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The Practical Application of New Productive Forces: The Practice Logic and Optimization Path of Distributed Photovoltaic Enterprises Promoting Rural Revitalization

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Abstract: Developing new quality productive forces is an internal requirement and important focal point for high-quality development, as well as a driving engine for promoting rural revitalization and common prosperity for all people. As a typical representative of new quality productive forces, distributed photovoltaic enterprises play a key role in promoting rural revitalization. Based on the theory of new quality productive forces and Marxist theory of productive forces, taking Tianhefujia as a typical case, this paper explores the specific path of distributed photovoltaic enterprises promoting rural revitalization through innovative business models, summarizes the valuable experience of Tianhefujia in implementing rural revitalization strategies, and analyzes the urgent practical problems in the process of distributed photovoltaic enterprises promoting rural revitalization. Finally, based on practical analysis, it proposes a path for optimizing the model of distributed photovoltaic enterprises promoting rural revitalization, aiming to form and promote a more efficient and sustainable rural revitalization development model.

Keywords: distributed photovoltaics, rural revitalization, new productive forces.

1. Introduction

With the profound transformation of global energy structure and the promotion of sustainable development concepts, the development and application of new energy technologies have become a key force driving the green transformation of social economy. Against this background, distributed photovoltaics, as an emerging force in the field of new energy, has gradually become an important carrier to promote rural revitalization and achieve high-quality development, owing to its flexibility, high efficiency, and environmental friendliness. This study, with the theme of "The practical application of new production forces: The practice logic and optimization path of distributed photovoltaic enterprises promoting rural revitalization", aims to explore the role mechanism and optimization strategies of distributed photovoltaics in the rural revitalization strategy, providing theoretical basis and practical guidance for the transformation and upgrading of rural economy and the construction of ecological civilization.

On a theoretical level, this study is rooted in the theory of new productive forces and Marx's theory of productive forces, believing that distributed photovoltaics as a new form of productive forces, its development and application are not only related to the optimization of energy structure,

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but also an important force to promote the transformation of rural production methods, improve the quality of rural life, and promote overall social progress. On a practical level, Tianhe Fufu is selected as a case study, using its successful business model as a starting point, aiming to analyze how distributed photovoltaic enterprises effectively integrate into rural economic and social development through technological innovation and business model innovation, and explore their specific paths and effects in promoting rural revitalization.

Given the urgent need for rural revitalization and the rapid development of new energy industries, this study focuses on three core issues: the promotion model, practical experiences, and challenges of distributed photovoltaic enterprises, as well as the optimization path of the model. Through in-depth case analysis and theoretical discussion, the aim is to extract a replicable and scalable solution that leverages distributed photovoltaics to help rural revitalization, to further activate rural development potential, accelerate the energy structure towards clean and low-carbon transformation, and contribute to the construction of a harmonious, livable, and vibrant modern rural society.

This study not only provides theoretical value for deepening the understanding of the role of distributed photovoltaics in rural revitalization, but also offers empirical reference and strategic insights for government decision-making, enterprise operations, and the participation of various sectors of society in rural revitalization, injecting new vitality and momentum into the comprehensive revitalization of rural areas in the new era.

2. The problem presentation

The new quality productivity refers to an advanced form of productive forces characterized by innovation, efficiency, green and low-carbon, open integration, and human-centeredness formed with the progress of science and technology and social development. The 11th collective study session of the Central Political Bureau pointed out, "The new quality productivity features high technology, high efficiency, high quality, and is in line with the advanced productive forces qualities of the new development concept. It is generated by technological revolutionary breakthroughs, innovative allocation of production factors, and deep transformation and upgrading of industries. It is based on the leap of optimized combinations of laborers, labor materials, and labor objects as the fundamental connotation. Technological innovation can generate new industries, new models, new dynamics, which are the core elements for developing the new quality productivity."

During the deliberation of the Jiangsu delegation at the Second Session of the 14th National People's Congress, General Secretary Xi Jinping emphasized the need to firmly grasp the primary task of high-quality development and develop new productive forces tailored to local conditions. As a typical "new productive force," the flexible adaptability and green development of distributed photovoltaics are particularly helpful in promoting high-quality development.

