Research on Renewable Energy Policies and Pricing Mechanisms

Wang Fengyun\textsuperscript{a}, Wang Lufei\textsuperscript{b}

School of Economics & Management, Beijing Institute of Petrochemical Technology, Beijing, 102617, China
\textsuperscript{a}wangfengyun@bipt.edu.cn, \textsuperscript{b}1123571620@qq.com

Abstract. At present, China’s renewable energy development is in a critical period of transformation and upgrading. Developing renewable energy has important practical significance for environmental protection, as well as energy security in China. This paper analyzes the current status of renewable energy development and the problems existing in the development of renewable energy in China. And then, through studying the policies and pricing mechanisms of renewable energy in Germany and the United States, it investigates the successful experience of renewable energy development and its revelation. Finally, on the basis of China's national conditions, this paper proposes feasible suggestions for the optimization and development of China's renewable energy.

1. Introduction

The current global energy structure is undergoing profound changes. Global renewable energy continues to grow. The development of renewable energy has become an inevitable trend in the global energy revolution and green and low-carbon economy. With the development of renewable energy, China has become one of the fastest growing countries in the renewable energy of the world. In 2017, installed capacity of hydropower reached 340GW, installed capacity of wind power reached 164GW, installed capacity of photovoltaic power reached 130GW, and renewable energy generation accounted for 26% of total power generation in China. China's total energy consumption was 4.49 billion tons of standard coal, an increase of 2.9% from the previous year. Non-fossil energy consumption accounted for 14.2% of total primary energy consumption, but coal and oil accounted for 79.2% of the total energy consumption, renewable energy accounts for only 3% of the total energy consumption. China's energy consumption is still dominated by fossil energy. Overall, the development of renewable energy still lacks of balance in China. It is far from meeting the needs of the green revolution in energy.

Under the background of sustainable economic growth and rapid urbanization, China's per capita energy consumption is rising. Although the Chinese government is actively promoting the transformation of its energy structure, it has great pressure to upgrade the quality of renewable energy development and accelerate energy transformation. At the same time, the Chinese government promised that non-fossil energy consumption will account for 20% of primary energy consumption by 2030, and renewable energy generation will account for 76% of total energy generation by 2050. To realize the long-term goal of building a sustainable energy system based on renewable energy, China must actively promote the scale development of renewable energy, optimize the layout of development and utilization, pay more attention to the consumption of renewable energy, and build a new mechanism of stimulating the production and consumption of renewable energy. Therefore, formulating supportive policies for the development of renewable energy that suits the realities of the
country and establishing a price mechanism that promotes the development of renewable energy are major issues that China urgently needs to study and solve at the strategic level.

This paper takes the renewable energy support policies and pricing mechanisms as the research object, and studies the problems of renewable energy development in China. What’s more, it analyzes the policies and mechanisms for the promotion of renewable energy development in Germany and the United States, takes some successful experience as lesson for China as well. Finally, it proposes feasible suggestions for the development of renewable energy in China.

2. Literature review
With the development of renewable energy, the study on the support mechanism of renewable energy has become a hot topic in the world (Tahvonen and Salo, 2001; Anthony, 2006; Maltsoglou, 2008), which mainly focused on the electricity market transaction forms in auction bidding methods, Renewable Energy Certificate (REC) transactions mechanism, technical support for renewable energy, government subsidies for renewable energy, etc. Ingmar and Stefan (2016) found that switching from fixed electricity prices of renewable energy to market-oriented electricity price mechanisms allowed prices to be higher than market returns in order to reduce the uncertainty of price fluctuations. Philip et al. (2017) employed ARDL, FMOLS, CCR, SCVAR and the Multivariate BN to examine the driving forces of uncertain renewable energy electricity price. This study showed that in the short-run and long-run, increasing the share of renewable power in total power generation enhances the difference in electricity prices. Yuxin Zhai et al. (2017) researched the use of renewable energy by energy responsive production scheduling under a real-time electricity pricing condition. It showed that dynamically updating the manufacturing schedules by forecasting the electricity price and wind power per hour can reduce the cost of renewable energy and carbon footprint. Minhyun et al. (2017) applied the life cycle cost analysis to establish the minimum REC price required for reaching the target investment payback period of the residential solar photovoltaic generation, which provides support for the installation of solar photovoltaic generation systems in the United States.

