

Analysis of Energy Optimisation Paths for Supply-Side Structural Reforms

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Abstract: This study explores the important role of energy optimization paths in supply-side structural reforms. It analyzes the relationship between energy and economic development, elaborates on the promoting role of energy optimization in supply-side structural reforms, including reducing costs by improving energy efficiency and promoting industrial upgrading. Through three aspects of technological innovation, policy guidance and enterprise practice, it analyzes the energy optimization paths, points out the shortcomings of the research and looks forward to the future integrated development.

Keywords: Energy optimization, Supply-side structural reforms, Technological innovation.

1. Introduction

With the rapid development of the global economy, energy demand continues to grow, while environmental problems are becoming increasingly serious. Against this background, energy optimisation has become a key part of supply-side structural reform. Supply-side structural reform aims to adjust the economic structure, improve the quality and efficiency of the supply system, and achieve sustainable economic development. And energy, as an important support for economic development, its optimisation path is of great significance for supply-side structural reform.

On the one hand, energy optimisation can help improve energy efficiency, reduce energy waste and energy costs, thus improving economic competitiveness. On the other hand,

energy optimisation can promote the development of clean energy, reduce the dependence on traditional fossil energy, reduce environmental pollution, and achieve the coordinated development of economy and environment [1]. In addition, energy optimisation can also promote energy technology innovation, cultivate new economic growth points, and provide impetus for sustainable economic development.

This study aims to explore the important role of energy optimisation paths in supply-side structural reform, and to provide theoretical support and practical guidance for achieving sustainable economic development. Through the analysis of energy production, consumption and technological innovation, it puts forward specific paths and policy recommendations for energy optimisation, providing reference for governments and enterprises to formulate energy policies and development strategies.

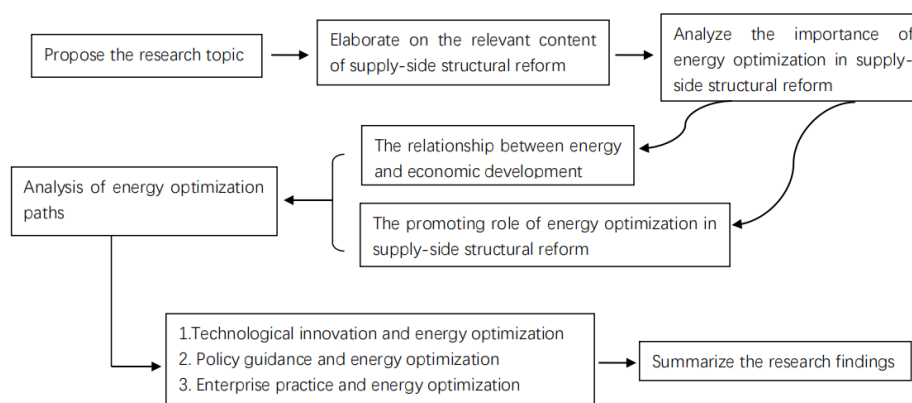


Figure 1. Main research process

2. Overview of Supply-Side Structural Reforms

2.1. Connotation of Supply-Side Structural Reforms

Supply-side structural reform starts from improving the quality of supply, promoting structural adjustment by means of reform, correcting distortions in the allocation of factors, expanding effective supply, improving the adaptability and flexibility of the supply structure to changes in demand, increasing total factor productivity, better meeting the needs

of the general public, and promoting the sustained and healthy development of the economy and society. Specifically, this includes cutting ineffective supply, such as resolving overcapacity, removing zombie enterprises, and restructuring some inefficient and highly polluting industries; fostering new growth drivers, promoting the development of emerging industries and high-end manufacturing through technological innovation and industrial upgrading; and lowering the cost of the real economy, including lowering the burden of enterprise taxes and fees, lowering the price of electric power, pushing forward the reform of electricity prices on a market basis, improving the coal and electricity price linkage mechanism,

and reducing logistics costs.

