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Enhancing Educational Financing Efficiency through Renewable Energy Integration: A Case Study of Solar Power Utilization at School

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ABSTRACT*:*
As educational institutions worldwide face increasing pressure to deliver quality education amid limited budgets, infrastructure management and energy efficiency have become critical concerns. This study explores how the integration of solar photovoltaic (PV) systems can serve as a strategic tool to improve education financing efficiency, using Muhammadiyah 1 Junior High School (SMP) Berbah in Indonesia as a case study. Employing a qualitative case study method, this research analyzes planning, implementation, and management processes of solar PV systems in the school's infrastructure. Findings indicate that although the solar power plant has not yet reached optimal savings, its integration supports operational cost reductions, aligns with environmental goals, and enhances long-term financial planning. The study underscores the importance of infrastructure-based energy strategies and recommends wider adoption of solar PV in educational settings, complemented by audits, stakeholder partnerships, and curriculum integration on sustainability. Despite its local focus, the study highlights scalable practices for schools globally, while acknowledging limitations in generalizability and long-term performance tracking. Future research should examine broader contexts and policy variables to strengthen the evidence base for renewable energy in education.

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ABSTRAK:
Ketika institusi pendidikan di seluruh dunia menghadapi tekanan untuk memberikan pendidikan berkualitas di tengah keterbatasan anggaran, pengelolaan infrastruktur dan efisiensi energi menjadi isu krusial. Penelitian ini mengeksplorasi bagaimana integrasi sistem tenaga surya fotovoltaik (PV) dapat menjadi strategi untuk meningkatkan efisiensi pembiayaan pendidikan, dengan mengambil studi kasus SMP Muhammadiyah 1 Berbah di Indonesia. Melalui pendekatan studi kasus kualitatif, penelitian ini menganalisis proses perencanaan, pelaksanaan, dan pengelolaan sistem PV surya dalam manajemen infrastruktur sekolah. Temuan menunjukkan bahwa meskipun penghematan belum terasa secara optimal, keberadaan pembangkit listrik tenaga surya mendukung pengurangan biaya operasional, sejalan dengan tujuan keberlanjutan lingkungan, serta memperkuat perencanaan keuangan jangka panjang. Studi ini menekankan pentingnya strategi energi berbasis infrastruktur dan merekomendasikan adopsi lebih luas sistem PV surya di institusi pendidikan, yang didukung audit energi, kemitraan dengan pemangku kepentingan, dan integrasi pendidikan keberlanjutan dalam kurikulum. Meskipun bersifat lokal, studi ini menawarkan praktik yang dapat direplikasi secara global, dengan pengakuan atas keterbatasan dalam generalisasi dan pemantauan kinerja jangka panjang. Penelitian selanjutnya disarankan untuk mencakup berbagai jenis sekolah, kondisi regional yang berbeda, serta variabel kebijakan yang memengaruhi kelayakan implementasi energi terbarukan di sektor pendidikan.

Kata kunci: Efisiensi Infrastruktur Pendidikan; Fotovoltaik Surya; Energi Terbarukan di Sekolah.

INTRODUCTION

Education plays a pivotal role in national development, with financing and infrastructure serving as fundamental pillars in achieving educational objectives. As global educational demands rise, schools are increasingly required to provide quality learning environments supported by efficient physical and technological infrastructure. Yet, persistent budget constraints remain a key challenge, especially in low- and middle-income countries. Efficient infrastructure management has thus emerged as a strategic response to maximize resource utilization while maintaining service quality. Within this context, the integration of renewable energy sources—particularly solar photovoltaic (PV) systems—offers both environmental and economic benefits to educational institutions.

Previous studies have demonstrated that infrastructure optimization is closely linked to the effectiveness of education financing. In the Indonesian context, efficiency in resource utilization has been emphasized in national policy frameworks such as the Regulation of the Minister of Education and Culture No. 24 of 2007, which mandates adequate and efficient educational facilities. Empirical evidence from MTs-PPTQ Assalaam shows that infrastructure financing supported through community-based ZISWAF contributions enables independent and sustainable educational operations. Additionally, the implementation of School Operational Assistance (BOS) policies further highlights the importance of school-level autonomy in managing infrastructure and budgeting (Kementerian Pendidikan dan Kebudayaan, 2007; Quratul Aini et al., 2020). These policies align with the broader need to ensure that infrastructure contributes directly to educational quality while minimizing financial waste.

