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Efficiency of Solar Power Plants and Economic Impacts on Businesses

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Abstract: Solar energy is gaining increasing importance with its clean and renewable nature. This study aims to analyze the factors affecting the efficiency of solar power plants (SPPs) and their economic impacts on businesses. This analysis covers several topics such as panel technology, installation location, irradiation times and economic returns, but also indirect effects such as environmental benefits and corporate reputation. The paper also covers topics such as SPP incentives in Turkey, carbon footprint impact, sustainability strategies and technological trends. The results underline the long-term economic and strategic benefits of SPP investments for businesses.

Keyword: Solar energy, businesses, energy efficiency, economic impact, renewable energy, sustainability, carbon footprint, incentive policies

JEL Classification: O33

1. Introduction

Global energy demand is increasing rapidly in parallel with industrialization, population growth and technological developments. This increase puts pressure on existing fossil fuel reserves and brings environmental problems. Carbon emissions from the combustion of fossil fuels trigger serious problems such as climate change, global warming, air pollution and environmental degradation. Therefore, the search for sustainable and environmentally friendly alternatives in energy production is at the forefront of both the scientific and political agenda. Increasing industrial investments and urbanization rates in developing economies indicate that this demand will continue to increase in the coming years. There is a direct relationship between energy consumption and economic growth, which leads countries to more efficient, clean and sustainable energy sources.

Renewable energy sources are among the main alternatives that can offer solutions to these needs. Solar energy stands out as one of the most accessible and least environmentally damaging options

among these sources. Solar energy is obtained by converting rays directly from the sun into electrical energy through photovoltaic cells. This process is a carbon-free, silent and resource-inexhaustible form of energy production. In addition, solar energy is accessible to all regions of the world, making it widespread and suitable for local production. In addition, the advantages of reducing dependence on energy imports, providing energy supply security and complying with environmental policies also make solar energy attractive.

The increasing role of solar energy in the energy portfolio is transforming not only energy policies but also the production and cost structure of businesses. Businesses, especially those operating in energy-intensive sectors, are turning to renewable energy solutions to control rising energy costs, ensure energy supply security and achieve sustainability goals. At this point, solar power plants (SPPs) are considered as strategic investments that provide both economic and environmental benefits.

The aim of this study is to examine the technical factors affecting the efficiency of solar power plants, their installation costs, payback periods and economic impacts on businesses with a holistic approach. It will also include assessments of the future potential of SPP investments in the light of government incentives, sustainability policies, carbon footprint reduction and technological developments. In this context, the study aims to reveal why solar energy has become a strategic element for businesses in the axis of energy efficiency and corporate sustainability. Furthermore, this research also analyzes the strategic role of solar energy investments in the process of compliance with carbon emission targets, sustainability reporting standards (e.g. GRI, CDP) and international regulations (e.g. EU Border Carbon Regulation).

2. Technical Factors Affecting SPP Efficiency

The efficiency of solar power plants is determined by a combination of various technical parameters such as the design of the system, the technology used and environmental conditions. Analyzing these factors correctly ensures maximum efficiency from the SPP.

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2.1. Panel Technology

The type of panels used in SPP systems has the most direct impact on efficiency. The most commonly used panel types today are as follows: Monocrystalline Panels: It is the panel type with the highest efficiency rate (20-23%). It provides long life, aesthetics and high production capacity in small areas. However, their costs are higher than other types.

Polycrystalline Panels: Although lower cost, the efficiency rate is usually between 15-18%. Preferred for installation in large areas.

Thin Film Panels: Thanks to their flexible structure, they can be mounted on various surfaces. However, they have lower efficiency rates (10-12%) and require more space (Fraunhofer ISE, 2023).

2.2. Installation Location and Angle

The positioning of the panels in SPPs directly affects the duration and amount of sunlight. Panels;

South oriented placement (for the Northern Hemisphere),

Optimizing the angle of inclination according to the latitude (e.g. approximately 30-35° for Istanbul),

Planning in such a way that no shadow falls maximizes energy production.

