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Enhancing Security in Affordable Housing: The Case of Prince Fawaz Project

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Abstract
At a time when the world is passing through a climate change crisis, the mosque reveals how sustainable developments can help in mitigating global warming. This paper presents a case study of a suggested renovation project for a mosque in Sudan. The aim is to present numerical predictions of energy consumption before and after renovation. Comprehensive field measurements were carried out to be used as input data in the building energy simulation tool. The mosque suggested renovation project has resulted in a 23% reduction in energy demand and 38% of the total energy consumption covered by solar energy generation. The results also show that the choice of renovation measures, such as level of insulation, U value used for openings, and efficiency of the cooling system need careful consideration. Choice of lighting system also has a major effect.
Keywords: Renovation, Mosque, Simulation, Energy saving, Solar energy.

1. Introduction
The building sector consumes approximately 40% of total energy in the world. Governments accordingly setting codes that will help to reduce diminishing energy sources (Marie, 2012). It is recommended that buildings should be designed to provide good environment for users, but at the same time reduce energy consumption. According to the concept of the Zero Energy Buildings, buildings can also generate more energy than they consume (Ding, 2013).
A project studied in this research has provided case study evidence that the backbone of the design process of successful low energy building is the use of building performance software. It has also been noted that design decisions made in the very early stages of design have the greatest effect on performance. Performance simulation software permits an analyst to make a detailed model of the building and to examine the details of its performance. Exploring the feasibility of suggested renovation requirements for the model to enhance energy performance. For the purpose of this study, the researcher has chosen the project in Khartoum (Masjid Al-Sahaba in Al-Nakheel City).
The goal of this study is to renovate the mosque to become one of the first developments in Sudan to be low energy building; to achieve this, the energy strategy selected uses a combination of energy efficiency in buildings as well as strategy to improve the generation of renewable energy produced by photovoltaic panels integrated in the mosque envelop.

2. Material and Methods
The application of solar energy and building integration technology in buildings, mainly has three aspect: solar thermal technology, solar photovoltaic technology, solar optical technology, and mainly set on roofs, balconies, exterior walls and somewhere with ample sunshine.

2.1 Solar Thermal Technology
Solar energy is mainly used to supply domestic hot water, heating and refrigeration. In designing the integration of solar hot water system in buildings, the need is not only for considering the layout of solar hot water system, but also to improve the form of the system itself. Traditional solar hot water system with vacuum tube cannot meet the needs of the ever-changing layout and style of the buildings (Baon, 2011). Beyond that, it has other deficiencies, such as the difficult installation, easy destruction of waterproof layer of the roof, security risks if the lightning protection and draught exclusion devices are not in place, vacuum tube wear quickly, and water pipes that exposed to the outdoor cause large heat loss, etc. In short, the traditional solar hot water system with vacuum tube cannot meet the need of integration of solar energy in buildings either in quality or in performance. Now, the flat plate solar collector system is gradually replacing the solar hot water system with vacuum tube, for, it has higher adaptability, and the its installation can better achieve the perfect combination with the construction (Wang,2010). Solar collector system mainly operates on the split double-cycle under pressure. The hot water tank can be located in the basement, attic, staircase room, balcony and/or any other adequate places. In order to achieve a large amount of water, water tank can be a single one, double or even a multi-tank. If the tank capacity is increased, the installation area will corresponds to meet the hot water needs. Hot water is not only used in

bathrooms, but also used for heating and cleaning kitchen utensils. The water quality should be clean to meet the drinking water standards. Integrating solar collector with the roofs, balcony rails of the south façade, bay windows and walls, can make the appearance of buildings be overall unified, and have rich hierarchies (Dagne, 2010). When installed on the sloping roof, the solar collector can be embedded in the roof like a sunroof or flat out on the roof, integrating with the construction to increase the building beauty. When installed on the flat roof, the flat-plate solar collector can act as roof covering or insulation layer, not only conforms to the residential modelling requirements, but also avoids the repeated investment and reduce the cost. In addition, the flat-plate solar collector can be combined with balconies, bay windows, outside walls of buildings, to maximize the use of solar energy and provide new ways and means to the residential façade design, and achieve the aim of multi-purpose as well.

