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Optimizing green sustainable mosque criteria : A case study of Trisakti University nagrak campus mosque design

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Abstract. Trisakti University initiated a campus master plan that elevates the criteria of green buildings in its planning. One of the facilities in the master plan is the campus mosque. In the modern era, the roof design of the mosque tries to get out from the paradigm of the Andalusian and Mediterranean domed roofs. This study aims to determine optimal design strategies for implementing the green building concept on campus mosque design. Simulation methods are applied using Autodesk Revit to create the main mosque design of Trisakti University Nagrak Campus. BIM models can be more accurately integrated into simulated, analyzed, and decided schematic designs. Based on the simulation results of the square bowl roof design, it optimized the maximum power obtained from Photovoltaic is 1.369.104 kWh/year and can harvest rainwater 22,507,929.6 Liters per year. In Addition, in the surrounding parks, which can be used as additional outdoor prayer spaces, the concept of integrated bio-pores and composter is applied, which can increase the absorption of rainwater that precipitates in the surrounding area of the mosque, increase groundwater reserves in the environment, and maximalize sustainable mosque design.

Keywords: Green building, square bowl roof, sustainable mosque design

1. Introduction

Indonesia is often called the land of a million mosques, this is due to Indonesia's demographic conditions, which Muslims dominate. Historically, a particular Islamic mosque was built. Where the mosque is the center of civilization, every norm in Islamic society develops from here. The mosque is an architectural vital object to Islamic civilization and activities. Apart from being a functional space, the mosque is also a symbol of Islamic civilization, where every human behavior and manner should symbolize the values contained in activities in the mosque. Mosque building designs also have a long history that has developed over time. In Indonesia, mosques at the beginning of the era of the spread of Islam, acculturated local architecture with Islamic values. So, in terms of form, mosques at the beginning of the development of Islam in the archipelago had thick shapes and forms with local symbols. As time passed in the colonial era, many Indonesian citizens began to make the Hajj and study in the Middle East. The discovery of image-capture technology caused the paradigm of mosques in the archipelago to begin to change by adopting Mediterranean and Andalusian architectural styles with dome formations and classic columns as well as the arc beam shape characteristic of mosques in the Middle East at that time. In the modern era, mosque design is developing rapidly, moving away from the paradigm of domed roofs and arc shapes typical of Andalusia and the Mediterranean. Modern architecture has become a new paradigm in designing mosques in the post-World War 2 era. We can see mosques in the form of the Istiqlal mosque, a national mosque with a modern solid architectural style with simple and firm geometric shapes. This shows that the mosque's design as the center of Islamic civilization is dynamic and adaptive to the times and human needs[1].

In the modern era one of the current trends in mosque development is mosques with a green building concept[2]. The green building concept is one of the essentials to apply in mosque architecture[3] because mosques have quite complex functions for Muslim activities[4]. Mosques on a regional scale have become the center of worship activities and Islamic civilization, which has developed and become more complex over time. The values in designing mosques have also become a new trend in the development of mosque architecture. Many mosques symbolize an event or serve as a reminder of Islamic values in some form[5]. Mosques in campus areas are also an important focus that needs to be studied. Mosque occupancy in educational areas will impact the campus environment by producing water waste[6]. The mosque is a vital facility because as long as campus academic activities take place, the mosque will always be in use. Applying green and sustainable building concepts is essential in the current era, where the climate and energy crisis has become a crucial issue to be immediately followed up with sustainable steps. One way is to implement green and sustainable buildings, where this concept is a concrete step that can be taken so that a building does not cause harmful effects in the future. One of them is Trisakti University, which has initiated a campus master plan that emphasizes the concept of green building in its planning[7]. The master plan focus is the design of supporting facilities that can optimally apply the concept of green building and sustainable design. Green building concepts that can be optimally applied to mosques are waste, water, energy, and climate change [8]. In its application, these three main criteria are translated into the form of building systems, especially building utilities and enclosures. The mosque building must meet general criteria for public buildings, which must strive for visual[9], thermal [10], and acoustic comfort. These three comfort conditions will support solemnity in carrying out worship activities therein. Functionally, the mosque is a place for worship activities involving relatively high water and energy resources[11]. Therefore, there must be real efforts to reduce the use of raw water resources with alternative raw water sources such as rainwater harvesting [12] and gray water management to support the flushing function[6]. Meanwhile, in the energy aspect of mosque buildings, mosque buildings must be able to integrate alternative electrical energy source systems[13]. Photovoltaics is an effort to reduce the use of electricity sourced from PLN Grid.

