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Title Page

Title: **The role of the state in sustainable energy transitions: A case study of large smart grid demonstration projects in Japan**

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A case study of large smart grid demonstration projects in Japan

Abstract

Smart grids represent one of the most significant evolutionary changes in energy management systems as they enable decentralised energy systems, the use of large-scale renewable energy as well as major improvements in demand-side-management. Japan is one of the pioneers in smart grid deployment. The Japanese model is characterised by a government-led, community-oriented, and business-driven approach with the launch of four large-scale smart-community demonstration projects. Our case study of large smart grid demonstration projects in Japan found that the Japanese government has demonstrated its high governing capacity in terms of leadership, recombinative capacity, institutional capacity, enabling capacity, and inducement capacity. However, the major limitations of the government in introducing some critical regulatory changes have constrained the smart grid deployment from advancing to a higher-order form of smart grid developments. This paper calls for more attention to be given to the importance of regulatory changes that are essential to overcome the technological lock-in, and the complementary roles of non-state actors such as the business sector and consumers to strengthen the governing capacity of the state.

Key words: smart grids, Japan, state

1. INTRODUCTION

Climate change impacts, rising energy costs, and renewed concerns over nuclear risks after Fukushima have heightened the urgency for a transition to a low-carbon future. Smart grids represent one of the most significant evolutionary changes in energy management systems. Through applying information technology to existing electric distribution networks, smart grids provide opportunities to integrate more decentralised supply systems (e.g. renewable energy) and allow consumers to take more proactive roles in demand-side-management (Verbong et al., 2013). Such grids are increasingly being adopted and implemented in developed and developing economies (e.g. EU, the US, South Korea, Japan, and China) (World Energy Council, 2012).

Smart grids have adopted different development pathways across the world (Verbong et al., 2013). For example, despite of some pockets of successes in, for example, Texas in the US and Ontario in Canada where millions of households have installed smart meters (Faruqui et al., 2011), smart grids in many other places have been mostly limited to demonstration projects and have not achieved market diffusion. Despite these differences, a common strategy is the emphasis on the use of pilots and demonstration projects. The four large-scale smart community demonstration projects in Japan, the smart grid testbed on Jeju Island in South Korea, and a large number of dynamic pricing pilots in the US are some examples of this global trend (Faruqui and Palmer, 2011; Ling et al., 2012; Mah et al., 2012b).

This paper presents a case study of the four major smart community demonstration projects in Japan. Our analysis focuses on the role of government in the process of smart grid diffusion in

Japan. We examine, evaluate and explain the mechanisms, achievements and limitations relating to the role of government in smart grid diffusion.

Japan is a major hi-tech, industrialised country. It merits study because its government-led, community-based and business-driven approach to developing smart grids appears to differ from development pathways in other Western and Asian countries such as the US, South Korea and China. The establishment of the four large-scale smart grid community demonstration projects in four cities - Kyoto, Yokohama, Kitakyushu and Toyota – which involves more than 5,000 households is a notable characteristics of the Japanese approach to smart grid developments. The post-Fukushima energy policies as well as unique developments of smart grids in Japan can provide useful data for analysis.

This project adopts a qualitative methdology to derive rich data for ascertaining the interrelationships between the government and other stakeholders, and the impacts of these relationships on smart grid deployment in Japan (Yin, 2003; Miles and Huberman, 1994). The qualitative methodology involves desk-top research, field observations and in-depth interviews with key stakeholder groups. We conducted fieldwork in May 2012 in Tokyo and three of the four localities where the demonstration projects are located, namely Kyoto, Yokohama and Kitakyushu. Eight face-to-face interviews were conducted with respondents from major stakeholder groups in Japan including the government, business, academics and NGOs. All of the face-to-face interviews were audio-recorded and transcribed. A list of the interviewees is provided in Appendix 1.

This paper is organised as follows: Section 2 discusses theoretical perspectives and provides a framework for our analysis. Section 3 provides an overview of the development of smart grids in Japan. It highlights some key contextual factors, and the features of the four large smart community demonstration projects. Section 4 examines and characterises the role of government. Section 5 critically assesses the achievements as well as the limits of state involvement, and the role of non-state actors particularly the business sector and electricity consumers. The final section offers some concluding thoughts.

2. SMART GRIDS FROM A THEORETICAL PERSPECTIVE: LARGE DEMONSTRATION PROJECTS, THE ROLE OF THE STATE AND GOVERNING SUSTAINABILITY TRANSITIONS

To develop our analysis of smart grid developments in Japan, we examine social science theories in the areas of technological innovation and energy governance. One of the major challenges in the development of emerging technologies such as smart grids, renewable energy, and electric vehicles is mainstreaming: moving from demonstration projects to larger scale diffusion (Egmonda et al., 2006; Hellsmark and Jacobsson, 2012) - a stage in technological innovation processes which has been identified by some scholars as the “valley of death” (Norberg-Bohm, 2000). 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 (see for example Berkhout et al., 2010; Hendry et al., 2010). Large-scale demonstration projects, which may take various forms including field trials, government-funded pilot projects and sustainability experiments (Berkhout et al., 2010), represent an important new source of innovation and capability-formation which are required to overcome the “valley of death”. These demonstration projects may provide a process through which socio-technical learning can take place and new networks can be formed. They can also offer a protected space for emerging technologies to better manage cost reduction, technology innovation and market competition before they can become commercially viable and compete with established technologies (Berkhout et al., 2010; Norberg-Bohm, 2000).

Work on technological innovation has conceptualised this transition process – from development (technologies at the prototype and demonstration stage) to niche markets and to mass market - in different ways (The Danish Government, 2011). The work by Hendry et al. (2010), for example, has identified three structural steps for firms to get to market via demonstration projects: validate an application for a particular market, cultivate partners, and use discounts and incentives to encourage ordinary customers to participate – to create satisfied customers and “product champions”.

In the context of smart grid technologies, the Department of Energy (DoE) in the US has based on a number of funded research projects (Litos Strategic Communication, 2008; SEI, 2009, 2011) and published a smart grid maturity model. This model provides a framework for smart grid transformation by conceptualising the transformation process into five stages. These are: initiating, investing, integrating, optimising and innovating. This model contributes to the literature on smart grid in two major ways. Firstly, it provides a framework for examining and evaluating the current state of smart grid deployment as well as developing future strategies (SEI, 2011). Secondly, it sheds light on the non-technical elements, in particularly the business and societal ones, in smart grid development. It highlights the importance of the business cases, environmental and societal benefits in the higher levels of the smart grid maturity model. This model suggests that in order to move away from the lower levels which feature the existence of visioning and strategies, new business models must be in place so that not only operational benefits but also environmental and societal benefits can be realised.

