

Analysis of the Mechanism and Path for Green Transformation of Traditional Energy Enterprises——A Case Study of Longmei Mining Group Co., Ltd.

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Abstract. Driven by the "dual carbon" goals, technological progress and policy support, China's energy industry is at a historical turning point from "high-carbon expansion" to "green reconstruction". This paper takes Heilongjiang Longmei Mining Group Co., Ltd. as a case and uses the case analysis method to systematically sort out its green transformation path and mechanism. The research finds that Longmei Group has achieved a systematic reshaping from a traditional coal enterprise to a green and low-carbon mining area through five paths: "system first, source reduction, resource recycling, industrial upgrading, and ecological restoration", forming a replicable "Heilongjiang solution". It has been discovered that policies, technologies and the industrial chain play a significant role in the green transformation of traditional energy enterprises. The research not only provides practical references for the green transformation of traditional energy enterprises, but also enriches the theoretical achievements of sustainable development of resource-based cities, and has important implications for the revitalization of Northeast China and the transformation of resource-exhausted cities in Heilongjiang.

Keywords: Green transformation; traditional energy enterprises; Longmei Group; sustainable development.

1. Introduction

With the progress of society and the rapid development of the economy, the traditional energy industry mainly relies on fossil fuels such as oil and coal. The use of these energy sources generates a large amount of waste gas, wastewater, and waste residue, which not only pollutes the environment but also causes the greenhouse effect and global warming. To protect the Earth and the home of mankind, it is urgent to complete the "green transformation". China has made an overall deployment of "five-in-one" in terms of economy, politics, culture, society, and ecological civilization. On October 29, 2015, China proposed the development concepts of innovation, coordination, green, openness, and sharing. On September 22, 2020, China announced its commitment to peaking carbon dioxide emissions before 2030 and striving to achieve carbon neutrality before 2060. On August 2024, the Central Committee of the Communist Party of China and the State Council issued the "Opinions on Accelerating the Comprehensive Green Transformation of Economic and Social Development", making a systematic deployment for the "all-round, all-domain, and all-region" green transformation at the national level and setting two-stage goals for 2030 and 2035. This fully demonstrates that China is comprehensively transforming from traditional high-speed development to high-quality development that is resource-conserving and environmentally friendly.

China is one of the world's largest energy-consuming countries. At present, the three major fossil energy sources - coal, oil and natural gas - still dominate China's energy consumption. The chemical elements of coal, oil and natural gas are all carbon and hydrogen. Therefore, environmental problems such as air pollution, wet room effect and ecological damage will occur during the energy supply process. The competition among major powers continues to heat up, and the countercurrents of globalization are obvious. Energy security and self-reliance have once again become the focus of energy strategies for all countries. To protect the Earth and the ecological environment on which human beings depend for survival, the global green transformation continues to advance, investment in clean energy keeps growing, and energy has become the intersection of political, economic,

security and technological competition. Today, the green transformation of the energy industry is no longer a single environmental protection issue, but a convergence point of national strategy, economic security, industrial upgrading and international competition. Driven by the "dual carbon" goals, technological progress and policy support, China's energy industry is at a historical turning point, transitioning from "high-carbon expansion" to "green reconstruction".

This article takes promoting the "green transformation" of Longmei Mining Holding Group Co., LTD. (hereinafter referred to as "Longmei Group") as the research object. It mainly adopts the case analysis method to study and sort out the path for Longmei Mining Holding Group Co., Ltd. to achieve green transformation, summarize the path experience in its green transformation, and extract the optimization plan for the green transformation of coal enterprises. To enrich China's research theories on the green transformation and development of traditional energy enterprises, it is expected to provide feasible references and lessons for the green transformation of existing coal enterprises. The innovation point of this article is, first of all, to focus on the micro level and pay attention to the social benefits of green transformation. Secondly, taking Longmei Mining Holding Group Co., Ltd. as an example, this paper analyzes the green transformation mechanism and path of local traditional energy enterprises. Finally, it is necessary to put forward in-depth thoughts on the transformation of resource-exhausted cities in Heilongjiang and the revitalization needs of Northeast China. The aim is to summarize the path mechanism for the green transformation of energy enterprises, enrich the existing research theoretical achievements, and provide feasible references and lessons for the green transformation of existing coal enterprises.

