A Comparative Analysis of the Policy Frameworks and Formation Mechanisms of the Biofuel Industry in China and the United States

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Abstract. At present, the world is facing the great challenge of climate change, and there is an urgent need to transform the energy system to cope with the environmental crisis. As a kind of clean energy with great potential, biofuel is regarded as an effective way to get rid of fossil fuel dependence and reduce carbon emissions. Both China and the US, the world's two largest carbon emitters, see biofuels as a key strategy to reduce the environmental burden and ensure energy self-sufficiency. However, the two governments' incentives for the biofuel industry are very different. This paper aims to explore the policy structures and incentives in the biofuel sector in China and the United States, and analyze the root causes of these differences in detail. This study aims to reveal the similarities and differences between the policies of the two countries through comparative analysis, provide useful references and enlightenment for policy makers, and help build a more scientific and reasonable biofuel development blueprint.

Keywords: Biofuels, renewable energy, biofuel policy, financial support, policy formation.

1. Introduction

In the contemporary era, the global community is grappling with the formidable challenge of carbon emissions, which are a primary driver of climate change and global warming. Countries around the world have acknowledged the critical nature of this issue and are positively establishing future objectives to achieve net-zero carbon emissions. The United States has set a target of achieving this goal by 2050, while China has set a target of becoming carbon neutral by 2060 [1]. In this context, biofuels have emerged as a potential alternative to traditional carbon-intensive fossil fuels. They offer a means of reducing overall carbon emissions, as biofuels can often be produced with a lower carbon footprint and contribute to a more sustainable energy system, thereby aiding the global energy transition. The incorporation of biofuels into the global energy matrix represents a pivotal step in curbing the reliance on fossil fuels and achieving the ambitious carbon reduction objectives set forth at the international level. A study revealed that input subsidies and tax incentives were the primary motivators for biofuel utilization, as determined by an analysis of global biofuel policies [2]. Consequently, research endeavors about the biofuels sector are of paramount importance.

As the world's two largest economies and the two largest carbon emitters, the United States and China dedicate significant efforts to achieving low-carbon development. In response, the two countries have developed robust biofuel industries. This paper aims to elucidate the rationale behind the government's policy decisions in China and the United States. This paper will also project probable future developments in the industry and the trajectory of policy evolution. This paper aspires to serve as a reference point for the global community through a comparative analysis of the policies of the two countries.

Biofuels represent a significant component of the United States energy portfolio, and the advancement of the biofuels industry has the potential to mitigate greenhouse gas emissions and reduce reliance on fossil fuels. In the United States, biofuels are primarily derived from corn ethanol and lignocellulosic biomass. Ethanol and biodiesel are produced from soybean oil, animal fats, and waste grease. The United States government has facilitated the growth of the biofuel industry through

policies such as the Renewable Fuel Standard and substantial subsidies, positioning the United States as a leading producer and consumer of biofuels globally.

China's biofuel industry is a relatively recent phenomenon, with a primary focus on bioethanol derived from a range of raw materials, including corn, cassava, sugar cane, and rice straw. The industry has attracted significant investment in scientific research aimed at developing second and third-generation bioethanol technologies. The Chinese government has adopted a multifaceted approach to promoting the production and utilization of biofuels, utilizing subsidies and policy support to bolster energy security, advance environmental stewardship, and stimulate rural economic growth.

This paper aims to examine the policy choices of both countries and the mechanisms that shape them. To this end, the following questions will be enlarged upon on: How do the policies and strategies of the United States and China affect their respective strengths and future competitiveness? What are the reasons behind their respective development paths and policy choices, and how will they affect the energy security and sustainable development goals of both countries?

Furthermore, an examination of the status, strengths, policies, and prospects of the biofuels industry in China and the United States is crucial for understanding the pivotal roles of both countries in the global energy transition. By conducting a comparative analysis, the distinctive approaches to energy security employed by each nation can be discerned. This analysis also considers the impact of policies on industrial development, as well as the role of technological innovations and economic competitiveness in combating climate change and achieving the Sustainable Development Goals (SDGs). Furthermore, it provides insights into the future competitive prospects of the international energy market, which can inform the policies of other countries.

