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Planning and Analysis of Green Building Concept Implementation for a Hospital Building in Koto Tangah District, Padang City

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ABSTRACT

The increasing number of healthcare facilities in Indonesia has resulted in higher energy and water consumption, while hospitals are required to operate continuously for 24 hours. According to Statistics Indonesia (Badan Pusat Statistik), the country has 2,636 general hospitals and 519 specialized hospitals, contributing to greater resource consumption and non-medical waste generation. Therefore, implementing green building and green hospital concepts has become a strategic necessity for sustainable healthcare development. This study employed a descriptive quantitative approach using a case study of the proposed Restu Ibu Koto Tangah Hospital in Padang City, with a total building area of 4,000 m². The analysis evaluated energy consumption, electricity generation from a 150 kWp photovoltaic solar power system, clean water demand, rainwater harvesting potential based on actual rainfall data, and carbon emission reduction. The results indicate that the proposed design could reduce grid electricity consumption by 43.9%, harvest approximately 3,870 m³ of rainwater annually, and reduce carbon emissions by approximately 523 tons of CO_2 per year. The study recommends optimizing passive design, integrating rainwater harvesting with the clean water supply system, and pursuing Greenship certification to support compliance with the Indonesian Hospital Accreditation Standards (STARKES).

INTRODUCTION

Hospital buildings are among the most energy intensive building types compared with other commercial buildings, as they operate continuously for 24 hours a day while supporting energy demanding medical equipment, Heating, Ventilation, and Air Conditioning (HVAC) systems, and uninterrupted lighting. According to Statistics Indonesia[1], Indonesia has 2,636 general hospitals and 519 specialized hospitals. The increasing number of hospitals has been accompanied by higher water consumption and the generation of non-medical waste that has not yet been managed optimally[1]. This condition has made the green building concept an approach that integrates energy efficient and environmentally friendly building products and resource utilization from the planning stage [2] a strategic necessity for the healthcare sector rather than merely an aesthetic design option. This issue is particularly relevant in the local context of Padang City, which is characterized by a very high rainfall climate. In March 2024, Padang recorded a daily rainfall of 394.6 mm, exceeding Jakarta's highest daily rainfall record that had stood for 154 years [3]. This finding highlight both the significant potential for rainwater harvesting as an alternative water resource and the urgent need to integrate climate risk mitigation into building design[2].

This study aims to calculate the building's energy consumption before and after the implementation of energy efficiency measures, assess the contribution of photovoltaic solar panels to the building's energy demand, estimate clean water demand and potential water savings, evaluate the potential for rainwater harvesting based on actual rainfall data from Padang City, quantify the resulting reduction in carbon emissions, and formulate green building strategies that are relevant to the local climatic conditions and regulatory framework. Practically, this study is expected to provide a quantitative technical reference for hospital planners and managers in preparing resource efficiency feasibility studies from the early design stage while supporting compliance with the Indonesian Hospital

Accreditation Standards (STARKES) related to environmental health, as stipulated in the Regulation of the Minister of Health of the Republic of Indonesia No. 7 of 2019. Academically, this study contributes to the advancement of the green hospital literature in Indonesia by presenting an integrated calculation model that simultaneously evaluates energy, water, and carbon emission aspects within a single case study, whereas previous studies have generally examined these aspects separately[3].

