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Conceptualising government-market dynamics in socio-technical energy transitions: A comparative case study of smart grid developments in China and Japan

Daphne Ngar-yin Mah

Department of Geography, Asian Energy Studies Centre, Hong Kong Baptist University, 12/F, Academic and Administration Building, 15 Baptist University Road, Kowloon Tong, Hong Kong

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ABSTRACT

Smart grids (SGs) have been increasingly regarded as an enabling technology for post-Fukushima energy transitions. SGs require new policies and market infrastructures to deliver their potential, but the roles of governments in increasingly market based energy systems have not been well conceptualised. Advancing the socio-technical energy transitions literature, this paper proposes five functions of government-market dynamics in an integrated framework, and applies the framework in the field of smart grid developments in two Asian countries, China and Japan. Based on interviews with 38 key stakeholders, this study has three main findings. First, both countries have in common that the five functions of government-market dynamics are critical in developing, diffusing and utilising SG technologies. Second, China and Japan exhibit distinctive characteristics in the ways that government actors engage market actors. While the Chinese approach is more hierarchical, fragmented and homogenous led by two monopolised grid companies, the Japanese approach is a relatively systemic, bottom-up, and heterogeneous system mainly operated through four large-scale SG demonstration projects. Third, national contextual differences, most notably the advancement of electricity market reforms, explain the variety of the dynamics and outcomes. This paper concludes that consideration of optimising government-market dynamics is vital to create conductive conditions for realising the potential that SGs can offer in energy transitions.

1. Introduction

SGs, characterised by digitisation and big data analytics, have the potential to achieve deep cuts in emissions in a cost-effective manner (EDF, 2017; IEA, 2017). By integrating IT technologies into power grid systems, SGs have been increasingly regarded as an enabling technology that can optimise a major uptake of distributed renewable energy and effectively engage electricity customers in demand-side management (IEA, 2017). However, global development of smart grids, and the associated deployment of renewable energy and demand response programmes have fallen short in terms of technology diffusion (Pätäri and Sinkkonen, 2014). Renewable energy currently accounts for only approximately 10% of the world's total energy consumption (2016 data) (REN 21, 2018). Demand responses have been developed in many parts of the world but most dynamic pricing schemes are applied in the industrial sector only; residential applications are mostly confined to pilot projects (GSGF, 2016).

SGs are fundamentally different from conventional grids. They require a move away from supplier-oriented energy systems to one that is more customer-oriented associated with the emergence of new market actors (e.g. prosumers, electricity retailers) and two-way utility-customer relationships in more decentralised energy systems (IEA, 2011; Mah et al., 2013; Tricoire, 2015). SG-driven energy transitions therefore present major governance challenges (see, for example, Buchmann, 2017; Mah et al., 2012). These challenges are associated with path dependence, market power, resistance to electricity market reforms, and behavioural inertia in typical centralised power systems (Mah et al., 2012; Parag and Darby, 2009).

To overcome these challenges, governments around the world have introduced policy frameworks to support SG developments. The national smart grid roadmaps of the US, and South Korea are notably examples (Mah et al., 2012). On the other hand, market forces are

Abbreviations: CSG, China Southern Power Grid; DSM, demand side management; NEA, National Energy Administration; NDRC, National Development and Reform Commission; EPCOs, electric power companies; METI, The Ministry of Economy, Trade and Industry; MIIT, Ministry of Industry and Information Technology; MOST, Ministry of Science and Technology; NEDO, New Energy and Technology Development Organisation; PPS, Power Producers and Suppliers (特定規模電気事業者); REFIT, Renewable Energy Feed-in Tariff; SEP, Strategic Energy Plan; SGCC, State Grid Corporation of China; TEPCO, Tokyo Electric Power Company

E-mail address: daphnemah@hkbu.edu.hk (Daphne N.Y. Mah).

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critical to SG deployment. Demand side management which is supported by dynamic pricing and real-time electricity data has started to spread from the US and Europe to non-western economies such as Japan and China (Powells et al., 2014; Zafar et al., 2018). These global trends raise various questions: What are the roles of government in increasingly market-based energy systems? How do governments and markets interact and with what impacts? Concepts such as the multi-level perspective on socio-technical transitions shed important light on how niche innovations may scale up and disrupt established energy regimes (Geels, 2001; Smith et al., 2010). But these concepts do not adequately explain the changing role of government in such market-based societies.

This paper aims to advance the socio-technical transition perspective by proposing a conceptual framework and applying to China and Japan. In so doing, we seek to provide a better understanding of whether, where, how, and under what conditions government actors and market actors interact, and how such interactions shape, facilitate, or inhibit energy transitions.

This study is a comparative case study of China and Japan. Most literature on socio-technical transitions is in the western context but the Asian perspective is increasingly important in energy studies. Asian countries, most notably China and Japan, have played a pivotal role in global climate change impacts and responses (Stern and Rydge, 2012). Both are also centres of SG deployment in Asia as well as at the global scale. China houses the world's largest SG investment; Japan is projected to rank second in the Asia-Pacific region with the largest number of installed smart meters by 2020 (ITA, 2016; Uribe-Perez et al., 2016). However, China and Japan show significant variations in their approaches to SG development. China's vision for super-grids and Japan's community-oriented approach are remarkably different (Mah et al., 2013, 2017). More importantly, China and Japan are both undergoing partial electricity market reforms through which major changes have been introduced into the logics of governance, government-utility-customer relationships, and market structures (REI, 2017; Zhang et al., 2017a, 2017b). But the pace of liberalisation differs between these two countries and hence may exert different impacts on energy transitions (Mah et al., 2013, 2017).

This study focuses on two main technological applications enabled by SGs: a major uptake of renewable energy sources and demand-side-management. Smart meters can facilitate management of distributed renewable energy sources by providing more accurate, frequently-updated, and real-time generation metering data from distributed systems (Uribe-Perez et al., 2016). Smart meters, on the other hand, when supported by dynamic pricing and in-home displays, may enable progress in energy saving and peak-load shift (Uribe-Perez et al., 2016).

The rest of the paper is structured as follows. Section 2 provides a review of the theoretical perspectives of energy transitions. It then proposes an integrated framework to specify and predict the key interactional processes of government actors and market actors, and the associated impacts on energy transitions. Section 3 discusses the methodological approaches and the country contexts. Section 4 presents two case studies of China and Japan, followed by a discussion from a comparative perspective. The final section offers some concluding thoughts and policy recommendations.

2. Theoretical perspectives on government-market dynamics in energy transitions

2.1. Understanding SG deployments from the socio-technical transitions perspective and the function framework of technological innovation systems

SGs have been regarded as an enabling technology for realising energy transitions. From an energy system perspective, energy transitions entail transitions from fossil fuel/nuclear-based, mostly centralised, system to one that is based on more renewable energy in a decentralised system (Mullally and Byrne, 2016). These transitions involve major changes of existing technologies, organisations, and complex political struggles of key actors such as incumbent utilities, rapid diffusion of new energy technologies and innovative business models (Markard, 2018).

A rapidly growing literature on energy transitions points to the nature, complexity, and challenges of the systemic transitions of energy systems associated with SG deployment. A key part of understanding the dynamics of energy transitions is the multi-level perspective (MLP). Rooted in the socio-technical transitions literature, MLP argues that energy transitions require not only technological advancements but also the co-evolution of user practices, regulations, industrial networks, infrastructure, and symbolic meaning or culture which collectively shape energy socio-technical systems. MLP gives special attention to the co-evolutionary interactions of technologies, institutions, policies, and actors that take place at the landscape, regime, and niche levels (Geels, 2002; Kemp and Parto, 2005; Loorbach and Shiroyama, 2016; Newell and Phillips, 2016). The literature argues that a landscape at the macro level, such as global view on climate change, demographic trends and societal values, influences dynamics at the levels of regimes and niches (Geels, 2011). Niches scale-up, diffuse, accumulate, and subsequently become strong enough to weaken, destabilise, and replace regimes (Geels, 2011).

The notion of path dependency in the MLP is particularly useful in explaining the complex interactions of the niche-regime-landscape dynamics. The MLP considers transitions processes are path-dependent – there exist carbon or nuclear lock-in because established energy technologies and incumbent utilities are re-inforced in energy regime systems by their own ideas, culture, rules, user practices, network, and technical competence that have developed over time (Smith et al., 2005; Szatow et al., 2012). The literature found that lock-in comes from many sources, including technological, societal, institutional, organisational, and industrial, and tend to constrain technological choices and policy options in energy transitions (Unruh, 2002).

The notion of path dependency, on the other hand, can be forward-looking. A sub-theme of the path dependency literature emphasises the importance of positive feedback that may contribute to path creation. The literature sheds light on the path-breaking conditions that allow the emergence and reinforcement of divergent paths (Foxon et al., 2013; Laird and Stefes, 2009). Learning, scale economies, adaptive expectations and networks are some of the favourable conditions (Foxon et al., 2007). The literature also argues that internal forces for changes are not sufficient; external forces are needed to create escape conditions (Unruh, 2002). The literature has however remained limited in conceptualising the conditions under which divergent paths can emerge and scale up.

Other studies in the technological innovation systems (TIS) field develop a function framework that conceptualises key processes or activities (i.e. functions) serves to develop, diffuse, and utilise energy technologies. Although scholars conceptualise the "functions" in slightly different ways (see, for example, Beaulieu et al., 2016; Haley, 2018), key functions of these transitions include entrepreneurial experimentation, knowledge development and diffusion, guidance of the search, market formation, resource mobilisation, and creation of policy legitimacy (Beaulieu et al., 2016; Haley, 2018; Hekkert et al., 2007). This functional framework has been applied in various important subfields of energy transitions including sustainable technology development (Hekkert et al., 2007), renewable energy (Haley, 2018), and green buildings (Kieft et al., 2017). However, theory of the functions does not adequately reflect the nature of SG-related energy innovation sectors: there are at least two key processes that have been overlooked by the TIS studies.

The first relates to public-good issues associated with SG deployment. Public goods are goods that cannot be excluded from consumption by others (Picot and Wernick, 2007). When compared with private goods, public goods tend to be under-provided by private firms which are profit-maximisers (Picot and Wernick, 2007), but are critical to the long-term sustainability of the concerned sectors (Mattes et al., 2015; Popa, 2015). This justifies government intervention to ensure a minimum level of provision (Popa, 2015). Public goods which are central to SG deployment include R&D and demonstration activities (Mah et al., 2013), standardisation (Mah et al., 2013; Muto, 2017), and data and information management (Buchmann, 2017; EDF, 2017).