With the rapid development of renewable energy in China, researches on renewable energy policies and pricing mechanisms are increasingly drawn attention from scholars. The relevant literatures are mainly focused on renewable energy policies, Feed-in tariffs (FIT), electricity price subsidy mechanisms and so on. Sun Peng et al. (2016) compared the three kinds of pricing models in the price regulation policy of the renewable energy generation industry by constructing a three-stage dynamic game model: fixed price, constant premium, and variable premium. They thought that the policy makers would choose different pricing mechanisms according to the corresponding policies and different preferences. Huang Junyi (2016) proposed a complete electricity price subsidy mechanism of renewable energy from the aspects of preferential subsidies, diversification subsidies, and supporting policies by constructing a theoretical model of the optimal subsidy for renewable energy prices. Zhao Zijian et al. (2012) applied Ramsey's pricing theory to the power sales and studied the apportionment mechanism of FIT for renewable energy. This pricing pattern not only enhanced the willingness of the grid accepted renewable energy power, but also improved the price system of electricity sales and allocated effectively the FIT of renewable energy. Wang Fengyun (2017) reviewed the pricing mechanism from renewable energy support policies, the renewable energy electricity price subsidies, renewable energy pricing theory model, and put forward China's renewable energy pricing mechanism research emphasises in the future, which are the implementation effect evaluation of pricing mechanism and renewable energy electricity price subsidies dynamic adjustment mechanism.

Some scholars have studied the Renewable Portfolio Standard (RPS). Wu Wenjian et al. (2013) analyzed and compared the income distribution functions of different stakeholders under different renewable energy policies by using game theory and two-level supply chain theory. They found that RPS can not only ensure to achieve the objectives of renewable energy development, but also can effectively regulate the distribution of benefits between two sides of the supply chain through the market mechanism. RPS is one of the important directions of renewable power policy. Sun Peng et al. (2015) constructed an oligopolistic game model and compared FIT with RPS. The empirical results
show that the FIT is more effective in increasing installed capacity of renewable energy and saving costs. However, in terms of reducing carbon emissions, RPS is better than FIT. These studies showed that RPS is one of the effective means that China can adopt in the development of renewable energy.

In short, most of the existing literatures focus on the design and evaluation of renewable energy support policies. The research on the renewable energy price mechanism mainly focuses on the defects of the price mechanisms and the effects of subsidies. These literatures lack of studying on the optimization of electricity pricing mechanism for renewable energy under the expected goals. To realize the goal of gradual reduction of renewable energy subsidies until its cancellation, and to create the advantage of market competition that renewable energy can compete with the conventional energy, China must promote the development of renewable energy through the market price mechanism. This is also the issue to be studied in this paper.

3. The status analysis of renewable energy development

The development of renewable energy plays an important role in the adjustment of energy structure and the protection of the ecological environment. Therefore, developing renewable energy has become the primary task of global energy development. The International Renewable Energy Agency (IREA) predicted that global clean energy will account for more than 30% of the world's total energy by 2030. Traditional energy development mode, which is given priority to fossil fuels, is unsustainable. Clean and low-carbon renewable energy are the ultimate goal of global energy development. In 2015, the global newly increased installed capacity of renewable energy was 147GW, with year-on-year growth of 8.3%. It exceeded the newly increased installed capacity of fossil energy generation for the first time, and the renewable energy generation accounted for 23.7% of total generated energy. This has caused a structural change in the construction of electric system, and various types of renewable energy have entered the stage of large-scale application. In 2016, renewable energy production increased by 14.8% from the previous year, of which more than 50% of renewable energy generation growth came from wind power, and 30% of it from solar energy. There is a significant growth trend in global renewable energy development. Europe is the leader of renewable energy development in the world. The European Union has established renewable energy development targets that the proportion of renewable energy in energy consumption will reached 20% by 2020 and 27% by 2030. Among Europe, Germany’s renewable energy development is particularly significant and has led the development of renewable energy in Europe.