Distributed photovoltaics have shown strong momentum in recent years worldwide, especially in China. China has issued a series of policies since 2021 to accelerate the development of distributed photovoltaics. In recent years, the power efficiency of photovoltaic modules has been continuously improving, not only widely used in ground power stations but also gradually popularized in rooftop distributed photovoltaic projects. According to data from the National Energy Administration, in 2023, the newly added grid-connected photovoltaic capacity will be 216.3GW, with distributed photovoltaics accounting for 96.286GW, an 88.3% year-on-year increase. As a dominant player in the Chinese photovoltaic industry, distributed photovoltaics has entered a key period of industrial development due to its advantages such as user proximity, short construction period, small investment scale, minimal land space occupation, diverse business models, and digital operation management. At the same time, the development of distributed photovoltaics comes with new

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challenges for managing existing facilities such as the power grid, leading to a trend towards the development of smart grid technology and energy storage solutions.

The rural revitalization strategy is an inevitable choice to achieve common prosperity for all people. Rural revitalization is not only related to the transformation and upgrading of rural economy, but also involves comprehensive progress in multiple dimensions such as culture, ecology, and social governance. It is an important part of realizing the great rejuvenation of the Chinese nation and the Chinese Dream. The advancement of rural revitalization involves the overall situation of social stability and development. By promoting the prosperity of rural industries, the return of talents, the flourishing of culture, the livability of ecology, and the strengthening of organizations, it can effectively solve the serious problems of current imbalances and inadequacies in rural development, help consolidate poverty alleviation achievements, prevent relapse into poverty, effectively address the urban-rural development gap, promote social fairness and justice, and build a harmonious society.

With the advancement of the rural revitalization strategy, rural development has exacerbated high carbon emissions, while also demonstrating the spatial resource advantages of ecosystem carbon sink resources and new energy development. The promotion of household photovoltaic projects has increased farmers' property income, especially in former impoverished areas. Distributed photovoltaics has become a stable and sustainable way of increasing income, helping to consolidate the achievements of poverty alleviation. The widespread application of distributed photovoltaics in rural areas has driven the development of related industrial chains, created new job opportunities in rural areas, and promoted the diversified development of the rural economy. At the same time, photovoltaic power generation has promoted the optimization of rural energy structure, not only reducing carbon emissions in rural areas, but also improving energy utilization efficiency and environmental sustainability. This is in line with the national strategy to promote energy transition and achieve the "dual carbon" goals, benefiting the improvement of rural residents' quality of life and meeting the requirements of ecological livability.

This article focuses on the research core of "The practice logic of distributed photovoltaic enterprises as representatives of new productive forces promoting rural revitalization", and aims to address the following three issues:

1. As a representative of new productive forces, how do distributed photovoltaic enterprises promote rural revitalization?

2. What valuable experiences can be borrowed and promoted in the process of promoting rural revitalization by distributed photovoltaic enterprises? What are the urgent practical problems that need to be solved?

3. How to improve and optimize the model of distributed photovoltaic enterprises to better play its effectiveness in promoting rural revitalization?

3. Literature review

3.1. Research Status at Home and Abroad

3.1.1. Distributed photovoltaic enterprise

Search the China National Knowledge Infrastructure (CNKI) full-text database for "distributed photovoltaics" as the main theme. As of May 9, 2024, 4909 journal articles were retrieved. In terms of time, scholars began to focus on distributed photovoltaics around 2001, and the research quantity has been increasing continuously. The attention rapidly increased around 2011, and the number of publications showed a fluctuating distribution pattern starting from 2014. In terms of subject

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distribution, it mainly focuses on the electric power industry, and in terms of research level, it mainly focuses on the technical research level.

Research on the economic benefits of distributed photovoltaic projects mainly focuses on the following four aspects. First, from the perspective of investors such as residents, commercial and industrial users, and energy investors, the economic benefits of distributed photovoltaic projects are studied. For example, Shao Hanqiao[1] et al. found that the internal rate of return of distributed photovoltaic projects selected in six regions for residents and commercial and industrial users was higher than 8%, with a static investment payback period of 5-11 years, showing good economic benefits. Second, starting from operation modes such as "self-generation and self-use with surplus electricity fed into the grid" and "full grid access," the economic benefits are analyzed. Qiutengfei[2] et al. established a whole lifecycle cost-benefit model and calculated that the economic benefits of distributed photovoltaic projects in the "self-generation and self-use with surplus electricity fed into the grid" mode were higher than those in the "full grid access" mode. Third, the optimal investment time for photovoltaic projects is calculated to evaluate the economic benefits of distributed photovoltaic projects. For example, Zhang Mingming[3] et al. applied the real options method to construct an investment evaluation model for photovoltaic projects and found that photovoltaic projects could be profitable, but the current timing was not optimal. Fourth, the economic benefits of distributed photovoltaic projects are studied from different levels such as the national level, solar resource areas, and provinces and cities. For example, Yang[4] et al. calculated the profitability of distributed photovoltaic projects in 344 prefecture-level cities in China without electricity price subsidies, and found that 21.80% of cities in the country had high returns, 44.19% had moderate returns, and 34.01% had low returns.

