

Research on Incentive Mechanisms for New Energy Integration under the “Dual Carbon” Goals

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Abstract

Facing the severe challenges of global warming and the deterioration of the ecological environment, "carbon peaking" and "carbon neutrality" have become the common goals pursued by the international community. China has responded actively to this by formulating a strategic plan to achieve carbon peaking by 2030 and carbon neutrality by 2060, aiming to promote the optimization of the energy structure and the improvement of energy efficiency. Under this grand goal, new energy, as an important clean and renewable energy source, plays a crucial role in this process. However, due to the intermittent and fluctuating characteristics of new energy, the problem of its accommodation has become the core difficulty in the transformation of the energy structure. Currently, it is facing many challenges such as the lack of regulation ability of the power system, the imperfect market mechanism, and the unbalanced development among regions. How to efficiently accommodate new energy has become the top priority in achieving the "dual-carbon goals". Therefore, through in-depth analysis of the current situation of new energy accommodation and the challenges it faces, the necessity of constructing a scientific and reasonable incentive mechanism has been explored, and the promoting effects of various aspects including policy-driven, market mechanism optimization, and technological innovation on new energy accommodation have been studied. At the same time, it has further elaborated on how these incentive mechanisms work in synergy to increase the accommodation proportion of new energy in the power system, assist in the transformation of the energy structure, and provide a solid guarantee for achieving the "dual-carbon" goals.

Keywords

Dual-carbon Goals; New Energy Accommodation; Incentive Mechanism; Energy Transformation.

1. Introduction

With the growing global focus on environmental protection and sustainable development, the role of renewable energy within the energy system is becoming increasingly prominent. Thanks to their clean and renewable nature, renewable energy sources such as solar, wind, hydro and biomass are accounting for an ever-increasing share of the energy supply, particularly solar and wind power. In recent years, global installed capacity for solar photovoltaic and wind power has grown rapidly. As a major producer and consumer of energy, China has also made significant achievements in the field of new energy. According to data from the National Energy Administration, as of the end of June 2024, the country's installed renewable energy generation capacity stood at 165.3 million kilowatts, accounting for approximately 53.8% of China's total installed power generation capacity, [1] with both new wind power and solar photovoltaic installations ranking first in the world. However, the rapid development of new energy sources has also brought with it a series of challenges, with the issue of grid integration being particularly prominent.

The characteristics of renewable energy lie in its randomness, discontinuity and variability, which have a certain impact on the stability of the power grid. For example, wind power generation tends to be higher at night when wind speeds are strong, whilst solar power generation peaks at midday in summer when sunlight is abundant; this creates a mismatch with people's electricity demand, leading to the problem of "curtailed wind and solar power". According to data, in 2015 and 2016, the amount of curtailed wind and solar power in China reached a peak, with the curtailment rate for wind power exceeding 15% and that for solar power also exceeding 10%; the situation was particularly severe in the north-west. [2] Although the National Energy Administration has introduced a series of policies that have alleviated the problem of curtailed wind and solar power, the issue of integrating renewable energy into the grid remains an unresolved challenge. To address this challenge more effectively, innovative incentive mechanisms are particularly crucial. Well-designed incentive mechanisms can encourage all relevant stakeholders to actively participate in the development, utilisation and integration of renewable energy, thereby increasing the utilisation rate of renewable energy and driving the sector's sustainable development.

2. The Necessity of Establishing an Incentive Mechanism

2.1. Improve the Legal System and Standardize Law Enforcement Practices.

Firstly, this will help to fill a legal gap. Although China has already issued a number of policy documents and technical standards relating to the development of new energy, there remain legal deficiencies in the practical implementation of new energy integration. For example, the legal framework governing how to effectively incentivize diverse stakeholders to participate in the development, operation and consumption of renewable energy is not yet sufficiently developed. Establishing a comprehensive incentive mechanism requires corresponding laws, regulations, or policies that clearly define incentive mechanisms, implementation methods and regulatory requirements, so as to ensure that all measures are carried out in accordance with the law and follow established procedures. The formulation and implementation of these documents are of great significance in filling the gaps in the legal framework regarding the integration of renewable energy and in driving the continuous improvement of the legal system. Furthermore, incentive mechanisms for the integration of renewable energy are often linked to specific policy measures, such as electricity price subsidies, tax incentives and green power certificate trading. By refining the relevant regulations to transform these incentives into operational institutional arrangements, the enforceability of the legal framework can be enhanced.

