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Impact of Climate Extremes on Green Energy Security and Economy

– A Case Study of 2022 China Heat Wave

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Abstract: These days, climate change has intensely influenced energy security. Energy is necessary in human's daily live. Low energy security causes huge health and financial risk for people, also economic pressure on the government. This paper analyses a case study of heat wave in Sichuan, China. This paper finds that traditional methods including putting quota on industrial usage of electricity and continuing using fossil fuels have severe limitations. There are many other energy systems dependent on water. Correspondingly, this study explores some possible effective solutions, not only from the perspective of government policy, but also from the perspective of energy supply, which will provide practical ideas for solving energy problems. First, governments can ameliorate the supply structure of new energy. This ensures that there are alternative ways on power generation under extreme weather conditions. Furthermore, governments can use different tools including tax incentives and subsidies to encourage more investors participating in energy projects and motivate scientists developing new technology on sources and storage.

Keywords: heat wave, energy crisis, energy supply, extreme climate

1. Introduction

Climate changes are happening continuously, and there is interaction between it and energy security. Rise in temperature, photochemical smog and acid rain are all harming human. Energy security is concerned with these changes. Appropriate conditions on climate are required for some technology. Common wind, can affect the electric system in many countries [1]. Global warming influences hydrologic system negatively. The National Environment Commission (2020) indicated that climate change is detrimental for all sectors in Bhutan [2]. Once effect means that when one degree rose in temperature, the demand for several products tended to have large fluctuation. In recent years, the rise in temperature is significant, as a result, there is huge increment in the usage of electricity.

Because of the combination of covid-19 and limited energy sources, the inflation rate in America between 2020-2021 increases from 1.23% to 4.7% [3]. Fiscal policies, monetary policies and supply-

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side policies are used by many countries. Energy consumption plays an important role in economic growth. Energy is ubiquitous in human' s live. For instance, people can drive cars by using fossil fuel or renewable sources. Thus, energy security is essential for human's live. Unsafe use of energy can cause emergencies, and sometimes threat people's live. The consequence of the accidents can make immeasurable loss to both of households and the society. For individual households, they may face health issues and lose their source of income. Their shelters may be destroyed [4]. For the society, as people ceased and infrastructure be destroyed, some investments used on education and training and infrastructure will be wasted. In addition, the government needs to use their expenditure on compensation and reconstruction.

Furthermore, when energy security level in a country is low, social panic will occur because people do not have good standards of live, which will bring more pressure to policy makers. As mentioned at beginning, climates are vital for energy security. Most of the current research articles separate the energy crisis caused by climate change from the economic problems caused by the energy crisis, and do not connect them in series to form a complete chain [5]. Therefore, more policies that include consideration of both climate change and energy security are needed. Some scholars have investigated the relationship between oil conditions and economic development, and found that during the three oil crises, the sharp increase in oil prices greatly affected the total production of each country in that year. Since then, governments of various countries have had to formulate more perfect and strict policies on oil to ensure oil supply [6]. Nonetheless, the economic problems caused by the energy crisis that results from climate change are not concerned by many people.

Focusing on this, the paper conducted research based on the case of China's heat wave in 2022, analyzed various reasons and specific data, and found that energy problems caused by such extreme weather, especially power problems, will seriously hinder economic growth. Simultaneously, the author explores some possible effective solutions, including various perspective. First, governments can ameliorate the supply structure of new energy. This ensures that there are alternative ways on power generation under extreme weather conditions. Furthermore, governments can use different tools including tax incentives and subsidies to encourage more investors participating in energy projects and motivate scientists developing new technology on sources and storage.

2. Case Study on 2022 China Heatwave

Global warming has made the range of high temperatures and heat waves in China more and more widespread. The frequency of heat waves has increased significantly, and the number of days with extreme high temperatures has also increased significantly in most regions [7]. The 2022 China Heatwave was a recent case of extreme weather that hugely influenced the energy supply and economy in Southwest China. As a type of extreme high-temperature event, a heat wave (HW) is usually a persistent overheating phenomenon that has intensity, frequency, and duration [8]. This heatwave had multiple impacts, especially regarding electricity supply, energy production, and consumption. In this hot weather, people use more air conditioners, fans, and other cooling devices to reduce indoor temperature. This leads to rising demand for electricity, especially in urban areas, posing challenges to grid stability and power supply capacity. Moreover, in the face of high-temperature weather and pressure on the energy supply, the government and society may adopt energy efficiency and energy-saving measures to alleviate the demand and stress on energy. For example, during the 2022 China Heatwave, in Sichuan Province, some factories had to close due to an energy crisis caused by increased power consumption due to drought and heat. At the same time, the local government urgently issues relevant policies to limit and stop the supply of industrial and commercial electricity to ensure the stability of the civilian power system. Due to insufficient energy supply, these policies often sacrifice economic development to ensure the stable supply of basic civil electricity.