The second relates to policy learning. Having its origins in organisational learning (Busenberg, 2001), policy learning as a concept is distinguished from other related terms such as policy innovation in some subtle ways. Policy learning is a policymaking process in which policy makers and policy stakeholders deliberately adjust the goals, rules and techniques of a given policy in response to experiences and new information (Bennett and Howlett, 1992; Hall, 1993). A relatively extensive body of the literature in knowledge transfer and mobility sheds light on the ways new economic sector, including renewable energy industries, requires diffusion of new technology, knowledge and information, most often through inter-firm collaboration, scientist mobility, and personnel mobility (Edler et al., 2011; Herrera et al., 2010; Kuada and Mensah, 2018; Pan and Wang, 2010).

In the context of SGs, an emerging body of empirical evidence suggests that experimental, learning-by-doing feedback processes from end-users, industrial practitioners and other stakeholders are critical components of policy learning (Verbong et al., 2013). The SG literature is however scant in conceptualising the learning process. The broader literature on socio-technical transition demonstrates the effects of learning-by-using feedback processes in weakening lock-in mechanisms, but the literature tends to focus on the business sector (Klitkou et al., 2015) and end-users (Hargreaves et al., 2010) while largely ignoring the need for governments to learn, and the literature is particularly scant in the specific technological context of SGs.

2.2. The roles of government and market as an on-going debate in energy transitions

Situated in a large literature on governance, the on-going debates on the role of government and markets has underpinned major policy areas that range from public health (Adshead and Thorpe, 2007), to housing (Laskowska and Torgomyan, 2016), high-tech industry (Merchant, 1997), and to telecommunication (Picot and Wernick, 2007). Governance is a highly dynamic term which generally refers to the structures and processes that influence decisions made by three main types of actors, government, market, and society (Foxon et al., 2013). Central to the governance perspective is that there is a need for a shift from "government" towards "governance", and that governments has been increasingly engaged with more informally-based, decentralised, shared, and inclusive governing arrangements, with various forms and levels of engagement with market actors and societal actors (Gray, 2005).

The governance literature draws important distinction between governance and government. Government, in a strict sense, is represented by government agencies, administration entities, government regulators, government officers (Shen, 2017). It is also important to note that over the past decades the governance literature has given growing attention to the blurred boundaries of government, market, and society. Market and civil society manage public assets for nature conservation in South Africa (Ndeinoma and Wiersum, 2017), state-owned energy utilities in Europe and China (Meyer and Pac, 2013), GONGOs (government organised nongovernmental organisations) in China (Wu, 2002), and business-society alliances in climate policy network in South Korea (Yun et al., 2013) are some examples to illustrate that diversity and hybrids of governance arrangements for sustainability emerge in various forms and in different contexts.

In the field of energy governance studies, growing attention has been given to alternative governance approaches between government-led and market-led energy transition pathways (Foxon et al., 2013). One adopts a state-centric approach, arguing that nation states assume a central role for technological and industrial innovation through, for example, regulatory arrangements and planning-oriented mechanisms (Evans, 1995; Goldthau et al., 2010; Zhao et al., 2012). Another strand of literature focuses on the role of markets, which could be the key to fostering technological innovation through market liberalisation and the use of pricing signals (Faruqui et al., 2010; Zhao et al., 2012).

However, government action alone is often found to be ineffective and insufficient (Smith et al., 2005; Zhao et al., 2012) while markets may fail, leaving problems such as externalities and information asymmetry ineffectively addressed (Markard & Truffer, 2006). Work by, for example, Hochstetler and Kostka (2015) examine the tensions in state-business relations and the associated policy outcomes in the renewable energy sector in China. Some scholars on the other hand argue that rather than having to choose between the relative merits of the two approaches, government action and market mechanisms can complement and support each other (Goldthau et al., 2010; Zhao et al., 2012). Hoppmann et al. (2013), for example, study the role of deployment policies in inducing market growth in the solar PV industry. However, with the exception of work by, for example, Goldthau et al. (2010) and Zhao et al. (2012), very few studies have specified the normative conditions under which an optimal combination of these two approaches may occur, particularly in the context of technological innovation including smart grid technologies.

2.3. Knowledge gaps

Government and market actors have important roles to play in energy transitions. There are however four knowledge gaps. First, there is a lack of theoretical linkage between the socio-technical transitions literature and energy governance studies. The conceptualisation of the complex government-market dynamics in which regime and niche actors interact and subsequently influence transition pathways has not been well developed. Specifically, while the intensive interactions between government and market has become a feature of energy governance in recent decades, the dilemmas faced by government and market actors, and the interplay between enabling forces and constraining forces for change in energy transitions, have not been well conceptualised.

Second, the function frameworks of the TIS literature (see, for example, Haley, 2018) are not sensitive to some critical functions in the specific technological context of SGs, including managing public goods and policy learning. Third, few studies have systemically examined the socio-technical energy transitions perspectives in Asia (see, for example, Mori, 2017, 2018; Wolfram, 2018), and SG technologies in particular (see, for example, Mah et al., 2012, 2013, 2017). Fourth, studies on systematic cross-national socio-technical energy transitions are lacking.

Table 1
The five functions of government-market dynamics in socio-technical energy transitions: An integrated conceptual model.

	Indicators (A function where…)	Description and contemporary examples
F1:Market Formation	F1/I1: Government develops visions and clear policy objectives in order to provide guidance of technological search, create stable market conditions for future investment (IEA, 2015; Quitzow, 2015; Shen et al., 2014; World Economic Forum, 2010); F1/I2: Public policies introduce pricing signals of energy products (Quitzow, 2015); F1/I3: Government can facilitate cost reduction through economies of scale (Trindade et al., 2017).	• Government develops a SG national roadmap (Mah et al., 2012); [F1/I1] • Government policies create favourable market environments for business models (Gabriel and Kirkwood, 2016) and a diversity of financial channels (Dong et al., 2016); [F1/I1] • Public policies can drive utilities and private entities to invest in renewable energy and demand response technologies (IEA, 2015; Quitzow, 2015; (Shen et al., 2014; World Economic Forum, 2010); [F1/I1] • Government introduces carbon taxes, renewable feed-in-tariff policies which partially address the issues of externalities and can create new markets (Quitzow, 2015); [F1/I2] • Government create substantial domestic market demand through public procurement (Trindade et al., 2017).[F1/I3]
F2:Market Regulation	F2/I1: Government sets the rules, monitors market actors' behaviour, enforces rules, and penalises misbehaviour; F2/I2: Government introduces electricity market reforms which can open up market structure, and create a level-playing-field that is conducive to new market entrants (Brunekreeft et al., 2015); F2/I3: Government sets up incentive structure in order to influence the uptake of different types of technologies.	• In regulated markets, governments ensure transparent and fair grid access rules for low-carbon generation (IEA, 2015); [F2/I1] • In liberalised market, governments need to introduce policy instruments that increase investment certainty in low-carbon technologies (IEA, 2015); [F2/I1] • There is a growth of new market actors who can be competitors to incumbents (Brunekreeft et al., 2015); [F2/I2] • Government sets up incentive systems to decouple revenue so as to allow utilities to cover fixed costs regardless of energy sales and remove their disincentives to implement large-scale renewable development (Zpryme, 2014).[F2/I3]
F3: Managing public goods	Government intervenes to ensure a minimal level of provision of public goods which do not have immediate market appeal and are often vulnerable to free-riding and overuses (Mattes et al., 2015; Popa, 2015). Three main types of public goods which are highly relevant to technological innovation: F3/I1: R&D and demonstration activities; F3/I2: Standardisation; F3/I3: Information sharing. These government interventions aim to ensure fair competition and enable the creation of new market projects and services such as energy management solutions (Buchmann, 2017; Cuijpers and Koops, 2013; EDF, 2017; IEA, 2017; Lin and Monga, 2010; Mah et al., 2014; Van Vliet et al., 2016).	In relation to R&D and demonstration activities: • Government and market interactions can foster R&D activities to facilitate experiments in alternative technologies, validate customer response, etc. (Mah et al., 2013); • Government can provide public funding for the R&D and demonstration of SG technologies. Such government-funded projects could emerge in the forms of start-up programme, research labs, and demonstration projects. [F3/I1] In relation to standardisation: • Standards are developed to enable interoperability of smart grid-related products (such as smart meters) and systems in order to reduce costs and improve efficiency (Muto, 2017). This is critical to technological diffusion from R&D to market deployment (Beerepoot & Beerepoot, 2007; IEA, 2015); • Non-government bodies, such as public–private partnership can be set up and tasked with driving the coordination of smart grid standards interoperability. An example: the Smart Grid Interoperability Panel in the U.S. (Muto, 2017). [F3/I2] In relation to information sharing: • Governments can invest in the collection, generation, processing, and dissemination of massive amounts of energy usage data, and to make such information available freely to firms. • Governments introduce regulations and policies to address privacy issues; third parties and industrial associations can also introduce initiatives (see, for example, Milaj et al., 2016). [F3/I3]
F4: Networking and resource mobilisation	F4/I1: Linkages can be built between governments and other stakeholders to mobilise human, financial, and physical (e.g. infrasturucture) resources from the private, public, and societal sectors for technological innovation (Haley, 2018; Polzin, 2017).	• Government can initiate and/or facilitate the formation of networks between utilities and new market players, between academics and industries, between buyers and suppliers, and between global and local networks (Polzin, 2017); [F4/I1] • The existence of R&D collaboration, university-industry links, regional clusters, supply chain, financial networks (Faulkner and Senker, 1994; Mah et al., 2017). [F4/I1]
F5: Policy learning	F5/I1: Policy learning is a policymaking process in which policy makers and policy stakeholders deliberately adjust the goals, rules and techniques of a given policy in response to experiences and new information (Hall, 1993).	• A policymaking process which emphasises trial-and-error and experimental approaches: learning from the past, increased knowledge of the problems (including the problem attributes and the factors affecting them), adjustments, feedback loops (Sabatier, 1988) (e.g. collect feedback from energy end-users) (ISGAN, 2017);[F5/I1] • The development of new policies which reflect significant departures from previous responses to public problems (Deyle, 1994);[F5/I1] • Knowledge transfer between policy stakeholders and that involves the diffusion of new technology, knowledge, and information (Edler et al., 2011; Herrera et al., 2010; Kuada and Mensah, 2018). [F5/I1]

2.4. Towards an integrated framework: Functional dynamics of government and market in energy transitions

This study develops an integrated framework that links theoretical approaches on multi-level perspectives, functional approaches of TIS, and energy governance. It comprises two dimensions. The first dimension highlights the five critical functions of government-market interactions in energy transition. Based on the literature, we specify five functions are: market formation (Quitzow, 2015; Trindade et al., 2017), market regulations (Brunekreeft et al., 2015), managing public goods (Buchmann, 2017; Mah et al., 2014; Van Vliet et al., 2016), networking and resource mobilisation (Haley, 2018; Polzin, 2017), and policy learning (Hall, 1993). The second dimension specifies the indicators and mechanisms of each function (Table 1).

