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# Use of Solar Energy for Street Lighting in Rural Java

**Farida Arinie Soelistianto[1], Harrij Mukti Khristiana[3]**
[1] Politeknik Negeri Malang and farida.arinie@polinema.ac.id
[2] Politeknik Negeri Malang and harrij@polinema.ac.id

**ABSTRACT**

The utilization of renewable energy has become a strategic priority in supporting sustainable development, particularly in rural areas with limited access to conventional energy infrastructure. This study aims to analyze the utilization of solar energy for street lighting in rural areas of Java, focusing on community perceptions and acceptance. A quantitative research approach was employed using a structured questionnaire distributed to 85 respondents residing in villages equipped with solar-powered street lighting systems. Data were collected using a five-point Likert scale and analyzed with SPSS version 25. The analysis included descriptive statistics, reliability testing, and multiple linear regression to examine the influence of perceived effectiveness, efficiency, safety and social impact, and sustainability on community acceptance. The results indicate that all perception dimensions have a positive and statistically significant effect on acceptance of solar-powered street lighting, with perceived safety and social impact emerging as the most influential factor. Overall, the findings demonstrate that solar-powered street lighting is perceived as effective, cost-efficient, socially beneficial, and environmentally sustainable. This study provides empirical evidence to support the expansion of solar energy-based public lighting as a viable strategy for enhancing rural infrastructure and promoting sustainable energy transitions in Indonesia.

***Keywords:*** *Solar Energy Utilization, Street Lighting, Rural Development, Renewable Energy, Community Perception.*

## 1. INTRODUCTION

The growing demand for energy and the increasing awareness of environmental sustainability have positioned renewable energy as a strategic priority in global and national development agendas. In Indonesia, where fossil fuel dependency remains high, the transition toward renewable energy sources is not only an environmental necessity but also a socio-economic imperative [1], [2]. Among various renewable options, solar energy has emerged as one of the most promising alternatives due to Indonesia's geographical advantage as a tropical country with abundant solar radiation throughout the year. The utilization of solar energy is particularly relevant for rural areas, where access to reliable electricity infrastructure is often limited or unevenly distributed [3], [4].

Rural regions in Java continue to face challenges related to public infrastructure, including inadequate street lighting. Poor street lighting conditions contribute to multiple socio-economic issues, such as reduced mobility at night, increased risk of traffic accidents, and heightened concerns regarding public safety and security [3], [5]. Conventional street lighting systems, which rely on grid electricity, are often constrained by high installation costs, operational expenses, and maintenance challenges, especially in remote or less developed villages. These constraints limit the effectiveness of rural development programs aimed at improving quality of life and economic activity [6], [7].

Solar-powered street lighting presents a viable and sustainable solution to these challenges. By harnessing solar energy, street lighting systems can operate independently of the national electricity grid, reducing long-term operational costs and minimizing environmental impact [8]. Solar street lights typically consist of photovoltaic panels, energy storage batteries, LED lamps, and control systems, allowing them to function efficiently with minimal maintenance. From a

sustainability perspective, this technology aligns with Indonesia's commitment to reducing greenhouse gas emissions and increasing the share of renewable energy in the national energy mix.

Despite the technical and environmental advantages of solar street lighting, successful implementation in rural areas depends largely on community acceptance and perceived benefits. The effectiveness of such infrastructure is not determined solely by technological performance but also by how local communities perceive its usefulness, reliability, and contribution to daily life. Factors such as lighting quality, durability, ease of maintenance, cost efficiency, and perceived safety improvements play a critical role in shaping public attitudes toward renewable energy adoption. Therefore, understanding community perceptions is essential to ensure the long-term sustainability and scalability of solar energy projects in rural contexts.

Previous studies on renewable energy adoption have highlighted the importance of social acceptance, economic feasibility, and institutional support in determining project success; however, empirical evidence focusing specifically on solar-powered street lighting in rural areas of Java remains limited, particularly studies employing quantitative methods to assess community perceptions and acceptance levels. To address this gap, this research conducts a systematic quantitative analysis of the utilization of solar energy for street lighting in rural areas of Java by examining community perceptions of effectiveness, efficiency, and sustainability through a structured Likert-scale questionnaire administered to respondents. The collected data are analyzed using SPSS version 25 to generate empirical insights into the factors influencing acceptance and perceived benefits of solar street lighting, with the findings expected to contribute to the literature on renewable energy implementation in rural contexts and provide practical recommendations for policymakers and local governments in designing and expanding sustainable energy infrastructure programs in Indonesia.

