

Feasibility Report on China's 2060 Carbon Neutrality Target

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Abstract: Global warming is an urgent threat requiring immediate action. China's dedication to attaining carbon neutrality by 2060 is a critical development in the global climate initiative, with significant implications for environmental sustainability, economic development, and energy policy. The article provides a thorough investigation of the viability of China's ambitious objective to achieve carbon neutrality by 2060. By examining the current environmental landscape, policy frameworks, and technological advancements, the study explores China's potential to decrease the emission of carbon dioxide, enhance energetic efficiency and accelerate the transition to clean energy. The analysis identifies key opportunities and challenges, providing insights into the strategies necessary to meet its carbon neutrality goals within the stipulated timeframe.

Keywords: The Carbon neutrality, Feasibility analysis, Environmental policy.

1. Introduction

The accelerating pace of the 21st century has brought with it an escalating concern over global warming, which increasingly threatens the ecological stability of the planet. This issue is primarily driven by rising concentrations of anthropogenic carbon dioxide (CO₂), a byproduct of activities such as fossil fuel combustion, deforestation, and various industrial processes [1]. The resultant intensification of the greenhouse effect has led to significant disruptions in the Earth's climate system, manifesting in global temperature increases, erratic weather patterns, and ecological imbalances [2].

In response to this pressing environmental challenge, the concept of carbon neutrality (CN) has gained prominence as a potential strategy to mitigate the adverse impacts of climate change. Carbon neutrality, often equated with achieving net-zero emissions, refers to a state in which CO₂ emissions released into the atmosphere are effectively balanced by removal or offsetting measures [3]. This approach requires careful management to ensure that carbon emissions are reduced to levels where their net impact on the climate is neutral, with no overall increase in atmospheric CO₂ concentrations.

The urgency of addressing climate change led 197 nations to adopt the Paris Agreement, which aims to restrict global warming to a level much below 2 degrees Celsius. [4]. This international treaty provides a framework for countries to navigate the complex path toward carbon neutrality within specified timeframes. The varying developmental stages and demographic characteristics of different nations have resulted in diverse trajectories towards these goals, with Nordic countries achieving early progress, while major global economies like the United States and Germany have targeted carbon neutrality by 2050 [5].

Comparative analysis of international emissions and projected trajectories offers valuable insights into the challenges and potential solutions associated with carbon neutrality. The European Union (EU), for instance, has made notable strides in this endeavor, achieving a 30% reduction in net greenhouse gas emissions between 1990 and 2021 [6]. Preliminary estimates for 2022 indicate a further reduction of 1.9%, in line with the EU's commitment to a 48% reduction in net emissions by 2030 compared to 1990 levels [7]. However, a seven-percentage-point gap to the 2030 target underscores the necessity for accelerated action.

In 2022, the United States continued to exhibit high greenhouse gas emissions, with total emissions amounting to approximately 5,554 million metric tons of CO₂ equivalent, maintaining its position as one of the highest per capita emitters globally [8]. Despite this, the U.S. has set ambitious climate targets, aiming to reduce greenhouse gas emissions by 50-52% below 2005 levels by 2030 [9]. While its current emissions are significant, these targets reflect a commitment to substantial reductions in alignment with global carbon neutrality objectives.

China presents a distinct case, with per capita emissions slightly below the CDI average. Although its direct emissions are moderate, China exhibits negative embodied emissions in trade, reflecting emissions embedded in goods consumed elsewhere [10]. In order to achieve carbon neutrality by 2060, China aims to reach its peak carbon dioxide emissions by 2030, decrease carbon intensity by 60-65% from 2005 levels, increase non-fossil fuel energy to around 25% of primary energy consumption, and expand forest stock volume by 6 billion cubic meters[11]. Despite recent efforts to reduce emissions intensity and implement a new economic growth model, China still faces challenges in aligning with global climate targets [12].

Table 1: Comparison of Carbon Neutrality Goals and Greenhouse Gas Reduction Achievements Across Selected Countries.

