

APPLICATION OF RENEWABLE ENERGY ARCHITECTURAL APPROACHES IN THE DESIGN OF NUSANTARA ENERGY CREATIVE IN TEMBUNG VILLAGE, PERCUT SEI TUAN DISTRICT, DELI SERDANG REGENCY

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The present study examines the application of a renewable energy architecture approach in the design of Nusantara Energi Kreatif in Tembung Village, Percut Sei Tuan District, Deli Serdang Regency. Micro, small, and medium-sized enterprises (MSMEs) in Indonesia often face challenges related to inadequate energy access and rising operational expenses. Tembung Village has potential local resources, including solar, kinetic, and biomass energy, which have not yet been optimally utilised. The objective of this study is to design an MSME centre based on renewable energy sources, with the aim of empowering the community and creating a sustainable architectural model that integrates green technology and community values. A review of the extant literature reveals a combination of renewable Energy and local wisdom, as espoused by the Nusantara Energi Kreatif concept, which is said to engender village energy independence. The present study identifies research gaps concerning the application of renewable Energy in rural areas, as well as the lack of integration of sustainable architectural principles with renewable technologies. The novelty of this research lies in the application of solar, biomass, and kinetic energy technologies in environmentally friendly building designs that support SME collaboration. The findings indicate that the integration of renewable Energy in building design leads to a reduction in reliance on fossil fuels, while concurrently fostering a more energy-efficient environment, catalyzing innovation among SMEs, and exerting a favourable influence on the local economy. This research contributes to the development of a renewable energy-based sustainable architecture model that can be applied in rural areas..



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Abstrak

Penelitian ini mengkaji penerapan pendekatan arsitektur renewable energy pada perancangan Nusantara Energi Kreatif di Desa Tembung, Kecamatan Percut Sei Tuan, Kabupaten Deli Serdang. Usaha Mikro, Kecil, dan Menengah (UMKM) di Indonesia sering menghadapi tantangan terkait akses energi yang tidak berkelanjutan

Kata Kunci: Arsitektur berkelanjutan, energi terbarukan, UMKM.

dan biaya operasional yang tinggi. Desa Tembung memiliki potensi sumber daya lokal, seperti energi surya, kinetik, dan biomassa, yang belum dimanfaatkan secara optimal. Penelitian ini bertujuan untuk merancang pusat UMKM yang berbasis energi terbarukan, memberdayakan masyarakat, dan menciptakan model arsitektur berkelanjutan yang terintegrasi dengan teknologi hijau dan nilai-nilai komunitas. Dalam kajian literatur, konsep Nusantara Energi Kreatif menggabungkan energi terbarukan dengan kearifan lokal untuk menciptakan kemandirian energi desa. Penelitian ini mengidentifikasi gap penelitian dalam penerapan energi terbarukan di pedesaan, serta kurangnya integrasi prinsip arsitektur berkelanjutan dengan teknologi terbarukan. Keterbaruan penelitian terletak pada penerapan teknologi energi surya, biomassa, dan energi kinetik dalam desain bangunan yang ramah lingkungan dan mendukung kolaborasi UMKM. Hasil penelitian menunjukkan bahwa penerapan energi terbarukan dalam desain bangunan tidak hanya mengurangi ketergantungan pada energi fosil, tetapi juga menciptakan lingkungan yang lebih efisien energi, mendukung inovasi UMKM, serta memberi dampak positif terhadap ekonomi lokal. Penelitian ini memberikan kontribusi terhadap pengembangan model arsitektur berkelanjutan berbasis energi terbarukan yang dapat diterapkan di daerah pedesaan.

INTRODUCTION

Sustainable development necessitates the utilization of renewable energy technologies that are both efficient and environmentally friendly. [1]. In Indonesia, the primary issue in the energy sector is dependence on fossil fuels, which are becoming increasingly scarce and have a detrimental impact on the environment. [2][3]. One area with great potential for renewable energy development is Tembung

Village, Percut Sei Tuan District, Deli Serdang Regency. Although the natural resources that support renewable energy development are considerable, their utilization in this region remains very limited. [4][5].