Another theme of the literature which is useful to our analysis is the literature on energy governance. Governance is a purposive guiding process in which a social system coordinates, steers and manages itself (Paquet, 1999). The design and operation of smart grids are fundamentally different from conventional systems which are centralised, fossil-fuel based (Mah et al., 2012a). Important features of smart grids – including the emergence of new two-way utility-consumer relationships, new actors (e.g. independent power producers) and new business models in more decentralised energy systems (Devine-Wright, 2007; Parag and Darby, 2009) – present major governing challenges in the transition process of the energy socio-technical system. These governing challenges are associated with path dependence, monopoly power, resistance to pricing reforms, and behavioural inertia (Mah et al., 2012a).

A major part of understanding the governing processes is the focus on the role of the state in the literature of governance. The state is broadly understood as the executive, legislative, and judicial apparatus of the nation (Hall, 1993). The literature has argued that states assume a central role for technological and industrial innovation (Evans, 1995; Jänicke, 2005). Due to externalities of emissions and the existence of monopoly power and inertia (Goldthau et al., 2010;

Norberg-Bohm, 2000; Zhao et al., 2012), the government has two major functions: firstly, to introduce policies that facilitate structural changes by overcoming information, coordination and externality issues; and secondly, to introduce policies that aim at protecting some selected firms and industries (Lin and Monga, 2010). Bulkeley and Kern (2006), on the other hand, introduce an important distinction between four types of governing modes through which governments may govern: self-governing, governing by authority, governing by provision and governing through enabling.

The literature has specified the roles of governments for governing. Hammer (2008), for example, in his study on renewable policies in New York and London, specifies six key roles of government. These include direct service delivery, regulator, buyer, landowner or developer, safeguarder of public health and environmental protection, and advocator/ educator. Among all these important roles of government, the regulatory ones are particularly relevant to smart grid policies. Regulatory changes which may introduce new tariff systems and liberalise electricity market are perceived as critical to facilitate the large-scale deployment of smart grids (Cossent et al., 2009; Eurelectric, 2011; Mah et al., 2012b). A balanced regulatory framework that provides long-term incentives for efficiency and innovation on the one hand, and provides the necessary financial resources for R&D investment on smart grids on the other hand are of critical importance (Eurelectric, 2011). The need for such government intervention has been widely recognised as a way to overcome externalities, information and coordination issues (Lin and Monga, 2010).

Recent empirical trends have indicated that it is government, rather than utilities, which assumes important roles particularly in the early stage of smart grid development. The national policy framework for smart grids in the US (Executive Office, 2011) and the smart grid vision and testbed in South Korea (Mah et al., 2012b) are some examples. However, few studies have specified the governing mechanisms in which the state plays a role in facilitating the sustainability transition process, and the literature is particularly limited in the context of Asian countries, except the work by for example Bai et al. (2010).

This paper therefore aims to bring these key concepts together to conceptualise the key elements and processes through which the state affect the smart grid diffusion in Japan. In particular, based on the DoE's smart grid maturity model, this paper has developed a refined model as a conceptual framework for assessing the smart grid deployment in Japan (Table 1). The DoE's framework was originally developed as a business tool for use by electric power utilities and may not fully reflect the key elements in the policy context relating to smart grid technologies. Our refined model therefore integrates the DoE's framework with the key concepts from the literature that we discussed in the preceding sections (Faruqui et al., 2011; Litos Strategic Communication, 2008; Mah et al., 2012b; Markard and Truffer, 2006; SEI, 2009, 2011). Work by Faruqui et al. (2011) which introduce the important distinction between three types of smart grid benefits – operational benefits, customer benefits and societal benefits – are particularly useful for us to refine our framework. In addition, we highlight the role of state in the areas of visioning, policy formulation and regulating the electricity markets in our model.

Our refined smart grid maturity model differentiates the smart grid transformation process into three orders. These three orders of development evolve progressively from one another and each of them can be characterised by the indicators listed in Table 1.

Table 1: The Refined Smart Grid Maturity Model

Orders of transformation	**Indicators**
First-order transformation	▪ The importance of smart grid is recognised. Visions and policy strategies are in place. ▪ But business cases not in place and benefits (including operational, customer and societal benefits) of smart grids are not realized.
Second-order transformation	▪ Business cases are emerging and investments are being made. ▪ Operational benefits are realised but not customer and societal benefits. But some applications for particularly markets are validated. ▪ Operational linkages are established between two or more technological aspects of smart grid; cross-functional benefits are achieved; partnerships are cultivated. ▪ Some minor regulatory changes such as new incentive systems for smart meter installations are introduced, mostly in pilot scale. But major regulatory changes involving tariff structure and market structure are not introduced.
Third-order transformation	▪ Smart grid functionality and benefits (including operational, customer and societal benefits) are realised. ▪ New business models are economically sustainable. New products, services and markets are created. ▪ Major regulatory changes involving tariff structure and market structure are also introduced.

(Source: authors; adapted from Faruqui et al. (2011); Hendry et al. (2010); Litos Strategic Communication (2008); Mah et al. (2012b); Markard and Truffer (2006); SEI (2009, 2011))

3. SMART GRIDS IN JAPAN: THE CONTEXTUAL BACKGROUND AND THE FOUR SMART COMMUNITY DEMONSTRATION PROJECTS

3.1 The energy context and post-Fukushima energy policies in Japan

Japan has a geographical area of 362,220 km^2 and a population of 128 million in 2010 (Statistics Bureau, 2012). It is an island nation comprises the four major islands of Honshu, Hokkaido, Kyushu and Shikoku. This OECD country is a major developed and industrialised country in Asia, which is ranked third globally by GDP in 2011 after the U.S. and China (The World Bank, 2013).

Japan relies on fuel imports to meet most of its energy needs. In 2010, about 82% of Japan's primary energy supply is from imports (Statistics Bureau, 2012). Japan's energy supply is mainly from fossil fuels. Oil, coal, natural gas, nuclear, renewables and other sources account for 40%, 22%, 19%, 11%, 7% respectively (Statistics Bureau, 2012). Fossil fuels are also the major source for power generation, of which about 60% is generated by thermal, followed by 31% by nuclear and 8% by renewables (Statistics Bureau, 2012).

Electricity consumption increased by 8% between 2000 and 2010 and reached 1,056 TWh in 2010 or 8,250 kWh per capita (Statistics Bureau, 2012). CO_2 emissions have been rising since 1990 and peaked in 2007 at 1,296 million tons, but since then they have gradually decreased to 4% higher than the 1990-level in 2010 (Statistics Bureau, 2012).

