Exploration of Shared Energy Storage Business Model

Bingcong Zhai[1,a*], Baomin Fang[2,b], Xiaoyu Liu[1,c], Xichao Wang[2,d], Lianfang Wang[2,e]
Yanhe Li[2,f] and Xiangjun Li[1,g]

{18601167058@163.com[a*], fangbaomin@163.com[b], liuxiaoyu@epri.sgcc.com.cn[c], 303049906@qq.com[d], 517281391@qq.com[e], lyhe0416@163.com[f], lixiangjun@epri.sgcc.com.cn[g]}

[1] China Electronic Power Research Institute, Beijing, 100192, China
[2] State Grid Qinghai Electronic Power Company, Xining, Qinghai, 630100, China

Abstract. This article takes the shared energy storage business model as the discussion object. Based on the definition and classification of business models, it analyzes shared energy storage from three dimensions: pricing mechanism, investment model, and profit model. Firstly, it analyzes some policies related to shared energy storage at the national level in China and in various provinces and cities; Secondly, Using the business model for shared energy storage as the subject of study, this paper discusses the pricing mechanism of shared energy storage from four aspects: game theory, auction mechanism, fixed electricity price, and time of use electricity price, and lists the research on the pricing mechanism of shared energy storage by domestic and foreign scholars; Thirdly, three investment models for shared energy storage were proposed, and their concepts were explained and their advantages and disadvantages were analyzed;Finally, the profit model of shared energy storage was explored, mainly through participation in the auxiliary service market, capacity leasing, and the difference in charging and discharging electricity prices to generate revenue. Using Hunan Province shared energy storage power plant economic analysis was done, and recommendations for the future advancement of shared energy storage were compiled and put forth.

Keywords: Shared Energy Storage policy, Pricing Mechanism, Profit Model, Investment Model.

1 Introduction

Under the goals of "carbon peak" in 2030 and "carbon neutrality" in 2060, new energy will be integrated into the power grid on a large scale. Due to its characteristics of volatility, intermittency, and randomness, large-scale integration will fundamentally change the balance mode of "source follows load" in the power grid. Peak shaving becomes more necessary in the power system since conventional power sources have to balance the output fluctuations of new energy in addition to responding to changes in load. A series of issues, such as increasing difficulty in ensuring power supply and increasing risks to grid security. Energy storage has the characteristics of suppressing fluctuations in renewable energy and ensuring supply and demand balance in the power system. In the context of a high proportion of renewable energy, the value of energy storage is prominent, and it is one of the most important flexible regulation resources in the power system. However, there are generally low utilization rates, a lack of relevant policy support, and unclear profit methods at existing energy storage power stations. To support the wholesome and sustainable growth of the future energy storage industry, it is

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necessary to conduct a policy review and investigate business models for energy storage. Shared energy storage has the characteristics of high flexibility and can improve the economic benefits of energy storage, which to some extent solves the shortcomings of low energy utilization and low profits and has received widespread attention from scholars at home and abroad.

2 Analysis of policies related of shared energy storage

In recent years, the country and various provinces and cities have issued a series of relevant policies to support the development of the shared energy storage industry. These policies clearly accelerate the exploration and construction of shared energy storage, injecting strong impetus into the development of shared energy storage.

2.1 Qinghai shared energy storage development policy

In 2018, the province of Qinghai introduced the "Qinghai Electric Power Auxiliary Service Market Operation Rules (Trial)" and first presented the idea of "shared energy storage", which clearly stipulates that shared energy storage is allowed to participate in market transactions as an independent theme. In June 2020, Qinghai officially launched the shared energy storage auxiliary service market. On June 13, 2023, the Qinghai Provincial Energy Bureau organized a large-scale electrochemical shared energy storage project scheduling meeting on the grid side, and conducted scheduling on the grid side shared energy storage project. The meeting emphasized that promoting the construction of shared energy storage on the grid side is a specific measure to implement the provincial government's "Work Plan for Promoting the Construction of National Clean Energy Industry Highland with a New Power System (2022-2035)", which is of great significance for supporting the construction of national energy storage demonstration zones and creating a national clean energy industry highland.

