aniyar, W. Baumol, C. Bliss, B. Bolin, P. Dasgupta, P. Ehrlich, C. Folke, and I. GREN, “Resilience in natural and socioeconomic systems,” *Environ. Dev. Econ.*, vol. 3, no. 2, pp. 221–262, 1998.
[99] W. B. Arthur, *Increasing returns and path dependence in the economy*. University of Michigan Press, 1994.
[100] T. J. Foxon, “Technological and institutional ‘lock-in’as a barrier to sustainable innovation,” *Imp. Coll. Cent. Energy Policy Technol. ICCEPT*, 2002.
[101] A. Smith and A. Stirling, “The Politics of Social-ecological Resilience and Sustainable Socio-technical Transitions,” *Ecol. Soc.*, vol. 15, no. 1, p. 11, 2010.
[102] G. C. Gallopin, “Linkages between vulnerability, resilience, and adaptive capacity,” *Glob. Environ. Change*, vol. 16, no. 3, pp. 293–303, Aug. 2006.

[103] S. Carpenter, B. Walker, J. M. Anderies, and N. Abel, "From metaphor to measurement: resilience of what to what?," *Ecosystems*, vol. 4, no. 8, pp. 765–781, 2001.
[104] B. Walker, C. S. Holling, S. R. Carpenter, and A. Kinzig, "Resilience, Adaptability and Transformability in Social–ecological Systems," *Ecol. Soc.*, vol. 9, no. 2, p. 5, 2004.
[105] A. Smith, A. Stirling, and F. Berkhout, "The governance of sustainable socio-technical transitions," *Res. Policy*, vol. 34, no. 10, pp. 1491–1510, Dec. 2005.
[106] G. Yohe and R. S. J. Tol, "Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity," *Glob. Environ. Change*, vol. 12, no. 1, pp. 25–40, Apr. 2002.
[107] F. Berkhout, A. Smith, and A. Stirling, "Socio-technological regimes and transition contexts," *Syst. Innov. Transit. Sustain. Theory Evid. Policy Edw. Elgar Chelten.*, pp. 48–75, 2004.
[108] B. Smit and J. Wandel, "Adaptation, adaptive capacity and vulnerability," *Glob. Environ. Change*, vol. 16, no. 3, pp. 282–292, Aug. 2006.
[109] W. N. Adger, D. I. Lorenzoni, and K. L. O'Brien, Eds., *Adapting to Climate Change: Thresholds, Values, Governance*, 1 edition. Cambridge ; New York: Cambridge University Press, 2009.
[110] D. R. Nelson, W. N. Adger, and K. Brown, "Adaptation to Environmental Change: Contributions of a Resilience Framework," *Annu. Rev. Environ. Resour.*, vol. 32, no. 1, pp. 395–419, 2007.
[111] S. L. Cutter, L. Barnes, M. Berry, C. Burton, E. Evans, E. Tate, and J. Webb, "A place-based model for understanding community resilience to natural disasters," *Glob. Environ. Change*, vol. 18, no. 4, pp. 598–606, Oct. 2008.
[112] N. L. Engle, "Adaptive capacity and its assessment," *Glob. Environ. Change*, vol. 21, no. 2, pp. 647–656, May 2011.
[113] D. von Hippel, T. Suzuki, J. H. Williams, T. Savage, and P. Hayes, "Evaluating the Energy Security Impacts of Energy Policies," in *The Routledge Handbook of Energy Security*, B. K. Sovacool, Ed. Routledge, 2011, pp. 74–95.
[114] B. Walker, L. Gunderson, A. Kinzig, C. Folke, S. Carpenter, and L. Schultz, "A handful of heuristics and some propositions for understanding resilience in social-ecological systems," *Ecol. Soc.*, vol. 11, no. 1, p. 13, 2006.
[115] D. C. North, *Institutions, institutional change and economic performance*. Cambridge university press, 1990.
[116] J. D. Wilson, "Northeast Asian Resource Security Strategies and International Resource Politics in Asia," *Asian Stud. Rev.*, vol. 0, no. 0, pp. 1–21, 2013.
[117] F. Umbach, "Global energy supply and geopolitical challenges," *Asia Eur. Coop. Energy Secur. Counc. Asia-Eur. Coop. CAEC-Task Force Rep. Paris IFRI*, pp. 137–168, 2004.
[118] P. Andrews-Speed, X. Liao, R. Dannreuther, and others, *The strategic implications of China's energy needs*. Oxford University Press for The International Institute for Strategic Studies, 2002.
[119] M. L. O'Sullivan, "The Entanglement of Energy, Grand Strategy, and International Security," in *The Handbook of Global Energy Policy*, A. Goldthau, Ed. John Wiley & Sons Ltd., 2013, pp. 30–47.
[120] D. F. S. Cohen and J. Kirshner, "The cult of energy insecurity and great power rivalry across the Pacific," in *The nexus of economics, security, and international relations in East Asia*, A. Goldstein and E. D. Mansfield, Eds. 2012, pp. 144–176.
[121] K. Koyama, "Japan's New National Energy Strategy," 2006.
[122] IEA, "World Energy Outlook-2014," International Energy Agency (IEA), 2014.
[123] METI, "Interim report of the Energy Security Study Group," Agency for Natural Resources and Energy, Japan, 2006.
[124] METI, "Energy in Japan 2010," Agency for Natural Resources and Energy, Japan, 2010.
[125] The Energy Conservation Center, Japan, *EDMC Handbook of Energy & Economic Statistics*, 2015th ed. The Institute of Energy Economics Japan, 2015.
[126] B. Jones, D. Steven, and E. O'Brien, "Fueling a New Order? The New Geopolitical and Security Consequences of Energy," The Brookings Institution, 2014.
[127] A. Yanagisawa, "China will soon become the largest net oil importer and will spend the most for its net fossil fuel imports," IEEJ, 2013.
[128] World Bank, "Learning from Megadisasters," World Bank, 2014.

[129] FEPC, "Electricity Review Japan 2015," Federation of Electric Power Companies of Japan, 2015.
[130] JEPIC, "Information of Japanese Electric Power Industry," Japan Electric Power Information Center, 2014.
[131] FEPC, "Energy & Electricity," 2015. [Online]. Available: http://www.fepc.or.jp/english/energy_electricity/index.html. [Accessed: 26-Oct-2015].
[132] JAIF, "Nuclear Power Plants in Japan (in operation and under construction)," Japan Atomic Industrial Forum, 2015.
[133] Nuclear Energy Institute, "Japan Nuclear Update," 22-Oct-2015. [Online]. Available: http://www.nei.org/News-Media/News/Japan-Nuclear-Update. [Accessed: 26-Oct-2015].
[134] Asahi Shimbun, "Nuclear operators push to open new plant, extend life of aging reactors," *AJW by The Asahi Shimbun*, 14-Nov-2014. [Online]. Available: http://ajw.asahi.com/article/0311disaster/fukushima/AJ201411140068. [Accessed: 26-Oct-2015].
[135] Asahi Shimbun, "Japan needs 35 nuclear reactors operating by 2030, says industry minister," *AJW by The Asahi Shimbun*, 11-Jun-2015.
[136] N. Chapman, K. Berryman, P. Villamor, W. Epstein, L. Cluff, and H. Kawamura, "Active faults and nuclear power plants," *Eos Trans. Am. Geophys. Union*, vol. 95, no. 4, pp. 33–34, 2014.
[137] METI, "Announcement Regarding the Present Status of Introduction of Facilities Generating Renewable Energy as of June 30, 2013," 2014. [Online]. Available: http://www.meti.go.jp/english/press/2013/1004_02.html. [Accessed: 29-Apr-2015].
[138] Nuclear Regulation Authority (NRA), "Operational Status of Nuclear Facilities in Japan," Nuclear Regulation Authority (Japan), 2004.
[139] IEA, "Energy Policies of IEA Countries: Japan 2003 Review," 2003.
[140] Nuclear Energy Institute, "US Nuclear Capacity Factors - Nuclear Energy Institute," 2015. [Online]. Available: http://www.nei.org/Knowledge-Center/Nuclear-Statistics/US-Nuclear-Power-Plants/US-Nuclear-Capacity-Factors. [Accessed: 03-Aug-2015].
[141] EIA, "Electricity Data," 04-Aug-2015. [Online]. Available: http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b. [Accessed: 03-Aug-2015].
[142] ABB Group, "Japan energy efficiency report," ABB Group, 2013.
[143] METI, "Electricity supply-demand measures taken by the fice electric utilities in Western Japan this summer," Ministry of Economy, Trade and Industry of Japan (METI), Nov. 2011.
[144] METI, "The Electricity Supply-Demand Verification Subcommittee Has Compiled a Report," 01-Apr-2015. [Online]. Available: http://www.meti.go.jp/english/press/2015/0430_01.html. [Accessed: 22-Oct-2015].
[145] IEA, "IEA Data Services," 22-Oct-2015. [Online]. Available: http://wds.iea.org/WDS/ReportFolders/ReportFolders.aspx. [Accessed: 22-Oct-2015].
[146] Asahi Shimbun, "59% oppose restart of nuclear reactors," 18-Mar-2014. [Online]. Available: http://ajw.asahi.com/article/0311disaster/fukushima/AJ201403180058. [Accessed: 10-May-2015].
[147] U.S. Nuclear Regulatory Commission, "High-Level Waste," 2015. [Online]. Available: http://www.nrc.gov/waste/high-level-waste.html. [Accessed: 06-Nov-2015].
[148] METI, "Final disposal plan for designated radioactive waste (特定放射性廃棄物の最終処分に関する計画を定めた件)," METI, 2008.
[149] RIST, "Results of actual shipments of vitrified high-level waste received," Research Organization for Information Science and Technology (RIST), 2015.
[150] METI, "Basic Policy on the Final Disposal of Designated Radioactive Wastes was Revised / Ministry of Economy, Trade and In," 2015. [Online]. Available: http://www.meti.go.jp/english/press/2015/0522_01.html. [Accessed: 06-Nov-2015].
[151] JFTC, "Proposals for the electricity market from competition policy," Japan Fair Trade Commission, 2012.
[152] D. Schwartz, Ed., "The Energy Regulation and Markets Review - Japan," *Energy Regul. Mark. Rev.*, vol. Fourth edition, 2015.

[153] H. Ohashi, "Challenges in Japan's Electricity Utility Reform: Preventing a rise in power rates and supply shortage," RIETI, Aug. 2014.
[154] IEA, "Energy Policies of IEA Countries - Japan 2008 Review," International Energy Agency (IEA), 2008.
[155] IEA, *Energy Supply Security 2014 - Japan*. Paris: Organisation for Economic Co-operation and Development, 2014.
[156] The Japan Gas Association, "Gas Facts in Japan," The Japan Gas Association, 2015.
[157] California Energy Commission, "LNG terminals in Japan," 2005.
[158] Gas Infrastructure Europe, "The European LNG terminal infrastructure 2015: Status and Outlook," Gas Infrastructure Europe, 2015.
[159] The Japan Gas Association, "Gas Facts in Japan," The Japan Gas Association, 2014.
[160] S. Shimizu, "CHP Market & Policy Movement in Japan," Japan Gas Association, 2013.
[161] Y. Harada, "Clearing the Smoke about Nuclear Energy Costs — The Tokyo Foundation," Tokyo Foundation, 2011.
[162] J. Adelman and M. Suga, "Japan Props Up More Power Utilities to Avoid Rate Increases," *Bloomberg.com*, 01-May-2014.
[163] Y. Matsuo and Y. Yamaguchi, "The Rise in Cost of Power Generation in Japan after the Fukushima Daiichi Accident and Its Impact on the Finances of the Electric Power Utilities," IEEJ, 2013.
[164] A. Yanagisawa, "Population decline and electricity demand in Japan: myth and facts," IEEJ, 2015.
[165] G. O'Brien and A. Hope, "Localism and energy: Negotiating approaches to embedding resilience in energy systems," *Energy Policy*, vol. 38, no. 12, pp. 7550–7558, Dec. 2010.
[166] H. Blum and L. F. L. Legey, "The challenging economics of energy security: Ensuring energy benefits in support to sustainable development," *Energy Econ.*, vol. 34, no. 6, pp. 1982–1989, Nov. 2012.
[167] REN21, "Renewables 2014 Global Status Report," REN21, 2014.
[168] S. V. Buldyrev, R. Parshani, G. Paul, H. E. Stanley, and S. Havlin, "Catastrophic cascade of failures in interdependent networks," *Nature*, vol. 464, no. 7291, pp. 1025–1028, 2010.
[169] G. H. Stankey, R. N. Clark, and B. T. Bormann, *Adaptive management of natural resources: theory, concepts, and management institutions*. US Department of Agriculture, Forest Service, Pacific Northwest Research Station Portland, OR, 2005.
[170] J. H. Miller and S. E. Page, "Complex adaptive systems: an introduction to computational models of social life," *AMC*, vol. 10, p. 12, 2002.
[171] A. Cherp, J. Jewell, and A. Goldthau, "Governing Global Energy: Systems, Transitions, Complexity," *Glob. Policy*, vol. 2, no. 1, pp. 75–88, Jan. 2011.
[172] R. Mendelsohn, "The role of markets and governments in helping society adapt to a changing climate," *Clim. Change*, vol. 78, no. 1, pp. 203–215, 2006.
[173] A. Duit and V. Galaz, "Governance and Complexity—Emerging Issues for Governance Theory," *Governance*, vol. 21, no. 3, pp. 311–335, 2008.
[174] IEA, *Security of Gas Supply in Open Markets*. Paris: Organisation for Economic Co-operation and Development, 2004.
[175] OECD, "OECD guiding principles for regulatory quality and performance," OECD, 2005.
[176] OECD, "Measuring Regulatory Quality," OECD, 2008.
[177] N. Gunningham and D. Sinclair, "Designing smart regulation," in *Economic Aspects of Environmental Compliance Assurance. OECD Global Forum on Sustainable Development*, 1998.
[178] D. Loorbach, "Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework," *Governance*, vol. 23, no. 1, pp. 161–183, 2010.
[179] R. Kemp, D. Loorbach, and J. Rotmans, "Transition management as a model for managing processes of co-evolution towards sustainable development," *Int. J. Sustain. Dev. World Ecol.*, vol. 14, no. 1, pp. 78–91, 2007.
[180] L. M. A. Bettencourt, J. E. Trancik, and J. Kaur, "Determinants of the Pace of Global Innovation in Energy Technologies," *PLoS ONE*, vol. 8, no. 10, p. e67864, Oct. 2013.
[181] J. Meadowcroft, "What about the politics? Sustainable development, transition management, and long term energy transitions," *Policy Sci.*, vol. 42, no. 4, pp. 323–340, Nov. 2009.

[182] C. Hendry, P. Harborne, and J. Brown, "So what do innovating companies really get from publicly funded demonstration projects and trials? innovation lessons from solar photovoltaics and wind," *Energy Policy*, vol. 38, no. 8, pp. 4507–4519, Aug. 2010.
[183] F. Berkhout, G. Verbong, A. J. Wieczorek, R. Raven, L. Lebel, and X. Bai, "Sustainability experiments in Asia: innovations shaping alternative development pathways?," *Environ. Sci. Policy*, vol. 13, no. 4, pp. 261–271, Jun. 2010.
[184] F. Berkes, J. Colding, and C. Folke, *Navigating social-ecological systems: building resilience for complexity and change*, vol. 393. Cambridge University Press Cambridge, 2003.
[185] C. Folke, T. Hahn, P. Olsson, and J. Norberg, "Adaptive governance of social-ecological systems," *Annu Rev Env. Resour*, vol. 30, pp. 441–473, 2005.
[186] P. Olsson, L. H. Gunderson, S. R. Carpenter, P. Ryan, L. Lebel, C. Folke, and C. S. Holling, "Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems," *Ecol. Soc.*, vol. 11, no. 1, p. 18, 2006.
[187] METI, "Energy in Japan 2001," 2001. [Online]. Available: http://www.meti.go.jp/english/aboutmeti/data/a231201e.html. [Accessed: 25-Jul-2015].
[188] Japan Renewable Energy Foundation (JREF), "General Renewable Energy Statistics," 2015. [Online]. Available: https://jref.or.jp/en/energy/general.php. [Accessed: 29-Apr-2015].
[189] Advanced co-generation and energy utilization center of Japan, "CHP current state in Japan," 2015. [Online]. Available: http://www.ace.or.jp/web/en/currentstate/currentstate_0010.html. [Accessed: 30-Apr-2015].
[190] METI (Agency for Natural Resources and Energy), "ANRE's Initiatives for Establishing Smart Communities," METI (ANRE), 2014.
[191] Japan Renewable Energy Policy Platform, "Renewables 2010 Japan Status Report," *Jpn. JREPP*, 2010.
[192] FEPC, "Efforts of Electric Power Companies and Opinions regarding Best Mix of Energy Sources," Federation of Electric Power Companies of Japan, 2012.
[193] JOGMEC, "Stockpiling : Petroleum and Liquefied Petroleum Gas," 2014. [Online]. Available: http://www.jogmec.go.jp/english/stockpiling/stockpiling_001.html?recommend=1. [Accessed: 27-Oct-2015].
[194] JOGMEC, "Gas Production from Methane Hydrate Layers Confirmed : News Releases | JOGMEC," 2012. [Online]. Available: http://www.jogmec.go.jp/english/news/release/release0110.html. [Accessed: 30-Apr-2015].
[195] BBC News, "Japan extracts gas from methane hydrate in world first," *BBC News*, 12-Mar-2013.
[196] Nikkei Asian Review, "Alternative energy: Japan to widen hunt for methane hydrate," *Nikkei Asian Review*, 03-Jan-2015.
[197] JAPEX, "Annual Report | JAPEX－Japan Petroleum Exploration Co.,Ltd.," Japan Petroleum Exploration Co. Ltd., 2014.
[198] Ecofys, "International comparison of fossil power efficiency and CO2 intensity," Mitsubishi Research Institute, 2014.
[199] FEPC, "Electricity Review Japan 2014," Federation of Electric Power Companies of Japan, 2014.
[200] J. Nakano, "Japan's Energy Supply and Security since the March 11 Earthquake," Center for Strategic and International Studies, Mar. 2011.
[201] M. Iwata, "Japan's Utilities Adapt to Changing Fossil Fuel Forecast," 25-Mar-2011. [Online]. Available: http://downstreamtoday.com/(X(1)S(tnd0vsnkbum4nhiesa5dpcaa))/News/ArticlePrint.aspx?aid=26140&AspxAutoDetectCookieSupport=1. [Accessed: 22-Oct-2015].
[202] IEA, "Energy Policy Highlights 2013," IEA, 2013.
[203] R. S. Jones and M. Kim, "Restructuring the Electricity Sector and Promoting Green Growth in Japan," *OECD Econ. Dep. Work. Pap.*, no. 1069, Jun. 2013.
[204] H. Mori and T. Wakiyama, "Changing behaviours - the Japanese Setsuden experience post- Fukushima," Institute for Global Environmental Strategies, 2012.
[205] CRIEPI, "Analyses of Energy Saving and Environment Institutions from an Economics and Energy Security Perspective," Central Research Institute of Electric Power Industry, 2013.

[206] O. Kimura, “Japanese Top Runner Approach for energy efficiency standards,” Central Research Institute of Electric Power Industry, 2010.
[207] WEC, “Policies for the future: 2011 Assessment of country energy and climate policies,” World Energy Council, 2011.
[208] MOFA, “Diplomatic Bluebook 2015- Japan’s Foreign Policy to Promote National and Worldwide Interests,” 2015. [Online]. Available: http://www.mofa.go.jp/policy/other/bluebook/2015/html/textfiles/c030302.txt. [Accessed: 29-Apr-2016].
[209] MOFA, “Diplomatic Bluebook 2013- International Situation and Japan’s Diplomacy in 2012,” *外交青書英語要約版2013*, 2013. [Online]. Available: http://bluebook.awce.jp/policy/other/bluebook/2013/html/html/chapter1/japansdiplomacy.html. [Accessed: 29-Apr-2016].
[210] K. Goto, “Japan’s Role as Leader for Nuclear Nonproliferation,” *Fed. Am. Sci.*, Dec. 2012.
[211] A. Miyamoto, C. Ishiguro, and M. Nakamura, “A Realistic Perspective on Japan’s LNG Demand after Fukushima,” *Oxf. Inst. Energy Stud.*, 2012.
[212] A. Shimizu, “Silver-lining to Japan’s energy crisis,” 24-Feb-2014. [Online]. Available: http://www.atimes.com/atimes/Japan/JAP-01-240214.html. [Accessed: 29-Apr-2016].
[213] MOFA, “Japan-Australia Economic Partnership Agreement,” *Ministry of Foreign Affairs of Japan*, 2015. [Online]. Available: /policy/economy/fta/australia.html. [Accessed: 02-May-2016].
[214] Inpex, “Inpex and Total make final investment decision on Ichthys LNG project, Australia.” 13-Jan-2012.
[215] METI, “Keynote Address by Mr.Toshimitsu Motegi, Minister of Economy, Trade and Industry, at the Second LNG Producer-Consumer Conference,” 10-Sep-2013. [Online]. Available: http://www.meti.go.jp/english/speeches/20130910.html. [Accessed: 03-Oct-2013].
[216] Nikkei Asian Review, “Japan to finance offshore LNG projects to support domestic firms,” *Nikkei Asian Review*, 27-Mar-2014.
[217] EIA, “Country Analysis Briefs- Japan,” U.S. Energy Information Administration, 2013.
[218] Petroleum Association of Japan, “Petroleum Industry in Japan 2014,” 2014. [Online]. Available: http://www.paj.gr.jp/english/industry/index.html. [Accessed: 25-Mar-2015].
[219] WIPO, “World Intellectual Property Indicators - 2012 Edition,” World Intellectual Property Organization, 2012.
[220] New Energy Promotion Council, “Japan Smart City Portal (JSCP),” 2015. [Online]. Available: http://jscp.nepc.or.jp/en/index.shtml. [Accessed: 07-Aug-2015].
[221] METI, “Selected Areas in Creating Master Plans under the Project for Promoting Introduction of Smart Communities / Ministry of Economy, Trade and Industry (METI),” 2012. [Online]. Available: http://www.meti.go.jp/english/press/2012/0417_01.html. [Accessed: 15-Aug-2015].
[222] Cabinet Office (Kantei) of Japan, “The Eco-Model City Project and Future Directions,” Cabinet Office, Government of Japan, 2009.
[223] Japan for Sustainability, “Concept Of ‘FutureCity’ Initiative ｜FutureCity Eco-model City,” 2014. [Online]. Available: http://www.japanfs.org/en/projects/future_city/index.html. [Accessed: 15-Aug-2015].
[224] C. Pham, “Smart Cities in Japan,” EU-Japan Centre for Industrial Cooperation, 2014.
[225] NEDO, “Smart Communities,” New Energy and Industrial Technology Development Organization (NEDO), 52, 2014.
[226] NEDO officials, “Interviews with NEDO officals,” 22-Mar-2016.
[227] METI, “Launching international feasibility studies on ‘Smart Community,’” 2012. [Online]. Available: http://www.meti.go.jp/english/press/2012/1105_01.html. [Accessed: 07-Aug-2015].
[228] New Energy Promotion Council, “Dynamic Pricing for Households Results in Approximately 20% Savings in Electricity,” 2014. [Online]. Available: http://jscp.nepc.or.jp/article/jscpen/20140325/389545/index.shtml. [Accessed: 17-Aug-2015].

