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Implementation of Solar Panel-Based Renewable Energy to Support Energy Efficiency in Rural Areas

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Abstract— The ever-increasing energy demand and dependence on fossil fuels demand environmentally friendly and sustainable energy solutions. This study aims to analyze the effectiveness of solar panel implementation in providing electricity in remote rural areas. The method used is a case study with quantitative and qualitative approaches to solar panel installations in Sukamakmur Village, Langkat Regency, North Sumatra. The results show that the solar panel system is capable of supplying daily electricity needs with an average efficiency of 78%. This technology can also reduce household operating costs by up to 35% compared to conventional solar panels with the use of fossil fuel generators.

Keywords—Energy and solar panels and energy

I. Introduction

Electricity is a basic necessity for human life, particularly in supporting economic activities, education, and healthcare. However, many rural areas in Indonesia still lack optimal access to the national electricity grid (PLN). Limited infrastructure, high network construction costs, and difficult geographic locations are the main factors hindering energy distribution to remote areas.

On the other hand, Indonesia has enormous solar energy potential due to its location on the equator, which provides high levels of sunlight year-round. However, the use of solar energy as an alternative energy source remains underutilized, particularly at the village level. Solar panel technology, or photovoltaic systems, is an environmentally friendly and sustainable solution to address the energy crisis in areas without access to the electricity grid.

Apart from providing a solution to limited energy supply, the use of solar panels can also increase energy efficiency and reduce dependence on electricity.

Fossil fuels, such as diesel for generators, are expensive and polluting. By utilizing renewable energy based on solar panels, it is hoped that rural communities will have access to stable, affordable, and clean energy.

Based on this background, this study aims to examine the effectiveness of implementing solar panel-based renewable energy in supporting energy efficiency and supporting community welfare in rural areas.

II. Theoretical Basic

A. Teori Energy

According to Boyle (2004), renewable energy is energy derived from natural sources that can be naturally renewed in a relatively short period of time, such as sunlight, wind, water, and biomass. Renewable energy is considered an important solution to reduce dependence on fossil fuels and address the problems of climate change and the sustainability of energy supplies. Utilizing solar energy through solar panels is one form of renewable energy implementation that is particularly suitable for rural areas.

III. Methode Reseach

This research used a case study approach with direct observation and technical data collection of 3,000 Wp solar panel systems installed in 10 homes. Measurements were conducted over 30 days to assess the system's efficiency and performance.

IV. Results And Discussion

A. Increased Electricity Availability

- The implementation of solar panels has successfully provided independent electricity to households and public facilities (such as schools and village halls) in rural areas previously without PLN network access.

- Approximately 85% of respondents reported increased 24-hour electricity access, especially at night.

B. Energy Cost Efficiency

- Electricity cost savings of up to 60–80% can be achieved after switching to solar panels, especially for households that previously used oil-fired generators.
- Before installing solar panels, monthly energy costs reached Rp 200,000–Rp 400,000, but afterward, they dropped to less than Rp 100,000 (maintenance costs).

C. Energy Utilization for Economic Productivity

- Solar panels are used to power simple agricultural machinery, livestock lights, and refrigerators for storing fish catches.
- This has resulted in increased community incomes of up to 15–25% due to more optimal production and storage.

D. Community Acceptance

- Approximately 90% of the community accepts and supports the use of solar panels.
- Adoption rates have increased due to system training provided by project management and ease of maintenance.

E. Technical Obstacles

- Several technical issues were encountered, such as inverter damage, decreased efficiency due to prolonged cloudy weather, and limited battery storage capacity.
- However, these issues can be resolved with the support of local technicians and regular training.

V. Conclusion

A. Renewable Energy Efficiency

- Research results show that solar panels can increase energy efficiency by utilizing solar energy, which is available year-round in rural areas of Indonesia.
- This aligns with the IEA's (2020) energy efficiency theory, which states that efficiency is not only seen from a technical perspective, but also from a social and economic perspective.

B. Contribution to Energy Sustainability

The use of solar panels contributes to reducing dependence on fossil fuels, supporting the sustainable development goals (SDGs), particularly the pillar of clean and affordable energy. Solar panels also reduce carbon emissions and noise generated by conventional generators.

C. Positive Socio-Economic Impact

- Sustainable electricity access improves the community's quality of life: children can study at night, economic activity increases, andReducing monthly household expenses.
- Solar panels are an inclusive energy solution, especially for remote and isolated villages.

1) Problems and Recommendations

- Despite its effectiveness, the implementation of solar panels still faces technical challenges and high initial costs.
- Therefore, it is necessary to:
  - Subsidy schemes or soft financing from the government/NGOs
  - Local technical training
  - Regular system monitoring and evaluation

- 2. Solar panels have proven to be an effective alternative energy solution in increasing the availability and access to electricity in rural areas that are not yet connected to the conventional electricity grid.
- 3. The application of solar panels can reduce household and public facility energy costs, thereby increasing the efficiency of energy use and encouraging budget allocation for other needs.

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