The Transformation of Major Power Generation Channels and Comparative Analysis of Policies in China and the United States in the Context of Carbon Neutrality

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Abstract. The primary contributor to global warming is human emissions of greenhouse gases. In order to prevent the continued warming of the global climate, the realization of carbon neutrality is a necessary way to achieve this goal. Although both China and the United States have made corresponding strategic deployments to achieve carbon neutrality, the difficulties faced by the two countries to attain the goal still need to be analyzed and resolved. This article compares the primary power generation methods and the differences in policies between the two countries over the years. It analyzes the changes and difficulties China and the United States faced in achieving carbon neutrality. Preliminary analysis shows that China and the United States generate electricity mainly through thermal power. Due to the difference in resources between the two countries, the United States uses natural gas as a raw material. In contrast, coal is the primary raw material for China's thermal power generation. China and the United States have developed ambitious policy plans to meet their respective carbon neutrality objectives. However, in contrast to China's more stable policies, the US strategy needs equivalent stability.

1. Introduction

Global action is required to tackle climate change and keep warming to 1.5 degrees. One hundred ninety-four parties, including the European Union, joined the Paris Agreement in 2016. China and the United States, two major world powers, have received much attention for their actions. Electricity powers a number of vital services, including banking, transportation, and healthcare, in all contemporary economies [1]. It would be very hard to imagine the modern societies without a secure supply of electricity [1]. Currently, the main source of carbon dioxide (CO_2) emissions worldwide comes from the power sector [2]. The United Nations reports that coal power has the highest ratings for greenhouse gas emissions, with a minimum of 751 g CO_2 eq./kWh (IGCC, USA) and a maximum of 1095 g CO_2 eq./kWh (pulverized coal, China) [3]. Therefore, the way China and the United States accelerate the energy transition and achieve a low-carbon conversion of power generation is critical to achieving carbon neutrality. According to the National Energy Administration, China will increase efforts to plan and develop power systems based on large-scale wind photovoltaic bases and speed up the construction of large-scale wind photovoltaic power generation bases, focusing on deserts and the Gobi areas. This is done to support the rapid development of new energy in the new era. Additionally, the Biden administration pledged to cut greenhouse gas emissions in the United States by 50% to 52% below 2005 levels by 2030 and net-zero by 2050 [4]. As a result of this, the United States has set a target to generate all of its electricity without releasing any pollution or carbon by the year 2035. This paper's main goals are to compare the major power generation structures of China and the United States over the last five years, to macro-analyze the current state of power generation and the transformation of major power generation in China and the United States concerning carbon neutrality, and to highlight the challenges encountered in achieving the goals in conjunction with the policies of the two countries.

2. Current situation of power generation in China

The National Bureau of Statistics reports that in 2022, China generated 8,848.71 billion kWh nationwide, with an increase of 3.7% year over year. Among them, thermal power production reached 5,888.79 billion kWh, up by 1.4% over the previous year; hydroelectric power production reached 1,352.2 billion kWh, up 1.0%; and nuclear power produced 417.78 billion kWh, up 11.3% from the previous year. Solar power generation was 427.27 billion kWh, up 31.2% from the previous year, and wind power generation was 762.67 billion kWh, up 16.2%.

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China has a growing installed base of power generation, and for five years running, the nation's total installed base of new power generation has exceeded 100 million kilowatts. The new installed capacity expanded dramatically, reaching an increase year over year of 9.5%, especially in 2020, driven by the strong growth of hydroelectric power, solar power, and wind power generation (Figure 1). Additionally, the wind power photovoltaic base project in China is progressing steadily. Since 2020, wind energy and photovoltaic power generation have had new installed capacity that has topped 100 million kilowatts thrice (Figure 2). In 2022, wind and photovoltaic power generation will surpass 1 trillion kWh for the first time, reaching 1.19 trillion kWh, an increase of 21% over the previous year. This generation will account for 13.8% of society's overall electricity consumption, roughly equal to the domestic electricity consumption of urban and rural residents nationwide [5].