[229] D. N. Mah, Y.-Y. Wu, J. C. Ip, and P. R. Hills, “The role of the state in sustainable energy transitions: A case study of large smart grid demonstration projects in Japan,” *Energy Policy*, vol. 63, pp. 726–737, Dec. 2013.
[230] A. Maeda, “Fuel cell technologies in the Japanese national innovation system,” in *International Conference on Innovation in Energy Technologies Energy Technologies*, 2003.
[231] T. Kasu, “Why does Japan believe in domestic fuel cell? Adaptation to European market?,” Osaka Gas, 2013.
[232] Japan Gas Association, “Sales of Residential Fuel Cell ENE-FARM Surpass 100,000 Units,” 18-Dec-2014.
[233] World Bank, “World Governance Indicators 2014,” 2014.
[234] METI, “Ensuring Electricity Security in Japan’s Electricity Market Reform Project,” Ministry of Economy, Trade and Industry of Japan (METI), 2014.
[235] T. Yamazaki, “Electricity System Reform in Japan,” Agency for Natural Resources and Energy, Japan, 2013.
[236] METI, “Japan’s energy and environmental policies - Reference Materials,” Agency for Natural Resources and Energy, Japan, 2009.
[237] METI, “Bill for the Act for Partial Revision of the Electricity Business Act and Other Related acts (Outline),” METI, 2015.
[238] H. Takahashi, “Regulatory reform in the City Gas industry, and competition between energy companies,” The Japan Gas Association, 2005.
[239] Osaka Gas, “Japanese gas business.” 2010.
[240] Osaka Gas, “Osaka Gas Group- Annual Report 2010,” Osaka Gas, 2010.
[241] Nuclear Energy Agency (OECD), “Public Attitudes to Nuclear Power,” OECD, 2010.
[242] Asahi Shimbun, “Asahi Shimbun poll,” 2011. [Online]. Available: http://yukokulog.blog129.fc2.com/blog-entry-542.html. [Accessed: 22-Jul-2015].
[243] Asahi Shimbun, “80% distrust government’s nuke safety measures,” 13-Mar-2012. [Online]. Available: http://ajw.asahi.com/article/behind_news/social_affairs/AJ201203130031. [Accessed: 10-May-2015].
[244] Asahi Shimbun, “Asahi Shimbun poll,” 2014. [Online]. Available: http://ajw.asahi.com/article/0311disaster/fukushima/AJ201403180058. [Accessed: 22-Jul-2015].
[245] M. Toyoma, “Power system damage, recovery and challenges from Great East Japan Earthquake,” Federation of Electric Power Companies of Japan, 2013.
[246] M. Nilsson, “Energy security should have more weight in low carbon scenarios,” The Stockholm Environment Institute (SEI), 2014.
[247] H. Turton and L. Barreto, “Long-term security of energy supply and climate change,” *Energy Policy*, vol. 34, no. 15, pp. 2232–2250, Oct. 2006.
[248] D. L. McCollum, V. Krey, and K. Riahi, “An integrated approach to energy sustainability,” *Nat. Clim. Change*, vol. 1, no. 9, pp. 428–429, Dec. 2011.
[249] K. Fujime, “An Overview of the New ‘Long-term Outlook for Energy Supply and Demand’ and Its Challenges for the Future,” IEEJ, 2004.
[250] Ministry of Environment, Japan, “Japan’s Progress in Developing its Intended Nationally Determined Contribution,” 2015. [Online]. Available: https://www.env.go.jp/en/earth/cc/jpdindc.html. [Accessed: 07-Sep-2015].
[251] Government of Japan, *Basic Act on Energy Policy of 2002 - Japan*. .
[252] METI, “New National Energy Strategy,” Agency for Natural Resources and Energy, Japan, 2006.
[253] M. Sommer, “Why Has Japan Been Hit So Hard by the Global Recession?,” International Monetary Fund (IMF), 2009.
[254] World Nuclear Association, “Nuclear Power in Japan | Japanese Nuclear Energy,” 2015. [Online]. Available: http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Japan/. [Accessed: 20-Jul-2015].
[255] NEDO, “Clean Coal Technologies in Japan,” New Energy and Industrial Technology Development Organization (NEDO), 2006.

[256] T. Toichi, “LNG development at the turning point and policy issues for Japan,” *Energy Policy*, vol. 22, no. 5, pp. 371–377, May 1994.
[257] METI, “Strategic Energy Plan of Japan (2010),” Ministry of Economy, Trade and Industry of Japan (METI), 2010.
[258] BBC News, “Japan vows big climate change cut,” *BBC*, 07-Sep-2009.
[259] Ministry of Environment, Japan, “Warsaw Climate Change Conference, November 2013 [MOE],” 2013. [Online]. Available: https://www.env.go.jp/en/earth/cc/cop19_summary.html. [Accessed: 04-Sep-2015].
[260] Cabinet Office (Kantei) of Japan, “Global Warming Prevention Headquarters (The Prime Minister in Action) | Prime Minister of Japan and His Cabinet,” 02-Jun-2015. [Online]. Available: http://japan.kantei.go.jp/97_abe/actions/201506/2article1.html. [Accessed: 06-Sep-2015].
[261] FEPC, “Establishment of an Action Plan for the Electricity Business for Achieving a Low-Carbon Society,” Federation of Electric Power Companies of Japan, 2015.
[262] United Nations, “UN Comtrade | International Trade Statistics Database,” 2015. [Online]. Available: http://comtrade.un.org/. [Accessed: 26-May-2016].
[263] World Nuclear News, “Business calls for stable power supply in Japan,” 2013. [Online]. Available: http://www.world-nuclear-news.org/NP-Business-calls-for-stable-power-supply-in-Japan-0212131.html. [Accessed: 04-Sep-2015].
[264] The Energy and Environment Council (Japan), “Options for Energy and the Environment.” Government of Japan, 2012.
[265] UNFCC, “G20 Back Climate Action as Japan Pledges $1.5 Billion,” *UNFCCC*, 16-Nov-2014. [Online]. Available: http://newsroom.unfccc.int/unfccc-newsroom/now-japan-pledges-15-billion-to-green-climate-fund/. [Accessed: 19-Sep-2015].
[266] METI, “Cabinet Decision on the New Strategic Energy Plan,” 11-Apr-2014. [Online]. Available: http://www.meti.go.jp/english/press/2014/0411_02.html. [Accessed: 08-Mar-2016].
[267] J. S. Duffield and B. Woodall, “Japan’s new basic energy plan,” *Energy Policy*, vol. 39, no. 6, pp. 3741–3749, Jun. 2011.
[268] Y. Kobayashi, “Enhancing Energy Resilience: Challenging Tasks for Japan’s Energy Policy,” Center for Strategic and International Studies, 2014.
[269] K. Koyama, “Japan’s Post-Fukushima Energy Policy Challenges,” *Asian Econ. Policy Rev.*, vol. 8, no. 2, pp. 274–293, Dec. 2013.
[270] J. Meltzer, “After Fukushima: What’s Next for Japan’s Energy and Climate Change Policy?,” 2011.
[271] P. J. Scalise, “Hard Choices: Japan’s Post-Fukushima Energy Policy in the 21st Century,” in *Natural Disaster and Nuclear Crisis in Japan*, J. Kingston, Ed. Routledge, 2012.
[272] M. Hayashi and L. Hughes, “The policy responses to the Fukushima nuclear accident and their effect on Japanese energy security,” *Energy Policy*, vol. 59, pp. 86–101, Aug. 2013.
[273] M. Harada, T. Ichikawa, H. Takagi, and H. Uchida, “14 - Building a hydrogen infrastructure in Japan A2 - Veziroğlu, Michael BallAngelo BasileT. Nejat,” in *Compendium of Hydrogen Energy*, Oxford: Woodhead Publishing, 2016, pp. 321–335.
[274] N. Behling, M. C. Williams, and S. Managi, “Fuel cells and the hydrogen revolution: Analysis of a strategic plan in Japan,” *Econ. Anal. Policy*, vol. 48, pp. 204–221, Dec. 2015.
[275] T. Wakiyama, E. Zusman, and J. E. Monogan III, “Can a low-carbon-energy transition be sustained in post-Fukushima Japan? Assessing the varying impacts of exogenous shocks,” *Energy Policy*, vol. 73, pp. 654–666, Oct. 2014.
[276] S. Cornot-Gandolphe and C. Mathieu, “Japan’s Energy and Climate Policy: Towards Dispelling the Uncertainties,” Institut Francais des Relations Internationales (IFRI), 2015.
[277] A. Rip and R. Kemp, *Technological change*. Battelle Press, 1998.
[278] F. W. Geels, “Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study,” *Res. Policy*, vol. 31, no. 8, pp. 1257–1274, 2002.
[279] F. W. Geels, “From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory,” *Res. Policy*, vol. 33, no. 6–7, pp. 897–920, Sep. 2004.

[280] J.-P. Voss and B. Bornemann, "The politics of reflexive governance: challenges for designing adaptive management and transition management," *Ecol. Soc.*, vol. 16, no. 2, p. 9, 2011.

[281] V. Smil, *Energy transitions: history, requirements, prospects*. ABC-CLIO, 2010.

[282] F. W. Geels and J. Schot, "Typology of sociotechnical transition pathways," *Res. Policy*, vol. 36, no. 3, pp. 399–417, Apr. 2007.

[283] A. Smith, J.-P. Vo\s s, and J. Grin, "Innovation studies and sustainability transitions: the allure of the multi-level perspective and its challenges," *Res. Policy*, vol. 39, no. 4, pp. 435–448, 2010.

[284] J. Simmie and R. Martin, "The economic resilience of regions: towards an evolutionary approach," *Camb. J. Reg. Econ. Soc.*, vol. 3, no. 1, pp. 27–43, Mar. 2010.

[285] H. Heclo, *Modern Social Politics in Britain and Sweden, Second Edition*, Second edition edition. Yale University Press, 1974.

[286] P. M. Sacks, "State Structure and the Asymmetrical Society: An Approach to Public Policy in Britain," *Comp. Polit.*, vol. 12, no. 3, pp. 349–376, 1980.

[287] P. A. Hall, "Policy paradigms, social learning, and the state: the case of economic policymaking in Britain," *Comp. Polit.*, pp. 275–296, 1993.

[288] P. Andrews-Speed, "The Institutions of Energy Governance in China," *Cent. Energy Pet. Miner. Law Policy*, pp. 1–49, 2010.

[289] D. Helm, *The new energy paradigm*. Oxford University Press, 2007.

[290] S. Itoh, "Japan's Energy Strategy and Development of Energy Cooperation in the Asia-Pacific," *ERINA Rep.*, vol. 77, pp. 35–48, 2007.

[291] METI, "METI's mission," Ministry of Economy, Trade and Industry of Japan (METI), 2014.

[292] Cabinet Office (Kantei) of Japan, "Japan Revitalization Strategy (2015 revision)," Cabinet Office, Government of Japan, 2015.

[293] METI, "Major discussion points toward the establishment of a new 'Basic Energy Plan for Japan,'" Ministry of Economy, Trade and Industry of Japan (METI), 2011.

[294] METI, "Annual Report on Energy - 2013 (White Paper)," Ministry of Economy, Trade and Industry of Japan (METI), 2013.

[295] METI, "Report of the Electricity System Reform Expert Subcommittee," Ministry of Economy, Trade and Industry of Japan (METI), 2013.

[296] ANRE, "Japan's Electricity Market Deregulation," METI (ANRE), Jun. 2015.

[297] IEEJ, "IEEJ e-Newsletter, No. 29," 10, Jan. 2014.

[298] METI, "Long-term Energy Supply and Demand Outlook (Energy mix targets)," Ministry of Economy, Trade and Industry of Japan (METI), Jul. 2015.

[299] METI, "METI FY2015 Budget," 2015. [Online]. Available: http://www.meti.go.jp/english/aboutmeti/policy/index.html. [Accessed: 08-Feb-2016].

[300] Kankyō Business Online, "Ministry of the Environment requesting an increase of 62% in its FY 2016 budget for energy conservation and renewable energy (Japanese)," 環境ビジネスオンライン, 02-Sep-2015. [Online]. Available: http://www.kankyo-business.jp/news/011232.php. [Accessed: 13-Feb-2016].

[301] M. Aoki and G. Rothwell, "A Comparative Institutional Analysis of the Fukushima Nuclear Disaster: Lessons and Policy Implications," Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 1940207, Jun. 2012.

[302] P. A. Hall and D. Soskice, "An Introduction to Varieties of Capitalism," in *Varieties of Capitalism*, Oxford University Press, 2001.

[303] D. C. North, *Understanding the Process of Economic Change*, Revised edition edition. Princeton, N.J: Princeton University Press, 2005.

[304] P. A. Hall and R. C. Taylor, "Political science and the three new institutionalisms*," *Polit. Stud.*, vol. 44, no. 5, pp. 936–957, 1996.

[305] P. L. Berger and T. Luckmann, *The Social Construction of Reality: A Treatise in the Sociology of Knowledge*. Anchor Books, 1967.

[306] W. R. Scott and J. W. Meyer, *The organization of societal sectors*. publisher not identified, 1982.

[307] W. R. Scott, "Approaching adulthood: the maturing of institutional theory," *Theory Soc.*, vol. 37, no. 5, pp. 427–442, Jun. 2008.

[308] O. E. Williamson, "The new institutional economics: taking stock, looking ahead," *J. Econ. Lit.*, pp. 595–613, 2000.
[309] C. Kingston and G. Caballero, "Comparing theories of institutional change," *J. Institutional Econ.*, vol. 5, no. 2, pp. 151–180, 2009.
[310] G. Capoccia, "Critical junctures and institutional change," *Adv. Comp.-Hist. Anal.*, p. 147, 2015.
[311] P. Pierson, *Politics in time: History, institutions, and social analysis*. Princeton University Press, 2004.
[312] R. Boyer, "Coherence, diversity, and the evolution of capitalisms—the institutional complementarity hypothesis," *Evol. Institutional Econ. Rev.*, vol. 2, no. 1, pp. 43–80, 2005.
[313] M. Aoki, *Toward a Comparative Institutional Analysis*, 1 edition. Cambridge, Mass: The MIT Press, 2001.
[314] S. Lechevalier, *The Great Transformation of Japanese Capitalism*. London: Routledge, 2014.
[315] M. Hufty, "Investigating policy processes: The governance analytical framework (GAF)," *Res. Sustain. Dev. Found. Exp. Perspect.*, pp. 403–424, 2011.
[316] P. B. Hartzog, "21st Century Governance as a Complex Adaptive System," *Proc. Pista 2004*, pp. 300–5, 2004.
[317] R. M. Axelrod, R. Axelrod, and M. D. Cohen, *Harnessing complexity: Organizational implications of a scientific frontier*. Basic Books, 2001.
[318] E. G. Dinmore, "A Small Island Nation Poor in Resources: Natural and Human Resource Anxieties in Trans-World War II Japan," Princeton University, 2006.
[319] B. Singh, *Japan's Security Identity: From a Peace State to an International State*, vol. 45. Routledge, 2013.
[320] W. Vosse, R. Drifte, and V. Blechinger-Talcott, *Governing Insecurity in Japan: The Domestic Discourse and Policy Response*. Routledge, 2014.
[321] The Sasakawa Peace Foundation, "The Fukushima Nuclear Accident and Crisis Management," The Sasakawa Peace Foundation, 2012.
[322] J. Ahn, C. Carson, M. Jensen, K. Juraku, S. Nagasaki, and S. Tanaka, Eds., *Reflections on the Fukushima Daiichi Nuclear Accident*. Springer International Publishing, 2015.
[323] N. Onishi, "'Safety Myth'Left Japan Ripe for Nuclear Crisis," *N. Y. Times*, vol. 24, 2011.
[324] METI, "METI organization," 2016. [Online]. Available: http://www.meti.go.jp/english/aboutmeti/profiles/aMETIlist01e.html#anre. [Accessed: 09-Feb-2016].
[325] METI, "METI to Reorganize the Systems of three Councils (shingikai)," 2013. [Online]. Available: http://www.meti.go.jp/english/press/2013/0625_03.html. [Accessed: 09-Feb-2016].
[326] Ministry of Internal Affairs, Japan, "Advisory Committee on Energy and Natural Resources Ordinance," 2013. [Online]. Available: http://law.e-gov.go.jp/htmldata/H12/H12SE293.html. [Accessed: 15-Apr-2015].
[327] METI, "METI Deliberative Councils (shingikai)," 2013. [Online]. Available: http://www.meti.go.jp/english/committee/index.html. [Accessed: 06-Feb-2016].
[328] MLIT, "White Paper on Land, Infrastructure, Transport and Tourism in Japan," Ministry of Land, Infrastructure, Transport and Tourism - Japan, 2014.
[329] METI, "Challenges and Actions in Economic/Industrial Policies," Agency for Natural Resources and Energy, Japan, 2011.
[330] Government of Japan, "Cabinet Office- Japan." 07-Feb-2016.
[331] Cabinet Office (Kantei) of Japan, "Regulatory Reform Council," 2014. [Online]. Available: http://japan.kantei.go.jp/96_abe/actions/201301/24kiseikaikaku_e.html. [Accessed: 02-May-2015].
[332] C. Montin, "Smart Regulation: Japan PM makes regulatory reform 'top priority,'" 13-Feb-2015. .
[333] S. K. Vogel, *Japan remodeled: How government and industry are reforming Japanese capitalism*, vol. 224. Taylor & Francis, 2006.
[334] METI, "Establishment of Subcommittee for Reforming Systems Related to Introduction of Renewable Energy," 2015. [Online]. Available: http://www.meti.go.jp/english/press/2015/0904_01.html. [Accessed: 06-Feb-2016].
[335] METI, "Establishment of Basic Policy Subcommittee on Electricity," Oct-2015. [Online]. Available: http://www.meti.go.jp/english/press/2015/1022_02.html. [Accessed: 06-Feb-2016].

[336] J. A. A. Stockwin, *Governing Japan: divided politics in a resurgent economy*. Wiley-Blackwell, 2008.
[337] J. Kingston, *Japan's Quiet Transformation: Social Change and Civil Society in the Twenty-first Century*. RoutledgeCurzon, 2004.
[338] A. Ogawa, "The new prominence of the civil sector in Japan," *Routledge Handb. Jpn. Cult. Soc.*, pp. 186–197, 2011.
[339] C. Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975*, 1 edition. Stanford University Press, 1982.
[340] H. Sasada, *The evolution of the Japanese Developmental State: institutions locked in by ideas*, vol. 75. Routledge, 2012.
[341] J. Amyx and P. Drysdale, *Japanese Governance: Beyond Japan Inc.* Routledge, 2003.
[342] Cabinet Office (Kantei) of Japan, "Restructuring of National Administrative Organs," 2001. [Online]. Available: http://japan.kantei.go.jp/central_government/02_restructuring.html. [Accessed: 09-Feb-2016].
[343] Cabinet Office (Kantei) of Japan, "Press Conference by the Chief Cabinet Secretary Friday, April 11, 2014," 2014. [Online]. Available: http://japan.kantei.go.jp/tyoukanpress/201404/11_a.html. [Accessed: 09-Feb-2016].
[344] Cabinet Office (Kantei) of Japan, "The Policy on Electricity System Reform." Cabinet Office (Kantei) of Japan, 2013.
[345] I. Motoshige, P. at the G. S. of E. of U. of T. I. A. Junichi, and E.-C. of Chuokoron, "Electricity Reform Is the Best Performer for the Growth Strategy," 2015.
[346] METI, "Annual Report on Energy - 2014 (White Paper)," Ministry of Economy, Trade and Industry of Japan (METI), 2014.
[347] METI, "Establishment of the Electricity Market Surveillance Commission," 2015. [Online]. Available: http://www.meti.go.jp/english/press/2015/0901_02.html. [Accessed: 03-Feb-2016].
[348] EMSC, "Electricity Market Surveillance Commission," 2015. [Online]. Available: http://www.emsc.meti.go.jp/english/committee/. [Accessed: 03-Feb-2016].
[349] METI, "Authorization for Establishment of the Organization for Cross-regional Coordination of Transmission Operators (OCCTO)," 2014. [Online]. Available: http://www.meti.go.jp/english/press/2014/0822_05.html. [Accessed: 02-May-2015].
[350] Asahi Shimbun, "New power supply adjustment entity has vital role in market liberalization," *Asahi Shimbun*, 02-Apr-2015.
[351] New Energy Promotion Council, "Proving Experiment of '1-Hour-Ahead DR' in Combination with '1-Hour-Ahead Market' for Electric Power | Keihanna (Kyoto) | Smart City," 2015. [Online]. Available: http://jscp.nepc.or.jp/article/jscpen/20150407/441722/. [Accessed: 10-Feb-2016].
[352] NEDO, "New Energy and Industrial Technology Development Organization," 2016. [Online]. Available: http://www.nedo.go.jp/english/. [Accessed: 10-Feb-2016].
[353] Carbon Pulse, "Japan business lobby wants scaled-back renewables target in 2030 plan | Carbon Pulse," 07-Apr-2015. .
[354] Japan Gas Association, "JGA NEWSLETTER- No. 20," 19-Dec-2012. [Online]. Available: http://www.gas.or.jp/en/newsletter/vo_20.html. [Accessed: 15-Feb-2016].
[355] ISEP, "Institute for Sustainable Energy Policies (ISEP)," 2016. .
[356] JREF, "JREF Overview," Japan Renewable Energy Foundation (JREF), 2016.
[357] A. DeWit, "Japan's Bid to Become a World Leader in Renewable Energy," *Asia-Pac. J.*, Sep. 2015.
[358] Nikkei Asian Review, "Japan's energy deregulation: Wielding discounts, new power providers battle for households," *Nikkei Asian Review*, 05-Jan-2016.
[359] Kyodo News, "As reform looms, Kansai Electric acquires first power plant in greater Tokyo," *The Japan Times Online*, 28-Jun-2015.
[360] T. Nishioka, "Japan's energy sector: Electricity joint venture appoints foreign boss," *Nikkei Asian Review*, 11-Feb-2016.
[361] Japan for Sustainability, "New Power Companies Soar in Japan in 2014, Increase of 1.8 times from 2013," *JFS Japan for Sustainability*, 28-Nov-2015. [Online]. Available: http://www.japanfs.org/en/news/archives/news_id035401.html. [Accessed: 13-Feb-2016].

