



The Review of Present and Future Energy Structure in China

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Abstract

Both the economy and energy demand increase rapidly in China. The government is facing severe problems from energy security, carbon emissions and environmental issues. The past trends and future plans of energy will have great influence on the transportation, construction and industry development. This paper summarizes the present and future energy structure in China. Conventional fossil energy, nuclear energy and renewable energy are all included. Electricity will account for more proportion in total energy consumption in the future, and the structure of electricity will be cleaner. That will promote the development of electric vehicles and the transformation of China's automotive industry. The optimization of energy structure will accelerate the low-carbon development in China. China's energy development will enter a new stage from the expansion of total quantity to the upgrading of quality and efficiency. In order

to realize the Paris Climate Agreement, China must steadily control the total energy consumption. The energy consumption in China will be in a period of slow growth. Constantly optimizing the energy structure and promoting renewable energy will both ease the energy crisis and ensure that China's goal of reducing CO₂ emissions can be achieved. China will further strengthen international cooperation in energy projects in the future. Through the cooperation, the energy structure in China will be further optimized. The efficient technology research & development and infrastructure construction of energy storage and remote power transfer will be vital to energy development. It will have influence on the future promotion of various renewable energy resources. The government will propel the reform of the oil and gas industry, and gradually open the market to the social capital. This measure will emphasize the role of the market in the energy development.

Introduction

The economic development in China has entered a middle-low speed growth stage from high speed growth stage. The demand for energy is still increasing, but the growth rate gradually slows down. The Gross Domestic Product (GDP) of China increased from 458.8 billion yuan to 68550.6 billion yuan between 2000 and 2015, with an annual growth rate of 13.7%, and in the same period, the energy consumption increased from 1.47 billion tons of standard coal equivalent to 4.30 billion tons of standard coal equivalent, with an annual growth rate of 7.4% [1]. The growth rate of energy consumption is much lower than that of economic development. However, with the improvement of living standard, the energy demand will still maintain its continued growth trend [2]. The cost of environment cannot be used for economic development, and saving energy at the expense of the economic development also cannot be implemented. The Chinese government will face great and continuous pressure from the energy production and demand.

Energy consumption is closely related to energy structure, energy supply security, low-carbon development, etc. In terms of energy structure, the energy production and consumption in China are still heavily based on traditional fossil fuel. In

2015, 72.1% of total energy production and 64.0% of total energy consumption were from coal, 8.5% and 18.1% were from oil, and 4.9% and 5.9% were from natural gas [1]. Severe fossil fuel dependence causes many significant problems, such as shortage of resources, low energy efficiency, high carbon emissions, etc. [3]. Heavy dependence on fossil fuel also has impact on energy security. In 2009, China's dependence on foreign oil exceeded 50%, and in 2016, this figure reached 65.4% [4]. To solve this problem and make the energy supply secure, China has established collaborative relationship with neighboring countries, such as One Belt One Road strategy [5]. However, compared with the expansion of energy sources, energy saving in traditional fossil fuel may be a more effective and safe way for China from a long-term perspective. China has already taken great efforts to improve energy structure and develop renewable energy, but the effect was not obvious. In 2007, Chinese government released the Medium and Long Term Development Plan of Renewable Energy, which indicated that in 2020, the renewable energy consumption in the total energy consumption would reach 15% [6]. This figure is still less than 20%, which is the target of European Union (EU). CO₂ emissions is another problem caused by tremendous energy consumption. China has already committed to

peak carbon emissions by 2030, and reduce the CO₂ emissions per unit of GDP by 60-65%, compared with 2005 [7]. It is a tough way for China to optimize the energy production and consumption structure to meet with the target.

This review summarizes the energy development and energy structure in China over the past few decades and generalizes the measures of Chinese government.

