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A comparison of innovation policy in the smart grid industry across the pacific: China and the USA

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HIGHLIGHTS

- This research describes the policy tools used by China and USA and presents results that indicate national preferences for innovation policy that differ in the ways in which they are linked with the state of the power system.
- China has preferred to use "supply-side policy," which focuses on "public enterprise, scientific and technical development and legal regulation."
- The USA has preferred to use "environmental-side," policy, which focuses on "scientific and technical development, financial, political and public enterprise."

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ABSTRACT

Utilities are increasing their investment in smart grid technologies because of the rising demand for electricity, the aging transmission and distribution infrastructure in developed countries and the need for real-time visibility of energy supply and demand to optimize service reliability and cost. Government policies are contributing to this rising investment in the smart grid in many countries around the globe. Using Rothwell and Zegveld's innovation policy framework as a starting point, this paper compares innovation policy in smart grids across the Pacific; specifically, China and the USA. This research describes the policy tools used by both countries and presents results that indicate national preferences for innovation policy that differ in the ways in which they are linked with the state of the power system. China has preferred to use "supply-side policy," which focuses on "public enterprise, scientific and technical development and legal regulation." The USA has preferred to use "environmental-side policy," which focuses on "scientific and technical development, financial, political and public enterprise." This paper also describes in detail a number of innovation policies being pursued in the smart grid industry in both China and the USA.

1. Introduction

Given the rising demand for electricity resulting from rapid economic growth, problems related to climate change, environmental protection and sustainable development have become increasingly important. As the fundamental industry that combines production materials with living essentials, the electricity industry is inevitably attracting much attention from government and the public. Additionally, as the largest user of primary energy resources, the electricity industry cannot shirk its responsibilities with respect to lowering greenhouse gas emissions and attenuating its negative impact on climate; this is particularly true in the USA and China. Because China is the largest producer of carbon emissions and the USA is ranked second (WRI, WRI CAIT, 2009), it is urgent that these countries conserve energy and abate carbon emissions by promoting conservation-minded and environmentally friendly practices in their societies.

One of the measures that can effectively reduce carbon emissions in industrial development is the use of renewable energies, such as sunlight, wind, rain, tides, and geothermal heat to replace the conventional combustion of fossil fuels (Xia et al., 2011; Subramani et al., 2011). However, the use of renewable energy currently suffers from technological bottlenecks associated with increasing the efficiency and decreasing the costs. At the same time, with the development of digital information technology, the

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requirements of consumers regarding the accurate control of power supply reliability, power quality and services have increased (Peace and Julian, 2009; Fang et al., 2011). Therefore, the integration of various renewable energy technologies and changes in power supply and demand via a smart power system are increasingly important. Given this challenge, many countries, including large carbon producers such as China and the USA, have made great efforts to solve the related problems according to their unique circumstances over the past several years. The achievements accomplished include the application of distributed generation and power electronics technology, the development of the electricity market, and the rapid development of renewable energy sources; further, the concept of the "smart grid" has been developed (Gellings, 2009; Farhangi, 2010).

As a result, the promise of smart grids and their benefits have been widely publicized in recent years. Such a modernized electricity network is increasingly being promoted by many governments as a way of addressing energy independence, global warming and emergency resilience issues. By definition, a smart grid is a digitally enabled electrical grid that gathers, distributes, and acts on information about the behavior of all energy or power suppliers and consumers in order to improve the efficiency, importance, reliability, economics, and sustainability of electricity services (Massoud and Wollenberg, 2005; Gellings, 2009). Briefly, the electrical grid is not a single entity but an aggregate of multiple networks and multiple power generation enterprises run by multiple operators employing varying levels of communication and coordination, most of which is manually controlled. A smart grid will increase connectivity, automation and coordination among these suppliers, consumers and networks that perform either long-distance transmission or local distribution tasks. Therefore, although the transition to the smart grid is a continuous process that will take many years before the first tangible results are seen, this process will be driven by the interests and desires of the primary beneficiaries: utilities, individual consumers, and society in general (Farhangi, 2010). According to Lawbrain (2010), the motivations for adopting the smart grid and its technology are raised for each of these stakeholders. The study also explains why the smart grid assists in reducing carbon emissions from industry. For instance, using a smart grid system, consumers will be able to view how much electricity they use, when it is being used and its cost to them. They will also able to calculate and reduce their greenhouse gas emissions. Therefore, more renewable energy sources will be created and tapped, as consumers sell their surplus electricity created from green sources back to the grid. The adoption of the smart grid is intended to aid in the efficient transmission of electricity and the rapid restoration of power after outages. Reduced operation and management costs, lower electricity rates and improved security are other benefits that can be achieved by implementing a smart grid (McDaniel and McLaughlin, 2009).

With a view to developing these advantages of smart grid systems, the focus of a top-down policy in the energy sector should be emphasized in academic research due to the characteristics of smart grids, which have been touted to revolutionize economic, environmental, and national security issues. Private entities or enterprises will find it difficult to develop their own smart grid models without the support of governmental policy; research on smart grids at the firm level may also not be able to clearly explain the development of this energy network (Farhangi, 2010). However, based upon the findings of a literature survey, issues relating to smart grid policy have been discussed only very slowly and in a scattered way. Only recently have smart grid studies focused primarily on the issues of energy efficiency, benefits, the management system, smart grid security and business (Chao, 2010; Jackson, 2010; Wade et al., 2010; Perry, 2009; Hledik, 2009; Renewable Energy Focus, 2008); some policies in specific countries (Wissner, 2011a, 2011b; Lund et al., 2012; Acharjee, in press; Mah et al., 2012, a,b) and a few studies have offered a comprehensive analysis of cross-national policy (Willrich, 2009). The lack of research on systematic cross-national policy regarding smart grids will make it difficult for the stakeholders involved in smart grids to see the broader context of the development of effective smart grid systems under different national circumstances, particularly when comparing developing and developed countries such as the two primary carbon producers, China and the USA. The sum total of carbon emissions in these two large countries accounted for 37.56% of world carbon emissions, and these countries are the two largest producers of electricity and greenhouse gases (USA CIA, 2010); nevertheless, it appears that cross-national policy has not been widely discussed in relation to the smart grid systems in these countries.

In this context, we conduct a comparative study of innovation policy within the smart grid industry between China and the USA. We examine the innovation policies involved in implementing and developing the smart grid industry in the two different contexts. The study also summarizes differences in how the two governments prioritize their innovation policies to fulfill the vision of smart grids.

This paper is organized as follows: Section 2 reviews the relevant literature on policy instruments. Section 3 introduces the development of smart grid policy recently. Section 4 explains the innovation policy framework used in this study. The data survey and pattern matching approach used in this research are presented in Section 5. Sections 6 and 7 show the results of innovation policies for smart grids in China and the USA, respectively. In Section 8, the results are compared and discussed. The limitations and implications of this study are discussed in Sections 9 and 10, respectively and conclusions are also presented in Section 10.

2. Development of smart grid policy

For the design of policy instruments in the energy sector, Sawin (2004) offers a classification of national policy instruments for renewable energy technology. In practice, some governments have proposed a number of options that they can use to promote renewable energy technologies in the energy sector IEA (2004a, 2004b). Other researchers have also described the type of policy support that can encourage and strengthen innovation and technological development in the renewable energy sector (Banales-Lopez and Norberg-Bohm, 2002); these policies are mostly categorized as price-based and quantity-based policies (also known as price-based and quantity-based instruments or price-based and quantity-based technology support models) (Weitzman, 1974; Norberg-Bohm, 2000). For innovation policy in the energy sector, price-based policies usually have an effect on the price, e.g., the production costs of renewable electricity or subsidies on investments. Quantity-based policies usually affect the amount subject to environmental regulations, such as imposing a mandatory share of renewable electricity (Finon and Philippe, 2004; Stranlund and Ben-Haim, 2008).

