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Energy Saving Strategy for Sustainable Vertical Housing Design

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ABSTRACT

Background: Providing housing with the Eco-Friendly Architecture concept is one of the plans to solve the problem of livable housing for the poor in Bengkulu Province. Through a strategy to maximize the use of natural energy to achieve efficient energy conditions, it aims to reduce energy consumption in the operational use of buildings by residents.
Method: The research method used is the experimental method. Furthermore, an analysis is carried out using EDGE software to assess whether the proposed design meets the eco-friendly principles related to energy efficiency.
Results: Maximizing natural energy in design is conducted by performing treatments between maximizing openings for natural lighting and natural conditioning, using bluescape in the form of an artificial lake as a reservoir for green water from bathrooms and washing areas, using roof gardens and installing solar panels to capture solar heat energy, and collecting drainage water as water to be reprocessed as water for washing, bathing and watering the garden.
Conclusion: Various design alternatives are produced to obtain optimal results in terms of energy saving, water efficiency and material efficiency.

1. Introduction

Nowadays, the problem of housing for the poor and low-income communities is one of the challenges facing by the government in Indonesia. In Bengkulu province, the problem of housing for the lower middle-income community is still an unresolved problem (1). The decline in the ability to provide environmentally friendly and energy-efficient housing is one of the challenges that must be resolved in the next 30 years.

Bengkulu City has an area of 152 km² with a population of 394,192 people in mid-2024, up from 371,828 people in 2020. With a population density of around 2,600 people per km², the need for decent housing is increasingly urgent (2). The poverty rate in Bengkulu City is relatively high, around 20% of the total population (3). Many low-income families have difficulty finding decent housing, so the construction of vertical housing can be a solution to provide affordable housing (3). The Bengkulu City Government is committed to improving community welfare through the provision of decent housing (1). This policy support is important to facilitate the construction of vertical housing, especially in the context of better urban planning (4,5,6).

Efforts to provide decent and environmentally friendly vertical housing and living space can be made in several ways, including (1,7,8):
1. Providing houses with a multi-storey concept / apartments
2. Making detailed spatial plans for each district and city in Bengkulu province
3. Building in locations that are not prone to disasters
4. Maintaining green open spaces greater (>) than 20%
5. Using environmentally friendly building materials

Providing housing with Eco Friendly Architecture is one of the plans to solve the problem of livable housing for the poor in Bengkulu. This plan is to implement the design in the vertical housing in Bengkulu City (1). By maximizing natural energy to achieve efficient energy conditions, it aims to reduce energy consumption in the operation of building use by the occupants (5, 8). Through energy efficiency, water energy efficiency and material selection, it is expected that the building will reach the desired condition in overall energy savings.

The EDGE (Excellence in Design for Greater Efficiencies) application is an initiative developed by the International Finance Corporation (IFC), part of the World Bank Group. This program is designed to help architects, developers, and building owners design more energy and resource efficient buildings (9,10,11). EDGE provides tools and standards for measuring energy, water, and material efficiency in the design of new buildings or renovations. Measuring building performance using the EDGE application can provide an overview of the level of energy efficiency in buildings (8). The building performance measurements applied include the following elements:

a. Energy Efficiency. The EDGE application allows users to calculate energy savings that can be achieved by implementing various design strategies, both passive and active. These measures include: (1) Optimizing the use of energy-efficient devices and systems and (2) Use of renewable technologies: Such as solar panels (photovoltaic) to reduce dependence on conventional energy sources.
b. The efficiency of water uses in buildings. The water use efficiency measured includes: (1) Use of water-efficient equipment (faucets and toilets designed to reduce water consumption) and (2) the use of water-efficient equipment, such as faucets and toilets designed to reduce water consumption.
c. Energy Efficient Materials. Assessment of the efficiency of materials used in the construction of the designed building includes: (1) Calculating carbon emissions resulting from the material production process and (2) selecting materials that have a lower environmental impact compared to conventional alternatives.
b. Carbon Emissions. Measuring carbon emissions related to energy and material use in buildings is also a focus. This application helps in reducing carbon footprint, through the process of analyzing and designing strategies to reduce greenhouse gas emissions from buildings.

The use of the EDGE application provides a systematic approach to measuring and improving energy, water, and material efficiency in building design (9). EDGE not only helps in designing more sustainable buildings but also supports global sustainability goals. The minimum requirement applied to the energy efficiency calculation standard through the EDGE application is a minimum of 20% for each category (10, 11, 12). Green Building is an existing concept to support development of low carbon through policy and program of efficiency improvement of energy, water, and building material and the improvement of using low carbon technology use (12, 13). The implementation of Green Building not only gives ecological benefits, but also economic one, by decreasing the operational cost and building maintenance (13, 14).