As a novelty in research and design, in designing the main mosque of Trisakti University, Nagrak campus, the design development process used BIM-based software, namely Autodesk Revit. In studies that use BIM as simulation tools, most of them focus on post-design simulation to calculate energy via Autodesk Insight. It is still rare to find BIM calculations for mosque design study objects. Usually, research uses measurement and calculation methods to evaluate the green design application, so the process will take longer and make it more difficult to create alternatives. BIM Software is very helpful in carrying out comprehensive design analysis, from calculating the volume of work, generating the types of materials used, estimating energy use by the building, and lighting simulations to green building analysis using the Autodesk Insight Building integrated system.[14]. BIM models will make it easier to determine alternatives in design so that every decision taken can see the level of optimization of the building's sustainability [15]. The use of BIM in this design also has several limitations, including the incomplete directory and library of families, so the production of non-standard families is required in designing. This will also hamper the design process, so that it takes more time to produce it. However, compared to using entity-based software such as CAD or SketchUp, BIM is much easier to proceed to the simulation stage because the tools are integrated into one software. Based on the above background, in designing the main mosque building of Trisakti University Nagrak Campus, it is necessary to consider comprehensively implementing green buildings. So that later, we will get a design that can positively contribute to the surrounding environment. This research aims to study and optimize green building applications in the main mosque building at Trisakti University Nagrak campus. The optimization strategy is based on previous literature studies about green and sustainable mosque criteria to obtain comprehensive design element applications in mosque objects. These strategies will later be simulated in a BIM design model to obtain design decisions that can optimize the application of green and sustainable mosques to building objects. In this way, it is hoped that the planned mosque design will be able to apply green building criteria optimally.

2. Literature Review And Research Method

2.1. Green and Sustainable Mosque Criteria

The development of mosque design in the world and Islamic civilization developed. The design of the mosque building has a style according to the civilization that founded it [16]. At the beginning of Islamic civilization in Indonesia, mosque buildings in Indonesia adopted local architectural forms. In that era, Indonesian society entered the era of Hindu Buddhist kingdoms. So, in the early Islamic era, mosque buildings had a shape similar to Hindu Buddhist houses of worship. This shows that Islam came peacefully and acculturated with local culture. This also caused the development of mosque architecture to follow the times. The main elements that are permanent in forming mosque architecture include three things. First, the element of the idea of a mosque, which is the house of Allah (Baitullah). Second, elements of mosque behavior, including the function of the mosque and manners of behavior in the mosque. Third, the language element is a typical term for Islam to refer to a place of worship for Muslims, namely the mosque. The supporting elements dynamic in forming mosque architecture are elements of mosque artifacts that can experience development and change within boundaries, including Islamic values. Second, the form of mosque artifacts reflects the idea of the mosque and forms a quality space suitable for accommodating worship in the mosque. The value and position of the mosque's architectural form reflect the level of Islamic civilization. Muslims need its presence to comfort their body and soul so they can carry out worship activities in the mosque properly. The only architectural element of the mosque is an open space oriented toward the Qibla, surrounded by a barrier to mark the mosque as a holy space, called the Idghah model. In green and sustainable design, the function and activities of the space must be accommodated by the building, so that in designing a mosque, function and quality of the space are the main things. In Indonesia, the Islamic community is also aware of protecting the environment. This is proven by the many developments of green mosques, green Islamic boarding schools, and green schools based on Islam, where functions and activities in buildings can be accommodated without damaging the environment[17].

In its application, the green mosque concept focuses a lot on several things, including energy use and water resource conservation. These two things are the main focus because the mosque will functionally consume massive energy and water[11]. According to several studies, using renewable energy in the green mosque concept can be optimized using photovoltaics with various systems. The hybrid system is one of the systems considered capable of being implemented quite well in Indonesia, where the main source of electrical energy still uses sources from the PLN grid. This Photovoltaic system must be integrated with the battery system so that power can be used when the sun does not illuminate the PV [18]. Apart from focusing on renewable energy sources, conservation of water resources is the main principle in designing green and sustainable mosques. Reducing the use of raw water sources from groundwater or PDAM is a step that must be implemented in mosques with a green and sustainable concept. The strategies often taken are rainwater harvesting and greywater wastewater management, which can reduce raw water sources from groundwater[6], [12]. Rainwater harvesting, in the case of mosques, can be used to supply clean water for ablution, where, according to the Islamic sharia, this rainwater is holy and purifies. So that rainwater harvesting can reduce the use of raw water from groundwater used for ablution. Rainwater harvesting installations must meet the criteria of having a catchment area, namely the roof of the building, which will later collect and channel water for processing and storage [19]. Excess rainwater from harvesting will flow into the environment and open spaces and later be infiltrated to increase groundwater reserves [20]. Meanwhile, for the management of gray water, it can be used for watering gardens and flushing toilets. In contrast, greywater from mosques is not allowed for purification because it is contaminated by dirt, and according to Islamic Sharia, it is mandatory. The greywater wastewater management system can be hybridized with rainwater for other purposes, such as watering plants [21].

Apart from the water and energy utility aspects, the green mosque concept must also increase the comfort of the space inside with a passive design and climate-responsive strategy. A shading device with a proportional width can protect solar radiation on building walls. This strategy is a mandatory passive design in Indonesia's tropical climate[22]. On each mosque floor, there is a shading device with a length equivalent to the height of the wall. The use of curtain walls around the mosque also increases the penetration of daylight into the interior of the building. This will also optimize the daylight factor in the building [23], [24]. Additionally, skylights are a real solution to fulfilling a building's green rating [25]. Roof shape strategies can also be applied to optimize lighting and the application of the various criteria described above. Green roofs can also be implemented to optimize rainwater harvesting[26], [27]. The roof's slope and shape also greatly influence the maximum renewable energy production if Photovoltaics are installed on the roof's slope. So, the roof design will also be the focus of the design[28], [29].