Secondly, it plays a positive role in promoting judicial practice. At the judicial level, the absence of clear legal guidance may lead to courts in different regions applying differing standards when adjudicating disputes relating to the integration of renewable energy, thereby undermining the uniform application of the law. Having a comprehensive legal framework not only regulates the adjudicative practices of judicial authorities, narrows the scope of discretionary power, and ensures greater consistency and fairness in the handling of similar cases; it also drives reform in judicial practice. By establishing incentive mechanisms for the integration of renewable energy, judicial authorities can adopt new judicial philosophies, methods and procedures when handling relevant cases, thereby ensuring that cases are dealt with fairly, equitably and efficiently.

Finally, it helps strengthen the regulatory and enforcement capabilities of administrative authorities and clarifies their responsibilities and obligations. Incentive mechanisms for the integration of renewable energy require administrative bodies to take practical circumstances into account and adhere to the requirements of higher-level legislation, thereby acting as forward-thinking policy designers to foster a favourable policy environment for the healthy

development of the renewable energy sector; furthermore, the effective implementation of such policies can enhance their credibility and bolster the government's authority and influence.

2.2. Promoting Economic Development and Industrial Upgrading

The development of the renewable energy sector spans a wide range of fields, including equipment manufacturing, installation and operation and maintenance. The implementation of incentive measures can open up broader market opportunities for the renewable energy sector, drive the flourishing development of related industrial chains, and thereby create more employment opportunities and sources of economic growth. Establishing an incentive scheme to promote the uptake of renewable energy can accelerate the rapid development of the renewable energy sector and facilitate the transformation and upgrading of the economic structure. Furthermore, this mechanism can attract more investment and innovation resources, thereby injecting new vitality into the development of the industry. By providing financial support to renewable energy power generation companies, their operating costs can be reduced and their profitability enhanced, thereby attracting more private investment into the renewable energy sector, driving continuous technological advancement and boosting the industry's competitiveness.

2.3. Ensuring the Security and Stability of Energy Supply

Incentive mechanisms can promote the integration of renewable energy and reduce reliance on traditional fossil fuels. [3] Traditional energy sources are highly dependent on imports and subject to significant price fluctuations, posing a risk of supply instability, [4] conversely, the widespread adoption of renewable energy can provide more options for energy supply, thereby enhancing its security and stability. The implementation of incentive schemes to encourage the development and application of energy storage technologies can effectively mitigate the impact of the unpredictability of renewable energy on the power grid, ensuring a reliable energy supply under varying weather conditions and electricity demand scenarios.

2.4. Promoting Environmental Protection and Addressing Climate Change

As a form of clean energy, renewable energy emits virtually no greenhouse gases or pollutants during power generation. Increasing incentives for the integration of renewable energy can boost its share in the energy mix, thereby reducing emissions of carbon dioxide and other greenhouse gases and alleviating the pressures of global warming; at the same time, it helps to mitigate environmental issues such as air and water pollution, protect the ecological environment and human health, achieve a harmonious coexistence between the economy and the environment, and advance the realisation of sustainable development goals.

3. The Current Situation and Challenges in Integrating Renewable Energy

3.1. Technical Constraints and Significant Regional Variations in Grid Integration Capacity

At present, China's energy mix remains dominated by traditional fossil fuels such as coal, oil and natural gas, and research and development efforts are largely focused on the clean and decarbonised utilisation of these fossil fuels. Consequently, there is a lack of confidence in the efficient utilisation of new energy sources, and technological innovation in this area is also somewhat lacking. [5] As key technologies such as high-efficiency energy storage and smart grids are still in the research and development phase, technical bottlenecks are limiting cross-regional transmission capacity. This makes it impossible to meet the demand for transmitting renewable energy from certain regions, resulting in difficulties in integrating renewable energy and leading to frequent curtailment of solar and wind power. Surveys indicate that the curtailment rate for solar power in regions such as Gansu, Xinjiang and Heilongjiang exceeds

15%, highlighting the acute challenges in integrating renewable energy. [6] This is mainly because these regions have abundant wind and solar resources, but their local consumption capacity is limited and the transmission capacity of the interconnection lines is insufficient.

Meanwhile, due to certain inter-provincial barriers within the electricity trading market, the capacity to absorb renewable energy across regions is significantly constrained, making the effective allocation and utilisation of renewable energy across different provinces increasingly difficult. Take Xinjiang as an example: although the region boasts abundant solar and wind energy resources, its remote location—a considerable distance from the densely populated power-consuming areas in central and eastern China—combined with the relative lag in the development of transmission infrastructure, means that during peak periods of renewable energy generation, surplus electricity cannot be transmitted out of the region in a timely manner, resulting in the forced curtailment of wind and solar power. Furthermore, the level of economic development and industrial structure in different regions also influence the integration of renewable energy. In some less economically developed regions, industrial electricity demand is low, making it difficult to absorb large volumes of renewable energy; whilst in certain economically developed regions, despite high electricity demand, the integration of renewable energy may be restricted to some extent due to the protection of local traditional energy enterprises and concerns regarding the stability of renewable energy supply.