2. Literature Review

The concept of "green economy" was first proposed in 1989 by British environmental economist Pearce in his "Green Economy Blueprint". It emphasizes resource conservation and low-carbon development in the production and consumption processes, making the economy and the environment coordinated and compatible [1]. Shi Boyu believes that the proposal of "green transformation" involves cross-disciplinary research in fields such as environmental science, management, and economics, with a focus on the environmental sustainability of corporate activities [2]. Jiang Jinhua et al. found that the research perspectives, purposes, and methods on green development vary both at home and abroad. Abroad, "green growth" is taken as the starting point of research, while in China, more attention is paid to related themes of green development such as low-carbon economy, resource economy, and environmental economy [3]. In the industrial sector, Gu Jiaqin holds that the green transformation of chemical enterprises lies in the major changes of innovation-driven sustainable development under the guidance of the green development concept [4].

Regarding the influencing factors of green transformation, first of all, green transformation is guided by the concept of green development. Jiang Jinhua et al. found through constructing an empirical analysis model of the Green Transformation Potential Index (GTPI) that the level of green innovation (green patents), attracting foreign investment, and enhancing the public's awareness of green environmental protection are conducive to promoting green transformation [3]. Secondly, for energy enterprises, Li Yalin et al. believe that under the background of the "dual carbon" goals, their transformation is mainly driven by national strategic adjustments and high-quality development, as well as the enterprises' own needs to seize the market and improve energy conservation and efficiency [5]. From the perspective of internal leadership, scholars Begum et al. used questionnaires to examine data through structural equation modeling to analyze hypotheses and found that green transformational leadership has a significant impact on green thinking and green innovation, and that green transformational leadership will bring about green innovation [6].

With the gradual deepening of sustainable development and the continuous optimization of the green transformation path, Wu Hengyu holds that the solution to environmental problems mainly relies on market-based mechanisms and administrative control mechanisms. The economics community believes that market-based means are more superior, mainly including emission trading

mechanisms and tax mechanisms [7]. This requires new quality productivity to empower the green industry. Gu Jiaqin mentioned in her research that the three major paths for the green transformation of chemical enterprises are to adjust the industrial structure through technological innovation, develop emerging industries related to energy conservation and emission reduction, and optimize the development of traditional industries [4]. Yang Ning holds that green transformation is based on the new form of productivity of "technology - ecology - economy", and explores the practical path of green transformation through the internal logic of innovatively providing production factors, continuously transforming development momentum and revolutionarily reconstructing production models [8].

With the deepening of the energy revolution, China's energy system is transforming and upgrading towards the goals of being clean, low-carbon and efficient. Regarding the issue of how to achieve a green transformation of traditional energy, Yuan Wenhui mentioned in his article that in the supply side, the energy supply guarantee capacity is constantly strengthening, and in the consumption side, the energy consumption structure is accelerating its transformation towards being clean and low-carbon [9]. Li Wei summarized the transformation path of traditional energy enterprises as changing concepts, optimizing paths and focusing on innovation [10]. For the coal industry, Ma Wenchao believes that coal enterprises should, on the basis of ensuring stable supply, focus on improving the clean and efficient utilization level of coal, building green mines, and intensifying the integration of coal chemical industry and new energy [11]. However, Yuan Liuyan pointed out that the green transformation of traditional energy enterprises also faces many challenges, such as the dual pressures of ensuring supply and low-carbon development, assets and human resources, the immaturity of technologies supporting the transformation of traditional industries, and the exploratory stage of cross-industry cooperation mechanisms between upstream and downstream of the industrial chain [12].

In conclusion, research on green transformation is an interdisciplinary integration of the economic and environmental fields, focusing on the environmental sustainability of economic development. With the progress of The Times, the exploration of green transformation practices has been continuously deepened, covering multiple aspects such as productivity, production structure, and production factors. In response to the declining traditional energy enterprises, many scholars are studying the transformation model that emphasizes both environmental protection and efficiency. However, they inevitably encounter numerous difficulties and challenges in the early stage of transformation. There are both research achievements and some deficiencies. First of all, most of them focus on theoretical analysis at the macro level, especially performance evaluation in the economic field. Secondly, there is a lack of micro-level thinking and summary on exploring the path of green transformation in accordance with local conditions and the actual situation of the region. Finally, most studies focus on the predicament of traditional energy transition in places like Shanxi and Inner Mongolia, lacking attention to resource-exhausted cities in Heilongjiang region.