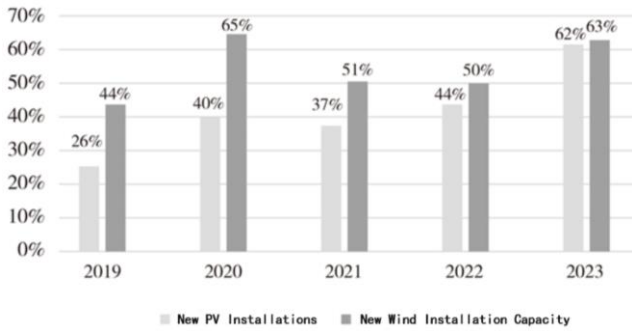


Figure 2. China's Percentage in Global New Energy Expansion

Supply-side structural reform is of great significance to economic development. Firstly, it helps enhance the vitality of the real economy. Through measures such as removing production capacity and lowering costs, it improves the profitability and competitiveness of enterprises and promotes the revitalisation of the real economy [2]. For example, the main business income of industrial enterprises has been increasing under the impetus of supply-side structural reform, and the industrial economy has been recovering. Secondly, supply-side structural reform can optimise the economic structure. On the one hand, medium- and high-end industries have been steadily improving, new industries and new modes of business have been growing faster, and the proportion of added value of high-tech manufacturing and equipment manufacturing has been increasing; on the other hand, the industrial structure has been continuously optimised, and in addition to the traditional manufacturing industry, emerging industries such as the sharing economy and the digital economy have become an important engine of economic growth, and the emerging service industry has also been developing rapidly. In addition, the supply-side structural reform can also promote the further release of the vitality of market players. With the promotion of the 'release of administrative services' reform, the process of enterprise registration and establishment has become more convenient, the market access environment has been optimised, and a large number of new enterprises have emerged, which lays a solid foundation for the sustained growth of the economy. In short, supply-side structural reform is an inevitable choice to adapt to and lead the new normal of economic development, and has an irreplaceable and important role to play in promoting the high-quality development of China's economy and achieving long-term stable economic growth.

2.2. Development History of Supply-Side Structural Reforms

Since the Third Plenary Session of the Eleventh Central Committee in 1978, China has started the road of reform and opening up. During the process of economic reform, China's ownership structure, economic system, industrial structure, and industrial system have undergone profound changes.

Single socialist public ownership system, and then, after the reform and opening up, to the coexistence and co-prosperity of multiple ownership economies. The economic system has evolved from a new democratic economic system, through a planned economic system, to a socialist market economic system. In terms of industrial structure, the proportion of agriculture has declined sharply, the proportion of industry and services has continued to rise, and the three industries have moved towards synergistic development. The

industrial system has also developed from a backward state in which the output of several major industrial products accounted for a very low proportion of the world's total output to a stable second-largest economy in the world.

The supply-side structural reform proposed by the central government at the end of 2015 has a profound background. Since the reform and opening up, China's economy has achieved sustained high growth, but the side effects of demand-side management have become more and more obvious over time. Since 2003, productivity reform of China's central enterprises has become slow[3]. China's supply and demand relationship faces a structural imbalance, with inefficiencies on the supply side leading to a failure to meet demand, and the 'supply-demand mismatch' has become the biggest roadblock to China's sustained economic growth.

The goal of supply-side structural reform is to improve the quality of supply, promote structural adjustment by means of reform, correct distortions in the allocation of factors, expand effective supply, improve the adaptability and flexibility of the supply structure in response to changes in demand, increase total factor productivity, better satisfy the needs of the masses, and promote the sustained and healthy development of the economy and society. Specifically, this includes cutting ineffective supply, such as resolving overcapacity, removing zombie enterprises, and restructuring some inefficient and highly polluting industries; fostering new growth drivers, and promoting the development of emerging industries and high-end manufacturing industries through technological innovation and industrial upgrading; and lowering the cost of the real economy, including lowering the burden of enterprise taxes and fees, lowering the price of electric power, pushing forward the reform of electricity prices on a market basis, improving the coal and electricity price linkage mechanism, and reducing logistics costs.

