IJHSR
ijhighschoolresearch.org
REVIEW ARTICLE

Policy towards a Renewable World

Sophie Xu, Parker Warburton

Future Energy Research Club, Urbana High School, 3471 Campus Dr., Ijamsville, MD 21754, USA; sophiex639@gmail.com
Mentor: Shawn Schuman

ABSTRACT: As concerns about the environmental impacts of fossil fuels increase, there is a strong push to transition to renewable energy sources, which are crucial for today's and future societies. Policy plays a vital role in promoting the development of renewable energy. In this context, we systematically analyze the policies and their impacts on renewable energy development in the United States and China, with a focus on wind and solar energy. Perspectives on future policymaking are discussed in terms of global cooperation, technological innovation, resource allocation, information exchange, and artificial intelligence. We hope this analysis will aid in developing more efficient strategies to promote the transition to a cleaner, more renewable world.

KEYWORDS: Climate Change, Renewable Energy Policies, Environmental Protection, Greenhouse Gases, Carbon Emissions, Wind Energy, Solar Energy.

Introduction

Our planet has been heavily polluted by large amounts of greenhouse gas (GHG) emissions, primarily CO_2, produced by the widespread use of fossil fuels that began in the 19th century. From 24,500 Mt in 1970 to 53,786 Mt in 2020, global GHG emissions have increased by more than 100% (Figure 1).[1] In particular, emissions have increased more rapidly due to global economic growth. This has led to severe environmental pollution and climate change, thereby presenting a major threat to our living environment. The temperature has increased by 1 °C compared to the pre-industrial era, leading to more extreme weather conditions.[2] In recent years, there have been several air pollution events that have killed thousands of people, such as the Great London Smog of 1952, the Eastern China Smog in 2013, and the severe smog in Delhi, India.[3-5] People have been more concerned with GHG emissions and have been taking action to change and stop the increasing trend of GHG emissions. Although GHG emissions are still increasing in developing countries, including China, India, Brazil, Russia, and others, they have gradually decreased in developed countries since the 21st century.[1]

With the agreement that protecting the environment is a common task for all people globally, action has begun. The Paris Agreement, a global international treaty on climate change, was established in 2015 and has been adopted by 196 parties.[6] It aims to hold "the increase in the global average temperature to well below 2 °C above pre-industrial levels" and to pursue efforts "to limit the temperature increase to 1.5 °C above pre-industrial levels." Many countries have committed to reducing greenhouse gas (GHG) emissions and setting target goals for achieving net-zero emissions, which involves balancing all types of greenhouse gases, not just CO_2. For instance, most countries aim to reach net-zero emissions by 2050, including the United States, Japan, the EU27, Brazil, and Russia. Meanwhile, China has pledged to peak its CO_2 emissions before 2030 and achieve carbon neutrality, balancing CO_2 emissions with an equivalent amount removed from the atmosphere, by 2060 (Figure 1). The essential strategy is transferring energy resources from non-renewable fossil fuels to renewable energies, such as wind, solar energy, and hydropower. This transition requires substantial societal reform and designated action from all parties to reduce and eventually eliminate the use of non-renewable fossil fuels.

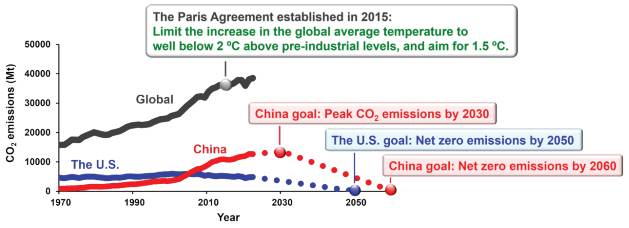

Figure 1: CO_2 emissions of global, China, and the U.S., and the targeted goals of China and the U.S. (Data sources: International Energy Agency). The Paris Agreement, a global international treaty on climate change, was established in 2015, and the U.S. and China have pledged to reduce GHG emissions and set target goals to reach net-zero emissions.

To reduce carbon emissions and promote the use of renewable energy, the United States and China, the two largest economies in the world, have implemented a series of policies to provide strong support since the 21st century. China has enacted numerous laws, regulations, and strategies to develop renewable energy technologies, achieving exceptional outcomes, particularly in the wind, solar, and hydropower sectors. The United States is also working to advance renewable energies. Federal and state governments have enacted various acts, regulations, and strategies to support the transition to renewable energy.

Here, we analyze the influence of policies in the United States and China on the development of renewable energy, focusing on wind and solar power as representative examples due to their rapid growth and renewability. We hope this can help in developing more efficient strategies to promote the transition to a more renewable and cleaner world. Besides domestic policies, the implementation of policies and the development

DOI: 10.36838/IJHSR813.89

of renewable energy technologies are largely influenced by international dynamics and geopolitics. Finally, perspectives on future policy-making are discussed in terms of technology, resources, marketing, and artificial intelligence.

Discussion

Renewable Energy Policies and Development of China:

China has been the world's largest consumer of energy since 2009.[8] To meet its energy demand, it has largely relied on fossil fuels with limited use of renewables. Accordingly, China has been the largest emitter of GHGs since 2004,[1] responsible for around one-fourth of global CO_2 emissions and facing significant air pollution problems. Although it faces substantial challenges in reducing GHG emissions without interrupting economic development, China has taken actions to address climate change. China has also made public commitments to the international community on many occasions regarding its climate change and energy development goals.