3. Current Status of Case Development

3.1. Basic Development Situation

Longmei Group is a landmark state-owned coal enterprise in Heilongjiang Province and one of the three key enterprises in Heilongjiang, China. Established at the end of 2004, it was formed by the merger of four key state-owned coal enterprises in Jixi, Hegang, Shuangyashan and Qitaihe, which were transferred from the central government to local management. The four mining companies have a long history and have made significant contributions to the founding of the People's Republic of China and the country's economic construction. They have also assisted in the construction of more than ten coal enterprises such as Pingdingshan, Dayan and Panjiang, and have provided a large number of management and technical talents for the establishment of Shenhua.

There are currently 16 affiliated enterprises. The largest one, Longmei Co., LTD., is composed of 13 shareholders, including state-owned and private ones. Longmei Holding Group holds 85.58% of

the shares. There are 41 production and under-construction mines (36 within the province), with a verified production capacity of 48.81 million tons per year. The geological reserves of coal are 6.85 billion tons, and the recoverable reserves are 3.56 billion tons. Metallurgical coal accounts for about 40% of the market in Northeast China. In addition to the main business of coal mining, a diversified industrial pattern has been formed, including washing and processing, cogeneration of heat and power, machining and repair, geological exploration, and mine construction. As of now, the total assets of the enterprise amount to 78.17 billion yuan, and the asset-liability ratio is 72.57%. Among the top 50 coal enterprises in China, it ranks 17th in coal output and 28th in operating income.

In recent years, among the 6.85 billion tons of geological reserves of Longmei Group, 46% are deep and thin coal seams, with an average mining depth exceeding 600 meters. The mining cost has risen by 28% over the past three years, and the full cost per ton of coal is 60 to 120 yuan higher than that of similar coal in eastern Inner Mongolia and northern Shaanxi. The area of coal mining subsidence in the old mining areas such as Jixi and Hegang, where Longmei belongs, has accumulated to 560 square kilometers, with 71 gangue mountains. Every year, an additional ecological debt of 230 million yuan is added, and the traditional "excavation-burning - drainage" model is no longer sustainable. Meanwhile, Longmei Group is responsible for ensuring 60% of the coal for power generation and 70% of the coal for heating in Heilongjiang Province. The provincial committee of the Communist Party of China in Heilongjiang Province and the provincial government have called for "transformation while ensuring supply and promoting supply through transformation", positioning Longmei as a "leading coal enterprise in green and low-carbon development in Northeast China", making the green transformation of Longmei Group extremely urgent.

3.2. Green Transformation Path

The green transformation of Longmei Mining Holding Group Co., Ltd. is not "single-point pollution control", but "systematic reshaping"(fig 1). Its green transformation is mainly achieved through five paths, including five main lines: system first, source reduction, resource recycling, industrial upgrading, and ecological restoration.

