International Journal of Energy Economics and Policy
Vol. 4, No. 2, 2014, pp.198-207
ISSN: 2146-4553
www.econjournals.com

An Analysis of Development Mechanism of China's Smart Grid

Xiaoling Yuan
School of Economics and Finance, Xian Jiaotong University,
Shaanxi, Xian, China, 71006. tel: 86 18629249038.
Email: xiaoling@mail.xjtu.edu.cn

Jiangyang Zhang
corresponding author,
Mailbox 96,74 West Yanta Rd, School of Economics and Finance,
Xian Jiaotong University, Shaanxi, Xian, China, postcode: 710061,
tel: 86 18729534630, Email: kairoc@stu.xjtu.edu.cn

ABSTRACT: Through the perspectives of socio-technical systems, this paper summarizes characteristics of China's smart grid and finds the influencing factors of development mechanism. We find that China's smart grid featured by company-led, government striven to develop renewable energy, indigenous and multinational corporation both-driven, consumer-participated passively approach appears to differ from development pathways compared with other Western counties such as US, South Korea and Japan, then we assess strength and weakness of the development mechanism from three aspects including government, industrial and consumer. From a long run, China should establish flattening social innovation organization with government-led, stakeholders-participated jointly, then enact national blue planning, laws and technical standards, at last, develop ultra high voltage properly and actively promote development of distribution generation and micro grid.

Keywords: Smart Grid; Development Mechanism; Government; Industrial; Consumer
JEL Classifications: 030

1. Introduction

Smart grid is a current world technological revolution in energy industry, and development of smart grid id one of economic recovery countermeasures. Jeremy Rifkin, renowned economist and one of world's famous prophets, thought the third industrial revolution is a combination of communication technology and new energy technology, so many countries attach great importance to develop smart grid. In 2009, United States announced to invest $3.4 billion on smart grid as an important part of energy strategy, in response to the subprime crisis and low-carbon economic. To accelerate the development of smart grid, U.S. Department of Energy with smart grid industry association released a blueprint, which will lead schools, American National Standards Institute, GE, IBM and so on to promote the development of smart grid. Soon afterwards, China, Japan, European Union, South Korea and other countries successively enact their smart grid planning and speed up implementation. However, Chinese State-owned grid enterprises-led approach to developing smart grid appears to differ from others countries. For example, Japan has formed government-led, community-based and business-driven mechanism; United States and South Korea has formed government-led, various stakeholders-promoted approach. Although Chinese government has played a leading role in power

utilization and distributed energy, but its two state-owned grid companies has been planned their own blueprint and began to implement. So why is Chinese development pattern of smart grid different from other countries? What is its intrinsic mechanism? What are the advantages and disadvantages? This paper will examine above questions.

This paper will investigate the influence factors of development mechanism of smart grid, explain particularity of development mechanism of China's smart grid, then examine and evaluate the intrinsic mechanism. This paper will be a useful supplement to research of development mechanism of smart grid in the world, and it has some meaning to take example by other developing countries to favor the development of smart grid.

2. Literature Review

Smart grid, as social-technical innovation, is influenced by different innovation pattern. There are three kinds of social innovation pattern; one is that scientists according their interests push innovation process; the second is market-driven innovation pattern which is promoted by corporations for meeting market demand. The third is innovation-governed which has become mainstream innovation pattern and emphasizes a positive role of the government who will speed up the technology innovation through innovation policies (Weiss and Bonvillian, 2009). For example, Chinese government's innovation policies focus on supply mainly related to public utility enterprises, the development of science and technology and regulation, United States policies focus on environment mainly related to the development of science and technology, finance, politics and public utility (Lin et al., 2013). Chinese government did not play a positive role in the process of smart grid innovation so that innovation policies are not systemic and unbalanced (Sun et al., 2011). Chinese government should establish a comprehensive innovation pattern to develop smart grid containing three innovation patterns above in the transition of socio-technical change (Yuan et al., 2012).

Western countries show different pattern on development mechanism of smart grid, but are same to emphasize the role of government. Japan has formed a government-led, community-oriented, market-driven development pattern of smart grid, putting emphasis on distributed generation, dispatching, distribution and utilization, however, the pattern is not enough attention to the establishment of new business models and consumer interaction (Mah et al., 2013). China should pay attention to market position, innovate promotion model of pilot project, extend diversified fields and actively explore international markets (Chen and Wan, 2013). South Korean has established government-led, various stakeholders-involved pattern ,which maybe can not obtain consumers' trust and obstruct reformation of electricity market, and indicate the different functions of government, enterprises and consumers in aspects of macro, industry and micro level (Mah et al., 2012).