2.2 Solar Photovoltaic Technology

Solar photovoltaic technology applying in buildings is mainly used for photovoltaic conversion and lighting. Building Integrated Photovoltaic (BIPV) is a new concept for the application of solar power. In short, it is installing the solar photovoltaic phalanx on the surface of the maintenance structure of the building to provide electricity (hang, 2011). Photovoltaic arrays do not take up additional floor space when integrate with the construction. It is the best installation way of photovoltaic generation system, thus attracting much attention. BIPV can be divided into two categories according to the forms that photovoltaic array integrated with the buildings (Jin, 2011). One is the combination of photovoltaic array with building, installing the PV array on the building, and the building plays a supportive role as a photovoltaic carrier. The other is the integration of photovoltaic array with building, PV modules appears as a building material, and the photovoltaic array becomes the integral part of the construction. Such as photoelectric tile roof, photoelectric curtain wall and photoelectric lighting roof, etc.

2.3 Solar Optical Technology

The main use of the solar optical technology in buildings is for lighting, natural light can enter into the function rooms through the light guide tube, thus improve the indoor daylighting situation, such as underground garage, equipment room and storage room. Because utilization of solar optical system is also subjected to the impact of the climate, this technology is suitable for the regions that have abundant natural light and less cloudy sky (Wang, 2003). The light guide tube is mainly composed of three parts: a light collector for collecting the daylight; tubing portion for transmitting light, and the light exit portion for controlling the distribution of the light in the room. Using the light guide tube on the roof must ensure that there have no obstructions, and well water treatment to avoid leaking during the installation (Qin, 2012). Moreover, as the instability of the natural light, the light guild tubes must in combination with the adjustable artificial light, to be an effective supplement when the daylight is insufficient (Peter, 2008).

3. Methodology

The main objective of this research is to reach better building energy performance for the nominated case study (Al-Sahabah Mosque) in Sudan, and to enhance the performance of the suggested solar photovoltaic system and provide proposal to increase solar energy produces on site to run the building systems. To reach the aims stated, the research applies the (Generated and Test Technique), where the researcher makes suggested ideas under test to perform them using the Autodesk Ecotect Analysis software. Initially the researcher constructs energy consumption models that simulate a building for energy consumption prediction or energy saving estimates, and simulate the existing situation as it is. Then starting simulating the different techniques of sustainable and environmental architecture. The researcher studied several scenarios to choose the best. Finally, a model was created for the mosque, which has a better energy performance than the first option (Figure. 1).