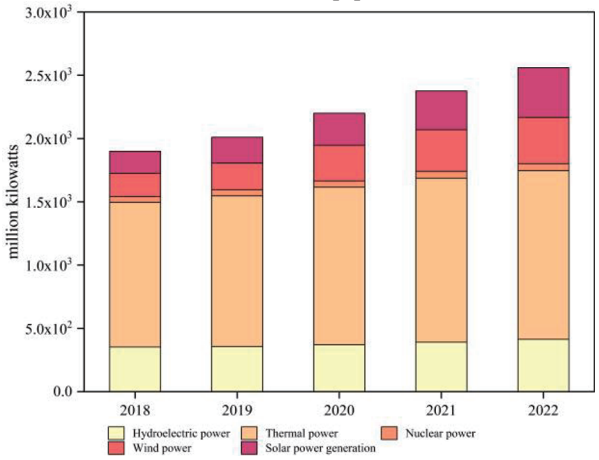

Fig. 1. Composition of China's full-caliber power generation capacity, 2018-2022. (Photo credit: Original)

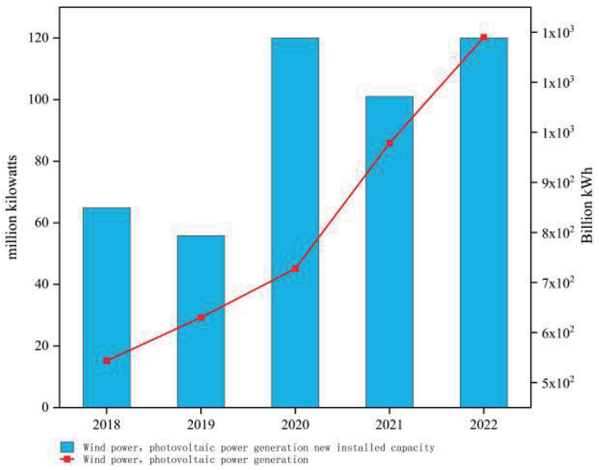

Fig. 2. The newly installed wind power and photovoltaic power producing capacity in China, 2018-2022. (Photo credit: Original)

3. Current situation of power generation in the United States

The U.S. Energy Information Administration estimates that in 2021, the nation's capacity to produce electricity will increase by 2.7% to 4115.540 billion kWh. Among them, the thermal power generation capacity was 2559.453 billion kWh or 62.19%. The capacity for producing hydroelectric power was 255.113 billion kWh or 6.20%. 379.767 billion kWh of wind energy was produced, or 9.23%. 778.152 billion kWh of electricity was produced using nuclear power, or 18.91%. The amount of solar energy generated, 114.678 trillion kWh, or 2.79%, was used. There was 28.373 billion kWh produced by other methods or 2.79%.

The United States power-generating structure has progressively altered in recent years, and the use of new energy has increased, particularly over the last five years. Burning coal is one of the most common ways to produce power in the United States. Still, natural gas and renewable energy sources are increasingly displacing coal over time as the most common method (Figure 3). One of the biggest renewable energy sources in the United States, hydroelectric power, continued to generate much electricity through 2020. Also, the capacity of renewable energy sources other than hydroelectric power is gradually increasing, particularly the capacity of wind and solar power generation (Figure 4).