Energy Structure

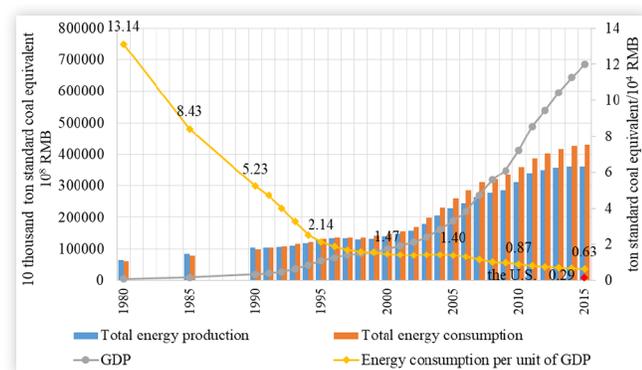
The domestic energy production and consumption in China from 1980 to 2015 are shown in Figure 1. The graph also illustrates the GDP and energy consumption per unit of GDP in China. With the rapid economic development, the energy consumption raised quickly. The energy consumption gradually exceeded the energy production, and the gap was growing. It is not a good energy development trend. Optimistically, the energy consumption per unit of GDP is gradually dropping in recent years. This figure decreased 55.0% from 2005 to 2015, and 70.6% from 1995 to 2015. That is a substantial improvement, but there is still a gap between China and developed countries. In 2015, the energy consumption per unit of GDP in the U.S. was 0.29 (assumed that the exchange rate is 7.6 RMB/USD), which was only 46% of that in China [8].

Coal

China is a country heavily dependent on the coal resources. Though the coal industry has made great progress in clean production, it still faces the problems of unbalanced, uncoordinated and unsustainable development. With the economic development slowing down and energy restructuring, the demand for coal is on the decrease, and the supply is excessive. Production efficiency is low, and the development levels of coal mines are unbalanced. The number of inefficient mines is excessive and they occupy too much resources. Thus, the governments' control and management are difficult.

With the transformation to clean energy, though the amount of coal consumption will increase steadily in short term, the ratio in total energy consumption will be down. Besides, the coal industry will be more intensified. Figure 2

FIGURE 1 Energy production/consumption and GDP development



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FIGURE 2 Coal production and consumption in 2020 by region in China



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shows the plan of coal resources development in 2020 [9]. The national coal production will reach 3.9 billion tons and the consumption will be around 4.1 billion tons. That means a 6% reduction in consumption, compared with 2017. The consumption in eastern region is much more than its production capacity. The unbalanced resources distribution will bring forward new requirements on long-distance freight transport. For reasons of energy security, China will also promote the exploration and exploitation of overseas coal resources. Besides, India and Southeast Asia have a continued high growth rate of coal consumption. It provides new opportunities for coal export to China. International cooperation will be a major trend in energy development in the future.

Oil

In 2016, China's dependence on foreign oil increased to 65.4%. It is the 8th year for China that this figure exceeded 50%, the international warning line. Table 1 shows the development of oil resource in the past few years and the plan in the future [10]. The oil production will be basically stable. The consumption will continue to grow, so the foreign oil dependence may still raise. The Chinese government begins to encourage social capital to participate in the investment and operation of commercial reserve facilities. The pipeline construction domestically and abroad will still be promoted. Because it is difficult to reduce dependence on oil in the military field and aviation field, China may take more effort to control the consumption of petroleum resources in road traffic, industry and construction. Thus, automotive industry will face new challenges.

TABLE 1 The development of oil resource

	Unit	2010	2015	2020
Total proven reserves	billion tons	31.28	37.17	42
Production	billion tons/year	0.203	0.214	>0.2
Consumption	billion tons/year	0.432	0.547	0.590
Import	billion tons/year	0.239	0.333	0.390

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Natural Gas

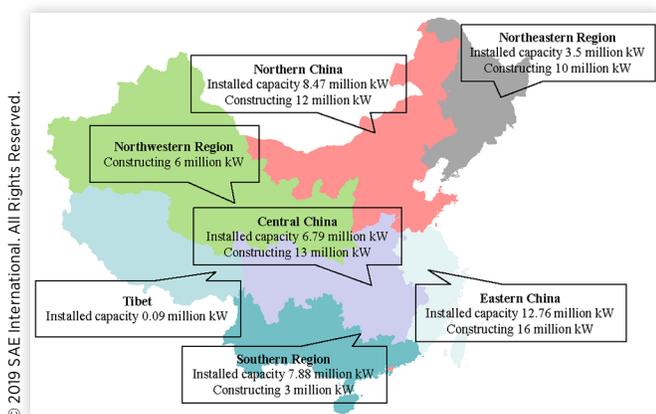
The exploration of natural gas in China is still in the early stage. Unconventional gas and import gas increase quickly. The proportion of natural gas in energy consumption has raised from 4.4% in 2010 to 5.9% in 2015, and in 2020, this figure will reach 8.3-10% [11]. Industry fuel (38.2%) and urban gas use (32.5%) are the two main use of natural gas. Power generation and chemical use separately account for 14.7% and 14.6%.