In recent years, as renewable energy technologies have matured, the driving force of energy sector development has increasingly moved from the supply side to the demand and environment sides (Strbac, 2008; Lund et al., 2012). Price-based and quantity-based policy instruments for technological advances no longer have strong impacts on the overall development of the energy industry. More policy instruments on the demand and environmental sides are now emphasized regarding energy grid establishment. Wolsink (2012) notes that ongoing problems with the deployment of renewable energy policy have shown that smart grid development is very important for further renewable deployment, but there is a tendency to continue the neglect of social determinants. As a result, policymakers in the energy sector have become fixated by the wide range of possibilities afforded by what has become known as the smart grid; planners, practitioners, and researchers are focusing more than ever on energy network infrastructures due to the impact of energy systems on society and the economy. In addition, Clastres (2011) demonstrates that the expanding use of smart grids will raise several new policy issues. First, public policies will need to be adapted to allow for the potential gains from smart grids and the associated information flow; second, such policies will be needed to regulate the new networks and act as incentives for investors.

However, research on smart grid policy has paid more attention to advancing the technological development of smart grids (McDaniel and McLaughlin, 2009; Farhangi, 2010; Krishnamurti et al., 2012; Giordano and Fulli, 2012; Wolsink, 2012; Lund et al., 2012) rather than reconsidering current policy barriers to remove problems that stem from misaligned incentives, such as facilitating business competition and innovation in smart grids and encouraging more R&D and risk-taking with new smart grid approaches. A group of studies regarding smart grid policy focuses on the role of government in the trend toward smart grid development. For example, Zio and Aven (2011) explain that the challenge facing government can be viewed in terms of facing an uncertain future regarding the evolution of technology and society. Future smart grid operators or policymakers will be faced with the challenge of operating the system with the required stability and reliability of service despite experiencing variability in power generation and utilization and the associated hazards and threats. Verbong et al. (2013) propose that a clear trend exists in which governments focus greater attention on users in new smart grid projects and that too much focus on technology and economic incentives can become a barrier. Innovative business models should be developed to explore different options to involve smart grid users in lowering institutional barriers. In addition, Lund et al. (2012) notes the importance of demand-side policy that focuses on smart grid users. These authors argue that the challenge of integrating fluctuating power from renewable energy sources in the electricity grid by using smart grids cannot be viewed as an isolated issue but should be seen as one of many factors involved in the development of effective sustainable energy systems. This argument implies that electricity smart grids must be coordinated with the utilization of renewable energy after conversion into forms other than electricity.

Another group of studies concerning smart grid policy examines different national development cases of smart grid planning. Consent et al. (2009) address the role of regulation policy in the EU and show that the current regulation of electricity distribution focuses only on those aspects that might hinder the future integration of smart grids. Pearson (2011) also studies smart grid policy in Europe and notes that the utility companies are increasingly using information and communication technology (ICT) to increase the efficiency and reliability of the grid and incorporating smaller sources of intermittent wind and solar power into the electricity supply. This integration should have a positive effect on Europe's energy policy objectives. Giordano and Fulli (2012) argue that the role of European government is to construct the smart home platform aggregator, thereby integrating the energy retailer, consumer, and distribution system operator (DSO) in the same grid network. Other European studies include the work of Wissner (2011a, 2011b), which details the potential for information and communication technology (ICT) to facilitate the restructuring and modernization of the German power system, in particular, with a view toward its development into a smart grid. Therefore, policy and regulation should be employed to remove existing barriers to ICT investment, thereby overcoming barriers to investment and exploiting productivity potential in all stages of the energy value chain as a necessary pre-condition for building smart grids in Germany. In addition, Lund et al. (2012) investigate Denmark and show that the policy regarding the integration of renewable energy into the electricity sector must be coordinated with other sectors, such as heat supply and transportation, as well as energy conservation and improved efficiency.

Willrich (2009) also offers an overview of electricity transmission policy regarding several aspects of the US smart grid involving transmission planning and sitting, transmission cost recovery and allocation, transmission grid modernization, and the improvement of independent system operator (ISO) coverage. The US government also adopts a supply-side policy for the development of smart grid technologies. Krishnamurti et al. (2012) found that the policy instrument features the installation of smart meters and related technologies in residential homes as part of efforts to transform the current electrical grid into a smart grid. Promoting this transformation requires consumers to accept these new technologies and take advantage of the opportunities that they create. Regarding the development of smart grids in Asian countries, Acharjee (in press) investigates the situation in India, where the government has designed a three-step smart grid program in effect until 2024 by deploying base technology, developing a customer program offered by utilities, and deploying smart grid components. This study shows that power enterprises in developed and developing countries, including India, are faced with massive challenges regarding the increasing size, grade and complexity of their grids, together with the risk of not achieving safe and reliable operation of their power systems. Mah et al. (2012a) analyze Korea's smart grid policy from the standpoint of its government-led approach and divide the policy into landscape, regime, and niche levels. This research group also examines the development of a smart grid in Hong Kong (Mah et al., 2012b). Smart grid users in Hong Kong tend to support a more dynamic tariff system, which encourages electricity conservation. Most of the users agree that tariffs should be differentiated among heavy/low-users and among on-peak/off-peak users. Therefore, this survey suggests that smart grid policy should focus on demand-side measures in which well-informed, price-sensitive and empowered electricity consumers have the potential to play a much more active role through smart grid technologies and applications. The government and the utilities will have an important role to play in developing new pricing mechanisms. These studies offer an overall view of smart grid policy in different national and industry contexts. Although cross-national studies remain uninvestigated from a systematic policy viewpoint, these discussions provide a referential framework for the present study of smart grid policy.

3. Innovation policy framework in the smart grid industry

To answer the research question concerning the comparative study of smart grid policies between China and the USA, we selected innovation policy as the policy category to analyze for China and the USA. In theory, it is difficult to select a portfolio of policy instruments applied to the energy sector because energy technology varies substantially along the continuum from relatively mono-disciplinary scientific research to multidisciplinary commercial innovation. This challenge in smart grid research is obvious. Blumsack and Fernandez (2012) note that smart grids represent the great advances in the electricity delivery infrastructure in the past century. Although the technologies that collectively comprise the smart grid have existed for decades, the potential for changing the way that electricity is generated, delivered, utilized and priced is revolutionary. Understanding the fundamental changes and policy difficulty that the smart grid is likely to introduce is important for the development of future energy scenarios and their environmental, social and economic implications.

Therefore, it is difficult to construct an analytical framework as a methodology for cross-national smart grid policy. At least two difficulties exist in selecting a policy framework or quantitative approach in this study: (1) according to our literature survey, current attempts at exploiting smart grid policy involve selecting a policy case and examining its impact on smart grid development. Very little attention is given to providing a systematic framework regarding the overall smart grid policy in a country, as noted above. (2) As a result of multidisciplinary development and integration, smart grid policies in the USA and China are still rare and difficult to find; therefore, it is almost impossible to form causal research hypotheses and quantitative research structures. Hence, this research adopts a descriptive analysis and descriptive statistics using the innovation policy framework proposed by Rothwell and Zegveld (1981, 1984). In accordance with our literature review, the majority of literature reviews on energy policy still rely on qualitative and descriptive analyses. Some reviews use descriptive analysis (Burns and Kang, 2012; Sanya, 2009; Yılmaz and Uslu, 2007), some use cross-national comparative analysis (Lau et al., 2009; Laird and Stefes, 2009), some use case studies (Kissel et al., 2006; Wiser et al., 1998; Kim and Kim, 1993), and others use additional qualitative evaluation techniques such as innovation policy instruments (Negro and Hekkert, 2008). Some quantitative simulation models are still used in the research field of energy policy. However, quantitative methods are not applied as frequently as qualitative methods. These analyses reveal that qualitative methodology is very useful in the exploration of energy policy changes, and energy policy analyses have experienced a number of successes to date. The advantage of qualitative research is that it begins by accepting that a range of different ways of making sense of energy policies exist and that it is concerned with discovering the perspectives of those who are being researched.