Several previous studies have investigated the implementation of green hospitals in Indonesia; however, most have focused on assessing institutional readiness or the level of policy implementation using qualitative approaches. For example, Perdini, Riani, and Nurhasanah formulated green hospital strategies to support compliance with STARKES using descriptive qualitative and quantitative methods in a hospital in West Java. Similarly, a study conducted at Panti Rapih Hospital in Yogyakarta reported that the implementation of environmentally friendly hospital practices had reached 65%, without providing detailed technical indicators underlying this achievement[4]. In terms of renewable energy, a rooftop photovoltaic (PV) simulation conducted at the Teaching Hospital of Udayana University produced more measurable technical findings, indicating an annual electricity generation of 1,528 kWh/kWp, capable of supplying approximately 22.6% of the hospital's total energy demand. However, the study did not simultaneously evaluate water conservation or rainwater harvesting. Regarding water management, a rainwater harvesting study at the Sumatra Institute of Technology reported a reduction of up to 40% in annual building water demand, while a residential area study in Jakarta achieved water savings of up to 87.12% on rainy days. Nevertheless, both studies were conducted on educational and residential buildings rather than healthcare facilities. Furthermore, a recent systematic review by Sahoo, Kumar, and Thakur published in the *Journal of Cleaner Production* emphasized that global green healthcare research continues to be dominated by policy analyses and conceptual frameworks, whereas integrated quantitative studies at the individual building level remain relatively limited[4].

Based on these research gaps, the novelty of this study lies in three main aspects. First, this study integrates four key components energy efficiency, solar energy generation, water conservation, and rainwater harvesting into a single, interconnected analytical framework for one hospital building, rather than examining each aspect separately as has commonly been done in previous studies. Second, this study utilizes actual rainfall data specific to Padang City, an area characterized by extreme rainfall conditions that has received relatively little attention in green hospital research compared with regions such as Java and Bali, which have dominated the existing literature. Third, this study presents an estimate of carbon emission reductions resulting from the combined effects of energy efficiency measures and renewable energy utilization simultaneously, rather than considering only one of these factors. This integrated approach provides a more comprehensive and realistic assessment of environmental impacts, offering valuable insights for planning similar hospital buildings in other tropical rainforest climate regions across Indonesia.

RESEARCH METHODS

This study employed a descriptive quantitative approach using a case study method on the proposed Restu Ibu Koto Tangah Hospital building in Padang City, a single-story hospital with a total floor area of 4,000 m². The case study approach was selected because the objective of this research is to develop a quantitative calculation model that is closely linked to the technical and climatological characteristics of a specific building, as commonly applied in green building planning studies at the individual building level[5]. The study object was chosen because it represents a medium scale hospital typology that is increasingly being developed in the urban coastal areas of western Sumatra and is located in a region characterized by extreme rainfall, making it highly suitable for evaluating the potential of rainwater harvesting, as discussed in the Introduction[6].

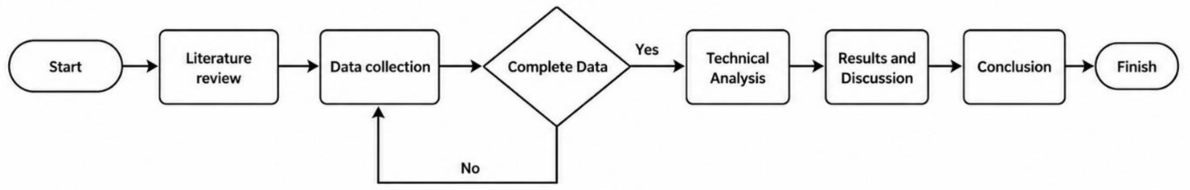

Figure 1. Research Flow

Based on the completed architectural design, the building adopts a tropical modern architectural style incorporating several passive design features that provide the basis for the analyses conducted in this study. The front facade is equipped with vertical aluminum fins that function as sun shading devices to reduce direct solar radiation while allowing natural daylight to penetrate the interior spaces. These elements are complemented by geometric lattice ornaments inspired by Minangkabau architecture, which serve as a secondary skin on the main facade.

Picture 1. Proposed Hospital Building Design in Koto Tangah District

The roof is constructed using red metal roofing tiles with a steep pitch suitable for a humid tropical climate, enabling rapid rainwater runoff and preventing water accumulation. In the center of the building layout, an open courtyard provides natural lighting and ventilation for the surrounding outpatient clinics and treatment rooms. At the rear of the building, a dedicated area has been allocated for photovoltaic solar panels and a water storage tank, indicating that both renewable energy infrastructure and rainwater harvesting systems were incorporated into the design from the initial planning stage rather than being introduced as later additions.