2.2 Shandong shared energy storage development policy

There is a serious shortage of peak shaving and new energy consumption in Shandong Province. At present, there are 87 new grid connected energy storage power stations in Shandong Province, with an installed capacity of 3.53 million kilowatts/7.14 million kilowatt hours. The "Implementation Opinions on Conducting Energy Storage Demonstration Applications" that Shandong Province released in April 2021 made it very clear that leasing shared energy storage facilities should take precedence over wind and photovoltaic power generation projects. Building new centralized wind and photovoltaic projects with a certain percentage of allocated or leased energy storage facilities to support the construction and operation of shared energy storage facilities is encouraged, according to Shandong Province's "14th Five Year Plan" for energy development. Additionally, wind and photovoltaic projects are encouraged to prioritize leasing shared energy storage facilities.

2.3 Zhejiang shared energy storage development policy

Power-side energy storage construction should be carried out in an orderly manner, Zhejiang Province noted in the Implementation Opinions of the Provincial Development and Reform Commission and the Provincial Energy Bureau on Accelerating the Demonstration

Application of New Energy Storage in Zhejiang Province in 2021. Encourage the development of power-side energy storage initiatives, such as "new energy+shared energy storage" and "microgrid + energy storage," and encourage the construction or purchase of new energy storage (services) for newly added offshore wind power and centralized photovoltaic power plants based on practical factors such as comprehensive new energy characteristics, system consumption space, regulation performance, and economy. Encourage centralized energy storage stations to provide capacity rental or purchasing services for new energy. Encourage coal-fired power plants to build new energy storage facilities and jointly regulate frequency with coal-fired units to enhance their comprehensive competitiveness.

2.4 Policies for shared energy storage in other provinces and cities

The shared energy storage policies of other provinces and cities are shown in Table 1.

Table 1. Policy in other province

Region	Policy Name	Content
Xinjiang	“Notice of the Development and Reform Commission of the Autonomous Region on Establishing and Improving Supporting Supporting Policies for the Healthy and Orderly Development of New Energy Storage”	Establish a mechanism of "new energy+energy storage". The energy storage capacity can be determined according to the above proportion through market leasing. For new projects, the allocation or leasing plan should be clearly defined when applying
Ningxia	“Notice of the Development and Reform Commission of the Autonomous Region on Accelerating the Healthy and Orderly Development of Energy Storage”	Provide a profit model for shared energy storage power plants and prioritize the building of shared energy storage facilities in regions with a surplus of fresh energy and limited power system transmission.
Hunan	“Implementation Opinions on Accelerating the Development of Electrochemical Energy Storage in Hunan Province”	Create a "new energy+energy storage" system. Market leasing can be used to calculate the energy storage capacity in accordance with the aforementioned proportion for projects without the necessary infrastructure to build energy storage power plants. When applying for new projects, the lease plan or allocation should be made explicit.

Through the support of relevant policies in different provinces, cities, and countries mentioned above, it can be seen that in the future, energy storage will usher in a period of rapid development, and government will continue to propose suggestions to support the development of the energy storage industry, introduce policies that are more conducive to market-oriented energy storage transactions, and further promote the development of energy storage from scientific research demonstration projects to commercial operations.

3 Pricing Mechanism of Shared Energy Storage

Shared energy storage is a concept proposed in recent years and has received widespread attention from scholars both domestically and internationally. Its fundamental idea is to share the right to use energy storage resources in order to accommodate the demands of various customers, which is a novel economic model. Its advantages are mainly reflected in: (1) for users, they can purchase corresponding energy storage usage rights according to their own needs and abilities without the need to pay for energy storage construction costs, reducing the cost of using energy storage for users; (2) shared energy storage operators can obtain considerable revenue by operating energy storage resources reasonably through specialized technical means. It is not difficult to see from the above advantages that shared energy storage has a vast market in China. This chapter will examine shared energy storage prices from four angles.

3.1 Pricing Mechanism Based on Game Theory

Game theory is a theory that studies the strategic interaction between multiple entities. Introducing game theory can better consider potential conflicts of interest between shared energy storage users. Both non-cooperative and cooperative games can be applied to the research of shared energy storage operation models.