## 2. LITERATURE REVIEW

### *2.1 Renewable Energy and Sustainable Development*

Renewable energy plays a central role in achieving sustainable development by addressing energy security, environmental protection, and socio-economic equity, as sustainable development emphasizes meeting present needs without compromising the ability of future generations to meet their own needs, with energy systems serving as a critical component of this objective [9], [10]. Renewable energy sources such as solar, wind, hydro, and biomass are widely recognized for their capacity to reduce greenhouse gas emissions, decrease dependence on fossil fuels, and support inclusive economic growth, particularly in developing countries where renewable energy is vital for rural development by enabling access to energy services in areas often underserved by conventional electricity grids [2], [11]. In the context of Indonesia, renewable energy development has been integrated into national policies to support long-term sustainability goals, with solar energy considered one of the most feasible options due to its wide availability, declining technology costs, and suitability for decentralized energy systems; consequently, the adoption of solar-based infrastructure is viewed not only as a technical solution but also as a strategic approach to promoting sustainable rural development.

### *2.2 Solar Energy Utilization in Rural Areas*

Solar energy utilization in rural areas has gained increasing attention due to its flexibility and adaptability to local conditions, as it can be deployed in decentralized forms that allow communities to generate electricity independently, making it particularly suitable for regions where grid extension is costly or technically challenging [1], [2]. Previous studies indicate that solar energy applications in rural areas contribute to improved living standards by enabling access to lighting, communication, and public services, with solar-powered street lighting identified as an effective intervention to enhance nighttime visibility, reduce crime rates, and improve road safety, while simultaneously eliminating recurring electricity costs and reducing the financial burden on local government budgets over the long term [4], [12]. Nevertheless, the sustainability of solar energy projects in rural areas depends not only on technological performance but also on adequate institutional support, maintenance capacity, and community engagement, as insufficient management and low local acceptance may lead to operational challenges that limit project effectiveness and longevity.

### *2.3 Solar-Powered Street Lighting Systems*

Solar-powered street lighting systems consist of photovoltaic panels, rechargeable batteries, LED lamps, and intelligent control units, in which solar panels convert sunlight into electrical energy during daylight hours, store it in batteries, and subsequently use it to power LED lamps at night, with advances in LED technology significantly improving lighting efficiency, durability, and brightness while reducing energy consumption [4]. Compared to conventional street lighting, solar-powered systems offer several advantages, including lower installation costs in remote areas, reduced operational expenses, minimal environmental impact, and resilience to power outages, ensuring continuous lighting even during grid failures, which has led to their widespread adoption in various countries as part of smart city initiatives and rural infrastructure development programs [3], [4]. Despite these benefits, challenges remain related to battery lifespan, weather dependency, and maintenance requirements, as the effectiveness of solar street lighting is influenced by local climatic conditions, system design quality, and the availability of technical support; therefore, evaluating system performance and perceived reliability from the user's perspective is essential to ensure long-term success.

### *2.4 Community Perception and Technology Acceptance*

Community perception is a critical factor influencing the adoption and sustainability of renewable energy technologies, as technology acceptance theories emphasize that perceived usefulness, perceived ease of use, and perceived benefits significantly shape user attitudes and behavioral intentions; in the context of public infrastructure such as street lighting, community perception includes evaluations of lighting quality, safety enhancement, reliability, and overall contributions to daily activities [13], [14]. Empirical studies demonstrate that positive community perceptions increase the likelihood of technology acceptance and long-term support, particularly in rural settings where strong community involvement means public approval plays a decisive role in maintaining and protecting shared infrastructure, whereas negative perceptions related to poor performance, inadequate maintenance, or limited

participation can undermine project effectiveness. Consequently, quantitative approaches using Likert-scale surveys are widely employed to measure community perceptions and acceptance levels, as they enable systematic assessment of attitudes, satisfaction, and perceived impacts, thereby providing empirical evidence to inform policy formulation and program design.