The policy framework examined in the study by Rothwell and Zegveld (1981, 1984) summarized a categorization of innovation policy including supply (public enterprise, scientific and technical, education, and information), demand (procurement, public service, commercial, and overseas agents), and environmental (political, legal and regulation, taxation, and financial) policy tools. This framework has been widely used in policy analysis (Norberg-Bohm, 1999; Loiter and Norberg-Bohm, 1999; Shyu and Chiu, 2002; Lai et al., 2004; Tuan and Ng, 2007) and covers the broader aspects and social collective benefits that innovation policy should consider. Fig. 1 (adapted and simplified from Rothwell and Zegveld, 1981) shows three main headings grouped by these policy tools and describes the policy targets for inducing innovation. For the purpose of policy analysis in different sectors, it is important to concentrate on innovation policy tools that are used by governments and similar institutions rather than policy instruments used by other organizations (business policy tools) or by individuals in their private lives (instruments used by consumers in the pursuit of their investment policies). This figure provides an overview of the interactive relations among each policy tool. Supply-side policy affects industry innovation and development by inducing R&D activities. Demand-side policy tends to create a market for industry development, and environmental policy influences both R&D and markets by building the related infrastructure.

To elaborate further, Rothwell and Zegveld (1981, 1984) provide an original definition of these three main groups of innovation policy based on a discussion regarding the determinants of innovation. They argue that successful innovation in industry depends upon a favorable combination of technology supply, market demand and an innovative environment (also see Allen, 1978; Freeman, 1979). On the supply side, the research and development of new products and processes is contingent upon

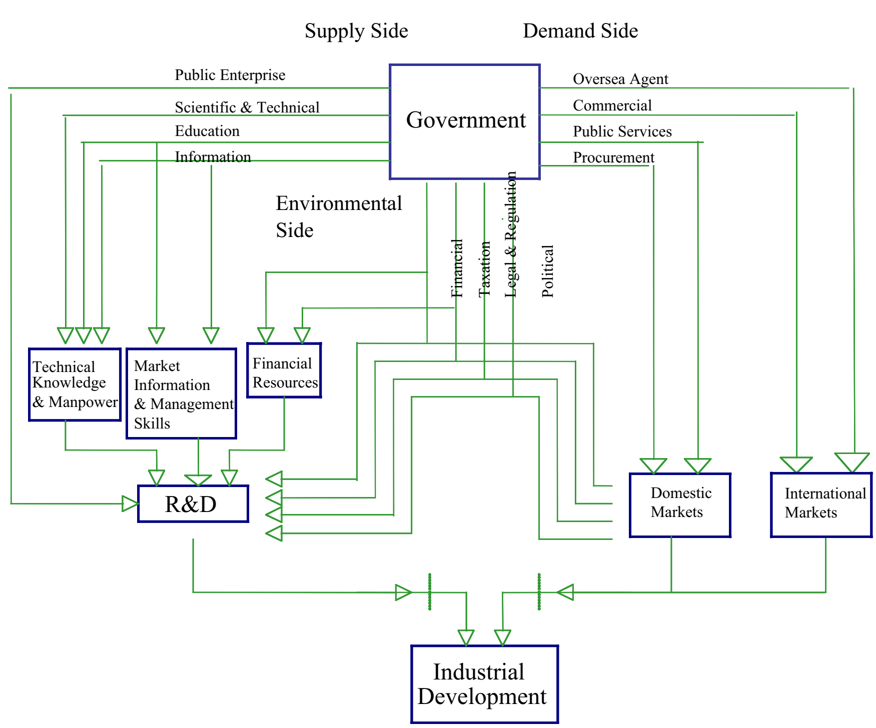

Fig. 1. Policy targets and tools for promoting innovation.
Source: adapted from Rothwell and Zegveld (1981).

an adequate presence of policy inputs such as scientific knowledge and manpower, information about the likely market for the innovation, and the management skills needed to ensure research. On the demand side, governments should improve the demand side of the innovation process and may do so in the domestic or international markets (Edquist and Hommen, 1999; Edler and Georghiou, 2007). On the environmental side, the role of policy is to alter the overall environment in which innovation takes place, such as the legal, financial, investment, or international trade environment and innovation system (in the energy sector, the environmental policy also includes the policy tools used to improve energy infrastructure and environmental quality) (Averch, 1985; Jacobs, 1998).

The reason the present study selects this innovation policy framework and why it may be useful in smart grid policy analysis compared with other innovation policy studies can be elaborated as follows: (1) this two-level innovation policy structure offers a more comparable base of policy tools using an overall and systematic policy view. Smart grid policies applied in different countries can clearly be categorized based on this supply, demand and environment policy grouping. Future strategic suggestions for smart grid policy can also be based on the categorized framework. (2) The framework of innovation policy was not generally designed for any specific industrial sector. According to our literature review, this framework has been widely used in comparable policy studies in different sectors, such as the electronics, semiconductor, and energy sectors (Rothwell and Zegveld, 1988; Norberg-Bohm, 1999; Loiter and Norberg-Bohm, 1999; Shyu and Chiu, 2002; Lai et al., 2004; Tuan and Ng, 2007; Huang et al., 2007). The advantages of covering different aspects of industrial development and technological advances are obvious in the energy sector and include smart grids combined with various subsystems and compatible technologies in other sectors. (3) Compared with qualitative descriptions, comparative studies need to use some quantitative data for cross-national comparisons. This framework is also suitable to the pattern-matching approach of policy tools because it provides a comparable quantitative base for smart grid policy in China and the USA. The proportion of different smart grid policies that adhere to each category of this framework can be used as a measure with which to understand the current policy priorities in the two countries. (4) The diagram of this framework, which is presented in Fig. 1, introduces the causal process of each policy tool and its impact on R&D and market development. This structure provides a guideline for policymakers to adjust the focus of their policy tools using a causal process based on the cross-national analysis and makes the comparison of smart grid systems in China and the USA more useful for further improving smart grid development.

4. Data survey and pattern matching

In our study, innovation policies regarding smart grids in China and the USA are investigated using content analysis. This section explains the collection of policy data in China and the USA and the pattern matching approach used.

First, the data sourced in this research were collected from journal papers, historical documents, newspaper stories, open-ended interviews, diplomatic messages, and official publications and then analyzed. Three issues that enabled us to produce a full comparison are discussed: (1) we survey the policy landscape and list a range of policies within China and the USA as presented in Appendices A1 and A2, (2) we introduce the character and tendency of each nation's smart grid innovation policy as presented in Appendixs A1 and A2, (3) we rank the priorities for each nation's smart grid industry innovation policy. This is followed by a comparison of each nation's smart grid policy that highlights differences in each country.

The cross-national analysis of the smart grid industry mainly depends on qualitative content analysis and descriptive statistics. Content analysis is therefore one of the main methods used to systematically gain an in-depth picture of policy tools used for the smart grid industry. Such datasets may not be statistically representative, but they provide a rich understanding of the innovation policy that can be employed for the development of the smart grid industry. Descriptive statistics are used to quantitatively explain the main features of a set of smart grid policies.

