A Study on Renewable Energy Generation in China

- Focus on Distributed PV Power Generation

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Chapter 1

Chapter 1 Introduction

1.1 Background

Energy is a critical foundation for economic growth and social progress. As economy advances and human society requires more energy, the lack of fossil energy and its pollution on the environment has given rise to the ever-serious contradiction among energy providing, environment protection and economic development. The four times worldwide Energy Crisis has already served as warning for human sustainable development.

As one of the largest energy consumption countries in the world, China faces severe energy-related challenges:

(1) The ever-increasing energy consumption

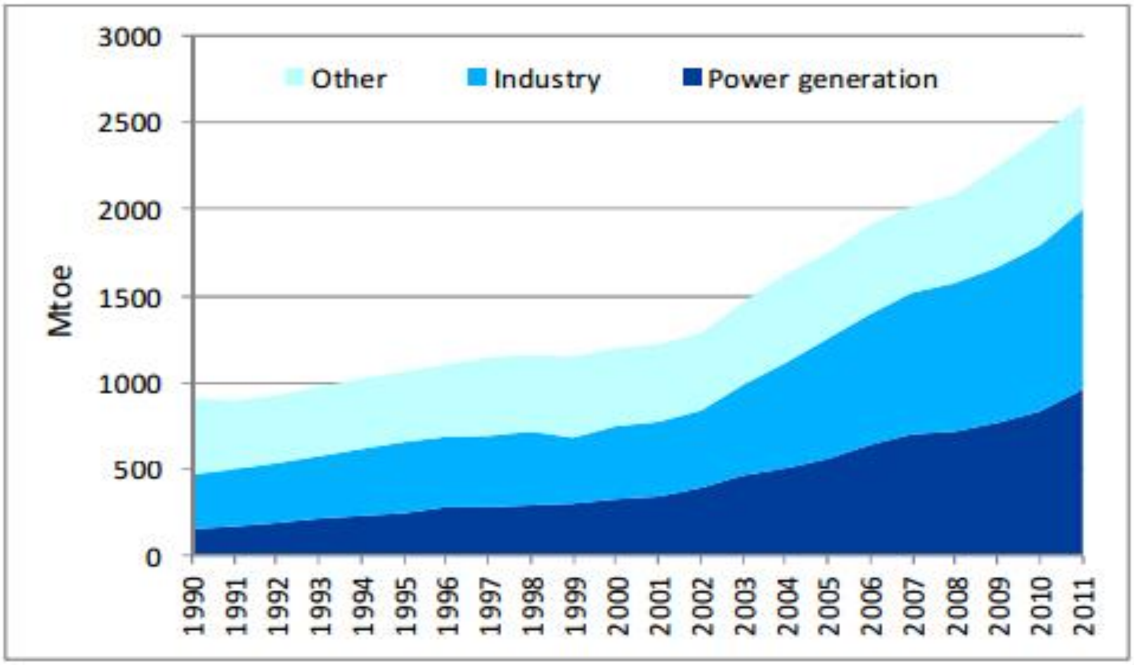

Fig.1-1 Energy consumption trend by sector from 1990-2011

Source: China Energy efficiency report by Enderdata

Fig. 1-1 illustrated the increase trend of China's energy consumption from 1990 to 2011. The energy consumption from power generation sector and industry sector is keep quickly increasing. As the pillar industry for China's economic development is manufacturing industry, it means China requires significant amounts of energy in the form of both electricity and petroleum-based fuels in order to operate. Since the new target for China's economic development set by the country's government is to quadruple the gross domestic product (GDP) accounted for in 2000 by 2020, ensuring China's attainment of a well-off society overall (Zhang, 2009). To achieve this target, the energy consumption will reach approximately 3 billion ton of standard coal equivalent (tce) (Zhou DD, 2003). Then, with economies grow, wealth and consumers' energy needs rise. Therefore, there would be a large increase of China's energy consumption to achieve the country's new social and economic development target, raising significant energy consumption concerns.

(2) The irrational energy consumption structure

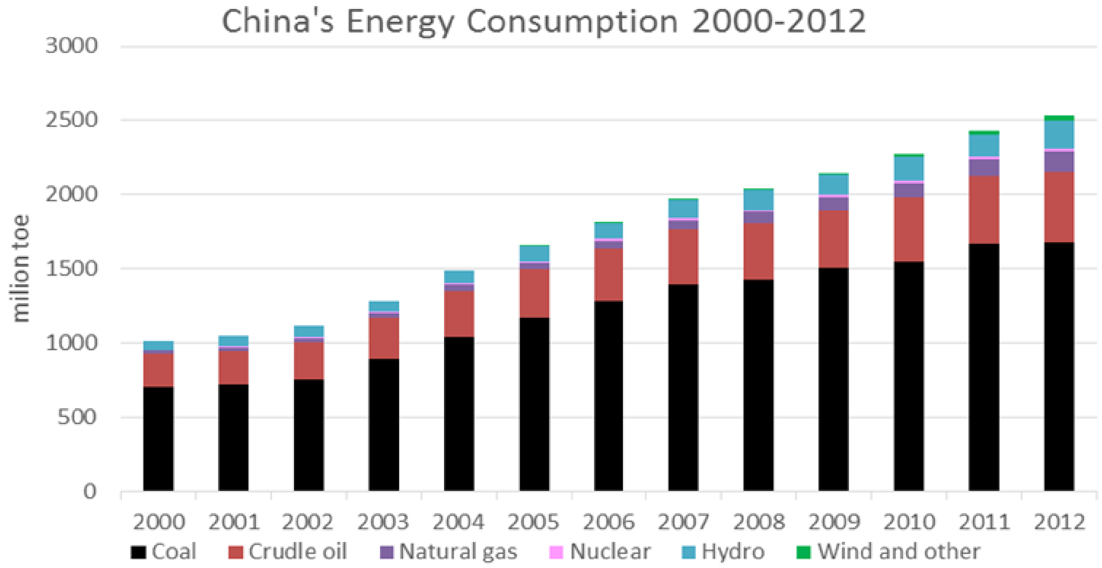

Fig.1-2 China Energy Consumption 2000-2012

Source: China Statistical Yearbook, Energy Data book 2012,

2013 China Energy Supply and Demand Projection Report.

No other nation depends on coal to the extent that China does. Fig.1-2 shows the energy consumption by sources from 2000 to 2012. Obviously, coal source has dominated China's energy structure. Coal accounts for 66.2% of China's energy consumption, and the world' average was 28% in 2012 (U.S.EIA, 2014). China's consumption of coal takes up more than half of global coal consumption (50.2%) for the first time in 2012 (BP., 2014). In addition, no industry depends on coal to the extent that electricity generation does in China. China's installed thermal power electricity capacity was 819.34 GW, or 70.9% of the total installed capacity in 2012 (more than 95% is coal-fired). In 2012, China's power production reached 4980.1TWh (CNREC, 2014), second by the United States' nearly 4256.1 TWh (BP., 2014). Coal accounted for 79.0% of all power generated in 2011 (World DataBank, 2014), far above the world average of 42% (U.S. EIA, 2012). According to the research by China Energy Research Society, if maintain the rate of coal-fired power, China is projected to require 4.1 billion tons of power coal by 2020 (CERS, 2014) .

(3) The low energy utilization efficiency

GDP per unit of energy use is the PPP GDP per kilogram of oil equivalent of energy use. PPP GDP is gross domestic product converted to current international dollars using purchasing power parity rates based on the 2011 ICP round. China's GDP per unit of energy use (PPP $ per kg of oil equivalent) was 4.9 in 2012, which is much lower than those of industrialized countries, such as Japan is 10.1, U.S.is 7.6 (World DataBank, 2014).Low energy efficiency results in high energy consumption for every unit of GDP.

(4) Increasing environmental pressure

Extensive development of fossil energy, particularly coal, has had a serious impact on the eco-environment. China's CO_2 emissions in 2012 have reached 9.86 billion tons, 28% of the world total. China has become both the largest energy consumer and CO_2 emitting country in the world. As China's high-speed economic growth is still dependent on massive energy consumption, and per capita energy consumption and CO_2 emissions are much lower than in developed countries. The increasing trends of energy consumption and CO_2 emissions are most likely to continue with China's plan to accomplish its socio-economic development goals. Premier Wen Jiabao promised on behalf of Chinese government that China would cut CO_2 emissions intensity by 40–45% below 2005 levels by 2020 on the 2009 United Nations Climate Change Conference. Additionally, the discharge of sulfur dioxide (SO_2), nitrogen oxides (NO_x) and toxic heavy metals remains high, and emissions of ozone and particles smaller than 2.5 micrometers (PM2.5) are also increasing. For a long time to come, fossil energy will continue to dominate the energy consumption mix, posing a growing challenge for protecting the environment and countering climate change. A more environment-friendly energy mix is urgently needed.

(5) The awaking public awareness of environmental protection

China's heavy dependence on coal, combined with its large population, and explosive economic growth have taken a heavy toll on the environment and pollution-related human health issues. As reported by China Central Television (CCTV), airborne pollution has become the hottest environmental topic among the public in 2013. China has pledged to fight pollution, according to the government work report submitted to the annual session of the National People's Congress in March. And the rising environmental awareness pushed the revisions to China's Environmental Protection Law in April of 2014. Particularly, China's Environmental Protection Law has not been revised since it took effect in 1989.

In light of China's current energy conditions, to promote energy efficiency and to adjust energy structure, and to raise the proportion of renewable energy (RE) in overall energy mix should be a promising way to maintain its sustainable development. On the basis of current situation, it is necessary for China to development various types of renewable energy to meet the growing demand for economy development while releasing the environmental pressure caused by usage of fossil fuels.

1.2 Literature review

China's RE development has attracted increasing attentions, a mass of studies have conducted related studies. These studies mainly can be divided into 5 categories.

(1) Overviews and reviews towards renewable energy

Ming Zeng, ChenLi and Lisha Zhou reviews on the policy system of renewable energy in China since Renewable Energy Law released in 2005 and appraise the achievements supported by the policy system of renewable energy (Ming Zeng, 2012).

Feng Wang, Haitao Yin and Shoude Li offers a review of the specific goals and measures that existing laws, regulations, and guide lines have set up to encourage investment in renewable electricity (Feng Wang, 2010).

Lixuan Hong, NanZhou, David Fridley and Chris Raczkowski assess the possible contribution of 12th Five Year Plan for China's future energy system and identify factors that might influence its impacts (Lixuan Hong, 2013) .

(2) Conducting renewable case studies in a region or province

Ping Liu and Shukui Tan explains the policies for wind power in China and abroad, points out the deficiency of China’s policies and puts forward improvement suggestions (Ping Liu, 2011).

Qiang Wang reviews the main policies regarding to China’s wind power, ends with the recommended best practice of China’s wind power installed capacity might be transferable to China’s photovoltaic power generation (Wang, 2010).

Wu Yun and Xu Ruhang present the current status, future potentials and challenges in Gansu by carrying out a detailed review of relevant studies (Ruhang, 2013).

(3) Outlook and prediction for future energy consumption and renewable energy

Liu Wu, and Henrik L discussed the perspective of renewable energy in China and to analyze whether it is suitable to adopt similar methodologies applied in other countries when China intends to approach a renewable energy system in the future (Wen Liua, 2009).

Qiang Wang and Yong Chen presented a reserves assessment, the current status, and barriers for further development, and finish with an outlook towards the renewable energy in China. They pointed out that China has plenty of free-carbon energy resources to revolutionize its electricity structure and redirect it towards low-carbon electricity systems. Needed are the effective energy policies to get to the way. (Qiang Wang, 2010)

Qimin Chai and Xiliang Zhang explored the technological and policy options for the transition to a sustainable energy system, and assessed China’s energy use and carbon emissions in the future by using the Low Carbon Energy Model (Qimin Chai, 2010).

1.3 Research Outline

1.3.1 Research objectives

(1) Research object

This research focuses on renewable energy generation. Not only because compared with biogas supply, heat supply and bio fuel, renewable energy generation occupies a higher percentage in China's total power generation, but also renewable energy generation has made remarkable achievement in the past decade and rather influential in economy and society.

(2) Research goals

- Comprehensive understanding of the operating mechanism between renewable energy generation industry and power administrative departments, to explore contradiction and barriers hinder the development of renewable energy generation.

- Systematically review the policy framework and development related to renewable energy generation.

- Explore the role of renewable energy generation in China's sustainable development

- Systematically review the status quo of China's PV power industry, especially the Residential Grid-connected PV Power industry.

- Identify the most significant opportunities and challenges for the development of Residential Grid-connected PV Power System from internal and external dimensions

- Present the suggestions for the future development of China's renewable energy generation.

1.3.2 Research originality

(1)Policy research

Focus on the administrative mechanism of renewable energy generation, and reviews the policies related to renewable energy generation from three levels of national planning level, national department level and local government levels, including Laws and regulations, Price policies, Financial and tax policies, respectively.

(2) Adopted SWOT method to analysis a renewable energy industry

(3) Systematically analyzed Residential Grid-connected Photovoltaic Power Systems (RGCPVS) in China, and confirmed the most significant factors affect the development of this industry, based on the evaluations from RGCPVS developing country and developed country.

Residential Grid-connected Photovoltaic Power Systems was officially started in the end of 2012, so it is a new product for China's renewable energy market. And there is little information available in literature on analyzing conditions about it in China. We investigated the status of this system and made an investigation to confirm the effect factors from Residential Grid-connected Photovoltaic Power Systems well developed country (Japan) and developing country (China).

(4) Assessed the correlation between renewable energy generation and China's sustainable development.

We discussed the correlation between renewable energy generations and China's sustainable development from three dimensions of CO_2 emissions reduction, GDP growth and fossil fuel electricity, respectively. And explore the reasons and problems behind the rapid development of renewable energy generations.

1.4 Framework of the research

The research is divided into 6 Chapters (see in Fig.1-3). In Chapter 2, the status of Renewable energy resources and reform history of China's electricity industry is systematically reviewed, and China's Renewable Energy Generation system and management mechanism is analyzed. In Chapter 3, the problems of Renewable Energy Generation industry and the correlations of Renewable Energy Generation and CO_2 emissions, economic growth and fossil fuel electricity are examined. In Chapter 4, RGCPVS as a renewable energy power system which is close related to residents/consumers are discussed. Finally, in Chapter 5, the suggestion and conclusion is presented

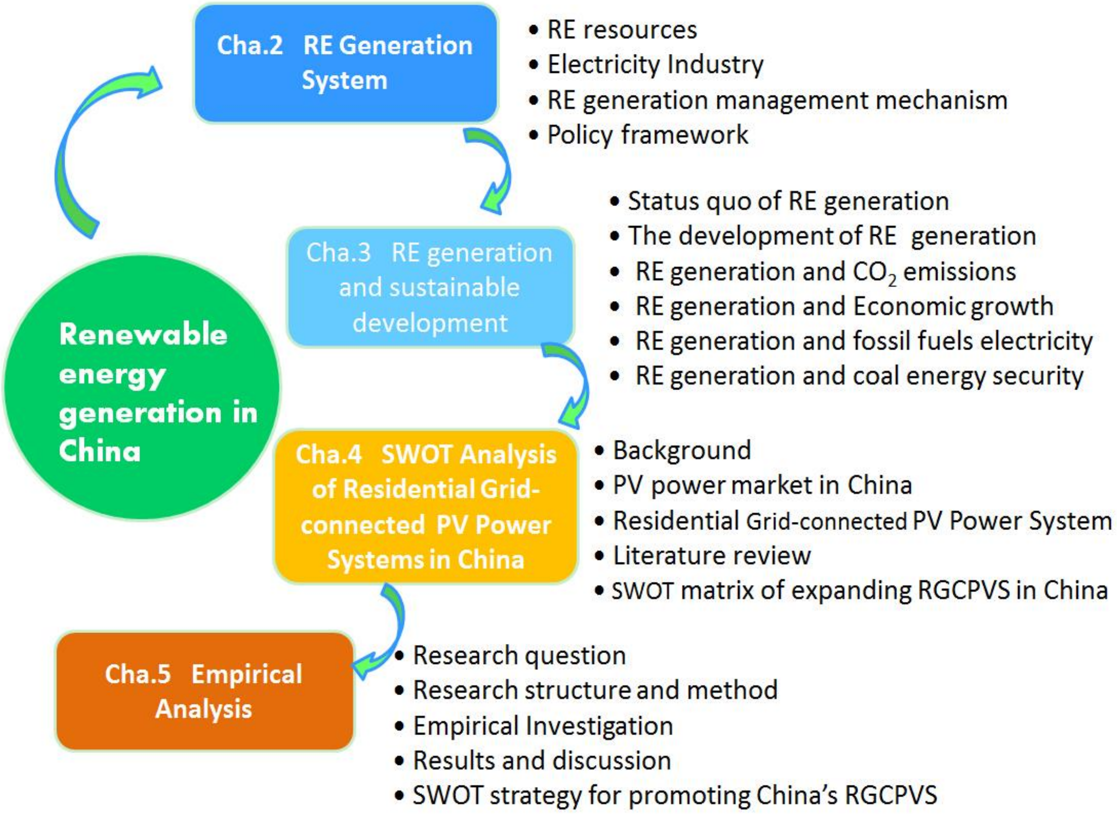

Fig. 1-3 Research structure

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Chapter 2

Chapter 2 Renewable Energy Generation System in China

Introduction

As the developing of economy and society of China, an increasing number of energy is required. However, an ever-serious contradiction among energy storage, environment protection and economic development has been made worse by the lack of conventional energy and its pollution on the environment.

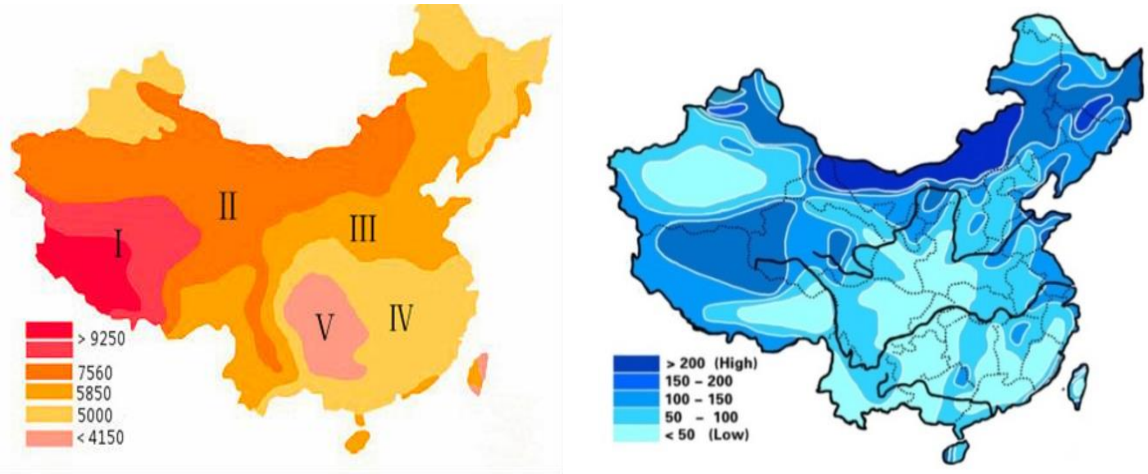
China is faced with a sequence of rigorous energy problem: first of all is the Energy Security. In the case of petroleum, since 1992, the total energy consumption of China was much more than total energy production. In 2008, China has become one of the largest oil importer and the second-largest oil consumer after the US, and foreign oil dependency is become to be more than 56% in 2011 (Barbour-Lacey, 2013). Second is the per capita resources shortage. Because of the large population, the per capita resource of China is less than the half of the world average. For instance, China natural resources total accounted for world 7th, but per capita value only occupy world per capita value of 60th; total mineral resources is world 3rd, but per capita value is world 80th; coal per capita value not to world per capita value of one-third; oil per capita value not to world per capita value of one-eighth; gas per capita value not to world per capita value of one-twentieth (People's Daily). Thirdly is the deterioration of the ecological environment caused by the conventional energy pollution. Mainly in the following areas: emissions of major pollutants, pollution structure change, destruction of biological diversity and so on. Fourthly is the climate change caused by GHG. With approximately 8% higher emissions than those of the USA, China now tops the list of CO_2 emitting countries in 2011, and the CO_2 emission occupied about one-fourth of the world (The guardian, 2011).

As a result, another kind of energy with the availability of its renewability and non-pollution should grow to be an effective and practical choice to guarantee the future development of not only China, but also the world.

Renewable energies refer to those resources existed in the nature that can be renewable, sustainable for use and never exhausted. They are clean energies and have no or very less hazards to the environment. In addition, they are widely distributed and found everywhere for easy development and utilization locally (Stover, 2011). Renewable energy mainly include: solar energy, wind energy, geothermal energy, hydropower, and ocean energy, and biomass energy.

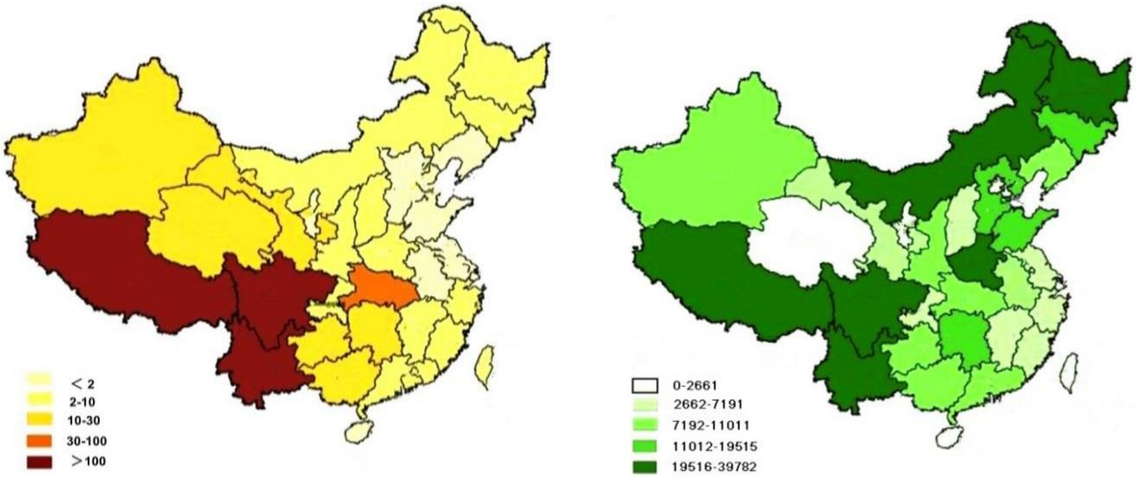
2.1 Renewable energy resources in China

China has rich renewable energy resources, which can play a stable supportive role in China's energy system. Fig. 2-1 and Table2-1 illustrated the distribution and potential of the renewables, respectively.



(a) Solar resource (MJ/m^2 per year)
Source: Chinese Weather Bureau

(b) Wind power resource (W/m^2)
Source: China Meteorological Administration



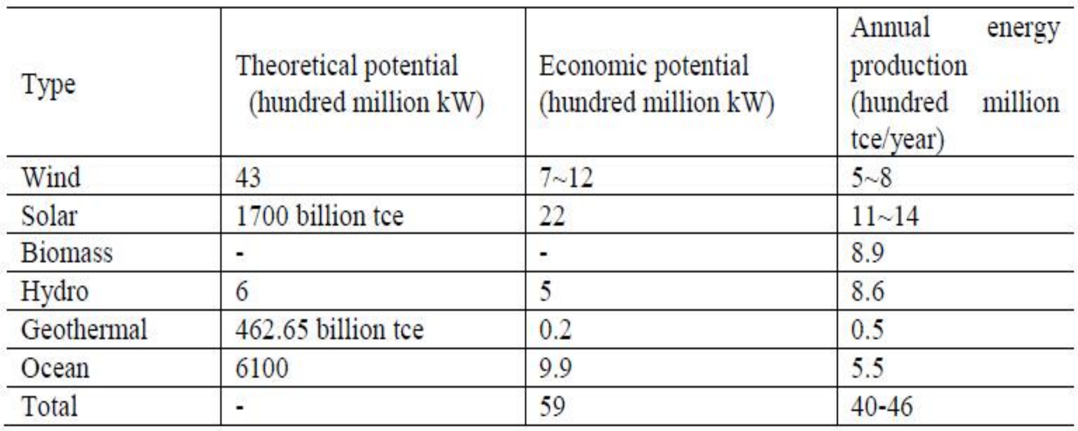
(c) Hydropower resource (GW)

Source: Series of China's renewable energy development strategy:hydropower

(d)Biomass energy (tce)

Source: Development potentials and policy options of biomass in China

Fig. 2-1 Resources distribution of renewables in China



Type	Theoretical potential (hundred million kW)	Economic potential (hundred million kW)	Annual energy production (hundred million tce/year)
Wind	43	7~12	5~8
Solar	1700 billion tce	22	11~14
Biomass	-	-	8.9
Hydro	6	5	8.6
Geothermal	462.65 billion tce	0.2	0.5
Ocean	6100	9.9	5.5
Total	-	59	40-46

Table2-1 China's renewable energy potential

Source: Renewable energy development strategy,

China Academy of Engineering, 2008

1). Solar Energy

China is privileged to own abundant solar resources, about 30% of the world's solar photovoltaic (PV). Its land surface receives an annual solar radiant energy of 1.7×10^{12}tce (see Table2-1). As shown in Fig.2-1(a), more than two-third of the country receives an annual radiation of more than 5.02×10^{6}kJ/m^{2} and sunshine of more than 2000 h (Center for renewable energy development of energy research institute(NDRC), 2010). In most areas, except Sichuan Basin and its surrounding areas, the solar energy equals or exceeds those foreign areas on the same latitude.

2). Wind Energy

China has the largest wind resources in the world and three-quarters of them are offshore (see Fig.2-1(b) and Table 2-1) (Biello, 2008). According to figures released by the China Wind Energy Association, in the year of 2011, China consolidated its position as the world's wind power leader in both newly and cumulative installed capacities, installing an impressive 17.6 GW of wind turbines (Daly, 2012). China has identified wind power as a key growth component of the country's economy.

3). Hydropower

Hydropower is currently the largest renewable energy resources in China (see Fig.2-1(c) and Table 2-1). It also has good industrial basis and specific resource. According to the national hydro resources investigation, the exploitable hydro capacity in China is 542 GW and the corresponding annual generating production is 2.47 trillion kWh, ranked first in the world (Research Group of China's Renewable Energy Development Strategy, 2008). The hydro power resources are mainly distributed in the west, which is the birth place of China's major rivers. The exploitable hydro capacities in Sichuan, Tibet and Yunnan are all larger than 100 GW. They account for over 61.3% of the nation total.

4). Biomass and Biofuel

The employable biomass energy in China mainly includes crop stalks, firewood, foul wastes, domestic garbage, industrial organic waste residue and waste water, etc. (Daly.John, 2012). And the geographic distribution of biomass by products is unbalanced (see in Fig.2-1(d)). China emerged as the world's third largest producer of ethanol bio-fuels (after the U.S. and Brazil) as of the end of the 10th Five Year Plan Period in 2005.

According to the goals, to the years of 2010 and 2020, the production of biological solid fuel would increase fastest, reaching 1.0×10^6ton and 5.0×10^7ton, respectively. Second to that is bio-diesel, reaching 2.0×10^9ton and 2.0×10^{10}ton, respectively. Fuel alcohol and biomass energy power generation would accelerate neck and neck, the former being 2.0×10^6ton and 1.0×10^7ton, respectively, and the latter being 5.5×10^6kW and 3.0×10^7kW, respectively. Marsh gas would amount to 1.90×10^{10}m^3 and 4.0×10^{10}m^3, respectively (State Council, 2005).