2.2. Research Methodology

The research methodology in this study uses a combined strategy where several methodologies are carried out in the research. In this research, a strategy case study was carried out with post-positivistic simulation [30]. Research procedures were carried out systemically and hierarchically. A literature study was carried out in the initial stage, formulating variables for the green and sustainable mosque design criteria. After determining the existing design criteria, the case study object was re-modeled using BIM-based software, namely Autodesk Revit [31]. Today, BIM is a popular design and approach method tool in architecture and construction research. Some studies usually involve BIM technology with green building analysis simulation [32]. It can fully capitalize on the advantages of the BIM model and is more efficient for evaluating green buildings. In BIM, we can input several parameters and modify them simultaneously until we give a more appropriate design that adheres to the building concept, especially sustainable or green buildings. BIM Models simplify changing and adjusting building designs for greater effectiveness and efficiency [33]. In the BIM design process, every development level in BIM is recorded and possible to simulate, especially for environmental impact throughout the building design. We must influence environmental impact through building design to achieve more sustainable building design. If the design goes through the simulation stage, it will be more comprehensive. In the case of an existing building, we can simulate a modified building design using a passive method such as orientation, shading, glazing, sealing, roofing, and opening. Then, a building performance simulation is carried out using several simulation tools and is carried out in each design process[15]. At this stage, a strategy analysis process is also carried out in applying the criteria for green and sustainable mosques as case study objects to obtain an optimal design by comparing design alternatives. In the final stage, a qualitative descriptive analysis was carried out on each optimization strategy implementation in the building. This is intended to ensure that the strategy can be applied to buildings. The research hypothesis is that modifying the shape of the roof and building utilities is the key to successfully implementing the optimization of reducing the use of energy and water resources.

3. Result And Discussion

Based on previous literature studies, there are several criteria for green and sustainable mosques. It can be concluded that the main criteria that must be applied focus on efficient use of energy and conservation of water resources. This primary principle must later be applied as the primary basis for design. When using criteria, energy efficiency can be translated into using renewable energy sources from photovoltaics [34]. This is because the sun shines throughout the year in Indonesia, so using this energy source as an alternative energy is very effective. Photovoltaic placement in buildings will be optimal if placed on the roof and rooftop area so that sunlight can be evenly distributed and maximally not covered or shadowed. Therefore, this will later become the focus in the simulation of optimizing the shape of the roof regarding the energy that can be generated by the photovoltaic above it. Meanwhile, water resource conservation criteria must also be applied to the design. Rainwater harvesting systems and wastewater management so that they can be reused are mandatory strategies that must be applied to the design[35]–

[37]. Meanwhile, other passive design criteria that must be applied to the design are shading devices with a length equal to the height of the walls, curtain walls to maximize indirect daylight penetration, skylights as a source of lighting on the roof, roof shape to maximize rainwater collection, use of green roofs on roofs, roof systems. Cross ventilation and secondary skin to reduce OTTV in the building [1], [4], [5], [10].

3.1. Research object

The object of study is one of the parts of the master plan design published in the master plan idea contest for Trisakti University Campus, Nagrak Bogor - West Java. The specific study object is the main mosque in the planned campus master plan. This mosque has a total floor area of 40.281 m^2 with 5-story Floors with a total Base Covered Area of 8.658 m^2. The mosque can accommodate up to 28,000 Congregants, whose capacity can still be increased if you utilize the landscape design around the mosque area, which also has a design that includes the mosque's prayer rows. This building is on the east side of the main lake at the Trisakti Nagrak campus, which has its potential and challenges in planning it. High humidity levels and lake water fluctuations can affect the environment around the mosque (Figure 1).