[362] O. Tsukimori and K. Hamada, "INTERVIEW- Tokyo Gas aims to lift share of retail power market," *Reuters India*, 01-Apr-2014. [Online]. Available: http://in.reuters.com/article/japan-tokyo-gas-president-idINL4N0MS07B20140331. [Accessed: 12-Feb-2016].
[363] C. Watanabe, "Electricity gold rush heralds end for monopolies," *The Japan Times Online*, 07-Jul-2014.
[364] TEPCO/Softbank, "Business Partnership Regarding Joint Sales of Electricity as well as Telecommunications and Internet Services, and New Business Development," 07-Oct-2015. [Online]. Available: http://www.tepco.co.jp/en/press/corp-com/release/2015/1262125_6844.html. [Accessed: 11-Feb-2016].
[365] Nikkei Asian Review, "Prepping for market liberalization: JX Nippon Oil to team with KDDI in retail power sales," *Nikkei Asian Review*, 25-Sep-2015.
[366] METI, "METI Has Conducted Prior Registration for Retail Electricity Suppliers," 26-Oct-2015. [Online]. Available: http://www.meti.go.jp/english/press/2015/1026_01.html. [Accessed: 09-May-2016].
[367] Nikkei Asian Review, "Japan's electricity deregulation: 54,000 clients jump to other power companies," *Nikkei Asian Review*, 05-Feb-2016.
[368] Nikkei Asian Review, "Japan's energy market: Osaka Gas enlists Docomo for home power sales," *Nikkei Asian Review*, 08-Dec-2015.
[369] Nikkei Asian Review, "Japan's energy deregulation: Wielding discounts, new power providers battle for households," *Nikkei Asian Review*, 05-Jan-2016.
[370] A. Sheldrick, "In a sign of reforms to come, newcomers snap at heels of Japan's utilities," *Reuters*, 15-Sep-2013.
[371] Nikkei Asian Review, "Japanese utilities: Chugoku Electric to buy into Malaysian plant," *Nikkei Asian Review*, 20-Jan-2016.
[372] Kyodo News, "Japan's biggest oil refiners eye ¥100 billion savings in merger," *The Japan Times Online*, 03-Dec-2015.
[373] CleanTechnica, "GE Financially Backing 230 MW Solar PV Power Plant In Japan," *CleanTechnica*, 15-Apr-2014. [Online]. Available: http://cleantechnica.com/2014/04/15/ge-financially-backing-230-mw-solar-pv-plant-japan/. [Accessed: 18-Feb-2016].
[374] Asahi Shimbun, "Foreign firms plugging into Japan's solar power industry," *AJW by The Asahi Shimbun*, 20-May-2014.
[375] CleanTechnica, "SPI Solar To Jointly Develop 500 MW Capacity In Japan | CleanTechnica," 12-Jun-2015. [Online]. Available: http://cleantechnica.com/2015/06/12/spi-solar-jointly-develop-500-mw-capacity-japan/. [Accessed: 18-Feb-2016].
[376] J. S. St. John, "4 Ways Tokyo's Smart Meter Plan Breaks New Ground," 19-Mar-2014. [Online]. Available: http://www.greentechmedia.com/articles/read/4-ways-tokyos-smart-meter-plans-break-new-ground. [Accessed: 12-Feb-2016].
[377] V. Bestor, T. C. Bestor, and A. Yamagata, *Routledge handbook of Japanese culture and society*. Taylor & Francis, 2011.
[378] S. M. Murphy, "Grassroots Democrats and the Japanese State After Fukushima," 2014.
[379] T. Suzuki, "Energy Security and the Role of Nuclear Power in Japan," Central Research Institute of Electric Power Industry, 2000.
[380] IAEA, "Country Nuclear Power Profiles - Japan," 2014. [Online]. Available: http://www-pub.iaea.org/MTCD/Publications/PDF/CNPP2014_CD/countryprofiles/Japan/Japan.htm. [Accessed: 14-Apr-2015].
[381] OECD, "Energy conservation policies and technologies in Japan - A survey," OECD, 1994.
[382] Government of Japan, *Energy Conservation Law (Act on the Rational Use of Energy)*. 1979.
[383] H. Nishiyama, "Japan's Policy on energy conservation," IEEJ, 2013.
[384] P. Shiel, N. Jeffers, and M. Dyar, "Energy conservation measures in Japan," Trinity College Dublin, 2011.
[385] IEA, "Renewable Energy Targets," 2015. [Online]. Available: http://www.iea.org/policiesandmeasures/pams/japan/name-24466-en.php. [Accessed: 14-Apr-2015].

[386] H. Shiroyama, “Nuclear Safety Regulation in Japan and Impacts of the Fukushima Daiichi Accident,” in *Reflections on the Fukushima Daiichi Nuclear Accident*, J. Ahn, C. Carson, M. Jensen, K. Juraku, S. Nagasaki, and S. Tanaka, Eds. Springer International Publishing, 2015, pp. 283–296.
[387] IEEJ, “Discussion Points in Japan’s Renewable Energy Promotion Policy,” IEEJ, 2003.
[388] METI, “Promotion of new energy (RPS Law),” 2004. [Online]. Available: http://www.enecho.meti.go.jp/about/whitepaper/2004html/intro1_5.html. [Accessed: 15-Apr-2015].
[389] Government of Japan, “Kyoto Protocol Target Achievement Plan.” Government of Japan, 2005.
[390] Information Security Policy Council, “Action Plan on Information Security Measures for Critical Infrastructures,” Cabinet Office, Government of Japan, 2005.
[391] METI, “New National Energy Strategy (Press Release).” Agency for Natural Resources and Energy, Japan, 2006.
[392] N. Yoshida, “Initiatives for the nuclear energy national plan,” 2006.
[393] IEA, “Tackling Investment Challenges in Power Generation,” IEA, 2007.
[394] METI, “Main Points and Policy Package in ‘Japan’s Nuclear Energy National Plan,’” Ministry of Economy, Trade and Industry of Japan (METI), 2006.
[395] S. Tanaka, “Nuclear Energy in Japan - current status and future plan, importance of nuclear nonproliferation,” University of Tokyo, 2008.
[396] J. Ogawa, F. Noda, and Y. Yamashita, “Japan’s Energy Management Policy Experiences and Their Implications for Developing Countries,” IEEJ, 2010.
[397] METI, “Cool Earth Innovative Technology Program,” 2008.
[398] Cabinet Office (Kantei) of Japan, “In pursuit of ‘Japan as a Low-carbon Society’ Speech by Yasuo Fukuda, Prime Minister,” 2008. [Online]. Available: http://japan.kantei.go.jp/hukudaspeech/2008/06/09speech_e.html. [Accessed: 16-Apr-2015].
[399] Government of Japan, “Action Plan for Achieving a Low-carbon Society,” Cabinet Office, Government of Japan, 2008.
[400] Japan for Sustainability, “Japanese Government Adopts Action Plan Emphasizing Solar Power Generation | Japan for Sustainability,” 2009. [Online]. Available: http://www.japanfs.org/en/news/archives/news_id028625.html. [Accessed: 16-Apr-2015].
[401] METI, “Excess Electricity Purchasing Scheme for Photovoltaic Electricity.” [Online]. Available: http://www.meti.go.jp/english/press/2011/0330_03.html. [Accessed: 08-Apr-2015].
[402] T. Munakata, “Outline of Japan’s energy efficiency technology strategy,” New Energy and Industrial Technology Development Organization (NEDO), 2010.
[403] Energy Conservation Center of Japan, “ECCJ / National Strategies and Plans,” 2015. [Online]. Available: http://www.asiaeec-col.eccj.or.jp/nsp/index.html. [Accessed: 17-Apr-2015].
[404] METI, “Biomass Policies and Assistance Measures in Japan,” METI, 2012.
[405] METI, “Basic Energy Plan (2010),” Ministry of Economy, Trade and Industry of Japan (METI), 2010.
[406] IEEJ, “Japan Energy Brief No. 8,” 8, 2010.
[407] IEEJ, “Japan Energy Brief No. 7,” 7, 2010.
[408] METI, “Annual Report on Energy - 2012 (White Paper),” Ministry of Economy, Trade and Industry of Japan (METI), 2012.
[409] National Diet of Japan Independent Investigation Commission, “Report of the National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission,” 2012.
[410] Investigation Committee, “Final Report from the Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company,” Cabinet Office, Government of Japan, 2012.
[411] Ministry of Environment, Japan, “Details on the Carbon Tax (Tax for Climate Change Mitigation),” 2012. [Online]. Available: https://www.env.go.jp/en/policy/. [Accessed: 20-Apr-2015].
[412] R. Maeda, “Japan’s new carbon tax to cost utilities $1billion annually | Reuters,” 2012. [Online]. Available: http://www.reuters.com/article/2012/10/10/us-energy-japan-tax-idUSBRE8990G520121010. [Accessed: 20-Apr-2015].
[413] Environmental Policy Bureau, “Details on the Carbon Tax,” Ministry of Environment Japan, 2012.

[414] Information Security Policy Council, "Cybersecurity Strategy," Cabinet Office, Government of Japan, 2013.
[415] METI, "Cabinet Decision on the Bill for the Act for Partial Revision of the Electricity Business Act (1st phase of 3-step electricity reforms)," 15-Oct-2013. [Online]. Available: http://www.meti.go.jp/english/press/2013/1015_03.html. [Accessed: 27-Oct-2015].
[416] METI, "Cabinet Decision on the Cabinet Order to Specify the Enforcement Date of the Amended Electricity Business Act," 2013. [Online]. Available: http://www.meti.go.jp/english/press/2014/0627_02.html. [Accessed: 21-Jul-2015].
[417] Ministry of Agriculture, Forestry & Fisheries Japan, "Act on the Promotion of Renewable Energy Electric Power Generation Harmonized with Sound Development of Agriculture, Forestry and Fisheries," MAFF, 2013.
[418] METI, "Cabinet Decision on the Bill for the Act for Partial Revision of the Electricity Business Act (2nd phase of 3-phase electricity reforms)," 28-Feb-2014. [Online]. Available: http://www.meti.go.jp/english/press/2014/0228_02.html. [Accessed: 27-Apr-2016].
[419] METI, "Cabinet Decision on the Bill for the Act for Partial Revision of the Electricity Business Act and Other Related Acts (3rd phase of 3-step electricity reforms)," 03-Mar-2015. [Online]. Available: http://www.meti.go.jp/english/press/2015/0303_02.html. [Accessed: 27-Apr-2016].
[420] METI, "Report on Analysis of Generation Costs, Etc. for Subcommittee on Long-term Energy Supply-demand Outlook," METI, 2015.
[421] Ministry of Environment, Japan, "Guidelines for Measures to Prevent Global Warming," 1998. [Online]. Available: https://www.env.go.jp/en/earth/cc/gw/index.html. [Accessed: 07-Jun-2015].
[422] IEA, "Energy Policies of IEA Countries: 2005 Review," 2005.
[423] J. Kingston, *Critical issues in contemporary Japan*. Routledge, 2013.
[424] H. Tabuchi, "Japan's New Premier Backs More Nuclear Plants," *The New York Times*, 30-Dec-2012.
[425] NRA, "Status of Applications for Review of Commercial Power Reactors," Nuclear Regulation Authority (Japan), 2015.
[426] Nuclear Energy Institute, "Japan Nuclear Update - Nuclear Energy Institute," 27-Aug-2015. [Online]. Available: http://www.nei.org/News-Media/News/Japan-Nuclear-Update. [Accessed: 29-Aug-2015].
[427] World Nuclear Association, "Nuclear Power Plants and Earthquakes," 2014. [Online]. Available: http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Nuclear-Power-Plants-and-Earthquakes/. [Accessed: 10-Aug-2015].
[428] NSC, "Measures against Severe Accidents at Light Water Nuclear Power Reactor Facilities," Nuclear Safety Commission, 2011.
[429] JAEC, "Strengthening of Japan's Nuclear Security Measures," Japan Atomic Energy Commission, 2011.
[430] NRA, "Nuclear Regulation Authority, Japan," Nuclear Regulation Authority of Japan, 2015.
[431] Prime Minister Shinzo Abe, "Summary Statement by Prime Minister Abe," *Ministry of Foreign Affairs of Japan*, 24-Mar-2014. [Online]. Available: http://www.mofa.go.jp/dns/n_s_ne/page22e_000341.html. [Accessed: 11-Aug-2015].
[432] Government of Japan, "Nuclear Security Summit 2014 - National Progress Report Japan," 2014.
[433] K. Itoh, "Reforming Japan's Power Industry," Stanford Institute for Economic Policy Research, Standford University, 2012.
[434] EIA, "Country Analysis Briefs- Japan," U.S. Energy Information Administration, 2015.
[435] Japan LP Gas Association, "Industry Information- Japan LP Gas Association," 2016. [Online]. Available: http://j-lpgas.gr.jp/en/index.html. [Accessed: 20-Apr-2016].
[436] JHSBA, "Japan Heat Supply Business Association," 2016. [Online]. Available: http://www.jdhc.or.jp/english/. [Accessed: 26-Apr-2016].
[437] M. Suga, "Abe Repeats Japan to Cut Nuclear Reliance as Much as Possible," *Bloomberg.com*, 27-Feb-2014.
[438] E. Hahn, "The Japanese Solar PV Market and Industry," EU-Japan Centre for Industrial Cooperation, 2014.
[439] METI, "Feed-in Tariff System in Japan." 2012.

[440] S. Nakakuki and H. Kudo, “Discussion Points in Japan’s Renewable Energy Promotion Policy - Effect, Impact and Issues of the Japanese RPS,” IEEJ, 2003.
[441] REN21, “Renewables 2013 Global Status Report,” REN21, 2013.
[442] C. W. Urabe, “Kyushu to Suspend Grid Access for New Renewable-Energy Producers,” *Bloomberg.com*, 24-Sep-2014. [Online]. Available: http://www.bloomberg.com/news/articles/2014-09-24/kyushu-to-suspend-grid-access-for-new-renewable-energy-producers. [Accessed: 24-Jul-2015].
[443] A. Sheldrick and J. Topham, “As Japan eyes nuclear restarts, renewables get shut out of grid,” *Reuters*, 16-Oct-2014.
[444] METI, “Promulgation of the Ministerial Ordinance and the Related Public Notices for Partially Revising the Ordinance for Enforcement of the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities,” 2015. [Online]. Available: http://www.meti.go.jp/english/press/2015/0122_02.html. [Accessed: 06-May-2016].
[445] ISEP, “Renewables 2014 Japan Status Report,” Institute for Sustainable Energy Policies (ISEP), 2014.
[446] Japan for Sustainability, “New Renewable Energy Law to Allow Conversion of Farmland in Japan to Wind Farms,” *JFS Japan for Sustainability*, 2014. .
[447] Asia Biomass Energy Cooperation Promotion Office, “Introduction Status for Small Hydro Power in Japan Since the Start of Its Feed-in Tariff Scheme for Renewable Energies,” 2013. [Online]. Available: http://www.asiabiomass.jp/english/topics/1308_06.html. [Accessed: 22-Jul-2015].
[448] METI, “METI Ministry of Economy, Trade and Industry,” 2015. [Online]. Available: http://www.meti.go.jp/english/. [Accessed: 21-Jun-2015].
[449] E. Johnston, “Small hydropower plants keep it local,” *The Japan Times Online*, 29-Sep-2011.
[450] JASHA, “Japan Small Hydro Association (小水力開発支援協会) (JASHA）,” 2015. [Online]. Available: http://jasha.jp/. [Accessed: 22-Jul-2015].
[451] T. James, “Japan’s Solar Photovoltaic (PV) Market: An Analysis of Residential System Prices,” National Renewable Energy Laboratory (US), 2013.
[452] B. Buckheit, “Japan’s path to sustainable electricity supply,” Kiko Network, 2015.
[453] C. Yang, “Pumped Hydroelectric Storage,” Duke University, 2012.
[454] K. Takase, “Renewable Energy Burst in Japan,” Nautilus Institute, 2014.
[455] Bloomberg New Energy Finance, “Japan’s approach to demand-side management,” Bloomberg, 2014.
[456] Asahi Shimbun, “Japan needs to be smart about installing ‘smart meters,’” *AJW by The Asahi Shimbun*, 14-Dec-2011.
[457] TEPCO, “TEPCO Illustrated,” 2016. [Online]. Available: http://www.tepco.co.jp/en/corpinfo/illustrated/index-e.html. [Accessed: 28-Apr-2016].
[458] TEPCO, “Power Demand - Peak Demand (daily peak at generation end) | TEPCO Illustrated | TEPCO,” 2016. [Online]. Available: http://www.tepco.co.jp/en/corpinfo/illustrated/power-demand/peak-demand-daily-e.html. [Accessed: 28-Apr-2016].
[459] METI, “A Report from the Smart Meter System Planning Conference Security Review Working Group was Compiled / Ministry of Economy, Trade and Industry (METI),” 2015. [Online]. Available: http://www.meti.go.jp/english/press/2015/0710_01.html. [Accessed: 31-Jul-2015].
[460] Nikkei Asian Review, “Japan’s power utilities accelerating plans for smart meters,” *Nikkei Asian Review*, 15-Mar-2014.
[461] METI, “Selected Devices to be Subsidized in the Project to Promote Introduction of the Home Energy Management System (HEMS),” 2012. [Online]. Available: http://www.meti.go.jp/english/press/2012/0410_01.html. [Accessed: 07-Aug-2015].
[462] Japan Times, “Lack of trading on new JEPX blamed on utilities,” *The Japan Times Online*, 26-May-2005.
[463] METI, “Japan’s Electricity Market Deregulation,” METI (ANRE), 2015.
[464] U.S. International Trade Commission, *Natural Gas Services: Recent Reforms in Selected Markets, Inv. 332-426*. DIANE Publishing, 2001.
[465] METI, “Strategic Energy Plan of Japan (2014),” Agency for Natural Resources and Energy, Japan, 2014.

[466] Asahi Shimbun, "EDITORIAL: Nuclear power proponents still scoffing at public safety concerns : The Asahi Shimbun," *The Asahi Shimbun*, 28-Mar-2016.
[467] Diane Barnes, Global Security Newswire, "Japan's Plutonium Plan Hits New, Local Obstacles | Global Security Newswire | NTI," 10-Apr-2014. [Online]. Available: http://www.nti.org/gsn/article/japans-plutonium-plan-hits-new-local-obstacles/. [Accessed: 10-May-2015].
[468] J. Hendry, *Understanding Japanese society*. Routledge, 2012.
[469] C. Nakane, *Japanese society*, vol. 74. Univ of California Press, 1970.
[470] J. Nash, "Prime Minister Abe Says Risk-Averse Culture Stifles Innovation," *Bloomberg.com*, 02-May-2015. [Online]. Available: http://www.bloomberg.com/news/articles/2015-05-02/prime-minister-abe-says-risk-averse-culture-stifles-innovation. [Accessed: 11-Dec-2015

List of publications

Peered-reviewed international journals

1. Kucharski, Jeffrey, and Hironobu Unesaki. 2015. “A Policy-Oriented Approach to Energy Security.” *Elsevier Procedia (Environmental Sciences)* 28: 27–36. doi:doi:10.1016/j.proenv.2015.07.005. (**Chapter 3**)
2. Kucharski, Jeffrey, and Hironobu Unesaki. 2016. “Energy Security and Sustainability in Japan.” *International Journal of Sustainable Future for Human Security (J-SustaiN)* 4 (1). http://www.j-sustain.com/. (**Chapter 4.3**)
3. Kucharski, Jeffrey, and Hironobu Unesaki. Adaptability and Energy Security: A Complex Adaptive Systems Approach (**Chapter 3**) *Submitted to *Energy*
4. Kucharski, Jeffrey, and Hironobu Unesaki. Japan’s 2014 Strategic Energy Plan: A Planned Energy Transition (**Chapter 5.1**) *Submitted to *Energy Policy*

Conference proceedings

1. Jeffrey Kucharski and Hironobu Unesaki, *A Policy-Oriented Approach to Energy Security*, 5th International Conference on Sustainable Future for Human Security (SustaiN 2014), (November 19-21, 2014), Bali, Indonesia. (oral)
2. Jeffrey Kucharski, Navaporn Kaerkitcha, Taichi Iwai, Takashi Sagawa and Kei-ichi N. Ishihara, *Utility-scale energy storage to support increased variable renewables in Japan by 2030*, The 6th International Symposium of Advanced Energy Science, Kyoto, Japan (September 30-October 1, 2014). (poster)
3. Jeffrey Kucharski and Hironobu Unesaki, *Energy security and sustainability in Japan*, 6th International Conference on Sustainable Future for Human Security (SustaiN 2015), (November 17-19, 2015), Bali, Indonesia. (oral)

Appendix A: Japan's energy policies, 2000-2013

Reference is made to various energy-related numerical targets set by the Japanese government between 1996 and 2010 throughout this Appendix. The targets are summarized in Table A-1.

A.1 Pre-2000 policies

Long-term energy policy planning became more formalized starting in 1967 when the Long-Term Energy Supply and Demand Outlook was first published by MITI. The Demand-Supply Subcommittee of the Advisory Committee for Natural Resources and Energy was tasked with developing the Outlook. The outlook has been updated every three or four years as warranted by changing circumstances (IEA, 2003, IEA, 2008).

Japan's energy policy in the 1970's and 80's focused on implementing various emergency measures to help mitigate shocks, as well as on long-term policies such as energy conservation measures and nuclear power development to help reduce dependence on oil. In 1974, Japan joined the IEA, passed the Petroleum Stockpiling Law (1975) and began developing oil stockpiles. Also in 1974, the Sunshine Project was implemented to promote the development of new energy technologies including solar, geothermal, coal liquefaction, coal gasification and hydrogen energy. As part of the Sun Shine Project, the government launched the Residential PV System Dissemination Program in 1994.

Although the first commercial nuclear reactor had begun operating in Japan in 1966, nuclear power development really only accelerated after the first oil shock with the passing of three electric power laws in 1974. These laws gave preferential subsidies for the building of nuclear power plants and also provided subsidies to local communities that hosted nuclear and other large scale power plants. By the mid 1980's, all of the nine major electric power companies owned nuclear power plants [379].

In 1975 energy security took on a much higher degree of importance when the Advisory Committee for Energy submitted a report to the Ministry of International Trade and Industry (MITI) recommending that developing a stable supply of energy should be regarded as a top priority [380]. On the basis of this, MITI developed a new set of policy recommendations with “stabilization of energy supplies” being given the highest priority. This was to be achieved by 1) reducing dependence on petroleum by diversifying energy sources, 2) stabilizing petroleum supplies, 3) promoting energy conservation and 4) research and development of new energy sources. Japan aimed to reduce dependence on international petroleum suppliers and enhance its energy security by promoting Japanese oil projects overseas, securing access to supplies through inter-governmental agreements as well as direct commercial transactions [381].

In 1979 amid the second oil crisis, the *Act on the Rational Use of Energy (the “Energy Conservation Law”)* was enacted and formed the basis for a comprehensive approach to energy conservation policies. The intention of the Act was to regulate the rational use of energy in four sectors: industrial (factories and workplaces), buildings (commercial/residential), machinery/equipment and transportation. The Act required MITI to develop a “basic policy” to set regulatory standards and guidelines. The Act has been amended eight times to extend coverage, specify reporting and introduce new measures such as the “Top Runner” program in 1999 [382]–[384].

In 1980, the Law concerning Promotion of the Development and Introduction of Alternative Energy established NEDO in order to pursue various alternative energy and technology R&D strategies.

In the 1990’s, Japan turned more attention to promoting regulatory reform and dealing with climate change issues. Reforms took place against a background of growing calls for lower electricity and gas rates, particularly from the industrial sector which saw Japanese industries leave Japan due to high costs – the so-called “hollowing out” phenomenon. As a result, reforms were aimed at lowering energy prices, simplifying regulations and further introducing competition based on market principles [238].