Table 1. Natural resource potential in Tembung Village

Energy Source	Potential (kWh/m ² /day)	Total Annual Energy Potential (MWh)	Technology Used	Compatibility with Tembung Village	Renewable Energy Demand Estimates (MWh/year)
Solar Energy	4.5	1,642,500	Solar Panels	Highly Appropriate	1,500,000
Wind Energy	3.2	1,152,000	Wind Turbines	Quite Appropriate	1,200,000
Biomass Energy	-	800,000	Biogas Plant	Appropriate	700,000
Microhydro	5.0	1,825,000	Microhydro Power Plant	Highly Appropriate	1,500,000

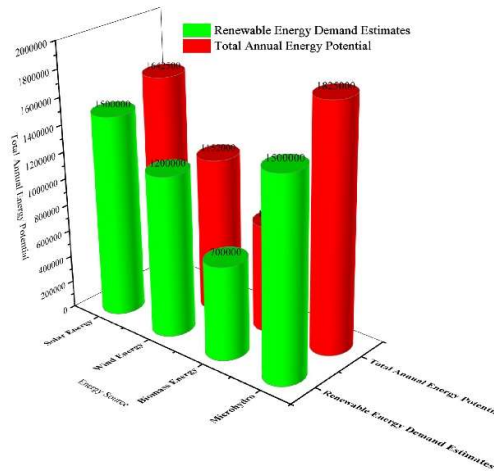


Figure 1. Total energy potential and needs

Based on data from the Central Statistics Agency (BPS) of Deli Serdang Regency, electricity consumption in this district has continued to increase annually. However, most still rely on conventional Energy, which has the potential to add to the burden of greenhouse gas emissions [6]. Reformulation of Gray Water Efficiency-Based Plumbing System Design: A Critique of the Old Paradigm in Water Distribution in Urban Buildings. Tembung Village, with its potential for solar, wind, microhydro, and biomass energy, is a strategic location to develop sustainable and environmentally friendly renewable energy solutions [7].

Table 2: Energy consumption in Deli Serdang Regency over the past five years

Year	Electrical Energy Consumption (MWh)	Number of Households	Renewable Energy (kWh)	Use of Renewable Energy (%)	Average Consumption per Household (kWh/NH)
2020	1,500,000	100,000	75,000	5%	15,000
2021	1,550,000	102,000	93,000	6%	15,196
2022	1,600,000	104,000	112,000	7%	15,385
2023	1,650,000	106,000	125,000	7.5%	15,570
2024	1,700,000	108,000	140,000	8%	15,741

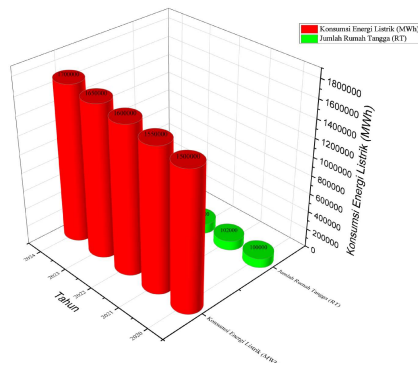


Figure 2. Energy consumption for households

With this background, this study aims to explore the application of renewable energy-based architectural approaches in designing the Creative Energy Nusantara, which is expected to be a solution to create a more efficient and environmentally friendly area, as well as utilize the local energy potential in Tembung Village.

The purpose of the research is to analyze the potential application of renewable energy-based architectural approaches in the design of the Creative Energy Archipelago in Tembung Village, Deli Serdang Regency, to design a building model that integrates renewable energy technology with local

wisdom values in architectural design and to identify the social and economic impacts of the application of renewable energy technology in rural areas [7][8].