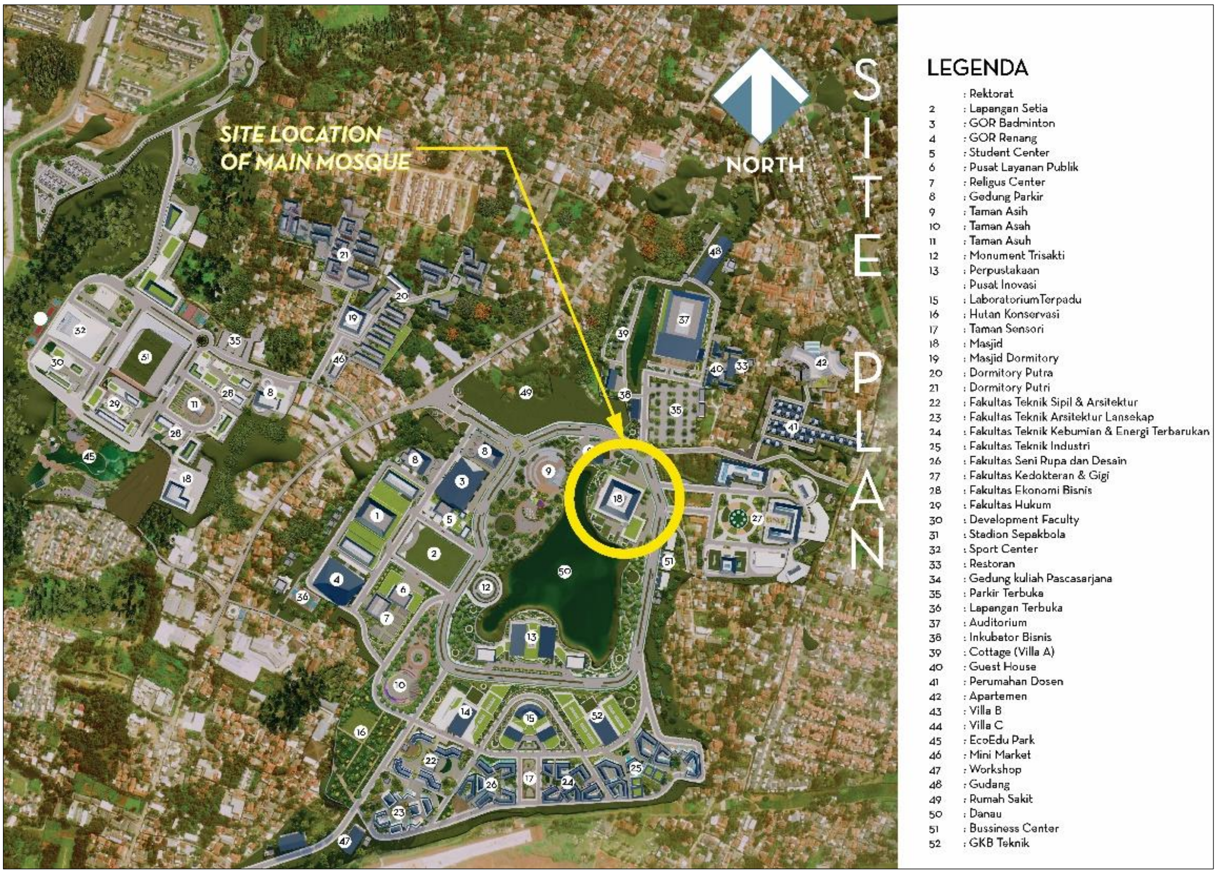

Figure 1. Site Location of Main Mosque of Trisakti University Nagrak Campus, Source: Masterplan of Trisakti University Nagrak Campus, Participant Number NG-159.

According to the master plan idea, this lake impounding was created from various sources. These sources include excess rainwater runoff from rainwater storage tanks, greywater from IPAL processing, and wastewater from mosques' ablutions (Figure 1). The mosque's mass is relatively cube-shaped, with almost equal sides on all four sides. A basement is a study room and an ablution and toilet area. The mosque design was initiated using a green building approach with a passive design approach so that the building can passively respond to the climate at the location. The climate conditions at the location are classified as humid tropical with high humidity, this shows that the climate at the location is wet within the range of temperature 15°C - 26°C. This is also caused by the geographical conditions of the location in the middle plains, where it often rains (Figure 2).