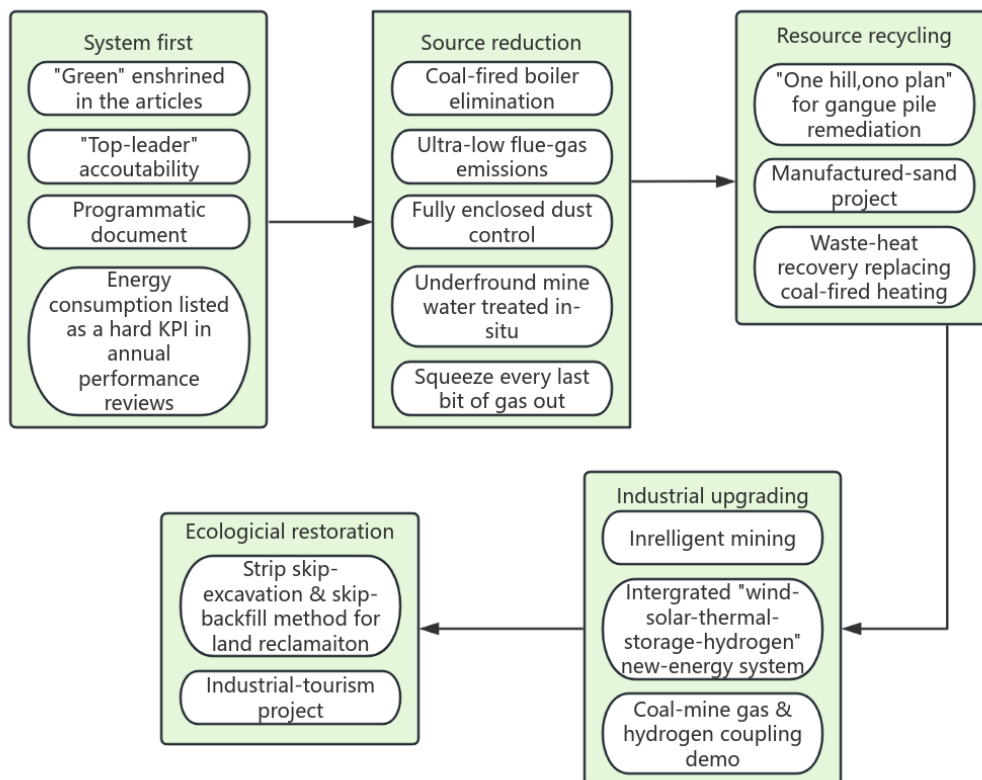


Fig. 1 The green transformation path of Longmei Group [13]

3.2.1 System first

In order to successfully complete its green transformation, Longmei Group first incorporated green into its articles of association, using rules and regulations to speak for itself. It established a "top leader" responsibility system and set up a leading group for energy conservation and environmental protection, ensuring that green and low-carbon development covers all three levels: the group, mining companies, and coal mines. It also issued guiding documents such as the "Measures for the Management of Ecological and Environmental Protection" and the "Implementation Plan for Carbon Peaking and Carbon Neutrality". List energy consumption, emissions and resource utilization rate as hard indicators for the annual performance assessment of the leadership team.

3.2.2 Source reduction

In order to reduce the weight of every ton of coal, every cubic meter of water and every wisp of gas, Longmei Group has carried out a series of renovation measures, including eliminating coal-fired boilers, achieving ultra-low emissions of flue gas and full enclosure of dust, underground treatment in mine Wells, and making full use of gas. If all coal-fired boilers were eliminated, a total of 324 coal-fired boilers were replaced or renovated, reducing self-used coal by 150,000 tons annually. Ultra-low emissions of flue gas have been achieved. Integrated desulfurization, denitrification and dust removal renovations have been carried out on 20 boilers in 5 thermal power plants. The concentrations of particulate matter, SO₂ and NO_x emissions are all below the ultra-low limit values. Dust is fully enclosed. In 38 coal storage yards, 30,000 meters of windbreak and dust suppression nets are built and sprinkler and fog cannon systems are installed to achieve "no dust when unloading coal and no visible coal when stacking coal". On-site underground treatment of mine water Wells has been completed. 21 deep utilization projects of mine water have been built, adopting the "Water Cube" ultrafiltration + reverse osmosis process. The target for the reuse rate of mine water by 2026 is expected to be $\geq 75\%$, saving 4.2 million yuan annually. The gas is being exhausted completely. There are 29 sets of ground fixed and underground mobile extraction systems, 21 gas power stations and 132 units, with a rated installed capacity of 73 MW. The gas utilization rate is over 35% and has been increasing year by year.

3.2.3 Resource Recycling

To reduce environmental pollution, Longmei Group has turned the "three wastes" into secondary resources. Firstly, a "one mountain, one policy" approach was implemented for the management of gangue mountains. A total of 51 gangue mountains were treated, with an annual consumption of 7 million cubic meters, which was used for road construction, backfilling, sand making and land reclamation. Secondly, a mechanism sand project was carried out, using gangue to produce construction sand. A total of 18,200 cubic meters of gangue were consumed, and 12,700 cubic meters of finished sand were produced, turning waste into building materials. In addition, the demonstration project of waste heat recovery to replace coal-fired heating and waste heat heating from exhaust and compression fans has been put into use in four mines, saving 11,000 tons of standard coal and reducing CO₂ emissions by 29,000 tons annually.