This study also uses a pattern-matching approach to fit the smart grid policies we collected from China and the USA into the innovation policy framework of Rothwell and Zegveld. Table 1 describes how the policy tools from each survey case or source match or do not match the innovation policy pattern using Yin's (1989) pattern-matching structure. Table 1 lists the example criteria (practical policy measures categorized under these three headings) used to determine the policy category to which the related policy tools belong. As the table shows, the policy tools

Table 1
Policy tool criteria for pattern matching.
Source: Rothwell and Zegveld (1981).

	Policy tool	Examples
Supply side	Public enterprise	Innovation by publicly owned industries, setting up of new industries, pioneering use of new techniques by public corporations, and participation in private enterprise
	Scientific and technical development	Research laboratories, support for research associations, learned societies, professional associations, and research grants
	Education	General education, universities, technical education, apprenticeship schemes, continuing and further education, and retraining
	Information	Information networks and centers, libraries, advisory and consultancy services, databases, and liaison services
Environmental side	Financial	Grant loans, subsidies, financial sharing arrangements, and the provision of equipment buildings or services, financial loan guarantees and export credits
	Taxation	Company, personal, indirect and payroll taxation, and tax allowances
	Legal regulatory	Patents, environmental and health regulations, inspectorates, and monopoly regulations
	Political	Planning, regional policies, honor or awards for innovation, the encouragement of mergers of joint consortia, and public consultation
Demand side	Procurement	Central or local government purchases and contracts, public corporations, R&D contracts, and prototype purchases
	Public services	Purchases, maintenance, supervision and innovation in health services, public building, construction, transport, and telecommunications
	Commercial	Trade agreements, tariffs, and currency regulations
	Overseas agents	Defense sales organizations

used to influence the supply side of the innovation process include the provision of financial, manpower and technical assistance, including the establishment of scientific and technological infrastructure. In addition, the policy tools used to influence the environmental side (the economic, political and legal environment) encompass taxation policies, patent policies and regulations, such as measures that establish the legal and fiscal framework in which an industry operates. In addition, the policy tools used to influence the demand side of the innovation process involve central and local government purchases and contracts, notably for innovative products, processes, and services.

In addition, in this pattern matching of policy tools for cross-national comparison, all policy tools are given equal weight even though they are not all likely to have an equal impact on smart grid development in China and the USA. This assumption was used to develop this cross-national policy analysis and should be considered a limitation of the research. The assumption regarding all policies having an equal weighting impact was introduced at this stage for two reasons: (1) little research exists in the area of cross-national policy in the smart grid industry. As a starting point in this emergent energy sector, it may be risky to assume different weights for each policy tool based upon our observations of other industry or energy sectors. This weighting may also result in further bias in possible future studies. (2) The weighting will probably differ depending on the country context because the resource restriction and policy infrastructures are different in China, the USA and other countries. Assuming that all policies deserve an equal weighting impact appears to be the most appropriate research strategy at this initial research stage.

5. Innovation policy in the Chinese smart grid industry

This section will explain the development of the smart grid industry in China and present the findings of our policy study.

5.1. Development of the smart grid in China

The construction of the smart grid is mainly controlled by the Chinese government, which adheres to unified planning, unified standards and independent innovation and promotes government demonstration sites. The State Grid Corporation of China (SGCC) is responsible for coordinating the national grid infrastructure, researching and developing key technologies, and (through political regulations to educate domestic policy makers) accumulating practical experience acquired during the demonstrations.

Several factors in the last decade have resulted in the demand for a smart grid system in China. First, the grid has developed rapidly given the large growth in electricity demand resulting from the rapid economic expansion in China. Second, breakthroughs have been made in UHV (ultra-high voltage) transmission technologies, which lay the foundation for improving the grids' capability for the optimal allocation of resources across a wide area (Liu, 2005; Sun et al., 2007). Third, electricity occupies a small part of terminal energy consumption. The efficiency of energy use is low, not enough users are participating, and the marketing of the electricity industry should be accelerated. Finally, problems concerning the grids' accommodating capability, the receiving end markets, dispatch and operation have become prominent due to the rapid growth of renewable energy capability.

Why does China's central government want to develop the smart grid system? One major purpose is to serve the development of the social economy, thereby building a resource-saving and environmentally friendly society and making the power supply secure, reliable, clean, and efficient. Secondly, the goal is

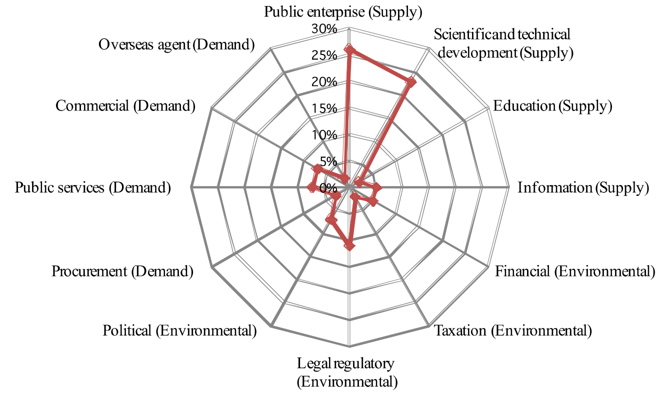

Fig. 2. The distribution ratio of smart grid policies in China (unit: %).

to serve both power sources and users, contributing to the coordinated and sustainable development of electricity generation, transmission, distribution and consumption. Enabling the optimal operation of power systems and improving the grids' capability for the optimal allocation of resources is another policy objective that realizes the efficient application of social resources and maximizes benefits. Finally, the government is focused on implementing the "plug-and-play" integration of renewable energy generation and distributed generation using strong network structures and flexible operation modes (State Grid Corporation of China, 2008; Han et al., 2009).

5.2. Policy tools used for the Chinese smart grid

Through secondary data collection, 57 innovation policy tools have been used by the Chinese government. Preliminary categorization results are shown in Appendix A1. Using this pattern-matching approach, all policy tools in China are given equal weight for the reasons described above and resulting in the research limitations also noted above.

Chinese governmental innovation policy tools have the greatest influence on *public enterprise*, which accounts for 26%, followed by *scientific and technical development* at 23%, and *legal regulatory* at 11%. Fig. 2 shows the distribution ratio of the smart grid policy in China. Furthermore, China's smart grid innovation policy accounts for 57% of the supply side, 24% of the environment side, and 19% of the demand side. The distribution of smart grid policies in China that adhere to each of the categories in the framework described above places emphasis on the supply and environmental sides, and the proportion of demand-side policies is correspondingly lower.

6. Innovation policy in the USA smart grid industry

This section introduces the development of the smart grid industry in the USA and presents the results obtained from our policy study.

6.1. The demand for a smart grid in the USA

Despite heavy power usage, the national grid in the USA is outdated and inefficient. Rolling blackouts and power outages are commonplace; therefore, the argument for a smart grid has never been stronger or had as much support. With ever-increasing demand, some believe that boosting carbon-producing power generation is necessary. The infrastructure of the national grid in the USA needs to be updated to better accommodate the differences and capitalize on the advantages. Smart-grid technologies could reduce overall electricity consumption by 6% and peak demand by as much as 27%. Reductions in peak demand alone would save between $175 billion and $332 billion over 20 years (Brattle Group, 2010).