The accident at Japan's Fukushima Daiichi nuclear power plant in March 2011 has triggered a stringent review of the country's historically pro-nuclear energy policy. Prior to the Fukushima accident, nuclear was regarded as the key to Japan's energy independence and low-carbon future. In the 2010 Basic Energy Plan, which was announced only months prior to the Fukushima accident, the government outlined its plan to double the use of nuclear-based electricity to 50% by 2030 (DeWit et al., 2012).

After the Fukushima accident, the former Prime Minister Yoshihiko Noda established the Energy and Environmental Committee (EEC) to review the mid- and long-term energy and environmental strategy. The EEC conducted a series of stakeholder engagement activities and a deliberative poll in the summer of 2012 to invite public views on three alternative energy-mix scenarios, namely having 0%, 15%, or 20-25% nuclear (CDD, 2012; DeWit et al., 2012). While nuclear power programs and future energy mix were under review, all of the 50 nuclear reactors in Japan were shut down by May 5, 2012 for approximately a month until two reactors at Oi were restarted in June (Srinivasan and Rethinaraj, 2013).

In September 2012, the EEC released the "Innovative Strategy for Energy and the Environment" which concluded their analysis and proposed to completely phase out nuclear energy by 2030. The EEC suggested to fill the energy demand gap through renewable, conservation, and efficiency improvements (Energy and Environment Council, 2012). Since then, a plan to triple renewable energy output has been introduced (Energy and Environment Council, 2012). An extension of the feed-in-tariff from solar power to wind and other renewable energy sources was also introduced in August 2012 (DeWit et al., 2012).

It is in these energy contexts that smart grids are expected to be given a more important role in Japan's energy management strategies after the Fukushima nuclear accident as there is less support for nuclear power and a higher level of support for renewable energy and energy efficiency (Ida, 2012; Interview 1). However, a recent change of the political regime has created uncertainties for this energy policy outlook. In December 2012, Shinzo Abe, who represented the Liberal Democratic Party, was elected as the new Prime Minister. This party has been pro-nuclear and pro-business. The Prime Minister openly stated that he is open to building new nuclear plants if this is accepted by the public (Tabuchi, 2012). He also recently instructed the Economy, Trade and Industry Minister to review the energy and environmental strategy (The Denki Shimbun, 2013).

3.2 Smart grid development in Japan: a state-led, community-oriented, and business-driven approach

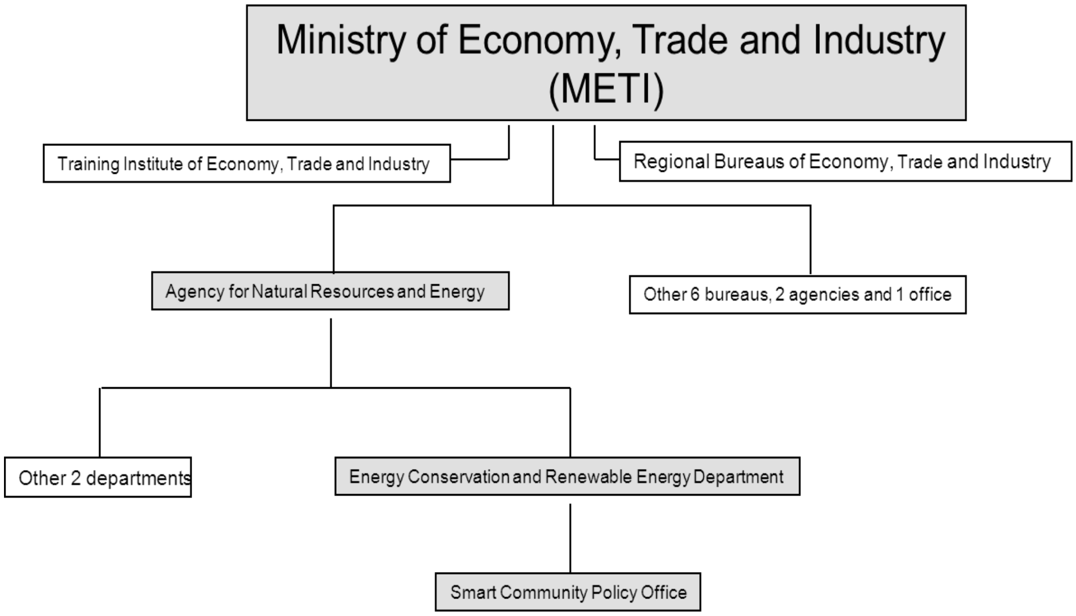
In Japan, smart grids have been developed in ways that differ from other countries in many important aspects. For example, the US's approach has focused on smart meter rollouts and grid enhancement while South Korea's is export-oriented with the establishment of a large-scale demonstration project on Jeju Island. China, on the other hand, has focused on the establishment of super-grids across the country (Lin et al., 2013; Mah et al., 2012b). In contrast, the Japanese model is characterised by its government-led, community-based and business-driven approach.

Government-led

The Japanese model is government-led. The Japanese national government has made major initiatives on steering the development of smart grids through deploying a mix of policy directives, direct government intervention, and partnerships with the private sector and local governments. The government has intervened in steering the growth of smart grids through heavy public expenditure. Budgets for the four pilots amounted to 126.6 billion yen, approximately US$1.38 billion,[1] of which 65% comes from the government and the rest comes from the private sector (Interview 1). In terms of the governmental structure, the Ministry of Economy, Trade and Industry (METI) is the agency at the national level responsible for overseeing the development of smart grids. Under the METI, the Agency for Natural Resources and Energy (經濟產業省能源廳) and its sub-division the Smart Community Policy Office are the key government agencies responsible for smart grid policies and development. At the local level, Project Facilitation Committees (項目推進協議會) in each pilot city are the key agencies to implement national smart grid initiatives (Figure 1).

[1] 1 JPY = US$0.0109, as of 27 February, 2013.

Figure 1: The government structure of smart grid policies in Japan



* The shaded boxes highlight the government agencies which are related to smart grid policies in Japan.

(Source: compiled by Authors; data from Interview 6; METI (2012)).