In 2009, China announced its first carbon dioxide emissions target, aiming to lower "carbon intensity" by 40%–45% by 2020 compared with the 2005 levels, with non-fossil energy accounting for about 15% of primary energy consumption.[9] In 2015, China pledged to achieve peak carbon dioxide emissions around 2030, with non-fossil energy accounting for about 20% of primary energy consumption.[10] In 2020, China announced the goal to "peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060," with a target to reduce carbon dioxide emissions per unit of GDP by more than 65% compared to the 2005 levels by 2030, and to have non-fossil energy account for about 25% of primary energy consumption.[11] To achieve these goals, a dramatic transformation in energy systems from fossil fuels to renewable energies is required.

China attaches great importance to strategic planning and leverages strategic planning's leading role, particularly the medium and long-term energy development strategies. Based on future economic needs, longer-term energy development goals are established to guide sustainable energy development. At the same time, China formulates priority development plans, action plans, and relevant laws to ensure effective implementation of these plans and achievement of these strategic objectives (Table 1). Since entering the 21st century, China has formulated a series of energy development plans, particularly for renewable energy, and has continuously adjusted its energy goals in line with economic growth. During this period, the Renewable Energy Law was introduced in 2005 to promote and regulate the development of renewable energy.[15] The most representative fields are wind and solar energy.

Table 1: Chinese plans and objectives for the development of renewable energies and the reduction of carbon emissions. China formulates priority development plans, action plans, and relevant laws, and has continuously adjusted its energy goals in line with economic growth to ensure effective implementation of these plans and achievement of these strategic objectives.

	Plans	Year	Goals
For 2010	The 11th Five-Year Plan for Energy Development (2006)[12]	2006	Reduce unit domestic energy consumption per unit of GDP by about 20% compared with 2005, and reduce the total emissions of major pollutants by 10%
	China's National Plan for Addressing Climate Change (2007)[13]	2007	
	The Renewable Energy Medium and Long-Term Development Plan (2007)[14]	2007	
For 2020	The National Medium and Long-Term Science and Technology Development Plan (2006-2020)[16]	2006	Reduce non-fossil energy to 15% of primary energy consumption and reduce carbon dioxide emissions per unit of GDP by 18% compared with the 2015 levels.
	The Renewable Energy Medium- and Long-Term Development Plan[17]	2007	
	The Energy Development Strategic Action Plan (2014-2020)[18]	2014	
	The National Climate Change Plan (2014-2020)[19]	2014	
	The 13th Five-Year Plan for Energy Development[20]	2016	
	The 13th Five-Year Plan for Renewable Energy Development[21]	2016	
	The Clean Energy Consumption Action Plan (2018-2020)[22]	2018	
For 2030	The Energy Technology Revolution and Innovation Action Plan (2016-2030)[23]	2016	Reduce the proportion of non-fossil energy in total energy consumption to reach about 20%, reduce carbon dioxide emissions per unit of GDP by 60%-65% compared with the 2005 levels, and peak carbon dioxide emissions around 2030, with efforts to achieve the peak as soon as possible.
	The Energy Production and Consumption Revolution Strategy (2016-2030)[24]	2016	
	The Carbon Peak Action Plan Before 2030[25]	2016	
	The 14th Five-Year Plan for Renewable Energy Development[26]	2021	
	The 14th Five-Year Plan for Modern Energy System[27]	2022	
	The Implementation Plan on Promoting the High-Quality Development of New Energy in the New Era[28]	2022	

Wind energy is one of the earliest renewable energy fields developed in China. Before 2003, wind energy development in China was slow and mainly relied on foreign technology. Since 2003, wind power concession bidding projects have been implemented to determine wind farm investors, developers, and grid-connected electricity prices, and a stable cost-sharing system was established through the implementation of the Renewable Energy Law and its rules, rapidly increasing the value of wind power (Figure 2). The National Development and Reform Commission has supported and encouraged the development of the domestic wind power manufacturing industry through policies such as wind power concession operations, requiring the localization ratio of domestic wind power projects to be no less than 70%,[29] and has brought the development of the domestic wind power market to a stage of rapid development. In 2004, imported equipment accounted for 90% of the wind power equipment installed nationwide; in 2007, newly added domestic wind power equipment exceeded imported equipment, accounting for 55.9%; in 2010, domestic wind power equipment installed nationwide accounted for 90%.[30] Although this policy was stopped in 2009, domestic technology has matured, wind power development continued to progress, and wind turbines began to be exported. To date, China has become a major player in the global wind power manufacturing industry. The development process of wind power equipment is also a typical development process of China's manufacturing industry, involving first introducing

international technology, then absorbing and innovating, and finally developing independently.

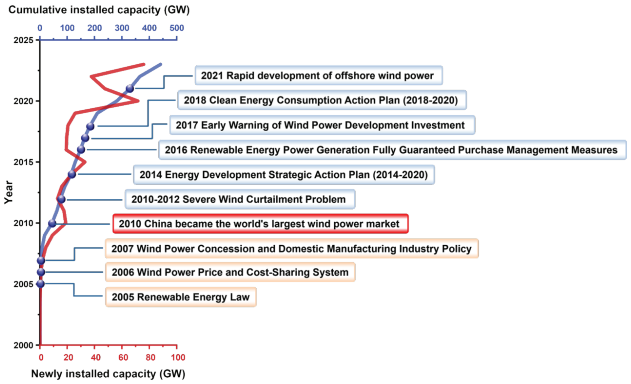

Figure 2: New and cumulative installed capacities of wind power in China with development marks. The policies enacted by the Chinese government have significantly promoted the development of wind energy.

