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Energy Efficient Low-Cost Housing in Ho Chi Minh using EDGE Buildings

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Abstract. Various forecasts on the urbanization rate in the world state that more than 50% of the world's population will live in cities by 2030. In the condition of land scarcity i.e. the land availability in the city is limited, a compact development is needed. Compact development will be closely related to Transit-Oriented Development (TOD). Transit-oriented development is not only about transit, but consisting of mixture development of housing, office, retail, and/or other amenities. In this type of development, vertical housing is unavoidable, including housing schemes for a low-income citizen, thus well-performed low-cost housing is important to be studied. Among the numerous studies, some focus on the construction materials and methods, some others on the comfort and health aspect, more on the management of the building, and not least focus on energy consumption of the housing building. This study develops an energy-efficient low-cost apartment through the calculation of various passive and active design strategies. The study uses two parameters i.e. energy saving percentage and incremental cost to determine the most optimal combination strategies. The case study in this research is in Ho Chi Minh City, Vietnam. The comparison of the design alternatives is done quantitatively using EDGE Buildings. The combination of low-cost housing design strategies can save energy by 49.86% with an incremental cost of 27,598,581 VND and the payback period in 5.21 years.

1. Introduction

Urbanization has become a major source of economic growth, especially in developing countries. The Organization for Economic Co-operation and Development [1] argues that by 2008 half of the world's population lived in cities, and by 2030 cities will house 60% of the world's population [1]. Based on data from the World Bank, more than 50% of the world's population in 2018 live in cities and will increase to 70% in 2050. The United Nation Population Division estimates the world rate of urbanization has reached 50% as of 2010. It is also projected that approximately 64% of developing countries and 86% of developed countries will be urbanized by 2050 [2]. Based on these data, it concluded that the movement of rural to the city will increase and the current cities will face the problems. The future cities would also be the same if they are not prepared. The problems are related to the fulfillment of the basic needs of the cities such as water, food, and house. The problem with housing is land scarcity i.e limited land availability in the city and the housing affordability. The limited availability of land makes several cities growing as urban sprawl that gives a direct or indirect impact on human life [3], such as



environmental quality, both air and water quality [4]. Based on the fact, urban sprawl is considered less sustainable than compact development. Thus, a compact city is always favored than the sprawling one

Housing development in compact city development is formed as vertical housing, especially affordable vertical housing. In terms of affordable housing –as it should be more concerned by city municipalities–, a city should not only consider the cost of construction, but also the health and comfort standard of the building. The building also should follow the principle of sustainable development [5]. Besides, sustainable vertical housing also needs to consider the socio-economic aspects, so the housing can be reached by the lower-middle class through a computational approach in optimizing affordable housing. The research focuses on affordable housing studies with an energy-saving concept to reduce the cost of electricity bills and reduce energy consumption.

Previous research has discussed energy-efficient buildings for several countries with different climates. However, there is a lack of previous research studies that discuss in tropical climates issue. It is generally conducted in non-tropical countries such as Hong Kong, the United Arab Emirates, Australia, and others. Based on these, this research study will focus on tropical climatic conditions. One of the countries that have a tropical climate, Vietnam. Therefore, the case study in this paper is Ho Chi Minh City, Vietnam. Ho Chi Minh is the largest city in Vietnam, located near the Mekong river delta. The city has a tropical climate with an average humidity of 75%. The year is divided into two distinct seasons it is a rainy and dry season. The average temperature is 28°C, with the highest temperature reaching 39°C and the lowest around below 16°C.

