Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Economics

Bachelor Thesis

Impact of Renewable Energy on China's economic development

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

BACHELOR THESIS ASSIGNMENT

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Economics and Management

Thesis title

The impact of renewable energy on China's economic development

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Objectives of thesis

1. An overall assessment of the current situation of China's trends and the trend of China's adoption of global innovation.

2. From an economic point of view, the assessment, challenge and prediction of converting solar energy into electric energy, converting wind energy into electric energy, and converting energy substances into thermal energy and electric energy.

3. From a strategic perspective and in-depth consideration of the steepv framework: social, technical, environmental, political and value factors, to review the results or various external factors that have a negative or positive impact on China's economy.

4. Check and confirm the key facts, forecasts and possible situations of China's economic changes in the next 15-20 years.

Methodology

Approximately 65% of globally generated electrical power in the last 2 decades came from fossil fuels. This number only goes higher when talking about developing countries, this means higher environmental risks, higher Co2 and greenhouse gas emissions, which only adds to the many problems and challenges already faced in developing countries.

environmentally cleaner alternative, especially that most of the developing countries are considered very suited for renewable energy, as they are rich in naturally distributed renewable energies resources (sun-shine), also most of the power sectors in developing countries are still in developing phase which will make it easier to shift to a renewable energy production plan.

In this thesis we will discuss the impact of adopting Renewable Energy Technologies on The Economic Growth in developing countries, we will also discuss the advantages and the challenges that could face the adoption process.

Impact of Renewable Energy on China's economic development

The proposed extent of the thesis

45-50

Keywords

Renewable Energy Technology industry China

Recommended information sources

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Impact of Renewable Energy on China’s economic development

Declaration

I declare that I have worked on my bachelor thesis titled " The Impact of Renewable Energy on China's Economic Development " by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any copyrights.

In Prague on 12.03.2022 _____Shichang Li_____

Impact of Renewable Energy on China's economic development

Acknowledgement

I would like to thank my supervisor Ing. Ghaeth Fandi, Ph.D for his advice and support during my work on this thesis.

Impact of Renewable Energy on China’s economic development

Abstract

On June 1, 2022, the Chinese government proposed that "China's carbon dioxide emissions aim to peak by 2030 and aim to achieve carbon neutrality by 2060. The most important measure to achieve this goal is to vigorously develop renewable energy. This thesis paper focuses on the analysis of China's energy development and summarizes the advantages and disadvantages of China's renewable energy development through the current situation of China's non-renewable and renewable energy development. In the middle of the thesis, a case study with Xinjiang province as a case study is discussed. Finally, in the practical part, a model is built through linear regression to analyze the impact of China's renewable energy on China's economy, and finally, reasonable suggestions are made for China's renewable energy to target China's 'carbon reduction target' and the development of China's economy.

Keywords: Renewable Energy, Non-Renewable Energy, China Economy, Technology, Industry, Solar, Wind power, Hydropower, Coal, Oil, Natural gas

Impact of Renewable Energy on China's economic development

Dopad obnovitelných zdrojů energie na hospodářský rozvoj Číny

Abstrakt

Dne 1. června 2022 čínská vláda navrhla, že "emise oxidu uhličitého v Číně mají dosáhnout vrcholu do roku 2030 a do roku 2060 se mají snažit o uhlíkovou neutralitu. Nejdůležitějším opatřením k dosažení tohoto cíle je energický rozvoj obnovitelných zdrojů energie. Tato práce se zaměřuje na analýzu rozvoje čínské energetiky a shrnuje výhody a nevýhody rozvoje obnovitelné energie v Číně prostřednictvím současné situace rozvoje neobnovitelné a obnovitelné energie v Číně. Uprostřed práce je rozebrána případová studie s provincií Sin-ťiang. Nakonec je v praktické části pomocí lineární regrese sestaven model, který analyzuje dopad čínské obnovitelné energie na čínské hospodářství, a nakonec jsou předloženy rozumné návrhy pro čínskou obnovitelnou energii, které mají směřovat k dosažení čínského "cíle snížení emisí uhlíku" a k rozvoji čínského hospodářství.

Klíčová slova: Obnovitelná energie, neobnovitelná energie, čínské hospodářství, technologie, průmysl, solární energie, větrná energie, vodní energie, uhlí, ropa, zemní plyn.

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1. Introduction

China has made noteworthy progress in the development of renewable energy in recent years, as the country seeks to transition to a low-carbon economy and reduce its reliance on fossil fuels. The push towards renewable energy has been driven by a combination of environmental concerns, energy security goals, and economic development objectives (Soava, 2018). The Chinese government has implemented a range of policies and initiatives to support the development of renewable energy in the country, including the implementation of feed-in tariffs, subsidies, and other incentives. These policies have encouraged the expansion of the renewable energy industry in China, which has led to significant growth in the sector. One of the key drivers of renewable energy growth in China has been the government's emphasis on reducing greenhouse gas emissions and addressing climate change. In 2009, China pledged to reduce its carbon intensity (the amount of carbon dioxide emitted per unit of GDP) by 40%-45% by 2020, compared to 2005 levels. (National Energy Administration, 2021)The government has also set targets for the share of non-fossil fuels in the country's total energy mix, with a goal of reaching 25% by 2030. To achieve these targets, the Chinese government has prioritized the development of renewable energy sources, such as wind and solar power (Zhongtang, 2022).According to the National Energy Administration, China's installed wind and solar capacity reached 281 GW and 253 GW, respectively, at the end of 2020, making it the world's largest market for both technologies. In addition to wind and solar power, China has also invested in other renewable energy sources, such as hydro and geothermal power. The country has the world's largest installed hydro capacity, with over 352 GW installed as of 2020, and is also exploring the potential of geothermal energy, with plans to increase installed capacity to 50 MW by 2025. (National Energy Administration , 2022)

The development of renewable energy in China has had significant economic benefits, created new industries, and generated jobs. According to the National Bureau of Statistics, the renewable energy industry employed over 11 million people in China in 2020, with a total output value of over 2.3 trillion yuan (approximately 360 billion US dollars). The sector has become an important source of economic growth and job creation, particularly in rural areas where renewable energy projects have been implemented (Soava, 2018). In addition to economic benefits, the development of renewable energy has also helped to address energy security concerns in China. The country has been heavily reliant on imported fossil fuels in recent years, which has posed a risk to its energy security (Al-Mulali, 2014). By investing in renewable energy sources, China has been able to reduce its dependence on imported fossil fuels, which has increased its energy independence and reduced its exposure to volatile

international energy markets. The development of renewable energy has also had important implications for China's environment and public health (Al-Mulali, 2014). China has been grappling with severe air pollution in many of its cities, with coal-fired power plants and heavy industry being major sources of pollution. By shifting towards renewable energy sources, such as wind and solar power, the country has been able to reduce its reliance on fossil fuels, which has helped to improve air quality and public health. Despite the progress made in the development of renewable energy in China, the sector still faces several challenges. One of the key challenges is the issue of grid integration, as the intermittent nature of wind and solar power can create difficulties for power system operators (Al-Mulali, 2014). To address this challenge, the Chinese government has implemented a range of policies and initiatives, including the development of energy storage technologies, the improvement of grid infrastructure, and the implementation of demand-side management programs.

It has been a long and inspirational story of China's development in energies and their roles in its economy of rapid growth. In the past two decades, China government has been ambitiously developing its social context, economic environment, political environment, and the legal system as well as technical intelligence to fit into the green contributing role for the international society and global home and especially for its economic development in the long run. Like other countries in the world, China has mainly relied on fossil oil and diesel oil as well as electrical power and has achieved economic miracles and surprising changes in its people's lives since the economic reformation policies started in 1978 (Apergis, 2014). As China has achieved a GDP of 370 billion in RMB in 1978, it has accomplished 114.92 trillion in 2021, which is about 311 times compared with that of 1978 and it is the second largest GDP value in the world. With its rapid development in economy and society, China has been paying significant prices, with its natural environment being destroyed, being polluted as well as natural resources being seriously consumed to the extent that they can hardly support China's sustainability and next miracles. While the world, including the developed countries in their earlier years of industrial economic booms, has experienced horrible difficulties in protecting their home and the earth, it has been researched that China has been burdened more because of its super large scale of economic activities dealing with raw technologies as well as negligent minds in crowded cities (National Energy Administration , 2022). In this case, governmental and non-government organizations like the International Union for Conservation of Nature and Natural Resources (IUCN) have worked for policies and practices for environmental protection. For green development, the western countries have been the first batch to develop innovations to repair polluted components, and especially they

have been focusing on applying green energies. In general, the China government has unhesitatingly walked on the sustainable road and followed the international and rich countries in the practices and solutions for green development, and green power has always been the national strategy especially in the last twenty years ago. (Qiao, 2020)

In 2021, China consumed a KW power of 8112.18 billion, and power produced by fossil fuels accounted for 70.08%. It is a prominent number to move towards green energy. There is no doubt that fossil fuels as they burn, and emissions can be polluted are not positive factors to the environment. In America, the percentage of power produced by fossil fuels was more positive in 2021, which only accounted for 62.19% of its total. Other sources of power in China include 14.60% hydropower, 8.04% wind power, 5.02% nuclear energy as well as 2.26% solar power. (National Energy Administration, 2021)And in the United States, it is green energy percentages that support power were 6.20% hydropower, 9.23% wind power, 18.91% nuclear energy as well as 2.79% solar power. When the world average level demonstrates around 65% of the power coming from fossil fuels, the United States did not stand out much in 2021, while China has gone far away from the average performance as being 70.08% and 5.08% more in 2021. In the United States, diversified solutions in total have contributed more to its power production compared to China, while green energies contributed less than the situations in China in 2021. During this year, China has relied on green energies, hydropower, wind power as well as solar power for its 26.61% power while this percentage in America was only 18.22%. In this case, China is in the right direction to green power while it must continuously work for more precise technologies as well as invest in much more capital as well as economic and social ideologies and solutions to boost its progress to renewable energy age, for its radical improvements in industries and lives (National Energy Administration , 2022).

2. Objectives and Methodology

2.1. Objectives

The main objective of this thesis is to analyze the current state of energy use in China by analyzing the current state of development of renewable energy sources and the current state of development of non-renewable energy sources in China. To analyze the role that renewable energy plays in China's economic development. Finally, to cater to China's current policy 'goal of reducing carbon emissions', suggestions are made for the development of renewable energy while promoting China's economic development.

