

## INNOVATION IN STATE-OWNED ENERGY ENTERPRISES: GLOBAL STRATEGIES AND TECHNOLOGICAL FRONTIERS

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### ABSTRACT

The research focuses on the global strategies and technological frontiers of innovation in state-owned energy enterprises. These enterprises play a crucial role in the global shift to sustainable energy. It explores innovation pathways and international cooperation strategies in the digital era. Through cross-border case studies, it analyzes the transformative impact of emerging technologies. Additionally, it compares international innovation models and delves into the construction of innovation ecosystems. The aim of this study is to offer valuable insights and references for the innovative development of state-owned energy enterprises.

**Keywords:** State-Owned Energy Enterprises; Innovation; Global Strategy; Technological Frontiers; International Cooperation

### INTRODUCTION

State-owned energy enterprises play a critical role in the global energy landscape. Amid the overarching trend of energy transition, innovation has become a key driver for achieving sustainable development and enhancing global competitiveness. As the challenges of global climate change intensify, the international community's demand for sustainable energy has grown increasingly urgent. The adoption of international agreements such as the Paris Agreement has prompted nations to set ambitious carbon neutrality goals, making the transformation of the energy sector imperative. Leveraging their unique advantages in resources, capital, technology, and policy support, state-owned energy enterprises have emerged as central players in this energy transition. Their innovative development not only influences their own growth and sustainability but also has profound implications for global energy restructuring, environmental protection, and sustainable economic development.

### OBJECTIVE

1. Clarifying Global Strategic Position: Analyzing the pivotal role of state-owned energy enterprises in the global transition to sustainable energy, and elucidating the profound impact of their global strategies on both themselves and the global energy landscape.
2. Exploring Technological Innovation Directions: Investigating the innovation pathways for state-owned energy enterprises in cutting-edge technologies such as new energy, energy storage, digitalization, and intelligentization, to grasp the trends in technological development.
3. Planning Innovation and Collaboration Strategies: Researching the innovation pathways and international collaboration strategies for state-owned energy enterprises in the digital era, to meet the demands of contemporary development.

### METHODOLOGY

Case Study Method: The text makes extensive use of case studies to illustrate key points. For instance, when discussing the global innovation strategies of state-owned energy enterprises, it cites examples such as State Power Investment Corporation's implementation of the "Balanced Growth Strategy" to promote clean energy development, as well as Power Construction Corporation of China's energy projects in Central Asia. These concrete examples bolster the arguments and enhance their persuasiveness. Similarly, when analyzing the empowerment of emerging technologies, the text references specific cases, such as State Grid Corporation of China's transmission projects in Brazil and Shengry Group's collaboration with Siemens Energy, providing tangible evidence to support the discussion.

**Comparative Research Method:** In exploring the innovation models of state - owned energy enterprises under green and low - carbon goals, the text compares the experiences of German state - owned energy companies in developing distributed renewable energy and applying energy storage technologies with the achievements of Chinese state - owned energy enterprises in ultra - high voltage transmission and large - scale renewable energy grid integration. This comparison clearly highlights the differences in innovation models across countries, offering a foundation for strategies aimed at collaborative development.

### ***Sub-Section 1: Global Strategies for Innovation in State-Owned Energy Enterprises***

#### **1.1 Serving Global Sustainable Development Goals**

State-owned energy enterprises are actively aligning with global carbon neutrality objectives by increasing investments in renewable energy development. For instance, the State Power Investment Corporation (SPIC), the world's largest clean energy power generation enterprise, has implemented a "Balanced Growth Strategy" to promote green, low-carbon, and sustainable development across Asia and beyond. By 2024, SPIC's clean energy capacity accounted for 72.71% of its total installed capacity, with plans to exceed 75% by 2025. This strategy emphasizes balanced growth, investment optimization, and the integration of digital technologies to create a smart energy ecosystem. These efforts not only enhance operational efficiency but also provide a valuable blueprint for global sustainable energy development.

#### **1.2 Strengthening International Energy Cooperation and Layout**

Through initiatives such as the Belt and Road Initiative, state - owned energy enterprises have carried out extensive international energy project collaborations. For example, Power Construction Corporation of China has implemented multiple wind and hydropower projects in Central Asia. These projects provide clean energy and drive the transformation of local energy structures. Power Construction Corporation of China has harnessed the region's rich wind and hydropower resources to construct a series of wind and hydropower projects. These endeavors not only offer clean and stable electricity, reducing the reliance on traditional fossil fuels and promoting diversified and green energy structures, but also generate local employment opportunities, enhance infrastructure construction, and improve technical capabilities, thus achieving synergistic economic and environmental development.

#### **1.3 Participating in Global Energy Governance**

State - owned energy enterprises give full play to their technological and resource advantages to participate in the formulation of international energy rules and standards, thereby enhancing their influence in global energy governance. For instance, within the International Energy Agency (IEA), Chinese state - owned energy enterprises actively contribute to the development of renewable energy plans and the establishment of energy - efficiency standards. They are playing an increasingly crucial role in promoting a fair, reasonable, and sustainable international energy order.