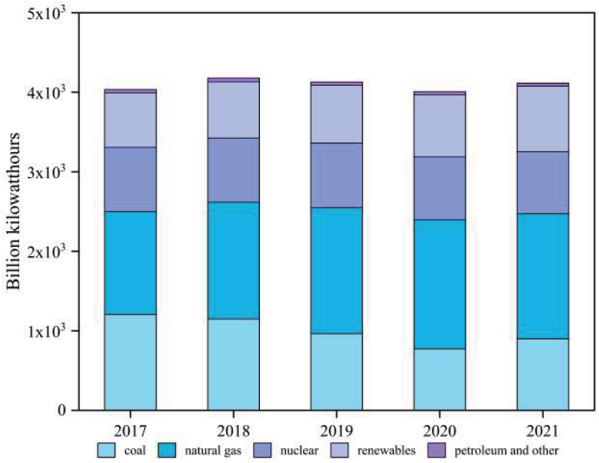

Fig. 3. U.S. electricity generation by major energy source, 2017-2021. (Photo credit: Original)

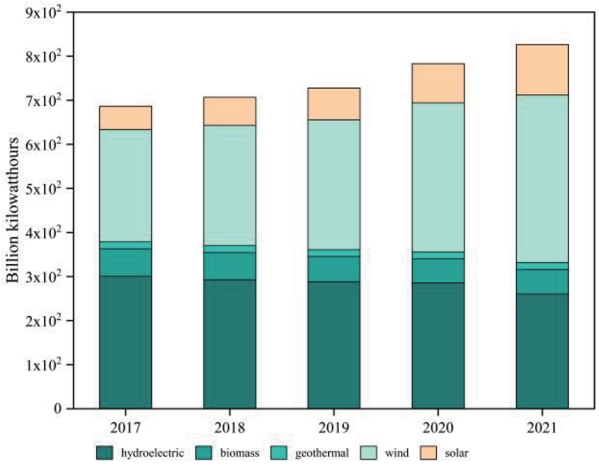

Fig. 4. U.S. electricity generation from renewable energy sources, 2017-2021. (Photo credit: Original)

4. Comparative analysis of China and the United States

4.1 Data representation and resource distribution

The National Energy Administration directly publishes annual national power industry statistics, such as those of thermal power generation, hydroelectric power, wind power generation, and other relevant data, in contrast to the United States, which does so by fuel type, such as coal, natural gas, fuel oil, etc.

Although thermal power generation still accounts for most of the world's energy output, China and the US have quite different fuel compositions. Coal-fired power generation in China, the country's primary source of electricity, accounted for 5339.1 billion kilowatt-hours in 2021 alone, or 52.1% of the world's coal-fired power output and 18.8% of the world's total power generation. Moreover, natural gas is the most significant source of electricity generation in the US, contributing 38% of the nation's electricity in 2021 via steam and gas turbines. This energy structure's composition results from the disparity in resource availability between the two countries.

Yet, as BP plc noted in its Statistical Review of World Energy published in 2020, China's reserve ratio is just 37 years, meaning that if China's production and remaining reserves remain unchanged, there will only be enough raw coal to mine for 37 years. Although this set of figures is still controversial, as a non-renewable energy source, raw coal will one day run out. Coupled with the impact of carbon emission reduction, energy structure reform, and other policies, the gradual withdrawal of thermal power generation from the Chinese market is an unchangeable fact.

4.2 China's photovoltaic power generation and American clean energy

A key component of renewable energy, photovoltaic technology is essential for accelerating the low-carbon transformation [6]. China will have over 1.2 billion kilowatts of solar and wind power capacity by 2030 at the 2020 Climate Ambition Summit. China reportedly will have 392 million kilowatts of installed photovoltaic power generation capacity by the end of 2022, placing it first in the world in terms of both newly installed capacity and cumulative installed capacity for many years a row. The National Energy Administration provided this information. China's new energy growth, exemplified by solar power generation, has produced impressive achievements in recent years. The installed capacity has consistently ranked first in the world, and the share of power generation has continuously climbed. China's solar power generation is progressively moving towards a new stage of development that is cheap and does not require subsidies due to the drop in the cost of photovoltaic power generation. However, due to the impact of COVID-19, the price of polycrystalline silicon has shown a fluctuating trend, and the polycrystalline silicon industry has no obvious willingness to expand production, resulting in an imbalance between supply and demand in photovoltaic power panels. At the same time, many studies have shown that geographical location, climate change, length of operation, etc. will affect the status of photovoltaic power generation. Different regions have different developments, resulting in different low-carbon levels, and the construction of large-scale photovoltaic bases will need more land resources. As a result, each region needs to start with its unique circumstances, carefully consider the scale of construction, carbon reduction indicators, and other influencing elements, and then develop a workable plan for the local photovoltaic power generation.

