

Overview of Photovoltaic Product Benefits and Photovoltaic Development Suggestions

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ABSTRACT

In order to improve these energy problems and environmental issues, many researchers have turned their attention to renewable and clean energy sources such as solar, wind, nuclear, and so on. Due to the relatively low cost of solar energy, solar photovoltaic power generation technology has been developed rapidly in recent decades and is gradually maturing. This paper focuses on the research progress of solar power generation technology and related applications, and is based on the current situation of the PV industry and the benefits of PV systems calculated based on comparative models such as NPV and LCOE. The development of the PV market and related policies in Germany and other countries with China are compared and analyzed by this paper. This paper also gives policy recommendations on the need for technological innovation, local adaptation and policies that can stimulate the healthy and rapid development of the PV industry, thus promoting the progress of PV power systems and their markets.

Keywords: *Photovoltaic, Net Present Value, Lelized Cost of Energy*

1. INTRODUCTION

1.1. Background

Solar photovoltaic (PV) technology is a photovoltaic effect using semiconductor materials, which creates a potential difference due to the electron movement of different parts of the semiconductor under light conditions. Photovoltaics has the advantages of being a sufficient source, no noise, no pollutant emissions, and in line with environmental trends. In the context of growing energy demand, the production and consumption of electric energy alternatives are essential to building a new energy system. In the development of energy sources, photovoltaic is currently a reliable, safe, and cost-effective clean energy source in the world. Based on this background, this paper studies the combination of photovoltaic and comes up with the most cost-effective combination, and gives the relevant definition.

1.2. Related Research

Some of the studies have used tools such as NPV (Net Present Value) to evaluate what combination of photovoltaic power systems should be used. The experiments were designed by Federica et al. to

determine if it was economically possible to combine lead-acid ESS with PV panels by analyzing profitability and the index using the DCF technique, NPV, and BEP. Their results revealed that the integrated PV battery's profitability was always lower than that of a PV plant, while it was profitable in some situations. Furthermore, a combined PV-ESS project is more profitable in this study by just 0.006% [1]. A. Nottrott, J. Kleissl, and B. Washom simulated the designs of a broad range of PV+ by developing a linear programming routine and made cost-benefit analyses in order to figure out the NPV of the battery storage system. Their research compared the financial benefits of an optimized energy storage dispatch schedule with a simple off-peak/on-peak and charging/discharging strategy. Their finding was that with optimal energy storage, the battery array's NPV may greatly rise [2]. Based on China's government's feed-in tariff policy, Ye et al. From 2011 to 2016, the NPV and IRR of seven provinces' FIT policies were examined. The net present value was included in the research. According to their results, with the supports of FIT policies, the NPV/IRR increased during these years. Also, the government should adjust tariffs frequently to stabilize the IRR value between 8% to 12% [3]. The NPV method was used by Niko Lukac et al. to find economically and environmentally viable candidates using LiDAR data and nonlinear efficiency

characteristics of PV systems. Their result carried out that the most appropriate roofs had economical NPV after 3 and 11 years and the higher NPV mostly happened in the situation of the surface had higher PV potential [4]. Liao et al. analyzed the economic benefits of two distributed systems with PV or PV and BES in the whole life cycle, pointing out that the NPV of a PV system alone is lower than the NPV of a PV-BES system that had an optimized configuration. Different characteristics can lead to different NPV and the NPV of li-ion, NaS, VFB, Pb-C were in descending order. Liao et al. suggested that in order to improve the self-consumption ratio and the utilization rate of grid electricity, a distributed photovoltaic system reasonably configured with a BES system was important [5].

