

Research on the Transformation Path of Energy System in Sichuan Province

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Abstract: Under the background of global energy structure reform and the implementation of the “double carbon” strategy, Sichuan Province, as a national clean energy base, its energy system transformation has important strategic value for ensuring regional energy security and promoting high-quality development. Based on the current situation of energy resource endowment and supply and demand in Sichuan Province, this paper analyzes the constraints of its transformation, and puts forward the collaborative optimization path of production end, output end and consumption end. The research results provide methodological support for the transformation of modern energy system in Sichuan Province, and provide paradigm reference for the transformation path design of the same type of regional energy system.

Keywords: Sichuan Province; Energy system transformation; Path research; Sustainable development; Energy security.

1. Introduction

The global energy system is undergoing the dual transformation of low-carbonization and intellectualization, and the transformation of regional energy systems has become the core issue of the carbon neutrality process [1]. The energy system plays a strategic fulcrum role in ensuring the operation of the national economy and the construction of ecological civilization. It is also a key area to achieve the goal of “carbon peak and carbon neutrality” [2]. Sichuan Province has both the dual attributes of the western energy base and the ecological barrier. Although it has significant resource endowment advantages, it still faces structural imbalances such as supply and demand dynamic adaptation problems and limited hydropower regulation capabilities.

2. The characteristics of traditional embroidery art

2.1. Overview of Fossil Energy

China’s energy resource endowment, coal occupies a dominant position in China’s energy system, supporting the development of China’s economy [3]. Different from other regions in China, Sichuan Province has a serious shortage of coal reserves and resources, and faces a shortage of supply for a long time. After years of high-intensity mining, the coal resources in the province are very few, almost overdrawn, and largely dependent on the supply of other regions. Although Sichuan Province has the reputation of “the land of abundance”, the fact is that the coal reserves in the province are 12.27 billion tons, accounting for 1.4% of the total coal in the country, mainly in the southern Sichuan coalfield. In the pursuit of sustainable development, there are many contradictions between coal use and environmental protection. There is a phenomenon of low utilization efficiency of coal, which leads to the waste of resources, and this phenomenon is very serious. In the combustion of coal, air pollution will inevitably occur. All kinds of phenomena show that if Sichuan Province wants to make steady progress in the process of building a resource-saving and environment-friendly society, it is urgent to solve the problems brought by traditional fossil

energy and promote energy transformation.

2.2. Clean Energy

2.2.1. Water energy

Sichuan Province is located across the Qinghai-Tibet Plateau, the Hengduan Mountains, the Yunnan-Guizhou Plateau, the Qinba Mountains, the Sichuan Basin and other major geomorphological units. The terrain is high in the west and low in the east. The unique natural geographical advantages form a huge flow potential energy, which makes hydropower resources particularly prominent in the energy structure of Sichuan Province. The three main stream water systems formed by Dadu River, Jinsha River and Yalong River are the main stream water systems, and the water energy gradient is huge, which creates the spatial advantage of hydropower cascade development in the basin. The control projects such as Shuangjiangkou, Wudongde and Lianghekou in the three main stream water systems play an important role in inter-provincial power allocation and become the hub of the country’s “west to east power transmission”, which further consolidates the status of Sichuan Province as a national clean energy base and highlights its energy strategic significance. According to the re-examination statistics of hydropower resources in Sichuan Province, the theoretical reserves of hydropower resources in the province are 143 million kilowatts, accounting for 21.2% of the total amount in the country, which is equivalent to 12,500 kilowatt-hours of electricity generated each year. The technical development capacity is 103 million kilowatts, accounting for 27.2% of the country, and the economic development capacity is 7611.2 million kilowatts, accounting for 31.9% of the country, ranking first in the country. Gezhouba and Three Gorges hydropower stations covering the mainstream of the Yangtze River have been built. Large-scale water grids in the Wujiang River, Jialing River, Minjiang River, Dadu River, Yalong River, Jinsha River and other basins.

2.2.2. Solar energy

Affected by the terrain climate, Sichuan Province is rich in solar energy resources, and the distribution shows the characteristics of “more in the west and less in the east”. In the western Sichuan Plateau, the amount of solar radiation is

large, and more solar energy resources are obtained. In Aba Prefecture, Ganzi Prefecture, Liangshan Prefecture and Panzhihua City, the “three states and one city” energy base is the most obvious. In the eastern Sichuan region, the amount of solar radiation is relatively small, and the solar energy resources obtained are not as good as those in the western Sichuan region [4]. According to the ‘2025 energy work guidance’ issued by the National Energy Administration, it is proposed that the new installed capacity target of Sichuan photovoltaic in 2025 is 11 million kilowatts, including distributed and centralized, and the development prospect of the optical industry is great.