5). Geothermal Energy

China abounds in geothermal resources. Chinese geothermal energy is mainly located at the circum-Pacific tropical zone and Himalaya–Mediterranean tropical zone. More than 320 geothermal spots have been found, with an annual naturally relieved heat of 1.04×10^{17}kJ, i.e. 35.6×10^8tce, among which 80% are geothermal hot land below 100 8C (Chinese Academy of Science Energy Strategy Study Team, 2006). Currently, more than 1300 geothermal resource spots have been exploited and used. They are mainly distributed in Beijing, Tianjin, Hebei, Jiangsu, Jiangxi, Shaanxi, Guangxi, etc., employed in plantation, breeding industry, heat providing and medical service; geothermal power generations are now inadequate, which could be represented by 2.52×10^4kW Tibet Yangbajing geothermal power plant with power generation of about 1×10^8 (kW h)/a (Xu J, 2005).

6). Ocean Energy

Because of the long shore line, China has enjoyed abundant Ocean energy resource. China's ocean energy resources include among others tidal energy, wave energy, oceanic flow energy, temperature difference energy, and salt difference energy. According to rough estimate, the theoretical reserve of China's tidal energy is up to 1.9×10^8kW, the total installed capacity of developable resources is 2.16×10^7kW and the average power generation is 6.19×10^{10} kWh/a, among which 90% are distributed in Zhejiang and Fujian (people.cn, 2011). The average theoretical reserve of wave energy resources is 1.29×10^7kW, which are distributed in a rather uneven manner.

2.2 Reform of China's electricity industry

The development of China's electricity industry can be separated into five stages. This section analyzes the restructuring trajectory in the aspects of administrative framework, price and investment mechanisms, and legislative and policy settings. Special attention is placed on the milestone reform in 2002 and the recent initiative to bring renewable energy into the electricity portfolio. **Table 2-2** summarizes the transition of organizational structure in China's electricity industry during the past few decades.

1) Stage 1: pre-reform state monopoly (1949–1985)

Before 1979, the electricity industry was under the administration of the Ministry of Water Resources and Electric Power (MWREP). The MWREP was combined and separated several times into two parts—water resources and electricity generation—partly due to the tensions between the two sides over budgetary priorities for hydropower vs. thermal power (Lieberthal, 1990).The MWREP was phased out in 1979 and divided into the Ministry of Electric Power (MOEP) and the Ministry of Water Resources. These two Ministries were merged to the MWREP again in 1982. These administrative Ministries played dual roles of government administration and business operation. For example, the MWREP functioned as policy maker, plan implementer, industry regulator, state-owned assets manager, and business operator, with parallel counterparts co-existed at the state as well as provincial levels.

Period	Overseeing	Plan/price/ investment/ regulation	Independent regulator	Generation	Transmission/ distribution
1949–1953	•Post-war reconstruction; •old bureaucratic structure maintained	-	-	-	-
1953–1985	State Council (since 1955)	State Planning Commission	-	•Ministry of Fossil Fuels (1953–1955) •MOEP (1955–1958) •MWREP (1958–1979) •MOEP (1979–1982) •MWREP (1982–1988)	-
1985–1997	State Council	State Planning Commission	-	•MOE (1988–1993) •MOEP (1993–1998) •Provincial power bureaus •IPPs	-
1997–2006	State Council	SDPC and SETC	-	•State Power Corporation •Local power corporations •IPPs	-
		NDRC	SERC	•Huaneng •Datang •Huadian •Guodian •Power Investment •Other IPPs	•State Power Gird •Southern Power Grid
2006–present				Renewable	

Table 2-2. Organizational structure of China's electricity industry

Actually, the dual-role feature is common to all major industries in the old central planned economic system. China has gradually started deregulation and decentralization of its economy since the start of its economic reform in 1978. The electricity industry is among the latest few sectors that were reformed and deregulated. Before 1985, the administration, resources allocation, investment decisions, and prices in the electricity industry were fully controlled by the central government.

During this pre-reform period, there were no independent generation prices for power plants and T&D prices for grid usage. Because the whole industry was organized as a vertically integrated state-owned utility (VISOU) and all prices were simply internal transfer prices. Electricity prices were used virtually for accounting purposes rather than as a means for resources allocating. On the retail side, prices are guided by catalog prices, which were first published in Electricity and Heat Prices Catalog 1965 and then amended in 1975 by the MWREP (Catalog 1965 and Catalog 1975). The prices have been deliberately kept low to support economic growth.

The investment strategy for this period was known as 'walking on two legs': centralized large-scale projects and decentralized rural electrification. Unlike other countries that have gradually expanded their electric network into rural areas, China has relied on decentralized plants gradually linked together to form local and then regional grids (Wirtshafter, 1990). The industry had long been inflicted by capital constraints and the capacity expansion further slowed down in early 1980s. Lewek (1986) attributed the slowdown to constrained capital and bad planning: (1) cutbacks in national investment in heavy industry beginning in 1979–1980 (industry structure adjustment) also affected the power industry; (2) too many expansion projects started within a short period of time without adequate resources actually diluted available capital; (3) and an increase in investment for power transmission facilities further reduced the funds available for plant construction. To make things worse, under state monopolistic system, there was no room for investments from other sources, which limited the increase of generation capacity (Lewek, 1986). In fact, investments from other sources were not even allowed to enter this industry because the electricity industry was considered as of strategic significance, which must be controlled by the state.

The advantage of a highly centralized system is that resources can be allocated and mobilized effectively (but not necessarily efficiently) for specific national goals. However, this economic framework was unable to meet the needs of the accelerated economy. The artificially lowered electricity prices, insufficient investment in the generation and transmission facilities, and inadequate ability to produce generating equipment jointly resulted in a chronic power shortage, which became a serious bottleneck when the modernization speeded up (Li, 1995).

2) Stage 2: generation promotion (1985–1997)

In 1988, the Ministry of Coal Industry, the Ministry of Oil Industry, the Ministry of Nuclear Industry, and the MWREP were all cancelled and merged into the newly established Ministry of Energy (MOE). In 1993, the MOE was cancelled and the MOEP was established again. The highly centralized administrative style did not change significantly at this stage. However, some reform policies introduced had ultimately profound effects. A groundbreaking policy document was issued in 1985 by the State Council—Interim Provisions on Promoting Fund-Raising for Electricity Investment and Implementing Multiple Electricity Prices 1985 (Interim Provisions of 1985). Major elements include: (1) provide guidelines to separate the responsibilities of government and business. Although the actual separation did not happen until 1997, this initial step paved the way to the eventual separation; (2) make Bureaus of Electric Power at the provincial level the operational entities and give local government appropriate jurisdiction over the development of the electricity industry so that specialized policies could be made locally; (3) make favorable policies to encourage investment in the electricity industry from various local, foreign, and private investors; (4) while the generation price of electricity for the VISOU was still the internal transfer price, the government provided guided price to the newly built non-utility generators or independent power producers (IPPs) (Chunbo Ma, 2008). The guided prices are determined according to the rule of 'repayment of principal and interest' to guarantee profits.

The focus of these reform policies was mainly to remove the capital bottleneck that had constrained the country's electricity industry for over 30 years, and to promote more generation to meet the increasing demand driven mostly by the accelerated economic growth. For this purpose, the policies were quite effective. By 1997, the nationwide chronic power shortage had been by and large relieved (Xu, 2006). Additionally, the newly built IPPs diversified the market entities and for the first time introduced the element of competition on the generation side. Although there was little real competition at the time due to tight supply, the introduction of IPPs initially nurtured the market environment that would be needed in later reforms.

Despite the progress, the reforms at this stage also brought new challenges. One result of the reform policies at this stage was a complicated and inefficient price scheme.

3) Stage 3: state entrepreneurialism (1997–2002)

To make business operation independent of frequent government interferences and make the VISOU real market entity, the State Power Corporation (SPC) was founded based on the VISOU in March of 1997. The SPC no longer took the responsibility of industrial administration as the MOEP, but became an electricity business operator in the real sense. The SPC and the MOEP coexisted for 1 year to ease the transition. In 1998, MOEP was dissolved and its administrative functions were transferred to a new department under the State Economic and Trade Commission (SETC). The focus of the state entrepreneurialism reform at this stage was to clarify and separate the responsibilities of governmental administration and business operation, and it included two key components: (1) separation of the government and enterprise and (2) separation of the ownership and operation. However, the transition did not happen. The Chinese task was much more challenging due in part to the historical "cradle to grave" responsibilities for workers inherited from the old planned economy. The transition involved fundamental changes and created new problems in many aspects such as the financial administration, the role of officials, and the treatment of the workers (Duckett, 2001). Fortunately, the electricity industry was among the last few industries where state entrepreneurialism was carried out. There were experiences and lessons that could be learned from practices in other industries. State entrepreneurialism was a necessary and first step to restructure the VISOU. However, the reform had not touched the organizational base of the VISOU. The monopolistic position of the newly founded SPC remained unchanged. The SPC still controlled half of the country's generation assets and almost all of the T&D assets, which became a key obstacle to build a competitive electricity market. In 1999, pilot practices to separate electricity generation from T&D, and access the grids through competition were carried out in five pilot provinces—Heilongjiang, Liaoning, Jilin, Shandong, and Zhejiang, and one pilot city—Shanghai. The pilot practices were short-lived mainly because the construction of these power markets was still constrained by old monopolistic practices of the SPC. However, these practices provided initial experiences and paved the way for the eventual dismantlement of the SPC in 2002.

4) Stage 4: monopoly dismantlement (2002–2006)

The reform at this stage really marked a milestone in the development of China's electricity industry. The major features were presented in a key governmental document— Scheme of the Reform of Electricity Industry (Scheme of 2002), which was approved by the State Council in April of 2002. It mapped out the general platform for following reforms. The focus was to break the vertical monopoly of the SPC and introduce competition (mainly on the generation side) through diversifying the generating entities, which was aimed primarily to lower cost and improve efficiency.

The first important action was the dismantlement of the SPC on December 29, 2002. Total assets were divided into 11 new corporations including two grid operators—State Power Grid and China South Power Grid, five IPPs (Big Five)—Huaneng Group, Datang Group, Huadian Corporation, Guodian Corporation, and Power Investment Corporation, and four auxiliary corporations—Power Generation Consulting (Group) Corporation, Hydropower Engineering Consulting (Group) Corporation, Hydraulic and Hydroelectric Construction (Group) Corporation, and Gezhouba (Group) Corporation. State Power Grid includes five regional grids: Northwestern Grid, North Grid, Northeastern Grid, Central Grid, and East Grid. The division of generation assets and transmission assets were not completed all at once.

Secondly, a series of new policies on pricing schemes have been introduced and detailed in Scheme of 2002, Scheme of the Reform of Electricity Prices 2003 (Scheme of 2003), and Procedures for Implementation of the Reform of Electricity Prices 2005 (Procedures of 2005). Operation period prices and yardstick prices are still used in regions where competitive regional wholesale market has not been established. For regions where competitive wholesale transaction has been introduced, the price consists of two components: capacity price which is determined by the government according to the average cost of all generation units in the market, and volume price which is determined competitively in the market. On the retail side, the catalog was simplified to include only five categories. A unit-price scheme is implemented in residential and agricultural electricity sales and a two-component price scheme, which is similar to the counterpart on the generation side, is implemented in industrial and commercial electricity sales. Additionally, differentiated prices were introduced in 2004 and refined in Notice on Refining the Policy of differentiated Electricity Prices (Notice of

2006). Electricity uses in energy-intensive industries are charged with higher prices.

Thirdly, competition mechanisms are also introduced through the construction of wholesale and retail markets. Competitive regional wholesale markets—Power Coordination and Transaction Centers (PCTCs)—were scheduled to be established by the end of 2005. Power plants will bid through PCTCs and gain grid-accessing priorities according to their bids.7 It is aimed to create incentives for cost control and efficiency improvements. Due to the resurgent power shortage since 2002, the construction of PCTCs is delayed. However, the reform has regained momentum recently. Pilot practices have been conducted in Northeast and East China regional markets. Wholesale market in South China has entered into simulated operation. On the retail side, large-volume users will be allowed to directly purchase electric power from generators. Pilot practices have also been introduced in Jilin and Shandong provinces and 12 other provinces have filed applications to the SERC to start similar reforms (commission, 2006).

5). Stage 5: renewable energy generation (2006–present)

The new stage of renewable energy development is marked by the approval of the Renewable Energy Law in February, 2005, which has been effective since 2006. While the law is about renewable energy in general, it pays special attention to renewable power. It established the legislative foundation and articulated the development direction for China's renewable power. The National Energy Administration is established to take over the State Electricity Regulatory Commission. The existing Renewable Energy Generation management mechanism is further explained in the following section.

2.3 Renewable Energy Generation management mechanism in China

1) Government Agencies

As shown in **Fig.2-2,** there are mainly four government agencies, ministry or commission related the renewable energy industry, and they are:

•The National Energy Administration (NEA) is China's top energy administrate agency, and is responsible for development and policy planning with respect to energy, including planning for renewable energy development.

• The National Development and Reform Commission (NDRC) is in charge of collecting funds from the renewable energy surcharge and distributing them to grid companies, and the Ministry of Finance is in charge of the Renewable Energy Development Special Fund and its supported programs.

• The National Development and Reform Commission Pricing Bureau is responsible for setting prices for energy, among other economic goods; including setting the on-grid price for wind generated power, biomass power, solar PV power, etc.

• The original State Electricity Regulatory Commission (SERC) is a government agency responsible for regulating China's electricity industry, including the integration of renewable electricity into the grid. Since March of 2013, it was merged into NEA.

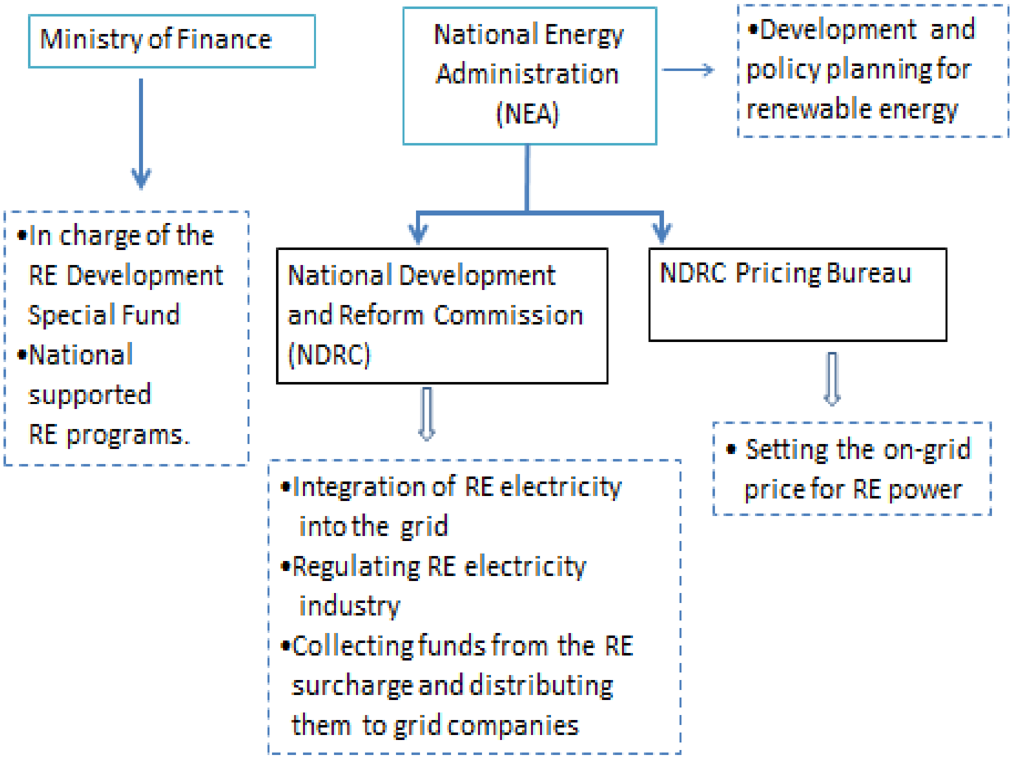


Fig.2-2 The structure of government agencies towards renewable energy

2) Renewable Electricity Generators

・The five large state-owned power generators in China (Huaneng, Datang, Huadian, Guodian and Power Investment Corporation, often referred to as the 'Big Five') account for most of China's electricity generation and are all active in developing renewable energy projects.

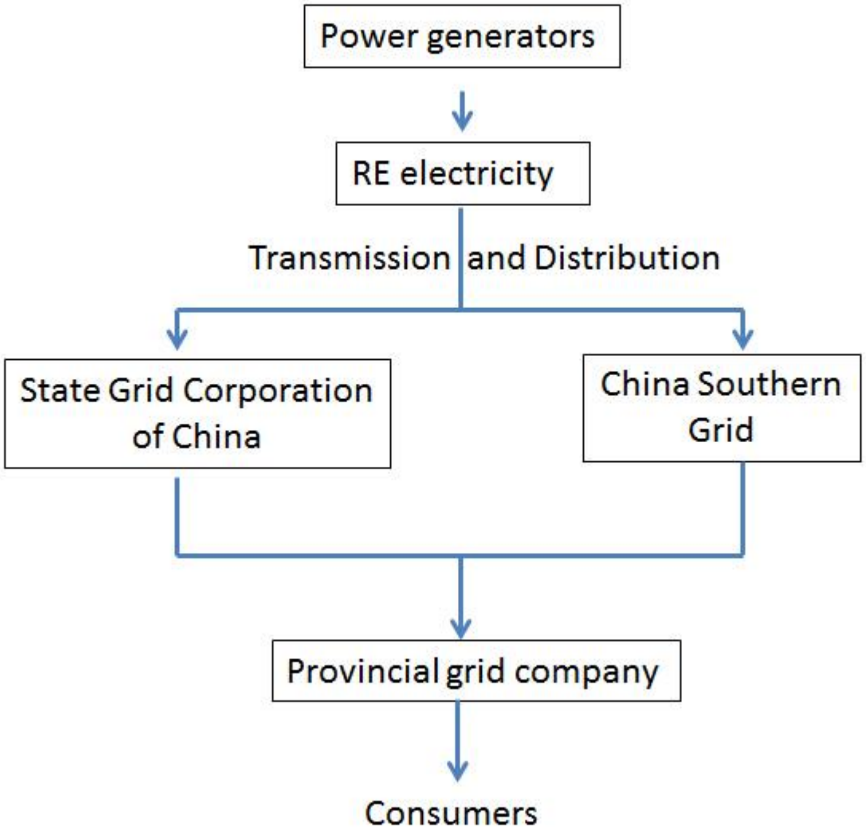


Fig.2-3 The relations between renewable electricity generators and grid companies

・ Guodian's subsidiary, Longyuan, is currently the largest producer of wind in China in terms of installed capacity, with Datang, Huaneng, Huadian, and Guohua (a subsidiary of Shenhua) following in the rankings.

・ Other renewable power generators, such as China Wind Power, represent a smaller portion of renewables installed capacity and power generation.

3) Grid Companies

• There are two main transmission and distribution companies that provide coverage for the entire country, State Grid Corporation of China and China Southern Grid, both of which are state-owned enterprises. In addition, there are two smaller, local grid companies, the Inner Mongolia Power Grid (covering the western part of Inner Mongolia) and Shaanxi Provincial Power Grid (covering 30% of Shaanxi).

• State Grid's coverage area accounts for about 80% of China's total electricity consumption. Covered provinces/ municipalities are: Inner Mongolia East, Liaoning, Shaanxi (70% market share),Gansu, Xinjiang, Heilongjiang, Jilin, Ningxia, Shandong, Hebei, Shanxi, Beijing, Tianjin, Qinghai, Jiangsu, Hunan, Henan, Sichuan, Fujian, Shanghai, Anhui, Jiangxi, Zhejiang, Hubei, and Chongqing.

• Southern Grid operates in Guangdong, Guangxi, Guizhou, Hainan and Yunnan provinces through its subsidiaries.

2.4 The policy instruments of Renewable Energy

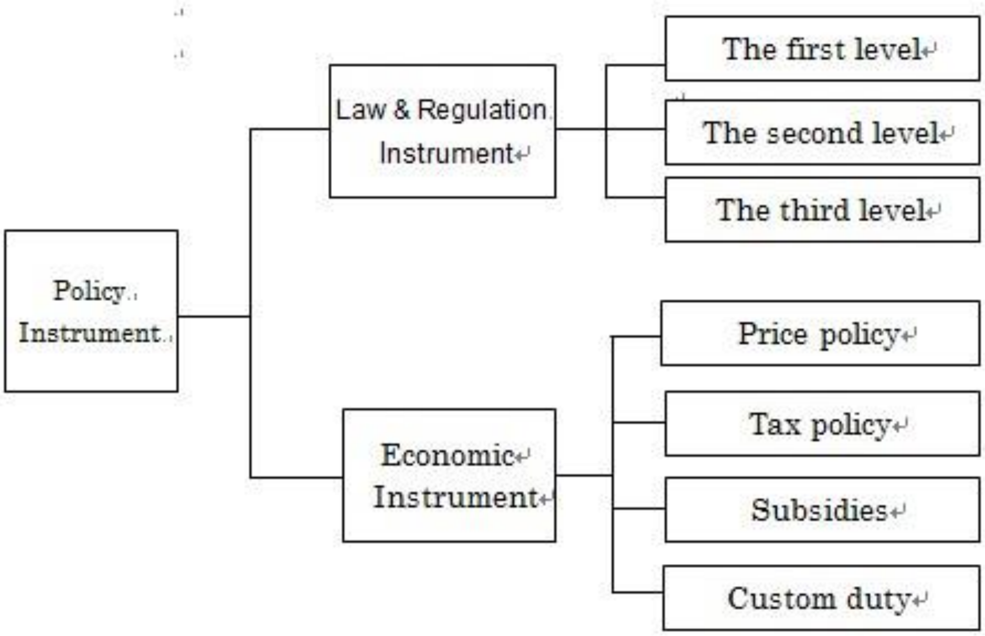


Fig.2-4 Policy instrument of renewable energy in China

Policy instruments are the term used to describe some methods used by governments to achieve a desired effect. The two basic types of policy instruments are regulatory and economic instruments.

Regulatory instruments, specifically laws and regulations, are the most commonly used policy instruments in China (see in **Fig.2-4**). Economic instruments, such as tax credits for certain types of investment or subsidies for certain products, are also used as a way of influencing the actions of individuals and corporations. **Table2-3** and **Table 2-4** summarizes the formulation of the policy system of renewable energy in China

2.4.1 Laws and regulations instrument

China's policy on renewable energy can be fall into three levels. The first two levels of policy are established by China's central government in which contains Laws and departmental rules. The first level provides general direction and guidance of renewable energy. The second level policies attempt to specify and standardize goals and development plans of renewable energy development from different viewpoints. Some departments propose concrete policies and regulations. Local governments, including provincial, municipal, and county governments, establish the third level of policy with overall direction from the central government.

Prior to adoption of the national Renewable Energy Law in 2005, a variety of Chinese laws had encouraged the development f clean energy, particularly renewables. These include Electricity Law of 1995, the Energy Conservation Law of 1997, and the Law for Prevention and Control of Air Pollution of 2000. These laws, however, provided little guidance on utilizing renewables, since at that time renewable energy comprised only a small part of the national economy and was considered only in the context of rural energy. The situation has changed since the inception of the national Renewable Energy Law.

The Renewable Energy Law created for the first time a national framework for promoting renewable energy development in China, by establishing four key mechanisms to promote the growth of renewable energy in China:

(1) A national renewable energy target and central and local renewable energy development and utilization planning.

(2) A mandatory connection and purchase policy by which grid companies are required to sign an agreement with renewable electricity generators in their jurisdiction to purchase all of the electricity generated from the generators, and provide grid connection services.

(3) An on-grid electricity price for renewables, akin to a national feed-in tariff system, which pays renewable electricity generators a fixed, additional amount for each kilowatt hour (kWh) of electricity generated, above the whole sale electricity price for desulfurized coal-fired power.

(4) A cost-sharing mechanism, funded by a surcharge on electricity sales, to pay for feed-in tariffs, grid connection projects, and independent, public renewable energy grids, as well as a Renewable Energy Development Special Fund to cover activities such as science and technology research for renewables, standard setting, pilot projects, rural utilization of renewables, and renewable resource assessments.

First level	
1983	Suggestions to Reinforce the Development of Rural Energy
1995	Outline on New and Renewable Energy Development in China, State Planning Commission (SPC), SSTC, State Economic and Trade Commission (SETC)
1995	Electric Power Law
1996	Guidelines for the Ninth Five-Year Plan and 2010: Long-term Objectives on Economic and Social Development of China
1996	State Energy Technology Policy
1997	Energy Conservation Law
2000	Prevention and Control of Air Pollution
2002	Cleaner Production Promotion Law
2003	Renewable Energy Promotion Law
2005	Renewable Energy Law
2009	Decision on Revising Renewable Energy Law

Table2-3 Policies related to Renewable Energy on the First Level

Second level	
1994	Brightness Program and Ride the Wind Program, formulated by State Planning Commission (SPC)
1995	New and Renewable Energy Development Projects in Priority (1996-2010) China, by State Science and Technology Commission (SSTC), State Power Corporation, and State Economic and Trade Commission (SETC)
1996	Ninth Five-Year Plan of Industrialization of New and Renewable Energy by SETC
1996	Ninth Five-Year Plan and 2010 Plan of Energy Conservation and New Energy Development by the State Power Corporation
1998	Incentive Policies for Renewable Energy Technology Localization by State Development and Planning Commission (SDPC) and Ministry of Science & Technology (MOST)
1999	The Notice on further support for Renewable energy development
2001	Tenth Five-Year Plan for New and Renewable Energy Commercialization Development by SETC
2003	Rural Energy Development Plan to 2020 for Western Areas
2006	Interim measure for Management of special funds of Renewable energy development
2006	Regulations on the Administration of power generating from Renewable energy
2007	The Interim measure for the allocation of income from Surcharges on Renewable Energy Power Prices
2007	The Measures for energy-saving power generation dispatching
2008	The 11th Five-year Plan for new energy and Renewable energy
2009	Notice on the Launch of Pilot Project of Demonstration and Promotion of Energy-saving and New Energy Cars
2011	Notice on Further Promoting the Construction and Application of Renewable Energy
2011	Tentative Procedures for the Administration of Wind Power Development and Construction: Regulate the development scale and speed of wind power

Table2-4 Policies related to Renewable Energy on the Second Level

2.4.2 Economic Instrument

	***Price* policies**		**Subsidies *and tax policies***	
	Statute	Function	Statute	Function
2006	*Tentative Procedures for Administration of RE Price & Additional Expenses Allocation*	•Government guided price •Feed-in tariffs (FIT)	*Tentative Procedures for the Management of Special Funds on RE*	•Promote special Funds for RE
2007	*Tentative Procedures for the Allocation of RE Additional Price*	• Measure for allocating additional price of RE		
2009	*Notice on Perfecting the Price Policy of Wind Power Accessed to Grid*	•Categorized on grid price of located in 4 regions based on wind resource	*Solar Roofs Program and Golden Sun Demonstration Program*	•Upfront subsidy for PV systems in buildings •50% subsidy of bidding price for PV critical components •Subsidies for large scale PV systems
2010	*Notice on Perfecting Price Policy of Agriculture and Forest Biomass Generation*	•Set biomass on grid benchmarking price		
2011	*Notice on Perfecting Price Policy of PV Accessed to Grid*	•Set PV benchmarking on grid price		
2012	*Notification on Renewable-Energy Power Price Subsidy and Quota Transaction Program*	•On-grid price of RE is based on desulfurizing price •Subsidy will be undertaken by the provincial electrical grid	*Notification on Declaring Model New Energy Cities and Industrial Parks*	•Special funds from central and local finance •Specific indexes for utilization modes of RE

Table2-5 Important economic instrument policies about RE in China

There are mainly four kinds of important economic instruments in China towards renewable energy; they are price policy, tax policy, Subsidies Policy and Custom duty (see in Table 2-5).