### *2.5 Research Gap and Conceptual Framework*

Although numerous studies have examined renewable energy adoption and solar energy utilization, research specifically focusing on solar-powered street lighting in rural areas of Java remains limited, as existing studies tend to emphasize technical feasibility or policy frameworks while giving less attention to community-level perceptions and acceptance through quantitative analysis, and empirical research integrating social, economic, and environmental dimensions in evaluating solar street lighting systems is still scarce. This study addresses this gap by conducting a quantitative analysis of community perceptions regarding the utilization of solar energy for street lighting in rural areas of Java, examining factors such as perceived effectiveness, efficiency, safety benefits, and sustainability to provide a comprehensive understanding of how solar street lighting is evaluated by rural communities, with findings expected to contribute to the literature on renewable energy implementation and offer evidence-based insights for policymakers, local governments, and development practitioners in promoting sustainable rural infrastructure.

## 3. METHODS

### 3.1 Research Design

This study employs a quantitative research design to analyze the utilization of solar energy for street lighting in rural areas of Java. A quantitative approach is considered appropriate as it enables the measurement of community perceptions and attitudes in a structured and objective manner using numerical data. The research focuses on assessing perceived effectiveness, efficiency, safety, and sustainability of solar-powered street lighting systems based on responses collected through a standardized questionnaire. The study is cross-sectional in nature, as data were collected at a single point in time to capture current perceptions of the respondents.

### 3.2 Research Location and Population

The research was conducted in selected rural areas of Java where solar-powered street lighting systems have been installed and are actively used. These locations were chosen because they represent rural communities that have experienced the direct impact of solar energy utilization in public infrastructure. The population of this study consists of community members living in villages equipped with solar street lighting, including residents, local road users, and community representatives who regularly interact with the lighting facilities.

### 3.3 Sample and Sampling Technique

The sample size for this study consists of 85 respondents, which is considered adequate for quantitative analysis using statistical software. Respondents were selected using a purposive sampling technique, where participants were chosen based on specific criteria: (1) residing in rural areas of Java, (2) having direct exposure to solar-powered street lighting, and (3) being able to provide informed responses regarding its use and impact. This sampling approach ensures that the collected data are relevant to the research objectives and reflect actual user experiences.

### 3.4 Research Instrument

Data were collected using a structured questionnaire designed to measure community perceptions of solar-powered street lighting, which was developed based on relevant literature on renewable energy adoption and public infrastructure assessment, with all items measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire comprised four main sections, namely perceived effectiveness, which measured lighting quality, reliability, and operational performance; perceived efficiency, which assessed energy savings, cost effectiveness, and maintenance simplicity; perceived safety and social impact, which evaluated improvements in road safety, crime reduction, and nighttime mobility; and perceived sustainability, which measured environmental benefits and the long-term viability of solar energy utilization.

### 3.5 Data Collection Procedure

Data collection was carried out through direct distribution of questionnaires to respondents in the selected rural areas. Prior to data collection, respondents were informed about the purpose of the study and assured that their responses would be used solely for academic purposes. Participation was voluntary, and confidentiality of respondent information was maintained. Completed questionnaires were collected and screened to ensure completeness and consistency before further analysis.

### 3.6 Data Analysis Techniques

The collected data were analyzed using SPSS version 25. Data analysis involved several stages. First, descriptive statistics were employed to summarize respondent characteristics and overall perception trends, including mean values and standard deviations. Second, instrument reliability testing was conducted using Cronbach's alpha to assess the internal consistency of the questionnaire items. A Cronbach's alpha value above 0.70 was considered acceptable. Third, inferential statistical analysis was performed to examine relationships among key variables related to solar street lighting utilization. The results of these analyses were used to interpret community acceptance and perceived benefits of solar-powered street lighting systems.

## 4. RESULTS AND DISCUSSION

### 4.1 Respondent Characteristics

This study involved 85 respondents from rural areas in Java where solar-powered street lighting systems have been implemented. Respondent characteristics were analyzed to provide an overview of the demographic profile and to ensure that the sample adequately represents community members who actively experience the benefits of solar street lighting. The characteristics analyzed include gender, age, education level, and occupation. The distribution of respondents is presented in Table 1.