3.2.4 Industrial upgrading

Longmei Group has completed the transformation from "dominant coal mining" to "multi-energy complementary" intelligent mining. It has built six intelligent demonstration mines, and 65% of the main underground transportation, drainage, power supply and other systems have achieved unmanned operation, reducing the number of workers per shift by 50%. The integration of new energy "wind, solar, thermal, storage and hydrogen" has been completed, and the grid-connected photovoltaic projects generate 48 million kWh of electricity annually. The 200MW wind power project under construction in Shuangyashan is expected to be put into operation by the end of the year. By 2025, the installed capacity of new energy will reach 2,891.6 MW, with an annual power generation of 3 billion kWh, equivalent to planting 250,000 trees. The demonstration of gas-hydrogen energy coupling has been completed. Relying on the hydrogen-rich characteristics of gas, the "gas reforming

hydrogen production + hydrogen fuel cell" experimental line has been launched to build a green hydrogen industrial chain in the mining area.

3.2.5 Ecological restoration

In order to restore the value of the collapsed land, Longmei Group has carried out land reclamation using the "strip jumping excavation and jumping filling method", investing a total of 210 million yuan to reclaim 610 hectares of collapsed land. The shallow collapsed areas have been transformed into high-standard crab rice fields, while the deep collapsed areas have developed fishery and photovoltaic complementary and ecological aquaculture, increasing the average income per mu by 2,000 yuan. Longmei Group actively develops industrial tourism projects. For instance, the open-pit mine in Lingbei, Hegang, has been transformed into a national mine park, integrating science popularization, study Tours and leisure. It can receive 300,000 tourists annually。

4. Case Analysis

4.1. Key Experience

Longmei Group has transformed its "ecological balance sheet" into a "green balance sheet". It first calculates the "liabilities" of emissions, land occupation and energy consumption, and then designs the "assets" for pollution reduction and carbon emission reduction. Realize the dual-wheel drive of "internal circulation within the mine - cross-border outside the mine". Within the mine, make full use of gas, waste heat, mine water and gangue. Outside the mine, utilize the land in the shut down mining area, grid connection and technical talents to develop wind, solar, hydrogen and storage. Implement the system and technology in harmony, with the top leader taking the lead and carbon indicators included in the assessment, to clear the institutional obstacles for the implementation of technology. Technology (intelligence, gas power generation, clean energy use) in turn solidifies the institutional achievements. For ecological restoration to "grow" new economy, the collapsed land should not be simply backfilled, but rather "reclamation + fishery and photovoltaic complementary + industrial tourism", so that the restoration itself can generate cash flow. This is a key experience for Longmei Group's green transformation.

4.2. Before-and-After Comparison

Looking at the current path of green transformation of Longmei Group, the achievements are remarkable. Before the green transformation, traditional coal mining was dominant, and there were problems such as pollution from coal-fired boilers, gas emissions, and accumulation of gangue, which put considerable pressure on the ecological environment. After the transformation, 324 coal-fired boilers were replaced, reducing self-used coal by nearly 150,000 tons. 40 mine water plants were built, and the utilization rate of mine water has been continuously improving. At the same time, Longmei Group actively developed new energy, completing multiple photovoltaic power generation projects and 21 gas power stations. In addition, a total of 51 gangue mountains have been treated, with an annual utilization volume of gangue reaching over 7 million cubic meters. The ecological environment of the mining area has been significantly improved, achieving a win-win situation for economic development and environmental protection. Nowadays, the cities where Longmei is located are no longer the "coal cities" where people are covered in dust and smog fills the air when they go out. Instead, they have transformed into "tourist cities" with green mountains and clear waters, fresh air and happy people's lives.

4.3. Core Issue

However, Longmei Group's green transformation also faces multiple core issues. Firstly, the traditional coal industry chain is highly dependent on fossil energy, resulting in a "high-carbon lock-up", with the space for emission reduction being locked down layer by layer by processes, equipment, and concepts. Secondly, in the past, the "three wastes" of waste gas, waste water and waste residue

from mining surrounded the city. Gangue mountains, mine water, gas, dust and subsidence land were piled up in multiple ways, forming an "environmental debt". Furthermore, under the expectation of "single structure" and resource depletion, enterprises have weak risk resistance capabilities and urgently need to find a "second growth curve".