The integration of solar PV in schools is gaining traction as a practical step toward cost-saving and environmental stewardship. For instance, the on-grid solar power system installed at SMP 1 Terak, Bayangkara, West Kalimantan, was shown to supply 65.6% of the school's electricity needs. Similarly, the Darul Bayan Islamic Boarding School reported a monthly cost reduction of IDR 1,500,000 through solar power use. These findings reinforce the economic potential of renewable energy solutions in educational contexts. However, such studies largely center on the technical aspects of solar implementation and fall short in exploring its integration within strategic infrastructure management frameworks (Barri et al., 2021; Jenni Lisdawati et al., 2022). This gap presents a timely opportunity for more holistic inquiry.

Globally, empirical studies confirm the relationship between education, financial development, and renewable energy consumption. Research in South Asia reveals that educational attainment significantly enhances renewable energy use, reflecting the importance of human capital in driving energy transition. Financial literacy, while beneficial, tends to exert a smaller influence compared to income levels and energy costs. Moreover, studies in the Next-11 and EU post-transition countries emphasize that financial systems and educational investments have varying effects depending on regional and institutional contexts (Ankrah Twumasi et al., 2022; Sart et al., 2025; Villanthenkodath & Velan, 2022; Wang et al., 2022). These findings highlight the

multifaceted dynamics shaping energy decisions in different educational environments.

In the context of China and other rapidly developing economies, education and digitalization are seen as long-term contributors to renewable energy consumption. Several studies show that education influences renewable energy uptake both directly, by increasing environmental awareness, and indirectly, by enabling better financial and technological decisions. For example, in China, education is found to reduce reliance on non-renewables and promote green growth, particularly when integrated with financial inclusion and supportive policy environments. Likewise, broader regional studies across Asia, Europe, and America demonstrate that education consistently supports renewable energy production when paired with effective institutional mechanisms (Hongzuo et al., 2025; Li et al., 2022; Qamaruzzaman, 2025; Xu & Ullah, 2023). These findings suggest that education is a key enabler in transitioning toward more sustainable infrastructure management.

Despite this growing body of literature, there remains a notable gap in understanding how solar PV systems can be strategically managed within educational infrastructure to enhance financing efficiency. Much of the existing research focuses on isolated variables—such as financial development, literacy, or technology access—without adequately examining their interaction in educational settings. Furthermore, the operational role of infrastructure management in sustaining renewable energy systems in schools is rarely addressed. There is also limited discussion on how renewable energy can be aligned with institutional goals, budget planning, and long-term sustainability outcomes. Addressing these gaps is essential for providing actionable insights for education policy and infrastructure planning.

This study focuses on analyzing infrastructure management strategies that optimize the use of solar PV systems to improve the efficiency of education financing. By using a case study at Muhammadiyah 1 Junior High School Berbah, the research investigates how renewable energy integration can contribute to operational cost reduction and sustainable infrastructure utilization. The study contributes to bridging theoretical understanding and practical implementation by offering a model for educational institutions to integrate renewable energy within their infrastructure systems. Ultimately, it aims to inform both policy and

practice, providing evidence-based insights that can be replicated in other school settings, particularly within resource-constrained environments.

METHODS

This research was conducted at Junior High School (SMP) Muhammadiyah 1 Berbah, using a qualitative approach with a case study type. The qualitative approach aims to describe, disclose, explain and analyze the use of solar power plants in an effort to improve the efficiency of education financing in schools (Fadli, 2021). The case study was chosen because it focuses on one school as a single object that is analyzed in depth, thus allowing for a more comprehensive understanding of the topic being researched (Syahrizal & Jailani, 2023). The subject of this study is infrastructure management at Junior High School (SMP) Muhammadiyah 1 Berbah, especially parties involved in the management of solar power plants in schools.

Data was collected through three main techniques: 1) Observation: Researchers conducted hands-on observations in schools to see how solar PV is used in daily activities. This observation is a way of collecting data through systematic observation and recording of phenomena that occur (Syahrizal & Jailani, 2023). 2) Interview: The researcher also conducted a question and answer session with Mrs. Afri Suyanti, S.Pust who acted as the head of public relations & infrastructure to obtain information related to material relevant to the research topic. An interview involves face-to-face communication between two parties with the aim of digging for information directly (Fadhallah, 2021). 3) Documentation: The researcher collected documentation in the form of secondary data such as electricity payment receipts to complete the data obtained. Documentation is a data collection technique in qualitative research obtained from documents, archives or other processed materials (Ardiansyah et al., 2023). The data that has been collected is then tested for validity using triangulation validation techniques of sources, techniques, and time. The triangulation technique is used to verify data from various informants by double-checking the data found with field data (Nurfajriani et al., 2024). Furthermore, the data were analyzed using the Miles, Huberman, and Saldana analysis model, namely data condensation, data presentation, and conclusion drawing (Miles et al., 2014).