Industry Type Contribution to GDP (%)

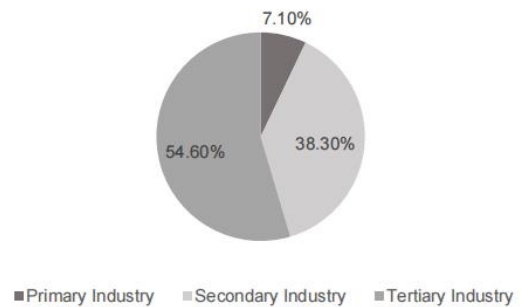


Figure 3. Industry Type Contribution to GDP

3. The Importance of Energy Optimisation in Supply-Side Structural Reforms

3.1. Relationship Between Energy and Economic Development

Energy is the material basis for the survival and development of society, and has a fundamental role in economic development. On the one hand, energy is the power source of industrial production, providing indispensable power support for industrial production. For example, traditional industries such as iron and steel, coal and new manufacturing industries are inseparable from the supply of energy. From the actual situation of China's energy abundance, energy plays a huge role in promoting economic and social

development. The energy industry has a large investment and strong driving effect, and accelerating the construction of a modern energy system can better guarantee energy security and serve the high-quality development of the economy and society [4].

There is an interdependence and interaction between energy supply and economic growth. First of all, energy supply is the basic condition of economic development, only to ensure the supply of energy resources to support the normal operation of the economy. For example, during the epidemic, although China once appeared part of the material shortage situation, but Wuhan and other cities have never appeared power interruption or fuel, natural gas supply tension, which fully reflects the importance of energy supply in ensuring stable economic operation. Secondly, economic growth is also increasing the demand for energy, and economic development will contribute to the consumption of energy. Assessed from a macro perspective, trends in indicators such as national economic growth rates, energy consumption intensity and energy dependence reflect the long-term impact of energy supply on economic growth. For example, as the economy grows, the demand for energy in all sectors increases accordingly, and the lack of supply of energy or the conflict between supply and demand may lead to bottlenecks in economic activities and impede economic growth. At the same time, a stable supply and reasonable prices of energy also play a key role in economic growth. Fluctuations in energy prices can have a positive or negative impact on economic growth by influencing corporate production and individual consumption decisions. A stable energy supply and reasonable prices can provide a favourable production environment, stimulate business investment and innovation, and promote sustained economic growth. In addition, the sustainable use of energy is crucial to economic growth. The active development and use of renewable energy and the improvement of energy use efficiency can not only reduce dependence on traditional energy sources, but also promote economic restructuring and the development of a green economy, thereby achieving sustainable development. There is also an interactive relationship between economic growth and energy demand. Economic development is usually accompanied by an increase in energy demand, especially during the period of accelerated industrialisation and urbanisation. The expansion of the economy and the improvement of people's living standards contribute to increased energy consumption. The demand for economic growth drives the development of the energy industry and technological innovation, which in turn meets the energy needs of more people. However, economic growth can also bring side effects of energy consumption. An energy-intensive economic growth model may lead to overexploitation of energy resources and environmental pollution problems. Over-exploitation and use of fossil energy not only exacerbates the shortage of energy resources, but also contributes to the emission of greenhouse gases, exacerbating environmental problems such as climate change. Therefore, economic growth needs to be based on ensuring the supply of energy, strengthening the management and sustainable use of energy, and achieving the coordinated development of the economy and energy.

3.2. The Role of Energy Optimisation in Promoting Supply-Side Structural Reforms

Energy optimisation has a multifaceted role in promoting supply-side structural reform. First, improving energy efficiency is one of the important ways of energy optimisation, which can significantly reduce costs. By adopting advanced energy-saving technologies and equipment, enterprises can reduce energy consumption, lower production costs and improve economic efficiency. For example, in traditional industries such as iron and steel, coal and other traditional industries, the promotion of energy-saving technologies can effectively reduce the energy consumption per unit of product, improve production efficiency and enhance the competitiveness of enterprises.

