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Reducing the energy consumption of buildings by implementing insulation scenarios and using renewable energies

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Abstract

The reduction of fossil energy sources, the harmful environmental effects caused by high energy consumption, and the increase in the share of energy consumption in the building sector have increased the need to pay attention to building energy consumption. This study offers an intricate examination of a residential locality in Florida, with a particular emphasis on the architectural design of a building, issues related to the local environment and several possibilities for enhancing energy efficiency. It examines the influence of the environment in the area on architectural design and investigates two different possibilities for improving energy efficiency. The first scenario focuses on assessing thermal insulation and shading, while the second scenario envisions utilizing photovoltaic cells to achieve a zero-energy building. The proposed initiatives seek to optimize energy efficiency, save expenses, and foster environmental sustainability in the region. In this research, the total energy consumption of a building with residential use in the climate of the case study was validated by DesignBuilder® simulation software, and the results obtained from the software. Then, using the standard of energy consumption of the building, various strategies for optimizing energy consumption have been simulated. Using energy simulation software, solutions for using external horizontal awnings and installing a thermal insulation sheet on the external wall of the building were investigated, which resulted in a reduction of 200 kWh of energy consumption compared to the normal state. Then, the building's energy consumption intensity was calculated for each of the proposed solutions, and the building's energy classification was determined with energy star and LEED standards.

Keywords: Building energy system, DesignBuilder®, PV system, Renewable energy

Introduction

According to historical records, the earliest uses of human energy were for warmth and self-defense, followed by cooking and transportation. During the early phases of his evolution, a man undoubtedly considered creating a shelter (Kargar Sharifabad and Jalilian 2016). Due to technological development and population increase, the annual energy demand continues to rise. This is primarily because energy drives the majority of the global economy (Moosavian et al. 2022). According to a study released by

the International Energy Agency (IEA), a significant event that occurred in 2018 was a growth in electricity usage that was nearly double that of 2010 (Chwieduk 2017). Carbon dioxide emissions increased significantly from 1.7 to 33.1 G.t in 2018 due to the rising energy demand. The majority of people across the world spend the majority of their time inside; thus, we must investigate how buildings can conserve energy. Indirectly, the performance of buildings accounts for around 1.2 percent of global energy use today (Jo et al. 2018). Moreover, fifty percent of the energy consumed in buildings is for heating and cooling, ten percent for lighting, and the remainder for other energy needs (Fathalian and Kargarsharif 2020). The energy consumption of buildings is influenced by various factors, which include (Zahedi et al. 2022a):

A. Local weather;
B. Location and orientation of the building;
C. Type of building design;
D. Type of use and how to use the building;

In addition, energy management in buildings can be considered by considering the following factors (Ebrahimi et al. 2022):

A. Location of the building;
B. Covering the building;
C. Various installation systems;

The limitation of energy resources and the increasing consumption of it on the one hand and the excessive consumption of energy by different societies on the other hand, in addition to environmental pollution and wasting national funds, have put the future life of humans at risk (Liu et al. 2012). Although, building's weather conditions are determined by the location chosen for the structure. The building envelope determines the impact of local circumstances on the inhabitants of a structure (Lang et al. 2016). This cover is a porous shell that transfers energy, light, gases, and water vapor between its two sides, the building, and the environment (Sharifi et al. 2017). The power of cooling, heating, and light that may be gained from the surrounding natural environment is supplemented by installation systems. Energy consumption may be decreased so long as the usage of these extra systems is proportional to the capabilities of the building envelope and its regional features.

If a building is planned without environmental variables in mind, that is, if the building envelope and mechanical and electrical systems are constructed independently and in isolation from other elements, it is anticipated that the structure's energy consumption will achieve its maximum level (Zhu et al. 2013). General guidelines for optimizing energy usage in building architecture are:

A. The architectural design of a structure should take into account the local climate;
B. The structure's orientation should be chosen to receive optimal solar and wind exposure;
C. Utilize trees, their shade, and their natural effects;
D. Utilize plants and flowers to enhance the local environment;

E. Shades should be used to limit the amount of heat absorbed by the sun during the summer and to mitigate energy losses;
F. To decrease energy consumption, the size, surface area, and volume of the building should be adjusted;
G. The building's exterior should be reinforced and insulated to decrease energy loss and air infiltration;
H. The design of windows incorporates double or more panes of glass to minimize thermal energy loss;
I. The window sealing should be improved so that air penetration and air loss are minimized.
J. The capacity to store thermal energy within the structure must be supplied;
K. Solar cells should be utilized as construction materials;
L. The entrances should be carefully built, and the patio idea should be utilized as much as possible;
M. Before planning the structure, discuss and cooperate with the designers of the building's mechanical and electronic systems.

The building sector is one of the major energy-consuming sectors, and it is necessary to pay special attention to the category of fuel consumption optimization in buildings. As it is known, the rational use of energy resources and planning in the fields of optimizing energy consumption have a special priority. Most of the solar house plans were implemented as individual villa houses in one space, and the use of this technology in a large area and residential neighborhood has rarely happened.

In this research, two scenarios to minimize energy consumption by simulating a building complex consisting of 9 communities and 90 structures in the city of Florida, USA on the design software is simulated and also the effect of shading and the use of solar energy systems are implemented. Energy analysis is done using PV-Syst® software. This study offers a thorough analysis of the historical development of human energy usage, the challenges related to increasing energy needs, and the impact of architectural design on global energy consumption. It focuses on the factors affecting energy consumption in buildings, energy management strategies, and the significance of optimization. The outline provides clear guidelines for designing energy-efficient buildings. It presents a case study in Florida, USA, which involves simulating a complex to optimize energy usage by implementing shading and solar energy systems.

Literature review

A case study of a one-story residential building with an area of 110 square meters with 4 people living in the cold and dry climate of Mashhad in northeastern Iran. For thermal simulation, climate studies (air temperature, sundial, wind, precipitation, and hourly sunlight) of the study area were prepared from the meteorological station of the region and the meteorological database of Climate software. DesignBuilder® software is used to simulate and dynamically analyze the heat of the structure. The results of this simulation show a 10% reduction in the annual energy consumption of the building by observing the principles of passive design (optimal direction selection, Trump wall, canopy, selection of suitable insulation) from 0.44 kWh to 0.77 kWh The solar photovoltaic system

was designed with PV-syst® software and the annual extraction energy of the system is estimated at kWh 0.4. According to this study, the most energy is produced in June, July, August, and September; and the lowest is in November, December, January, and February. A comparison of this amount of energy production with the average monthly energy demand has shown that in July and August we had surplus energy that was injected into the electricity distribution network, and in December and January, we had a shortage of energy that had to be supplied through the electricity distribution network. The amount of annual extraction energy of this solar system is, 4142 kWh (Kuhn 2017).

The EU aims to create a guideline that requires all new buildings to comply with the use of renewable energy. The average reduction in energy consumption in 2040 compared to the reference year of 2012 is likely to reach 5.69%. In addition, the installation of 20 square meters of solar panels on the roof of each residential building produces 6.53% of renewable energy, which ultimately shows that more than 90% of the current energy can be reduced with solar panels and building renovation (Nematchoua et al. 2021).

Siamak Hosseinzadeh et al. in a study have addressed the issue that, In the main part of this article, the use of DesignBuilder® software has determined the amount of energy consumption of the building. For this purpose, an average of 63 square meters of solar panels was considered. In general, based on the results, it is shown that by performing activities and the amount of electrical energy consumed for air conditioning of the building is freed up to 80% and reduced from 34 to 7 MW by calculating the energy required by the building and reducing it to a minimum. It can be supplied with electricity from photovoltaic panels and solar water heaters on sunny days. The worst-case scenario is in the months when the sunlight is low. 218 square meters of a solar panel is needed to supply electricity to the building, while in the best sun condition, this area has been reduced to 63 square meters to supply the required electricity in the remaining 4 months. Using the methods of saving the necessary electricity consumption, the necessary electricity can be purchased from the network and instead of paying for these four months, the surplus electricity can be paid for another eight months (Hoseinzadeh et al. 2020).

Abdeen Mustafa Omer et al. These days, the rapid development of wind energy and technology has replaced conventional energy, and this development of the wind energy system is of great importance, and this energy can be used in remote places, even on a small scale. Wind turbines are often used on Farms and windy beaches are used. But if you have enough space, you will also be able to use small wind turbines to extract wind energy. In the case of wind turbines, some limitations have reduced their popularity in-home use. These limitations include an ugly appearance, making a lot of noise, and taking up space. Depending on where you live, wind turbines are more energy efficient than solar panels. One of the proposed proposals is to install a solar thermal collector with coverage of 60% of the annual energy demand for domestic hot water. Also, mandatory solar hot water in new constructions is a significant procedure (Omer 2010).

Lucas Mosca et al. In this study conducted in the Hamburg region of Switzerland, the wind speed in the region at an altitude of 50 m is 4.7, and one kilometer south of this region the wind speed is 5.8 m per second. And due to the distance of wind turbines, the sound was low. Due to the complementarity of solar energy and PV wind panel, the capacity is 600 kW, and with 8 turbines is 95 kW. Wind speeds are higher in winter than in summer, so it partially compensates for the reduction in power generation from the

PV panel. During the summer, when wind power generation is lower, it offsets the PV panel. The annual electricity potential of PV in Hamburg is 5249 MW on the ceiling and 5177 MW is produced in clear PV mode, the ratio of electricity production and demand is 274%, which is due to the loss in the heat pump and its conversion into It is electricity and electricity generation is not equal to its peak consumption (Guen et al. 2018).

