

Promoting the Transformation of Old Industrial Bases Through Energy Revolution

Huang Qili¹, Li Quansheng², Li Weiqi³, Li Jizu⁴, Zhang Kai²

1. State Grid Corporation of China, Beijing 100031, China

2. China Energy Investment Group Co., Ltd., Beijing 100011, China

3. Sichuan Energy Internet Research Institute, Tsinghua University, Chengdu 610213, China

4. College of Economics and Management, Taiyuan University of Technology, Taiyuan 030024, China

Abstract: Old industrial bases in China currently face various challenges owing to the contradiction between the institutional mechanism and the economic structure. The energy revolution offers valuable support for the transformation of these bases. In this study, the basic characteristics and development status of old industrial bases in Northeast China and Shanxi were investigated, and the key problems regarding energy transformation in these locations were analyzed. Moreover, an energy-transition strategy for the old industrial bases was proposed, and strategic measures and policy suggestions were suggested. Based on a quantitative analysis and strategic study, we investigated the connotation and strategic positioning of energy revolution in the old industrial bases and proposed strategic goals for their transformation by 2035 and 2050. The following measures are proposed to transform and upgrade the energy industry in the old industrial bases and to optimize the energy production: the construction of a special energy economic zone within Shanxi, Eastern Inner Mongolia, and Northeast China; the encouragement of shale oil development; the promotion of the comprehensive utilization of abandoned oil and gas reservoirs and abandoned mines; support for the transformation of resource-dependent areas; the promotion of the diversified utilization of fossil energy resources; the construction of a demonstration base for the diversified utilization of renewable energy; and the establishment of a talent incentive mechanism.

Keywords: energy revolution; old industrial base; diversified utilization; energy cooperation; shale oil development

1 Introduction

With the changes in the global energy structure, China has presented important discourse on the energy revolution, introduced a new realm of energy development theory with Chinese characteristics, and provided a fundamental basis for the energy development of the country. Owing to the differences in the regional energy resource endowments, as well as economic and social development, the energy revolution needs to integrate regional development strategies, focus on the active role of economic and social development as well as ecological environmental protection, and promote the energy revolution in accordance with local conditions to provide strong support for China to achieve high-quality development [1].

The old industrial bases include Northeast China (Heilongjiang Province, Jilin Province, and Liaoning Province) and Shanxi Province, which have played pivotal roles in promoting economic and social development. With the in-depth development of the reform and opening up policy, the institutional and structural contradictions of the old industrial bases have become increasingly prominent, and numerous problems and challenges are currently faced in the development process. The promotion of a revolution in energy production and consumption as well as the

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Corresponding author: Li Quansheng, professor of engineering of China Energy Investment Group Co., Ltd. Major research field is coal mining and ecological restoration in mining area; E-mail: quansheng.li@chnenergy.com.cn

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construction of a clean, low-carbon, safe, and efficient energy system are essential for improving the quality and efficiency of economic development and realizing the rapid, healthy, and sustainable economic development of the old industrial bases.

The energy revolution should promote the transformation and development strategy research of the old industrial bases. Moreover, transformation and development measures for the old industrial bases need to be proposed. Such measures will be conducive to enhancing the energy security capacity of Northeast China, Shanxi Province, and other regions; improving the quality of economic development; and promoting the transformation and upgrade of the energy industry. The fundamental transformation of energy production and consumption patterns will provide strategic support for the construction of ecological civilization in the old industrial bases.

2 Status quo and problems of energy supply and demand in old industrial bases

2.1 Analysis of status quo of energy supply and demand

2.1.1 Status quo of energy supply and demand in Northeast China

The characteristics of the energy resource endowment in Northeast China are focused on oil, unconventional oil and gas, biomass, wind energy, and solar energy rather than on fossil fuel such as coal and natural gas.