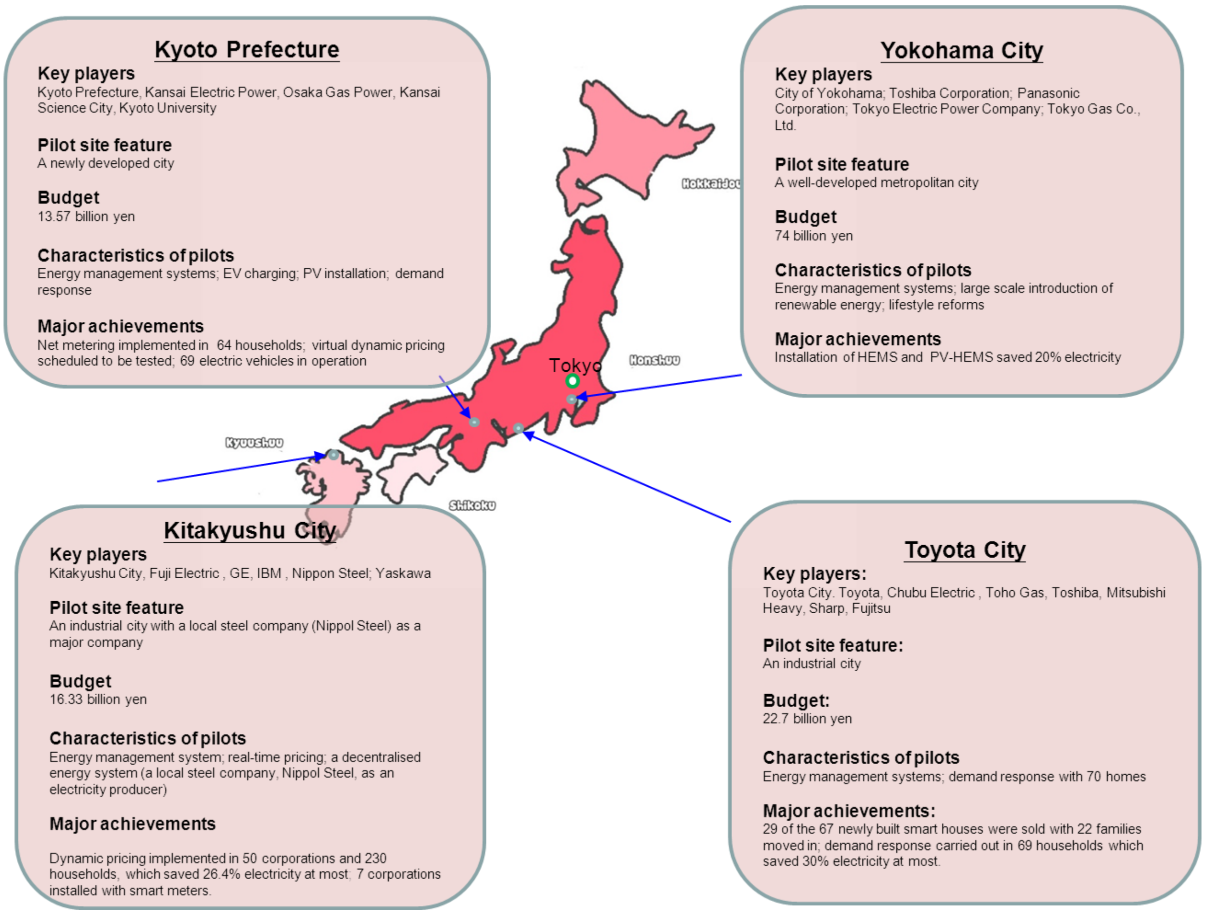
Community-oriented

A notable feature of the Japanese model is the establishment of four large-scale smart community demonstration projects in Kyoto, Yokohama, Kitakyushu, and Toyota City (Interview 1) (Figure 2). These projects were established in 2010 and are expected to be completed in 2014. They are planned to involve more than 5,000 households and a number of major Japanese corporates such as Mitsubishi and Toshiba. They are administered by METI as a strategy to establish "Next- Generation Energy and Social Systems Demonstration Areas" by integrating smart grid technologies into communities.

The feature of this community-oriented approach is the emphasis on piloting dynamic pricing systems and demand response measures to test behavioural changes among household customers (Ida, 2012; Ling *et al.*, 2012). Apart from testing various smart grid technologies such as smart meters, home energy management system (HEMS), electric vehicles, battery storage and PV, visualisation of electricity consumption through the use of smart meters, dynamic pricing and demand response programmes are some of the feature elements of these pilots. Another feature of these projects is the pilot of a decentralised power system in Kitakyushu City in which a local steel company (Nippon Steel) has planned to recover waste energy to supply electricity to its neighbourhood (NSSMC, 2008).

The four sites were strategically selected in April 2010 from 16 bidders. These demonstration projects vary in their local contexts, pursue different objectives on various scales and with differing achievements (Figure 2; Tables 2 and 3).

Figure 2: The four large-scale smart-community demonstration projects in Japan



(Source: compiled by authors; data from Interview: 6; ANRE (2012); City of Kyoto (2010); City of Kyushu (2010); City of Yokohama (2010); FIS (2012); Next Generation Energy and Social System Advisory Committee (2012); Toyota City (2010b))

Note: HEMS – Home energy management system

Table 2. An overview of the four smart community demonstration projects

Demonstration Projects	**City/area overview**	**Project overview**	**Characteristics and strengths as a demonstration project**
Yokohama City	Location: capital city of Kanagawa Prefecture Geographic area: 427 km^2 GDP: 12.4 trillion Yen Population (households): 3,696,419 (1,604,819)	Area of pilot: 60km^2 Population (households) in pilot area: 420,000 (170,000) Population involved in the pilot: 4,000 households	A developed area with high population and mixed landuse which include industrial, commercial and residential areas. A city that has a good track record in meeting national environmental targets such as a 30% waste reduction target.
Kyoto Prefecture	Location: Kyoto Keihanna District Geographic area: 4,613 km^2 GDP: Nil Population (households):2,625,563 (1,130,608)	Area of pilot: 154 km^2 Population (households) in pilot area: 171,203 (63,870) Population involved in the pilot: 900 households	A newly developed area; mainly young residents who will become major electricity consumers in the future, and they are more receptive to new technologies.
Toyota City	Location: In the Mikawa region of Aichi Prefecture Geographic area: 918 km^2 GDP: 9.1 trillion Yen Population (households): 422,865(164,040)	Area of pilot site: 918 km^2 Population (households) in pilot area: 422,865(164,040) Population involved in the pilot: 67 households	Historical strength in R&D of batteries for cars; world class R&D in hybrid cars.
Kitakyushu City	Location: Northern part of the Kyushu Island Geographic area: 480 km^2 GDP: Nil Population (households): 972,328 (425,240)	Area of pilot: 1.2 km^2 Population (households) in pilot area: 600 (200) in 2010; 1,800 (1,000) in 2014. Population involved in the pilot: 70 companies and 200 households	A local steel company can pilot decentralized energy system by generating electricity (partly from recovered waste energy) and supplying electricity to residents and companies in the neighhourhood.