\Recently, the electrical grids in the USA have experienced major problems, including an aging electricity infrastructure, transmission congestion, low market efficiency, poor reliability and the gap between the secondary systems and digital and information technologies. At the same time, numerous electricity utilities and various management modes exist. Most balances between power generation and power consumption are achieved locally. Long-distance transmission is rarely performed. In addition, permission to construct power lines is difficult to obtain because public concerns regarding environmental protection are high, and raising money is difficult to develop new generation facilities on the electricity market. Although national interconnection exists, there are problems in management and security due to a lack of nationwide backbone networks and uniform dispatch control (U.S. Department of Energy, 2010; Han et al., 2009).

As a result, the US government aims to digitally upgrade transmission and distribution (T&D) systems, thereby optimizing their operation, opening markets for alternative energies and offering diverse options for electricity consumers. Second, the goal of building smart grid systems is to increase the reliability, security and efficiency of power transmission and consumption using advanced information, control and communication technologies. The policy objective is to turn future networks into smart grids that exhibit resilience, reliability, interactivity and self-balance (Lyn, 2009; Han et al., 2009).

6.2. Policy tools for the US smart grid

Through secondary data collection, 64 innovation policy tools have been used by the US government. Preliminary categorization results are shown in Appendix A2. Using this pattern-matching approach, all policy tools in the USA are given equal weight for the reasons described above and resulting in the research limitations also noted above.

Government innovation policy tools in the USA have the greatest influence on *scientific and technical development* and *financial*, which both account for 20%, followed by *political* at 19%, and *public enterprise* at 11%. Fig. 3 shows the distribution ratio of smart grid policies in the USA. Furthermore, USA smart grid policy instruments account for 39% of the supply side, 53% of the environment side, and 8% of the demand side. The distribution of smart grid policies in the USA places emphasis on the supply and environmental sides, and the proportion of demand-side policies is correspondingly lower.

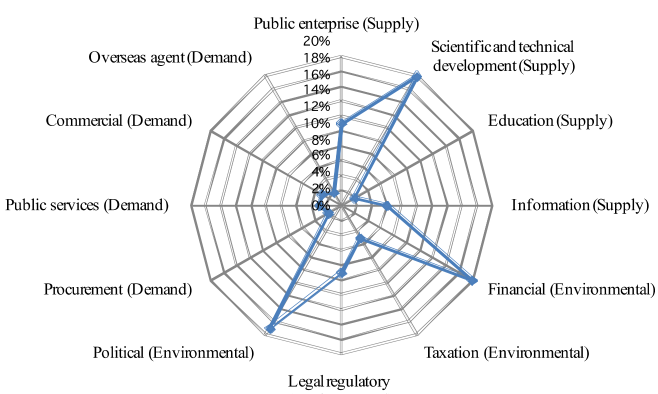

Fig. 3. The distribution ratio of smart grid policies in the USA (unit: %).

7. Findings and discussion

This section discusses the findings of the cross-national analysis. The differences in policy regarding the development of the smart grid industry between China and the USA are explored below. Then, practical implications and recommendations for future research are presented.

7.1. Comparison of the innovation policies for smart grids in China and the USA

In this study, we present two cross-national comparative analyses within China and the USA, as shown in Appendices A1 and A2. The first analysis is a cross-national innovation policy comparison (Table 2), which compares the emphasis of each innovation policy between China and the USA and lists all policies with their associated percentages. In China, *supply-side* policy is more common than *environmental-side* policy, which, in turn, is more common than *demand-side* policy. In the USA, *environmental-side* policy is more common than *supply-side* policy, which, in turn, is more common than *demand-side* policy.

In this cross-national comparison, all policy tools are also given equal weight, although they probably do not all have an equal impact on smart grid development in China and the USA. This assumption is used to develop this cross-national policy analysis and should be considered a research limitation, as noted above.

The second analysis mainly compares the weights of individual innovation policies (Table 3). In China, major policies focus on *public enterprise*, *scientific and technical development* and *legal regulatory* aspects. *Public enterprise* policies (26%) are more common than *scientific and technical development* policies (23%), which, in turn, are more common than *legal regulatory* policies (11%). In the USA, major policies focus on *scientific and technical development*, *financial*, *political* and *public enterprise* aspects. *Scientific and technical development* policies (20%) are as common as *financial* policies (20%), both of which are more common than *political* policies (19%), which, in turn, are more common than *public enterprise* policies (11%).

Table 2
Cross-national innovation policy comparison.

Policy Tool	**China**		**US**	
	Quantity	%	Quantity	%
Supply side				
Public enterprise	15	26	7	11
Scientific and technical development	13	23	13	20
Education	1	2	1	2
Information	3	5	4	6
Sub-total	**33**	**57**	**24**	**39**
Environmental side				
Financial	3	5	13	20
Taxation	1	2	3	5
Legal regulatory	6	11	6	9
Political	4	7	12	19
Sub-total	**14**	**24**	**34**	**53**
Demand side				
Procurement	2	3	1	2
Public services	4	7	2	3
Commercial	4	7	2	3
Overseas agent	1	2	1	2
Sub-total	**11**	**19**	**6**	**8**
Total	57	100	64	100

Table 3
The percentage of each innovation policy compared between China and the USA.

Policy tool weight rank			
China		**USA**	
1. Public enterprise	26%	1. Scientific and technical development	20%
2. Scientific and technical development	23%	1. Financial	20%
3. Legal regulatory	11%	3. Political	19%
4. Political	7%	4. Public enterprise	11%
4. Public services	7%	5. Legal regulatory	9%
4. Commercial	7%	6. Information	6%
7. Information	5%	7. Taxation	5%
7. Financial	5%	8. Public services	3%
9. Procurement	3%	8. Commercial	3%
10. Education	2%	10. Education	2%
10. Taxation	2%	10. Procurement	2%
10. Overseas agent	2%	10. Overseas agent	2%

7.2. Major findings

Based upon results comparable to those presented above, five major findings regarding policy differences between China and the USA are discussed in this section.

(a) "*Scientific and technical development*" *is the most significant policy tool for smart grids*
The results of this study indicate that both China and the USA use a high ratio of "scientific and technical development" in their policy tools for developing the smart grid industry. We refer back to the definition proposed by Rothwell and Zegveld (1981) and their causal process of policy tools presented in Fig. 1. These tools of "scientific and technical development" will enhance technical knowledge and manpower in the sector, thereby improving the R&D activities during development of the industry. In the smart grid industry, this means that the Chinese and the US governments tend to adopt these policy tools first when developing the related R&D base and further upgrading R&D and technical knowledge and manpower, which are critical to the initial integration of smart grid technologies and their associated components (Farhangi, 2010; Krishnamurti et al., 2012).

(b) *China highly relies on a* "*supply-side policy*" *and focuses on* "*public enterprise*" *to foster the smart grid industry*
The present study indicates that public enterprise is a major feature of China's smart grid policy. The Chinese government dominates smart grid development through centralized planning and a "supply-side policy" used to stimulate aggregate demand in the smart grid industry, and 11 state-owned power companies are viewed as allies in the execution of the smart grid policy for China and are responsible for smart grid-related activities. This trend is not surprising because the central government of China still controls the majority of electrical power and the development of smart grid systems by these stated-owned enterprises. This is obviously a more efficient policy measure for building the grid system in its initial stage because fewer private enterprises were allowed to invest in the related infrastructure at this stage. A number of new public enterprises were created and subsidized based on the related supply-side policy of the new 12th Five Year Plan. Conversely, in the USA, although the federal government supports state governments by joining forces to implement smart grid demonstration projects, the initiative is expected to respect the views of the states, not centralized, federal planning. The role of state-owned companies in China is more important than in the USA. The federal government of US plays a relatively passive role in creating an environment that is conducive to the development of the smart grid industry, the industrial environment, and nurturing the growth of new industries.