2.2. Methodology

This paper is preceded by a histogram, line graph, and pie chart analysis by collecting data on renewable and non-renewable energy sources to visualize the data share and growth rate. The SWOT analysis is used to make a general analysis of the development of renewable energy in China, and finally the impact of the consumption share of renewable energy on China's economy is analyzed by constructing a linear regression through Gretl, using ordinary least squares estimation, and making predictions and recommendations on the future consumption and development of renewable energy in China.

3. Literature review

3.1. The concept of energy transition

The term "energy transition" first came from the report "Energy Transition: Growth and Prosperity without Oil and Uranium" published by the German Academy of Sciences, which proposed to shift the dominant energy sources from oil and nuclear to renewable energy. The enactment of the Renewable Energy Act in 2000 marked the official start of Germany's energy transition. After 2002, the meaning of "energy transition" in Germany gradually evolved to "shift to distributed renewable energy and energy efficiency" and declared that the goal is to establish a 100% renewable energy-based energy system. In many reports and papers, the term "energy transition" is also often used interchangeably with "renewable energy transition", "low carbon transition", "green transition "green transition," etc.

However, the meaning of energy transition is not only about renewable energy development. Driven by the global wave of energy transition, the concept and connotation of energy transition has undergone a continuous development process, and many scholars have further researched the concept of energy transition from the perspectives of energy motive, energy structure, energy system change, etc. Energy transition is the process of replacing old prime movers by new energy "prime movers" with higher efficiency, and the energy structure is constantly changing. (Smil, 2010)The Global Energy Transition, published in October 2014 by the World Energy Council and Conyers Consulting, defines the energy transition as "a fundamental change in a country's energy mix, such as an increase in the share of renewable energy, energy efficiency improvements, and the phase-out of fossil energy." Energy transition is defined as "a process of long-term structural change in primary energy sources

driven by energy prime movers and accompanied by profound changes in the energy system. (Zhu & Wang, 2019)The core of the energy system transformation is to replace the fossil-based high-carbon energy system with a low-carbon energy system based on new and renewable energy sources, and ultimately achieve near-zero CO2 emissions. (Jiankun, 2015)The energy transition is "a way for the global energy sector to move from fossil energy to zero carbon by the second half of this century."

3.2. The trend of energy transition

The international trend of energy transition in various countries is to change from non-renewable, inefficient, and highly polluting fossil energy to renewable, efficient and low-carbon clean energy. The goal of Germany's energy transition is to establish a system that encourages low-carbon energy development and improves energy efficiency to cope with future energy shortages and climate change crises. The UK released an energy white paper in 2003, proposing a gradual shift from fossil energy sources such as coal, oil, and gas to clean, smart, low-carbon energy sources. In addition to government planning, for the general direction of energy transition, scholars at home and abroad have conducted research from low carbonization, smart energy, energy efficiency and other aspects. In the context of global climate change and oil supply scarcity, energy transition presents a general trend of replacing the traditional fossil energy-based energy system with a new energy system based on non-fossil energy. (Solomon, 2011) (Shi, 2015)Energy structure to accelerate the transition to low-carbon carbon-free, distributed energy, intelligent energy system will accelerate the development, the level of electrification of end-use energy will be significantly increased, energy development and utilization gradually to low operating costs change. (Zhang Yousheng, 2015)The energy transition is the replacement of a centralized fossil-based energy system with a distributed, smart energy system that integrates digital technology with renewable energy sources. (Xiangwan, 2020)The main trends of the global energy transition include the overall improvement of energy efficiency, the transformation of existing energy utilization systems, and the large-scale development and utilization of renewable energy. (Gao Hui, 2020)

3.3. Renewable Energy Development

Along with the world's energy to accelerate the transition to green and low carbon, renewable energy gradually become the core of energy transition. The current research on renewable energy development focuses on renewable energy support policies, renewable energy technologies, renewable

energy consumption and other aspects. Tax relief, feed-in tariff subsidy, green certificate, renewable energy quota and other incentive policies are important forces to promote the rapid development of renewable energy industry. (ZhenYu, 2011)To promote the development of new energy industry, tax incentives are widely implemented to facilitate the production and sales of new energy products. Tax incentives provide an important mechanism for new energy development, and tax incentives from incentives may encourage more investment. (Bonazzi, 2016)The study found that tariff subsidies were the best mechanism to increase the profitability of solar PV systems and wind projects, while green certificates favored the most competitive technologies such as hydropower. (Milenka, 2019) (Falconett, 2010)Feed-in tariff subsidies are more effective in increasing installed renewable energy capacity and stimulating R&D investment to reduce costs than renewable energy quotas, which are more effective in reducing carbon emissions. (Peng, 2015)Subsidies, carbon markets and energy prices are important factors affecting the development of renewable energy technologies. It is pointed out that renewable energy subsidy policy plays a guiding role in the development of renewable energy industry and technological innovation, and the development of renewable energy technology R&D is influenced by the subsidy policy. (Wei, 2019)However, as the renewable energy sector grows, government subsidies are unsustainable. Carbon finance has provided financial support and significantly boosted renewable energy technology innovation. (Qi Shaozhou, 2019)In addition to subsidies and carbon markets, energy prices can also influence the development of renewable energy technologies. Reasonable electricity price increases portend higher profits in the future, which can improve the competitiveness of renewable energy and will drive innovation in renewable energy technologies. (Ouyang & Lin, 2014) (Schleich, 2017)

With the determination of the "carbon neutral" target strategy, the issue of renewable energy consumption has attracted much attention, and some experts and scholars have carried out a lot of research on renewable energy consumption problems and solution measures. The reason why renewable energy is difficult to be consumed is not only the factors of technology and infrastructure, but also the reasons of power system, price mechanism, economic incentives and other policies and systems, and proposed to scientifically plan the layout of renewable energy, strengthen the construction of power grid, and promote local consumption. (Jingli, 2015)It compares the serious situation of renewable energy consumption in the "three northern" and southwestern regions, analyzes the necessity of promoting renewable energy consumption in a market-oriented way, and proposes the market model and mechanism of inter-regional power spot trading of surplus renewable energy. (Pei Zhenyi,

2018)The lack of market-oriented mechanism and the lagging construction of energy system is one of the main reasons to restrict the consumption of renewable energy in China. (Fan, 2021)Although China's renewable energy consumption situation is constantly improving, but there are still local areas, local time consumption difficult problem, which restricts the quality development of renewable energy. (Yu, 2021)Optimize the electricity market structure, improve the market trading mechanism, promote renewable energy consumption by market-based means, and promote the strategic transformation of the energy system. Actively developing renewable energy to produce hydrogen is one of the main paths to solve the problem of renewable energy consumption. (Zhang, 2021)

4. Renewable Energy Reviews China

Data from the IEA study shows that the most significant contributor to carbon emissions is the thermal power sector, which is particularly evident in China. The Chinese government has been promoting the energy saving and emission reduction of traditional thermal power in recent years in order to ensure the fulfillment of carbon peak, carbon neutral, and other related commitments, and has formulated a series of carbon emission reduction related policies from three perspectives and levels: national energy strategy, special development of energy saving and emission reduction technology in thermal power industry, and carbon emission trading. The implementation of China's carbon emission reduction policy is not only a higher requirement for the traditional thermal power industry, but also an incentive to accelerate the development of China's renewable energy power industry. The development of renewable energy is the best choice to effectively reduce carbon dioxide emissions and is an important way to fundamentally alleviate and solve environmental problems.

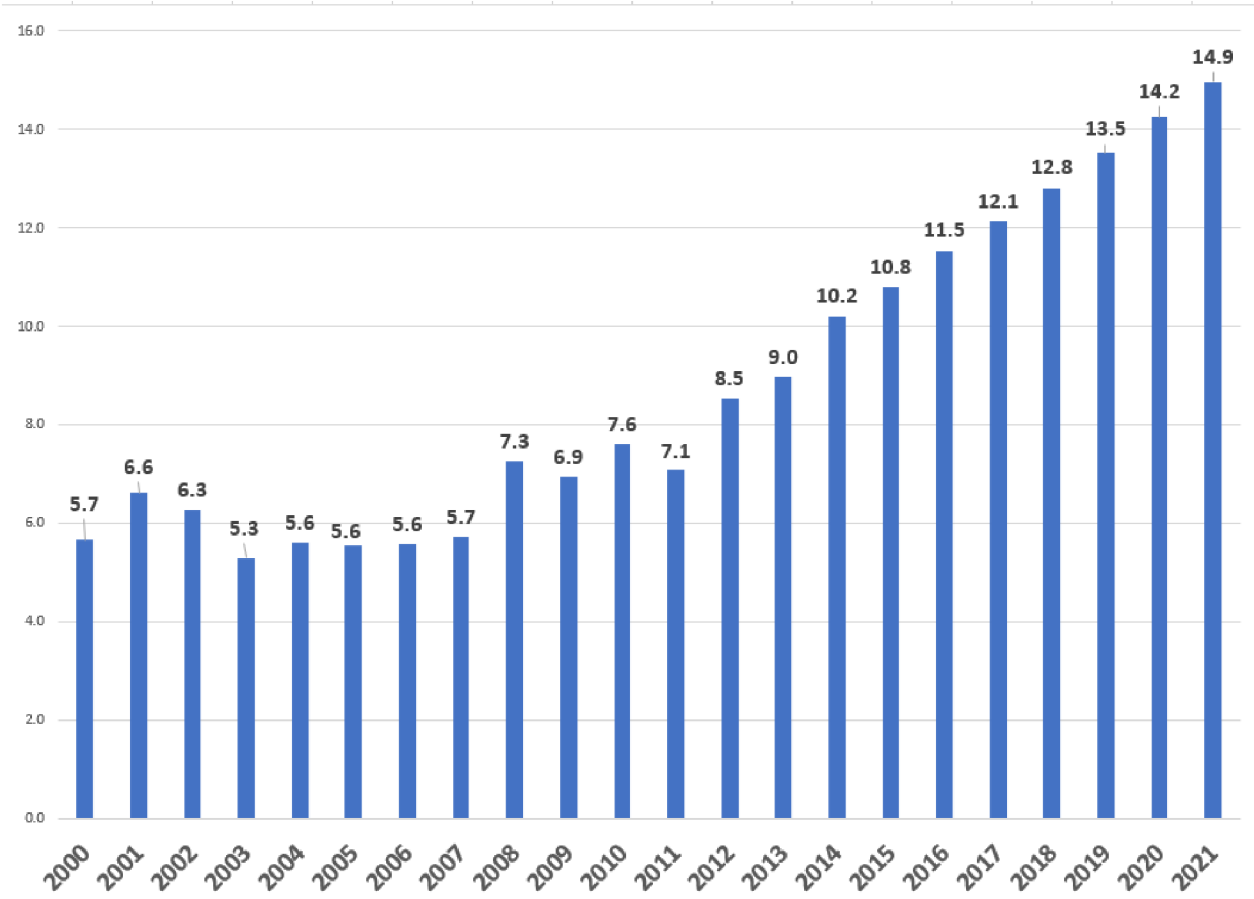

Figure 1 Renewable energy consumption as a percentage of total energy consumption from 2000 to 2021[1][2]

As can be seen from the graph, the share of renewable energy (here is the sum of hydropower, wind, solar, geothermal, modern biomass and wave and tidal energy.) in disposable energy is growing and has reached its current high of 14.9% in 2021. China is trying to develop renewable energy sources and trying to use renewable energy to replace traditional fossil energy sources such as coal. Renewable energy has been listed as a priority area for energy development in China and is also an important part of China's sustainable development strategy.