After designing cost-effective PV products, it is also necessary for the government to make relevant policy changes and establish a reasonable market-oriented mechanism. Piotr Gradziuk used NPV and IRR to figure out the efficiency of a photovoltaic system. Their research was based on a simulated calculation to perform the efficiency of the system. The payback period and net present value were calculated using the total investment cost and the average yearly value of electricity produced in this research. Also, their research performed different NPV and IRR of three payback periods to carry out that although it was economically efficient with support, the payback would be about 20 years [6]. Chong Li made a study to access and compare whether it was economical to use a hypothetical 5kWp grid-connected residential solar PV system with and without batteries in Northwest China. The system advisor model was used in this research to do financial analysis. Li also introduced LCOE as a measurement. His result showed that loan term was the main impact on real LCOE and NPV. Under the grid-connect PV/battery system, the NPV raised with the increasing loan term, but the real LCOE decreased [7]. Mevin Chandel et al. analyzed the potential and the cost-effectiveness of the solar photovoltaic power plant to perform NPV, IRR, and payback periods. It explored four scenarios which were pre-tax or post-tax scenarios, pre-tax in equity, or post-tax with equity for both on-site and off-site options. According to the result, the off-site options were the best because of the lack of land near the city [8]. Idiano D'Adamo et al. evaluated an Italian developed market in which had re-introduced PV plants with a nominal capacity. The differences between subsidy and non-subsidy scenarios in terms of NPV and DPBT were also measured in this study. According to the results, profits reduced with the lack of subsidies, and half of the NPV of the examined cases were negative [9]. Gobind Pillai and Husain Ali Yaqoob Naser analyzed the economic performance of the optimized 1MW grid-connected photovoltaic (PV) system in Bahrain is analyzed from the LCOE, NPV, PBP, and EPBT. The positive trend demonstrated that large-scale solar was a

viable choice to meet future electricity needs. According to the analysis results, Bahrain was proposed to implement a large-scale grid-connected photovoltaic system to reduce power generation costs and diversify energy sources [10].

1.3. Objective

This article is to compare and analyze the investment cost and cost-effectiveness of traditional power generation mode and photovoltaic power generation mode, different photovoltaic power generation technologies, so as to come up with the most cost-effective investment mode and photovoltaic industry development mode. The first part of this paper is the background introduction and related research of PV, the second part is the significance of energy transition and the current situation of the PV power industry, and the third and fourth parts are the application research and prospect of the PV power system. At the same time, the paper concludes with recommendations that are in line with the current situation.

2. CURRENT STATUS OF THE PHOTOVOLTAIC POWER GENERATION SYSTEM

2.1. The Overall Situation Of The Photovoltaic Market

Photovoltaic is a new type of power generation system that directly converts solar radiation energy into electrical energy by using the potential difference generated between the parts of an inhomogeneous semiconductor or a combination of semiconductor and metal when illuminated. It is the cleanest, safest, and most reliable energy source of the future.

In the global economic downturn, the instability of the oil economy and environmental pollution is becoming more and more prominent, and governments are taking active measures to encourage domestic enterprises to reduce their dependence on foreign disposable fossil energy, the development, and utilization of solar energy provides a highly feasible solution. All major countries have set targets for the share of electricity generated from renewable sources to drive a global move toward "carbon neutrality". In some of the world's leading countries today, particularly in developed countries, government agencies at all levels are actively providing subsidies and financial incentives in the form of rebates, tax credits, and other incentives to end-users, distributors, system integrators, and manufacturers of solar products. For example, photovoltaic investment using the tax credit program had also shown greater economic convenience in areas in Italy where the sun is not full. In northern Italy, even

considering a 20% reduction in solar radiation, the DPB period is equivalent to 17.60 years [11]. After 2010, major countries in Europe and the United States began to slow down their support for the PV industry and its development, while China focused its efforts on the rapid rise of the PV industry and gradually took a global market share, with a cumulative installed PV grid-connected capacity of 16GW. From a global market perspective, the global installed PV capacity surpassed 100 GW for the first time in 2018, reaching 102.4 GW. Also, the installed demand for PV in the world's major PV markets has decreased, but due to the growth in installed demand for PV in other countries and regions, it still plays a larger role in driving the global PV industry forward as a whole.

2.2. Germany PV Development Status

Germany has played an active role in the global transformation and upgrading of photovoltaic power generation. Germany, as the largest economy in Europe, has accumulated nearly 20 years of experience in fixed feed-in tariffs. Germany is currently one of the best countries in Europe for renewable energy marketization. Germany has enacted the Renewable Energy Act since 2000, and the installed capacity of wind power and photovoltaic power has grown rapidly by establishing new energy priority and feed-in tariff subsidies. Germany's new EGG program will increase solar photovoltaic power generation to 100GW (currently 52GW). At the same time to promote the "customer rented electricity program, German homeowners through the installation of solar panels on the roof and charge feed-in tariffs. In the context of a large installed capacity, Germany's abandonment rate of only about 1%, to achieve such a high rate of consumption, mainly because Germany pays great attention to the growth of

installed capacity to synchronize with the construction of the grid.