The data used in this study consist of both primary and secondary data. The primary data include the building's technical specifications, such as the total floor area, baseline energy consumption intensity, photovoltaic (PV) solar panel capacity, per capita water demand, and roof catchment area for rainwater harvesting, all of which were obtained directly from the project planning documents[7]. The secondary data comprise climatological information obtained from rainfall station databases provided by the Meteorology, Climatology, and Geophysics Agency (BMKG), while the grid electricity emission factor was adopted from the national reference values published by the Directorate General of Electricity, Ministry of Energy and Mineral Resources (MEMR)[8]. Several parameters that were not explicitly specified in the project planning documents namely the specific electricity generation of the photovoltaic system and the estimated daily number of building occupants were determined using an analogy approach based on similar case studies of hospital buildings in Indonesia, as well as space capacity estimations derived from the building layout, as presented in Table 1.

Table 1. Planning Data and Assumptions

Parameter	Value	Source/Description
Building floor area	4,000 m²	Project planning data
Baseline energy consumption	350 kWh/m²/year	Project planning data

Parameter	Value	Source/Description
Potential energy savings (passive design, LED lighting, occupancy sensors, energy efficient air conditioning)	30%	Project planning data
Photovoltaic (PV) system capacity	150 kWp	Project planning data
Specific electricity generation of the PV system	1,300 kWh/kWp/year	Assumption, adjusted from the Teaching Hospital of Udayana University case study (1,528 kWh/kWp/year) to account for the higher cloud cover and rainfall conditions in Padang compared with Bali [7]
Clean water demand	50 liters/person/day	Project planning data
Estimated daily building occupants	300 persons/day	Assumption based on the space capacity shown in the building layout (approximately 20 outpatient clinic/administrative rooms and 20 inpatient beds/treatment rooms)
Water saving sanitary fixture efficiency	20%	Project planning data
Rainwater catchment roof area	1,250 m²	Project planning data

The calculations were carried out using standard environmental engineering and energy equations commonly adopted in similar studies[9]. Building energy consumption was calculated by multiplying the energy intensity (kWh/m²/year) by the total building floor area (m²). Electricity generation from the photovoltaic (PV) system was estimated by multiplying the installed capacity (kWp) by the annual specific electricity generation (kWh/kWp/year). Clean water demand was determined by multiplying the estimated number of building occupants by the per capita water consumption (liters/person/day) and the number of days in one year. The rainwater harvesting potential was calculated using the roof catchment area (m²), annual rainfall (m), and the roof runoff coefficient. Carbon emission reduction was estimated by multiplying the amount of energy saved or generated (kWh) by the grid electricity emission factor (kg CO_2/kWh)[10].

RESULTS AND DISCUSSION

Based on the planning data and assumptions described in the research methodology section, the analysis was conducted systematically across seven key aspects that constitute the focus of this study: building energy consumption before and after the implementation of energy efficiency measures, annual electricity generation from the photovoltaic (PV) system, the remaining electricity demand supplied by the grid, the percentage of energy savings achieved, clean water demand before and after the implementation of water efficient fixtures, the potential for rainwater harvesting, and the reduction in carbon emissions resulting from the combined application of energy efficiency measures and solar energy utilization. These seven aspects are presented sequentially in the following sections, each accompanied by detailed technical calculations and a discussion that compares the findings with those of previous studies. This approach provides a clear context for evaluating the significance of the results and positioning this study within the existing body of research on green hospital and green building implementation.