2. Method

The research method used is the experimental method. The experimental method phase are: first activity carried out is to find out the basic problems that occur in the community, the conditions and needs desired by both the prospective residents and government programs, and the selection of a location that is in accordance with the land use and in accordance with the eco-friendly concept (16). Furthermore, an analysis is carried out using EDGE software to assess whether the proposed design meets the eco-friendly principles related to energy efficiency (5,7,14). The next step is to create various alternative designs to obtain optimal results in achieving energy saving, water efficiency and material efficiency.

The use of the EDGE application was chosen because this application has complete features. The EDGE application allows users to simulate energy efficiency based on various elements of building design, both from passive design aspects (such as building orientation and use of natural lighting) and active design (such as HVAC systems and use of renewable energy) (9,10,11). In this way, users can identify areas where significant energy savings can be achieved. Analysis in the EDGE application is based on accurate data on energy, water, and material consumption. With this information, designers can make better decisions about the choice of materials and technologies to be used, thereby increasing the overall efficiency of the building (10,11).

The location of this research is in Bengkulu City. The selection of Bengkulu City as a research location considers population growth data, social and economic problems, and government policy support. This makes Bengkulu City a strategic choice for the development of vertical housing as a viable and sustainable housing solution for the community.

3. Result

Design data for each unit of residential area is 36 m^2, consisting of 2 bedrooms in each unit. The number of residential units is 116 units arranged on 4 floors. The building occupancy is 4 people per unit. Each residential unit with an area of 9 $m^2$for the bedroom, kitchen area = 3.2 square meters, living room/dining room with an area of 7.5 square meters, bathroom with an area of 2.25 square meters. Wall area = 4 square meters and roof area = 36 square meters (Table 1).

Table 1. Initial design data, division of room area per building unit (base data on building and user)

Building data			User data		
1.	Tipe of units	Apartmen/flats	1.	Bedroom	9 unit
2.	Average unit area (m^2)	36	2.	Kintchen (m^2)	3.2
3.	Bedroom / unit (no.)	2	3.	Living dining (m^2)	7.5
4.	Floors (no.)	4			
5.	Units (no.)	116	4.	Bathroom (m^2)	2,25
6.	Occupancy (people/units) (no.)	4	5.	Common area/unit(m^2)	14.05
7.	Unity, balcony, service shaft (m^2)	14.05			
8.	Gross internal area (m^2)	36			
9.	Window to floor ratio	6.7%	6.	Building system	Not used to AC Not used to heating system
10.	Eksternal wall length m/unit	4			
11.	Roof area/unit (m^2)	36			

Source: database design, 2024

The proposed exterior-interior perspective and elevation design drawings can be seen in Figure 1 and Figure 2. In the elevation drawing, the four sides of the building are visible with a shadow design that helps reduce sunlight exposure into the building. While the exterior and interior perspectives show a three-dimensional illustration of the design.

Figure 1. Building views
Source: Researcher design concept, 2024

Figure 2. Perspective image and atmosphere of the built area

Source: Researcher design concept, 2024

In this base case design, UV panels are installed on the roof of 215 square meters. Walls with UV walls of 2.06 square meters. Glass U value of 5.8 square meters. Glass SHG 0.8, and the use of AC system efficiency of 2.7. as stated in table 2.

Table 2. Data Design (Key Assumptions Base Case)

No	User Entry	Number
1	Cost of electricity (thousand Rp/kWh)	1.35
2	Cost of diesel fuel (thousand Rp/L)	6.4
3	Cost of LPG/Natural Gas (thousand Rp/…..)	2.62
4	Cost of water (thousand Rp/kL)	2.96
5	CO emission g/kWh of electricity g/ K….	891.000
6	Window to wall ratio (%)	20%
7	Solar reflectivity to paint wall (%)	40%
8	Solar reflectivity to paint roof (%)	2.15%
9	HotnWater boiler effiency (%)	80%
10	Roof U-value ($Wm^2.K$)	2.15
11	Wall U-value ($Wm^2.K$)	2.08
12	Glass U-value ($Wm^2.K$)	5.80
13	Glass SHGC (factor)	0.80
14	AC System efficiency (COP)	2.7

Source: database design, 2024

Energy Efficiency Calculation Baseline

In the diagram (Fig.3), the energy usage for hot water is 24 kWh/m2/year (= 26 %). The energy usage for artificial lighting is 43 kWh/m2/year (= 46 %), the energy usage for public facilities such as street and area lighting are 9 kWh/m2/year and the energy usage for household appliances such as washing machines, stoves, magic jars, stoves, etc. is 18 kWh/m2/year. Energy usage can be made more efficient by taking several design steps in the use of artificial energy, water treatment and possibly by adding several material elements that can reduce the amount of energy needed in building maintenance.