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At present, relevant studies have revealed the continuous negative impact of extreme weather on the energy supply and the economy. However, there needs to be more research on the threat of extreme weather to the development of green new energy and the improvement of the long-term energy structure. Because the economic impact of extreme heat waves is not directly caused by the damage caused by overheating but by a series of systemic problems in social operation caused by the instability of the energy supply. Under the current circumstances, extreme weather has the most significant impact on green new energy, such as hydropower, wind power, and solar energy. Associated model data show that the risk of summer heatwaves in Europe and China is overgrowing, with extremely high monthly temperatures doubling over the past century [8]. In the foreseeable future, extreme weather will affect green energy facilities more frequently.

However, the measure to remedy the energy shortage is often to increase the proportion of fossil energy. However, as the frequency of extreme weather increases, long-term use of this method will increase carbon emissions, accelerate climate change, and fall into a vicious cycle. Climate change and air pollution driven by fossil fuels will cause great harm to human beings. Also, continued use of fossil fuels will increase such risks [9]. Therefore, reducing greenhouse gas emissions in the energy system is an essential step in adapting to climate change, and full use of clean and sustainable energy is an irreversible trend. Therefore, it is necessary to start the research direction from the energy perspective, discover the potential harm to energy under extreme conditions, and propose practical solutions and policies to improve the supply ratio of the clean energy system. Correspondingly, the solution can no longer rely too much on the abuse of fossil energy but should further improve the stability of green new energy.

2.1. Climate Extremes Undermining Green New Energy

In this 2022 China Heatwave case, Sichuan Province had the No.1 hydropower generation in China, but the heatwave destroyed this water cycle in the summer and led to rivers being droughted. This puts Sichuan, which relies heavily on hydropower in summer, in a problematic situation regarding electricity consumption. Under the original climate conditions, Sichuan is extremely rich in water resources in summer, and summer is also the peak period of hydropower generation. It is not only necessary to ensure the electricity demand in this province but also to transmit electricity to the eastern coastal industrial belt. However, under such extreme climate conditions as 2022, this energy supply balance was broken.

The Related records showed that in the summer of 2022, the upper reaches of the Yangtze River encountered the most severe drought in the past 60 years. The droughts were mainly caused by severe shortages of precipitation and superimposed rare high temperatures. Sichuan, located in the upper reaches of the Yangtze River, experienced a particularly severe drought from July to August. In July, the province's average temperature was 25.8°C, about 2°C higher than average, which is the highest in the same period. The province's average high-temperature days were 11.7 days, 8.6 days more than the same period of average years. The province's average precipitation in July was only 99.6 mm, 50% less than the average period, the lowest in the same period in history. The province's average temperature in August was 27.4°C, which was 3.9°C higher than normal in the same period of the year, ranking first in history for the same period. The province's average precipitation in August was 104.8 mm, 40% less than average [10]. Therefore, in such extreme weather, hydroelectric power generation has been seriously affected.

First, the high-temperature weather will speed up the evaporation rate of water in the reservoir, causing the water level to drop. Falling water levels reduce the amount of water available in the reservoir, reducing the kinetic energy of the water flow and reducing the efficiency and production capacity of hydroelectric power. Secondly, the sudden drop in rainfall reduces the water resources available for hydroelectric power generation. Rivers and reservoirs in arid regions lack sufficient

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water flow, leading to a drastic reduction in power generation. To the relevant records of climate, in July, 40% of the hydropower network in Sichuan was completely depleted, and the water inflow of the Yalong River, Dadu River, Minjiang River, and Jialing River basin decreased by 38.5%, 43.5%, 45.4%, and 10.9% respectively compared with the multi-year average. In August, the degree of depletion exceeded 50%, and the inflow of the Yalong River, Dadu River, Minjiang River, and Jialing River basin was 54.6%, 51.4%, 42.2%, and 42.5% lower than the average for many years, respectively [10]. Extreme climate anomalies lead to the rare phenomenon that reservoirs are depleted during the flood season. This caused the hydropower to drop from 840 million kW h at the beginning of July to 400 million kW h, which is less than half of the power generation capacity of incoming water in normal years, and the power supply capacity has fallen off a cliff [10].

The excessive reliance on hydropower has also led to a single power structure and a poor ability to resist disasters. Sichuan is a province with a significant hydropower resource in China and an essential base for the country's "West-to-East Electricity Transmission". The province's hydropower installed capacity accounts for more than 80%, and 30% of hydropower generation will be sent to East China and Central China [10]. However, the current solutions are mainly to re-increase the proportion of fossil energy and urgently introduce a policy of power rationing. However, these two methods can only be used as a temporary emergency and do not have long-term sustainability. On the one hand, fossil energy, such as some thermal power stations using steam turbines to generate electricity, also requires a large amount of water resources to cool equipment. It will also put pressure on using local water resources during heat waves and droughts. Thermal power generation produces a large amount of greenhouse gases and pollutants such as carbon dioxide, nitrogen oxides, and sulfur oxides, which will further aggravate extreme climate and environmental pollution. On the other hand, due to the limitation of power supply, some enterprises may have to reduce production scale or adjust production plans, resulting in a decline in production capacity. Therefore, power cuts may affect the production activities of the entire economy, resulting in a slowdown in economic growth. If policies such as power rationing are used for a long time, the economic growth rate will show an L-shaped trend, and part of the growth momentum will be permanently lost.