To sum up, scholars generally recognize that the development mechanism of smart grid is influenced by national background, innovation pattern, innovation policy. Some of them have researched Japan and South Korea's pattern, but ignored China's, this article will complete.

3. Smart Grid in China: An Overview

3.1 Background

Smart grid is an important technology as to impede climate worming and develop low- carbon economy. The world climate conference was held in Copenhagen in 2009, and China committed to reduce carbon dioxide emissions by 40% ~ 45% per unit GDP in 2020 lower than in 2005. According to British Tyndall climate change research center, China is faced with severe pressure to reduce carbon

emissions ,which total of carbon emissions has become first in the world in 2011,and energy consumption per unit GDP is 8 times of Japan, 4 times of United States. At the same time, the developed countries resort to its low carbon economic advantage to vigorously advocate green trade and force carbon tax which will cut down the export of Chinese products. Smart grid can be instrumental in improving the efficiency of energy supply and use , and accommodating a broad range of renewable energy, help to ease the severe pressure of energy saving and emission reduction.

Smart grid is a natural fusion of power industrialization and informatization in China, which is an important content of China's modernization. In 2008, Chinese government set up Ministry of Industry and Information Technology of the People's Republic of China which implies industrialization and informatization have become a national strategy. Smart grid is essentially a cross revolution of electric power technology and information technology, which will realize informatization on power generation, substation, transmission, distribution, dispatching and utilization, make power flow, business flow, information flow bilateral interaction, which will greatly improve the operating efficiency of electric electricity industry and the level of intelligent decision.

Abroad vigorous development of smart grid boosts China's construction of smart grid. In 2009, the United States, Japan, South Korea, India one after another develop smart grid as a national strategy aiming at acquiring well position in future competition of energy field, and ensure energy security and independence. In 2010, smart grid has become one of strategic emerging industries in China. The power grid companies have played an important role in smart grid, and been guiding the research of key equipment and technology, comprehensively carrying out demonstration projects, promoting to develop national standards and technical regulations, actively participating in international standards.

The power grid enterprises will get a lot of benefits from development of smart grid. The implement of the smart grid will further consolidate the dominant position of the enterprises in the electric power industry, bring a new source of income and improve the efficiency of asset utilization and operation. The enterprises will strengthen their ability to control the power industry through upgrading of grid asset, locate new profit from construction of new energy power station charging station for electric vehicle. Therefore, the enterprise is a huge advocate for smart grid.

3.2 Characteristic

China has not yet to form a national smart grid planning, but the power grid companies has been implementing their own planning in all over the country. National Energy Administration has successively enacted the Twelfth Five-year Plan of distribution energy, solar energy, wind energy, biomass and natural gas, but still has not release the plan of grids. To accelerate development of new energy and distributed generation, National Energy Administration has issued "the temporary regulations of distributed generation ", announced to build 100 new energy demonstration city, and vigorously promoted wind power through concession bidding projects, gave abundant subsidies for new energy and electric cars. There are three gird utilities including State Grid Corporation of China (SGCC), China Southern Power Grid and West Inner Mongolia Power Grid. SGCC is the largest one which serves 26 provinces covering 88% area of the state territory and provides electrical utility services for more than 1.1 billion people. In 2012, SGCC had 2.21 trillion ¥ assets, sold 3.09 trillion KWH, 1.67 trillion ¥ revenue, ranked the seventh in Fortune Global 500 in 2011. In 2009, SGCC released its own smart grid blueprint that contains three sages. The first called plan and pilot stage from 2009 to 2010 is expected to invest 1 trillion ¥.The main task is to focus on the smart grid planning, develop technical and management standards, research and develop key technology and equipment, demonstrate comprehensive pilot project. The second called comprehensive construction

stage from 2011 to 2015 is expected to invest 1.5 trillion ¥. The main task is to accelerate the construction of ultra high voltage grid, urban grid and rural grid, preliminarily complete the construction of power grid operation control and interactive service system, and achieve a major breakthrough on the key technology and equipment; The third called leading and promoting stage from 2016 to 2020 is expected to invest 2 trillion ¥. The main task is to completely built unified strong smart grid so as to notably improve ability of energy resource allocation, safety, efficiency, level of interaction between grids, supplier and user. At that time, smart grid will pay an important role in serving development of clean energy, security of energy supply, and promoting economic and social development.

