Research on the Development and Economic Value of EU Household Energy Storage Systems

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Abstract: With the acceleration of the global energy transition process, household energy storage systems, as an important form of distributed energy management, have gradually become an important link in promoting household energy self-sufficiency, improving grid stability, and optimizing energy efficiency. Unlike traditional centralized power generation and supply models, household energy storage systems can achieve intelligent energy scheduling in small-scale applications, providing more efficient power solutions for household users. At the same time, against the backdrop of stricter energy and environmental policies, the application of household energy storage systems is an inevitable result of technological development and represents a new energy consumption model, which has profound significance for reshaping the energy economic landscape. Based on this, the article conducts relevant research on the current development status and economic impact assessment of household energy storage systems in the European Union for reference.

Keywords: European Union; Household Energy Storage System; Economic Value

1.Introduction

As an advocate for addressing climate change and reducing greenhouse gas emissions, the European Union has always been at the forefront of policy-making and implementation. In 2015, EU member states actively initiated and signed the Paris Agreement, committed to achieving global greenhouse gas emissions reduction and climate protection goals. Afterwards, the EU further launched a series of action plans to address climate change, setting a goal of reducing greenhouse gas emissions by at least 40% compared to 1990 by 2030, and stipulating that the proportion of renewable energy in total energy consumption should reach 32%. In 2016, the European Commission launched the "Clean Energy Package for All Europeans" plan, aimed at accelerating the transition to clean energy and laying the foundation for a broader low-carbon economy. In 2019, the legislative proposal for the European Climate Law was passed, further establishing the EU's ambitious goal of achieving carbon neutrality by 2050 and demonstrating its leadership position in global climate policy. Driven by a series of climate policies, household energy storage systems have become an important component in achieving the EU's low-carbon goals and promoting the transition to clean energy. The rapid development of household energy storage systems in the European Union is both a result of policy guidance and influenced by economic drivers. With the large-scale development of renewable energy such as photovoltaic power generation and wind energy, the problem of energy supply volatility has become increasingly prominent. Household energy storage systems can effectively store excess renewable energy generation, enhance community energy self-sufficiency, reduce dependence on traditional power grids, and provide support for the stable operation of the power grid. In addition, household energy storage systems can bring direct economic benefits to users through peak valley electricity price arbitrage, becoming an emerging choice in household energy management. The high electricity bills of residents in many EU countries are also an important driving force for the rapid development of household energy storage systems. In Germany, the cost of purchasing electricity for households reached 0.314 euros/kWh in 2020, showing a continuous upward trend. Compared to this, household energy storage systems using lithium iron phosphate battery technology have a levelized cost of electricity (LCOE) ranging from 0.081 US dollars/kWh to 0.14 US dollars/kWh, which is significantly lower than the cost of purchasing electricity from the grid, as shown in Figure 1. The cost difference provides residents with more

cost-effective energy options, prompting more and more households to invest in energy storage systems. Therefore, the development of household energy storage systems in the European Union is both a result of policy promotion and an economic driven choice. It can be seen that under the constantly changing energy landscape, the development of household energy storage systems provides new directions for climate governance.