2.2.3. Natural gas

Sichuan Province is rich in natural gas resources. It is one of the main oil and gas basins in China, showing the characteristics of “full basin gas” [5]. According to the data of the Southwest Petroleum Bureau, the total natural gas resources in the Sichuan Basin amount to 40 trillion cubic meters, accounting for about one-third of the total resources in the country. Conventional gas, shale gas, and tight gas resources are all ranked first in the country. Storage, production and maintain rapid growth at the same time, the growth rate to maintain the forefront of the country. At present, the proven reserves of natural gas resources are 7.5 trillion cubic meters, accounting for about 19% of the total natural gas resources in China. It is mainly distributed in the high gas-bearing zone in southern Sichuan, the transition zone in central Sichuan and the deep tectonic zone in northeastern Sichuan, and there is also a chance to discover more natural gas resources. Despite the complex geological conditions in Sichuan Province, natural gas exploration is in the middle and early stage of resource discovery, and the proportion of proven resources is less than one fifth of the total resource potential [6].

2.3. Energy Production and Consumption Structure

2.3.1. Energy production structure and change trend

“Less coal, less oil, rich gas and more water” can show the characteristics of energy production structure in Sichuan Province. In the energy production structure, water energy and natural gas are prominent, accounting for a large proportion, while coal and oil account for a small proportion. Sichuan Province is rich in hydropower resources, with a theoretical reserve of 143 million kilowatts, accounting for about 21.2% of the country. Natural gas resources are abundant, accounting for about 18.7% of the total resources, and the development potential is huge. The total amount of coal resources is only 12.27 billion tons, accounting for 1.4% of the country’s reserves, and the proven reserves only account for 0.9% of the country. Petroleum resources are scarce and mainly depend on provincial input. In recent years, Sichuan Province has continuously optimized the energy production structure, and the raw coal production has gradually declined. In this process, the proportion of natural gas and electricity production has continued to rise, and the share of natural gas production has expanded year by year. The installed capacity of wind power and photovoltaic power generation is growing rapidly, but its proportion in total energy production is still relatively small. In the future, Sichuan Province will further increase the proportion of clean energy production such as natural gas, hydropower, wind power and photovoltaic power generation [7, 8].

2.3.2. Energy consumption structure and main consumption areas

The industrial characteristics are more prominent in the energy consumption pattern of Sichuan Province. Industrial areas continue to dominate, especially electricity, natural gas and coal are widely used in industrial production. With the development of the economy, the demand for energy in the transportation sector is also increasing, and it is increasingly dependent on natural gas and electricity. Residents’ living energy is also gradually changing to natural gas and electricity, which further promotes the proportion of clean energy in the consumption field [7, 8].

2.4. Problems in Energy System

2.4.1. Single energy structure, over-reliance on hydropower

The energy supply of Sichuan Province is mainly hydropower. The proportion of hydropower installed capacity is as high as 78%, and the proportion of power generation is more than 80%. Among them, hydropower accounts for 75%, followed by thermal power generation, wind power generation and solar power generation.

Sichuan Province is leading in clean energy, mainly relying on hydropower, but there are also obvious seasonal fluctuations in hydropower supply. In the summer wet period from June to October, the runoff is abundant, forming a power generation surplus; in the dry season from December to April of the next year, the flow will be greatly reduced, and the hydropower output will be significantly attenuated. In this case, Sichuan Province urgently needs to find other energy sources to fill the gap. However, the province faces the reality of insufficient allocation of traditional thermal power reserve capacity. Therefore, Sichuan Province needs to make up for the lack of energy supply through purchased electricity. The purchased electricity mainly comes from thermal power generation, which increases the dependence on coal. The problem of coal supply is prominent, and the advantages of large hydropower provinces are weakened. Coupled with the frequent extreme climate in recent years, such as the “electricity shortage” crisis in the summer of 2024 when the temperature exceeds 40°C, the power load has increased dramatically.