Up to this time, Japan had heavily regulated the refining industry in order to help ensure oil security through the 1962 Petroleum Industry Law. In the late 1980’s the government began a liberalization process that led to the elimination of various regulations on refining facilities and petroleum imports and in 1996, began the full liberalization of the retail gasoline market [139]. Electricity deregulation and the introduction of competition into the generation market was introduced in the late 1990’s when independent power producers (IPP’s) were allowed to bid in wholesale power to the GEU's. In gas markets, liberalization began in 1995 when retail markets were partially liberalized, and further in 1999 when end use customers with a demand of 1mcm or more were allowed to choose their supplier and negotiate rates. Third party access was provided to existing gas pipelines owned by the four largest gas utilities [139].

Attempts to further diversify away from Japan's heavy dependence on oil included promoting new energy sources. In 1996, the Japanese government set a target of 3.1% (or 19.1m kl of oil equivalent) of renewable energy sources (excluding hydro and geothermal) in total primary energy supply by fiscal 2010 (see Table A-1) [385]. It also passed the *Special Measures Law Concerning Promotion of the Use of New Energy* (Act No. 37 of 1997) which provided the legal framework for promoting the introduction of New Energy (renewable and alternative energy sources) in Japan. The law included a budget for loan guarantees and financial assistance for PV systems, clean energy vehicles, supports to businesses, local projects and other areas (IEA 1999).

Table A-1. Energy-related numerical targets specified in key energy plans and policies, 1996-2010

Year	Description	Target
1996	New and renewable energy targets (excludes hydro and geothermal)	o New Energy: 3.1% (19.1 mkl oil equiv) in TPES by 2010 Targets for 2010: o PV: 4820 Mw (from 330Mw in 2000) o Solar thermal: 4.39 m kl (from 890,000 kl in 2000) o Wind: 3000Mw (from 144 Mw in 2000) o Biomass waste power: 4170 Mw (from 1030 Mw in 2000) o Waste thermal utilization: 140,000 kl (from 45,000 kl in 2000) o Biomass (non-waste) power: 330 Mw (from 69 Mw in 2000) o Biomass thermal utilization: 670,000 kl o Others: 5.52 m kl (from 4.945 m kl in 2000)
2001	New and renewable energy target revisions for 2010	o PV: 4820 Mw (from 637 MW in 2002) o Solar thermal: 900 000 kl (from 740 000 kl in 2002) o Wind: 3000 Mw (from 463 Mw in 2002) o Waste power and Biomass generation: 4500 MW (from 1618 MW in 2002) o Waste thermal use: 1860 000 kl (from 1640 000 kl in 2002) o Biomass thermal use: 3.08 million kl o Others (black liquor, waste wood, etc) 4.83 million kl (from 4.71 million kl in 2002)

	Nuclear reactor targets in the Long-term Energy Supply and Demand Outlook	o Build 10-13 additional reactors by 2010 (from 51 reactors in 2002) o Nuclear power supply to reach 42% by 2010
2003	Renewable Portfolio Standards (RPS Law)[97]	o Produce 12.2 Twh per annum of renewable electricity by 2010. Applies to wind, solar, geothermal, small hydro (<1000kw) and biomass. o In 2007 this was increased to 16Twh by 2014 (see Table 4).
2004	Nuclear Power Development Plan	o 6 new nuclear reactors to commence operation by 2010
2005	Kyoto Protocol Target Achievement Plan targets for 2010	o Reduce GHG emissions by 6% below 1990 levels. Targets for power generation (oil equiv.): o Solar PV: 1.18 M kl (from 277,000 kl in 2004) o Wind: 1.34 M kl (from 378,000 kl in 2004) o Waste and biomass: 5.86 M kl (from 2.27 M kl in 2004) Targets for thermal utilization (oil equiv.): o Solar thermal: 0.9 M kl (from 650,000 kl in 2004) o Waste: 1.86 M kl (from 1.65 M kl in 2004) o Biomass: 3.08 M kl (incl. 500,000 kl biofuel for transportation), (from 1.22 M kl in 2004) o Unused energy[98]: 50,000 kl (from 46,000 kl in 2004) o Black liquor, other[99]: 4.83 M kl (from 4.7 M kl in 2004) o Total ratio of New Energy in primary energy supply: about 3% or 19.1 M kl (from 11.19 M kl or 1.9% in 2004) Demand side targets: o Clean energy vehicles[100]: 2.33 million o Natural gas co-generation (i.e.: CHP): 4,988 MW o Fuel cells: 2,200 MW
2006	New National Energy Strategy	Targets for achievement by 2030: o Reduce the dependence on oil in primary energy supply to 40% or less. o Reduce dependence on oil in transportation fuels to around 80%. o Promote nuclear power development by increasing its share in the electricity mix to between 30 and 40% or more. o Improve energy intensity by 30%. o Promote upstream investment in overseas equity oil projects by Japanese companies so as to account for 40% of total oil imports. o Reduce the cost of solar PV generation down to the same level as thermal power generation by 2030.
	Energy conservation "Frontrunner Plan"	o Improve energy consumption efficiency by at least 30% by 2030 compared to 2003.
2008	New and renewable energy target revisions for 2010	o New Energy: In 2008, the 3.1% target was revised to be considered the upper case and 15.1 m kl as the lower case.

97 METI: http://www.enecho.meti.go.jp/about/whitepaper/2004html/intro1_5.html
98 Includes snow-ice cryogenic energy
99 Dependent on the level of pulp and paper production
100 Includes electric, fuel cell, natural gas, hybrid, methanol and diesel alternative LPG vehicles

	Renewable energy targets revision (Target range, in million kl of oil equiv)[101]	o PV: 7.3 to 11.8 (from 4.2 in 2006) o Wind: 10.1 to 13.4 (from 6.1 in 2006) o Waste and biomass generation: 44.9 to 58.6 (from 29.1 in 2006) o Biomass in heat utilization: 28.2 to 30.8 (from 15.6 in 2006) o Other renewable heat utilization: 65.5 to 76.4 (from 7.1 in 2006)
	Action Plan for Achieving a Low Carbon Society	o Reduce GHG emissions in Japan by 60 to 80% from present levels by 2050 o Increase solar PV capacity 10-fold by 2020 and 40-fold by 2030. o Reduce the current price of solar power generation systems by 50% within three to five years (Kawabata 2009). o Raise the ratio of electricity generated from zero-emission sources from 40% in 2006 to over 50% by around 2020. o Build 13 new nuclear reactors by 2017 and beyond
2010	Basic Act on Global Warming Countermeasures	o A reduction in GHG emissions of 25% below 1990 level by 2020 and 80% below 1990 level by 2050 o Increase share of renewable energy out of total primary energy supply to 10% by 2020
	Basic Act for the Promotion of Biomass Utilization	Utilize 26 million tons (CO2 equivalent) of biomass by 2020 including: o Food waste: 27-40% o Sewage: 77-85% o Agricultural residue: 30% o Forest residue: 0-30% o Creation of a new industry worth 500 billion JPY
	Strategic Energy Plan	Targets to be achieved by 2030 that will help reduce domestic CO2 emissions by 30% or more: o Double the energy self-sufficiency ratio (from 18%) o Double the self-developed fossil fuel supply ratio (from 26%) o Raise the energy independence ratio to about 70% (from 38%) o Raise the zero-emission power source ratio to about 70% (from 34%) o Cut CO2 emissions from residential sector by 50% o Build 9 new or additional nuclear power plants (with capacity utilization of about 85%) by 2020, and more than 14 plants by 2030 (with capacity utilization about 90%)

Sources: METI (Long-term Energy Supply-Demand Outlooks), Strategic Energy Plans and related plans, IEA (Polices and Measures database).

In 1998, the *Act on Promotion of Global Warming Countermeasures* (Act No. 117) was the first step towards dealing with actions to address Japan's commitments under the Kyoto Protocol. The Long-Term Energy Supply and Demand Outlook was revised in June 1998 to

[101] Source: IEA – *Renewable Energy Targets*

present Japan's supply and demand outlook to 2010 and incorporate Japan's commitments under the Kyoto Protocol (IEA, 1999). In 1999, Japan stepped up its focus on improving energy efficiency through development of the "Top Runner" program which encourages competition among manufacturers to improve the energy efficiency of end-use products in 23 product categories[102] including equipment, household appliances and passenger and freight vehicles.

A.2 Policies and targets, 2000-2010

Key energy policies impact on Japan's long-term energy security

The context surrounding the development of energy policy in the 2000-2011 period was dominated by the importance of achieving Japan's environmental commitments under the Kyoto Protocol while developing and strengthening policies and measures to enhance Japan's energy security.

In 2000, further steps were taken to liberalize electricity markets with an amendment to the Electric Utilities Industry Law that allowed for new entrants into the electric power services sector. This allowed large scale electricity users (2 MW or higher) to choose their supplier, whether from the GEU's or from independent power producers. Regulated third-party access (TPA) was also introduced to ensure IPP's could gain access to transmission grids for their power by paying "wheeling tariffs" [139].

In January 2001 as part of a government-wide reorganization, the newly constituted METI assumed sole responsibility for nuclear power regulation. The Nuclear and Industrial Safety Agency (NISA) was established with the responsibility for overseeing nuclear safety and attached to ANRE. The purpose was to have a clear mission for the agency while ensuring a degree of independence, although it still came under METI's authority [386].

The Basic Act on Energy Policy and the Basic Energy Plan

In 2002, Japan took a major step toward a more comprehensive and systematic approach to energy policy by passing the Basic Act on Energy Policy (Act No. 71 of June 14, 2002)[251],

102 As of July, 2009. For a detailed list please see: [384].

[267]. This law set up a framework to guide energy policy based on three fundamental principles, commonly known as the "3-E's":

- ensuring a stable supply of energy (energy security)
- reducing the burden on the environment (environmental protection)
- applying market principles (economic efficiency)

Based on these principles, the law directs that the government develop a Basic Energy Plan (also called the Strategic Energy Plan) at least once every three years. The Minister of Economy, Trade and Industry must formulate a draft of the plan and consult with the heads of relevant government ministries and the Advisory Committee for Natural Resources and Energy, and then seek a cabinet decision on the draft.

The first Basic Energy Plan published in October 2003 placed a priority on energy security, ensuring stable energy supply and confirming nuclear power as an basic source of energy supply that can contribute to environmental protection as a carbon-free source of power. The plan also called for electricity market liberalization [154].

In 2001, the New Energy subcommittee of the Advisory Committee for Natural Resources and Energy called for expanding the introduction of renewable energy for the purpose of meeting Japan's Kyoto targets as well as meeting energy security goals [387]. Following on these recommendations, the Special Measures Law Concerning the Use of New Energy by Electric Utilities (Act. No. 62) was passed in 2002. Also known as the "RPS Law", the Act explicitly defined the term "New Energy[103]" and established renewable portfolio standards for various types of new and renewable energy sources. Targets were also set for renewables share ("New energy") in electricity generation (see Table A-1) The law, which came into effect in 2003, obligated utilities to purchase about 1.3% of their sales volume from new energy sources so that renewables generation would increase to 12.2 Twh by 2010. The standards applied to wind, solar, geothermal, small hydro (<1000kw) and biomass [139], [388].

[103] In Japan, the term "New Energy" is somewhat ambiguous but it used to describe renewable and alternative energy sources that have yet to be used widely but that can assist in reducing Japan's dependence on oil and contribute to meeting environmental goals (IEA 2008). New energy is considered to include the following: photovoltaic (PV), wind power, solar thermal, waste power, thermal utilization of waste, fuel production from waste, temperature difference energy, clean energy motor vehicles, natural gas cogeneration and fuel cells. In addition, Japanese government published statistics often do not distinguish between renewables and other new/alternative energy sources making comparisons with other countries difficult.

Electricity market reforms continued in 2004 when high voltage customers using more than 500kW became eligible to choose their supplier and in 2005 the threshold was lowered again to 50kW or above [154]. In 2005 wholesale electricity transactions commenced on the Japan Electric Power Exchange (JEPX) to provide spot and forward trading for its members. JEPX members are made up of the GEU's, wholesale electric companies, power producers and suppliers, and others. In gas markets, end use customers with a demand of 500,000 m3 or more were allowed to choose their supplier and negotiate rates [154]. In the same year, the Electric Power System Council of Japan (ESCJ) was established as a rule-setting body for the grid so as to maintain fair and transparent use of the electric power transmission and distribution system.

In the 2005 Long-term Energy Outlook, a 2030 forecast scenario was included in order to provide a longer term planning horizon [249]. This longer-term horizon was later reflected in the NNES and in subsequent Basic Energy Plan revisions in 2007 and 2010.

Japan ratified the Kyoto Protocol in 2002 with the Kyoto Protocol itself entering into force in February 2005. Under the Protocol, Japan committed to reduce its greenhouse gas emissions by 6% from 1990 levels. Japan's base year emissions of all greenhouse gases were 1.237 billion tons of CO_2. In order to achieve the 6% reduction commitment, it was necessary to reduce annual average total emissions to 1.163 billion tons of CO_2 per year in the first commitment period (2008-2012) [389].

The Law Concerning the Promotion of Measures to Cope with Global Warming (Law No. 117 of 1998) stipulates that the Kyoto Protocol Target Achievement Plan is to be formulated when the Kyoto Protocol enters into force. The Kyoto Protocol Target Achievement Plan was therefore implemented in 2005 and was the guiding plan for Japan to reach its commitments. The plan set an objective to meet the 6% target by reducing domestic GHG emissions by 0.6% compared to base year (1990) combined with 3.8% from a forest sink and 1.6% by employing Kyoto mechanisms.

The plan included various policies, measures and targets for the reduction of emissions from major industrial, transport, commercial and household sectors. Many of the programs focused on reductions through improvements in energy efficiency in equipment and transport vehicles, as well as the promotion of new energy sources.

Japan also implemented a voluntary emissions trading scheme in 2005 and a domestic offset scheme for small businesses to enhance their efficiency and lower emissions (IEA 2008).

Japan's approach to the protection of critical infrastructure took a major step forward in 2005 with the publication of the *Action Plan on Information Security Measures for Critical Infrastructures* issued by a Cabinet level body called the Information Security Policy Council (ISPC). The plan introduced the concept of critical infrastructure protection for the first time and defined its purpose as being to "protect critical infrastructures from IT functional failures…which may have a significant impact on people's social lives and economic activities" [390]. The plan named 10 sectors designated as critical infrastructures which included the electricity and gas sectors. Business entities within these sectors were encouraged to work within the guidelines of the plan to enhance cyber security in their respective sectors.

The "New National Energy Strategy"

In the context of rising energy prices and perceived global risks including from competition for energy resources, increased state control over energy resources in supplier countries, and political unrest, instability and terrorism (especially in the Middle East), the Japanese government undertook a major re-examination of Japan's energy policy and energy strategy. This resulted in the development of the New National Energy Strategy [391]. Published in May 2006, the NNES was the first long-term strategy that considered a time horizon up to 2030 with the main focus being on energy security. It also served to provide context for revisions to the 2007 Basic Energy Plan.

- Specific strategies and numerical targets to be achieved by 2030 (see Table A-1) were to:
- Reduce the dependence on oil in primary energy supply to 40% or less.
- Reduce dependence on oil in transportation fuels to around 80%.
- Promote nuclear power development by increasing its share in the electricity mix to between 30 and 40% or more.
- Improve energy efficiency by 30%.
- Promote upstream investment in overseas equity oil projects by Japanese companies so as to account for 40% of total oil imports.

To achieve these numerical targets, a number of supporting programs and initiatives were proposed [252]:

- *Energy conservation "Frontrunner Plan"* which included an energy technology strategy, establishing "Top-runner" type standards for various sectors, developing an energy conservation standards and assessment system and promoting it internationally, and improvement in the efficiency of road networks.
- *Transport Energy for the Next Generation Plan* was designed to reduce oil dependency in the transport sector by establishing new fuel efficiency standards, promoting ethanol mixed gasoline, expanding bioethanol and biomass derived fuels, promoting high efficiency ethanol production technology and promoting the dissemination of electric and fuel cell vehicles, hydrogen storage and next-generation vehicles.
- *New Energy Innovation Plan* included targets to reduce the cost of solar PV generation down to the same level as thermal power generation by 2030, promote local electricity supply and consumption through regional-based biomass energy and wind power, and to promote the introduction of electric and fuel cell vehicles.
- *Nuclear Power Generation Plan* included plans to promote investment in new and replacement nuclear power facilities, establishing the nuclear fuel cycle for LWR's, starting full operation of the Rokkasho Reprocessing Plant, recommencing operation of the Monju fast-breeder reactor, support global development of the Japanese nuclear industry, selecting a final disposal site and commence disposal of radioactive waste materials by the mid-2030's, improving safety regulations and procedures and improving relationships in local communities where nuclear facilities are located.
- *Comprehensive Strategy for Securing Resources* to be achieved through increasing the percentage of Japanese equity oil exploration and development in targeted countries, strengthening relationships with supplier countries through resource diplomacy, technology and R&D cooperation, providing financial incentives for exploration and development projects (including through JOGMEC), promoting corporate tie-ups between Japanese and foreign energy firms and supporting the development of uranium resources overseas.
- *Asia Energy and Environment Cooperation Strategy* intended to enhance cooperation with other countries in Asia where energy demand is rapidly increasing, especially in China and India. Plans included establishing energy conservation programs in Asia with technical and advisory support to be made available, supporting the introduction of "new energies" in Asian countries, promoting the utilization of clean coal

technology, building an energy resource stockpiling system in Asia and promoting regional cooperation on nuclear power for the purpose of enhancing safety and regulation as well as promoting Japanese nuclear technology.

- *Enhancement of Emergency Response* including reassessing and strengthening the existing oil stockpiling system in Japan, introducing LPG stockpiling, conducting feasibility studies for underground natural gas storage, promoting improvement of the domestic gas distribution network and promoting the use of risk management systems in companies to improve emergency response.
- *Formulate an Energy Technology Strategy* which is to be a cooperative effort between government and industry to develop a medium to long term energy technology development roadmap to support innovative technologies and thereby gain or retain Japan's leadership, especially in areas such as energy efficiency.

The government also committed to work closely with industry to coordinate the strategies and programs under the plan in order to strengthen Japanese energy companies, to provide budget resources and tax policies for programs and to engage the public to gain public understanding and improve energy-related public relations.

Based on the "Framework for Nuclear Energy Policy" developed by the Atomic Energy Commission in 2005, METI compiled the "Nuclear Energy National Plan" in 2006, which set out specific policies for promoting nuclear energy over the long-term. The plan included increasing the level of nuclear power to at least 30% to 40% of electricity supply by 2030 and beyond and this target was incorporated into the New National Energy Strategy.[392], [393]. The plan also promoted the nuclear fuel cycle, the introduction of fast-breeder reactors by 2050, assistance for Japan's investment in overseas uranium mine projects, measures to deal with radioactive waste and strategic support of related industries [394], [395].

In 2007, further gas market liberalization allowed end use customers with a demand of 100,000 cm or more to choose their supplier and negotiate rates. This effectively included all gas customers except for the household sector [154].

Basic Energy Plan of 2007

In March 2007, METI published as new version of the Basic Energy Plan which was an update on the 2003 version. The plan was based on the 2006 NNES and reflected recent changes in the domestic and international environment. The principal threats and issues in international energy markets that informed the development of the plan included: rising demand for energy resources particularly in Asia, intensification of competition to secure energy resources, continued destabilization in the Middle East, the tightening of state controls over energy in supplier countries and the anticipated increase in the use of nuclear power in several countries to help meet climate change and energy security goals. The plan also noted that given the risks as noted above, energy security has become all the more urgent [154], [290].

Basic policy amendments in the BEP included:

- Promoting energy conservation through new technologies and strengthened efforts in the residential, transport and industrial sectors.
- Diversification of energy sources, especially from low-risk suppliers.
- Promotion of nuclear power generation including nuclear fuel cycle and encouraging the development and utilization of new energy.
- Strengthening of strategic and comprehensive measures toward securing stable supplies of energy, enhancing resource diplomacy with supplier countries, diversifying transport routes and assisting Japan's international energy companies to be globally competitive.
- Strengthening the stockpiling system for oil and LPG.
- Improving the reliability and stability of the domestic energy supply system.

In 2008 progress toward meeting goals in the Kyoto Target Achievement Plan were reviewed by the government. The resulting assessment was that Japan would fall short of its GHG emissions target by about 22-36 million tons CO2 equivalent. As a result, the plan was revised to obtain additional energy consumption savings from voluntary industry action plans as well as from increased energy savings from factories and workplaces. Following this review, the Long-term Energy Outlook was revised to reflect these changes and to include targets set out in the New National Energy Strategy (NNES) and the Basic Energy Plan of 2007 [396](see Table A-1).

Building on the Cool Earth 50 policy announced in May 2007 that was aimed at reducing global GHG emissions by 50% by 2050, the *Cool Earth Innovative Energy Technology Program* was introduced in March 2008 to focus on innovative technologies to help achieve Japan's objectives. Thus in addition to achieving climate goals, the program has a strong economic and technology aspects with a focus on 21 innovative technologies whose development and deployment should be prioritized to achieve the target. Each technology was accompanied by a technology development road map extending to 2050. These technologies include high efficiency natural gas and coal fired power generation, CCS technology, advanced nuclear power generation, intelligent transport systems, fuel cell vehicles, plug-in hybrid/electric vehicles, efficiency improvements of industrial processing and materials production and stationary fuel cells [397].

In the lead up to the G8 Summit that Japan was to host in July 2008, Prime Minister Fukuda set up an advisory panel in February called the Panel on a Low-Carbon Society to examine issues related to global warming and to develop a plan regarding how Japan could contribute globally to creating a low-carbon society (the so-called "Fukuda Vision"). In line with this vision, the Cabinet approved the *Action Plan for Achieving a Low Carbon Society* in July outlining the steps to be taken toward achieving the vision. The plan called for developing advanced and innovative technologies that were expected to contribute significantly to the reduction of greenhouse gases by 2050. This was to be achieved through the *Cool Earth Innovative Energy Technology Program*, and a new program called the *Low Carbon Technology Plan* which was allocated a budget of US$30 billion over five years. A significant thrust of the plan was regaining Japan's leadership in solar PV technology, expanding PV installations, promoting nuclear power (by building new reactors and improving capacity utilization), and accelerating the introduction of low-emission vehicles, low-energy lamps, energy efficient appliances, housing and office buildings (see Table A-1) [398]–[400].

To further support these efforts, Japan introduced its first feed-in tariff for solar PV in 2009 through the Excess Electricity Purchasing Scheme for Photovoltaic Power. Under the scheme, electric utilities were mandated to purchase surplus electricity generated by residential customers' PV installations at a fixed price for 10 years. Specific targets were set for the amount of generation to be purchased in each year to 2014. In 2011, costs required to buyback the surplus electricity were shifted to electricity customers in the form of the PV surcharge [401]. This program was subsequently rolled into the new FIT scheme for renewables introduced in 2012.

In April 2009, the *Energy Conservation Technology Strategy* was released, as stipulated in both the New National Energy Strategy and the 2007 Basic Energy Plan. The plan took a very long-term perspective on technology development (i.e.: 2050 and beyond) in recognition of the fact that technology development requires long term lead times and sustained efforts between the public and private sectors. The plan was designed to support innovative technologies in all industry sectors for the purpose of maintaining Japan's global leadership in the area of energy efficiency. Various promising energy technologies were identified along with the technical and other hurdles associated with them and roadmaps were formulated to guide technology development[402], [403].