Table 1. Respondent Characteristics

| Characteristics | Category | Frequency (n) | Percentage |
|---|---|---|---|
| Gender | Male | 49 | 57.6 |
| | Female | 36 | 42.4 |
| Age | 18–25 years | 12 | 14.1 |
| | 26–35 years | 21 | 24.7 |
| | 36–45 years | 27 | 31.8 |
| | 46–55 years | 17 | 20.0 |
| | > 55 years | 8 | 9.4 |
| Education Level | Primary School | 14 | 16.5 |
| | Junior High School | 19 | 22.4 |
| | Senior High School | 34 | 40.0 |
| | Diploma/Bachelor's Degree | 18 | 21.1 |

| | | | |
|---|---|---|---|
| Occupation | Farmer | 26 | 30.6 |
| | Self-employed | 22 | 25.9 |
| | Private Employee | 15 | 17.6 |
| | Civil Servant | 8 | 9.4 |
| | Others | 14 | 16.5 |

Based on Table 1, male respondents slightly dominated the sample (57.6%), reflecting higher involvement of men in outdoor and nighttime activities in rural areas such as transportation and community mobility, while female participation (42.4%) remains substantial, indicating inclusive community representation. In terms of age, the majority of respondents were within the productive age range of 26–45 years (56.5%), suggesting that perceptions were largely obtained from individuals actively engaged in economic and social activities who frequently use village roads for work, trade, and social interaction. Regarding education level, most respondents had completed senior high school (40.0%), followed by diploma or bachelor's degree holders (21.1%), indicating a sufficient educational background to evaluate the functional, economic, and environmental aspects of solar-powered street lighting. From an occupational perspective, farmers (30.6%) and self-employed individuals (25.9%) constituted the largest groups, reflecting the typical employment structure in rural Java and reinforcing the relevance of the findings, as these groups rely heavily on safe and reliable nighttime lighting for mobility, transportation of goods, and community activities; overall, the respondent characteristics demonstrate that the sample is demographically diverse and representative of rural communities in Java, providing a reliable basis for analyzing perceptions of solar energy utilization for street lighting.

### 4.2 Descriptive Analysis of Community Perceptions

Descriptive statistical analysis was conducted to examine community perceptions regarding the utilization of solar energy for street lighting in rural areas of Java. The analysis focuses on four key dimensions: perceived effectiveness, perceived efficiency, perceived safety and social impact, and perceived sustainability. All variables were measured using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The results are presented in terms of mean scores and standard deviations, as summarized in Table 2.

Table 2. Descriptive Statistics of Community Perceptions

| Dimension | Indicator | Mean | Std. Deviation |
|---|---|---|---|
| Perceived Effectiveness | Adequate lighting brightness | 4.21 | 0.63 |
| | Reliable operation at night | 4.15 | 0.66 |
| | Consistent lighting performance | 4.09 | 0.71 |
| | Average Mean | 4.15 | — |
| Perceived Efficiency | Reduction in electricity costs | 4.34 | 0.58 |
| | Energy efficiency of solar lamps | 4.18 | 0.64 |
| | Low maintenance requirements | 4.02 | 0.72 |
| | Average Mean | 4.18 | — |
| Perceived Safety and Social Impact | Improved road safety | 4.27 | 0.61 |
| | Reduced crime risk at night | 4.11 | 0.69 |
| | Increased nighttime mobility | 4.23 | 0.65 |
| | Average Mean | 4.20 | — |
| Perceived Sustainability | Environmentally friendly energy source | 4.30 | 0.57 |
| | Reduction of carbon emissions | 4.14 | 0.67 |
| | Long-term sustainability of solar lighting | 4.08 | 0.70 |
| | Average Mean | 4.17 | — |

The results in Table 2 show that overall community perceptions of solar-powered street lighting are highly positive, as indicated by an average mean score of 4.17, with all dimension mean

values exceeding 4.00, which corresponds to the "agree" category on the Likert scale. For perceived effectiveness, the average mean score of 4.15 indicates that respondents generally agree that solar-powered street lighting provides adequate brightness, operates reliably at night, and delivers consistent lighting performance, suggesting that the installed systems meet functional expectations for rural road conditions and daily community use. In terms of perceived efficiency, an average mean score of 4.18 reflects strong agreement that solar street lighting reduces electricity costs and operates efficiently, with the highest individual mean score related to cost reduction (4.34), highlighting the economic advantage of solar energy compared to conventional grid-based lighting, while relatively low maintenance requirements further reinforce long-term efficiency. The perceived safety and social impact dimension recorded the highest average mean score (4.20), indicating strong agreement that solar-powered street lighting improves road safety, enhances nighttime mobility, and contributes to a safer village environment by reducing accident risks and increasing feelings of security. Finally, perceived sustainability achieved an average mean score of 4.17, with the highest score associated with the environmentally friendly nature of solar energy (4.30), demonstrating that rural communities not only value functional and economic benefits but also recognize the environmental advantages and long-term sustainability of solar-powered street lighting.