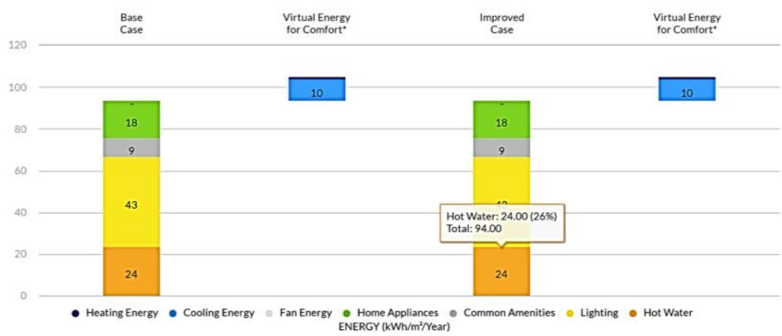

Figure 3. Diagram on energy usage base case and improved case
Source: Researcher analysis, 2024

Water Efficiency Calculation Baseline

Based on data on water usage, the amount of water used for washing and cleaning is 38kL/unit/year. Water usage for toilets is 35 kL/unit/year. Water usage for faucets is 53 kL/unit/year, water usage for kitchens is 35 kL/unit/year and water usage for showers is 61 kL/unit/year. The number of residential units plus public facilities is 116 units. Public facilities are calculated at 10-15% (Regulation of the Minister of Public Works and Public Housing (PUPR) No. 22/PRT/M/2018 concerning the Development of Flats). The total is 116 + (116x15%) = 133.4 (rounded up = 134 units). Therefore, the water usage for this case is 222 kL/year Material x 134 units = 29,748 kL/year.

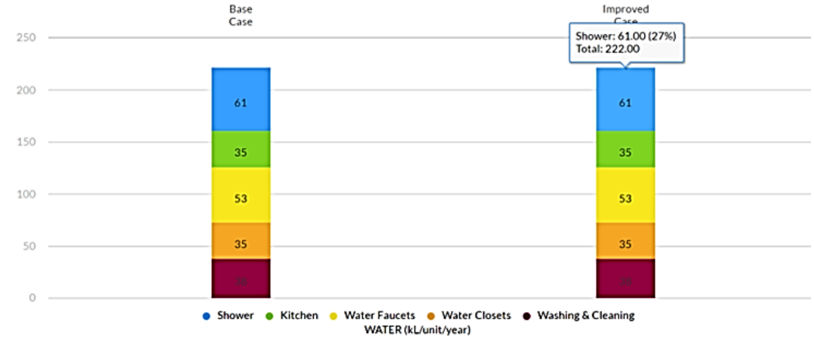

Figure 4. Diagram on Water Efficiency Calculation Usage Base Case and Improved Case
Source: Researcher analysis, 2024

Energy Efficient Materials Calculations Baseline

Based on energy efficiency materials calculations via the EDGE application, there is no difference in value between the base case and the improved case. The material elements analyzed include floor slabs, roof construction, external walls, internal walls, flooring, windows, and insulation as embodied energi.

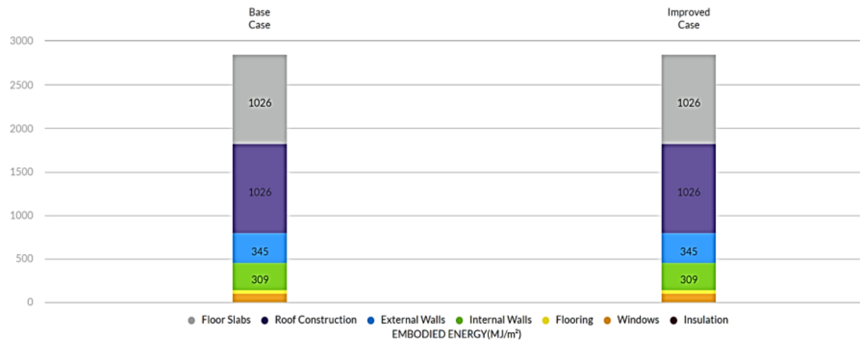

Figure 4. Diagram on Energy Efficiency Materials Calculation Base Case And Improved Case
Source: Researcher analysis, 2024

4. Discussion

4.1 Energy Efficiency Measures

Maximizing natural energy in design is conducted by performing treatments between maximizing openings for natural lighting and natural conditioning, using bluescape in the form of an artificial lake as a reservoir for green water from bathrooms and washing areas, using roof gardens and installing solar panels to capture solar heat energy, and collecting drainage water as water to be reprocessed as water for washing, bathing and watering the garden.