(1) Price Policy

China has introduced a variety of preferential pricing schemes for renewable power generation. The price level is determined by several factors, including the source of the renewable energy and the project location. It means, there is no national standard price-setting mechanism or system exists for renewable energy products. Price is set on a case-by-case basis with protracted negotiation between power producer and the grid or utility.

In terms of wind power, currently, the tariff for wind power is fixed and is classified into four levels according to local wind resources. The region with the richest wind resources, located mainly in China's north and west, has a tariff of RMB0.51 (US cent 7.4) per kWh; the region with modest resources, mainly in the east and along the southern coastline, has tariffs of RMB0.54 (US cent 8.2) per kWh and RMB0.58 (US cent 8.5) per kWh; and the region with relatively low wind resources, in the middle of the country, has a tariff of RMB0.61 (US cent 8.9) per kWh (REN21, 2010).

In terms of solar power, at beginning, an approved feed-in tariff rate was applied on an individual project basis and ranged between RMB4–9 (USD0.58–1.32) per kWh until 2009. Since early 2009, the government has established price regulation with a concession program in Western China's Dunhuang region. The first round of bidding for a 10 MW program resulted in a price of RMB1.09 (USD0.16) per kWh. This price level is expected to be applied to local projects in surrounding regions with similar solar resources (REN21, 2010). Because the pricing system for solar PV is still at the early stages, however, there are uncertainties.

(2) Tax Policy

Based on Chinese collection and distribution rights, tax can be classified as central government tax, local government tax, and shared tax. And there is a unique tax

policy only can be found in China, which is Favorable taxation. Besides the various measures to promote the development of renewable energy in China, the Renewable Energy Law commits to offer tax incentives to stimulate renewable energy development. One of tax incentives includes the Implementing Regulations for China Enterprise Income Tax Law promulgated on Jan. 1, 2008, which provides a tax concession consisting of a three-year exemption plus three years of taxation at 50 percent of the full tax rate for enterprises engaging in projects involving energy conservation and improvement on emissions reduction technology20). Such tax incentives effectually promote the development of renewable energy. In July 2009, Chinese government took a step further in the promotion of the development of the solar energy with the announcement of the implementation of the "Golden Sun" pilot project.

(3) Subsidies Policy

Subsidies as one of the most popular economic incentives for renewable energy development are usually provided by the Chinese central and local governments. These include: R&D for the development and industrialization of core renewable energy equipment, Construction of renewable energy generation systems, Township Electrification Program, Subsidies for rural end-users, Production subsidies. For instance, The Ministry of Water Resources (MWR) provides low-interest loans of about 26 million USD or 300 million CNY for small hydropower development. Western Province Project Subsidy: A project called the Township Electrification Program was implemented by the NDRC from 2001–2003. The program aims to electrify more than 1000 townships in remote areas in nine provinces including Xinjiang, Qinghai, Gansu, Inner Mongolia, Shaanxi, Sichuan, and Tibet by using PV, wind, or hybrid systems. Total investment in the program is approximately 241 million USD or 2 billion CNY with nearly half of the grant allocated to Tibet (Junseng, 2011).

(4) Custom duty

In order to get in the overseas market and the World Trade Organization, import customs duty in China has been adjusted several times, and due to promote the development of China's most advanced wind turbine manufacturers, since 2010, Import Duties on Wind and Hydro Equipment were removed. However, removes import duties previously applied to a range of products, including imported components for building wind turbines (excluding the completed turbines) and hydropower (Finamore, 2010). Some bio-energy equipment, such as power generators for biogas, if classified as high-tech and, they will also be exempt from customs duty.

2.5 Low-carbon policy influence on consumers' energy efficiency household appliance purchase behavior

Over the past decade, climate change has been regarded as one of the greatest environmental challenge for human beings. Since China has become the biggest CO_2 emitter from the year of 2007, Chinese government announced a national strategic CO_2 mitigation goal to reduce CO_2 emissions per unit GDP (CO_2/GDP) by 40-45% by 2020 compared with the 2005 level in 2009. According to a report from the Academy of Social Sciences, as a country with 1.3 billion population, residential sector accounts for more than 35% of China's GDP in 2010, and 31% of final energy consumption in 2009 (Enterdata, 2010). Accordingly, to promote the energy efficiency in residential sector is important and helpful to achieve this CO_2 emission reduction goal. However, in order to increase the residential energy efficiency, prior to effective utilization, the first step ought to purchase a high efficiency household appliance.

As a matter of fact, a number of policy measures have been implemented to guide the residential consumers' purchase behavior. Nevertheless, not all the policies are useful to guide consumers' energy efficiency household appliance purchase behavior. As consumer's purchase behavior is not only affected by internal factors but also external forces.

2.5.1 Mechanism of consumers' energy efficiency appliance purchase behavior

Fig.2-5 illustrates the mechanism of residents' energy efficiency appliance purchase behavior (EEAPB). The mechanism is composed of two parts: one is the affecting factors, the other is influencing process. The first part concerns factors which influence consumers' purchase behavior towards energy efficiency household appliance. Lewin's Equation $B=f$ (P, E) is generally regarded as the most well-known formula in social psychology, in which behavior (B) is a function of the person (P) in their environment (E), (Sansone, 2003). In this study, we combined it with the traditional consumer behavior theory. Consequently, residential consumers' EEAP is affected by the influence of personal characters and the external environmental force. The personal characters mainly includes 'age', 'occupation', 'income', 'education

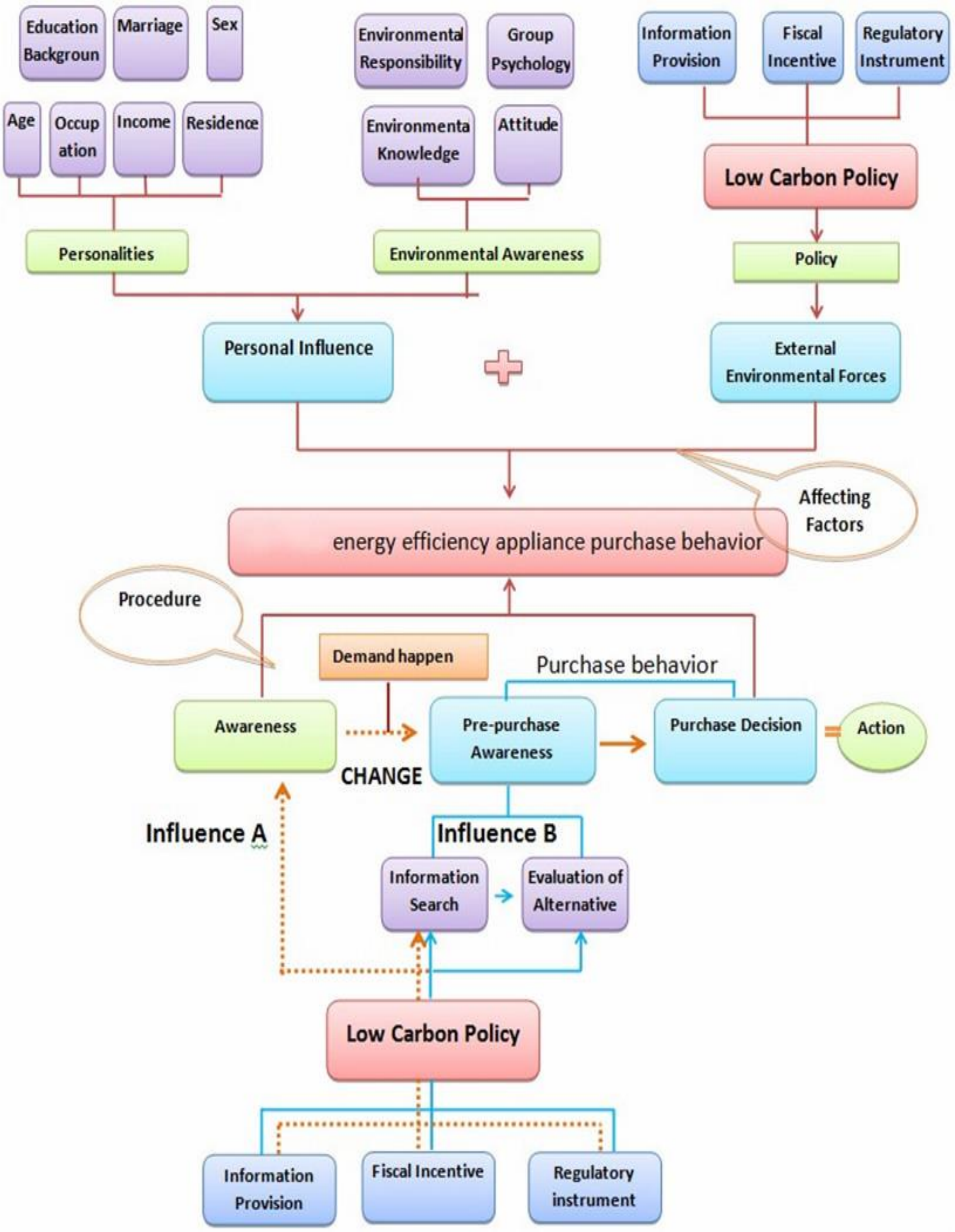


Fig.2-5 Mechanism of consumers' energy efficiency appliance purchase behavior

background', 'marital status', 'sex', 'residence' and 'environmental awareness'. Especially, we measure the 'environmental awareness' by three indicators: 'environmental knowledge', 'environmental responsibility', 'attitude to the environment' and 'group psychology'.

This mechanism also contains influencing process of consumer's EEAPB. During this period, the effect of policy instruments (such as information provision, fiscal incentive and regulatory instrument) will change. The Engel, Kollat and Blackwell (EKB) Model is a comprehensive model of consumer behavior which was elaborated by James F. Engel, David T. Kollat and Roger D. Blackwell (1973). According with EBK Model (Engel, Warshaw & Kinnear, 1979), there are five distinct stages of consumer decision making: problem recognition → internal search and evaluation → external search and evaluation ⟶ purchase processes ⟶ decision outcomes. We considered that because the demand of consumers in every stage is different, thus the influence of the three policy instruments should be different too. Therefore, we developed this model to consumer's EEAPB model. In this model, before consumer's demand of a certain household appliance happen, they under the influence of three policy instruments (such as information, fiscal or regulatory). During this period, these policies are playing an Influence A to consumer's awareness. Next, when consumer's demand of a certain household appliance happened, consumers will have an eye on the information relate to their demands. Now they will do the information search work and evaluate the alternatives. In this period, the policies play Influence B to consumers' pre-purchase awareness. Then, a purchase decision will be made.

2.5.2 The influence of policy instrument on consumers

In order to verify that whether policy instruments play different role in different purchase process or not? A survey was conducted in October 2012 at the capital city of Sichuan province, China. The samples were selected randomly from the top three shopping malls in Chengdu. All items from the questionnaire quoted in this paper have been translated in English by the authors. From 500 questionnaires sent out, 375 were retrieved (response rate 75%). The information about the questionnaire distribution and returned is listed in Table 2-6. The structure of respondents is listed in Table 2-7.

Distribution	Returned	Effective
500	375	295
Returned rate	75%	
Effective rate	78.7%	
Invalid rate	21.3%	

Table 2-6 status of questionnaire distribution and returned

Sex	Frequency	Valid Percent (%)
Female	149	50.5
Male	146	49.5
Age		
19-29	127	43.0
30-49	101	34.3
50-	67	22.7
Residence		
Capital City	113	38.3
County Town	53	18.0
Townships Villages	34	11.5
Prefecture-Level City	95	32.2
Education background		
-High School	74	25.1
University	185	62.7

Marital Status	Frequency	Valid Percent (%)
Married	188	63.7
Single	107	36.3
Income		
-2500	92	31.2
2500-4000	106	35.9
4000-5500	61	20.7
5500-	36	12.2
Occupation		
Enterprise's Employee	103	34.9
Civil Servants	45	15.3
Teachers & Students	74	24.1
Private Business	37	12.5
Freelance Work		
EE appliance purchase experience		
Yes		75.3
No		24.7

Master	25	8.5
Doctor	11	3.7

Table2-7 Structure of the respondents

There was no incentive for participation in the survey other than a bottle of water. The 4-page survey consisted of 10 parts. They are personal characteristics, low-carbon basic knowledge testing, attitude for the environment of China, environmental responsibility testing, reaction for 3 policy tools, low-carbon information policy's influence testing, financial subsidy influential for citizen's purchase decision, legal incentive influential for citizen's purchase decision and reason analysis part respectively.

The total of effective respondents amounts to 295 (effective rate 78.7%) of which 50.5% are female, 49.5% are male. About 63.7% of respondents are married. And 43.1% of respondents are aged 19-29 years old, 34.3% of consumers are between 30 and 49 years old, 22.7% of respondents are older than 50 years old. Applying a USD/RMB exchange rate of 6, majority of the respondents, about 35.9% (n= 106), earns USD 400 to USD 660 a month, 12.2% of respondents' monthly income is more than 900 dollar. 34.9% of respondents are enterprises' employees, and 24.1% of them are teachers and students. 70.5% of people are living in cities; while 62.7% of the respondents graduated from university.

2.5.3 Influence of policy instrument

1) Influence comparison

Respondents were asked to evaluate their external environment by answering three questions, which are aimed to compare the conformity and policy's potency. 45.1% of respondents agree with 'My family and friends are caring about environment protection', and 38.6% of respondents hold the neutral options about it, only 16.3% of consumers do not think so. Meanwhile, people's family or friends' concern about environmental problem has significant correlation with consumers' EEAPB (as shown in Table 4-5). When respondents were asked: 'if the people around them would like to buy energy efficiency appliance, would they to follow'. Almost all the respondents

	Family concern	Others' purchase behavior	Government appeals
Sig.	0.001	0.000	0.071
Mean	3.48	4.62	4.67

Table 2-8 External Environmental influence

(86.8%) thought they would like to do it. And its significance probability is smaller than 0.05; majority of the respondents can be affected by others' purchase behavior. The consumers were also asked about their attitude towards the government appeals (which can be deemed to be a kind of representation of information provision), 84.4% of the respondents (249 people) said they would obey the policy. However, we found out only 52 consumers who said they would abide by the policy bought energy efficiency household appliances. And the significance probability is 0.071 which is bigger than the criterion. Therefore, even if a lot of consumers provided positive response to the appeal of the government to buy energy efficiency appliance, results showed that not much people put it into practice.

Despite the significance probability, the results in Table 2-8 also show that the government has the biggest influence, 4.67, to consumers' awareness in the three external environmental factors.

As discussed above, information provision has a big effect on consumer's daily awareness

2) Influence of policy instruments on consumers' attention in daily lives

How do consumers care about the three policy instruments in their daily lives? The fiscal incentive gets the highest average score, 3.31; followed by information provision which is 3.19; and regulation instrument owns the lowest attention 3.15. Anyhow, all the three policy tools do not receive too much attention from consumers. And on the basis of result of ANOVA, there is no significant difference during the three policy tools attention.

3) Influence of policy instruments on EEAPB

How do consumers evaluate the influence of fiscal incentive, information provision, as well as regulation instrument on their energy efficiency household appliance purchase behavior?

More than half consumers (53.2%) responded that they would not buy any energy efficiency appliance unless they learned it from the government information channels. Meanwhile, the mean of its effect is 3.22. When citizens were asked the question: 'Only fiscal subsidy available, I'm willing to buy energy efficiency appliance', 50.9% of respondents agree with it, while 33.2% consumers disagree with it. And the mean of fiscal subsidy is 3.17, which is smaller than information provision. When people were asked to evaluate the effect of regulation instrument, 81.4% of consumers think that if the appliance meets the standards and requests of government, they would buy it. Remarkably, the mean of regulation instrument influence is the highest in the three tools (4.23).

Compared with the influence of the three policy tools on daily lives we have analyzed, the influence of three policy tools on consumer's EEAPB is different (as illustrated in Fig.2-6) The figure showed that the regulation instrument's has the biggest influence on consumer's EEAPB. But people are used to not paying too much attention on regulation instrument in their daily lives. The fiscal incentive has the biggest influence on consumer's daily lives attentions. The influence of information provision does not have significant changes for people's daily lives attention and EEAPB.

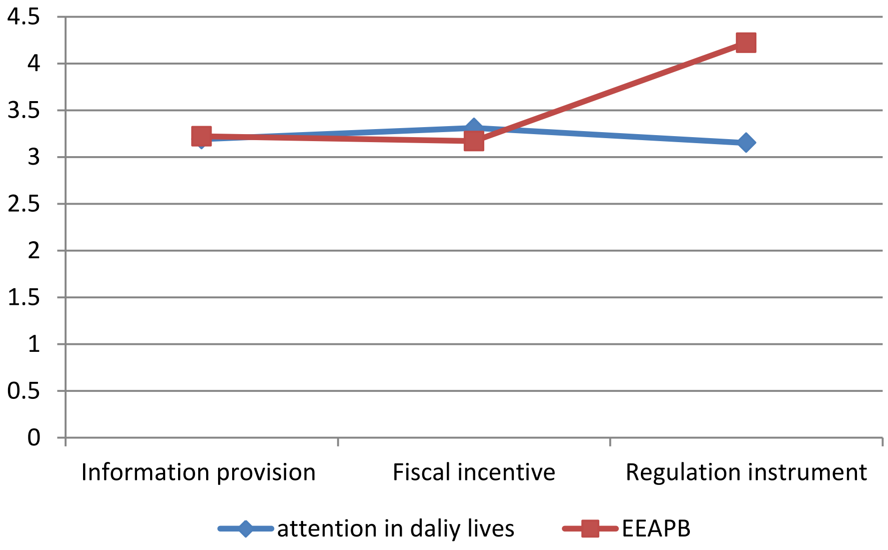


Fig.2-6 Influence of three policy instruments on consumer's attention in daily lives and EEAPB

2.5.4 Discussion and Conclusion

In this paper, we analyze to what extent consumers are affected by the mechanism of public policy promoting energy-efficient household appliance the mechanism of it. In order to prove our hypothesis and new developed theory, we conducted a one month survey in China. Based on the results of this survey, we came up with the following conclusions:

Firstly, consumers' energy efficiency appliance purchase behavior can be affected not only by personal influence but also by external environmental forces. The most significant personal influence factors are 'age' and 'occupation'. The youth and enterprise employees have higher enthusiasm to purchase energy efficiency household appliances. Meanwhile, there are three external environmental factors that have significant positive correlation to energy efficiency household appliance purchase behavior: (1) environmental knowledge, (2) environmental responsibility, and (3) conformity. Secondly, as a kind of performance of policy instrument' influence, government appeal to buy energy efficiency household appliance has a major effect on consumers' purchase behavior, this influence is even bigger than the effects of the family's concern and others' purchase behavior. Thirdly, in the daily life, the environmental policy instruments do not receive too much attention from consumers. And the attention does not contribute to the purchase behavior of efficiency household appliances. Further, the influences of the three policy tools on consumers' energy efficiency household appliance purchase behavior are different with each other. Lastly, the regulation instruments have the most important influence on consumers purchase behavior.

2.6 Conclusion

As China has become the top energy consumer is the world, the renewable energy is a necessary choice. Though being blessed with abundant renewable resources and promulgated a series of laws and regulations, even leading the world in renewable energy investment, there are still a great many of shortages not only caused by the imperfection of policy but also by renewable energy prevent the development of renewable energy. The policy enforcement needs to be enhance to reinforce the execution and encourage; the national standard ought to be formulated as soon as possible to conduct this industry;

integrated planning and area layout design are required to avoid overlapping investment and virtuous circle; a powerful general administration agency are demanded to Integration of resources and refrain from responsibility; a clearly feed-in tariff system will be useful to improve the renewable energy price structure.

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Chapter 3

Chapter 3 Renewable Energy Generation and Sustainable Development in China

Introduction

For the ever increasing generation and newly installed capacity, Renewable Energy (RE) in China has attracted growing concerns during recent years. RE is generally regarded as an important measure to deal with the challenges of energy security and climate change as well as sustainable development. So, with this rapid development of RE generation industry in China, does it play a bigger role in preventing greenhouse gases emissions, relieving the pressure on coal energy security, speeding up the economic growth or decreasing fossil fuels consumptions? The answer is not pretty clear yet. Therefore, this study focus on examine the links of RE generation with clime change, economic development, fossil fuel electricity and coal energy security. And this research is expected to provide a deeper understanding of the renewable energy generation's influence in China, instead of only growing numbers of its facilities.

The work is consists in the following sections. The status quo of renewable energy generation in the China is reviewed in Section 3.1. In Section 3.2, the development and the problems of renewable energy power in China is discussed. The role of renewable energy electricity in CO_2 emissions reduction is analyzed in Section 3.3. The links of RE generation with other three important indicators of sustainable development such as: economic development, fossil fuel electricity and coal energy security are discussed based on the results of statistical analysis in Section3.4, 3.5, and 3.6, respectively. Finally, the reasons and further feasible proposals are given.

3.1. The status quo of renewable energy generation in China

3.1.1 Electricity structure in China

The total installed capacity of China was 1.16TW in 2012, of which renewable energy accounted for 27.94%. The largest share of renewable installed capacity located in hydropower with 248GW, which reached 21.5 percent of total installed capacity, following by wind 62.66GW and solar 4.19GW (China National Renewable Energy Centre (CNREC), 2014). In 2012, China total power generation reached 4980TWh, and renewable energy generation accounting for 20.2 percent of the total. Hydro power accounts for 17% of total power generation (see in Fig.3-1). Both installed capacity and power generation of renewable energy in China experienced a stable growth in the past half-decade. Wind has become the second largest generation source of renewable energy with the best scale-up development, its power generation could account for 10% of total renewable electricity; biomass development kept in stable and accounted 4 percent of renewable generation; unlike other renewables, solar PV only took a small share of renewable power generation as the scale-up utilization just get started.

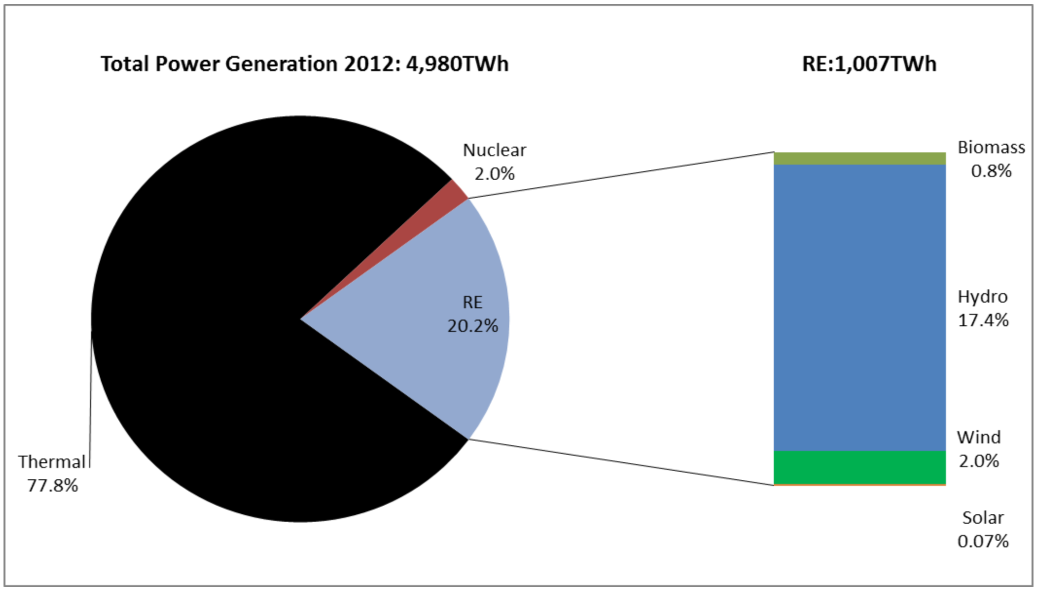

Fig.3-1 China Power Generation Mix in 2012 (%)

Source: China Wind Installed Capacity Statistics; Power Industry Statistics 2011; China Energy Supply Demand Projection Report 2013.

3.1.2 Interprovincial generation mix

As illustrated in **Fig.3-2**, hydropower has dominated RE generation in China for decades, but because of resource unbalance, the main utilization of hydropower plants are limited in southwest and northwest(such as Yangtze River, Yarlung Tsangpo River). Some areas such as north of China have generated around 1% of their electricity just from wind power for their affluent wind resource from the sea and advances in wind power technology. Feasibility studies also show that all China has strong potential for RE utilization at least in one source. RE is expected to play a bigger role in replacing fossil fuel energy in whole China.

Fig. 3-2 Generation mix of the six interprovincial power grids in 2008

Source: Ten cities and thousand vehicles program (Hong Huo, 2010)

3.1.3 Provinces with top 10 RE power installed capacity

In contrast to the fossil fuel plants, RE power plants are built in the resourceful areas since RE resource is not able to be transported. **Fig.3-3** presented the top 10 provinces with RE installed capacities in 2012. And these power plants are mostly centralized in central regions of China. Particularly, regions consume much electricity (such as northeast and east coastal areas) are lack of RE plants. For the high transmission losses and expensive power network, to transmit RE electricity to these higher electricity demand areas is not cost-effective. It means the power used in these places has to be generated by fossil fuels, and the role of RE electricity is limited.

Rank	Province	Hydro power	Wind Power	PV power	Biomass power	Total
①	Sichuan	39640	20	-	116	39780
②	Hubei	35950	170	12	406	36540
③	Yunnan	33060	1310	30	122	34520
④	Inner Mongolia	1080	16930	210	151	18370
⑤	Guizhou	17280	960	-	-	18240
⑥	Guangxi	15360	100	-	60	15520
⑦	Guangdong	13060	1390	8	439	14900
⑧	Hunan	13720	190	-	218	14130
⑨	Gansu	7300	5970	380	1	13650
⑩	Fujian	11400	1130	1	208	12740

Fig.3-3 The provinces with top 10 RE power installed capacity in 2012 (MW)

Source: 2012 China Renewable Energy Outline by CNREC

3.2 The development of renewable energy generation in China

Fig.3-4 shows the trend of electricity generation and installed capacity of RE in recent years. This big progress is mainly stimulated by three factors: first is China's official goal of CO_2 emissions reduction. China promised to cut the carbon intensity of its economy by 40%-45% by 2020 compared with 2005 levels. From 2006 through 2013, China has cut carbon intensity by 28% (Jing, 2013). Second is the enormous investment on RE in past years. Indeed China was in the lead of the world with USD 64.7 billion invested in RE industry in 2012, which is approximate 26 times more than that in 2004 (REN21, 2013). Third is the promulgation of Renewable Energy Law in 2005. As the most important law for RE, this law sets the basic framework of RE industry, as well as stages for the widespread development of RE. What's more, this law also offers financial incentives, such as a national fund to foster renewable energy development, and discounted lending and tax preferences for renewable energy projects.

