Renewable Energy Consumption and Economic Growth in China

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ABSTRACT

Environmental pollution is becoming more and more serious, and people gradually realize the harmfulness of environmental pollution, so they pay more and more attention to environmental problems. Also, the conflict between environmental issues and economic growth, and the renewable energy consumption is increasing. The emergence of renewable energy in China has improved the problem of energy shortages and further protects the environment. This article studied the renewable energy resources and the status quo of development and utilization, examined China's renewable energy development countermeasures and suggestions, and conducted an empirical analysis of the effect of renewable energy on economic growth in China. The empirical research concluded that energy consumption and renewable energy consumption have a positive and significant impact on economic growth, and the driving effect of traditional energy on GDP growth is still greater than the driving effect of renewable energy on GDP growth.

Keywords Renewable energy consumption; Environmental pollution; Economic growth

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1. Introduction

Renewable energy refers to non-fossil energy such as wind energy, solar energy, hydro energy, biomass energy, and geothermal energy. Renewable energy is low-carbon green energy essential to China's multi-engine power supply system. This is necessary to improve renewable energy, protect the environment, combat climate change and achieve sustainable economic and social development (Dai et al. 2018).

In 2020, China's renewable energy production capacity reached 2,214.8 billion kWh, an 8.4% over the same period last year. By the end of 2020, China's installed renewable energy production capacity has reached 934 million kilowatts, an increase of 17.5% over the same period last year[1]. General Secretary Xi Jinping made a series of important speeches, clearly suggesting that China's carbon dioxide emissions would peak by 2030 and strive to achieve carbon neutrality by 2060. By 2030, non-fossil energy will make up about 25% of primary energy. Consumption[2].

Wind power and The total installed capacity of solar power has reached more than 1.2 billion kilowatts, further pointing out the strategic direction of China's energy transformation and reform and setting a new beacon for China's renewable energy development[3]. Practice has proven that renewable energy sources can provide clean alternative energy and, more importantly, stimulate the development of equipment manufacturing and other related industries (Sun et al. 2020). This is an effective way to accelerate the transformation of the economic development system and adjust the economic structure after the global financial crisis. Developing and using renewable energy sources is essential to ensuring energy security, protecting the environment, and achieving sustainable development (Dai et al. 2018). It is necessary to take renewable energy development as a major strategic measure and earnestly grasp it.

2. Literature review

2.1 Renewable energy resources

People often refer to new energy and renewable energy together in the energy field. At present, the meaning of renewable energy has been clarified at the technical level; based on new technologies and new materials, and traditional renewable energy sources can be modernized,

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1) China's renewable energy generation will increase by 8.4% year-on-year in 2020 https://baijiahao.baidu.com/s?id=1690367672848388098&wfr=spider&for=pc
2) By 2030, the proportion of non-fossil energy in China's primary energy consumption will reach about 25% http://www.xhyb.net.cn/news/yaowen/2021/0330/147128.html
3) By 2030, the total installed capacity of wind and solar power will reach over 1.2 billion kilowatts https://m.thepaper.cn/baijiahao_15070198

used, and replaced by inexhaustible renewable energy sources. Fossil energy with limited resources and environmental pollution focuses on developing solar energy, wind energy, biomass energy, marine energy, underground hydrogen energy, etc (Shi 2009).

2.2 China's renewable energy resources

China has abundant renewable energy resources, including marine energy, geothermal energy, solar energy, biomass energy, and hydropower.

(1) Solar energy. China is one of the countries with abundant sources of solar energy. According to long-term observations collected by more than 700 weather stations across the country, the annual total solar radiation in all parts of China is roughly between 3.35×10 MJ/m2, and the average value is about. 86×10 megajoule/square meter[4].

(2) Wind energy. The total reserves of wind energy resources at the 10-meter level in China are 3.226 billion kilowatts. The actual accounts of wind energy resources that can be developed and utilized are 253 million kilowatts[5].

(3) Biomass energy. China's existing shrubs, firewood, and forestry residues can provide forestry biomass energy for the development of about 300 million tons each year, equivalent to about 200 million tons of coal equivalent. If everything is used, it can reduce the number of fossils by one-tenth. Energy consumption.

(4) Ocean energy. The coastline of mainland China is rich in ocean energy resources. Among them, the available tidal energy resources are about 22 million kilowatts, and the theoretical resources of wave energy and tidal energy are 13 million kilowatts and 14 million kilowatts, respectively[6].

(5) Geothermal energy. China's geothermal recoverable reserves are approximately equivalent to 462.6 billion tons of standard coal, and the resource potential accounts for 7.9% of the global total. If we only consider the currently proven high-temperature geothermal conditions and the mid-low-temperature geothermal exploration and drilling conditions, China's geothermal resource potential is 5.82 million kilowatts, and the power generation potential is 30-40 billion kWh/year. Medium and low-temperature geothermal resources can be used soon. The amount is equivalent to 86.4 billion kWh/year of power generation, and This is equivalent to the annual energy production of 50 million tons of standard coal[7].

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4) World-Energy: http://www.ny21.cn/
5) China Renewable Energy Industry Development Report 2008
6) Many countries develop Marine energy: http://www.nea.gov.cn/2006-02/09/c_131056260.htm
7) Development status and prospect of Geothermal power generation in China in 2017:https://www.chyxx. com/industry/201612/473279.html

2.3 Current status of the development and utilization of renewable energy in China

The development and use of renewable energy sources in China have the following main characteristics (1) The wide utilization range of new energy and renewable energy. With the discovery of new energy, it is gradually expanding. From the perspective of the significant categories of energy, China's use of renewable energy has gone from the initial hydropower and biological functions to the current wind, solar, ocean, geothermal, and hydrogen energy. From the perspective of the breadth and depth of various types of renewable energy utilization, it is also expanding and deepening. Take the use of biomass energy as an example. At first, we only directly burned surplus crops such as straw and fuelwood to obtain traditional coal energy—high-quality chemical raw materials[8].

(2) The renewable energy industry started late but developed rapidly. At the end of the 1970s, renewable energy was gradually developed as a part of rural energy construction. In recent years, renewable energy consumption has accounted for about 22% of the total energy consumption (total hydropower and biomass energy). It has become an essential part of the energy supply system. During the tenth five-year period, China has made great strides in the development and utilization of wind energy, solar energy development and utilization (solar photovoltaic development, solar thermal utilization, and solar building), small hydropower development and utilization, development and use of biomass energy, development and use of primary renewable energy sources[9]. As a result, the renewable energy industry is gradually developing and taking shape on a particular scale. It is estimated that China's renewable energy industry has provided people with more than one million jobs and created tens of billions of economic value. (China Renewable Energy Report 2007).