4.4. Specific Path Analysis

Longmei Group has completed its green transformation through multiple channels. Among the green transformation paths of Longmei Group, the establishment of systems first has shortened the decision-making chain, ensuring smooth funding and approval, which has improved work efficiency. It has directly linked environmental protection indicators to annual salaries, providing the strongest enforcement rigidity. However, there may be problems such as excessive reliance on the will of the "top leader", personnel changes easily leading to policy wavering, and assessment focusing on "quantity" easily neglecting the long-term ecological quality. In the green transformation path of Longmei Group, the technologies for source reduction are mature, such as ultra-low emissions and closed networks, which have immediate effects and can meet the standards within 2 to 3 years. The transformation cycle is short. However, there may be the issue of "end-of-pipe treatment", with no constraints on the total amount of coal. Once production capacity expands, it can lead to a rebound in emissions. In addition, the operating costs are high, and enterprises are under greater pressure during the period of coal price decline. In the green transformation path of Longmei Group, the resource recycling process turns the "three wastes" into cash flow. Gas power generation, gangue sand making, and waste heat heating are all profitable. The technology has a high degree of localization and can be rapidly replicated within the mining area. However, the extraction of gas is restricted by geological conditions. High-gas mines have high benefits, while low-gas mines have almost no profits. The production of sand from gangue needs to solve the problems of heavy metal pollution and market saturation. Once the infrastructure construction in the surrounding areas slows down, the sales channels will be limited. In the green transformation path of Longmei Group, industrial upgrading has led to a reduction in the number of workers and an increase in efficiency through intelligentization. The number of workers per shift has been reduced by 50%, and the cost per ton of coal has dropped by 8-12%. The "ready-made interface" between wind, solar, hydrogen, storage and the power grid in the mining area has been established, and the grid connection conditions are superior to those of projects in the wasteland. There is a problem that the one-time investment in intelligentization is large, such as 300 to 500 million yuan for a single mine, which small and medium-sized mines cannot afford. Although the installed capacity of new energy is large, it is affected by the consumption capacity in Northeast China and fluctuations in electricity price policies, and the rate of return is uncertain. In Longmei Group's green transformation path, reclamation combined with fishery and photovoltaic complementarity has simultaneously addressed the triple demands of "land indicators + energy indicators + cash flow". Industrial tourism has enhanced the company's brand, and the annual ticket and related revenue can cover 30-40% of the reclamation costs. There are problems such as a pre-investment of 200 to 300 million yuan per thousand hectares for reclamation, a long payback period, high requirements for cash flow, a high reliance on transportation and marketing for tourist flow, and a high risk of secondary abandonment once the popularity wanes.

5. Conclusion

Longmei Mining Holding Group Co., Ltd. has adopted a closed-loop measure of "system - pollution reduction - recycling - industry - restoration", with five main lines of system first, source reduction, resource recycling, industrial upgrading and ecological restoration. It has transformed "governance costs" into "investment logic" and "environmental constraints" into "industrial opportunities". Efforts have been made to achieve a systematic reshaping from a "black coal city" to a "green mining area", providing a replicable "Heilongjiang solution" for the high-quality and sustainable development of resource-based enterprises. Policy opportunities, investment in

technological research and development, and the layout of green industrial chains play a significant role in the green transformation of traditional energy enterprises.

This article, through in-depth research on Longmei Group's "green transformation", has summarized the following suggestions. First, it is necessary to further promote the reform of state-owned enterprises in Longmei Group, introduce strategic investors to optimize and strengthen the coal industry, and explore the form of "participating in shares but not holding controlling stakes, distributing dividends but not operating" to open the door and let the water flow freely. Secondly, it relies on precise investment promotion to undertake the gradient transfer of domestic industries and on the transformation and upgrading of emerging industries. Finally, digital mines lead the upgrading of the industry, using automation and informatization as new market drivers to promote the iterative upgrading of mines.

This study adopts the case study method to explore the issues of enterprise green transformation through in-depth analysis of individual cases. However, this method has led to the individuality and limitations of the conclusions of this study. As it is impossible to obtain all the information on the green transformation of enterprises, the case analysis in this article is relatively one-sided. To draw a more comprehensive analysis, it is necessary to further collect more annual data and internal materials to support the reliability and extensiveness of the research conclusion. In the future, as the green transformation gradually deepens, Longmei Group will present more researchable indicators. At that time, models and empirical research can be utilized to study the green transformation paths of traditional energy enterprises more objectively and comprehensively, and extend to the benefit level.

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