3.2. High Investment Costs and Significant Economic Risks

Energy storage technology is regarded as a key solution to the challenge of integrating renewable energy into the grid. However, current energy storage technologies are relatively expensive, and the investment, operation and maintenance, and depreciation costs associated with storage equipment all contribute to higher operating costs for renewable energy generators. For companies and investors, the initial investment in renewable energy projects is typically substantial, and the construction and maintenance of related facilities also require significant capital outlay, with a relatively long payback period. Furthermore, as renewable energy generation is highly susceptible to weather conditions such as high temperatures, [7] heavy rainfall and drought, the pricing of renewable energy projects is also subject to factors including weather conditions, seasonal variations and market demand. This creates significant uncertainty and poses high economic risks, which may undermine investor confidence and dampen their willingness to invest.

3.3. Policy Environment Dilemma

1. The Complexity of Policy Formulation and Implementation

The integration of renewable energy spans multiple policy areas, including energy, electricity, environmental protection and finance. This necessitates a comprehensive consideration of various factors during the policy-making process to ensure that policies are scientifically sound, reasonable and feasible. However, the formulation and implementation of such policies often present significant challenges.

One issue is the coordination of policies across departments; the integration of renewable energy involves multiple departments, such as the National Energy Administration, the National Development and Reform Commission, and the Environmental Protection Bureau, and there are sometimes differences in the policy objectives and priorities of these departments. For example, whilst the Energy Bureau focuses on the development, utilisation and scaling up of new energy sources, the Environmental Protection Bureau pays greater attention to the effectiveness of new energy sources in reducing pollutant emissions; this discrepancy may result in a lack of effective coordination between policies.

Another issue concerns policy coordination between the central and local governments. Policies on the integration of renewable energy formulated by the central government are often

devised from a macro perspective and have overarching objectives; however, when implementing these policies, local governments must take into account differences in regional economic development, resources and energy demand, which may result in policies not being fully implemented or failing to align with local circumstances. And when formulating policies for the integration of renewable energy, the government often sets ambitious targets, such as increasing the share of renewable energy generation and reducing the rate of curtailed wind and solar power. In practice, however, renewable energy sources such as wind and solar power are inherently intermittent, resulting in significant fluctuations in output, which poses a major threat to the stable operation of the power grid, [8] increases the pressure on the construction and upgrading of power grid infrastructure, and makes it difficult to achieve policy objectives.

2. Insufficient policy support

In recent years, the policies introduced in China in the field of energy storage have been divided into two main categories: “development plans for the energy storage industry” and “policies to incentivise the application of energy storage in the electricity market”, [9] but policies regarding investment subsidies for energy storage facilities and electricity pricing mechanisms are not yet sufficiently developed. Secondly, there are shortcomings in cross-regional consumption policies. Given the geographical imbalance between renewable energy resources and energy demand in China, the transmission and consumption of electricity across regions places greater demands on system flexibility than local consumption, [10] and is more conducive to improving the overall utilisation rate of renewable energy. However, there are currently numerous obstacles to cross-regional power integration. For instance, with regard to the construction of transmission lines, the planning, construction and operation of cross-regional transmission lines involve the coordination of interests across multiple regions. Current policies lack clear provisions on the allocation of transmission costs and electricity trading rules, resulting in high transaction costs and inefficiency in cross-regional power integration.

3. Lack of policy regulation and evaluation

The effective implementation of policies on renewable energy integration is dependent on sound regulatory and evaluation mechanisms. However, there are currently some issues with these mechanisms. Firstly, oversight of renewable energy integration targets is inadequate. Although relevant policies stipulate that electricity retailers must meet a certain proportion of renewable energy integration targets, the regulatory mechanisms in place for actual implementation are insufficiently robust, meaning that some companies may resort to improper means to evade their integration responsibilities for their own gain. Secondly, there is a lack of regulation regarding market entry and exit. In the renewable energy integration market, loopholes remain in the mechanisms governing the entry and exit of market participants. This has led to some enterprises lacking the necessary technical and financial capabilities entering the market, resulting in quality issues or broken capital chains during project construction and operation.