Behzad Rismanchi et al. Integration of renewable energy technologies and building renovation are the two main procedures. For this purpose, QGIS and homer pro software were used. The hourly energy demand of buildings was analyzed through current demand. The results show that heating demand with building renovation Space has been reduced by 70 to 85 percent. And the reduction in fluctuations in energy demand thus allows for more integration of renewable energy according to the simulations. Integrated PV solar panels in the building can reduce annual energy demand. However, energy system evaluations have shown that it is difficult to achieve more than 60% when integrating non-distributable renewable technologies. Finally, it is more important to use wind energy alongside solar energy, which is very efficient (Wells et al. 2018). In another study, Jing et al. found that the amount of fuel consumed in a building in Xi'an City was 32 percent natural gas, 67 percent LPG, about 34 percent gasoline, 48 percent electricity, and 51 percent natural gas for winter heating. We need to improve fuel efficiency and use cleaner energy sources such as solar panels and biogas and wind energy (Cai and Jiang 2008).

In another study, researchers argued that fossil fuel energy sources are becoming increasingly scarce. Given the negative environmental impacts (such as greenhouse gas emissions) associated with their use, it is not surprising that the development of renewable energy has become a top priority in today's world. Andalusia, with average solar radiation of 4.75 kWh per square meter per day and an area of 87,597 square kilometers, is the region in Europe with the highest potential for solar energy and is the best place to use solar energy and solar panels in residential areas in this region (Zahedi et al. 2023a). This research study has determined the solar energy potential in Andalusia for grid-connected photovoltaic systems installed on residential roofs A method was developed for this purpose, which first involves describing the characteristics of the building and then calculating the useful area of the roof on which the photovoltaic arrays can be installed. In the next stage of the study, the average characteristics of solar radiation as well as the technical parameters of photovoltaic systems are defined. All of these factors allow us to estimate the amount of electricity that can potentially be generated per year by solar panels, and to use and benefit from clean and pure solar energy such as solar and wind energy (Ordóñez et al. 2010).

In another article by Loclasso et al. On the economics of using renewable energy in residential neighborhoods, there is a growing interest in reducing energy consumption and associated greenhouse gas emissions in every sector of the economy. The residential sector consumes a significant amount of energy in each country and therefore focuses on energy consumption efforts. Because the characteristics of energy consumption in the residential sector are complex and interrelated, comprehensive models are needed to assess the technical and economic effects of adopting energy efficiency technologies and renewable energy sources suitable for residential applications. Two distinct approaches have been identified: top-down and bottom-up. The top-down approach considers the

residential sector as an energy source and is not related to individual end-users. Uses total historical energy values and reduces housing energy consumption as a function of high-level variables such as macroeconomic indicators (such as GDP, unemployment, and inflation), energy prices, and public climate. The bottom-up approach estimates the energy consumption of a set of individual houses at the regional and national levels and consists of two distinct methods: the statistical method and the engineering method (Swan and Ugursal 2009). Balaras et al. (2000) investigated the potential of energy conservation in buildings. They followed the EPIQR methodology and software. Of course, this article deals with the issue that most of the solar house designs were implemented as single villas in one space and the use of this technology in a large area and residential neighborhood has rarely happened. One of our goals is to find the methods that should be used to save energy in these large dimensions, and also see their effects on modeling with DesignBuilder® and PV-syst® System software, and the gap between the previous articles will be visible in the form of a villa building and a town of such a large size. In this article, the entire community and residential area is designed and its special features and energy-savings are mentioned.

In a study conducted in Denmark, various factors were considered about changes in energy consumption for apartments and residential buildings (Gilani and O'Brien 2017). These factors include orientation, building systems (i.e., heating and ventilation systems), and the composition of the building envelope. These coefficients are comparable across different buildings (Medrano-Gómez et al. 2022). Nielsen et al. found that the demand for lighting is indirectly related to daylight (Hviid et al. 2008) and depends on the location of the building. Previous research has indicated that lighting accounts for 11% of energy consumption in the United States, compared to 6% in Australia. This highlights the importance of considering location-specific energy consumption methods. Operational differences, such as the amount of access to sunlight and the behavior of residents, create limitations, and it is essential to acknowledge the impact of resident behavior on energy consumption (Azar and Menassa 2012).

Sadersky et al. reported that in terms of domestic energy usage, heating and cooling accounted for 48% of the energy consumed in US households in 2009, a decrease from the previous figure of 58% in 1993. The reason for this is the use of more advanced machinery, improved insulation, and the utilization of efficiency regulations and technological advancements (Sadorsky 2012). Studies conducted in China (Zhou et al. 2014) have demonstrated a significant disparity in air conditioning power usage in summer among apartments of the same size in the same building. This discrepancy can be as high as 10, particularly for energy-efficient buildings that depend on passive design characteristics (Hong et al. 2017). The focus is primarily on passive strategies like natural ventilation and the use of daylight, as well as active interaction between occupants and building systems (An et al. 2018). Research has indicated that buildings that adhere to high-efficiency standards, including the implementation of internal and external insulation to minimize energy consumption, are associated with passive house design, which has the potential to reduce energy usage. These buildings have made a substantial contribution and positive impact on their occupants' comfort, satisfaction, and productivity. However, achieving these benefits necessitates advancements in science and technology (Day and Gunderson 2015).

Different countries have different systems to reduce energy consumption, and different models are used according to the climate, behavioral culture, and economic and cultural issues, which can be considered limitations. At the beginning of this research, we showed that this research is considered an important issue from the perspective of energy analysis because the goal of reducing energy consumption is not a villa building. However, we are facing a broader level of residential settlement, so it is a must to consider multiple scenarios where we have to supply more than one house. However, the whole town can be extended to all residential houses, which is the limitation of our research because the number of people living in the houses—the thermal comfort point of each household may be different from others—the direction of the building—change Latitude and these topics were the main research limits.

Also, scenarios should be selected that are up-to-date and scenarios that can be implemented in the dimensions of a residential settlement, so three main scenarios were defined: (1) Use of internal shade, (2) Use of thermal insulation in the wall and ceiling in addition to the roof, which has a significant contribution in reducing energy consumption by 35 to 45%, (3) Use of solar energy that can also be generalized at the residential settlement level to go towards zero energy settlement in future studies. Also, economic analysis of the scenarios has been also discussed. Finally, different sectors are analyzed separately from the perspective of investment rate of return, which adds to the operational soundness of this research.

Methodology

Case study

Florida City is a city in Miami, Florida, and was founded in 1914. The city had a population of 11,245 at the 2010 census and an area of 18.3 square kilometers (Ghoshchi et al. 2022). It is 721 km long and 582 km wide. The climate of this city is cold in winter and sometimes the cold weather is mild. Coastal areas in all parts of Florida average warm temperatures and cold winters. South Florida is one of the hottest places in the United States in winter. Lightning strikes about half of the summer days. Most of these thunderstorms cause the temperature to drop rapidly by 10 to 20 degrees. The highest temperature recorded in Florida was 109 degrees. The lowest recorded temperature was 2 degrees below zero.

The study explores energy-saving tactics for residential communities in Florida, focusing on thermal insulation and photovoltaic cells for Zero Energy Buildings (ZEB). The selection of approaches is based on clear and objective criteria, considering aspects such as the influence, cost-effectiveness, technological feasibility, environmental considerations, suitability to the local climate, long-term sustainability, ease of implementation, and socio-economic ramifications. The selection process is guided by these criteria, which aim to achieve significant energy savings, economic viability, practical implementation, and favorable environmental and social results.

Building description

The buildings in question are residential neighborhoods defined in 9 different blocks as shown below in Florida. The building has two floors and the area of the first floor is about 769 ft (234.39 Meters), the second floor is 944 ft (287.73 Meters), the area of the

balcony is 59 ft (17.98 Meters) and the total area is 2021 ft (616 Meters). The plan for the whole residential neighborhood of the building is under study. The spaces in this simulation of a building include different parts living room, bedroom, hallway, entrance, bathroom and kitchen, and parking. The building descriptions and the residential area under study are shown in Figs. 1, 2, 3 and Table 1.

Air conditioning

Heating installations: heater unit

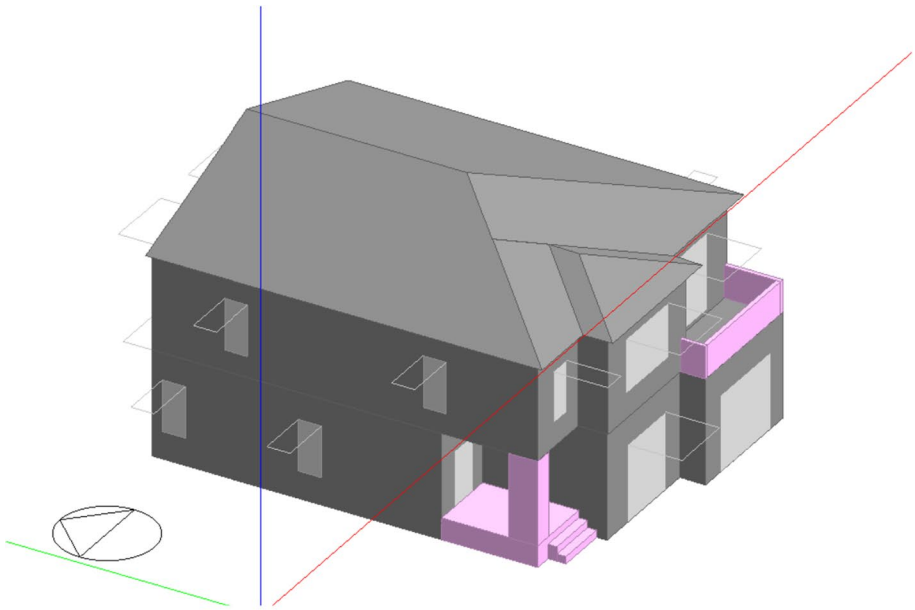
This device is used to heat residential neighborhoods. The heater unit system is available in wall, ceiling, and industrial types. Because these systems have a heating fan, they have a higher heating power than radiators and can easily heat large spaces with high ceilings according to the shape of the building. In this system, water is heated in the boiler and enters the heater pipes (Shaghaghi et al. 2024). Then, air passes through the coils of the heater unit using a centrifuge fan, and finally, hot air comes out of it. This device consists of a simple structure of the metal body, a copper coil with an aluminum fin, an electric motor, a water inlet, and outlet pipes.