In the development process of wind power in China, the wind power price and cost-sharing system have played a significant role in promoting the industry (Figure 2). In 2006, a wind power price and cost-sharing system was implemented, where the portion of the wind power grid-connected power price that is higher than the benchmark grid-connected power price of local thermal power units is settled by levying a price surcharge on power users.[31] This electricity price sharing system has been extended to 2020. Since 2008, on the basis of concession bidding, a benchmark electricity price policy for onshore wind power grids has been introduced. According to the revised Renewable Energy Law, a fully guaranteed purchase system for renewable energy power generation was required to address challenges related to large-scale wind power grid connection and market consumption. Due to insufficient coordination between developers and grid operators, China experienced a serious wind curtailment problem after 2010, with some wind power not being connected to the grid.[32] In 2012, the national average wind curtailment rate reached 17.1%. Wind farm developers' income from electricity sales shrank, affecting investment in new wind power projects. Wind power development slowed down relatively in the following years. The main reasons for the wind curtailment problem included imperfect wind power construction planning, with wind farms mainly built in economically underdeveloped areas; backward power grid construction, which prevented wind power from being exported; and a planned power distribution system with low dispatch levels. To address the wind curtailment issue, the Chinese government introduced a series of policies to promote sales, such as the Energy Development Strategic Action Plan (2014-2020) (2014), the Renewable Energy Power Generation Fully Guaranteed Purchase Management Measures (2016), and the Clean Energy Consumption Action Plan (2018-2020) (2018).[22,33-35] The implementation of these policies has significantly improved the consumption of renewable energy. In 2020, the national average wind power utilization rate reached 96%, effectively solving the problem of wind power consumption. Starting from 2021, newly approved onshore wind power projects will fully achieve grid parity, and the state will no longer provide subsidies, gradually establishing an electricity market system and mechanism that adapts to new energy power generation. China has been leading in wind power in terms of newly added capacity and equipment production each year, and has become a major player in the international market.[36]

China has developed rapidly in the field of solar energy. In the early years of the 21st century, China became a major solar cell manufacturing country, although it still lagged in solar energy applications compared to Germany and the United States. However, this situation reversed after 2010. China has formulated a series of policies to promote the development of solar energy. Since 2010, China has ranked first in the world in newly installed solar power capacity every year. In 2013, China surpassed Germany for the first time, becoming the world's largest photovoltaic application market. China is also the largest country in the solar equipment industry and dominates the international solar market. According to data from the International Energy Agency (IEA), China produced 80% of the world's solar panels, 85% of solar cells, and 97% of solar wafers in 2023.[37]

China's achievements in renewable energies not only contribute to addressing climate change but also enhance its status as an economic and technological power. The development pathway of renewable energy in China has established a model for effectively addressing climate change and achieving a sustainable world. Key points for creating a new market system include strong policy support, setting long-term technological and market goals, advancing technology, enhancing investment, expanding the market, and enforcing consumption. However, given its high dependence on government decisions and policies, China requires a smart government that formulates the right strategies.

Renewable Energy Policies and Development of the United States:

The U.S. is the second-largest global consumer of energy and greenhouse gas emitter, producing 6,343 million metric tons of carbon dioxide equivalents, which accounts for 13.49% of global emissions.[2] With rapidly increasing energy consumption and a growing population, energy demand is soaring. In 2022, non-renewable resources, such as natural gas, accounted for approximately 39.8% of U.S. energy generation, while renewable energy contributed only 21.5%.[38] Rising concerns about greenhouse gas emissions and environmental pollution have driven the U.S. to intensify its transition to renewable energy. This shift is crucial, as the dependence on non-renewable energy sources remains a significant issue. Recently, the U.S. has been implementing numerous policies, commitments, and plans to address these challenges.

In 2015, the U.S. joined the Paris Agreement with 195 other countries to address carbon emissions and promote global renewable energy goals.[6] To ensure progress, the U.S. has set several ambitious targets, including reducing emissions by 65% by 2030, transitioning to 100% carbon pollution-free electricity by 2030, reaching 100% zero emissions for vehicle acquisitions by 2035, and finally achieving net-zero emissions by 2050.[39]

DOI: 10.36838/IJHSR813.89

As one of the leading nations in renewable energy development, the U.S. has a long history of involvement in this field (Figure 3). The debate on clean energy in the United States has evolved significantly since the establishment of the Environmental Protection Agency (EPA) in 1970.[40] The EPA plays a crucial role in creating and enforcing regulations to ensure that energy production does not harm the environment or public health. Before the EPA, the groundwork for environmental regulation was laid by earlier legislation such as the Air Pollution Control Act of 1955 and the Air Quality Act of 1967.[41] These acts initiated federal efforts to address air pollution, providing funding for research and establishing early regulatory frameworks. The 1970 Clean Air Act, which amended the original 1963 version, introduced the National Ambient Air Quality Standards (NAAQS).[41] These standards, enforced by the EPA, set limits on harmful pollutants in the air, marking a significant milestone in air quality protection. Following the establishment of NAAQS, states were required to develop their own state implementation plans to ensure compliance. In addition to air quality regulations, the EPA also implements New Source Performance Standards (NSPS),[42] which set guidelines for controlling emissions from new sources of pollution.