The novelty of this proposed conceptual framework is that it focuses on government-market dynamics while specifically conceptualising how the interactions of government actors and market actors could be optimised and become *functionally* desirable. The premises behind this framework are that (1) government actors and market actors are interdependent; (2) they need to interact in the five functions which are critical to the deployment of smart grids; and (3) the more the government actors interact with market actors, the greater the potential for favourable conditions that can foster niche accumulation and regimes shifts.

In this study, *government actors* are represented by government agencies, administration entities, government regulators, government officers (Shen, 2017). *Market actors* are broadly understood as private entities which are profit-maximisers. Typical market actors associated with the SG sector include renewable energy investors, renewable energy generation and equipment manufacturers, solar installers, energy service companies, information and communication corporations, alternative energy automotive companies, and home appliance companies (Mah et al., 2017).

In between traditional government and market actors, there exist quasi-government actors which are affiliated with the state. State-owned utility companies, government-affiliated intermediary organisations, quasi-autonomous government agencies, and government-initiated foundations fall into this category. They differ from market actors whose actions are primarily profit-driven (Kivimaa, 2014). Some of these quasi-government actors in the field of SGs include the state-owned power utilities in China, and the city-based Project Facilitation Committees in the four smart community demonstration projects in Japan. Political obligations also play a role in influencing the decisions and actions of these quasi-government actors (Mah, 2019; Mah et al., 2017).

3. Methodology

3.1. Research questions and a comparative case study approach

To fill the knowledge gaps, this study addresses the following research questions:

(i) How do government actors and market actors interact?
(ii) To what extent and how do the observed government-market interactions re-inforce the "lock-in" effect of established energy technology, and/or weaken the established regimes?
(iii) Are there distinctive elements of such government-market dynamics across the two cases? If so, what could be the explanatory factors of such differences?

This study adopts a comparative case study approach. Each case study country is considered and analysed as a whole case, followed by comparison across cases (Yin, 2013). We identify similarities and differences in the government-market dynamics across China and Japan. Through reconciling evidence across cases, a comparative case study approach allows for new theoretical insights through comparing and contrasting (Chesbrough and Burgelman, 2001; Eisenhardt, 1989). A comparative study can also help enhance robustness in analysis by reducing researcher bias which may result from armchair and axiomatic deduction (Chesbrough and Burgelman, 2001; Eisenhardt, 1989).

3.2. Case context

China and Japan are both major economies in Asia but their socio-economic and political systems differ in many aspects (Table 2). China surpassed Japan in 2009 and has ranked second in the world in terms of GDP since then (World Bank, 2016). China, with a coal-based electricity sector, has become the world's largest GHG emitter since 2007. In Japan, the Fukushima nuclear accident in 2011 has forced the country to reduce its use of nuclear energy from 29% in March 2011 to 1.7% in 2016 (WNA, 2018; Interviewee: JP/14/2018). Both countries need to envision, develop, and deliver energy transitions which are required to secure significant amounts of low-cost, low carbon electricity while managing nuclear energy as a controversial energy option (IEA, 2016; Mori, 2017, 2018). These two countries have committed to international climate goals including the recent Paris Agreement goals (METI, 2017; Zhang, 2017). Such commitments have been reflected in major national energy plans including China's Five-year Plans (NDRC, 2016) and Japan's recent 5th Strategic Energy Plan (SEP) (METI, 2017, 2018).

China and Japan have been developing SG in different ways. China is a late-comer but a fast-mover. China's utility-led approach started in the late 2000s when the two state-owned monopoly grid companies, the State Grid Corporation of China (SGCC) and China Southern Power Grid (CSG), launched major SG plans. Since then, China has focused on building super-grids with ultra-high voltage across the nation (Mah et al., 2017; Zpryme, 2011). Japan's model, on the other hand, is community-based mainly operated through the establishment of four large-scale smart-community demonstration projects (also known as Demonstration Projects for Next Generation Energy and Social Systems (ITA, 2016) in four cities namely *the Keihanna Eco City* (in Keihanna Science City which extends across Kyoto, Osaka, and Nara Prefectures), *Kitakyushu Smart Community* (in Fukuoka prefecture), *Toyota Low Carbon Community* (in Aichi prefecture), and *Yokohama Smart City* (in Kanagawa prefecture (Pham, 2014). These projects were all started in 2010 and completed in 2014.

Electricity market reforms which are still on-going in both China and Japan have a major influence on the SG developments. The 2002 electricity market reform in China marked the end of the vertically integrated system by separating power generation from power grid sectors. The reform also introduced competition in the generation sector. SGCC and CSG, and five state-owned power generation companies (commonly known as the Big Five) have however remained the dominant players until now. Japan, on the other hand, Japan has been advancing electricity market reforms since 1995. Among a number of major changes (Table 2), Japan has completed the liberalisation of the retail sector in April 2016 by extending competition from large electricity end-users to residential end-users (Shinkawa, 2018). At present,

Table 2
An overview of China and Japan and features of their SG developments.

Features	China	Japan
Economic and socio-political systems	GDP: US$11.62 trillion (2016) Population: 1.382 billion (2016) Economy: rapidly industrialising Politics: centralised, authoritarian society	GDP: US$4.891 trillion (2016) Population: 126.9 million (2016) Economy: high-tech industrialised Politics: a representative democratic political system with a strong bureaucracy
Electricity sectors	Total installed capacity (2017 data): 1777 GW; thermal: 62.24%; hydro: 19.2%; wind: 9.21%; solar PV: 7.32%; nuclear: 2.02%.	Total installed capacity (2015 data): 324 GW; coal: 24%; gas: 47%; oil and other: 19%; hydro: 6%; nuclear: 2%.
Electricity market reforms	Partial, ongoing reforms: ● 2 state-owned regionally monopolised grid companies. ● 5 major state-owned generation companies with competition. ● Retail market has not been liberalised yet. ● State Electricity Regulatory Commission (SERC), the "independent" regulator, dissolved in 2013; regulator function subsumed to NEA under NDRC.	Partial, ongoing reforms: ● 10 vertically-integrated incumbent utilities; all are privately-owned, except TEPCO.[1] ● Some new players (e.g. renewable energy suppliers). ● Since 2003, wholesale market has been opened up with the establishment of Japan Electric Power Exchange (JEPX). ● In 2015, two new regulatory bodies Organisation for Cross-Regional Coordination of Transmission Operators (OCCTO) and the Electricity and Gas market Surveillance Commission (EGC) were set up to oversee cross-regional transmission plans and to enhance fair competition. ● Starting from April 2016, retail market liberalisation completely liberalised: competition expanded from large end-users to residential end-users. ● Transmission and distribution sectors have not been liberalised yet; reforms expected to be fully completed by 2020.
SG developments	Incumbent-led model: two regionally monopolised grid companies focus on building super-grids with super high voltage and high capacity across China.	Government-led, community-oriented, and business-driven model. Four large-scale smart community demonstration projects in Yokohama City, Toyota City, Kyoto Prefecture and Kitakyushu City (2010–2014).

Source: Author; data: *China's basic characteristics*: NBSC (2017); *Japan's basic characteristics*: CabinetOffice (2016); Jones and Ström (2018); Mishima (2013); Statistic Bureau (2016); *China's electricity sector*: China Energy Portal (2018); UNSD (2015); *Japan's electricity sector*: Shinkawa (2018); UNSD (2015); *China's SG developments*: Mah et al. (2017); Zpryme (2011); *Japan's SG developments*: Mah et al. (2013); Zpryme (2012).

[1] TEPCO has been nationalised in 2012 in the aftermath of the Fukushima nuclear accident.

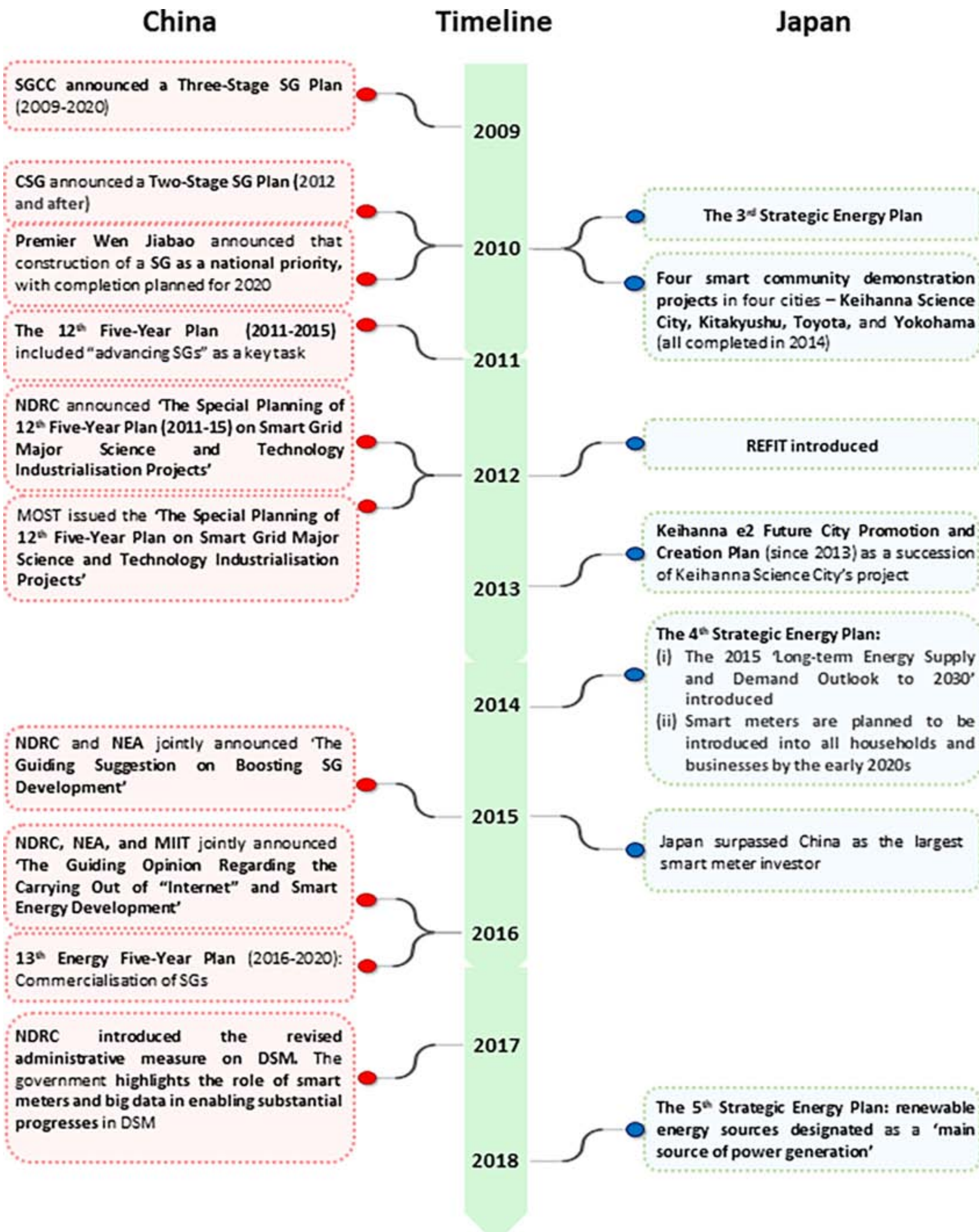

Fig. 1. The chronological development of major SG-related policy initiatives in China and Japan. Sources: *China*: IEA (2011); Mah et al. (2013, 2017); NDRC and NEA (2015); NDRC (2017, 2018); The Trade Council (2013); *Japan*: ITA (2016), Mah et al. (2013, 2017), METI (2014), Zpryme (2012).

the market is still dominated by 10 vertically integrated electric power companies (EPCOs) which are all privately-owned, except the Tokyo Electric Power Company (TEPCO) which was nationalised in 2012 in the aftermath of the Fukushima nuclear accident (Tanaka, 2013). Competition has not been introduced in the transmission and distribution sectors.