Cooling facility: air handling unit

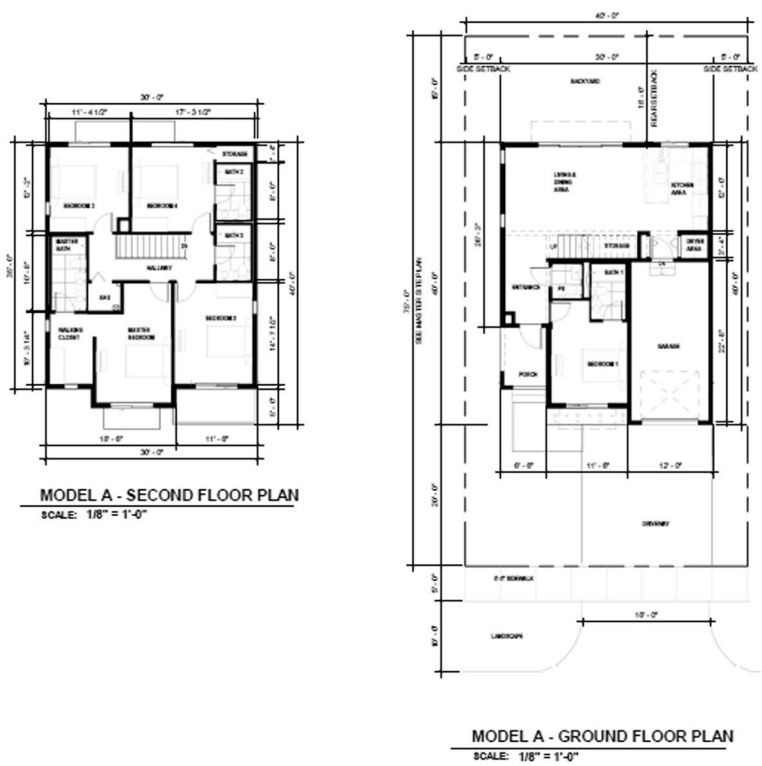
A home air conditioner is the best home air conditioning system. The system of this type of air conditioner is central and providing heating and cooling of this type of home air conditioner requires proper ventilation and excellent performance of the central system equipment, including chillers and other devices (Zahedi et al. 2023b). These types of air conditioners are generally installed on the balcony and outside and are channeled inside the house or environment.

As for how to control the heating equipment, it was most common that it was mostly set to one temperature and the occupants left the place in the same way. About 40% of homes stay that way during the day. Several households adjusted the temperature based on the time of their stay. This number makes up about 26% of households. About 17% of households adjust the temperature to one degree by programming with a thermostat, and about 15% of households manually increase or decrease the temperature by turning the thermostat. Most of the time, the house temperature is set around 70 degrees Fahrenheit (21.11 °C).

Fig. 1 Schematic of the modeled building



a)



b)

Fig. 2 **a** Schematic of the modeled building in DesignBuilder® **b** Plan of the first and second floors of the building

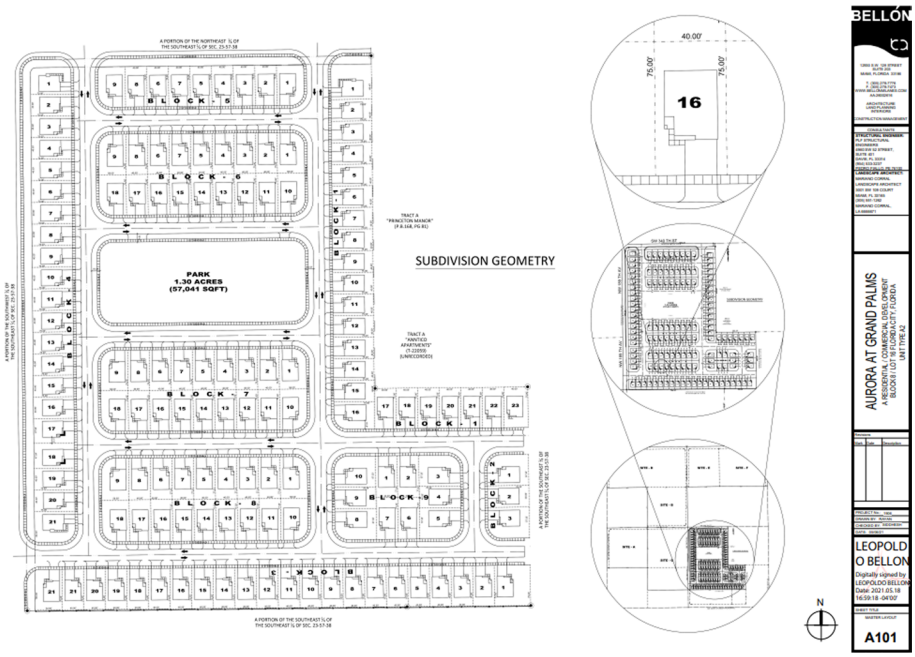


Fig. 3 Overview of the residential area (Zahedi et al. 2022)

Scenarios used in this model

Scenario 1—using thermal insulation

The thermal parameters affecting the thermal load of the building are as follows:

A. Receiving direct radiation: The heat that enters the space through the direct entry of radiation from windows and other transparent surfaces;
B. Receiving through the shell: The heat obtained from the absorption of radiation by the components of the shell such as walls and windows and the ceiling is returned to the room. Scenario 1 depends on which material is used to improve the energy;
C. Receiving through ventilation and air leakage: Heat resulting from the exchange of indoor air with outdoor air, such as leaks from gaps and locations that are not well sealed, such as porous materials or the sea;
D. Internal receipt: heat from lighting equipment such as LED lamps and other equipment and the number of people present in residential buildings and the type of activity of people in the residential neighborhood;
E. Internal reception of zones: The heat transferred between adjacent zones due to the temperature difference between them through the wall of the window and the ceiling and floor between the two floors of a building in a residential neighborhood that consists of 9 blocks.

One of the best and easiest ways to keep the house warm in the winter and cool in the summer is insulation. If your house is insulated, it will be 5 degrees warmer in winter and 10 degrees cooler in summer. The most important thing to keep in mind when choosing insulation for your home is its thermal resistance. The higher the thermal resistance of the insulation, the less heat will pass through the insulation. As a

Table 1 Different plans and views

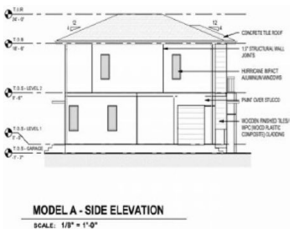
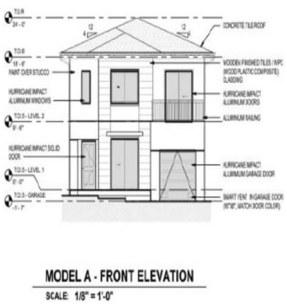
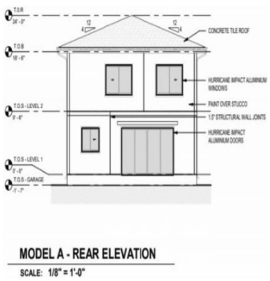
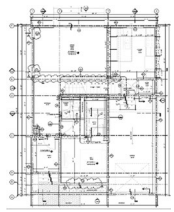
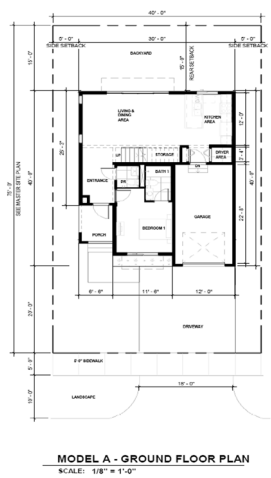
Sample	Sample plan	Description
Example number 1		MODEL A—SECOND FLOOR PLAN SCALE: 1/8″ = 1′-0″ Bedroom No. 3 is on the southeast side with two windows facing south and east The master bedroom is in the middle of the building on the south front Changing room to the left of the master bedroom on the south front Bedroom number 2 on the northwest front with a northern skylight Bedroom number 4 on the northeast side with a northern skylight
Example number 2		MODEL A—SIDE ELEVATION SCALE: 1/8″ = 1′-0″
Example number 3		SCALE: 1/8″ = 1′-0″ MODEL A—SIDE ELEVATION
Example number 4		SCALE: 1/8″ = 1′-0″ MODEL A—FRONT ELEVATION The garage is on the south side The bedroom is on the south side The entrance to the house is on the left The stairs are in the middle of the house
Example number 5		SCALE: 1/8″ = 1′-0″ MODEL A—REAR ELEVATION

Table 1 (continued)

Sample	Sample plan	Description
Example number 6		SCALE: 1/8″ = 1′-0″ MODEL A—GROUND FLOOR PLAN
Example number7		CALE: 1/8″ = 1′–0″ MODEL A—GROUND FLOOR PLAN The kitchen is on the northeast front The living and dining room is located on the north side The garage is on the south side The bedroom is on the south side The bathroom is located in the middle of the house The entrance to the house is on the left The stairs are in the middle of the house