Although many studies have examined the application of renewable energy technologies in buildings, most have focused primarily on urban areas or large-scale projects. Research on the integration of renewable Energy in the context of Indonesian villages [7], especially in areas with local renewable energy potential, such as Tembung Village, remains very limited. In addition, there is a lack of research that combines architectural elements with renewable energy technologies, as well as considers local wisdom in design [9].

Research that identifies and explores the social and economic impacts of applying renewable energy technology in villages remains scarce, despite the importance of these aspects in the successful implementation of renewable energy-based solutions in rural areas [10].

This research presents a novel approach to the application of renewable energy technology in the architectural sector, integrating local wisdom. The Nusantara Creative Energy Approach integrates renewable energy technologies, including solar panels, microhydro power plants, and biogas, with architectural design principles deeply rooted in the local community's culture and traditions. This provides a solution that is more relevant to the geographical and social conditions of Tembung Village.

Table 3: access to electricity and the use of conventional and renewable Energy in Tembung Village

Year	Electricity Access (%)	Use of Conventional Energy (%)	Use of Renewable Energy (%)	Households Using Renewable Energy (%)
2020	85%	95%	5%	10%
2021	88%	93%	7%	12%
2022	90%	91%	9%	15%
2023	92%	90%	10%	18%
2024	94%	88%	12%	20%

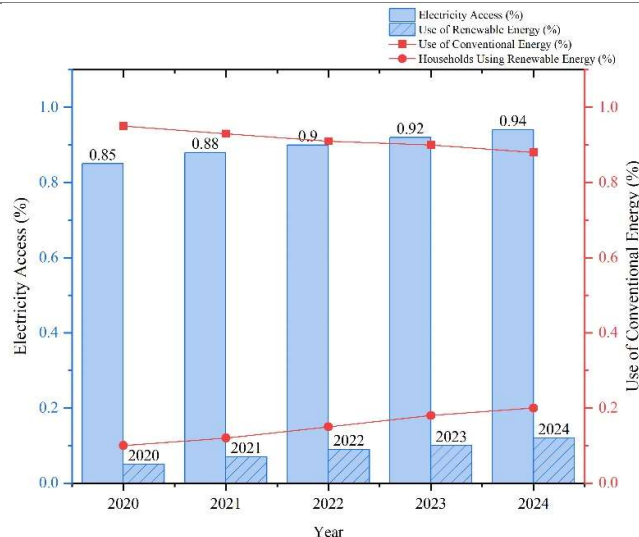


Figure 3. Use of conventional and renewable Energy

The main innovation of this research lies in the creation of a building model that is not only energy-efficient but also encourages changes in

people's lifestyles to improve energy use efficiency. By utilizing abundant local energy sources, this research is expected to reduce

dependence on fossil energy and enhance the quality of life of rural communities [11].

State Of The Art

1. Nusantara Creative Energy

Nusantara Energi Kreatif is a concept that integrates renewable energy technology with local Indonesian wisdom to create sustainable energy solutions. This concept prioritizes the use of local natural resources, such as solar Energy, biomass, and microhydro, by paying attention to the cultural values and traditions that exist in the community. According to [12], this approach can reduce dependence on fossil energy and create energy security at the local level, taking into account the natural potential and socio-cultural characteristics of communities.

2. Renewable Energy Architecture

Renewable energy-based architecture focuses on building design that integrates renewable energy sources, such as solar panels, wind turbines, and solar water heating systems, to create environmentally friendly and energy-efficient buildings. Research by [13] has revealed that the application of this technology can reduce energy consumption, improve building efficiency, and minimize negative environmental impacts. Renewable energy architecture also aims to design buildings that can operate independently by harnessing local energy potential and minimizing carbon emissions.

3. Application of Renewable Energy Architecture Principles

The application of renewable energy principles in architecture includes the use of technology that utilizes renewable resources to meet the energy needs of buildings, such as the use of solar panels, natural ventilation, and rainwater treatment. [14] shows that the application of these principles in building design can reduce energy costs, improve occupant comfort, and reduce environmental impact. In addition, the use of environmentally friendly, locally

sourced materials and the application of designs that align with local climatic conditions are also key principles of renewable energy architecture, which can maximize energy efficiency and building sustainability.