### ***Sub-Section 2: Technological Frontiers in State-Owned Energy Enterprises***

#### **2.1 Innovation in New Energy Technologies**

In the fields of solar and wind energy, continuous efforts are being made to enhance power generation efficiency and cut down costs. For example, China Huaneng intends to promote the application of technologies such as the 18 MW direct - drive offshore wind turbine on a larger scale. This type of turbine boasts advantages like large single - unit capacity and high power generation efficiency. It can capture more wind energy and significantly boost power output under the same wind conditions. The direct - drive technology reduces intermediate transmission components, thereby decreasing failure rates and maintenance costs, and providing strong support for large - scale and efficient offshore wind development.

#### **2.2 Innovation in Energy Storage Technologies**

Energy storage technologies are crucial for tackling the intermittency and instability issues of renewable energy. State - owned energy enterprises are ramping up investments in battery and hydrogen - based energy storage technologies. For instance, a new battery technology developed by an energy enterprise has not only enhanced charge - discharge efficiency but also cut down costs. Breakthroughs in lithium - ion batteries and flow batteries have led to increased energy density, prolonged lifespan, and improved safety. Hydrogen energy storage, characterized by its high energy density and long - term storage capabilities, is being explored for cross - season and long - term energy storage and utilization. This effectively addresses the fluctuations in renewable energy generation and ensures a stable energy supply.

#### **2.3 Digital and Intelligent Technologies**

State - owned energy enterprises are leveraging big data, artificial intelligence, and 5G technologies to construct smart grids and intelligent energy systems. Take the "Cloud - based Hydropower" platform of China Energy Investment as an example. This platform has propelled the digital and intelligent development of the hydropower industry. It employs big data to conduct real - time monitoring of equipment operation, hydrological conditions, and weather data. This enables precise monitoring and fault prediction, optimizes power generation scheduling, and, through 5G technology, ensures real - time remote control and monitoring, thus enhancing the overall intelligent level of the hydropower industry.

### ***Sub-Section 3: Innovation Pathways and International Cooperation Strategies in the Digital Era***

#### **3.1 Innovation Pathways**

State - owned energy enterprises are required to boost their investment in digital transformation and establish energy big - data platforms to attain intelligent management of energy production, transmission, and consumption. Meanwhile, they ought to strengthen cooperation with technology firms and universities to foster the synergy among industry, academia, research, and application, thus expediting the commercialization of technological achievements. Energy big - data platforms integrate data from diverse stages of the energy industry chain, uncovering latent value through data analytics. For example, during the energy production stage, production processes can be optimized according to equipment operation data to enhance efficiency. In the transmission stage, real - time monitoring of grid operations enables the timely identification and resolution of problems such as line losses. In the consumption stage, analyzing user electricity consumption patterns facilitates precise demand - side management. In terms of industry - academia - research - application collaboration, state - owned energy enterprises can form partnerships with technology companies to introduce advanced digital technologies and collaborate with universities on research projects to cultivate specialized talents. This, in turn, accelerates the transformation of technological achievements from the laboratory to practical applications.

#### **3.2 International Cooperation Strategies**

State - owned energy enterprises ought to set up multilateral cooperation mechanisms to collaboratively formulate energy digital standards and norms. They should proactively engage in international energy technology cooperation projects, share digital technologies and experiences, and facilitate cross - border energy data flow and sharing. Multilateral cooperation mechanisms can be established via international energy organizations, leading to the formation of energy digital cooperation alliances. These alliances are tasked with developing data formats and interface standards to ensure system compatibility and interoperability. International energy technology cooperation projects can center around smart grid technology development and secure sharing of energy big data, aiming to tackle the technical challenges and security issues arising from digital transformation.

### ***Sub-Section 4: Empowering Innovation in State-Owned Energy Enterprises with Emerging Technologies: Cross-Border Case Studies and Development Trends***

#### **4.1 Cross-Border Case Studies**

State-owned energy enterprises from various countries should strengthen cooperation in the research and development of green and low-carbon technologies, establish joint R&D centers, and collaboratively tackle key technical challenges. In terms of project investment and construction, they should engage in cross-border energy project collaborations to achieve resource sharing and complementary advantages. These enterprises can establish joint R&D centers in critical areas of green and low-carbon technologies, such as energy storage and carbon capture, utilization, and storage (CCUS), pooling research capabilities and resources from all parties to jointly conduct technological breakthroughs. For cross-border energy projects, such as offshore wind power projects, energy companies from different countries can collaborate in development, with one party providing technology and equipment, and the other offering sites and markets, thereby achieving resource sharing and complementary advantages, and jointly promoting the global transition to green and low-carbon energy.