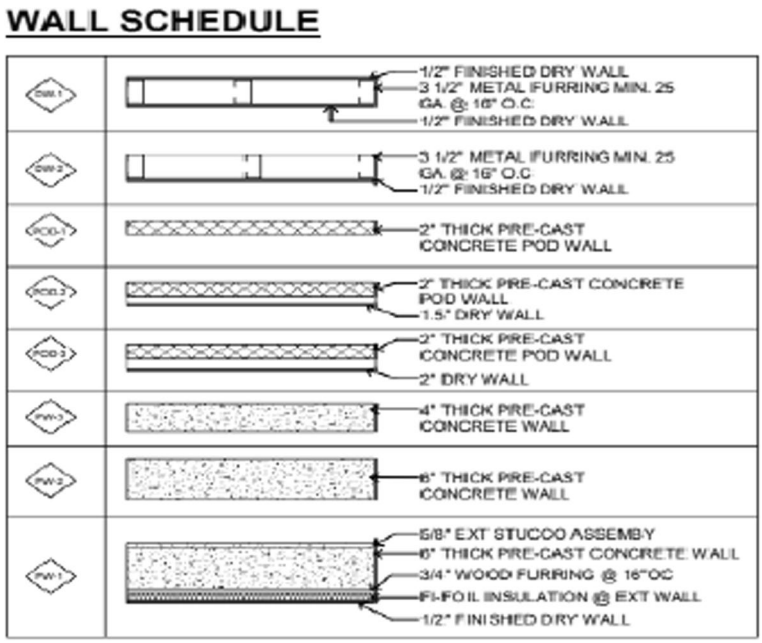
result, the amount of savings in fossil energy consumption will also increase. Note that the thermal resistance of the insulation does not mean that its diameter is thicker.

A. Roofs of buildings;
B. The roof of buildings is one of the most significant and main parts that must be insulated. Insulating roofs by 35–45% will reduce energy consumption in buildings;
C. External walls;
D. Insulating the walls of houses prevents the penetration of heat and cold from outside the building into it. Wall insulation can reduce energy consumption in homes by 15%.

One of the best and easiest ways to keep the house warm in the winter and cool in the summer is insulation. If your house is insulated, it will be 5 degrees warmer in winter and 10 degrees cooler in summer. The most significant thing to keep in mind when choosing insulation for your home is its thermal resistance. The higher the thermal resistance of the insulation, the less heat will pass through the insulation. As a result, the amount of savings in fossil energy consumption will also increase. Note that the thermal resistance of the insulation does not mean that its diameter is thicker. Table 2 shows the layers used in the wall (Aslani et al. 2023).

The roof of buildings is one of the most (Significant) and main parts that must be insulated. Insulating roofs by 35–45% will reduce energy consumption in buildings.

Table 2 Layers used in the wall



Insulating the walls of houses prevents the penetration of heat and cold from outside the building into it. Wall insulation can reduce energy consumption in homes by 15%.

One of the strengths of this article that distinguishes it from other articles is that one of the innovations of this building on a large scale is the use of thermal insulation in the outer shell. The building causes the heat from natural heating sources such as solar radiation, heat from residents, and heat from electrical devices to remain inside and to be used as an auxiliary heating source.

As a result, if in this area with a high cooling demand, a suitable canopy is not provided on the windows, not only the indoor temperature becomes unbearable in the hot season, but also the cooling load of the building increases significantly and a lot of energy is needed to provide the necessary cooling. To prevent this, awnings with appropriate depth should be installed on the windows of the buildings located in these areas. For this purpose, for latitudes of 25 to 37 degrees North and ows located in different geographical directions, awnings have been proposed that provide up to 100% shade on the window in hot weather. In order suitable canopy, various shapes can be provided for the canopy by using the angles suggested in the software, so that the three desired can be created on the entire window in addition to the freedom in designing and preserving the beauty (Zahedi et al. 2022b).

$$W = DR \times tg\,(Z - N)$$

W: the width of the shade and from the side of the shade, *D R*: shade depth, the direction of radiation *Z-N:* the angle between the perpendicular to the window and true south

Also, in this settlement, according to the climatic conditions of cold winter and hot summer and the energy supply of the building for heating and cooling, renewable

energy such as solar energy has been used. It has been discussed in the report, but one of the important points is that among the cases of using solar energy:

Hot water supply In active solar systems, hot water is mainly provided by solar water heaters using flat collectors.

Providing the required cold: cooling is done by solar energy in different ways, including absorption systems. Providing the required cooling capacity of buildings during the heat period is provided by absorption systems in such a way that the heat required by absorption generator chillers is provided by solar systems such as flat collectors with high efficiency, etc.

Providing lighting The lighting of the building should also be provided using photovoltaic cells. That is, by calculating the energy required to light the building, the number of photovoltaic panels (each panel is formed by placing several cells in parallel), and the capacity of the required storage battery is determined, and as a result, the lighting required for the building will be provided by using solar panels and a charge regulator (which prevents excessive charging and discharging of the battery). Since a lot of energy is spent on heating and cooling buildings every day, it is very important and useful to design and implement a building that can take maximum use of solar energy. The art of designing this building is that it is designed in a standard way and exposed to sunlight so that they can use this light even naturally, which is called a passive heating system, such a system provides the possibility that the building works without the need of fossil energy and ultimately with very little energy consumption, and it is oriented so that one of the main walls and many of the windows face south. Insulation work and the use of suitable windows (double-glazed glass) have been used in this sample. Also, some windows facing east and west have good shade for summer. South windows can also be protected with canopies. Curtains and internal insulating shades can also be useful. They are used in these buildings and compared with the normal state.

Scenario 2—using PV- cells to ZEB (zero energy building)

A large part of the energy produced in the country is spent in buildings and to produce comfortable temperature conditions. This not only imposes a significant cost on the economy to produce this energy, but also reduces the country's export power in the field of energy. Therefore, energy management in the building is of great importance. In industrialized countries, the increase in oil prices in 1973 forced these countries to pay more serious attention to the issue of energy production in other ways (other than the use of fossil fuels). In addition, taking into account the plan to remove the subsidy paid by the government in the energy sector, from now on this cost will be imposed on consumers and will form a large part of the household budget. According to the order, reducing the energy consumption in the building, in addition to the growth of the national economy, will also reduce household expenses and improve people's living standards.

From an environmental point of view, the use of renewable energy reduces the consumption of fossil fuels. The surveys conducted in the energy consumption field show that the building sector has the highest share among other sectors, consuming more than 40% of the country's total energy consumption. Meanwhile, energy consumption in the country's buildings is much higher than the world standard. The use of zero-energy

buildings in the construction industry and urban development has significant advantages. Apart from the removal of pollutants and fossil fuels, these benefits also have a direct and significant impact on other sectors. These benefits include (Forootan et al. 2022):

A. The owner does not have to worry about the increase in energy prices;
B. Uniform internal temperature;
C. Less energy required;
D. Lower maintenance cost due to higher energy efficiency systems;
E. Reducing monthly living expenses;
F. Increasing the credibility of energy production and consumption systems. Like photovoltaic systems with a long-term warranty;
G. Minimizing the cost of construction using new technology;
H. Increasing the price of zero energy buildings compared to similar buildings;
I. Optimal use of different wastes;
J. Balance in energy consumption;
K. Reduce electricity consumption;
L. Removal of additional energy-consuming systems;
M. Fifty percent reduction in drinking water consumption;
N. Using a ventilation system without a mechanical device.

The economic study of proposed solutions

Based on the assumptions and according to the collection of available information, we reached this result in the economic dimension in the previous section, 13 solutions were proposed and technically reviewed to optimize energy consumption in the nominal building of Florida. In this section, these solutions are examined from the economic aspect, and the suggestions regarding energy efficiency in residential neighborhoods become more practical. Payback time is estimated for each solution to prioritize and categorize solutions. To calculate the cost savings provided by each solution, the energy savings (in kWh) of each is multiplied by the price rate per kWh ($0.0238). The payback time is obtained from the following relationship. The equation below lists the fees and payback periods for all solutions (Yi et al. 2021; Li et al. 2020; Shaikh et al. 2014; Shehata et al. 2021; Jouhara et al. 2018).

$$Payback\ Time = \frac{innitial\ investment}{net\ annual\ saving}$$

Results and discussion

Using thermal insulation

The use of thermal insulation in buildings in North America is of critical significance as it significantly enhances energy efficiency, diminishes expenses related to heating and cooling, and improves the overall comfort for inhabitants. The insulation requirements vary depending on the climate zones, building codes, and construction procedures. The following are essential elements of thermal insulation in buildings in North America:

Geographical regions with distinct climate characteristics

North America exhibits diverse temperatures, ranging from frigid in the northern regions to sweltering and muggy in the southern portions. The Building America program, which the U.S. Department of Energy funds, categorizes the United States into several temperature zones in order to ascertain the most suitable insulation levels.

Construction regulations

The International Energy Conservation Code (IECC) in the United States and the National Building Code of Canada (NBCC) are examples of building regulations in North America that establish minimum insulation criteria. The codes are regularly updated to incorporate progress in energy efficiency standards.

Typical insulation materials

North American structures utilize a range of insulation materials, such as fiberglass, cellulose, foam board, spray foam and mineral wool. Material selection depends on cost, R-value (thermal resistance), moisture resistance, and regional accessibility.

Requirements for R-value

The R-value quantifies the ability of an insulating material to resist heat transfer. Greater R-values offer superior insulation. Building codes frequently stipulate minimum R-values for various components, including walls, roofs, and floors. In colder climates, it may be necessary to have greater R-values in order to comply with insulation standards. Air sealing refers to the process of closing off any gaps or cracks in a building's envelope to prevent the leakage of air.

Proper air sealing is essential to prevent air leaks that can undermine the efficacy of insulation and insulation itself. Optimal energy efficiency can be achieved by tightly sealing building envelopes to minimize heat transfer.