The U.S. Energy Information Administration reports that 4,090 MWh of power was generated in the country. For the first time, renewable energy sources like solar, wind, biomass, hydro, and geothermal surpassed coal-fired generation in producing electric power in 2022. Data from Power Monthly show that utility-scale wind capacity in the U.S. climbed from 133 GW in 2021 to 141 GW in 2022, while utility-scale solar installed capacity increased from 61 GW in 2021 to 71 GW in 2022. By 2030, the new utility-scale wind and solar power needed for each of the five Net-Zero America routes range from 400 to 750 GW, requiring thousands of large-scale projects [7]. According to studies, between 50 and 95 GW of additional renewable energy capacity must be added yearly in the United States during the next ten years, with most estimates lying between 60 and 70 GW annually-roughly double the 35 GW installation rate that broke records in 2020 [8]. The entire establishment of renewable energy projects currently takes an average of 7 years in the United States, per statistics. For the United States to achieve its 2030 goals, it must ensure that significant volumes of clean energy are deployed quickly. This is due to the demand for clean energy expansion and power generation. In addition, ensuring the development of the power generation end must also provide the expansion of the transmission end and ensure the stability of the transmission end. These are the problems that the United States needs to face and solve to achieve the 2030 goal.

4.3 Policies

The broad meaning of the carbon neutrality goal is to achieve the neutrality of all greenhouse gases, which requires that the CO_2 related to energy activities be deeply reduced and negative emissions by 2060 [9]. In terms of policy, the United States plans to achieve carbon neutrality by 2050, ten years earlier than China's target of becoming carbon neutral by 2060. Moreover, China's low-carbon and carbon-reduction projects started late. Changing China's power generation structure is tough if thermal power generation is gradually withdrawn from the market. China has a long way to go before its carbon emissions

peak in less than ten years, fundamentally turning around the pattern of steadily rising total emissions and becoming carbon neutral in under thirty years [10]. Although the United States has more developed clean energy technologies with their benefits, there is little time left to reach the target of becoming carbon neutral by 2050. Based on this background, the problem for the United States is how to deploy large amounts of renewable energy quickly. Second, stable policies are necessary for the accomplishment of carbon neutrality goals. Yet, U.S. renewable energy policy is as cyclical and inconsistent as climate policy due to nonpartisan politics, corporate interest groups, and leaders' personalities [11]. Obama's administration proposed a number of initiatives to demonstrate the country's commitment to combating climate change, including the Presidential Climate Action Plan and the Clean Power Plan. Trump revoked Obama-era regulations after entering office and even withdrew from the Paris Agreement. As quickly as possible after taking office, Biden returned to the Paris Agreement and announced initiatives like the Executive Order on Tackling the Climate Crisis at Home and Abroad. As a result, the United States faces a challenging challenge in establishing long-term stable policies and exercising government leadership to achieve carbon neutrality by 2050.

5. Conclusion

Achieving carbon neutrality goals is a tried-and-true strategy for reducing carbon dioxide emissions and global warming. The main power generation structures of China and the United States over the last five years are compared in this essay, along with the current state of clean energy production in China and the United States, as well as the differences between the two countries policies on carbon neutrality. According to the findings, China and the United States primarily rely on thermal power for their power generation methods. However, due to resource differences, China relies primarily on coal for its thermal power generation, whereas the United States relies mainly on natural gas. Technically, with the rapid expansion of clean energy in the United States and the rapid development of photovoltaic power generation in China, the United States and China have great opportunities to achieve their respective carbon neutrality goals. In terms of policy, the US policy is less stable than China's, which is relatively steady.

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