In 1975, the Energy Policy and Conservation Act was enacted in response to the oil crisis, which increased the demand for renewable energy.[43] In 1980, a decade after the establishment of the EPA, the Energy Security Act was signed into law, marking a significant step in the United States' response to the increasing demand for renewable energy. This comprehensive legislation introduced various energy policies aimed at promoting renewable sources, including biomass, solar, and hydroelectric energy. The Energy Security Act recognized the need for a more diverse set of renewable technologies to enhance energy security and reduce dependence on fossil fuels.[44] By fostering advancements in these areas, the act aimed to encourage innovation and investment in renewable energy sources, setting the stage for the more expansive development of clean energy technologies in the years to come.

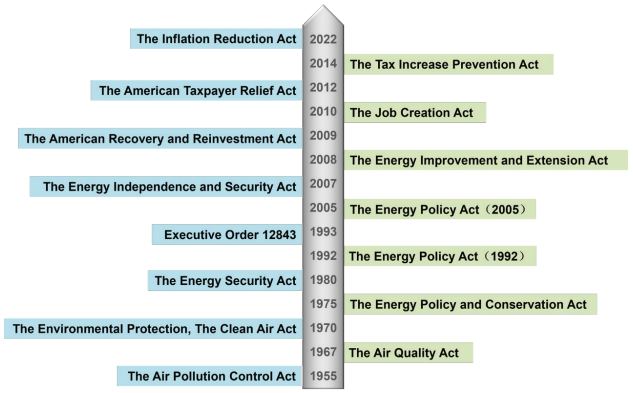

Figure 3: Major U. S. polices for the development of renewable energies. The U.S. government has implemented numerous policies, commitments, and plans to address climate change and carbon emissions, as well as to promote the development of renewable energy.

In 1992, the Energy Policy Act was enacted, further advancing the United States' commitment to renewable energy.[45] This legislation not only focused on promoting renewable sources but also aimed to reduce reliance on petroleum by encouraging the use of alternative fuels. Following this, in April 1993, Executive Order 12843 was issued, establishing procurement requirements for federal agencies regarding ozone-depleting substances.[46] This order was a direct response to the United States' ratification of the Montreal Protocol in 1987, which aimed to phase out the use of substances harmful to the ozone layer.[47] The executive order directed federal agencies to transition to alternatives to these substances, reinforcing the government's commitment to environmental protection and sustainability. Together, these initiatives reflected a broader strategy to address energy security and environmental concerns through legislative and regulatory measures.

Entering the 2000s, the United States intensified its renewable energy initiatives with a series of strategic policies. The Energy Policy Act of 2005 introduced comprehensive regulations encompassing energy research, efficiency, taxation, and renewable technologies.[48] It set specific targets for sectors like wind, biomass, and solar energy while encouraging homeowners to install solar equipment and promoting the purchase of clean energy vehicles. This marked the first comprehensive energy policy update since the turn of the century, significantly influencing the nation's energy landscape. As a result of these concerted efforts, the contribution of renewable energy to electricity generation increased markedly, rising from 9% in 2005 to 22% in 2022.[38] During this period, U.S. policy heavily focused on providing financial incentives to stimulate the adoption and development of renewable energy sources.

Recent regulations have indeed played a crucial role in advancing the development of renewable energy in the U.S. Since the 2010s, there has been a notable shift towards enhancing public awareness and establishing renewable energy as a national priority. The government has introduced significant investments and incentives to support this transition. Key legislative measures, such as the American Taxpayer Relief Act of 2012,[49] the Tax Increase Prevention Act of 2014,[50] and the Inflation Reduction Act of 2022,[51] have been pivotal in providing financial incentives like tax credits and loans for renewable energy projects. The Inflation Reduction Act, for example, includes provisions for energy storage development under the Powering Affordable Clean Energy program,[52,53] highlighting the government's commitment to fostering innovation in renewable technologies. These initiatives are complemented by state-level regulations that further promote renewable energy development, ensuring a comprehensive approach to achieving sustainability goals across the nation. The focus on financial support mechanisms, such as loans and tax incentives, is essential for encouraging both private entities and local governments to invest in renewable energy infrastructure.

Wind energy is an essential renewable energy source in the US, comprising about half of the US's total renewable energy use. Since the first large windmill by Charles F. Brush in 1888, the sector has expanded dramatically. Since 2005, the U.S. has seen a rapid increase in installed wind power capacity, resulting in a significant rise in wind power generation. From 2005 to 2022, wind power capacity in the U.S. grew twenty-fourfold.[38] In addition, the U.S. is revitalizing its offshore wind initiatives,

adding 2-6 GW of new offshore wind capacity each year.[54] The Offshore Wind Energy Strategy aims for 30 GW by 2030 and 110 GW by 2050, with an expected cumulative installed capacity of 11.5 GW by 2026. The average annual installed capacity projections highlight continued growth, with 2.9 GW expected from 2022-2026, 4.6 GW from 2026-2030, and 4.0 GW from 2030-2050.