FINDINGS AND DISCUSSION

FINDINGS

Educational facilities and infrastructure play an important role in supporting the smooth learning process. At Junior High School (SMP) Muhammadiyah 1 Berbah, electricity is an important component to support school activities, ranging from lighting to the use of technological devices in learning. One of the main challenges in managing infrastructure in schools is the high operational costs that are often absorbed by energy needs, so it becomes a significant burden (Windarta et al., 2020). According to data from the Ministry of Education and Culture, the operating costs of electricity in Indonesian schools can absorb up to 20% of the total budget available for schools (Bakti, 2020). With this large proportion, schools often face challenges in allocating funds for other needs, such as the procurement of teaching materials and the maintenance of facilities, so efficiency in the use of electrical energy in the educational environment is needed. To overcome these problems, several initiatives have been carried out such as the implementation of solar power plants to become a more cost-effective and environmentally friendly solution (Armanda & Abdul, 2023).

Sutanpri, the principal of Senior High School (SMA) Muhammadiyah 4 Bengkulu who also uses solar power plants, said that the use of solar power plants is not only an innovative step in managing solar power plants as a cost-efficiency strategy, but also builds environmental awareness of children while they are still in educational institutions (Herlina, 2021). The implementation of solar power plants at Junior High School (SMP) Muhammadiyah 1 Berbah is seen as a solution that can save education costs significantly, as well as strengthen the management of infrastructure that is more environmentally friendly.

In some literature, it is stated that schools that use solar power plants have managed to lower their energy costs significantly. A study conducted by Jenni et al. (2022) at Junior High School (SMP) 1 Terak, Bayangkara, West Kalimantan, which implements an on-grid solar power system with a power of 6600 W has contributed 65.6% to the total electricity needs of schools (Jenni Lisdawati et al., 2022). In addition, research by Barri et al. (2021) at the Darul Bayan Islamic Boarding School stated that with the use of solar PV, electricity operational costs can be reduced by up to IDR 1,500,000 per month, thereby

easing the burden of costs that must be borne by students and pesantren managers (Barri et al., 2021). This shows that the use of solar power has been proven to help schools in significantly efficient educational costs.

By examining the role of infrastructure management in Junior High School (SMP) Muhammadiyah 1 Berbah in implementing and managing solar PV, this study will reveal how solar energy can be strategically integrated into infrastructure management to create more efficient and sustainable management. This research will also explore how energy cost savings can be realised to improve the quality of educational facilities and infrastructure and support teaching and learning activities more optimally.

In the long term, the use of solar energy in educational institutions such as Junior High School (SMP) Muhammadiyah 1 Berbah not only reduces routine electricity expenditure, but also provides strategic benefits in the form of energy independence. Electricity cost savings that are recurring every month are calculated as the return on investment (ROI) of the initial installation of solar PV, which can generally be achieved within 4-6 years depending on the capacity and subsidy scheme applied (Atonergi, 2023). Once the break-even period is achieved, the savings become a budget surplus that can be allocated for other educational strategic purposes, such as the procurement of props, teacher training, or facility maintenance. This is in accordance with Barney's (1991) theory of strategic resource management, which states that the use of valuable, scarce, and non-replicable resources – such as the implementation of renewable energy systems integrated with school management – can provide a sustainable competitive advantage for organizations including educational institutions (Barney, 1991).

Strengthened by a study conducted by Nugroho and Kurniawan, it shows that schools that integrate solar PV in their management systems experience an increase in budget efficiency of up to 30% in five years, accompanied by an increase in public perception of the school's commitment from the implementation of solar PV is not only direct (saving electricity costs), but also creates a positive reputational effect, which can ultimately increase public trust and potential new student acceptance (Nugroho & Kurniawan, 2021).

Junior High School (SMP) Muhammadiyah 1 Berbah has a vision of "Islamic schools excel in Imtaq, Science and Technology, Culture and Environment". In line with this vision, it is hoped that the implementation of infrastructure management through the use of solar power plants as an

alternative to conventional energy can significantly reduce school electricity costs. Thus, Junior High School (SMP) Muhammdiyah 1 Berbah can allocate larger funds for other educational needs. Effective infrastructure management through the use of solar power plants can create more cost-effective and environmentally friendly schools. In addition to increasing budget efficiency, it also helps maintain the quality of educational services without burdening school finances, as well as creating a conducive and environmentally friendly learning environment. This research is also expected to be a reference for other schools that want to utilize solar power as a renewable energy technology.