(c) *The USA relies heavily on* "*environmental-side policy*" *with a particular focus on* "*financial*" *and* "*political*" *policies to foster the smart grid industry*
Environmental-side policies account for as much as 53% of all smart grid polices in the USA, and particularly emphasis is placed on "financial & political". Financial policy includes providing business loans and tax subsidies to aid favored businesses. For example, the DOE has announced $750 million in loan guarantees for Conventional Renewable Energy Projects and Advanced Energy Tax Credits. In addition, the US government has introduced bills to help implement the smart grid and other renewable energy technologies, for example, in the American Recovery and Reinvestment Act (ARRA) and the Clean Renewable Energy and Economic Development Act. Although the US government attempts to promote the smart grid industry, it tends to do so by upgrading the industrial environment that enhances industrial competitive advantages and giving local companies incentives to support the relevant goods rather than by directly stimulating industrial demand. Considering the causal process illustrated in Fig. 1 (Rothwell and Zegveld, 1981), these policy tools will be helpful toward developing R&D and the domestic market environment by allocating financial resources and developing politically supported industrial structures.

(d) *The existence of few* "*demand-side policies*" *in both nations imply that the smart grid industry is still at the initial development stage*
"Demand-side policy" might rarely be adopted compared with "supply-side policy" and "environmental-side policy" because these smart grid technologies have not yet fully reached the commercialization stage. This industry is still at an early stage of development, but it is worth noting that several well-known US companies have directly or indirectly invested in the Chinese smart grid market, which implies that currently, business opportunity and market demand indeed exist in the Chinese energy sector. This finding also demonstrates that demand-side policy can also be globally applied by creating international markets, as illustrated in Fig. 1.

(e) *The major purpose of* "*legal regulatory*" *policy is to set industry standards*
As can be seen from the results, China and the USA both plan to announce a set of industry standards to provide a platform for developing new innovations and industry-leading technological development because the development of industry standards may contribute to industrial

Table 1A
The smart grid policies for China.

	Policy tool	Policy	Qnty	%
Supply side	Public enterprise	1. Creating STATE GRID Corporation of China (SGCC) 2. Creating China Southern Power Grid Corporation Limited (CSG) 3. Creating NARI Technology Development Co., Ltd. 4. Investing in Guodian Nanjing Automation Co., Ltd. 5. Creating Xjdzc Co., Ltd. 6. Creating Beijing Sifang & Huaneng Power System Control Co., Ltd. 7. Investing China Huaneng Group 8. Investing China Datang Corporation (CDT) 9. Investing smart grid by China Huadian Corporation 10. Investing ChinaGuoDian (Group) Corporation 11. Investing smart grid by China Power Investment Corp. 12. Developing alliance in State Grid Corporation (North China Grid, Northeast China Grid, East China Grid, Central China Grid, Northwest China & Tibet Grid) 13. Designing and developing the Shanghai expo integrated smart grid demonstration project 14. The smart community demonstration project undertaken by North China Power Grid Company of SGCC—Xin'ao Golf Garden residential block in Langfang, Heibei province was completed on September 20th, 2010 15. The first one of a Smart Building demonstration project in China and one of the smart grids pilot projects in Shanghai by State Power Grid Corp of China, Shanghai Yuefuhaoting Community is applied with PFTTH (power fiber to the home) (2010)	15	26%
	Scientific and technical development	1. The Plan on Research and Manufacturing of Smart Grid Key Equipment (System) has for the first time worked out a systematic research and production plan for key equipment including seven technical areas, 28 technical projects and 137 items. Based on the plan, the SGCC will carry out smart grid key equipment research and production in three stages 2. In 2010, SGCC announced that it would invest RMB 24.3 billion in building a strong smart grid in the Three Gorges reservoir area. SGC's subsidiaries including those in Beijing, Tianjin, Zhejiang and Shaanxi have kicked off trial operation of smart grid by sector 3. In April 2010, SGCC issued a green development white paper, predicting basic completion of the smart grid in 2020 4. As part of its current 5-year plan, China is building a Wide Area Monitoring system (WAMS) and by 2012 plans to have PMU sensors at all generators of 300 MW and above, and all substations of 500 kV and above 5. China's smart grid project will proceed in 3 key development periods from this year. During 2009–2010, detailed layouts and pilot projects will be launched to test related standards and products as well as to improve them. And the full scale deployment is expected to take place in 2011–2015 by speeding up the constructions of ultra-high voltage power lines and the reconstruction of distribution grids in urban areas. From 2016 to 2020, the unified "Strong & Smart Grid" will fully cover the jurisdictional region of SGCC and global leading techs and equipments will be deployed and installed to realize the ambition 6. 863 Program 7. 973 Program 8. Torch Program 9. Spark Program 10. The 11th Five year plan (2006–2010) 11. The 12th Five year plan (2011–2015) 12. The 13th Five year plan (2016–2020) 13. Smart Power Technology Research and Testing Center	13	23%
	Education	1. Education-sector, academia, and industry have shown tremendous enthusiasm in the research on the smart grid, many universities and research institutes, academia, experts and scholars held a variety of workshops	1	2%
	Information	1. SMART GRIDS China 2009 2. The 1st China International Smart Grid Technology and Equipment Exhibition (Smart Gridtec) will be held from 5 to 7 May 2011 at the Shanghai New International Expo Center (SNIEC) 3. China Power Grid Networks: 1.Northeast Grid; 2. East Grid; 3.North Grid; 4.Central Grid; 5.Northwest Grid; 6. Southern Grid; 7.Tibet Grid; 8. Inner Mongolia Grid	3	5%
Environmental side	Financial	1. In 2010, the Chinese government will lead the way with investments in smart grid technology of more than $7.3 billion. 2. Total investment in China is expected to reach US$7.3 billion in 2010 and could rise as high as US$99 billion by 2020. 3. In 2010, SGC announced that it would invest RMB 24.3 billion in building a strong smart grid in the 3 Gorges reservoir area	3	5%
	Taxation	1. China will spend more than $7.3 billion in the form of stimulus loans, grants and tax incentives this year, compared to $7.1 million by the U.S., according to an analysis by Zpryme, a Texas-based research firm (2010).	1	2%

Table 1A (*continued*)