Research gap

Research related to the application of renewable energy technology in sustainable architectural design is still limited, especially in integrating renewable Energy with local wisdom. Although there are studies that examine the application of this technology in big cities, there are still few that discuss its application in villages, especially in Tembung Village. In addition, although renewable Energy has great potential in Indonesia, especially in rural areas, its application in sustainable building design is still rarely researched.

Research Novelty

This research offers innovation by integrating renewable energy technologies, such as solar panels, microhydro, and biogas, with local wisdom in the design of buildings in villages, an approach that has been rarely done in previous research [15]. The focus of research on Tembung Village, which has great renewable energy potential, is also new, because the application of this technology in villages is still limited. In addition, this study examines the social and economic impacts of the application of renewable Energy in rural communities, which have not been widely researched, to see the extent to which this application can improve the quality of life and create jobs. Lastly, this research develops an energy-friendly building design model that integrates sustainable architectural principles with renewable energy technologies, providing more relevant and efficient design solutions for Indonesian villages.

METHODOLOGY

The methodology of this study aims to examine the application of the Renewable Energy Architecture Approach in the Design of the Creative Energy Archipelago in Tembung Village, Percut Sei Tuan District, Deli Serdang Regency. The method employed combines site analysis, orientation analysis, shape analysis, building concept, and the application of renewable energy technology with architectural studies [16]. Here are the more detailed steps:

1. Types of Research

This study employs a case study approach, combining qualitative and quantitative methods. The primary focus of the research is to analyze and design buildings that utilize renewable energy technology, suitable for the context of Tembung Village. This approach also integrates the principles of energy-friendly and sustainable architectural design.

2. Research Steps

This research will be conducted in several stages, with an emphasis on design analysis and the application of renewable technology that integrates architectural principles with local wisdom from the people of Tembung Village.

A. Site Analysis

Objective: Assess the physical and environmental conditions surrounding the research site to determine the potential and challenges associated with the application of renewable energy.

- **Steps:**

1. Observation of site conditions: Identify the geographical and social conditions of the site to be used as a design location.
2. Natural resource mapping: Map natural resources that can be utilized for renewable energy technologies such as solar, wind, or microhydro energy.
3. Topographic and climate analysis: Analyze the local topography and climate to determine the most efficient type of renewable energy technology.

B. Onboarding Analysis

- **Objective:** Determine the optimal building orientation to maximize the efficiency of

renewable energy use, especially solar Energy.

- **Steps:**

1. Building orientation to sunlight: Determine the direction and angle of the building to maximize solar panel reception, thereby optimizing their performance.
2. Wind analysis: Examine the dominant wind direction in the region to harness the potential of wind energy with small wind turbines where possible.
3. Influence of temperature and humidity: Analyze the microclimate to ensure buildings can maximize the use of natural ventilation, thereby reducing the need for cooling energy.

C. Shape Analysis

Objective: To examine the shape and configuration of buildings that can support energy efficiency and adapt to local climatic conditions. Langkah-langkah:

1. Building shape design: Designing an energy-efficient building, such as one that can maximize the reception of sunlight or that reduces overheating (e.g., with the use of green roofs or cross ventilation).
2. Building material considerations: Choose building materials that have sound thermal insulation, which can reduce energy requirements for heating and cooling.
3. Open space design: Constructing open spaces that can be used for rainwater treatment or planting plants that support the concept of sustainability.

D. Building Concept

Objective: To design a building concept that integrates sustainable design principles with the application of renewable energy technology.

Langkah-langkah:

1. Utilization of local materials: Select materials that are readily available and environmentally friendly, thereby supporting the concepts of sustainability and local wisdom.
2. Environmentally friendly building design: Designing buildings that have high energy efficiency, reducing carbon footprint, and

utilizing renewable energy to meet the building's energy needs.

