

# Paths and Challenges of Green Collaborative Innovation from the Perspective of High-Quality Development

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**Abstract:** This paper initiates with an overview of the prevailing landscape of green collaborative innovation, encompassing the viewpoints of policy-makers, enterprises, and academic and research institutions. A comprehensive analysis is conducted on the specific execution strategies of green collaborative innovation, which include policy formulation and guidance, technological innovation and advancement, optimization of energy structures and the promotion of multi-energy synergy, enhancement and innovation of market mechanisms, as well as the facilitation of international cooperation and open knowledge exchange. Simultaneously, the paper identifies the challenges inherent to this developmental paradigm, spanning across policy, technological, industrial, and market domains. In conclusion, the paper presents pertinent strategies and recommendations aimed at informing governmental policy-making, guiding corporate practices, and enriching scholarly research. These insights are intended to collectively steer the energy sector towards a trajectory characterized by enhanced greenness, reduced carbon footprint, and improved efficiency.

## 1. Introduction

At present, the sustainability of energy utilization has become a major challenge faced by the global community. The continuous growth of global energy demand and the overdevelopment and utilization of traditional fossil energy not only threaten the balance of the natural ecosystem but also profoundly affect the sustainable development of human society, new integrative, collaborative, and innovative approaches are needed to overcome global sustainability challenges<sup>1</sup>. Green collaborative innovation, as a key path to promote the high-quality development of the energy field, integrates innovative resources through in-depth cooperation across disciplines, fields, and industries throughout the entire process of energy production, transformation, storage, and consumption. It can promote the optimization and upgrading of energy structure, effectively alleviate resource and environmental pressure, promote strategic adjustments in economic structure, enhance the country's energy security capabilities, and provide strong support for achieving carbon peak and carbon neutrality goals<sup>2</sup>. Therefore, in-depth research on the paths and mechanisms of green collaborative innovation is of profound strategic significance for leading the high-quality development of the energy field and promoting the construction of a community with a shared future for mankind.

## 2. Current Status Analysis of Green Collaborative Innovation Development

### 2.1. Policy Level

In terms of policy formulation and strategic planning, many governments worldwide have incorporated green development into their national strategic plans, setting specific targets such as energy conservation and emission reduction, and the development of renewable energy. For instance, China has set the goals of "carbon peak and carbon neutrality" and formulated documents such as the "Action Plan for Carbon Peak Before 2030" and the "14th Five-Year National Informatization Plan," clarifying the timetable and roadmap for green development. Financial subsidies, tax incentives, green credit, and green finance have become important means to reduce the cost of corporate green innovation and stimulate market vitality. Some countries and governments also provide financial support for the development of green collaborative innovation by establishing special funds and increasing R&D investment.

### 2.2. Enterprise Level

Inter-enterprise collaborative innovation, enterprise-government collaborative innovation, and enterprise-institution collaborative innovation have a significantly positive impact on innovation performance. Therefore, companies have begun to incorporate green innovation

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and development into their long-term strategic planning, clarifying the goals and pathways for green development<sup>3</sup>. Increasing R&D investment, exploring new technologies and processes, improving green management systems, and enhancing green operation concepts have become the main practical measures of various companies. Of course, there are still confusions and contradictions at the corporate level, such as high costs, great risks, unstable market demand, and complex and changeable policy environments.

### **2.3. Research Institutions and Universities Level**

Research institutions and universities, as important forces in green innovation, play an irreplaceable role in basic theoretical research, key technology research, and talent cultivation. They promote green technology from the laboratory to the market by forming interdisciplinary research teams and establishing industry-university-research collaborative innovation systems, providing continuous intellectual support for green development in the energy field. Scholars conduct a large number of cutting-edge studies, actively participate in international green science and technology project cooperation, establish cooperative relations with international advanced research institutions, and jointly carry out green technology research and development and application of results. This has promoted the international dissemination and sharing of green technology<sup>4</sup>. However, the development of green technology requires a large amount of financial investment, and currently, the financial investment in green research by research institutions and universities is still insufficient, and there are still many obstacles to be faced.