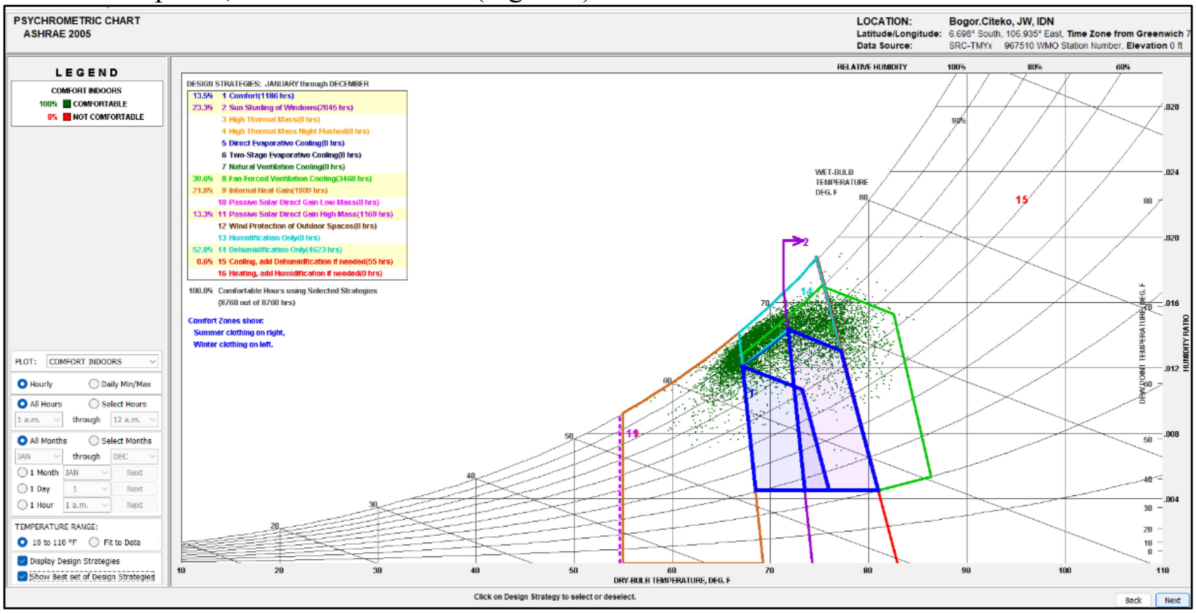

Figure 2. The Climate of the building Location, Source: Climate Consultant Psychrometric Chart ASHRAE 2005

3.2. Building Modelling Using Autodesk Revit

The case study object is the main mosque of the Trisakti Nagrak campus, which will be modeled using Autodesk Revit architectural modeling software. This aims to make it easier to simulate calculating the level of green building performance of the object under study. In modeling, several control variables need to be adjusted, namely the existing location and the orientation of the building towards the sun. This is important because different results will be obtained at different locations and orientations. The case study object is modeled as in Figure 3. The modeling is carried out comprehensively and adapted to the space's functional needs and various other design considerations.

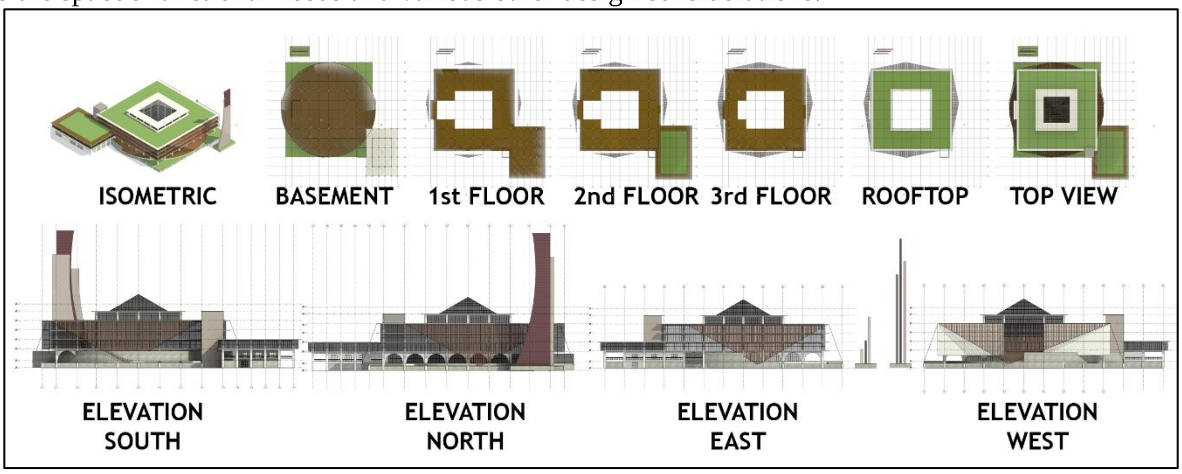

Figure 3. BIM Model of Main Mosque of Trisakti University Nagrak Campus by using Autodesk Revit

After the building has been modeled, a running simulation will be carried out using several essential tools, namely System Analysis, which can calculate the annual energy consumed by the building. Then, we can also run a Solar Analysis, It can also simulate how much renewable energy can be generated from PV placed in buildings. A simulation was also carried out using Autodesk Insight to determine the green building performance achieved in several alternative design forms. In this tool, we can later set several model variables such as Wall window ratio, use of anti-radiation glass, use of shading devices with a specific ratio, alternative use of energy-saving equipment, and maximize the use of PV in buildings. Everything can be calculated and simulated.

3.3. The Alternative of Roof Design

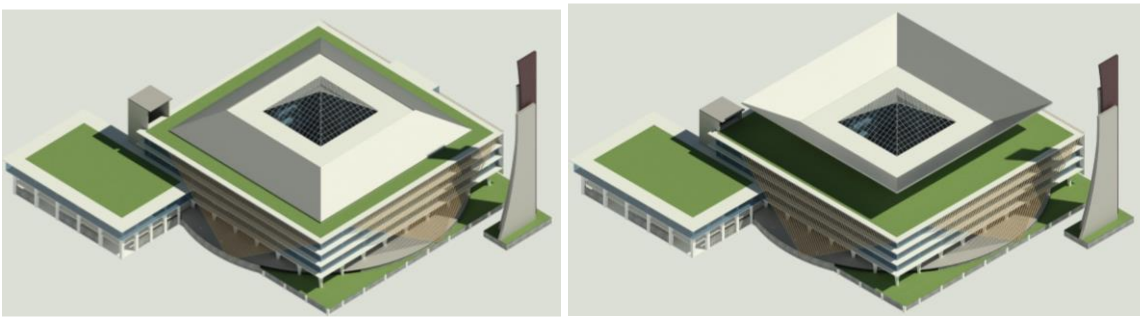

Figure 4 The Comparison of the roof design Alternative on the Main Mosque of Trisakti University Nagrak Campus

In the initial simulation stage, roof modeling was carried out using a truncated pyramid roof model with a slope angle of 30 degrees, as in (Figure 4 Left). After the modeling, another alternative roof was carried out with the same area but using a square bowl roof shape with the same slope angle of 30 degrees, and the same simulation was carried out as in (Figure 4 Right). From the two models, we will compare which object performs better in increasing the building's green rating.