The social innovation organization of smart grid in China which is grid companies-led and stakeholders-driven tends to be vertical while western countries flat. For example, in 2009, SGCC who has had its own electric power equipment company, new energy company, electric power design institute took over tow important companies: one is called Pinggao Group Co.,Ltd, whose main business is the R&D, manufacture, sales and service of high voltage, extra-high voltage and ultra-high voltage switchgears ,another is called XuJi electric group co., LTD whose main business is the power grid dispatching automation, distribution automation, substation automation , power grid security and stability control and so on. So far, SGCC has covered every fields of smart grid. However, in western countries, such as US, Japan, their government lead various organizations who compete or cooperate with each other, such as power grid companies, power generation companies, R&D institutes, information corporations and other stakeholders. They also provide financial subsidies, financial support, and information consulting services so as to accelerate the technological change.

The construction of China's smart grid is prominently characteristic of ultra-high voltage (UHV) and centralized power generation. As early as 2003,SGCC advocated UHV technology so as to realize the projects of West-East and North-South power transmission and encouraged people use more electricity for substitute of oil and gas. As so far, the centralized power generation, long distance transmission through UHV is basic characteristics of China's smart grid, but the construction of distribution automation was promoted slowly, distributed generation and micro power grid were promoted cautiously. In program of smart grid, SGCC plan to realize connection of north China, central China, east China through establishing "three vertical and three horizontal" UHV power grid with 1000 kV voltage or above.

China's smart grid was constructed quickly and widely. In planning, for example ,SGCC plan to accomplish the construction of smart grid in 2020 before western countries in 2030. In standards, for example, SGCC has established system technology standards of smart grid containing enterprise standards 356, industry standards 90, international standards 19, especially UHV standards had become an international standard. In power transmission, China has completed 6 UHV demonstration projects and operated successfully. SGCC established 2 UHV demonstration projects using ac voltage technology and 2 UHV using dc voltage, and China Southern Power Grid established 2 UHV using dc. In substation, as so far, SGCC has established 500 smart substations with voltage from 500 kV to 750 kV. In distributed generation, Shannxi Regional Glectric Power group Co., Ltd established a distributed generation pilot project containing wind energy called LangErGou in Shaanxi province; SGCC established several distributed generation projects such as Zhangbei wind-solar-store integrated pilot project in Hebei province; the expo garden integrated pilot project of smart grid in Shanghai in 2010 ; the Sino-Singapore eco-city in Tianjin and so on. In user side, SGCC has accomplished bidding of smart meters about 233 million and set up 67 electric vehicle charging stations until 2012.

4. The Development Mechanism of China's Smart Grid

The development of smart grid will refer to many industries containing electric power equipment manufacturing industry, information and communication industry, new energy industry, electric cars, chips, batteries and other industries, which will cause a great change in the field of social-economy. The development mechanism of smart grid has general law of science and technology revolution but has a certain particularity due to the different national conditions.

4.1 The Influence Factors of Development Mechanism of Smart Grid

The factors will include national factors, government factors, industry factors and users. National factors determine particularity of the mechanism; government, enterprises or users who have the most power at different development stage of smart grid will lead smart grid and the harmony between them will determine development speed of smart grid. National factors include territorial area, resources endowment, consistency between spatial distribution of energy and economic development; government factors include international responsibility of environmental protection, maturity of regulation, innovation mode; Industry factors include natural monopoly of electricity industry, firm nature of Grid Company, concentration degree of electric industry and technology endowment. User factors include user preference for environmental protection, user income. The role of factors shows respectively as follows.

4.1.1 National Factors

The factors including size of territory, endowment of energy, consistency between spatial distribution of energy and economic development have an important influence on the choice of smart grid technology. Country like Japan has smaller territory chooses smart grid technology focusing on distributed generation, distribution automation, electricity utilization automation. On the contrary, China may consider developing UHV transmission technology. Endowment of energy determines energy structure and relative price of different energies. If natural gas or oil is richer and the price is lower than other energies, the nation may transports energy using pipeline technology instead of UHV. For example, USA whose shale gas increases significantly in recent years, the unit cost of gas power plant using gas turbine technology is about 30% lower than unit cost of coal-fired power so that distributed generation has greater advantages than other countries. If spatial distribution of energy and economic development is mutual consistency, regardless of the size of territory, a country is suitable for development of distributed generation and micro-grid technology. However, if the development of regional economic is long-term unbalanced and transport of energy with rail and pipeline can't meet demand of economy development, it necessary to choose UHV technology.