In parallel, solar energy is emerging as the fastest-growing renewable energy source in the United States, fueled by rapidly decreasing costs and fiscal incentives such as the Inflation Reduction Act.[52] Since 2012, the U.S. has experienced a remarkable increase in installed solar power capacity, with a thirty-threefold growth from 2012 to 2022.[55] This surge has led to a significant rise in solar power generation across the country. In 2023, the U.S. installed 35.3 GW of photovoltaic (PV) systems, a significant jump from 23 GW in 2022.[56] This rapid expansion has pushed the total installed solar capacity in the country beyond 100 gigawatts, providing around 5% of the nation's electricity. To support this growth, the Federal Solar Investment Tax Credit (ITC) offers a 30% tax deduction on solar installation costs for homeowners from 2022 through 2032, encouraging further adoption of solar energy.[57]

The share of wind and solar energy in the United States' renewable energy consumption surged from 2% in 2001 to 28% in 2022, representing nearly one-third of total renewable energy use.[58] However, the U.S. still lags behind global benchmarks. While global renewable energy generation has increased sixfold, the U.S. share of renewable capacity decreased from 18.3% in 2012 to 11.8% in 2022.[58,59] This indicates an urgent need for stronger policy measures to promote domestic renewable energy development. The Inflation Reduction Act aims to reduce U.S. greenhouse gas emissions by 40% by 2030 compared to 2005 levels,[52] but achieving this goal will require sustained focus on advancing wind and solar power.

Remarks on the Renewable Energy Development of the United States and China:

As global leaders in renewable energy development, the United States and China exhibit many similarities in their strategies. Both nations are among the top greenhouse gas emitters globally, which drives their commitment to transitioning from conventional fossil fuels to renewable energy. They have implemented extensive policies, plans, and financial support to achieve a substantial increase in renewable energy use within the next few decades, including a rapidly growing share of renewable energy in their total energy consumption.

Both the United States and China embarked on their renewable energy development journeys in the late 20th century. Initially, they faced significant challenges, including difficulties in meeting set goals and a lack of established research frameworks. Acknowledging the need for substantial investment and strong political backing, both countries worked to overcome these obstacles to progress their renewable energy agendas.

Despite these similarities in their approaches to renewable energies, there are notable differences in their strategies.

China's approach focuses on domestic development in the early stages. Initially, China attracts global technology, often requiring that manufacturing and technology transfer occur within its borders. With low manufacturing costs, robust supply chains, and supportive policies, China quickly establishes and expands markets, often advancing its technology beyond the initial innovations. The powerful government ensures rapid policy formulation and effective implementation, contributing significantly to greenhouse gas reduction and climate change mitigation. China's policies mostly followed the process of trying to convert all technology and markets to domestic, either requiring their own domestic factories to engage or allowing other countries to establish their factories in China. By trying to lead all existing technology onto its land, China aims to evaluate and support domestic renewable energy development. In order to attract leading technologies, China offers financial incentives globally, giving everybody an opportunity. This strategy also promotes the development of new technologies and global markets. China has become a major player in renewable energies, including wind, solar, lithium-ion batteries, and electric vehicles, and will play a critical role in climate change.

The United States also provides strong political support for renewable energy. The U.S. government promotes the adoption of renewable energy through state programs and industry incentives. But it takes a more selective approach to technology incorporations. Concerns about over-reliance on foreign technology and risks of monopolistic control form the US's selective strategy for domestic development. This selective strategy ensures that all domestic technologies remain accessible. But developing new technologies without corporations can be resource-intensive, requiring significant financial and political support, and it faces challenges in balancing immediate renewable energy development needs with long-term technological projects. For instance, the Inflation Reduction Act offers subsidies of up to $7,500 for new energy vehicles to encourage their development and reduce carbon emissions. However, this subsidy comes with conditions: clean energy vehicles involving foreign entities of concern (FEOCs) in the production of batteries or critical minerals are ineligible for these tax exemptions. Countries of concern include China, Iran, North Korea, and Russia. Given China's dominance in producing lithium batteries, electric vehicles, wind turbines, solar cells, and other key materials, excluding it from eligibility could pose significant challenges. Finding suitable alternatives in the short term may be difficult, potentially slowing the development of clean energy in the U.S. and impacting climate change goals. However, while the selective strategy is challenging, it ensures the security and accessibility of currently owned technologies.

Both China and the United States face challenges in grid integration, energy storage, and transmission capacity for wind and solar power. In China, the main issue is the mismatch between renewable generation and demand, leading to energy curtailment. To address this, China is investing in long-distance transmission and energy storage. In the U.S., outdated grid infrastructure limits renewable integration, prompting

DOI: 10.36838/IJHSR813.89

efforts to modernize the grid and incentivize storage technologies.

The development of lithium batteries illustrates another key difference between China and the United States, as these batteries are crucial for enabling high levels of renewable energy integration into modern power systems. The inherent intermittency and variability of solar and wind power create operational challenges, and battery energy storage systems offer an efficient solution to balance generation and demand. China follows a state-led industrial strategy, embedding battery development into its long-term economic planning. Instead of relying mainly on market price signals, Chinese authorities use administrative mandates, direct subsidies, and preferential financing to boost both manufacturing capacity and grid deployment. As of now, China controls 70% of the global market for batteries and electric vehicles. In contrast, the United States primarily employs market-based incentives within liberalized electricity markets. The Inflation Reduction Act provides tax credits for standalone storage and domestic battery manufacturing, aiming to attract private investment while maintaining competitive market dynamics. Regulatory reforms by the Federal Energy Regulatory Commission are working to eliminate market barriers and allow energy storage to compete in wholesale electricity markets.