3.4. The Market has Certain Shortcomings

1. The pricing system is inadequate

Pricing for new energy sources fails to accurately reflect their costs and value. In China, there has long been a system of cross-subsidisation, whereby electricity prices for industrial and commercial users subsidise those for residential and agricultural users. Electricity prices have not been fully liberalised, and prices for certain categories of users are still set by the government, meaning that feed-in tariffs for renewable energy generation cannot accurately reflect changes in costs. [11]

The cost structure of renewable energy generation also differs significantly from that of conventional energy sources, as it requires substantial upfront capital investment for

equipment procurement, installation and infrastructure development. However, variable costs during the operational phase are relatively low, consisting mainly of routine maintenance, spare parts and a small amount of management costs. [12] In contrast, the costs associated with traditional energy sources consist primarily of fuel costs and operational and maintenance costs, with fuel costs continuing to accrue throughout the power generation process. However, most current electricity pricing mechanisms are formulated with reference to the cost structure of traditional thermal power generation, without fully taking into account the characteristics of renewable energy generation—namely, high fixed costs in the early stages and low variable costs in the later stages. This results in challenges for renewable energy generators in terms of cost recovery and profitability, and fails to accurately reflect the true cost of renewable electricity. Furthermore, renewable energy is a low-carbon energy source that plays an irreplaceable role in addressing climate change and reducing greenhouse gas emissions. However, under the current electricity pricing mechanism, this environmental value is not fully reflected in monetary terms, and no corresponding price premium is applied to reflect its low-carbon advantages. This also means that when choosing their energy sources, electricity consumers are unable to directly perceive the environmental benefits of renewable energy through price signals, thereby reducing their incentive to actively opt for renewable electricity.

2. Lack of a trading mechanism

At present, demand for power transmission capacity is growing rapidly, yet the inter-provincial trading mechanism remains underdeveloped. In resource-rich regions, the installed capacity of wind and solar power is growing rapidly, with generation capacity far exceeding local electricity demand, whilst the eastern regions are relatively scarce in renewable energy resources, leading to an increasing demand for inter-provincial transmission corridors. However, inter-provincial and inter-regional transmission has not been incorporated into the cross-regional power supply and consumption plans formulated under the national energy strategy. This has resulted in an uneven spatial distribution of renewable energy absorption capacity, and a lack of enthusiasm among local authorities for integrating renewable energy. [13] At the same time, given that renewable energy is characterised by unpredictable output and significant fluctuations in power generation, it is better suited to meeting continuous and real-time trading requirements. However, as the current electricity market primarily operates under medium- to long-term trading rules, there is a slight lack of flexibility; consequently, the relevant market mechanisms still require further refinement.

3. The phasing out of subsidies has created difficulties

With the development of the renewable energy sector, technological advances and economies of scale have played a part in reducing generation costs, leading to a gradual phase-out of renewable energy subsidies. [14] However, there is often a lack of stable expectations regarding factors such as the timing and scale of subsidy reductions; this uncertainty makes it difficult for new energy companies to undertake long-term investment planning and cost estimation. Furthermore, the renewable energy sector faces high costs and insufficient market competitiveness during its development phase, making it largely reliant on government subsidies to maintain economic viability. This long-term dependence leads renewable energy companies to prioritise securing subsidies rather than enhancing their competitiveness through technological innovation and cost control. Consequently, should subsidies be significantly reduced, some renewable energy generation projects may face operational difficulties or even cease operations due to an inability to bear the cost pressures, ultimately adversely affecting the scale of renewable energy integration.

4. Approaches to Establishing Incentive Mechanisms for the Integration of Renewable Energy

4.1. Policy Support Mechanism

1. Optimise the legal framework for new energy and strengthen legal safeguards

Firstly, the legislative purpose must be clearly defined. The “dual carbon” goals represent a key strategic direction for the development of an ecological civilisation and also serve as the core guiding principle for energy legislation. [15] The development of new energy plays an indispensable role in advancing this objective. It is therefore necessary to introduce a national-level plan for the new energy industry, to enshrine in law the prominent position of new energy within the energy mix, and to provide guidance for its development. Furthermore, laws and regulations must be continually revised and refined in line with the progress and rapid development of new energy technologies, ensuring they remain adapted to the evolving circumstances and new requirements of the sector. In the legislative process, the legislature should break away from traditional legislative models and move beyond the notion that legal provisions must be operationally feasible, [16] whilst fully recognising the unique characteristics of new energy sources. At the same time, local governments at all levels should formulate specific implementation plans for the development of new energy in accordance with national strategies and in light of local circumstances, to ensure the smooth achievement of new energy development targets.

Secondly, a mechanism for the dynamic adjustment of new energy laws and regulations should be established, with legal provisions amended in a timely manner in response to actual conditions, thereby providing ongoing legal safeguards for the establishment of incentive mechanisms for the integration of new energy. This will not only help to regulate market order within the industry but also provide reliable legal safeguards for its sustained and stable development.

Finally, inter-departmental policy coordination is essential; establishing an incentive mechanism for the integration of new energy requires close cooperation among multiple departments, including those responsible for energy, finance, environmental protection and science and technology. These departments should strengthen communication and coordination to form a concerted policy effort and jointly promote the development of the new energy industry.