4.1. Solar Power

China is rich in solar energy resources, and the annual solar radiation energy received by the land surface is equivalent to 4,900 billion tons of standard coal, which is equal to the total power generation capacity of tens of thousands of Three Gorges projects. In addition, China has 1.08 million

[1] *Data source: Our World in Data Organization, https://ourworldindata.org/energy/country/china*
[2] *Data source: National Bureau of Statistics of China, www.stats.gov.cn*

km2 of desert, mostly in the west, which is extremely rich in solar energy resources. If 1/10 of China's deserts were used to install grid-connected photovoltaic power generation systems, more than 100,000 billion kilowatt-hours of electricity could be generated each year, which is equivalent to more than 5 times of the current national electricity consumption. China's solar photovoltaic industry started in the 1970s, entered a stable development stage in the mid-1990s, and after more than 30 years of efforts, has now ushered in a new stage of high development. As early as the 1980s, China began to promote the application of off-grid photovoltaic systems in western areas without electricity, and with the implementation of pioneering projects such as the "Brightness Project" and the "Countryside Access Project" and the strong pull of the world PV market, China's photovoltaic industry and photovoltaic Technology has been developed rapidly, has basically formed an industry chain covering polysilicon, pulling monocrystal, cell, system integration, PV application products and professional equipment manufacturing, some special equipment and professional materials have been localized and have been partially exported abroad. In 2007, China's PV industry has made great progress, with the total output of solar cells reaching 1088MW, accounting for 27.2% of the world's output and ranking first in the world, and there are 10 PV companies in China

In 2007, China's PV industry has made great progress, with the total output of solar cells reaching 1088MW, accounting for 27.2% of the world's output and ranking first in the world. In recent years, the manufacturing process of high-purity polysilicon, a serious constraint on the development of China's photovoltaic industry, has received a major technological breakthrough. With the strong support of the State Ministry of Science and Technology and the Development and Reform Commission and other relevant departments, three enterprises, including Xinguang Silicon, Luoyang Zhong silicon and Jiangsu Zhong Neng, have respectively built kilo-ton high-purity silicon production lines in 2007, resulting in a significant increase in the annual production of high-purity silicon in China. In 2008, Jiangsu Zhong Neng and Chongqing Daquan made major breakthroughs in reduction tail gas recycling technology and polysilicon reduction furnace manufacturing technology. As a result, the comprehensive energy consumption in the production of polysilicon will be greatly reduced, and the significant increase in production has also eased the tension between supply and demand of polysilicon in China.

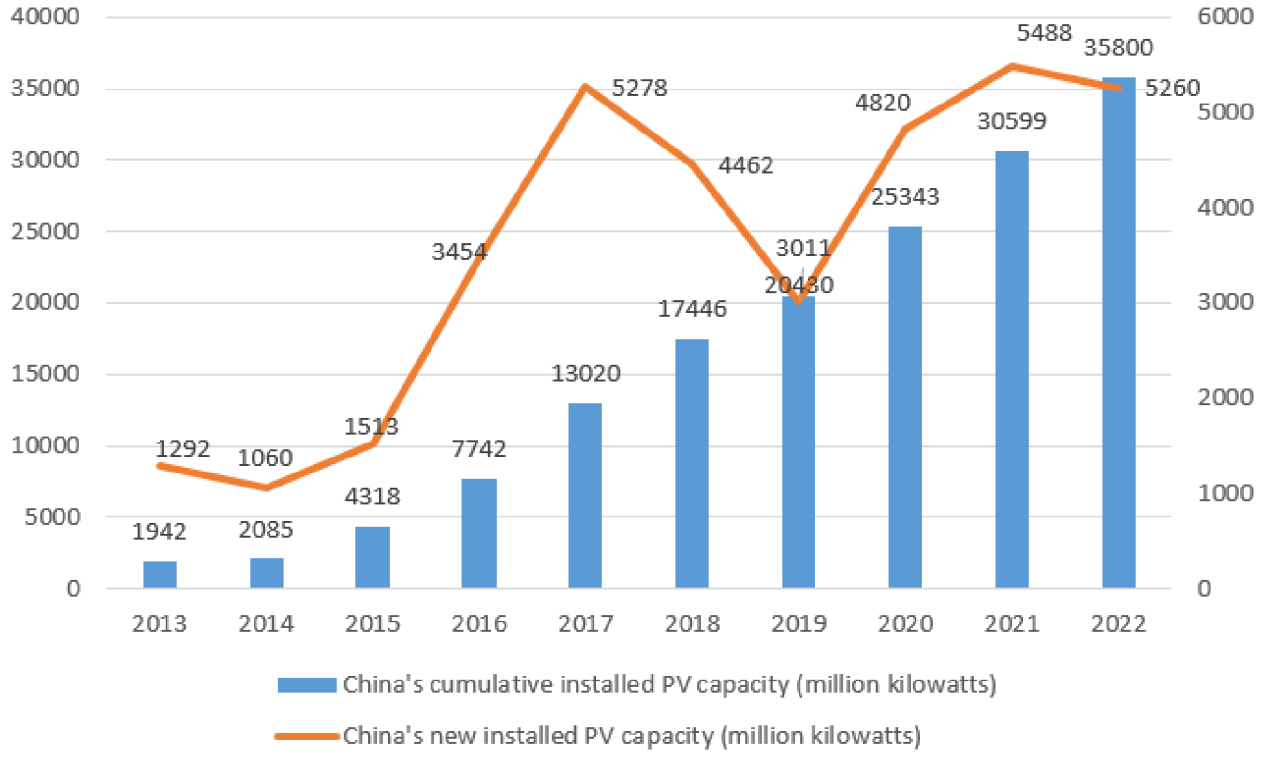

Figure 2 Photovoltaic Power Generation in China 2013-2022[34]

The chart above shows the PV generation in China, and the data for 2022 is only for the first 9 months. We can clearly see that China's cumulative installed PV capacity has grown by leaps and bounds from 1942 MW in 2013 to 30599 MW in 2021, and it can be noted that the cumulative installed PV capacity for the first 9 months of 2022 has reached 35,800 MW, which is already significantly higher than that of 2021.

There are three parts for China government to demonstrate its solutions to achieve solar power prosperity, the individual families' contribution, the cooperation between individual families and the local governments, as well as the big projects led and constructed by the governments. First, the China government tries its best to encourage individual families to apply solar power through family appliances. In this case, the governments have encouraged big enterprises to invest in researching appliances that can be supported by solar energy. The governments have boosted their motivations and actions with tax policies, e.g., tax concessions as well as solar science and technologies subsidies. In addition, the governments also help factories of the next levels for their production, with tax

[3] *Data source: National Bureau of Statistics of China, www.stats.gov.cn*
[4] *Data source: Our World in Data Organization, https://ourworldindata.org/energy/country/china*

concessions. What is more, to encourage individual families to use solar power appliances, the governments have covered 300 RMB to 1200 RMB from the price values of those appliances when one bought an item during the years 2005 to 2015. As a result, home-used solar panels and appliances like water heaters have been developed outstandingly in China and 50% of families in cities and fine-developed suburban areas have used solar products. Secondly, the governments have cultivated cooperation with individual families for the wider application of solar energy. It is reported that the China government is planning while adopting initial steps to construct solar systems around countryside fields. The farmers who own the lands can obtain payment from the governments and at the same time they can consume free electric power, and the balance of powers is applied to industries and public sectors. With this solution, the local families, as well as other power consumption in the area, can be fulfilled with renewable energy, effectively and affordably, which is relying on the rich and spare land resources in the countryside. By 2022, the scheme has shown a bright future based on abundant flexibility research and has seeded its ideas in about 10% of rural areas and received positive feedback from local governments as well as citizens.

4.2. Wind Power

China is rich in wind energy resources, land wind energy reserves month 253 million kw (land 10 meters above the ground height information calculation), the sea can be exploited wind energy reserves of about 750 million kw, a total of 1 billion kw. onshore wind power refers to the wind and resources on the road and the electricity generated. China's onshore wind distribution is concentrated in the northeast, northwest, and northern China.

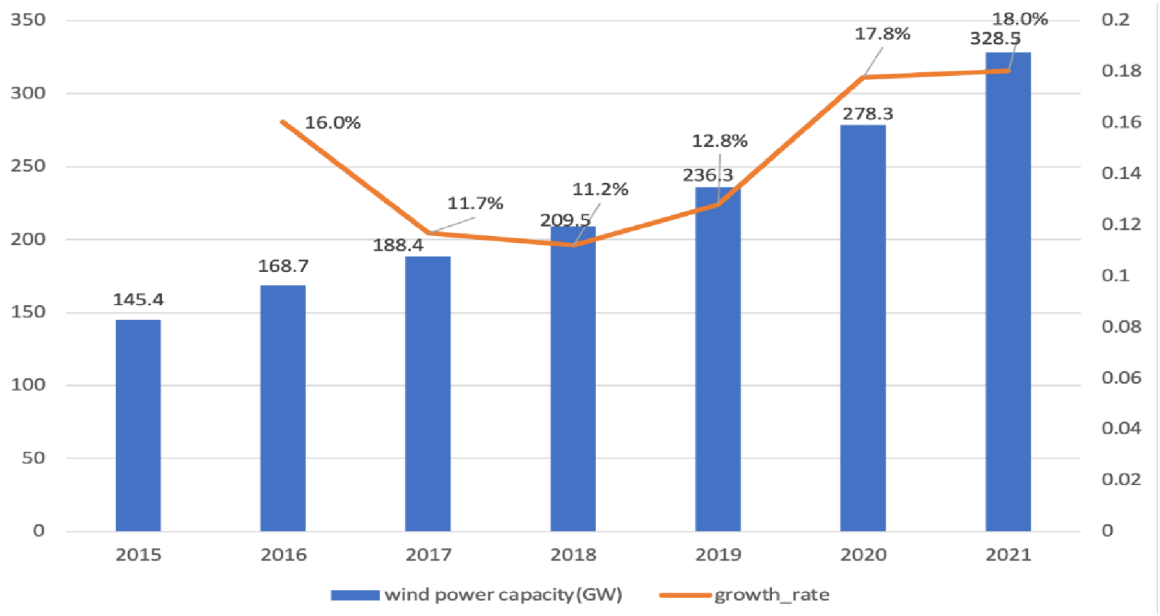

Figure 3 Installed Wind Power Capacity in China 2015-2021[5]

In the last seven years, China's installed wind power capacity has been increasing, from 145.4GW in 2015 all the way to 328.5GW in 2021, with a growth rate of greater than 10% each year compared to the previous year, with the highest growth rate of 18% achieved in 2021. China's wind power is the fastest growing and has more potential in the wind energy industry. The scale of installed capacity continues to expand, and the industry continues to mature, which has led to the transformation of the wind power industry into a subsidy-free, high-quality renewable energy industry.