Table 2 below provides an overview of the two case countries in terms of their economic and socio-political features, characteristics of their electricity sectors, major developments of their electricity market reforms, and features of their SG developments. Fig. 1 below highlights the chronological developments of major SG-related policy initiatives in the two countries.

3.3. Data collection and analysis

This study draws on data and information derived from desktop research, semi-structured interviews, and field visits as well as secondary data, including policy documents, legislation, industry reports, news reports, and academic publications. The completion reports of Japan's four smart community demonstration projects and a large number of meeting reports of various energy-related committees made publicly available at the government website provide a wealth of detailed and credible data for the case study of Japan.

A main source of our data comes from semi-structured interviews with 38 interviewees conducted in Beijing, Guangzhou, Foshan, Tokyo, Kyoto, and Hong Kong between 2012 and 2018, involving six field trips. Several rounds of interviews provided this study a better understanding of the evolving developments of the subject matters in the respective national contexts. The interviewees were carefully selected informants knowledgeable about the subject issues studied (Johnson, 1990). They were drawn from a range of stakeholder groups, including national and local government, energy utilities, independent power producers, SMEs, energy services companies, private solar installers, private consultancy, academia, and researchers. All interviews were face-to-face interviews, lasting from 30 min to two hours each. All interviews were recorded and transcribed. A grounded theory approach was used to identify themes, commonalities, and differences across interviewees (Charmaz, 2006; Strauss and Corbin, 1997). Four site visits were conducted in Sino-Tianjin eco-city (in Tianjin, China) in 2014, Yokohama smart community project in 2015, and Keihanna Science City Next Generation Energy and Social Systems Demonstration Project (two visits; in 2016 and 2018).

Various analytical techniques were employed to enhance the robustness of the findings including the use of the integrated framework to guide each case study, pattern matching, cross case synthesis (Miles et al., 2014; Yin, 2013), and triangulation of data derived from multiple sources including primary data from semi-structured interviews, direct observations from site visits, and secondary data sources (Creswell, 2014).

4. Findings and discussions

4.1. China's SG development and the key functions of government-market dynamics

4.1.1. Market formation

The Chinese government has not introduced an explicit national SG plan. The national SG policy framework underpinned by major national energy plans such as the 13th Energy Five-year Plan is also rather loose. But the SG plans introduced by the two grid companies in 2009 and 2010 alongside a number of effective SG-related policies introduced by the NDRC, most notably the renewable energy feed-in tariffs (REFIT) (Zhang et al., 2017a, 2017b), have effectively driven the growth of the domestic market associated with SG technologies. SOEs are major investors in China's SG sector. SGCC and CSG were expected to invest RMB 1.6 trillion and RMB 66 billion in SGs, primarily for grid infrastructure and smart meter installations (Mah et al., 2017; The Trade Council, 2013). The Big Five, the state-owned generation companies, on the other hand, dominated investments in utility-scale wind farms and solar PV projects (Zhang et al., 2017a, 2017b; Interviewees: CH/14/2015; CH/22/2017).

Private investment beyond the state-owned companies has remained limited (CH/05/2014). New market entrants in, for example, the energy services sector, are emerging but their growth has been modest. Some of these energy services companies are subsidiaries of SGCC and CGS, and are literally state-affiliated market actors (interviews: CH/14/2015; CH/16/2015).

State-owned banks and insurance companies also started to play some critical roles in SG deployment in China. In Guangdong, for example, the state-owned Bank of China, and People's Insurance Company of China (PICC) provide solar loans and solar insurance for solar houses (Han, 2016; Li and Luo, 2017; Interviewees: CH/22/2017; CH/23/2017).

4.1.2. Market regulation

Even though Chinese grid companies are required by national regulations to allow grid access to renewable sources, disincentives to facilitate large-scale grid connection to intermittent renewable sources have remained. These disincentives are the result of the lack of effective incentive schemes to offset the additional costs of ancillary grid facilities for grid companies. Delays in grid connections are not uncommon (Interviewees: CH/05/2014; CH/18/2016). Significant amounts of wind power and solar electricity have to be curtailed due to grid congestion (Brunekreeft et al., 2015; Interviewees: CH/18/2016; HK/01/2018).

Secondly, regulations are lagging behind in supporting new market entrants. A good example is the Sino-Singapore Tianjin Eco-city project in which a prospective electricity retailer (Keppel Group) faced difficulties in entering the electricity retail market. Keppel Group, a district cooling systems developer and operator originated in Singapore, was the provider of water, gas, and heat for the eco-city which was initiated in 2007. Keppel is also an investor of a solar project in the eco-city. Keppel could have entered the electricity by selling renewable electricity. As new regulations have not been introduced to open up the residential retail market (Interviewee: CH/06/2014), Keppel cannot be regarded as an eligible retailer and so this market development cannot take place in Tianjin (Interviewee: CH/11/2014; Site observation).

Thirdly, pricing-setting is a major regulatory function but pricing signals do not function effectively in the China's retail electricity market. Electricity retail prices for residential end-users have been set lower than average generation costs to contain inflation (Brunekreeft et al., 2015). The Chinese government has introduced a three-tier-based tariff to residential customers since July 2012, and opt-in time-of-use tariffs since December 2013 (Mah et al., 2018). However, responses from residential electricity end-users have been lukewarm. In Foshan, one of the pilot cities of China's national demand-side-management programme, only a handful of households voluntarily subscribed to time-of-use tariffs with negligible impacts (Interviewees: CH/19/2017; CH/20/2017).

4.1.3. Managing public goods

The Chinese government has relied on the state-owned utilities to provide some key SG-related public-good services. Firstly, in relation to *R&D activities*, the two grid companies act as the key implementors of most SG pilot projects funded by the Ministry of Science and Technology (MOST), the top government agency in charge of China's national S&T programmes. SGCC led key pilot projects include the Sino-Singapore Tianjin Eco-city project and the 2010 Shanghai World Expo pilot (IEA, 2015; The Trade Council, 2013). By 2011 SGCC alone implemented approximately 240 SG pilot projects which ranged from connecting wind power plants to metering households (The Trade Council, 2013). In recent year, the involvement of SGCC has become even more institutionalised through a new funding scheme "The NSFC-SGCC Smart Grid Federation Foundation". The scheme has been jointly launched by SGCC and the National Natural Science Foundation of

Table 3
Major non-energy industries which are active in the Japan's SG sector.

	Examples
Real estate	Daiwa House, Ichijo, Mitsui Fudosan, Misawa Home, Mitsubishi Estate Home, Toyota Home Mitsui Fudosan
Consumer electronic manufacturers	Toshiba, Mitsubishi Electric, Panasonic
Telecommunication	AU, Softbank
Automobile	Toyota

Sources: Adshead and Thorpe (2007); IEA (2016); Mah et al. (2013); Site observation.

Fig. 2. Photo credit: Author, 2015. Household solar PV systems are marketed as a "household appliance" side-by-side with microwaves and refrigerators in this Toshiba's customer service centre in Tokyo. Toshiba provides one-stop-shop service from solar assessment to PV panel installation to solar households.

China since 2017 (NSFC, 2017; Wang, 2017).

In terms of *standardisation,* since SGCC, CSG and the Big Five have established a strong internal supply chain, they have taken the lead in developing their own specifications and standards for the SG industry (Mah et al., 2017; Zpryme, 2014; Interviewee: CH/01/2014).

In terms of data and information sharing, a National Demand-side-management Platform was launched in 2014 as a major state-led initiative (JSDSM, 2018). This Jiangsu-based platform involves collaboration between the Economic and Information Commission of Jiangsu Province, other government agencies, SGCC and CSG. The objective of this Platform is to facilitate sharing of electricity consumption data (Interviewee: CH/03/2014). The institutionalisation of this Platform has been strengthened recently as the NDRC introduce a revised administrative measure in 2017. That administrative measure emphasises the use of big data analytics as major approaches to engaging electricity end-users and developing new energy projects and services (NDRC, 2017).

However, it is important to note that the extent to which information can be effectively consolidated, shared, and enabled big data analytics has remained an area of concern. Some academics encountered difficulties in requesting electricity data from power utilities. An academic commented that:

> "We filed a request to the Tianjin Municipal Electric Power Company (a subsidiary of SGCC) for electricity data but they cannot provide the data to us. There are management problems associated with data collection. Moreover, even though the data are collected, no one uses them. The power company also has no idea how to analyse the data" (Interviewee: CH/09/2014).

4.1.4. Networking and resource mobilisation

SG developments in China have provided opportunities for the government to reach out to a wide range of market actors and quasi-government actors through different types of networking. Some locally grown industrial networks have emerged. The smart grid industrial cluster in Yangzhou, Jiangsu province (MOST, 2016), and the solar PV-industrial cluster in Sanshui City, Guangdong province are some examples (SEMI, 2014; Interviewees: CH/21/2017; CH/22/2017). The alignment of local industrial growth and low-carbon energy policies has become a key motive for local governments to implement central policies (Interviewee: CH/21/2017). These industrial networks are active in mobilising private investments in solar PV and micro-grid projects (SEMI, 2014; Interviewees: CH/21/2017; CH/22/2017). However, when compared to the financial inputs from the state-owned power utilities, the financial resources and human capital mobilised from private SMEs has been relatively minor (Interviewee: CH/22/2017). In addition to industrial networks, financial networks that link state-owned banks and state-owned enterprises have found to be critical in channeling preferential low-interest loans to state-owned utilities (Mah et al., 2017).