	EU	US	China	Germany	Japan
Year Goal of CN	2050	2050	2060	2045	2050
Achievements in GHG Reductions	30% Reduction compared to 1990	1/3 of 2030 Reduction Target	48.4% Reduction compared to 2005	35.7% Reduction compared to 1990	16.9% Reduction compared to 2013
Current Emission Ton Per Capita	7.77	18.84	8.39	10.19	9.99

Simultaneously, China is striving to reduce existing carbon content and address environmental pollution. International comparisons reveal technological variations, with developed nations focusing on advanced carbon capture and storage technologies [13], while China emphasizes large-scale afforestation initiatives and sustainable urban planning to tackle existing pollution [14,15].

Current measures to achieve carbon neutrality include reducing reliance on fossil fuels, decreasing existing carbon content, addressing pollution, and promoting waste recycling [16]. China's commitment to reducing dependence on "brown" fuels, such as coal, aligns with the international movement towards transitioning to cleaner energy sources. This involves a shift towards more environmentally friendly alternatives like solar, wind, and nuclear energy [17]. However, China faces unique challenges due to its vast population and growing energy demand, requiring distinct approaches.

As China sets ambitious goals for achieving carbon neutrality by 2060, the global community awaits concrete milestones to gauge the nation's progress. Translating these goals into tangible

reductions in carbon emissions requires meticulous planning, technological innovation, and robust policy implementation. This essay aims to unravel these complexities, and conduct an in-depth analysis of China's current technological contributions and policy advancements in the effort of attaining carbon neutrality. Through a comprehensive examination of both quantitative data and textual summaries, the essay aims to evaluate the achieved progress. Furthermore, the focus extends to identifying the future technological domains that China should prioritize at the technical level. This strategic emphasis is crucial for optimizing efforts towards realizing the ambitious carbon neutrality goal set for the year 2060. The essay will provide scientific decision-making reference for the Chinese government and all sectors of society to facilitate the continuous achievement of the carbon neutrality objective and attain stable growth results in economic, social, and environmental aspects.

2. Background and current situation analysis

2.1. Carbon emissions in China: present state and potential tendencies

China, being one of the major contributors to global carbon emissions, holds a crucial position in the overall carbon accounting, contributing approximately 25% of all the carbon dioxide (CO₂) in the world emissions [18]. China's carbon emissions primarily originate from three key sectors: energy consumption, industrial production, and transportation[19]. Although the government's concerted efforts to mitigate emissions and improve efficiency, the country's carbon output continues to rise, encouraged by its fast economic expansion and increasing energy requirements for infrastructural development[20].

2.1.1. Energy Consumption

Energy consumption remains the predominant source of carbon emissions in China, with the country's energy mix heavily reliant on coal. In 2021, coal accounted for 60.4% of China's total energy consumption, making coal combustion the largest contributor to CO₂ emissions [21]. While the Chinese government has actively promoted the development of renewable energy sources, such as wind, solar, and hydroelectric power, the transition has been slow due to the immense scale of the country's energy needs[22]. Consequently, the share of clean energy in the overall energy mix remains relatively low, limiting its impact on reducing carbon emissions due to needs for further technological and policy improvements [22,23].

The ongoing reliance on coal poses significant challenges to China's carbon neutrality goals. Despite the construction of new renewable energy infrastructure, the sheer volume of energy required to sustain economic growth means that coal remains a dominant force in the energy sector [24]. Moreover, the construction of new coal-fired power plants, intended to meet short-term energy demands, threatens to lock in carbon emissions for decades[25].

2.1.2. Industrial Production

Industrial production is another major source of carbon emissions in China. The rapid expansion of heavy industries, such as steel, cement, and chemicals, has resulted in a substantial increase in CO₂ emissions [26]. Industrial processes alone account for nearly 30% of China's total carbon emissions, with significant contributions from both direct fuel combustion and indirect electricity use [27].