By 2015, the total mileage of natural gas pipeline has reached 64 thousand kilometers in China, and covered every province, only expect Tibet [12]. The promotion of natural gas is now facing many difficulties, like inadequate investment in exploration and infrastructure construction, small consumption growth, etc. Planned natural gas production will reach 207 billion m³ by 2020. Strengthening natural gas exploration and exploitation, and expanding the natural gas market will be the main tasks in the future.

Hydropower

In 2015, national hydropower generation reached 1100 billion kWh, which accounted for 19.4% of the total power generation, and 73.7% of the renewable energy power generation. The share of hydropower in total power installed capacity change from 8.8% in 1949 to 20.9% in 2015 [13, 14]. With the development of hydropower and expansion of development scale, the exploration conditions of the remaining hydropower stations are relatively poor. That means great ecological environment protection pressure and high cost in future development. The target of hydropower output will be 1250 billion kWh in 2020, and the installed capacity will reach 340 million kW. In 2017, the power generation had reached almost 1195 billion kWh, so another 4.6% will be need to reach the target in the next 3 years. Figure 3 shows the sub-region hydropower construction plan in 2020. Compare with 1064.3 billion kWh in 2014, the electricity generated from hydropower only will increase 17.9%.

FIGURE 3 The development of hydropower by region in 2020



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Wind Power

In 2016, new-built wind power installed capacity was 19.3 million kW, and total installed capacity reached 0.15 billion kW, which accounted for 9% of total power installed capacity. Power generation from wind accounted for 4% of total. Yunnan, Hebei, Jiangsu, Inner Mongolia and Ningxia Hui Autonomous Region are the provinces with relatively fast development of wind power in recent years [15].

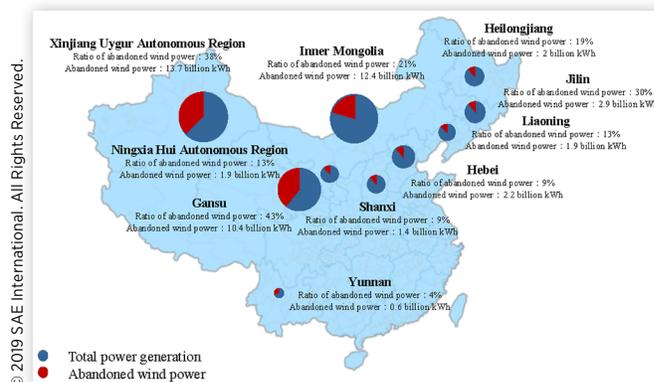
The most serious problem of wind power is the waste [16]. The volatile and intermittent wind power is determined by the randomness and intermittence of wind speed. This characteristic of wind power put forward the demand for power network technology and energy storage technology. Besides, the distribution of wind power plants is uneven, and the geographical distribution of waste wind power is illustrated in Figure 4. The provinces that abandon the wind power are concentrated in the middle and western regions in China, such as Xinjiang Uygur Autonomous Region, Inner Mongolia and Gansu. The power consumption in these areas are extremely low and they are far away from the high power consumption areas in southeast coastal areas. How to reduce the ratio of abandoned wind power and construct energy storage facilities will become the key factors of the wind power development in the future.

The development layout of wind power in the future will change from northwestern region and northeastern region to middle and eastern regions. In the next five years, 58% of new stalled capacity will locate in the middle and eastern regions. This measure will effectively reduce the transmission distance and the scale of power. As for the provinces that waste heavily, constructing nearby consumption pilot projects and developing high energy load industries, such as hydrogen production industry, are both valid solutions.

