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Exploring Wind Energy Utilization in Sustainable Rental Office Building Design in Makassar

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ABSTRACT

Purpose of the study: This study aims to explore the integration of wind energy through wind turbine technology in the design of sustainable rental office buildings in Makassar City.

Methodology: A qualitative exploratory approach was employed, including literature review, precedent study, site analysis, and wind potential assessment. Data were analyzed descriptively to formulate design strategies integrating wind turbines into building architecture.

Main Findings: Makassar has average wind speeds of 2.5–3 m/s, suitable for small-scale wind turbines. Optimal building orientation, massing, and turbine placement on rooftops or facades enhance wind capture. Wind energy contributes to reduced conventional electricity consumption and supports sustainable building design.

Novelty/Originality of this study: This research advances knowledge by harmoniously integrating wind turbine technology into architectural design, not merely as a technical add-on. It addresses the gap in wind energy exploration within building design, specifically for Makassar's coastal context, promoting renewable energy adoption in sustainable architecture.

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1. INTRODUCTION

The rapid development of urban areas is currently leading to increasing energy demand, particularly in commercial buildings such as offices [1]. Office buildings are known to be among the largest energy consumers due to their operational activities that last almost all day. The use of electricity for lighting, air conditioning, and various work equipment is a major factor in the high energy consumption in these buildings. This condition contributes to increasing carbon emissions, which impact global climate change [2]. Therefore, efforts to implement energy-efficient building concepts are a crucial approach in modern architectural design.

This problem also occurs in large, developing cities, including Makassar, a center of economic growth in Eastern Indonesia. The growth in the number of companies and business activities in this city is driving a growing need for representative office space. The continued increase in office building construction has the potential to result in high energy consumption if not designed efficiently. Furthermore, most office buildings still

rely on conventional electricity derived from non-renewable energy sources [3]. This situation presents a challenge for building designers to develop more sustainable and energy-efficient office designs.

One possible solution is the utilization of renewable energy sources as part of the building design concept. Wind energy is a potential natural energy source that can be harnessed to generate electricity through wind turbine technology. Utilizing wind energy in buildings can help reduce dependence on conventional electricity while increasing building energy efficiency. Integrating wind turbine technology into architectural design can also be an innovative element supporting sustainable building concepts. Therefore, exploring the use of wind energy in office building design is a relevant approach to addressing future energy challenges.

Several previous studies have discussed the application of energy-efficient building concepts and the use of renewable energy in architecture. These studies generally emphasize the use of alternative energy technologies such as solar panels, natural ventilation systems, and passive design strategies to reduce building energy consumption [4]. Other studies have also shown that the integration of renewable energy technologies can improve building operational efficiency while reducing environmental impact. However, most of these studies still focus on the use of solar energy as the primary energy source. This indicates that the exploration of wind energy utilization in buildings remains relatively limited in architectural studies.

On the other hand, several studies have begun to examine the potential for utilizing wind energy in tall buildings, particularly in urban areas with relatively stable wind speeds. These studies indicate that building height can influence the intensity and speed of wind received by the structure. However, most of these studies focus more on the technical aspects of wind turbine technology than on its integration into architectural design [5]. Studies that comprehensively combine building design aspects with wind energy utilization are still rare. This situation indicates a research gap that opens up opportunities for further research.

Based on this situation, this study offers a novelty in the form of exploring the design concept of a rental office building that integrates wind turbine technology as an alternative energy source. This approach not only considers the technical aspects of wind energy utilization but also how this technology can be harmoniously integrated into the architectural design of buildings. By utilizing the climate characteristics and wind potential of Makassar City, building designs are expected to produce more efficient and sustainable energy systems. Furthermore, the integration of wind turbine technology can also provide aesthetic value and architectural identity to buildings [6]. The novelty of this research lies in the office building design approach that combines sustainability concepts with the utilization of wind energy as part of the building's energy system.