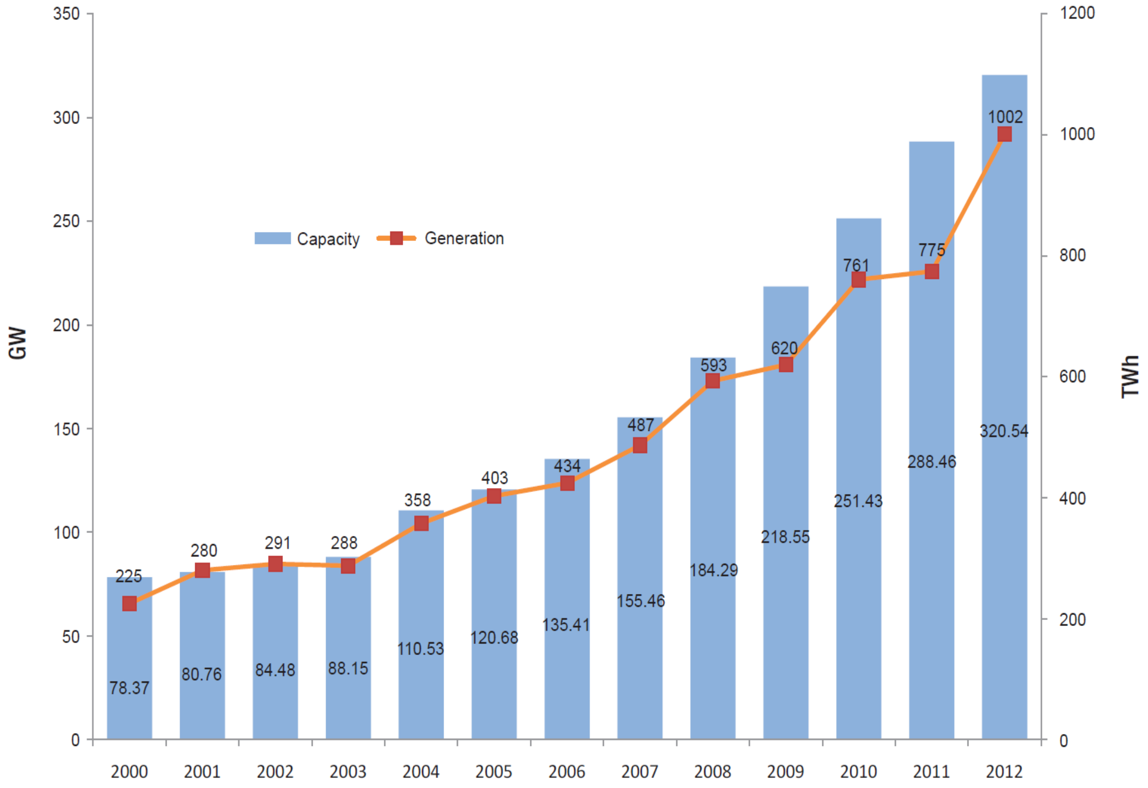

Figure.3-4 Renewable electricity installed capacity and generation in China

Source: National Renewable Energy Centre:

2012 China Renewables Utilization Data

3.2.1 Installed capacity

Fig.3-5 described the trends of installed capacity of RE by sources from 2000 to 2012. Table3-1 listed the growth rate of installed capacity of renewables, respectively. Clearly, the hydropower has the whip hand of accumulative installed capacity, but compared with other renewables, its growth rate is the lowest. We consider the root reason should be that hydropower's growth is from a higher baseline. Additionally, for the heated controversy about the ecological influence of hydropower exploitation, China stopped the approval of new large-scale hydropower plants in 2009. Even then because of the heavy pressure of reducing CO_2 emissions, they restarted the approval again in 2010, but the growth rate of newly installed capacity is much slower than before. And the new constructions are focused on small size hydropower stations.

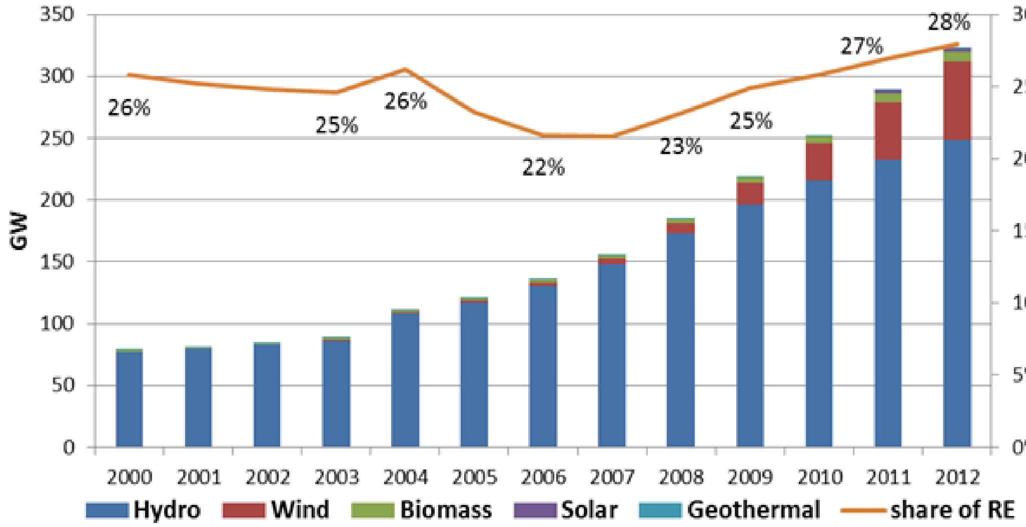

Fig.3-5 Installed capacity of RE in China from 2000 to 2012(GW)
Source: 2012 China Renewable Energy Outline by China National Renewable Energy Center (CNREC)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Hydro	3.1	4.6	3.7	25.8	8.4	11.0	13.8	16.4	13.7	10.1	7.8	6.8
Wind	12.1	17.6	21.9	36.1	69.6	106.3	61.6	99.8	109.8	68.1	56.3	35.5
PV	-	-	-	-	-	-	-	-	-	766.7	753.5	47.8
Biomass	0.0	0.0	50.0	0.0	33.3	25.0	20.0	9.0	40.7	19.6	27.3	14.3

Table 3-1 Growth rate of installed capacity of RE in China (%)

In terms of wind power, as shown in Table 3-1, which replaced hydropower to own the biggest newly installed capacity from 2010, and enjoyed the highest growth speed till 2009. We considered the reason should be to meet the rising power demands in northeast industrial areas and developed eastern coastal areas (where are plenty for wind resource as shown in Fig.3-5. China turned to focus on enlarging the scale of wind power plants in these regions since 2000. And a plenty of market-oriented policies has been set out. For example, the concession bidding of wind power was implemented between 2003 and 2007. It aimed at promoting the competitive mechanism and a reasonable feed-in tariff of wind power, and urged the multiply increase in installed capacity of wind power.

From 2010, PV has displaced the wind power as the fastest growing RE (Table3-1). This amazing growth could be attributed to three reasons. Firstly, contrary to hydropower, PV's growth is from a pretty low baseline. Consequently, it is easier to achieve a high growth rate. Secondly, the development of PV installed capacity is mainly pushed by China's manufacturing industry of solar cell. Actually, since China has become the biggest PV cell producer of the world in 2007, its heavy dependency on oversea market has given rise to the appeal of expanding the domestic PV market. Meanwhile, the declining demands of oversea market also forced China to explore domestic market to solve excess capacity. Thirdly, the national PV support project such as 'Golden Sun' was launched from 2009 to 2013, which aimed to increase 500 MW for PV installed capacity.

3.2.2 Power generation

In the field of electricity production, Fig.3-6 depicted annual proportion of RE in total power generation and renewables generation by sources from 2001 to 2012, respectively. Table 3- 2 tabulated the growth rate of RE generation during the same period. Similar as installed capacity, hydropower has the highest generation and lowest growth rate. And compared with other renewables, hydropower is more fluctuant for the instability of water resource, and which greatly affected the ratio of RE power in China's gross generation (Fig.3-6). Wind power keeps a stable increase. PV power has most explosive growth, but its generation is insignificant for the low baseline. About 72% of PV power came from centralized PV stations (China National Renewable Energy Centre(CNREC), 2013). This is different with PV power well developed countries, where distributed PV system is the mainstream. But for a distributed power market, it is imperative to break China's electricity monopoly. That will be pretty difficult in a short time.

In sum, China's progress in RE generation is largely led by hydropower and wind power, and government plays an important role. Meanwhile the domestic market-driven mechanism is forming, and the links between RE generation and external conditions are stronger. But, electricity monopoly has blocked the further growth of RE generation.

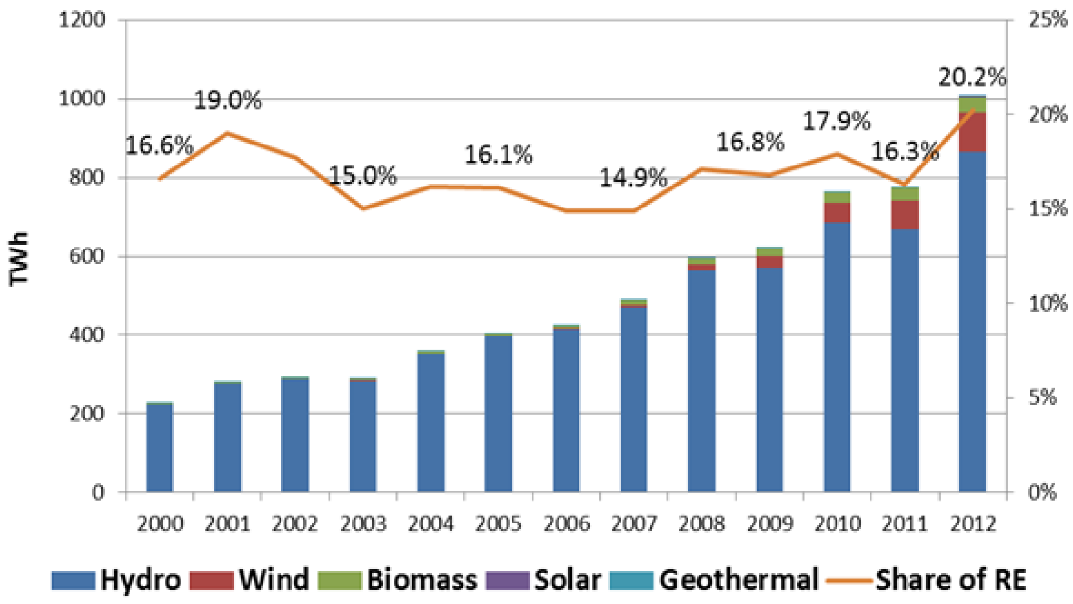

Fig.3-6 Power generation of RE in China from 2000 to2012 (TWh)

Source: 2012 China Renewable Energy Outline by China National Renewable Energy Center (CNREC)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Hydro	24.7	3.8	-1.5	24.6	12.1	4.6	13.6	20.0	1.1	20.1	-2.7	29.3
Wind	12.1	17.6	21.9	36.1	69.6	106.3	125.3	129.8	110.8	78.9	50.0	36.0
PV	-	-	-	-	-	-	-	-	-	-	600.0	400.0
Biomass	0.0	0.0	50.0	0.0	57.6	34.6	39.1	51.1	40.7	19.6	27.3	20.6

Table 3-2 Growth rate of RE generation in China (%)

3.2.3 Problems for the development of RE generation

As compared Fig.3-5 with Fig.3-6, we observed that the share of RE is close to one third of the total installed capacity, but the share of RE in gross generation is only one fifth. This problem might in part because RE is susceptible to weather condition. But, we considered that the figure revealed the 'Blindly expand' of RE generation. It means that the installed capacity of RE is already considerably larger than the output capacity of power grid. Taking wind power as an example, we found a phenomenon called 'wind curtailment' has already happened in Inner Mongolia. The abandon rate of China's wind power was 17% in 2011, that means more than 120 GW of wind power was wasted. The reasons could not only be the low utilization level, but also the unplanned exploration. If the grid is not capable enough to accept the increase of RE electricity in a time, instead of accelerating the installed capacity, they should focus on update the grid and related management systems.

3.3 Renewable energy electricity and CO_2 emissions reduction

One of the most important benefits of RE is to reduce the CO2 emissions. As the biggest CO_2 emitter in the world, China has made great effort to develop the RE electricity, is it resentful or not? In this section, we analysis it by two parts: first is Spearman's rank correlations analysis between renewables generation and CO_2 emissions, and then the estimation about the contribution of RE generation on CO_2 emissions reduction.

On account of the limited database about RE generation in China, this research collected yearly data mostly from 2005 to 2012 as the sample. The data mainly come from the U.S. Energy Information Administration (EIA), International Energy Agency (IEA), China Energy Statistics Yearbook, World Development Indicators (WDI) & Global Development Finance (GDF) and so on.

In this study, statistical analysis of the parameters is carried out using the SPSS software. Since the relationship between two variables is not very clear and the sample size is small, Spearman's rank-order correlation has been taken to assesses how well the relationship between two variables can be described using a monotonic function.

Spearman's rank correlation coefficient (r_s) always gives an answer between −1 and 1. The numbers are like a scale, where −1 is a negative correlation, 0 is no link, and 1 is a positive correlation. And closer |r_s| is to 1, stronger is the correlation. The p-value (labeled as a 'Sig.' value on the SPSS output) is a measure of the probability of obtaining a result at least as extreme as the one that is actually observed, so the lower the value (usually below 0.05 or 0.01) the more significant the result (Field, 2010).

3.3.1 Estimation of CO_2 emissions from electricity generation in China

According with IPCC (IPCC, 2006), the annual CO_2 emissions from electricity generation (E_{power}) can be estimated by the following formula:

$$E_{power} = \sum_n Q_i \times EF_i \qquad (1)$$

Where the subscript ***i*** represents fuel type;

Q_i denotes electricity production based on fuel type i (MWh);

EF_i is the CO_2 emissions factor of the ***i*** th fuel for the power plant in China.

Fuel type	*EF* (t CO_2/MWh)
Coal	0.8042
Gas	0.3799
Oil	0.5282

Table3-3 CO_2 emission factor of power plant (*EF_i*) in China

Source: National Development and Reform Commission (NDRC): 2010 Baseline Emission Factors for Regional Power Grids in China

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Coal	1713761	1971772	2301896	2659622	2744147	2940869	3250390	3723244	Total 3910800
Gas	7203	11931	14217	30539	31028	50813	69027	84022	
Oil	72210	61252	51984	34258	23411	16494	13255	7857	

Table 3-4 Fossil fuels electricity generation from 2005 to 2012 (10^3MWh)

Source: Fossil Fuels Electricity from World Development Indicators (WDI) & Global Development Finance (GDF), 2013; Fossil Fuels Electricity 2012 from State Electricity Regulatory Commission

	2004	2005	2006	2007	2008	2009	2010	2011	2012
Coal		1585.70	1851.18	2138.87	2206.84	2365.05	2613.96	2994.23	
gas		4.53	5.40	11.60	11.79	19.30	26.22	31.92	
Oil		32.35	27.46	18.10	12.37	8.71	7.00	4.15	
Total	1419.08	1622.58	2382.64	2168.57	2231.11	2393.06	2647.18	3030.3	3072.32

Table 3-5 The annual CO_2 emission from electricity generation in China (Mt)

Based on the Table3-3 and Table3-4 the annual CO_2 emission from fossil fuels electricity can be calculated by the Eq. (1), the result of CO_2 emissions from electricity generation is shown in Table3-5.

3.3.2 Spearman's rank correlations of RE generation with CO_2 emissions and growth rate of CO_2 emissions

According with the result of Spearman's rank correlations (shown in Table.3-6), the renewables generation is strongly positive correlated with CO_2 emissions from electricity generation, and this link is statistical significant (r_s ＞0.9, Sig.＜0.05). It suggesting that the CO_2 from electricity generation increases along with the renewables generation grows.

		CO_2 from fossil fuel electricity	Growth rate of CO_2 from fossil fuel electricity
RE generation	r_s	0.929**	-0.238**
	Sig.(2-tailed)	0.001	0.570

**Correlation is significant at the 0.01 level (2-tailed).

Table 3-6 Spearman's rank correlations of RE generation with CO_2 emissions and growth rate of CO_2 emissions

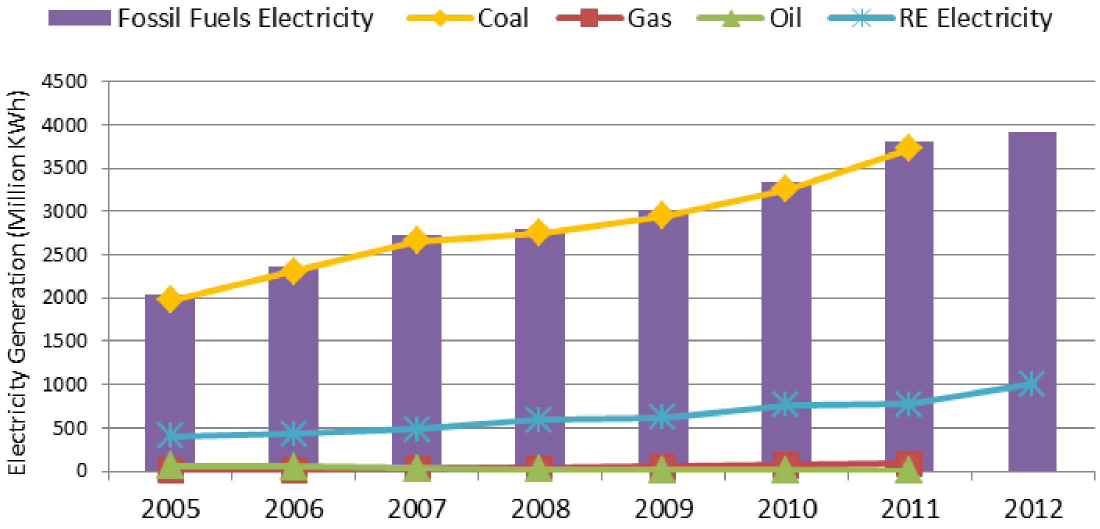

Fig.3-7 Electricity generated by source in China (GWh)

As shown in Table 3-6, the renewables generation is significantly positive correlated with CO_2 from electricity generation ($\rho > 0.9$, $Sig. < 0.05$), suggesting that the CO_2 from electricity generation increases along with the renewables generation grows. It is not hard to understand, as indicated in Fig.3-7, RE generation rapidly grows from 2005, in the meanwhile the fossil fuels electricity climbs up as well. Particularly the coal fired power, which develops by a faster speed and greater capacity than the RE electricity. Consequently, even though renewable consumption and generation in China keeps growing or more than 20% in 2012 (CNREC, 2013), this growth is from a low baseline. The growth in RE generation was more than offset by a 6.4% increase in coal consumption, which has a higher baseline. Therefore, the CO_2 emissions from electricity are growing. On the other hand, because of the negative correlation between the renewables generation and growth rate of CO_2 from electricity generation ($\rho<0$, $Sig.>0.05$), suggesting that as the renewables generation goes up, to some extent the growth rate of CO_2 from electricity generation slows. However, this relationship is not statistical significant.

As the statistical analysis above, the renewables generation has a positive correlation with CO_2 emissions from electricity generation, but we cannot ascertain that RE does not play a role in reducing CO_2 emissions. Therefore, the following paragraphs try to figure out the contribution of RE electricity on CO_2 emission reduction.

3.3.3 The contribution of renewable energy electricity on CO2 emission reduction

The contribution of CO_2 emissions reduced by using RE can be calculated as fowling equation:

$$C_{RE}= \frac{\sum_n E_{RE_i}}{E_{RE} + E_{Power}} \tag{2}$$

C_{RE} is the contribution of CO_2 emissions reduced by using RE

E_{REi} is the amount of CO_2 emissions reduced using i th RE

E_{power} is the amount of CO_2 emissions from electricity generation

Electricity Generation (tce)	2005	2006	2007	2008	2009	2010	2011	2012
Hydropower	14667	15223	16782	19510	19437	22867	22047	28170
Wind on-grid	59	103	203	452	939	1645	2445	3273
Biomass	178	239	323	474	662	772	977	1163
Solar on-grid	0	0	0	0	0	3	23	114
Geothermal & Ocean	4	4	4	3	3	5	5	5
Total	14908	15569	17312	20439	21042	25293	25497	32724

Table 3-7 Ton Coal Equivalent (tce) of RE electricity generation (10^4 ton)

Source: Energy Research Institute & CNREC

Because the CO_2 emissions factor of RE in generation is regarded as 0, in order to calculate the contribution of RE generation in CO_2 reduction, we use Ton Coal Equivalent (tce) of RE electricity generation, as shown in Table 3-7.

According with Energy Research Institute of National Development and Reform Commission, the CO_2 emission factor of Ton Coal Equivalent in China is 2.493 t CO_2/tce. Then based on the Eq. (1), we can get the reduction of CO_2 emission by RE generation (E_{RE}) in Table 3-8.

	2005	2006	2007	2008	2009	2010	2011	2012
E_{RE}	371.65	388.13	431.58	509.54	524.57	630.55	635.64	815.81

Table 3-8 Reducing CO_2 emissions by using RE (Mt)

Based on the Table 3-5 and Table 3-8, the contribution of RE on CO_2 emissions reduction can be calculated by the Eq.(2), the result is shown in **Fig. 3-9**.

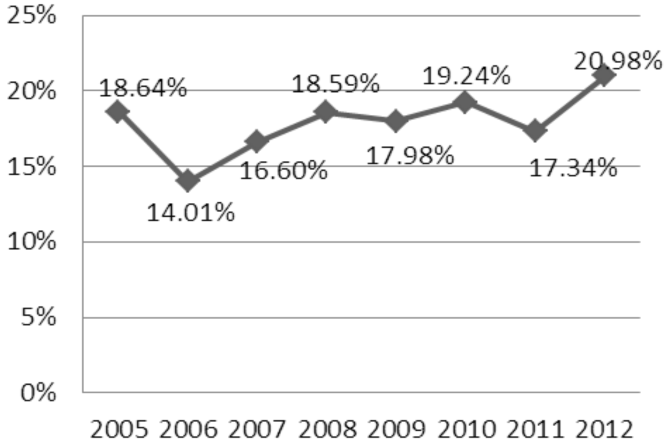

Fig.3-9 The contribution of RE on CO_2 emissions reduction (C_{RE})

3.4 The RE generation and Economic growth

GDP is regarded as a primary indicator used to gauge the health of a country's economy. RE generation is supposed to be a bright industry which benefits the economic development. For the sake of exploring the relationship between economy and RE in China, we discuss the GDP and its related measure gauge in the following section.

Based on Table 3-9, the renewables generation is strongly positive correlated to GDP, and this link is statistical significant ($r_s > 0.95$, Sig.< 0.01). It could be comprehended that the renewables generation grows while the GDP increases. As an important driving force of GDP, the enormous investment on RE not only greatly promote the installed capacity of RE, but also stimulate its related industries within China (such as the raw material supply and manufacturing industries of RE plants, the technology companies).

		GDP	Energy intensity by GDP	Real GDP growth rate
RE generation	r_s	1.000**	-1.000**	-0.667
	Sig.(2-tailed)	0.000	0.000	0.071

Table 3-9 Spearman's rank correlations of renewables generation

and economic growth

On the other hand, the real GDP growth rate does not have a significant link with RE generation. That revealed that even the economic growth rate of China is slow down; there is no direct and certain correlation with RE generation. For instance, the GDP growth of China in 2013 is deemed to ease (around 7%), but the RE generation in this year still goes up. The reason is that compared with the manufactory industry which is regarded as the pillar industry to promote the economic development of China, RE generation industry is more depend on the government support policies and natural conditions, instead of market economy.

In terms of energy intensity, this is a measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of GDP. High energy intensities indicate a high price or cost of converting energy into GDP. Low energy intensity indicates a lower price or cost of converting energy into GDP (EIA, 2013). From the Table 3-9, we can find the renewables generation is strongly negative correlated with energy intensity by GDP, and this correlation is statistical significant ($r_s < -0.95$, Sig.<0.01). This indicates that when more RE electricity generated the lower energy intensity by GDP get.

3.5 RE generation and fossil fuels electricity

As shown in Table 3-10, RE generation is strongly positive with the fossil fuels electricity, and this link is statistical significant (rs>0.95, Sig.<0.01), suggesting that when RE generation upwards the fossil fuels electricity goes up too.

		Fossil Fuels Electricity	growth rate of fossil fuels electricity
RE generation	r_s	1.000**	0.238
	Sig. (2-tailed)	0.000	0.493

Table 3-10 Spearman's rank correlations of renewables generation and Fossil fuels electricity

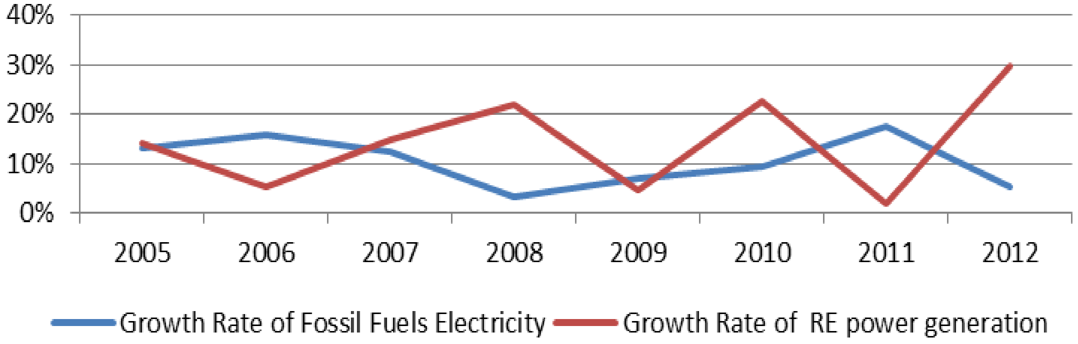

Fig.3-10 The growth rate trend of RE generation and fossil fuels electricity

The reason can be attributed to the ever-increasing power demand in China. This growth in demand not only leads to higher fossil fuels consumption, but also encourages the renewables generation. Meanwhile, the RE generation does not have a significant correlation with the growth rate of fossil fuels electricity, but we cannot conclude there are no indirect relationships.

For instance, the **Fig.3-10** shows a reverse trend of growth rate between RE generation and fossil fuels electricity, this indicating followings. Firstly, compared with RE, the fossil fuels electricity suffers more from macro environment, such as international energy price, economic conditions and demand. Therefore, in a sense, the trend of growth rate for fossil fuels electricity reflects the economic conditions of China in this year. Secondly, the growth of RE generation highly depends on the hydropower and wind power. When the energy demand keeps a steady increase, in order to meet the demand, energy supply increases too. But RE generation is easy to be affected by the natural conditions (such as weather, geographical conditions) and fluctuating, and the fossil fuel electricity must change with this insufficient anytime.

3.6 RE generation and coal energy security

Mined in over 50 countries around the world, coal is in a unique position to support national and regional energy security (WCI, 2006). Coal resource has occupied in China's energy structure for decades.

		Total coal consumption	Coal external dependence
RE generation	r_s	1.000**	0.929**
	Sig.(2-tailed)	0.000	0.001

Table 3-11 Spearman's rank correlations of renewables generation and coal energy security

As indicated in **Table 3-11**, RE generation is strongly positive with the total coal consumption and this link is statistical significant ($r_s > 0.9$, Sig.< 0.01). This suggests that when RE generation grows, the total coal consumption and coal external dependence of China increases. It also reveals that RE generation does not have a statistical link with coal consumption reduction. The reason is understandable, as discussed previously, the RE generation is significant correlated with fossil fuel electricity. And based on the existing coal energy efficiency, more fossil fuel electricity generated more coal consumed.

In terms of coal external dependence, which is strongly positive with RE generation, and this link is statistical significant ($r_s > 0.9$, Sig.< 0.01). It indicating that in spite China owns the third abundant coal reserves in the world, but the coal external dependence climbs up as the RE generation increase. The reasons could be explained as follows: firstly, the cheaper price of imported coal. Most coal reserves are located in the north and north-west of China, which poses a large logistical problem for supplying electricity to the more heavily populated coastal areas. Including the transportation cost and tax, the total cost is higher than import the coal. Secondly, from the beginning of this century, China has become the world factory. Since then the energy demand soared. More demand more supply. Thirdly, the low coal energy efficacy required more coal than the developed countries.

3.7 Discussion and Conclusion

China is on the developing period of industrialization, and its economic growth is driven by large scale production. But the scale economy not only comes with large sum of energy consumption but also the by-product of environmental damage. And RE is always regarded as the key to address this dilemma. However, in this study, we found that RE generation has a greater correlation with GDP growth while less related with fossil fuel electricity consumption decrease and CO_2 emissions reduction. We discussed it as follows.