2.4.2. Difficult energy consumption, lack of system regulation

In recent years, the proportion of new energy sources such as wind power and photovoltaics has continued to rise. However, these new energy sources “rely on the sky”, energy volatility is strong, and the installed capacity is relatively low. The capacity of Sichuan Province’s delivery channel is about 40 million kilowatts, most of which serve the delivery of hydropower. The scale of new energy delivery is limited and the capacity of the delivery channel is insufficient. Not only that, these large electricity users in East China and Central China, their peak hours of electricity consumption, and the time of power transmission outside Sichuan Province often do not match, and the power grid wants to adjust flexibly, resulting in unsmooth transmission and energy waste. A large artery such as the 800 kV Yahu DC, whose backbone channel design capacity does not match the characteristics of new energy output, will result in the forced abandonment of more than 5 billion kilowatt-hours of clean power in 2023. The more prominent contradiction is that the regional power grid with more new energy is not well coordinated, the power supply is unbalanced, and the hydropower generation is

affected by seasonal changes, forcing the power system to find solutions, accelerate the construction of a sound market mechanism, and upgrade the system regulation technology.

2.4.3. Energy infrastructure construction is not perfect, power grid regulation ability is insufficient

In the energy-rich area, not only the grid structure is fragile, but also the voltage support capability is still flawed. In 2023, the transmission capacity of the power grid in some areas of western Sichuan is insufficient, which can only meet 60% of the installed capacity of local new energy power generation. The problem is that the infrastructure construction supporting the coordinated development of source-grid-load-storage is not perfect, and there are spatial differences between cities with more electricity and places rich in clean energy, which leads to low efficiency of clean energy consumption. Power system regulation capacity supply and demand imbalance, traditional thermal power. According to the data of the State Grid, the maximum peak-valley difference of power load in Sichuan Province is more than 20 million kilowatts, while the thermal power regulation capacity is only 5.5 million kilowatts. Coal supply is limited by geography and transportation, resulting in unstable energy supply and weakening traditional energy supply capacity.

3. Restrictive Factors of Energy System Transformation in Sichuan Province

3.1. Economic Development Level

Affected by many factors such as cost, market expansion, etc., in the process of industrial transfer, economically underdeveloped areas have mainly become the recipients of high-energy-consuming industries. Some environmental problems have also followed the “move”, bringing additional ecological burdens to the receiving areas. New governance challenges have also widened the gap in energy consumption per unit of GDP in different regions. For example, the energy consumption per unit of industrial added value in the ecological function area of the western Sichuan Plateau is significantly higher than that in the core economic zone, which aggravates the pressure on the realization of the dual carbon goal. On the other hand, in recent years, Sichuan’s economy has continued to deepen and transform to high-quality development. The growth of per capita regional GDP has been decoupled from the growth of fossil energy and electricity demand. In this context, cultivating new productivity of energy saving and carbon reduction is the key to break through the bottleneck of development and achieve steady economic growth and low-carbon development in Sichuan Province [9].

3.2. Technological Innovation Bottlenecks

Despite the endowment of hydropower resources in Sichuan Province, its regulation capacity is generally insufficient, and the proportion of hydropower stations with annual regulation performance is limited. It is difficult to effectively stabilize the power fluctuations in wet and dry seasons, making seasonal power shortage a long-term regional challenge. In view of the intermittent and fluctuating problems of new energy, energy storage technology will become the key to solve the problem. At present, the application and research and development of energy storage technology in Sichuan Province is still in its infancy. It is necessary to overcome the problem of large-scale energy storage in order to make green power not waste and stable. In

terms of natural gas development, there are also technical barriers to the development of deep gas reservoirs. The technology of developing deep gas reservoirs is not mature enough, and the update of exploration methods is slow, which delays the process of turning resources into production. For the field of clean coal utilization, the key is to improve the quality of low-quality coal and build an independent intellectual property system.

3.3. Inadequate Market Mechanism

The imperfect market mechanism will limit the efficiency and transparency of energy transformation, hinder the application and promotion of emerging technologies, and delay the development process of innovation models. The traditional energy market structure in Sichuan Province is characterized by centralization, which is heavily dependent on large-scale energy enterprises and regulatory authorities, and cannot keep up with the flexibility and innovation needed for energy transformation. In the field of distributed energy trading, due to the lack of effective market mechanism support, the direct transaction process between energy producers and consumers is complicated and the cost is high. On the other hand, with the deepening of energy transformation, new market participants and trading patterns are also emerging like mushrooms. The current market rules and regulatory framework still lack regulatory response strategies and will encounter legal obstacles.