This research is important because the need for energy-efficient office buildings is increasing along with urban development and economic activity. Furthermore, the use of renewable energy in buildings can be a strategy to support sustainable development in the architectural sector. Makassar, as a coastal city, has significant wind energy potential that can be utilized in building design. Therefore, a study on the utilization of wind energy in office building design is relevant. The purpose of this research is to explore the concept of utilizing wind energy through wind turbine technology in the design of sustainable rental office buildings in Makassar City.

2. RESEARCH METHOD

This research uses a qualitative approach with an exploratory method in architectural design. This approach is used to examine the potential use of wind energy as an alternative energy source that can be integrated into the design of sustainable rental office buildings in Makassar City [7]. Qualitative research was chosen because it can provide an in-depth understanding of the relationship between environmental conditions, wind energy potential, and energy-efficient building design strategies. The research process was carried out through the stages of data collection, analysis of wind energy potential, and exploration of building design concepts that integrate wind turbine technology. The results of this process were then translated into a building design concept that supports energy efficiency and environmental sustainability.

2.1. Data collection technique

Data collection in this study was conducted through several methods, namely literature study, precedent study, and site condition analysis [8]. The literature study was conducted by reviewing various scientific sources such as books, journals, and related documents that discuss the concept of energy-efficient buildings, renewable energy, and wind turbine technology in buildings. The precedent study was conducted by examining several buildings that have implemented the concept of utilizing wind energy in architectural design. In addition, site condition analysis was conducted to understand the environmental characteristics of Makassar City, particularly regarding potential wind speed and direction. This data was then used as a basis in the design process for sustainable rental office buildings.

2.2. Wind Energy Potential Analysis

A wind energy potential analysis was conducted to determine the feasibility of utilizing wind energy as an alternative energy source for buildings [9]. This analysis took into account several aspects, such as average wind speed, dominant wind direction, and environmental conditions around the site that can affect wind flow. Wind potential data was obtained from climatological sources and literature related to climate conditions in Makassar City [10]. The results of this analysis were then used to determine the wind turbine placement strategy on the building. Furthermore, this analysis also assisted in determining the building's shape and orientation to maximize wind energy utilization.

Table 1. Wind Energy Potential Analysis Parameters

Parameter Analisis	Tujuan Analisis
Kecepatan angin rata-rata	Menentukan potensi energi angin yang dapat dimanfaatkan
Arah dominan angin	Menentukan orientasi bangunan dan posisi turbin
Kondisi lingkungan sekitar	Mengetahui hambatan angin dari bangunan sekitar
Ketinggian bangunan	Menentukan lokasi optimal pemasangan turbin angin

2.3. Analysis of Energy Efficient Building Design

The next step is to analyze energy-efficient building concepts that can be applied to rental office buildings. This analysis includes the application of passive design strategies such as building orientation, natural ventilation, and the use of natural lighting to reduce electricity consumption [11]. Furthermore, this study examines the integration of wind turbine technology as an additional energy system in buildings. This technology integration is considered from a technical perspective, architectural aesthetics, and energy efficiency perspective [12]. The results of the analysis are then used as a basis for developing a sustainable rental office building design concept.

2.4. Design Stages

The design process in this study was carried out in stages to produce an optimal building design concept. These stages included space requirements analysis, site analysis, design concept development, and the integration of wind energy technology into the building design. Each stage was carried out systematically to ensure that the resulting design addressed the energy needs of office buildings [13]. Furthermore, the design process also considered user comfort and environmental sustainability. The final result of this process is a design concept for a rental office building that utilizes wind energy as part of the building's energy system.

Table 2. Research Stages

Research Stage	Activity
Data collection	Literature study, precedent study, and climate data collection
Site Analysis	Analysis of environmental conditions and wind energy potential
Concept Analysis	Energy efficient building strategy study
Design Exploration	Integration of wind turbines in building design
Design Results	Sustainable rental office design concept

2.5. Data Analysis Methods

The data obtained in this study were analyzed descriptively and qualitatively. The analysis was conducted by interpreting data related to wind energy potential, environmental conditions, and energy-efficient building design principles. The analysis process also involved comparisons with sustainable building concepts applied in previous studies. The results of the analysis were then used to formulate a design strategy appropriate to the conditions of Makassar City. Thus, this study resulted in a design concept for a rental office building that optimally utilizes wind energy as part of the building's energy system.