2.2. Policy Solutions and Improvements

The traditional solutions are finite and have disadvantages. One method is putting a quota on industrial usage of electricity. This decreases the Consumption of electricity and investment in it and further decreases the aggregate demand. The need for workers is also reduced to cut costs, employees are redundant, and the unemployment rate increases. Aggregate supply will decrease, and the economy will face recession. Some economies in the slump cannot grow to their average level virtually. Another method is resuming burning fossil fuel. This enhances air pollution because pollutants, including carbon monoxide, carbon dioxide, nitrogen oxides, sulfur oxides, and lead, are produced. Moreover, the duration of the policies applied should be considered. In the short run, the negative effects are not noticeable, and people are on the way to transferring their purchasing habits as there is reaction time for people to adapt to the new policies. Both of these methods are available. Nevertheless, they are not sustainable in the long run due to their drawbacks.

To face the threat of extreme climate to green energy, new comprehensive solutions are needed to replace implements such as fossil energy and frequent power limiting. First of all, the supply structure of new energy should be optimized, not dependent on a single energy supply. In the case of the 2022 China Heatwave, the shortage of energy supply in Sichuan was caused by the vast decrease in Hydropower generation. In such an emergency, there is no other effective and stable clean energy to replace it. Using fossil energy to save this emergency has caused new environmental pollution and excessive carbon emissions. Therefore, it is necessary to carry out further improvement and comprehensive development of the energy structure and carry out risk hedging transformation. For

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example, increase the proportion of electricity generation from solar, wind, and biomass. These new energy systems are less dependent on water resources and can still guarantee regular operation and power generation in the face of high temperatures and water resource depletion. Especially for solar power generation, under high temperatures and continuous drought conditions, the power generation efficiency and capacity will be further increased, complementing and risk hedging with hydropower generation. Moreover, various new energy supply facilities can further increase supporting energy storage equipment, which can provide more flexibility for grid dispatching power under extreme weather conditions.

At present, some policies and plans have begun to promote the coordinated development of various new energy sources to ensure that the new energy system can adapt to climate change. For example, according to the "14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and Outline of Long-term Goals for 2035" and other documents, it is clearly proposed to "promote the synergy and complementarity of hydropower, wind power, and solar power in Southwest China "and "build a number of multi- Complementary clean energy base" [10]. In addition, government policies should not only rely on electricity limiting after extreme weather occurs but also should be forward-looking to encourage the development of new energy and related energy storage fields. In terms of policy incentives, the government can attract investors and enterprises to participate in the development and deployment of new energy projects by providing tax incentives, subsidies, or incentive programs. Such measures help to reduce the cost of new energy projects and improve their competitiveness.

The government can also increase financial support for new energy and energy storage technology research and development and encourage scientific research institutions and enterprises to devote more resources to research and innovate sustainable energy solutions. The government should strengthen the supervision of environmental rules and implement green environmental laws and regulations. At the same time, providing more grants to local governments will help promote green innovations and related technologies, which will ultimately help reduce energy emissions and ecological footprints [11]. Moreover, the government can promote various energy storage technologies, such as battery energy storage and water pump energy storage, to balance energy supply and demand. This will improve system stability and flexibility. These policies not only provide an economic environment for the development of new energy but also prepare for unpredictable climate risks. In general, the government needs to formulate a long-term and stable policy framework to support the development of new energy and energy storage fields. Such forward-looking measures will help mitigate the impact of climate change, promote the transformation of the energy structure, and lay a solid foundation for future sustainable development.

3. Conclusion

This paper researched the impact of climate extremes on green energy security and the economy. Also, this paper took the 2022 China Heatwave as a case to illustrate the impacts. This research has found that green new energy is often affected by climate extremes, which are prone to instability and insufficient supply, especially in areas with a single green energy structure, such as Sichuan Province. This will lead to hindering regional economic development. At the same time, the current policy solutions have unsustainable disadvantages like excessive restriction of electricity use and increasing fossil fuel use. These solutions are only emergency operations and cannot be considered long-term sustainable solutions. Therefore, this paper advocated that society needs to prepare comprehensive new energy facilities to hedge against the threat of climate extremes to a single new energy. The different kinds of green energy facilities can play the role of hedging risks. When one of the energy sources is in shortage due to extreme climate, other parts of green energy can be replaced. This would be more sustainable than direct fossil fuel replacement. Also, government policies and incentives can

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help create such sustainable, flexible, integrated, green energy systems. Some relevant policies are advancing this step.

The energy security issue is complex and diverse, and it will be different depending on geography, politics, and humanities. This article is limited to discussing 2022 China Heatwave energy security issues in Sichuan Province. For other different regions, this research's conclusions and solutions proposed may not be directly suitable. The relevant research should be analyzed according to the specific conditions of the local energy structure and economic background. Moreover, in the economic aspect, this article has not found suitable data showing the cost of the solution, and there was no intuitive cost comparison with fossil energy. Therefore, future related research could focus on the cost and long-term sustainability of integrated green energy facilities.

Authors Contribution

All the authors contributed equally, and their names were listed in alphabetical order.

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