Energy star and certification programs

The Energy Star program, administered by the U.S. Environmental Protection Agency (EPA), establishes energy efficiency criteria for various products, including insulation materials. In addition, third-party certification programs such as the Green Building Initiative's Green Globes or the Leadership in Energy and Environmental Design (LEED) accreditation promote the adoption of energy-efficient building methods.

Financial rewards and discounts

Several regions in North America provide incentives and refunds for adopting energy-efficient construction methods, such as including top-notch insulation. These incentives can mitigate the initial expense of improving insulation.

Perpetual insulation

Continuous insulation is installing an uninterrupted insulation layer around a building, effectively eliminating thermal bridges. This method aids in improving the overall energy efficiency of the building's envelope.

In general, the emphasis on thermal insulation in buildings in North America is in line with the larger objective of enhancing energy efficiency, mitigating carbon emissions, and establishing more sustainable and pleasant living environments. Builders, contractors, and homeowners must prioritize staying updated on local building codes and optimal techniques to guarantee that their structures are adequately insulated and energy-efficient.

The building thermal insulation industry expects consistent expansion over the projected timeframe. Examining the market's dynamics in various geographical regions impacted by temperature extremes is essential. Properly insulating buildings is crucial for maintaining stable temperatures and optimal conditions, which is advantageous for residents and the environment. It aids in energy conservation by inhibiting the dissipation of heat or cooling, making an essential contribution to sustainability.

The prediction of global building thermal insulation market, valued at USD 38.55 billion in 2022, and it will increase to USD 56.57 billion by 2030. The market is projected to experience a compound annual growth rate (CAGR) of 4.91% from 2023 to 2030. The type sector of the worldwide building thermal insulation market is dominated mainly by "plastic foam" due to its exceptional insulation properties,

Table 3 Layers used in the walls

RM. number	Room	Schedule of finish				
		Wall finish	Ceiling finish	Floor finish	Skirting	Area
1	Porch	Matte paint	Matte paint	Tile	Tile	55 SF
2	Entrance	Matte paint	Matte paint	Tile	Tile	54 SF
3	Living & dining area	Matte paint	Matte paint	Tile	Tile	270 SF
4	Kitchen area	Matte paint	Matte paint	Tile	Tile	122 SF
5	Powder room	Semi-gloss paint/tile	Matte paint	Tile	Tile	22 SF
6	Bath 1	Semi-gloss paint/tile	Matte paint	Tile	Tile	46 SF
7	Bed 1	Matte paint	Matte paint	WPC floor	WPC	138 SF
8	Dryer area	Matte paint	Matte paint	Tile	Tile	13 SF
9	Storage	Matte paint	Matte paint	Tile	Tile	42 SF
10	Garage	Matte paint	Matte paint	Concrete	Tile	249 SF
11	Hallway	Matte paint	Matte paint	Tile	Tile	115 SF
12	Ahu	Matte paint	Matte paint	Concrete	Tile	21 SF
13	Master's bedroom	Matte paint	Matte paint	WPC floor	WP	167 SF
14	Walking closer	Matte paint	Matte paint	WPC floor	WPC	60 SF
15	Master bath	Semi-gloss paint/tile	Matte paint	Tile	Tile	55 SF
16	Bedroom 2	Matte paint	Matte paint	WPC floor	WPC	132 SF
17	Bedroom 4	Matte paint	Matte paint	WPC floor	WPC	139 SF
18	Bath 2	Semi-gloss paint/tile	Matte paint	Tile	Tile	45 SF
19	Bath 3	Semi-gloss paint/tile	Matte paint	Tile	Tile	45 SF
20	Bedroom 3	Matte paint	Matte paint	WPC floor	WPC	162 SF
21	Balcony	Matte paint	Matte paint	Tile	Tile	59 SF

Table 4 Total energy consumed in this building simulation

	Total energy [kBtu]	Energy per total building area [kBtu/ft2]	Energy per conditioned building area [kBtu/ft2]
Total site energy	222,711.93	127.06	127.06
Net site energy	222,711.93	127.06	127.06
Total source energy	364,259.92	207.81	207.81
Net source energy	364,259.92	207.81	207.81

Table 5 Final cooling report in normal mode

	Electricity [kBtu]	Natural gas [kBtu]	District cooling [kBtu]	District heating [kBtu]	Water [gal]
Heating	0.00	0.00	0.00	1.11	0.00
Cooling	0.00	0.00	161,933.92	0.00	0.00
Interior lighting	34,826.07	0.00	0.00	0.00	0.00
Water systems	0.00	0.00	0.00	1853.36	2245.40
Total end uses	58,923.54	0.00	161,933.92	1854.47	2245.40

Table 6 Final cooling report in shade mode

	Electricity [kBtu]	Natural gas [kBtu]	District cooling [kBtu]	District heating [kBtu]	Water [gal]
Heating	0.00	0.00	0.00	8.83	0.00
Cooling	0.00	0.00	143,048.68	0.00	0.00
Interior lighting	34,826.07	0.00	0.00	0.00	0.00
Interior equipment	24,097.47	0.00	0.00	0.00	0.00
Water systems	0.00	0.00	0.00	1853.36	2245.40
Total end uses	58,923.54	0.00	143,048.68	1862.19	2245.40

adaptability, cost-effectiveness, and moisture resistance. The market reports provided by Data Bridge Market Research offer comprehensive information on market scenarios, including market value, growth rate, segmentation, geographical coverage, and significant players. These reports also feature in-depth expert analysis, geographically represented company-wise production and capacity, network layouts of distributors and partners, detailed and updated price trend analysis, and supply chain and demand deficit analysis.

According to scenario one, the results related to the insulation done in building materials are shown in Tables 3, 4, 5, 6, 7.

According to Table 3, the layers of each building are specified from the inner to the outer layers of the buildings, and the type of spaces occupied by these walls is also mentioned, which number between 55 and 167, and 249.

Validation Energy consumption data of the buildings were analyzed as a first step to making the comparison. Electricity can be considered the main source of energy (fuel) for the building. One of the comparisons made in the amount of cooling of the building of sample number one is in the normal state and the shaded state. The difference

Table 7 Economic study of proposed solutions

Solutions	Energy saving/ generation (kwh)	CO_2 emission reduction (kg)	Capital costs (US$)	Net annual cost savings (US$)	Payback time (year)
Roof thermal insulation	32,820.15	11,164.1	60,700.0	8158.9	7.43
Walls thermal insulation	30,233.26	5976	8671.37	7198.37	1.20
Low-emissivity film for the windows	900.66	200	9750	210.49	46.32
Shading for windows	40,594.75	10,827.07	39,875	9924.7	4.017
LED light bulbs	999.8	389	3093.38	423.79	7.29
BMS	20,679.49	3824	25,974.4	6923.6	3.75
Green walls	9281.61	2062.92	4761.9	3389.9	1.40
Rooftop PV	21,876	14,113	37,214.2	7208.5	5.1625
PV on facade	6479	518.96	11,285.7	2842.61	3.97
Solar collector	2752	1825	9047.61	758.59	11.5169
Solar absorption cooling	Considering the humid climate of Florida, the evaporative cooling tower will not perform effectively. Hence, an absorption cooling system is not suitable for the region				
Greenhouse	The greenhouse slightly reduces the heating load, while causing a significant cooling load during nine warm months. Therefore, the solution is not suggested				
Solar heat reservoir	Florida s climate is continuously warm, making the solution unsuitable for the region				

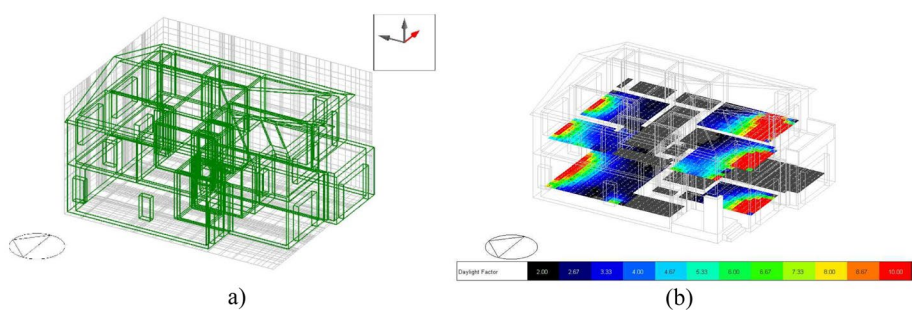


Fig. 4 **a** CFD distribution for building and **b** CFD Daylighting factor

between scenario (1) and scenario (2) is that the reduction of electricity demand is 200 kWh.

The energy used in the building considering that the building is located in the Florida region of the United States is a total of 364,259 kilos and, it is mainly consumed by electric energy, other fuels such as gas, diesel, and coal will not be used, and also when the amount of cooling of the building in normal mode is We will check the cooling of the building in shade mode together and, we will come to the conclusion that about 200 kilo BTU's have been saved in shade tap mode.

According to Tables 5 and 6, the cooling number in normal mode is 161,933, which has a huge difference between these numbers. If this number is about 163,048 for cooling in the shade mode, the heating value in the normal mode is 1854 in the shade and 1862 in the shade. And the amount of brightness in both modes is 34,826.07 kilo BTU.