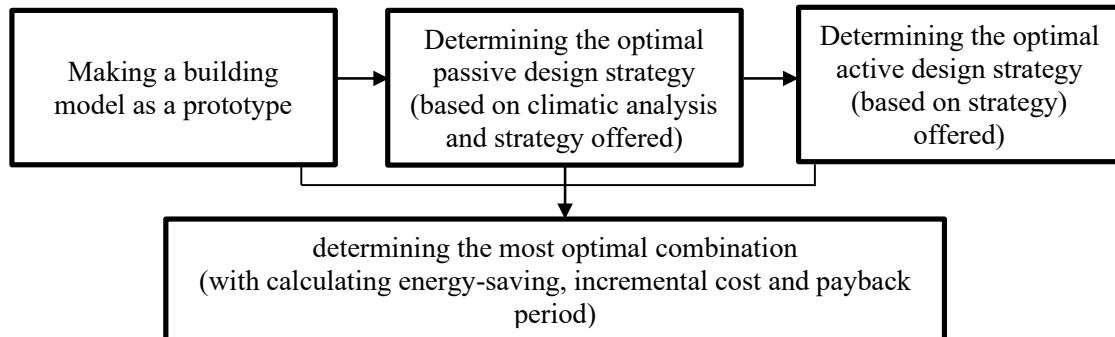
The highest temperature in Ho Chi Minh is 39°C. This is an extreme temperature and very influential on operational energy such as equipment for cooling. Similarly, the lowest temperature of 16°C will make the building needs heating equipment. Previous research said that passive design and active design strategies will affect the reduction in operational energy loads [10]. Therefore, this research proposes an energy-efficient design strategy for affordable low-cost housing in Ho Chi Minh City, because it is important to be researched and developed. The low-cost housing consideration of passive and active strategy. Also, the study describes the energy-saving percentage to determine the most optimal combination strategies by considering incremental costs in Vietnam. This study is beneficial for residents in operational activities, such as lighting, ventilation, air conditioning, and equipment usage. This research also can be used by planners for the optimal design strategy of energy-efficient low-cost housing.

2. Methodology

This research is a quantitative study [6] with a computational approach with the EDGE Building application as its tool. EDGE Building is an online platform that helps to determine the most cost-effective options for designing green within a local climate context. EDGE Building is an application, with universal standards from the green building certification system for emerging markets. The EDGE application was developed by IFC (International Finance Corporation) which is part of the World Bank Group. EDGE can be used for buildings of all vintages, including new construction, existing buildings, and major retrofits [7][4].

In this case, this study will use the weather data of Ho Chi Minh City to be simulated. This simulation is done by inputting the physical data of the building and choosing a strategy that will be applied. Based on the data inputted, total energy savings will be obtained. Standard savings based on EDGE applications are at least 20% energy savings, 20% water savings, and 20% energy savings contained in materials. However, this study will focus on energy saving.

Data collection is carried out by collecting literature studies on condition and trends in the construction of low-cost housing in Ho Chi Minh, then make a prototype model for simulated. Besides that, data is collected through a literature study on passive and active design strategies that can affect operational energy reduction. The selection of a passive and active design strategy also considers the minimum cost and building data on case studies. It also carried out trial and error in its simulations to determine which design components were the most optimal. In the EDGE Building, there are a variety of strategies that can be applied, both passive and active strategies. The combination of passive and active design strategies is also determined using graphical. The steps of the research are as follows:



The location of the case study in this paper is in Ho Chi Minh City, Vietnam. Below is a location map that will be simulated to obtain the optimum passive design and active design strategies (figure 1).



Figure 1. Location map of low-cost housing that will be simulated

3. Result and Discussion

3.1. Energy-efficient buildings

The Chartered Institute of Building Service Engineers [8] describes an energy-efficient building as one that provides the required internal environment, thermal and visual comfort with minimum energy use in a cost-effective. Therefore, high-density living is one of the solutions. Affordability of access is urgently needed in crowded cities, thus called TOD. TOD is one of the urban development approaches that adopt mixed spatial planning and maximizing the use of transportation. There are several characteristics of mixture development that can be achieved easily by walking or cycling, one of them is apartment buildings or condominiums. If related to sustainability, TOD is one of a solution in energy efficiency, because the fuel used for transportation is reduced. Likewise, residential facilities also need to consider energy efficiency, so energy-efficient building designs can be one of the solutions for development to continue but with low energy consumption. Previous research has established that by making a concept design stage can achieve a significant effect on the potential energy performance. Furthermore, designing energy-efficient buildings can reduced running costs, environmental impacts, improved ambient conditions, and increased equipment life [5][9]. An energy-efficient building needs to carry out various design strategies, namely passive design strategies and active design strategies.

3.2. Passive design strategy and active design strategy

The passive design strategy is a strategy that applied to the building envelopes to achieve thermal and visual comfort with low energy consumption such as keeping a coolness, avoiding solar heat radiation,

and providing natural lighting [10], thus that the intensity of the equipment usage related to electrical energy is reduced [11]. Strategy to be developed by EDGE Building simulation parameters.