Next, in terms of social benefits, Shen Yizhou[5] et al. believe that distributed photovoltaic energy projects have the social benefits of liberating labor and promoting the transfer of labor from the second to the third industry; Li [6]et al. explained that photovoltaic greenhouses can provide 0.28-2.65 new jobs for each enterprise, local and central governments can receive annual tax revenues of 8600-24000 yuan from photovoltaic greenhouses, and photovoltaic greenhouses can reduce carbon emissions by 68.77-211.60 tons per year for each enterprise.

In terms of environmental benefits, Jiang Ling[7] analyzed the energy performance of the entire life cycle of solar photovoltaic systems from production to operation, and also applied an energy recovery model to analyze the total energy generated and emission reduction capabilities of photovoltaic power plants throughout the entire life cycle. Cheng Xuehui [8]explored the impact of urban photovoltaic projects in grassland areas on air quality, ecological environment, and water quality. Zhang Min [9]and others used the emission factor method to explore the contribution of roof-mounted distributed photovoltaics to carbon reduction, sulfide reduction, and nitrogen oxide reduction.

3.1.2. Enterprise support for rural revitalization

The path and model of supporting rural revitalization by enterprises are diverse, involving various aspects such as empowering industries, technological innovation, and activating culture. Successful cases often rely on the close cooperation between enterprises and rural areas, combining actual rural needs, flexibly utilizing enterprise resources, and government policy support.

Private enterprises participating in rural development, namely the issue of "enterprises going to the countryside" and "capital going to the countryside," has always been a focus of academic discussion. Hu Dongsheng[10] and others believe that enterprises going to the countryside can effectively enhance the organizational level of farmers, promote win-win cooperation between farmers and enterprises. Zhang Qi [11]and others have conducted in-depth analysis of the win-win cooperation mechanism between farmers and enterprises, advocating the rational use of rural

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resources to promote the synchronous development of enterprises and rural areas. Li Yining[12], starting from the perspective of narrowing the urban-rural income gap, emphasizes the positive role of capital going to the countryside in improving agricultural production efficiency and promoting social harmony. Huang Chengwei and Zhou Jing[13] also affirm the important position of private enterprises in poverty alleviation, believing that they can achieve the dual unity of economic goals and social values, as well as the win-win situation of economic and social benefits. Chen Yiyuan[14] further elaborates the significant positive impact of capital going to the countryside on restructuring the traditional agricultural industry chain, tapping agricultural added value, and increasing farmers' income.

State-owned enterprises play a key role in promoting the rural revitalization strategy, and the exploration of mechanisms in this process is particularly important. Fu Derong[15] proposed that creating a favorable market and policy ecosystem, and continuously improving the participation mechanisms of state-owned enterprises, are the core elements to more effectively promote the comprehensive integration of state-owned enterprises into the rural revitalization cause. Fang Zhiquan[16] summarized four effective models of Shanghai's state-owned enterprises participating in rural revitalization, emphasizing the key paths to achieving state-owned enterprises driving rural development, such as enhancing the management level and service system construction of state-owned enterprises, streamlining the government-enterprise cooperation mechanism, and strengthening policy support. Lin Luming[17] suggested that state-owned enterprises should utilize their advantages in brand influence, technological innovation, and other aspects to participate in rural revitalization from multiple dimensions, demonstrating the social responsibility of state-owned enterprises.

3.2. Gap Analysis Research

In the process of promoting rural revitalization, there are some gaps in the literature research of distributed photovoltaic enterprises, reflecting the gap between theoretical research and practical needs. Firstly, the exploration of business models, existing literature lacks sufficient research on strategies for innovating business models by combining agricultural insurance, green credit, and other financial tools to reduce the initial investment burden of farmers, as well as a lack of systematic analysis of new business models such as "photovoltaic+". Secondly, agricultural photovoltaic complementation technology, although the concept of agricultural photovoltaic complementation is widely mentioned, research on how to design it precisely according to different crops and integrate technologies to maximize agricultural production and electricity generation benefits is still insufficient. Thirdly, case studies, despite some case studies, there is not enough systematic compilation and comparative analysis of successful cases and lessons from failures; how to extract replicable and scalable experience patterns and how to promote the more widespread application of successful experiences through a support system of policies, technologies, funds, etc., are also blank points in current research.