These distinct policies and strategies reflect the countries' differing priorities and strategic goals, showcasing how each nation approaches global environmental challenges and the promotion of renewable energy.

Conclusion

The challenge of climate change demands a unified global response involving extensive cooperation across various sectors. To ensure sustainable development and effectively combat climate change, countries must work together in key areas. Addressing these areas collectively will be crucial for achieving long-term global goals and overcoming the barriers currently hindering progress. Political factors play a critical role in shaping renewable energy policies, and the following aspects should be considered for future policymaking to promote renewable energy development (Figure 4). Well-designed policies are anticipated to accelerate renewable energy development, reduce carbon emissions, protect the environment, and ultimately drive economic growth.

Figure 4: Future policies toward a renewable world. To promote renewable energy development, policies should focus on global cooperation, technology innovation, resource allocation, information exchange, and the integration of artificial intelligence.

(1) Global cooperation:

Countries should develop policies that consider not only their national interests but also the broader global impact. This involves transcending political and ideological barriers to prioritize collective human needs. International agreements, such as the Paris Agreement, offer a framework for global policies. However, the current political landscape often prioritizes national benefits, which can impede global progress. To enhance cooperation, global policies should be designed to support development worldwide and ensure that all nations can contribute to and benefit from advancements in renewable energy.

(2) Technology innovation:

No single nation possesses all the advanced technologies needed for renewable energy development. To address this, countries must collaborate to overcome technical barriers and facilitate the global development of these technologies. While protecting intellectual property rights is important, there should be increased efforts to share and access advanced technologies through global platforms and international collaborations. This will enhance productivity and accelerate technological progress in renewable energy, benefiting the global community as a whole.

(3) Resource allocation:

The uneven distribution of resources presents a significant challenge to global renewable energy development. Essential materials for modern technology are not evenly distributed across countries, leaving some nations struggling to access the resources they need. Recognizing that natural resources belong to all of humanity, they should be managed and shared more equitably. Unified policies and international trade agreements can help address local shortages and promote widespread renewable energy development, ensuring that all countries have access to the resources required.

(4) Information exchange:

The availability of skilled professionals greatly influences the advancement of renewable energy technology. Progress in this field relies on knowledge exchange, particularly through the collaboration of experts such as engineers, technicians, scientists, and other specialists. By leveraging global expertise, countries can overcome individual limitations and drive collective progress. Knowledge exchange facilitates technology sharing and collaboration, exemplified by initiatives like international climate agreements. Such cooperation can significantly enhance renewable energy development and foster global advancements.

(5) Artificial intelligence:

Artificial Intelligence (AI) has substantial potential to advance renewable energy development by optimizing resource use, enhancing technological processes, and fostering global collaboration. AI can analyze data to manage energy intermittency, optimize the placement of renewable energy infrastructure, and improve resource distribution. Integrating AI into renewable energy development can tackle challenges

related to cost and resource management, resulting in more effective and widespread adoption of renewable energy technologies. Additionally, AI can optimize materials systems and device configurations, supporting global efforts to combat climate change and promote sustainable development.

Acknowledgments

The authors thank Mr. Shawn Schuman for supervision.