Secondly, energy optimisation promotes industrial upgrading. With the adjustment of the energy structure and the development of clean energy, the traditional high energy consumption and high pollution industries are facing the pressure of transformation, prompting them to shift to high-end manufacturing and green development. For example, in the iron and steel industry, by optimising the energy structure and improving the efficiency of energy use, enterprises are pushed to increase investment in technological innovation, develop high-end steel products, and enhance the added value of the industry. At the same time, energy optimisation also provides opportunities for the development of new industries. The rise of new energy industries, such as solar energy, wind energy, etc., not only injects a new impetus for economic growth, but also drives the development of related industrial chains and promotes the optimisation and upgrading of industrial structure.

Specific cases are used to illustrate the practical effects of energy optimisation in supply-side structural reform, such as the role of energy optimisation in reducing production costs in the process of market-based capacity reduction in the iron and steel and coal industries.

Taking the steel and coal industries as an example, energy optimisation plays an important role in the process of market-based capacity removal. The CPC Central Committee and the State Council attach great importance to the work of removing production capacity in iron, steel and coal, and through the joint efforts of all regions, all relevant departments and all relevant enterprises, significant results have been achieved.

On the one hand, the task has been completed ahead of schedule. In 2016, the national iron and steel industry reduced crude steel production capacity by more than 65 million tonnes, and the coal industry dissolved production capacity by more than 290 million tonnes, which exceeded the annual task ahead of schedule. As the work of removing production capacity continues to progress, problems such as tight cash flow, outstanding safety investment and delayed payment of wages have been eased.

On the other hand, the situation of the industry has improved significantly. With the promotion of energy optimisation, the production and operation situation of the iron and steel and coal industries has improved as a whole. 2016 profits of member enterprises of the Iron and Steel Industry Association turned from a loss of 84.7 billion yuan in 2015 to a profit of about 35 billion yuan; coal enterprises above designated size achieved a profit of 95 billion yuan, which was about 2.1 times of that of 2015.

In the process of removing production capacity, energy optimisation has played a key role in reducing production costs. For example, by eliminating outdated production capacity and adopting advanced energy-saving technologies and equipment, energy utilisation efficiency has been improved and energy wastage reduced. At the same time, it actively promotes mergers and reorganisations to optimise the industrial structure, achieve economies of scale and reduce production costs. In addition, the development of clean energy and the reduction of dependence on traditional fossil energy sources also help to reduce energy costs and environmental pollution.

In short, energy optimisation has played an important role in the market-based capacity removal process in the steel and coal industries, providing strong support for supply-side structural reform.

4. Path Analysis for Energy Optimization

4.1. Technology Innovation and Energy Optimisation

4.1.1. Introduce the application of new technologies in the field of energy, such as Internet + energy and new energy technologies

In today's era, new technologies are constantly emerging and being widely applied in the energy field. The 'Internet + Energy' model is gradually changing the pattern of the traditional energy industry. Through Internet technology, intelligent management of energy production, transmission, distribution and consumption can be realised, and the efficiency and reliability of the energy system can be improved. For example, smart grids make use of advanced sensors, communication technologies and data analysis to achieve real-time monitoring and optimal scheduling of the power system, improving the stability and efficiency of power supply. At the same time, the development of new energy technologies provides a strong impetus for energy optimisation. Renewable energy technologies such as solar energy, wind energy, water energy, geothermal energy and other renewable energy technologies continue to innovate, the cost is gradually reduced, and the scope of application is constantly expanding. Solar photovoltaic power generation technology is becoming increasingly mature, and is not only widely used in the household and commercial sectors, but also plays an important role in the construction of large-scale power stations. Wind energy technology continues to progress, with the development of large-scale wind turbines and the promotion of distributed wind energy improving the efficiency of wind energy utilisation. Innovations in hydropower technology have promoted the development of hydropower generation, and highly efficient hydropower equipment and optimised hydropower engineering design have improved the utilisation efficiency of hydropower resources [5]. Geothermal energy technology innovation has also provided new options for energy supply, and the development and utilisation of geothermal energy has a broad prospect in the fields of heating and power generation.