Given the above, this article attempts to analyze the case of Tianhe Fufu, explore its business model, analyze this enterprise case from the perspective of new quality productivity, try to integrate it with agricultural light complementarity technology, extract and promote effective strategies and models, in order to better serve the rural revitalization strategy with distributed photovoltaics.

4. Research Methods

This research uses a case study approach and semi-structured interview method as the main research methods.

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One, case study method. Take Jiangsu Province, Changzhou City, Tianhe Fuhu Energy Co., Ltd. as a typical example. Established in October 2016, Tianhe Fuhu Energy Co., Ltd. is affiliated to Tianhe Solar Group, specializing in the distributed photovoltaic power generation market. Tianhe Fuhu focuses on establishing a complete system integrating product research and development, market sales, installation and after-sales service, and intelligent operation and maintenance based on its core strategies of brand, product, and service. It has constructed a digitized, omni-channel ecological network. Relying on strict original standards, Tianhe Fuhu provides customers with full-chain quality control from products to services and has accumulated more than 300 honors in the industry. The main service targets of the company are rural self-built house owners, focusing on rooftop distributed photovoltaic system solutions. Its market layout is extensive, with 9 regional marketing centers established nationwide, including Jinan, Jining, Qingdao, Hebei, Henan, Jiangsu, Zhejiang, Shanghai, Guangdong, Shanxi, and Northwest China. Tianhe Fuhu's cumulative shipments of original household photovoltaic systems exceed 1GW, ranking among the industry leaders; the number of county-level distributors exceeds 1000, and the number of township service outlets exceeds 15,000.

Secondly, semi-structured interview method. Using semi-structured interviews to gather information through in-depth interview records. The interviewees include 3 employees from more mature distributed photovoltaic enterprises represented by Tianshuhu, 3 farmers who have installed distributed photovoltaics, and 3 employees from enterprises that have initially entered the distributed photovoltaic market. For employees of distributed photovoltaic enterprises, design interview outlines based on their understanding of distributed photovoltaics, understanding of the enterprise, brief description of the current model, experience and problems encountered with current solutions, and understanding of the enterprise's contribution to rural revitalization. For farmers who have installed Tianshuhu's distributed photovoltaics, design interview outlines based on the reasons for choosing Tianshuhu, services provided by Tianshuhu, changes in life after installation, and problems encountered during the process. For employees of other related enterprises, design interview outlines based on the difficulties in the distributed photovoltaic field, disadvantages of the enterprise, and experiences worth learning from Tianshuhu. Conduct semi-structured interviews, and follow up with specific questions and responses from the interviewees during the interview process. After the in-depth interviews, randomly visit some villagers in the village and surrounding areas for household interviews.

5. Theoretical Foundation

5.1. The correlation between the new quality of productivity theory and Marx's theory of productivity

The new theory of productive forces is the inheritance and deepening of Marx's theory, the product of the Sinicization of Marx's theory of productive forces, and an important component of Xi Jinping's thought on socialism with Chinese characteristics in the new era. It runs through the vast system of Marxist philosophy, political economy, and scientific socialism, providing theoretical support and practical guidance for the development of socialism with Chinese characteristics.

Marx pointed out, "The main elements of labor are: individual activity... the object of labor... the means of labor."[18] Traditional productivity focuses on labor intensity and mechanized production in the industrial age. In contrast, the new qualitative productivity emphasizes the qualitative change in productivity under the background of the new technological revolution, especially driven by digitalization, networking, and intelligent technologies. It is dominated by intelligent labor, with intelligent workers as the main body, and intelligent, digital production materials as the object of labor, embodying a new form of productivity. This reflects the evolution of productivity with

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changes in technology and social conditions, confirming Marx's theory that productivity changes over time.

The formation and development of new productive forces emphasize the transformation of production methods, such as improving total factor productivity, optimizing industrial structure, and adjusting production relations to adapt to and promote the development of these productive forces. Marx believed that "when changes occur in the mode of production and exchange in society, changes also occur in the form of social organization and the entire system. The new production relations... develop through the destruction and disintegration of these ancient forms of social organization, under the influence of revolution and violence." Therefore, the development of new productive forces also requires the corresponding adjustment of production relations to meet the requirements of higher levels of productivity, thus promoting the improvement and development of the social system. This means developing new quality production relations, stimulating new vitality of factors such as capital, labor, and technology, and promoting the optimization and upgrading of economic and social structures.