The Basic Act for the Promotion of Biomass Utilization was enacted in 2009 and set principles and a governance framework for the development of biomass utilization. Based on the Act, a national plan was developed in 2009 with targets to be achieved by 2020 (see Table A-1). However this wasn't the first time targets for biomass utilization had been developed – Japan had set targets in the late 1990's. The first strategy was the Biomass Nippon Strategy developed in 2002 (later revised in 2006) by the Ministry of Agriculture Forestry and Fisheries with cooperation with METI [404].

On April 19, 2010, METI submitted a draft of the third Basic Energy Plan (also known in English as the "Strategic Energy Plan") to the Basic Energy Planning Committee, a subcommittee of the Advisory Committee for Natural Resources and Energy. After revisions, the final version was approved by the Cabinet of Prime Minister Yukio Hatoyama and released on June 18, 2010. The plan contained the following seven "basic perspectives" or goals for Japanese energy policy [405]–[407]:

- Strengthening energy security
- Improving measures to counter global warming
- Promoting economic growth, with energy as the key driver
- Ensuring the safety of the energy supply
- Strengthened focus on the economic efficiency of energy markets
- Restructuring of the energy sector to achieve enhanced competitiveness
- Gaining public understanding of energy security and environmental policies

To help achieve these goals, the revised plan also set long-term numerical targets for improving Japan's energy security and meeting its climate change objectives by 2030 (see Table A-1).

While the 2010 BEP – as with the other versions before it – was based on the three fundamental principles of the Basic Act on Energy Policy, two of the additional "perspectives" were of key importance in the new version: energy-based economic growth and restructuring of the energy sector. In this way energy policy would be more closely linked to broader economic development strategies, as reflected in the "New Growth Strategy" released by Prime Minister Kan's government in June, 2010. The principles and perspectives outlined in the 2010 BEP were intended to fundamentally change Japan's energy supply and demand system by 2030 [257].

Other specific measures designed to achieve the targets in the plan included both supply-side and demand-side measures [257]. Supply-side measures included:

- Increasing the introduction of renewable energy by expanding the feed-in tariff system and strengthening other supports for renewables.
- Promoting nuclear power generation by building additional nuclear power plants.
- Limiting CO2 emissions of coal power plants to the level of IGCC plants by 2020 and requiring new coal power plants to be CCS-equipped by 2030.
- Constructing "next-generation" interactive electricity grid networks by the early 2020's.
- Deepening strategic relationships with resource-rich supplier countries and conducting resource diplomacy.
- Enhancing support for risk capital used by Japanese companies to develop upstream energy projects in foreign countries.
- Energy sector restructuring and liberalization to enhance competition in the market.

Demand-side measures included:

- Building a low-carbon energy demand structure through technological and regulatory strategies designed to improve energy efficiency in the industrial and transportation sectors, residential and commercial buildings and in cities and local communities.
- Promoting energy management systems, the installation of smart meters, constructing smart-grids and smart communities as well as promoting fuel cells and a hydrogen supply infrastructure.
- Developing and disseminating innovative energy technologies.

A.3 Post Fukushima policies and targets

The Great East Japan Earthquake and tsunami and subsequent disaster at the Fukushima Daiichi nuclear power plant on March 11, 2011 caused extensive damage and loss of life, and "significantly damaged public trust in the safety of nuclear power", according to the government's own energy White Paper of 2012 [408]. As a result, the government initiated a series of measures to deal with disaster recovery and strengthen energy security and safety.

In the immediate aftermath of the disaster, the government decided that nuclear reactors that had been shut down before the Fukushima accident occurred and those shut down for regular maintenance in the period following the nuclear accident would not be permitted to restart until they had passed safety inspections by a new nuclear regulator that was to be formed. As a result, by May, 2012 all of Japan's commercial nuclear power plants had been shut down[104], leaving Japan without any nuclear power for the first time since 1966.

After the triple disaster several reports of investigations into the disaster were published and recommendations made for improvements in Japan's disaster management system and nuclear power regulatory frameworks. The most prominent report was the 10-member *Nuclear Accident Independent Investigation Commission (NAIIC)* established by legislation passed in the Diet and which officially launched on December 8, 2011 and published its report in July, 2012. One of the mandates given to the NAIIC was to provide suggestions regarding the "re-examination of an optimal administrative organization" for nuclear safety regulation based on its investigation of the accident [409]. Another major report was *The Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company* which was established by a Cabinet decision on May 24, 2011, for the purpose of "making policy recommendations on measures to prevent the further expansion of damage caused by the accident and a recurrence of similar accidents in the future" [410]. The Committee's final report was issued in July, 2011.

As a result of these and other recommendations, major changes were made to the regulation of nuclear power in Japan. In June, 2012 the government passed the *Act for Establishment of the Nuclear Regulation Authority* in order to separate the responsibility for promotion of the nuclear power from regulatory oversight of the nuclear industry. In October, 2012 the

---

[104] In July 2012, two reactors at the Ohi power plant were restarted to temporarily relieve power shortages but were shut down again in September 2013.

Nuclear Regulation Authority (NRA) was created under the Ministry of the Environment in order to remove a conflict of interest between nuclear regulation and promotion within METI, and to unify nuclear safety regulation within an independent regulatory body. The former Nuclear & Industrial Safety Agency (NISA) under METI and the Nuclear Safety Commission (NSC) under the Cabinet Office were incorporated within the NRA immediately, and the Japan Nuclear Energy Safety Organization (JNES) followed in March 2014 [346].

In the face of a severe electricity supply shortage (particularly in Eastern Japan) and the possibility of electricity blackouts during the summer of 2011 after the triple disaster, the government introduced the *Setsuden* energy conservation program in July. Setsuden combined mandatory electricity demand limits for large scale electricity users (over 500 kW demand) with educational programs and voluntary actions for smaller users and consumers designed to encourage the public to conserve electricity and adopt an "energy-saving" lifestyle [383].

In the absence of nuclear power and to stimulate the introduction of renewables, the *Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities* (Law No. 108 of 2011), also known as the *Feed-in Tariff Act,* was approved by the Diet in August 2011, introducing a comprehensive FIT program. The program started on July 1st, 2012. The Act obliges electric utilities to purchase electricity generated from renewable energy sources (solar PV, wind, hydro (under 30 Mw), geothermal and biomass) based on a fixed-period contract with fixed price. The costs incurred by utilities in purchasing renewable energy are borne by electricity customers who pay a renewable energy surcharge in proportion to their use of renewable electricity.

The government of Prime Minister Noda released the *Innovative Strategy for Energy and the Environment* on September 14, 2012 as a Cabinet document. The intent of this post-Fukushima policy was to strive to reduce reliance on fossil fuels by maximizing "green energy" including energy efficiency and renewable energy and to phase out nuclear energy by the 2030's. However, the zero nuclear power aspects of the policy encountered stiff resistance from the business community who complained that the resulting increase in electricity costs would make Japan uncompetitive and that 20-25% of Japan's electricity should be nuclear to avoid very severe economic effects. The plan even provoked expressions of concern from the United States about the fate of Japan's nuclear stockpiles. As a result, the government backtracked on the strategy calling it a "reference document".

To help Japan reach its emissions targets and vision of a low-carbon society, the Ministry of Environment implemented a *carbon tax* in October, 2012 on petroleum, natural gas and coal [411]. The tax rate corresponds to the CO2 emissions factors for each fuel. Nearly a third of the tax burden would fall on power companies [412]. The tax will be phased in over three and a half years to reach a total of 289 Yen per ton of CO2 by April, 2016. The net cost impact on the average household fuel bill was expected to be about Yen 1200 per year. The tax revenue generated will be used for various "green" initiatives, including CO2 reduction programs, energy-conservation measures, promotion of renewable energy, and clean and efficient use of fossil fuels [413]. Business groups such as the Keidanren vigorously opposed the tax on the grounds that it would burden small and medium sized businesses and force other companies to relocate offshore due to the higher costs in Japan.

The general election of December 2012 saw the Democratic Party of Japan defeated by the Liberal Democratic Party. The incoming Shinzo Abe administration quickly abolished the Energy and Environment Council (Enecan) and the National Policy Unit (NPU) advisory bodies, and assigned responsibility for the development of energy related plans to METI's Advisory Committee for National Resources and Energy. At the same time, the Ministry of Environment's Central Environment Council was tasked with focusing on climate change issues [254]. The new government also announced that: "The Minister of Economy, Trade and Industry should carry out a zero-based review on the former administration's energy and environmental strategy and establish a responsible energy policy which also ensures a stable supply of energy and reduced energy costs" [294]. In January of 2013, the Prime Minister announced that the decision by the former administration to phase out nuclear power lacked a "concrete basis" and that a new energy policy would be developed in its place with an emphasis on "stable supplies of energy" (energy security) and reduced energy costs [294]. A decision on the possible restart of nuclear reactors would only be made after a thorough safety review within the subsequent three years. Deliberations began on the development of a new Basic Energy Plan with a target of completing it by the end of 2013 [294].

In April, 2013 the Cabinet endorsed the *Policy on Electricity System Reform* which outlined three further steps toward full liberalization of the electricity sector. This three-step process of completing power sector reforms consists of the establishment of OCCTO (completed in 2015), transition to full retail competition in the residential sector starting in April 2016, and legal unbundling of power generation from transmission/distribution in 2020. A revision to the Electricity Business Act will finalize these steps. Regulations on household rates are expected to be abolished sometime after April 2020.

In June of 2013 the Information Security Policy Council released a *Cybersecurity Strategy*. This document outlined the approach and measures the country would take to address growing cyber threats arising from the increasing dependence of critical infrastructures on information technologies such as SCADA that control energy infrastructure systems. The report noted that certain energy infrastructure (including so-called “smart cities”) and transportation infrastructure would henceforth be considered “critical” and the report called for improving and integrating the analysis of cyber incidents, enhancing information sharing, strengthening risk-based approaches and responding more effectively to threats and incidents [414].

On October 15, 2013, the Cabinet approved the *Bill for the Act for Partial Revision of the Electricity Business Act* which was later passed in the Diet in November 2013. These revisions to the *Electricity Business Act* enabled the first step of electricity market reform as outlined in the *Policy on Electricity System Reform* (see above), including the enhancement of national supply-demand balancing and to formally establish the national transmission operator (OCCTO) [415], [416].

Also in November 2013, the government passed the *Act on Promotion of Generating Renewable Energy Harmonized with Healthy Development of Agriculture, Forestry and Fishery* (the "REAFF Law"), which will ease restrictions on agricultural land to allow for the expansion of renewable energy facilities, including solar, wind and other renewables [417].

On February 28, 2014, the Cabinet approved the *Bill for the Act for the Partial Revision of the Electricity Business Act and Other Related Acts* which finalized the second step of electricity market reform with the establishment of full retail completion by 2016, eliminating all regulations for entering electricity retail markets, obliging retailers (in addition to GEU’s) to purchase renewable energy, and other related measures [418].

In March 2015, the Cabinet approved the *Bill for the Act for the Partial Revision of the Electricity Business Act and Other Related Acts* which aimed to “drastically reform” the regulatory framework for the electricity, gas and heat supply businesses. The bill included finalizing the third step of electricity market reform, gas market reforms, reforms to the heat supply market and the establishment of the new regulatory authority for electricity and gas [419].

A.4 Nuclear policy

As a result of the two oil shocks in the 1970's, Japan made nuclear energy development a cornerstone of its energy policy to reduce reliance on oil. This policy saw the country build up the majority of its current nuclear fleet in the 1980's and early 1990's. Japan's nuclear power policy targets in the 2000-2013 period and its performance relative to those targets have already been discussed in Chapter 4.3. Here the focus is on nuclear policy and regulation.

In Japan, nuclear power has been viewed as an important "quasi-domestic" source of energy that can play a key role not only in reducing reliance on imported fossil fuels but also as a source of zero-emission electricity thereby contributing to the achievement of Japan's climate change goals [269]. Nuclear power has also been shown to have the lowest generation cost per kWh among all of Japan's electricity generation sources [420]. The 1998 *Guidelines for Measures to Prevent Global Warming* and subsequent statements by the government have specifically called for the construction of nuclear power plants in order to help meet Japan's climate change commitments [421]. Nuclear power technology is also viewed as an important source of technological development, trade and employment in Japan, and the country actively promotes the export of nuclear power technology.

Japan has adopted a closed nuclear fuel cycle policy. This involves importing uranium, enriching it, utilizing it in its nuclear reactors, reprocessing the spent nuclear fuel and then reusing the extracted plutonium and uranium as "MOX" fuel in fast breeder reactors. The benefits of a closed nuclear fuel cycle are that it enhances long-term energy security by reducing dependence on imported fuels, conserves uranium resources, and reduces the amount of high-level radioactive waste that needs to be disposed of. Left-over nuclear waste materials are to be stored permanently at an underground storage facility. The Nuclear Waste Management Organization of Japan (NUMO) was established in 2000 and is tasked with nuclear waste disposal issues. NUMO has targeted the early 2030's as the date by which Japan should commence disposal operations. However, as of 2014, no community in Japan had yet agreed to host the disposal facility and community consultations were continuing. In the meantime, nuclear waste is stored at a number of nuclear reactors sites around Japan, as well as overseas.

Based on the 1955 Japan-U.S. Nuclear Power Cooperation Agreement, Japan became the only country in the world without nuclear weapons to reprocess nuclear fuel. For this purpose, the Rokkasho nuclear fuel reprocessing plant project was begun in 1993. The plant has experienced a number of delays and operations were set to begin in October 2013. However these plans were delayed until the plant can be approved under the NRA's new nuclear safety regulations.

The Japan Atomic Energy Agency owns a 280-MWe sodium-cooled fast-breeder reactor, Monju which first produced power in 1994. The Monju reactor has been considered as central to the achievement of the nuclear fuel cycle. However, a series of accidents, incomplete safety inspections and cover-ups resulted in a loss of public confidence. As a result, the reactor has been offline almost from the time it was commissioned in 1994 (IEA 2008). The viability of the Monju project remains in doubt 20 years after it was started.

As already noted, Japan experienced a number of nuclear accidents and "scandals" in the 2000-13 period that resulted in a loss of public confidence and put nuclear safety and nuclear power regulation into question. These issues were a direct cause of the shut down or delayed start-up of a number of nuclear plants, including facilities integral to Japan's fuel cycle aims. For example, between 2002 and 2005, 17 of TEPCO's nuclear power plants had to be shut down due the falsification of records, affecting Japan's power supply situation [422]. In 2003, the IEA noted that safety related incidents undermined public confidence and made nuclear targets difficult to reach, recommending that the government address safety shortcomings [139]. The government responded with the creation of the Japan Nuclear Energy Safety Organization (JNES) which was tasked with carrying out a review of the safety inspection system.

The government and regulators responded with a number of initiatives to improve safety and regulation, including time-based inspections with intervals of no more than 13 months between inspections. This resulted in increased down-time and lower availability of the country's reactors as exemplified in steadily falling nuclear capacity factors over the period [154]. Yet incidents continued to occur suggesting deeper endemic problems with nuclear safety in Japan.

Finally, nuclear safety issues came to a head after the Fukushima disaster and the release of several reports on the accident that implicated nuclear regulators, exposed weaknesses in the regulatory system and recommended major changes.[105] Both the Cabinet-appointed Similar to the NAIIC report, it also called for an independent regulator, improved communications and information-sharing, and better regulatory staff training and personnel policies [410].

Notwithstanding these issues and the disaster in Fukushima, in late 2012 nuclear power was reaffirmed in as an important energy source by the Japanese government for meeting both energy security and climate change goals [424]. As of June 15, 2015, 25 applications for safety reviews of nuclear power units had been received by the NRA [425]. On August 14, 2015 , Sendai No. 1 became Japan's first nuclear reactor to come back on line since the shutdown of Japan's entire nuclear fleet to meet new post-Fukushima safety standards [426].

Life extension of nuclear reactors

The Japanese government limited the service life of nuclear reactors to 40 years after the Fukushima disaster. However operators can obtain a one-time 20-year life extension if the reactors are refitted and pass inspections from the Nuclear Regulation Authority. Three reactors were being reviewed for life extensions by the NRA as of April, 2015.[106] However as more than half of Japan's nuclear reactors will reach their 40 year service life over the next 15 years, they must pass inspections and receive life extensions or will be decommissioned. Spent fuel from decommissioned reactors will likely further compound disposal and storage issues and resistance from local communities could stall the construction of new reactors to replace the aging fleet.

Nuclear power regulatory policies

Given the magnitude and high level of seismic activity in Japan, the country has adopted strict requirements for the siting, design and construction of nuclear power plants.[107] Over the

[105] Madarame Haruki, a former Chairman of the Nuclear Safety Commission testified in February 2012 at the Diet inquiry into the Fukushima accident that nuclear safety regulations were minimally enforced and fundamentally flawed, that regulatory capture was an issue and that regulators had little power and were often subsumed by utility interests [423].

[106] Kansai Electric (KEPCO)'s Mihama No. 3 and Takahama 1 and 2.

[107] Earthquake resistance requirements for nuclear power plants are much more stringent than those applying to non-nuclear facilities. Japanese nuclear power plants are designed to withstand seismic events with specific intensities. Guidelines require that main reactor facilities maintain safety functions even under seismic

2000-2013 period a number of revisions to the country's seismic guidelines were made by the Nuclear Safety Commission (NSC). As a result of the study of recent earthquakes and information from seismology, earthquake engineering and seismic design technologies, the NSC ordered a full review of the country's seismic guidelines resulting in the new *Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities* which was published in September 2006. The NSC and the Nuclear and Industrial Safety Agency (NISA) required nuclear power plant operators to undertake plant-specific reviews of seismic safety which were to be completed in 2008 [427].

After the earthquake struck the Tohoku region on March 11, 2011, eleven reactors at four nuclear power plants in the region that were operating at the time all shut down automatically when the quake hit. Subsequent inspections showed no significant damage to any of the reactors from the earthquake. The reactors proved robust to the earthquake itself but proved to be vulnerable to the tsunami.

In October 2011, the Nuclear Safety Commission issued *Measures against Severe Accidents at Light Water Nuclear Power Reactor Facilities* to strengthen procedures to enhance the robustness of nuclear power reactors to external events (i.e.: natural disasters including earthquakes and tsunami) beyond design basis [428]. In March 2012, the Japan Atomic Energy Commission issued *Strengthening of Japan's Nuclear Security Measures* making recommendations for enhancing the security of nuclear materials and high-level radioactive wastes [429].

Following the establishment of the Nuclear Regulation Authority in 2012, the roles and responsibilities of nuclear safety and security regulations for nuclear facilities and radioactive materials were integrated within the NRA [430]. Japan has also been strengthening measures to protect against terrorism at nuclear facilities as part of the *Strategy to Make Japan the Safest Country in the World* approved by the Cabinet in December, 2013 [431]. After the accident at Fukushima Daiichi nuclear power plant, Japan decided to further enhance the collaboration among the relevant authorities and have conducted counter terrorism exercises for nuclear power plants and other nuclear related facilities. In 2013, the police and the Japan Coast Guard as well as operators jointly implemented thirty exercises and the police and the

---

forces equivalent to the largest earthquake which can reasonably be expected to occur at the site of a nuclear power plant, based on seismicity surveys of the area and local active faults. All nuclear power plants are equipped with seismic detectors that automatically shut the plant down if ground motion exceeds a certain level.

Japan Self Defense Forces (JSDF) jointly implemented two field training exercises at eighteen nuclear power plants. Also, the police and the JSDF implemented thirty joint counter terrorism exercises for important facilities including nuclear power plants. Japan has committed to continue such countermeasures for nuclear security [432].

A.5 Electricity policy

The *Electricity Business Act* is the principal source of regulatory authority over the generation, transmission and distribution of electricity. As for nuclear power, the *Atomic Energy Fundamental Act*, the *Act on Compensation for Nuclear Damage* and other related acts govern the nuclear power sector. Together, these laws have shaped the structure of Japan's electricity sector since the early 1950's. METI exercises regulatory authority over the electricity sector.

Electricity markets

Japan's electricity sector consists of a mixture of ten vertically integrated (i.e.: generation, transmission, distribution and retailing), regionally-based GEU's with near-monopoly market power. Two other utilities, J-Power (or Electric Power Development Company) and Japan Atomic Power Company are wholesale utilities selling power to the GEU's. Up to the time of full electricity liberalization beginning in 2016, a variety of different classes of independent generators existed. For example, wholesale power suppliers (including IPP's - independent power producers) could only supply the GEU's while so-called power producers and suppliers (PPS) could supply the GEU's or customers in the deregulated segment. The regional GEU's will continue to have sole responsibility for transmission and distribution infrastructure within their region even after liberalization.

During the 2000-2013 period Japan's electricity system could be characterized as partially liberalized with about 63% of total demand[108] deregulated in 2013 [125]. In 2013, about 86% of total electricity demand was supplied by the GEU's, 12% by industry-owned auto producer

[108] Excludes power generated by auto producer plants

plants and 2% by other suppliers[109] [125]. The residential sector (users with demand of 50kW or less) is served solely by the GEU's under regulated rates.[110]

Electricity market liberalization

Between 1951 and 1995, the generation and transmission of electric power was run by Japan's 10 GEU's each of which had a regional monopoly in their respective regions. Increasing power prices started to affect Japan's manufacturing competitiveness and this provided the impetus for beginning electricity system reforms in 1995. Although there were plans to pursue full liberalization in 2003, resistance from the GEU's, a lack of political will and fears arising from California's power market reforms slowed the process [433]. Despite these issues, liberalization measures proceeded on a gradual basis with further changes in 2004 and 2005. The triple disaster of March 2011 however provided the impetus for accelerating electricity market reforms, especially in light of rapidly increasing power costs due to the increased cost of fossil fuels in the 2011-2013 period.

Electricity market reforms can be divided into 6 stages, starting in 1995 when independent power producers (IPP's) were allowed to bid in wholesale power to the GEU's. Reforms gradually expanded the level of retail competition between 2000 and 2016. These stages are described in Table 5.

In April, 2013 the Cabinet endorsed the *Policy on Electricity System Reform* which outlined three further steps toward full liberalization of the electricity sector. The Cabinet approved a series of 3 bills in 2013, 2014 and 2015 entitled *Cabinet Decision on the Bill for the Act for Partial Revision of the Electricity Business Act* which amended the *Electricity Business Act* and other related acts in order to implement the final three phases of reforms to the electricity sector.

The first step is the creation of a nationwide transmission system operator in 2015, to be known as the "Organization for Cross-regional Coordination of Transmission Operators" or "OCCTO". The mandate of this organization is to promote "wide-area grids" to better

---

109 "Other producers" is comprised of power companies defined by METI as "Power Producers and Suppliers" (PPS) and "Special Electric Utilities".

110 In the regulated sector, utilities pass on the costs of generation including the cost of building and operating power plants and T&D infrastructure to users, with rates subject to approval from METI.

facilitate nationwide electricity supply-demand balancing, coordinate regional transmission operators, develop frequency conversion capacity between Japan's two electricity grid frequency areas, and facilitate grid interconnections for new power sources (such as renewables).