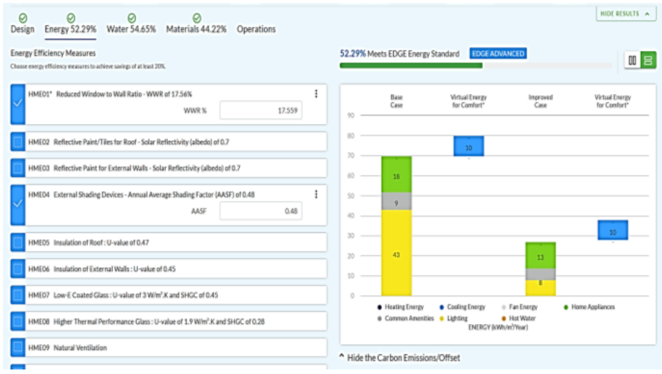

Figure 5. Calculation on Energy Efficiency by EDGE Application
Source: Researcher analysis by EDGE Application, 2024

The energy efficiency measures by EDGE application is 52.29%, with the details of energy usage as Figure 5. From the Table 3, the amount of energy required in each energy element (Ligthing, Common amenities, and Home Appliance) is reduced. The reduced strategy is achieved by using Reduce Window to Wall Ratio/WWR 17.56%. And the use of external shading devices in the form of Annual Average Shading Factor/AASF of 0.48.

Table 3. Details Data on Energy Efficiency Measurements

No	Energy	Base Case (kWh/square meter/year)	Improve case (kWh/square meter/year)
1	Lighting	43	8
2	Common amenities	9	1
3	Home appliance	18	13

Source: Researcher analysis by EDGE Application, 2024

4.2 Water Efficiency Measures

Efficient use of water with a double shower is to maintain water usage that exceeds the ability to fill in the building and process green water and drainage water for secondary needs. Efforts to become a building that is self-sufficient in providing water as much as possible with green water processing.

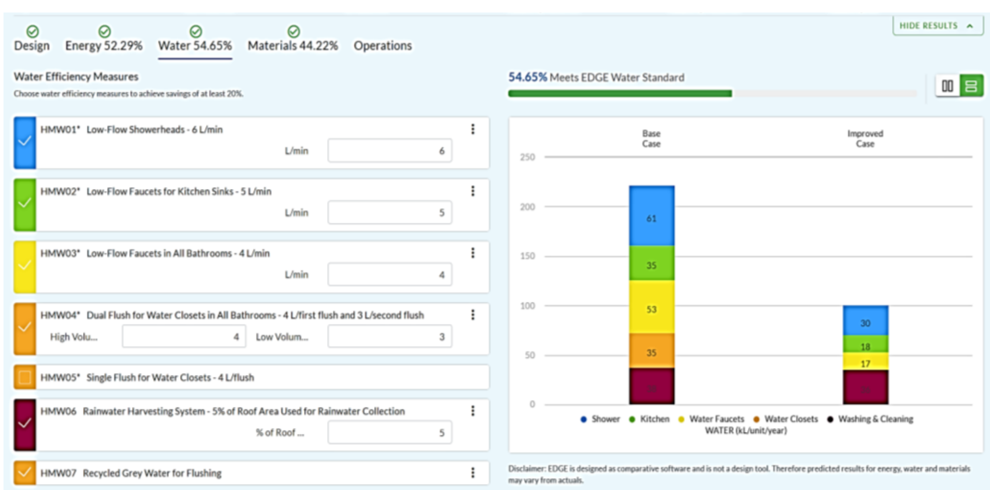

Figure 6. Calculation on Efficient use of Water by EDGE
Source: Researcher analysis by EDGE Application, 2024

From Figure 6, the amount of water needed in each element is reduced. This can be achieved by improving the use of showers with Low flow shower heads = 6l / m, low flow faucets for kitchen sinks 5 l / m, low flow faucets in all bathrooms 4 l / m, dual flash water closets in all bathrooms 4l / first flash and 3l / m second flash, rainwater harvesting system 5% of roof area used for rainwater collection and recycled gray water for flooring. To improve water, design adjustments are made which result in the following water efficiency (washing cleaning, water closet, water faucets, kitche and shower (Table 4).