The Chinese government has implemented a series of environmental protection policies aimed at reducing industrial carbon emissions, including stricter emissions standards and incentives for adopting cleaner technologies. However, challenges remain due to inconsistent policy enforcement at local levels and the economic imperative to maintain industrial growth [28]. In some regions, local

governments prioritize economic development over environmental regulations, leading to continued high levels of industrial emissions [29].

2.1.3. Transportation

Transportation is one of the fastest-growing sectors contributing to China's carbon emissions. As urbanization accelerates and car ownership rates increase, emissions from the transportation sector have risen sharply. In 2020, transportation accounted for approximately 10% of China's total carbon emissions, with road transport being the largest contributor [30].

To curb emissions from transportation, the Chinese government has promoted the adoption of low-carbon transportation modes, including public transit systems and electric vehicles (EVs). The deployment of EVs has been particularly successful, with China now leading the world in both production and sales of electric vehicles [31]. However, the overall impact on emissions is mitigated by the fact that a significant portion of the electricity used to charge EVs is still generated from coal-fired thermal power [32]. Moreover, more comprehensive policy support and technological innovation are required to further reduce emissions from the transportation sector, particularly in areas such as freight transport and aviation.

3. Policy and regulatory analysis

3.1. The Chinese government's policies and regulations on carbon neutrality goals

The Chinese government has adopted a series of policies and regulations to promote carbon emission reduction, promote clean energy development and achieve carbon neutrality goals. These policies and regulations provide policy guarantee and market guidance for China to achieve its carbon neutrality goal, and provide strong support for carbon emission reduction and green development.

Carbon Market Construction: In 2017, the Chinese government launched the establishment of a national carbon emission trading market to promote corporate emission reduction, low-carbon technology innovation, and industrial transformation and upgrading through the establishment of a carbon trading system. Multiple studies using difference-in-differences methods have found that the ETS significantly promotes green innovation, particularly in energy and resource-based industries [33].

Energy policy adjustments: The Chinese government has stepped up its support for clean energy and introduced a series of policy measures, including increasing the proportion of renewable energy consumption, formulating renewable energy generation subsidy policies, and encouraging the development of distributed energy resources to reduce dependence on high-carbon energy sources [34].

Carbon emission reduction target setting: The Chinese government has formulated a series of carbon emission reduction targets, including energy consumption intensity, energy consumption per unit of GDP, carbon dioxide emissions per unit of GDP, etc., to achieve the goal of long-term carbon emission reduction and carbon neutrality [35].

Support for scientific and technological innovation: The Chinese government has stepped up support for the R&D and application of key technologies such as clean energy and carbon capture, utilization and storage, and encouraged scientific research institutions, enterprises and other parties to increase investment and promote technological innovation [36].

However, despite these efforts to promote clean energy usage and restructure the carbon market, China's energy consumption remains heavily dependent on coal, contributing to persistently high carbon emissions each year [37]. This reliance on coal is driven by the need to meet the substantial energy demands of China's rapidly expanding economy and large population, coupled with its relatively low cost, which also makes it an attractive energy source for other developing nations

experiencing similar rapid industrial growth [38]. Consequently, the carbon intensity of China's energy sector remains a significant challenge in achieving the nation's carbon neutrality goals. Moreover, the slow pace of transitioning from coal to renewable energy sources, coupled with the existing infrastructure of coal-fired power plants, poses substantial barriers to reducing overall carbon emissions. To address these challenges, more aggressive policy interventions, technological innovations, and accelerated deployment of renewable energy sources are essential to reduce the carbon footprint of China's energy sector and make meaningful progress toward its long-term climate objectives. Strategic approaches to achieve carbon neutrality include expanding the proportion of non-fossil energy, implementing technologies that produce negative emissions, encouraging local low-carbon growth, and creating a nationwide 'green market'. [39].

