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Hydropower Industry Development in China and United States

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Abstract: With growing concerns about global warming, climate change, and social progress, there has been a significant increase in support and concern for clean energy solutions. Among them, the hydropower industry has been the focus of attention of governments around the world. Many countries started hydropower early, establishing comprehensive industrial frameworks and policies. Moreover, emerging countries are rapidly enhancing technology to close the development gap. Together, these efforts have contributed to the sustainable development of the hydropower industry. Against this background, this paper examines the progress and future prospects of the hydropower industry in China and the United States. Through reviewing the policies and industrial patterns of the two countries, it can seen that the development potential of the hydropower industry in the two countries is huge, and each has its own characteristics. Finally, this paper advocates that China and the United States work together to achieve sustainable development goals in hydropower.

Keywords: Hydropower, China, United States, policy

1. Introduction

In the context of the rapid development of global green energy, human society is eager to replace traditional fossil energy and green energy demand. Hydropower is a mainstay and has long been hailed as one of the foundations of renewable energy production. The history of hydropower is intertwined with the development of human civilization, dating back hundreds of years to the ancient days of waterwheel-driven mills and irrigation systems. Today, as the world grapples with the urgent need to curb carbon emissions and mitigate the effects of climate change, hydropower continues to play an essential role in the future. The world's hydropower industry is at a critical juncture where industry leaders need to balance energy demand, environmental stewardship and technological innovation. Renewable energy is gaining more and more attention as a key solution to climate change and occupies a prominent position due to its reliability, scalability and relatively low carbon emissions of hydropower. However, the continued use of hydropower is not without challenges and controversy. While dams and hydroelectric plants offer significant advantages in terms of electricity generation, they also carry environmental and social consequences. The channel of water life is blocked by the river dam, which inevitably changes the living environment of fish, especially wandering fish, blocking their reproduction and spawning way, which may lead to the extinction of some fish [1]. Concerns about habitat destruction, water quality degradation and community displacement have sparked debate around the sustainability of large hydropower projects. In addition, the industry is

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under pressure to adapt to changing national policies and adopt new technologies to improve efficiency and reduce environmental impact. From small-scale rivers to large-scale reservoir schemes, the diversity of hydropower reflects a range of technological advances and operational concepts. On a global scale, the acceptance and utilization of hydropower resources varies from region to region. Countries with abundant water resources tend to rely heavily on hydropower to meet their energy needs, while others lacking suitable locations prioritize alternative energy sources. Geopolitical dynamics surrounding transboundary river basins further complicate the management and development of hydropower projects, requiring international cooperation and diplomacy. In recent years, a renewed focus on sustainability and climate resilience has driven innovation in hydropower technology and management practices. As stakeholders seek to strike a balance between energy production and environmental protection, concepts such as various types of eco-friendly power generation equipment, sediment management equipment, and ecosystem-based approaches to dam construction are gaining increasing attention in countries with high demand for hydropower. As the world continues to transition to a green energy future, the role of hydropower remains indispensable, and understanding the complexities and trade-offs of the hydropower industry is essential to gain insight into the broader challenges and opportunities inherent in the sustainable energy transition.

This report focuses on the hydropower sector, particularly in China and the United States. The rapid growth of the global economy has brought great environmental pressure. As a major resource consumer in the world, China has not effectively gotten rid of its high dependence on energy and the environment [2]. First, the development of the hydropower industry in the two countries is introduced, and how hydropower is special compared with wind and solar energy is discussed. Then, there are the rules and plans that China and the United States have developed for hydropower. Through these rules, this paper can see how serious each country is about hydropower. After that, the report takes a real look at the Chinese and American hydropower industries through a method called SWOT analysis. It looks at what they are good at, what they are not good at, and what opportunities and challenges they face. Finally, the report speculates on what might happen in the future for the hydropower industry in the U.S. and China, and explores how the two sides can better work together.