After more than 30 years of development, China has become the world's largest energy producer and consumer, but the coal-based energy structure has also brought serious problems of environment pollution and energy security. In 2016, China's total energy consumption was 4.36 billion tons of standard coal, accounting for 23% of global energy consumption. Although coal production decreased by 7.9%, it still accounted for 61.83% of total energy consumption in China. Clean energy consumption such as natural gas, hydropower, wind power, and nuclear power accounted for 19.7% of total energy consumption, which increased 1.7% compared with the energy consumption in 2016. In 2017, the total energy consumption was 4.49 billion tons of standard coal, which was an increase of 2.9% from the previous year. Coal consumption accounted for 60.4% of the total energy consumption, which was a decrease of 1.6%. Clean energy consumption such as natural gas, hydropower, wind power, nuclear power accounted for 20.8% of total energy consumption, which increased 1.3% from the previous year. Although the energy consumption structure has been adjusted, the percentage of renewable energy in the clean energy structure is very low, and the percentage of renewable energy in primary energy is only 3%. Therefore, it is the key to develop sustainable energy by optimizing the energy structure and vigorously developing renewable energy in China.

In 2016, installed capacity of renewable energy has reached 600 billion watts in China, and ranked first in the world. At present, China has become the largest wind power market in the world. In 2016, China's grid-connected wind power installed capacity was 14.864 GW, which was an increase of 13.2%

---

Data sources: Renewable Energy Capacity Statistics 2017 and China Energy Statistics Yearbook 2017.
from the previous year; China's grid-connected solar power installed capacity was 7.742GW, which was an increase of 81.6% from the previous year. In 2017, China’s grid-connected wind power installed capacity was 16.367GW, which was an increase of 10.1%; China’s grid-connected solar power installed capacity was 13.025GW, which was an increase of 68.2% from the previous year. Although installed capacity of renewable energy generation is rapidly rising, the proportion of renewable energy generation in China's energy consumption is still very low. As the development of power grid is backward relatively, some renewable power cannot be connected to the grid. In recent years, the issues of “abandoning wind, abandoning light, abandoning water” of renewable energy have become more serious in China. In 2016, the rate of abandoning wind was 17.2% and the rate of abandoning solar power was 10.3%. In 2017, China’s renewable energy generation was 1.7 trillion kWh, the rate of abandoning wind of the total electricity generation was 12%, and the rate of abandoning solar power of the total electricity generation was 6%. Comparing to the above data, we can find there is a decrease in curtailment of wind and solar power, but integrating the renewable energy to the grid is still a serious problem. Meanwhile, with the rapid development of renewable energy in China, the burden of financial subsidies for renewable energy has been aggravated. As a result, the accumulative gap in renewable energy subsidies has been increasing. China's subsidy gap of renewable energy reached 67.8 billion Yuan in 2017. The renewable energy industry has encountered bottlenecks in its development. At the same time, there is a serious overcapacity of thermal power generation and the structural contradictions of the energy system are sticking out.

Although the development of renewable energy is facing enormous challenges, China must vigorously develop renewable energy from the perspective of environmental protection and national energy security. To realize the middle and long-term development goals of non-fossil energy in China, it is necessary to maintain a moderate increase in the scale of renewable energy, and to solve the problems of supply shortage and overcapacity in the energy industry caused by the positive externalities of renewable energy through market mechanism and government regulation. Meanwhile, China must establish a reasonable pricing mechanism through the market to ease the problem of market accepting capacity due to the excessive development of renewable energy industry, and avoid the drastic fluctuation of the renewable energy industry.

4. Research on Foreign Renewable Energy Development Mechanism
At present, renewable energy is in a stage of rapid development in China. However, the rate of renewable energy power to the grid is relatively low, and curtailment of wind and solar power is a serious phenomenon. Some developed countries, such as Germany and the United States, have promoted the development of high-efficiency and high-quality renewable energy by formulating renewable energy pricing mechanisms. These remarkable achievements in the development of renewable energy market mechanisms deserve to be learnt by China.

4.1. Germany
Germany has always been committed to the transformation of its energy structure. Germany has continuously explored and adjusted the pricing mechanism of renewable energy generation based on the development of renewable energy, which promoted the continuous expansion of the scale of renewable energy applications. It makes Germany's energy structure transformation achieve remarkable effects and Germany becomes the global leader in renewable energy. Germany's successful experience in the development of renewable energy is worth learning.