(3) Concerning the development and technology of using renewable energy sources, independent research and development opportunities continue to grow. China has made rapid progress in developing and using renewable energy sources such as wind power, biomass energy, and solar energy. In some areas, it has reached the forefront of the world[10]. Grid wind power in China has developed very rapidly. Total installed capacity increased from 350,000 kilowatts in 2000 to 1.26 million kilowatts in 2005, with an average annual growth rate of 30%. The installed wind power capacity ranked 10th globally in 2004 and rose to 7th globally in 2005. In terms of energy production from biomass, we have mastered technologies such as agriculture and forestry biomass

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8) China's policies and actions on climate change: http://www.gov.cn/zhengce/2008-10/29/content_2615768.htm
9) In the 14th Five-Year Plan, renewable energy will account for 50% of the increase in primary energy consumption and become the main body of the increase in energy consumption: https://baijiahao.baidu.com/s?id=1706274465865209683&wfr=spider&for=pc
10) Development of Renewable Energy Technology in China(1949-2019): 中国可再生能源技术的发展(1949-2019)

power generation, municipal waste power generation, and biomass compact fuels. Solar photovoltaic power generation is currently a mature technology. China's photovoltaic product production capacity is rapidly expanding, including the production capacity of broom silicon wafers and solar cells and the encapsulation capacity of solar cell modules, which has formed a group of international competition. It is an internationally renowned photovoltaic cell manufacturer[11].

3. Literature review

3.1 Theoretical basis

Economic growth theory is a theory in economics that analyzes and studies the law of economic growth and the factors that influence financial constraints. Like economics, the theory of economic growth has more than 200 years of development history. There are two stages in the development of economic growth theory, the foundation stage, and the mature stage, with Ramsey's classic paper in 1928 as the watershed. The growth theory before 1928 was called classical growth theory, and the growth theory included the Solow growth model or modern economic growth theory and endogenous growth theory.

3.2 Classical economic growth theory

Classical economic growth theory is the ideological origin and theoretical cornerstone of modern economic growth theory based on mercantilism. It broke through the money illusion of mercantilists on national wealth, thus shifting the focus of research to actual material production. We began to explore the factors and mechanisms that affect long-term economic growth. With Adam Smith, Classical economists, represented by John Smith, John David Ricardo, Thomas Malthus and John Muller, put forward the problem of economic growth and put their views.

The main work of Adam Smith, a British economist, is a study of the nature and causes of national wealth. Jane Said the wealth of nations, and the core problem is to study the increase of national wealth, namely economic growth. Adam Smith's Secret put forward "the biggest increase in labor productivity, as well as the more familiar with the mastery of labor, technology, and analytical ability, and it seems that it comes from a clear division of labor. Adam Smith believes that the driving force of a country's national wealth growth is the main. It comes from the division of labor and capital accumulation. Adam Smith put forward economic growth for the first time in

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11) Analysis on the growth of installed power generation in China since reform and opening up: https://baijiahao.baidu.com/s?id=1671542079173662932&wfr=spider&for=pc

this work, Long, thus becoming the pioneer of modern economic growth theory. Big David Ricardo continued the essence of Adam Smith's economic growth theory and put forward the self through research Own economic proposition. Adam Smith published the book Political Economic and Taxation Principles in the early 19th century. A special chapter focuses on a series of issues such as international trade and finally puts forward the famous comparative advantage trade Theory.

David Ricardo pointed out that the value of a commodity can be exchanged. The quantity of other commodities depends on the relative labor required to produce this commodity. David Ricardo focus shifted from wealth growth to income distribution. Malthus endogenous population growth to per capita output, emphasizing population growth Importance of long factors in economic growth. Malthus pointed out that the growth rate of means of subsistence and the evolution of population speed is not matched, and population growth meets the current growth law, but the related birth population does not meet its growth law. The level of agricultural development limits the population in the same period, it increases more. The population will always decrease accordingly until it meets the corresponding agricultural development level. Modern economists put this. The theory was analyzed and named "Population Trap Theory". Muller's "Principles of Political Economy Classical Economics" was synthesized for the first time, and economic growth was extensively and profoundly discussed. It has influenced the evolution of economic growth theory since then. Classical economic growth theory was formed in the early stage of economic development and had a long history. Nearly half a century Since then, mathematical methods have been regarded as the only way to study economics in western mainstream economics. Gradually, In China, there is also a tendency or proposition to follow the mathematical method as the only method of economic research. The result is that The study of economics is highly mathematical, which ultimately hinders the development of economics. At the same time, due to the research, The tools are relatively backward. They lack enough relevant economic data, so there are great difficulties in logical deduction and empirical analysis complex, the development of economic growth theory is limited, and finally, a complete system is not formed.

3.3 Modern economic growth theory

Modern economic growth theory is a theory that applies economic models to analyze economic growth quantitatively. According to the development process, modern economic growth theory can be split into the following four types: solow growth model and new growth theory, structuralist development theory, and institutional change theory. Among them, it can be called endogenous

growth theory will be introduced separately in the next section. Harold published on Dynamic Theory in 1939, trying to make Keynes's short-term comparative static equilibrium analysis. Then, Keynes systematically mentioned in the book "Dynamic Economics" published in 1948. Out of their own dynamic equilibrium economic growth theory. At the same time, American economist thomas in 1944 In 2000, Thomas posted a paper with the same idea, Debt Burden and National Income. The following year, Thomas also published "Capital," this expansion, growth rate and employment and other articles, these articles were compiled and included in the classics economic growth theory. Because Harold's growth model is basically consistent with Thomas's growth model in meaning, later generations called their growth model the Harold-Domar growth model. Harold-Domar model false capital and labor are irreplaceable, so there are certain limitations in research so american economists claim Luo relaxed this hypothesis, and after analysis and research, finally formed a new classical economic growth theory, Australia Swan, a sub-economist, perfected it, and later generations called their growth model Solow-Swan economic growth model. Solow-Swan model uses the neoclassical Cobb-Douglas production function to satisfy the hypothesis that capital and labor can be substituted in the model. Unlike the classical economic growth theory, in the Solow growth model, the factors that can cause economic growth include technology, technological progress, capital accumulation and labor force increase, etc. Still, there is only one factor in the long run: technological progress. Although the neoclassical economic growth theory has been further developed, it has not explained the exogenous technological progress thoroughly. Health reasons so still need to be further improved. Solow growth model and the "new" growth theory have their advantages, but they all ignore the structure in variables. To solve this problem, structuralism development theory introduces demand structure variables and labor in multi-sector model Dynamic structural variables, and targeted to re-study the model, and finally found that economic growth and various Structural factors are interactive. The institutional school puts forward a brand-new view on economic growth, and they focus on institutional changes. In fact, it is believed that the system determines the economy. The system's evolution is the fundamental reason for economic growth, while technological progress and capital Factors such as cost accumulation and labor force increase are more regarded as economic growth.