(Source: compiled by authors; data from: site visits, interviews 2 and 6, City of Yokohama (2013), Kyoto Prefecture (2013), Toyota City (2013), City of Kitakyushu (2013); NSSMC (2008); Climate Change Policy Headquarters (2010); Toyota City (2010a); Keihanna Eco-City (2010); Smart Community Creation Project Committee (2010); City of Yokohama (2010); Toyota City (2010b); City of Kyoto (2010); City of Kyushu (2010))

Table 3. The four demonstration projects: key features and achievements/ progresses

Demonstration projects	Emission reduction target for Year 2014 – compared to the 2005 level	Budget (billion yen)	Characteristics/focus of pilot	Key players	Achievements/ progresses (As of July 2011)
Kyoto Prefecture	12,798 tonne CO_2 (34%) ▪ Household:63% reduction compared to the 2007 level; Commercial: 54% reduction compared to the 2007 level; Transportation and others: 38% reduction compared to the 2007 level	13.57	▪ CEMS, HEMS, BEMS,EV charging, PV installation, Demand response	Kyoto Prefecture, Kansai Electric Power, Osaka Gas Power, Kansai Science City, Kyoto University.	HEMS were experimented in 50 existing and 14 newly built households in mid 2011 Virtual dynamic pricing is scheduled to be tested between July to September 2012 in 14 out of some 800 households; token-based incentives are to be provided Demand response programmes are scheduled to be tested, starting from July 2012, in 700 out of some 800 households; cash-based incentives are to be provided 69 electric vehicles have been in operation as of May 2012
Yokohama City	64,000 tonne CO_2 ▪ Household: Maxi. 30% per household; Commercial: 30% per building; Transportation and others: 15% ▪ RE target: 5.8% electricity from solar PV for households in the pilot area	74	▪ Large scale introduction of renewable ▪ Energy management systems at different levels: HEMS, BEMS, CEMS ▪ Thermal energy management at the district level ▪ Next-generation transport systems ▪ Lifestyle reforms	City of Yokohama; Toshiba Corporation; Panasonic Corporation; Meidensha Corporation; Tokyo Electric Power Company, Incorporated; Tokyo Gas Co., Ltd.; Accenture Japan Ltd.; NEC Corporation; Nissan Motor Co., Ltd.	A new battery as R&D output has been accredited in the U.S. and submitted for international standardization Installation of HEMS and PV-HEMS saved 20% electricity IT communication modes were developed and selected for smart grids
Kitakyushu City	34,000 tonne CO_2 ▪ Household: 35% CO_2 reduction/household; Commercial: overall 40% reduction in CO_2 emission; Transportation and others: Nil ▪ RE target: Electricity from renewable energy accounts for 32% in the pilot area	16	▪ Energy management system: HEMS, BEMS ▪ Real-time pricing ▪ Demand side management ▪ A decentralised energy system is to be piloted by a local steel company (Nippon Steel) which plans to recover waste energy to produce electricity for its neighbourhood.	Kitakyushu City, Fuji Electric , GE, IBM, Nippon Steel; Yaskawa	New energy applications (e.g. PV, wind, fuel cell and solar thermal) installed in 6 areas 218 households installed with HEMS 7 corporations installed with smart meters Installation of CEMS & BEMS completed by February 2012 DSM implemented with dynamic pricing and incentive program. Peak time dynamic pricing was experimented in 50 corporations and 230 households with 2-hour advanced notice about the changing price.
Toyota City	265,000 tonne CO_2(30%) ▪ Household: 182 tonne CO_2 reduction/year; Commercial:30.5 tone CO_2/year; Transportation and others: 7,781 tonne CO_2 reduction/year ▪ RE target: Electricity from renewable energy accounts for 61% in the pilot area	22.7	▪ HEMS + Vehicle to Home ▪ Low carbon transportation ▪ V to CVS /School ▪ Energy Management systems: EMS; EMS /EDMS ▪ Demand response with 70 homes	Toyota City. Toyota, Chubu Electric , Toho Gas, Toshiba, Mitsubishi Heavy, Denso, Sharp, Fujitsu	44 of the 67 newly built smart houses were sold, and 22 families moved in Demand response experiment with token-based reward was carried out in 69 households in December 2011. Electricity consumption reduced as high as 30% 31 PV-charging station for cars were completed as of May 2012 Electricity from vehicle (V to CVS) was piloted in a school

(Source: compiled by authors; data: Interview: 6; ANRE (2012); City of Kyoto (2010); City of Kyushu (2010); City of Yokohama (2010); FIS (2012); Next Generation Energy and Social System Advisory Committee (2012); Toyota City (2010b)

Note: HEMS – Home Energy Management System; BEMS – Building Energy Management System; CEMS – Community Energy Management System

Enterprise-driven

Another distinctive feature of the Japanese approach is the prominent role of the business sector. Toyota, Mitsubishi, Sharp, Toshiba, Fujitsu, Panasonic, NEC and Nissan Motor are some of the major corporates involved in these four demonstration projects. The business sector was the major sources of capital investment and innovation in the four demonstration projects. Financing the massive investments has been widely identified as a key barrier for smart grid deployment (Eurelectric, 2011; Giordano and Fulli, 2012). In Japan, approximately one third of the total budgets of the four demonstration projects came from the business sector. Apart from financial resources, many of these corporates possess historical strengths in various smart grid-related technologies. For example, Toyota Motor Corporation, which has been a driving force in the Toyota City pilot, has a historical strength in R&D of car batteries and hybrid vehicles.

These corporates also took a leading role in funding applications which determine the direction and scale of each smart community demonstration project. It was the corporates, rather than the local governments or the Project Facilitation Committees of the pilots, which directly submitted funding applications to the national government. Government funding is allocated directly to those enterprises (Interview 2).

In addition, corporates also played an important role in the decision-making and management of the demonstration projects. In each Project Facilitation Committee (項目推進協議會) of the four pilots, the majority of board members come from the business sector. For example, the Project Facilitation Committee of the Yokohama pilot has seven of its board members from the business sector.

4. THE ROLE OF STATE IN THE FOUR SMART COMMUNITY DEMONSTRATION PROJECTS

Based on the literature on the role of states (Bulkeley and Kern, 2006; Hendry et al., 2010), our case study has found that the Japanese government has high governing capacity in the following five aspects.

(1) Leadership

Leadership is the ability to "articulate a vision, inspire people to act, and focus on concrete problems and results" (Ryan, 2001): 230. Unlike South Korea which has a high-profile national smart grid vision (Mah et al., 2012b), the Japanese government has not introduced a grand plan nor an ambitious target for its smart grid developments. The Japanese government instead has demonstrated its leadership in an alternative approach that is more adaptive: through coordinating government-business partnership, steering systematic progress, and taking up tasks which are public goods in nature.

The establishment of the four demonstration projects is a good example to illustrate the coordinating capacity of the Japanese government. The four demonstration projects are strategically coordinated in ways that they are different from, but highly complementary to, each other. The projects are planned to pilot different elements of smart grid technologies at a community level. Apart from this, these projects are further complemented by the seven new pilots which were recently launched in early 2012 as the second phase of Japan's demonstration projects. These second-phase pilots are planned to focus on validating the market – an area which has not been adequately addressed in the four demonstration projects.