4.1.2. Analyse how technological innovation improves energy efficiency and reduces energy waste

Technological innovation improves energy efficiency and reduces energy waste in several ways. First, in the energy production chain, advanced energy conversion technology

can improve the efficiency of energy conversion from one form to another. For example, high-efficiency power generation technology can reduce the loss of energy in the power generation process and improve the efficiency of power generation. High-efficiency heat pump technology, on the other hand, can improve the recovery rate of energy in the process of energy utilisation and reduce the waste of energy. Secondly, optimising the energy system is also an important way to improve energy efficiency. Smart grids achieve rational distribution and effective use of energy through real-time monitoring and optimal scheduling to avoid energy waste. Distributed energy systems, on the other hand, can flexibly adjust energy supply according to users' needs and improve energy utilisation efficiency. In addition, technological innovation can also improve the energy recovery rate. Recycling of waste energy such as waste heat and pressure in the process of energy use can not only reduce the waste of energy, but also reduce energy costs. For example, in the industrial production process, the recycling of waste heat can be used for heating or power generation, improving the comprehensive use of energy efficiency. At the same time, the application of new energy technologies can also reduce dependence on traditional fossil energy sources, reducing energy waste and environmental pollution. The use of renewable energy sources such as solar, wind and water energy can not only provide clean energy, but also reduce the exploitation and consumption of limited fossil energy sources and achieve sustainable development.

4.2. Policy Guidance and Energy Optimisation

4.2.1. Explore the role of government policies in energy optimisation, such as tax incentives and subsidy policies

The government plays an important policy guidance role in energy optimisation. On the one hand, tax incentives can reduce the operating costs of energy enterprises and motivate them to increase their investment in energy optimisation. For example, tax breaks are given to enterprises engaged in clean energy research and development and production, encouraging them to actively explore new energy technologies and improve the efficiency of energy use. On the other hand, subsidy policies can directly support the implementation of energy optimisation projects. The government can provide financial subsidies for new energy projects and energy-saving technological upgrading to promote the adoption of advanced energy technologies and equipment by enterprises. For example, subsidies are given to enterprises and households that install solar photovoltaic power generation equipment to promote the development of the solar industry.

4.2.2. Take specific policies as examples to illustrate the promotion effect of policy guidance on energy optimisation

Taking China's new energy industry policy as an example, the government supports the green innovation of new energy enterprises through financial allocations, tax rebates, and financial interest subsidies. For example, the '14th Five-Year' Comprehensive Work Programme on Energy Conservation and Emission Reduction deploys the promotion of energy conservation and emission reduction and the fight against pollution, accelerates the establishment and improvement of a green, low-carbon and recycling economic system, and pushes forward the comprehensive green transformation of the economy and society. These policies have promoted the

development of new energy industries, improved the efficiency of energy use, and reduced reliance on traditional fossil energy sources.

In Sichuan, the government implements green investment policies, focusing on the 'double carbon' target requirements, implementing the concept of green investment, the implementation of precision investment, targeted investment, to eliminate high pollution, high energy consumption, high emissions of the project to take the road of green, low-carbon and sustainable development. At the same time, the leading enterprises to play a supporting role in fostering a number of 'speciality, speciality and new' small and medium-sized enterprises, to build a reasonable division of labour, complete support, strong protection of the industrial ecosystem, to accelerate the formation of a centralised layout, clusters into a chain, intensive and efficient green and low-carbon advantageous industrial development pattern.