Photovoltaic Power

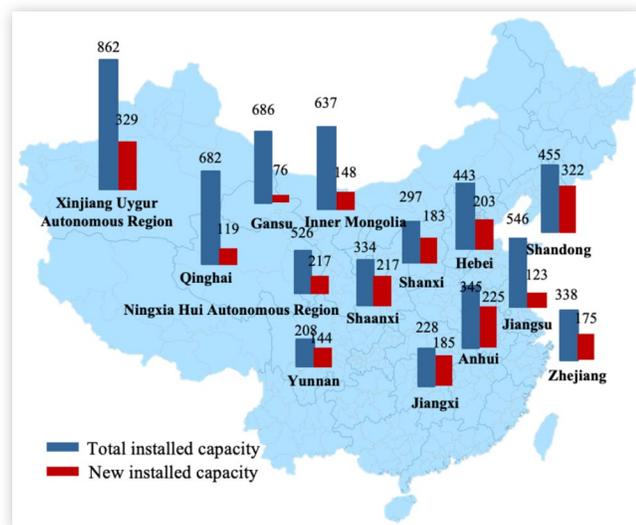
New installed photovoltaic power capacity and total installed capacity in China are both the most in the world. In 2016, total installed photovoltaic power capacity reached 77.42 million kW, and 44.6% of that were newly installed in 2016 [18]. The cumulative installed capacity has increased about seventy-fold from 2005 to 2016 [19]. The construction of

FIGURE 4 The abandoned phenomenon of wind power



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FIGURE 5 The development of photovoltaic installed capacity in 2016



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TABLE 2 The abandoned phenomenon of photovoltaic power

Province	Ratio of abandoned power
Xinjiang Uygur Autonomous Region	32.23%
Gansu	30.45%
Ningxia Hui Autonomous Region	7.15%
Qinghai	8.33%
Shaanxi	6.89%

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photovoltaic power facilities is shifting to middle and eastern regions in China. Among the new installed power capacity, only 28% was located in the northwestern region, and 72% was distributed in other areas, as shown in [Figure 5](#).

Photovoltaic power generation also faces the problem of waste. As shown in [Table 2](#), around 1/3 of power generated by photovoltaic were abandoned in Xinjiang Uygur Autonomous Region and Gansu. The total quantity of abandoned photovoltaic power in 2016 was 7.04 billion kWh, and the ratio was up to 19.8% [18]. Though, in the western region of China, the solar energy resources are abundant, fragile ecosystems, scarce water resources, and the windy climate are all unfavorable factors. Low photoelectric conversion efficiency and high cost are also the limits. In the future, distributed generation of photovoltaic power may be a solution to solve the problem of uneven distribution of solar energy and high power consumption in eastern and southern areas.

Distributed photovoltaic power generation becomes a popular topic in recent years. Thus, off-grid use of photovoltaic power is promoted by the government in China to reduce the pressure of power transmission and encourage users to consume renewable energy nearby. With the deployment of electric vehicles, off-grid use may become more important to support the interaction between vehicle and power use. However, there is still no statistical data about this part.

Nuclear

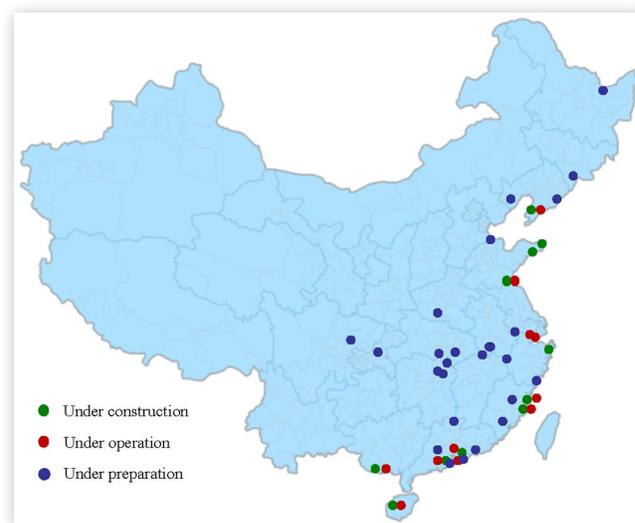
Based on the prediction of Organization for Economic Co-operation and Development (OECD) and International Energy Agency (IEA), in 2050, the power generated by nuclear will account for 17% of total power generation. At present, this ratio in China only reaches 3%, much lower than the global average of 11%. In the future, the location of nuclear power plants will change to northeastern and middle regions, to optimize the productivity layout as shown in [Figure 6](#). Plants on the sea will also be promoted. Though the plants are moving inland, coastal plants may still be the development emphasis. There may be a long preparation period for inland plants construction.