The government has demonstrated its leadership through steering systematic progress that moves away from testing and advancing technologies to exploring market applications and promoting take-off in selected markets through incentives and subsidies (Hendry et al., 2010). While a comprehensive evaluation of the achievements of the four on-going pilots is yet to be available, it is evident that testing new technologies in an operational environment and validating consumers' need for the technologies – the key features of a systematic progress from technology to market - are some of the priorities of these demonstration projects.

The Japanese government also demonstrated its leadership through taking up important tasks which are public goods in nature. The standardisation of Japanese smart grid technologies is of strategic importance for Japan to secure a leading position in global markets. Standardisation, however, is a public good in nature and may not be adequately provided by the business sector. In Japan, the government has taken major initiatives in promoting standardisation. Major initiatives include the introduction of the "International Standardization Roadmap for Smart Grid" by the Ministry of Economy, Trade and Industry (METI) and the establishment of the

Working Group on International Standardisation of Smart Grid (Interview 3; Mathews and Tan, 2012).

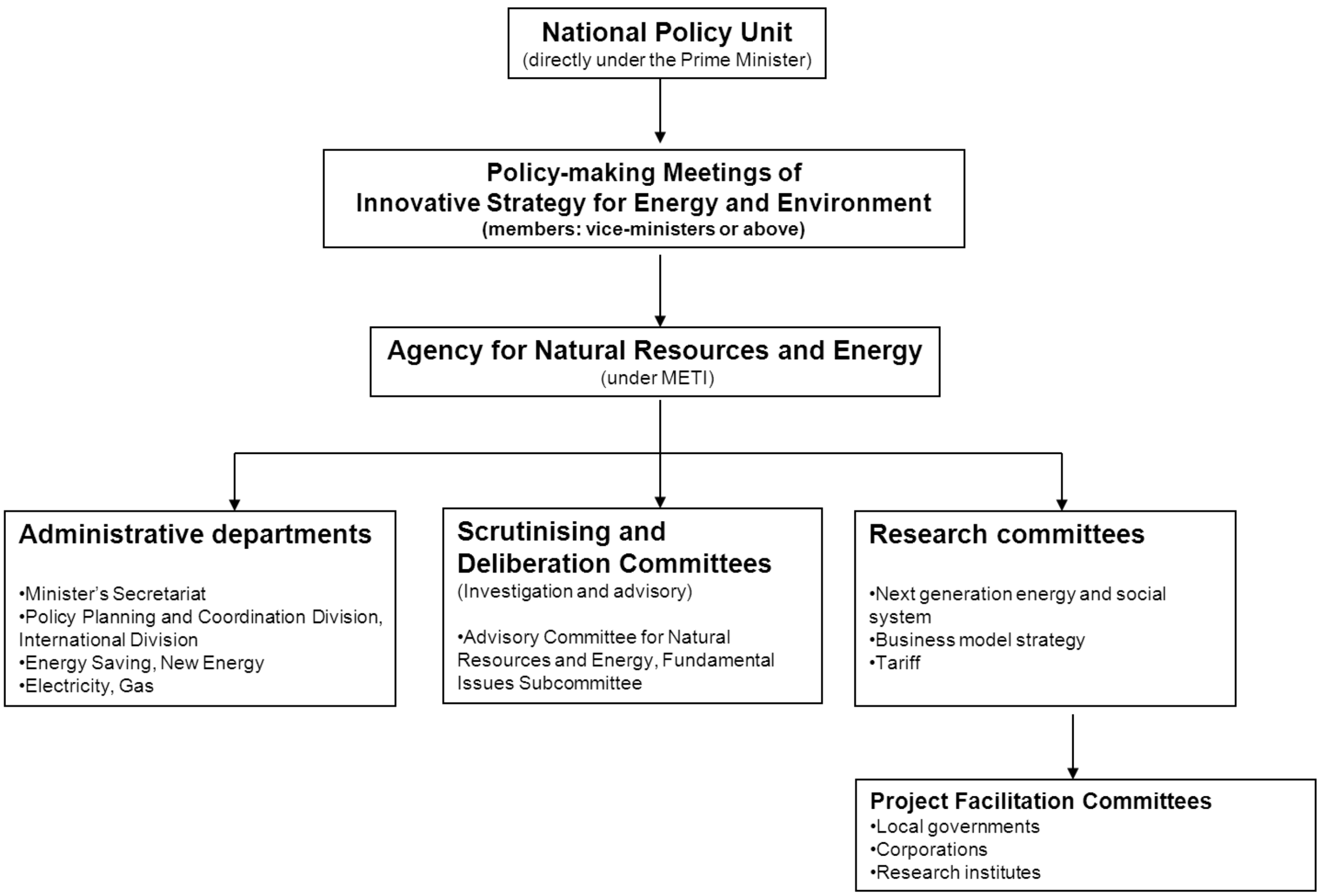
(2) Recombinative capacity

The Japanese government has also demonstrated its recombinative capacity. It strategically aligned pre-existing strengths of the country and emerging global markets relating to smart grid technologies. Recombinative capabilities are the capabilities for synthesising knowledge into new productive configurations (Sharif and Baark, 2005). The Japanese enterprise-driven approach has created opportunities for internationally well-known Japanese enterprises such as Toshiba, Mitsubishi, Sharp, Panasonic and Nissan Motor which have historical strengths in various smart grid-related technologies including electric vehicles, to collaborate in testing and advancing the technologies.

(3) Institutional capacity

The Japanese government has demonstrated its strengths in institutional capacity in three important aspects. Historically, the government has a well-established and sophisticated energy decision-making system with active involvement of committees and research institutes. This decision-making system tends to promote consensus building, policy legitimacy and more informed decision-making on energy issues. Since the early 2000s, particularly after the Kyoto Protocol came into force in 2005, METI has set up a number of research institutes in major energy policy areas such as strategic energy planning and low carbon development. Since 2009 the METI has set up research institutes on specific smart grid issues, including the study committees on business model strategies and tariffs (Figure 3).

Figure 3: The smart grid policy-making system in Japan



(Source: authors; data from ANRE (2013))

Institutional initiatives have facilitated the central-local coordination on the four smart community demonstration projects. While METI is the government agency at the national level which plays a central role in steering the developments of smart grids, the Project Facilitation Committees (項目推進協議會) of each of the four demonstration projects are the key agencies that implement SG initiatives at the local level. These local committees play an important role in coordinating and facilitating collaboration among participating enterprises (Interview 6).