Table 4. Details Data on Water Efficiency Measurements

No	Water	Base Case (kL/unit /year)	Improve case (kL/unit/year)
1	Washing cleaning	38	36
2	Water closet	35	0
3	Water faucets	53	17
4	Kitchen	35	18
5	Shower	61	30

Source: Researcher analysis by EDGE Application, 2024

4.3 Materials Efficiency Measures

Selection of potential local materials around the selected location, as one of the energy savings for shipping transportation. In addition, the selection of exterior glass and the selection of paint that is efficient and safe for the environment is one of the alternatives for selecting materials.

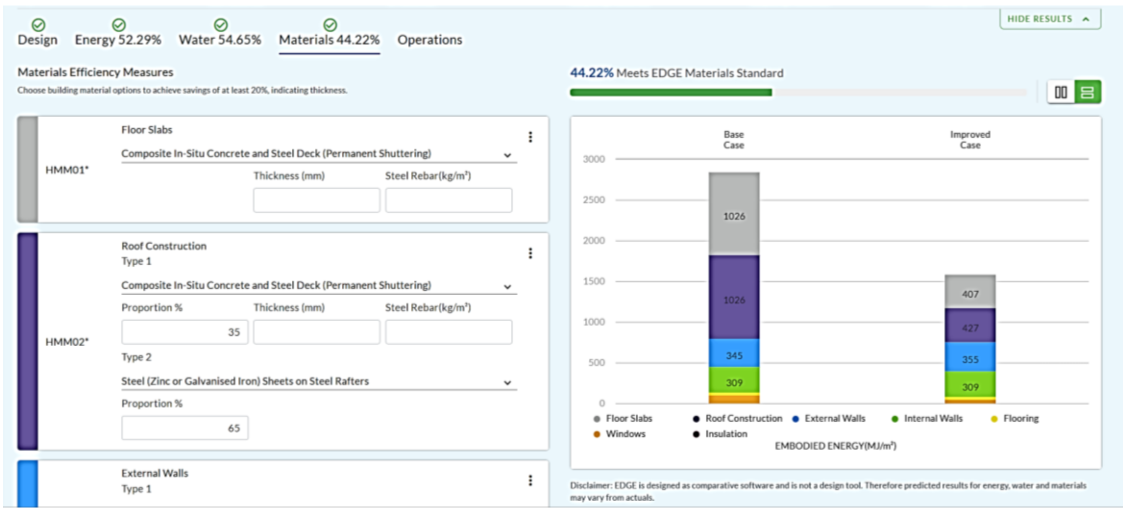

Figure 7. Calculation on Material Efficiency Measures by EDGE
Source: Researcher analysis by EDGE Application, 2024

Figure 7 shows the reduction in material efficiency is 44,22%. This is achieved by improving the following materials: roof construction with composite in-situ construction and steel deck (permanent shutting) with proportion 355 and steel (zinc of galvanized iron) sheets on steel rafters 65%. Material improvisation was also carried out, but it did not significantly affect its energy efficiency. The following is the data from the material improvisation results (Table 5).

Table 5. Details Data Energy Efficiency Measurements

No	Material	Base Case (MJ/square meter)	Improve Case (MJ/square meter)
1	Internal wall	309	309
2	External wall	345	355
3	Roof construction	1026	427
4	Floor slab	1026	407

Source: Researcher analysis by EDGE Application, 2024

4.4 Environmental Quality Improvement

Environmental quality is planned in categories to provide comfort, well-being, and productivity of its occupants, indoor air quality, thermal quality and lighting quality including effects on the environment (14, 15). The use of bluescape is one alternative to reduce environment heat (13).