Firstly, the enormous investment on RE is an important driving force of China's GDP. China's investment at RE has reached 66.6 billion dollars in 2012, which occupied 0.81% of GDP. The huge investment not only greatly promoted RE generation, but also stimulated related industries (such as the raw material supply and manufacturing industries of RE plants, the technology companies). For another perspective, just like we discussed previously in section 2, the over fast growth of RE installed capacity might be used as a way to boost economic growth of China. Besides, in order to achieve the target of 'RE accounts for 30% of total installed capacity in 2020' set by National Development and Reform Commission, we believe the installed capacity of RE will keep growing. But, the gap between RE installed capacity and generation should be attached more importance. After all, the electricity production by RE is more essential than inapplicable huge installed capacity.

Secondly, the ever-increasing power demand has improved the growth of both RE electricity and fossil fuels electricity, but RE electricity is hard to challenge the fossil fuel electricity in a short term. Since fossil fuel electricity has dominated China's energy system for decades. And RE generation is easy to be affected by weather conditions generation (especially hydropower), meanwhile the fossil fuel electricity could be transported and change with the insufficient anytime. Moreover, the cost of coal power is much cheaper than RE generation, and which is hard to be changed in a short period. Thus, RE's effect on reducing fossil fuels electricity will not be effective.

Thirdly, the CO_2 emission is positively correlated with the fossil fuel electricity consumption. China's RE generation has experienced a rapid expansion since 2000, but that is from a lower baseline. Meanwhile the fossil fuels electricity climbs up as well by a faster speed and greater capacity than the RE electricity (Figure 5). Consequently, even though RE consumption and generation keeps fast growing, but this growth in RE generation was more than offset by a 6.4% increase in coal consumption (CNREC, 2013). For which has a higher baseline while most of CO_2 emission is attributed to the low-efficient coal power plants. Moreover, the fluctuating growth rate of RE generation leads to a floating ratio of RE generation in gross electricity generation. So, although a new peak of RE generation got in 2012, but its share is not stable and big enough to contend with coal power. Thus, to reduce CO_2 emissions in China, the more important should be increasing energy efficiency.

Based on the problems we explored, some recommendations are given as follows: Firstly, China should focus on increasing energy efficiency of coal power. Because of bigger base number, the efficiency of thermal power plants will be more significant on CO_2 emissions reduction. Secondly, enlarging transmission capacity prior to explore installed capacity of RE. If only with a huge installed capacity, but a laggard power transmission system, it means more RE generation will be wasted. Thirdly, complete the policy planning and decision making mechanism. Fourthly, expanding the concession bidding system in all kinds of RE generation industry. Because this system is proved by wind power department that which could act as a buffer between competitive mechanism and policy-oriented industry. Fifthly, open up the distributed RE power market and to break the electricity monopoly. In addition, a comprehensive and objective understanding about the influence of hydropower should be conducted both for the public and policy makers. Lastly, the loss in GDP for decelerating new construction of RE could be shifted to the promotion of power system and energy efficiency. So, even the growth in installed capacity of RE is slow down, but the influence on economy can be minimized.

At present, RE generation is hard to drive a fundamental transition in China's energy system because its limited effects on CO_2 emissions reduction and fossil fuel electricity decrease. If China expect to expand the RE's influence , it will require sharply limiting the use of fossil fuels on which more than 80 percent of today's Chinese energy system depends. And that, in turn, would set off a sweeping transition of one of the most extensive, technologically complex, and deeply embedded elements of China's physical infrastructure: the national energy system, economic growth and industrial structure. But these transformations are incredibly difficult to be finished in a decade. Therefore, China will necessarily continue to rely on fossil fuels in the coming decades. And during this period, compared with a bigger ratio of RE in generation, to raise the energy efficiency of fossil fuels is more useful and practical for China's sustainable development.

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Chapter 4

Chapter 4 SWOT Analysis of Residential Grid-connected Photovoltaic Power Systems in China

4.1 Background

During the winter of 2012, a large amount of Chinese cities have experienced severe air pollution. According with a report from National Development and Reform Commission (NDRC), about a quarter of this country has been shrouded by thick fog and haze, and around 6 hundred million Chinese are involved in this pollution (NDRC, 2013). Yale Center for Environmental Law & Policy pointed out that one of the most significant contributing pollutants by far, is fine particulate matter (PM 2.5) and an important causes of the PM 2.5 is over increasing coal-fired power plants (Angel Hsu, 2013).

According to a report from International Energy Agency (IEA), since 2004 to 2012, the thermal power (its main resources including coal, oil and natural gas) has occupies around 78% of annual generated energy and keep increasing in China (IEA, 2012). The coal power has accounted for more than 70% of thermal power generation in China since 1978 (CCED, 2012).

Country	Thermal power	Coal power	Dependency on coal
China	78.58%	75%	66%
Japan	78.9%	25%	22%
U.S.A	68%	37%	22%
EU	52%	25.3%	-

Table 4-1 Dependency on coal energy in four areas

Source: Eurostat, IEA, Energy Balances of OECD Countries2011 Edition

Table 5-1 lists the percent share of thermal power and coal power in four different areas, as well as their dependency on coal. Not hard to find that the percentage of China in coal power is three times that of Japan and EU area, more than twice of U.S.A, though not too much difference in thermal power with Japan (Post Fukushima). As demonstrated in Fig.4-1, Chinese dependency for coal power is far more than the rest countries and areas, and consumes nearly as much coal as the rest of the world combined in 2011.

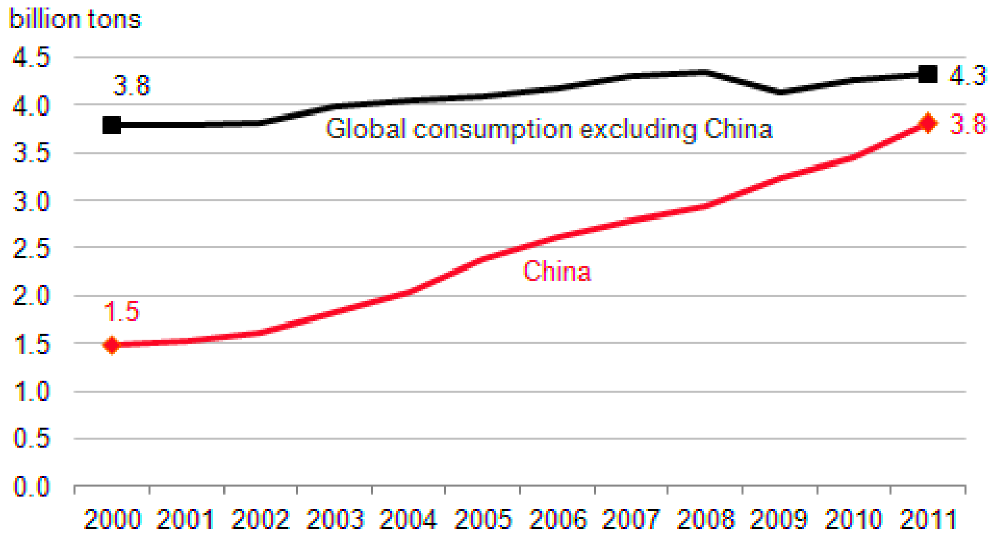


Fig.4-1. Coal consumption: China rivals the world

Source: U.S. EIA

In order to decrease Chinese dependent on coal power, renewable energy has received increasing attentions. However, the renewable sources are not all equivalent, from the resource reserve to development cost. Solar resource is more over than 200 times larger than all the others combined (Richard Perez, 2011) (see in Table 4-2). Fortunately, China is privileged to own abundant solar resources-about 30% of the world's solar resource; its land surface receives an annual solar radiant energy of 1.7×10^{12}tce (tons of standard coal equivalent), and more than two-third of the country receive an annual radiation of more than 5.02×10^{6}kJ/m2 and sunshine of more than 2000 hours annual (Ariel, 2009).

Not only solar resource, but also China has rapidly positioned itself as one of top solar PV manufacturers and the fastest growing solar PV market in the world in the world during recent years. PV should have the distinctive advantages compared to other renewable energies in China. Consequently, photovoltaic (PV) is one of the fastest growing renewable energy technologies that is expected to play an important role in the future of electricity generation mix in China.

4.2 PV power market in China

Chinese PV market is dominated by large-scale grid connected power plant or centralized grid-connected PV plants (as shown in Table 4-2). Its domestic PV generation is far from satisfactory. During the past 2012, the grid-connected PV power only made up 0.1% of the gross generation which is smaller than other renewable energy power (such as nuclear power, hydroelectric, wind power and biomass power) (CNREC, 2013). Meanwhile in the best practice countries of PV power (for instance German, Japan, and the US) the dominant PV system is distributed grid-connected PV power system, a comparison is tabulated in Table 4-3 below. Obviously, the mainstream of PV generation is the distributed grid-connected PV power system. If China expects to decrease the dependency on coal power and increase the PV power, the distributed grid-connected photovoltaic power system should be expected to play more and more important role.

	Market Sectors	Annual Ins.（MWp)	Share（%）
Stand-alone PV system	Rural Electrification	10	0.4
	Communication & Industry	5	0.2
	PV Products	5	0.2
Grid-connected PV system	BIPV & BAPV	480	19.2
	Large-scale PV	2000	80.0
Total		2500	100.0

Table 4-2 The five PV sub-markets in China of 2011

*BIPV: Building-integrated Photovoltaic

*BAPV: Building Attached Photovoltaic

Source: IEA, National Survey Report of PV Power Applications in China 2011

Country	Share of distributed PV power system
German	86.02%
Japan	99.33%
USA	82.47%
China	28.67%

Table 4-3 Share of distributed PV power system in four countries

Source: IEA, National Survey Report of PV Power Applications in China 2011

4.3 Residential Grid-connected PV Power System

Residential Grid-connected PV Power System (RGCPVS) is a popular application, which generally has a capacity less than 10 kW, can meet the load of most consumers （U.S. Department of Energy, 1997）. In countries where PV power is applied and extensively developed, RGCPVS is the mainstream application. For instance, in Japan, RGCPVS takes up approximately 70% of total install capacity of PV power in 2012 （IEA, 2013）. In Germany, this number is more than 99 %(IEA.2012). RGCPVS is the trend of the PV application in the world.

To promote the use of RDGPVS in Chinese residential area has great significance as follows:

①Optimize energy structure, decrease the proportion of coal power;

②Expanding domestic market, reduce dependence on exports;

③ Improve the security of electricity supply, especially for emergency purposes;

④Remarkable effective in energy conservation and emission reduction, and so on.

However, unlike these countries where PV application is dominated by RGCPVS, in China, large PV power stations are the majority. Actually, RGCPVS was not allowed until October, 2012. Therefore, China's RGCPVS is at a primary stage, a systematic analysis about the advantages and barriers that it faces is necessary and needed.

Literature review shows that studies related to China's PV power are mostly analysis for the entire renewable energy of China that focuses particularly on policies (Chao BAO, 2013) (Xiliang Zhang, 2010). Only some studies on China's PV power development largely center on the PV manufacturing. Moreover only few studies discuss the distributed PV power systems based on the architectural or technical perspective. There is scarce information available that analyzes the conditions that RGCPVS faces in China, without taking into account the perspectives of RGCPVS experts from developed and developing countries.

4.4 Literature review

Recently, a key tool used to analyze national sustainable development is SWOT analysis; this was originated from the business management literature and adopted in the 1980s in public administration (N. Markovska, 2009). 'SWOT' is the abbreviation for capital word of Strength, Weakness, Opportunities and Threat. 'Strength' and 'Weakness' are considered as internal factors while 'Opportunities' and 'Threat' are external factors (Weihrich H Cannice MV, 2008). Internal factors can be defined as the industry's internal characteristics such as resources, skills, or assets an industry has, which made this industry be different with its competitors, and they are controllable. Further, external factors such as market, economic environment, political, social, legal, or cultural factors; cannot be directly controlled by the industry but it reacts to its own ad-vantage. Specifically, there are several examples of successful application of SWOT analyses in the fields of regional energy planning (Terrados J Almonacid G, 2007). Recently, SWOT analysis was applied to environmental management in Greek mining and mineral industry, this analysis was carried out by Nikolaou (Nikolaou I.E, 2010). A number of European countries also used SWOT analysis for selection of policy priorities and ensuring horizontal policy coherence in national sustainable development strategies (European Commission, 2004).

It is evidently demonstrated in those studies that the SWOT analysis approach is an appropriate tool for investigating problems from a methodical perspective (Yuan Hongping, 2011). Thus, we adopted SWOT analysis method to systematic analyze RGCPVS in this paper.

4.5 SWOT matrix of expanding RGCPVS in China

In this section we analyze the internal and external environment for the application of RGCPVS in China from four dimensions. Strengths and Weaknesses demonstrate that the RGCPVS's internal characteristics and resources are controllable and different from others. These internal aspects mainly consist of resource, production, technology, and its own characteristics by nature. Opportunities and Threat are determined by external factors, on which residential grid-connected PV power generation industry has no direct control but can react by its own advantages. External factors are generally related to the legal, administrative and procedural framework in operation and competitors.

Based on the literature review's analysis, statistical reports, government regulations and policies, the SWOT matrix of the factors which affect the development of RGCPVS in China can be draw, as shown in Fig.4-3. Then, an investigation is conducted to examine the top SWOT factors, and these factors require our focus in the following sections.

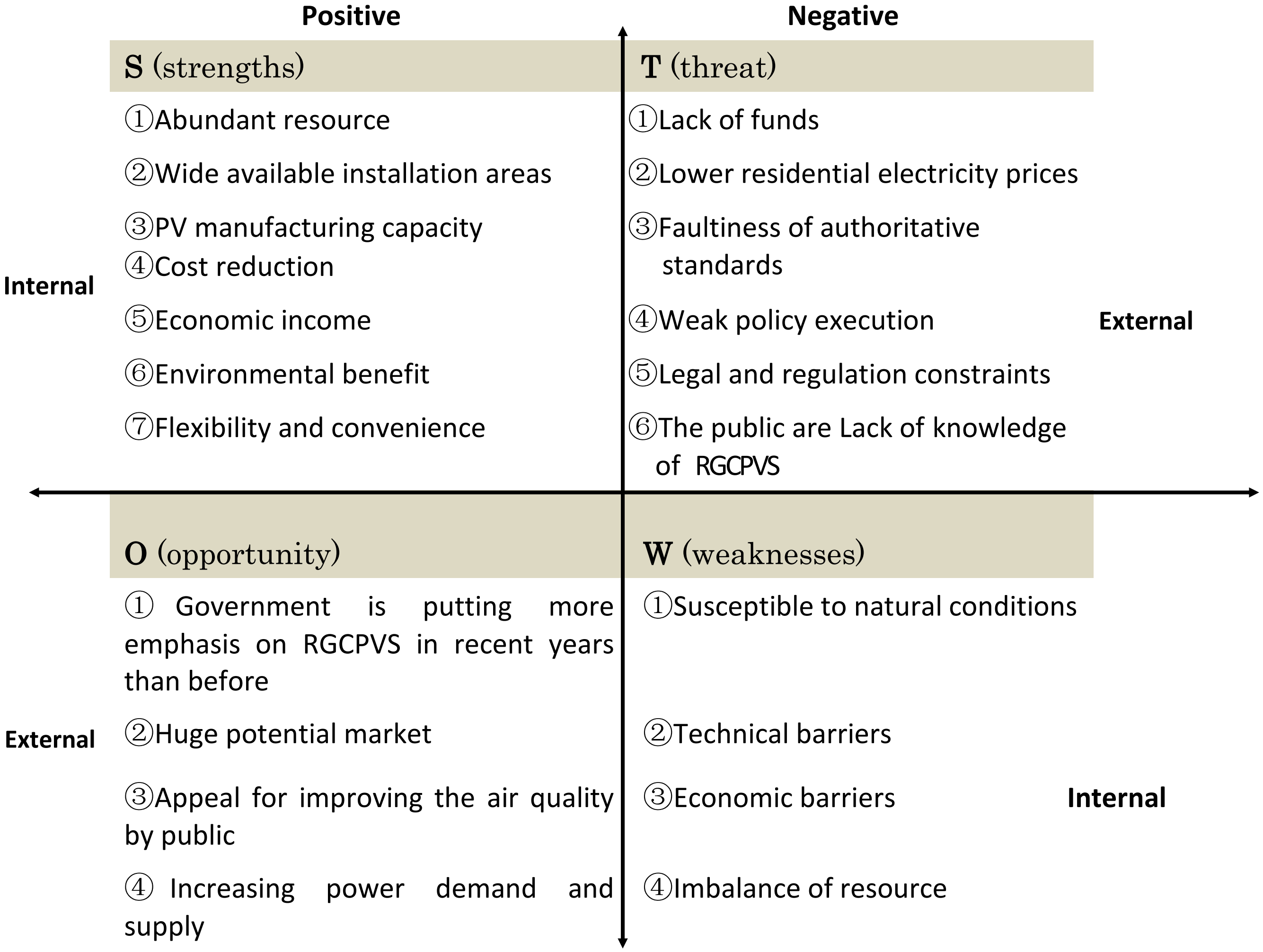


Fig.4-3 SWOT matrix of developing RGCPVS in China

4.5.1 S (strengths)

S1: Abundant resource reserves

China is privileged to own more abundant solar resource than other renewable resources, such as hydropower, geothermal energy and wind power. As displayed in Table 4-4. According to Chinese Weather Bureau, areas located in different latitudes have different level of solar irradiation (as shown in Fig.4-5 and Table 5-8). In the area Ⅰ, Ⅱand Ⅲ, because of their more than 2200 hours' annual sunshine hours and 120 kJ/cm^2, annual solar radiation, we can suppose the three areas are abundant in solar energy, and these areas have taken up two-thirds of China.

		Potential exploitation	Standard Coal Equivalent (billion tce)
Hydropower	Economically developable	0.4×10^9 kW	4.8~6.4
	Technically developable	0.5×10^9 kW	
Geothermal energy		3.3×10^9 tce	33
Wind power		1×10^9 kW	8
Solar energy		170×10^9 tce	170

Table 4-4 The main renewable resources in China

Source: NDRC, Renewable energy middle and assessment long-term plan

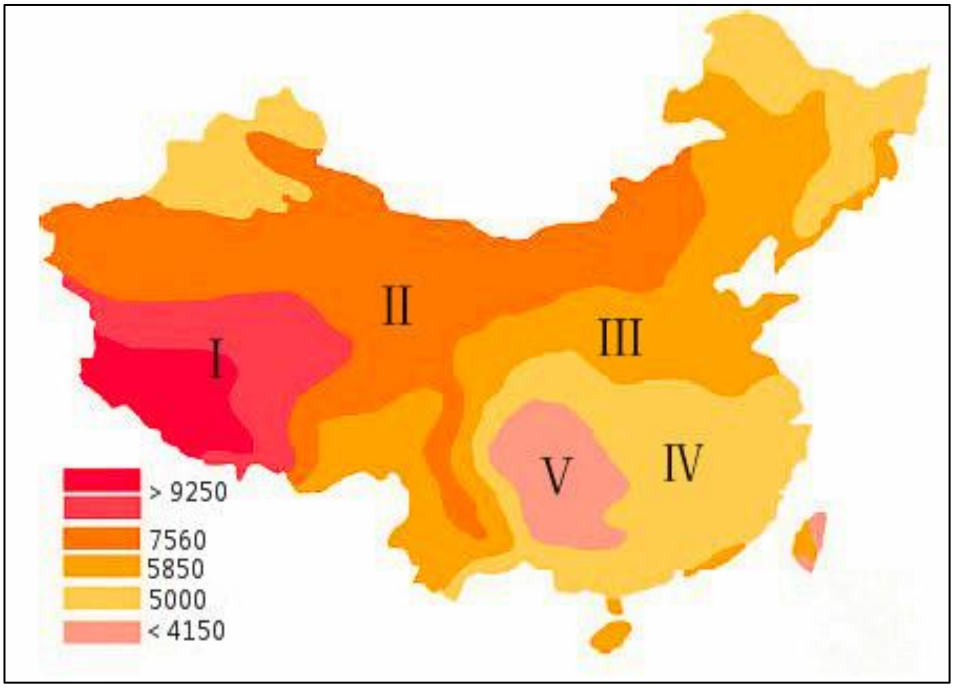


Fig.4-5 China's solar resource distribution pattern (MJ/m^2)

Source: Chinese Weather Bureau

Area	Annual sunshine hours	Annual solar radiation (kJ/cm² ·Year)	Total annual solar radiation on per m² by standard coal (kg)
I	3200-3300	160-200	225-285
II	3000-3200	140-160	200-225
III	2200-3000	120-140	170-200
IV	1400-2200	100-120	140-170
V	1000-1400	80-100	115-140

Table 4-5 The solar resource in different areas of China

Source: Center for wind and solar energy resources

S2: Wide available installation areas

China's total building area of houses is about 40 billion square meters, of which the total usable area of the building roofs is about 0.316 billion m^2; if on the basis of the 100W/m^2 installation density and 1000 hours annual operation, the total electricity output will be 31.6 TWh (Shenghong, 2011).

S3: PV manufacturing capacity

Fig.4-6 and Fig.4-7 demonstrates the development of annual world PV cell/module and PV industry production. In 2001 China produced 1% of the world's solar cells and modules; by 2010 it produced nearly half. At present, four of the top five solar cell producers are Chinese; three of the five module producers are in China (A Kearny Alliance Project, 2012). In 2008, only 33 percent of solar cells were made in China, a share that grew to an impressive over 57 percent in 2011, ranking the first globally. It's not hard to find that China has become the largest producer of cell sand modules since the year of 2007. Chinese PV production is able to meet the needs of the quickly development of domestic RGCPVS market.

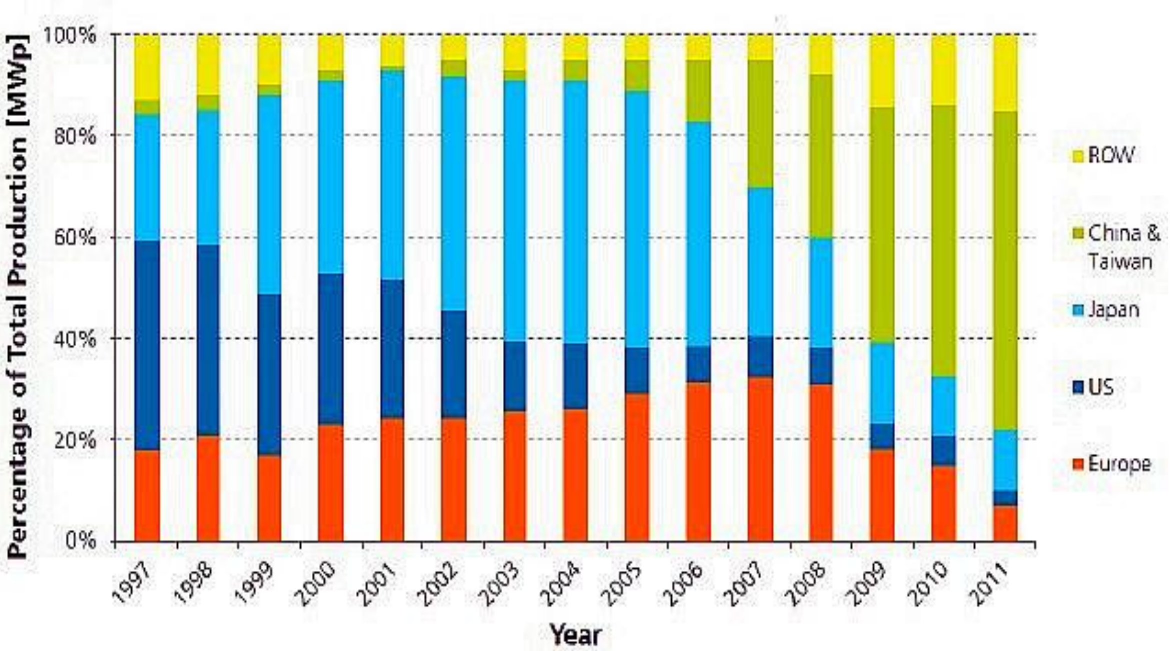


Fig.4-6 PV Cells/Modules Production by Regions (1997-2011)

(Percentage of Total MWp Produced)

Resource: Navigant Consulting Graph: PSE AG 2012

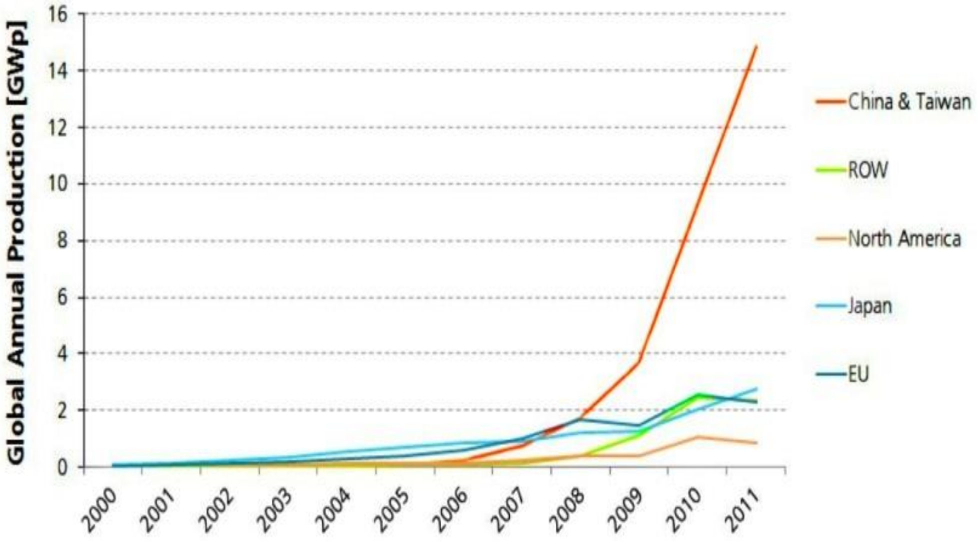


Fig.4-7 PV Industry Production by Region (2000-2011)

Resource: Navigant Consulting Graph: PSE AG 2012

S4: Cost reduction

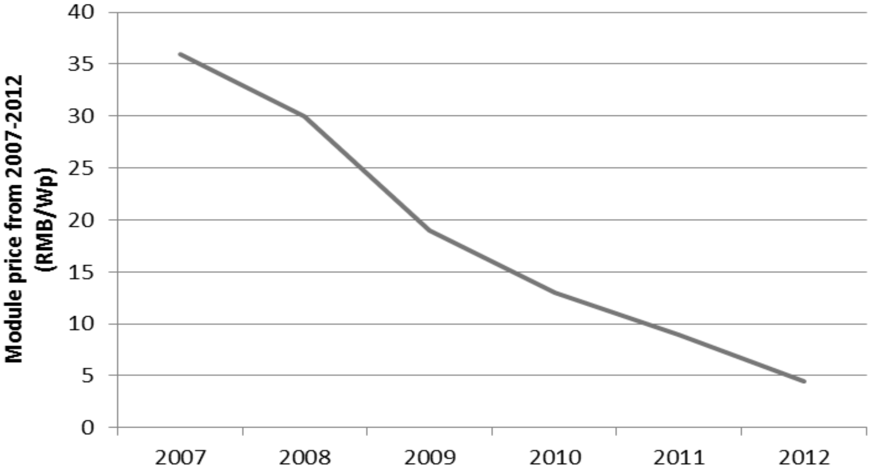


Fig.4-8 Module price falls from 2007 -2012

Source: IEA, (2013). National Survey Report of PV Power Applications in China 2012

The decrease trend of PV module price is depicted in Fig.4-8. As illustrated in this graph, the price of PV system in 2012 was less than one seventh of 2007's. Besides, for an inexpensive labor cost, lower energy price, cheaper infrastructures, some access to low-cost finance and no customs duty, Chinese PV modular price is always at the lowest level in the world, even with the suffered anti-dumping sanction by EU and America. Thus we suppose that the decreasing price should be a big strength for China's RGCPVS.

S5: Economic income

The economic income for RGCPVS can be divided into 3 parts as shown in Fig.4-9. They are Average residential electricity price (0.6 Yuan/kwh) residents can save, National Financial support for clean energy (0.42 Yuan/kwh) and Desulfurizing price (0.42 Yuan/kwh) for the PV power.