3.4 Endogenous growth theory

Endogenous growth theory emphasizes imperfect competition and increasing income. The core idea is that sustained economic growth is not affected by The influence of external forces is only determined by endogenous technological progress. For a long time, the neoclassical growth model has been increasing Long theory is dominant, but it has some limitations. To overcome this

problem, the United States A group of growth theorists represented by economists Romer and Lucas established human capital as the core Heart of the technological progress equation, and then in the theoretical model of a lot of research and analysis, successfully explained by The endogenous mechanism of economic growth, the endogenous growth theory was born. One of Arrow's essential achievements in development is the "learning by doing" model, and Romer to overcome this Due to the deficiency of the model, the technological progress is endogenous to the model, and other parts of the model are improved. Romer recognized. The key to economic growth lies in knowledge accumulation, so the knowledge spillover effect is used to solve the phenomenon of economic growth Interpretation. Romer also studied the role of human resources capital in economic increase. Romer introduced the manpower capital production department into the theoretical framework, establish AK growth model, which was widely used in later economic research. It is also the model basis of this paper. Romer found in his study that human capital accumulated in the process of financial increase that it plays a decisive role, and this discovery just confirms his previous hypothesis. After decades of development, endogenous growth Long theory has formed a preliminary theoretical system, and it is still developing and perfecting.

3.5 The effect of renewable energy consumption on environmental pollution and economic growth

Since the industrial revolution, the large-scale development and utilization of fossil energy such as coal, oil, and natural gas by human beings has excessively changed the ecological environment, which has led to the continuous rise of greenhouse gas concentration in the atmosphere and triggered a series of environmental problems, which seriously affected the sustainable development of human beings. However, unbalanced energy resources and limited non-renewable energy make the energy structure security problem prominent. The key to dealing with global environmental pollution, climate warming, and energy structure is to adjust the energy structure. Tahvonen and Salo (2001) "European Economic Review" studied the transition between non-renewable energy and renewable energy at different stages of economic development. Bhat (2018) "Environmental Science and Pollution Research" studied how renewable energy and non-renewable energy consumption affect five emerging market economies' economic growth and carbon emissions. Stuermer and Schwerhoff (2015) "Non-renewable resources, extraction technology, and endogenous growth" studied the importance of substitutability between non-renewable and renewable inputs in guiding endogenous technological change. Adedoyin et al (2020) "Growth impact of transition from non-renewable to renewable energy in the EU" pointed out that the transformation from non-renewable energy to renewable energy may have a negative impact on economic growth.

Abdullah et al (2019) pointed out that Malaysia, as a developing country and a member of the Association of Southeast Asian Nations, studied inexhaustible alternative energy sources, namely renewable energy sources, such as solar energy, wind energy, micro-hydro power generation and biomass energy. Also, some research has studied the economic aspects of hydrogen production from wind energy in Afghanistan. Solomon and Banerjee (2006) analyzed the present situation and prospect of developing hydrogen energy in Europe, and gave some suggestions on developing hydrogen energy in China.

According to Glenk and Reichelstein (2019) "Economics of converting renewable power to hydrogen. Nature Energy". Proposed the economic front of transforming renewable resources into hydrogen energy by PTG process from the perspective of potential enterprise investors. In recent years, the traditional hydrogen production method is characterized by high cost, high energy consumption and environmental protection, which makes the biological hydrogen production method widely used Universal attention. Sharma et al. (2021) studied the "Circular economy approach in the solid waste management system to achieve UN-SDGs" research puts forward that to improve the commercial feasibility of biological hydrogen production is to realize circular economy Department and the key to sustainable development. Lin et al. (2021) introduced the electrolyzer technology for hydrogen production from wind energy and analyzed the technology. The economic feasibility of the technology in solving the serious problem of wind abandonment and power limitation in China is present, and the possible problems in actual operation are pointed out In the situation.

We analyze the relationship between renewable energy consumption in China and economic growth from the perspective of econometrics (Gujarati, 2011). The analysis mainly includes two steps: first, the sequence stationarity test is performed, and on this basis, the Granger causality test and the coordination analysis of individual factors are performed. We find that the increase in the consumption of renewable energy leads to an increase in the size of the economy as a whole, while the growth of the total economic volume is not the main reason for the growth of total energy consumption. It is economic growth has not driven the growth of energy consumption.

4.

4.1 Model selection and setting

When calculating the proportional relationship between renewable energy consumption and economic growth, this paper slightly modified the three-factor production function method, splitting energy into renewable energy and traditional energy.

The equation is given by $Y_i = f(K_i, L_i, E_i)$ turn into $Y_i = f(K_i, L_i, E_i, \neq_i)$

In the new equation, Y is the real GDP, K is the actual capital stock, L is the total employed population, E is the traditional energy, including coal, oil, and natural gas, and NE is the renewable energy. Economic growth is expressed by real gross domestic product (GDP). Real capital stock is expressed by national fixed asset investment. Both traditional energy consumption and renewable energy consumption are expressed by standard coal equivalent. Assume that GDP, capital, labor, and energy consumption satisfy the Cobb-Dachglass production function, namely:

$$Y = A K^a L^\beta E^\gamma NE^\theta e^\mu$$

Among them, K is the fixed asset investment of the whole society, L is the number of employees, E is the total consumption of traditional energy, and NE is the total consumption of renewable energy. A、α、β、γ、θ is an unknown parameter. It can be linearized by logarithmic transformation. Taking the logarithm of both sides of the above formula, there are:

$$In\,GDP = In\,A + \alpha In\,K + \beta In\,L + \gamma In\,E + \theta In\,NE + \mu$$