2. Refine subsidy and tax policies for new energy

Financial subsidies play a vital role in driving the establishment and development of the new energy sector. On the one hand, the government should formulate sound and reasonable subsidy policies tailored to the different types, scales and stages of development of new energy projects, providing appropriate financial support to new energy power generation companies, equipment manufacturers and R&D projects, thereby encouraging enterprises to increase investment in technological research and development and improve the stability and generation efficiency of new energy sources. At the same time, the government can take appropriate measures to procure new energy products that offer high energy efficiency and cost-effectiveness, thereby removing certain market barriers. [17] On the other hand, tax relief or preferential policies should be introduced, not only to reduce the operating costs of renewable energy power generation companies through corporate income tax relief, but also to provide subsidies to consumers—such as purchase subsidies for new energy vehicles—in order to encourage greater use of renewable energy and enhance the capacity to absorb it.

3. Establish and improve the regulatory framework for the integration of renewable energy

The rapid development of the renewable energy sector is underpinned by an effective regulatory framework. It is necessary to refine the legal provisions governing the regulation of

renewable energy, setting out detailed requirements for every stage of renewable energy projects—from approval and construction to oversight—to ensure the sector's orderly development. First of all, the regulatory responsibilities and powers of the various functional departments in the new energy sector should be clearly defined in the legislation to avoid overlapping or gaps in regulation, and to strengthen the enforcement of the law. For example, the development of China's modern energy market system has been achieved by curbing government power; property rights are directly subject to administrative authority, and the efficiency of property rights depends on the efficiency of administrative authority. Only by making the enhancement of property rights efficiency a guiding principle can the government promote the healthy development of the consumption market. [18] New energy projects must be reviewed on a regular basis, and the qualification review procedures for new energy enterprises must be strictly enforced, with any illegal or non-compliant conduct promptly rectified to ensure that laws and regulations are effectively implemented. At the same time, strengthening regulatory oversight also requires the establishment of a sound information disclosure system, requiring new energy enterprises to disclose information such as project progress and financial status in a timely and accurate manner, thereby enhancing market transparency and facilitating public oversight.

Secondly, legislation must clearly define the parties responsible for the integration of renewable energy, stipulating the specific obligations and rights of relevant authorities, power generation companies and consumers in this regard. A robust accountability mechanism should be established to penalise parties that fail to fulfil their integration responsibilities and to impose severe penalties for non-compliance. Mandatory targets for the integration of renewable energy could be set, requiring market entities such as grid operators and electricity retailers to integrate renewable energy up to a specified proportion. Penalties should be imposed on enterprises that fail to meet their consumption targets, whilst rewards should be granted to those that exceed them. This approach will ensure that renewable energy is fully utilised and boost the enthusiasm of renewable energy power generation enterprises.

4.2. Technological Innovation and Talent Development

1. Increase investment in research and development

The government should establish a dedicated research fund to encourage universities, research institutions and enterprises to actively pursue innovative research into new energy technologies, overcome technical bottlenecks in key areas such as new energy power generation, energy storage and smart grid technologies, and improve the efficiency and stability of new energy power generation. Financial incentives could be provided to enterprises adopting advanced new energy technologies through means such as research project funding and rewards for innovative achievements, thereby stimulating the enthusiasm of researchers for innovation. It is also necessary to channel private capital into the field of new energy technology R&D to establish a diversified R&D investment system. As the primary drivers of technological innovation, enterprises should also increase their own R&D investment. By expanding the scope of their research funding, they can continuously enhance their technological innovation capabilities and launch new energy products and technologies that are competitive in the market.

2. Establishing a Technology Innovation Platform

Firstly, by integrating resources from all relevant parties, we will establish national and provincial-level new energy technology innovation centres and laboratories to provide advanced experimental equipment and technical support for new energy technology R&D, thereby accelerating the process of research, development and commercialisation.

Secondly, we will develop smart grid technology to enable the efficient integration and consumption of new energy. By installing advanced monitoring equipment and sensors, we will

track the operational status of the power system in real time, including key indicators such as voltage, current and power. Furthermore, utilising big data and artificial intelligence technologies to process and analyse grid data, predict the risk of faults, and enhance the flexibility and adaptability of the grid.

Finally, improve flexible DC transmission technology to enable the long-distance transmission of renewable energy. Flexible DC transmission technology offers advantages such as flexible power regulation, high reliability and a small footprint; it can replace traditional DC transmission methods, facilitate the grid integration of large-scale renewable energy and distributed power sources, [19] and effectively resolve the challenges associated with the large-scale, long-distance transmission of renewable energy.