Tracking systems, where panels follow the sun throughout the day, can increase efficiency by 20-25%.

2.3. Insolation Potential

The annual sunshine hours of the region should be taken into account when selecting the installation location. For example, this period is around 3000 hours in the Southeastern Anatolia region, while it is below 1800 hours in the Black Sea region (TÜİK, 2023).

2.4. Maintenance, Cleaning and Monitoring Systems

Regular cleaning and monitoring of the panels can reduce annual efficiency losses by up to 5%. This factor is especially important in systems installed in dusty or industrial areas.

Thanks to smart monitoring systems, instantaneous production values and fault detection can be performed.

3. Investment Costs and Return Analysis

Initial investment costs in SPP projects vary depending on system size, panel type, infrastructure and connection costs. Especially in rooftop applications, installation costs can shorten the payback period. Although average payback periods vary between 5-8 years, government subsidies can further reduce this period (EIA, 2021).

The table below shows the decline in solar installation costs over the years:

4. Economic and Strategic Contributions

4.1. Energy Cost Savings

SPP investments provide direct financial benefits to businesses by reducing energy bills by up to 60% (BloombergNEF, 2022).

4.2. Brand and Sustainability

In today's business world, sustainability has become not only an environmental imperative but also a strategic value of brands. Consumers, investors and even employees attribute more value to brands that are environmentally conscious and socially responsible. In this context, solar energy investments stand out as an important component of organizations' sustainability policies.

Investments in solar power plants allow businesses to reduce their carbon footprint and minimize their environmental impact. This increases corporate transparency and strengthens stakeholder trust by providing positive indicators in sustainability reports. In addition, companies that align with the United Nations' Sustainable Development Goals (SDGs) are more visible on international platforms and have easier access to various incentive programs.

Sustainability-oriented strategies play a decisive role in strengthening brand equity. Businesses that use green energy can increase customer loyalty by influencing the preferences of environmentally conscious consumers (Rehman et al., 2024). This

provides businesses with a significant marketing advantage, especially in highly competitive sectors. In addition, creating an "environmentally friendly brand" perception on social media and digital platforms is at the center of communication strategies.

As a result, solar energy investments make it possible for businesses not only to reduce their energy costs, but also to increase their brand value and achieve their sustainability goals by fulfilling their environmental responsibilities.

4.3. Incentives and Government Supports

Solar energy investments in Turkey are supported by both the central government and local governments through various incentive mechanisms. These incentives are provided to reduce investment costs, encourage domestic production and promote the use of renewable energy.

KOSGEB and TÜBİTAK provide grants and non-refundable support to small and medium-sized enterprises for R&D and energy efficiency projects. TÜBİTAK's 1501 and 1507 programs can be used for technology development projects in the field of solar energy , while KOSGEB's "Energy Efficiency Support Program" contributes to the financing of energy investments.

In addition, the following support elements are provided for solar energy projects under the Investment Incentive Certificate issued by the Ministry of Industry and Technology:

Value Added Tax (VAT) exemption,
Customs duty exemption,
Tax relief,
Insurance premium employer share support, Interest or
dividend support,
Investment location allocation.

The Investment Incentive Certificate may provide support at different rates depending on the region in which the investor operates. Investments in the 5th and 6th regions are incentivized at higher rates. (Ministry of Industry and Technology, 2023)

This provides a more attractive investment environment, especially for SPP projects to be established in OIZs in Anatolia.

In addition, the YEKA (Renewable Energy Resource Areas) model supports large-scale projects within the framework of public-private sector cooperation. The tenders held within the scope of YEKA are shaped in line with criteria such as domestic production, technology transfer and long-term energy purchase guarantees, ensuring permanent capacity increase in the sector.

Thanks to these incentives, the payback periods of SPP investments are shortened, the feasibility of the investment is strengthened and the interest of the private sector in this field is increasing.