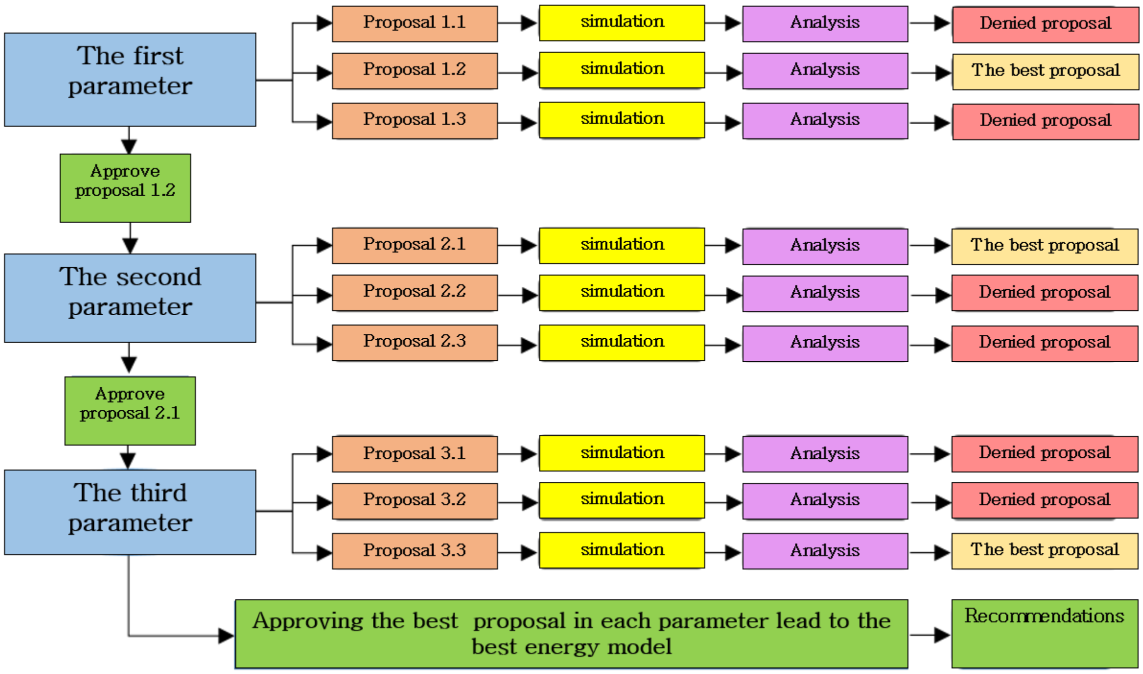


Figure 1. Methodology to reah the best energy model of the case study

4. Case Study Project Description

The case study shown below depicts the efforts done to create energy-efficient buildings integrated solar cells with its construction. The short project summary describes key features and lessons learned from the project. Masjid Al-Sahabah is a mosque in Khartoum, Sudan. The two story building finished in 2009. Its construction began in 2005. The ground floor Area is 1100 square meters. The total plot area is 3000 square meters. The total number of floors is two floors with a total height of 11 meters in addition to the minaret, which is 30 meters high.

4.1 Al-Sahabah Mosque Characteristic

Al-Sahabah Mosque has the following characteristics:

- Thick walls of concrete blocks plastered from both sides with a mixture of cement and sand.
- The finishing for the wall doesn't include thermal insulation only 2 layers of smooth paint.
- The roof is 20 cm thick concrete slab with an upper level of damp roofing coat.
- All windows are single glazing windows with a steel frame of 3 cm thickness.
- Interior finishing materials: The floors were finished with natural stone in addition to the plain concrete and carpet; no false ceiling was used only 2 coats of paint over plastered concrete slab.
- All light bulbs are florescent with 28% of halogen bulbs added to the main wall.

As shown in figure 2 below the exterior of the building has been finished with plaster and paint, in addition to single glass with steel frame for the windows.

Figure 2. Al-Sahabah Mosque aerial photo and elevations.

4.2 Prepare a Model for The Mosque to Be Analysed

The simulation work begins by building a model that conforms to the specifications of the existing building using Autodesk - Revit 2016 software. The construction is done step by step, taking into account all the openings, internal divisions and materials. Energy setting is adjusted and entered accurately to the program. Then starting simulating the existing situation and the different proposals to study several scenarios and choose the best. The following table (Table 1) shows the nine design parameters which fall under three main categorize (HVAC, Lighting and Solar cells), the table also shows the specification for the existing situation and the three options simulated:

Table 1. The Design parameters specification

	Design Parameters	**The existing situation**	**The first proposal**	**The second proposal**	**The third proposal**
HVAC	Thermal Insulation	Only one layer of polystyrene polyurethane Insulation on the roof.	2 layers of polystyrene polyurethane Insulation on the exterior walls and the roof.	One layer of polystyrene polyurethane Insulation in the middle of the block walls + one layer of Nano technology insulation on the exterior walls and roof.	2 layers of polystyrene polyurethane Insulation on the exterior walls + one layer of polystyrene polyurethane Insulation on the interior walls and roof.
	U- Value	Opening is 34% of the total are of the building envelop, with U – Value 0.85	Opening is 34% of the total are of the building envelop, with U – Value 0.45	Opening is 34% of the total are of the building envelop, with U – Value 0.55	Opening is 34% of the total are of the building envelop, with U – Value 0.65
	Colors	Light orange color	Dark brown color	White color	Dark green color
Lighting	bulb type	72% used in the building is florescent bulbs and 28% halogen bulbs.	100% of florescent bulbs.	100% of compacted florescent bulbs	100% of LED bulbs
Solar energy	Inclined Degree of the solar cells	Vertical, inclined 0◦ degree.	Inclined 30◦ degree. see Fig.6, a	Inclined 20◦ degree. see Fig.6, b	Inclined 10◦ degree. see Fig.6, c
	Additional options for production	None	Integrate 260 square meters of solar cells in the south western elevation.	Integrate 260 square meters of solar cells in the north eastern elevation.	Additional 450 square meters of solar cells on the roof

The Inclined Degree of the solar cells is identified to get 90 Angle, as shown in figure 3, by applying the equation (Angle of Optimal tilt = 90 – Angel of the Sun, this ensure that sun rays will always be perpendicular to the solar cells:

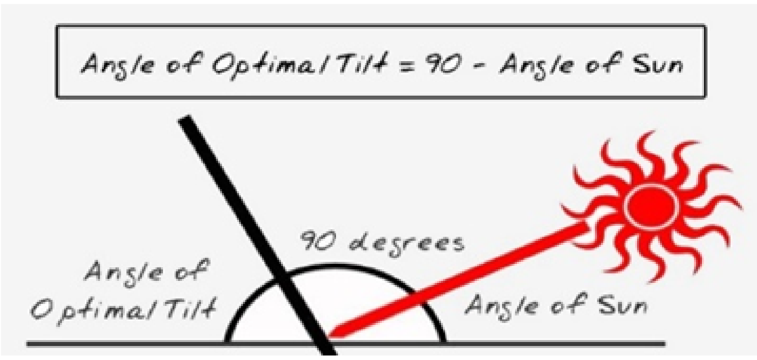
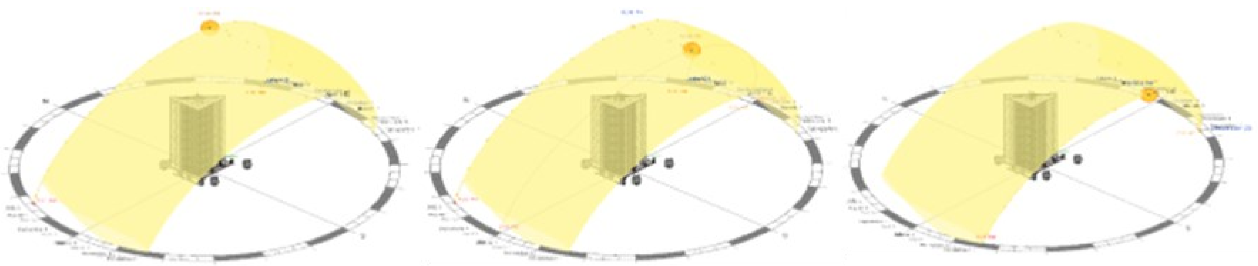


Figure 3. Identification of the Angle of the solar cells

The study tested 3 options of the inclined degree:

- 30°, it considers sun angle equal 60° (maximum degree toward the South on 23rd December).
- 20°, it considers sun angle equal 70° (on 23rd December).
- 10°, it considers sun angle equal 80° (maximum degree toward the North on 16th June).

As shown in figure 4.



a: 10°, it considers sun angle equal 80° **b:** 20°, it considers sun angle equal 70° **c:** 30°, it considers sun angle equal 60°

Figure 4. Identification of the Angle of the solar cells

5. Alternative simulation result

- **First:** Design Parameter: (Thermal Insulation):

Three alternatives will be tested for insulation as shown in Table 1; internal temperatures are also derived from the simulations of the three alternatives in the hot period. The researchers notice that the second alternative which uses nanotechnology was the lowest temperature in the warm season with a slight difference of 1°, while the worst was option 1 which achieves the highest internal temperature, figure 5.

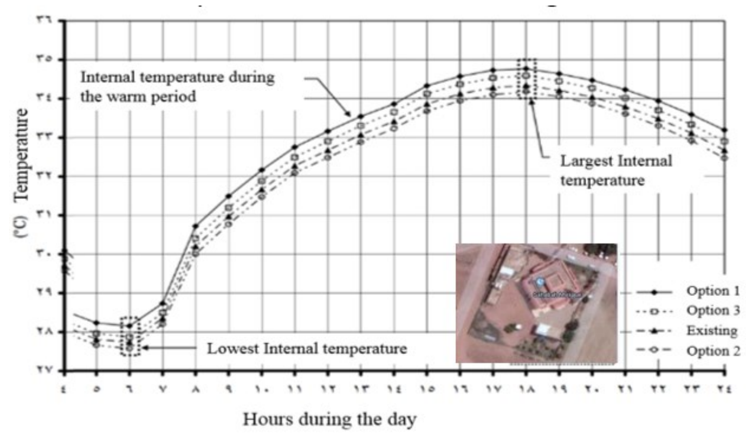


Figure 5. Internal temperatures in the different alternatives of thermal insulation

- **Second:** Design Parameter: (U-Value for glass of openings):

One of the most important components of the building's envelop is the openings, so designers have to consider the use of glass with good thermal properties. This is determined by the U-value of the glass used, where it represents the coefficient of heat transfer and its absorption and emission of the solar radiation falling on it. The window should reduce the heat passing from outside to inside by:

- Preventing direct solar radiation by improving the type of glass, noting the direct effect of solar radiation on thermal comfort. (U- Value) will be tested by 0.85 for the current situation and compared to other amounts (0.65, 0.55, and 0.45).