4.1.5. Policy learning

China is a geographically extensive country with a great diversity of local socio-economic contexts. A bottom-up and experimental approach is therefore particularly needed to formulate effective SG policies in China (Interviewees: CH/04/2014; CH/05/2014). The intensive direct communication between the NDRC and power utilities, often in the form of policy consultation meetings and working meetings, has been a useful means for policy-makers to invite direct and timely feedback from the industry (Interviewees: CH/04/2014; CH/05/2014; Shen, 2017). In addition, the Energy Research Institute (ERI), and the China National Renewable Energy Centre (CNREC), both under the National Development and Reform Commission, serve as the think tanks of the central government contributing to the important process of policy learning (Brunekreeft et al., 2015; Interviewee: CH/03/2014). The continuous downward adjustment of the REFIT policy for wind power and solar PV is an example of how trial-and-error and experimental approaches to policymaking take place in China (Interviewees: CH/18/2016; CH/24/2018).

China's energy policy-making system has however been characterised as a fragmented authoritarian one. It is a top-down, closed, and fragmented system (Lema and Ruby, 2007; Lo, 2015). China's project-based approach for conducting SG R&D and demonstration projects is also not conducive to policy learning. Feedback loops and peer learning among SG pilot projects were limited (Interviewee: CH/09/2014).

On the other hand, although residential end-users were not responsive to dynamic pricing systems, the Chinese government was unresponsive to market feedback. Political considerations associated with tariff changes appears to constrain the government from introducing more radical pricing schemes to incentivise customers (Interviewees: CH/20/2017; CH/22/2017).

Table 4

A comparison between government-market dynamics associated with SG diffusion in China and Japan.

Governance Modes	China Hierarchy; fragmented; homogeneity	Japan Bottom-up; coordination; diversity
Active actors	● Central government; two state-owned geographically monopolised grid companies; five major state-owned power generation companies; state-affiliated entities (e.g. state-owned banks; state-owned insurance company).	● Central and city governments; incumbent utilities; incumbents from non-energy industries such as real estate and telecommunication industries, intermediaries (including ESCOs, new energy suppliers, demand response aggregator).
F1: Market Formation	● Grid company-led SG plans and effective SG-related renewable policies created sizable domestic markets. [F1/I1] ● Dominance of the two state-owned grid companies alongside an early emergence of new market entrants and new energy products. [F1/I1, I2] ● Incumbent grid companies introduced incremental changes, but there is a lack of agents of change who made radical moves. [F1/I1] ● Government relied on SOEs for SG investment that drove down costs [F1/I3]; but not effective in mobilising private finance. The Big Five contributed to more than 50% of wind farm investment in 2013 (Shen, 2017). [F1/I1] ● Demand response programmes experienced minimal growth with lukewarm responses from residential end-users. [F1/I2]	● Active in national energy roadmapping exercises which have included SGs as a key element. [F1/I1] ● Effective renewable policy led to strong growth of residential solar PV. [F1/I1, I2, I3] ● Incumbent utilities active in SG deployment. Modest growth of new market entrants from non-energy sectors – primarily from real estates and telecommunication sectors. [F1/I1] ● Some are small private companies such as renewable energy suppliers, ESCOs. [F1/I2] ● Niche markets: demand response exists beyond pilot projects, and is emerging in the electricity market but not yet active (GSGF, 2016). [F1/I2] ● Government effectively opened up SG investment to the private sector through the four large SG demonstration projects. [F1/I1] ● Residential electricity customers involved based on pricing signals. [F1/I2]
F2: Market Regulation	● New laws and regulations introduced but lagging behind to support market development e.g. new regulations on grid connection, but grid connection remained hindered. [F2/I1] ● Partial electricity reforms: monopolistic market in power grid sector; some competition in generation but dominated by SOEs [F2/I2]; no new entrant in the retail market which is not yet open. [F2/I2] ● Moderate incentive for SOEs to invest in renewable [F2/I3] ● Lack of an independent market regulator. State Electricity Regulatory Commission was dissolved in 2013. Since then, the regulatory function has been subsumed under the National Energy Administration of the NDRC. [F2/I1]	● Retail market reform in 2016 triggered incumbents to introduce new business and models for demand response programmes. Kansai Electric has been keen to develop new business models particularly because of the opening up of the retail market. [F2/I2, I3] ● Noticeable growth of new retail suppliers and demand response aggregator (Enel, 2018). [F2/I2] ● Incentive systems: Regulations and a new "system operator" (OCCTO) set up but grid connection for major uptake of RE hindered due to the lack of cross-regional grid connection. [F2/F2/I1]
F3: Management of public goods	● Government R&D policy and funding provided incentives of the two grid companies and the state-owned enterprises to invest in SG R&D activities and standardisation initiatives.[F3/I1, I2] ● Public good issues in relation to standardisation and information sharing did not play an important role in the government SG policies.[F3/I2, I3] ● R&D and demonstration activities: Project-based approach – addressed R&D problems by the traditional way of organising R&D projects (e.g. 863).[F3/I1] ● R&D focused on technological break-through; less attention to business model innovations. [F3/I1]	● The government has emphasised the public good character of SGs in terms of R&D, standardisation, and information sharing. [F3/I1, I2, I3] ● Government relied on incumbent conglomerates such as Toyota, Toshiba, Panasonic which have strengths in in-house R&D capacity.[F3/I1] ● R&D has a strong focus on the residential sector and consumer engagement projects. [F3/I1] ● Standardisation received great government attention. [F3/I2] ● Information sharing: some initial attempts to open up consumers' electricity consumption data in pilot projects. [F3/I3]
F4: Network and resource mobilisation	● SOEs possess strong networks – to access human resources, financial resources, and infrastructure resources. [F4/I1] ● Industrial networks grew in number; but remained small in scale and lacked a systemic approach to mobilise substantial financial and human resources. [F4/I1]	● The four large SG demonstration projects: developed extensive and dense network between industries and university. [F4/I1] ● Keihanna: Proximity to R&D clusters and local culture [F4/I1] ● NEDO: proactive role in strengthening and expanding international energy innovation networks. [F4/I1]
F5: Policy learning	● Direct, intensive communications between NDRC and incumbent utilities.[F5/I1] ● Fragmental authoritarian policy-making traditions; relatively closed system. [F5/I1] ● End-users not active in feedback process. [F5/I1]	● A wide range of public, market, and societal actors build knowledge on SGs. [F5/I1] ● Government: continuous monitoring to feedback result. [F5/I1] ● Inclusive decision structure; expert-led, user-oriented policy-making structure; strong focus on feedback from (1) local governments, (2) experts (local and overseas), (3) industry), and (4) End-users (consumers). [F5/I1] ● Inclusive and learning processes have built up competence of the government in making energy decisions. [F5/I1] ● Institutionalised policy-making processes are in place to invite stakeholder feedback. [F5/I1]

Source: Author's interviews, unless otherwise indicated.

4.2. Japan's SG developments and the key functions of government-market dynamics

4.2.1. Market formation

A defining feature of Japan's energy policy-making is its traditional competence in developing long-term energy roadmaps which emphasise a systemic approach to guiding energy transitions (METI, 2014, 2017; NEDO, 2010). SGs have been incorporated in all major national energy roadmaps in recent years (Fig. 1), showing the Japanese government's commitment to fostering structural change in industries and markets to support SG technologies. The Fifth Strategic Energy Plan (SEP), which was approved by the Japanese Cabinet in early July 2018 is a good illustrative example of this systemic approach. The SEP designates renewable energy as the country's main source of power, emphasising storage batteries as a key "next-generation technology" and SGs as enabling technologies (METI, 2018; Yūzō, 2018). Such as systemic approach is also evident in Japan's renewable energy policies. One of the key objectives of renewable energy policies in Japan is to transform solar PV systems into "household appliances" which are supported by household rechargeable batteries and smart meters (METI, 2012a), and the wider real estate industry as we will discuss in sequent sections.

Alongside this approach, a policy-driven market formation process is also evident in Japan. The surplus electricity purchase system introduced in 2009 and the renewable feed-in tariff policy introduced in 2012 have led to a substantial increase in renewable energy, particularly in residential solar developments (METI, 2012a; Muhammad-Sukki et al., 2014). Solar PV installed capacity rose from 5 gigawatts (GW) in 2011 to 42 GW in 2016, which is more than nuclear power capacity (REI, 2017). Residential use of solar PV accounts for 80% and non-residential use accounts for 20% of output. The ratio is the opposite in Europe and the US (METI, 2012a).

It is evident that Japan's policy approaches have influenced the formation of SG-related energy markets in at least two important ways. Firstly, even though the 10 vertically integrated utilities played prominent roles in SG development, an enterprise-driven approach with a large number of corporates from other industries actively participating in the SG market is also evident. These non-energy corporates in the SG sector include real estate agencies, consumer electronics manufacturers, ICT firms, and automobile corporations (Adshead and Thorpe, 2007; IEA, 2016; Mah et al., 2013) (Table 3).

Secondly, when compared with the Chinese model, the Japanese model is more advanced in developing SG-related markets for new energy products and services have emerged. Electric appliance manufacturers such as Toshiba have entered the market, providing one-stop-shop services for solar households (Fig. 2). Major house builders have been active in SG developments as they regard "smart homes" as a way to differentiate their product and appeal to new customers. Sekisui House partner, which holds a Guinness World Record for "the most solar powered houses built" (PV Science, 2013), have partnered with domestic battery suppliers to build solar houses already equipped with batteries for householders to store solar electricity (Interviewee: JP/08/2015; site observation).

4.2.2. Market regulation

The private sector is much more prominent in SG developments in Japan than in China for three reasons. Firstly, the ten EPCOs, which are all private companies except TEPCO, have been key players in smart community demonstration projects. Kansai Electric, for example, has played a leading role in the Kansai Science City demonstration project (Interviewees: JP/10/2018; JP/11/2018). Secondly, the completion of the retail market liberalisation in April 2016 has led to a noticeable growth in the number of electricity retailers: as of January 2018, there were 453 small electricity retailers (小売電気事業者) and 19 "designated electricity suppliers" (特定送配電事業者) registered under METI. Both types of retailers are regarded as Power Producers and Suppliers (PPS; 特定規模電気事業者),[1] providing electricity to meet approximately 7% of total electricity demand in the residential sector in 2017 (Shinkawa, 2018).

Thirdly, in contrast to the Chinese market in which residential end-users have remained passive, Japanese residential electricity customers have become more active customers as they now have choices. According to government data, approximately 820,000 customers (about 1% of all residential customers of the 10 EPCOs)[2] switched electricity suppliers by the end of April 2016 (IEA, 2016) – a noticeable record that was made only in one month after retail market was liberalised on the 1st of April. The number of customers switching suppliers increased to 4.6 million by September 2017 (Shinkawa, 2018). About 3 million customers (about 5%) switched to other tariff menus (e.g. time-of-use menus) (Shinkawa, 2018; Interviewee: JP/11/2017, 2018). Such changes in customer demand have driven the EPCOs to develop new business models in order to remain competitive (REI, 2017; Interviewee: JP/11/2017, 2018).