(1) In Northeast China (particularly in Liaoning Province), energy supply is limited, and the energy consumption is dependent on supply from other regions. In 2017, the total primary energy production in Northeast China was 1.72×10^8 tce, and the total energy consumption was 4.08×10^8 tce. The energy self-sufficiency rate was only 42%, which was significantly lower than the national average; this rate has continuously decreased in recent years [2]. (2) The consumption of fossil energy in Northeast China exceeds the national average. In 2017, coal accounted for 69% of the total energy consumption in Heilongjiang Province, and oil accounted for 22% and 32% of the total energy consumption in Heilongjiang Province and Liaoning Province, respectively, significantly exceeding the national average [2]. (3) The proportion of non-fossil energy consumption in Northeast China is lower than the national average, and the wind curtailment rate is relatively high in certain areas. East Inner Mongolia, which is a typical energy-exporting region, is the main coal base of China, and its energy consumption is significantly lower than its output.

2.1.2 Status quo of energy supply and demand in Shanxi Province

(1) From the perspective of supply, in Shanxi Province from 2013 to 2018 (Table 1), the primary energy output accounted for >97.5% of the raw coal output. Additionally, the proportion of hydropower and wind power increased to 1.51% (2018) [3]. More than 50% of raw coal can be converted into secondary energy. In 2018, the energy required for raw coal processing and conversion in Shanxi Province accounted for 71.97% of the primary energy output, among which clean coal and other washed coal accounted for 47.43%. (2) From the perspective of consumption, the energy produced in Shanxi Province is not used only within the province. Since 2010, the coal export volume of Shanxi Province accounted for >50% of the coal production. In 2017, the external power transmission accounted for 30% of the total power generation. In 2018, the external power transmission in Shanxi Province reached 9.27×10^{10} kW·h, exhibiting a yearly increase of 19.6%—second only to Inner Mongolia and Sichuan [3]. As the energy output continues to increase, the local energy consumption of Shanxi Province has also been increasing. In 2016 and 2017, the total energy consumption of the province increased by 0.09% and 3.38%, respectively. (3) The energy consumption in Shanxi Province is dominated by coal. In 2017, coal consumption accounted for 86.42% of the total energy consumption; electricity consumption ranked the second, accounting for 6.57%; and oil and natural gas consumption accounted for 4.14% and 2.87%, respectively. Compared with the consumption in 2012, the proportion of coal consumption in Shanxi Province decreased by 2.12% in 2017, whereas the proportions of electricity, natural gas, and oil consumption increased by 0.39%, 1.45%, and 0.28%, respectively. The proportion of non-fossil energy in the primary energy consumption is significantly lower than the national average [4].

2.2 Problems faced in energy development of old industrial bases

The problems facing the energy transformation and development of the old industrial bases include insufficient utilization of non-fossil energy; a high proportion of fossil energy consumption and a high energy consumption intensity; significant problems in the consumption of renewable energy; and the large amounts of environmental pollution and pollutant discharge. In Shanxi Province, the task of reducing the coal production capacity is challenging. Even if the coal production capacity is controlled within 1.0×10^9 t, an excess capacity of

approximately 4.0×10^8 t to 5.0×10^8 t remains to be resolved, and the innovation ability of the renewable energy industry is insufficient.

Table 1. Primary energy output and composition in Shanxi Province.

Year	Primary energy production (10^8 tce)	Proportion of raw coal in primary energy production (%)	Proportion of hydropower and wind power in primary energy production (%)	Proportion of processing and conversion energy output in primary energy output (%)			
				Thermal power	Clean coal and other washed coal	Coke	Total
2013	6.89	98.95	0.45	11.44	46.13	12.79	70.36
2014	6.84	98.83	0.52	11.54	47.71	12.44	71.69
2015	7.25	98.76	0.60	9.95	44.14	10.77	64.86
2016	6.30	98.21	0.99	11.36	50.82	12.62	74.80
2017	6.59	97.94	1.23	11.72	51.70	12.36	75.78
2018	7.08	97.63	1.51	11.83	47.43	12.71	71.97

There are further core issues regarding the energy transformation and development of the old industrial bases. These issues include lagging concepts that restrict the transformation and development; outdated systems and mechanisms, which are key factors restricting the transformation and development; an imperfect talent mechanism, which is a common factor that restricts transformation; and the negative effects of industrial transformation of the old industrial bases. Furthermore, the irrational labor employment structure is a significant problem. Taking Shanxi Province as an example, the labor force employment ratio in the primary and secondary industries is relatively high, whereas the labor force employment ratio in the tertiary industry is relatively low. There exists a trend of labor transfer from the primary and secondary industries to the tertiary industry across the country, and the gap between the labor employment structures of Shanxi Province and the entire country appears to be widening.