An active design strategy is an optimization step towards HVAC by considering the combination and performance of appropriate technology [9]. An active strategy is also an anticipatory way of completing the passive strategy optimization, such as equipment installed in a building. Parameters of active design strategy will be offered by EDGE Building simulation. Saving energy by applying a passive design to a building is a solution, but the technological approach for a building will be able to save energy more effectively [12][11].

This research is done quantitatively with a computational approach using the EDGE Building application. EDGE Building is an online platform that helps to determine the most cost-effective options for designing green within a local climate context. EDGE can be used for buildings of all vintages, including new construction, existing buildings, and major retrofits. In the EDGE Building, there are a variety of strategies that can be applied, both passive and active strategies that need to be analyzed first. The parameters in this study are incremental costs and the amount of energy saving.

The research focuses on calculating passive design strategies and active design strategies. The first stage in this research is determining the optimal passive design strategy using diagrams based on an analysis of climate conditions in Ho Chi Minh City, Vietnam, and considers incremental costs, as well as the amount of energy saving. The next stage is determining the optimal active design strategy that also considers incremental costs and saving. The final stage is determining the most optimal combination of design strategies, calculating energy-saving potential, incremental costs, and payback periods based on the EDGE Buildings simulation.

3.3. Energy simulation of base-case

The base case model in this study is made to resemble the characteristics of a vertical residential building in Ho Chi Minh City. The base case model serves as a vertical housing consisting of 6 floors including a basement, has 100 units, each measuring 50 m² which can be filled by 4 occupants. The base-case model was simulated to determine the annual energy consumption. The final energy use based on EDGE Building simulation is about 495.02 kWh/month/unit. This value is obtained from building data, location, and type of building that offered by the EDGE Building. Furthermore, this value would be used as the base for comparison after applying the passive design and active design measures to improve the energy efficiency for low-cost housing. Below is the base-case chart that will be improved in this study (diagram 1).

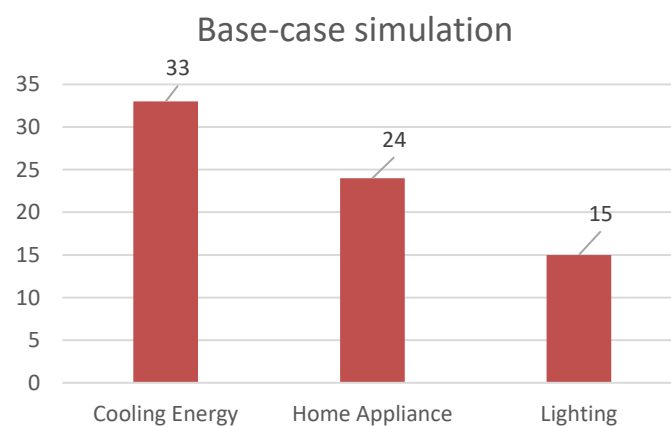


Diagram 1. Base-case simulation of case study

3.4. Design Passive Strategies Analysis

The strategies through passive design are carried out with a tropical climate analysis and simulation. Design passive strategies that can be simulated in EDGE Building are reduced WWR, using reflective paint for roof and external walls, using external shading devices, adding insulation of roof and external walls, using low-E coated glass, using higher thermal performance glass, and applying natural

ventilation. In the simulation, all strategies are combined. EDGE Building simulation finds 4 options in a combination of passive design strategies that can be applied to low-cost housing. The following are passive design strategies in diagram 2.