2. Policy Framework for the Biofuel Industry Between China and the United States

2.1. Policy Framework for China's Biofuel Industry

In 2010, the Chinese legislative body promulgated the Renewable Energy Law, providing clear policy support and encouragement for the production and application of bio-liquid fuels. In 2016, the National Energy Administration further promoted the development of bioenergy. It released the "13th Five Year Plan for Biomass Energy Development", emphasizing the large-scale development of natural gas, facilitating the application of biomass-formed fuel in the heating field, steadily expanding the scale of biomass power generation, and accelerating the demonstration and promotion of bio liquid fuels, especially the promotion and application of fuel ethanol and biodiesel in the transportation field.

In March 2022, the National Development and Reform Commission and the National Energy Administration jointly issued the "14th Five Year Plan for Modern Energy System", which clearly stated the need to vigorously develop nongrain biofuels such as biodiesel to promote the optimization of energy structure and the utilization of renewable energy. In May 2022, the National Development and Reform Commission released the "14th Five Year Plan for the Development of Bioeconomy", emphasizing the importance of demonstration projects in the bioenergy and environmental protection industry. It proposed to carry out industrial demonstrations of cellulose ethanol, biodiesel, and biogas in areas where organic waste is concentrated in urban and rural areas, aiming to connect key links such as biomass raw material collection and organic fertilizer production and use and enhance the production scale of biofuels. In addition, the planning report also proposes to carry out pilot projects for the promotion of biodiesel in areas with mature conditions and promote the demonstration application of bio aviation fuel to achieve the comprehensive upgrading and sustainable development of the bioenergy industry. In the fields of biodiesel and renewable aviation fuels, although China has not yet implemented extensive policies, it has built significant production capacity, especially for the international market. At present, China has a production capacity of about 2 million tons per year for first-generation biodiesel, mainly for export. At the same time, the production capacity of second-

generation biodiesel and renewable aviation fuel has also reached about 2.5 million tons per year. These production capacities not only demonstrate China's technological progress in the field of bioenergy but also contribute to the global supply of sustainable aviation fuel.

2.2. US Biofuel Industry Policy Framework

In 2005, the United States established the Renewable Fuel Standard (RFS) program through the Energy Policy Act to increase the use of biofuels, reduce dependence on oil, and lower greenhouse gas emissions. The US Environmental Protection Agency (EPA) is responsible for implementing this standard and will consult with both the US Department of Agriculture and the Department of Energy during the implementation process. In 2007, the United States passed the Energy Independence and Security Act, which further expanded RFS by requiring fuel producers and importers to mix a certain proportion of renewable fuels in gasoline and diesel. These renewable fuels include cellulose biofuels, biodiesel, advanced biofuels, and traditional biofuels [3, 4].

The "Renewable Fuel Standards" system establishes Renewable Identification Numbers (RINs) as a marker of whether refineries and importers have fulfilled their obligation to add them. If a company fails to meet the RFS requirements, it will be fined by the US Environmental Protection Agency and the economic benefits resulting from the failure to meet the requirements will be refunded.

The implementation of the RFS project has had a significant positive impact on energy security, greenhouse gas emissions reduction, and agricultural income in the United States. It is expected that by 2022, the RFS project will replace approximately 13.6 billion gallons of oil with renewable fuels, save approximately $41.5 billion in oil import funds, and reduce greenhouse gas emissions by approximately 138 million tons. In addition, the RFS project also helps to increase income in rural areas.

Meanwhile, the RFS project also faces some controversies, particularly regarding its impact on grain prices. However, the EPA believes that the impact of the RFS project on food prices is minimal and will not cancel the implementation of this policy. The latest update shows that on August 3, 2023, the EPA corrected the applicable quantity requirements and percentage standards for cellulose biofuels, biodiesel, advanced biofuels, and all renewable fuels in the Renewable Fuel Standard (RFS) for 2023-2025, but did not make any substantial changes.