	Policy tool	Policy	Qnty	%
	Legal regulatory	1. Renewable Portfolio Standard (RPS) 2. State council, plan for modifying and promoting the equipment manufacturing industry 3. China Electric Power Research Institute (CEPRI), "the Low Voltage Power Line Carrier Communication" standard 4. China Electric Power Research Institute (CEPRI), "Intelligent Control Net-work Data Terminal" standard 5. Setting up smart grid standard system and framework 6. Participating in the work of international organizations, such as the IEEE and IEC	6	11%
	Political	1. The draft amendment to the Renewable Energy Law 2. The 11th Five year plan (2006–2010) 3. The 12th Five year plan (2011–2015) 4. The 13th Five year plan (2016–2020)	4	7%
Demand side	Procurement	1. In 2009, the government released draft guidelines regarding the creation of official product catalogs (two of the six broad categories of products are energy efficient products and new energy technology equipment), and linking such product catalogs to government procurement decisions 2. The State put into effect a system guaranteeing the complete purchase of electricity generated from renewable energies	2	3%
	Public services	1. However, the big business opportunity of China's development of smart grid has attracted eyes of world electric giants. Siemens has become a major equipment supplier of converter transformer and direct current ground for the demonstration project of Yunguang extra high-voltage direct current transmission (2010) 2. G.E. announced a partnership with the city of Yangzhou to develop a smart grid demonstration center to promote its technology in the Chinese market (2010) 3. The whole power grid in China is managed by three companies: (1) Inner Mongolia Power (Group) Co., Ltd.; (2) State Grid Corporation of China; (3) China Southern Power Grid Co., Ltd. 4. The series of agreements on clean energy collaboration coming out of the US–China presidential summit of November 2009 represents a concrete agenda to develop just this sort of public–private partnerships that can lead to mutual gains	4	7%
	Commercial	1. Most expect foreign companies to get a sizable chunk of early contracts from this market, since it's foreign companies that have taken the lead on smart grid technology. Siemens (NYSE:SI) struck a deal with holding company Wasion Group (3393:HKG) to conduct feasibility studies in an effort to launch new smart grid pilot projects in the Middle Kingdom (2010) 2. IBM recently announced that it expects annual revenues from Chinese smart grid development to top $400 million for the next four years. IBM is the only corporation that is providing a full portfolio of smart grid infrastructure including hardware, software, and consulting services 3. GE, for one, recently announced plans to build a demonstration center for smart grid technology in Yangzhou. Their major players including ABB, Accenture, Cisco, Hewlett-Packard, Oracle, and Westinghouse have also staked generous claims in China's developing smart grid market 4. World electric giant Schneider, lured by the big business opportunity in China's smart grid, moved its Asia-Pacific Region Headquarters and China headquarters to the Wangjing Sci-Tech Park of Beijing in May this year	4	7%
	Overseas agent	1. US–China Clean Energy Research Center	1	2%
100%			57	

Data Resource: Bo (2010) Han et al. (2010), SGCC (2010), Research In China (2010), Market Intelligence & Consulting Institute (2010), China Southern Power Grid (2010), Lu (2010) and Chinese Academy of Sciences (2006).

competitiveness, domestic market development and the positive R&D feedback effect described in Fig. 1. In the smart grid industry, industry standards can play an important role in the network building of any country, especially in those regions that actively participate in the global industrial chain of smart grid components. Standardization also serves as a quality check for complicated smart grid technologies.

8. Research limitations

The method of content analyses adopted in this paper is the qualitative method for management research most often used to gain an in-depth picture of world energy policies. Such datasets are not statistically representative but provide a rich understanding of the types of energy policies that are mainly employed for smart grid development. However, this study faces several

Table A2
The smart grid policies for USA.

	Policy tool	Policy	Qnty	%
Supply side	Public enterprise	1. Building the U.S. Department of Energy's (DOE) Electricity Advisory Committee (EAC) 2. The National Institute of Standards and Technology (NIST) ''Advanced Research Projects Agency for Energy'' (ARPA-E) within the U.S. DOE with the goal of funding cutting edge research in energy and climate 3. GridWise Alliance within U.S. DOE and development of a roadmap by December 2009 for a coordinated nationwide cost-effective deployment of smart grid technologies 4. The GridWise Architecture Council (GWAC) was formed by the U.S. DOE to promote and enable interoperability among the many entities that interact with the nation's electric power system 5. Forming National Energy Technology Laboratory within the U.S. DOE 6. The Alstom Grid (formerly Areva T&D) demonstration project was designed to efficiently integrate distributed energy resources into the electric grid (2010) 7. These 32 demonstration projects: 1. 44 Tech Inc. Smart Grid Demonstration Project; 2. Amber Kinetics, Inc. Smart Grid Demonstration Project; 3. Battelle Memorial Institute, Pacific Northwest Division Smart Grid Demonstration Project; 4. Beacon Power Corporation Smart Grid Demonstration Project; 5. Center for the Commercialization of Electric Technologies Smart Grid Demonstration Project; 6. City of Painesville Smart Grid Demonstration Project; 7. Columbus Southern Power Company (doing business as AEP Ohio) Smart Grid Demonstration Project; 8. Consolidated Edison Company of New York, Inc. Smart Grid Demonstration Project; 9. Duke Energy Business Services, LLC Smart Grid Demonstration Project; 10. East Penn Manufacturing Co. Smart Grid Demonstration Project; 11. Kansas City Power & Light Company Smart Grid Demonstration Project; 12. Ktech Corporation Smart Grid Demonstration Project; Long Island Power Authority Smart Grid Demonstration Project; 13. Los Angeles Department of Water and Power Smart Grid Demonstration Project; 14. NSTAR Electric & Gas Corporation Smart Grid Demonstration Project; 15. NSTAR Electric & Gas Corporation Smart Grid Demonstration Project (2); 16. National Rural Electric Cooperative Association Smart Grid Demonstration Project; 17. New York State Electric & Gas Corporation Smart Grid Demonstration Project; 18. Oncor Electric Delivery Company, LLC Smart Grid Demonstration Project; 19. Pacific Gas & Electric Company Smart Grid Demonstration Project; 20. Pecan Street Project, Inc. Smart Grid Demonstration Project; 21. Power Authority of the State of New York Smart Grid Demonstration Project; 22. Premium Power Corporation Smart Grid Demonstration Project; 23. Primus Power Corporation Smart Grid Demonstration Project; 24. Public Service Company of New Mexico Smart Grid Demonstration Project; 24. Seeo, Inc Smart Grid Demonstration Project; 25. Southern California Edison Company Smart Grid Demonstration Project; 26. Southern California Edison Company Smart Grid Demonstration Project (2); 27. SustainX, Inc. Smart Grid Demonstration Project; 28. The Boeing Company Smart Grid Demonstration Project; 29. The Detroit Edison Company Smart Grid Demonstration Project; 30. Waukesha Electric Systems Smart Grid Demonstration Project etc.	7	11%
	Scientific and technical development	1. ''The National Electric Delivery Technologies Roadmap'' is the implementation document for the Grid 2030 vision 2. ''US–China Clean Energy Research Center'' would facilitate joint research and development on clean energy by teams of scientists and engineers from the US and China 3. National Institute of Standards and Technology (NIST) will assist with the development of standards and Roadmap for Smart Grid Interoperability Standards 4. ARPA-E Awards $151 million for 37 transformational energy projects (2009) 5. ''The Smart Grid System Report'' established in section 1303, shall, after consulting with any interested individual or entity as appropriate, no later than one year after enactment and every two years thereafter, report to Congress concerning the status of smart grid deployments nationwide and any regulatory or government barriers to continued deployment 6. ''Strategic Power Infrastructure Defense System (SPID)'' has been developed by Advanced Power Technologies (APT) Consortium. By incorporating multi-agent system technologies, the SPID system is able to assess power system vulnerability, perform the failure analysis and adaptive control actions to avoid catastrophic power outages 7. The Modern Grid Strategy—DOE—National Energy Technology Laboratory (NETL) 8. GridWise: project to modernize the US electric grid system and create a collaborative network 9. GridWorks: this project takes an integrated perspective of the entire electric system. It is organized to create a comprehensive portfolio of equipment that will be introduced into the electric system in a manner that will ensure safe and efficient operation 10. Modern grid initiative (MGI): it is sponsored by US DOE. It seeks to establish a consensus vision for the future grid. And then to create an open process for coordination, collaboration and sharing 11. ''Clean Renewable Energy and Economic Development Act'' will promote investments in transmission to increase access to renewable power 12. ''Nationwide Transmission Superhighway'' 13. The Modern Grid Strategy project of the National Energy Technology Laboratory (NETL)	13	20%
	Education	1. Energy Dept. invested $100 M in Smart Grid education, pledging to be more transparent about energy policy shifts and to better educate the market about efficiency initiatives. A major part of the latter goal is teaching people about the benefits and importance of the Smart Grid—a concept that consumers and some utilities have yet to rally behind (2010)	1	2%
	Information	1. ''Smart Grid E-Forums'': DOE is conducting a series of Smart Grid E-Forums to discuss various issues surrounding Smart Grid including costs, benefits, value proposition to consumers 2. The joint PA and Pepco team analyzed all Smart Grid documentation that was relevant to its federal stimulus application 3. The Smart Grid: an ''Introduction'' (DOE) 4. Smart Grid Resource Center. This site serves as a home for information about EPRI's Smart Grid research, demonstration projects, and the Smart Grid Use Case Repository	4	6%
Environmental side	Financial	1. DOE expands loan guarantee program to include private funding 2. DOE announces $750 million in loan guarantees for conventional renewable energy projects (2009–2010)	13	20%