Externally, the Japanese government has reached out to the global community through the establishment of the New Energy and Industrial Technology Development Organisation (NEDO). NEDO is a semi-governmental organisation and is Japan's largest public R&D management body (Nakama and Watanabe, 2009). NEDO acts as the executive arm of the Japanese government to develop overseas markets for smart grid. A smart grid alliance, with NEDO as the secretariat, was established in 2011 to help Japanese companies develop smart grid projects overseas (Interview 3).

(4) Enabling capacity

National and local governments have played an important role in enabling the government-business collaboration in the demonstration projects. The demonstration projects have created a platform for major Japanese enterprises such as Toyota as well as a large number of SMEs, which are either the subsidiaries or component suppliers of those major enterprises, to collaborate. The major enterprises were important sources of investment and innovation. Twothirds of the budget for the demonstration projects comes from the government while one-third comes from the participating enterprises. Historically, some Japanese enterprises such as Mitsubishi and Toyota possess high R&D capabilities, which may be even greater than those of the government. Through these demonstration projects, the Japanese government was able to pool together financial resources and consolidate the capabilities which exist within the government and in the private sector.

Apart from facilitating government-business partnerships, the government has also enabled the participation of households. For example, in Yokohama, in part due to the existence of trust between local governments and local people, it was the local government rather than the participating enterprises which reached out to the households and recruited them to participate in the pilots (Interview 2).

(5) Inducement capacity

While the four pilot projects are major initiatives in government-business collaboration, the Japanese government has strategically induced competition between collaborating companies as well as among the participating localities through an annual fund bidding system (Interview 1). Under the system, the national funding for the four demonstration projects is set aside to ensure project continuity. However, the four localities are required to submit an application and bid for funding annually. Participating enterprises can formulate and submit their own proposals directly to the national government upon the endorsement by the Project Facilitation Committee of each demonstration project (Interview 2). As such, this Japanese government-business collaboration is characterised by a healthy coexistence of collaboration and competition which tends to promote efficiency as well as novelty.

5. ACHIEVEMENTS AND LIMITATIONS OF THE GOVERNMENT-LED MODEL IN JAPAN

The government-led model in Japan has made some important progresses although some major problems still remain. On the basis of the refined smart grid maturity model that we developed (Table 1), our analysis suggests that the Japanese model was able to attain the second-order of smart grid development, but not yet to the highest level (Table 4).

Table 4: An assessment of the smart grid transformation in Japan

Orders of transformation	Our assessment	Illustrative examples
First-order transformation	●	▪ Smart grid vision is formulated and supported with policies and the establishment of the four smart community demonstration projects.
Second-order transformation	◐	▪ Some functionality and benefits of smart grids are realised. ▪ Some examples of operational linkages between different technological aspects of smart grids. For example, in Kitakyushu, renewable applications and HEMS are both tested. ▪ But no major customer benefits nor societal benefits were realised.
Third-order transformation	○	▪ No major customer benefits nor societal benefits were realised. ▪ No major business model was developed. ▪ No major regulatory change has been introduced.

●: Strong evidence

◐: Moderate evidence

○: Indiscernible evidence

Our case study showed that the Japanese government has initiated, steered and incubated an early stage of smart grid deployment. The four high-profile demonstration projects were instrumental in pooling together resources from the business sector and local communities with the support of government funding and policies. We found that this model of government-business-community partnership has demonstrated that the government did possess high governing capacity in terms of leadership, recombinative capacity, institutional capacity, enabling capacity, and inducement capacity. Such government actions have created some favourable dynamics that appear to be critical in the smart grid diffusion. These dynamics include resource pooling, innovation and diversity, learning, policy legitimacy, and consensus building.

In particular, these projects acted as a platform in which some functionality and benefits of smart grids are realised. For example, home energy management systems (HEMS) and electric vehicles were piloted. The Japanese model is also distinguished by its emphasis on extending from technological advancement to validating the applications of smart grids for particularly markets, which is an area which has received minimal attention in some other countries such as South Korea (Mah et al., 2012b). This model has therefore attained the first and second-order transformation of smart grids (Table 4).

However, our analysis suggests that the Japanese model has not been able to advance to the third-order transformation. Consumer participation has remained limited in the demonstration projects. Although more than 5,000 households are planned to be involved in the pilots, the overall number of participating households are still far from adequate to test consumer responses to feedback and to understand potential consumer concerns such as privacy issues (Interviews 1 and 2). On the other hand, although dynamic pricing programmes have been tested in some demonstration projects with recorded customer benefits (for example in Toyoto City and Kitakyushu City, electricity consumption reductions of up to 30% and 26.4% respectively), such achievements must be interpreted with caution to a large extent because these are on-going pilots with a limited scale of operation.

Another limitation of the Japanese model is that the development of business models in the four demonstration projects has been minimal. The only exception is the Toyota city demonstration project that recently applied for a fund for developing business models in 2012. As such, the Japanese model has not advanced to the third-order transformation in which the presence of economically viable business models is one of the defining features (Table 4).

These observations give rise to a number of important questions: What are the constraints that undermine Japan's advancement to the highest order of smart grid deployment? Are there limits of the state in the government-led model in Japan? What are the complementary roles of non-state actors such as the business sector and electricity consumers in facilitating the smart grid deployment in Japan?

Our analysis indicates that the Japanese government has limitations in two aspects. Firstly, it did not take up a major regulatory role to introduce new incentive systems and dynamic pricing – which is one of the key functions of the government in the context of technological and industrial innovation in order to overcome the technological lock-in (Markard et al., 2012; Walker, 2000).

In Japan, electricity market liberalisation began in 1995 in Japan, and is still on-going (Goto et al., 2013). Currently, market competition in the power sector is still limited. The electricity sector in Japan is operated by ten privately-owned vertically-integrated incumbent utilities. Retail liberalisation has been introduced to all users but excluding households (Goto et al., 2013). In addition, the tariff system is a flat-rate one (Interview 3).

This partial market liberalisation has created barriers to the deployment of smart grids in Japan. There is little evidence suggesting that these incumbent utilities, including the Tokyo Electric Power Company Ltd. (TEPCO) have active involvement in the four demonstration projects. Some of them have made some progresses in smart metering installation. For example, Kansi Electric has installed approximately one million smart meters, accounting for 10% of the total customers it serves (Interview 4). TEPCO has planned to install 17 million smart meters by 2019 (Zpryme, 2012). However, these initiatives are either relatively small in scale or still in the planning stage. There is no evidence suggesting that there is a sectoral-wide commitment to scaling up smart grid deployment. More importantly, there is a lack of evidence suggesting that these utilities would support major regulatory changes relating to, for example, dynamic pricing which may facilitate smart grid deployment. Although further market liberalisation to extend the open market to residential customers and to introduce dynamic pricing has been in discussion (Takase and Suzuki, 2011), the lock-in situation has prevailed.