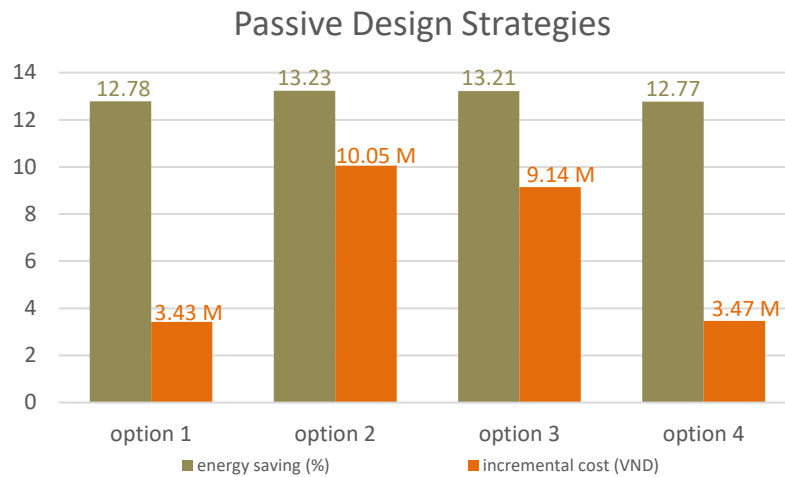


Diagram 2. Combination variation of passive design strategies

Diagrams above show possible options for applying to low-cost housing passive strategies, it is optional 1 with a reduced WWR, using reflective paint for a roof, reflective paint for external walls, applying external shading devices, using low e-coated glass and applying natural ventilation. Therefore, modeling applications will be designed by intervening in the building design. Based on these data, the model design is shown below to see the savings. A visualization of a strategy design concept that adapted from simulation results will be shown in figure 2 below.



Figure 2. Visualization of a passive design concept

3.5. Reduced WWR

WWR greatly affects energy reduction in buildings [13]. Previous research said that WWR should not be more than 24% [16]. in this study, the model in each orientation is made based on design and sizes calculation for simulation. WWR values in each orientation in the model are simulated differently. WWR in the northeast side is 23.32%, northwest is 40.63%, southeast is 40.63%, and southwest is

23.32%. Based on these values, the total WWR is 34.59%. To reducing the total wall window ratio to 34.59% in a different orientation, it can save energy about 0.07%.

3.6. Reflective paint for roof and external wall

The reviewed literature reveals that by simply changing the roof and external wall color to white and reflective can reduce energy [13]. Based on the simulation, energy saving that occurs with using reflective paint is 6.19% for roof and 0.45% for the external wall.

3.7. External shading device

Shading component in a building is not free, but cost-effective due to the amount of reduction in cooling load, thus the energy saving that achieved is 2.10%. The overhang type that used in low-cost housing is a vertical overhang for the northeast and southwest area, and combined overhang type for southeast and northwest area. Furthermore, the AASF value used for the external shading device is 0.41.

3.8. Low-e coated glass

Material selection for glass needs to be considered. Based on the simulation, if the glass material for low-cost housing is replaced with Low-E coated glass, which U-value is 3 W/m².K and SHGC value is 0.45, the savings will be around 1.72%.

3.9. Natural ventilation

Based on previous research, a natural ventilation system is a potential for reducing the energy load. The simulation result shows that natural ventilation applications can be saving 22.65% energy. The following are the savings that occur from each design passive strategy. (diagram 2).

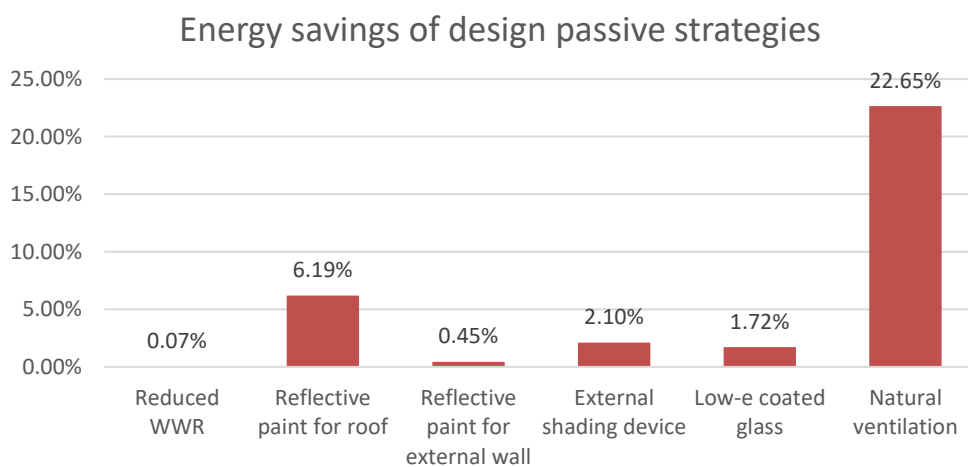


Diagram 3. Energy-saving of each design passive strategies

3.10. Design Active Strategies Analysis

Design active strategies that can be simulated in EDGE Building are using ceiling fans in all habitable rooms, using AC system, using energy-efficient refrigerators and clothes washing machines, using energy-saving light bulbs in internal and external spaces, using lighting controls for common areas and outdoors, using solar photovoltaics, and using smart meters. The saving strategies by applying active design have 7 options. These strategies will be chosen based on incremental cost and savings. The following are active design strategies in diagram 3.