Table A2 (*continued*)

	Policy tool	Policy	Qnty	%
		3. DOE distribute more than $3.4 billion in stimulus funds for smart-grid technology development grants (2009) 4. The power sector has committed to investment, bringing the amount to be plowed into the industry to $1.6 billion (2009) 5. In 2010, the US a close second with smart grid grants from the Department of Energy (DOE) close to $7.1 billion. 6. Department of Energy announces five awards to modernize the nation's electric grid 7. Total public–private investment of more than $30 million to increase reliability, efficiency and security (2010) 8. Obama announces availability of $3.9 billion to invest in smart grid technologies and electric transmission infrastructure 9. US to spend $100 million on making grid workforce smart (2009) 10. US announces $57 million in funding for smart grid initiatives. The US Energy Secretary Steven Chu on Monday announced $57 million from the American Recovery and Reinvestment Act (ARRA) for smart grid initiatives (2009) 11. Since 2009, the Federal has awarded US$4.5 billion in stimulus funds to spur smart grid investment and demonstration 12. $3.375 billion for Smart Grid Investment Grant Program (2009) 13. In 2009, the DOE announced awards of $620 million for projects around the country to demonstrate advanced Smart Grid technologies and integrated systems that will help build a smarter, more efficient, more resilient electrical grid. These 32 demonstration projects, which include large-scale energy storage, smart meters, distribution and transmission system monitoring devices, and a range of other smart technologies. This funding from the ARRA will be leveraged with $1 billion in funds from the private sector to support more than $1.6 billion in total Smart Grid projects nationally		
	Taxation	1. Advanced Energy Tax Credit 2. China will spend more than $7.3 billion in the form of stimulus loans, grants and tax incentives this year, compared to $7.1 million by the US, according to an analysis by Zpryme, a Texas-based research firm 3. The IRS recently issued important guidance regarding the taxation of Smart Grid Investment Grants made by the US Department of Energy (2010). These grants, which represent one of the largest group of Recovery Act clean energy grant awards to date, were awarded to private companies, utilities, manufacturers, cities and other applicants to further their efforts in developing technologies to improve the reliability and efficiency of the electrical grid throughout the US	3	5%
	Legal regulatory	1. NIST will assist with the development of standards for a smart grid network 2. Summaries of use, application, cybersecurity, and functionality of smart grid interoperability standards identified by NIST which release standard 1.0 (2010) 3. Initial Smart Grid Interoperability Standards Framework1.0 (2009) 4. The Electric Power Research Institute (EPRI) is to work together on an interim roadmap for the development of a smart grid 5. IEEE P2030 6. IEEE 1901	6	9%
	Political	1. Grid 2030, a national-vision for electricity second 100 years (2030) 2. "Advanced Research Projects Agency for Energy" (ARPA-E) 3. Initial Smart Grid Interoperability Standards Framework1.0 (2009) 4. Energy Policy Act 5. Federal Power Act 6. American Recovery and Reinvestment Act (ARRA) 7. Clean Renewable Energy And Economic Development Act 8. Critical Electric Infrastructure Protection Act 9. EISA: Energy Independence and Security Act of 2007 10. The Clean Renewable Energy and Economic Development Act of 2009 11. Nationwide Transmission Superhighway 12. One is $4.5 billion for a Smart Grid, specifically for a Smart Grid as contemplated by a statute Congress adopted in 2007, the Energy Independence and Security Act	12	19%
Demand side	Procurement	1. President Obama quietly signed Executive Order 13514, which also stipulates that federal agencies immediately start purchasing 95% through green certified programs and achieve a 28% greenhouse gas reduction by 2020 (2010)	1	2%
	Public services	1. Petra Solar lands $3 million smart grid contract from US DOE 2. Nevada first state in the nation with a private utility signing a major contract to build and implement smart grid	2	3%
	Commercial	1. GE, VC Partners Invest $55 M in New Smart-Grid Tech (2009) 2. IBM has been contracted by the Maltese electricity and water utilities—Enemalta Corporation (EMC) and Water Services Corporation (WSC) to set up a smart grid for the country	2	3%
	Overseas agent	1. US–China Clean Energy Research Center	1	2%
			64	100%

Data resource: US Department of Energy (2010), Energy Efficiency News (2010), NIST (2010) and Fuji-Keizai USA (2009).

limitations. First, there are many policy tools in these leading countries, and due to resource constraints regarding overseas exploration, not all of them have been adequately analyzed. The main weakness of this study is the absence of precise indicators and quantitative data regarding the magnitude of the effects caused by the application of innovation policies to smart grid technology.

Furthermore, as noted above, all policy tools are given equal weight in this cross-national analysis even though it is likely that they do not all have equal impact on smart grid development in China and the USA. This is also a research limitation because the development of smart grids in each country is insufficient to understand the effect of policy on grid network building at this stage. This issue is recommended for future cross-national study after the weighting impact of each policy tool can be clarified with respect to the development of smart grids

Due to this limitation, the findings of this study may not easily be generalized to all energy sectors and may be subject to other interpretations (Creswell, 2003). The quality of the research will also depend on the individual skills of the researcher and is more easily influenced by the researcher's personal biases and idiosyncrasies. These limitations will raise new starting points for the future study of the energy industry.

9. Practical implications

In practice, this study solves the problem of how to design an innovation policy for developing a smart grid. This cross-national study offers useful guidelines for designing policy portfolios in developing and developed countries. For developing countries, it is critical to develop policy guiding the direction of energy sector development using supply-side policy because private enterprises are not advanced in the smart grid network and innovation systems. Conversely, environmental-side policy tools may be strongly emphasized in developed countries where the energy infrastructure is well established and the government only guides the development of subsystems for the smart grid in the right location within the energy network. This result offers practical implications for smart grid development in different national contexts. It is worth noting that both selected cases, China and the USA, are large countries with abundant resources and very large energy demand within the domestic market. These cross-national findings will have limited application to small countries or new industrialized economies with an export-oriented policy direction.

10. Conclusions

This research provides a theoretical analysis of innovation policy but adopts a rather pragmatic approach. It describes in detail a number of innovation policies currently being pursued in the smart grid industry and contributes to smart grid policy research by applying the innovation policy framework to explore policy dynamics in China and the USA. The results reveal that national preferences for innovation policy differ in ways that are linked with the state of the power industry. China prefers to use "supply-side policy," with a focus on "public enterprise, scientific and technical development and legal regulatory" policies. The USA prefers to use "environmental-side policy," with a focus on "scientific and technical development, financial, political and public enterprise" policies. Based on this finding, policymakers in the energy sector can enhance the implementation, outcomes and quality of their initiatives. Planning based on innovation policy should consider the temporal dynamics of such policies and attempt to mitigate disadvantages at each stage. By integrating this perspective into policy planning, both the necessary resources and the potential outcomes can be optimized.

Appendix

See Tables A1 and A2.

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