In contrast to the retail market, liberalisation in the transmission and distribution sectors has however made moderate progress, presenting major constraints on mainstreaming renewable. Cross-regional grid interconnection and cross-regional electricity transactions have remained very limited. The establishment of the Japan Electric Power Exchange (JEPX) in 2003 represents important progress but its impacts have been limited. JEPX, for example, only traded 1.3% of total retail market sales in 2013 (METI, 2015). In 2015, the Japanese government set up two new regulatory bodies, Organisation for Cross-Regional Coordination of Transmission Operators (OCCTO) and the Electricity and Gas market Surveillance Commission (EGC) to oversee cross-regional transmission plans and to enhance fair competition. Renewable energy contributed only 4.7% of the national electricity generation in 2015 (Shinkawa, 2018) and the renewable target set in the 5th SEP is significantly lower than similar targets set by other G7 countries (Bungate, 2018). It has been widely expected in the industry that major deployment of renewable would only be realised when the market reforms are fully completed with competition expanded to the transmission and distribution segments by 2020 as scheduled (ITA, 2016; METI, 2015; Shinkawa, 2018).

4.2.3. Public goods

The Japanese government has proactively engaged market actors to address major SG-related public goods issues. Regarding R&D and demonstration projects, the METI, as the central government agency responsible for all energy policies, proactively engaged the business sector through the establishment of the four large-scale smart community demonstration projects. The projects provided major testbeds for the corporates to test whether the functionality and benefits of SG technologies can be realised in the local context (Mah et al., 2013; Interviewees: JP/10/2018; JP/11/2018).

As it aspires to attain a leading position in global markets, the Japanese government has placed standardisation at the forefront in its SG development strategies. The New Energy and Technology Development Organisation (NEDO), the representative of the METI abroad for smart city projects, has been a key driving force of these standardisation initiatives (NEDO, 2010; Interviewee: JP/10/2018). Alongside NEDO's initiatives, a major government initiative was the introduction of the International Standardisation Roadmap for Smart Grid in 2012 which was supported by the establishment of the Working Group on International Standardisation of SG in the same year (Mah et al., 2013).

[1] PPS is different from independent power producers (IPP) while PPS do not possess their own grids and transmission systems and have to rely on utilities for electricity transmission.

[2] There were 77.3 million residential customers under the 10 EPCOs in 2015 (METI, 2015).

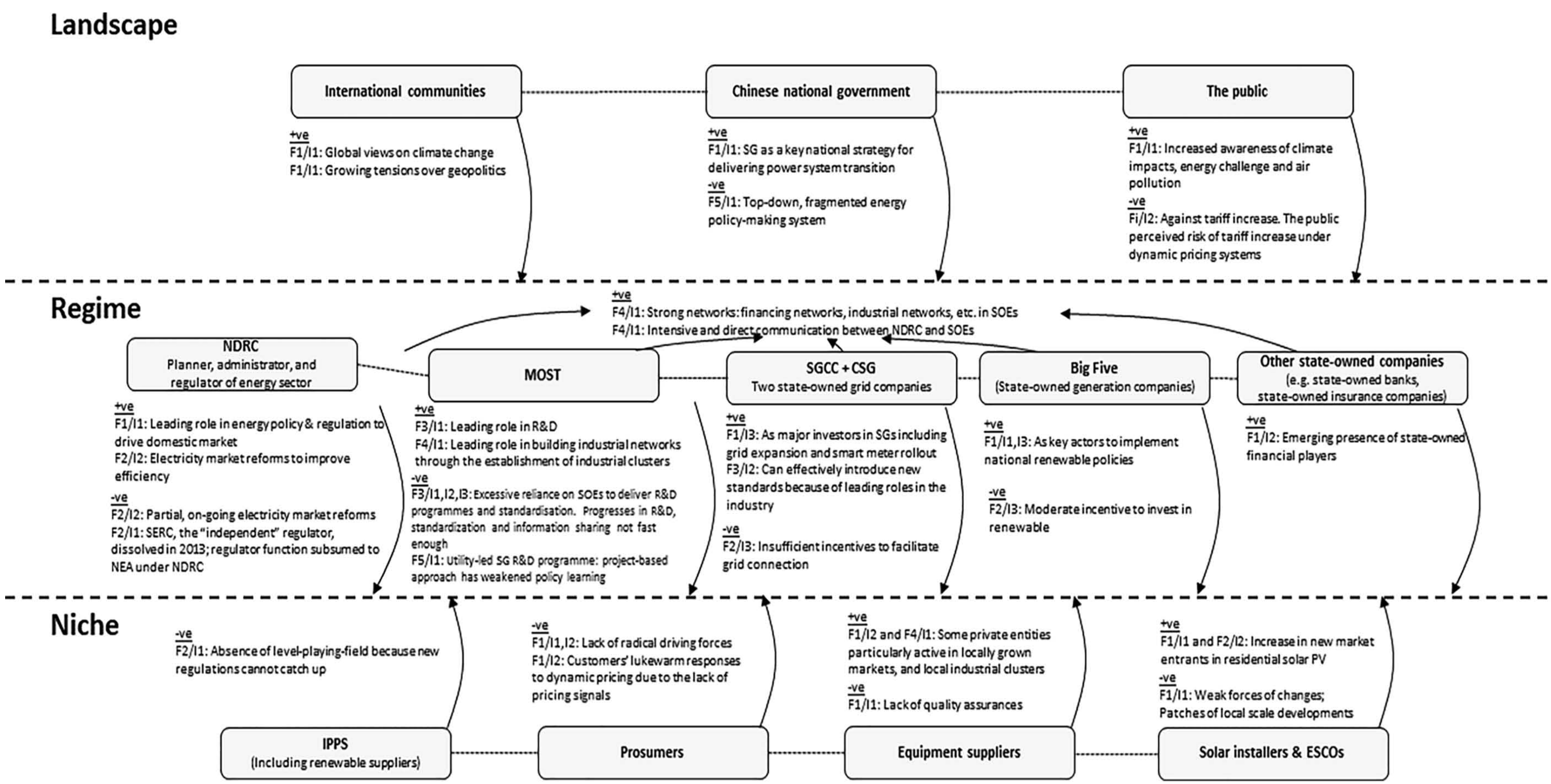

Fig. 3. China's smart grid developments with emerging government-market relationships.

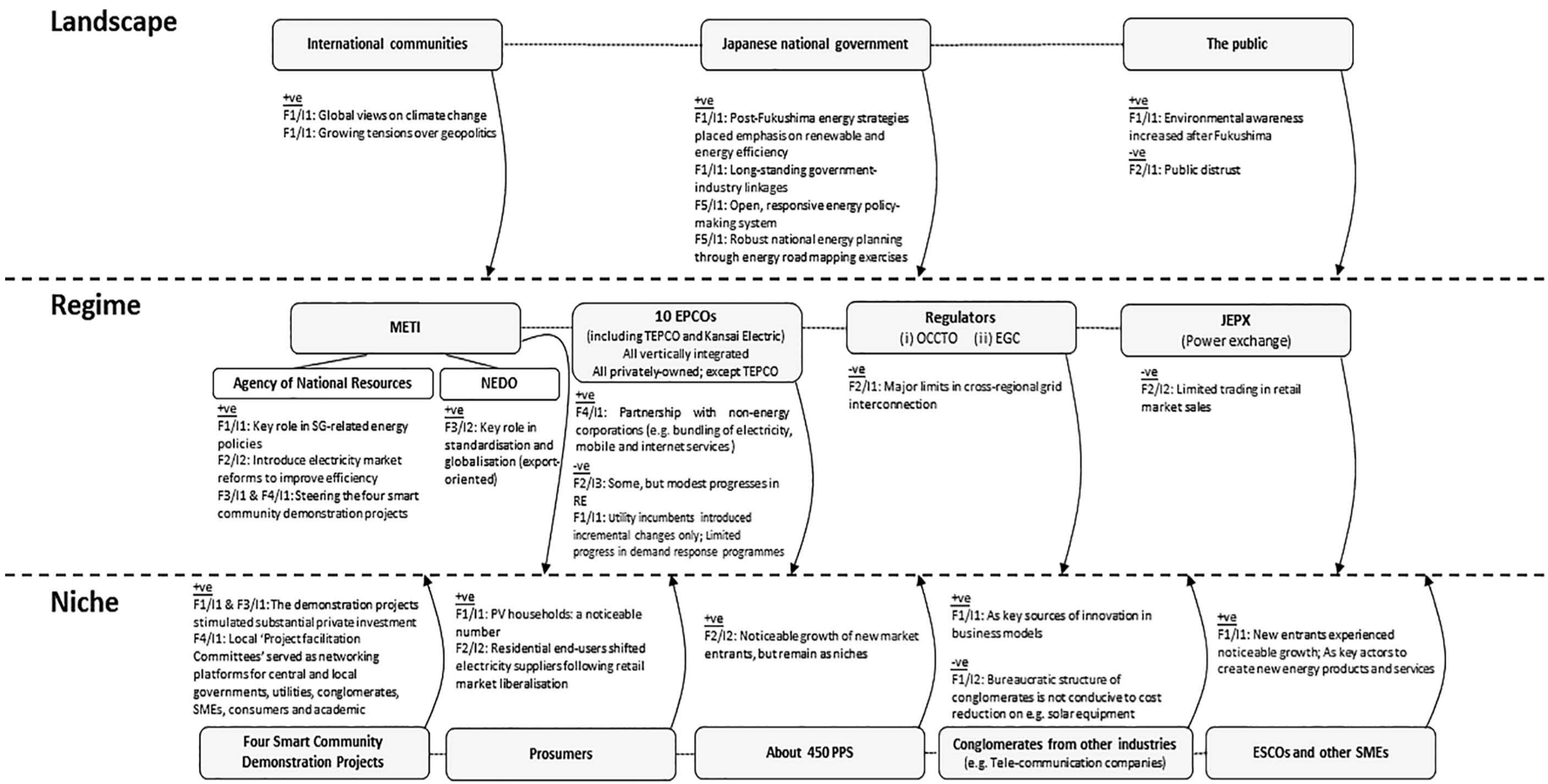

Fig. 4. Japan's smart grid developments with emerging government-market relationships.

The Japanese government showed an early recognition of the need for information sharing to foster new market entrants. As one of the supplementary pilot projects to the four large-scale SG demonstration project, a pilot project introduced in Toyota City was launched in 2012 which focused on validating SG-related EV markets through consumer engagement. One of the objectives of the pilot was to open up consumers' electricity consumption data in order to provide a conducive market environment for new entrants and local SMEs (METI, 2012c).