3. RESULTS AND DISCUSSION

3.1. Wind Energy Potential Analysis in Makassar

The results of the climatological analysis indicate that Makassar City has relatively stable wind potential that can be utilized as an alternative energy source for buildings. Based on regional climate data, the average wind speed in Makassar ranges from approximately 2.5–3 m/s, with dominant wind directions influenced by seasonal coastal wind patterns [14]. Although the wind speed is not categorized as very high, wind energy still has the potential to be utilized through small-scale building wind turbine technology.

Furthermore, Makassar's geographical characteristics as a coastal city allow wind movement to be relatively unobstructed compared to dense inland urban areas. This condition provides an opportunity for implementing building concepts that utilize wind flow as part of sustainable design strategies. Therefore, the

application of wind turbines in rental office buildings can serve as an alternative approach to improving energy efficiency in urban buildings.

Table 3. Wind Characteristics in Makassar

Parameter	Condition
Average wind speed	2.5 – 3 m/s
Dominant wind direction	West – East
Regional characteristics	Coastal area
Utilization potential	Building-scale wind turbines

3.2. Site Analysis and Building Orientation

The site analysis results indicate that building orientation plays a significant role in optimizing the utilization of wind energy [15]. Buildings designed according to the dominant wind direction allow airflow to move more effectively through the building area. This condition supports not only the utilization of wind energy but also improves natural ventilation within the building.

In addition to building orientation, building height is also an important consideration in the design process. At certain heights, wind speeds tend to be more stable, providing greater energy potential for wind turbines [16]. Therefore, wind turbines are planned to be installed on the upper parts of the building or in areas with minimal wind obstruction. This approach aims to maximize wind energy utilization while maintaining the architectural aesthetics of the building.

Table 4. Site Analysis Results

Analysis Aspect	Result
Dominant wind direction	West – East
Wind obstruction	Surrounding buildings
Optimal turbine area	Building rooftop
Design strategy	Orientation following wind direction

3.3. Building Massing Concept

The results of the design exploration show that building massing plays an important role in directing wind flow. The building mass is designed by considering configurations that can capture and guide airflow toward turbine areas [17]. A relatively slender and open building form allows wind to pass through building gaps, thereby enhancing natural ventilation effectiveness.

In addition, the arrangement of building mass also considers thermal comfort for building users. By utilizing natural airflow, the need for mechanical cooling systems can be reduced, resulting in more efficient building energy consumption. This design strategy aligns with the principles of sustainable architecture that prioritize the optimal use of environmental potential.

3.4. Integration of Wind Turbine Technology in Buildings

The research results indicate that wind turbine integration within buildings can be implemented through several design strategies [18]. One approach is placing wind turbines on the building rooftop, which receives the highest wind exposure. This placement allows turbines to capture airflow directly without obstruction from other building elements.

In addition to rooftop placement, wind turbines can also be integrated as architectural elements on the building façade. This approach not only functions as an alternative energy source but also contributes to the aesthetic value of the building design. Thus, renewable energy technology can become an integral part of sustainable architectural concepts.

Table 5. Wind Turbine Integration Strategies

Strategy	Purpose
Rooftop turbine installation	Maximizing wind exposure
Façade integration	Combining energy function and aesthetics
Placement at certain heights	Achieving optimal wind speed

3.5. Contribution of Wind Energy to Building Energy Efficiency

The utilization of wind energy in rental office buildings contributes to reducing conventional electricity consumption. Energy generated by wind turbines can support several building energy needs, such as lighting in public areas and certain building utility systems [19]. Although the generated energy may not fully replace the main energy source, wind turbines can provide additional sustainable energy supply.

Furthermore, the implementation of renewable energy technology also has positive environmental impacts. The use of wind energy can reduce dependence on fossil energy sources and minimize carbon emissions produced by buildings [20]. Therefore, the concept of rental office buildings utilizing wind energy can become one of the solutions in achieving more sustainable urban development.