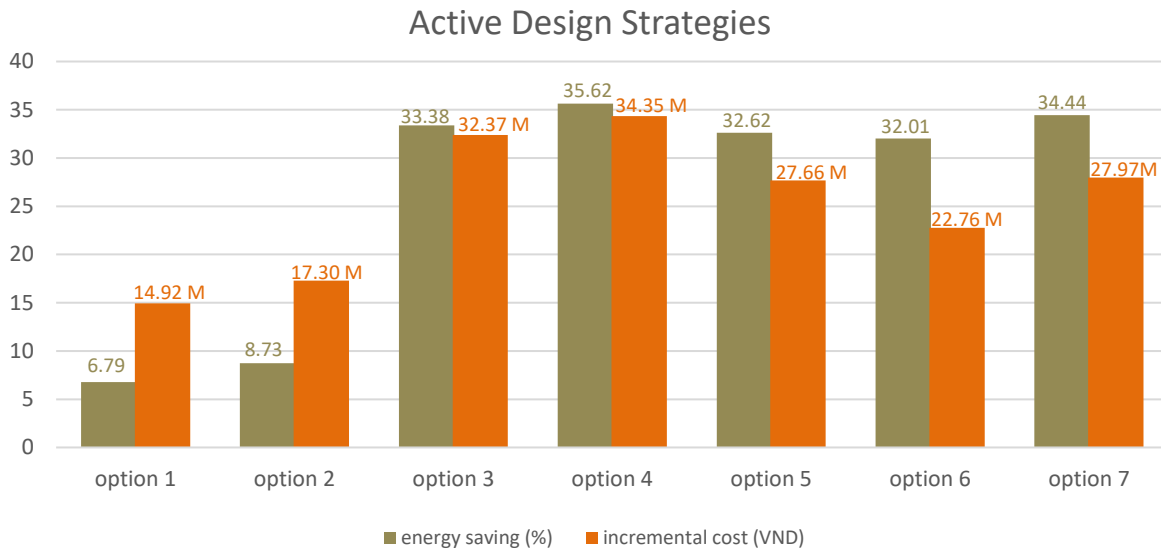


Diagram 3. Active design strategies

Diagrams above show possible options for applying to low-cost housing passive strategies. Based on the analysis, optional 7 is possible for active design strategies using AC System, using energy-saving light bulbs for internal and external spaces, applying solar photovoltaic, and using smart meters.

The active design strategy for low-cost housing is simulated. The simulation result shows the savings of each strategy. For using the Air Conditioning (AC) system, energy-saving that occurred is about 4.33%. For the appliance, the energy savings will occur about 2.86% for energy-saving light bulbs for internal spaces usage and 0.99% for energy-saving light bulbs for external spaces usage. Beside it, using photovoltaic on the roof will save 27% energy, and the last, using smart meters in the low-cost housing, will saving 3.36%.

Based on the simulation, energy savings will be shown. The following are the savings that occur from each design passive strategy. (diagram 3).