The government also enhances the scientific and technological innovation ability of enterprises by strengthening the key core technology research and development. It builds an enterprise-oriented and market-oriented industry-university-research system and vigorously promotes the deep integration of industry-university-research and application. For example, it has accelerated the construction of the Tianfu Yongxing Laboratory, strengthened its technological research and industrial transformation capabilities, and strived to launch a batch of representative scientific research results in key areas such as resource carbon neutrality, zero-carbon energy, geothermal energy, green transportation and carbon sequestration, and made significant progress in productisation and industrialisation.

In addition, government innovation and policy guidance also play an important role in the development of new energy technologies. The government has set up special funds for the research and development of new energy technologies, established a standard system for new energy technologies, promoted the development of new energy technology clusters, strengthened the transformation and promotion of new energy technology R&D results, and improved the international competitiveness of the new energy industry. For example, the government has set up special funds to provide enterprises with loans, guarantees and other financial services to reduce the cost of financing; introduced relevant policies to encourage enterprises to increase R&D investment in new energy technology and promote industrial upgrading; invested in the construction of charging piles, smart grids and other infrastructure to provide protection for the application of new energy technology; and constructed industrial parks for new energy technology to attract enterprises to move into the parks and form an industrial clustering effect.

4.3. Enterprise Practice and Energy Optimisation

4.3.1. Analyse the main role of enterprises in energy optimization, such as enterprises reduce energy consumption through technological transformation and management innovation

As the main body of energy optimisation, enterprises play a key role in reducing energy consumption. On the one hand, technological transformation is an important way for enterprises to achieve energy optimisation. For example, enterprises in traditional industries such as iron and steel and coal can improve the efficiency of energy conversion and reduce the loss of energy in the conversion process by

adopting advanced energy-saving technologies and equipments, such as high-efficiency industrial boilers and intelligent motor systems. At the same time, enterprises can also introduce smart grid technology to optimise the operation of the power system, improve the efficiency of power distribution and reduce power losses. On the other hand, management innovation can also help enterprises reduce energy consumption. Enterprises can refine the management of energy use by establishing a perfect energy management system. Regular energy audits are conducted to identify the links of energy waste and take corresponding improvement measures. For example, installing energy monitoring systems to monitor energy use in real time and adjust production processes in a timely manner to achieve energy saving and emission reduction. In addition, like the National Green Factory of Boshiwa Household Electric Appliances Co., Ltd, through improving production, upgrading technical management and operation levels, and realising production potential, it has established an energy management system for the purpose of energy saving, and formulated energy management methods and facility management systems, and set clear assessment indicators and rules for the company's major consumed energy and raw materials, from procurement, transportation, storage and consumption of each link. In terms of specific technical solutions, gradually improve energy efficiency, increase photovoltaic power generation and energy saving, plan to invest in the construction of distributed rooftop photovoltaic power generation projects, increase the proportion of green power generation to total power consumption, and achieve the carbon neutral goal of the enterprise.

4.3.2. Introduce the enterprise's successful cases in energy optimisation to provide reference for other enterprises

Ma'anshan Iron and Steel Co., Ltd. has achieved refined management and dynamic optimisation of energy through the establishment of an energy data centre. This case study references the national standards for the construction of green factories, and encompasses the comprehensive deployment of hardware facilities such as equipment, sensors, gateways, and communication devices. By integrating advanced information technologies like intelligent sensing, data collection, digital twinning, and big data, along with management modules including intelligent experience design, energy control optimisation, and the "three flows and one state", systematic analysis and comparison have been conducted. The system provides timely warnings and guidance for energy production and system balance, effectively aligns with production and sales plans, and directs the organisation and supply of energy production, monitoring the usage of energy throughout the production process in a multi-tiered, multi-angular, and multi-granular manner. This initiative has facilitated the tracking, monitoring, statistical analysis, and analysis of the energy efficiency of key equipment; it has analysed the input and output of key energy consumption sources, integrated this with the information of key energy-using equipment, optimised energy configuration and structure, effectively reduced costs, and transitioned from energy consumption management to energy value management. The construction of the energy data centre has led to a 6% reduction in comprehensive energy consumption per unit of product and an 8% decrease in carbon dioxide emissions per unit of product.