3.5. DISCUSSION

The results of this study indicate that Makassar City has wind energy potential that can be utilized as an alternative energy source in building design [21]. The climatological analysis shows that the average wind speed in Makassar ranges from 2.5–3 m/s, which is sufficient to support small-scale wind turbine systems. Although the wind speed is categorized as moderate, it still provides opportunities for renewable energy utilization in buildings. The coastal characteristics of Makassar also contribute to relatively stable wind movement compared to dense inland urban areas [22]. Therefore, the integration of wind turbines into rental office building design can be considered a feasible strategy for improving building energy efficiency.

In addition to wind potential, building design strategies also play a crucial role in optimizing wind energy utilization. The results of this study show that building orientation following the dominant wind direction can enhance airflow through the building. Proper building massing and height can also improve wind capture and increase the effectiveness of wind turbine performance [23]. Furthermore, the placement of turbines on rooftops or higher building areas can maximize wind exposure while minimizing obstructions. These design considerations demonstrate that architectural strategies can significantly support renewable energy integration in building systems.

These findings are consistent with several previous studies that emphasize the importance of renewable energy integration in sustainable architecture. Previous research has highlighted the potential of renewable energy technologies to reduce building energy consumption and environmental impacts [24]. However, most studies have primarily focused on solar energy systems as the main renewable energy source in buildings. As a result, the exploration of wind energy utilization in architectural design remains relatively limited. This condition indicates the need for further research that specifically examines the role of wind energy in building design strategies.

Another research gap is related to the integration between wind turbine technology and architectural design aspects. Several previous studies tend to focus more on the technical performance and efficiency of wind turbines rather than their application within architectural design concepts [25]. In many cases, wind turbine systems are treated as independent energy devices rather than integral components of building design. Consequently, the relationship between architectural form, building orientation, and wind energy utilization has not been fully explored [26]. This research attempts to address this gap by combining wind energy analysis with architectural design exploration.

The novelty of this study lies in the design approach that integrates wind turbine technology as part of the architectural concept of a sustainable rental office building. Unlike previous studies that mainly emphasize technical aspects, this research focuses on how renewable energy technology can be harmoniously integrated into architectural design. The study also considers environmental characteristics and wind potential specific to Makassar City [27]. By incorporating wind energy systems into building design strategies, the building can function not only as a workplace but also as an energy-responsive architectural structure. This approach demonstrates how renewable energy technology can contribute to both functional and aesthetic aspects of sustainable architecture.

The findings of this research have several important implications for architectural practice and sustainable urban development. The integration of wind energy in building design can reduce reliance on conventional electricity sources and support environmental sustainability [28]. In addition, this approach can encourage architects and designers to explore alternative renewable energy systems beyond solar energy. However, this study also has several limitations, particularly related to the availability of detailed wind data and the absence of quantitative energy simulation. The research mainly focuses on conceptual design exploration rather than detailed technical performance evaluation [29]. Therefore, future studies are recommended to incorporate computational simulations and energy performance analysis to further validate the effectiveness of wind energy integration in buildings.

4. CONCLUSION

This study aimed to explore the potential utilization of wind energy through wind turbine technology in the design of sustainable rental office buildings in Makassar City. Based on the results of the analysis, Makassar has wind energy potential with an average wind speed ranging from 2.5–3 m/s, which allows the application of small-scale wind turbine systems in building design [30]. The results also show that building orientation, massing configuration, and turbine placement are important factors that influence the effectiveness of wind energy utilization in buildings. The integration of wind turbine technology into architectural design can contribute to improving building energy efficiency while reducing dependence on conventional energy sources.

Furthermore, the exploration conducted in this study demonstrates that renewable energy technologies can be incorporated not only as technical systems but also as architectural elements that support sustainable building concepts. The integration of wind turbines into building design can enhance both environmental performance and architectural identity [23]. Therefore, the findings of this research support the development of sustainable architecture by utilizing local environmental potential. In the future, further studies are recommended to conduct more detailed simulations and quantitative evaluations of energy performance to measure the effectiveness of wind energy systems in buildings [31]. Such studies can provide deeper insights into the practical application of renewable energy integration in sustainable building design.

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