3.4. Photovoltaic Application

In buildings with the first roof alternative, a performance simulation of the building's renewable energy potential via PV is carried out with the following data results. Before carrying out the simulation, the roof was modeled with different shapes according to alternative 1 and alternative 2. Each roof slope had an angle of 30°. The roof area where photovoltaics will be installed is 3,881 m2, with a PV type power of 20.4% / $3.47/Installed Watt. Building power load information is input based on data from green building model simulations using Autodesk Insight.

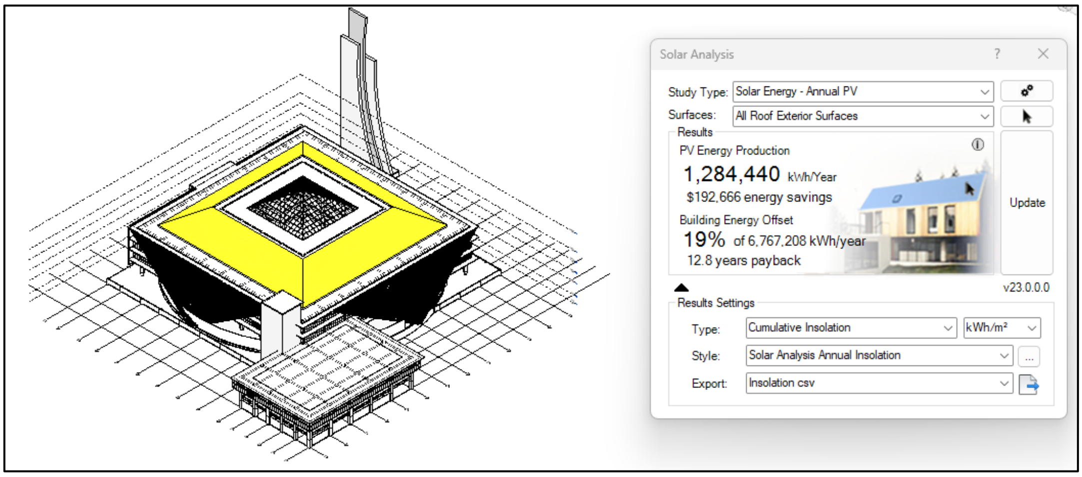

Figure 5. Solar analysis of pv energy production of first alternative roof of main mosque

The first alternative can produce alternative electrical energy of 1.284.440 kWh per year. This amount of energy can cover 19% of the total energy needed for building operations, namely 6,767,208 kWh/Year. Meanwhile, the payback period for PV installation is 12.8 years.This value will compare buildings with a second roof alternative using a square bowl roof. Based on the simulation results of the building's renewable energy potential performance through PV in the second alternative, the following results were obtained:

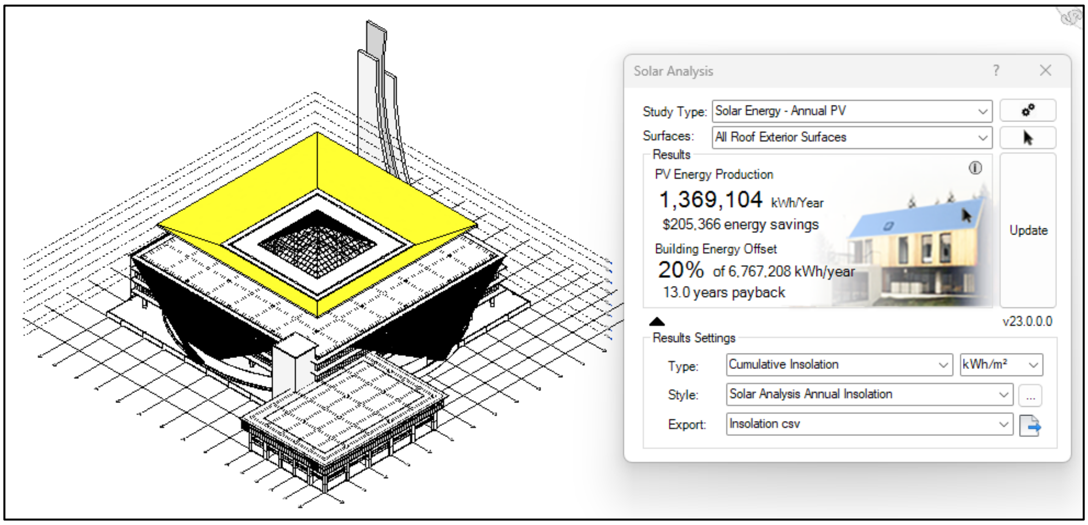

Figure 6 solar analysis of pv energy production of second alternative roof of main mosque