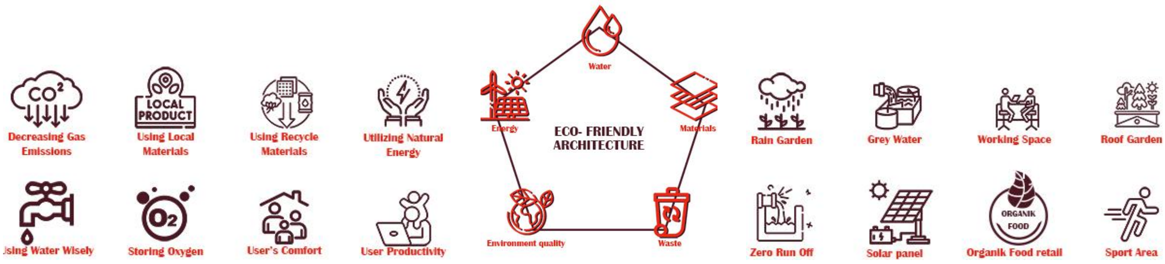

Figure 8. Design Implementation Strategy on Eco Friendly Architecture
Source: Researcher analysis, 2024

Design Strategy consists of several elements: decreasing gas emissions, using local materials, using recycled materials, utilizing natural energy, using water wisely, storing oxygen, user's comfort and user productivity (Figure 8). Moreover, the design involves rain garden, grey water, working space, roof garden, zero runoff, solar panel, organic food retail and sport area. The concept of eco friendly architecture will facilitate 5 elements, ie: water, materials, waste, environment quality, and energy (17).

4.5. Design Implementation

The site location is in Bengkulu City, Selebar District, Bengkulu City, Bengkulu Province. The site is used in accordance with the RPJMD of Bengkulu City with the regulations of KDB: 60%, KLB: 4 Floors KDH: 30% and GSB: 10 Meters (1). The design implementation on site and zoning analysis are in Figure 9.

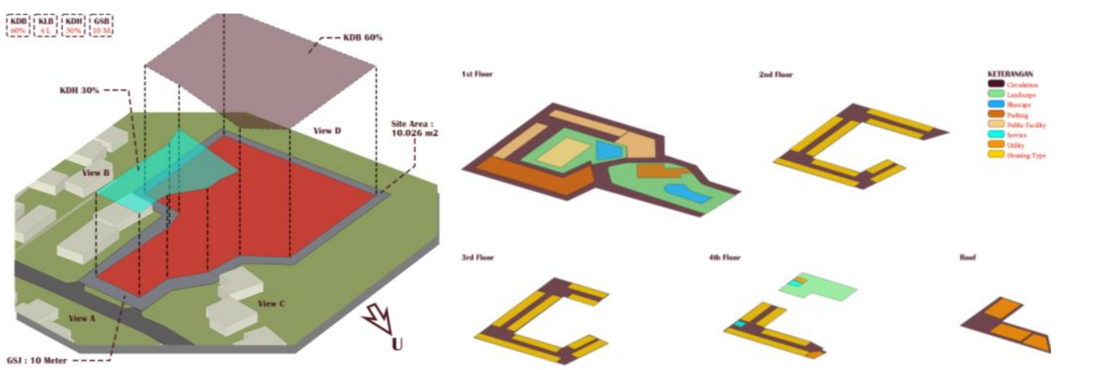

Figure 9. Site and Zoning Analysis
Source: Researcher analysis, 2024

In site analysis (Figure 9), the one that influences energy efficiency is the orientation of the building. The orientation of the building in the design is northwest, which will affect the amount of energy efficiency related to the amount of natural light energy that affects the heat and air condition in the building. In this building orientation position, several design adjustments are made:

1. Use of secondary skin on the west side of the building that is open / perforated as a window or open space.
2. Installation of solar panels on the side of <u>South</u> & <u>West</u> an area of <u>512</u> square meters. With the presence of solar panels on the side of <u>South</u> & <u>West</u>, the natural light energy from the morning and evening rays can be captured maximally
3. Division of residential zones on the site with consideration of capturing the maximum amount of natural energy and optimal views from inside the building. So that the residential zoning is

on the side of West extending to form a cluster mass configuration as shown in the following image

Zoning is divided into four floors. The first floor consists of circulation, parking area, landscape, Bluescape, public facility, housing type. The second floor consists of circulation and public facility. The third floor consists of circulation and housing type. The fourth floor consists of circulation, utility, and service. The rooftop consists of circulation and utility. After some design adjustments were made, the data was entered into the EDGE application to assess how much energy efficiency was generated from the existing design adjustments. The results are shown in the following EDGE table and diagram.