The new theory of productivity in the framework of Marxist political economy puts forward the concept of intelligent labor and intelligent digitized means of production, which goes beyond the traditional productivity theory centered on industrial labor and mechanized means of production. This innovative development reflects the process of continuously enriching and improving the theory of productivity with the development of practice.

5.2. Distributed photovoltaic enterprises embody the practical representation of new productive forces

The new theory of productivity emphasizes the leading role of technological innovation in the development of productivity. Distributed photovoltaic enterprises have promoted technological advancement in the photovoltaic industry through continuous research and innovation, such as improving the conversion efficiency of photovoltaic modules, developing more efficient inverter technologies, and applying artificial intelligence and big data for operation and maintenance management. These technological innovations not only improve the economy of photovoltaic power generation and reduce the cost per kilowatt-hour, but also enable distributed photovoltaic systems to better adapt to different application scenarios, achieving the diversification and personalization of energy supply.

The new productivity theory advocates transforming production methods through innovation. Distributed photovoltaic enterprises actively adopt new generation information technologies such as the Internet of Things, cloud computing, and blockchain to build intelligent photovoltaic management systems. This digital and intelligent operation and maintenance mode significantly improves operational efficiency, reduces operation and maintenance costs, and also provides users with more precise and convenient services, enhancing the core competitiveness of enterprises.

The new quality of productivity often requires efficient collaboration at all levels of the industrial chain to form an innovative ecosystem. Distributed photovoltaic enterprises not only innovate in their own products and technologies, but also actively participate in building the photovoltaic industry ecosystem, cooperating with material suppliers, equipment manufacturers, energy service providers, financial institutions, and others to promote supply chain optimization, financial innovation, and business model innovation. For example, by integrating with the aquaculture industry to create a "photovoltaic +" industrial model, cross-industry resource integration and value co-creation are achieved, creating a green energy industry chain with higher added value.

Distributed photovoltaics, as a clean energy source, is in line with the global trend of low-carbon transformation, contributing to the achievement of the "dual carbon" goals, meeting the

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requirements of the new quality productivity to consider both environmental friendliness and social responsibility. At the same time, distributed photovoltaic projects can drive local economic development, create job opportunities, improve energy self-sufficiency, help rural revitalization, and achieve the unity of economic benefits, social benefits, and environmental benefits.

6. Summary of the experience and issues of distributed photovoltaic enterprises promoting rural revitalization

6.1. Experience of distributed photovoltaic enterprises promoting rural revitalization

Tianhe Wealth focuses on the distributed photovoltaic market, especially the "sinking market", which targets users in rural and remote areas by providing suitable photovoltaic solutions for residential roofs to meet specific needs in this market. "Tianhe Wealth has launched five business models for the household photovoltaic market, providing differentiated services to meet the needs of users at different levels." The company continuously innovates in the field of photovoltaics and product optimization, such as improving the photoelectric conversion efficiency, developing intelligent operation and maintenance systems, forming a product evolution power including high efficiency, intelligence, and easy maintenance. These innovations directly enhance the product performance and user experience, serving as an important source of its core competitiveness.

Tianhefujia proposes the concept of "original photovoltaic system", emphasizing the full-chain control from the development and manufacturing of photovoltaic panels, inverters and other hardware devices, to system design, installation and construction, and to later operation and maintenance services, reducing the potential quality inconsistencies caused by multiple suppliers, simplifying the decision-making process and subsequent maintenance for users, ensuring product quality and service levels. The integrated system design and implementation process also enables Tianhefujia to more quickly apply the latest scientific research results and technological innovations to practical products and services, promote the rapid application of technological innovations, and maintain technological leadership and market competitiveness.

Through efficient review processes and full-cycle management, Tianhefujia can maintain flexibility and responsiveness in the fast-changing market environment, adjust strategies in a timely manner, and seize business opportunities. By widely applying information systems, business processes are standardized and automated, improving work efficiency, reducing human errors, and providing real-time and accurate data support for management, assisting in scientific decision-making. The company optimizes its organizational structure by establishing a flat and flexible organizational framework, reducing management levels, and improving decision-making efficiency.