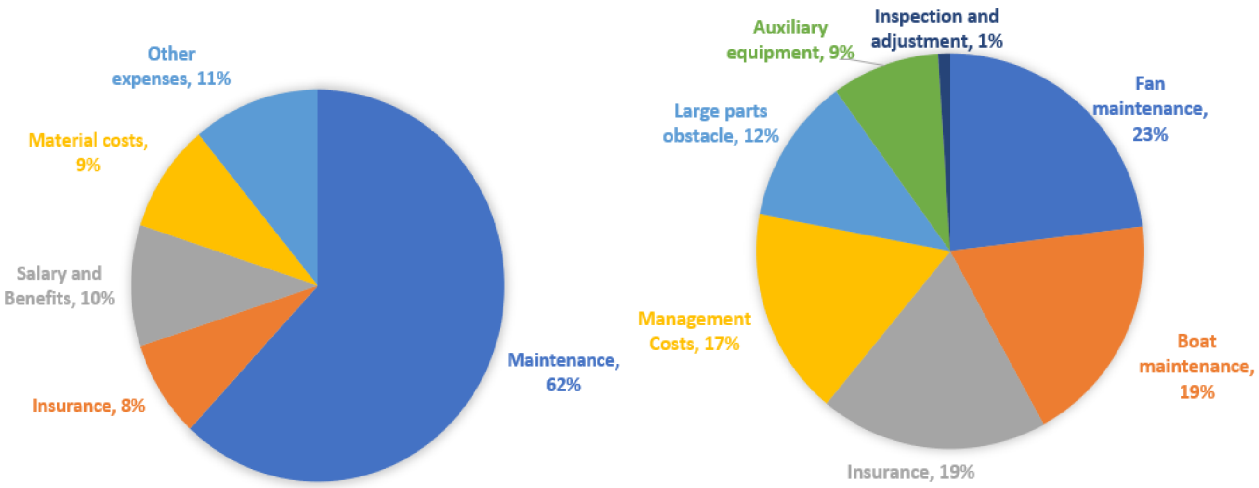

Figure 4 Cost share of power generation for Land wind vs. Sea wind[6]

[5] *Data source: National Bureau of Statistics of China, www.stats.gov.cn*
[6] *Data source: Our World in Data Organization, https://ourworldindata.org/energy/country/china*

Impact of Renewable Energy on China's economic development

China is rich in wind energy resources, land wind energy reserves month 253 million kw (land 10 meters above the ground height information calculation), the sea can be exploited wind energy reserves of about 750 million kw, a total of 1 billion kw. Onshore wind power refers to the wind and resources on the road and the electricity generated. China's onshore wind distribution is mainly concentrated in the northeast, northwest, and northern China. In the operating cost structure of onshore wind projects in China, maintenance services for onshore wind are currently mainly operational maintenance, accounting for 62% of the total, with less predictive maintenance. Chinese onshore wind turbine operational maintenance places less emphasis on data integration. Predictive maintenance based on big data analytics can significantly reduce operational maintenance costs and enhance grid integration collaboration. This predictive maintenance relies on advanced analytics, including predicting the timing, cause and effect of failures. In the future, operational maintenance for onshore wind will focus more on data integration. The core includes predictive generation, enhanced planned maintenance, and real-time feedback of maintenance information. Offshore wind is concentrated in the southeast coast. Compared to onshore wind, the biggest difference in the operation and maintenance of offshore wind is the poor accessibility and high logistics costs. Accessibility refers to the percentage of time that maritime coordination can safely access the construction area (depending on sea conditions, waves, etc.). Digital technology covers the entire offshore wind value chain and is now used in operations, supply chain, maintenance, and offshore facilities to enhance supply chain coordination. Data analysis can be used to optimize spare parts inventory and logistics transportation, and to perform fault detection and visual inspections of infrastructure.

For the wind power sector, the key word for 2021 is "equipment price reduction wave". The supply-side contraction, abundant liquidity and demand recovery and other factors, commodity prices continued to rise throughout the year, under the influence of new energy-related raw material prices also remain high. However, in the upstream price increases, downstream price parity, profit margins are squeezed in the background, wind power midstream machine manufacturing but began to reduce prices in turn. At present, the technical progress of the wind turbine is mainly reflected in the large-scale unit, and the large-scale fan is seen as the most effective path to reduce the cost of the wind power industry chain. Although the large-scale unit can indeed achieve cost reduction, but for this fast and fierce equipment price reduction, compared to technical progress, the market competition between enterprises is a more important factor. Simply put, this round of price war can be summarized as the second-line OEMs to expand the market, to seize orders to take the initiative to reduce prices, a line of

OEMs forced to passively follow the process of market pressure. At the same time, the market for offshore wind power is very wide, and currently limited by the cost, industry maturity and other conditions, the development space of the market has not been fully released. In the future, with the realization of offshore wind power price parity, the development opportunities of this market will emerge together.

4.3. Hydropower

The twelve provinces (autonomous regions and municipalities directly under the Central Government) in western China account for about 80% of the country's total hydropower resources, especially in southwest China, Yunnan, Guizhou, Sichuan, Chongqing, Tibet 5 provinces (autonomous regions and municipalities directly under the Central Government) accounted for two-thirds. these areas of the river hydropower resources concentrated, conducive to the realization of the basin terrace rolling development, conducive to the establishment of a large hydropower energy base, conducive to give full play to the scale benefits of hydropower resources to implement "West to East". China's conventional energy, hydraulic resources second only to coal, occupies an especially prominent position. From the consideration of power generation, the technically exploitable number of hydraulic resources can replace 114.3 billion tons of raw coal per year, and 14.3 billion tons of raw coal can be replaced in 100 years. Therefore, the development of hydropower resources to develop hydropower is an effective way to adjust China's energy structure, develop low-carbon energy, energy conservation and emission reduction, and protect the ecology. In addition to the benefits of power generation, hydropower projects also have comprehensive benefits such as flood control, irrigation, water supply, shipping, and tourism. Along with the development of hydropower, China's hydropower engineering survey, design and construction technology, large hydro generator set manufacturing, long-distance transmission technology, etc. has ranked among the world's advanced level. The development of the rich hydropower resources in the west is an important part of the development of the west, the implementation of the "west to east" is conducive to the optimal allocation of China's energy resources and the economic development of the western region. Therefore, hydropower construction plays a significant role in the sustainable development of China's economy and society.

Impact of Renewable Energy on China's economic development

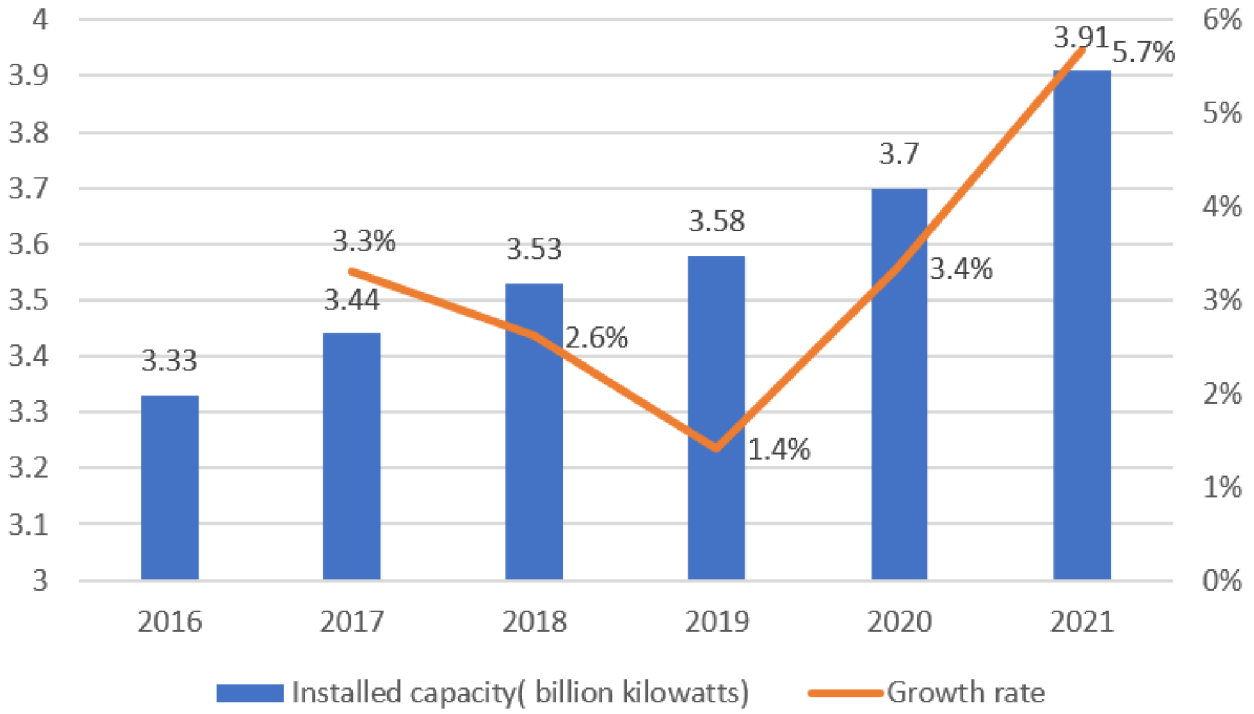

Figure 5 Installed Hydropower Capacity in China from 2016 to 2021[7][8]

In recent years, China's installed hydroelectric power generation capacity has grown year on year in recent years, from 333 million kW in 2016 to 391 million kW in 2021 (including 36 million kW of pumped storage), an increase of 5.7%. Although the growth rate drops to 1.4% in 2019, China's installed hydro capacity has continued to increase since the epidemic.