DISCUSSION

Efficiency Of Education Financing Through the Use of Solar Power Plants at Junior High School (SMP) Muhammadiyah 1 Berbah

Solar power plants (PLTS) are technologies that convert solar energy into electrical energy using devices called solar panels. The energy generated from solar panels can be used directly or stored in batteries for later use. Solar PV is a form of renewable energy that is environmentally friendly, because it does not produce greenhouse gas emissions and utilizes an abundantly available resource, namely sunlight.

In the context of education, solar power plants can be integrated into energy management in schools as an alternative energy source. The use of solar power in schools has the potential to reduce dependence on electricity from conventional grids that usually rely on fossil fuels and are costly. Thus, solar power plants can help reduce school operational costs related to electricity consumption, which can ultimately be allocated for other more essential needs, such as improving the quality of learning, building teacher capacity and providing other educational facilities.

SMP Muhammadiyah 1 Berbah is a private junior high school with a complete address at Jl. Berbah-Krikilan No.20, Krikilan, Tegaltirto, Kec. Berbah, Sleman Regency, Special Region of Yogyakarta. The school facilitates its students with many programs, such as broadcasting, karawitan, smart, mukri boga, mukri voice, dance, volleyball, soccer, tapak suci, hizbul wathan, tahsin and tahfidz. So it is not surprising that the school led by Mr. Tri Muriana Budianto, ST has accreditation A. In its effort to create a quality generation of the nation, SMP

Muhammadiyah 1 Berbah has a vision as "Superior Islamic School in Imtaq, Science and Technology, Culture and Environment".

One of the efforts to realize this vision is to carry out the teaching and learning process effectively and efficiently, where the process requires supporting factors such as adequate facilities and infrastructure so that the quality of education is improved. Like schools in general, SMP Muhammadiyah 1 Berbah also experienced problems related to budget limitations. This causes the importance of optimal use of infrastructure, so that education financing can be allocated equally to other sub-sections. Based on this identification and with a tough negotiation process, it was agreed together to procure solar power plants as infrastructure that will later be managed and used to reduce the efficiency of education financing at SMP Muhammadiyah 1 Berbah.

The management of solar power plants (PLTS) at SMP Muhammadiyah 1 Berbah is one of the innovative efforts to achieve the efficiency of education financing. With energy costs that tend to increase and high electricity needs to support the learning process, such as the use of electronic equipment, lighting, air conditioning and information technology devices, the use of renewable energy such as solar power plants is believed to be a strategic solution. The implementation of solar power plants not only helps in reducing school operational costs, but also supports the creation of a sustainable and environmentally friendly educational environment.

The efficiency of education financing through the use of solar power plants at SMP Muhammadiyah 1 Berbah can be carried out optimally if there is good management. The management of solar power plants carried out by SMP Muhammadiyah 1 Berbah includes several steps or stages, such as planning and feasibility studies, procurement and installation, use and integration with the electrical system in the institution, as well as maintenance and monitoring.

Planning and Feasibility Studies

The first stage in the management of solar power plants is to conduct a feasibility study. The study includes an analysis of the potential of solar energy at the institution's site, an estimate of electrical energy needs and a cost-benefit analysis. The feasibility study should consider the geographical conditions and intensity of the sun light, the school's energy needs and the estimated cost of procurement and installation of solar PV. Based on the results of interviews with resource persons, it is known that the cost of procurement of solar panels is Rp.

30,000,000.00 per unit excluding the installation price, while in SMP Muhammadiyah 1 Berbah there are as many as 10 units of solar panels. From the beginning of procurement until now, solar power plants can meet the needs of electrical energy in institutions during 1x24, the installation of strategic solar panels is considered influential to accommodate the intensity of sunlight.

Procurement and Installation

After careful planning, the next step is the procurement and installation of solar panels and their supporting devices. Procurement must go through transparent procedures and in accordance with applicable regulations, the procurement of solar power plants at SMP Muhammadiyah 1 Berbah starting from January 2023. Solar panel installation must be performed by trained professionals to ensure the system runs optimally and safely. In this case, Muhammadiyah Junior High School collaborates with energy service providers or solar PV installation companies. In the procedure, SMP Muhammadiyah is looking for vendors who offer the most attractive concepts with good quality standards, but at a minimum cost. The institution then conducts a re-survey and other comparisons until finally realizing the procurement at the best price that the institution is able to provide.