The result shows that there is a clear discrepancy between the internal temperature in each case, lower degree was registered in option one (U- Value=0.45).

- **Third:** Design Parameter: (External colors):

In this section, the effect of the colours of the external facades of the mosque was studied. The current situation in addition to four options (dark green, white, dark brown, light orange). Figure 6 shows the results of the simulations with the internal temperature values of the mosque in each case. It shows that there is a difference in temperature in the warm period between the colours, with increasing the difference from 8 am to midnight until the it reaches two degrees Celsius, while for the rest of the day the graph shows convergence in temperature Up to 1 ° C, maximum internal temperature at 6pm and lowest temperature at 6 am.

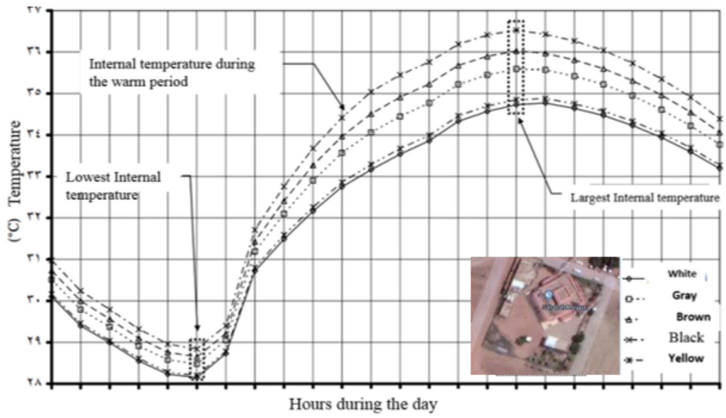


Figure 6. Internal temperatures in the different alternatives of façade colour

- **Fourth:** Design Parameter: (Bulb type):

The standard (incandescent) bulbs are replaced with Fluorescent Lamp. The standard incandescent bulbs are replaced with Compact Fluorescent Lamp (CFL). The last alternative is to replace all lamps used with energy-saving LED bulbs, while maintaining the same intensity of light. The following table shows a comparative study of the advantages of using energy saving lamps, incandescent bulbs and LED lamps, table 2.

Table 2. Comparison of electricity consumption for three options of lighting

	Third option	Second option	First option	Existing situation	unit
Electrical consumption / each bulb	8	15	60	100	Watt/Hour
Number of bulbs in each floor	210				bulb
Operation time for each bulb	12				hour
Total Electrical consumption for all bulbs	20	37.8	151	252	Watt/Hour
Saving Percentage compared to existing situation	%92	%85	%40	%100	

- **Fifth:** Design Parameter: (Inclined Degree of the Solar cells):

Solar energy systems perform best when sunlight directly fall on them, regardless of the technology used. Any partial shading of their matrices can result in a significant reduction in the rate of electricity generated. Fortunately, the studied site has no obstructions to the sun; it is on a main street. But the question remains (which angle should the solar panels be directed to?). The question is simple, but in fact the answer is a bit complicated. For example, if we talk about a city on the equator, the direct answer would be to make the solar panels look straight up directly. If we talk about a place on the southern continent, the answer would be to make solar panels vertical. But in the case of middle countries, as in the case of Sudan, we installed the solar panels depending on the angle of the Sun.

This leads us to the fact that the angle of inclination must vary in each season from the other in order to achieve maximum benefit in each season. But this will not happen often due to the high cost of moving all this quantity of panels. The paper reviews the simulation results for the three angles under study and see what will be the best solution.The result shows that there is a clear discrepancy between the levels of generation of energy from the solar system adopted at the installation at a specific tilt angle and was above angle 20 and exceeded angles by approximately 0.5 kW at peak hour. The slanted structure gives a better result than vertical stabilization. In all cases, generation is more than generation in the vertical position of more than 10%.

- **Sixth:** Design Parameter: (Additional Solutions for Solar Energy):

There are additional solutions worthy of experimentation, including:

- Adding solar cells to the roof where there are 800 square metre available.