Immigration is currently the biggest difficulty in hydropower construction, facing a series of problems and making it exceedingly difficult to advance. With the gradual development of hydropower in the southwest, these areas are high and steep, lack of arable land, ecological fragility, limited resettlement capacity, coupled with a substantial proportion of ethnic minority immigrants, migration resettlement difficulties increase, migration resettlement methods are in need of innovation and standardization. At the same time, with the economic and social development, the relocation and resettlement of immigrants and local development expectations have been increasing. With the development of hydropower gradually to the west, new hydropower project's remote location, natural conditions, geological conditions, complex, backward infrastructure, difficult external transportation conditions, engineering survey, construction difficulties, hydropower project direct construction costs

[7] *Data source: National Bureau of Statistics of China, www.stats.gov.cn*
[8] *Data source: Our World in Data Organization, https://ourworldindata.org/energy/country/china*

will continue to increase. At the same time, with the social and economic development and people's living standards improve, arable land occupation tax and other tax standards, land acquisition and immigration investment increased significantly, ecological, and environmental protection investment increasing, prices continue to rise and other factors, hydropower development costs increased sharply, will to a certain extent affect the competitiveness of hydropower.

To develop water conservancy projects, China should currently improve policies and mechanisms, improve migration policies, strengthen the management of the hydropower industry, improve the project-based investment management mechanism, coordinate the independent decision-making of enterprises and the macro-control of the government, so that the state, local, enterprises and other relevant parties participate together with clear responsibilities. With the continuous development of China's basin terrace hydropower, the number of exploitable resources decreases. In the future, the basin company will also expand through a variety of ways such as development and mergers and acquisitions, and will even get involved in thermal power, nuclear power, new energy, energy conservation and emission reduction to become a comprehensive energy industry company.

4.4. The economic dilemma of renewable energy industry and suggestions

With the support of national policies, wind power, photovoltaic and other renewable energy power generation has been developed rapidly, however, influenced by factors such as insufficient renewable energy surcharge and redundant subsidy issuance procedures, the problem that renewable energy subsidies are not issued in a timely manner and are not in place is very prominent. In order to maintain the capital chain, enterprises can only try to finance, and at the same time, they will owe a lot of money to equipment manufacturers, thus forming a vicious circle, and the debt ratio of enterprises is getting higher and higher, and there are more and more enterprises in financial difficulties. If the subsidy problem and enterprise debt problem is not solved for a long time, multiple risks lead to renewable energy power plant investment income cannot be guaranteed, investors tighten power plant financing, seemingly hot domestic wind power, photovoltaic power plant market may appear a precipitous decline. At the same time, for renewable energy enterprises, the collateralized assets are limited and the growth rate of collateralized assets is much lower than the growth of enterprise financing demand; in addition, the high risk, high technology and high investment characteristics of renewable energy industry are not compatible with the principle of banks focusing on sound capital return, commercial banks take cautious credit practice for renewable energy industry for the

consideration of credit risk, the above reasons The above-mentioned reasons make it difficult for renewable energy enterprises, especially small and medium-sized enterprises, to obtain loans in banks. In the capital market, the high threshold of listing and complicated procedures makes many renewable energy enterprises unable to go public, thus unable to raise funds through the stock market, and even for those enterprises that have been listed, they cannot get enough financing due to poor business performance. At the same time, due to the unsound development of China's capital market, the funds available from venture capital are very limited and cannot support the development of renewable energy industry. The contradiction between the lack of financial support and the growth of financing demand has become the bottleneck for the development of renewable energy industry.

At present, China should simplify the procedure of granting renewable energy subsidies and improve the subsidy mechanism as much as possible. In order to solve the problem of difficult financing in renewable energy industry, it is suggested to carry out the synergistic innovation between energy To solve the problem of difficult financing for renewable energy industry, it is recommended to carry out collaborative innovation between energy industry and financial field, explore new financing methods, and promote the application of "Internet + financial leasing" in renewable energy industry. In order to solve the problem of financing for renewable energy industry, it is recommended to carry out collaborative innovation between energy industry and financial field, explore new financing methods, and promote the application of "Internet + financial leasing" in renewable energy field. In addition, for in addition, for the risks faced by enterprises in their development, it is recommended to establish a third-party assessment institution, and to establish an intelligent monitoring platform with the help of technological means. The market and capital power should be used to promote the industry's success and health. The market and capital forces can promote the superiority and healthy development of the industry. When effective supervision and a third-party certification system are established, it is recommended to establish a third-party certification system. When an effective regulatory and third-party certification system is established, the basis for insurance participation in renewable energy projects will be established. The basis for insurance participation in renewable energy projects is established. Through the reasonable application of insurance mechanism, the risk of renewable energy development can be avoided and solved. The purpose of optimizing risk management can be achieved through the reasonable application of insurance mechanisms. After the enterprise After the operational risk of the enterprise is transferred, it will help to enhance the confidence of financial institutions in renewable energy projects. The confidence of financial institutions in investing in renewable energy

projects will be enhanced, and the financing ability of high-quality projects will be continuously improved. The financing ability of high-quality projects will also be improved. In this way, the whole industry will develop in the direction of a virtuous cycle.

5. Non-Renewable Energy

Non-renewable energy sources will be exhausted or not renewed in our lifetime, or in many, many lifetimes. Coal, oil and natural gas are the main fossil fuels used as non-renewable energy sources. The main component of fossil fuels is carbon. The formation of fossil fuels occurred between 360 and 300 million years ago, hence the name Carboniferous (Aneja et al., 2017). These non-renewable energy sources are now found in large subsurface areas called reservoirs around the world. Favorable and unfavorable characteristics Fossil fuels are a major source of energy. They are not particularly expensive to extract. They may also be stored, piped, or transported anywhere in the world (Selin, 2021). However, the use of fossil fuels has a negative impact on ecosystems. Particulates may be released into the air, water, and land because of burning coal and oil. While some of these particles are collected and conserved from the air, others are released. The world's "carbon budget," which balances the carbon content of the atmosphere, oceans, and ground, is also reduced using fossil fuels. When fossil fuels are burned, carbon dioxide is released into the atmosphere （heat）. When a gas called carbon dioxide absorbs heat in the Earth's atmosphere, a phenomenon called the "greenhouse effect" occurs. The greenhouse effect is necessary for life to exist on Earth, and it depends on a balanced carbon budget. Carbon in fossil fuels has been buried or otherwise stored for millions of years. As this accumulated carbon has been absorbed from the ground and released into the atmosphere, the world's carbon budget has become unbalanced. As a result, temperatures are rising faster than organisms can adapt. Over the past three decades, China has been working to improve fossil fuel power processes. There are two main components to demonstrate the results, improving the combustion efficiency of fossil fuels and reducing pollution emissions. On the one hand, the Chinese government has guided fuel fossil power plants to achieve higher combustion efficiencies. Typically, modern furnaces with huge capacities can perform at 90% to 94% efficiency of fossil fuel properties, while in the last two decades, most fossil fuel power plants were unable to run furnaces precisely according to their theoretical properties. The efficiency of fossil fuel furnaces is only 85.30% to 88.66% due to incomplete combustion and the presence of 10% to 13% carbon in the ash. In this case, the Chinese government is focused on developing technologies to maintain stable gas pressure, temperature, and evaporation in

the furnace. Technologies are also available to allocate suitable cooling water for the reheater. In these cases, the system can have a higher heating efficiency.

5.1. Coal

China is in the middle and late stages of industrialization and urbanization, the total energy demand still has room for growth, and coal reserves account for more than 90% of China's fossil energy reserves, is a stable, economic, the highest degree of independent security of energy varieties. In the 2020 national energy work conference, the National Energy Board also stressed the need to "continue to stabilize the foundation, excellent production capacity, and effectively grasp the coal undercover security. This shows that, based on the existing resource endowment and technical conditions, in the longer-term coal will still play an important role in ensuring energy security supply and supporting economic and social development. (Medium and long-term China coal consumption forecast and outlook).

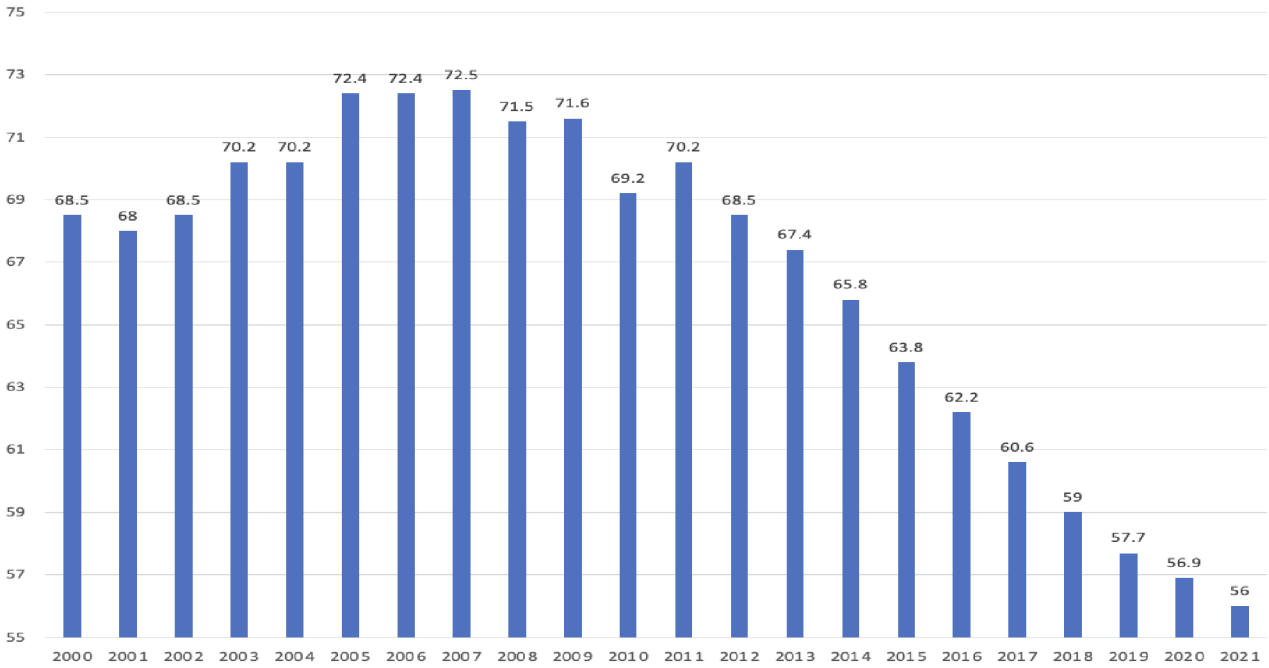

Figure 6 Energy Consumption Proportion of Coal (%) 2000-2021[9]

From the graph, we can see that the proportion of coal consumption in China is gradually decreasing, from 68.5% in 2000 to 72.5% in 2007 due to rapid economic development, but then decreasing rapidly to 56% in 2021. China is gradually strengthening its awareness of green energy in

[9] *Data source: National Bureau of Statistics of China, www.stats.gov.cn*

parallel with its economic development, and the share of coal in China's energy consumption structure is gradually decreasing as the coal industry is facing the dual challenges of environmental protection and CO2 reduction. However, based on the current situation of China's development, the future demand for coal may be large. Therefore, China is trying to build green and clean energy, and substantial capacity removal and reduction of coal consumption may need to be at the cost of slowing down the rate of capital accumulation, as well as reducing the rate of economic growth. In addition, the sustainable use of stockpiled coal and coal power assets is important to ensure a reliable supply of energy and electricity and to guarantee the stability of the industry and social development. At present, coal power is still the main power source and basic power source in China's power supply.