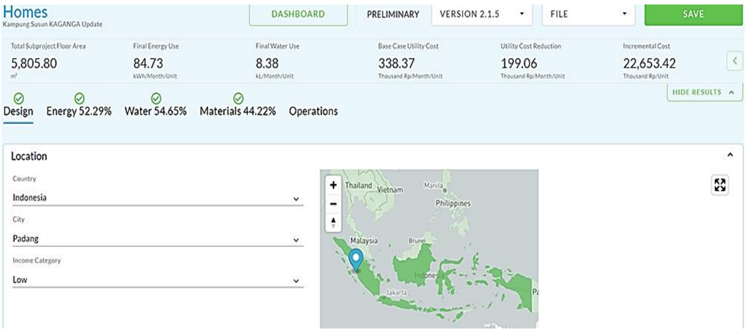

Figure 10. Interface of EDGE Application shows calculation of the design
Source: Researcher analysis, 2024

In the Edge menu, the location is taken from Padang city. Considering that the location on Padang city is closest to Bengkulu city and has the same climate (Figure 10). The design of the stacked village is intended for middle to lower income people, most of whom are low-income people.

4.6. Thematic Concept on Implementation Efficiency & Eco-Friendly Architecture

After measuring the efficiency level of energy, water and material use using the EDGE application, adjustments were made to the design that had been designed at the beginning. This adjustment aims to apply the results of efficiency measurements by improving the use of several shading designs, the overall implementation of cross ventilation flows, equipment that uses sensors, the use of solar panels and the implementation of gray water utilization systems.

Air conditioning consists of two cross ventilation flows. The air conditioning scheme is in the form of hybrid air conditioning. There are three types of air conditioning: air conditioner (27degrees), slow rotation fan, and cross ventilation. The comfort is set at 24-25 degrees. Kinetic façade uses perforated metal which is used for air circulation although it is on closed condition to reduce sunlight. Wooden lattice is used to release heat from the building. Fan mounting space is where the fans are installed in every housing unit, working space, and communal space (Figure 11).

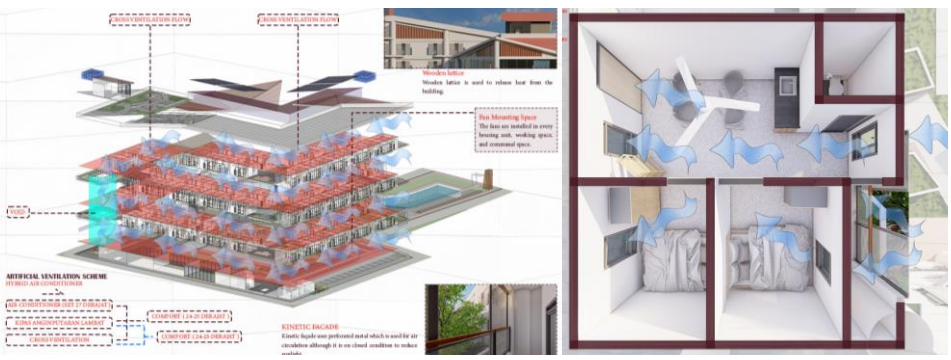

Figure 11. Thematic concept design on Artificial Ventilation
Source: Researcher design, 2024

Cross ventilation design implemented in room ventilation and corridor. Air conditioning is made using ventilation on each door and window based on the principles of building physics in which air with higher pressure will go to lower pressure. A fan with slower rotation will stabilize the air in a closed space.

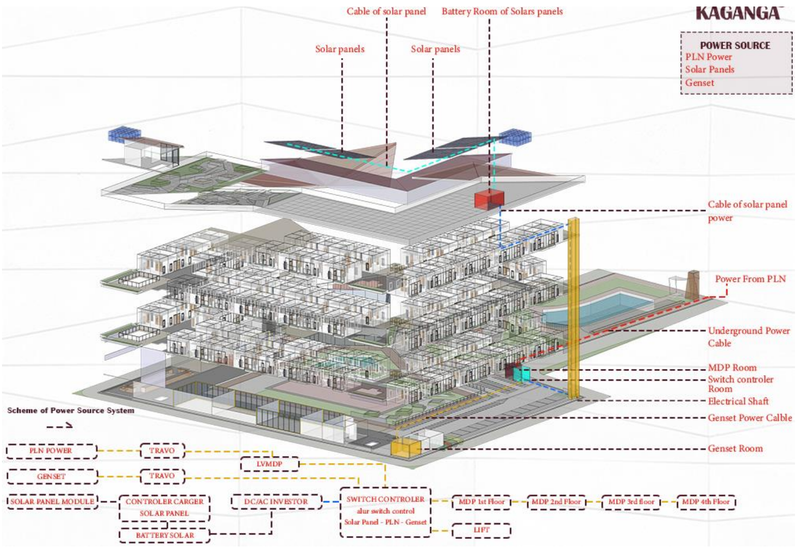

Figure 12. Thematic concept design on Power Resource Design
Source: Researcher design, 2024

Power sources provided by state electricity (PLN), solar panel and generator system. Solar panels consist of cables of solar panel, and battery room of solar panels. The power by state electricity (PLN) is divided into several parts; underground power cable, MDP room, Switch controller room, and electrical shaft, while power from genset consists of genset power cable and genset room.