The CFD sample is shown in Fig. 4a and b shows the CFD Daylighting factor. From the figure, it can be seen that on the side of the windows and the lighting factor in the places

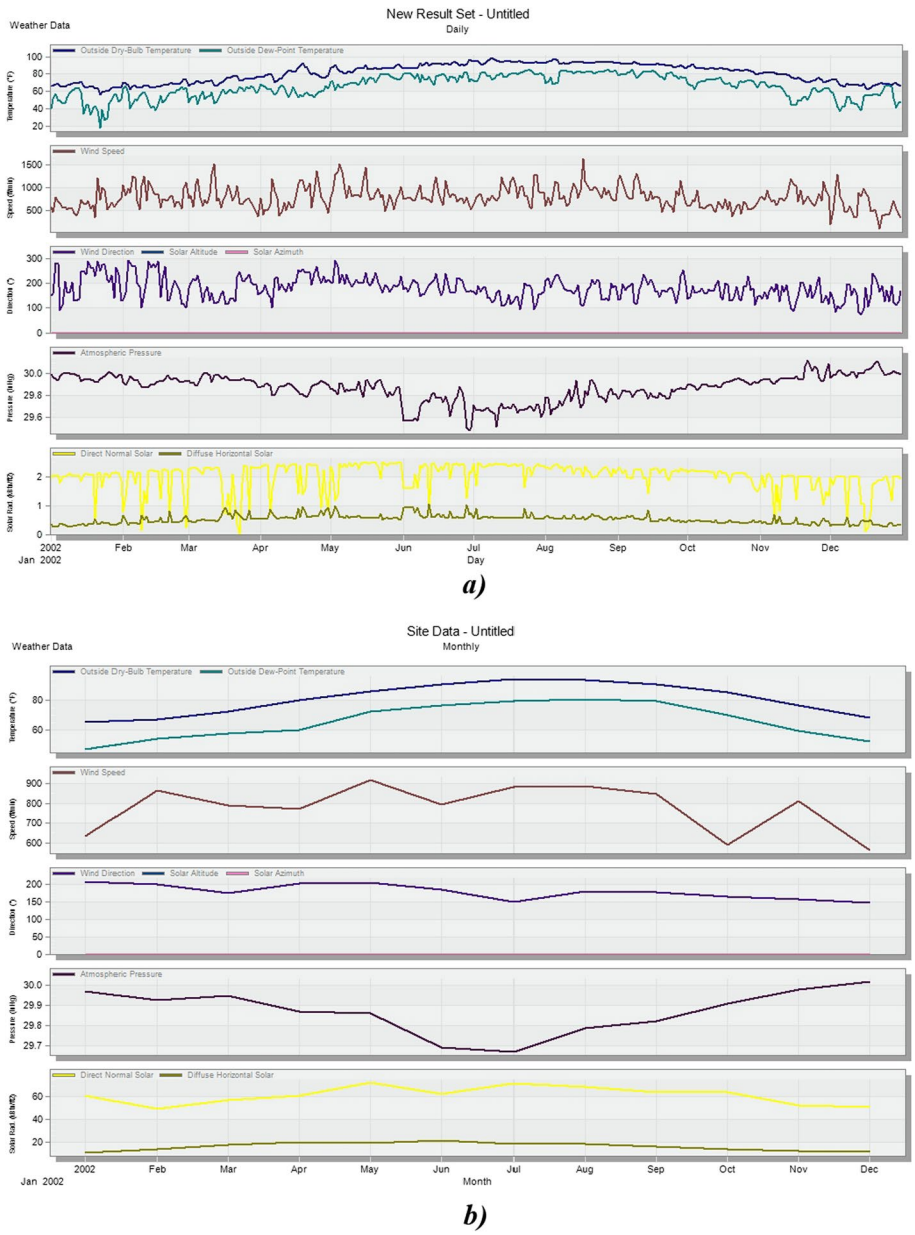


Fig. 5 **a** Site Data–Daily and **b** Site Data–Monthly

where the window is located, lightning has reached its highest value with score 10. In the middle part of the building, where almost no light will reach it, at the time of the stairs, this factor is set at 2 to 2.67.

Figure 5a and b, in which our data site and the daily horse are considered, are used from the data of temperature, speed, pressure, and other things. 80 degrees Fahrenheit (26.66 °C) to about 20 degrees Fahrenheit (− 6.67 °C) daily, which is clear that in the months of January, this temperature has decreased more in winter, and in the summer, it reaches its peak value of 80 degrees in terms of wind speed. Something between 500 and 1500 degrees will change in part of the summer and early October and November seasons. This value, which has a high-speed value of 100 km/h, also in

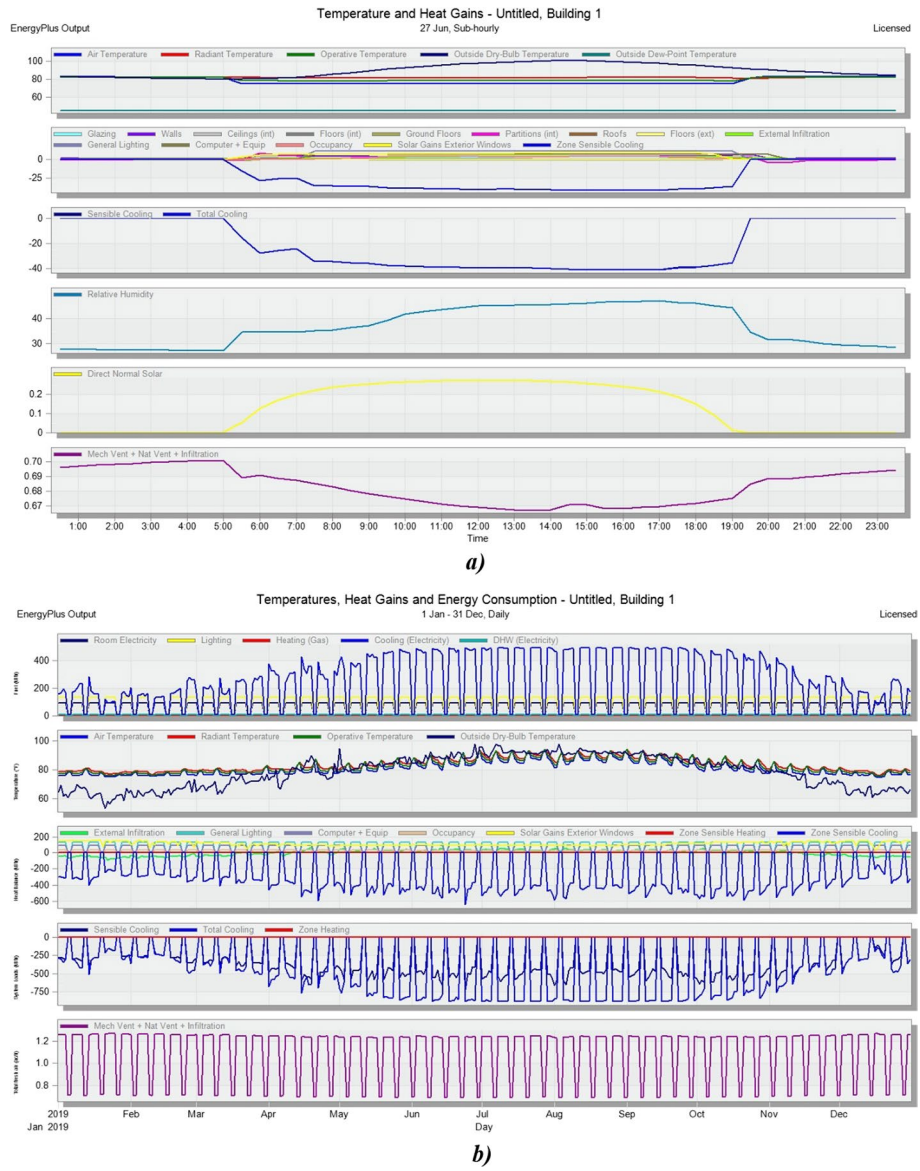
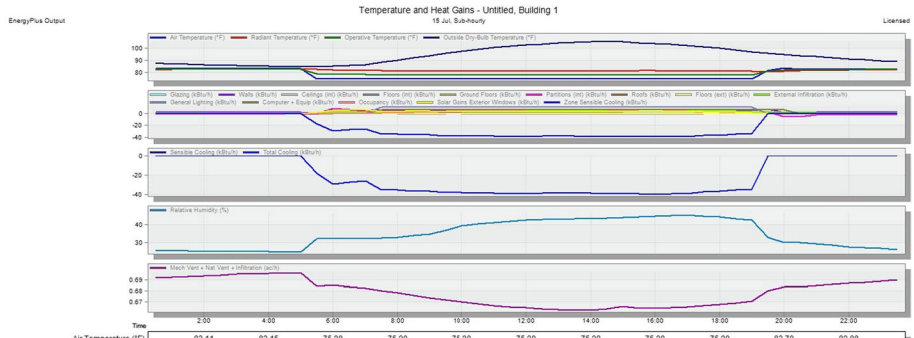


Fig. 6 **a** Temperature and heat gains and **b** Temperatures, heat gains, and energy consumption

terms of pressure, is between 30 and 35 at the beginning of winter and in the middle of summer, this value will reach about 29.6

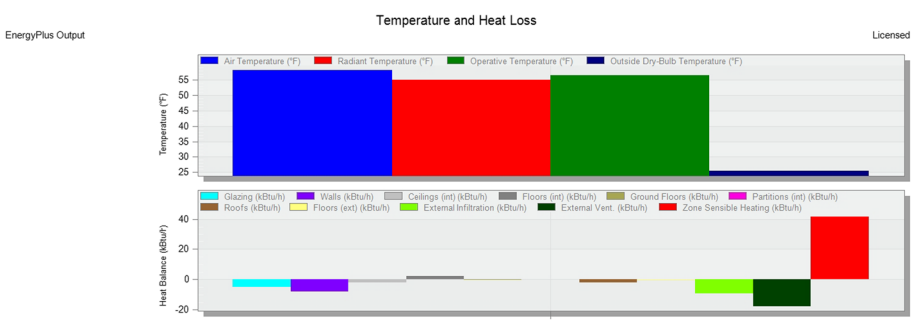
Among the points to be considered for checking the energy produced in terms of cooling, it can be seen in Fig. 6a and b, this value will reach something like 400. Also, in terms of heating, this constant soft value will follow 100. Our heating according to Climatic conditions will be very low,and it will follow the number 100 from Lat.