6.2. Problems existing in the promotion of rural revitalization model by distributed photovoltaic enterprises

6.2.1. The problems generally faced by enterprises are already solved by Tianhe Wealth Enterprises

First, funding issue.The core equipment of distributed photovoltaic systems, such as photovoltaic panels and inverters, have high technological content and are costly to purchase. Farmers or rural collective economic organizations often rely on agricultural income, with limited financial reserves, making it difficult to bear such a high investment at once. To encourage the development of renewable energy, governments often introduce photovoltaic subsidy policies, but in practice, there is uncertainty in subsidy disbursement, sometimes even with long delays. Compared to urban areas, financial services in rural areas are not well-developed, with few credit products available. Farmers may give up on loans and financing due to being unable to bear high interest rates.

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Given the above issues, Tianhe Wealth actively takes on risks, providing four solutions, among which "Rent-Electric Praise" and "Benefit-Agriculture Treasure" can realize zero-cost equipment installation, addressing the problems of insufficient funds and uncertain policy subsidies; "Industrial PV Loan" can provide reliable loan schemes without the need for down payments or deposits, solving the issues of unsound rural financial systems and farmers' difficulties in repaying loans.

However, the healthy development of distributed photovoltaics in rural areas still needs to fundamentally solve the funding problems in the promotion of distributed photovoltaics in the countryside, rather than require farmers or enterprises to bear the risks. The reality of unbalanced urban-rural development means that there is a fundamental weakness in rural areas in terms of funding. It is more necessary for the government, financial institutions, and various sectors of society to work together to make up for the shortcomings and thereby stimulate the enthusiasm of both enterprises and farmers to build distributed photovoltaics and promote the green revitalization of rural areas.

In some cases, the rapid development of the photovoltaic market has outpaced the pace of regulatory policies, resulting in a low market access threshold and a lack of strict product quality and performance standards. In certain tender procurement processes, there is an excessive emphasis on price factors while neglecting product quality and service guarantees, which seriously affects the overall power generation efficiency and service life of photovoltaic power stations.

In response to quality issues, Tianhefujia, as a vertically integrated enterprise incubated by Tianhe Solar, proposes the concept of "original solar PV systems", ensuring full-chain control from the research and development of hardware equipment such as PV modules and inverters, to system design, installation, construction, and later operation and maintenance services, reducing the potential problem of inconsistent quality due to multiple suppliers participating, and ensuring product quality and service levels.

6.2.2. Issues that most enterprises commonly face and which even Tianhe Wealthy Family Enterprises have not yet resolved

Firstly, technical and management issues.

Shortage of technical talents in installation, operation, and maintenance of distributed photovoltaic facilities in rural areas. Farmers or rural collective economic organizations, as the ultimate users of photovoltaic projects, often lack understanding of the performance, quality certification, and maintenance knowledge of photovoltaic products, making it difficult to distinguish the pros and cons of photovoltaic products in the market. They are also at a loss when it comes to daily maintenance and simple troubleshooting of photovoltaic systems. Serious dust accumulation on photovoltaic panels, aging of connectors, inverter failures, and other issues left unresolved in a timely manner greatly shorten the effective operational life of the system, increasing the difficulty and cost of operation and maintenance.

The issues of rural electrification grid services and equipment compatibility, as well as the lagging of grid renovation, affect the effective access and integration of distributed photovoltaic power. The problems existing in the electrification grid services mainly manifest in two aspects: the lack of uniform technical standards and the complex and lengthy approval process for grid connection. Due to the fast pace of technological iteration, there may be compatibility issues between new and old equipment such as communication protocol mismatch and uncoordinated control strategies, which affect the stable operation and efficient interaction of the system. The lagging of grid renovation is a key bottleneck that hinders the development of distributed photovoltaics. Traditional grid designs are mostly based on centralized power supply models, while the large-scale integration of distributed photovoltaics requires grids to have stronger bidirectional

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transmission capabilities, more flexible scheduling and management, and a higher level of intelligence. This gap limits the grid's capacity to accept and distribute renewable energy sources.

Secondly, policy support and implementation.

Although there are many favorable policies in place, there may be problems in the specific implementation process such as insufficient policy enforcement and information asymmetry. In many cities and regions, the planning and approval of distributed photovoltaic projects need to go through multiple government departments, including urban and rural planning departments, development and reform commissions, housing and construction departments, etc. This process not only takes a long time, but also often requires repeated modifications of plans to meet various regulations and requirements, increasing the uncertainty and upfront costs of projects. Distributed photovoltaic projects typically involve various forms such as rooftop installation, agricultural-photovoltaic complementarity, or floating on water, each of which has specific land use considerations. The complex land relationships and approval processes can sometimes become more challenging due to differing policy interpretations or local protectionism.