References

1. EDGAR, Emissions database for global atmospheric research, 2023, https://edgar.jrc.ec.europa.eu/report_2023. Accessed August 1, 2025.
2. IPCC, Special report: global warming of 1.5 ºC, https://www.ipcc.ch/sr15/chapter/chapter-1/. Accessed August 1, 2025.
3. London government. 70 years since the great London smog, 2022, https://www.london.gov.uk/programmes-strategies/environment-and-climate-change/environment-and-climate-change-publications/70-years-great-london-smog. Accessed August 1, 2025.
4. Fang Huang, Renjie Chen, Yuetian Shen, Haidong Kan, Xingya Kuang. The impact of the 2013 eastern China smog on outpatient visits for coronary heart disease in Shanghai, China, International Journal of Environmental Research and Public Health, 2016, 13, 627. https://doi.org/10.3390/ijerph13070627.
5. Dyani Lewis, Why is Delhi's air pollution so bad right now? Nature, 11, 10, 2023. https://www.nature.com/articles/d41586-023-03517-1.
6. United Nations, Paris Agreement, 2015, https://www.un.org/en/climatechange/paris-agreement. Accessed August 1, 2025
7. Climatewatch, Net-Zero Tracker, https://www.climatewatchdata.org/net-zero-tracker. Accessed August 1, 2025.
8. International Energy Agency, China: World's largest energy consumer; surpasses the U.S. 2010, https://www.instituteforenergyresearch.org/fossil-fuels/coal/china-worlds-largest-energy-consumer-surpasses-the-u-s/. Accessed August 1, 2025.
9. Government Documents of China, Action targets for controlling greenhouse gas emissions, November 26, 2009, https://www.gov.cn/ldhd/2009-11/26/content_1474016.htm. Accessed August 1, 2025.
10. Government Documents of China, China's 2030 low carbon commitment, July 1, 2015, https://www.gov.cn/zhengce/2015-07/01/content_2887645.htm. Accessed August 1, 2025.
11. People's Daily, China sets hard targets to reduce carbon emissions, September 30, 2020, https://www.gov.cn/xinwen/2020-09/30/content_5548478.htm. Accessed August 18, 2025.
12. National Development and Reform Commission of China, The Eleventh Five-Year Plan for Energy Development, 2006, http://www.nea.gov.cn/2007-04/11/c_131215360.htm. Accessed August 18, 2025.
13. Government Documents of China, China's National Plan for Addressing Climate Change, 2007, https://www.gov.cn/zwgk/2007-06/08/content_641704.htm. Accessed August 18, 2025.
14. National Development and Reform Commission and National Energy Administration of China, The Renewable Energy Medium and Long-Term Development Plan, 2007, https://www.ndrc.gov.cn/xxgk/zcfb/tz/200709/t20070904_965446.html. Accessed August 18, 2025.
15. Government Documents of China, The Renewable Energy Law, 2005, https://www.gov.cn/ziliao/flfg/2005-06/21/content_8275.htm. Accessed August 18, 2025.
16. Government Documents of China, The National Medium and Long-Term Science and Technology Development Plan (2006-2020), 2006, https://www.gov.cn/gongbao/content/2006/content_240244.htm. Accessed August 18, 2025.
17. National Development and Reform Commission and National Energy Administration of China, The Renewable Energy Medium- and Long-Term Development Plan, 2007, https://www.ndrc.gov.cn/xxgk/zcfb/tz/200709/t20070904_965446.html. Accessed August 18, 2025.
18. Government Documents of China, The Energy Development Strategic Action Plan (2014-2020), 2014, https://www.gov.cn/zhengce/content/2014-11/19/content_9222.htm. Accessed August 18, 2025.
19. National Development and Reform Commission of China, National Climate Change Plan (2014-2020), 2014,https://zfxxgk.ndrc.gov.cn/web/iteminfo.jsp?id=298. Accessed August 18, 2025.
20. National Development and Reform Commission and National Energy Administration of China, The Thirteenth Five-Year Plan for Energy Development, 2016, https://www.ndrc.gov.cn/xxgk/zcfb/tz/201701/t20170117_962873.html. Accessed August 18, 2025.
21. National Development and Reform Commission and National Energy Administration of China, The Thirteenth Five-Year Plan for Renewable Energy Development, 2016, https://www.ndrc.gov.cn/fggz/fzzlgh/gjjzxgh/201706/t20170614_1196797.html. Accessed August 18, 2025.
22. National Development and Reform Commission and National Energy Administration of China, The Clean Energy Consumption Action Plan (2018-2020), 2018, https://www.ndrc.gov.cn/xxgk/zcfb/ghxwj/201812/t20181204_960958.html. Accessed August 18, 2025.
23. National Development and Reform Commission and National Energy Administration of China, The Energy Technology Revolution and Innovation Action Plan (2016-2030), https://www.ndrc.gov.cn/fggz/fzzlgh/gjjzxgh/201706/W020191104624264919689.pdf. Accessed August 18, 2025.
24. National Development and Reform Commission of China, The Energy Production and Consumption Revolution Strategy (2016-2030), https://www.ndrc.gov.cn/xxgk/zcfb/tz/201704/t20170425_962953.html. Accessed August 18, 2025.
25. Government Documents of China, The Carbon Peak Action Plan Before 2030, 2021, https://www.gov.cn/zhengce/content/2021-10/26/content_5644984.htm. Accessed August 18, 2025.
26. National Development and Reform Commission and National Energy Administration of China, The 14th Five-Year Plan for Renewable Energy Development, 2018, https://www.ndrc.gov.cn/xxgk/zcfb/ghxwj/201812/t20181204_960958.html. Accessed August 18, 2025.
27. National Development and Reform Commission and National Energy Administration of China, The 14th Five-Year Plan for Modern Energy System, 2022, https://www.ndrc.gov.cn/xxgk/zcfb/ghwb/202203/t20220322_1320016.html. Accessed August 18, 2025.
28. Government Documents of China, The Implementation Plan on Promoting the High-Quality Development of New Energy in the New Era, 2022, https://www.gov.cn/zhengce/content/2022-05/30/content_5693013.htm. Accessed August 18, 2025.
29. National Development and Reform Commission of China, Requirements for wind power construction, 2005, https://www.ndrc.