According to Fig. 7, all information such as temperatures, dry air temperature, leasing, roofs, walls, interior space, exterior space, these internal and external locations, and the amount of cooling and heating in the above diagram is presented accurately and in detail during different hours of the day.



Time	2:00	4:00	6:00	8:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00
Air Temperature (°F)	83.11	83.15	75.20	75.20	75.20	75.20	75.20	75.20	75.20	83.70	82.88
Radiant Temperature (°F)	82.63	82.76	82.23	81.48	81.42	81.45	81.46	81.52	81.33	81.29	82.04
Operative Temperature (°F)	82.87	82.95	78.72	78.34	78.31	78.32	78.33	78.36	78.26	82.49	82.46
Outside Dry-Bulb Temperature (°F)	86.35	85.14	85.14	89.98	97.24	102.28	104.90	103.69	100.06	94.82	91.19
Glazing (kBtu/h)	-0.31	-0.43	0.76	1.35	2.32	2.88	3.15	2.83	2.35	0.58	0.15
Walls (kBtu/h)	2.01	1.81	7.16	4.92	4.76	5.07	5.38	4.92	5.43	1.90	2.30
Ceilings (int) (kBtu/h)	0.79	0.86	4.23	2.31	1.62	1.11	1.08	0.73	1.89	0.22	0.55
Floors (int) (kBtu/h)	-1.24	-1.10	1.53	1.30	0.98	0.71	0.62	0.26	0.65	-1.10	-1.34
Ground Floors (kBtu/h)	-1.20	-1.20	-0.04	-0.45	-0.56	-0.68	-0.68	-0.85	-0.50	-1.47	-1.15
Partitions (int) (kBtu/h)	-0.89	-0.60	8.62	1.36	0.57	0.17	0.13	-0.38	0.48	-5.11	-2.10
Roofs (kBtu/h)	-0.04	-0.04	0.06	0.04	0.14	0.23	0.27	0.26	0.20	0.02	-0.01
Floors (ext) (kBtu/h)	0.01	0.01	0.07	0.02	0.06	0.10	0.12	0.11	0.10	0.02	0.03
External Infiltration (kBtu/h)	0.55	0.34	1.69	2.49	3.66	4.46	4.87	4.68	4.11	1.86	1.40
General Lighting (kBtu/h)	0.00	0.00	0.00	11.11	11.11	11.11	11.11	11.11	11.11	0.00	0.00
Computer + Equip (kBtu/h)	0.35	0.35	0.35	6.54	6.54	6.54	6.54	6.54	6.54	6.54	0.35
Occupancy (kBtu/h)	0.00	0.00	0.00	1.06	4.22	4.22	3.17	4.22	2.11	0.00	0.00
Solar Gains Exterior Windows (kBtu/h)	0.00	0.00	4.97	3.66	2.19	3.59	3.47	5.54	2.54	0.00	0.00
Zone Sensible Cooling (kBtu/h)	0.00	0.00	-29.14	-35.38	-38.23	-39.11	-38.84	-39.57	-36.69	0.00	0.00
Sensible Cooling (kBtu/h)	0.00	0.00	-29.14	-35.38	-38.23	-39.11	-38.84	-39.57	-36.69	0.00	0.00
Total Cooling (kBtu/h)	0.00	0.00	-29.14	-35.38	-38.23	-39.11	-38.84	-39.57	-36.69	0.00	0.00
Relative Humidity (%)	25.13	24.84	32.14	32.99	39.24	42.72	43.23	44.64	44.23	30.00	27.53
Mech Vent + Nat Vent + Infiltration (ach)	0.69	0.70	0.69	0.68	0.67	0.66	0.66	0.66	0.67	0.68	0.69

Fig. 7 shading analysis



Air Temperature (°F)	58.12
Radiant Temperature (°F)	55.02
Operative Temperature (°F)	56.57
Outside Dry-Bulb Temperature (°F)	25.52
Glazing (kBtu/h)	-4.84
Walls (kBtu/h)	-7.87
Ceilings (int) (kBtu/h)	-2.20
Floors (int) (kBtu/h)	2.20
Ground Floors (kBtu/h)	-0.26
Partitions (int) (kBtu/h)	0.00
Roofs (kBtu/h)	-2.13
Floors (ext) (kBtu/h)	-0.11
External Infiltration (kBtu/h)	-9.24
External Vent. (kBtu/h)	-17.49
Zone Sensible Heating (kBtu/h)	41.94

Fig. 8 Temperature and heat loss

According to Fig. 8, the value of the final temperatures up to 55 degrees Fahrenheit (12.78 °C), the reflection temperature up to 50 degrees Fahrenheit (10 °C) and the temperature of dry air up to 53 degrees Fahrenheit (11.67 °C) were considered. Also, the value of our Sensible heating was considered to be about 40 kBtu/h.

By examining Table 7, the priorities of the solutions are as follows:

A. The biggest reduction in the building's electricity demand is achieved by installing shades on the south windows, with a return time of 4.017. This measure not only shows the short payback time but also brings convenience to the residents;

B. The second way to save energy consumption is to insulate the walls and roof, with a payback of 1.2 and 7.43 years, respectively. This solution brings peace to the residents and prevents the penetration of moisture;
C. Next appropriate action is to use BMS with 3.75 years of payback time. This saves energy and provides comfort and peace of mind for the occupants, as the indoor temperature is adjusted to the desired level after some time after the occupant's return;
D. The next proposed solution is the construction of green walls on the facade of the building, which has both an aesthetic aspect and an aspect of saving cooling/heating energy with a payback time of 1.40 years. Another solution that significantly reduces the electricity bills of the building is to replace the lights with LED lamps. If applied to all building units, the payback time would be 7.29 years, which is an ideal period considering energy savings and capital costs;
E. The use of ceiling and wall photovoltaic systems as well as the use of solar water heaters are suggested considering their environmental aspects. The repayment time of these solutions is 3.97 and 11.51 years, respectively. Glazing south windows with low-emissivity film reduce energy consumption by 900.66 kWh with a payback period of 46.32 years. This solution is not recommended.

Therefore, 9 of the 13 studied solutions are technically and economically suitable, and their implementation can reduce the energy consumption of the building by 70% to 32,114.25 kwh and also prevent the emission of 54,021 kg of CO2.

Using PV- cells to ZEB (zero energy building)

Utilizing photovoltaic (PV) cells to achieve zero-energy buildings is a highly efficient approach that is effective both in North America and globally. Zero-energy buildings achieve a balance between energy generation and consumption by implementing energy-efficient measures and utilizing renewable energy sources, with photovoltaic technology playing a significant role. Below are key considerations surrounding the utilization of photovoltaic (PV) cells to attain zero-energy buildings in North America:

Solar capacity

North America's geographic position and climate diversity, including the United States and Canada, contribute to its significant solar potential. Areas characterized by abundant sun radiation, such as the southwestern United States, are especially suitable for photovoltaic (PV) installations.

Integration with energy efficiency measures

To achieve a zero energy building, it is necessary to produce renewable energy and adopt energy efficiency techniques. This entails utilizing energy-efficient appliances, lights, insulation, and HVAC systems to mitigate the overall energy consumption.

Standards for net zero energy buildings (NZEBs)

Multiple standards and certifications exist for zero-energy buildings, including the Net Zero Energy Building (NZEB) standard. These standards frequently encompass

requirements for energy efficiency, the production of renewable energy on-site, and the overall ecological footprint of the structure.

Government incentives and policies

Both the United States and Canada have implemented a range of government incentives and programs to encourage the widespread use of renewable energy, specifically photovoltaic (PV) technology. These incentives may encompass tax credits, rebates, and grants to promote the adoption of solar panels on residential and commercial structures.

Financial feasibility

The declining cost of photovoltaic (PV) technology has rendered it increasingly economically feasible for homeowners, businesses, and institutions to allocate resources toward solar energy installations. The ROI of PV installations is impacted by variables such as regional energy costs, accessible incentives, and the efficacy of the PV system.

Integration into the power grid and the use of net metering

Several zero-energy buildings are nevertheless reliant on the electricity grid. Net metering enables the extra electricity the PV system produces to be returned to the grid while the building owner receives credits for the excess energy. This aids in achieving equilibrium between the generation and utilization of energy.

Technological progress

The continuous progress in photovoltaic (PV) technology, including enhancements in the efficiency of solar cells and the development of energy storage solutions, plays a significant role in making solar energy a progressively appealing choice for attaining zero-energy objectives.

Education and awareness

It is crucial to raise awareness and educate architects, builders, and homeowners about the advantages of incorporating PV systems into building design. This encompasses factors such as accurate alignment, inclination, and comprehensive assessment of shadows to maximize solar energy generation.

Projects involving the community and large-scale initiatives

Communities and large-scale developments strive to achieve net-zero energy objectives by integrating solar farms or shared solar installations. This method enables various structures to derive advantages from a centralized renewable energy source.

In summarry, utilizing solar cells in North America to achieve zero-energy buildings is a feasible and progressively prevalent approach. The incorporation of solar energy into building design is facilitated by energy efficiency measures, government backing, technology breakthroughs, and increasing awareness. This adds to the promotion of sustainable and environmentally friendly construction methods.

By implementing this scenario, all the electricity needs are provided by PV cells, which can be without the need for grid electricity. The following results have been obtained according to Fig. 9.