1. Annual Energy Consumption Before and After Green Building Implementation

$\boldsymbol{E_{before}}$ = 350 × 4,000 = 1,400,000 kWh/year

$\boldsymbol{E_{after}}$ = 1,400,000 × (1 − 0.30) = 980,000 kWh/year

The annual energy savings of 420,000 kWh are consistent with the findings of Firmawan, Purwanto, and Rahmawati, who analyzed the implementation of green construction in the Integrated Emergency Department (IGD) development project at K.R.M.T. Wongsonegoro Regional General Hospital in Semarang. Their study identified energy efficiency as one of the key indicators within the Green Construction Site Index. These findings demonstrate that passive design strategies and energy efficient building systems not only reduce operational costs but also serve as measurable performance indicators in green construction assessment frameworks, which are increasingly being adopted in hospital development projects across Indonesia.

2. Annual Electricity Generation from the Photovoltaic (PV) System

$\boldsymbol{P_{pv}}$ = 150×1.300=195.000 kWh/year

The photovoltaic (PV) system generates an estimated 195,000 kWh of electricity annually, representing approximately 19.9% of the building's energy demand after the implementation of energy efficiency measures (980,000 kWh/year). Compared with the study conducted at the Teaching Hospital of Udayana University, where the rooftop PV system supplied approximately 22.6% of the hospital's total energy consumption, the planned PV contribution for this building can be considered realistic and slightly more conservative. This is because the installed capacity of 150 kWp was designed to provide a partial contribution to the building's electricity demand rather than to achieve complete energy self-sufficiency or a net zero energy building[11].

3. Grid Electricity Demand After Green Building Implementation

$\boldsymbol{E_{jaringan}}$ = 980.000 − 195.000 = 785.000 kWh/year

The remaining annual electricity demand of 785,000 kWh must continue to be supplied by the utility grid. Therefore, a reliable backup power system remains essential, considering that hospital operations cannot tolerate even brief interruptions in electricity supply.

4. Percentage of Grid Electricity Savings

Penghematan = $\frac{1.400.000-785.000}{1.400.000}$ x 100 % = 43,9 %

The achieved 43.9% reduction in grid electricity consumption represents a significant level of energy savings for a medium scale healthcare facility and falls within a reasonable range compared with the performance of green hospital implementation in Indonesia. For comparison, a study on the implementation of green hospital practices at Panti Rapih Hospital in Yogyakarta reported an overall green hospital implementation score of 65%, covering the combined assessment of energy, water, waste management, and other environmental aspects. Therefore, the 43.9% savings achieved specifically in the electricity sector in this study demonstrate a competitive performance, although further improvements could still be achieved through additional optimization measures.

5. Clean Water Demand Before and After the Implementation of Water Efficient Fixtures

$\boldsymbol{Q_{before}}$ = 300 × 50 × 365 = 5.475.000 liter/year (5.475 m3/year)

$\boldsymbol{Q_{after}}$ = 5.475.000 × (1 − 0,20) = 4.380.000 liter/year (4.380 m3/year)

The annual water savings of 1,095 m^3 are particularly significant because clean water management is explicitly regulated under the Regulation of the Minister of Health of the Republic of Indonesia No. 7 of 2019 on Hospital Environmental Health. Consequently, this level of efficiency contributes not only to reducing operational costs but also to supporting compliance with national environmental health regulations for hospitals[12].

6. Annual Rainwater Harvesting Potential

$\boldsymbol{V_{hujan}}$ = 1.250 × 3,87 × 0,8 = 3.870 m3/year

The estimated annual rainwater harvesting potential of 3,870 m³ is equivalent to approximately 88.4% of the building's total annual clean water demand after the implementation of water efficient fixtures (4,380 m³/year). This result is consistent with previous rainwater harvesting studies in Indonesia, which generally reported water saving potentials ranging from 40% to 87.12%, depending on local rainfall intensity. Since Padang City is characterized by exceptionally high annual rainfall (exceeding 3,800 mm/year), the projected performance of the rainwater harvesting system is close to the upper limit reported in previous studies. Therefore, harvested rainwater has strong potential to serve as the primary water source for non-potable applications, including toilet flushing, landscape irrigation, and cleaning of service areas[13].