4.1.1. Renewable energy policy development
Germany is the fourth largest economy in the world and its industry is very developed. However, Germany’s energy self-sufficiency rate is seriously insufficient, and is only about 30%. Germany is a country which is rich in coal, but lacks of oil and natural gas. The oil and natural gas needed for industrial production and residents’ lives mainly relies on imports. Therefore, the government pays more attention to the development of renewable energy.
In order to promote the development of renewable energy, the German government promulgated the "Renewable Energy Law" in 2000 to determine the fixed pricing mechanism, which laid the legal foundation for the development of renewable energy. The German government made five additional amendments to the law in 2004, 2009, 2011, 2012, and 2014. After several revisions, the mandatory acquisition subsidy system was determined by the “Renewable Energy Law”. That is renewable energy generation has preferential access to power grid and acquisition rights, and long-term subsidy at a fixed price, which has effectively stimulated the rapid development of renewable energy in Germany. The government advocates the market development of renewable energy, gradually reduce subsidies and promote the integration of the renewable energy to the grid.

In July 2016, the “2017 Renewable Energy Law” (EEG 2017) promulgated by Germany stipulates the implementation of the bidding mechanism for renewable energy projects. The government no longer buys green electricity by a specified price, but through the market auction. The government subsidizes new renewable energy plants according to the lowest bidder’s price. The development of renewable energy will enter a new market competition stage. Nowadays Germany is at a mature stage of renewable energy development, and the renewable energy has already achieved sales through market competition. The law greatly promotes the development of renewable energy in Germany. In 2017, installed capacity of electricity generation in Germany reached 200.2GW. Installed capacity of wind power was 51.7GW, which accounted for 25.8% of the total installed capacity of electricity generation; Installed capacity of solar power was 41.7GW, which accounted for 20.8% of the total installed capacity of electricity generation. Installed capacity of renewable energy accounted for 53% of the total installed capacity of electricity generation. It can be seen that the development of renewable energy in Germany, especially in solar energy and wind generation, has achieved remarkable results.

4.1.2. Renewable energy pricing mechanism
In 2000, Germany established a renewable energy incentive policy based on fixed-grid electricity prices. Since then, it has implemented fixed-price pricing mechanisms and subsidized renewable energy power companies. These measures and policies have promoted the high-speed development of renewable energy in Germany. Since 2017, Germany has fully implemented the bidding mechanism for renewable energy projects. Through tendering, renewable energy generation will be provided fair competition and the role of the market will be better played. The bidding mechanism is that the government subsidizes new renewable energy power companies at the minimum price according to bidding price, instead of subsidizing the power companies by purchasing REC. The development of renewable energy has entered a new stage of market competition in Germany.

Vasilios et al. (2017) studied the onshore wind power bidding pattern pricing model by compared the single pricing mechanism with the PAB (Pay-as-Bid) mechanism. The average price, average profit, minimum project cost, and average project cost are calculated and analyzed in order to compare two pricing rules. Vasilios et al. found that the average price of PAB is 1.08% lower than that of uniform pricing, and the same as the average cost is 14.69% lower. The results showed that onshore wind power auction of PAB is more efficient than the uniform pricing in Germany. The pricing model based on PAB makes onshore wind power costs and prices lower.

China's current renewable energy power companies are still supported vigorously by the government. If only relying on the government's regulation, it is impossible to solve the problems of overcapacity and "abandoning wind, abandoning light" caused by renewable energy. Therefore, China can learn from the auction-based payment mechanism of Germany's onshore wind power, maximize the use of market bidding methods, reduce the on-grid electricity price of renewable energy, and increase the rate of on-grid renewable energy.

4.2. United States
The United States is the first country in the world to practise the Renewable Portfolio Standard (RPS), and the implementation of RPS has been relatively successful. According to the development of
renewable energy, the United States constantly adjusts the pricing mechanism for renewable energy generation. RPS has been widely used in many countries, such as the United Kingdom, Japan, and Australia, and so on. At the same time, RPS has cooperated with the Renewable Energy Certificate (REC) trading system to implement.