#### **4.2 Development Trends**

Emerging technologies are expected to be more extensively applied in the energy sector, thereby accelerating the transformation of state - owned energy enterprises towards intelligent, green, and efficient development. The integration of energy with information and materials technologies will deepen, giving rise to more innovative energy business models. Technologies such as artificial intelligence, the Internet of Things, and blockchain will facilitate more intelligent management of energy production, transmission, and consumption. Smart meters can monitor users' electricity consumption in

real - time, while blockchain technology can enable decentralized and secure power transactions. The integration of energy and materials technologies will drive the development of new energy materials, including high - performance battery materials and new energy storage materials. These materials will offer more efficient solutions for energy storage and conversion, further promoting innovation in the energy industry.

#### ***Sub-Section 5: International Comparison and Collaborative Development of Innovation***

##### ***Models in State-Owned Energy Enterprises under Green and Low-Carbon Goals***

###### ***5.1 International Innovation Model Comparison***

German state-owned energy enterprises have rich experience in distributed renewable energy development and energy storage technology application, while Chinese state-owned energy enterprises have achieved significant results in UHV transmission and large-scale renewable energy grid integration. German enterprises focus on distributed renewable energy development, building small-scale renewable energy facilities in communities and enterprises to achieve local energy production and consumption, reducing transmission losses. In energy storage technology application, Germany actively promotes battery and pumped storage technologies, improving the stability and reliability of renewable energy. Chinese enterprises lead in UHV transmission technology, enabling large-scale, long-distance, and low-loss power transmission, effectively addressing the reverse distribution of energy resources and load centers. In large-scale renewable energy grid integration, technological innovation and management optimization have increased the proportion of renewable energy in the grid, ensuring grid safety and stability.

###### ***5.2 Collaborative Development Strategies***

State-owned energy enterprises should strengthen cooperation in green and low-carbon technology research and development, establish joint research centers, and jointly tackle key technical challenges. In project investment and construction, they should engage in cross-border energy project collaborations to achieve resource sharing and complementary advantages. For example, in offshore wind projects, enterprises from different countries can collaborate, with one providing technology and equipment and the other providing sites and markets, achieving resource sharing and complementary advantages, and jointly promoting global green and low-carbon energy transition.

#### ***Sub-Section 6: Building Innovation Ecosystems in State-Owned Energy Enterprises:***

##### ***Integrating International Experience and Local Practices***

###### ***6.1 Learning from International Experience***

Statoil ASA has established an innovation alliance, collaborating with universities and research institutions to create an open and collaborative innovation ecosystem. The innovation alliance of Statoil ASA brings together the innovative resources of universities, research institutions, and related enterprises. Universities and research institutions provide the company with cutting-edge research achievements and innovative ideas, while enterprises transform and apply these achievements, forming a complete innovation chain from basic research, technology development to industrial application. Through the operation of the innovation alliance, Statoil ASA has achieved a series of innovative results in offshore oil and gas extraction technologies and new energy development, enhancing the company's core competitiveness and injecting vitality into the local energy industry.

###### ***6.2 Exploring Local Practices***

Chinese state-owned energy enterprises are improving innovation incentive mechanisms and strengthening intellectual property protection based on their actual conditions. For example, China Energy Investment Corporation has established a technology research and development system comprising "1 research headquarters, 6 industry research institutes, 4 technology industrial companies, and N enterprise research centers." This system forms a multi-level and multi-field collaborative innovation pattern. The research headquarters focuses on basic research and frontier technology exploration, providing theoretical support for the group's technological innovation. Industry research institutes conduct applied research for different energy sectors, solving key technical problems. Technology industrial companies commercialize research outcomes, promoting market application of new technologies. Enterprise research centers focus on actual technical needs in production and operation, conducting technical improvements and innovations. The corporation also improves innovation incentive mechanisms, rewarding teams and individuals with outstanding technological innovation achievements, stimulating employee innovation, and strengthening intellectual property protection to safeguard innovation outcomes and legal rights.

### CONCLUSION AND FUTURE WORK

The innovation of state-owned energy enterprises in global strategy and technological frontiers is of paramount importance. By implementing global strategies, strengthening technological innovation, exploring innovative pathways, and fostering international cooperation, state-owned energy enterprises will play a more significant role in the global transition to sustainable energy, driving the global energy sector toward a greener, low-carbon, and intelligent future. During this critical period of global energy transformation, state-owned energy enterprises must continue to shoulder the mission entrusted by the times, increase investment in innovation, actively engage in international cooperation, and persistently explore innovative models and pathways suitable for their development, thereby building a robust innovation ecosystem. In terms of technological innovation, it is essential to stay abreast of cutting-edge technologies such as renewable energy, energy storage, and digitalization, continuously breaking through key technical challenges. On the global strategic front, deepening international energy cooperation and expanding global presence, while actively participating in global energy governance, are crucial. In building an innovation ecosystem, drawing on international best practices while adapting them to local conditions will help refine incentive mechanisms and strengthen intellectual property protection systems. Through these efforts, state-owned energy enterprises will make greater contributions to the sustainable development of global energy, paving the way for a brighter energy future.

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