3. THE IMPORTANCE OF ENERGY TRANSITION AND REASONABLE POLICIES

3.1. The Significance Of Energy Transition

Zhu first analyzed the current energy situation in China through three aspects: China's energy resource endowment, energy consumption, and production. Then, the author analyzed the current situation of China's economic and social development and predicted the results of China's energy demand projections in 2030, which showed that China's future energy demand would be still large, and electric energy as an important secondary energy source had decisive significance and role in China's energy transition, and the process of electric energy substitution largely determined the process of building a new energy system in China.

Zhu analyzed the economic benefits of electricity substitution for coal and improves the LCOE (Levelized Cost of Energy) model to account for the externalities of the cost of photovoltaic power generation [11]. This approach provided a more comprehensive picture of the cost of clean energy. A comparative analysis of the LCOE (Levelized Cost of Energy) of wind, PV, and thermal power and sensitivity analysis of the influencing factors were carried out through arithmetic examples. The analysis showed that the investment cost of clean energy and grid start time had a greater impact on the LCOE (Levelized Cost of Energy) of clean energy, while other influencing factors had a smaller impact on the LCOE (Levelized Cost of Energy) of clean energy.

Table 1. Comparison LCOE of photovoltaic and thermal power

project	Thermal power	photovoltaic
Total invest(million)	772000	503.9
Life cycle(year)	30	25
Annual fixed costs(million)	25733.33	25.356
Operating costs(million)	4988.50	5.5
Annual fuel costs(million)	250000	0
Transmission and substation costs(million)	0	12.25
Salvage value(million)	38600	0
Grid-connected surcharge(million)	0	1.19
installed capacity(kW)	2000000	1000
Average annual start time(h)	5500	1563
Average annual internet start-up time(h)	4998.20	1250
Average annual feed-in tariff(MkW · h)	9996400	1250
Annual Sewage Charges(million)	1588.11	0
LCOE(Yuan/kW · h)	0.28	0.31

By comparing the cost items of thermal and wind power in Table 1 and calculating the corresponding costs per unit of power, it can be seen that wind power has the advantage of having no fuel costs and no emissions

costs. The comparison of the cost per unit of power shows that wind power has a higher investment cost compared to thermal power and a lower operating cost compared to thermal power. At the same time, wind

power may incur some transmission and grid connection costs due to grid connection.

The final conclusion of Zhu's paper was that there was a certain degree of uncertainty in the electricity energy substitution process, which was influenced by the relevant coefficients and variables. Therefore, policy support and science and technology innovation were needed to support the development of relevant variables and coefficients that would favor the direction of substitution [12].

3.2. The Importance Of Reasonable Policies

Federica Cucchiella et al. assessed the profitability of residential photovoltaic systems without subsidies and the profitability of energy storage in the mature market in Italy. And Federica Cucchiella et al. used NPV and sensitivity analysis of important indicators to define the economic benefits of the integrated photovoltaic cell system. At the same time, this economic analysis model can be used in countries with different regions and consumption patterns. Their research concluded that ESSs can be profitable when the combination of supply and demand can lead to a significant increase in energy self-consumption [13].

The development of photovoltaic technology and mass production had led to a continuous reduction in the cost of photovoltaic systems. However, concerns remain about the financial viability of photovoltaic system investment, which was facing a reduction in global government support. Wang et al. studied in the case of the UK, evaluated the investment attractiveness of rooftop photovoltaic installations and the impact of energy storage systems [14]. The application of electric vehicles as an alternative to ESS to complementary photovoltaic systems was also studied. This study used net present value and discount payback period (DPP) as economic indicators of the project different solar energy impact radiation levels were also evaluated in different geographical locations. The application of electric vehicles as an alternative to ESS for complementary PV systems was also investigated. Using optimization technology to arrange the energy exchange for ESS and electric vehicles can maximize the return on investment. That research was further shown that with government support for photovoltaic technology declines, by combining ESS, benefits can increase by 46% in 2017 with photovoltaic systems. The shrinking margins of photovoltaic investment in recent years can be compensated by installing additional ESS to make better use of photovoltaic generation. The economic future of new energy vehicles and electric vehicles was expected to be brighter, judging by the trend of lower battery costs, energy demand, and increased tariffs .