4.2.4. Networking and resource mobilisation

As in China, networking activities between government and market actors are also evident in Japan. What is interesting to note is that the four large-scale smart community demonstration projects have enabled such networking activities to be much more intensive and more institutionalised in the Japanese model.

Building on the historical linkages between the Japanese government and incumbent conglomerates, the budgeting arrangements of the four major smart community demonstration projects have strengthened such government-industry networks. Budgets for the four pilots amounted to approximately US$1.38 billion, of which 65% came from the government and the remaining one third had to come from the private sector (Mah et al., 2013). The demonstration projects not only mobilised financial and human resources from the public and private sectors, but also pooled together resources between incumbents and SMEs. The METI formulated the funding schemes for those demonstration projects in ways to incentivise partnerships between incumbents and SMEs. Project proponents of demonstration projects were required to enter into annual bidding processes to get funding support from the METI. Under the funding schemes, the EPCOs (such as TEPCO and KEPCO) and incumbents (such as Toshiba and Panasonic) were given incentives to partner with locally grown SMEs because such collaboration was often regarded as a strength in a proposal (Interviewees: JP/08/2015; JP/08/2016).

In addition, the institutional set-ups of Project Facilitation Committees (プロジェクト推進協議会) at the local level in each of the four smart community demonstration projects were found to be critical in facilitating higher-order networking across central and local governments, utility incumbents, corporates from other industries, SMEs, as well as consumer groups and citizen associations. In the Keihannan demonstration project, the Project Facilitation Committee comprised representatives of the local government, major corporates (such as Mitsubishi Heavy Industries, Ltd.), 26 enterprises (including some SMEs), as well as citizens associations (such as the Doshisha Yamate Sustainable Urban City Council) (Interviewee: JP/10/2016, 2018). The Committee served as the key agency to implement SG initiatives at the city level as well as coordinating and facilitating collaboration (Mah et al., 2013; Interviewee: JP/10/2016, 2018).

Market conditions in Japan were also conducive for incumbents to develop strategic alliance with new market entrants. TEPCO and KEPCO, for example, have developed strategic partnership through the bundling of electricity, mobile and internet services (Interviewees: JP/02/2015; JP/11/2017, 2018). To illustrate, AU, a leading information communication technology service provider, has bundled telecommunication services as part of an electricity retail package (IEA, 2016; Site observation).

4.2.5. Policy learning

SG deployments in Japan have been supported by a relatively open, inclusive, and responsive energy policy-making system. The METI has a policy tradition that relies on the active involvement of government committees, research institutes, and experts to strengthen energy policy planning and formulation (Mah et al., 2013). A feature of the Japanese policy learning system is that it has paid great attention to continuous monitoring of the four smart community demonstration projects. METI-organised annual conferences became important venues for the project leaders to report progress and to share experiences on policy effectiveness, responses of end-users, latest developments of social changes and overseas markets (METI, 2012b; Interviewee: JP/10/2018). Detailed project completion reports were made publicly available on the METI website (METI, 2012b).

The METI also placed emphasis on collecting feedback from industrial practitioners, end-users of SG technologies, and electricity consumers. One of the extraordinary achievements of the Keihanna smart community demonstration project was its high success rate in engaging local residents to co-develop new energy social systems. About 1,000 households, approximately 10% of households in the locality, participated in the demonstration project. Participating households provided important feedback for the government and the industry to verify electricity demand, and the effectiveness of demand response programmes (Kyoto Prefecture Government, 2018; Interviewee: JP/10/2018).

4.3. Discussions from a comparative perspective

So what then can we discern from our analysis of the two national cases? We compare the interactions of key government and market actors, and the dynamics across landscape-regime-niche level in China and Japan. There are four key observations which can be derived from this comparative perspective as we discuss below. The major points are set out in Table 4. Schematic views of these observations are provided in Figs. 3 and 4.

(1) Our two Asian case studies have in common that the five functions of government-market interactions are critical in developing, diffusing, and utilising SG technologies.

Both cases show that the five functions based on government-market dynamics are critical conditions for the countries to advance on the deployment of SGs. The existence of these functions in the two cases is not a surprising finding in itself. But this makes contribution to the western socio-technical transitions literature as this finding suggests that the conceptualisation of these functions of government-market dynamics can travel from the West to Asia.

More importantly, this study further advances the socio-technical transitions literature by conceptualising the complexity and mechanisms of such government-market dynamics. In both case countries, we found that the government-market dynamics can create positive, as well as negative forces of change within and between the landscape, regime, and niche levels in the socio-technical systems. In Figs. 3 and 4, we differentiate positive effects (indicated with a symbol "+ve") from negative effects (indicated with a symbol "−ve") on niche accumulations and the weakening of established sociotechnical configurations.

We observe that (1) effective policies and pricing mechanisms which can create incentives for SG-related investments, (2) liberalised market structures that can foster market competition, and (3) networks that widen access to resources, information, and expertise are some of the key *positive forces of changes*. We also observe that (1) public perception on risks associated with dynamic pricing, (2) the lack of regulatory competence due to incomplete market reforms, and (3) the excessive reliance of government actors to provide public goods are some of the *negative forces against changes*.

(2) Government-market dynamics are a multi-scalar phenomenon in energy transitions

Evidence from our two case countries suggest that it is important to examine government-market dynamics at multiple scales when explaining how important functions evolve. As Figs. 3 and 4 show, in both case countries government and market interacted in complex ways across niche, regime, and landscape levels. In China, positive forces for change existed in the niche level. The emergence of new market actors such as energy services companies and new market products such as solar loans was noticeable. These niche forces were however subsumed at the regime level where regime actors, in particular state-owned enterprises, remained dominating. Forces for change did exist at the Chinese landscape level but the lack of public acceptability of tariff increase, for example, cancelled out the positive effects of an increased awareness of climate impacts. Similarly in Japan, PV prosumers and new market entrants played some noticeable roles at the niche level. Their impacts were however modest because there existed major limits in cross-region grid interconnection at the regime level. Post-Fukushima anti-nuclear sentiment among the public has become one of the key forces for change at the Japanese landscape level, but such forces have not yet strong enough to destabilise the regime systems.

(3) Distinctive forms of government-market dynamics are discernable across the Chinese and Japanese cases.

Although the same set of government-market dynamics appeared to be common ground across China and Japan, the approaches differ. As shown in Table 4, the Chinese approach appeared to be distinguished by three characteristics: hierarchy (in a way that the national government has retained commanding role in directing the behaviour of SOEs) (Interviewees: CH/04/2014; CH/19/2017), fragmentation (e.g. a project-based approach for organising SG-R&D activities (Interviewees: CH/12/2015), and homogeneity (the rather uniform stakeholder landscape in which SOE dominates while new market actors have remained under-developed with minimal impacts in regime shifts). In contrast, the Japanese approach is characterised by a systemic and multi-level strategy (as the four large-scale SG demonstration projects have showed the effectiveness of a national SG policy framework in creating strong incentives to the business sector to engage community in SG developments), coordination (as the SG policy framework has emphasised synergistic effects between the developments of solar energy, household rechargeable batteries, and low-carbon houses), and diversity (that is associated with a relatively open market structure that has attracted a substantial number of new market entrants coming from the real estate, ICT, and automobile industries). Whilst it is beyond the scope of this study to discuss whether these Asian varieties are significantly different to the western mainstream forms, this finding made an important contribution to the socio-technical transitions literature by offering a better understanding of the diversity of transitions pathways in the Asian context (see, for example, Foxon et al., 2010; Verbong and Geels, 2010).

(4) National contextual factors, most notably the existence of incomplete electricity market reforms, are a key factor in explaining the different government-market dynamics and the resulting outcomes.

This study is not about evaluating the comparative merits of the Chinese and Japanese approaches for smart energy transitions. It is however evident that Japan is more advanced than China in SG developments in at least some important aspects. By adopting an evaluative framework of SG transformation developed by SEI (2009, 2011) and adapted by Mah et al. (2013), we distinguish SG transformational process into three orders. First-order transformation is characterised by the recognition of the importance of SG and the formulation of visions and policy strategies to support SG deployment. Second-order transformation represent an intermediate stage in which new business cases and new investment emerge. In this stage, operational benefits have started to be realised but not yet customer and societal benefits. Minor regulatory changes such as new incentive scheme for smart meter installations are introduced, but changes involving tariff systems and market structure are not introduced. Third-order transformation represent a stage of mature developments in which SG functionality and benefits (including operational, customers and societal benefits) are realised. Major regulatory changes and market structure are also introduced.

We found that the Japanese model shows some emerging trends of advancing to the third-order (the highest-order) of transformation while the Chinese model has attained second-order transformation of SGs only. In Japan, although large-scale uptake of renewable and consumer engagement has not yet be realised, customer benefits and new business models of these new energy products associated with SG developments have become more discernable. In contrast, the Chinese model appears to attain second-order transformation of SGs only as some functionality and benefits of SGs are realised, but no major customer benefit nor societal benefit is discernable.

This research found out that the relative advancements of the electricity market reforms in Japan can, to some extent, explain some of the relative advanced developments of SG in Japan. For example, the full retail market liberalisation in April 2016 was impactful in driving a noticeable growth in retail electricity suppliers. In contrast, in China where transmission, distribution and retail sectors of the electricity market has remained monopolised, the growth of retail electricity suppliers and prosumers has remained negligible. This finding is consistent with a growing body of the energy literature that argues electricity market liberalisation is a core, and critical strategy to achieve energy transitions (Chapman and Itaoka, 2018; Gao et al., 2018).

5. Conclusions

SGs have the potential to enable optimisation of supply-side and demand-side energy solutions for energy transitions. This study argues that the co-evolution of government-market interactions alongside SG technological developments is critical if SGs are to deliver their full potential. However, the theoretical understanding of such interactions is insufficient. The primary aim of this study is to advance the literature on the socio-technical transitions perspective by combining two concepts – functions from the TIS literature and energy governance - into an integrated framework. Two case studies of China and Japan were conducted to illustrate the application of the framework. We contribute to the transitions literature in four ways.

Firstly, as the previous studies on the TIS tend to focus on the functional dimensions (Carlsson et al., 2002; Edquist, 1997; Johnson, 2001), this study has made an important contribution by emphasising and conceptualising the dynamics between government and market in implementing energy transitions. Our findings highlight the limitations of simplistic conceptions of the relative merits of government-led and market-led models. We found that government-market dynamics take on various forms across China and Japan, but it is evident that the two governments have been evolving in increasingly market-based socio-technical energy systems. We conclude that consideration of optimising government-market dynamics with the aim to create the desirable functions, rather than a choice of government or market, is much more vital to realise the potential that SGs can offer in energy transitions.