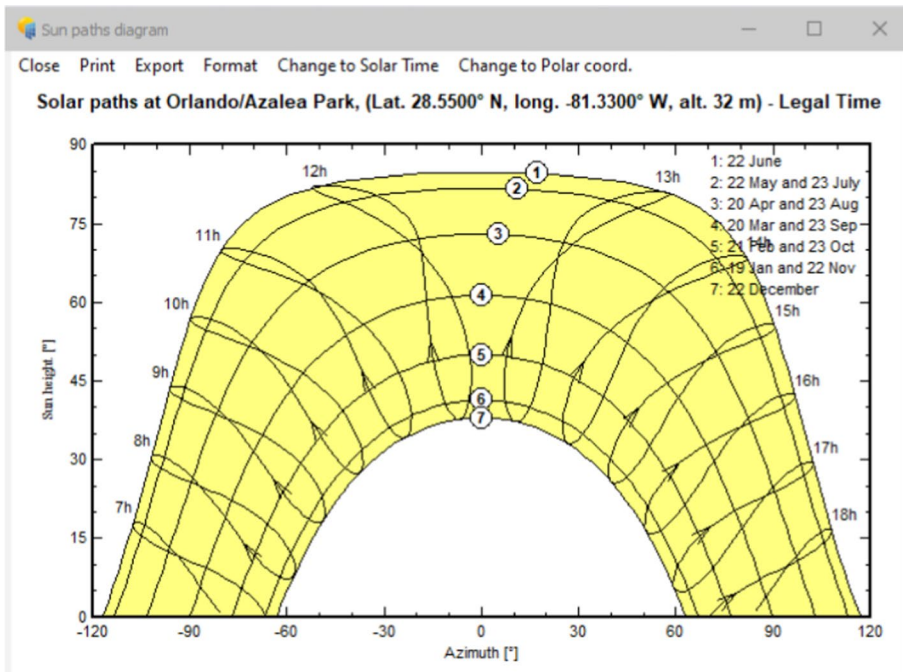


Fig. 9 Sun Trajectory depending on parameters set for Orlando, Florida

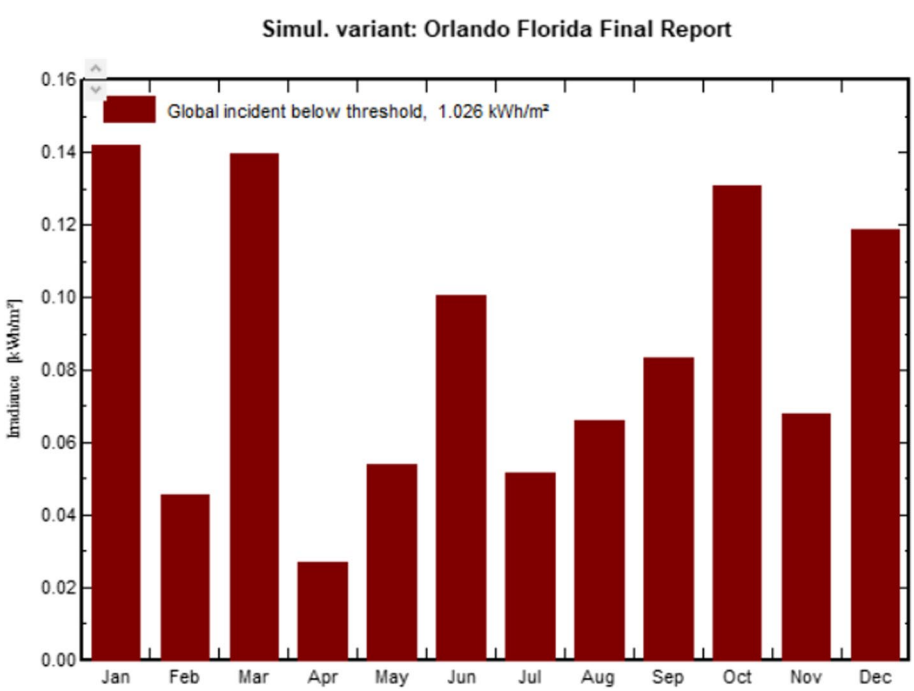


Fig. 10 Normalized energy production graph

In Fig. 10, the normalized energy production, which is distributed over the whole year, is demonstrated. The highest generated energy production is less than 0.14 kWh/kWp/day and would occur in January, March, and October. On the contrary, the

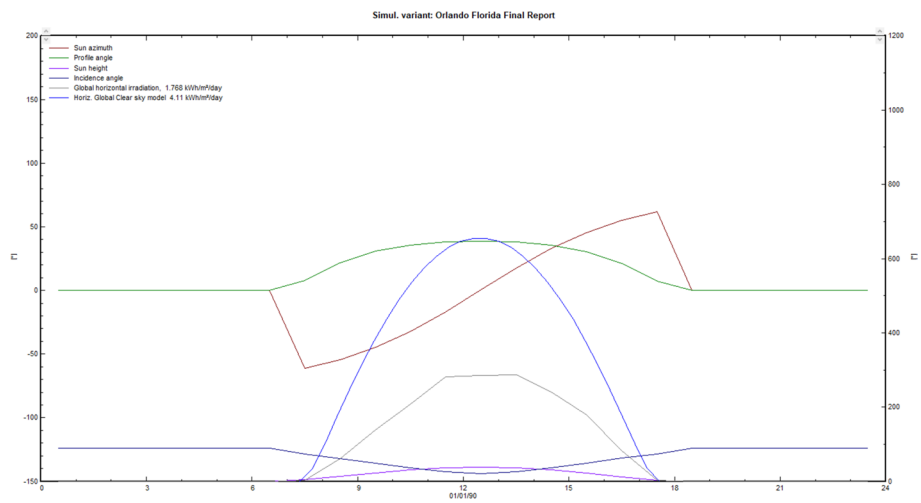


Fig. 11 Comparison of sun azimuth and global irradiation in Orlando, Florida

lowest production would occur in winter in February and April with a value of above 2 kWh/kWp/day. As shown in Fig. 10, the most losses of PV modules occur in October, November, and December. Furthermore, the highest unused energy is in August.

Figure 11 shows sun azimuth and global irradiation compared with our specific location, Orlando, Florida.

Creating shadows on windows or glass walls prevents direct sunlight from hitting the glass surface, and as a result, the heat created by the sunlight in the space behind the glass is greatly reduced. This amount of reduction depends on the location of the created shadow. When a shade is created on the outer surface of the glass, a very small amount of the sun's thermal energy is transferred to the space behind the glass. Because the heat transfer, in this case, is in the form of (conduction) and (radiation) heat transfer is rarely conducted through the glass and transparent objects do not pass long wavelength rays. But when the internal shutter curtain is used to prevent direct sunlight from entering, the direct sunlight passes through the glass and the shutter curtain is affected by its thermal effect. After the shutter curtain is heated, it transfers its heat to the surroundings using long-wavelength waves, and since this heat cannot pass through the glass, it is only transferred to the interior space, causing this space to heat up. The result of this modeling report that was done in this case shows that external canopies can reduce up to 90% of the thermal effect of sunlight inside a room. In retractable awnings, it is possible to open the awning in times of intense sunlight or heavy rain and provide protection against them. Studies show that the air under the canopy can be up to 20 degrees cooler. Also, the lack of direct sunlight entering the interior of the house prevents excessive heat and more use of air conditioning. It is necessary to point out that this reduces the cost of air conditioning.

Also, the use of solar energy can reduce the annual heat load by 80% in cold and sunny areas and by 50% in cloudy areas by using PV- syst® software with good design. The correct canopy and ventilation strategy in buildings with high thermal mass can reduce 80% of the annual cooling load.

Conclusion

This work technically-economically studied 13 solutions to bring energy efficiency to a residential neighborhood in a Florida city. Since Florida has good solar radiation, the use of solar systems for air conditioning and power generation for the building has been explored. Beyond the different energy solutions mentioned above, economical and technically feasible housekeeping solutions are presented to reduce the building's energy consumption. Based on the results, insulation of walls and ceilings, replacement of lights with LED lamps, installation of PV modules on the roof and wall, and use of solar water heaters are among the causes that are economical and environmentally friendly solutions for implementing insulation of walls and roof are the most energy efficient.

In addition, the consumption of electrical energy in residential buildings has almost doubled and is expected to increase by more than fifty percent until 2035. Improving the energy efficiency of buildings can reduce the annual consumption of the residential sector and reduce the energy costs of families. Solutions for using external horizontal awnings reduce energy consumption by 15.1% compared to the normal state accompanied. The important discussions of this conclusion related to the building according to the results, installing shades on the south windows, insulating the walls and ceiling, and suggesting the replacement of lights with LED lamps are economical and environmentally friendly solutions. Installing shades on the south windows and implementing insulation for the walls and roof are the most energy-saving.

The proposed solution, which is suitable for this climatic condition, can reduce the energy consumption of the building by 81% and also prevent the emission of 63,022.66 kg of CO_2. The proposed solutions can be considered as a tool for managing the energy and environmental crisis of the regions. Also, directions for future research are suggested, some of which are mentioned.

A. It is suggested to focus more on hospital buildings to reduce energy consumption because the hospital building has a different air conditioning system, and the impact of energy consumption reduction scenarios can be checked differently.
B. Also, using recycled materials can be more effective in reducing energy consumption and getting closer to zero energy building for future research.
C. The issues of energy consumption optimization in terms of the building's dimensions, surface, and volume should be investigated in the pre-construction or design stage.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by AS and RZ. The first draft of the manuscript was written by MA and AS and all authors commented on previous versions of the manuscript. AA supervised the manuscript. All authors read and approved the final manuscript.

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Data availability

Datasets analyzed during the current study are available and can be given following a reasonable request from the corresponding author.

Declarations

Ethics approval and consent to participate
The authors herewith do confirm that this manuscript has not been published elsewhere and is not also under consideration by the other journals. The authors approve the presented manuscript and do agree with the submission under your management as the editor in chief of Energy Informatics. The current study was carried out under the University of Tehran, Department of Energy Systems Engineering, Tehran, Iran.

Consent for publication
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