The lock-in situation is further complicated by the presence of a powerful pro-nuclear coalition in Japan. The literature, for example the work by Walker (2000), has shed lights on the way technological lock-in may be reinforced by the close relationships between governments and incumbent power producers. In Japan, the socio- technical regime of the power sector is characterised by the presence of a strong pro-nuclear advocacy coalition (i.e. the "nuclear village" which is a pro-nuclear coalition between the regulators, political parties, utilities, business federation and academia) and this coalition has remained intact even after the Fukushima accident (Basu, 2013). Despite the emergence of an anti-nuclear movement in Japan after Fukushima (Ling et al., 2012), the change in the political regime to a pro-nuclear party in the recent prime minister election indicates that the "nuclear village" may continue to exert influence with political parties and through the top leaders. The prospects for Japan to move away from the technological lock-in to smart grid technologies therefore need to be evaluated with caution in consideration of this contextual feature in Japan's power sector (Basu, 2013; Vivoda, 2012).

Another major weakness of this government-led approach is the lack of incentives for cross-pilot collaboration. Horizontal linkages between the four demonstration pilots could be critical to the achievements of "operational linkages" between various technological aspects of smart grids and the cross-functional benefits – which are the defining feature of more advanced levels of smart grid deployments as highlighted in our refined smart grid maturity model. However, although the four demonstration projects have their strategic strengths and complementary role as shown in Tables 2 and 3, there was limited cross-pilot collaboration. Each of these demonstration projects submitted their budget proposal to the national government individually and no co-application has been made. This limitation is to a large extent resulted from the policy style and institutional system in Japan which do not pay much attention to cross-prefecture collaboration (Interview 3).

In relation to the complementary roles of non-state actors, our analysis suggests that the business sector and electricity consumers may have two key roles to play, the development of business models and consumer engagement. These roles will be critical for Japan to advance to the highest order, i.e. the third-order of smart grid development. Business models are important because they explore different economically viable options to involve users (Verbong et al., 2013). New products, services and markets have to be created in order to realise large-scale customer benefits, which in turn are critical to consumer engagement (Faruqui et al., 2011; Litos Strategic Communication, 2008; SEI, 2009, 2011). Worldwide, a number of business models related to smart grid technologies have been emerging (Budde Christensen et al., 2012; Giordano and Fulli, 2012; San Román et al., 2011; SGIC, 2013). For example, in the US, some energy companies offer utilities with peak capacity through automated load control of contracted industrial clients (Kanellos, 2008). In fact, business models are expected to be a prioritised area for the next phase of demonstration projects when the existing ones are to be completed in 2014. The international experiences would provide useful insights to the business sector in Japan.

6. CONCLUSIONS

This paper presents a study of the smart grid policy in Japan. This paper has examined how and to what extent the state played a role in governing the sustainability transition with a case study of the large-scale smart grid community demonstration projects in Japan. We have addressed a seriously under-research area (the role of government) in energy-related low-carbon transition studies in the Asian context.

This paper has three major findings. Firstly, we have characterised the Japanese model of smart grid development as a government-led, community-oriented, and business-driven approach. Secondly, we have contributed to the literature on energy governance by shedding lights on the mechanisms of the role of government in smart grid diffusion. We have specified the five governing capacities the Japanese government has demonstrated in its way of governing the smart grid deployment process. Thirdly, on the basis of our refined smart grid maturity model, we have critically evaluated the achievements and limitations of the Japanese approach. We found that the Japanese model has limitations in advancing to the highest order of smart grid transformation. We have identified that the government's failure in taking up a major regulatory role, the absence of active involvement of established utilities such as TEPCO, and the limited involvement of the broader business sector and electricity consumers in the areas of business model development and consumer engagement are some of the major barriers for the further advancement of the Japanese model.

This paper has made contribution to the literature on smart grids, technological innovation and energy governance in several important ways. The smart grid maturity model that we have refined provides a framework for policy makers, utilities, regulators, customers and NGOs and other stakeholders in smart grid to evaluate the progress of grid deployment. Our findings have reinforced the view that states play a central role for technological innovation (Evans, 1995; Jänicke, 2005). Our specification of the capacities of the government has provided a better understanding of distinct patterns of governing that are more conducive to the sustainability transition. Furthermore, we have shed light on the limits of the government, and the important role of the business sector and consumers in strengthening the governing capacity of the sustainability transition.

Our findings are country- and technology-specific. However, they may be generalisable to other countries, such as China and South Korea, which share some of the characteristics of partially liberalised power markets. Further research on a comparative study of these countries may improve generalisability of the findings. Our findings of this case study can also provide a better understanding of the complexity and variety of governing mechanisms which may emerge for a more effective sustainability transition.

The lesson for smart grid policies is that much more attention needs to be given to three areas: the regulatory role of the government, the development of business models, and programmes to encourage consumer engagement. These areas are critical to overcoming the technological lock-in, and thus to achieve more advanced levels of smart grid deployment.

Another policy implication of this paper is that our refined smart grid maturity model can provide useful guidelines to the countries that are on early stage of the smart grid deployment to critically evaluate current status and develop future strategies.

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Appendix 1: List of Face-to-face Interviews

Code	**Interviewee Background**	**Date of Interview**
1	A senior government official, Smart Community Policy Office, Energy Conservation and Renewable Energy Department, Ministry of Economy, Trade and Industry	14 May, 2012
2	A government official, Project Promotion Division, City of Yokohama Climate Change Policy Headquarters	14 May, 2012
3	An officer, Smart Community Department, New Energy and Industrial Technology Development Organization (a semi-government organisation)	15 May, 2012
4	This is a group interview with the following interviewees: ▪ A manager, Power Grid Engineering Section, Mitsubishi Electric Corporation ▪ A manager, Switchgear Department, Mitsubishi Electric Corporation ▪ A manager, Switchgear Department, Mitsubishi Electric Corporation ▪ A manager, Overseas Switchgear Engineering Section, Switchgear Department, Mitsubishi Electric Corporation ▪ An executive, Overseas Marketing Section, Marketing Department, Mitsubishi Electric Corporation ▪ A manager, Overseas Marketing Section, Marketing Department, Mitsubishi Electric Corporation ▪ An executive, Overseas Marketing Section, Marketing Department, Mitsubishi Electric Corporation	16 May, 2012
5	A professor, School of Engineering, Electrical and Electronic Engineering, Daido University	17 May, 2012
6	This is a group interview three senior government officials of the Department of Policy Planning, Kyoto Prefectural Government	18 May, 2012
7	A professor, Department of Intelligence Science and Technology, Graduate School of Informatics, Kyoto University	18 May, 2012
8	A professor, Academic Center for Computing and Media Studies, Kyoto University	18 May,2012