Find the derivative of time t from the above formula, then:

$$\frac{dGDP}{dt}\frac{1}{GDP} = \alpha\frac{dK}{dt}\frac{1}{K} + \beta\frac{dL}{dt}\frac{1}{L} + \gamma\frac{dE}{dt}\frac{1}{E} + \theta\frac{dNE}{dt}\frac{1}{NE}$$

Adding the constant term and error term that meet the standard assumptions, the above formula becomes:

$$\frac{A\,GDP}{GDP_i} = C + \alpha\frac{\triangle K}{K_i} + \beta\frac{\triangle L}{L_i} + \gamma\frac{\triangle E}{E_i} + \theta\frac{\triangle NE}{NE_i} + U_i$$

4.2 Data selection and feature analysis

This paper adopts the data of China's GDP, capital, labor force, total Conventional energy consumption, and total renewable energy consumption in 2011-2020 in the statistics of the World Bank. GDP and capital stock are the real GDP after eliminating the inflation factor. Common energy sources include coal, oil, and natural gas. Both conventional and renewable energy sources use 10,000 tons of coal.

(1) GDP: We have selected the actual GDP index based on the price in 2011, and the unit is 100 million yuan. This can be seen from Figure 1. that since 2011, China's real GDP has been growing rapidly.
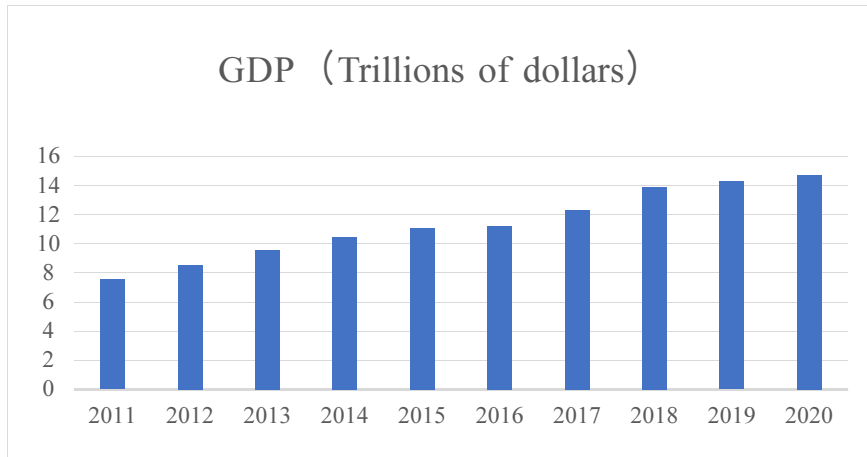
GDP（Trillions of dollars）

Figure 1. China's actual GDP over the years

(2) Capital stock: We use the annual capital formation volume and the capital stock in 2011, assume that the annual depreciation rate of capital is 6%, and use the Continuous inventory method for the annual assessment of fixed assets in China. China has developed from a backward agricultural country to a modern industrial nation, and primitive capital accumulation has played a significant role.
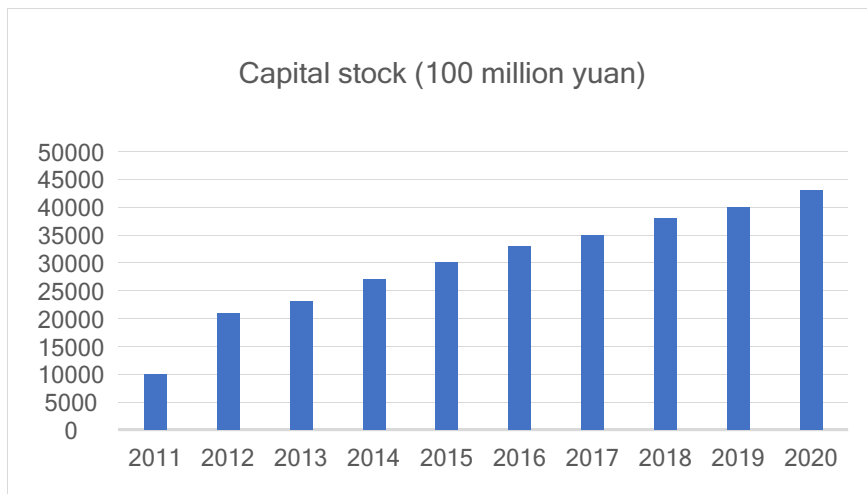
Capital stock (100 million yuan)

Figure 2 China's capital stock over the years

(3) Labor population: We use the annual national employment data from 1980 to 2008. China has been enjoying economic growth brought about by the demographic dividend in the past ten

years. Due to the sufficient labor supply and the relatively low labor cost, China has also brought conditions for engaging in many processing trades. In the 30 years, China has adopted the correct policy of actively attracting foreign investment to encourage exports, giving full play to the cost advantage of China's labor force and enabling China's processing trade to develop rapidly. In the end, China became the world's factory. In the process, China has enjoyed a demographic dividend, and its economy has embarked on a path of rapid development.
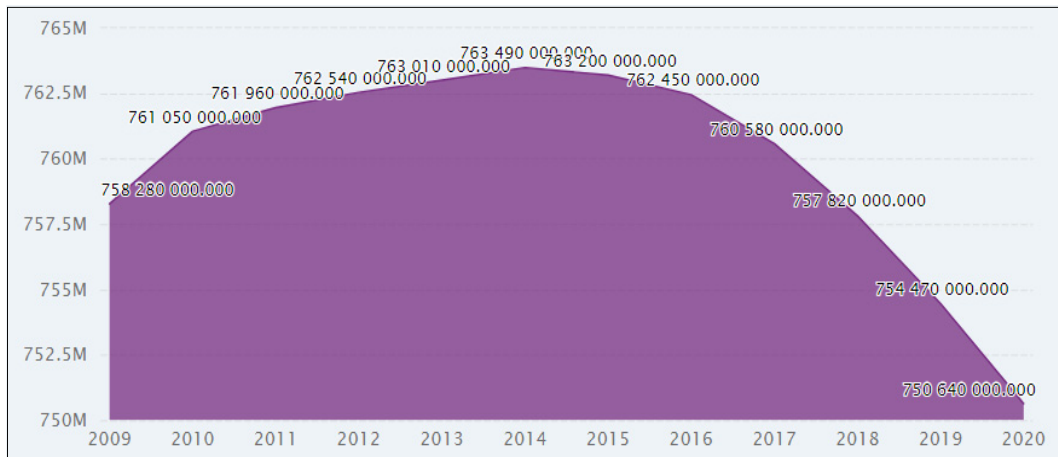
Figure 3. China's employed population over the years(Tens of billions)