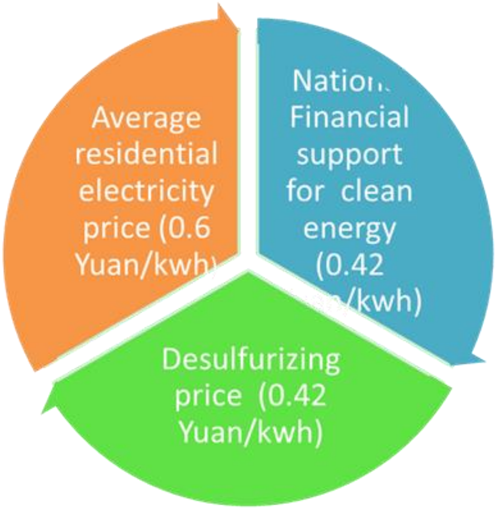


Fig.4-9 Three kinds of the economic income for RGCPVS

For a further understanding about the economic benefit, another investigation has been conducted. The investigation targets are three owners of RGCPVS located in Shandong, Shanghai and Hubei provinces. Detailed information are listed in Table 4-6.

Serial NO.	No.1	No.2	No.3
Owner	XU pengfei	CHEN jiling	GAO song
location	Qingdao(SHAN DONG)	SHANG HAI	Wuhan (HUBEI)
Installed capacity	2KW	2.5KW	4.5KW
Annual sunlight hours	2360	1650	1752
Grid-connected start time	2012.12.21	2013.1.5	2013.5.22
Practical generation (Y/KWH)	2701	2450	5400
Theoretical generation (Y/KWH)	2 × 2360＝4720	2.5 × 1650 ＝ 4125	1752×4.5 ＝ 7884
Practical generating efficiency	57%	60%	68%

Table 4-6 Practical generation status of RGCPVS

Area	Annual sunshine hours
Ⅰ	3200-3300
Ⅱ	3000-3200
Ⅲ	2200-3000
Ⅳ	1400-2200
Ⅴ	1000-1400

Table 4- 7 The solar resource in different areas of China

Source: Center for wind and solar energy resources

Based on the practical information about RGCPVS, the average Practical generating efficiency could be taken as 62% in this case. Then, if take the area where has the lowest solar resources (such as area Ⅴ as an example), the lowest economic benefit is available.

The annual Practical Generation (kWh) can be calculated by the following formula:

$$\mathbf{G = I \times S \times E}$$

G is the annual Practical Generation (kWh)

I is Installed capacity of a system (kw)

S is Annual sunshine hours (h/y)

E is Average generating efficiency

The result of practical generation for RGCPVS in area Ⅴ is listed in Table 4-8

Installed capacity	Annual sunshine hours (h/y)	Average generating efficiency	Practical Generation (kwh)
1 kw	1200	62%	1 ×1200 × 0.62＝744

Table 5-6 practical generation for RGCPVS in area Ⅴ

①A：If sale all the power to State Grid

Economic income＝

（①National Financial support for RGCPVS＋②Desulfurizing price ）× Practical Generation

＝(0.42 Yuan/kwh＋0.42 Yuan/kwh) ×744 kwh

＝624.96 Yuan/Year

②B：If all the power used by yourself

Economic income＝（①Average residential electricity price＋②National Financial support for RGCPVS ））×Practical Generation

＝(0.6 Yuan/kwh ＋ 0.42 Yuan/kwh) ×744 kwh

＝ 758.88 (Yuan/year)

If depositing the money, with the interest 3.5%, the money the residents' can earn is 10000×3.5%＝350 yuan.

In China, according to the size and quality of RGCPVS, the cost is different. Generally speaking, taking a 1 kW system as an example. The initial cost is around 10 thousand RMB. For most Chinese families consider it as large amount of money at present. However, in the long run, it will be a reasonable and low risk investment. Since the RGCPVS could generate the electricity and sale the rest to a fix buyer - State Grid Company in the daytime, then purchase the electricity from this company in the evening. For instance, if the selling price of RGCPVS is 0.42 RMB/kW (as desulfurizing price), the payback period will be around 10~15 years; while the service life of RGCPVS is around 25 years. This means that - in the rest 10~15 years, the residents not only would do not need to pay for the electricity bill, but also can earn from State Grid. Comparing with low interest rates on bank deposits (0.35%), economic benefit cost ratio of RGCPVS is more attractive.

S7: Flexibility and convenience

①As to the RGCPVS, the most important strength is that any excess electricity produced by this system can be fed back into the China's State Grid. When solar resources are unavailable, electricity from the grid supplies consumers' needs, eliminating the expense of electricity storage devices like batteries. Consequently, extra battery system and the expensive transmission line are needless too. And which also made the electricity be possible in some emergency situations or remote areas.

② Compared with the large scale solar energy generation plate, RGCPVS installation can be finishes in 3 days in general, short constructing period and little cost.

③ Thirdly, dislike large PV power station, RGCPVS can be built on the roof or outer wall without taking the precious land source and made full use of Chinese vast available installation space (about 40 billion square meters).

④ Improving emergency responding mechanism. Emergency power play critical role and assure the power supply for communication, relief and rescuing and refuge facilities electricity use as the conventional power fails. Installation of RGCPVS will not rely on conventional energy, no energy consuming and without pollution, and safe, reliable and free of maintenance. For instance, during the Tohoku earthquake in Japan, RGCPVS has plays an important role in emergency power supply, since then the RGCPVS has attracted increasing importance and the installations hitting fresh highs.

4.5.2 W (weaknesses)

W1: Susceptible to natural conditions

Solar power is a variable energy source, as the common weaknesses of all the PV products, RGCPVS's energy production dependent upon the sun. For instance, in summer season (from Jun to August) the generating capacity by RGCPVS occupies 30%-33% of the annual total generating capacity; in winter (December to February), the percentage declines to 10%. When weather conditions are fluctuating (e.g. sensitive to cloud shading) conditions under which PV efficiency is further decreased.

W2: Technical barriers

First of all, a renovation and transformation for Chinese electricity distribution management system is needed. As a result of a large sum of electricity generated by RGCPVS, it could be accessed by the grid at the same time, the designed load growth model will be changed and hard to make load forecasting, meanwhile, the voltage variation will become inevitable. Secondly, the PV cells material technology restricts the PV industry development in China. The silicon purifying is a high technology and the purity of silicon significantly affects the efficiency of PV power transformation13). This compared to other renewable energy sources (such as solar thermal), PV systems have a relatively low efficiency level ranging between 12-20%. Although there is continuous technological progress in PV materials for improving existing systems' performances or creating new products, PV systems are still limited by the capabilities of the materials used in PV cells. Thirdly, in addition to solar cells, the energy storage technology and batteries had become another vital issue for the sustainable development of China's RGCPVS, how to balance their advance will be a problem. Additionally, there are severe environmental concerns, such as advanced technologies requires to deal with toxic substances that accompany the silicon purifying and the energy consumption evaluation and other environmental influence caused by PV manufacturing.

W3: Economic barriers

Economic barriers mainly contains of two aspects: one is the high initial and repair costs, the other is long payback period. The initial cost of a RGCPVS comprises the hard ware and installation cost. Hardware cost includes PV panels, mounting hardware, circuit breakers and inverters and cables. Such items can be very expensive. In China, the average cost (for a 1kW system) so far is around 10,000 RMB and the cost is all covered by consumer themselves.

①. Cost

Installation cost and Opportunity cost / cost of capital (Interest on deposit 3.5 %).

However, in China the installation cost is all afforded by the residents themselves, without any government support. That means the cost for the 1st year is

$$\text{Cost} = 10{,}000 + 10{,}000 \times 3.5\% = 10350 \text{ Yuan}$$

And the Nth year's cost is

$$\text{Cost} = 10{,}000 + 10{,}000 \times 3.5\% \times n$$

②. Payback period

A：If sale all the power to State Grid

Payback period ＝installation cost ÷ (economic benefit - cost of capital)

$$= 10000 \div (624.96 - 350)$$

$$\approx 27.5 \text{ year}$$

B：If all the power used by yourself

Payback period ＝installation cost ÷ (economic benefit - cost of capital)

$$= 10000 \div (758.88 - 350)$$

$$\approx 24.5 \text{ year}$$

In terms of long payback period, which is an economic measure, indicating the number of years an investment takes to pay for itself; we suppose that in China, if the FIT or selling price for RGCPVS is 0.42 RMB/kWh; the initial installation cost is 30,000 RMB for a 3kW system(despite the repair costs), and if the daily average generation is 10 kWh, the payback period will be at least 10 years. Oppositely, if the consumers use the electricity from the State Grid, instead of generating by their own power system, they do not need wait for the 10 years period with taking the risk of price decline. Hence, long pay back period also baffles residences' interest to RGCPVS.

W4: Imbalance of resource

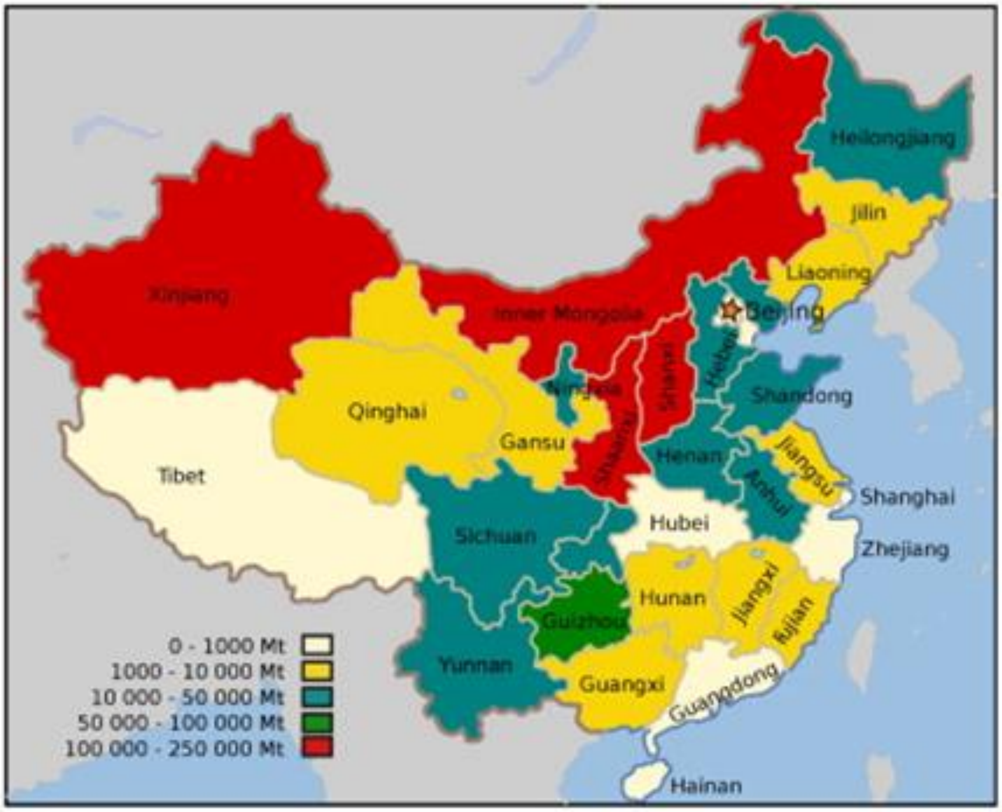


Fig.4-9 The distribution of China's coal resources

China is privileged to own solar energy and on top of that coal resource is rich too. However, the distribution of these two resources is uneven. For instance, Shanxi province deposits about one third of China's coal total as illustrated in Fig.4-9. Meanwhile, it enjoys the second abundant solar energy as well; Gansu, Xinjiang etc. are in the same circumstances. Rich in coal resource which made the coal power in low price and low-cost. As a result, despite of abundant solar energy, the higher RGCPVS will not be attractive as coal-power, and the development of PV would be impeded in these places.

4.5.3 O (opportunity)

O1: Government is putting more emphasis on RGCPVS in recent years than before

Year	National planning
2001	The 10th FYP for Renewable Energy Development (2001-2005) •To build scale productive capacity for PV industry •To construct grid connected centralized PV demonstration station
2007	Medium and Long-Term Development Plan for Renewable Energy •To set the target of installed capacity of PV as 1800 MW in 2020 •To improve the small scale PV power system in remote area •To construct Large- Scale PV station
2008	The 11th FYP for Renewable Energy Development (2006-2010) •To achieve 100 MW installed capacity of PV power system in the areas without electricity •To develop the grid-connected LSPV power plants with a total installed capacity as 50 MW
2012	The 12th FYP for the Development of Solar Energy (2011-2015) •To expand the domestic PV market •To set the same target of installed capacity for distributed PV system and LSPV plants •To support the grid connected PV power system •To implement Feed-In Tariff

Table 4-6 National plans for the development of distributed PV generation

① National planning

As a crucial important document that outline the strategic vision for Chinese economic, social and environmental development, from the '10th FYP' which set target to promote the productive capacity and PV demonstration project in 2001 to the '12th Five-year Plan' which set the same size of installed capacity for distributed PV generation and LSPV (Large scale PV stations) for the first time (as listed in Table 4-6). We can consider that the Chinese central government amidst increasing emphasis on the distributed PV generation and grid –connected power system.

② Support policies related to distributed generation and RGCPVS

In the past years, Chinese government has formulated plenty of policies to promote the application of PV and has achieved remarkable results. In 2006, 'Renewable Energy Law' has taken effect, which created for the first time a national framework for the promotion of renewable energy development in China.

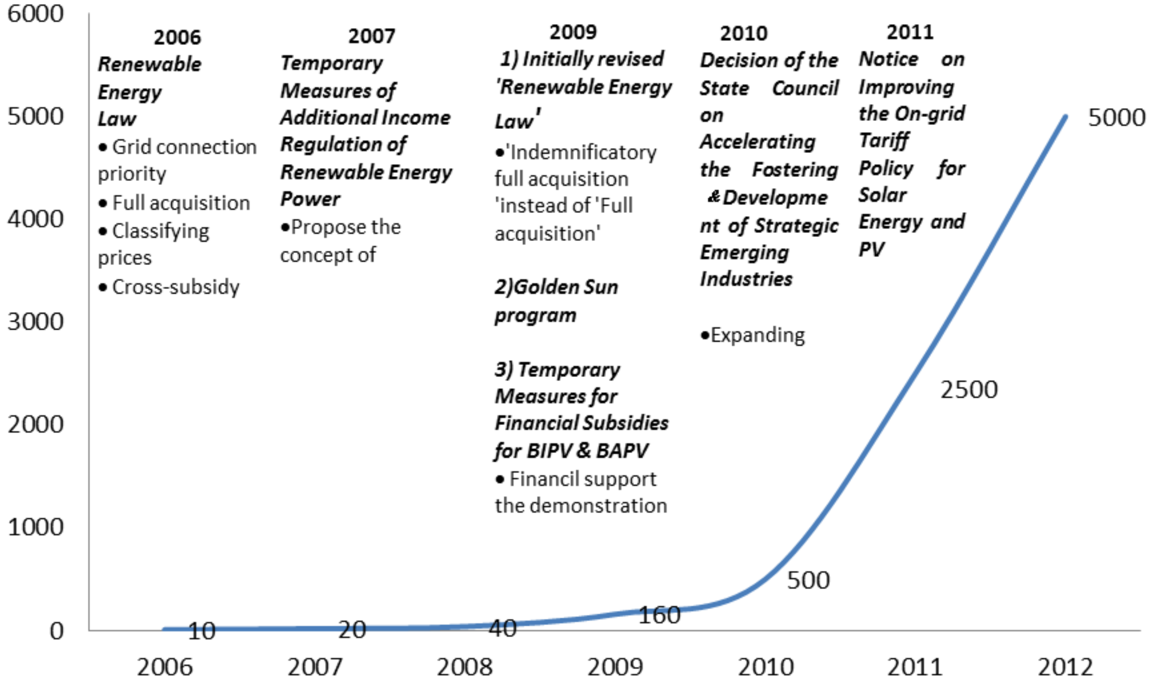


Fig. 4-10 Annual PV installations and policies related o distributed generation and RGCPVS (MW)

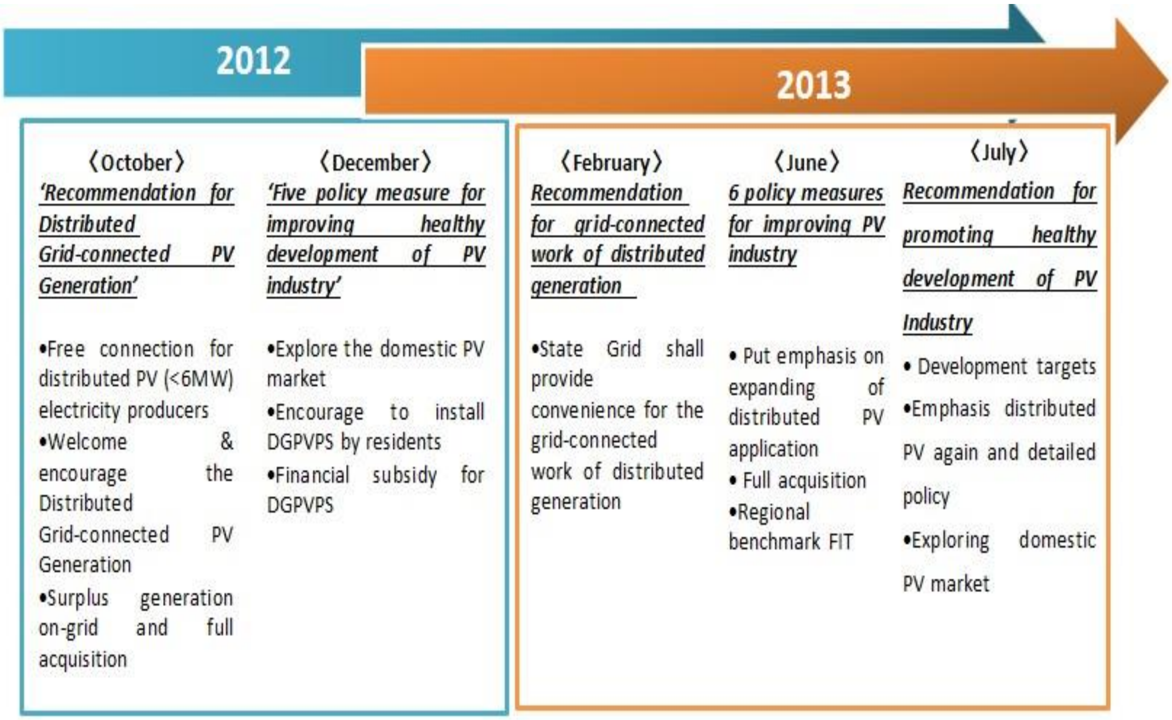


Fig. 4-11 Important support policies related to RGCPVS in 2012 and 2013

On the basis of this law, State Grid companies are officially required to purchase all of the electricity generated from the renewable generators (including PV generator), and provide grid connection services. In the next year of 2007, Chinese PV installation doubled the last year and the biggest manufacturer of PV. In the same year, as the concept of 'Rationing Transaction' for the renewable energy was proposed by NDRC, in 2009 the PV installations has reached 160 MW which is 16 times of 2006. Along with the financial support program of 'Golden Sun program' and 'Temporary Measures for Financial Subsidies for Building-integrated photovoltaic (BIPV) & Building Attached Photovoltaic (BAPV)', the polices became no longer focus on the large PV plants, but also distributed PV generators. In 2011, the State Council announced ' Decision of the State Council on Accelerating the Fostering & Development of Strategic Emerging Industries, in which ' expanding diversified solar PV market' was put forward. Then the installation of 2011 achieved 2500 MW that made 5 times compared with the former year.

Since in 2012 the installation was at its highest ever of 5000MW, the policies has become more detailed and practical. The policies have changed to explore the domestic market as well as RGCPVS. Just in 2 years, there are more than five important policies related to promote the development of RGCPVS. And these policies support the RGCPVS mainly from three aspects: ① officially support the RGCPVS; ② its price of electricity and subsidy will be paid by Renewable Energy Fund; ③ complete finance support policies. These changes can be clear found from the Fig.4-10 and Fig.4-11.

O2:Huge potential market

As a comparison between cumulative and newly installed capacity of PV in China is shown in Fig.4-12. It indicates that the cumulative installation is comparatively small, but the annual growth rate of new installations is getting higher. Additionally, in line with the ambitions of the government, the installed capacity of PV is targeted to 50 GW in 2020. However, until the end of 2012, the actual number is only 3.28 GW(China National Renewable Energy Center, 2013). Therefore, it is supposed that there should be a big room to grow for the RGCPVS to fill the gap.

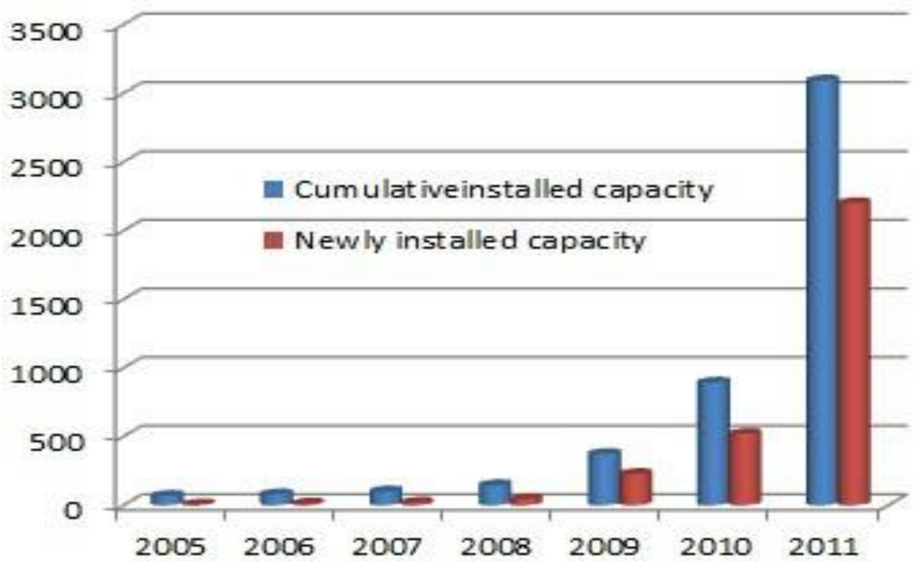


Fig.4-12 Cumulative and newly installed capacity of PV in China (MW)

Source: China National Renewable Energy Center(CNREC): 2012 China Renewables Utilization Data,2013

On the other hand, Chinese Renewable Energy Industries Association (CREIA) estimated the technical potential of PV applications in China in 2008. If 20% of rooftops and building facades in China install it, there will be 100 GWp of distributed PV systems (Junfeng LI, 2013). Let along the plenty of open space for system except for roofs. Just for these reasons, a promising development space and market of RGCPVS can be expected .

O3: Appeal for improving the air quality by public

Since the winter of 2012, around 6 hundred million Chinese people have experienced the thick fog and haze that has stirred up considerable concern about air quality all over the country. In response to thick fog and haze, Ministry of Environmental Protection (MEP) has already set about the revision research of 'Environmental Protection Law' and 'The atmospheric pollutant prevention and harnessing law '; State Grid has proposed to accelerate the development of alternative-energy; Shandong provincial government made 'Master Planning of Air Pollution Control' in which the air quality will be improved by about 50% in 2020. Not only the government or administrations, but also Chinese people have been awakening of emergency air quality. 'PM2.5' and 'thick fog and haze' has become the popular phrase; reports about the daily air quality are hot topics.

O4: Increasing power demand and supply

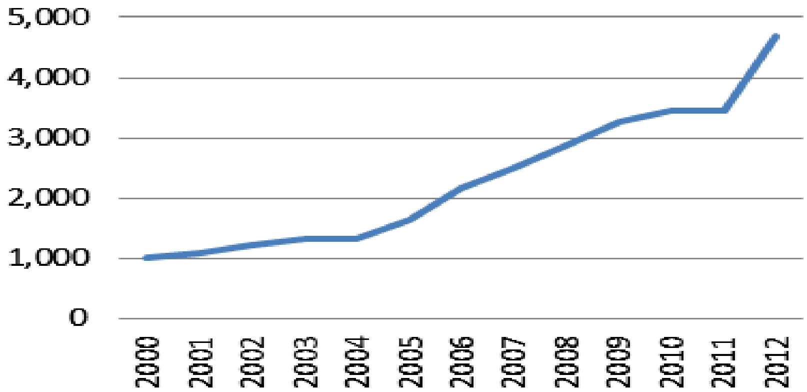


Fig.4-13 Electricity consumption of China (billion kWh)

Source: CIA World Factbook

The electricity demand and supply in China has been increasing in the past years as shown in Fig.4-13. From the long term perspective, the conventional power is not able to meet the increasing electricity demand, where the rapid development of renewable energy power including the PV power will fill in this gap. As the flexibility of RGCPVS, we can suppose it will play increasing role to solve this problem.

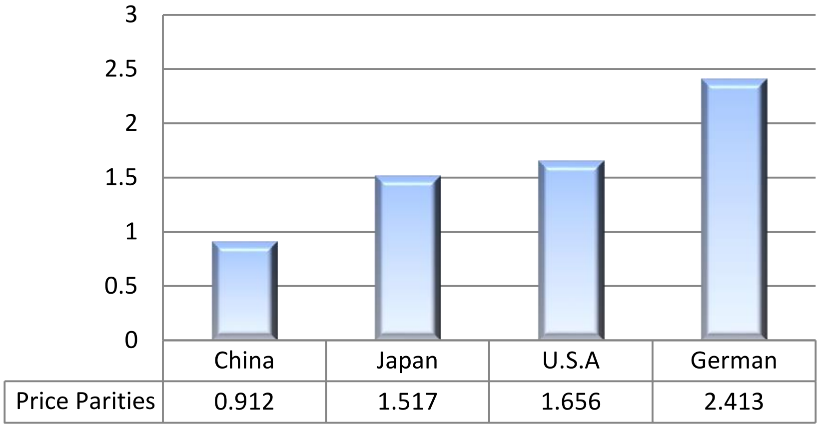
4.5.4 T (threats)

T1: Lack of funds

There are two important and main national solar subsidy programs in China. One is called the 'Solar Roofs program' issued by the Ministry of Finance (MOF), the Ministry of Housing, and the Ur-ban–Rural Development of China (MOHURD) in 2009. The other program is the 'Golden Sun program', which was initiated by the MOF, the Ministry of Science and Technology (MOST) and the National Energy Administration (NEA) in the same year. The former one requires that the scale of the PV project should be more than 50kWp, which is apparently excessive for the RGCPVS. The latter project is at least 300kWp capacity. Evidently, these existing national subsidy programs rule out the RGCPVS, and other practical financial support for this system is almost nonexistent. For a new green product, it's hard to get any progress all by itself in the startup phase.

T2:Lower residential electricity prices

The existing Chinese electricity pricing system is quite complicated. There are eight basic categories as follows: residential, non-residential lighting, commercial, non-industrial, general industry, major industry, agricultural production and an eighth "other" category. The residential electricity price is the lowest. In order to reveal Chinese low residential electricity prices, we made a comparison among China and other 3 successfully applied RGCPVS countries (shown in Fig.5-12), China price parities is the only one which value is smaller than 1, around 60% of Japan's and 38% of German's. A lower residential electricity price decreases the economic profit of RGCPVS. For instance: the average user-end rate of electricity from State Grid company was 0.58 RMB/kWh (JPY:9.61) in 2010, and if the end-user was for residential use, this rate would be 0.47 RMB/kWh (JPY:7.79), while for commercial use it was 0.81 RMB/kWh (JPY:13.43)18). Hence, if the residents use the electricity generated by RGCPVS systems, and sell the rest power to the State Grid with an average desulfurizing price at 0.42 RMB/kWh (JPY:7.40), despite the high initial and maintain costs, there would not be too much difference between their electric charge and money earned by RGCPVS for the first 10 years.