DOI: 10.36838/IJHSR813.89

gov.cn/xxgk/zcfb/tz/200508/t20050810_965825.html. Accessed August 18, 2025.
30. National Energy Administration of China, Wind power equipment industry of China and the global wind power industry pattern, 2011, http://www.nea.gov.cn/2011-09/19/c_131147065.htm. Accessed August 18, 2025.
31. National Development and Reform Commission of China, The Renewable Energy Power Generation Price and Cost Sharing Management, 2006, https://www.ndrc.gov.cn/xxgk/zcfb/tz/200601/t20060120_965897.html. Accessed August 18, 2025.
32. National Development and Reform Commission of China, The China Wind Power Development Roadmap 2050, 2014. Accessed August 18, 2025.
33. Government Documents of China, The Energy Development Strategic Action Plan (2014-2020), 2014, https://www.gov.cn/zhengce/content/2014-11/19/content_9222.htm. Accessed August 18, 2025.
34. National Development and Reform Commission and National Energy Administration of China, Renewable Energy Power Generation Fully Guaranteed Purchase Management Measures, 2016, https://www.gov.cn/xinwen/2016-03/29/content_5059383.htm. Accessed August 18, 2025.
35. National Energy Administration of China, The Notice of the National Energy Administration on the Release of the 2017 Wind Power Investment Monitoring and Early Warning Results, 2017, https://zfxxgk.nea.gov.cn/auto87/201702/t20170222_2604.htm. Accessed August 18, 2025.
36. National Bureau of Statistics of China, National annual statistical data, https://www.stats.gov.cn/sj/tjgb/ndtjgb/. Accessed August 18, 2025.
37. International Energy Agency, Special report on solar PV global supply chains, 2022, https://iea.blob.core.windows.net/assets/d2ee601d-6b1a-4cd2-a0e8-db02dc64332c/SpecialReportonSolarPVGlobalSupplyChains.pdf. Accessed August 28, 2025.
38. International Energy Agency, Renewables of U.S., https://www.iea.org/countries/united-states/renewables. Accessed August 28, 2025.
39. U.S. Office of the Federal Chief Sustainability Officer, The Federal Sustainability Plan of 2021, https://www.sustainability.gov/federalsustainabilityplan/. Accessed August 28, 2025.
40. U.S. Environmental Protection Agency, The origins of EPA, https://www.epa.gov/history/origins-epa. Accessed August 28, 2025.
41. U.S. Environmental Protection Agency, Clean Air Act Overview, https://www.epa.gov/clean-air-act-overview/evolution-clean-air-act. Accessed August 28, 2025.
42. U.S. Environmental Protection Agency, New Source Performance Standards, https://www.epa.gov/stationary-sources-air-pollution/new-source-performance-standards. Accessed August 28, 2025.
43. U.S. Congress, The Energy Policy and Conservation Act, 1975, https://www.congress.gov/bill/94th-congress/senate-bill/622. Accessed August 28, 2025.
44. U.S. Congress, The Energy Security Act, 1980, www.govtrack.us/congress/bills/96/s932.
45. U.S. Congress, The Energy Policy Act of 1992, https://www.congress.gov/bill/102nd-congress/house-bill/776/text. Accessed August 28, 2025.
46. The White House, Executive Order 12843, https://nodis3.gsfc.nasa.gov/displayEO.cfm?id=EO_12843.
47. United Nations, About Montreal Protocol, https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol. Accessed August 28, 2025.
48. U.S. Congress, The Energy Policy Act of 2005, https://www.congress.gov/109/plaws/publ58/PLAW-109publ58.pdf. Accessed August 28, 2025.
49. U.S. Congress, The American Taxpayer Relief Act of 2012, https://www.congress.gov/bill/112th-congress/house-bill/8. Accessed August 28, 2025.
50. U.S. Congress, The Tax Increase Prevention Act of 2014, https://www.congress.gov/bill/113th-congress/house-bill/5771. Accessed August 28, 2025.
51. U.S. Congress, The Consolidated Appropriations Act of 2016, https://www.congress.gov/bill/114th-congress/house-bill/2029. Accessed August 28, 2025.
52. U.S. Congress, the Inflation Reduction Act of 2022, https://www.congress.gov/bill/117th-congress/house-bill/5376. Accessed August 28, 2025.
53. U.S. Department of Agriculture, Powering Affordable Clean Energy Program: Project Announcements, https://www.rd.usda.gov/powering-affordable-clean-energy-program-project-announcements. Accessed August 28, 2025.
54. U.S. Energy Information Administration, Developers plan to add 6 gigawatts of U.S. offshore wind capacity through 2029, https://www.eia.gov/todayinenergy/detail.php?id=52940. Accessed August 28, 2025.
55. Solar Energy Industries Association, Solar industry research data, 2024, https://seia.org/research-resources/solar-industry-research-data/. Accessed August 28, 2025.
56. John Fitzgerald Weaver, US solar up 52% in 2023 as nation deploys 35.3 GW of capacity, 2024, https://www.pv-magazine.com/2024/02/29/us-solar-up-52-in-2023-as-nation-deploys-35-3-gw-of-capacity/#:~:text=From%20pv%20magazine%20USA,growth%20in%20total%20clean%20electricity. Accessed August 28, 2025.
57. U.S. Department of Energy, Guide to the federal investment tax credit for commercial solar photovoltaics, 2024, https://www.energy.gov/sites/prod/files/2020/01/f70/Guide%20to%20the%20Federal%20Investment%20Tax%20Credit%20for%20Commercial%20Solar%20PV.pdf. Accessed August 28, 2025.
58. International Energy Agency, Energy systems of the United States, https://www.iea.org/countries/united-states/energy-mix. Accessed August 28, 2025.
59. Energy Institute, Statistical review of world energy, 2024, https://www.energyinst.org/statistical-review. Accessed August 28, 2025.

Authors

Sophie Xu is a high school (11th grade) student. She is the president of the Future Energy Research Club and plans to major in STEM.

Parker Warburton is a high school (11th grade) student. He is a member of the Future Energy Research Club and plans to major in STEM.