2. Comparison of Hydropower Industry Policies between China and the United States

2.1. Analysis of Chinese Water Policy

The Chinese government has long been working to expand China's hydropower capacity. According to the 14th Five-Year Plan for Renewable Energy, In the first quarter, China's renewable energy installed capacity continued to expand, the national renewable energy installed capacity of 47.4 million kilowatts, an increase of 86.5%, accounting for 80.3% of the new installed capacity. Among them, 1.21 million kw of conventional hydropower was connected to the grid, 1.5 million kW of pumped storage, 10.4 million kW of wind power, 33.66 million kW of photovoltaic power generation, and 630,000 kW of biomass power generation [3]. According to the Plan, the Chinese government will promote the construction of hydropower projects on the upper Jinsha River, the middle Yalong River, and the upper Yellow River. This Plan will develop hydropower in the lower reaches of the Brahmaputra River.

In recent years, the Chinese government has been cutting taxes and providing subsidies to the hydropower industry. In 2022, the State Administration of Taxation issued the Guiding Opinions on Preferential Tax Policies to Support Green Development, exempting some hydropower stations from urban land use tax and hydropower enterprise income tax. In an interview with the State Administration of Taxation, Luo Ling, deputy director of the accounting center of the Upper Yellow River Hydropower Development Co., LTD., said: "In the past two years, benefiting from the various preferential tax policies of the state to reduce taxes and fees, enterprises have reduced costs by nearly

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25 million yuan, saved value-added tax expenditure of 30.2 million yuan, and reduced enterprise income tax by 488 million yuan. Laying the foundation for sustainable development [4].

2.2. Analysis of American Hydropower Policy

The United States is recognized as one of the most powerful countries in the world. Since taking office, President Biden has introduced a number of policies to support the development of the U.S. hydropower industry. These policies mainly focus on the provision of financial assistance. According to the U.S. Department of Energy, in October 2022, they announced more than $28 million in grants for research and development projects aimed at advancing and protecting hydropower as a clean energy source. In addition, in March 2023, the Department of Energy announced nearly $600 million in grants to modernize hydropower and promote Marine energy development across the United States. On March 22 of that year, the Biden-Harris Administration announced more than $200 million in grants to strengthen and expand the nation's hydropower industry. In addition, in 2022, President Biden signed the Inflation Reduction Act, which includes production tax credits for renewable energy, including hydropower, and $1 billion in electricity infrastructure loans for renewable energy projects in rural America.

3. Analysis of Water Resources in China Based on SWOT Model

3.1. Strengths

Abundant Hydropower Resources: China is rich in water resources, and the total water resources in 2022 will reach 278.81 billion cubic meters [5]. The Yangtze River, Yellow River, Yarlung Zangbo River, Lancang River and other major rivers originate from the Qinghai-Tibet Plateau, the world's highest plateau, and are rich in water resources. The average elevation is over 4,000 meters [6]. The difference in elevation between the upper and lower reaches of the river gives China abundant hydropower potential.

Transportation Value: In addition to power generation, the hydropower industry has intrinsic transportation value. A case in point is the Three Gorges Dam, the world's largest hydropower station. According to the Ministry of Transport of the People's Republic of China, the Three Gorges Lock provides a huge cargo throughput and passenger service for visiting the iconic Three Gorges Dam. The hydropower industry not only generates electricity, but also has shipping value. Take the Three Gorges Dam, the world's largest hydropower station. The Three Gorges Lock has 10,148 locks with a throughput of 156 million tons, according to the Ministry of Transport, PRC. In 2022, the shipping volume of the Three Gorges hub reached 159.8 million tons, a year-on-year increase of 6.12% and another record high. Among them, the cargo volume of the Three Gorges Hub was 159.65 million tons, an increase of 6.53%; The passing volume of the Three Gorges lock was 15.618 million tons, an increase of 6.65% over the same period last year, exceeding its designed passing capacity by 56%. Three Gorges ship lift through 3.62 million tons, due to the suspension of maintenance decreased by 12.60% [7].