5.2. Oil

Contrary to the declining trend of coal consumption, oil consumption has continued to rise for many years, and the continued industrialization and urbanization of China will certainly bring about continued growth in oil demand, further leading to an increase in oil imports. This poses a huge risk to national energy and economic security

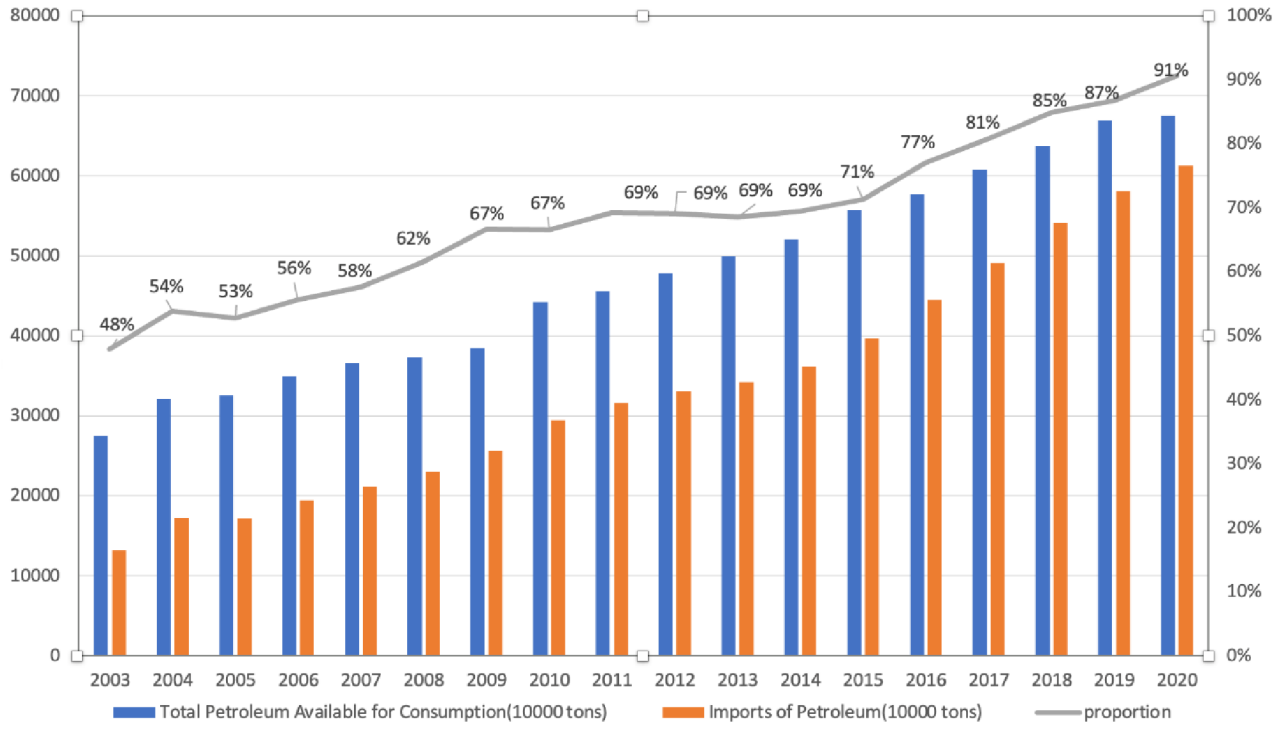

Figure 7 Total Consumption of Petroleum (10000 tons of SCE)[10]

[10] *Data source: National Bureau of Statistics of China, www.stats.gov.cn*

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As can be seen from the graph, China's oil consumption has been growing steadily, but China's oil imports are growing even more dramatically. The proportion of imports in total consumption shows that China's oil consumption is becoming increasingly dependent on imports, from 48% in 2003 to 91% in 2023, and China's oil consumption is now heavily dependent on imports. On the one hand, China is considering that its own stock of resources cannot meet the demand, and on the other hand, China is protecting its own exploitation. But this strict dependence also poses a threat to the future.

To this end, China's Energy Production and Consumption Revolution Strategy (2016-2030) calls for firm control of total energy consumption, which includes a focus on controlling total coal consumption and the increase in oil consumption. The energy mix reform and oil and gas reforms that China is undergoing provide an opportunity to peak oil consumption as soon as possible. An important part of the energy transformation in the oil and gas sector is to reduce oil extraction and consumption, increase the share of natural gas and renewable energy, and transform traditional oil and gas companies into clean, low-carbon or even zero-carbon companies, promoting a safe, efficient, green and low-carbon sustainable development path for China's oil industry.

The transportation and petrochemical sectors are the focus of oil consumption control. The transportation industry should take the direction of de-oiling, electrification and efficiency, and promote the early peak of oil consumption from both supply and demand. In the near to medium term, the focus should be on efficiency and structural adjustment, accelerating the popularization of energy-saving and new energy vehicles, speeding up the establishment and improvement of the transportation infrastructure system with high-speed railroads and public transportation as the core, and increasing the R&D demonstration and promotion of key technologies such as energy storage, fuel cells and hydrogen energy. The petrochemical field should be reduced, efficient, alternative as the direction, reduce the growth rate of oil consumption, to achieve the reduction of green provincial development. Import and export policies for petroleum products and raw materials, control the excessive growth of oil dependence on foreign countries, to ensure energy security, and achieve the main goal of ecological civilization through green and low-carbon development. (China's oil consumption peaking and total control).

5.3. Natural Gas

The natural gas industry in China is facing severe challenges in 2021 due to the ongoing impact of the new pneumonia epidemic. In terms of natural gas production, China's natural gas output is

growing steadily, but problems remain in terms of difficulties in domestic natural gas extraction, deterioration of resources, and inadequate mechanisms and institutions. In terms of natural gas imports and exports, China's total natural gas imports will grow steadily in 2021, and the sources of imports will continue to diversify.

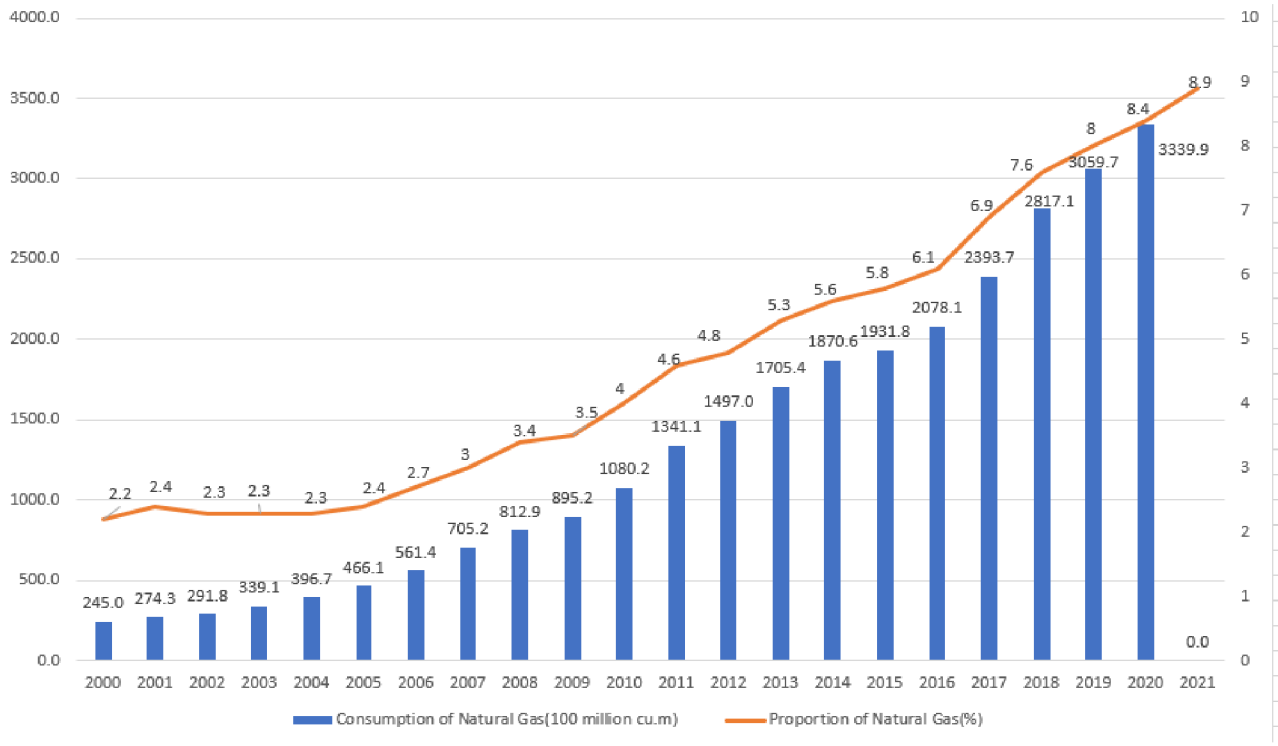

Figure 8 Natural gas consumption in China and its share in total energy consumption in China from 2000 to 2020.[11]

The graph shows that the consumption of natural gas in China has been increasing from 2000 to 2020, and the proportion of natural gas in China's total energy consumption has been flat from 2000 to 2005 but has been increasing from 2006 to 2021. From the natural gas consumption side, the scale of natural gas consumption continues to expand, and the market system is gradually improving. Overall, there are both opportunities and challenges for the natural gas industry in the new situation and landscape.