The transformation of the old industrial bases involves energy transformation as well as the transformation of concepts, mechanisms, systems, and industries, all of which are indispensable. To realize the transformation and development of the old industrial bases, we must adopt new ways of thinking, overcome misunderstandings, and fully revitalize the economy of the old industrial bases in Northeast China and Shanxi Province.

3 Energy transformation development strategy for old industrial bases

3.1 Connotation of energy revolution in old industrial bases

The energy revolution in the old industrial bases in Northeast China is as follows: the energy structure is transformed from high-carbon to low-carbon; the energy industry is upgraded from low-value-added to high-value-added; and the operations of energy companies are adjusted from the development and utilization of a single energy form to a diversified direction. The energy revolution can be embodied as follows: (1) Gradually increase the proportion of renewable energy; accelerate the industrialization process of the development and utilization of terrestrial shale oil; strengthen the clean and efficient development and utilization of coal; implement mixed combustion and achieve diversified utilization of biomass; and gradually form a safe and sustainable energy structure and supply system. (2) Make fundamental adjustments to the energy-consumption structure through the scientific implementation of clean energy heating, multi-energy coordinated utilization, and demand-side management to adjust the energy structure, improve the energy efficiency, and improve energy utilization. (3) Promote the in-depth integration of energy and modern information technology, with a focus on the research and development of key technologies such as land shale oil extraction, wind abandonment of hydrogen, wind power heating, the resource utilization of abandoned mines, and the conversion of abandoned oil and gas reservoirs into gas storage. (4) Energy system revolution: Give full play to the decisive role of the market in resource allocation as well as the role of the government in resource allocation and policy support; establish and improve mechanisms such as the electricity trading market and auxiliary service market; and focus on the transformation of development concepts as well as the improvement of talent mechanisms. (5) Energy open cooperation: Exploit the location

advantages of the Northeast region; actively participate in the Belt and Road international energy cooperation; vigorously promote interconnection among energy markets, equipment, technology, and services; and build an oil and gas import and export hub.

The energy revolution in the old industrial base of Shanxi can be explained as follows: On the premise of ensuring the green, clean, and efficient development of energy, the diversified development of the industrial structure is a priority, and energy companies taking the lead in demonstration are used as starting points. The energy revolution can be embodied as follows. (1) Energy consumption revolution: Implement total energy-consumption control for high-energy consumption industries and industries with an overcapacity to construct a conservation-oriented society. (2) Energy supply revolution: Increase the advanced coal production capacity, promote green mines and ecological environment management, and establish the cleanest coal-fired power system in the world. (3) Energy technology revolution: Promote industrial structure optimization and economic transformation with energy technology innovation, advance energy technology, and attach importance to engineering applications. (4) Energy system revolution: Restore the attributes of energy commodities, develop innovative energy-regulation mechanisms, and implement market-oriented reforms. (5) Strengthen open cooperation; vigorously promote the globalization of energy equipment, technology, and services; and construct energy special economic zones [5].

3.2 Strategic positioning

The transformation and development of energy in the old industrial bases in Northeast China and Shanxi Province exhibit similarities and differences. The commonalities are reflected in the adjustment of the energy structure, transformation of the energy production and consumption methods, construction of an ecologically civilized energy system, enhancement of energy security capabilities, and improvements in the economic development quality and efficiency. The resource endowments and the transformation and development foundations of the two old industrial bases differ. The old industrial base in Northeast China is rich in unconventional oil and gas, wind energy, solar energy, and biomass energy; has complete supporting facilities and strong equipment manufacturing capabilities; and encompasses Northeast Asia. The advantageous location conditions of the economic circle provide a foundation for the construction of strategic energy channels and the development of the equipment industry. In contrast, Shanxi Province is rich in coal resources, and the direction of energy transformation involves the construction of a modern coal industry system as well as the use of clean and efficient coal.