(4) Traditional energy: The units of various energy sources are different. We unified the energy to a unified equivalent of 10,000 tons of standard coal. The data comes from the "China Statistical Yearbook" over the years.
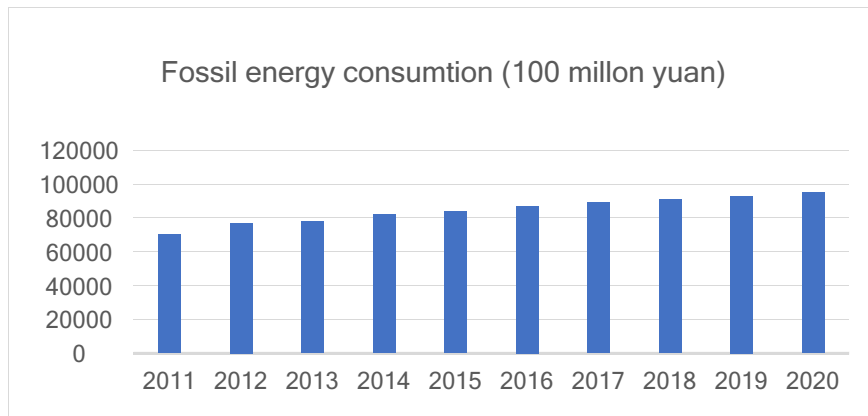
Figure 4. China's traditional fossil energy consumption over the years

(5) Renewable energy: China's renewable energy sources mainly include hydropower, nuclear power, wind power, and solar power. The data comes from the "China Statistical Yearbook" for several years. Compared with developed countries, my country's renewable energy utilization started late, and the level of renewable energy utilization technology is relatively low. At present, a large part of China's renewable energy core technology and equipment manufacturing still relies on imports, which has led to the high cost of renewable energy in China. Therefore, its effect on economic growth is different from traditional cheap fossil energy.
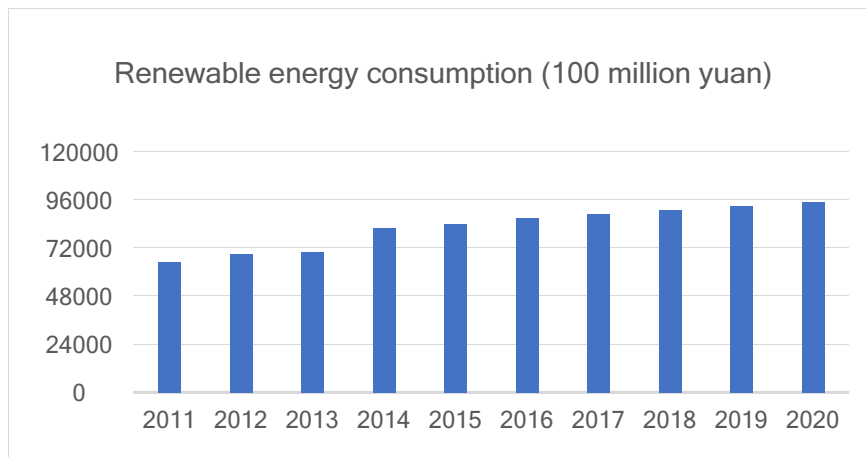

Figure 5. China's renewable energy consumption over the years

4.3 Empirical analysis of Data stationarity test

In this paper, the natural logarithm of the data area of all variables will also eliminate the anomalies that may appear in the model. The data sample used in this article is a time series. When performing regression, the string must be stable, and the time series of many macroeconomic variables are not constant. When performing statistical inferences on non-stationary time series data, pseudo-regression problems will occur. Therefore, we must consider the instability of the time series. We used the extended Dickey-Fuller test method, the ADF test method (Mills 1999) to test the stability of the sample sequence.

ADF test is a statistical analysis method proposed by Dickey and Fuller to test the stationarity of time series. The ADF model is:

$$\triangle X_i = \alpha + \beta X_{i-1} + \sum_{i=1}^{n} \theta X_{i=1} + \epsilon_i$$

When testing, reject the null hypothesis $H_o : \beta = 0$, Means sequence X_i Is a stationary series. If the hypothesis is not rejected, consider the sequence X_i Non-stationary. What we call a time series P-order stationary means that the time series is stationary after P-order difference. The critical value of the ADF test can be obtained by looking up the table.

Table 2. Dickey-Fuller test result

	ADF value	Critical value a =1%	Critical value a =5%	Critical value a =10%	Conclusion
LOG (GDP)	-0.941239	-3.769596	-3.004859	-2.642239	unstable
DLOG(GDP)	-4.093974	-3.737851	-2.991873	-2.635538	steady
LOG (L)	-2.471219	-3.689192	-2.971856	-2.625127	steady
DLOG (L)	-4.750086	-3.699869	-2.976256	-2.627419	steady
LOG (K)	-0.761791	-3.699825	-2.976252	-2.627417	unstable
DLOG (K)	-3.874127	-3.699691	-2.976266	-2.627416	steady
LOG (E)	0.762765	-3.752951	-2.998061	-2.638748	unstable
DLOG (E)	-2.984822	-3.752948	-2.998062	-2.638747	steady
LOG (NE)	1.083251	-3.689191	-2.971855	-2.625119	unstable
DLOG (NE)	-4.634849	-3.699869	-2.976261	-2.627418	steady

Table 2 calculates the ADF statistics of the unit root test of the time series within the sample interval. The test results show that, at a significance level of 1%, the time series variables all accept the null hypothesis that there is a unit root; these variables are differentially transformed and expressed as DGDP, DL, DK, DE and DNE, respectively, and the difference series are further Carrying out the stationarity test, it can be found that these sequences are all non-unit root processes at a significance level of 10%, that is, these variables are all stationary after the first difference.

Do an ADF unit root test for each sequence, and find that the sequence itself is not stable, and these sequences are stable at the first-order difference level. In this way, regression methods cannot be used for data processing because this will lose a lot of important information in the metadata. The current conditions meet the conditions of cointegration analysis, so we will perform cointegration analysis on these data.