3.2. Technical feasibility analysis

The development trend of clean energy technology is to develop in the direction of more efficient, low-cost and sustainable. This includes, but is not limited to, renewable energy technologies such as solar, wind, and hydro, as well as clean energy technologies such as nuclear and biomass. With the continuous advancement of technology and the expansion of economic scale, the cost of clean energy technologies has steadily decreased, while their efficiency has significantly improved, making them increasingly the mainstream choice for replacing traditional high-carbon energy sources [40].

China has made remarkable progress in renewable energy fields such as solar, wind and hydropower, and has become one of the countries with the largest installed capacity of new energy in the world. Among these technologies, solar energy has garnered significant attention and investment. China has emerged as a global leader in solar photovoltaic (PV) technology, not only in manufacturing solar panels but also in promoting large-scale solar power projects. Over the past decade, China's photovoltaic (PV) industry has witnessed substantial development; Chinese PV production surpassed 1200 megawatts (MW) in 2007, representing 35% of the global market share and establishing China as the world's foremost PV producer [41]. The expansive solar infrastructure contributes substantially to the generation of clean and sustainable electricity. Wind energy is another pivotal component of China's clean energy landscape, witnessing substantial growth in both onshore and offshore wind farms, doubling its capacity since 2004 [42]. Hydropower, a well-established form of renewable energy, continues to play a crucial role in China's energy portfolio, where large hydropower stations contribute significantly to electricity generation, providing a reliable and clean source of energy. For example, the Three Gorges Dam, the world's largest hydropower plant with a generating capacity of 22,500 megawatts, demonstrates significant advancements in renewable energy but has also faced criticism for its ecological damage and the displacement of millions, underscoring the need to address environmental and social considerations in future green energy projects [43].

At the same time, China has also increased its support for emerging energy technologies such as electric vehicles and distributed energy resources, and promoted the widespread application and popularization of new energy technologies.

Carbon capture, storage, and utilization technologies are one of the important means to achieve the goal of carbon neutrality. China attaches great value to this technology as it has an advantage in ecosystem carbon sequestration because of the vast land it possesses, having 3.4 times of cumulative research in this field compared to Canada [25]. The Chinese government attaches great importance to the development and application of carbon capture, utilization and storage technologies, and has carried out a series of pilot projects in the energy, steel, chemical and other industries, and has gradually expanded the scale [44]. Additionally, the Chinese government has shown strong support for CCUS through policy frameworks and inclusion in national carbon mitigation strategies since the 12th Five-Year Plan [45]. With the continuous maturity of technology and the reduction of costs,

carbon capture, carbon storage and carbon utilization technologies is expected to gradually become an important means to reduce carbon emissions, which is of great significance to achieve the goal of carbon neutrality [46].

Moreover, carbon dioxide capture systems are essential not only for removing pollutants during the natural gas refining process but also for generating a range of by-products, including hydrogen (H₂), methane (CH₄), and other chemicals, which are vital for various industrial applications [47]. Another form of CCS technology involves the production of biofuels and organic products derived from biomass, although this technology has not yet fully matured, presenting high capture costs and uncertainties [48]. On the other hand, hydrogen became a versatile energy source, serving as a primary energy source in transportation and industry, while also acting as an energy carrier for applications like fuel cell vehicles and industrial processes, thereby providing a clean alternative to traditional fossil fuels [49]. Nonetheless, hydrogen fuel generated from CCS technologies and electrolysis remains a negligible fraction of the industry (Figure 1, adapted from Kumar and Lim)[49]. According to the Global CCS Institute [50], currently approximately 120 million tonnes of hydrogen are produced annually, with about 75 million tonnes being pure hydrogen and the rest mixed with other gases, primarily carbon monoxide (CO) in syngas (synthesis gas). The 2021 report also stated that the majority, approximately 98%, of current hydrogen production stems from methane reforming or non-renewable coal gasification, both of which involve fossil fuels, while only about 1% of fossil fuel-based hydrogen production incorporates CCS technologies. The limited industrial application of these by-products stems from the fact that only a few technologies can simultaneously produce high-purity hydrogen and transport-quality CO₂, presenting ongoing challenges for widespread industrial implementation and promotion [51].