The scheme of solar panel system is illustrated as Figure 12. State electricity (PLN) is connected to travo then is connected to LVMDP to switch controller and it is generated to MDP first floor until fourth floor. In addition, genset is connected to travo then to switch controller and it is generated to MDP first floor until fourth floor. Furthermore, the module solar panel is connected to controller charger solar panel and solar battery then connected to DC/AC Investor. Then it is connected to switch controller to MDP first floor until fourth floor and the lift.

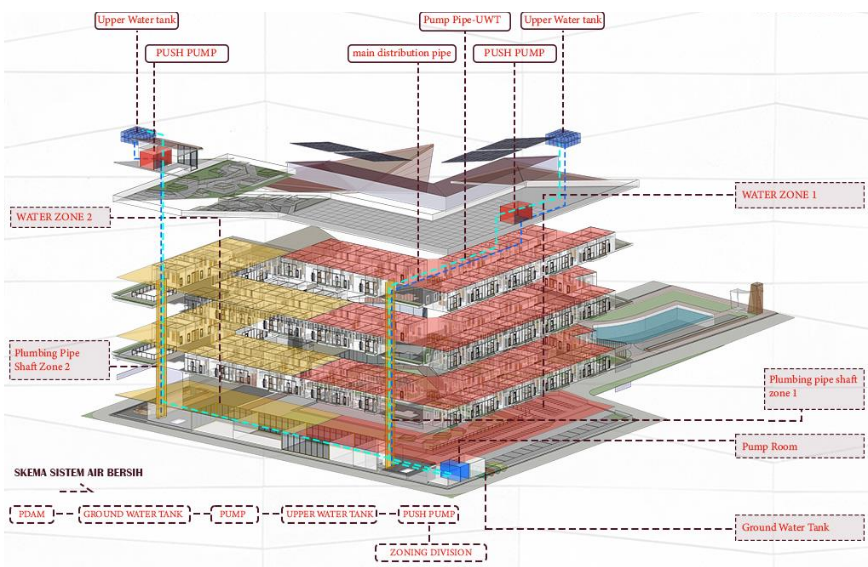

Figure 13. Thematic concept design on Clean Water Network Usage Design
Source: Researcher design, 2024

Nowadays, the implementation of greywater system in vertical housing design is an increasingly popular strategy in implementing eco-friendly concepts (13,18). Greywater, which comes from domestic waste such as water from washing hands, bathing, and washing dishes, can be reused for various purposes, including irrigation and filling toilets (19). The following is an analysis of the use of greywater in vertical housing design and the implementation of eco-friendly strategies.

Clean water networks are divided into two water zones (Figure 13). Water distribution is divided per building zone so that water pressure is more stable for each residence and public facility in each water zone. Shaft is used for clean water, dirty water, fire protection, and grey water. In addition, the pumping room is used for clean water, fire protection, and grey water. Ground water tank is separated from clean water and fire protection. The scheme of clean water system consists of PDAM, ground water tank, pump, upper water tank, push pump, zoning division.

5. Conclusion

Alternative designs are produced to obtain optimal results in achieving energy saving, water efficiency and material efficiency. Energy use can be made more efficient by taking several design steps in the use of artificial energy, water treatment and possibly by adding several material elements that reduce the amount of energy needed in building maintenance. The energy efficiency resulting from the final design is 84.73 kWh/month/unit. The efficiency of saving water use is 8.38 kL/month/unit. With this design, there can be savings in utility costs of 199,060 rupiah/month/unit (Figure 14).

Figure 14. Calculation on Material Efficiency Measures by EDGE
Source: Researcher analysis by EDGE Application, 2024

The eco-friendly architecture concept is implemented in the building design with the use of secondary skin, rain garden, grey water management, zero run off design application, application of solar panels and the use of recycled materials as an important basis in the energy efficiency scheme applied to the design. Through the EDGE application, the calculation of efficiency or energy savings can be known to provide an initial understanding to design users regarding the importance of green design.

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