Beijing Huada Zhibao Electronic System Co., Ltd., based

on the industrial internet, has undertaken the construction project of a building energy optimisation management system, serving the National New Media Industry Base. The project has established a complete set of energy control devices and platforms based on the industrial internet, providing comprehensive, convenient, and intelligent energy optimisation management services across a 10-square-kilometre area of the industry base. This includes thermal network balance transformation, hydraulic balance adjustment, safe operation of stations, emergency rescue, pipeline network construction, and engineering management. By utilising digital twinning technology, the project simulates the flow of energy, monitors, analyses, and diagnoses the urban energy network, formulates energy-saving optimisation strategies, and achieves refined guidance and scheduling of energy operations. Since the project's completion, the energy-saving rate for building energy consumption at the industry base has increased by approximately 20% compared to before the transformation, saving over 2 million yuan in energy costs annually. Following the construction of the platform, and based on optimised scheduling algorithms and industrial control devices, the annual energy-saving rate has reduced energy loss by approximately 20% compared to before the system transformation, demonstrating significant energy-saving and emission-reduction effects.

5. Research Findings

The energy optimisation path plays a crucial role in supply-side structural reform, providing strong support for sustainable economic development by improving energy efficiency, promoting industrial upgrading and reducing production costs.

In terms of the relationship between energy and economic development, energy, as the power source of industrial production, plays a fundamental role in economic development. Energy supply and demand interact with economic growth, and a stable energy supply and reasonable prices are crucial to economic growth, while the sustainable use of energy is also important to economic growth.

The role of energy optimisation in promoting supply-side structural reform is mainly reflected in improving energy efficiency, reducing costs and promoting industrial upgrading. By adopting advanced energy-saving technologies and equipment, adjusting the energy structure and developing new energy industries, enterprises can reduce production costs,

improve competitiveness and promote industrial upgrading. Taking the iron and steel and coal industries as an example, energy optimisation has played an important role in the process of market-based capacity removal, reducing production costs and improving industry efficiency.

In terms of path analysis of energy optimisation, technological innovation, policy guidance and enterprise practice are important ways to achieve energy optimisation. The application of new technologies in the energy sector, such as 'Internet + Energy' and new energy technologies, has improved energy efficiency and reduced energy waste. The government plays a policy-guiding role in energy optimisation, motivating enterprises to increase their investment in energy optimisation through tax incentives and subsidies. Enterprises, as the main body of energy optimisation, reduce energy consumption and achieve sustainable development through technological transformation and management innovation.

In summary, the energy optimisation path has important practical experience and practical significance in the supply-side structural reform. In order to further promote energy optimisation, it is necessary to strengthen technological innovation, improve policy guidance, strengthen enterprise practice, and jointly achieve the goal of sustainable economic development.

References

- [1] Wei W, Zhang G, Wang R, et al. An online train-grid integration energy optimization method for urban rail system [J]. *Energy*, 2024, 313:133842-133842.
- [2] Cambambi A C, Canha N L, Sperandio M, et al. Energy exchange optimization among multiple geolocated microgrids: A coalition formation approach for cost reduction [J]. *Applied Energy*, 2025, 379:124902-124902.
- [3] Mustafa A, Anwar M, Khan I T. Energy optimization of an institutional building to reduce the energy and air conditioning demand [J]. *Journal of Building Engineering*, 2024, 98:11309-11309.
- [4] Jing Z, Wang Q, Chen Z, et al. Optimization of energy acquisition system in smart grid based on artificial intelligence and digital twin technology [J]. *Energy Informatics*, 2024, 7(1):121-121.
- [5] S K, Rao D D, Jain A, et al. Effectual Energy Optimization Stratagems for Wireless Sensor Network Collections Through Fuzzy-Based Inadequate Clustering [J]. *SN Computer Science*, 2024, 5(8):1022-1022.