In the non-cooperative game model, it is like the group headquarters has a unique perspective and resource advantage in the current business environment and can occupy a favorable position in the game to formulate reasonable strategies. The group subsidiaries, after the headquarters makes decisions, follow the headquarters' decisions to make the best response based on their own situation. In the non-cooperative game mode, shared energy storage mainly adopts the master-slave game method. Shared energy storage operators, energy storage owners, and energy storage users face conflicts of interest in different competitive environments, with demands for resource complementarity. The master-slave game method can balance the resource and interest demands of multiple participants, thereby maximizing their respective interests. Reference [1] uses Stackelberg's master-slave game method to price the leasing of shared energy storage equipment, achieving the optimal interests of users, energy storage companies, and power companies. Taking user-side energy storage as the research object, an optimized configuration model for energy storage capacity based on the entire life cycle was established. Peak users with short-term electricity demand were considered, and a shared concept-based business model for energy storage cooperatives was proposed. Finally, the feasibility of the proposed shared energy storage business model was verified through numerical examples and on-site experiments. Reference [2] proposes a two-level energy trading strategy based on mixed game theory from the perspective of the electricity market to address the issue of energy trading. Developed a mixed game optimization model involving integrated energy microgrid aggregates and shared energy storage operators, and guaranteed that the advantages of cooperation can be fairly divided among participants using Nash negotiation theory.

In the cooperative game model, the game mainly involves mutual confrontation between groups. In a cooperative game, the interests of both or more parties increase, or at least one party's interests increase while the other interests are not harmed, resulting in an increase in the overall interests. In the cooperative game model, the cost-benefit allocation methods for shared energy storage usually include the Sharpley value method and the Nash equilibrium theory. The main idea of Nash equilibrium theory is that each participant aims to maximize their personal interests, resulting in their overall interests being damaged. Each participant is unable to improve their situation and can only seek new solutions through cooperative negotiations, thereby maximizing their overall interests. Reference [3] proposes a cloud service platform for energy storage aggregators to implement a joint scheduling operation mode for small energy storage devices. Based on Nash equilibrium theory, a cooperative game model is established for each participating entity under constraint conditions. Finally, the optimal shared energy storage pricing scheme is solved through simulation analysis. Reference [4] established a cooperative operation model for shared energy storage power stations, industrial users, and various operating entities based on Nash negotiation theory. Finally, through case analysis, it was verified that the efficiency of each entity can be effectively improved. The Sharpley value method is a compromise utility allocation scheme that comprehensively considers the requirements of all parties in a conflict, emphasizing fairness.

3.2 Based on auction pricing mechanism

An auction is a form of competition where fairness can be guaranteed. Within the specified time, buyers and sellers bid to sell or purchase electricity, and the higher bidder wins the bid. The auction process generally consists of four steps. Firstly, in the bidding stage, the auctioneer issues a start bidding signal, and each energy storage buyer and seller submits bidding information to the auctioneer. Then there is the resource matching and pricing stage, where the auctioneer calculates the total expenses and income of the buyer and seller based on bidding information and corresponding transaction prices for energy storage resources; Secondly, there is the issue of determining the winning bid, where the auctioneer notifies each participant of the winning bid result, pricing result, revenue, and expenditure situation based on previous bidding information and calculated transaction prices; Finally, in the fund settlement stage, the auction results will be executed by the dispatch instructions issued by the microgrid control center or distribution network dispatch center. The funds will be transferred from the buyer to the auctioneer, and then from the auctioneer to the seller, ending the entire auction process.

Auctions can be divided into single auction mechanisms and combination auction mechanisms, and shared energy storage is generally divided into two types: capacity right auction or power right auction. Under a single auction mechanism, the items auctioned for shared energy storage are usually capacity or power. Under the combined auction mechanism, a diversified variety combination is adopted according to the different needs of users. Reference [5] proposes a shared energy storage combination auction mechanism for load aggregation and constructs a bidding decision model with the goal of maximizing social welfare. Finally, the effectiveness of this mechanism is verified through numerical examples. Reference [6] adopts a hybrid energy storage combination auction method based on multi-item auction theory and establishes an electric-thermal hybrid energy sharing model with the goal of maximizing social welfare. The final computational results show that in terms of social welfare, hybrid energy storage combination auctions have more advantages compared to general shared energy storage models.

3.3 Pricing mechanism based on fixed electricity price

Fixed electricity prices are defined as prices that are independent of time, supply and demand relationships, etc. The owner of shared energy storage resources sets the rental price for shared energy storage based on market environment, personal needs, and other factors, which is suitable for users who are not sensitive to price. Therefore, it is suitable for scenarios where price sensitivity is not significant but user needs and preferences are evident. Reference [7] discusses the policy formulation, policy impact, and policy effectiveness between fixed electricity prices and renewable energy quota systems. And propose the development and prospects of future fixed electricity prices.