4.4 Cointegration analysis

Angle and Granger proposed the concept of cointegration in the 1980s. Cointegration test is a method for diagnosing the long-range 1-inch dependence between variables over time, and it is also a method for establishing long-range stability equations between variables. The main idea of cointegration is that although each of two or more variables is not constant, its linear combination can neutralize the influence of directional elements on each other, making the group a stable variable. Cointegration theory lays a theoretical foundation for finding the equilibrium relationship between two or more non-stationary variables, and using existing co-integration relationship variables to establish a dynamic model. If multiple variables are integrated, there is a long-term equilibrium relationship between them. Therefore, the regression equation established with these variables is meaningful. Only single integer variables of the same order can be cointegrated. The importance of co-integration is to show whether there is a stable equilibrium relationship between variables. Variables that satisfy co-integration cannot deviate too far from each other. A shock can temporarily deviate them from the equilibrium position, but they will automatically return to the equilibrium point in the long run.

Commonly used methods of co-integration test are E. G (Engl e. Granger) two-step test and Johansen test. You can use John's vector-based autoregressive model for the co-integration relationship between multiple variables. Morey test. The British Granger test is usually used to test the co-integration relationship between two variables. This article explores the co-integration relationship between energy consumption and GDP, so the Johansen maximum likelihood test is used.

The Johansen test method is based on the VAR model. In the co-integration test, the VAR model between variables must first be established. The key to building a VAR model is to determine the number of lag periods of the variable. This paper determines the lag period based on the AIC and Schwartz Information Criteria (SC) and the effectiveness of parameter estimation considering the sample size. After repeated calculations and analysis, according to the above criteria, the lag period of the VAR model is selected as 2. When the cointegration test selects the variable with a linear trend and the cointegration equation has only the outcome, the results of the Johansen cointegration test are shown in the table:

Table 3. Cointegration test results

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	Critical Value
None*	0.799635	104.6107	69.81887
At most 1*	0.646782	28.09849	27.58431
At most 2*	0.536289	21.74921	20.13159
At most 3*	0.273729	14.63552	8.264601
At most 4*	0.128753	3.821386	3.741465

It can be seen from the above table that the probability ratio statistic is greater than the critical value at the 5% significance level, so the null hypothesis of no cointegration is rejected, and the result shows that there is a relationship between all variables of cointegration. We have added the lag terms of LOG (GDP) and LOD (K) in the explanatory variables. We use the eviews software to obtain the co-integration equation as shown in the following table:

The coefficient of LOG (NE) is smaller than that of LOG (E), indicating that traditional energy has a greater influence on China's GDP, while renewable energy has a smaller effect on GDP. This result shows that the above four variables of China's economic growth have long-term two-way causality in the sample interval, indicating that there is a long-term equilibrium between China's economic growth, capital stock, employment, China's traditional energy consumption, and renewable energy consumption. relation.

Next, we use the Dickey-Fuller test to test the stationarity of the error term to test whether the cointegration relationship exists. If it is stable, it has a cointegration relationship and can be used as an explanatory variable of the difference equation. The test results are shown in the following table, and the error term is stable.

The above analysis shows that there is a long-range co-integration relationship between variables. Therefore, we can use the difference equation to create an error correction model (ECM) to analyze the impact of short-term energy fluctuations on GDP growth. The error correction model obtained is shown in the following table:

Table 4. Error correction model results

Variable	Coefficient	Std. Error	Prob.
D(LOG(K))	0.918869	0.329433	0.0109
D(LOG(L))	0.365321	0.382995	0.0409

Variable	Coefficient	Std. Error	Prob.
D(LOG(E))	0.633454	0.268524	0.0279
D(LOG(NE))	0.188417	0.142519	0.0203
C	-0.049068	0.063939	0.4513

The model shows that there is no difference in the long-term equilibrium ratio, while the difference equation reflects the solution of short-term fluctuations, and the error term reflects the impact of long-term equilibrium on short-term fluctuations. As shown in the above table, the error correction model describes the short-term correlation between variables, and the difference coefficient of traditional fossil energy is still significantly larger than that of renewable energy. This shows that in the short term, the driving effect of traditional energy on GDP growth is still greater than the driving effect of renewable energy on GDP growth.

4.5 Granger Causality Test of Renewable Energy Consumption and Economic Growth

Granger causality test is currently used in econometrics. To explore causality, of course, we must first define what is causality. From a statistical point of view, causality is embodied in a function or probability distribution: assuming that all other events in the universe are constant, if event A occurs or does not occur, it is more likely to be related to other events B Occurrence (if a random variable is determined by an event, we can also say that the distribution function) has an effect, and the two events are arranged in chronological order (from a to b), then we can say that a is the cause.

Early causality is simply defined by probability, that is, if $P(B|A) > P(B)$, then A is the cause of B; however, this definition has two major flaws: 1. Time is not considered Sequence; 2. From $P(B|A) > P(B)$, the conditional probability formula can immediately deduce $P(B|A) > P(A)$. Obviously, the above definition is self-contradictory (and the definition in ">" is unreasonable, and it makes sense to replace it with "<". Later, the ">" in the definition was changed to an inequality sign "together through improvement. In fact, according to the same reasoning, this definition is also untenable).

In fact, the above definition has a bigger flaw, this is a matter of collecting information. In fact, to truly determine the causal relationship, a full range of information must be considered. In other words, to conclude that "A is the cause of B", all events in the universe must be fully considered, otherwise it will happen frequently. misunderstanding. The most obvious example is if there is another event C, which is the common cause of A and B, consider an extreme case: if $P(A|C)=1$, $P(B|C)=1$, then obviously there is $P(B|AC) = P(B|C)$, at this time it can be seen that whether

incident A happened has nothing to do with incident B.

Therefore, Granger proposed the definition of causality. Recognition is based on a complete set of information and the order of appearance.We used eviews software to conduct a Granger causality test on the Granger causality between traditional energy consumption and GDP growth and the Granger causality test between renewable energy consumption and GDP growth.

The significance level indicates the likelihood of accepting the null hypothesis. The smaller the number, the greater the independent variable's ability to explain the dependent variable. Both the conventional energy consumption report and the economic growth test reject the null hypothesis that conventional energy consumption has a significant impact on economic growth. The increase in overall energy consumption also contributes to economic growth; the renewable energy consumption and GDP growth report shows that renewable energy consumption is not the main driving force of GDP growth. However, the impact of economic growth on the growth of renewable energy consumption is relatively weak.