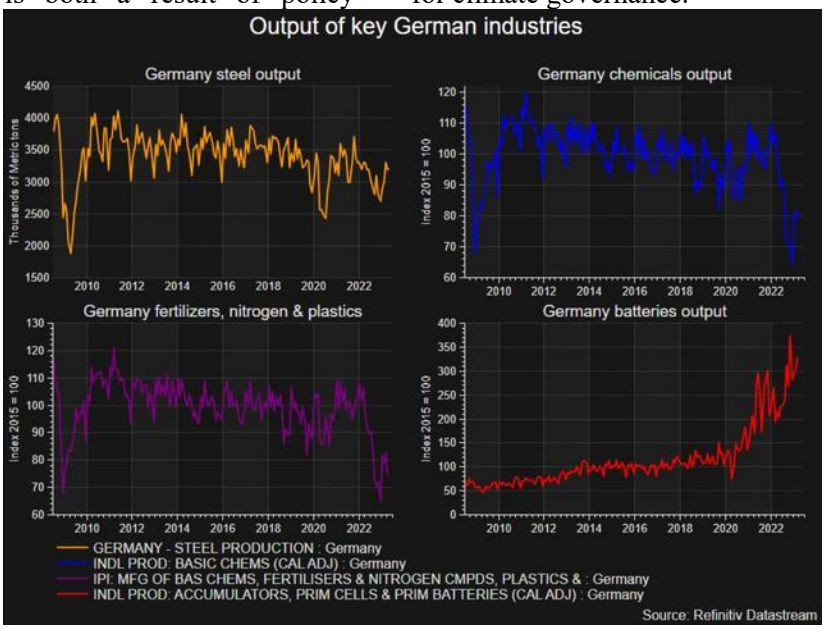

Figure 1. Development Trend of Residential Electricity Charges in EU Countries

2. Development Status of Household Energy Storage Systems in the European Union

2.1 Technical Status Analysis

Currently, lithium-ion batteries dominate the market. Lithium ion batteries are widely used in household energy storage systems due to their high energy density, long lifespan, and relatively low self discharge rate. In addition to lithium-ion batteries, lead-acid batteries, as a traditional energy storage technology, still have a certain market, but their market share is gradually decreasing due to their short service life, low energy density, and environmental pollution issues. Meanwhile, new energy storage technologies such as vanadium flow batteries are gradually being applied in some scenarios due to their advantages of long cycle life.[1]Overall, the development trend of household energy storage systems in the European Union is moving towards efficiency, safety, and environmental protection. In terms of innovation, the current research focus is on improving battery efficiency, extending service life, reducing costs, and improving the integration level of energy storage systems. For example, through the application of nanomaterials, the next generation of solid-state batteries is expected to achieve improved energy density, which is expected to further promote the widespread application of household energy storage systems.

2.2 Market Situation Analysis

The EU household energy storage system market has shown a rapid growth trend in recent years. According to market research data, the market size of household energy storage systems in the European Union has exceeded 1 billion euros in 2023, and is expected to continue maintaining double-digit annual growth rates in the coming years. Germany, Italy, and France are the three major energy storage markets in the European Union. The German market has the highest installation volume of household energy storage systems due to its high electricity prices and good policy support; The Italian and French markets are also gradually expanding, thanks to the relatively high penetration rate of photovoltaic power generation in the country.[2]

The driving factors of market demand mainly include the following aspects: firstly, as the cost of photovoltaic power generation decreases and the installation volume increases, the demand for self generated electricity from household users continues to rise, and energy storage systems have become an essential component. The second is the volatility of electricity prices, which makes it possible for household users to arbitrage electricity prices through energy

storage systems. Thirdly, national policies are also important factors in promoting market development, such as the low interest loans provided by Germany's KfW bank and Italy's "super discount" tax reduction policy. However, the high initial cost of energy storage systems remains a significant economic burden for ordinary household users.

2.3 Policy Status Analysis

Under the overall policy framework of the European Union, policies such as the Clean Energy Package and the Energy Efficiency Directive have set clean energy development goals for member states, encouraging the integration of renewable energy and energy storage technologies. Various countries have introduced specific policies, such as subsidies, tax reductions, loan incentives, and net measurement policies, to promote the promotion of household energy storage systems. In Germany, the government has promoted the rapid development of the energy storage market through various policies such as energy storage subsidies and low interest loans implemented by the Federal Ministry of Economy and Energy (BMWi) and KfW Bank. Italy has implemented a "super discount" policy, providing up to 110% tax relief for household users who install energy storage systems, greatly stimulating market demand.[3]The French government also encourages users to install energy storage systems through energy efficiency renovation subsidy programs and special support policies for low-income families. However, the consistency of policies among countries is poor, and there are significant differences in policy intensity among different countries, which may lead to imbalanced market development. Especially in times of economic environment changes, policy changes may have a significant impact on the market. Therefore, how to develop a more unified policy framework at the EU level has become an important issue for current development.