Based on the two simulation results above, it can be seen that the performance of a roof shape with the same area, the second roof alternative form, is more capable of producing alternative energy of 1.369.104 kWh per year compared to the first roof alternative form, which only produces 84.664 kWh per year. This proves a difference of 6.5% between the truncated pyramid and square bowl roof shapes. This energy can cover 20% of the total energy needed for building operations, 6,767,208 kWh/Year. Meanwhile, the payback period for PV installation is 13 years. The square bowl roof shape can increase the green rating level of the building.

3.5. Rainwater Harvesting and Greywater Recycling

The rainwater harvesting system is a crucial factor in reducing the use of raw water resources. This also reduces the use of treated water, such as PDAM, which requires quite a lot of energy to process it. The rainwater harvesting system at Trisakti University, Nagrak campus's main mosque uses a scheme as in Figure 7.

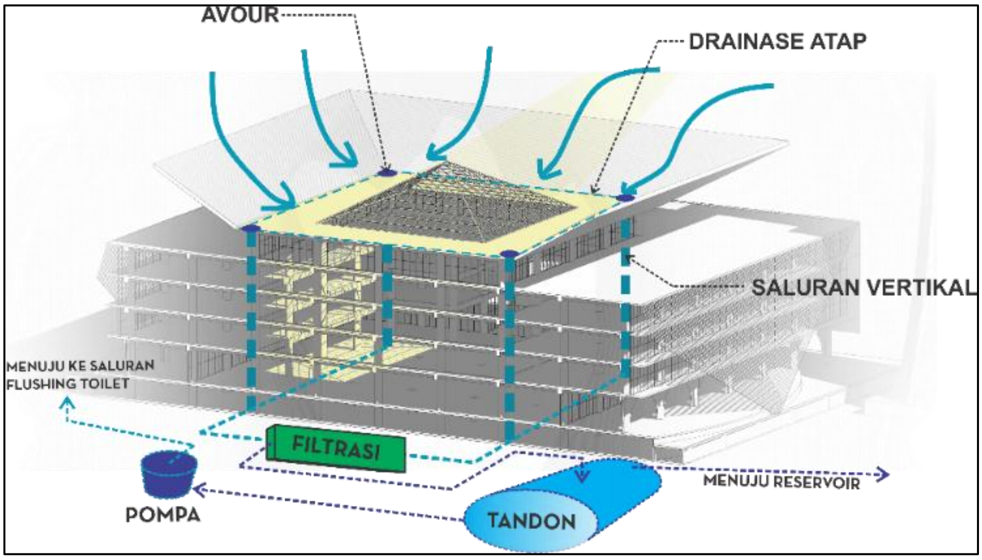

Figure 7. Rainwater harvesting scheme of trisakti university, nagrak campus's main mosque

To maximize rainwater harvesting, the roof design is also very influential, and this is also related to how much rainwater can be captured and channeled into rainwater harvesting channels. With a square bowl roof shape, we can maximize rainwater harvesting because the amount of rainwater reflected or vented by the building is reduced. After all, the roof shape forces rainwater that touches the roof area to bounce out of the roof area. As in Figure 7, rainwater will be collected in the square bowl roof's center to maximize harvesting. This has great potential considering that the building location is in Bogor, with quite high average rainfall levels. Based on the mode it can be calculated that the volume that the building can harvest is 22,507,929.6 L / Year. This is quite good considering the need for clean water for purification, especially ablution for mosques with a very high capacity of worshipers 28.000 of people. so that by harvesting rainwater, the level of raw water consumption can be reduced significantly. Apart from that, for the outside area of the building, according to the concept offered, bio pores and composters are also applied to support the absorption of rainwater runoff that falls in the open area around the building (Figure 8). The presence of bio pores will certainly increase the absorption capacity of rainwater, which will later become raw water for buildings.