4.1.2 Government Factors

A government who undertakes bigger international environmental responsibility will tend to make more new energy connect to smart grid. Development of low-carbon economy has become a mainstream in all over the world. Energy demand of electricity industry which accounts for about a quarter of the world's greenhouse gas emissions consumes about 40% of the world's primary energy ,and its cleanness and efficiency will do matters to complete environmental targets. For example, China, a developing country, have to undertake a certain international environmental responsibility, but whose extensive growth mode with energy-intensive and highly pollution emissions make him be in a very passive position in the aspects of international energy conservation and emissions reduction. Therefore, Chinese government has an incentive to develop the smart grid featured by cleanness and efficiency and support new energy to connect to power grids.

The maturity of energy governance has an important influence on whether government leads

development of smart grid or not. The indicators of maturity is measured by whether the government has unified department of energy governance, the past regulation performance and effectiveness of regulation. Once above indicators are performed well and smart grid is on the agenda in a country, government would lead smart grid in the initial phase and overcome information, coordination and externality issues through propaganda, fiscal policy and financial support so as to accelerate the technological change. For example, USA's DOE not only play an important role in global energy governance, but also play an important role in USA's energy development. DOE timely issued a smart grid planning and authorized GridWise Alliance Architecture Council to guide the stakeholders to jointly promote development of smart grid. In comparison, Chinese Electricity Regulatory Commission who made poor performance because of various reasons was set up in 2003 and was incorporated into National Energy Administration in 2013 which means failure of electricity regulatory. So far, National Energy Administration undertake the duty of electricity regulation, but plays a limited role in the smart grid and has not yet to form a national smart grid planning and energy law.

The choice of different innovation model has an important influence on whether government plays a bigger or smaller role in innovation. In above literature, we show there are three innovation pattern as follows: interests-pushed, market-driven and innovation-governed. The first exists disadvantages such as slow speed of innovation, unclear innovative target. The second is directly pushed by market which has clear targets but exists lock-in effectiveness which means the slow speed of technological marketization. The third exists advantages such as government can play a positive role in initial and promotion stage of innovation to solve externalities issues and protecting some selected firms and industries.

4.1.3 Industry Factors

The natural monopoly of electricity industry and the firm nature of grid company are a theory foundation of government regulation. With development of electricity technology, natural monopoly of electricity industry has been getting more and weaker and the field of generation and utilization of the industry has realized effective competition. But natural monopoly of electricity transmission and distribution which are strictly regulated by government still are unchanged. The regulations include rationality of electricity price, effectiveness of innovation, and efficiency of operation. The firm nature of Grid Company requires that it must maximize shareholder's profit through pursuit of profit maximization and at the same time the manager maximize his own profit. Therefore, it is inevitable that the grid company will resort to its monopoly advantage to eliminate competition and make price beyond price marketed, which must lead to efficiency loss of market and firm. For example, SGCC has formed monopsony power to suppliers such as the electric power equipment manufacturers, information providers, electric power contractor and so on, on the other hand, has formed partly monopoly power to users with its powerful lobby influence on making electricity price of government.

The endowment of technology means currently stock of electric power technology and information technology in a country, which have direct impact on the pattern of innovation organization of smart grid. A country who has not enough technologies to develop smart grid have to import the technologies and foreign companies will become more important in innovation organization. For example, in development of China's smart grid, number of transnational corporations played a more important role, such as IBM, GE, Acenture, ABB, Siemens and so on.

4.1.4 User Factors

The environment preference and income level both play an decisive role to demand response. Smart grid provides the possibility to make new energy connected to the grid, if user's environment

preference gets more and more strengthen, they will actively support and participate in the construction of smart grid, and are willing to bear tax burden caused by state subsidies. For example, China has been suffering from serious environmental pollution and increasingly hazes weather which has been a focus problem in current society, which will be in favor of promotion of solar and wind energy. For example, a Chinese user has established his own photovoltaic power station in his roof, and he will sell extra electricity to SGCC. In addition, these two factors will be benefit of development of electric vehicles. Currently the price of electric cars is still more highly than traditional cars except government subsidies due to technical bottlenecks and large-scale production, in addition, rare charging piles causes inconvenience. However, If users are willing to pay for environment, it is beneficial to promote the electric car.