The Renewable Portfolio Standard (RPS) stipulates that the sale of a certain proportion of renewable energy power be required. The companies which cannot achieve the target will be punished by the government. It is an effective way to create demand for renewable energy power. In 2017, more than thirty states in the United States have established and implemented the system based on local resources, markets, and policy implementation background. It is estimated that RPS will make American renewable energy power increase 76750 MW by 2025.

In 2002, the California government introduced RPS, which stipulated that all retailers in the state must be obligated to purchase a certain percentage of renewable energy power. The current RPS target of the ratio of renewable energy in electricity sales will reach 33% by the end of 2020. In addition to the RPS, the United States Solar Renewable Energy Certificate (SREC) has become another important driver of the United States in renewable energy development. However, fluctuations of SREC prices caused uncertainty in the sales of SREC revenues, which has become an obstacle to the installation of solar photovoltaic systems. In order to research this problem, Minhyun et al. (2017) used life-cycle cost analysis to study the minimum renewable energy certificate price system required to achieve the target solar photovoltaic recovery period. Minhyun et al. collected data from eight cities in the United States and established theoretical assumptions to determine the minimum price of renewable energy certificates for these cities’ residential solar photovoltaic systems during the target payback period. By establishing the benchmark price for SREC, the government encourages the installation of residential solar photovoltaic system in the United States. The results showed that the shorter the target payback period, the lowest SREC prices increased rapidly in all target cities. This means that in order to achieve a shorter investment payback period, renewable energy price certificates require relatively high prices to take back the investment costs of solar photovoltaic systems.

In 2017, China has also implemented REC for renewable energy, which stipulates that power companies must produce a certain percentage of renewable energy power or purchase a corresponding proportion of REC in order to promote the development of renewable energy. However, there is no effective pricing method of REC. Through analyzing the pricing method of REC in the United States, China should find the lowest renewable energy certificate price which is suitable for China’s realities, and establish a unified national renewable energy certificate trading mechanism in China. The government should set up the lowest sales price of REC according to regional difference between the western area and the eastern area of China. By trying to minimize the target investment payback period of the renewable power companies to reduce the cost of power companies, the efficiency and quality of renewable energy generation will be increased.

5. Suggestions

In order to accelerate the development of renewable energy, China has implemented incentive policies, such as benchmarking Feed-in Tariffs, financial subsidies, and tax incentives, but it still relies on government policy support and lacks the assist of market mechanisms. According to the above analysis of incentive policies and pricing mechanisms for renewable energy in Germany and the United States, this paper thinks that China can learn from foreign renewable energy bidding mechanism, RPS, and SREC for renewable energy. Based on China's realities and the status of renewable energy development, the following countermeasures are proposed in this paper.

5.1. Introducing the market bidding system

High costs are still a major obstacle to the development of renewable energy in China. It is difficult to maintain renewable energy development by depending on the government’s subsidies. Market mechanisms must be adopted to promote technological advancement and industrial upgrading of renewable energy. Taking into account the multiple factors such as the gradual decline in the cost of
5.2. Deepening the market-oriented reform of renewable energy price
Due to the large differences in the degree of renewable energy richness and demand between the eastern and western regions, there is a mismatch between supply and demand of electricity. Chinese government should impel and improve the voluntary subscription rules for REC and the RPS. What’s more, according to different regions, the government needs to formulate reasonable REC prices and standardize the national renewable energy certificate subscription. RPS should be promoted to realize scale development of renewable energy. In this way, we can ease the pressure of financial subsidies and solve the overproduction problem of renewable energy power in the western region in China, so as to promote the sustainable development of renewable energy power.

5.3. Promoting the cooperative development of renewable energy
Now China's renewable energy generation enterprises have formed a scale, and installed capacity of renewable energy has also ranked first in the world. However, China’s current energy system cannot fully accommodate renewable energy. Chinese government must strictly implement the institution of full-scale to the grid of renewable energy, and encourage consumption of renewable energy in developed regions and polluting enterprises, which can increase the cost of environmental improvement in developed regions, and reduce the costs of fiscal subsidies. The phenomenon of “abandoning wind, abandoning light, abandoning water” can be eliminated through the development of distributed energy such as micro-grid and new energy demonstration cities. Renewable energy is used locally by developing vigorously energy storage technologies. According to the dispersive and intermittent nature of renewable energy, a modern regional energy network will be established to promote the coordinated development of renewable energy through the method of multi-energy complementation.