3.4 Pricing mechanism based on time-of-use electricity price

The time of use electricity price is divided into three stages: peak, flat, and valley, based on the load situation of the power system and the supply and demand situation of energy storage services by users. The pricing for each period can refer to the purchase and sale prices of the distribution network or the average marginal cost of the operation of the shared energy storage system. This model is closely related to time and supply-demand relationships, which is conducive to stimulating and encouraging users to purchase shared energy storage services for peak and valley shifting, price arbitrage, and optimizing electricity consumption methods. It is suitable for scenarios with obvious price arbitrage and increased photovoltaic penetration rate. Reference [8] formulated a time of use electricity price based on historical user electricity consumption, and established a pricing strategy for shared energy storage electricity based on a master-slave game based on the time of use electricity price. The final results showed that shared energy storage achieved high profits and user expenses were also reduced to a certain extent. Reference [9] established a day-ahead energy storage scheduling model for intelligent building cluster operators considering the differences in time-of-use electricity prices. Finally, practical examples have confirmed that this model can better enhance the economic benefits of intelligent buildings.

4 Investment model of Shared Energy Storage

The integration of distributed energy storage resources on the grid, user, and power supply sides and their submission to the grid for unified coordination to perform frequency regulation, peak shaving, balanced output, and reduce power fluctuations for the grid is known as shared energy storage basic function. There are basically three ways to invest in shared energy storage.

The first mode is self-investment plus self-operation mode [10], which refers to energy storage operators having their own huge funds as support and being able to independently invest in the construction, operation, maintenance, and repair of their own shared energy storage power stations, and all operating income they receive belongs to themselves. This model is suitable for energy storage operators who have sufficient financial support, rich experience in operating energy storage power stations, and a grasp of future policies for shared energy storage power stations.

The second mode is leasing, when the energy storage operator leases the energy storage station that has already been constructed and assumes responsibility for its upkeep and operation [11]. Throughout the entire leasing period, the energy storage operator has the right to operate the energy storage station and can sell the electricity to users for profit. The advantage of this model is that it does not need to consider the huge amount of funds during the early construction of energy storage power stations, which can reduce the pressure on enterprises' early investment. It is suitable for energy storage operators who do not have sufficient early construction funds but have rich experience and can achieve profits based on market conditions and energy storage-related policies.

The third mode is the financing mode, which refers to the joint investment and construction of energy storage power stations by energy storage operators and other manufacturers [12]. The manufacturer can be responsible for providing equipment, and the energy storage operator is responsible for the construction, maintenance the energy storage power station. The advantage of this mode is that it can reduce investment in early construction funds, and has higher annual profits than the second leasing mode, and has a shorter investment payback period than the first self-investment operation. It is suitable for energy storage operators with certain financial support and rich investment and operational experience.

5 Profit method of shared energy storage

In the context of existing policies, the main benefits of energy storage are divided into three types: participating in the capacity market, auxiliary service market, and medium to long-term trading market to obtain capacity leasing, peak shaving auxiliary services, and charging and discharging electricity price differences. However, there are still problems with low profitability and difficulty in promoting business models in energy storage. There are now barriers to peak shaving on the grid side due to the inability of energy storage to be incorporated into the transmission and distribution electricity pricing structure; On the user side, energy storage can only be self-storage and self-use, making it difficult to make profits; In terms of power supply, the effectiveness of policy allocation and storage still needs further observation.In this context, shared energy storage can transform the traditional 1-to-1 operation mode into a 1-to-N, N-to-N operation mode [13], in order to achieve resource sharing and maximize the commercial value of energy storage through the sharing economy.

At present, the main profit modes of the shared energy storage model include capacity leasing, participation in auxiliary service markets, peak valley price arbitrage (participation in spot electricity market transactions), capacity subsidies, and other charging methods. Under the capacity leasing fee system, energy storage owners lease energy storage capacity to shared energy storage operators, who then lease it to new energy power generation enterprises or users to obtain rental income from users, which is used to compensate for the construction costs, operation costs, depreciation costs etc, and enable energy storage owners and operators to make profits. Under the market approach of participating in energy storage auxiliary services, shared energy storage power stations mainly participate in two types of peak shaving auxiliary services and frequency modulation auxiliary services. Peak shaving auxiliary services mainly compensate for energy storage based on charging and discharging prices and electricity levels; FM auxiliary services generally provide economic compensation for energy storage based on FM mileage. The arbitrage of peak valley price difference mainly refers to the discharge of energy storage during peak hours of the power grid, charging during low hours, and profiting through the difference in electricity prices.