The overall strategic positioning of the energy revolution of the old industrial bases consists of the construction of a national-level fossil energy production and renewable energy development base. The Northeast region and Shanxi should engage in cooperation and collaborative innovation to create a Shanxi–Eastern Inner Mongolia–Northeast China energy special economic zone. The strategic development priorities of the energy revolution in the old industrial bases are as follows: (1) The Northeast old industrial base should make full use of the abundant oil and gas and renewable energy, accelerate the optimization and upgrading of the traditional petroleum industry chain, increase the development and utilization of continental shale oil, expand the diversified consumption channels of renewable energy, and develop the energy industry economy. Moreover, it should construct a diversified utilization base of new energy, a deep processing base for oil and gas, a clean development and utilization base for coal and electricity, a development base for terrestrial shale oil, and a comprehensive utilization base for biomass energy. The Northeast old industrial base should be converted into a national energy transformation and development demonstration zone. (2) The old industrial base in Shanxi Province should focus on the clean and efficient development and utilization of coal, construct a clean and green coal industry system, and upgrade to an industrial model of “coal + thermal power + new energy + energy equipment + technical service provider.” Furthermore, it should develop the coal economy and the new energy industry economy, as well as construct a collaborative innovation base for coal and new energy, so that the old industrial base of Shanxi Province will be in a leading position with regard to green development, efficient use, clean conversion, and reduced consumption of coal.

3.3 Strategic objectives

3.3.1 Strategic goal of energy transformation in Northeast old industrial base

To overcome the challenges of the high-carbon energy structure and gradual exhaustion of fossil resources in the old industrial base in Northeast China, the Northeast region should actively explore the development of shale

oil technology, promote the comprehensive development and utilization of wind and solar energy, and promote the implementation of mixed combustion and the utilization of biomass. While renewable energy consumption accounts for a proportion of the consumption, the region should continue to make the aforementioned adjustments to its industrial structure, and the energy industry should be transformed from low-value-added to high-value-added.

The primary energy consumption of the Northeast old industrial base is expected to reach 5.8×10^8 tce and 5.5×10^8 tce by 2035 and 2050, respectively. The proportion of coal, oil and gas, and non-fossil energy is expected to change from 5:3:2 in 2035 to 4:3:3 in 2050. This is consistent with the structural goals of the 2050 energy revolution of the country. The total power generation of wind and solar energy in the Northeast will reach 1.89×10^{11} kW·h and 3.12×10^{11} kW·h by 2035 and 2050, respectively, through the vigorous development of wind and solar resources. The proportion of thermal power generation will continue to decline, decreasing to 58% and 37% in 2035 and 2050, respectively.

3.3.2 Strategic goal of energy transformation in Shanxi old industrial base

According to the coal development plan of Shanxi Province, the coal output will be 1.0×10^9 t in 2020. Using the top-down computable general equilibrium model, it can be predicted that the coal production in Shanxi Province will be 8.24×10^8 t and 7.46×10^8 t in 2035 and 2050, respectively [6]. Therefore, it is necessary to promote coal production capacity reduction replacement and reduction reorganization, eliminate the outdated production capacity, and increase the proportion of the scientific production capacity so that it can reach 85% by 2035 and 100% by 2050.

In the field of power generation, according to the energy conservation and emission reduction goals of China, as well as the strategic positioning and resource endowment of Shanxi Province, simulations were performed using the MARKAL-EFOM energy technology model. The results indicated that, in 2035, the non-fossil energy power generation of Shanxi Province will account for 22% of the total power generation, and this figure will reach 32% in 2050. The non-fossil energy power generation of Shanxi is expected to reach 5.81×10^{11} kW·h and 5.99×10^{11} kW·h by 2035 and 2050, respectively, among which the total power generation from wind, solar, and hydropower will reach 1.28×10^{11} kW and 1.92×10^{11} kW·h in 2035 and 2050, respectively. Furthermore, the proportion of thermal power in the total power generation of Shanxi will decrease to 78% and 68%, respectively.

4 Strategic measures for development of energy transformation in old industrial bases

4.1 Strategic measures for old industrial base in Northeast China

4.1.1 Promote development of continental shale oil

Shale oil and gas are inevitable future options for the global oil and gas industry. The continental shale oil revolution is a vision for the petroleum industry of China. If the country can take the lead in realizing a breakthrough in the commercial development of shale oil, this will be of great significance for improving its crude oil protection capabilities and leading the development of the global petroleum industry. The Northeast region should leverage its advantages to develop into a national shale oil development demonstration base, contribute to the revitalization of the old industrial base in the Northeast, and realize the historical mission of energy transformation in the Northeast.