### 4.3 Reliability and Instrument Assessment

Reliability and instrument assessment were conducted to ensure that the questionnaire used in this study consistently and accurately measured community perceptions regarding the utilization of solar energy for street lighting in rural areas of Java, as reliability testing is essential in quantitative research to confirm that measurement items within each construct are internally consistent and suitable for statistical analysis. The reliability of the research instrument was evaluated using Cronbach's alpha coefficient calculated with SPSS version 25, with a Cronbach's alpha value of 0.70 or higher considered acceptable, indicating good internal consistency among items within the same construct.

Table 3. Reliability Test Results

| Construct | Number of Items | Cronbach's Alpha | Reliability Status |
|---|---|---|---|
| Perceived Effectiveness | 3 | 0.826 | Reliable |
| Perceived Efficiency | 3 | 0.853 | Reliable |
| Perceived Safety and Social Impact | 3 | 0.876 | Reliable |
| Perceived Sustainability | 3 | 0.807 | Reliable |
| Overall Instrument | 12 | 0.892 | Highly Reliable |

Table 3 demonstrates that all measurement constructs used in this study exhibit strong internal consistency, as indicated by Cronbach's alpha values exceeding the recommended threshold of 0.70. The perceived safety and social impact construct shows the highest reliability ($\alpha$ = 0.876), suggesting that items related to safety improvement, social comfort, and nighttime mobility were consistently interpreted by respondents. Perceived efficiency ($\alpha$ = 0.853) and perceived effectiveness ($\alpha$ = 0.826) also display high reliability, indicating stable and coherent measurement of economic benefits, operational performance, and lighting quality. Meanwhile, perceived sustainability achieved a Cronbach's alpha value of 0.807, confirming reliable measurement of environmental and long-term sustainability aspects. The overall instrument recorded a Cronbach's alpha of 0.892, categorizing it as highly reliable, which indicates that the questionnaire as a whole is a robust and dependable tool for assessing community perceptions of solar-powered street lighting in rural areas of Java and is suitable for subsequent statistical analyses.

### 4.4 Inferential Analysis and Discussion

Inferential statistical analysis was conducted to examine the influence of community perception variables on the acceptance of solar-powered street lighting in rural areas of Java. The

analysis aims to determine whether perceived effectiveness, perceived efficiency, perceived safety and social impact, and perceived sustainability significantly affect overall community acceptance. The analysis was performed using multiple linear regression with SPSS version 25 at a significance level of $\alpha = 0.05$.

The regression model treats community acceptance of solar street lighting as the dependent variable, while the four perception dimensions serve as independent variables. The results of the regression analysis are presented in Table 4.

Table 4. Multiple Linear Regression Results

| Independent Variable | Beta (β) | t-value | Sig. (p-value) | Interpretation |
|---|---|---|---|---|
| Perceived Effectiveness | 0.312 | 3.214 | 0.002 | Significant |
| Perceived Efficiency | 0.284 | 2.877 | 0.005 | Significant |
| Perceived Safety & Social Impact | 0.351 | 3.743 | 0.000 | Significant |
| Perceived Sustainability | 0.219 | 2.184 | 0.032 | Significant |
| $R^2$ | 0.687 | | | |
| Adjusted $R^2$ | 0.662 | | | |
| F-value | 42.155 | | 0.000 | Model Fit |