Use and Integration with School Electrical Systems

Once the solar power plant is installed, the institution must ensure that the system is properly integrated into the school's electricity grid. If the institution uses a grid-tied system scheme, the energy generated from solar PV can be used to reduce electricity use from the public grid. If there is excess energy, the excess can be returned to the grid to obtain energy credits through the net metering system. As for SMP Muhammadiyah 1 Berbah, solar power plants are integrated through a grid-tied system scheme. The use of solar power plants with this scheme is the result of identifying the existing budget, considering that the procurement of batteries requires a budget that is not cheap. Meanwhile, the integration of solar power plants into the institution's electricity network is carried out by PLN services hired by institutions.

Maintenance and Monitoring

Solar PV maintenance is very important so that the system continues to function properly in the long term. The maintenance of solar power plants at

Muhammadiyah Junior High School is carried out routinely, such as cleaning solar panels and checking inverters, which must be done periodically. In addition, the agency monitors energy production from solar power plants continuously to find out if there is a decrease in efficiency or damage that requires repairs.

To determine the efficiency of the use of solar power plants in reducing education costs, it is necessary to compare the value between before and after the use of solar power plants or the power used with the nominal amount paid. The following is a detailed on the Table 1 of electricity payments at SMP Muhammadiyah 1 Berbah as of November 2022 – March 2023:

Table 1. Electricity Payments at SMP Muhammadiyah 1 Berbah

Time	Stand Meter	Electric Power	Tariff
11 November 2022	-	-	Rp. 621.600.-
06 Desember 2022	-	-	Rp. 621.600.-
11 Januari 2023	00016488-00017375 (887)	7700 VA	Rp. 976.300.-
09 Februari 2023	00017375-00018647 (1.272)	7700 VA	Rp. 964.800.-
14 Maret 2023	00018647-00019726 (1.079)	7700 VA	Rp. 971.100.-

Based on the results of the research, it can be seen that the solar power plant at SMP Muhammadiyah 1 Berbah is managed well by referring to the existing procedures or stages. However, the details of the data in the table above regarding the comparative value between before and after the use of solar power plants conclude that the use of solar power plants in supporting the efficiency of education costs at SMP Muhammadiyah 1 Berbah has not been optimally felt. Even though it can only make a small savings, Muhammadiyah Junior High School still believes that the use of solar power plants will be felt as soon as possible, so that the efficiency of education financing can be allocated for other activities or programs in the plan to improve the quality of education.

Other educational institutions can consider the implementation of rooftop solar systems as a long-term operational cost saving strategy. It is recommended that schools conduct an energy audit first to find out the actual energy needs, then develop a solar PV installation plan that suits their capacity

and budget. Collaboration with government or private institutions of renewable energy providers can also accelerate the implementation of this project. Additionally, the integration of renewable energy education into the curriculum can increase students' awareness of sustainability and the benefits of clean energy. These measures not only support energy efficiency, but also build an eco-friendly culture in the educational environment.

CONCLUSION

The management of facilities and infrastructure at SMP Muhammadiyah 1 Berbah begins with planning, procurement, use, maintenance and transfer. Management is carried out in line with the previous theory, where infrastructure management is defined as the process of organizing, coordinating, and controlling all activities related to the management of facilities and infrastructure. The efficiency of education financing through the use of infrastructure is a strategic approach that can help schools allocate funds more wisely to support the improvement of the quality of education. The management of solar power plants at Muhammadiyah 1 Berbah Junior High School has been carried out well. Management includes several steps or stages, such as planning and feasibility studies, procurement and installation, use and integration with the electrical system in the institution, and maintenance and monitoring. However, the use of solar power plants in supporting the efficiency of education costs at Muhammadiyah 1 Berbah Junior High School has not been optimally felt.

Although this study provides an overview of the potential savings from the use of solar power plants in Muhammadiyah 1 Berbah Junior High School, there are several limitations that need to be considered. The study focused only on one location with specific geographical, economic, technical conditions, so the results may not be fully generalizable for all educational institutions. In addition, the study did not consider long-term maintenance costs and variations in system efficiency over time. Future research is suggested to cover different types of schools, different regional conditions, as well as external factors such as subsidy policies or government incentives that may affect the feasibility of renewable energy implementation in the education sector.

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