Thirdly, social participation level.

Farmers, as the main audience for the promotion of distributed photovoltaic projects in rural areas, play a crucial role in the successful implementation of the projects. Currently, farmers show a variety of attitudes towards distributed photovoltaics due to reasons such as lack of sufficient information channels, technical knowledge, or concerns about profit security. Some farmers adopt a wait-and-see or even skeptical attitude towards distributed photovoltaics, which directly affects the popularization and promotion of the projects in rural areas. The insufficient promotion efforts mainly manifest as a lack of targeted publicity and education activities, especially in remote rural areas where limited information dissemination channels result in reduced effectiveness of publicity. At the same time, the imperfect community participation mechanism restricts the extent to which farmers participate in project decision-making in reality, often limiting them to passive acceptance of established plans. This not only restricts farmers' enthusiasm and creativity but may also lead to a disconnect between project design and actual needs, affecting the project's sustainability and social impact.

Forthly, Corporate risk.

Top companies like Tianhe Fufamily face intense competition in the photovoltaic household industry, so it is necessary to maintain procurement, sales, operation, and response efficiency at a relatively high level. A slowdown in turnover efficiency can lead to an increase in procurement costs, resulting in performance losses and potential repayment risks. Rising raw material costs may lead to losses and risks in a sales-to-procurement model. During price declines, the overall default rate in the photovoltaic industry is very high, which may force Tianhe Fufamily to adjust prices. Therefore, there are certain risks in price and profit control. At the same time, if national policies change, the boom period of the photovoltaic industry will also disappear.

Exploring enterprises: Distributed photovoltaic projects require a certain level of technical expertise and rich project experience, including station design, installation, operation, and other aspects. For enterprises that are at the initial exploration stage, the challenge lies in how to quickly accumulate these technical skills and experience. At the same time, projects require substantial financial investment, and the return period is relatively long. When considering entering this field, enterprises need to balance the capital investment with potential risks. How to stand out in the fierce market competition and establish their own brand advantage is the most pressing issue for exploring enterprises.

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7. Optimization of the model for promoting rural revitalization by distributed photovoltaic enterprises

7.1. Macro Measures

The government strengthens policy support. Formulate more unified and clear grid connection standards, accelerate the intelligent and flexible transformation and upgrading of the electricity grid, introduce advanced energy storage technologies and microgrid management strategies to enhance the grid's acceptance and regulation capacity for distributed solar and other renewable energy sources. Explore simplifying approval processes, implement "one-stop" services, improve approval efficiency, and reduce the burden on enterprises. The government should provide more financial support and risk-sharing measures, strengthen market supervision, and establish a sound quality standard system. In addition, promoting the healthy development of distributed solar projects is also critical through formulating clearer and more flexible policy guidance, as well as enhancing the transparency and predictability of policies.

Increasing R&D investment in distributed photovoltaics by enterprises is a key measure to promote the progress and industrial upgrading of this clean energy technology. Enterprises should increase R&D on core components, improve photoelectric conversion efficiency, reduce electricity costs, and make distributed photovoltaic projects more economically competitive. At the same time, research on the integration technology of the entire system is also needed, including how to achieve the best layout and most efficient energy management in different scenarios. Promote innovation in grid connection technology, improve compatibility and interoperability between devices, and use technology to make up for the lack of rural infrastructure. Considering the diversity of climate and environmental conditions in different regions, enterprises should also develop photovoltaic products suitable for extreme weather, salt spray corrosion, high temperature and humidity, and explore the recycling and reuse technology of photovoltaic components.

Pattern innovation and promotion should go from "point" to "area". As a leading enterprise in the distributed photovoltaic industry, TBEA Sunoasis has provided solid "frontline" support for distributed photovoltaic applications at the household end with its deep integration capabilities across the entire chain of hardware equipment, system design, construction installation, and operation and maintenance services. However, to truly tap into the potential of distributed photovoltaics in rural revitalization, it is necessary to further deepen the promotion strategy from the "point" to the "area" for households, through precise positioning, extensive coverage, community effects, and demonstration guidance, to achieve comprehensive radiation and boosting of green energy on the rural economy, environment, and social development.