The second step, to take effect around 2016, is to fully liberalize the electricity market to enable all consumers, including the household sector, to choose their own electricity supplier; tariff regulations on general electricity utilities will be abolished after a transitional period; and full liberalization of power generation will be implemented.

The third step, to be implemented between 2018-2020 will see legal unbundling of power generation and transmission/distribution business activities of the GEU's[111], measures to ensure grid neutrality and fair access to transmission infrastructure, and measures to enhance disaster response [344], [419]. It also will abolish regulated rates for retail prices by 2020 after "a review of the competitive situation" [237]. Finally, the bill established a new regulatory authority for the electricity market within METI, subsequently named the *Electricity Market Surveillance Commission (ESMC)*.

A.6 Gas policy

The *Gas Business Act* is the principal source of regulatory authority over the gas sector. LPG is governed by the *LP Gas Act*. Market entry has been controlled by METI which required licenses for operators of gas businesses. The requirements under the Gas Business Act have been structured such that only one city gas provider is normally granted a license to operate in a single service area, providing de-facto monopoly power in that area. The largest gas provider in Japan is Tokyo Gas whose service area in the Kanto region accounts for about 37% of the Japanese market. Osaka Gas, Toho Gas and Saibu Gas account for an additional 36%. These four providers therefore account for 73% of the Japanese market with the remainder divided among a larger number of service providers [152].

Gas utilities that possess a monopoly in their service area are required to base their rates on costs while "under efficient management", plus a reasonable rate of return as stipulated under

[111] Transmission/distribution businesses will continue to hold a regional monopoly and return on investment for lectricity transmission/distribution grids will be institutionally guaranteed through tariff regulations including fully distributed cost methods [344].

METI's rules. Rate increases must be approved by METI. LPG prices are not subject to regulation [152].

Gas markets

There are eight gas supply regions in Japan served by a total of 26 public utilities and 181 private gas utilities [156]. Regulations that have been in place for over 50 years grant many of these gas utilities monopolistic privileges within their respective regions and service areas. The retail market remains dominated by three large gas utilities: Tokyo Gas, Osaka Gas and Toho Gas, which together have over 70% share of the market [434].

There are two main types of gas used in Japan, "city gas" (or "town gas"), and liquid petroleum gas (LPG). Over 90% of city gas is produced from imported LNG and then adjusted for caloric value. Approximately 70% of the LPG consumed in Japan is imported from overseas, while the remaining 30% is produced domestically through the petroleum and petrochemical refining process. City gas is distributed to customers through distribution pipelines in major urban centers in Japan while LPG is transported by truck from coastal receiving terminals to secondary facilities where it is put into compressed gas cylinders for distribution to customers [159], [435].

LNG used for town gas increased by 61% between 2000 and 2013 while LNG used for electricity generation increased by 51%. Looking at LNG demand by sector, residential sales made up the majority of gas sales in 2000 and demand has been flat over the 2000-2013 period. Industrial use has increased sharply, representing 53% of demand in 2013 compared with 26% by residential users [125]. As a result of rising demand, imports of LNG rose from 54.1 million tons in 2000 to 87.7 million tons in 2013. On the other hand, the demand for LPG has seen a declining trend with total supply (imports and domestic production) falling from 19.5 million tons in 2000 to 15.4 million tons in 2013 [125].

Gas market liberalization

Liberalization of Japan's gas market began in 1995 and has proceeded in stages. By 2007 the market had been fully liberalized except for the residential user segment which comprised 37% of the market (see Table 6).

As a result of these measures, city gas suppliers can compete for commercial customers in the service area of another supplier and companies other than gas suppliers can enter the commercial gas supply market. Regulated rates for the commercial has business have also been abolished (see Table 6).

In March 2015, the Cabinet approved the *Bill for the Act for the Partial Revision of the Electricity Business Act and Other Related Acts* which aimed to "drastically reform" the regulatory framework for the electricity, gas and heat supply businesses. The bill included a number of new measures affecting gas markets. The bill revised the *Gas Business Act* to implement full retail competition in the gas market by 2017. It also provided for legal unbundling of the gas pipeline service sector by 2022. Gas pipelines are to remain under the management of the gas utilities with regulated tariffs and mechanisms are to be developed to recover the cost of building and maintaining inter-regional pipelines [237]. Market entry will no longer be controlled by METI and business license requirements will be relaxed. Third-party access will be granted to LNG terminals. Regarding the heat supply sector, the *Heat Supply Business Act* was amended to abolish regulated rates on heat suppliers in 2016. Finally, a new regulator for electricity and gas market surveillance was established through the bill[237]. The *Electricity Market Surveillance Commission (ESMC)* will assume regulatory authority over the gas business starting in sometime in 2016.

Gas pipeline infrastructure will continue to be operated and maintained by the gas utilities under regulated tariffs and with full third-party access. Regulated rates will also be maintained as a transitional measure, providing last resort services to consumers.

The heat supply business (i.e.: district heating and cooling- DHC) is the third largest energy "utility" in Japan, after the electricity and gas sectors [436]. As of April 2015 there were 76 licensed utilities and 137 licensed DHC districts in operation. Liberalization measures include relaxing market entry regulations and abolishing the regulated tariff system except where consumers have difficulty finding alternative suppliers [237].

A.7 Petroleum policy

Petroleum deregulation

Japan initiated the liberalization of the petroleum refining sector in the late 1980's and in the ensuing years, various regulations have been eliminated. This process was completed in January, 2002 with the abolition of the 1962 Petroleum Industry Law [139]. The retail gasoline market is fully liberalized although a delayed price "pass-through" system remains in place for gasoline prices.

Appendix B: Summary of energy policies and strategies in the 2000-2013 period

Prior to the development of the first Basic Energy Plan in 2003, Japanese energy policies, strategies and targets were articulated mainly through the Long-term Energy Supply and Demand Outlooks which have been issued every 3-4 years since 1967. Since 2003, the Basic Energy Plans (or Strategic Energy Plans) issued every 3-4 years provide overall direction for energy policy in line with the "3-E's" of energy security, environmental protection and economic efficiency.

Energy policies that prevailed between the time of the oil shocks of the 1970's and the issuance of the first BEP can be summarized as follows [139]:

- Energy efficiency policies, including energy conservation standards.
- Diversification of energy supply sources, fuel switching in the power generation sector (from coal to natural gas).
- Promotion of nuclear power.
- Promotion of renewables.
- Support for energy R&D.
- Development of upstream domestic and international energy resources.
- Developing oil stockpiles.
- Promoting strategies to strengthen international energy cooperation within Asia and with energy supplier countries.

The first Basic Energy Plan published in October 2003 placed a priority on energy security, ensuring stable energy supply and confirming nuclear power as an basic source of energy supply that can contribute to environmental protection as a carbon-free source of power. This plan also addressed market structure issues, and calling for electricity market liberalization [154].

The 2007 BEP reflected newly emerging threats to Japan's energy supplies in the domestic and international environment and noted that strengthening energy security had become all the more urgent [154], [290]. Energy policies included:

- Promoting energy conservation through new technologies and strengthened efforts in the residential, transport and industrial sectors.

- Diversification of energy sources, especially from low-risk suppliers.
- Promotion of nuclear power generation including nuclear fuel cycle and encouraging the development and utilization of new energy.
- Strengthening of strategic and comprehensive measures toward securing stable supplies of energy, enhancing resource diplomacy with supplier countries, diversifying transport routes and assisting Japan’s international energy companies to be globally competitive.
- Strengthening the stockpiling system for oil and LPG.
- Improving the reliability and stability of the domestic energy supply system.

The 2010 BEP describes energy-based economic growth and energy policy as a function of safety and public understanding, and proposes reform of the energy and social system. The plan included both supply side and demand side policy measures including [257]:

- Increasing the introduction of renewable energy by expanding the feed-in tariff system and strengthening other supports for renewables.
- Promoting nuclear power generation by building additional nuclear power plants.
- Limiting CO2 emissions of coal power plants.
- Constructing “next-generation” interactive electricity grid networks by the early 2020’s.
- Expanding the electricity wholesale market.
- Deepening strategic relationships with resource-rich supplier countries and conducting resource diplomacy.
- Enhancing support for risk capital used by Japanese companies to develop upstream energy projects in foreign countries.
- Energy sector restructuring and liberalization to enhance competition in the market.
- Building a low-carbon energy demand structure through technological and regulatory strategies designed to improve energy efficiency in the industrial and transportation sectors, residential and commercial buildings and in cities and local communities.
- Promoting energy management systems, the installation of smart meters, constructing smart-grids and smart communities as well as promoting fuel cells and a hydrogen supply infrastructure.
- Developing and disseminating innovative energy technologies.

Appendix C: Outstanding energy security policy issues

C.1 Robustness issues

In Chapter 3.1, infrastructure adequacy and security was assessed for Japan's electricity infrastructure. The analysis showed that Japan's electricity generation and gas infrastructure was robust to disturbance between 2000-2010. This robustness can be explained by the fact that the electricity and gas systems were able to deliver energy adequately and reliably over the period with very few interruptions.

After the triple disaster, a number of issues related to electricity and gas related infrastructure vulnerabilities became apparent, with consequences for robustness policies. These issues are discussed here in more depth.

Electricity infrastructure

Note: This issue is discussed in Chapter 4.1.

Nuclear power adequacy

Soon after its election in December 2012 and again in 2014, the new administration under Prime Minister Abe confirmed its commitment to retaining nuclear power in Japan's energy future while also stating that it would try to reduce reliance on nuclear "as much as possible" [437]. It premised this position on nuclear's role as an "important baseload energy source" and to meet climate change commitments. In so doing, the government has effectively decided to accept a certain level of risk that comes with nuclear power in order to achieve an acceptable level of energy security and sustainability.

The 2015 Long-term Energy Supply Demand Outlook set targets for Japan's future electricity mix, including a target for nuclear to provide 20-22% of power generation by 2030. However, the risk is whether a sufficient number of nuclear reactors will be on line by 2030 to meet that target. Due to long standing public concerns over nuclear power safety and local opposition to nuclear power plant operations, there have been only 5 reactors commissioned since 2000. After the triple disaster, public opinion turned less favorable to nuclear power and the uncertainty surrounding the restart of nuclear power plants complicated energy policymaking, leading to a four-year period lasting from March of 2011 to April of 2015 during which the government provided no firm guidance or targets for the electricity generation sector. Given the foregoing and in the absence of the ability to pass safety inspections, obtain life extensions, receive local approval for restarts or build new plants on a scheduled basis over the next couple of decades, there is a strong risk that nuclear infrastructure may be inadequate in meeting long-term electricity demand, energy security and GHG emissions goals.

By late 2015, the NRA had approved a limited number of plants for restart and nuclear power was slowly reassuming a role in Japan's electricity generation mix. Yet, the level and pace of restarts is still very uncertain. With nuclear power plants requiring at least 10 years to plan, build and commission, the energy system is vulnerable to delays and further uncertainty surrounding nuclear power. Much will depend on issues that lie outside of the government's direct control, including safety approvals, life extensions and local politics.

Gas infrastructure

Note: This issue is discussed in Chapter 4.1.

C.2 Resilience issues

As already discussed, Japan's energy system proved to be highly resilient over the 2000-2010 period. However a number of vulnerabilities were either exposed or exacerbated after the triple disaster, with consequences for resilience-oriented policies. These issues are explored in more depth in the following section.

Increased dependence on fossil fuels

Note: This issue is discussed in Chapter 4.1

Issues constraining renewables expansion

The Japanese government implemented a number of policies and programs designed to increase renewables generation in the period prior to the triple disaster. The *Residential PV System Dissemination Program* started in 1994 and provided subsidies for the purchase of residential PV systems. As a result, over 250,000 residential PV systems were installed between 1994 and 2005, increasing total cumulative solar PV capacity from 43.3 MW to 1,422 MW and enabling Japan to take an early global lead in PV installations and manufacturing [438]. However, with the cost per watt of solar PV having been drastically reduced and judging that the market had become self-sufficient, the Japanese government decided to terminate the program in 2005. This led to a decline in residential installations in FY 2007 and 2008 which prompted the government to reinitiate the program in 2009. Additionally, the government implemented *The Excess Electricity Purchasing Scheme for Photovoltaic Power* in 2009 that applied to both residential and non-residential installations. As a result, Japan's total installed capacity rose from 2.8GW in 2009 to 4.7GW by the end of June, 2012 when a new FIT scheme was introduced [137].

With the introduction of the RPS Law in 2003 (see Appendix A), Japan had targeted 12.2 Twh of renewable electricity generation[112] by public utilities by 2010.[113] In 2007 the target was increased to 16 Twh to be achieved by 2014. However, weaknesses in the design of the program were such that electric utilities were able to meet their obligations under the program even though actual production of renewable electricity fell short of the original targets.[114] Thus, total renewable electricity supply under the program[115] was just over 10 Twh in 2010 falling short of the target by about 2 Twh [439]. In addition, the structure of the RPS was such that it may have favored low-cost new energy sources (such as waste materials) over more higher-priced but more promising long-term options such as solar PV [440]. As a result,

[112] The RPS program applied to wind, solar, geothermal, small hydro (<1000kw) and biomass.

[113] It is important to note that Japanese government statistics do not capture the full extent of renewables generation in Japan. While renewables generation supplied by public utilities is reported, generation of electricity from private solar PV, small hydro and other renewables are not fully reflected in government statistics and so must be estimated. The ISEP statistics used in this study multiply installed capacity figures by an established utilization rate for each type of renewable source to obtain estimates of renewables generation.

[114] Since utilities could utilize banked credits under the RPS scheme, this provided incentives for them to reduce their annual investments in renewable energy in order to draw down their banked credits and/or to reduce electricity tariffs [31].

[115] These figures are from METI and based on facilities accredited by the RPS Law. Electricity generated before the RPS Law was enacted, electricity generated by facilities that are not accredited by the RPS Law, and electricity that is generated by facilities accredited by the RPS Law and consumed in-house are not included in this data [439].

the program failed to reach even the modest targets that were originally set at a time when increasing renewables production could have contributed to meeting climate change and energy security goals.

In July 2012, Japanese renewables policy received a major boost in the wake of the Triple Disaster with the establishment of the *Feed-in Tariff Act* that established a FIT system that was designed to encourage renewable energy deployment through subsidies that were among the highest in the world [441]. *Capacity additions in FY 2012 for solar PV, wind and other renewables under the program totaled 1.77 GW, although solar PV accounted for 95% of the total.* The new policy also shifted focus from the residential segment to the non-residential segment where potential for significant expansion is greatest. In FY 2013 about 77 percent of the PV capacity installed in that year was for non-residential utility-scale PV systems, whereas up to July 1, 2012 when the program started, about 84% of Japan's total installed PV capacity was for residential use [137]. The FIT scheme has helped Japan has regain the momentum lost in the mid-2000's with an increase of 76% in new investment (USD 23 billion) in solar PV, making Japan the top country in the world for investments in small-scale distributed renewables and the country with the fourth largest solar PV capacity in 2013 [167].

However, problems with the FIT program design and implementation have hampered the program's effectiveness. Despite the increase in utility-scale installations, many more projects were approved under the program than were built due to shortages of land, funds, grid access, qualified engineers and construction companies, and Japanese-brand equipment [167]. Also, concerns that the rapid increase in solar PV threatened grid stability Kyushu Electric Power decided to restrict access to their grid for all renewable energy projects (except residential solar under 10kW) in September, 2014 [442]. By October 2014, seven of Japan's 10 GEU's were restricting grid access for renewables and concerns were growing in Japan that high subsidies for solar PV could be adding to the rapidly increasing cost of electricity [443].

In response, METI called for public comments and compiled a report which led a revision of the *Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities* in January, 2015. The revisions reduced the amount of the FIT and also made provisions to prevent applicants from applying for renewables projects without a concrete business plan. Another change allows utilities to limit access of renewables generation without compensation to the operator based on priority given to base load power plants (including nuclear and thermal plants) [444]. While the lower FIT and application requirements are not likely to significantly impact on the expansion of renewables, the provision that allows utilities to deny grid access for renewables may be problematic. Those large-scale projects that have long-term contracts with the utilities are unlikely to be affected, however small-scale generators and large projects without a contract or PPA[116] that ensures grid access at an agreed price will likely find it difficult to secure financing or be profitable.

The type and level of renewables capacity that can realistically be increased in Japan is also somewhat limited by the availability of suitable sites and locations. For example, suitable locations for wind turbines are largely centered on the Tohoku, Hokkaido and Kyushu regions that are far from major population centers. Locations suitable for large hydro projects such as dams and reservoirs have already been largely exploited. Geothermal generation capacity has not grown at all since 2000 because many potential new sites are located in national parks or other areas where development is restricted or opposition from the hot spring industry is strong.[117] The expansion of solar PV has also been constrained to some extent by the availability of land for PV installations. In response, the government passed the "REAFF Law" in November, 2013, which is expected to expand the use of agricultural land for wind farms, and also for solar, biomass and other renewable energy projects [446].

Renewables expansion has also been held back by high costs, regulatory requirements, technical hurdles, available support programs or other factors. For example, small hydro facilities can have very high generation costs ranging between ¥15-¥100 per kilowatt-hour[118] [449], [450]. In the case of wind power, the availability of grid connections and environmental regulations have been cited as barriers to more rapid expansion [445]. Factors affecting the expansion of residential PV systems include the relatively smaller rooftop areas and higher prices for PV installations due to higher equipment, distribution and labor costs compared to some other countries [451]. Also the terms of the power purchase agreements under Japan's 2012 FIT program do not provide for so-called "take or pay" provisions that

---

116 PPA- Power Purchase Agreement

117 Recently however, regulatory restrictions have been eased, relationships with local hot springs have started to improve and surveys for new geothermal facilities have begun [445].

118 Small hydro is defined as facilities with generation capacity of 10MW or less. Most of Japan's small hydropower plants were built before 1990, and since then there has been only about 190 MW in capacity additions [445]. On the other hand, potential locations for new small hydro facilities was estimated by METI in 2008 to be around 1600 for a total potential capacity of 645 MW [447], [448].

ensure that the utility will purchase all the electricity that is generated, whether it is used or not. This creates financial disincentives for renewables installations [452].

In addition, electricity interchange connections are weak between the GEU-controlled regions which limits the ability to move power around the country to help balance the use of variable renewables. Wheeling tariffs are high which has also discouraged renewables expansion. Increased volumes of renewables in an electricity grid require methods to stabilize the grid through peak shaving, load balancing, frequency control, and reserve generation [453]. Many of these capabilities were limited or not used up to the time of the triple disaster.

In summary, up to the time of the triple disaster, several programs designed to significantly increase non-hydro renewables generation were implemented but with mixed results. Program design and administration issues, technical and regulatory hurdles and a lack of commitment from the GEU's combined to limit the expansion of renewables in Japan's electricity generation. Several studies have pointed to the resistance of the Japanese electric power utilities whose near-monopoly control over the power generation, transmission and distribution has frustrated growth for renewables and served as an impediment to change in the electricity sector [13], [454].

In the post-Fukushima period, efforts to enhance the use of renewables were significantly increased with the new FIT program of 2012 which was rapidly implemented in response to the shutdown of nuclear generating capacity and uncertainty surrounding the future of nuclear power. The government also began to view the enhancement of renewables as a potential economic driver and an opportunity to develop domestically produced technology [269]. As a result, capacity additions increased sharply especially for solar, while wind and other renewables capacity additions continued to lag.

The Long-term Energy Supply Demand Outlook of July 2015 set out targets for Japan's energy mix in 2030. Renewables are targeted to account for between 22-24% of total power generation by that date.

Demand-side management

As pointed out in the analysis in Chapter 4.2, Japan's energy efficiency policies have centered on energy efficiency standards for manufactured products. Yet, residential energy consumption has grown faster than consumption in the industrial sector. Industrial energy consumption grew only about 4.5% between 1990 and 2005 while residential/commercial consumption grew by over 30% [125]. While residential/commercial consumption declined slightly after 2005, its share in total energy consumption rose between 1990 and 2013, while the share of the industrial sector declined (see Figure C-1 below).

Figure C-1. Final energy consumption by sector

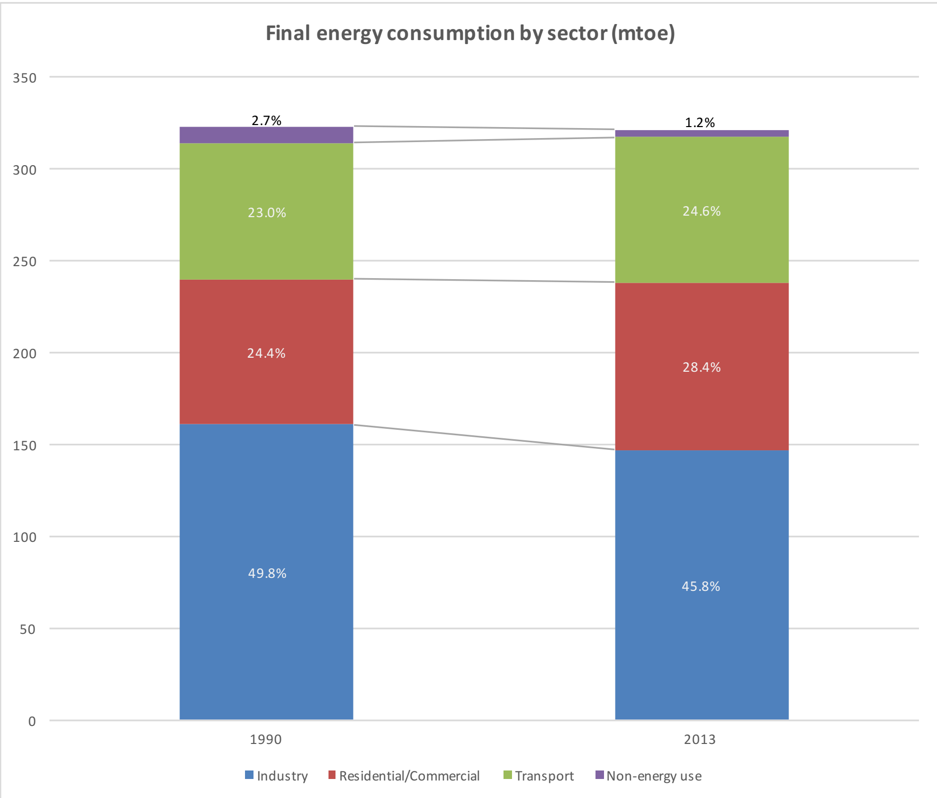
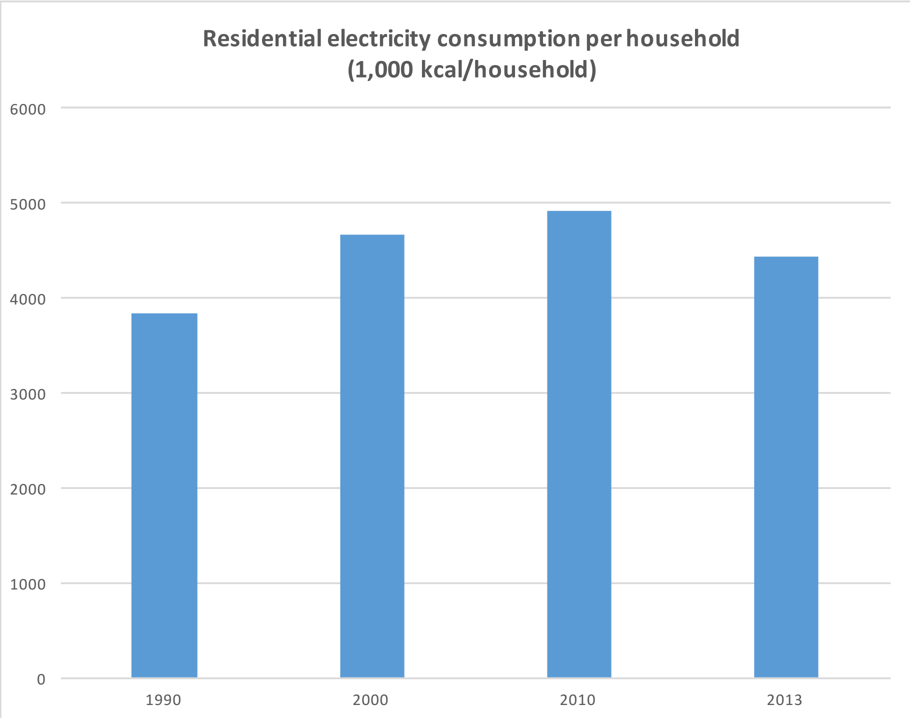


Figure C-2 below shows that household electricity consumption grew between 1990 and 2010, before falling in 2013 after the triple disaster. The recent decline is most likely due to ongoing voluntary conservation efforts rather than specific policies.