4.1.2 Promote diversified use of renewable energy

The development of wind power for use in the heating industry should be promoted, and the capacity of wind power consumption should be increased. The use of surplus wind power generation in the valley period can increase the electricity load and can indirectly reduce the lower limit of cogeneration, which is an effective means of overcoming the problem of wind power consumption. The development of industrial cooperation in hydrogen energy utilization as well as the diversified utilization of biomass should be promoted. Material heating should be commercialized and developed on a large scale. Bio-natural gases can be used in the distributed energy stations of villages and towns as well as car refueling stations; biogas residue and biogas slurry can be used in ecological agriculture, and CO₂ and other waste gases can be used in welding shielding gas and gas fertilizers.

4.1.3 Low-carbon and intelligent transformation of coal-fired power plants

The large-scale development of biomass blending in coal-fired power plants should be promoted in an orderly manner. Presently, the biomass-coupling transformation technology of coal-fired power plants is relatively mature. Regarding the construction of smart power plants, under the condition that the country strictly restricts the thermal

power production capacity, the growth of the thermal power installed capacity in Northeast China has been significantly controlled. Coal power companies must continuously improve their self-management, increase their peak-shaving capabilities and market competitiveness, eliminate outdated production capacity, and realize high-quality production capacity [7].

4.1.4 Demonstration project for comprehensive use of resources in abandoned mining areas

The comprehensive utilization of abandoned mine resources plays an important role in the process of the low-carbon energy transformation of China. The comprehensive use of abandoned mine resources in the Northeast must satisfy the needs of the national energy security strategy and the revitalization strategy of the old industrial base. This should mainly arise from the comprehensive utilization of renewable energy in abandoned mining areas and the transformation of gas storage [8].

4.1.5 Promote coordinated development of traditional equipment manufacturing, agriculture, forestry, and animal husbandry and emerging high-tech industries

On the premise of handling the energy stock and increase in the old industrial base in Northeast China, it is necessary to revitalize the traditional equipment manufacturing industry to make full use of the complete supporting facilities and major equipment manufacturing capabilities in the region and to integrate the national Belt and Road initiative. The optimization and upgrade of the industrial structure should be promoted, and an advanced equipment manufacturing base should be constructed. High-end technology industries should be developed; the construction of the industrial Internet should be accelerated; traditional manufacturing industries should be aided in optimizing their production links and supply chains; the production efficiency should be improved; and the transformation of traditional manufacturing into “modern intelligent manufacturing” should be promoted. Moreover, the modernization of agriculture, forestry, and animal husbandry should be accelerated, and high-quality development should be promoted. It is necessary to grasp the strategic opportunities of rural revitalization firmly, rely on Internet technology, vigorously develop smart agriculture, and start with green, high-quality branding and specialization.

4.2 Strategic measures for old industrial base in Shanxi

4.2.1 Realize scientific production capacity and promote green development of coal industry

The problem of coal overcapacity should be scientifically solved. The solution of coal overcapacity should be combined with the adjustment of the industrial structure; the remaining problems of reorganization and integration should be rationally solved; and industrial optimization, upgrading, and healthy development should be promoted. According to the geological conditions and mine layout, on the premise of production reduction and replacement, priority should be given to the development of large mines that are safe and efficient, with high resource utilization and strong anti-risk abilities; the reasonable setting of the coal development time, sequence, and intensity; and protective mining of special and scarce coal resources [9]. Conceptual innovation as well as adherence to green leadership are necessary. The transformation of the coal industry from extensive to intensive, from mechanization to intelligence, from labor-intensive to technology-intensive, and from purely production-oriented to production/service-oriented should be promoted.

4.2.2 Strengthen exploration, development, and comprehensive utilization of coalbed methane resources and improve comprehensive utilization level of coal-associated resources

Coal and coalbed methane should be accurately managed to improve the intensive and economical utilization of resources. Full coverage of gas drainage should be implemented, and the three-dimensional development of full coverage before, during, and after mining, as well as above and below the mines, should be realized. The drainage systems and technology must be improved; the drainage management should be strengthened; the utilization channels should be expanded; a large-scale base should be constructed; demonstration projects should be established; and pipeline improvements should be implemented.