In the next 5 years, new installed power capacity will be 30 million kW, under construction power capacity will be 30 million kW, and the accumulated power capacity will reach 58 million kW [20]. At the moment, China has 30.5 million kW nuclear power capacity under construction, and this number ranks first in the world. From a long prospective, the nuclear power has large development space. It can substantially reduce the dependence on thermal power plants, and solve the problem of clean energy. However, nuclear power technology, safety, and cost will also be the key factors [21, 22].

Summary

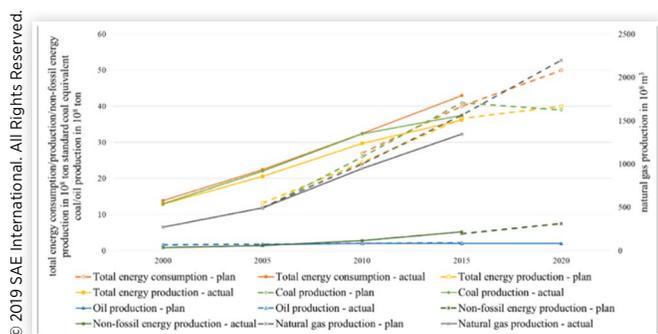
[Figure 7](#) summarizes the development of energy production, energy consumption, and the stage plans in China [23]. Every five years, China's government releases a Five-Year Plan for the country in many aspects, including energy. Comparing the actual energy production or consumption, for most kinds of energy, the actual value is larger than the plan value. Natural gas is an exception. The production of natural gas is always unable to reach the planning value, and the gap expands. How to speed up the development of China's natural gas industry will be a burning issue. In 2015, total energy production and coal production exceeded the target value. The target of coal production in 2020 is dropped, compared

FIGURE 6 The distribution of nuclear power plant under construction/operation/preparation

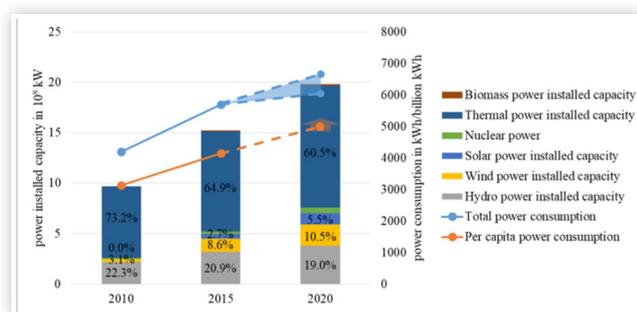


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FIGURE 7 Energy production/consumption of various energy types

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FIGURE 8 Power installed capacity sorted by energy types

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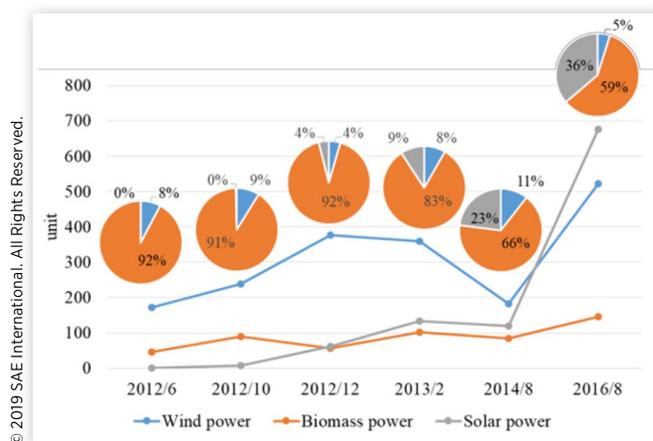
to that in 2015. Other kinds of energy are still growing. Adjusting the energy structure is still a difficult task. Non-fossil fuel production grows rapidly. This will be a good and inevitable trend.