Figure C-2. Residential electricity consumption per household



This data demonstrates that there is significant opportunity for Japan to improve energy efficiency in the residential/commercial sector. Further dramatic improvements in industrial/manufacturing sector energy efficiency or in voluntary energy conservation are unlikely and so Japanese policy attention should turn to other demand-side strategies. One particularly promising area may be in demand response.

Up to the time of the triple disaster, Japan had been relatively slow to implement demand-side management technologies on a broad scale. Until 2010, smart meter diffusion in Japan was minimal, with their use confined mainly to large industrial users although they have been employed in Japan's Smart Community program. While smart meter deployment had already been started by U.S. and European utilities, Japan was lagging behind with only Kansai Electric (KEPCO) having begun demonstration projects [455]. The Japanese GEU's had been reluctant to install smart meters, the units were expensive and there were no uniform standards for their use [456].

The opportunities for demand response and related technologies can be illustrated by the pattern of electricity consumption in Japan, which is characterized by wide variations in both daily and seasonal demand. Figure C-3 shows the daily electricity demand curves for July – the summer peak demand period – since 1960 for TEPCO [457]. In 2010, daily peak demand was about 60GW and averaged about 55GW between 10am and 7pm in the evening. After the triple disaster, daily peak demand fell by 10GW to 50.8GW in 2012 and has remained at around 50GW through 2014 [458].The lowest demand occurs late at night and during the early morning hours with a wide variation of about 22GW between peak and low demand periods (2014).

Figure C-3. Daily load curves for July (for Tokyo area)

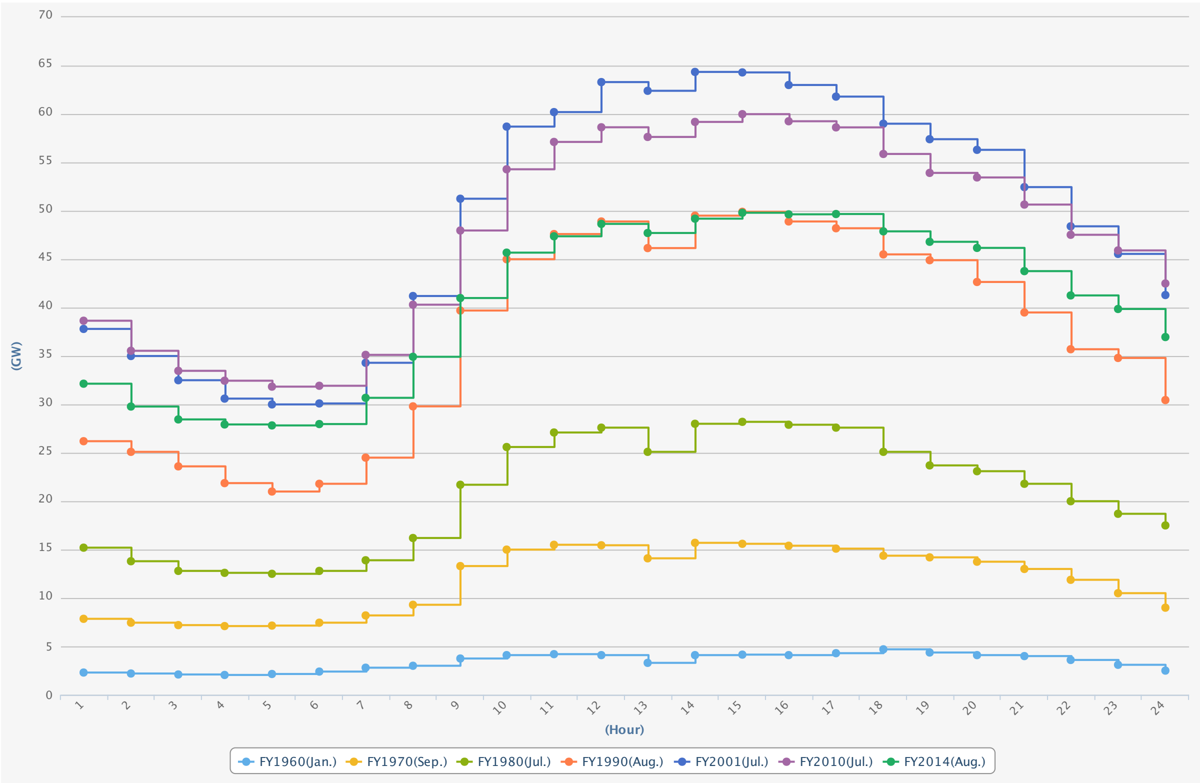
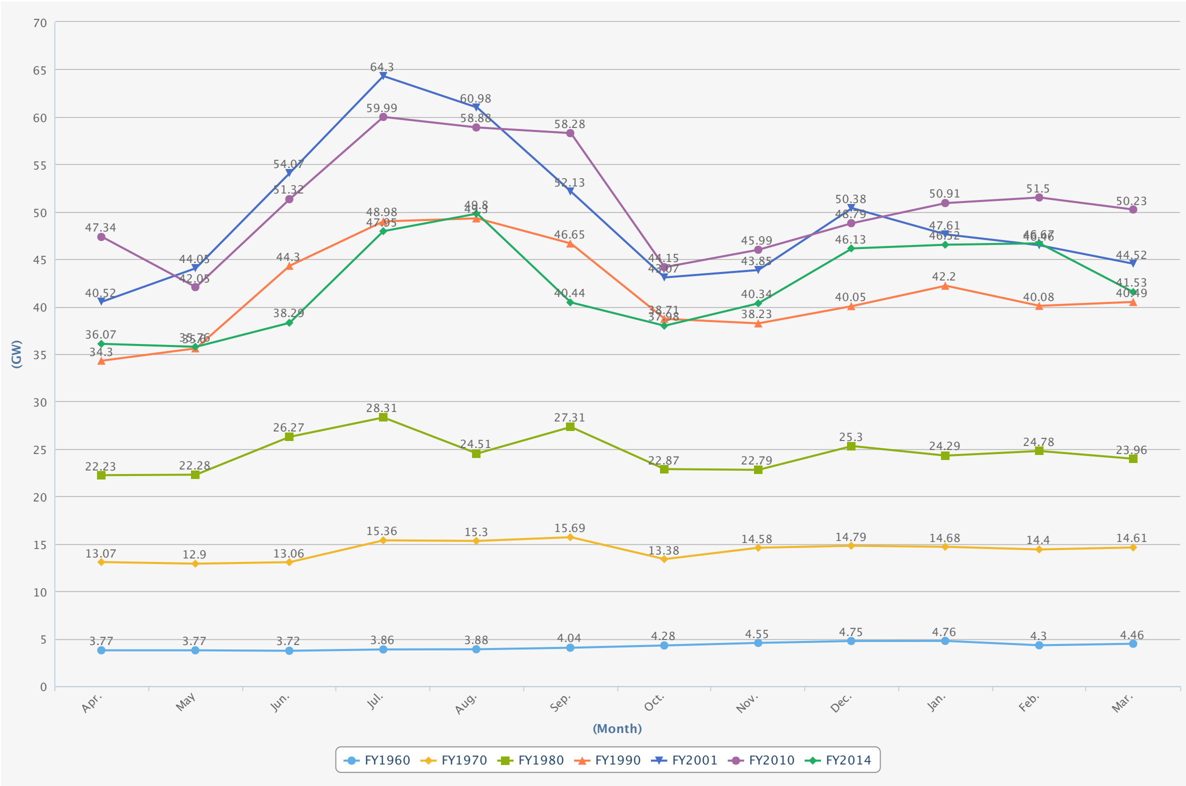


Figure C-4 describes the trend in peak electricity demand by month since 1960 for TEPCO [457]. In 2010, peak load reached about 60GW in July and remained near that level over the hot summer months. However after the triple disaster, the demand curve shifted down and by 2014 monthly demand was lower by an average of about 7GW compared to 2010. Load variation is the greatest between early spring and summer. The demand curve is noticeably flatter for 2014 compared with previous years.

Figure C-4. Monthly peak electricity demand (for Tokyo area)



In July 2011, the government instituted energy conservation measures which called for a 15% reduction in electricity usage for all energy consumers in order to reduce summer peak demand and avoid blackouts or other interruptions. Mandatory restrictions were made for large energy users during peak times in the Tohoku and TEPCO (Tokyo) service areas. As a result, power demand decreased, not only in 2011 but also in subsequent years as companies and households have voluntarily maintained reduced consumption levels.

The daily variation between peak and low demand has also been shrinking since 2012. However, other longer-term strategies will be needed other than voluntary energy conservation measures. There remains ample opportunity for demand response strategies based on "time of use" and other methods to shift demand and smooth out the load curve so as to reduce prices and make more efficient use of Japan's generation assets without placing undue pressure on Japanese consumers.

While demand response measures have yet to be exploited on a large scale in Japan, the government has made efforts to further address demand-side issues. For example, the disaster made clear that TEPCO had been unable to target its rolling blackouts because it had poor demand information from users [455]. In response, the roadmap for smart meter rollouts, standards setting and procurement issues were significantly clarified and accelerated. Commercial installations are expected to be completed by 2016, while installations for all residential and low-use customers will be completed 8 years earlier than originally planned in the case of TEPCO which will install 27 million meters by 2020. The last utility in Okinawa will finish by 2024 [459], [460]. As a result, Japan is expected to have one of the most advanced smart metering infrastructures in the world by 2020 [455].

In addition, METI announced a series of subsidy programs including support for HEMS, BEMS and MEMS installations as well as for large scale (10,000 unit) demonstration projects to improve demand-side efficiency and reduce peak power demand. In the case of HEMS, residential users could receive a subsidy of up to ¥100,000 or one third of the installation cost [461]. In June, 2014 METI reported that the HEMS subsidy program led to 90,000 HEMS installations by the time the program ended in September 2013, and 110,306 MEMS installations as of May 2014, mostly within existing buildings [455]. However, a subsidy program for BEMS installations in small to medium sized commercial buildings (which account for the largest portion of peak demand in urban areas) was less successful achieving less than 10% of the original target set in the program [455].

C.3 Adaptive capacity issues

Japan’s investments in enhancing energy system adaptive capacity over the 2000-2013 period have been impressive. In addition, the adaptability displayed by the energy system and the actors in it was exemplified by the rapid recovery and response to the events of the triple disaster.

However a number of vulnerabilities related to the adaptive capacity of Japan’s energy system were either exposed or exacerbated after the triple disaster. The implications for energy policies arising from these issues are explored in more depth in the following section.

Regulatory quality

While the results in the preceding section shows that Japan has maintained a high level of regulatory quality in comparison with its peers, it was also noted that this indicator is a general one and not specific to energy. In this section, regulation is discussed in the context of post-Fukushima energy policy.

Nuclear regulation

As noted in Appendix A.3, several investigations were conducted into the Fukushima disaster. Two of the most prominent were the *Nuclear Accident Independent Investigation Commission (NAIIC)* established by Diet whose mandate included making recommendations regarding the "re-examination of an optimal administrative organization" for nuclear safety regulation based on its investigation of the accident, and the *The Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company* which was established by Cabinet for the purpose of "making policy recommendations on measures to prevent the further expansion of damage caused by the accident and a recurrence of similar accidents in the future" [409], [410].

The published reports from these investigations concentrated on documenting regulatory failures and implicated nuclear regulators, exposed weaknesses in the regulatory system and recommended major changes.[119] The NAIIC report concluded that the causes of the accident were foreseeable and that TEPCO, the nuclear regulatory bodies including the NSC and NISA and the government ministry METI all failed to adequately develop and enforce safety requirements, did not maintain up to date advances in knowledge and technology and failed to take adequate preventative measures. The report also noted that a potential conflict of interest existed because while NISA was the agency in METI responsible for regulating the nuclear power industry, METI itself was also responsible for promoting of nuclear power. It noted that METI was guilty of "regulatory capture" since its officials lacked the necessary expertise to properly monitor and supervise nuclear safety. Furthermore the report accused the FEPC of using its influence with regulators to water down regulations affecting the industry [409].

The Cabinet-appointed Investigation Committee's report made seven recommendations that included improving safety measures, emergency preparedness, preventative measures

[119] Madarame Haruki, a former Chairman of the Nuclear Safety Commission testified in February 2012 at the Diet inquiry into the Fukushima accident that nuclear safety regulations were minimally enforced and fundamentally flawed, that regulatory capture was an issue and that regulators had little power and were often subsumed by utility interests [423].

(including comprehensive risk analysis), emergency response systems, damage prevention and mitigation, evacuation procedures and harmonization with international practices. Similar to the NAIIC report, it also called for an independent regulator, improved communications and information-sharing, and better regulatory staff training and personnel policies [410].

Prior to the establishment of the NRA, thirteen different organizations had been responsible for various nuclear regulatory activities in Japan [386]. Most of these were integrated into the NRA and lesson's learned from the accident were incorporated into a new, strengthened regulatory framework (see also Chapter 5.2). Soon after its establishment, the NRA announced that reviews of Japan's nuclear power plants would be undertaken and would consist of both a safety assessment of the plant, as well as a briefing of affected local governments by power plant operators. The assessment would be based on safety guidelines developed by the NRA in July 2013 after public consultations [254].

Shiroyama (2015) reviewed Japan's nuclear regulatory environment prior to Fukushima and also analyzed post-Fukushima regulatory policy responses. He points out that the Fukushima nuclear power plant accident revealed two key weaknesses in the nuclear safety regulatory system in Japan. The first was the inability to communicate and share up-to-date information on the risks posed by tsunami's and earthquakes, causing inaction and delays in incorporating these findings in regulatory guidance. The second was the failure to properly account for external events such as earthquakes and tsunami's in disaster management measures because regulatory policy relied heavily on voluntary efforts by plant operators. It was under these circumstances that Probabilistic Safety Assessments (PBA) were limited in scope to internal events and excluded external events [386].

With respect to Japan's post-Fukushima regulatory policy responses to the disaster, Shiroyama suggested that the establishment of the NRA may help solve some of these and other issues raised in the various investigation reports into the Fukushima disaster. Specifically, the independence of the NRA may serve to restore some degree of public confidence in nuclear power over time. In addition, the integration of regulatory activities (including safety, security and disaster management) under a single organization may help to improve information sharing, coordination, and communication among the various specialized areas of nuclear regulation. However, he also cautioned that institutional reform is not necessarily a panacea because many of the issues the regulator is dealing with go beyond the authority of the NRA, including the need to attract and develop skilled regulatory staff.

Other regulatory issues

Energy regulation in Japan has been centered at METI and specifically within ANRE. However, this can potentially create conflict of interest issues since other METI bureaux are responsible for industry promotion. This was most notably brought to the fore by the independent commissions that investigated the Fukushima accident and which recommended that an independent nuclear regulator (i.e.: the NRA) be established to avoid just such problems.

Other regulatory issues concerned the types of rules and reporting requirements that METI imposed on new entrants to electricity and gas markets and that frustrated their ability to compete with the incumbents. A new electricity and gas market regulator was established in 2015 (i.e.: ESMC) however it too is located within ANRE, although it has been positioned as independent from the rest of METI by making it a commission. Fairness, neutrality and transparency issues that existed up to 2013 in electricity and gas markets remain as issues to be fully dealt with.

Structural issues in electricity markets

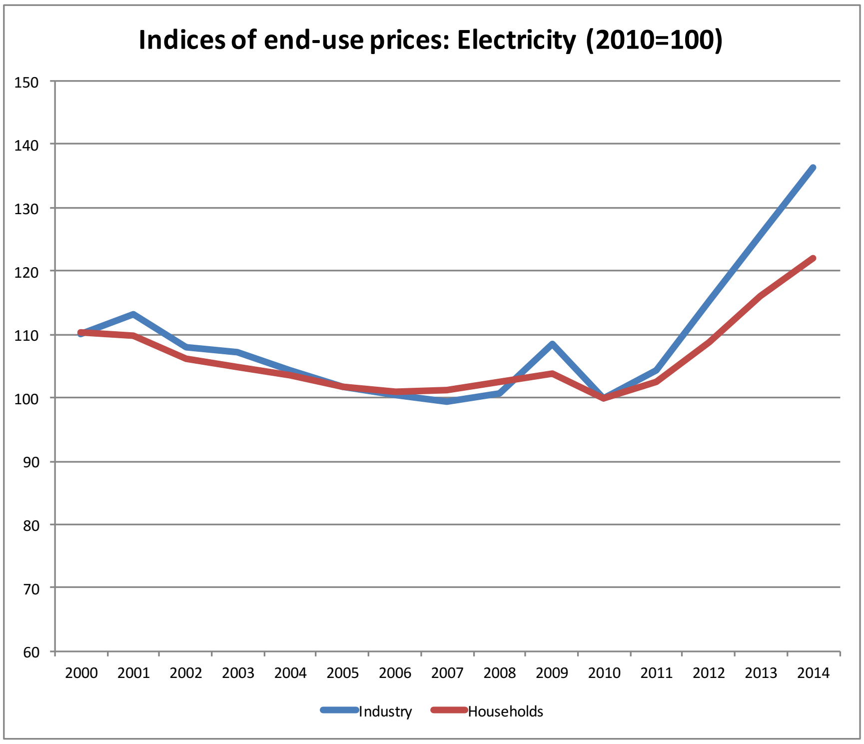
The indicators for the effectiveness of electricity market liberalization in the preceding analysis clearly demonstrate the low level of competition despite liberalization policies that began in 1995. The reasons for this can be attributed to a number of factors which are discussed below, drawing upon the IEA's country reports for Japan as well as independent studies.

Competition

In order to promote competition in electricity generation, the government instituted a bidding system to promote the entry of independent power producers (IPP's) in the wholesale generation sector in 1995. As a result, about 7000 MW of IPP capacity entered the wholesale market at prices that were significantly below the "upper limit" prices set by the utilities [139]. Household and industry electricity prices fell steadily in Japan between 2000 and 2006 (see Figure C-5) and this has been attributed largely to the increased competition from IPP's [161]. Other reasons included efficiency improvements in the power sector (mostly the result of fewer employees), lower cost of capital, and depreciation of generating assets [154].

Despite the fall in prices, competition was slow to develop. At the end of 2001, there were only 6 new IPP supplier entrants into the liberalized market, representing only about 0.46% of the liberalized segment and the share of power supplied by IPP's never exceeded 1% [139], [161]. In addition, there were two large wholesale power companies[120].

Figure C-5. Indices of electricity prices



Competition in the retail sector was introduced in three stages starting with large industrial end-users in 2000, and expanding to smaller scale factories and commercial operations in 2004 and 2005 (see Table 5). Despite these changes, the share supplied by non-utility power producers and suppliers (PPS) grew only marginally and shown in the previous analysis. Competition among the GEU's themselves also did not materialize and they did not sell power into each other's service areas. In 2006 when the deregulated segment represented 63% of total demand, end-users making up only 2.4% of this amount chose to switch to a PPS. In fact, the level of switching from GEU's to PPS declined after 2006 and almost all of those who did switch were high-demand customers in the industrial sector [154]. Consequently, discussion within the Electricity Industry Committee in 2007 recommended

120 J-Power (also known as Electric Power Development Corporation) and Japan Atomic Power Corporation

against proceeding with full retail competition (to include the household sector) as it was judged that even with liberalization measures taken to date there were still insufficient supplier options available to end-users [154].

PPS have also had difficulty in sourcing power supplies at competitive prices to sell to their customers because of the limited amount of power offered to the exchange by the GEU's [462]. JEPX was set up in 2003 in order to provide a spot market and forward market for electricity. However, power transactions on JEPX accounted for about 0.1% of total Japanese demand in 2005 and were still under 2% ten years later in 2015. Successful exchanges in other countries account for between 20% and 70% of total demand [154]. Exchange-based spot markets serve as an important reference price for long-term contracts. Yet almost all of Japan's power is contracted directly between the utilities and their customers and market rules have reinforced this practice. In addition, GEU's with high marginal costs have only been offering their most expensive thermal power (typically oil-fired), keeping their lowest-cost power (i.e.: nuclear) for themselves.[121] As a result, a transparent and liquid market for power has not yet developed in Japan with the consequence that volume is insufficient for PPS's to purchase, and prices are higher than they likely would be if most electricity was being traded on JEPX.

Regulatory issues

The Electric Power System Council of Japan (ESCJ) was set up in 2003 to oversee the functional separation between generation and transmission/distribution in the GEU's and to regulate third-party access to regional grids. Its members consisted of all the GEU's, wholesale utilities and PPS. However, as an independent body governed by its own members, its ability to ensure transparency and neutrality proved to be limited. GEU's retained control over access to their grids and could approve or deny connections for new generation. Thus the ability of new entrants, including renewables generation developers, to access the regional grids and maintain a profitable business continued to be limited by high wheeling tariffs and the power of the GEU's [154], [454]. The lack of effective deregulation is also partly responsible for restricting the expansion of renewables over the period. ANRE continued to regulate the sector up to 2015[122], but regulatory functions were not fully independent of the

121 Interview with MET officials.
122 The Electricity Market Surveillance Commission (ESMC) was established as an independent regulatory agency within METI in September 2015.

government and a potential conflict existed between METI's industry promotion role and its regulatory role.

Policy implications for the 2000 - 2013 period

The reasons for the continued lack of competition in the electricity market despite various liberalization measures taken over the period can be summarized as follows. Firstly, the goal of electricity liberalization in Japan was driven primarily by the desire to lower power prices. This was to be achieved by deregulation and promoting new entrants into both the wholesale power and retail services sectors. However, the number of new companies entering the wholesale were sector were few and the GEU's did not compete with each other outside of their own regional markets.