4.2.3 Promote deep coal processing and extend coal industry chain

It is necessary to establish the concept of the scientific development of the modern coal chemical industry, placing the focus of resource-based industry development on resource transformation and value adding, and to develop the modern coal chemical industry on the basis of the rational allocation of the traditional coal chemical industry according to local conditions and reliable research. Attention should be paid to the development of a resource-based industrial chain that improves the level and efficiency of the comprehensive utilization of coal, and

the construction of modern coal chemical production demonstration bases should be promoted. The comprehensive conversion efficiency and intensive processing of coal resources should be improved, and the development of the industry to the high end and products to the terminals should be promoted. Numerous modern industrial parks with distinctive specialties, prominent brand images, and perfect service platforms should be cultivated and expanded.

4.2.4 Construct investment and operation model for abandoned mine construction and pumped energy storage and encourage preliminary planning and construction based on local conditions

The abandoned mines in Shanxi Province still have large amounts of usable resources. If secondary development is not conducted, a large amount of energy resources would be wasted, leading to serious environmental and social problems. At present, the overall resource development and utilization of abandoned mines in the province remain in their infancy, and the comprehensive use of abandoned mines will be strengthened in the future. The pumped energy storage power station serves the entire power system. It can perform numerous functions in the power grid system, and its service functions can only be fully realized by the unified dispatch of the power grid. At present, power-grid companies play a leading role in the construction of pumped energy storage power stations, which is conducive to the unified planning, unified scheduling, and orderly development of these stations. In the future, we can attempt to establish a diversified investment and operation model for pumped energy storage; we can also encourage coal-power and renewable-energy companies to participate in the investment and operation of pumped energy storage power plants.

4.2.5 Promote consumption and development of renewable energy and optimize the energy structure

It is important to adhere to the combination of local consumption and clean delivery, as well as the principle of new energy supply as the main demand for new energy. The ability to exploit new forms of energy through policy guidance and technological innovation should be developed. Moreover, the establishment of new energy power generation bases and transmission channels should be coordinated; various peak-shaving power sources of the power system should be deployed; and the energy transmission capacity and economy should be improved. The model of “wind energy + solar energy + hydropower + thermal power” can be adopted to establish Beijing–Tianjin–Hebei as a clean and low-carbon energy supply base and a national new comprehensive energy base. New energy equipment manufacturing and related supporting industries should be actively cultivated.

5 Countermeasures and suggestions

5.1 Layout at top level to construct energy special economic zone “Shanxi–Eastern Inner Mongolia–Northeast”

It is recommended to establish a “Shanxi–Eastern Inner Mongolia–Northeast China” energy special economic zone for constructing a Northeast Asian energy cooperation platform. The level of infrastructure in the region should be improved; the new installed capacity of thermal power should be strictly controlled; clean energy should be developed in an orderly manner; and power transmission channels should be constructed. Location advantages outside the region should be exploited; the construction of free trade zones should be accelerated; the free circulation of products and services should be realized; and the local and global exchange of knowledge and technology should be facilitated. An active foreign policy should be adopted; a better geopolitical environment should be created; and the economic volume and vitality of the Asia-Pacific region should be enhanced. The interconnection, intercommunication, complementarity, and interaction with the central and eastern regions of the country should be strengthened, and the establishment of old industrial bases should be promoted to achieve complementary advantages, regional linkages, and integrated development.

5.2 Encourage shale oil development

At the national policy level, it is recommended to provide financial subsidies to shale oil or to reduce taxes and fees, such as resource and mineral taxes. Government departments have implemented policies to reduce the approval process for shale oil applications for test land. Green channels should be opened in laboratory construction, and key technologies should be introduced to promote the formation of supporting technologies. At the local and enterprise levels, basic theoretical research should be conducted to provide scientific understanding and guidance for the empowerment of enterprises. Research should be strengthened to provide breakthroughs in the core technologies that restrict the development of continental shale oil as soon as possible, and a domestic key technology system that is independently researched and developed should be formed. Various forces, such as

central enterprises, private enterprises, and social capital, should be integrated, and market means should be used to increase support for shale oil research [10].