5.1 Economic calculation of shared energy storage power stations

Taking a shared energy storage power station with a capacity of 100 thousand kilowatts/200 thousand kilowatt hours in Hunan Province as an example. The initial investment of its shared energy storage power station is calculated based on the current lithium battery market price and the installation and construction costs of the energy storage power station. The initial total investment is 451.45 million yuan, including equipment procurement costs of 363.37 million yuan and construction installation and other costs of 88.08 million yuan. The operating cost includes operation and maintenance fees, maintenance fees, insurance fees, financial expenses, etc., with a total average annual operating cost of approximately 15.6 million yuan. As shown in Table 2.

Table 2. Revenue statement of Hunan project

Investment	Numerical value	Average yealy earning	Numerical value
Initial Investment	451.45 million yuan	Auxiliary service income	10 million/year
Equipment purchase cost	363.37 million yuan	Charge and discharge electricity price difference income	11.7 million/year
Building installation and other expenses	88.08 million yuan	Capacity rental income	60 million/year
Total average annual operating cost	15.60 million yuan		

According to current policies, the operating income of shared energy storage power stations mainly includes peak shaving income in the auxiliary service market, income from charging and discharging electricity price differences, and shared energy storage capacity leasing. The income from auxiliary services, according to formula (1), is calculated at 0.2 yuan per kWh, with an annual income of about 10 million yuan per year.

$$V_{peak} = \sum_{d=1}^{D} \sum_{t=1}^{T} (P_d(t) - P_c(t))(M_{ff}(t) + \beta)\Delta t \quad (1)$$

In the formula (1), $P_c(t)$ and $P_d(t)$ respectively represent the charging and discharging power of the energy storage system at time t; $M_{ff}(t)$ represent peak shaving electricity prices for energy storage systems at time t; β represent peak shaving subsidy.

The income from the difference in charging and discharging electricity prices, according to formula (2), is calculated at 0.3 yuan/kWh (charging is about 0.2 yuan/kWh, discharging is about 0.5 yuan/kWh), with an annual income of about 11.7 million per year.

$$I_{elc} = \sum_{d=1}^{D} \sum_{t=1}^{T} (\beta_{low} \cdot Q_{ch})\Delta t - (\beta_{sta} \cdot Q_{dis})\Delta t \quad (2)$$

In the formula (2), $\beta_{low}$is the charging electricity price at the shared energy storage time t; Q_{ch} is the shared energy storage charge capacity at time t; $\beta_{sta}$is the discharging on-grid electricity price for energy storage t at any time; $Q_{bess}$is the shared energy storage discharge capacity at time t;

According to the Notice of the Hunan Provincial Development and Reform Commission and the Provincial Energy Bureau on Carrying out the 2022 New Energy Generation Project Configuration New Energy Storage Pilot Work, for projects included in the pilot and put into operation before the end of December 2022, the capacity leasing fees are calculated at 1.5 times the fees. In the case of full capacity leasing, the leasing fees for energy storage power stations can reach 60 million yuan per year. Based on the above calculate information, the income from the difference in charging and discharging electricity prices is about 11.7 million yuan per year. The income from auxiliary services is 10 million per year. Their value and revenue proportion is shown in **Figure 1.**

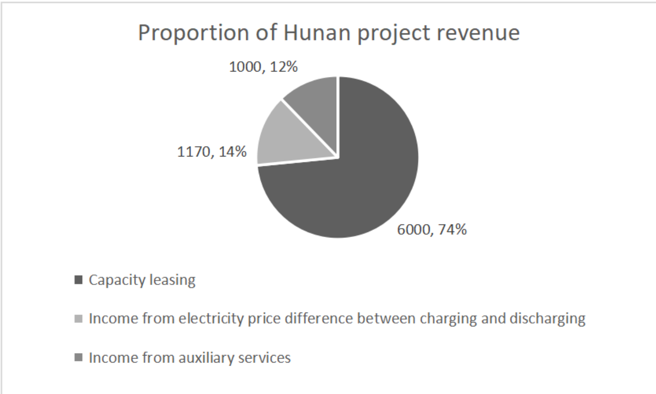

Figure 1. Proportion of Hunan project revenue

In order to evaluate the feasibility, profitability, and return period of shared energy storage projects, two commonly used key indicators are internal rate of return (IRR) and net present value (NPV).