3. Strengthening Talent Development

Universities should optimise the curriculum for new energy-related disciplines and integrate practical training to cultivate professionals with both a theoretical foundation and practical skills; secondly, enterprises should enhance staff training and education to improve their technical capabilities and innovative thinking; thirdly, a comprehensive incentive mechanism for new energy talent should be established to reward and honour those who have made outstanding contributions to technological innovation and industrial development in the new energy sector, thereby attracting more talented individuals to dedicate themselves to the development of the new energy industry. Building on this foundation, active international cooperation and exchange can be pursued to introduce advanced smart grid technologies and expertise from abroad; furthermore, collaboration with internationally renowned enterprises and research institutions can be fostered to jointly advance relevant projects, thereby raising the standard of smart grid development in China.

4.3. Market Mechanism

1. Flexible Pricing

A sound pricing mechanism is a key factor in promoting the integration of renewable energy. A system for dynamically adjusting renewable energy tariffs should be established. Given the intermittent and unstable nature of renewable energy generation, prices should be dynamically adjusted according to the time of day, season, and market supply and demand conditions. For example, during peak periods of renewable energy generation, prices could be appropriately reduced to encourage consumers to increase their usage; conversely, during off-peak periods, electricity prices could be raised to incentivise power generation companies to expand energy storage facilities or adjust their capacity planning. At the same time, the government should promptly adjust pricing strategies to align with actual demand, taking full account of factors such as market demand, cost fluctuations and technological advancements. [20] Through scientific and reasonable cost accounting, a base price for renewable electricity should be determined that reflects the intentions of all parties involved in the transaction and ensures a reasonable return.

Secondly, differentiated pricing should be implemented on a regional basis, with lower prices offered to areas that are rich in renewable energy resources and have strong consumption capacity, in order to promote the local consumption of renewable energy. Finally, a price linkage mechanism should be established to ensure that the price of renewable energy is linked to that of conventional energy. When conventional energy prices rise, the price of renewable energy should be adjusted upwards appropriately to reflect its environmental and sustainability benefits; conversely, when conventional energy prices fall, the price of renewable energy should also be adjusted accordingly to maintain market competitiveness, thereby enhancing the capacity to absorb renewable energy.

2. Establishing Diversified Trading Mechanisms

The scope and scale of renewable energy trading could be expanded to encourage greater participation by market players. By strengthening the development of cross-regional electricity trading markets and breaking down inter-provincial barriers, it is possible to achieve the optimal allocation and consumption of renewable energy across a wider area. [21] In this process, a unified cross-regional electricity trading platform should be established, and trading rules and pricing mechanisms should be refined to ensure that the value of renewable energy and market supply-demand dynamics are fully reflected.

Furthermore, innovative trading models should be developed. Building on traditional medium- and long-term trading and spot trading, renewable energy units should be encouraged to participate in the inter-provincial peak-shaving services market as independent market entities, submitting volume and price bids to enhance the overall integration rate of the energy system. [22] The opening up of the inter-provincial peak-shaving services market will attract more power generation enterprises to participate, providing them with trading opportunities and promoting the healthy development of the energy market. At the same time, joint trading models combining renewable and conventional energy sources could be explored to achieve complementary advantages and synergistic development between different energy sources.

It is worth noting that the emergence of green power trading models also marks a major innovation in China's electricity market system. On the one hand, as the scale of green power trading expands, the revenues of green power producers increase accordingly. Relevant research indicates that when green power accounts for more than 63% of the total, green power producers' profits exceed those of thermal power producers; this profit advantage will incentivise new energy power generation enterprises to actively expand their production scale, thereby increasing the share of new energy in the energy mix and accelerating the process of integrating new energy into the grid. [23]

4.4. Social Co-governance Mechanism

1. Public Awareness and Engagement

Firstly, efforts to promote new energy sources should be stepped up. This requires making full use of various media channels to widely publicise the advantages and importance of new energy sources, thereby deepening public awareness and understanding of them. Science popularisation and educational activities on new energy should be organised to disseminate knowledge about new energy sources to the public and strengthen their awareness of environmental protection and energy conservation. At the same time, the achievements and prospects of the new energy industry should be showcased to inspire public confidence in and support for the sector.

Secondly, we should encourage public participation in the consumption and utilisation of new energy. We should encourage the public to join the process of new energy consumption by purchasing new energy electricity and installing new energy equipment, whilst offering rewards and recognition to those who actively participate, thereby boosting their enthusiasm for involvement.

2. Strengthening international communication and exchange

In recent years, the energy sector has developed at an accelerated pace, and China has risen to become the world's leading producer and consumer of energy. We should therefore respond to the call to actively participate in international energy cooperation under the Belt and Road Initiative, establish sound energy partnerships with countries along the route, and act as a driving force for the global energy transition. [24] As a major energy-producing developing nation, we must learn from and draw upon the advanced experience and technology of other countries in the integration of renewable energy, thereby driving the continuous improvement of our domestic incentive mechanisms for renewable energy integration. Furthermore, China should showcase its achievements in the renewable energy sector to the international

community, contribute to the sustainable development of global energy, and help build an international incentive system for renewable energy integration.