Figure 8 shows the power installed capacity in China from 2010 to 2020. As can be observed, the ratio of thermal power installed capacity decreases from 73.2% in 2010 to 60.5% to 2020, with an annual growth rate of -1.9%. The proportion of hydropower capacity in total power installed capacity is also falling. Wind power and solar power installed capacity has sequential growth. The total power consumption in 2020 will reach around 6800-7200 billion kWh, and the power consumption per capita will be more than 5000 kWh annually. Because most of the thermal power stations are constructed in recent years with high initial investment, and the coal industry can effectively promote local industry development, it is difficult to shut off these stations in a short period for economic reasons. In the future development, though the renewable energy is essential to the country, traditional fossil energy will still be the main energy resources in an extended period. Thus, improvement of fossil energy efficiency will be as important as the optimization of the energy structure.

Policy

China's government has taken measures, introduced regulations and given subsidies to promote the development of clean energy. As shown in subsection 2, new plans for energy development is published every five years to establish objectives and formulate strategies.

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FIGURE 6 The distribution of nuclear power plant under construction/operation/preparation

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In view of the renewable energy, China's government has also introduced a series of subsidy measures. Interim Measures for the Administration of Additional Subsidy Funds for Renewable Energy are introduced to compensate the high cost of renewable energy power generation. Figure 9 shows the implementation of the subsidy [24]. The pie charts illustrate the proportion of subsidized installed capacity, and the curve charts demonstrate the number of renewable energy subsidy projects. As can be seen from the figure, the subsidized proportion of biomass is falling, and the proportion of solar is going up. However, by the first half of 2016, the subsidy gas reached 55 billion yuan. The original subsidy incentive model may be difficult to sustain. Thus, in the 13th Five-year Plan for Renewable Energy, the government mentioned the model of quota subsidy with green-certification. Quota subsidies are flexible. The amount can be adjusted according to the financial situations. High carbon emissions companies will have to pay the price and promote the development of clean energy. This will effectively relieve the burden of government, and strengthen the market function.

Conclusions

China's energy development will enter a new stage from the expansion of total quantity to the upgrading of quality and efficiency. In order to realize the Paris Climate Agreement, China must steadily control the total energy consumption. The energy consumption in China will be in a period of slow growth. Constantly optimizing the energy structure and promoting renewable energy will both ease the energy crisis and ensure that China's goal of reducing CO₂ emissions can be achieved.

China will further strengthen international cooperation in energy projects in the future. Through the cooperation, the energy structure in China will be further optimized. The efficient technology research & development and infrastructure construction of energy storage and remote power transfer will be vital to energy development. It will have influence on the

future promotion of various renewable energy resources. The government will propel the reform of the oil and gas industry, and gradually open the market to the social capital. This measure will emphasize the role of the market in the energy development.

Considered from each energy type separately, the energy development in China will face various development and technical problems. The subsequent development of hydropower will continue to increase. The exploration space and cost will both be the restrictive conditions. From the current development situation, wind power and photovoltaic power generation are greatly affected by the regions, and the phenomenon of waste is serious. The future promotion needs to rely on energy storage facilities and power network technology development. China continues to develop independent nuclear power technology to reduce dependence on traditional energy sources and meet with the electricity demand in the eastern coastal region.

The development of hydropower, wind power and photovoltaic power are restrained by many factors. Thus, if China wants to reduce the proportion of thermal power in a short period, achieve the peak of CO₂ emissions as soon as possible, and control the dependence on import oil to make sure the energy security, the development of nuclear power may be one of the few strategy options. Meanwhile, with large territory and various natural conditions, it is hard to pick a certain or the best solution.

The new energy and renewable energy costs are relatively high, so their competitive advantages in the market is not obvious. The main status of fossil energy is difficult to be replaced in the short term, and the government policy and financial support are still needed in the future. While, regulations on power-use side may become another solution in the long term. Carbon trading system and renewable energy credit may ask users to pay for the bills.

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Definitions/Abbreviations

GDP - Gross Domestic Product

EU - European Union

OECD - Organization for Economic Co-operation and Development

IEA - International Energy Agency

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