4.2 Development Mechanism of China's Smart Grid

Above all, China's smart grid currently has formed the development mechanism that is company-led, government striven to develop renewable energy, indigenous and Multinational Corporation both-driven, consumer-participated passively. Grid companies play a leading role in power generation, transmission, substation, distribution, scheduling, electricity six links, at the same time, expand their business to the field of electric power equipment manufacture and the electric car charging station so as to realize the goals of firm. The government who takes into account safety, economy, and rationality of smart grid faces many pressures from energy conservation, emissions reduction and control of total energy consumption. Therefore, in the development of smart grid, government actively supports new energy connected to grids through centralized or distributed mode and gives huge fiscal subsidies. The grid companies actively participate in the field of electric cars for catching new market opportunity from structure change of energy demand and the government for saving energy, reducing pollution emissions and improving air quality of the city. In the field of power equipment manufacturing and information industry, the market is shared across power grid companies, local enterprises and foreign capital enterprise. User is passively participated and many of them do not know that smart grid will bring the revolution of energy utilization.

5. The Evaluation of Development Mechanism of China's Smart Grid

The development mechanism of China's smart grid has made some important achievements including that smart grid was constructed comprehensively, number of pilot projects were completed successfully, and especially the UHV technology has reached the leading level of the world. But there are still three shortcomings as follows.

The mechanism maybe strengthens the monopoly position of the power grid company and will obstruct the reformation of electric power market, although it is conducive to accelerate the implementation of smart grid. The Chinese the reformation of electric power began in 1997, Ministry of Electric Power was canceled and set up State Power Company, at the same time, the responsibility of regulation on electricity industry was empower to State Economic and Trade Commission, then realized separation of enterprise from administration. The second stage of reformation began in 2002 came up with the target that is "separation of plant and grid, separation of principal activities and indirect activities, separation of transmission and distribution, determination of electricity price through bidding". Chinese Electricity Regulatory Commission established in 2003 was responsible for the target. In 2002, the Chinese government accomplished separation of plant and grid and firstly broke the vertical integration mode of electricity industry, and then State Power Company was split into three companies: SGCC, China Southern Power Grid and West Inner Mongolia Power Grid,

meantime set up the five power generation group. The third stage of reformation began in 2011 realized separation of principal activities and indirect activities that the assets of survey, design, construction was stripped from the grid companies and set up two companies called China Electric Power Construction Group co., LTD and China Energy Construction Group co., LTD. Under the existing development mechanism of smart grid, power grid companies resort to its dominant position, seize the opportunities brought by smart grid and actively extend its industrial chain. These actions of the grid companies will result in unfair competition to the electric power equipment manufacturing industry. SGCC for strengthening its dominant position chose UHV technology and support centralized generation rather than distributed generation and micro-grid which directly reduce the value of UHV power grid. The mechanism of grid companies-led due to lack of unified planning for power grid construction is responsible for the phenomenon of abandoning wind power and photovoltaic generation. According to the survey of Chinese National Energy Administration, 20 billion KWH valued more than 10 billion ¥ wind power is abandoned in 2012.

Chinese National Energy Administration actively advocated development of new energy and promoted distributed generation so as to achieve energy conservation and emissions reduction. But currently lack of unified technology standards and regulations for new energy increases the uncertainty of new energy investment. The UHV technology which can not avoid the risk of blackouts caused by war and natural disasters has not been chosen by other countries like USA and European. Another potential risk is that the premise of UHV technology is unbalanced between resource and economic development, there will be highly investment risk of UHV if regional economy has tendency of convergence.

Users still passively accepted smart grid and it has long road for realizing the goal of information and power bilateral interaction. An important feature of smart grid is the demand response of users which will shave peak of power utilization and reduce investment of reserve capacity through real-time price and energy storage facilities of users. The problem is that the reformation of cross electricity price and the real-time electricity price has not been pushed forward, although smart meters were stalled increasingly.