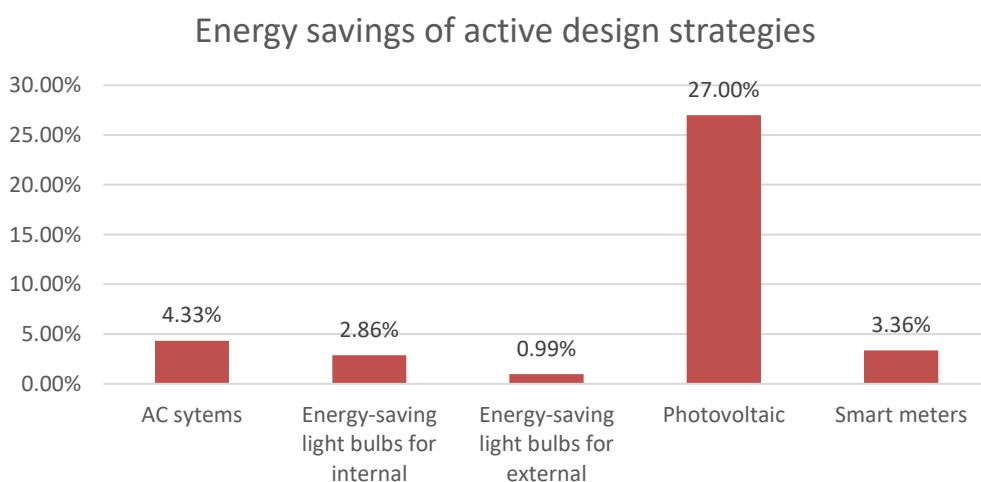


Diagram 4. Energy-saving of each design passive strategies

3.11. Energy Simulation of Improve-case

The energy simulation of the improved model resulted in lower final energy use of 495.02 kWh/month/unit to 248.21 kWh/month/unit. This simulation gives a difference between the base-case

energy use and the improved-case energy use, which is a 49.86% reduction in energy load as shown in diagram 5.

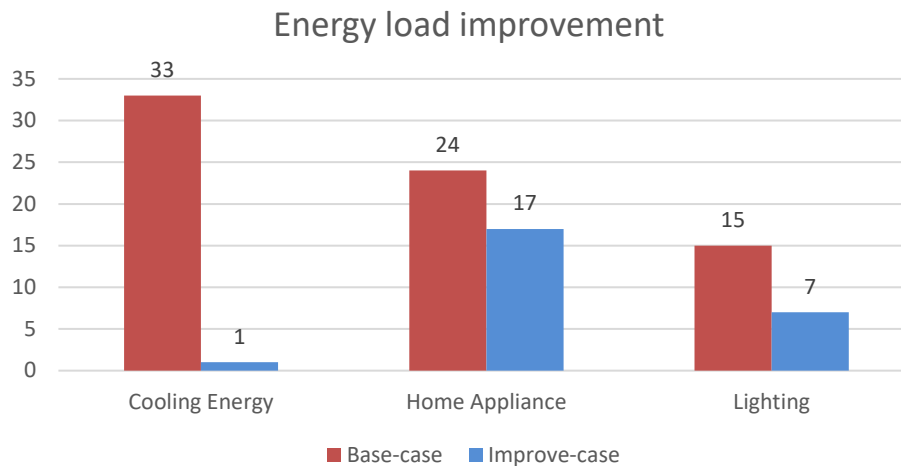


Diagram 5. Base-case and improve-case of case study simulation

Based on the diagram above, the application of a passive and active design strategy can save operational energy loads, including cooling loads, equipment loads, and lighting loads. In the case of cooling, the load coefficient on the base-case is 31 while the condition after designed or improve-case the load coefficient is reduced to 1. In equipment requirements, the load coefficient at the base-case is 24, while the improve-case condition is only 17. Furthermore, at the lighting load, the base-case condition has a load coefficient of 15, but after improving, the load coefficient becomes 7. This shows that appropriate design interventions can save energy, especially in operational energy.

3.12. Discussion

TOD is a solution to a dense region because nowadays urban sprawl has formed. Urban sprawl in the urban area needs to be addressed by compact development, resulting in vertical housing. The design needs to consider the socio-economic aspect to reach affordable low-cost housing. Based on the EDGE Building simulation, passive strategies can save 24.97% and 32.19% savings by active design strategies. The incremental cost for the construction of low-cost housing by combining the passive and active strategies is 27,598,581 VND which is affordable because a maximum incremental cost of low-cost housing in Vietnam is 2500 USD or equivalent to 58,184,125 VND. Besides, the annual payback period of low-cost housing by consideration of these strategies is around 5.21 years. Based on the results of the significant simulation, the TOD area must implement an efficient building design as one of the solutions to be able to maintain environmental and world sustainability.

4. Conclusion

Energy-efficient low-cost housing is designed by applying a combination of passive and active strategies through incremental cost and amount of energy-saving consideration. The combination of strategies chosen to be applied is reduced WWR by 34.59%, using reflective paint for the roof, using reflective paint for external walls, applying external shading devices with AASF 0.41, using low e-coated glass with U-Value 3 W/m².K, SHGC 0.45 and applying natural ventilation. Furthermore, the active design strategies are using the AC System with COP 3.20, using energy-saving light bulbs for internal and external spaces, applying 27% solar photovoltaic, and using smart meters. Based on the simulation result, the combination of these strategies can save 49.86% energy with an incremental cost of 27,598,581 VND and a payback period in 5.21 years.

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