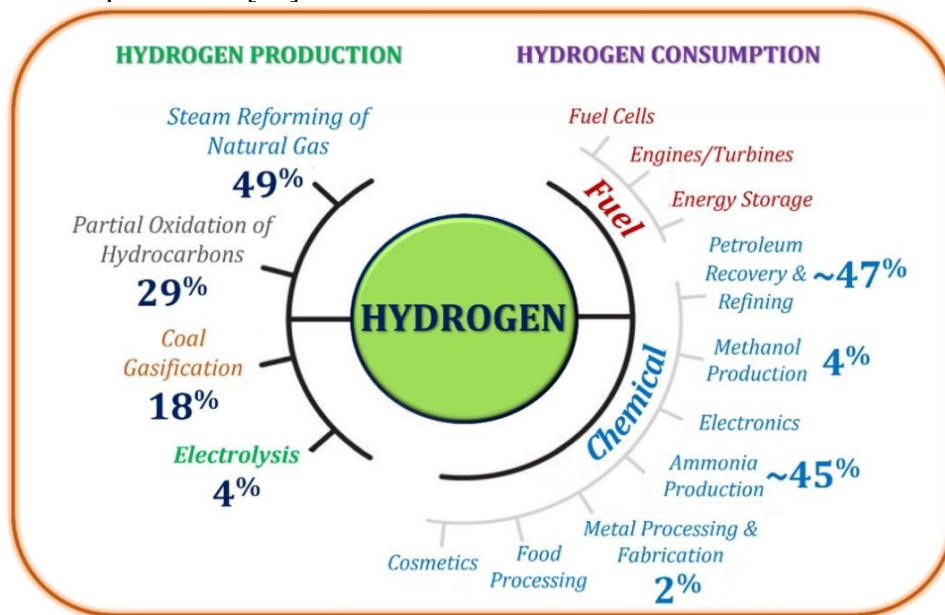


Figure 1: Major hydrogen production methods and applications (adapted from Kumar and Lim).

Furthermore, the rapid development in China has led to a substantial increase in the consumption and demand for chemical products, with methane playing a pivotal role in material production and energy security [52]. In this situation, CCU technology has the potential to function as a production method, effectively closing the disparity between the need and availability of resources [53]. Although the CCU technologies are immature, limited, and imbalanced in development, China is striving to encourage the development of CCU industrial projects, summarized in Table 2 (adapted from Zhang et al.) [52].

Table 2: Representative industrial projects of CCU technology in China (adapted from Zhang et al.).

Project	Scale ($\times 10^4$ t)	State
Production of building materials with solid waste in Anhui Province	15	Under operation
Co-production of methanol and liquified methane in Henan Province	11	Under construction
Production of fuel ethanol in Ningxia Province (Binze Tech)	6	Under construction
Production of fuel ethanol in Ningxia Province (Lanza Tech)	4.5	Under construction
Production of fuel ethanol in Beijing (Lanza Tech)	4.5	Under construction
Production of methanol in Zhejiang Province	2	Under construction
Production of minerals in Zhejiang Province	1.5	Under construction
Production of aromatic hydrocarbon in Nei Mongol Province	1	Under construction

Considering the development trends in clean energy technology, the application and promotion of new energy technologies in China, and the prospects for carbon capture, storage, and utilization technologies, it is evident that these technologies possess high technical feasibility for achieving carbon neutrality and are of significant importance to China's carbon emission reduction and green development efforts [54]. However, current technologies still face barriers and challenges that must be addressed to enable the widespread adoption of clean energy, underscoring the need for more robust policy support, incentive structures, and increased government funding.