3. Formation Mechanism of Biofuel Industry Policies in China and the U.S.

3.1. Internal and External Factors

In China, energy is a core component in supporting the country's large population and a key driver in keeping China's economy growing steadily. Like numerous other nations, China's overall energy consumption predominantly relies on fossil fuels, particularly coal, resulting in elevated carbon dioxide (CO2) emissions, posing significant threats to the environment and human health [5]. Considering these considerations, the Chinese government has identified the need to reduce its reliance on fossil fuels and has initiated the development of biofuels. This transition has the potential to enhance the country's energy security. Given the relatively late start of the biofuels industry in China and the country's limited agricultural resources, the government has allocated significant funding to research and development (R&D) in this sector. In 2007, The initial generation of bioethanol in China was briefly suspended due to the nascent state of bioethanol technology globally [6] and the extent of China's vulnerable grain production [7]. This prompted the Chinese government to recognize the pivotal role of technological advancement in bioethanol and the necessity of programmatic guidance for the biofuels sector. Thus, the government formulated the 14th Five-Year Plan and the 2030 Carbon Dioxide Peak Action Plan to direct the sector in a top-down way. Also, the Chinese government promulgated the Notice of the National Energy Administration on Strengthening the Management of the Production and Use of Biofuels (2024) to set production standards for biofuels. Furthermore, as per the Circular on Promoting the Production and Use of Biofuel Ethanol (2023), the

government intends to compel a rise in the percentage of ethanol in gasoline and construct infrastructure linked to biofuels, like filling stations for biodiesel.

Like China, the U.S. government has established objectives for the advancement of the biofuels industry. The Renewable Fuel Standard (RFS), for instance, provides a comprehensive framework for the production and utilization of renewable fuels. The production target for conventional biofuels, such as corn ethanol, is 1.51 billion gallons in 2024. However, beyond this, the U.S. government has adopted a more free-market approach. Incentives have been provided to encourage greater involvement from companies and firms in the industry. Funding assistance programs, such as the Biorefinery Assistance Program, have been implemented to facilitate the installation of alternative fuel infrastructure, as detailed by the Alternative Fuels Data Center [8]. Biodiesel Laws and Incentives in Federal, n.d. Furthermore, policies such as the 2022 IRA (Inflation Reduction Act), alternative fuel incentives (Section 13201), and others have provided varying degrees of incentive for biofuel producers and consumers.

Concerning external factors, the two countries exhibit considerable commonality. Climate change, as a global environmental and development issue, has long attracted the attention of numerous countries and international organizations. Sustainable biofuels, as alternative fuels, represent a particularly salient means of addressing this challenge. In response to international policies, or externalities, the significance of renewable energy, particularly bioenergy, in achieving global climate and development goals has been emphasized by international agreements such as the Paris Agreement and the Sustainable Development Goals (SDGs) [9]. Despite progress in policy development, there are still some challenges and limitations in the current approach to promoting bioenergy. For example, policy objectives related to bioenergy development may conflict with other policy objectives, such as those about food security, biodiversity conservation, and land use planning [9]. This can result in a need for a reorientation of policy choices within the country, which in turn contributes to some extent to some of the internal factors.

3.2. Policy Implementation and Regulatory Mechanisms

3.2.1. Implementation

The primary policy instruments employed by the Chinese government mainly include the establishment of production targets and the provision of financial and subsidy support, as exemplified by the 14th Five-Year Plan. However, mandatory mandates also constitute an integral aspect of the policy landscape. For example, the 2017 E10 standard (gasoline containing 10 percent ethanol) has been demonstrated to be highly effective. A study has projected that China's production of bioethanol in 2030 will be sufficient to meet the demand for nationwide use of E10 through modeling. The projected demand for bioethanol in 2030 is 35.6 mmt (44,551 million liters) [6]. As for the implementation, there are numerous parallels between the United States and China, including the renewable fuel standard (RFS) and the biorefinery assistance program. However, the U.S. government's impact on the biofuels industry is particularly evident in the form of credits and substantial subsidies, such as the Clean Fuel Production Credit, which covers renewable fuels including synthetic alcohol fuel (SAF), and will be effective from 2025 to 2027, reveals a contradiction between the implementation of substantial subsidies and the free market model. Nevertheless, in a purely free market, the environmental costs associated with fossil fuels, such as greenhouse gas emissions, are not fully reflected in their prices. Governments intervene with subsidies to biofuels as a means of internalizing these external costs by encouraging the adoption of lower-carbon alternatives that can contribute to a reduction in overall emissions. In the short to medium term, government support is directed towards the development of the industry's capacity to reduce Emissions from sectors that are challenging to electrify, allowing these technologies to mature and eventually compete more independently. These subsidies are justified because the free market alone may not achieve the socially optimal outcome, namely a reduction in emissions and mitigation of climate change. This is exactly how U.S. government policymaking responds to external factors.