Secondly, our multi-scale perspective provides greater clarity to the complex government-market dynamics across niche, regime, and landscape levels, and thus making important contribution to the MLP literature. A growing body of the sustainability transition literature argues that it is of central importance to conceptualise transitions on multiple spatial scales (Essletzbichler, 2012; Chowdhury et al., 2011; Sarrica et al., 2018). Evidence from our case studies shows that positive and negative forces for changes did co-exist across niche, regime, and landscape levels. Impacts of positive changes could be cancelled out by negative forces in some cases, but re-inforced by other positive forces under other circumstances. This complexity, at least to a certain extent, can account for the relatively slow progress and the indeterministic nature of the energy transitions in the two countries. Our finding is also consistent with the literature that scale-sensitive governance systems are required to deliver energy transitions (see, for example, Padt and Arts, 2014).

Thirdly, our findings on the distinctive forms of government-market dynamics across the Chinese and Japanese cases contribute to the understanding of diversity of energy transition pathways. Our case studies demonstrated that national contextual factors, most notably the existence of incomplete electricity market reforms (but with varying degrees across China and Japan) has set the two countries apart in their transition pathways. The relative advancements of the electricity market reforms with the retail market liberalisation in Japan alongside a relatively enduring SG policy framework has created strong market signals to a large number of corporates from non-utility industries to invest in SG markets. Our findings are consistent with the literature that market liberalisation is a critical driver for energy transitions (Markard and Truffer, 2006).

Fourthly, this study adds to a limited body of empirical work exploring energy transitions in non-western context. This is one of the first studies to understand energy transitions in Asian context by focusing on government-market dynamics. This study provides insights to transition studies as it suggests some uniquely Asian determinants relating to socio-economic, political and institutional contexts. The study fills an important gap by highlighting the important dynamics between government and market in the context of partial electricity reforms – one of the important features of energy transitions that is relatively common across Asia. The prominent role of the state and the lack of key driving forces from niche actors are features of partial electricity reforms which at least partly contribute to the roles of incumbents as both an enabler and as a barrier to energy transitions (Mah et al., 2017; Shen, 2017). This research also contributes to the broader literature on national systems of governance (Cashmore et al., 2015) by providing a better understanding of energy governance systems in partially liberalised energy regimes (To et al., 2017).

Specifically, this study contributes to the refinement of the classic TIS functions by a grounded theory approach (Charmaz, 2006; Strauss and Corbin, 1997). Our integrated conceptual model has been empirically tested. Our case studies have an illustrative function. Several important observations can be made based on the first application of the conceptual model. Our empirical evidence from the comparative analysis demonstrated that there existed theoretical linkages between the MLP, functional approaches of TIS, and the government-market relationships. We have demonstrated that government actors and market actors interacted in the five functions which were found to be critical to the deployment of smart grids. Empirical data derived from the two case studies were then utilised to enrich our integrated framework by making the scalar perspective more explicit.

This study has policy implications. By comparing the patterns of government-market dynamics in the two case countries, we argue that function-sensitive governance systems are still needed. Among the five functions, our empirical evidence suggests that the functions of market formation and market regulations appear to be the more important critical factors in creating path-breaking conditions for niche to emerge and regimes to be weakened. In both case countries, post-Fukushima pro-renewable policies have sent out strong signals for the business sector to invest in SG-related technologies. However, the existence of a relatively more deregulated market in Japan appeared to set this country apart from China in terms of SG developments. In Japan, new market entrants are more active in the electricity market, particularly in the retail segment. In contrast, new energy suppliers are relatively inactive in the Chinese electricity market as the retail segment is still monopolised. Our policy recommendation is that governments may need to give sufficient attention on the building of market infrastructure and regulatory systems in order to scale up SG-enabled energy transitions.

Another important policy implication relates to the complexity of the roles played by some key actors. In some cases, the same actor was associated with both positive and negative impacts on the functions of energy transitions. Incumbents utilities (especially two state-owned monopolised grid companies in China and the 10 EPCOs in Japan were found to be critical to as a policy implementator of SG strategies and plans. These well-established companies have however remained dominating and created forces again changes introduced by new market entrants. The Ministry of Science and Technology (MOST) in China is another example. MOST has been the main funding source for key SG-related R&D programmes conducted by the SOEs. It also played a pivotal role in building industrial networks through the establishment of several key industrial clusters for SG technological developments. However, the ways that it has relied too much on the SOE on R&D and standardisation has failed to speed up the transitions processes effectively. Sufficient policy attention should be given to institutional design so that SOEs and key government agencies could more effectively assume their pivotal roles which cannot be replaced by market, whilst releasing some functions to the market which could be more effectively delivered by the market.

Our findings may not be generalisable to all economies but may be transferrable, at least to a certain extent, to other Asian economies such as South Korea (Lee, 2017) and Singapore (Loi and Ng, 2018) where the state has a dominating role; and economies such as South Korea and Thailand (Wisuttisak, 2012) where retail electricity market reforms have been ongoing in recent years.

This study does not provide an evaluative framework for government-market dynamics in the context of energy transitions. The illustrative examples reported are not intended to provide a comprehensive review of the processes and outcomes of SG deployment in China and Japan. Comparative studies that include both western and Asian countries associated with economies in different stages of SG technological diffusion (from pre-commercialisation, early commercialisation, acceleration, and widespread diffusion) (Surana and Anadon, 2015) would contribute to the development of such an evaluation framework, and the enhancement of the generalisability and robustness of the analysis.

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Appendix A. A list of interviewees for the case study of China

Code	Background of interviewee	Date of interview	Location	Format of interview
CH/01	A senior executive of an energy-related consulting company, Beijing	23rd July 2014	Beijing	FI
CH/02	A middle-rank consultant of an energy-related consulting company, Beijing	23rd July 2014	Beijing	FI
CH/03	A Senior executive of the State Grid Energy Research Institute of SGCC	23rd July 2014	Beijing	FI
CH/04	A senior government official in the Department of Renewable and New Energy, NDRC	23rd July 2014	Beijing	FI
CH/05	A senior advisor in Energy Research Institute of NDRC	24th July 2014	Beijing	FI
CH/06	A researcher in Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences	24th July 2014	Beijing	FI
CH/07	A senior executive in State Grid Energy Research Institute of SGCC	24th July 2014	Beijing	FI
CH/08	A middle rank executive in State Grid Energy Research Institute of SGCC	24th July 2014	Beijing	FI
CH/09	A professor in the School of Electrical Engineering & Automation of Tianjin University	25th July 2014	Tianjin	FI
CH/10	A researcher in the School of Electrical Engineering & Automation of Tianjin University	25th July 2014	Tianjin	FI
CH/11	A senior executive in a green building research institute in Tianjin	25th July 2014	Tianjin	FI
CH/12	A senior executive in Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences	7th January 2015	Guangdong	FI
CH/13	A researcher in Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences	7th January 2015	Guangdong	FI
CH/14	A senior executive in Smart Grid Institute of CSG *supplementary data was provided by the interviewee through email correspondence, dated 12th May 2016	7th January 2015	Guangdong	FI/EC
CH/15	A researcher in Smart Grid Institute of CSG	7th January 2015	Guangdong	FI
CH/16	A researcher in Smart Grid Institute of CSG	7th January 2015	Guangdong	FI
CH/17	A middle-rank executive of a solar technology company in Zhuhai	14th March 2015	Guangdong	FI
CH/18	A professor at The Lab of Solar PV and Mico-grid Applied Technology, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences	3rd March 2016	Guangdong	FI
CH/19	A senior executive (specialising in demand response programmes), Foshan Power Supply Bureau, Guangdong Power Grid Corporation, CSG	24th March 2017	Guangdong	FI
CH/20	A senior executive (specialising in energy saving), Foshan Power Supply Bureau, Guangdong Power Grid Corporation, CSG	24th March 2017	Guangdong	FI
CH/21	A senior executive, the customer service centre, Foshan Power Supply Bureau, Guangdong Power Grid Corporation, CSG	24th March 2017	Guangdong	FI
CH/22	A senior executive, solar energy company A in Foshan	24th March 2017	Guangdong	FI
CH/23	A project manager, solar energy company B in Foshan	24th March 2017	Guangdong	FI
CH/24	A senior executive of an independent power producer (who has experience in investing in solar PV projects in China)	14th April 2018	Hong Kong	FI

*In order to keep our interviewees anonymous, this study indicates interviews by number. The first two letters indicate the location, the two digits indicate the interview numbers, followed by the year of interviews. The interview formats included face-to-face interview (FI) and email correspondence (EC).

Appendix B. A list of interviewees for the case study of Japan

Code	Background of interviewee	Date of interview	Location	Format of interview
JP/01	A senior executive, Policy Planning Division, Energy Conservation and Renewable Energy Dept., Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (METI)	15th June 2015	Tokyo	FI
JP/02	A senior executive, Smart Community Policy office, Energy Conservation and Renewable Energy Department, Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry (METI)	15th June 2015	Tokyo	FI
JP/03	A professor (specialises in digital grids), Graduate Course of Technology Management for Innovation, School of Engineering, The University of Tokyo	16th June 2015	Tokyo	FI
JP/04	An associate professor (specialises in digital grids), Department of Systems Innovation, Graduate School of Engineering, The University of Tokyo	16th June 2015	Tokyo	FI
JP/05	A senior executive, National Renewable Energy Laboratory (NREL), USA	17th June 2015	Tokyo	FI
JP/06	A senior executive, Smart Community Department, Energy and Environment Centre, New Energy and Industrial Technology Development (NEDO)	18th June 2015	Tokyo	FI
JP/07	A senior executive, Energy and Environment Headquarters, New Energy and Industrial Technology Development Organisation)	18th June 2015	Tokyo	FI
JP/08	A representative, Sekisui Heim (a house builder)	18th June 2015	Yokohama	FI
JP/097	An associate professor, Graduate School of Energy Science, Kyoto University	Three interview meetings: on 28th November 2016; 6th February 2018; 9th February 2018	Kyoto	FI
JP/10	A senior director, Public Foundation of Kansai Research Institute; A former senior executive, Department of Policy Planning, Kyoto Prefectural Government	Two interview meetings: on 29th November 2016; 8th February 2018	Kyoto	FI
JP/11	A general manager (planning), Kansai Electric Power	Three interview meetings conducted on 29th November 2016; 14th January 2017; and 6th February 2018	Osaka, Kyoto	FI
JP/12	A senior executive, Advanced Grid Strategy Group, Community Energy Division, Kansai Electric Power	29th November 2016	Osaka	FI
JP/13	An associate Professor, Graduate School of Global Environmental Studies, Kyoto University; a director and Secretary General, East Asian Association of Environmental and Resource Economics	7th February 2018	Kyoto	FI
JP/14/2-018	A researcher, Central Research Institute of Electric Power Industry (CRIEPI) (renewable energy policy analysis group)	23rd August 2018	Hong Kong	FI

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