3. Economic Value Analysis of Eu Household Energy Storage Systems

3.1 Economic Benefit Analysis

The EU household energy storage system has significant economic benefits at both the household and social levels. At the household level, the main economic benefits of installing energy storage systems are reflected in electricity cost savings and electricity price arbitrage. Household energy storage systems enable households to store excess electricity generated by photovoltaic systems during the day and use it at night or during periods of high electricity prices, thereby reducing dependence on the power grid and lowering household electricity costs. The "spontaneous self use" model has significant economic advantages, especially in countries implementing peak and valley electricity pricing mechanisms. For example, in Germany, due to the large peak valley price difference, households installing energy storage systems can achieve investment recovery in the short term through electricity price arbitrage. In addition, some countries such as Italy and Spain have further increased the economic attractiveness of energy storage systems through tax reduction policies, shortening the initial investment return period for users. At the societal level, the economic benefits of household energy storage systems mainly lie in reducing energy costs. Energy storage systems can effectively reduce peak loads on the power grid, alleviate the pressure on the power system, avoid the need for grid expansion, and thus save public investment costs. At the same time, the popularization of energy storage systems helps to better utilize distributed renewable energy, reduce the use of fossil fuels, and lower environmental governance costs. According to a research report by the European Union, the large-scale deployment of energy storage systems can significantly reduce greenhouse gas emissions, meet the EU's carbon neutrality goals, and even create employment opportunities in the green economy, promoting sustainable economic development.[4]

3.2 Cost Benefit Analysis

At present, lithium-ion batteries are the mainstream choice for household energy storage systems, and their cost structure mainly consists of battery cost, inverter cost, installation and maintenance costs. Although the price of lithium-ion batteries has significantly decreased in the past decade, their initial installation cost remains high, making it a significant investment for many household users. Therefore, the return on investment of the system has become the main factor affecting user usage. The recycling cycle is usually influenced by various factors such as electricity prices, the efficiency of

energy storage systems, local policy subsidies, and grid purchase electricity prices. In Germany, the average payback period for household users to install energy storage systems is between 8 and 12 years, depending on policy subsidies, electricity price fluctuations, and system usage patterns. In Italy, due to high tax incentives, the recycling cycle of energy storage systems can be shortened to 5 to 7 years. At the same time, the emergence of new energy storage technologies in the market, such as vanadium flow batteries, solid-state batteries, etc., despite their high initial costs, has advantages in long lifespan and low maintenance costs, and is expected to further optimize cost-effectiveness. The market environment in different countries also leads to differences in cost-effectiveness. For example, countries such as France and Belgium have relatively few subsidies for energy storage systems and slow market development; In Germany and Italy, where policy efforts are significant, the household energy storage market is growing rapidly with relatively high investment returns.

3.3 The Impact of the Market on the Economy

The market development of EU household energy storage systems has had a profound economic impact on the energy market, household economy, and related industry chain enterprises. The development of household energy storage systems is changing the traditional energy market landscape. With more and more household users installing energy storage systems and participating in distributed generation and electricity trading, the monopoly position of traditional power companies is threatened, and market competition is intensifying. Traditional energy suppliers must adjust their business models, increase investment in renewable energy and energy storage technologies, and develop new business models such as virtual power plants and energy aggregation platforms to cope with market changes. At the same time, the impact of household energy storage systems on household economy is gradually becoming apparent. In countries where the investment return rate of energy storage systems is high, energy storage systems can save electricity bills for households and become an asset with economic benefits. More and more households view energy storage systems as long-term investment tools for energy transformation, which helps to increase public recognition of energy storage systems and further promote market expansion. In addition, the development of the household energy storage market has a significant impact on the upstream and downstream industrial chains. On the upstream side, industries such as battery manufacturing, inverter supply, and installation services directly benefit from the expansion of the energy storage market, driving economic growth in related industries. Downstream, emerging industries such as distributed electricity markets, smart grids, and energy management services are also rapidly rising. In the process of promoting energy storage technology research and development, EU countries can further optimize their industrial structure and enhance their economic competitiveness.

4. Conclusion

The EU's energy transition goals are constantly driving innovation in energy storage technology, and household energy storage systems have become an important component of the transition process. With the continuous development of relevant technologies, the economic feasibility of energy storage systems is gradually emerging, showing significant influence under multiple factors such as residential electricity consumption patterns and energy market structures. Faced with the constantly changing market environment, EU member states still need to seek balance and breakthroughs in economic incentives, technological innovation, and market regulation while promoting the popularization of energy storage systems. With the further popularization and application of energy storage systems, the way energy is used is also constantly changing, reshaping the relationship between energy utilization and economic development, and promoting broader social changes.

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