4.4. Carbon Footprint and Zero Waste Policies

SPP systems reduce the carbon footprint by reducing greenhouse gas emissions and contribute to the zero waste vision of enterprises. These investments are especially critical for exporters preparing for the EU Green Deal process.

4.5. Sustainability and ESG Alignment

Environmental, Social and Governance (ESG) criteria are an important evaluation tool for investors today. In this context, SPP investments increase investor interest by strengthening environmental responsibility.

4.6.Risks and Challenges

SPP investments require careful planning and management due to their high initial costs and long-term payback periods. The main risks faced by these investments can be listed as regulatory changes, access to financing, technical infrastructure problems and environmental factors (Atılgan et al., 2025).

Political and Regulatory Risks:

The energy market is directly affected by government policies. The removal of incentives for solar energy or frequent changes in legislation may cause investors to experience uncertainty. In addition, delays in connection permits, license processes and bureaucratic procedures may extend the project schedule. The sustainability of incentive systems directly affects investment determination .

Financing and Economic Risks:

SPP investments require high capital. Factors such as rising interest rates, exchange rate fluctuations and difficulties in accessing investment loans can lengthen the payback period. Small and medium-sized enterprises (SMEs) are therefore more at risk in terms of financial sustainability.

Technological Risks:

Solar panel technologies are changing rapidly. The introduction of new and more efficient technologies may cause existing systems to become obsolete in a short time. In addition, technical failures in key components such as inverter systems directly affect production (Onursal et al., 2023).

Land Acquisition and Physical Constraints:

Large and unshaded areas are required for SPP systems. However, high land costs and zoning problems, especially in areas close to the city center, can challenge investors. In some cases, the use of agricultural land may also cause environmental or legal problems.

Maintenance and Operation Risks:

Environmental factors such as dust, snow, leaves and bird droppings can cover the surface of the panels and reduce efficiency. Therefore, systems need to be cleaned regularly. In addition, system failures, access to maintenance equipment and lack of technical services can also increase operational risks.

Impact of Climate Change:

Climate change can affect production continuity through extreme heat waves, prolonged cloudiness or unexpected natural events. This can lead to unforeseen revenue losses, especially for low-margin businesses.

5. Application Examples and Comparisons

For example, a 1 MW power plant in Germany in 2022 will pay back in 3.5 years on average, while in Turkey this period is 6 years on average (IEA PVPS, 2023). A 3 MW

system installed in an organized industrial zone in Turkey has saved up to 4 million TL per year (TESAB, 2023).

6. Technological Developments and Future Forecasts

Trends in solar energy technologies such as storage systems, battery integration, hybrid energy solutions and smart grid connections are attracting attention. In addition, artificial intelligence-supported system monitoring solutions are revolutionizing efficiency analysis. By 2030, energy storage capacities are expected to triple worldwide (IEA, 2024).

7. Conclusion

In particular, the unpredictability of energy costs and international sanctions on carbon emissions drive businesses towards renewable energy investments. SPP investments act as a shield against external pressures such as carbon taxes and green consensus.

Solar energy is not only an energy source, but also a strategic transformation tool for businesses. With lower energy costs, increased brand value, ESG compliance and contribution to sustainability goals, SPP projects will become even more widespread in the future. However, a detailed feasibility analysis is essential before every investment decision.

Considering the environmental, social and economic dimensions of SPP investments, these investments serve both the national economy and the long-term strategic plans of companies. Continued government support and easier access to technology will make investments in this field more attractive. Fulfilling their environmental responsibilities is vital not only for reputation, but also for access to financial resources, investor confidence and customer loyalty. This transformation can be further accelerated through financing models specific to solar energy investments, leasing solutions and green bonds.

Furthermore, the following recommendations can be developed for policy makers: 1) Tax reductions and subsidies for SPP investments should be increased; 2) Roof-type applications should be freed from bureaucratic obstacles; 3) Low-interest green credit facilities should be provided for SMEs. This will increase energy supply security and reduce industry-based carbon emissions.

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