6. Conclusions and Suggestions

The world smart grid is in the initial stage of demonstration, but Chinese smart grid is in the stage of comprehensive implementation. This paper investigates the development mechanism of Chinese smart grid, found that the mechanism is featured by vertical innovation organization, fast and comprehensive construction, development of UHV technology and centralized power generation, more construction of demonstration projects especially the UHV projects and smart substation, more installation of smart meters and electric vehicle charging station, has formed the mechanism of company-led, government striven to develop renewable energy, indigenous and multinational corporation both-driven, consumer-participated passively. The decision factors of the mechanism include national factors, government factors, industry factors and users, government, enterprises or users who have the most power at different stages of smart grid will lead development of smart grid and the harmony between them will determine the development speed of smart grid. The current mechanism is conducive to rapidly promote the development of smart grid and new energy, but strengthens the monopoly position of power grid company, increase the difficulty of electric power system reform, leads unfair competition in the electric power equipment manufacturing industry, contains the potential risk of safety and UHV investment, makes user passively involved.

According above conclusions, we give the following policy suggestions:

(1) Translate the grid company-led to government-led which will make the development of smart grid more rationally and quickly. Smart grid has been an important national strategy in many countries which has established flattened social innovation organization and led by government. For example, USA, Japan and South Korea government have directly invested money in construction of demonstration projects, actively promote technology standards and evaluation model of smart grid, fully take advantage of government role including institutions innovation, industrial integration, social propaganda. We suggest that China should carry out the development mechanism of innovation-driven and deepen the system innovation so that China will take a leading position in development of smart grid in the world.

(2) Synchronously promote the system reform of electric power and the development of smart grid. The smart grid will drive the market structure of electricity industry and integration of related industries. For example, the development of distributed generation and micro-grid will become new competitors in electricity market; the installation of smart meters will make it possible to integrate the telecommunication, internet of things, internet and broadcasting networks. The establishment of electric vehicle charging station will have a huge impact on traffic energy sector which maybe transform currently oligopolistic market structure to competitive one. Therefore, China should appropriately develop UHV technology and actively develop distributed generation and micro-grid, which make more effectively competition between backbone grid, distribution network, and micro-grid.

(3) Strengthen the regulation of power grid enterprises and appropriately deal with the relationship between firm nature and utility nature of power grid enterprise. Because of natural monopoly of electricity industry, historically power grid enterprise is state-owned or strictly regulated so as to ensure that it serves society as utilities in many countries. Currently, in China the State-owned Assets Supervision and Administration Commission of the State Council is responsible for preserving and increasing value of state property, which can't avoid the principal-agent problems that the manager will maximize his profit through expanding investment, pursuing monopoly profits, satisfying employee’s benefits and so on. However these actions of manager conflict with regulation goals of National Energy Administration.

(4) Improve a level of user interaction. The bidirectional interaction is an important characteristic of smart grid, especially between user side and grid side, the user side and generation side. The government should vigorously propagandize the significant role of smart grid in improving the efficiency of electricity utilization, elevating the quality of service , reducing cost. On the other hand, should introduce new incentive mechanism including expanding the scope of the direct power purchase pilot project, gradually realizing real-time electricity price in consumers including industrial user, commercial user and residential user.

Acknowledgements

This work was Supported by the [major project of State Social Sciences Fund: The Influence of Smart grid on Energy Supply, Energy Utilization , Energy Industry Structure and Development Strategy Research] under Grant [12AZD103].

References

Chen, Z., Wan, K. (2013), An Analysis of Development Mechanism of Japan's Smart Grid. Contemporary Economy of Japan, 4, 35-42.

Lin, C.c., Yang, C.H., Shyua, J.Z. (2013), A comparison of innovation policy in the smart grid industry across the pacific: China and the USA. Energy Policy, 57, 119-132.

Mah, D.N., van der Vleuten, J.M., Ip, J.C., Hills, P.R. (2012), Governing the transition of socio-technical systems: A case study of the development of smart grid in Korea. Energy Policy, 45, 133–141.

Mah, D.N., Wu, Y-Y., Ip, J-C., Hills, P.R. (2013), The role of the state in sustainable energy transitions: A case study of large smart grid demonstration projects in Japan. Energy Policy, 63, 726-737.

Yuan, J., Xu, Y., Hu, Z. (2012), Delivering power system transition in China. Energy Policy, 50, 751-772.

Sun, Q., Ge, X., Liu, L., Xu, X., Zhang, Y., Niu, R., Zeng, Y. (2011), Review of Smart Grid Comprehensive Assessment Systems. Energy Procedia, 12, 219-229.

Weiss, C., Bonvillian, W.B. (2009), Structuring an energy technology revolution. MIT Press.