3. Corporate Responsibility and Collaboration

As key players in the new energy sector, enterprises should actively fulfil their social responsibilities and promote the effective implementation of incentive mechanisms for the integration of new energy. Companies should increase investment in research and development, striving to improve the generation efficiency and stability of renewable energy. During production and operations, companies must also place high priority on environmental protection; the construction of renewable energy projects should adhere to environmental principles to minimise adverse impacts on the ecological environment. Furthermore, companies should strengthen collaboration with other enterprises, such as partnering with energy storage firms to jointly enhance the storage and integration of renewable energy, and collaborating with grid operators to optimise power dispatch and transmission, thereby ensuring the efficient operation of the renewable energy sector.

4. The Role of Civil Society Organisations

Civil society organisations can leverage their strengths in community service, public education and policy advocacy to enhance public awareness and acceptance of new energy sources, thereby promoting their widespread adoption.

In terms of public awareness and education, civil society organisations can carry out more targeted and specialised activities. Unlike government and corporate campaigns, civil society organisations are able to reach out to grassroots communities and specific demographic groups. For example, environmental NGOs can organise volunteers to visit schools and local communities to hold educational lectures and practical workshops on new energy. Through engaging experiments and vivid explanations, they can disseminate knowledge about new energy to students and residents. At the same time, civil society organisations can produce specialised promotional materials, such as comics and short videos, to explain in accessible terms the vital role of new energy in addressing climate change and improving environmental quality, thereby enhancing public awareness and support for its adoption.

In terms of oversight and coordination, civil society organisations play a vital role in monitoring corporate conduct and reconciling the interests of all parties. They are able to oversee the construction and operation of renewable energy projects, ensuring that companies comply with relevant environmental protection and safety regulations. Social organisations can also act as facilitators, building bridges of communication between enterprises, the government and the public. When conflicts arise between enterprises and local residents during the construction and operation of new energy projects, social organisations can convene both parties for dialogue and negotiation, seeking mutually beneficial solutions to facilitate the smooth progress of new energy projects.

In terms of policy promotion, social organisations are able to gather input from various stakeholders to inform policy-making. By identifying the technical and market challenges faced by businesses in integrating renewable energy, as well as the public's expectations and concerns regarding the development of renewable energy, and through means such as surveys and roundtable discussions, they can collate this information and provide feedback to the relevant government departments. This assists the government in formulating more scientifically sound and practical incentive policies for renewable energy integration, thereby promoting the healthy development of the industry and the efficient utilisation of renewable electricity.

5. Conclusion

Guided by the “dual carbon” goals, establishing incentive mechanisms for the integration of renewable energy is key to promoting the sustainable development of renewable energy in China. Through an in-depth analysis of the numerous challenges facing renewable energy integration at the technical, economic, policy and market levels, we have gained a profound understanding of the necessity and urgency of establishing such incentive mechanisms. We have therefore proposed four targeted strategies, including policy support, technological innovation, the improvement of market mechanisms, and social co-governance. The implementation of these strategies aims to accelerate the effective integration of renewable energy, promote the optimisation and upgrading of the energy structure, and enhance efficiency, thereby providing a robust foundation for achieving the “carbon peak” and “carbon neutrality” targets.

In summary, the construction of incentive mechanisms for renewable energy integration is a systematic undertaking that cannot be achieved without the joint efforts of the government, enterprises, research institutions and the general public. Through multi-faceted collaboration, we can overcome current challenges, achieve the efficient integration of renewable energy, and contribute to the shaping of a clean, low-carbon, safe and efficient energy system. However, it is also necessary to clearly recognise the limitations of the current research. For instance, studies on the synergistic optimisation of different incentive mechanisms remain insufficiently in-depth, and consideration of regional specificities is not comprehensive enough. In the future, we should continue to focus on cutting-edge developments in renewable energy technology, continuously refine incentive mechanisms, and optimise the environment for renewable energy integration to meet the new requirements of the energy transition and ensure the smooth realisation of the “dual carbon” goals.