3. Application of passive architectural design: Uses a passive design that utilizes natural ventilation, optimal building orientation to sunlight, and protection against hot winds.

E. Use of Renewable Energy Technology

Objective: To apply renewable energy technology that is in accordance with the natural potential in Tembung Village, such as solar panels, microhydro, and biogas.

- Steps:
 1. Solar Panels: Determining the number of solar panels needed based on the building's energy needs and the potential of sunlight in Tembung Village.
 2. Microhydro: Analyzes the potential flow of water for microhydro power plants if natural conditions are favorable.
 3. Biogas: Designing biogas systems for organic waste treatment and energy production for kitchen or water heating purposes.
 4. Energy Storage Systems: Designing energy storage systems to ensure a stable supply of Energy when renewable sources are inactive, such as the use of energy storage batteries.

F. Sustainable Architecture Studies

Objective: Integrate the concept of sustainable architecture with the application of renewable energy technology to create environmentally friendly buildings.

Steps:

1. Environmental impact evaluation: Examine the environmental impact of the technology applied, including the reduction of carbon emissions and the efficient management of natural resources.
2. Energy Efficiency: Calculates the energy efficiency that can be achieved by utilizing renewable technologies and analyzes the resulting energy cost savings.
3. Social and economic impacts: Analyze the social and economic implications of the

application of renewable energy technology in villages, such as the creation of new jobs and the improvement of people's quality of life.

g. Data Collection Techniques

1. Interviews and Focus Group Discussions (FGDs) will be conducted with local communities and village leaders to explore their perceptions of the application of renewable energy technology and building design based on local wisdom.
2. Field Observation
Observations were carried out to see firsthand the physical condition of the location that will be used as a building site and the potential for renewable Energy that can be utilized.
3. Use of Measuring Instruments
Using tools such as a synarometer to measure the intensity of sunlight, an anemometer to measure wind speed, and a kWh meter to measure existing energy consumption.

h. Tools and Materials

Tool:

- Design Software: SketchUp, AutoCAD, and energy simulation software (HOMER Pro, RETScreen).
- Measuring Instruments: Synarometer, Anemometer, kWh meter, humidity meter, and temperature meter.

Material:

- Building Materials: Solar panels, small wind turbines, microhydro systems, and biogas.
- Document: BPS data related to energy consumption and government reports on renewable energy potential

RESULTS AND DISCUSSION

1. Site Analysis

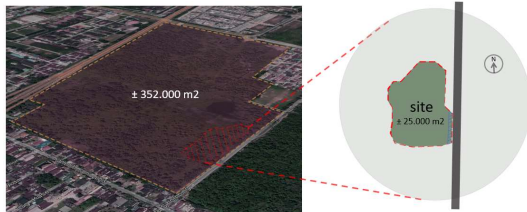


Figure 4 Tapak

Location: Jl. Kapten Batu Sihombing, Kenangan Baru, Tembung, Kec. Percut Sei Tuan, Deli Serdang Regency, North Sumatra 20371. Total area: ± 352.000 m². The area realized: ± 25,000 m².

2. Onboarding Analysis



Figure 5 Orientasi tapak

The view spreads around the site where there are albasia trees. The wind flow comes from the northwest and can change over time.

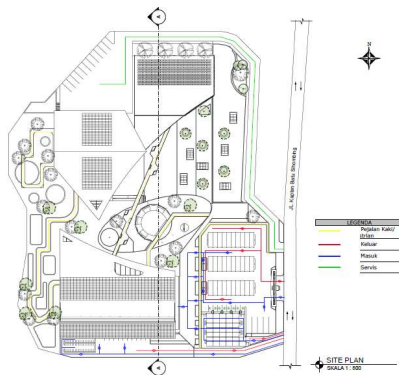


Figure 6 Siteplan

This circulation applies an inclusive design that allows visitors to explore any area they desire.