	China	Japan	U.S.A	German
Price Parities	0.912	1.517	1.656	2.413

Fig.5-12 The price parities between residential and commercial

Source: (China Electric Power Research Institute, 2009)

T3: Faultiness of authoritative standards

Since the first residential RGCPVS yield electricity on 12th of December, 2012, there is no authoritative standard on the concept and scope of RGCPVS or distributed PV by any government authorities. The only reference document at present is 'Recommendation for grid-connected work of distributed generation' issued by State Grid. In this document, the scope of RGCPVS is fixed to less than 10 KW. However, State Grid is a company and this document can only be effective within enterprise, instead of nationwide.

What's more, the authoritative standard for the technology of RGCPVS grid-connect is insufficient. There are only two national standard documents about this work: 'Technical requirements for PV system's grid-connect (GB/T19939-2005)' and 'Characteristics of PV system's access to grid' (GB/T20046-2006), that are currently in place only provide requirements for the quality of electric power and basic safety for small solar PV stations (Sufang Zhang, 2013). But in terms of equipment' specification, design, test, operational control and monitoring, the industry and national standard is almost blank. For instance, in EU or U.S a mandatory quality certification for the PV inverter and components is required; however, at present, this compulsory certification testing system has not established yet.

T4: Weak policy execution

Despite of the increasing support policy related to distributed PV or RGCPVS, not all of the government purposes or strategies has be realized. As early as 2006, according to 'Renewable Energy Law', the electricity generated by renewable energy (of course include RGCPVS) ought to be full acquired by Stat Grid, nevertheless, seven years past this rule has never be enforced.

T5: Legal and regulation constraints

①Firstly of all, lack of a national RGCPVS FIT scheme. As one of the most important factor to promote RGCPVS, a clear and fixed national FIT policy is needed. In spite that there are several RGCPVS owners have already received the money from Stat Grid because of selling electricity recently. However, in Beijing city 1 KWh sale price is 0.42 Yuan (US$0.0655), and this price increased to 0.46 Yuan/KWh in Jiangsu province. And the reason of this difference is no national FIT of RGCPVS. At present, the purchasing price of RGCPVS is based on the local desulfurizing price, instead of a national FIT price or RGCPVS proprietary price. Meanwhile, in the best practice countries in the world, such as German or Japan, the national FIT price is 24 ¢/kWh (US$0.32), and 42 Yen/kWh (US$0.431) respectively. This provision would discourage Chinese consumers to participate the RGCPVS since the deficiency of national FIT system. This problem also gives no definite period for its implementation

②Secondly, lack of identification for residential RGCPVS owner. As usual, when the State Grid purchases the electricity from the power plant, the value added tax invoice is required to be provided by power plant. As a result, when the individual owner of RGCPVS sales the electricity to State Grid, the value added tax invoice is required as well. However, according to the rules of Tax Bureau, the value added tax invoice is not allowed for individual's sale behavior. Therefore, if the identification of RGCPVS consumers cannot be determinate, for legal purposes, there will be a drop-dead halt for the

RGCPVS electric charge. Even though, some RGCPVS owners have already got money for kinds of temporary solutions.

③Thirdly, the right to using public areas. Dislike the German or Japanese city, in most Chinese cities, residents live in high buildings and several households share the same roof. As a result, the roof is not enough to make sure everyone own their own RGCPVS. In a another word, if a resident living in high building who wants to install a RGCPVS, he /she needs to get the permission by all the neighbors or it will be a tort.

T6: The public are Lack of knowledge of RGCPVS

Since in the best practice countries of PV, such as German, US and Japan, more than half of PV power generated from the residential RGCPVS. In order to popularize it, made the residents to fully aware of the RGCPVS is quite important. However, as a new product for Chinese, at present most of the owner of RGCPVS are PV relevant people instead of public.

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Chapter 5

Chapter 5 Empirical Analysis of Residential Grid-connected Photovoltaic Power Systems in China

5.1 Research question

In order to identify these preliminarily confirmed SWOT factors in Chapter 4 and distinguish their importance, an investigation is conducted. We aim to:

①verify the most significant SWOT factors for expanding RGCPVS in China;

②Finding out the factors which are given different evaluation by Japanese and Chinese experts, especially the factors have higher score by Japanese experts. It means these factors might be despised by Chinese experts.

③Examine the factors which are given different evaluation by experts with different background, to further confirm the objectivity of our research and respondents.;

④present the corresponding recommendations.

5.2 Research structure and method

Our research methodology structure is shown in Fig.5-1. Since a SWOT matrix for expanding RGCPVS in China is presented in Chapter 4, an investigation is conducted to verify this matrix and its SWOT factors. It is notable that the investigation targets for RGCPVS are from a developed country 'Japan' and a developing country 'China'. Chinese experts are relatively inexperienced about RGCPVS due to the fact that RGCPVS just started in China. Their judgments could be subjective; possibly it is based on China's PV manufacturing or related industries.

Therefore, evaluations from an external, objective and experiencer's standpoint are indispensable for objective reorganization of the expanding RGCPVS in China. Meanwhile, Japan's RGCPVS industry was developed in the 90's, after 20 years of development, it had become one of the best countries in applying RGCPVS around the world. Thus we consider that

Japanese experts' understanding and experience about RGCPVS will be useful and valuable for our study.

Based on the result of investigation,

① the most significant S, W, O and T factors are obtained by calculating the mean of each factor.

② Mann –Whitney U test is used to find the statistical significant different SWOT factors between the two countries'. The SWOT factors that were given by Japanese experts have a significant different score indicating that these factors might be placed excessive emphasis or neglected by Chinese experts. Therefore, they need to be placed special attentions for the future development of China's RGCPVS.

③ In order to further confirmation of the objectivity of our study and experts, an Analysis of Variance (ANOVA) method is adopted to examine the evaluation of the differences among the experts with different background. If the experts with different background are significant different among each other, this suggests that the considering factors are not objective and comprehensive enough, and vice versa.

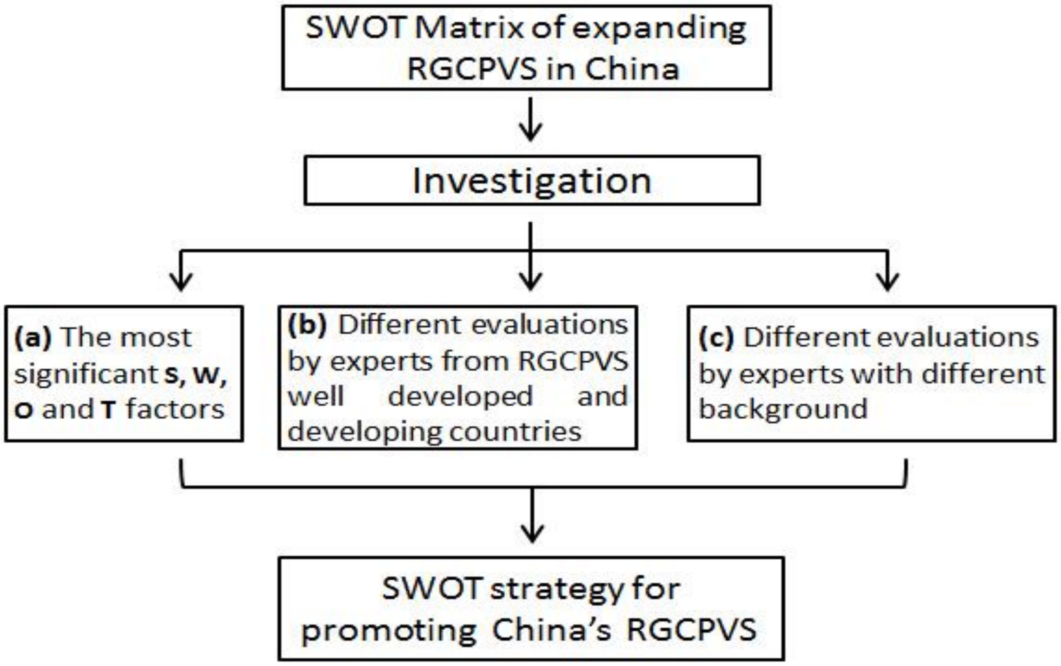

Fig.5-1 Research methodology structure

5.3 Empirical Investigation

This investigation sought to elicit the opinions of technical experts, researchers and professionals with knowledge and experience in solar energy related fields. Prior to conduct the survey, a group of 45 practitioners and academics, with knowledge on solar energy and related fields in Japan and China were identified from related publications and websites. We selected these experts based on two principles: First, their publications, research programs or work related to distributed energy system, renewable energies and sustainable society. The other one is their knowledge about RGCPVS. We considered 45 experts to be the sample for collecting opinions on the initial stage of applying RGCPVS in China (see in Table 5-1).

Classification of the considered experts	Numbers	
	Japan	China
Engineers	5	5
Architects	5	5
Professors and researchers	8	8
Government officials	2	2
Senior representatives of solar energy firms	2	3
	22	23
Total	45	

Table 5-1 Structure of the considered experts

It is worth mentioning that although the sample was small, it was constrained to the late development of RGCPVS in China reality. Since China's RGCPVS was officially allowed at the end of 2012, and until this investigation was conducted, no more than one year has passed. To our knowledge, the publications and researches that focus on RGCPVS in China were scarce. Moreover, the practitioners and academics those who are knowledgeable in China's RGCPVS that we could found and agree to participate in our investigation were much less. Therefore, under this circumstance, our sample is small, though it is still useful and meaningful to understand the RGCPVS in China.

Detailed profile	Classification of respondents	Numbers	
		JP	CN
Environmental Engineering Technology fabricating Solar Renewable energy grid connection techniques Distributed energy system	Engineers	2	1
City and Building Energy Planning Renewable energy and sustainable architecture	Architects	2	1
Low carbon society Social and Environmental system Resources circulation, LCA Power policy and management	Academic (Professors and researchers)	3	2
Government officials		1	1
Senior representatives of solar energy firms		1	2
		9	7
Total		16	

Table 5-2 Detailed profile and structure of respondents

Invitation letters and questionnaires were sent to the experts group, where up to 16 acceptances and useable questionnaires were received. The response rate was 36%. Which Includes 9 Japanese experts and 7 Chinese experts. The detailed profile and structure of respondents are listed in Table 5-2. The questionnaire comprised three parts: ① an explanation for all the SWOT factors from applying RGCPVS in China ; ② questions concerning the respondents' background; ③ opinions on the importance of SWOT factors which was preliminarily selected. Likert scale was used for respondents to record their opinions, with grades '0–10' denoting the least important and most important, respectively. Likert scales are commonly used for expert to rate the relative significance of individual factors. The investigation was carried out from October to November 2013. The respondents' backgrounds are over a wide range of disciplines, including engineers, architects, senior representatives of solar energy firms, professors and researchers, and government officials.

5.4 Results and discussion

5.4.1 The most significant SWOT factors

	Mean	Rank	Standard Deviation	Low (%)	Medium (%)	High (%)
S1	7.06	3	2.26	12.5	6.3	81.3
S2	6.75	4	2.27	6.3	43.8	50.0
S3	6.13	5	1.75	0.0	68.8	31.3
S4	7.63	2	1.75	0.0	25.0	75.0
S5	8.56	1	1.46	0.0	6.3	93.7
S6	5.69	7	1.85	0.0	75.0	25.0
S7	5.94	6	2.29	25.0	31.3	43.8
W1	6.56	3	1.67	6.3	25.0	68.8
W2	6.75	2	1.34	0.0	37.5	62.5
W3	8.63	1	1.50	0.0	12.5	87.5
W4	3.88	4	3.10	50.0	25.0	25.0
O1	8.13	1	2.42	6.3	18.8	75.0
O2	6.50	2	2.03	6.3	56.3	37.5
O3	6.19	3	2.14	6.3	56.3	37.5
O4	5.38	4	2.47	25.0	43.8	31.3
T1	8.88	1	1.26	0.0	6.3	93.7
T2	6.94	2	1.88	0.0	43.8	56.3
T3	5.88	5	2.00	12.5	50.0	37.5
T4	6.75	4	1.95	6.3	37.5	56.3
T5	6.88	3	1.82	6.3	37.5	56.3
T6	5.00	6	1.75	25.0	62.5	12.5

Table 5-3 Descriptive statistics of the SWOT factors

The surveyed variables that are investigated in this paper are outlined in Table 5-3. The significance of the SWOT factors are evaluated by using the value of the mean score. Standard Deviation provides an indication of how far the individual responses to a question vary or deviate from the mean. Besides, to identify the specific distribution of expert's attitude for each SWOT factor, their score was divided into three levels: '0-3'as 'low score level', '4-6'as 'mid-score level', and'7-10'as 'high score level'. The higher score is, the more important is.

As summarized in in Table 4-6, the most significant strengths include S5 'Economic benefit' with the highest mean value of '8.56', followed by S4 'Cost reduction'(7.63). The top two weaknesses were W3 'Economic barriers' (8.63) and W2 'Technical barriers'(6.75). The biggest opportunity was O1 'Government is putting more emphasis on RGCPVS in recent years than before' (8.13), followed by O2 'Huge potential market' (6.50). The greatest threat was T1 'Lack of funds' (8.88), followed by T2'Lower residential electricity prices' (6.94). Based on relatively small Standard Deviation scores of above 8 factors, it can be conclude that the distribution of experts' attitude is comparatively centralized in these factors.

5.4.2 SWOT factors in different categories

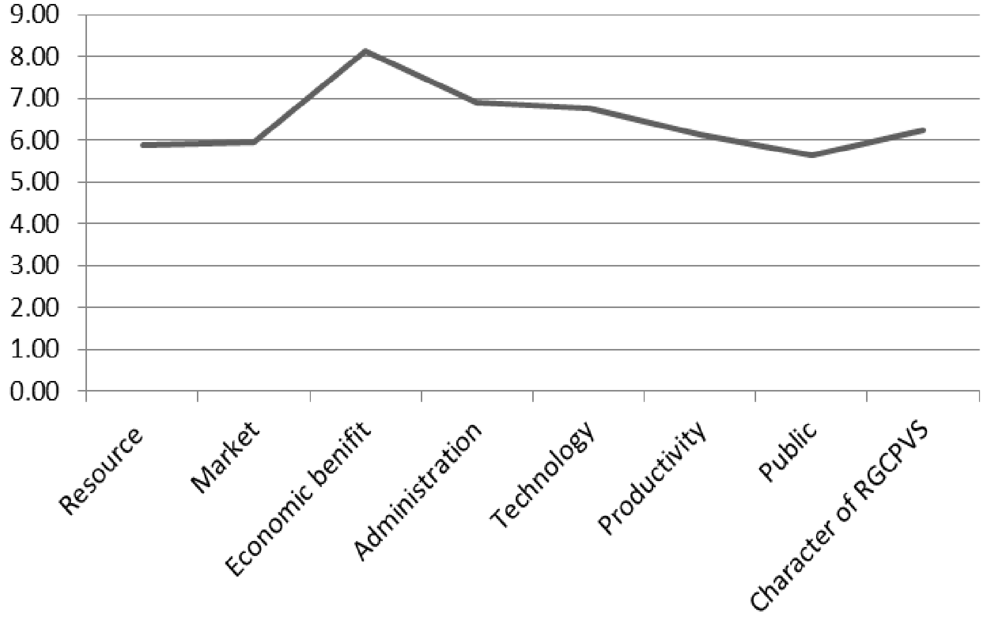

Fig.5-2 SWOT factors in different categories

In addition to the most significant factors that we discussed by using SWOT analytical method, for further understanding about these factors, they were divided into 8 categories (see in Fig.5-2): Re-source (S1, S2, W4), Market (O2, O4), Economic benefit (T1,T2,W3,S4,S5), Administration factors (O1, T3,T4,T5), Technology(W2), Productivity(S3) and Public awareness(S6,O3,T6). Clearly, factors related to Economic benefit are scored (mean score) far above others, followed by Administration factors and Technology, factors related to Public awareness, Resource and Market are less important.

The reasons are understandable. The RGCPVS is generally billed as a kind of investment and its target consumers are the residents. Consequently, the economic benefit related factors are regarded as the most significant factors. Firstly, the decreasing cost of RGCPVS has opened the possibility of being widely accepted and afforded by residents. The economic income makes the investment on RGCPVS be more attractive than bank deposits in a long run. Thus, a RGCPVS market can be getting formed. However, as 'every coin has two sides', on the other hand, the lengthy payback period also drive up the indetermination about the economic income. Besides, since the RGCPVS income is earned from the electricity saving and selling excess electricity, the lower residential electricity price not only leads to a longer payback period, but also less interest and willingness to change their traditional energy supply method. Meaning if the economic benefit of lengthy payback period is not able to meet the consumer/residents' expectation, it would be hard to attract them to accept RGCPVS. However, these problems could be improved by policy makers. A suggestion is presented in suggestion Section.

5.4.3 Comparison between Japanese and Chinese experts' evaluation on SWOT factors

As illustrated in Table 5-4, owing to the same rank and close mean score, the experts of two groups are consider to hold the similar opinions on the importance of majority SWOT factors. Particularly, they agreed with the biggest strength, weakness and threat are S5 'Economic income', W3 'Economic barriers' and T1 'Lack of funds', separately. However, experts' opinions are divided on the greatest opportunity. Japanese experts regarded O3 'Appeal for improving the air quality of Chinese' as the most important opportunity, while Chinese experts strongly support O1 'Government is putting more emphasis on RGCPVS in recent years than before' should be the top factor.

Next, in addition to the difference in rank, an independent-samples Mann–Whitney U test is adopted to verify the statistical significant difference between the two groups as well. Mann-Whitney U test is a non-parametric test used to determine whether two independent groups of data are different19). The p- value is the probability of obtaining either the observed difference or a more extreme value of the difference between the two groups. If the p-value＜0.05，then the result is considered significant. If the p-value ＞0.05, then the two of groups of data are not different (Scistatcalc, Mann Whitney U-test Calculator). Statistical analysis of the parameters in this paper was carried out by SPSS19.

	Mean		Rank			Mean		Rank	
	JP	CN	JP	CN		JP	CN	JP	CN
S1	6.78	7.43	3	3	O1	6.89	9.71	3	1
S2	6.78	6.71	3	4	O2	7.00	5.86	2	2
S3	6.67	5.43	5	5	O3	7.11	5.00	1	3
S4	7.11	8.29	2	2	O4	6.33	4.14	4	4
S5	7.78	9.57	1	1	T1	8.11	9.86	1	1
S6	6.22	5.00	7	7	T2	7.89	5.71	2	4
S7	5.67	6.29	5	6	T3	6.33	5.29	4	6
W1	6.22	7.00	3	2	T4	7.00	6.43	3	3
W2	6.56	7.00	2	2	T5	5.67	8.43	5	2
W3	7.78	9.71	1	1	T6	4.56	5.57	6	5
W4	5.56	1.71	4	4					

Table 5-4 Ranks of SWOT factors by Japan and China experts

	S5	W3	W4	O1	T1	T2	T5
p-value	0.009	0.004	0.010	0.013	0.003	0.025	0.002

Table 5-5 Result of independent-samples Mann-Whitney U Test

With the Mann–Whitney U test, the factors which p-value are smaller than 0.05 are listed in Table 5-5. Apparently, S5, W3, W4, O1, T1, T2 and T5 have a p-value smaller than 0.05, suggesting that the evaluations of two groups' experts are significantly different from each other in above 7 factors.

Then, for further confirmation and understanding of the key differences between the two groups' experts, a more detailed comparison focus on these 7 factors (see in Table 5-6) was conducted. Since S5, W3, and T1 are ranked first in all the S, W and T factors by both experts: Japanese and Chinese, respectively. Meanwhile, the score given by the two countries' experts about these three factors are also centralized in high score level. Therefore, the experts' evaluations on S5, W3, and T1 can be regarded as basically identical.

		Mean	Rank	Low (0-3)		Medium (4-6)		High (%) (7-10)	
S5	JP	7.78	1	0	0.0%	1	11.1%	8	88.8%
	CN	9.57	1	0	0.0%	0	0.0%	7	100%
W3	JP	7.78	1	0	0.0%	2	22.2%	7	77.8%
	CN	9.71	1	0	0.0%	0	0.0%	7	100%
W4	JP	5.56	4	2	22.2%	4	44.4%	3	33.3%
	CN	1.71	4	6	85.7%	0	0.0%	1	14.3%
O1	JP	6.89	3	1	11.1%	3	33. 3%	5	55.5%
	CN	9.71	1	0	0.0%	0	0.0%	7	100%
T1	JP	8.11	1	0	0.0%	1	11.1%	8	88.8%
	CN	9.86	1	0	0.0%	0	0.0%	7	100%
T2	JP	7.89	2	0	0.0%	2	22.2%	7	77.7%
	CN	5.71	4	0	0.0%	5	71.4%	2	28.6%
T5	JP	5.66	5	1	11.1%	6	66.6%	2	22.2%
	CN	8.43	2	0	0.0%	0	0.0%	7	100%

Table 5-6 Comparison between Chinese and Japanese experts

On the other hand, based on the obvious discrepancy between the two groups in mean, rank and score distribution and with the p-value＜0.05, the views of Japanese and Chinese experts are considered the most significant different in O1 ‘Government is putting more emphasis on RGCPVS in recent years thanbefore’,T2 ‘Lower residential electricity prices’ and T5 ‘Legal and regulation constraints’.

These differences revealed above mainly can be summed up to: Chinese experts stress towards to the attitude of policy makers and greatly expect government strategy, while Japanese experts emphasize on the attraction and benefit for public. It should be pointed out that there is nothing wrong about the two countries experts’ different evaluations towards the SWOT factors of applying RGCPVS in China. Since the RGCPVS is at the very initial forming stage in China, the Chinese experts are inexperienced about China’s RGCPVS industry, however, Japanese experts can give the judgments from an external, objective and experiencer’s standpoint. Particularly, the factors have a higher attention by Japanese experts indicating these factors might be neglected by Chinese experts.

Therefore, in the following parts, firstly, we try to find out the reasons why the two countries experts are different in these factors, then explore what should China’s RGCPVS industry pay particular attentions.

(1) Industry background

Firstly, in China, not only the entire power generation industry (including power generation, transmission and sale) is monopolized by State Grid company (belongs to the state), but also the PV industry is also largely rely on government investment and preferential policy. Thus, the government plays a irreplaceable role in these industry. The RGCPVS as a PV product and power system is easily be regarded to be greatly depend on government by Chinese experts. However, the RGCPVS is different from the traditional power system, as Japanese experts suggested: the development of the RGCPVS industry requires a positive participation of the residents. An important way to attract residential consumers should be developed for economic efficiency. Moreover, the role of government in a competitive market such as the RGCPVS market should be to keep its fairness and healthy competition.

Secondly, RGCPVS is generally regarded as a way to divert the excess production capacity of Chinese PV manufacturing. However, for the unexpected severe sanctions by Europe and America, the government has to accelerate the exploration of the domestic market without complete support policies; especially the policies related the resident's benefit. For instance, the FIT price for power generated by the RGCPVS has not been officially decided in most Chinese cities up to now unlike the well prepared and planed Japanese RGCPVS industry. As a successful industry, the RGCPVS in Japan started in the be-ginning of 1990s, pushed by Japanese government instead of external conditions. Before conducting the RGCPVS, Japan has not only completed the financial support system towards different types of PV power system, but also they owned the advanced PV cell technology. Based on well preparation, Japanese government started RGCPVS.

Therefore, the different industry background of RGCPVS might lead to the different evaluations by Japanese and Chinese experts. However, since RGCPVS is different from the traditional power industry or PV industry, the target consumer of RGCPVS is the resident, instead of governments. Thus, to provide an attractive economic efficiency more focus for China's RGCPVS industry should be paid.

(2) Consumers purchase decision-making

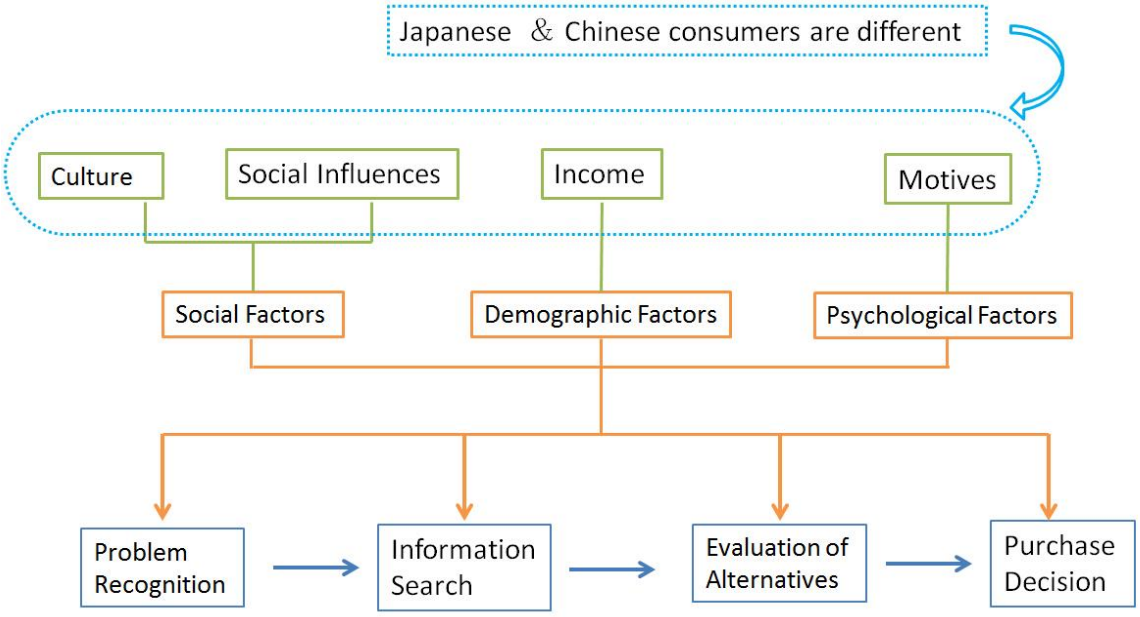

Fig.5-3 Consumers Purchase Decision-making model

Since the target and final consumer of RGCPVS is the residence, how to attract them should be the key point. Based on the Consumers Purchase Decision-making Theory, the consumer purchase process includes 4 steps: Problem Recognition, Information search, Evaluation of Alternatives and Purchase decision. As shown in Fig. 5-3, this whole process will be affected by personal (demographic factors), psychological (motives, perception) and social factors (culture, social influences). Obviously, as in Japan, environment protection is like a social culture which is not only closely linked with everyone's daily life but also this concept has taken root in people's community. Even the public's appealing and awareness is indelible for the Japanese government. Thus, though with a same economic benefit, this social factor will help consumers to make up a purchase decision of green products. Consequently, the green product will become easier to be accepted by Japanese residence.

On the other hand, the awareness is awaking in Chinese, but not strong enough to be a popular social culture in most places. Further, the prices of most green products are higher than the common products. Although some consumers are awarded of the importance of green products in the step of 'Information search', they easily are affected by personal factors (such as income) during 'Evaluation of Alternatives'. As a result, Chinese residents are not easily to accept a green product such as RGCPVS as Japanese residents.

Consequently, the economic efficiency would be more necessary to attract more Chinese residents to apply the RGCPVS.