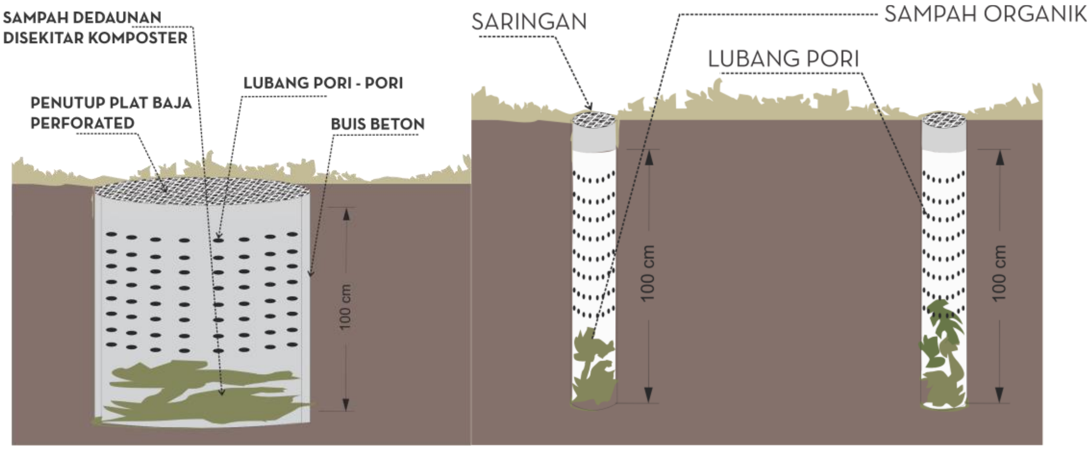

Figure 8. Composter and biopore scheme that applied on the mosque site

3.6. The Passive Design, Natural lighting, and Cross ventilation

Apart from that, to optimize the application of the green and sustainable building concept in the design of the main mosque at Trisaktui University, Nagrak Campus, lighting performance simulations were also carried out in the building. Using the lighting simulation tools method in Autodesk Revit, we can find out how light penetrates into the building so that adjustments can be made to improve the quality of the building's lighting. in the context of a mosque building, the minimum criteria for natural lighting must meet a minimum daylight factor of 5%, according to SNI 03-2396-2001. according to the simulation results in Figure 9, it can be seen that the performance of natural lighting through the building's daylight factor is an average of 5,5%, where this value is above the minimum threshold for lighting so that the building design can be said to be optimal, this is also inseparable from the use of a square bowl roof model which helps reflect light towards the skylight roof of the building in the middle. so that natural light can penetrate the mosque's central part during the day.

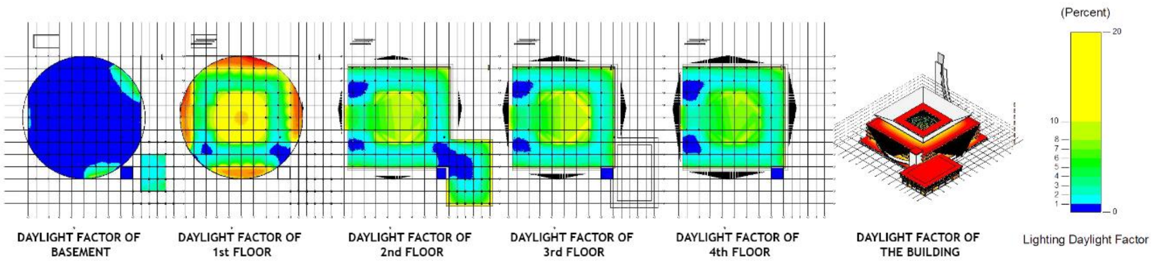

Figure 9 Daylight Factor Simulation of Trisakti University, Nagrak campus's main mosque

Apart from lighting, the ventilation factor with the right system can reduce the use of artificial air conditioning systems, this can be applied to the design of the atrium, which is a continuous void up to the top floor. This allows hot air from the lower area to rise upwards, and then it can escape. through the ventilation at the bottom of the Square bowl roof and the transparent skylight roof. this also reduces the building's cooling load massively. The shading device design, which blocks direct light exposure to the building walls, also increases the reliability of the building and the level of the building's green rating. The ratio of shading devices to openings is 1:1, where the length of the shading device is equivalent to the height of the openings and building walls. This makes the building's OTTV value very low to minimize air conditioning.

4. Conclusion

The roof shape design, the building code in the Trisakti Nagrak campus master plan planning, has become a unique and functional icon. This is because it departs from the domed roofs and canopies paradigm, often applied to mosque building designs in Indonesia. This square bowl roof shape can increase the power of capturing rainwater and focus the flow of rainwater into channels for rainwater harvesting. Apart from that, the shape of the roof also makes the sun's rays unobstructed from various sides and various angles of the sun's arrival, this increases the illumination power through the skylight opening. PV becomes more optimal. With the help of BIM software Autodesk Revit, the Trisakti University mosque design can be analyzed more accurately and integrated. However, it has the drawback of producing several custom families not yet in the BIM library. Based on the simulation results, it can be calculated that the maximum power obtained from PV is 6.407.602 KWh and can harvest rainwater 22,507,929.6 Liters per year. Using a green roof in the design also increases rainwater absorption in the roof area of the building. This is also integrated with the waste and wastewater management system by processing used ablution and shower water into water for flushing toilets and watering plants. Apart from that, in the surrounding park, which can be used as a prayer room location, bio pores and an integrated composter are applied, which can increase infiltration. rainwater and will later increase groundwater reserves in the environment. Based on this research, it can be seen that the square bowl roof shape design with an angle of 30 degrees for public buildings is symbolic and functional to optimize the application of green and sustainable building criteria. The use of a square bowl roof is not always relevant to building types with different designs. Therefore, further exploration is needed regarding roof designs on certain building objects using the same simulation method to obtain a design that is compatible with other building objects.

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