## **3. Pathways for Green Collaborative Innovation from the Perspective of High-Quality Development**

### **3.1. Policy Planning and Guidance**

Policy synergy includes policy coordination, policy consistency, and policy integration<sup>5</sup>. Against the backdrop of high-quality development, national and local governments can formulate clear green development plans for the energy sector, targeting aspects such as clean energy development, energy efficiency improvement, and carbon emission control. These plans should establish strategic goals and phased tasks for green development. Concurrently, establishing priority review and fast-track mechanisms for green projects can reduce the difficulty and cost of implementing green projects, stimulating the enthusiasm and creativity of market entities. Additionally, it is essential to improve the legal and regulatory framework and standard system related to green energy to provide legal protection for the innovation and industrial development of green technology.

### **3.2. Technological Innovation and Upgrading**

Key areas for green collaborative development include clean energy, energy storage technology, and smart grids. Continuously increasing R&D investment, while promoting the transformation and application of scientific and technological achievements through industry-university-research cooperation and international collaboration, can enhance the competitiveness of the country's global green energy technology. A study shows that companies can improve energy efficiency, new materials, new technologies, carbon emissions, and recycling management by actively participating in green innovation activities. Therefore, it is encouraged for companies to establish R&D institutions, cultivate innovative talents, introduce advanced technology and equipment, optimize production processes and management models, and promote the transformation of traditional industries towards a green and low-carbon direction<sup>6</sup>.

### **3.3. Energy Structure Optimization and Multi-Energy Complementarity**

The research indicates that there is a quantitative relationship between energy complementarity and economic benefits, which helps to propose optimal system configuration strategies<sup>7</sup>. In the process of energy structure optimization, the development of renewable energies such as solar, wind, and hydro power is of great significance. Policy guidance and market mechanisms can promote the large-scale and industrial development of clean energy, forming a diversified and clean energy supply system. Constructing a multi-energy complementary energy system achieves the complementary advantages and collaborative use of different energies. Multi-energy complementarity and optimal control is an inevitable trend for future development, as it enables efficient utilization of comprehensive energy at all levels<sup>8</sup>. Through means such as smart grids and energy storage technology, the coordinated operation and optimized allocation of renewable and traditional energies can improve the overall efficiency and reliability of the energy system.

### **3.4. Market Mechanism Improvement and Innovation**

Establish and improve the green energy market system, including market mechanisms such as green electricity certificate trading and carbon emission rights trading. In specific implementation, attempts can be made to guide the production and consumption of green energy through market mechanisms. Policy tools such as differentiated electricity prices and subsidy phase-out can guide the market to form a reasonable green energy price system. By establishing green funds and issuing green bonds, social capital can be attracted to invest in the green energy sector, reducing the financing costs of green projects.

### 3.5. International Cooperation and Open Sharing

In the face of common challenges, countries should actively participate in global energy governance and cooperation. Building international energy cooperation platforms and strengthening exchanges and cooperation with international organizations and advanced countries in green energy technology, standards, and markets can enhance collaboration. Strengthening cooperation with international advanced enterprises and introducing advanced green energy technology and equipment can lead to the development of core technologies and products with independent intellectual property rights. Active participation in the formulation and revision of international energy standards and rules can increase the country's say and influence in the field of international energy, promoting the international development of the country's green energy industry.

## 4. Challenges Faced by Green Collaborative Innovation in the Perspective of High-Quality Development

### 4.1. Policy Challenges

In the process of green collaborative innovation, policy challenges are one of the significant factors restricting its development, particularly the imperfect policy system and the inadequate incentive mechanisms. Policy formulation often lags behind, and the lack of coordination between policies results in an inability to keep up with market demands. This not only affects the effectiveness of policies but also fails to stimulate the innovation vitality of the market and enterprises effectively.

### 4.2. Technological Challenges

Green technology often involves the interdisciplinary integration of material science, energy science, environmental science, information technology, and more. However, the current research models and talent cultivation systems for interdisciplinary integration are not yet perfected, posing significant challenges to the development of green technology. The rapid pace of green technology updates and high innovation requirements increase the difficulty and uncertainty of technological research and development. Issues such as the choice of technical routes, control of experimental conditions, prediction of results, and low rates of technology transformation add to these challenges.