3.2.2. Regulatory mechanisms

In China, government regulation is well established, facilitating the potential for piloting biofuels from production to use. However, this approach has also created some hidden obstacles and led to a more fragmented Chinese market, with regional differences affecting the cohesion of the industry and resulting in a limited number of companies involved. Consequently, subsidies are provided to these companies. The subsidies are provided to the companies that utilize or market the biofuels, which results in a reduction in the cost of operating biofuels and an increase in their sales. This is analogous to a supply-side policy.

In the United States, the Biomass Crop Assistance Program (BCAP) was established. The program provides long-term, cost-shared assistance in the form of financial support to landowners and operators of biomass feedstock crops. The list of incentives made possible by the Inflation Reduction Act between 2022 and 2027 is presented in Table 1. Most of these incentives involve legislation that encourages the use of biofuels.

Table 1. Timeline of renewable energy tax credits (2022-2027)

Year	Credits
2022-2024	Extension of Biodiesel, Renewable Diesel, and Alternative Fuels Credits
2022-2025	Extension of Second Generation Biofuel Credit
2023-2025	SAF Credit (The Sustainable Aviation Fuel)
2025-2027	Clean Fuel Production Credit

Source: IEA Bioenergy [10]

4. Comparison and Implications of Biofuel Industry Policies between China and the United States

The United States has established renewable fuel standards through legislation to clarify the mandatory number of biofuels added and has also set incentives and penalties in addition to this. China's policies focus more on guidance and encouragement rather than mandatory standards. The US Environmental Protection Agency will be responsible for the implementation and regulation of RFS, and then ensure the achievement of goals through the RIN system, while China's policy implementation relies more on the participation of local governments and businesses. The development of the entire industry promoted by the RFS policy in the United States, especially in the fields of corn ethanol and biodiesel, has provided liquidity and increased transparency for market transactions through the RIN system, but it has negative impacts on food security and the environment. China's policies have promoted the initial development of the industry, especially in the field of bioethanol. Pilot projects and local special policies can explore development models that are suitable for the national conditions more quickly, while also facing challenges in raw material supply technology and market acceptance. China should pay attention to the consistency of legislation and policies, as mandatory policies and clear legislation can greatly help the development of the biofuel industry. Combined with the market, special incentive measures such as tax incentives and subsidies are set up to increase participants' enthusiasm. At the same time, ensuring the stability of raw material supply and promoting technological innovation to maintain sustainable development, as well as evaluating the impact on the environment and society and the absolute fairness of policies. It is also necessary to consider regional differences and develop policies and measures that are suitable for local conditions based on local characteristics.

5. Conclusion

China can learn from the experience of the United States, enforce the promotion of biofuels at the legislative level, and adopt certain market measures to increase the enthusiasm for using biofuels. The production and use of biofuels can also be combined with the emission reduction mechanism of the Political Academy (a mechanism for quantifying, verifying, and selling the carbon dioxide

absorbed by greenhouse gas reduction projects) to create a certain amount of carbon credits in the market for biofuel market participants to increase trading frequency and effectiveness. Furthermore, the introduction of more favorable tax incentives can be promoted from the perspective of achieving green energy transformation to provide more abundant raw materials for the development of biodiesel and renewable aviation fuel industries. Given the varying production capacity and supply and demand of biofuel raw materials in different regions of China, the policies for adding biofuels in China can be diversified to allow different regions to develop different addition ratios or quantities based on national standards according to their actual situations.

The biofuel policy in the United States lacks systematicity, and its policy framework is composed of multiple bills working together, resulting in a relatively loose system. There are not many mature policies in other biofuels besides bioethanol, such as biodiesel and sustainable aviation fuel, which have not yet formulated mandatory policies to promote decarbonization actions. The United States will continue to vigorously promote the development of the biofuel industry to meet the strong demands of the market and make appropriate adjustments in the face of domestic and international political and economic turbulence, such as the election results of the US President, which may have a significant impact on the biofuel policy system. So, the industry should closely monitor policy trends, adjust or transform promptly, and maintain technological innovation and market expansion to increase competitiveness in the biofuel industry.

Both countries are actively promoting the development of the biofuel industry, but they are in different political policy environments and have different emphases. China places more emphasis on pilot demonstrations and policy guidance, while the United States flexibly adjusts policy details based on the economic situation under mandatory policies. Both countries need to optimize technological innovation, enhance resource allocation, and strengthen market competitiveness.

Authors Contribution

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

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