5.3 Promote comprehensive utilization of abandoned oil and gas reservoirs and abandoned mines

A sound government supervision system should be established for the entire process of the application, approval, implementation, and supervision of abandoned coal mine development and utilization projects. It is recommended to establish special funds for the utilization and development of renewable energy such as solar energy and geothermal energy in abandoned mines. Furthermore, research should be conducted on various supporting policies such as financial subsidies, tax reductions, and special funds for related industries. A systematic study on basic information such as the distribution and quantity of downhole and uphole space resources is suggested. Standard systems and policies for the development and utilization of abandoned mines should be formulated. Regarding solar and geothermal power generation projects in abandoned mines, the power pricing mechanisms should be formulated, improved, and adjusted in due course.

5.4 Support transformation of resource-based regions

As a resource-rich region, the old industrial base must establish a long-term development plan in advance to promote industrial transformation in an orderly manner. It is recommended to accelerate the transformation and upgrading of traditional industries, such as equipment as well as oil and gas, and to optimize the product structure toward the high end. The resource tax rates for mining enterprises and low-abundance oil fields should be appropriately reduced in the period of exhaustion. Preferential tax policies should be formulated for high-tech industries; strategic emerging industries should be cultivated; and research should be conducted on key technologies such as new energy vehicles and electronic information. Coal mine reorganization policies should be researched and promulgated, and the state can propose basic guidelines to carry out pilot work in Shanxi Province. Coal resources should be integrated and transformed; overcapacity tasks should be classified; and relevant policies should be implemented.

5.5 Increase resource utilization of fossil energy

The following recommendations are proposed: strengthen the research and development of fossil energy resource utilization technology, increase scientific research investment in coal-based fine chemical projects, construct industrial production-based and market-oriented scientific research centers, accelerate the transformation and upgrading of petrochemical bases, and cultivate core competition in the petrochemical industry. The high-quality and sustainable development of the petrochemical industry should be promoted. The coal-based oil industry should be supported and protected, and it should be endowed with a market access mechanism that is equivalent to that of the traditional petroleum industry. Additionally, preferential policies that can promote industrial development should be supported. As the characteristics of coal-based oil products and fine chemicals do not apply to the scope of consumption-tax adjustment, they should be treated differently from petroleum-based refined oil and should not be included in the adjustment range of consumption tax.

5.6 Construct demonstration base for diversified utilization of renewable energy

It is recommended to perform top-level design of the national biomass fuel industry and to conduct research at the industrial scale. Furthermore, implementation plans and related policies, systems, and coordination mechanisms are suggested. A strategy for gradually replacing coal with biomass and transforming coal power into low-carbon thermal power should be developed. The price subsidy policy for biomass heating products should be improved, and biomass heating projects should be developed according to local conditions in response to the phenomena of excessive electricity and heat shortages during winter in Northeast China. The implementation of industry standards for the biomass-to-natural gas industry should be accelerated. It is important to coordinate the layout of wind and solar energy resources, as well as the power transmission and market consumption, and to improve the power dispatch and operation management mechanisms. Wind power plants should be encouraged to participate in local electric heating renovation projects and to obtain priority power-supply rights. The participation standards of electric heating users and wind-power companies should be standardized to ensure the effective execution of transactions of wind power, heating, and power market. Preferential policies such as taxes and land should be provided for wind-power hydrogen production projects, and wind-power hydrogen production and hydrogen-energy companies should be encouraged to invest in one another. Fully guaranteed purchases should

be implemented. The power-grid companies should be responsible for supporting power-grid projects other than booster stations, for example, and capacity ratios should be restricted.

5.7 Intensify introduction of talents and implement a talent incentive policy mechanism

It is recommended to cultivate and introduce professionals, accelerate the construction of talent platforms, formulate preferential treatment policies, support workers in changing jobs and starting their own businesses, and tap into the potential of human resources. Talents should be retained and exploited; a soft environment should be created for talents; attention should be paid to the optimal allocation of talent resources; and a talent siphon effect should be formed [11]. An international scientific and technological cooperation base should be formed; an information system for scientific and technological talents should be built; and the sharing and communication of regional scientific and technological talent resources should be facilitated. It is necessary to promote mass entrepreneurship and innovation, give full play to the role of the private economy in absorbing professionals, and realize industrial innovation by gathering talented personnel.

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