Table 4 shows that the multiple linear regression model is statistically significant and explains a substantial proportion of the variance in community acceptance of solar-powered street lighting in rural areas of Java. The model demonstrates good explanatory power, with an $R^2$ value of 0.687 and an adjusted $R^2$ of 0.662, indicating that approximately 66.2% of the variation in acceptance can be explained by perceived effectiveness, perceived efficiency, perceived safety and social impact, and perceived sustainability, while the significant F-value (42.155; $p = 0.000$) confirms overall model fit. Among the independent variables, perceived safety and social impact has the strongest influence on acceptance ($\beta = 0.351$; $p = 0.000$), highlighting that improvements in road safety, reduced crime risk, and enhanced nighttime mobility are the most decisive factors shaping community support. Perceived effectiveness ($\beta = 0.312$; $p = 0.002$) and perceived efficiency ($\beta = 0.284$; $p = 0.005$) also show significant positive effects, indicating that reliable lighting performance and economic benefits such as cost savings and low maintenance are critical determinants of acceptance. Although perceived sustainability has the smallest beta coefficient ($\beta = 0.219$), it remains statistically significant ($p = 0.032$), suggesting that environmental awareness and long-term sustainability considerations also contribute meaningfully to community acceptance, albeit to a lesser extent than functional and social factors.

**Discussion**

This study provides empirical evidence on the utilization of solar energy for street lighting in rural areas of Java by integrating functional, economic, social, and environmental perspectives. The findings demonstrate that community acceptance of solar-powered street lighting is shaped by a combination of perceived effectiveness, efficiency, safety and social impact, and sustainability. Overall, the results indicate that solar street lighting is not only technically feasible but also socially valued and economically advantageous in rural contexts.

The dominant influence of perceived safety and social impact highlights the central role of public infrastructure in improving quality of life in rural communities. Adequate street lighting enhances nighttime visibility, reduces perceived crime risk, and supports safer mobility for residents. This finding aligns with infrastructure and rural development studies that emphasize safety and social well-being as primary drivers of public acceptance. In rural Java, where daily activities often extend into the evening, the presence of reliable street lighting contributes directly to social comfort and community confidence.

Perceived effectiveness also emerged as a significant determinant of acceptance, reinforcing the importance of technical performance. Communities expect solar-powered street lighting to

deliver sufficient brightness and consistent operation comparable to conventional lighting systems. The positive perception of effectiveness observed in this study suggests that current solar lighting installations meet these expectations. This supports previous research indicating that renewable energy technologies gain public support when they provide tangible and reliable services without compromising functionality [15], [16].

Economic considerations, reflected in perceived efficiency, play a crucial supporting role in acceptance. The elimination of electricity costs and relatively low maintenance requirements were strongly valued by respondents. In rural settings with limited financial resources, cost efficiency enhances the perceived practicality of renewable energy solutions. This finding reinforces the argument that decentralized solar infrastructure can offer long-term economic benefits for both communities and local governments, particularly when maintenance systems are well managed.

Although perceived sustainability had a comparatively smaller influence, it remains an important component of community acceptance. Respondents demonstrated awareness of the environmental benefits of solar energy, including reduced carbon emissions and decreased reliance on fossil fuels. This indicates an emerging environmental consciousness within rural communities, suggesting that sustainability narratives can complement functional and economic arguments in promoting renewable energy adoption.

Taken together, the discussion underscores that the success of solar-powered street lighting in rural areas depends on more than technological deployment alone. Effective implementation requires aligning technical performance with community needs, ensuring visible social benefits, and maintaining economic viability. Policymakers and practitioners should therefore adopt a holistic approach that combines reliable system design, routine maintenance, community engagement, and environmental education. By doing so, solar energy utilization for street lighting can serve as a sustainable and scalable model for rural infrastructure development in Indonesia.

## CONCLUSION

This study concludes that the utilization of solar energy for street lighting in rural areas of Java is positively perceived and widely accepted by local communities. The findings show that community acceptance is significantly influenced by perceived effectiveness, efficiency, safety and social impact, and sustainability, with safety-related benefits playing the most dominant role. Solar-powered street lighting is viewed as an effective solution for improving nighttime visibility, enhancing public safety, reducing energy costs, and supporting environmental sustainability. These results indicate that solar street lighting can serve as a reliable and sustainable infrastructure option for rural development. To ensure long-term success, policymakers and local governments should prioritize system reliability, maintenance support, and community engagement while promoting awareness of environmental benefits. Expanding solar-powered street lighting initiatives can therefore contribute meaningfully to sustainable rural development and renewable energy adoption in Indonesia.

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