3.2. Weaknesses

Seasonal Differences in Precipitation: hydropower generation depends on river flow and is greatly affected by precipitation. The Yangtze and Yellow River considerations illustrate this point. In 2022, the annual variation range of precipitation in the Yangtze River basin is -46% to 40%, and that in the Yellow River basin is -50% to 93% [8]. Seasonal differences in precipitation create challenges that affect the reliability of power output.

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High Investment Costs: Building hydropower infrastructure requires significant investment. For example, the Baihetan hydropower Station, the second largest in the world, has a total investment of 220 billion yuan [9]. Financing barriers could hinder industry players, especially given the huge costs incurred in the upstream construction phase.

High Industry Entry Barriers and State Controls: There are significant barriers to overcome to enter the hydropower industry. Companies must have significant financial resources and technical expertise across upstream, midstream and downstream businesses. In addition, strict government regulations, coupled with the dominance of state-owned enterprises such as Changjiang Power and Huaneng Group, limit private sector participation.

3.3. Opportunities

China's Energy Restructuring: China's commitment to reduce its reliance on fossil fuels and shift to clean energy is a well-timed shift. In 2022, clean energy such as hydropower will account for 25.9% of total energy consumption, showing a steady upward trend. This shift highlights the broad development prospects of hydropower as a clean energy source [10].

Integration with Other Energy Sources: The ongoing exploration of the integration of hydropower with wind and solar offers a promising avenue. By coordinating these sources, China seeks to enhance renewable energy capacity and facilitate the green energy transition. The optimal scheduling and flexible adjustment of hydropower units can effectively alleviate the challenges brought by the fluctuations of wind and solar power generation and promote stable power generation.

3.4. Threats

Dangerous Geological Conditions: Currently, China boasts a total of 625 dams, with 416 situated in the western regions, constituting 66.56% of the total (comprising 32 in Guangxi, 21 in Chongqing, 155 in Sichuan, 44 in Guizhou, 100 in Yunnan, 13 in Tibet, 36 in Gansu, and 15 in Qinghai). The western parts of China lie along the Alpine Himalayan volcanic seismic belt, rendering them susceptible to frequent earthquakes. As reported by the Ministry of Emergency Management of China, mainland China experienced a total of 27 earthquakes with a magnitude of 5 or above in 2022, marking an increase from previous years' averages, with a significant concentration in western regions such as Qinghai, Sichuan, and Xinjiang. This seismic activity poses substantial threats to the hydropower industry, resulting in significant financial losses [11].

4. Analysis of American Water Resources Based on SWOT Model

4.1. Strengths

Financial Support Policies: In the Policy part, This paper shows that the United States Federal Government has given some financial support policies to help develop the hydropower industry. The federal government provides tax incentives to encourage investment in renewable energy projects, including hydropower. The Production Tax Credit have historically supported hydropower development. These credits provide financial benefits to the project developer based on the amount of electricity generated or the initial investment in the project.

Hydropower Expertise: The U.S. possesses a wealth of expertise in hydropower engineering, research, and development. Universities, research institutions, and private companies collaborate to advance hydropower technologies and address challenges related to environmental sustainability, efficiency, and grid integration.

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Abundant Water Resources: The United States boasts ample water resources, with numerous rivers and streams suitable for hydropower development. This abundance provides a reliable and consistent source of renewable energy across various regions of the country.

4.2. Weaknesses

High Degree of Privatization and Weak Risk Resistance: The top 5 hydropower companies in the United States are E Renewable Energy, Andritz AG, Siemens Energy AG, Voith Gmb & Co. KGaA, Duke Energy Corporation. All of them are private companies, which mean that when starting to lose money, these companies may quit the program, leaving the unfinished program.

Geographical Restrictions: Large rivers, like the Mississippi, are located in the central United States. It cannot provide much hydropower since the part is flat. Rivers with large drops in the United States are concentrated on the east and west sides, and their short length is not conducive to development.