4. Challenges and solutions

In terms of balancing socio-economic development and carbon neutrality goals, it is necessary to balance economic growth and carbon emission reduction goals in the process of achieving carbon neutrality goals. Excessive restrictions on carbon emissions may affect economic development and job growth, while excessive pursuit of economic growth may exacerbate carbon emissions and environmental pollution [55]. Governments need to develop comprehensive policy measures to balance carbon reduction and economic growth through economic, legal and market instruments. For example, the implementation of carbon emission pricing mechanisms, the establishment of carbon markets, the promotion of low-carbon technology innovation and industrial upgrading, while strengthening environmental protection and ecological restoration, to achieve a virtuous cycle of economic growth and carbon emission reduction [56].

The process of energy transition can exert a substantial influence on the configuration of conventional industries and the job landscape. Some traditional high-carbon industries may be impacted, resulting in the loss of some jobs and challenges in industrial restructuring [57]. The government needs to implement flexible job transfer training policies to help the affected workforce transition to new industries and improve their employability and competitiveness [58]. Emerging sectors like energy efficiency and electric mobility show potential for creating more local, permanent, and direct jobs compared to traditional energy generation, potentially helping to close the gender gap in the energy sector [59]. However, the transition may disproportionately affect certain regions and industries, particularly those reliant on fossil fuels [60]. Therefore, successfully managing this

transition will require a suite of policies, including structural reforms and skills development initiatives, tailored to each country's specific labor market and market structures [59,60].

In terms of capital investment and technological innovation, achieving the goal of carbon neutrality requires a large amount of capital investment and technological innovation support, including clean energy development, carbon capture, utilization and storage technology, and energy transition. However, there are certain risks and uncertainties in capital investment and technological innovation, which require the joint efforts of the government, enterprises and all sectors of society [61]. A diversified funding mechanism should be established, including government funds, market investment, social capital and other sources. At the same time, the government should enhance its support for technological innovation, motivate enterprises to increase their R&D investment, foster collaboration between academia and companies, and expedite the transformation and implementation of technological advancements.

5. Conclusions and prospects

This paper comprehensively analyzes the feasibility of China's 2060 carbon neutrality goal, proposes the path and strategy to achieve this goal, and looks forward to the possible impact and harvest of the implementation of the carbon neutrality goal in the future.

Analysis suggests that China's 2060 carbon neutrality target is likely unfeasible under the current technological capabilities, policies, and levels of governmental support. However, we should not dwell on pessimism; instead, we should view these challenges as reminders of the potential for improvement and take action to address them more effectively. In order to achieve this goal, it is necessary for the government, enterprises and all sectors of society to work together and adopt comprehensive policy measures, including strengthening the development and utilization of clean energy, promoting industrial restructuring, increasing technological innovation in carbon emission reduction, and establishing a carbon market mechanism.

Looking ahead, achieving carbon neutrality will have far-reaching impacts on China's economy, society and the environment. On the one hand, China should realize the transformation and upgrading of its energy structure, promote high-quality economic development, and enhance its international competitiveness. On the other hand, China should aim to reduce environmental pollution, improve the ecological environment, enhance the quality of life for its citizens, and promote social harmony and stability[62].

Nevertheless, challenges remain in achieving the goal of carbon neutrality, including insufficient technological innovation, inadequate capital investment, and imperfect policies and regulations. It is crucial for the government to reassess its priority objectives—whether to prioritize rapid economic growth or to build a balanced and sustainable society—as this decision will significantly influence policy direction over the coming decades. While achieving carbon neutrality may necessitate certain economic sacrifices as anticipated, enhanced support for technological innovation could enable mutually beneficial outcomes, as seen in G7 countries [63]. Furthermore, the government should meticulously design current policies to support clean energy development to minimize unintended consequences, while adopting a long-term perspective in environmental protection and future planning. Therefore, it is essential for all parties to intensify efforts, strengthen cooperation and coordination, and collectively advance the realization of carbon neutrality, contributing positively to the construction of a harmonious and sustainable modern nation.

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