In-depth understanding of the specific needs of different regions and types of farmers, such as agricultural photovoltaic complementary, fishery photovoltaic complementary, rooftop photovoltaic, and other different application scenarios, designing distributed photovoltaic solutions that meet local characteristics and farmers' actual needs. By precise positioning, improve the applicability and attractiveness of products; establish a multi-level distribution network and agency mechanism to ensure that products and services can reach a wider range of farmers. Provide a combination of online and offline training courses to enhance farmers' photovoltaic knowledge and self-maintenance capabilities. Build a photovoltaic community at the village level, organize photovoltaic exchange meetings, results showcases, and other forms to stimulate the participation of other farmers and form a self-promotion effect. Carry out public welfare projects such as "photovoltaic poverty alleviation" and "green countryside", using distributed photovoltaics to assist rural revitalization while enhancing brand image.

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7.2. Specific measures - agriculture-photovoltaic complementarity

Agriculture-Photovoltaic Complementary (APC) is an innovative model that combines solar photovoltaic power generation with agricultural production. It aims to achieve efficient composite utilization of land resources by simultaneously carrying out crop planting and photovoltaic power generation on the same piece of land, promoting the modernization of agriculture and the development of renewable energy. Typical APC models include winter-warm-style off-season photovoltaic agricultural greenhouses, weak-light-type photovoltaic agricultural greenhouses, photovoltaic aquaculture agricultural greenhouses, fishery-photovoltaic complementary agricultural greenhouses, fungus photovoltaic models, forest-light models, and medicinal herb photovoltaic models. Each of these models has its own focus, and by selecting the most suitable APC model based on geographic location, climate conditions, agricultural type, and land resources, its economic, social, and environmental benefits can be maximized.

The advantages of the agricultural-photovoltaic complementary mode, as an innovative integration strategy in the fields of agriculture and energy, are not only reflected in economic benefits, but also cover multiple aspects such as environment, society, and technology.

Utilizing agricultural land for both farming and solar power generation increases efficiency. By installing photovoltaic panels above the farmland, it enables the utilization of the same area in a three-dimensional manner. This approach preserves the space for crop cultivation while also generating clean electricity. It opens up new income sources for farmers, enhances agricultural profitability, and helps improve the living standards of farmers and the productivity of agriculture.

The shading effect provided by solar panels can effectively reduce the surface temperature, decrease water evaporation, and help combat drought and soil moisture retention. Additionally, solar agriculture reduces reliance on chemical fertilizers and pesticides, promoting the development of eco-friendly agriculture. The utilization of distributed solar energy reduces dependence on fossil fuels, significantly lowers greenhouse gas emissions, and contributes to the construction of "ecologically livable" rural areas. Furthermore, by reducing the use of chemical fertilizers and pesticides and improving water resource efficiency, the agri-photovoltaic complementary model also promotes the protection of biodiversity and the maintenance of ecological balance.

8. Conclusion

This article explores the practical logic and optimization path of distributed photovoltaic enterprises, with Tainhe Fupin as a typical representative, in the rural revitalization strategy, demonstrating the practical application of the new quality productivity theory and Marx's productivity theory in contemporary energy transformation and rural development. Distributed photovoltaics is not only an application of clean energy technology, but also an important manifestation of driving new quality productivity in rural revitalization. Its combination with agricultural photovoltaic complementary technology has created a new model to promote sustainable economic and social development in rural areas.

The practice of Tianhe Wealthy Family proves that through innovative business models and supporting systems, distributed photovoltaics can effectively improve the self-sufficiency of rural energy, increase farmers' income, and improve the rural ecological environment, which is an effective path to achieve the diversification and ecological transformation of rural economy. The promotional experience summarized in this study and the improvement measures proposed, such as enhancing policy support from the government, increasing technological input from enterprises, and promoting the radiation of "point" to "surface" in model innovation, provide practical guidance for the practice of rural revitalization with distributed photovoltaics in a broader range.

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However, rural revitalization is a complex systematic project, and the promotion of distributed photovoltaic enterprises and agricultural photovoltaic complementary models still face many challenges, requiring continuous attention and joint efforts from the government, enterprises, and all sectors of society. In the future, we should continue to deepen theoretical research, strengthen policy guidance, promote the deep integration of technological progress and mode innovation, in the hope that distributed photovoltaic enterprises can play a greater role in promoting green rural development and achieving common prosperity.

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