The approach to electricity reform over the 2000-2011 period can be characterized as incremental and lacking in commitment. The design of liberalization measures appears to have been built on a compromise between maintaining high reliability in the power grid – which for policymakers meant preserving the GEU's dominance – while at the same time trying to increase competitive pressures on the wholesale power supply side and more gradually on the retail side to try to bring prices down. Unlike in some other jurisdictions, no attempt was made to unbundle electricity generation from electricity retail services and with only weak separation between the generation and transmission/distribution side of the business, the GEU's could limit competition and retain market power. Market rules to ensure transparency, fairness and neutrality were insufficient or poorly enforced.

Factors limiting the ability of new entrants in the wholesale power generation sector included the cost of new generation facilities, the ability to secure suitable power plant sites, the time and cost required to secure environmental approvals, and competition from the GEU's which were able to exert market power (through their influence over prices and wheeling tariffs) to keep new entrants from making significant inroads. The combination of these factors made it difficult for new entrants to compete on a level playing field with the GEU's.

In its review of Japanese energy policies in 2008, the IEA recommended that fair and transparent mechanisms for balancing power and eliminating anti-competitive behavior be instituted. It also recommended better integrating the Japanese grid by allocating generation capacity on a national basis and setting up a national transmission operator, improving regulatory frameworks to make wheeling tariffs fair and transparent and further steps to improve market surveillance and improve price discovery in a transparent manner [154]. However, few of these reforms were introduced up to the time of the triple disaster.

Electricity reform measures since the Fukushima disaster

As noted in Appendix A.5, a number of significant reforms introduced after the triple disaster are designed to address some of the issues mentioned in this section. Perhaps somewhat belatedly, a new national transmission system operator was finally established (OCCTO) in 2015, wholesale and retail markets are to be fully liberalized in 2016, regulated tariffs are to be abolished and transmission/distribution businesses will be legally unbundled from the GEU's but will remain as regional monopolies by 2020 [415].

Liberalization implies that the timing and adequacy of infrastructure investments will increasingly be market-based, and less dependent on signals from the government. If this is the case, measures to ensure capacity will be required. Although the government has made retailers legally obligated to ensure adequate capacity to match their demand requirements, some aspects of ensuring long-term system adequacy remain to be clarified [463]. The inadequacies in power exchange capacity, frequency conversion, and national load balancing also have significant implications for future grid management and liberalization policies and will continue to challenge policymakers going forward.

Structural issues in gas markets

The indicators of gas market liberalization in the analysis demonstrate that as liberalization measures were expanded over the period and overall sales rose in the gas market, the share of the market gained by new entrants rose from near zero in 2000 to represent about 11% of total sales in 2011. The share of the incumbent utilities therefore remained nearly 90%.

Competition

As a result of liberalization, there were 11 new entrants into the gas business in 2003, including TEPCO, Nippon Steel and others. The total share of new entrants amounted to about 2% of total gas supplies in the deregulated segment in 2003. Liberalization resulted in a reduction of prices from some individual suppliers at the time but overall natural gas prices remained fairly stable from 2000 - 2010. By 2005, there were only 15 new entrants, including oil companies, electric power companies and trading firms. The low number of new entrants can be attributed to the fact that they must either have access to existing LNG facilities or construct their own facilities. This is because the incumbent electricity and gas utilities purchase LNG on long-term "take or pay" contracts to meet their own needs and were therefore unlikely to participate in the trading or wholesale market of gas [464]. Thus, even with mandatory third-party access new entrants could not contract with existing LNG suppliers because the supply of LNG in Japan is limited. As a result, only a few companies who could obtain their own sources of gas could enter the market [238].

The impact of liberalization measures can also be assessed by looking at the price trend of natural gas for industry and households in Japan (see Figure C-6). Real prices in Japan were flat between 2000 and 2006, before beginning to rise steeply in 2010. Japan has had historically high prices for natural gas and this can be partially accounted for by the cost of gas in Asia (the so-called "Asian premium" paid on long-term contracts), high shipping costs for imports and the high cost of pipeline infrastructure in Japan. Prices in Japan were higher than in other OECD (PPP basis) countries by a wide margin throughout the period under study (see Figure C-7).

Figure C-6. Indices of real natural gas prices

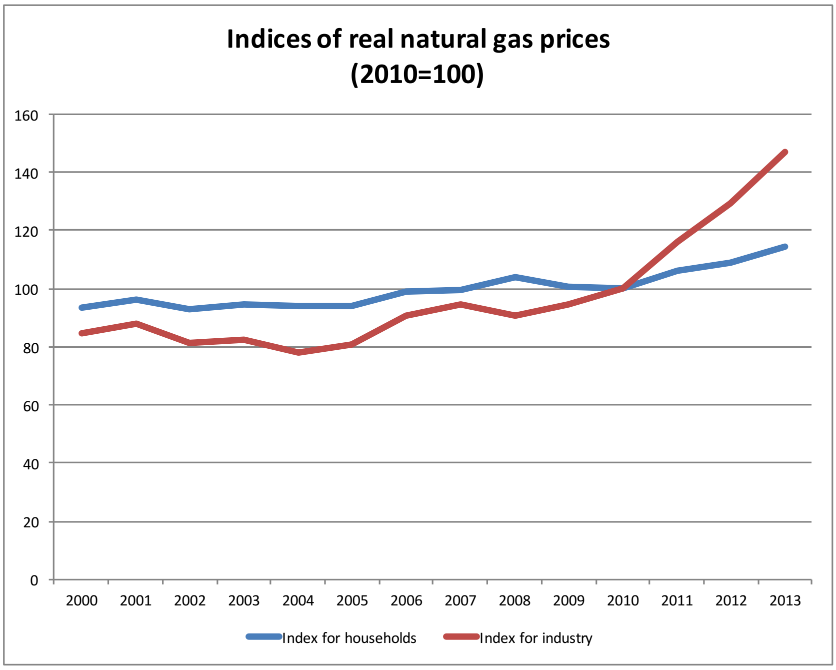
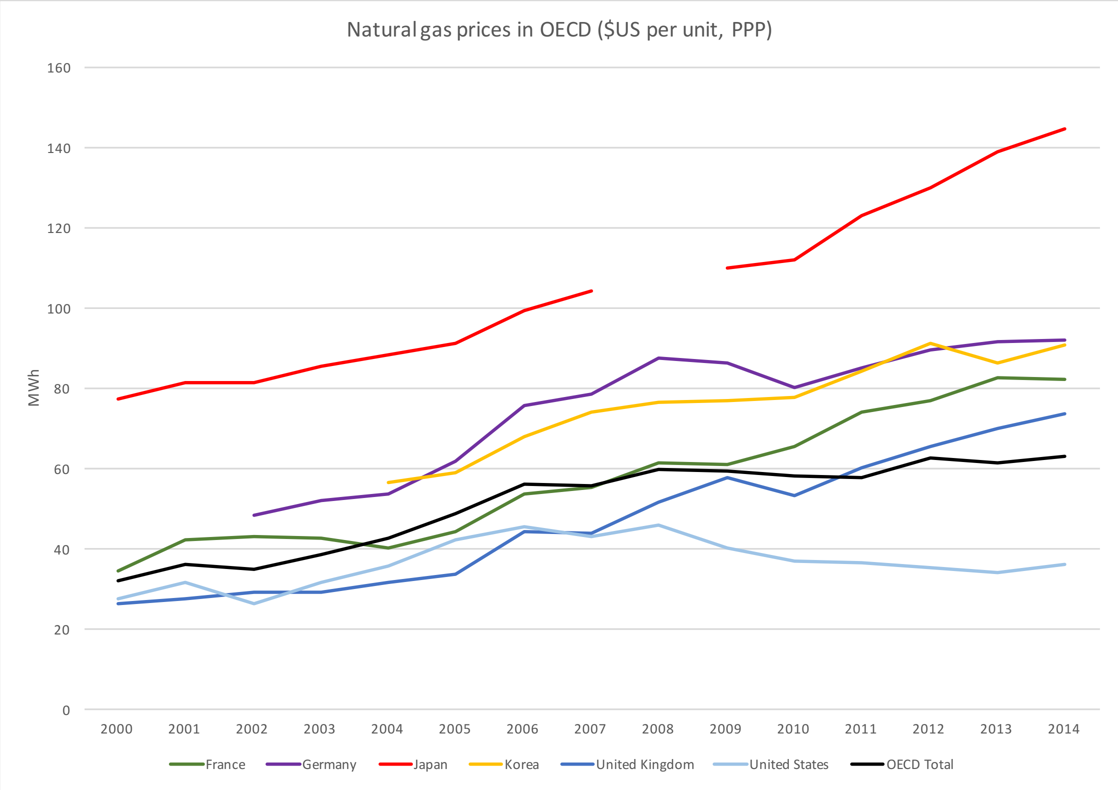


Figure C-7. Household natural gas prices in the OECD



Regulatory issues

In its 2003 and 2008 reviews, the IEA noted a number of concerns with regard to the regulatory framework governing gas markets. In particular, it noted METI rules that required market players to get advance permission before acquiring customers in the service areas of incumbent utilities. Other rules could be applied retroactively to prevent new entrants from carrying forward their supply plans. METI rules often acted to impede competition rather than encourage it and created uncertainty in gas markets that discouraged new entrants. In both 2003 and 2008, the IEA's comments suggested that insufficient competition had developed in Japan's gas markets despite the various measures taken [139], [154].

In an evaluation of institutional reforms in 2009, METI itself acknowledged that the number of new entrants in the gas sector was insufficient and that gas prices remained too high relative to overseas prices [236]. Furthermore, METI stated that it desired more intense competition from among city gas suppliers and between gas and other sources of energy and committed to reviewing the gas rate system and wheeling tariffs for gas transmission.

Policy implications for the 2000 - 2013 period

Similar to electricity reforms, METI took a very gradual, staged approach to gas market reforms and appeared to lack commitment to developing a truly competitive market. It is probably fair to say that METI was very cautious about gas market reforms given its desire to preserve energy market stability, realizing that most gas utilities are small locally owned operations that could be put in jeopardy by competition from larger new entrants. It is also likely that the incumbent utilities, as in the case with electricity, exerted influence with the government to try to delay or weaken reforms so as to protect their position in the market.

Gas market reform measures since the Fukushima disaster

As noted in Appendix A.6, a number of reforms introduced after the triple disaster are designed to address some of the issues mentioned in this section. In particular, the government announced it would "drastically reform" the regulatory framework for the electricity, gas and heat supply businesses in March 2015 [237]. The *Gas Business Act* was amended to implement full retail competition in the gas market by 2017. It also provided for legal unbundling of the gas pipeline service sector by 2022. Market entry will no longer be controlled by METI, business license requirements will be relaxed and third-party access will be granted to LNG terminals. In addition, a new regulator for electricity and gas market surveillance was established that will assume regulatory authority over the gas business starting in sometime in 2016.

Decline in public support for nuclear power

It is notable that broader public engagement did not appear as an explicit strategy in the strategic energy plans up to the 2010 version, although gaining "public understanding" for energy policies is briefly mentioned in the 2010 version. The 2014 SEP includes for the first time a comprehensive approach to "communications with all levels of society" which includes public relations, information dissemination, energy education and “two-way” communications between government and the public on energy issues [465].

The Japanese government and electricity utilities have extensively consulted with and provided financial and other support to local communities where nuclear facilities are located for several decades. Yet, the evidence from attitudinal studies, polling and court cases regarding nuclear power in Japan clearly show a trend of increasing resistance to and lack of support for nuclear power amongst the public and local communities. While some local governments support nuclear power because of the jobs and government subsidies provided to their communities, there is strong opposition in other communities. Recent court judgements have delayed the restart of some reactors and shutdown others even after they had passed inspections and were approved by the NRA [466]. In several cases, plans to restart reactors have been undermined by local opposition [467].

In summary, the trend in public attitudes toward nuclear power appears to indicate that engagement on nuclear energy issues with the public and stakeholders has been insufficient. Whether or not such attitudes are based on a rational and balanced view of the facts concerning nuclear power is certainly an issue for the government to consider, however the lack of support also creates risks to nuclear energy policy as demonstrated in the court cases that have delayed or shut down nuclear power plants. This situation adds uncertainty to the future of nuclear power and negatively impacts energy system adaptability and long-term energy security by undermining the ability to implement energy policies and achieve long-term goals (e.g.: energy mix targets).

Appendix D: Japan's embedded institutions (Level 1)

Among the three levels of institution pointed out in Chapter 5.2.2, the highest level is composed of societal traditions, customs, norms and beliefs. These cultural factors shape and influence institutions at the next level down. This section examines some of the key cultural factors and characteristics of Japanese society that have particular relevance to institutions, their evolution and the interactions amongst actors in the system. While certain generalizations are made about Japanese society based on its unique history and cultural development, it is recognized that society encompasses a variety of behaviors. While Japanese society is shaped and constrained by various social norms and values, these same norms and values have been gradually changing and evolving as a result of a range of factors including economic growth, changes in social mores, the impact of the internet and social media, internationalization, tourism, and other influences.

The following series of well-recognized propositions or generalizations about Japanese society are adapted from Stockwin [336], Hendry [468] and others and have been drawn from the broader scholarship on Japanese culture and society. These propositions are relevant for our purpose of identifying key underlying influences on Japan's institutions.

Group orientation

A strong sense of identification with the group characterizes Japanese society. Identification with and loyalty to the group can be contrasted with the Western emphasis on individualism and individual rights. Identification with the group can be traced to the concept of the "ie". The term "ie" in Japanese can best be translated as "house", as in the "House of Windsor" or the "House of Mitsui". This does not necessarily imply a physical structure nor a family unit as typically understood in Western terms; the ie concept has been used to explain group behavior in terms of a continuity of relationships. [468].

The ie concept is linked to the distinction between *soto* (outside) and *uchi* (inside). This distinction is analogous with the movement from inside the house where members may openly express their true feelings (*honne*) with each other, and outside the house where a public face (*tatemae*) is put on relations with others who are not part of the group. However this norm is not clear cut as group members may also have close relationships outside of their house, including as members of other groups such as relatives, neighbors, classmates, club members, and so on. The soto/uchi analogy can be extended to different scales, from the household to communities, companies, industry sectors and even Japan's relations with the outside world. In the latter case, the whole of Japanese society would be considered as uchi while other countries are soto (literally, outsiders).

The needs of the house or group are put before the needs of the individual members and this same principle can be applied to other areas of society, including company, university or other group affiliations. For example, it has often been observed that the Japanese company has taken over the role traditionally assigned to the ie, where company members view themselves in a way similar to members of an ie [468]. Thus *uchi* is used to describe one's own company, school or group affiliation and the *uchi/soto* distinction mentioned above underlies principles of relative ranking, including within and between different social groups [468].

Juxtaposed with these broader generalizations about group orientation is the more recent tendency to place a higher value on developing one's own individuality in Japanese society. In this vein, the term *kosei* represents praise for someone who displays original and interesting individual qualities. This suggests that values that emphasize traditional group membership and behavior are changing and that pursuits that distinguish individuals in positive ways are more becoming more highly valued. Examples include new ways of contributing to society through volunteerism, charitable activities, advocacy groups, a wide variety of hobbies and pastimes, and participation non-traditional civil society organizations such as NPO's.

Hierarchical social relations

In Japanese history, there have been clear status distinctions as far back as the Kofun or tomb period, in the 3rd to 6th centuries. In the seventh century, Chinese culture exerted a strong influence on Japan bringing the Chinese written script (kanji), art, Buddhism and Confucian ideals, principles and political/bureaucratic forms. These new influences had a profound impact on Japanese culture and served to reinforce hierarchical structures that were already in place, although Confucian and other influences were modified and adapted to accord with Japanese sensibilities.

While acquired status has been important throughout Japanese history, it has also been possible to achieve status through individual or cooperative behavior. In the Edo period – the two-hundred years immediately preceding the Meiji Restoration – Japanese society was divided into flour distinct classes with samurai at the top, followed by farmers, artisans and merchants, in that order. Everyone largely remained in their own class, however some individuals and families were able to cross these rigid barriers. Although the system was abolished in the Meiji Period, influences of class distinction remain and are often based on position or rank within an organization or group (e.g.: president, professor), the status of an organization itself (such as a top ranked company or university), age and seniority, and so on. In her seminal book, Nakane -, [469] pointed out that just as *ie* are ranked within a community, companies and other organizations such as government ministries or universities are assigned positions in a hierarchy and their members share in the status assigned their company by society. Accordingly, top ranked universities supply top ranked companies and government ministries with their graduates.

In general, Japanese find relationships that are based on strict personal equality difficult to manage. Japanese hierarchical relationships are often relative to the situation at hand and therefore different rules take precedence in different situations. A good example is in seating arrangements at formal meetings where guests (outsiders) are seated at higher status positions than their hosts (insiders) in order to show deference to their guests. Also, Japanese language contains different forms of expression such as keigo (respect language) which are used depending on the hierarchical relationship of the conversants, although contemporary usage of these forms is just as often a sign of courtesy and politeness than an indicator of status. It is important to state that despite the generalizations made here, any particular Japanese may be involved in any number of relationships in different situations and contexts, and that differences in status may govern some situations while merit, power or other qualities may govern others.

In contrast to these traditional hierarchical distinctions, the notion that Japan is a society that believes in fairness and equality has grown in recent years. Although differences between income levels and wealth have widened over the past couple of decades, the country is still relatively egalitarian in this regard when compared with other countries. Ostentatious displays of wealth are frowned upon and although pockets of poverty certainly exist, it is not currently a widespread societal problem.

Mutual obligation and human relations

The hierarchical principle highlights the importance of human relations and the sense of mutual obligation. Advancement within societal structures is dependent on being loyal to superiors and being cooperative and harmonious in their relations with others. There are certain expectations and obligations inherent in the relationships between people that must be respected. For example, “inferiors” are expected to defer to “superiors” when they differ, but superiors are also expected to consult with their inferiors and take their feelings into consideration. Reciprocity is also important, particularly in long-term relations; assistance or help with something creates an obligation to return the favor, either in material or intangible (e.g.: loyalty) terms. These relationships of mutual obligation and affection therefore serve as both a motivating and a binding mechanism. The failure to fulfill the expectations inherent in these relationships would result in “loss of face” since self-interest must be subordinated to the value of the relationship itself and the feelings of affection generated within it. The author’s own experience working for a Japanese company included instances where established domestic suppliers of a product were given preference over much less costly foreign sourced products of the same or better quality. The company had a long-established relationship of trust with the domestic supplier which it would not jeopardize simply for the sake of a marginal increase in profit.

Harmony and consensus decision-making

Harmony (or *wa*) is an important principle that dates back to Prince Shotoku in the 6th century who esteemed harmony over everything else. The term is somewhat different than the English meaning and connotes a unique Japanese sense of concord where absolutes are avoided and distinctions/differences are not made. This principle would seem to apply in the case of the Japanese courts where accountability is apportioned, the application of universalistic principles is avoided and judgements that reflect compromises between both parties are sought.

Harmony is also achieved through cooperation and consensus-making. For example, in the political sphere Japan’s parliament operates by majority vote but contentious decisions are often preceded by a lot of hard bargaining and consensus-building with key opposition parties. The formal vote is often an endorsement of a compromise that has already been reached behind the scenes. Consensus decision making in Japan ideally involves give and take and the adjustment of initial positions in order to reach a decision that all parties can claim to have been a part of and where harmony has been preserved.

Passive acceptance of authority

Japanese generally tend to accept the decisions of government and its agencies without resistance, avoiding overt criticism. Whereas Western democratic ideals promote the idea that citizens have the right and the duty to criticize government and make it accountable, the Japanese tend to view government as existing by right and that its decisions will by almost by definition be in the people's interest. Even when government does not appear to act in the interest of citizens, many Japanese often tend to react with a sense of resignation rather than protest and feel that there isn't much they can do about it in any case. This is not to say that Japanese citizens do not care or are apathetic, only that they seem to prefer leaving elected officials and bureaucrats with the responsibility of governing, and value harmony in broader society over particularistic concerns.

At the same time, Japanese hold ambivalent attitudes towards politicians and generally hold them in low esteem. Some citizens may support radical views (either left or right) more as a sort of protest than a genuine desire to elect parties advocating those views. The electorate is generally reluctant to jeopardize political stability which they highly value, and as a result incumbent politicians are usually re-elected into office.

Security and stability

Japan has been described as a conservative society, although not all Japanese are conservative and considerable variation in political and social attitudes exist. The desire for security and stability does however seem to be particularly important to Japanese. About 73 percent of Japanese describe themselves as risk-averse[123] and even the Prime Minister of Japan described Japanese business people as being risk-averse, adding that it stifled innovation [470]. Japanese society tends to favor well-established companies and firms in the same field are informally ranked in order of prestige. Talented new university graduates tend to gravitate toward the top firms rather than toward more risky entrepreneurial ventures.

[123] According to a 2008 study of 51 countries by Stockholm-based World Values Survey.

The preponderance of conservative attitudes is also reflected in the strength of the Liberal Democratic Party which has been repeatedly elected and has governed Japan for 56 out of the last 60 years. This has been attributed by some observers to the popularity of its moderate and conservative position on key political, economic and social issues. Attitudes to war and the exercise of force reflect a very cautious attitude among Japanese who still strongly support the peace clause in the constitution, while at the same time expressing strong support for the Self-Defense Forces in light of perceived threats from North Korea and China.

Japanese seem to have a deep sense of insecurity about the nation's long-term viability, viewing their country as extremely vulnerable to a wide range of potential threats. This concern with safety and security may have roots in Japan's vulnerability to and experiences with a wide variety of natural disasters including earthquakes, fires and typhoons throughout its history. In the Meiji period, fears of Western aggression or colonization helped fuel the rapid transformation of Japanese society and the economy. Government is seen as the principle guarantor of its citizen's safety. Disaster response drills (such as for earthquakes) are commonly exercised across the country and many companies, especially manufacturing and construction companies, place a strong emphasis on promoting safety in their companies.

Strong sense of "nation"

Japanese have a strong sense of identity and pride as Japanese. They also have a strong sense of nation, although they are not "nationalistic". Japan has not participated in any wars or aggressive actions since World War II and the so-called "peace constitution" prohibits military action except in the case of self-defense.

Contemporary social discourse in Japan today is varied and reflects a wide range of differing political, economic and social views and topics. Internationalization has made headway as Japanese have become increasingly exposed to the values, ideas and products from abroad either through tourism, the internet or through exposure to foreigners who visit Japan or who live and work in virtually all of Japan's major cities. Foreign-owned companies have expanded their presence in Japan and many Japanese, especially those with foreign language skills and experience, are employed by them. Despite this exposure to international influences and the relative success of Japanese businesses abroad, the Japanese have managed to retain their strong sense of uniqueness and identity and have been circumspect in adopting values, perspectives and approaches from abroad.

Summary

To summarize the embedded institutions in Japan as reflected in the perspectives and propositions detailed above, Japanese society can be characterized as strongly group oriented and highly structured so as to maintain stability and predictability. More generally, it can be characterized by outward harmony, consensus-based decision making, personal relationships, hierarchical social relations, deference to authority, and a strong sense of fairness and equality.

It is important to point out that societies evolve and change and Japan is no exception. While Japan's values, norms, and customs have not changed dramatically over the past 15-20 years, they continue to evolve beyond their historical roots. While these changes have made Japan appear to have been "westernized" in a superficial sense, at its root the country retains a strong sense of identity and uniqueness and this attitude carries over into the way other types of institution are designed and operate. These institutions are the subject of Chapter 5.2.