NPV is an indicator used to evaluate the net cash flow of energy storage projects and measure whether a project is worth investing in [14]. Based on the formula (3) and the data from above revenue statement of Hunan project, NPV of the shared energy storage power station is positive from the 10th year onwards, as shown in the **Figure 2,** with an investment payback period of about 9.5 years, which means the project has investment potential.

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{(\mathrm{CI}-\mathrm{CO})_t}{(1+i)^t} \tag{3}$$

In the formula (3), i is the expected return of shared energy storage, CI is the cash inflow, and CO is the cash outflow.

IRR is an indicator used to measure the return on investment of energy storage projects [15]. According to research, one of the red lines for project estimation by investors is usually IRR≥6%. Based on the formula (4) and the data from annual revenue of shared energy storage power stations, IRR is calculated 6.5% has been achieved to achieve investment return. With the decrease in energy storage costs in the future and an increase in the frequency of charging and discharging, the internal rate of return will be further improved, and shared energy storage power stations will further enhance investment efficiency.

$$\sum_{t=1}^{n} \frac{(\mathrm{CI}-\mathrm{CO})_t}{(1+\mathrm{IRR})^t} = 0 \tag{4}$$

In the formula (4), IRR is the internal rate of return of shared energy storage.

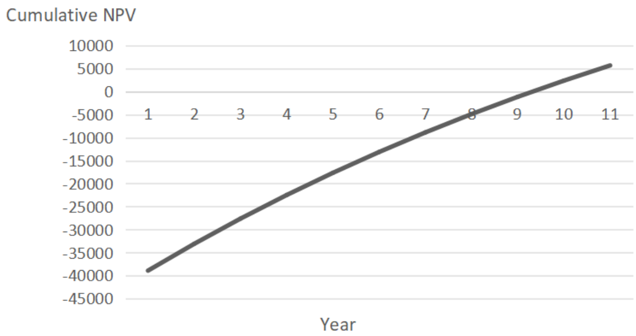

Figure 2. Cumulative NPV of Hunan project

6 Suggestions for the future development of shared energy storage in China

The shared energy storage business model is still in its early phases of development. The following ideas are put out to help shape shared energy storage going forward:

1. Increase the proportion of shared energy storage participating in the market and continuously enrich the variety of market operations. Introduce market operation varieties such as shared energy storage peak, climbing, and backup, and increase the enthusiasm of shared energy storage to participate in power supply guarantee. Accelerate the construction of the auxiliary service market and spot market, continue to improve the detailed rules for sharing energy storage to participate in power auxiliary service market transactions, clarify transaction types, establish price mechanisms, stimulate market operation vitality, improve the profit level of energy storage projects, promote the role of energy storage in the spot market, and obtain reasonable returns from the energy storage system through market means.

2. Accelerate the construction of shared energy storage demonstration projects. The government encourages the construction of independent energy storage-related demonstration projects, explores more shared energy storage application scenarios and business models, draws inspiration from more successful shared energy storage demonstration projects, imitates and learns from their commercial operation models, and promotes them. In business models, support the promotion of new business models on the basis of existing ones and encourage innovative operational mechanisms.

3. Encourage the diverse development of other types of new energy storage technologies, such as compressed air, hydrogen, and gravity energy storage. strengthen the technological foundations of several emerging energy storage initiatives, analyze the operation of various forms of energy storage, such as vanadium liquid flow, compressed air energy storage, and sodium ion battery energy storage, master the grid connection characteristics of new types of energy storage, and study corresponding business models.

4. Improve blockchain shared energy storage. Shared energy storage would encounter issues including regular transactions, heterogeneous entities, and complicated data after become market-oriented. It is critical to create a shared energy storage blockchain platform in order to

satisfy the standards of impartiality, openness, and fairness in power transactions. This will assure the timeliness, security, and fairness of transactions.

5. Explore the integration of carbon trading and shared energy storage. The Chinese government encourages enterprises and large state-owned enterprises to purchase green electricity, and promotes export-oriented enterprises to gradually increase the proportion of green electricity consumption. This will help promote the development of shared energy storage and open up a new path for the future business model of shared energy storage.

7 Conclusion

This article takes the shared energy storage economy as the starting point. Analyzes some policies of shared energy storage; Explored the pricing mechanism of shared energy storage ; Propose three shared energy storage investment models; Explored several main profit methods for shared energy storage and cited a shared energy storage power station in Hunan Province as examples for economic analysis. Based on the above content, proposed suggestions for the future development of shared energy storage, with the aim of contributing to the commercial development of shared energy storage.

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