5.4. Applying new technologies to promote the integration of renewable energy to the grid
The renewable energy can be consumed locally, which is an effective means to reduce transmission costs of the power grid. Information technologies such as block chain, cloud computing, and big data can be applied to calibrate the producers of renewable energy in the micro grid and to match the sales of renewable energy through the electricity sales platform. This will reduce the overall cost of grid transmission as a whole and facilitate the integration of renewable energy to the grid. On the consumer side, through propagandizing low-carbon consumption concepts, consumers are encouraged to purchase and use renewable energy by the Internet.

Acknowledgments
This research was supported by the National Social Science Fund Project (Grant No. 17BJY057) and URT (Grant No. 2017J00015).

References
[1] Tahvonen O and Salo S. 2001, Economic Growth and Transitions between Renewable and Nonrenewable Energy Resources[J]. European Economic Review, 45(8), pp. 1379-1398.
[2] Anthony D. Owen. 2006, Renewable energy: Externality costs as market barriers[J]. Energy Policy, (34), pp. 632-642.
[3] Maltsoglou I. 2008, Simulating Exogenous and Endogenous Technology When Depletables, Renewables and Pollution Co-exist: How to Achieve Sustainability?[J]. *Journal of Environmental Economics and Management*, 58(6), pp. 80-98.

[4] Ingmar Ritzenhofen and Stefan Spinler. 2016, Optimal design of feed-in-tariffs to stimulate renewable energy investments under regulatory uncertainty — A real options analysis[J]. *Energy Economics*, (53), pp. 76-89.

[5] Philip Kofi Adom, Michael Insaidoo, Michael Kaku Minlah, and Abdul-Mumuni Abdallah. 2017, Does renewable energy concentration increase the variance/uncertainty in electricity prices in Africa?[J]. *Renewable Energy*, (107), pp. 81-100.

[6] Yuxin Zhai, Konstantin Biel, Fu Zhao, and John W. Sutherland. 2017, Dynamic scheduling of a flow shop with on-site wind generation for energy cost reduction under real time electricity pricing[J]. *CIRP Annals - Manufacturing Technology*.

[7] Minhyun Lee, Taehoon Hong, et al.. 2017, Establishment of a base price for the Solar Renewable Energy Credit (SREC) from the perspective of residents and state governments in the United States[J]. *Renewable and Sustainable Energy Reviews*, (75), pp. 1066-1080.

[8] Sun Peng, Liu Ling, and Lou Runping. 2016, Feed in Tariff Regulation Policy of Renewable Energy Industry-Based on the comparison of Fixed Price, Constant-premium Price, Variable-premium Price[J]. *Systems Engineering*, (5), pp. 82-89.

[9] Huang Junyi. 2016, Research on Mechanism and Policy of Electricity Price Subsidy for Renewable Energy Generation Industry[J]. *Price: Theory & Practice*, (2), pp. 95-98.

[10] Zhao Zijian and Zhao Xu. 2012, Research on Sharing Mechanism of Renewable Power Feed— in Price[J]. *Science and Technology Management Research*, 23, pp. 193-195.

[11] Wang Fengyun. 2017, A review on the pricing mechanism of renewable energy[J]. *Price: Theory & Practice*, (8), pp. 52-55.

[12] WU Wenjian, Ren Yulong, and Shi Lefeng. 2013, Comparison of Renewable Energy Policy Based on Electricity Supply Chain Benefit[J]. *China Population , Resources and Environment*, 23(3), pp. 44-48.

[13] Sun Peng and Li Shijie. 2015, Which Is Better, Price Regulation or Quantity Regulation?— Based on the Comparative Research of Feed-in Tariff and Renewable Portfolio Standard Policy in Renewable Energy Industry[J]. *Collected Essays on Finance and Economics*, (11):105-112.

[14] Vasilios Anatolitis and Marijke. 2017, Putting renewable energy auctions into action—An agent—based model of onshore wind power auctions in Germany[J]. *Energy Policy*, (110), pp. 394-402.