There are still some problems in the development of the natural gas industry in China, as the exploration of natural gas is increasing and the development is becoming more difficult, the technology of natural gas development and utilization still needs to be improved. Unlike other non-renewable energy sources, natural gas is also a clean energy source, so the demand for natural gas is still high as China is still undersupplied with renewable energy, but natural gas is an energy source in the world,

[11] *Data source: National Bureau of Statistics of China, www.stats.gov.cn*

especially from the New Crown epidemic to the Russia-Ukraine war, and the market price fluctuation is high, which also affects China's economy. Therefore, the future development of natural gas in China should be focused on improving core technologies, reducing operating costs and improving the overall strength of the natural gas industry.

6. Case Study: Renewable Energy Transition in Xinjiang Province

6.1. Current Energy Situation in Xinjiang Province

Xinjiang is rich in renewable energy resources and large reserves, which is conducive to promoting the continuous optimization of energy structure. Xinjiang is rich in wind, solar and other renewable energy resources. Xinjiang has nine wind regions and solar energy covering the whole area, and the reserves of both wind and solar energy resources rank among the top in China. The total storage capacity of wind energy resources ranks second in China after Inner Mongolia, with a total installed capacity of over 80 million kilowatts, and onshore wind energy resources account for nearly 40% of the national total. By the end of 2021, Xinjiang had completed grid-connected wind power capacity of 24.08 million kilowatts, up 1.99% year-on-year, ranking third in China. The total solar light resources ranked second in the country, with a total annual radiation of 5000 - 6400MJ/m2, annual sunshine hours of 2550 - 3500 hours, sunshine percentage of 60% - 80%. The distribution of renewable energy resources in Xinjiang has obvious complementary advantages. Xinjiang has a large geographical span from north to south, covering a wide area, and its nine.

There are obvious spatial and temporal complementary advantages between the major wind areas and the PV in different states. The geographical climate difference is conducive to the realization of complementary scenery and power between eastern and western Xinjiang, southern and northern Xinjiang in the day and night seasons, to maximize the use and optimize the allocation of renewable energy resources, help Xinjiang's energy transformation, and build a clean, low-carbon, safe and efficient energy system.

6.2. Difficulties of Renewable Energy Development in Xinjiang Province

Grid construction lags to limit the consumption of clean energy. As wind power and photovoltaic power generation have greater volatility, large-scale grid connection will increase the pressure of power grid peaking and frequency regulation, bringing greater challenges to the scheduling operation of the power system. Xinjiang renewable energy development is rapid, but the supporting

grid infrastructure construction is relatively lagging behind, the existing photovoltaic, wind power projects lack of energy storage and peaking facilities, peaking capacity is insufficient, which restricts the renewable energy consumption. Market system mechanism is not perfect to limit the development of distributed photovoltaic. Distributed photovoltaic as a kind of power generation can be developed nearby, local consumption, can reduce transmission and distribution costs and losses, save land resources and development costs, and effectively improve the efficiency of clean energy consumption. Although Xinjiang has developed a series of policies and incentives to promote the development of distributed photovoltaic, but due to the current electricity market mechanism is not perfect, resulting in distributed photovoltaic industry is still facing high costs, grid consumption difficulties and other problems. For example, the cost of rooftop photovoltaic power generation in Xinjiang is close to the general commercial and industrial electricity prices, higher than the price of residential electricity, so the return on investment in rooftop photovoltaic projects is limited, and investors are not motivated to develop, which limits the development of distributed photovoltaic.

Renewable energy projects in Xinjiang are mainly centralized and distributed, among which centralized photovoltaic power plants and large wind farm construction. Take wind power as an example, as the scale of wind power industry in Xinjiang continues to expand, the construction funds required by enterprises are also increasing. Wind power generation is a capital-intensive industry with huge initial investment scale, which is at a disadvantage compared with fossil energy sources such as coal and natural gas, and the construction period is long, resulting in generally high financial costs and heavy loan interest burden after the completion of wind power projects, which brings heavy debt burden to the business development of enterprises. In addition, because renewable energy financing is faced with the characteristics of large initial capital demand and long investment cycle, the financing body to avoid risks and ensure returns, tend to adopt a stable financing cooperation, enterprise financing method is relatively single, mainly debt financing, capital financing is relatively small, which will lead to the enterprise capital chain is very fragile, the enterprise capital liquidity and funding capacity is insufficient, become the impact of enterprise and industry This will lead to a very fragile enterprise capital chain and insufficient liquidity and financing ability, which will become a stumbling block to the development of enterprises and industries.

The high-quality development of renewable energy requires strong policy support. The policy of renewable energy in Xinjiang mainly focuses on the current situation, problems and paths of renewable energy development to promote energy transformation, but lacks relevant laws and

regulations to protect investors' interests, perfect market financing guarantee system, special financial system design and other supporting policies and measures, which makes investors less active and difficult to attract a large amount of social capital to enter the renewable energy industry, thus making its The development of renewable energy industry has been hindered by the lack of policies and measures to protect the interests of investors, improve the market financing guarantee system and design special financial system.

6.3. Suggestions for promoting the development of renewable energy in Xinjiang Province

Promote industrial electrification. Use rich wind, solar and other renewable energy sources to replace coal-fired thermal power generation, reduce the use of coal-fired industrial boilers and coal kilns, and vigorously promote electric boilers and electric kilns. Second, accelerate the development of green transportation. Promote the application of new energy vehicles in the field of public transportation, accelerate the construction of electric vehicle charging piles and other supporting facilities. Third, promote the electric energy substitution in residential life. In urban centralized heating, industry and commerce and other areas to promote large-scale electricity instead of coal (gas) project, to carry out electric heating instead of coal-fired boilers demonstration project. In towns, villages, urban villages, and other coal consumption areas, to encourage "coal to electricity" project, in residential buildings to encourage the use of electric heating class heating equipment, in public buildings to promote the full range of heating cables.

To further enhance the capacity of renewable energy consumption, Xinjiang also needs to accelerate the transformation of energy consumption, and constantly promote green low-carbon life, consumption patterns. First, further accelerate the construction of new energy vehicle infrastructure, promote the charging pile (station) and other supporting facilities construction; Second, in residential buildings to promote electric heating, expand coal to electricity clean heating coverage area; Third, expand the scope of electrical energy replacement, vigorously develop green intelligent scenic, green electricity to help revitalize the countryside, promote electric heating shed, electrified storage base, electrified livestock farms, aquaculture farms and other construction. Continuously broaden new energy consumption channels. Xinjiang is rich in energy resources, but due to the limited local consumption capacity and the distance from load centers such as East China and Central China, it has long been difficult to turn the advantages of resource endowment into economic advantages. Due to the

limitation of total energy consumption and the requirement of energy conservation and emission reduction, the medium and long-term power supply guarantee in the central and eastern regions will still rely more on foreign power from the region. In the short term, the "outward transmission of electricity from Xinjiang" can help the eastern region achieve the goal of carbon reduction. In the medium and long term, with the increasing proportion of new energy transmission, it can not only significantly reduce China's energy carbon emissions, but also effectively promote Xinjiang's energy transformation, ecological protection, and green sustainable economic development.

For the characteristics of renewable energy industry, green financial product innovation can effectively disperse the various risks faced by renewable energy enterprises in the financing process, solve the problems of insufficient supply of renewable energy financing, maturity mismatch and risk aggregation, which is beneficial to renewable energy enterprises.

It is beneficial to renewable energy enterprises to improve their output efficiency and technology level. First, vigorously develop green asset-backed bonds, as renewable energy enterprises have long-lasting cash flow returns and long investment recovery cycles, bonds can be issued with high-quality assets as the underlying according to this characteristic to solve the problem of maturity mismatch; second, innovate and develop green equity collateral loans, appropriately extend the loan term, relax the restrictions on collateral, and provide financial support for green key areas such as photovoltaic glass production projects, wind power and solar power generation. The second is to innovate the development of green equity collateral loans, appropriately extend loan terms, relax the restrictions on collateral, and provide financial support for green key areas such as photovoltaic glass production projects, wind power and solar power generation, and use policy instruments such as refinancing, financial subsidies, guarantee mechanisms and risk compensation to enhance the enthusiasm of financial institutions to develop green credit. Third, set up special green financial institutions or departments to provide special financial support for renewable energy industry, such as renewable energy financing consulting business, renewable energy industry investment fund operation and management, etc.

7. SWOT Analysis

The impact of renewable energy on China's economic development will be analyzed using a SWOT analysis framework, these analyses include.

7.1. Strengths

China's heavy investment in renewable energy technologies has yielded several key advantages. First, there is a high strategic priority. In addition to considering renewable energy as an important pillar of the energy revolution strategy and highlighting its significance to energy security, environmental protection and combating climate change, China also regards the development of renewable energy-related industries as an important area for cultivating new growth points and forming new dynamics, and as an important support for deepening supply-side structural reform and building a modern economic system. Second, a more complete support policy system. The government has introduced renewable energy tariff policy, i.e., timely adjustment of wind power and photovoltaic power feed-in tariff according to technological progress and cost reduction, as well as clarified relevant subsidy policy, focusing on solving the policy and management method of renewable energy grid-connected power generation. In terms of financial incentives, the government has expanded the scale of funds to support renewable energy development and improved the management process for collecting and disbursing funds. Third, China's huge market for renewable energy technologies and products and China's growing manufacturing capacity form a virtuous circle. This virtuous cycle promotes China to become the world's No. 1 in both supply and demand, i.e., renewable energy equipment production and installed capacity, and to continuously improve its independent technology level and gradually move to the high-end in the global value chain. These advantages have created a favorable environment for the development of renewable energy in China.

7.2. Weaknesses

Although China has done a lot of work in the establishment of renewable energy market, but there are still many problems, mainly in: the establishment of the perfect renewable energy market of strategic, long-term, and arduous awareness; due to the relatively high cost and product characteristics of their own reasons, renewable energy is still lack of broad social recognition and perfect market environment. In order reduce the cost as soon as possible, to overcome the restrictions of external support conditions such as power grid, must rely on continuous technological innovation and industrialization application. Although our country in renewable energy use of key technology research and development level and innovation capacity has improved, but overall and foreign developed countries are still significantly behind, mainly in: (1) weak basic research, innovative, basic research work to carry out less, late start, low level, such as photovoltaic power generation technology, cellulose

ethanol and other technologies, the lack of large-scale development of the required technical basis; (2) The lack of a strong technical research support platform to support basic scientific and technological research and the provision of public technical services； (3) the lack of a clear, systematic technology development line and long-term development ideas, no continuous, rolling investment plan for research and development; (4) the obvious lack of financial support for research and development.