5. Conclusion and Discussion

Energy is one of the most basic elements related to the development of human society and the growth of national economy. The utilization level of renewable energy and new energy by human beings also reflects the advanced degree of social development. In the current era of great energy transformation, this paper mainly studies the relationship between renewable energy consumption and environmental pollution.

Renewable energy, including water energy, wind energy, solar energy, biomass energy, ocean energy, geothermal energy, etc., is inexhaustible, clean and environmentally friendly, and can continuously meet the energy needs of human beings. Faced with increasingly severe energy and environmental problems, many countries put forward such policies as developing renewable energy and reducing the use of non-renewable energy. At the same time, with the help of relevant laws and policies, the development speed of renewable energy is increased.

It is necessary to understand the strategic significance of renewable energy development and vigorously support the development of renewable energy such as solar energy and wind energy. At present, it is necessary to attach great importance to and focus on solving several problems in improving renewable energy consumption: First, through continuous scientific and technological progress and technological innovation, reduce the cost of renewable energy and promote the market-oriented development of renewable energy industry; Second, timely introduce national cross-regional renewable energy related systems; Third, accelerate the construction of renewable energy infrastructure. It is necessary to unify the development of renewable energy into economic

planning.

We can learn from EU policies. The European Commission has published a draft of the "Offshore Renewable Energy Strategy" to greatly increase the proportion of renewable energy in overall energy consumption. According to the draft, it is estimated that the overall offshore wind power production capacity of the EU will reach 60 GW by 2030 and increase to 300 GW by 2050. At present, the offshore wind power capacity in Europe is 23 gigawatts. Wind turbines are mainly distributed in the North Sea, the Baltic Sea, the Atlantic Ocean, the Mediterranean Sea, and the Black Sea. The North Sea is currently the best place for offshore wind power globally.

There is a reason why the European Union has formulated such an ambitious wind energy development strategy. On the one hand, it is to cope with climate change. According to the World Energy Outlook issued by the International Energy Agency (IEA), nuclear energy, solar photovoltaic, hydropower, and onshore wind energy will maintain a relatively stable development momentum after 2025 under the "sustainable development assumption" of keeping the global temperature rise below 2 degrees Celsius in line with the Paris Agreement. The EU coal market has almost disappeared, and natural gas consumption will have an inflection point after 2025. However, offshore wind power will usher in a period of rapid development. In other words, natural gas will be the key factor to ensure short-term emission reduction. At the same time, offshore wind power will be the leading factor in medium-and long-term emission reduction. Fatih Birol, Executive Director of the International Energy Agency, believes that if the large-scale deployment of offshore wind power is implemented smoothly, the EU's goal of achieving zero net emissions by 2050 can be achieved. Fatih Birol, Executive Director also asserted that a carbon-neutral Europe must prioritize offshore wind power in energy development.

On the other hand, it seeks to maintain the leading position in the world. The European Union is in the top position in offshore wind power generation globally. 42% of the global offshore power generation capacity is distributed along the European coast. European industry insiders are proud to say: "Offshore wind power is a story about Europe's undisputed technological innovation and industrial leadership." As early as 1991, the world's first offshore wind farm successfully operated in Wendebi, south coast of Denmark. However, competitors worldwide are catching up, especially China and India are challenging the first-Mover advantage of European wind power. In addition, the EU is now facing fierce competition from Britain. In the United States, it is speculated that the Democratic Party will restart the green energy policy, emphasizing promoting wind technology.

There is competition, and there is cooperation. Europe will make full use of its advantages in wind power technology. For example, Beihai Wind Farm has made great breakthroughs in cutting costs and improving efficiency, which has aroused strong interest from investors from China, the United States and other regions. According to analysis, by 2040, offshore wind power projects will

attract 1 trillion US dollars of investment globally. The most critical factor is that offshore wind power has less environmental protection pressure, and with continuous breakthroughs in technology, it can significantly reduce costs. This is also why many oil and gas companies with offshore oil and gas drilling experience began to intervene in offshore wind power development.

6. China's renewable energy development countermeasures and suggestions

6.1 Raise awareness of the importance of developing the renewable energy industry

On November 3, 2009, Wen Jiabao put the new energy industry at the top of the emerging strategic industries that the country attaches great importance to in his speech "Let science and technology drive China's sustainable development" One of the main directions. Renewable energy is an important strategic alternative energy that plays a very important role in increasing energy supply, improving energy mix, ensuring energy security and protecting the environment. The objective reality of energy shortages and even crises and Global climate change requires China to fully understand the important role of renewable energy sources from a strategic and comprehensive perspective; all relevant departments of the State Council and governments at all levels must full implementation of the Renewable Energy Law and formulation of relevant laws and sub-policies, formulate a unique plan to develop renewable energy as soon as possible, clarify the development goals, And using the development and use of renewable energy sources as development indicators to build a resource-efficient and environment-friendly society. At the same time, strengthen theoretical research and social awareness guidance.

6.2 Promote technological innovation of renewable energy

Promote innovation in renewable energy technology, promote independent institutional innovation, and raise the technological level of the renewable energy industry. Since the level of technology development in China and the use of renewable energy sources is still relatively low, some basic technologies and basic equipment are primarily dependent on imports, which severely limits the technological and industrial development of China's renewable energy industry. Therefore, China should attach great importance to the research and development of basic technologies and the development of technologies that can be applied in the renewable energy industry. It is essential to promote independent research and innovation possibilities for existing companies and to increase the level of industrial technology. The main ways are: Increase government support for the development and manufacture of critical technologies in the renewable energy sector; strengthen the construction of key laboratories for renewable energy

technology innovation, give key support to scientific research units with innovative advantages, and establish national-level renewable energy Technology R&D Center; use major scientific research projects as the link to promote the formation of industry-university-research alliances between renewable energy companies, universities, and scientific research units, form research teams, and build R&D bases, especially in core renewable energy technologies (such as non-grid-connected wind power technologies). Independent innovation capabilities; Create a public service platform for renewable energy technology innovation, strengthen intellectual property management and protection, and accelerate transformation and industrialization of innovations; accelerate the training of renewable energy technology talents and industrial management talents; encourage companies to carry out international cooperation Science and technology exchanges and cooperation have gradually shifted from the introduction of renewable energy technology and equipment import to independent research and development and export of technology equipment.