Based on the “Chengdu-Chongqing Economic Circle Carbon Market Collaborative Development Plan (2024)”, the current energy trading system in Sichuan Province presents an institutional mismatch between traditional centralized architecture and distributed innovation. The traditional market relies on the strict management from top to bottom to ensure the stability of the system. This approach is still difficult to adapt to the needs of the pilot project of the virtual power plant in Tianfu New Area for multilateral transactions. In the exploration of new transaction mode, Deyang International Railway Port multimodal transport demonstration project attempts to build a “green electricity + carbon quota” portfolio trading mechanism. Limited by the access restrictions of “Sichuan Electric Power Medium and Long-term Trading Rules”, it fails to achieve cross-provincial green electricity certification and mutual recognition. According to the “Sichuan Provincial Electricity Market Management Regulations (revised in 2024)”, Panzhihua Vanadium Battery Energy Storage Power Station pioneered the “capacity leasing + frequency regulation assistance” composite trading mode. Due to the lack of inter-provincial reserve capacity sharing mechanism, the regulation capacity is idle, revealing that there is a blind spot in the value identification of new flexible resources in the existing regulatory framework.

4. Transformation Path Selection of Energy System in Sichuan Province

4.1. Transformation Path of Energy Production End

4.1.1. Develop clean energy according to local conditions

Based on the characteristics of regional resource endowments, Sichuan Province has steadily and orderly promoted hydropower construction and developed clean energy in a centralized and distributed manner. The photovoltaic base in Liangshan Prefecture transmits power

through the Baihetan-Jiangsu UHV channel, sending power from the west to the east where it is needed. It can connect the resources in the west with the large electricity users in the east, and effectively solve the problem of seasonal energy surplus waste. In the cascade development zone of the Jinsha River Basin, a three-dimensional energy system with complementary water and light is constructed. When the water in the dry season is not enough to generate electricity, the photovoltaic panel power generation can play a complementary role and regulate the peak of electricity consumption. The southern Sichuan shale gas enrichment area innovates the technical path of “gas-electricity cogeneration + CCUS”. Luzhou block constructs a chemical and energy collaborative production system through the recycling of associated gas resources, manages the whole life cycle of carbon elements, and promotes the transformation of traditional gas fields to low-carbon parks. With the help of the national layout of the large computing center, the Tianfu data center cluster in the Chengdu Plain promotes green power supply, builds a trading platform based on blockchain, creates a symbiotic ecology of digital industry and clean energy, and promotes the development of regional economy towards intelligence.

4.1.2. Transformation and upgrading of fossil energy industry

As the core component of the energy security system, the coal industry needs to implement a three-dimensional transformation strategy. Under the framework of dual carbon strategy, through intelligent mining technology, the mining process is transformed and the production efficiency is improved simultaneously. Based on the technological innovation of coal chemical industry, the whole industrial chain transformation system of coal-based materials is constructed, and the closed-loop material flow of “resource-product-renewable resource” is formed.

Based on the theory of circular economy, Sichuan province should integrate power generation facilities and building materials production system, the key is to develop the grading utilization technology of coal gangue, so that solid waste can produce resource value again. On the other hand, from the market demand side, through the analysis of user needs, to provide customized products, to promote the transformation of production mode, from only the pursuit of large-scale transformation to accurately meet customer needs of service-oriented production.

4.2. The Transformation Path of Energy Output End

4.2.1. Upgrade grid infrastructure

In order to improve the efficiency of power transmission and meet the needs of the rapid development of clean energy, Sichuan Province needs to upgrade the power grid infrastructure, cooperate in many aspects, reduce the phenomenon of abandoned water, abandoned wind and light, and ensure the demand for electricity in the province. Expand the energy delivery path, accelerate the pace of UHV AC project construction, build a cross-regional transmission network based on Ganzi Yitianfunan and other projects, enhance the ability of power transmission, and alleviate the problem of energy consumption. In order to adapt to the rising trend of the proportion of new energy power generation, it is necessary to build an intelligent control system and adopt a dynamic adjustment algorithm to optimize the grid's ability to accept new energy. In the process of regional power grid

interconnection, it is necessary to establish a multi-level market coordination mechanism, optimize the allocation of power resources among provinces, improve energy utilization efficiency, enhance the flexibility and anti-risk ability of the power grid, and improve the overall efficiency and reliability of the energy output link.