(3) Policy intervention and public product life cycle model

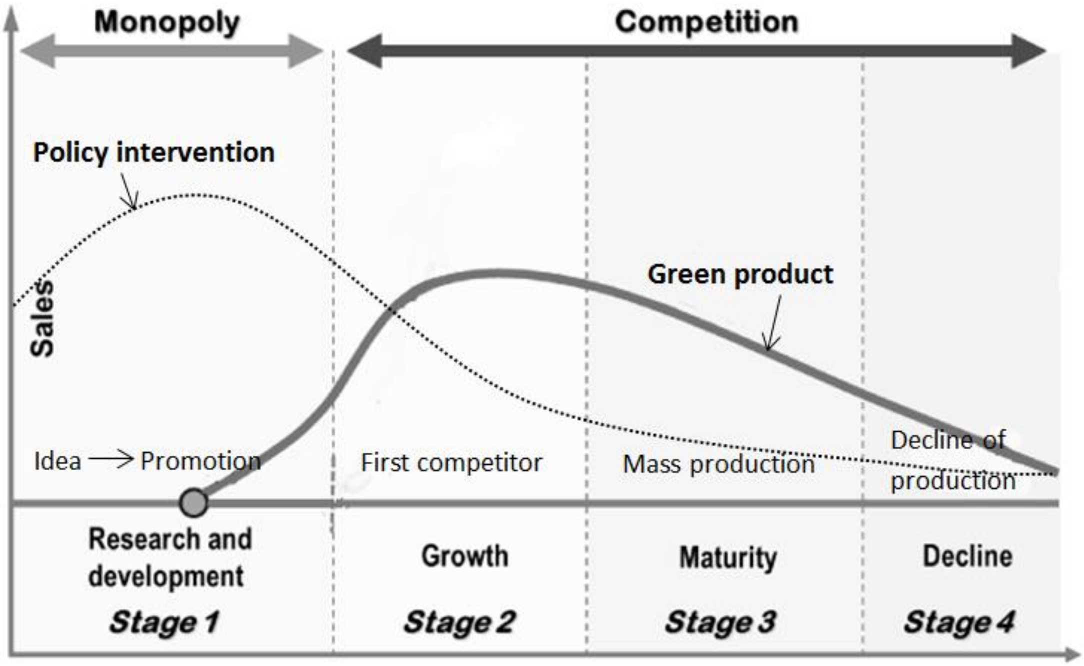

Fig.5-4 Policy intervention and green product life cycle model

According with the Product Life Cycle Theory, we developed a model of policy intervention and green product life cycle (see in Fig.5-4). As demonstrated in this chart, at the stage1, there should be a clear target and complete policy framework to support the promotion of green product, and the policy intervention should be the highest. The policy maker could set a demonstrative project or support a few superior enterprises. Meanwhile the number of consumers should be small, because of the high price, insufficient understanding and uncertainty for this green product. However, since the stage 2, along with the development of this green product, the number of consumers and competitors are getting larger. At this moment, the policy should focus on benign competition and monitor the development direction, as a supporting role. The government investment as well as the supportive policy should be decreased. Japan's RGCPVS can be regarded as a good example of this model, the government plays different and corresponding roles at the different development stages to achieve a constructive development. However, in our case, China's RGCPVS is already in the stage 1, but the policy framework just started. Thus, there is a gap between the developing RGCPVS and lagged policy intervention. Consequently, there could be a longer and more complicated road for Chinese RGCPVS in the first stage. The approaches to overcome this gap, one is accelerate the related policy making; the other is slow down the development of RGCPVS in China.

In short, unlike other existing renewable energy industry, RGCPVS's final target is the residents, their benefit should be always most significant. Of course, government's support is important and effective, especially in the start stage of a public product. Nonetheless, the technology breakthrough should not be based on government instead of considering how to encourage residents to accept this product. Even though there are some progress made by the strong policy support, if the policy changes a little or the residential power market is opened, this booming industry will be easily destroyed, just like 'be a flash in the pan'.

5.4.4 Comparison of experts with different background on evaluating SWOT factors

In this section, we try to confirm the correlations between experts with different backgrounds and their evaluations to verify the representability and objectivity of the SWOT factors.

To begin with, due to five groups of experts, Analysis of Variance (ANOVA) is used to observe if there is any difference between groups on variable. ANOVA is a collection of statistical models used to analyze the differences between group means and their associated procedures (such as "variation" among and between groups), developed by R.A. Fisher. As doing multiple two-sample t-tests would result in an increased chance of committing a statistical type error, ANOVAs are useful in comparing (testing) three or more means (groups or variables) for statistical significance21). The factors which p-value is smaller than 0.05 are listed in Table 5-7, it is assume that W3', O4'and T5' p-value are smaller than 0.05, indicating that the opinions of the experts with different backgrounds are alike in 18 factors, except on W3, O4 and T5.

	W3	O4	T5
p-value	0.033	0.007	0.046

Table 5-7 The result of ANOVA

	Senior representatives of solar energy firms
Architects	0.021

Table 5-8 Result of Tamhane's T2(m) test for T5

	Mean	Rank	Low	Medium	High

				(1-3)	(4-6)	(7-10)
T5	Senior representatives	8.40	2	0	0	3
	Architects	5.33	5	2	1	0

Table 5-9 Comparison among experts with different background

Then, according to the requirements and steps of ANOVA, if there is significant difference between the groups, a further examination is need to find out how they different are with each other. Because of Equal Variances not assumed (p-value$<$0.05) in W3, O4 and T5, Tamhane's T2(m) test was used to verify significant difference for multiple comparisons (see in Table 5-8). Based on the result, W3 and O4 are excluded (for p-value$>$0.05), and the most significant different factors can be determined as only T5 finally. Then, Table 5-9 outlines a detailed comparison among experts with different background for T5. We found that the Architects and Engineers have a high importance, especially the Engineers. The senior representatives of solar energy firms all agree that the T5 'Legal and regulation constraints' greatly threaten the development of RGCPVS in China, while the Architects disagree with it. This difference would be explained as PV companies' work must comply fully with rules and regulations; even a small deficiency will cause big troubles for them.

In summary, as discussed above there is no clear and strong correlations between the expert's opinion and their backgrounds. It reveals the opinion of the experts with different background on SWOT factors for promoting RGCPVS in China could be generally regarded as unanimous, and also proves the SWOT factors identified by our research could be regarded as objective.

5.5 SWOT strategy for promoting China's RGCPVS

Based on Weihrich's SWOT appropriate strategies, the four types of crossing analyses and the specific strategies are shown in Table 5-10 (Weihrich,1982).

Internal External	S (Strengths)	W(Weaknesses)
O(Opportunities)	SO strategy (Max–Max)	WO strategy (Min–Max)
T(Threats)	ST strategy (Max–Min)	WT strategy (Min–Min)

Table 5-10 SWOT matrix strategies

(a) SO strategies, that is, in according with the principles of maximizing both of the strengths and opportunities (Max–Max), enhance the merits and take advantage of chances.

(b) ST strategies, means in according with the principles of maximizing the strengths and minimizing threats (Max–Min), strengthen ad vantages and avoid risks.

(c) WO strategies, according with the principles of minimizing the disadvantages and maximizing the opportunities (Min–Max), reduce the weaknesses and utilize the chances.

(d) WT strategies, namely, in accordance with the principles of minimizing both of threats and disadvantages (Min–Min), decrease threats and overcome short comings.

The detailed SO, ST, WO and WT strategies for promoting RGCPVS in China are as follows:

5.5.1 SO strategies

① Seize the strategic opportunity in which the government greatly supports the RGCPVS and it is in accordance with the development planning made by the authority to promote China's RGCPVS development. Encourage more PV companies branch out to RGCPVS related service and attract small and medium sized companies or private capitals to participate in RGCPVS, and break the monopolistic situation by State Grid (O1, S4, S5).

② Take the opportunity of Chinese strong ap-peal for improving the air quality, based on a clear, long-term and reasonable FIT price, highlight the environmental and economic benefit, flexibility and convenience of RGCPVS to public(O3, S5, S6, O7).

③ Make full use of the rich resources reserves of solar and the materials of PV (such as metals) resource, vast available installation areas and market to accelerate participators and investors from both home and abroad, and also take the advantages of the flexibility and convenience of RGCPVS to try to meet the residential demand in electricity in the areas with rich solar resource (S1, S2, S3, O2, O4).

5.5.2 ST strategies

① Strengthen policy research of RGCPVS, complete strategic planning for it. Increase the supporting efforts, introduce more favorable policies, especially the sale price for the residence (S5, T1, T2, T4,T5).

② Set technology standards and clear the scope of RGCPVS, to ensure the right of using the public area for this system and some other legal question (S2, S7, T3, T5).

③ Encourage trained engineers or professional RGCPVS companies to build solar cell systems on the roof or other places (to avoid accidents of occurring again), and set a strict industry standard to regularize their behavior (S1, S2, T3).

5.5.3 WO strategies

① Positively introduce and absorb RGCPVS development advanced technologies, combine introduction and innovation to master the key technologies of RGCPVS development, open the RGCPVS market for foreign companies (W2,O2,O4).

② Formulate long term and certain FIT price, tax and subsidy policy (for the initial cost) based on the resource distribution and rich-ness(W1,W3,W4, O1) .

③ Implement pilot programs for applying RDGPVS. These pilot programs can be started from the areas where are rich in solar resource, and gradually extend from the small size public facilities to residents (W1, W4, O2,O3).

5.5.4 WT strategies

① Promote the construction of a power grid and related management systems, to make the power grid able to accept the power generated by RGCPVS, and meet the need of the local areas in the evening(W2,T3).

② More efforts should be made for supporting the RGCPVS industry, issue more kinds of favorable policies to attract investment parties from all walks of society to enter into the RGCPVS industry. Consequently, to form an diversified investment mechanism, instead of focusing on the energy costly, contaminative and over sea's market dependent PV manufacturing industry (T1, T4, T5, W2,W3).

③ Policy makers should solve the problems caused by policy lag, develop better planning of policies for every development stages of RGCPVS, and be prospective as well as quick response for the potential problems (T3, T4, T5, W2, and W3).

④ The policy makers or government should confirm and persist on their plan and decision on RGCPVS. Since with this system, to some extent, the state monopoly on China's electricity industry will be broken. Furthermore, as the corruption is a part of reasons that weak policy execution, it will greatly badly affect the enthusiasm both of the consumers and related business sectors, and also lead to weak policy execution. Therefore, the specific rules, regulations and supervisory mechanism towards the government agents and practitioners are urgently needed (T3, T4).

5.6 Conclusion

The development of RGCPVS in China is at its very early stage. Therefore, a methodical analysis about the advantages and barriers of the inner and exterior conditions is essential and useful. Thus, we discussed the factors which improves or impedes the development of RGCPVS in China by SWOT analytical method as follows:

In section 5.2, we analyzed the strengths, weaknesses, opportunities and threats that RGCPVS faces by using SWOT analysis method, and building a SWOT matrix.

In section 5.3 and 5.4, ① firstly, we conducted a survey to identify the importance of every factor. The result shows that the most important S, W, O and T factors were 'Economic benefit', 'Economic barriers', 'Government is getting values' and 'Lack of funds' , respectively. The factors that are related to economic benefit and administration were proved to be the top two factors with the highest value, while market and resource factors were less important.

② Secondly, we made a comparison between Japanese and Chinese experts. The result suggests that the two countries' experts agreed with the most factors, except the 'Government is getting values', 'Imbalance of resource', 'Lower residential electricity prices' and 'Legal and regulation constraints'. These differences are summed up to: Chinese experts value the attitude towards the policy makers and greatly expect government strategy, while Japanese experts emphasize on the attraction and benefit for residence or public. We explained the reasons from three aspects: industry background difference, the influence of social factors in consumers' green product purchase decision making and the different stages in policy intervention and green product life cycle model.

③Thirdly, in order to prove the correlation between experts' background and opinions, and our study's objectivity, we analyzed their statistical significant difference by ANOVA method. The result indicated that there was a not significant correlation between the experts' opinions and their backgrounds, and opinions in the experts with different background could be generally regarded as unanimous on this problem.

In section 5.5, we suggested SO, WO, ST and WT strategies for promoting China's RGCPVS.

Finally, RGCPVS is both a chance and a challenge for the Chinese public, government and related industry practitioner. For the public, they need to improve their environment protection awareness, learn how to do it and change the way of thinking 'if I do environment-friendly things, it's better than nothing'. For the government, the RGCPVS is a reasonable choice that would be useful to advertise Chinese air pollution crisis and the energy structure adjustment, even as the popularization of RGCPVS could even break its monopoly on electricity industry. The government should persist on it, accelerate to complete related policy framework about it, but also paying attention to over intervention. As to the con-tractors and other stakeholders, they should realize that government support is helpful but also dangerous. Poor policy interventions made the growth to be difficult, but excess intervention might destroy this industry too. The best period is when the government is completing policies, to slow down their ambitious expansion, and to concentrate on staff and engineer training, technology improving and consumers benefit creating.

Our findings presented a useful reference for governments, contractors and other stakeholders in providing insights into the barriers, advantages and possible approaches of promoting RGCPVS in China. Although, the RGCPVS is not cost-effective at the present time, as technology costs decrease, public environmental awareness increase and appropriate policy be formulated, we believe it will become progressively attractive in China.

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Chapter 6

Chapter 6 Conclusion

Global warming and energy crisis have shifted the focus of industrial development towards low-carbon renewable energy. China as the biggest energy consumer, the most populous and one of the fastest growing country in the world, it urgently needs to find a solution to balance the environmental protection, economic growth and fossil fuel energy saving. Under this circumstance, a systematic analysis towards renewable energy generation is important for China. In addition, compared with other renewables, Photovoltaic (PV) energy has advantages in resources and flexibility, especially since the October in 2012; the Residential Grid-connected Photovoltaic Power Systems is officially allowed in China. And this development has brought with great opportunities and challenges, not only for the PV power industry or renewable energy generation industry, but also for the whole China's electricity system. Therefore, this paper aims at renewable energy generation industry and its related policy framework in China, particularly focus on Residential Grid-connected Photovoltaic Power Systems.

The research is divided into 5 Chapters. In Chapter 2, the status of Renewable energy resources and reform history of China's electricity industry is systematically reviewed, and China's Renewable Energy Generation system and management mechanism is analyzed.

In Chapter 3, we elaborated the current status and trends of renewable energy generation in China both from the installed capacity and generation by sources. Then, based on a correlation analysis, we found the development of renewable energy generation has a greater correlation with GDP growth while less related with fossil fuel electricity consumption decrease and CO2 emissions reduction. Accordingly, we considered that to improve energy efficacy of fossil fuel power will be more helpful for China's sustainable development rather than promoting renewable energy generation in the short term. At last, some suggestions for China's renewable energy generation and sustainable development were presented.

In Chapter 4 and 5, we built a SWOT matrix for the factors we assumed to be the strengths, weaknesses, opportunities and threats to the development of RGCPVS in China. Next, we collected data from a survey towards Japanese and Chinese experts, and confirmed that the most significant S,W,O and T factors are 'Economic benefit', 'Economic barriers', 'Government is getting values' and 'Lack of funds', respectively. Then, through statistical analysis, we verified Japanese and Chinese experts share analogous views on 14 factors, while one of their most significant divergence is the evaluation for 'Government is getting values', we explained the reasons and built a policy intervention and green product lifecycle model to clarify it. Next, we revealed that experts with different backgrounds take a similar point of view for the vast majority of SWOT factors by using ANOVA method. Finally, the recommendations were presented.

6.1 Barriers of renewable energy development

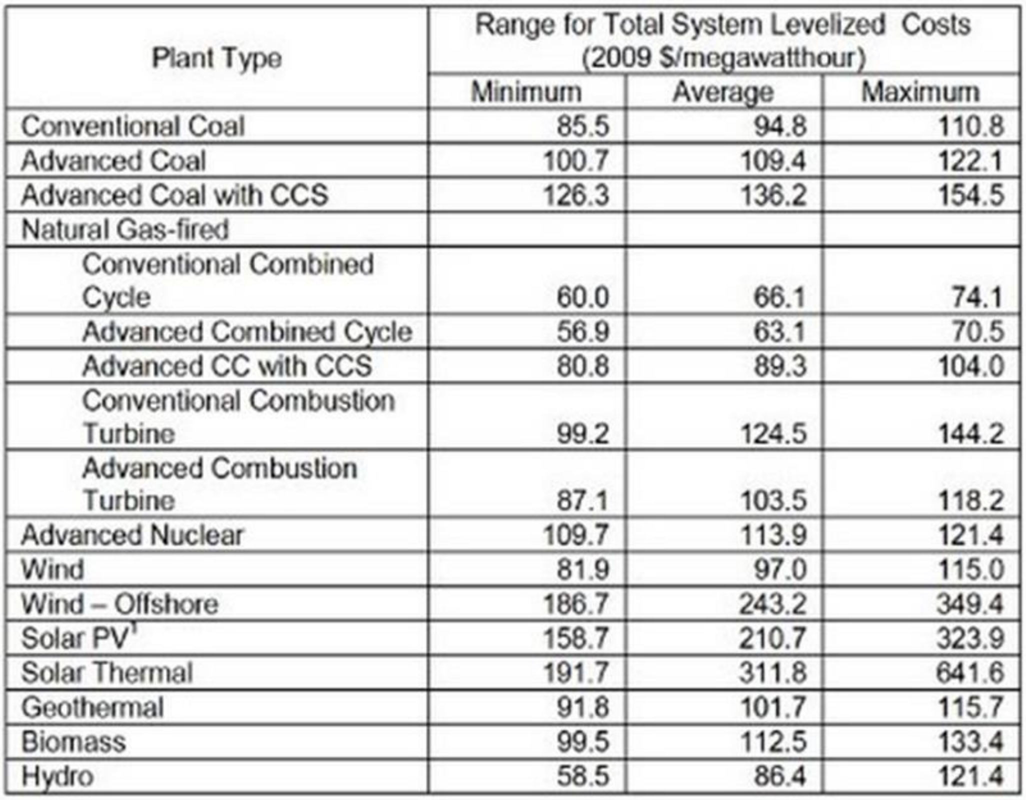
Rapid economic development throughout China has resulted in a significant increase in energy consumption, leading to a rise in harmful emissions and power shortages.

Kinds of renewable energy policy are designed to help develop renewable energy technology, protect the environment, prevent energy shortages, and reduce dependence on imported energy. However, since the internal and external causes' influence, not every policy is as effective as expected.

(1) The high price

Renewable energy is much more expensive than traditional energy sources, which is the biggest obstacle to market expansion. As a report from the US Energy Information Administration, in this report a comparison of levelized costs for different power generation sources was provided.

As the Table 6-1 shown, without considering the externalities, the levalized cost of Nature Gas-fired is less than most of renewable energy. Taking solar power as an example, the lowest price for it is 158.7, which is almost doubled the conventional coal's price. In the levalized cost average situation, wind and solar energy has occupied the highest price, and the conventional combined cycle, and advanced combined cycle are the cheapest energy.



Plant Type	Range for Total System Levelized Costs (2009 $/megawatthour)		
	Minimum	Average	Maximum
Conventional Coal	85.5	94.8	110.8
Advanced Coal	100.7	109.4	122.1
Advanced Coal with CCS	126.3	136.2	154.5
Natural Gas-fired			
Conventional Combined Cycle	60.0	66.1	74.1
Advanced Combined Cycle	56.9	63.1	70.5
Advanced CC with CCS	80.8	89.3	104.0
Conventional Combustion Turbine	99.2	124.5	144.2
Advanced Combustion Turbine	87.1	103.5	118.2
Advanced Nuclear	109.7	113.9	121.4
Wind	81.9	97.0	115.0
Wind – Offshore	186.7	243.2	349.4
Solar PV[1]	158.7	210.7	323.9
Solar Thermal	191.7	311.8	641.6
Geothermal	91.8	101.7	115.7
Biomass	99.5	112.5	133.4
Hydro	58.5	86.4	121.4

Table 6-1 Regional Variation in Levelized Cost of Renewable energy resources

Source: Energy Information Administration, Annual Energy Outlook2010

(2) The limited renewable energy market

The current market for renewable energy in China is small and full of uncertainty. Since the high price, the renewable energy is hard to be extended. As soon as possible to reducing production costs and improving technological reliability are crucial to cultivating and expanding the market further. Appropriate institutional arrangements would also be helpful in supporting these needs.

(3) Lack of core technology

As a newly risen industry, renewable energy abounds in technical bottlenecks. Chinese government has long been attaching importance to technical research and development on renewable energy. Especially, in 2011 China has invested $47.4 billion in total into renewable energy (Worthington, 2012). China has being the top most attractive place for renewable energy investments in its five-year outlook, scoring just ahead of the United States.

However, in a short time, it's hard to hand the advanced renewable energy technology. As a result, China's renewable energy industry has to spend a lot to purchase core technology form foreign countries just like U.S, German, and Japan. For example, ninety-seven percent of large-scale wind turbines currently installed in China are imported (this includes components) (al, 2012). It will be possible to create a vicious circle of 'Introduce→lag behind→ Introduce again'

(4) Industrial development far outstrips market cultivation

The most prominent sign of the trend is in PV industry. Since 2008, China has become the top producer of PV in the word, 98% of Photovoltaic would be exported. However, because of the financial crisis, the Chinese PV industry has experienced a huge impact on export, about 30% decreases. And the PV industry started to turn to national market instead of international market. Although since then, the government has carried out kinds of incentive policies, the most of them are still focus on attracting investment. Feed-In Tariff has become the key problem. Even none of a clear and definite Feed-In Tariff like 'Cost＋Reasonable Profit' has been practiced in any PV program. And most of existing Photovoltaic PV power plant is guided by government, and still in Experimental PV grid-connected period.

(5) Over capacity

In 2008, as the price of oil experienced a whopping price, which respond quickly to the sharp increase in the biomass and biofuel investment. However, the oil price shrank in a short time, the investment bubble in biomass and biofuel burst too, which also affect the development of biomass and biofuel. Taking the wind power as an example, in the year of 2009, the overcapacity in wind power generation was announced by State Council. What's more, after the financial crisis, increasing international giant maker of wind power has rushed into China and intensifying the competition and over capacity.

6.2 Disadvantage of renewable energy policy

(1) Lack of general administration agency which is able to regulate and control renewable energy policy independently.

Since the Ministry of Energy was repealed in 1993, energy management function has been decentralized. From then on National Development and Reform Commission, State-owned Assets Supervision and Administration Commission of the State Council, State Electricity Regulatory Commission, and Ministry of Finance, Department of Science and Technology and other relevant departments have divided the work of Ministry of Energy.

In the year of 2008, National Energy Administration was set up. It's the first national level department which is specialized in the new energy administration. In order to enhance the ability of energy strategic decision and make overall plans for coordinating, National Energy Commission was established in 2010, the government's top energy body. However, it's hard to say this this commission can integrate all the energy management functions of China. Up to now, energy management functions are still decentralize by National Development and Reform Commission, The Commerce Department, Ministry of Land and Resources, State Electricity Regulatory Commission, as well as State Administration of Work Safety and other ten more departments. A more powerful general administration agency is needed.

(2) The existing laws and regulations are short systematicness and operability, and relatively hysteretic.

In the early China, the most important supervisor mode of energy is administrative measures, and most of which belong to normative document and The Departmental Rules. Very few administrative measures can change to be national laws and regulations. As a result, these administrative measures are lake of coerciveness.

Although the Renewable Energy Law has filled in gaps in the renewable energy legislation, it is still only a general framework and hard to give effective guidance for actual implementations. Even though some related laws and regulations have been set up to support it, the absence of subsidy and preferential policy led to that a series of key policies are difficult to be enforce.

(3) Enforcing quotas policy is not put into practice well

There is not mandatory proportion of renewable energy for the energy related enterprise, and no policy can ensure the market for renewable energy in China. Such as in Renewable Energy Law, biodiesel fuel has been categorized in to Biomass energy, however, the standard of Bio-oil production has not been draw up, so it's difficult to be sale in the market. What's more, the Renewable Energy Law stipulates that utilities must buy all of the electricity generated from renewable sources. However, in some cases wind power producers, as well as those implementing BIPV, have faced significant difficulties in connecting to the grid and obtaining a government-approved price.

(4) Incomplete encouragement system.

Although since the last century 60s, Chinese government has started to support the renewable energy (just like small hydropower by constructing water conservation works in rural areas to meet the demand for electricity). Until nowadays, an accelerated encouragement system has not been built. Taking subsidies as an example, in the Renewable Energy Law, the difference between the costs incurred in interconnecting electricity generated from renewable sources to the grid and the costs normally incurred in interconnecting electricity generated from conventional sources is levied on the ultimate end user. The subsidies provided to the grid companies may be delayed and this created financial pressure on these companies. So a suitable encouragement system is quite important for the development of renewable energy.

6.3 Advice policy for renewable energy development in China

To address a series of disadvantages and barrier above, and be able to keep improvement in long time, the law and regulation instrument, and economic instrument should be make full use at the same time.

1) Strengthening policy enforcement

Some policies related to China's renewable energy tend to get unsmooth in their transmission to lower level of units, leading to the trouble that the function of policies are sometimes undermined. For example, the Renewable Energy Law stipulates that utilities must buy all of the electricity generated from renewable sources. However, in some cases, the wind power producers, as well as those implementing BIPV (Building Integrated Photovoltaic), have faced significant difficulties in connecting to the grid and obtaining a government-approved price.

(1) Making clear objectives

Renewable energy is a kind of externality product. Its benefit cannot be transmitted through prices, so it needs to be promoted by the government. Chinese government has made some effort in it; regarding with reports, China is poised to spend $473.1 billion on clean energy investments in the next five years since 201224). Despite the huge investment, how to make these money into full use and made the existing policies in to practice is a hot potato. Since Chinese national goal's is always adopted by the way of ①setting national targets→②assigning targets to provinces→③establishing a punishment system to ensure compliance. In the promotion of renewable energy the same also can be adopt. In the case of wind power, as China's National Energy Bureau plans to boost the country's offshore wind capacity to 5 gigwatts (GW) by 2015, this plan can be assigning to the province and made an annual plan, and then the National Energy Bureau will rely on the punishment system to ensure compliance.

(2) Making develop process management

Independent monitoring sections should be set up to monitor policy conveying and implementation. The lower levels of units' performance circs should be report and feedback in time by these teams. Upper levels and lower levels can complement each other thus from a complete and powerful policy communication system.

In addition, in the formulation and management of industrial development policies, renewable energy development offices should keep consistence in policy implementation as well as considering the risk and predicament that the changing environment brings to policy implementation. In this way, the offices are able to actively push the organic regulation, control and the reasonable optimization of industrial policies.

2) Formulating barriers to entry

As the analysis above, it is not hard to find that in these years, as the policy incentives, a great number of investors have crowded into renewable energy industry, regardless of their own technology or the over capacity market. As a result, a national standard and strict censorship should be built to formulate the industry development. In this standard the following information ought to be contained: the formulation of industrial technology norms; operating cost; investment cost performance, etc. the overcapacity in wind power and biomass and biofuel is a lesson for China.

3) Giving consideration to integrated planning and area layout design

As the popular of renewable energy is an irreversible trend around the world, which has played an increasing major role in China help meet its rising energy demand, improve its energy structure, reduce environmental pollution, stimulate economic growth, and create job opportunities. And the ever-increasing investment in this industry is attractive, which led to the signs of overheating.

As the government, especially the central government, should give the direct and macro-control when the symptom of this trend appeared. And the unreasoning investment must be availed. The integrated planning and area layout design should be practical in a long time, to direct the renewable energy enterprise as well.

4) Constructing and reinforcing the general administration agency

Although in 2008, National Energy Administration was set up to enhance the ability of energy strategic decision and make overall plans for coordinating. Until now, this commission cannot integrate all the energy management functions. Therefore, a more powerful renewable agency is needed. With a renewable agency, integrated planning and area layout design will be easier to be realize, and the departments also be hard to shift the responsibility.

5) Clarification of the feed-in tariff system

As the most authoritative law about renewable energy, Renewable Energy Law uses a feed-in tariff system for renewable power. However, the pricing system is too complicated and it takes considerable time for investors, especially international and small private investors, to understand how it works. It is therefore critical that policymakers in China improve the renewable energy price structure and clarify the feed-in tariff system. The most effective solution would be to establish a fixed-price structure for each technology based on its specific characteristics (e.g., resource potential, geographical distribution, and technological maturity).

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