4.3. Opportunities

Modernization and Upgrading: Many existing hydropower facilities in the U.S. are aging and in need of modernization. Upgrading these facilities with newer, more efficient turbines and equipment presents opportunities to increase energy generation capacity and improve overall performance. According to EIA's latest generator list, there are plans to convert 32 dams that do not currently generate electricity to hydroelectric dams, which will add more than 330 megawatts (MW) of generating capacity to the grid in the next few years. There are more than 90,000 dams in the United States, but only 3 percent currently support hydroelectric generators. As of February 2019, the total hydroelectric capacity of these generators is close to 80,000 MW. Other dams are used only for water management or navigation purposes and are known as unpowered dams (NPD) [12].

Innovative Technologies: The U.S. is at the forefront of developing innovative hydropower technologies, such as low-impact hydrokinetic turbines that generate electricity from rivers and tidal currents without the need for large dams. These technologies offer opportunities for sustainable energy production with minimal environmental impact.

4.4. Threats

The Change of Regulations: The governing philosophies of the two parties in the United States may differ. This may lead to conflicts between state and federal government policies. There may also be differences in policies and regulations between each federal government. This has led to the lack of a unified person to command the US hydropower industry, resulting in low efficiency in its development, inadequate information dissemination, and unfinished projects.

Market Competition: Hydropower generation varies from year to year, and its share of total electricity generation in the United States has generally declined from the 1950s to 2020, largely because of increases in electricity generation from other sources [13]. Hydropower faces competition from other forms of renewable energy, such as wind and solar, which have grown rapidly in recent years. Falling costs and policy incentives for wind and solar power compared to hydropower can make these technologies more attractive, especially for new projects.

Public Opposition: On April 3, 2021, mass protests took place in western Georgia following preparations to resume work on the controversial Namahvani hydropower plant. Protesters rallied to end construction, claiming that dozens of families would be forced to relocate and hundreds more could suffer adverse environmental and seismic impacts. Some hydropower projects face opposition from local communities, indigenous groups and environmental organizations due to concerns over

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land rights, cultural heritage and environmental impacts. Public opposition can delay or derail project development, causing financial losses and reputational damage to developers.

5. Conclusion

In China, the government's ambitious energy policies have driven rapid expansion of the hydropower sector. Policy initiatives such as the Five-Year Plan and significant government subsidies for hydropower provide an overall environment that is supportive of hydropower and encourages the industry to invest in large hydropower projects. This growth has also brought some challenges, including environmental degradation and the displacement of animals. Weaknesses such as environmental impact and limited public participation in the decision-making process highlight the need for greater attention in project planning and execution. However, China's abundant water resources and technological prowess offer significant opportunities for further development, especially in remote areas and major river basins. By prioritizing environmental sustainability, technological innovation and international cooperation, China can overcome its weaknesses and build on its strengths to continue to lead the global hydropower industry. The United States has a long history of hydropower development, and the country benefits from abundant water resources, well-developed infrastructure, and a diverse portfolio of hydropower facilities. However, ageing infrastructure, environmental concerns and regulatory complexities pose challenges to the growth and sustainability of the industry along with numerous opportunities. Still, the United States remains at the forefront of hydropower technology and research, and by addressing weaknesses, capitalizing on opportunities, and building on strengths, the United States can reaffirm its position as a global leader in sustainable energy production.

To sum up, the hydropower industry in China and the United States presents comprehensive advantages, disadvantages, opportunities and threats, which determine the development trajectory of the two countries. China's rapid growth underscores its commitment to energy security, limiting carbon emissions, and economic development, while the United States' longstanding expertise and innovation reflect its adaptability in the face of changing challenges. Cooperation and knowledge sharing between China and the United States have great potential to drive global advances in hydropower technology, policy, and management, paving the way for a greener, more prosperous world.

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