References

- [1] National Energy Administration. (2024, July 31). Transcript of the National Energy Administration's press conference for the first half of 2024. Retrieved December 1, 2024, from https://www.nea.gov.cn/2024-07/31/c_1310783380.htm.
- [2] National Energy Administration. (2016, February 2). Development of the wind power industry in 2015. Retrieved November 16, 2024, from http://www.nea.gov.cn/2016-02/02/c_135066586.htm.
- [3] Zhai, S. P. (2020). A personalised analysis of the demand response potential of electrical appliances taking user behaviour patterns into account [Doctoral dissertation, Shanghai Jiao Tong University]. (in Chinese)
- [4] He, Z. M., & Xie, R. J. (2023). A study on pathways for the coordinated development of traditional and new energy sources. *Natural Gas Technology and Economics*, 17(05), 39–46, 88. (in Chinese)
- [5] Song, Q. (2024). A study on legal measures for the green and low-carbon development of China's energy sector in the context of the “dual carbon” goals. *Shanghai Energy Conservation*, (05), 732–738. (in Chinese)
- [6] Si, R. G., Jia, Y. G., Cao, D., et al. (2019). Analysis of key factors affecting the integration of new energy sources and research into remedial measures. *Energy Conservation and Environmental Protection*, (10), 86–87. (in Chinese)
- [7] Gao, H., Li, H., & Yang, W. T. (2024). Promoting the coordinated development of new and traditional energy sources. *Science and Technology China*, (08), 10–16. (in Chinese)
- [8] Zhang, L. (2022). The impact of the “dual carbon” goals on renewable energy legislation in China and how to address it. *North China Journal of Jurisprudence*, 16(02), 16–26. (in Chinese)
- [9] Huang, Y. J., & Wang, M. Y. (2023). A system dynamics study on the economic viability of policy-driven energy storage deployment on the generation side. *Journal of Beijing University of Posts and Telecommunications (Social Sciences Edition)*, 25(06), 20–34. (in Chinese)

- [10] Guo, Y. (n.d.). A study on the short-term coordinated operation of complementary wind, solar, and storage systems adapted to cross-regional power transmission and consumption [Doctoral dissertation, Xi'an University of Technology]. (in Chinese)
- [11] Cheng, Z. C. (2023). A study on subsidy policies for renewable energy electricity prices in the context of the 'dual carbon' strategy. *Enterprise Reform and Management*, (18), 171–173. (in Chinese)
- [12] Zhang, M. M. (2016). A study on the investment evaluation of new energy power generation projects based on real options [Doctoral dissertation, Nanjing University of Aeronautics and Astronautics]. (in Chinese)
- [13] China Power Network. (2016, March 28). The difficult reality of renewable energy: The reasons behind the "three forms of curtailment" in hydropower and wind power. Retrieved December 1, 2024, from <http://www.chinapower.com.cn/cionews/20160328/22454.html>.
- [14] Dai, H. (2022). A review of price subsidy policies for new energy power generation and recommendations for improving incentive mechanisms. *Price Theory and Practice*, (03), 22–25. (in Chinese)
- [15] Zhang, Y., & Wang, Z. M. (2024). Adjustments to the objectives and value choices in China's energy legislation against the backdrop of the 'dual carbon' goals. *Environmental Pollution and Control*, 46(09), 1323–1328, 1333. (in Chinese)
- [16] Chen, X. H. (2022). Seizing the opportunity presented by the Energy Law to pioneering a new model of sectoral legislation: With a discussion on how to overcome the legislative challenges facing the Energy Law. *Journal of Zhongzhou*, (08), 61–64. (in Chinese)
- [17] Zhang, H. L. (2014). A study on the development of new energy in China [Doctoral dissertation, Jilin University]. (in Chinese)
- [18] Xiao, G. X. (2019). The energy system revolution and the need for an energy law revolution. *Law*, (12), 164–174. (in Chinese)
- [19] Xu, F. Y. (2017). Research on development trends and applications of international power grid transmission technology [Doctoral dissertation, North China Electric Power University (Beijing)]. (in Chinese)
- [20] Wang, F. Y., Chen, Q. B., Li, S. Y., et al. (2022). Lessons from the evolution of renewable energy tariff mechanisms and market-oriented development in Germany and Japan. *Price Theory and Practice*, (03), 68–71, 203. (in Chinese)
- [21] Zhou, X. (2019). A study on the formation mechanism of inter-provincial barriers in the electricity market [Doctoral dissertation, Zhejiang University of Finance and Economics]. (in Chinese)
- [22] Li, J., & Zhang, X. P. (2024). Optimisation of inter-provincial peak-shaving service transactions based on the integration of renewable energy. *Research on Coal Economics*, 44(08), 51–59. (in Chinese)
- [23] Liu, L. L., Feng, T. T., Cui, M. L., et al. (2024). Mechanisms and effects of green electricity trading on the electricity market. *China Population, Resources and Environment*, 34(04), 76–90. (in Chinese)
- [24] National Energy Administration. (2024, August 29). White paper on China's energy transition. Retrieved November 16, 2024, from https://www.nea.gov.cn/2024-08/29/c_1310785406.htm.