Thus, it seems particularly important to establish a reasonable market-based mechanism to stimulate and

promote the rapid and healthy development of electric energy, while promoting the development of clean energy. We can study the relevant policy formulation as well as the criteria of policy formulation and the evaluation system of policy implementation through the perspective of the energy system and electric power system.

4. RESEARCH ON THE LARGE-SCALE APPLICATION OF PHOTOVOLTAICS

4.1. Germany's Large-scale Application Of Photovoltaic Strategy

Photovoltaic technology has come down significantly in price, but further improvements in technology and cost reductions along the value chain are needed for the large-scale global application of PV. Public policy decisions in support of PV can serve as the basis for a comprehensive PV innovation strategy that combines R&D projects, support for innovative production technologies, and deployment options. The German government's Climate Action Plan 2030, published in 2019, refers to Germany's goal of achieving 2050 carbon neutrality. During this period, the cumulative installed PV capacity needs to reach 98 GW. According to Jiang , the relevant policies introduced in Germany to achieve this goal included guiding large-scale adaptation of PV power systems for industry and households through demand-side management, utilizing solar energy through grid-connected power generation, and granting subsidies on feed-in tariffs and loan subsidies [15].

4.2. China's Corresponding Policies And Lessons Learned

China has also introduced a corresponding feed-in tariff policy and lowered its PV feed-in tariff. According to He Jijiang and Ma Yu, China can learn from how Germany is developing PV. They predicted that China would have a higher proportion of installed PV than Germany and a higher per capita installed size than Germany under the 2060 carbon neutrality target [16]. At the same time, Jiang suggested that China needed to invest more in research for the PV industry and increase the number of researchers specializing in advanced technologies to reduce its dependence on imported products. What is more, China needed to focus on solar cell manufacturing to minimize the cost of PV systems. Meanwhile, Germany is a world leader in the promotion of photovoltaics. China also needs to set the goal of the cumulative installed PV capacity to promote the practice of PV for all and to integrate PV with buildings, agriculture, and transport. This will enable economic, environmental, and social synergies between PV and industry to be realized. Photovoltaics can also be combined with urban and rural planning and landscape

design to become a new highlight in urban and rural landscapes.

4.3. PV In Building Development Status And Outlook

From the perspective of a building, at the same time, building-integrated photovoltaics (BIPV) can be used in different ways in existing buildings and new buildings. It is developing particularly rapidly. Hagemann proposed to take full advantage of this potential of BIPV by focusing on non-technical issues such as the need to change the planning and design process of BIPV systems and to make BIPV a symbol of future-oriented environmental awareness for individuals and companies. Germany has made great progress in this regard [17]. Tilmann E. Kuhn et al. reviewed and analyzed different technical design options for BIPV components and systems [18]. Their analysis of the German BIPV market showed that BIPV systems are very important for the transformation of the German energy system. The installed PV capacity on buildings in Germany was expected to grow further strongly and is expected to exceed 200 gigawatts. China's PV industry is already at the forefront of the world, with the installed capacity of PV power generation rising and the overall cost falling. In this context, BIPV in China also has broad development prospects. For China, the application of photovoltaic buildings can be gradually focused on the actual national conditions, supplemented by photovoltaic ground power stations in the central and western parts of the country, as well as the installation of stand-alone photovoltaic systems for rural houses or the construction of small power stations in rural areas. During the development process, safety and reliability requirements also need to be strictly considered. At the same time, China needs to study and develop a standard system related to BIPV, form a unified standard, and encourage construction units to use BIPV. the government can provide policy or economic support for related projects to promote the development of BIPV.

5. CONCLUSION

PV is a good option when energy needs to be transformed and upgraded. This paper summarizes the current state of development of the photovoltaic industry, the NPV and return on investment of PV products are higher the better the energy savings and economic and geographical environment are realized. Also, they can be enhanced by suitable government subsidies. Compared to other developed countries, the development of China's PV industry has not yet reached its peak, and companies still need to rely on government support at this stage. Enterprises also need to change their inherent mode in the development process, learn from the successful experience of advanced enterprises in the world, pay attention to scientific research and

innovation, talent training and treatment, and need to develop high-end technology products to consolidate the market for better development.

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