7.3. Opportunities

In the renewable energy sector, China has the world's leading manufacturing capacity and high-quality production capacity, abundant capital capacity, and a large domestic market potential. China has become the world's top producer of wind turbine and photovoltaic equipment, and its international competitiveness has increased substantially. As a strategic emerging industry, renewable energy-related industries have become the pillar industries of wind and light resource provinces such as Xinjiang, Inner Mongolia, and Gansu, playing a key role in optimizing local economic structure, contributing to fiscal revenue, and creating employment opportunities. The development of renewable energy in China, including the improvement of technology level and the decrease of cost due to the expansion of market scale, has led to a significant lowering of the threshold of renewable energy utilization, which has contributed to the booming development of renewable energy in the world. In the process of transitioning to an innovative development path, China has demonstrated a sustainable development framework and shared its experience with other countries through the "Belt and Road" green cooperation, so that they can eliminate their dependence on the traditional high-carbon growth model and pursue an innovative and efficient development path with lower emissions and pollution, thus promoting a global low-carbon development transition. In the future, by deepening the global supply chain layout and specialized division of labor, and strengthening innovation in renewable energy technology R&D and business models, China will continue to reduce the cost of renewable energy technology applications, expand the market space for related technologies and products globally, reduce greenhouse gas emissions, promote economic prosperity and job creation, and achieve rebalancing of the global economy.

7.4. Threats

The rapid development of China's industry in recent years is built based on rapid investment of domestic and foreign capital. In terms of technology, China still lags behind the world's most advanced

level, and the products lack competitiveness; in terms of key processes, equipment and raw material supply, it still relies heavily on imports and is subject to the monopoly of foreign technology, such as bearings for large wind turbines, core production equipment for solar cells, and efficient biological enzymes required for cellulosic ethanol. Despite recent efforts, these situations have been improved, but from the long-term development of the industry, the weak industrial system is still an important problem plaguing the development of the industry. In addition, the biggest threat to renewable energy development in China still comes from competition from fossil fuels; fossil fuels are one of the most important energy sources, accounting for more than 86% of the world's energy consumption. Although the cost of renewable energy technologies has fallen significantly in recent years, fossil fuels still dominate the energy sector in China, and the government continues to heavily subsidize the fossil fuel industry.

8. An Empirical Analysis of Renewable Energy for China's Economy

Based on previous research on renewable energy, I have done an empirical study to explore whether the development and use of renewable energy has a significant impact on the Chinese economy by collecting data from 2000 to 2021.

8.1. Variable selection and assumptions

This empirical study discusses the relationship between renewable energy consumption and real GDP, based on the fact that annual energy consumption, both non-renewable and renewable, is growing, so I have chosen renewable energy as a percentage of total energy consumption in China. The table below is the data I collected.

Year	Real GDP (one hundred million yuan)	Employed Persons (10000 persons)	Proportion of Renewable Energy (%)	Total Investment in Fixed Assets (one hundred million yuan)
2000	100280.1	72085	7.3	32917.7
2001	110863.1	72797	8.4	37213.5
2002	121717.4	73280	8.2	43499.9
2003	137422	73736	7.4	53841.2
2004	161840.2	74264	7.6	66235
2005	187318.9	74647	7.4	80993.6
2006	219438.5	74978	7.4	97583.1

2007	270092.3	75321	7.5	118323.2
2008	319244.6	75564	8.4	144586.8
2009	348517.7	75828	8.5	181760.4
2010	412119.3	76105	9.4	218833.6
2011	487940.2	76196	8.4	238782.1
2012	538580	76254	9.7	281683.8
2013	592963.2	76301	10.2	329318.3
2014	643563.1	76349	11.3	373636.9
2015	688858.2	76320	12	405927.7
2016	746395.1	76245	13	434363.5
2017	832035.9	76058	13.6	461283.7
2018	919281.1	75782	14.5	488499.4
2019	986515.2	75447	15.3	513608.3
2020	1013567	75064	15.9	527270.3
2021	1149237	74652	16.6	552884.2

Table 1 Data collected for linear regression from 2000 to 2021[12][13]

Considering the influence factor of GDP, I collected both the number of people working and the amount of total investment in fixed assets. Real GDP is used as the dependent variable and the remaining variables are used as independent variables, and the following are the linear regression modeling and assumption details:

$y_t = f(x_1, x_2, x_3)$

y_t: Real GDP (100 million yuan)

x_1: Employed Persons (10000 persons)

x_2: Proportion of Renewable Energy (%)

x_3: Total Investment in Fixed Assets (100 million yuan)

Based on the practical implications of economics, I have made the following assumptions:

– $x_1\uparrow \rightarrow y_t\uparrow$ If the number of employed persons increases, then the real GDP also increases

– $x_2\uparrow \rightarrow y_t\uparrow$ If the number of proportions of renewable energy increases, then the real GDP also increases

– $x_3\uparrow \rightarrow y_t\uparrow$ If the number of total investments in fixed assets increases, then the real GDP also increases

[12] *Data source: National Bureau of Statistics of China, www.stats.gov.cn*

[13] *Data source: Our World in Data Organization, https://ourworldindata.org/energy/country/china*

8.2. First linear regression by Gretl

```
Model 1: OLS, using observations 2000-2021 (T = 22)
Dependent variable: y

             coefficient      std. error      t-ratio   p-value
  ------------------------------------------------------------
  const      245500            1.40356e+06    0.1749   0.8631
  X1             -4.42701      17.5124        -0.2528   0.8033
  X2          19211.9       19220.8            0.9995   0.3308
  X3              1.50017       0.377717       3.972    0.0009   ***

Mean dependent var   499445.0   S.D. dependent var   332956.4
Sum squared resid    2.59e+10   S.E. of regression   37918.33
R-squared            0.988883   Adjusted R-squared   0.987030
F(3, 18)             533.7272   P-value(F)           9.09e-18
Log-likelihood      -260.9594   Akaike criterion     529.9189
Schwarz criterion    534.2831   Hannan-Quinn         530.9470
rho                  0.683095   Durbin-Watson        0.728620

Excluding the constant, p-value was highest for variable 2 (X1)
```

Figure 9 First linear regression by Gretl

By the ordinary least squares estimation through Gretl based on the time series, and from the results we can clearly see that the total investment in fixed assets has a statistically significant and positive impact on the real GDP, which is consistent with my hypothesis, while the others are not significant. However, from the overall situation, the R-squared of the model is at 0.99, which reflects the extraordinarily strong fit of the model, while the p-value (F-test) of the model is very small, which indicates that, in general, our model is still statistically significant.

Considering that the effects of the other variables were not statistically significant, I removed x_1, which had the highest p-value, and modeled it again.

8.3. Second model adjustment by Gretl

```
Model 2: OLS, using observations 2000-2021 (T = 22)
Dependent variable: y

              coefficient     std. error    t-ratio   p-value
  ------------------------------------------------------------
  const      -109008          56590.9        -1.926    0.0692   *
  X2           23489.4         8890.13        2.642    0.0161   **
  X3               1.41304        0.150706    9.376    1.47e-08 ***

Mean dependent var    499445.0   S.D. dependent var    332956.4
Sum squared resid     2.60e+10   S.E. of regression    36972.45
R-squared             0.988844   Adjusted R-squared    0.987669
F(2, 19)              842.0449   P-value(F)            2.83e-19
Log-likelihood       -260.9984   Akaike criterion      527.9969
Schwarz criterion     531.2700   Hannan-Quinn          528.7679
rho                   0.651861   Durbin-Watson         0.782025
```

Figure 10 Second model adjustment by Gretl

In the second modeling, all variables are statistically significant, the R-square of the model remains at 0.99, showing a good degree of simulation, and the overall p-value (F-test) of the model is much less than 0.05, indicating that the model is statistically significant.

8.4. Conclusion of linear regression

With the OLS estimates established by Gretl, renewable energy consumption and total investment in fixed asset have a significant impact on real GDP and they both have a positive impact. When the consumption of renewable energy as a percentage of total energy consumption increases by 1%, the real GDP increases by 23489.4 units (100 million) and when the total investment in fixed assets increases by 1 unit (100 million), the real GDP increases by 1.41 units (100 million). As we can see, the consumption of renewable energy does have a positive and significant impact on the Chinese economy, so this again confirms that China should indeed develop and use renewable energy.

9. Conclusion

Through all the above analysis, renewable energy has a positive effect on China's economy and China should vigorously develop renewable energy technologies and promote the use of renewable energy. Make a good way to subsidize citizens with electricity price subsidies for renewable electricity and incentives to purchase renewable energy machines (e.g., cars), and give full play to the market price. Promote the role of citizens' support for renewable energy under a fully competitive, equal, and open market. At the same time, further improve the renewable energy industrial system around renewable energy technology innovation, industrial development, and service system support, etc. Establish a multi-level renewable energy technology innovation model composed of enterprises, universities, and research institutions, and cultivate a renewable energy industry system with independent intellectual property rights. The government should improve the policy coordination mechanism, strengthen the coordination of renewable energy development and land, environmental protection, forestry, and other policies, and establish a comprehensive planning system that integrates multiple regulations. Research and improve the target assessment mechanism, the implementation of renewable energy target responsibility and assessment mechanism, the establishment of medium and long-term renewable energy development target dynamic assessment and implementation supervision mechanism. Improve the market promotion mechanism, play the decisive role of market mechanism in resource allocation, and establish a renewable energy market system with diversified subjects, fair and open, and orderly competition. Improve the evaluation system for high-quality development, establish a dynamic evaluation mechanism covering planning and implementation, quality supervision, credit management, etc., and promote the healthy development of the renewable energy industry. China should also face up to and learn from the policies and mechanisms of other countries in the world, align with the standards of the international system, refer to the recommendations and guidelines of international organizations, and develop in tandem with the rest of the world.

But based on the production of renewable energy is far from meeting the consumption of raw energy in China, China should build a combined system with Chinese characteristics for excessive. If the proportion of coal decreases too fast, it will also cause a further decrease of energy self-sufficiency, which may cause a further dependence on external degree of oil and natural gas, thus affecting China's economic energy. Therefore, China needs to pay attention not only to the technology and development of renewable energy sources, but also to the clean utilization of non-renewable energy sources such as coal, which is of great significance to give full play to the advantages of China's coal resources, improve

energy efficiency, enhance environmental protection, and achieve sustainable development. From the perspective of environmental protection, the clean utilization of coal should be fully integrated with the more advanced fossil energy technologies such as oil and natural gas to form a combined transitional energy utilization technology system, which is necessary to enhance the clean utilization of coal in a faster and more economical way.

Overall, to better develop China's economy, China should continuously improve its technological development, which should be not only in renewable energy but also in the use of clean energy. In providing the energy needed for China's economic development, it is important to use clean energy as much as possible, to develop renewable energy sources, and to develop towards a better green China.

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