6.3 Establish a coordination agency for the development of the renewable energy industry

Establish a coordination agency to develop the renewable energy industry and establish a coordination mechanism for unified management. During the development of the renewable energy industry, problems such as the lack of synchronization between renewable energy power generation and grid planning, multi-sector management, and management in coordination have emerged. This requires the state to establish an inter-departmental coordination agency, a unified management coordination mechanism, and unified production management principles and system standards to facilitate the coordinated development of various industries and production chains in the renewable energy industry. Especially under the conditions of rapid changes in the economic development environment, the state should implement a dynamic industrial management system for the renewable energy industry; all relevant management departments should also make corresponding adjustments in a timely manner to cope with the changed renewable energy industry management system Implementation to achieve the coordination and unification of the management of the renewable energy industry.

6.4 Improving policies and regulations for the renewable energy industry

(1) Improve legislation related to renewable energy. Improving the legislation related to renewable energy and strengthening the implementation of the law Law is a regulator of social relations and an effective tool to solve social problems. In line with the characteristics and development of renewable energy, China is also committed to promoting and ensuring the

development and utilization of renewable energy through legislation. China's Electricity Law, Energy Conservation Law, Agricultural Law, Water Law, Solid Waste Pollution Prevention Act, Air Pollution Prevention Act, Radioactive Pollution Prevention Act, and many other laws. There are provisions for renewable energy sources. In 2005, China promulgated the Renewable Energy Law, which provides for several critical legal systems for developing and using renewable energy sources. To further revise the law, the Office of the Energy Leading Group of the State Council actively organizes experts and scholars to study and draft the energy law. From August 24 to 27, 2009, the Tenth Meeting of the Standing Committee of the Eleventh National People's Congress reviewed the Renewable Energy Law Amendment for the first time.

The current legislation, especially the promulgation and implementation of the Renewable Energy Sources Act, legally guarantees and promotes the development and use of renewable energy sources and will further promote renewable energy development. However, it needs to be improved in the following aspects. First, because it is a policy framework law, effective implementation also depends on the timely promulgation of supporting laws, regulations, technical specifications, and relevant development plans of the State Council and relevant departments. The letter is currently awaiting the issuance of the "Regulation for the Implementation of the Renewable Energy Law" and the regional regulation on implementing the "Renewable Energy Law" by local authorities. Second, the development and use of renewable energy sources is a very complex issue. It involves several issues in renewable energy and the relationship with traditional conventional energy. It is also closely related to various systems such as environmental resources, market development, and fiscal and taxation. Therefore, it is necessary to carry out legislative support and modify relevant laws and regulations such as the "Electricity Law" and taxation laws to ensure the "Renewable Resources Law" effect. Third, there is still difficulty in implementing renewable energy legislation. The "Renewable Energy Law" has set the obligation for many relevant authorities to formulate specific regulations, but stipulates the time limit and responsibilities for these authorities to formulate specific regulations, which prevents the implementation of these obligations and delays them. The establishment of related systems has affected the implementation of the Renewable Energy Law. Legislation should be passed as soon as possible to implement the obligations of relevant authorities.

(2) Implementing the policy of compulsory grid connection of Renewable energy sources. The mandatory grid system for energy and electricity is the basic system that ensures the development of the renewable energy industry, provided that the power distribution network has a monopoly and franchise operations. Application of the policy of mandatory grid connection the production of electricity from renewable energy sources is determined by the technical and economic characteristics of the renewable energy industry. Because the production of electricity from

renewable energy sources is intermittent and volatile, the power system rejects the production of electricity from renewable sources in terms of safety and technology and its economic importance. At the same time, under the conditions of existing technology and economic accounting mechanisms, most renewable energy products such as wind, solar and biomass energy cannot compete with fossil fuel products such as coal in terms of the cost of generating electricity. Therefore, renewable energy products are implemented. Implementing the policy of compulsory connecting to the power grid from renewable energy sources will help reduce the transaction cost of renewable energy projects and shorten the project access time, which will help promote the rapid development of the renewable energy industry by establishing stable market demand.

(3) Give the most leverage to taxation and increase support for taxation policies. Using preferential tax policies to promote the development of the renewable energy industry, the focus is to increase tax support for renewable energy research and development, Investment, production and consumption. The government can use taxes incentives such as lower tax rates, accelerated depreciation, investment credits, tax holidays, and loss compensation to encourage investment in renewable energy companies; increase non-renewable energy by imposing new taxes, raising tax rates, and abolishing tax incentives. Production prices promote the production and supply of renewable energy products. Therefore, implementing preferential tax policies will help improve the economic incentives and industrial competitiveness of the renewable energy industry.

(4) Formulate and gradually improve the investment and financing policies of the renewable energy industry. First, establish a renewable energy industry investment fund to encourage companies to diversify direct financing. The pilot work of the renewable energy industry investment fund should be promoted and the establishment of an industrial investment fund; actively support the listing of renewable energy companies on the main board of the stock market, Board of Directors for Small and Medium Enterprises and Emerging Markets for direct financing, so as to rapidly expand the scale of the industry; Investment from external companies in the renewable energy industry, especially wind power projects, can promote equity financing to introduce equity investments from external companies in the industry. Second, introduce high-tech investment capital to promote the organic integration of the renewable energy industry and venture capital. The establishment of a high-tech venture capital fund that provides financing services for technological R&D and independent innovation of the renewable energy industry should be accelerated to provide it with a solid guarantee of technological innovation funds.

(5) Strengthening the design of different type of regulations likes market-oriented green finance policy and laws or command-based environmental regulation for the renewable energy industry and providing institutional guarantees. The smooth development of the renewable energy industry cannot be separated from the guarantee of the legal system. In terms of institutional arrangements,

although the country has essentially established a relatively complete regulatory regime for the renewable energy sector, the development of the renewable energy industry requires the government to accelerate institutional innovation and institutional changes in terms of the demand for practical systems. A new institutional mechanism provides solid institutional guarantees for developing the renewable energy industry. At this point, China needs to implement the "Renewable Energy Lawfully". Governments at all levels should formulate and improve relevant regulations as soon as possible, based on further implementation of the "medium and long-term renewable energy development plan", etc., according to renewable energy sources. For the differences within the industry, the development plans and policy guidance of different sectors of the renewable energy sector should be drafted immediately, e.g. "New Energy Sector Development Plan". Polysilicon and renewable wind energy equipment industries suffer from overcapacity problems. In this regard, the state should speed up the formulation of the "Guiding Opinions on Renewable Energy Development" to prevent overcapacity in a single link due to a lack of systems, to contribute to the systematic development of renewable energy industry and its various industrial sectors and production relations.

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