3. Shape analysis

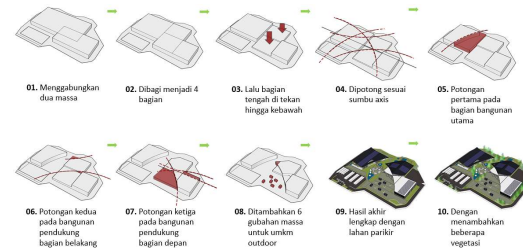


Figure 7 Shape transformation

The shape of the Nusantara Energi Kreatif building is designed based on the concept of the axis of the surrounding environment, making it more natural and adaptable, and also aligns with the prevailing wind direction around the site.

4. Building Concept



Figure 8 Main Building

Nusantara Energi Kreatif reflects an MSME center that combines local wisdom, the use of renewable energy, and the spirit of creative innovation to empower the people of Tembung Village. This building also has a futuristic feel but is still rooted in Indonesian culture.

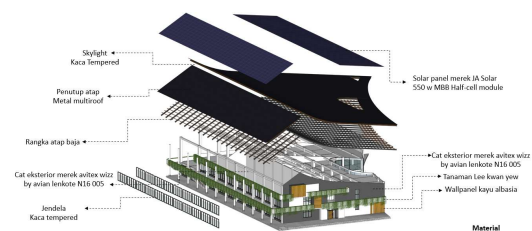


Figure 9: Use of renewable energy materials and technologies

The use of renewable Energy can be applied in the use of materials and technology for buildings.

5. Use of Renewable Energy Technology



Figure 10 Solar panels, rainwater retention, and kinetic energy sky bridge.

- The solar panel used is a JA Solar brand solar panel, a 550W MBB Half-cell module,

aiming to distribute an electrical power source to the building.

- Rainwater retention, aimed at flushing toilets, watering surrounding plants, or washing vehicles.
- The sky bridge, as a means of connecting the main building and supporting buildings, aims to distribute electricity sources to outdoor MSME buildings.

Table 4: Renewable energy waste utilization scheme

Sistem Renewable Energy	Types of Waste	Processing Technology	Recycling Results
Solar Panels	Photovoltaic/damaged module	Mechanical recycle	<ul style="list-style-type: none"> • Glass and aluminum for new construction materials or home décor • Copper waste for the electronics industry or craft products.
Rainwater Retention	Sludge & sedimentation	Biofiltration	Clean water for watering plants and toilets/flushes
Sky Bridge energi kinetics	Paving/broken paving fragments	Crushing & recasting	New floor construction materials with mosaic modifications

6. Utility System Implementation

The application of a utility system based on solar renewable Energy, biomass, kinetic Energy, and rainwater utilization can be an appropriate and sustainable solution with local potential and the needs of MSME actors. Rainwater containers and drainage systems can address flooding problems while providing water for irrigation or sanitation.

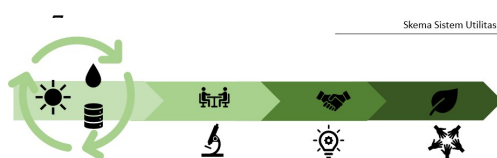


Figure 11 Utility system schema

However, the success of this integration depends on factors such as ease of care, affordable initial costs, and community

training. For example, piezoelectric technology (kinetic Energy) may need to be socialized to the community to make it easier to adopt. A gradual and participatory approach involving MSME actors in planning will ensure that this system is not only environmentally friendly but also increases productivity and economic value of MSME centers. Thus, this building is not only a symbol of sustainability but also a real green economy driver for the residents of Tembung village.

CONCLUSION

Based on the results of the research conducted, it can be concluded that the Creative Energy Archipelago Design in Tembung Village implements a sustainable energy transition model that combines technical, social, and economic aspects in an integrated manner. Through the application of energy efficiency,

the use of renewable resources, and flexible design, this design not only reduces dependence on fossil energy but also creates buildings that are adaptive to the tropical climate. The key to success lies in community-based energy buildings that ensure transparency, economic benefit-sharing, and local job creation and community involvement in planning to strengthen long-term sustainability.

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