Expected power to add = 110 x 800 = 88,000 watts Approx. 88 kW.

The total expected power will be = 365 x 88 = 32,120 kW.

The optimal orientation of the tower from previous findings of the evaluation matrix is the south-west orientation, other 2 options will not be added, because the north-east and south-east elevations do not receive enough direct solar radiation and it is useless to add solar cells.

(Figure 7) shows the generation values of solar radiation and their percentage in each of the seven orientation alternatives. It shows that the optimal orientation for obtaining the highest percentage of solar energy generation is the south followed by south-west.

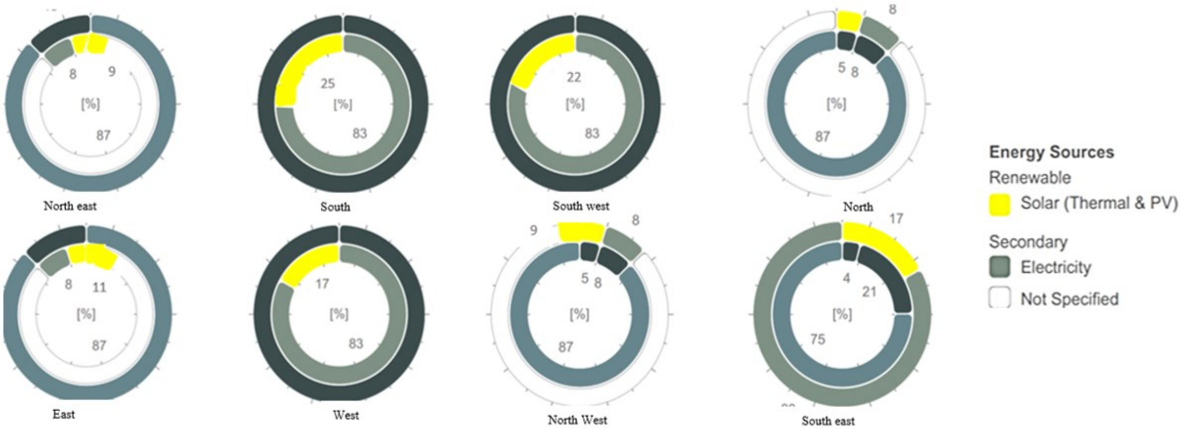


Figure 7. Result of energy generation values of solar cells in each of the seven orientation alternatives.

6. Recommendations to Modify the Current Situation Of The Mosque To Improve Energy Efficiency

Then several scenarios have been tested and the paper recommend the best solution in each of the design parameters studies (HVAC, Lighting and Solar system), the following table 3 shows the existing situation and the recommended modification to improve energy efficiency in the tower as follows.

Table 3. Details of the revised default model specifications

Categories	Design Parameters	Existing situation	Modified ideal model specifications
(HVAC)	Thermal Insulation	Polyurethane insulation has been applied as one outer layer in the outer block walls	Insulation of polystyrene as an intermediate layer in the walls of the external block, in addition to the outer surface of the walls with a nanotechnology insulating material
	The U-Value	The test will start for the actual and represent 43% and the U-Value of the glass used is 0.65.	U-Value of the glass used is 0.35
	Colors	Current Mode (Light Grey)	Use colors with a different reflective effect better than Grey User Alternative II (White)
(Lighting)	Bulbs type	Lamps used are halogen and fluorescent	. The option of halogen bulbs will be cancelled and only LED bulbs will be used for the entire tower.
(Solar System)	Inclined Degree	The current status of vertical solar cells is mounted along the height of the façade.	Angle of 20 ° C (in warm period) Cells are installed on 30° mode in cold period. See Figure 8-25.
	Additional options	None	Additional solar cells in the roof with an area of 800 m^2 Additional options for generating / additional options The solar cells are installed on the southwest facade.

7. Conclusion

Solar energy and building integration technology has broad application prospects, using simulation program will play a significant role in applying the use of solar energy in an efficient way, in the case shown for Al-Sahabah Mosque, the researcher was able to increase the percentage of energy consumption covered by the solar energy by approximately 40%. Finding an accurate and efficient way to model and simulate the building to evaluate the energy consumption is of upmost importance. Many future areas can be taken with this model. Use of real data should be used to refine the assumptions made and parameter calculations performed.

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Conflict of Interests

The authors declare no conflict of interest.

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