4.2.2. Power system digital empowerment

First, power system optimization. With the goal of “carbon peak and carbon neutrality”, the architecture of “source-network-load-storage” is coordinated, and real-time data is integrated through cloud computing to optimize the allocation of power resources and provide accurate support for the operation of power systems. By using digital Li Sheng technology, this paper promotes the two-way transmission of energy and information in smart grid from the direction of constructing multi-scale system model, and promotes scientific decision-making and intelligent decision-making.

Second, renewable energy management. The sensing network is constructed by using the Internet of Things, and the state of photovoltaic and wind turbines is monitored by high-precision sensors. The artificial intelligence algorithm enables the prediction of power generation output and improves the ability of new energy grid connection, thus forming a technical chain of monitoring-prediction-regulation.

Third, energy trading and market response. The energy trading system establishes a digital trading platform, relies on smart meters to collect and analyze users' electricity consumption data, and considers demand response adjustment. Digital technology and market rules are used to optimize the matching of power supply and demand, and balance transaction costs and system benefits.

4.2.3. Strengthen the construction of energy storage facilities

Implement a differentiated layout strategy in the construction of energy storage facilities. In areas where the utilization rate of new energy is high, the stability of the power grid is weak, and the power consumption changes greatly during peak and trough periods, priority should be given to the deployment of energy storage devices with multiple adjustment functions on a large scale, which can not only provide inertia support to the power system, but also improve the ability of the power grid to flexibly adjust power, thus forming a two-way enhancement mechanism. Establish a set of methods that can coordinate the management of energy storage facilities between different regions, and maintain the dynamic balance of electricity and power generation between different regions through time and space transfer of energy, so that the entire energy system is more economical and more efficient. The technical guidance rules for energy storage planning are formulated, covering power-side frequency modulation energy storage, grid-side emergency support energy storage, and user-side distributed energy storage. According to different usage scenarios, the selected technical standards and grid-connected operation specifications of energy storage equipment are clearly defined, so as to ensure that the energy storage system can cooperate well with the existing energy infrastructure. Energy storage facilities should be closely integrated with public infrastructure such as transportation hubs and data centers at the physical level and interconnected in terms of information. Using the Internet of Things technology energy Internet of Things to build an “online platform” for sharing energy storage devices, in this way, the state of each energy storage unit can be accurately grasped, and the control instructions

can be digitized to reach each device in an all-round way to achieve precise control. Deepen the research and development path of energy storage materials and system integration technology, establish a joint research mechanism among universities, scientific research institutions and enterprises, focus on breaking through the technical and economic bottlenecks of power and energy storage equipment, and expand the commercial application space of energy storage technology in power grid auxiliary services, so that it can truly produce benefits.

4.3. Energy Consumption End Transformation Path

4.3.1. Promote the electrification of terminal energy

In the case of imbalance between power supply and demand, priority is given to the generation and dispatching of gas-electric linkage units, so as to stabilize the basic disk of power supply and make the power supply more stable. Construct a market-oriented trading incentive mechanism, encourage users to adjust their electricity consumption habits through changes in electricity prices, actively save electricity when electricity is tight and electricity prices are high, and balance the power demand of the entire network. Promote government departments to introduce a set of overall policies covering electric vehicle promotion and electric heating projects, simultaneously establish a special planning for charging infrastructure, and create a cross-departmental collaborative promotion mechanism. Combined with a variety of policy tools, on the one hand, the cost of purchasing charging equipment is allocated to different stages, and then combined with the compensation measures for operating electricity prices to reduce the pressure on construction and operating costs; on the other hand, explore a differentiated billing model based on demand-side response to encourage rational use of electricity and improve the efficiency of charging facilities. In the process of promoting the modernization of power grid infrastructure, the collaborative upgrading project of urban and rural distribution network is carried out, focusing on overcoming the technical shortcomings of rural power grid in terms of power supply stability and reliability. The investment efficiency evaluation system of distribution network is constructed, and the areas with dense electricity demand and high equipment utilization rate are given priority. The capital investment structure of power grid construction is optimized, so that the equipment can operate efficiently throughout its service life.

4.3.2. Strengthened demand-side management

The price-based demand response mechanism uses the time-of-use electricity price signal to change the mode of electricity load, implements a dynamic electricity price gradient, guides users to change their electricity consumption behavior, and uses electricity load and power grid scheduling to achieve interactive operation, so that the entire power system The flexible adjustment ability is stronger. Construct a zero-carbon practice system, and establish an active carbon neutral classification certification system based on the clean energy power structure of Sichuan Province according to the “Sichuan Provincial Carbon Market Management Regulations”.