### 4.3. Industrial Challenges

Currently, the industrial structure is often irrational, with a high proportion of traditional industries, insufficient development of emerging industries, and a singular industrial structure. Many industries still face problems such as high energy consumption, high emissions, and low added value. Moreover, the close cooperation and collaboration of enterprises up and down the industrial

chain are required for green collaborative innovation, but the current level of industrial chain collaboration is low, with prominent issues such as poor information sharing and incomplete cooperation mechanisms.

### 4.4. Market Challenges

Consumer understanding of the performance and advantages of green products is still not in-depth. Although green products and services have environmental and energy-saving benefits, the higher production costs due to the use of environmentally friendly materials and energy-saving technologies result in relatively higher prices. This to some extent limits the market demand for green products. As the green market gradually rises, more and more enterprises are entering the green field, and the competitive environment is becoming increasingly fierce. The complexity of the market environment, including policy, technology, and uncertain international environments, adds risks to the green market.

## 5. Conclusion and Recommendations

The energy sustainability and environmental issues are becoming increasingly prominent in today's world. Green collaborative innovation represents an excellent concept and model for development. Although countries have gradually begun to focus on the research and practice of this issue and have achieved certain results, many challenges still exist. In light of this, we should start from the perspective of a community with a shared future for mankind, and through improving the policy support system, strengthening the construction of technological innovation systems, optimizing the industrial structure layout, and building a green industrial chain, we should also cultivate the market demand for green products. This will form a virtuous cycle of coordinated development between policies, technologies, industries, and markets, and help achieve high-quality sustainable development of the economy, society, and environment.

## 5. Recommendations

### 5.1. Perfecting the Policy Support System

A comprehensive policy support system is a necessary condition to safeguard the innovative development of green collaboration. Firstly, it is essential to formulate green development plans and policy measures that align with the requirements of high-quality development. These plans and policies should clarify the objectives and tasks of green development, propose specific implementation pathways, and ensure safeguard measures are in place. At the same time, the coordination and connectivity between policies must be strengthened to ensure that they work in concert to jointly promote the innovative development of green collaboration. Additionally, targeted support policies should be specific and actionable, reducing the costs and risks associated with corporate green development.

## 5.2. Strengthening the Construction of the Technology Innovation System

As the core driving force, technological innovation requires in-depth development across multiple dimensions. Firstly, an open and cooperative innovation ecosystem should be established, encouraging long-term and stable collaborative relationships between universities, research institutions, and enterprises, forming an innovation network that deeply integrates production, education, research, and application. This network should support joint efforts by enterprises, universities, and research institutions to tackle technical challenges, overcome bottlenecks, and enhance independent innovation capabilities. At the same time, intellectual property protection must be strengthened to provide innovators with solid legal protection and stimulate the innovative vitality across society.

## 5.3. Optimizing the Industrial Structure Layout

The reasonable spatial layout of industries is crucial to carbon reduction and high-quality economic development<sup>9</sup>. Currently, the Developing Countries are at a critical period of transformation and upgrading, and optimizing production systems is urgent and indispensable if companies are to cope with global competition<sup>10</sup>. It is imperative to accelerate the construction of a modern industrial system that is green, low-carbon and circular. For instance, the green transformation of traditional industries can be accelerated through the implementation of energy-saving and emission-reduction projects, resource recycling, and clean production technologies. Additionally, there is a significant potential for the development of green emerging industries, as well as the enhancement of collaborative efforts along the industry chain, from upstream to downstream. This approach can form a complete green industry chain, elevating the overall green standards and competitiveness of the entire industry chain.

## 5.4. Cultivating Green Market Demand

Cultivating green market demand is key to promoting the innovative development of green collaboration. Firstly, it is essential to strengthen the promotion and education of green consumption concepts, raise consumers' environmental awareness and sense of responsibility, advocate a simple and moderate, green and low-carbon lifestyle, and guide consumers to establish correct consumption concepts and values. Secondly, a green procurement system should be implemented. Government agencies and enterprises and institutions should give priority to green products and services in the procurement process, providing a broad market space for green products. In addition, a sound certification and labeling system for green products should be established. Through these measures, the implementation will effectively cultivate green market demand.

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