7. Carbon Emission Reduction

$EM_{efficiency}$ = 420.000 × 0,85 = 357.000 kg CO2/year

EM_{pv} = 195.000 × 0,85 = 165.750 kg CO2/year

EM_{total} = 357.000 + 165.750 = 522.750 kg CO2/year = 523 ton CO2/year

The combined implementation of energy efficiency measures and the photovoltaic (PV) system is estimated to reduce carbon emissions by approximately 523 tons of CO_2 per year. For comparison, a rooftop PV study conducted at Proklamasi 45 University reported a total carbon emission reduction of 576.3 tons of CO_2 over a 30 years period from an annual electricity generation of 31.17 MWh. When converted to an annual basis, the resulting annual carbon emission reduction is substantially lower than that achieved in the present study. This difference is reasonable because the proposed hospital building incorporates a significantly larger photovoltaic system (150 kWp) and accounts for the combined contribution of both building energy efficiency measures and renewable energy generation, rather than considering the contribution of the photovoltaic system alone[14].

Based on the calculation results and the literature review, several strategies are recommended to further enhance the green building performance of the proposed hospital. The existing passive design features should be optimized by maintaining the orientation of the vertical façade fins and geometric screening elements to ensure that the largest glazed surfaces are not directly exposed to the western sun, thereby minimizing afternoon solar heat gain. The central courtyard should be maximized as a source of natural daylight and ventilation, supporting indoor environmental quality, which is one of the key assessment criteria in the Greenship rating system developed by the Green Building Council Indonesia (GBCI). If additional service roof space is available, the photovoltaic (PV) system capacity should be expanded, as the current 150 kWp installation supplies only approximately 20% of the building's post-efficiency energy demand[15]. Such expansion would also improve the hospital's energy resilience against potential power supply disruptions caused by natural disasters, an important consideration in disaster-prone areas such as Padang. Furthermore, a hybrid integration of the rainwater harvesting and clean water supply systems is recommended, given that the estimated annual rainwater harvesting potential (3,870 m³/year) nearly matches the building's annual clean water demand. Under this approach, harvested rainwater can be allocated for non-potable uses, such as toilet flushing, landscape irrigation, and service area cleaning, while treated clean water is reserved for medical and potable purposes[16]. The implementation of a Building Automation System (BAS) is also recommended to enable real time monitoring of energy and water consumption as part of sustainable green hospital operations. Finally, pursuing Greenship certification from GBCI would provide independent validation of the building's environmental performance while supporting compliance with the Indonesian Hospital Accreditation Standards (STARKES) related to environmental health, as stipulated in the Regulation of the Minister of Health of the Republic of Indonesia No. 7 of 2019. In addition, the use of high emissivity roofing and wall materials (cool roof and cool wall systems) is recommended to reduce cooling loads on the HVAC system, considering the consistently high temperature and humidity associated with Padang City's humid tropical climate[17].

CONCLUSION

The implementation of the green building concept in the proposed Restu Ibu Koto Tangah Hospital, with a total floor area of 4,000 m², demonstrates significant quantitative benefits. The proposed design is estimated to achieve a 43.9% reduction in grid electricity consumption, 20% savings in clean water demand (equivalent to 1,095 m³/year), a rainwater harvesting potential of 3,870 m³/year, capable of supplying 88.4% of the building's non-potable water demand, and a carbon emission reduction of approximately 523 tons of CO_2 per year. These findings are consistent with previous green hospital and green building studies conducted in Indonesia and demonstrate that the proposed architectural design including vertical sun shading fins, a central courtyard, and infrastructure for photovoltaic (PV) systems and rainwater harvesting provides a strong technical foundation for further development toward formal green building certification and compliance with the Indonesian Hospital Accreditation Standards (STARKES)[18].

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