4.3.3. Multi-energy complementary comprehensive utilization

As the core bearing area of the national clean energy strategic layout, Sichuan Province has a unique geographical

location, which can provide a natural test site for the construction of multi-energy complementary systems. Under the framework of coordinated development of water, wind, solar and gas resources, a multi-energy coupling development paradigm of “river basin cascade-wind and solar cluster-gas and electricity peak shaving” is constructed to realize space-time compensation of different energy forms. The “hydropower regulation + wind and solar base” collaborative model created by the demonstration project in the Yalong River Basin provides a reliable solution to the instability of regional renewable energy power generation. In the transition zone from the western Sichuan plateau to the basin, the terrain is used to construct the energy system. During the day, the photovoltaic power generation of Ganzi Shiqu County is directly sent to Chengdu; at night, it mainly relies on the wind power in the basin and uses the pumped storage power station in the canyon to store energy and supply power. In addition, actively explore the “heaven and earth” energy to cooperate with each other’s model: in Aba Prefecture, high-altitude wind turbines and surface solar panels complementary power generation. Liangshan Prefecture has launched a new pilot system, using the surplus electricity of hydropower stations to produce hydrogen, and then using hydrogen fuel cells to store and use or peak shaving; with the elevation difference, the utilization and transportation of hydrogen energy are realized. The idea of flexible resource allocation of power grid is changing with the mixed deployment of batteries and lithium batteries. However, it is also necessary to realize that the existing energy storage is still too slow to cope with the long-term power shortage caused by extreme weather, which depends on the interdisciplinary integration of material science and power electronics technology.

5. Safeguard Measures of Energy System Transformation in Sichuan Province

5.1. Improve the Policy System to Support Top-Level Design

The three-dimensional transmission mechanism of policy incentive is designed, and the government regulation tools are subdivided into financial incentive transmission and market subject cultivation. Blockchain technology is used to open up multi-market clearing, so that policies and market rules are seamlessly linked. Formulate special laws and regulations, revise existing laws and regulations, establish an implementation supervision mechanism, strengthen law enforcement inspections, and maintain market order.

5.2. Application of Scientific and Technological Innovation to Promote Value Creation

Open up the channel from laboratory to market, promote the construction of industrial application development system, create a complete innovation pipeline through basic research, technology transformation and commercial landing, and form a closed loop of the whole chain. Industry-university-research cooperation, universities take the lead, integrate Sichuan industry-university-research resources, take Sichuan University, University of Electronic Science and Technology, Southwest Petroleum University as the source of technology, and jointly build an open and shared innovation network platform to attract enterprises, scientific research institutions and other forces to join the collaboration. The dynamic

monitoring and analysis center of scientific and technological information is established synchronously, which systematically tracks every step of the new technology of energy materials from the success of laboratory research to the real application in the market, so that R&D, talents, funds and other aspects can be coordinated and linked to form a joint force.

5.3. Government-Enterprise Cooperation Multi-Governance and Universal Participation

State Grid Sichuan Electric Power and local governments jointly set up operating entities, unified planning and development of resources, and promote the large-scale development of renewable energy and the simultaneous construction of people's livelihood infrastructure. Establish a cross-regional trading market platform, so that the company's energy consumption quota and green certificates can be linked to transactions, and the market mechanism can efficiently optimize the allocation of energy resources. In order to encourage the participation of the whole people, a personal carbon account is set up to convert new energy vehicle charging, rooftop photovoltaic power generation and other behaviors into green rights and interests; the implementation of green points, water and electricity consumption can be saved points directly deducted, so that the ecological value can be measured and convertible. At the community level, we will innovate "energy cooperatives", promote farmers' photovoltaic and community energy storage to jointly build a microgrid, and realize grassroots energy co-governance and sharing through property rights sharing and income sharing.

6. Conclusions and Prospects

The transformation of energy system in Sichuan Province is the key path to implement the national "double carbon" strategy. By analyzing the energy characteristics of Sichuan Province, this study constructs a three-dimensional implementation strategy covering energy generation, output and consumption, proposes a coordinated promotion plan for the differentiated development of clean energy, the optimization of power grid facility architecture and the multi-energy complementarity of terminal energy consumption, and simultaneously constructs an institutional guarantee system supported by policy innovation, technological innovation and governance innovation. By building a regional energy community mechanism, Sichuan Province is expected to form an energy system transfer. The typical paradigm of type provides reference path design experience for the same type of area.

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